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U.S. COMPUTER RESEARCH NETWORKS:

CURRENT AND FUTURE

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PREFACE

This document presents a summary of the report which was prepared by Contel Federal Systems for the NASA Lewis Research Center under Task Order 2 of the Contract NAS3-25083. Under this contract, Contel Federal Systems provides technical support to NASA for the assessment of the future market for satellite communications services. Task Order 1 focused on the costs and tariffs for telecommunications services. Task Order 2, the results of which are summarized in this Executive Summary, focused on the current and future telecommunications requirements of the United States research community.

ACKNOWLEDGEMENTS

The authors would like to thank members of the Federal Coordinating Council for Science, Engineering and Technology (FCCSET), members of the Federal Research Internet Coordinating Committee (FRICC), and other Federal agency representatives who provided information on their networks. Special thanks are due to EDUCOM representatives, directors and managers of the various computer research networks, and the staff of the Corporation for National Research Initiatives for their cooperation. These individuals and other government, industry and academic leaders provided much needed information and valuable insights for this study.

Special thanks are due also to the NASA Lewis Research Center and the technical officer of this study, Mr. James E. Hollansworth, for providing direction and guidance for this study.

SECTION 1

INTRODUCTION AND SUMMARY

1.1 STUDY OVERVIEW AND BACKGROUND

1.1.1 Study Overview

During the last decade, the NASA Lewis Research Center's Communications Program has conducted a series of telecommunications forecasting studies to project trends and requirements, and to identify critical telecommunications technologies that must be developed to meet future requirements. The Government Networks Division of Contel Federal Systems has assisted NASA in these studies, and the current study builds upon these earlier efforts.

1.1.2 Study Background

The current major thrust of the NASA Comunications Program is aimed at developing the high risk, advanced communications satellite and terminal technologies required to significantly increase the capacity of future communications systems. Also, major new technological, economic, and social-political events and trends are now shaping the communications industry of the future.

Therefore, a reexamination of future telecommunications needs and requirements is necessary to enable NASA to make management decisions in its Communications Program and to ensure the proper technologies and systems are addressed. This study, through a series of Task Orders, is helping NASA define the likely communication service needs and requirements of the future and thereby ensuring that the most appropriate technology developments are pursued.

Task Order 1 focused on "Costs And Tariffs For Telecommunication Services." Task Order 2, described below, focused on telecommunications requirements for the research community.

1.2 TASK ORDER 2 - PURPOSE, SUBTASKS, APPROACH AND REPORTS

1.2.1 Purpose

The purpose of Task Order 2 was to assist NASA in determining the U.S.'s current and future needs for research and development telecommunications networks. This understanding of network needs is helping NASA define the future technology requirements and thereby ensuring that the most appropriate technology developments are pursued.

1.2.2 Subtasks

Task Order 2 accomplished its purpose of determining current and future research communications needs by: identifying, defining and describing federal agencies' current research communications networks; sizing these networks; and developing an integrated research network to meet the combined current requirements of all research networks. Task Order 2 also projected the future communications requirements and estimated present and future costs to the federal government of the new network. Specifically, these activities were accomplished by conducting the following subtasks:

(1) Subtask 2.1 - Identify, Define And Describe Unique Networks (networks unique to a federal agency);

(2) Subtask 2.2 - Identify, Define And Describe Shared Networks (networks shared by two or more federal agencies);

(3) Subtask 2.3 - Size Current Intgrated Research Network (IRN);

(4) Subtask 2.4 - Project Future IRN;

(5) Subtask 2.5 - Estimate Present And Future Costs; and,

(6) Subtask 2.6 - Conduct Reviews and Prepare Reports.

1.2.3 Approach

To accomplish the purpose of Task Order 2, the study approach depicted in Exhibit 1-1 was used. Exhibit 1-1 is organized by subtasks. Subtasks 2.1 and 2.2 were conducted simultaneously, with the results being used to conduct Subtask 2.3. Subtask 2.3 fed into Subtask 2.4; and Subtasks 2.3 and 2.4 fed into Subtask 2.5. Subtask 2.6, because it is

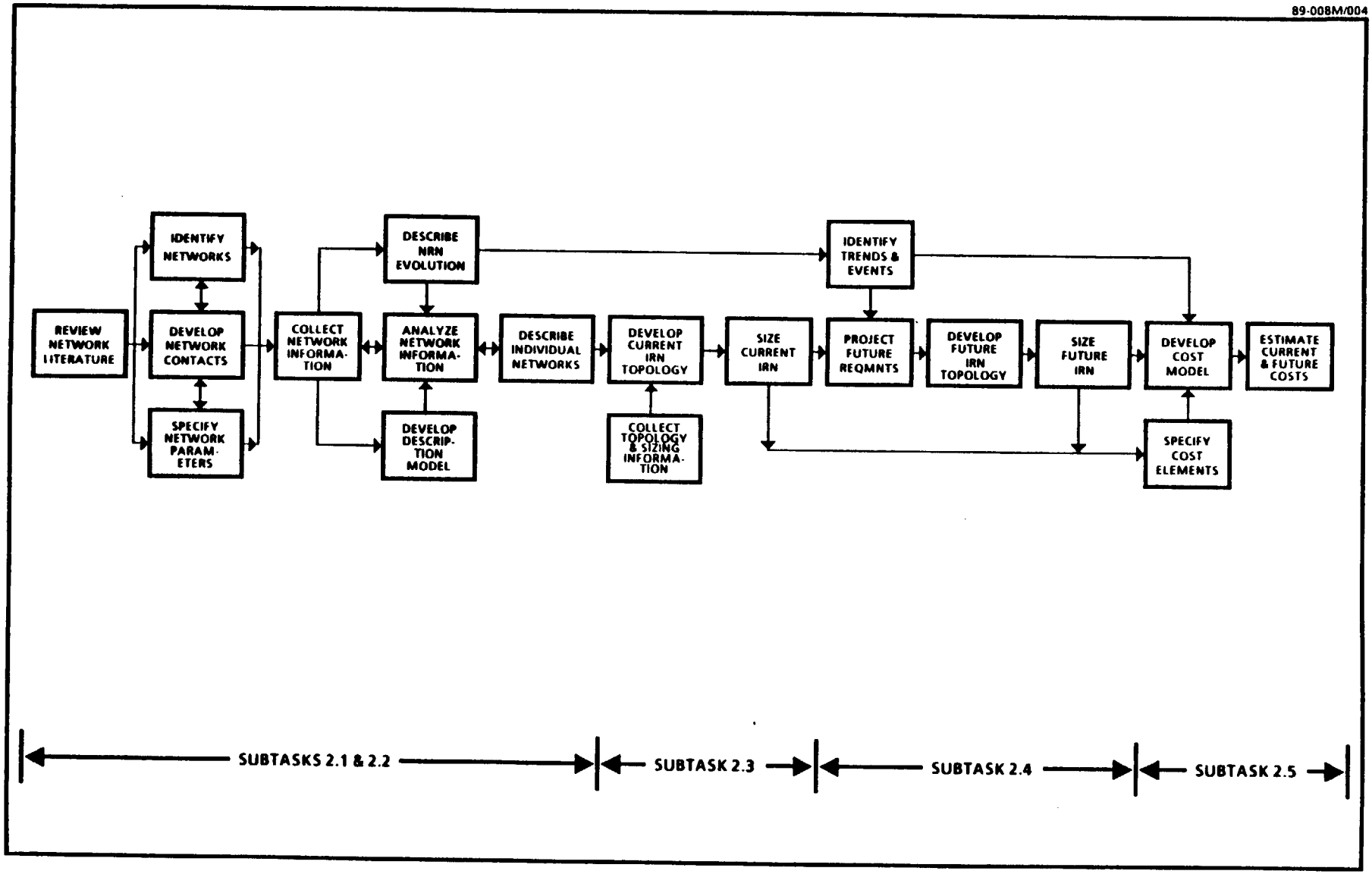


EXHIBIT 1-1. STUDY APPROACH

only the reporting task, is not depicted in this diagram.

Subtasks 2.1 and 2.2 identified, defined and described current computer research networks. These research networks were then used in Subtask 2.3, to develop the topology of an integrated research network (IRN) representing the aggregation of selected major current computer research networks, and to size the Current IRN.

In Subtask 2.4, trends and events (e.g., technological, economic, and social-political) were identified. Special attention was given to the national research network (NRN) planning efforts of the federal agencies such as the National Science Foundation. This information was used to develop the Future IRN topology and to size the Future IRN.

In Subtask 2.5 the results, from sizing the current and future IRN in Subtasks 2.3 and 2.4, were used to specify cost elements and to develop the cost model for estimating current and future costs of the IRN.

1.2.4 Reports

The procedures and results of Task Order 2 are presented in this Final Report and are summarized in an Executive Summary. The Executive Summary briefly summarizes the purpose and methodology and highlights the major findings of Task Order 2.

1.3 TASK ORDER 2 - MAJOR FINDINGS

The major findings from Task Order 2 are summarized below by subtask. The first group of findings (for Subtasks 2.1 and 2.2) pertain to the identification, selection and description of the computer research netwrorks. The next group of findings (for Subtask 2.3) are about the definition of the Current IRN. The third group of findings (for Subtask 2.4) deal with the projections of the Future IRN. The last group of findings (for Subtask 2.5) pertain to the estimates of costs for the Current and Future IRN.

1.3.1 Major Findings: Subtasks 2.1 AND 2.2 - Identification, Selection And Description of Networks

The major findings for Subtasks 2.1 and 2.2 pertain to the development of a model for describing networks, the evolution of a concept for a national research network, a review of the sponsorship and/or use of computer research networks by all major federal agencies, and the selection of computer research networks for comprehensive examination.

1.3.1.1 Model For Describing Networks

A computer research network was defined and a model for describing such a network was developed, so computer research networks could be selected appropriately, analyzed effectively and described thoroughly. The following is the definition, developed for this study, of a computer research network.

A computer network exists when independent computers are connected in some way that allows them to exchange information. For the purposes of this study, when such a network is used by scientists for scientific research purposes, it is designated as a computer research network. In a computer network, the computers can range in size from small microcomputers to supercomputers. These computers can be connected by a variety of media, such as optical fiber, microwave, copper, and/or satellites. The common conventions or rules that define how these computers communicate with each other are the communication protocols. Therefore, for the purpose of this study, a computer research network was defined as a communications network connecting a set of computers used by scientific researchers to exchange scientific data over a variety of communications media using common conventions or protocols.

Based on this definition, a model for describing computer research networks (CRNs) was developed. This CRN model is outlined in Exhibit 1-2 and is presented in detail in Section 3. The model includes descriptions of the following computer network topics: history; types; extent and size; computers, nodes and topologies; media; speed, throughput, and bandwidth; layers and protocols; services; uses; administration; and the future. The

EXHIBIT 1-2. MODEL FOR DESCRIBING NETWORKS

HISTORY

WHEN STARTED, IMPETUS, MAJOR CHANGES

TYPE OF NETWORK

NETWORK, INTERNET, METANETWORK

PURPOSES & SERVICES

WHY IT WAS DEVELOPED AND FOR WHOM, SERVICES OFFERED

EXTENT & SIZE

GEOGRAPHICAL COVERAGE, #NODES/HOSTS

TOPOLOGY

PICTURE - LOCATION & CONNECTIVITY OF NODES

COMPUTERS

PURPOSE AND SIZE OF COMPUTERS

MEDIA & LINK SPEEDS

TYPE OF MEDIA, SPEEDS IN BITS PER SECOND (BPS)

PROTOCOLS

NAME OF PROTOCOL SUITE (E.G., TCP/IP)

ADMINISTRATION

WHO - POLICY, OPERATION, INFORMATION

FUNDING

WHO PROVIDED SUPPORT

FUTURE

PLANS - TECHNOLOGICAL, POLITICAL

CRN model was used in subsequent activities to describe the networks that were selected for comprehensive review.

1.3.1.2 Evolution Of A National Research Network

An extensive amount of effort has been, and continues to be, devoted to the development of a conceptual National Research Network (NRN). The results of this effort were used to design and conduct the current study. Likewise, it is expected that the results of the current study will be helpful in the future planning of the NRN. To better understand this relationship between the current study and the development of an NRN, a summary of the activities underlying the development of an NRN and the organizations responsible for the NRN concept was developed. This summary is presented in Section 4.

The evolution of an NRN is diagramed in Exhibit 1-3. The history of the NRN summarized in this exhibit covers the period of 1984 through the present (i.e., Spring, 1989) and focuses on the interrelationships between four groups of events: the development of major research networks; the pursuit of related legislative agenda; the formation of national-level comittees and offices; and the performance of key national studies.

The results of this examination of the evolution of an NRN suggest that a number of key questions concerning an NRN remain to be answered. The key questions that remain to answered are listed below.

Key Questions

1. What do we mean by research? Is it limited to a miniscule scientific community engaged in advancing frontiers of science, or does it include supporting engineerging and development types of activities. While some have broadened research to include all of education, others expect an NRN to be more limited, especially in the near-term, in its application.

2. Who should use the network? Potential users range from the scientific researcher to the general public.

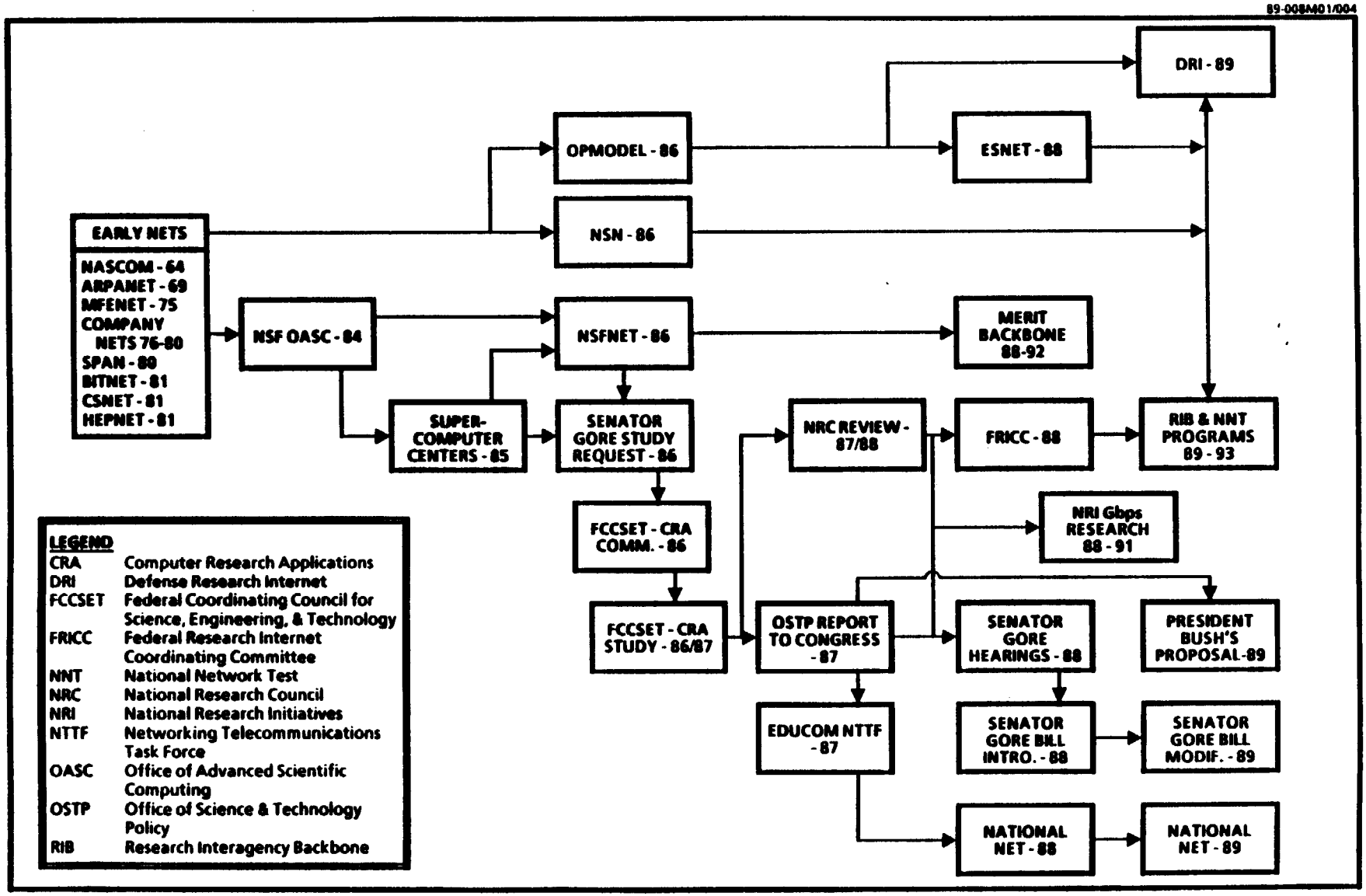


EXHIBIT 1-3. EVOLUTION OF A NATIONAL RESEARCH NETWORK (84-89)

3. Who should manage the network? Government? Academia? Not-for-profit organizations? Business/Industry? Or, some combination of these groups?

4. Who should pay for the network creation and operation? Suggestions range from treating the NRN as a government investment to a utility. Suggestions also have been made for basing payment on the stage of network development and on the user and usage.

5. What are the network needs and requirements? Will we really need to send giga bits per second (Gbps) traffic door-to-door, and if so, what requirements will this impose on the backbone network? If we need to send 1 Gbps door-to-door, will we need a backbone that supports data rates on the order of 10 to 100 Gbps?

6. How do we transition from where we are to where we need to be? What research and development steps must be taken? How do we ensure that all stakeholders are represented? What institutional changes are necessary?

7. What are the international implications? What are the implications of the sharing of ideas and resources on an international scale for our NRN requirements, our security, and our economic competitiveness? Should we work towards linking every scholar in the world with every other scholar?

1.3.1.3 Summary Of Federal Agency Network Use

All major federal agencies were contacted to identify the major computer research networks sponsored by the federal government. Based on the information obtained from the federal agencies, a brief summary of the computer networks sponsored by and/or used by these agencies was developed. Based on this review and analysis, the computer research networks to be comprehensively examined were selected.

To start this study, an initial list of federal agencies of interest was developed, and this list was reviewed to determine which agencies were

most likely to have computer research networking requirements and/or interests. Based on this review, a second list was developed of agencies expected to have such requirements and/or interests. This list, which is presented in Exhibit 1-4, includes those agencies which were actually contacted.

Information on these federal agencies' networks was collected through telephone interviews, personal interviews and analysis of existing publications and reports. For each of the agencies contacted, the following information was collected: name, address, telephone number of agency contact person; and type of networks the agency uses (i.e., those managed by and/or funded by them and those that they merely access). This information is presented in Section 5.1.

The majority of the agencies contacted have or use telecommunications networks for operational and administrative purposes. Most of these agencies do not have their own computer research network, but they usually have access to such networks when they need them.

The major computer research networks are sponsored by the following agencies: the Department of Defense (Defense Advanced Research Agency), the Department of Energy, the National Aeronautics & Space Administration, and the National Science Foundation. The National Institute of Standards And Technology (NIST) and the National Institutes of Health (NIH) are planning expansions of their computer research network capabilities. The NIST is in the process of installing its campus-area network that will interconnect with National Science Foundation Network and other research networks. The NIH has a modernization plan for direct high-speed links among its laboratories. The National Oceanic & Atmospheric Administration (NOAA) has a private network to communicate with NIST, while the Nuclear Regulatory Commission (NRC) has its own network (involving some research application) that connects its five regional offices.

Unique operational/administrative networks include those of the Department of Agriculture (DEPNET), the Federal Aviation Administration (ATDN), the Department of Interior (GEONET), the Library of Congress (LBNT), the Department of Treasury (CDN), the Department of Housing and

EXHIBIT 1-4. FEDERAL AGENCIES CONTACTED

Agriculture, Dept. of
Commerce, Dept. of
- National Institute of Standards & Technology (NIST)
- National Telecommunications & Information Administration (NTIA)
- National Oceanic & Atmospheric Administration (NOAA)

Defense, Dept. of
- Defense Advanced Research Projects Agency (DARPA)
- Defense Communications Agency (DCA)

Education, Dept. of
Energy, Dept. of
Environmental Protection Agency (EPA)
Health & Human Services, Dept of
- National Institutes of Health
- National Library of Medicine

Housing and Urban Development, Dept. of
Interior, Dept. of
- U.S. Geological Survey
- Bureau of Mines
- Office of Surface Mining Reclamation
- Fish & Wildlife Service
- Minerals Management Service

Justice, Dept. of
Library of Congress
National Academy of Sciences
National Aeronautics & Space Administration
National Science Foundation
Nuclear Regulatory Commission
Transportation, Dept. of
- U.S. Coast Guard
- Federal Aviation Administration

Treasury, Dept. of the
Veteran's Administration

Urban Development (HUDNET/HIIPS), the Veterans Administration (VADATS), the Department of Justice (SAMNET; CACN), and the Department of Commerce (connects labs and supercomputers). A number of unique, agency-specific operational/administrative networks carry research traffic to some extent such as the U.S. Geological Survey's GEONET. However, for all of these networks there is no information on the extent to which these networks are used for scientific research purposes, and there is no current effort to develop this information.

1.3.1.4 Selected Computer Research Networks

Based on the review and analysis described above and on the information obtained when examining the evolution of the NRN, a perspective on scientific research and computer research networks was developed. This perspective is depicted in Exhibits 1-5 and 1-6. In Exhibit 1-5, research is divided into "activities on ground" and "activities in space," and in both instances, the activities can be either national or international. A single scientific research effort may involve any of the possible combinations of research activities, i.e., on ground, in space, national or international. The current effort has focused primarily on national (i.e., the United States) research activities on the ground.

The types of United States computer research networks examined in this study are listed in Exhibit 1-6 and include various types of nationwide, mid-level and campus area networks. An inverted triangle is used to depict the various sizes of networks and the relationship of smaller networks to larger ones. The adjectives "smaller" and "larger" are used here to denote geographical areas rather than capacities. The smallest network, a local area network (LAN), is at the bottom of the inverted triangle, and the largest network, a national network (NN), is at the top. LANs are interconnected to form a campus area network (CAN); CANs are interconnected to form a mid-level or regional network (RN) which may serve part of a state, the entire state, or more than one state; the RNs are interconnected to form a nationwide network, which may be termed a network, an internet or a metanet, depending upon the variety of protocols used.

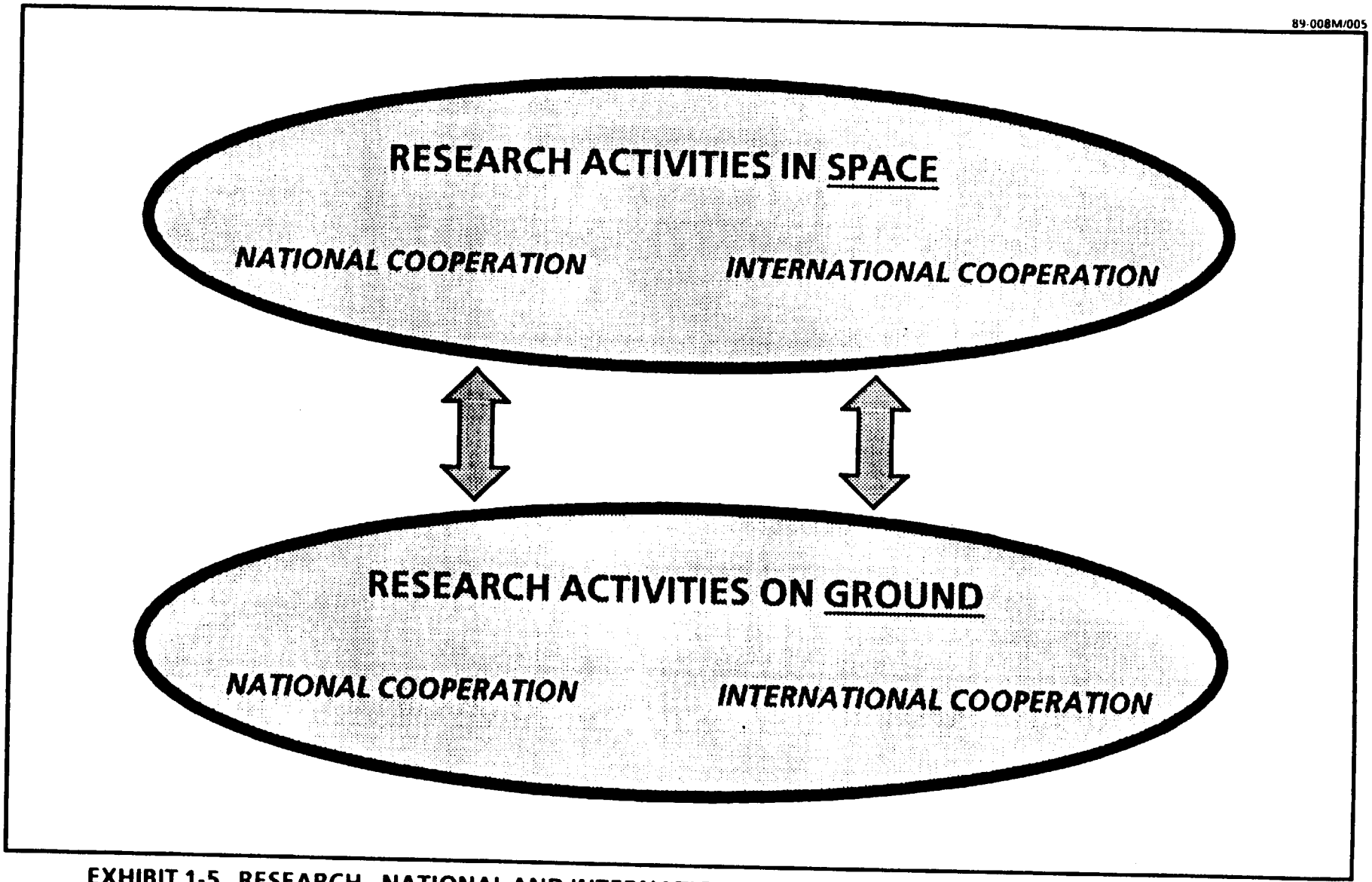


EXHIBIT 1-5. RESEARCH - NATIONAL AND INTERNATIONAL COOPERATION ON GROUND AND IN SPACE

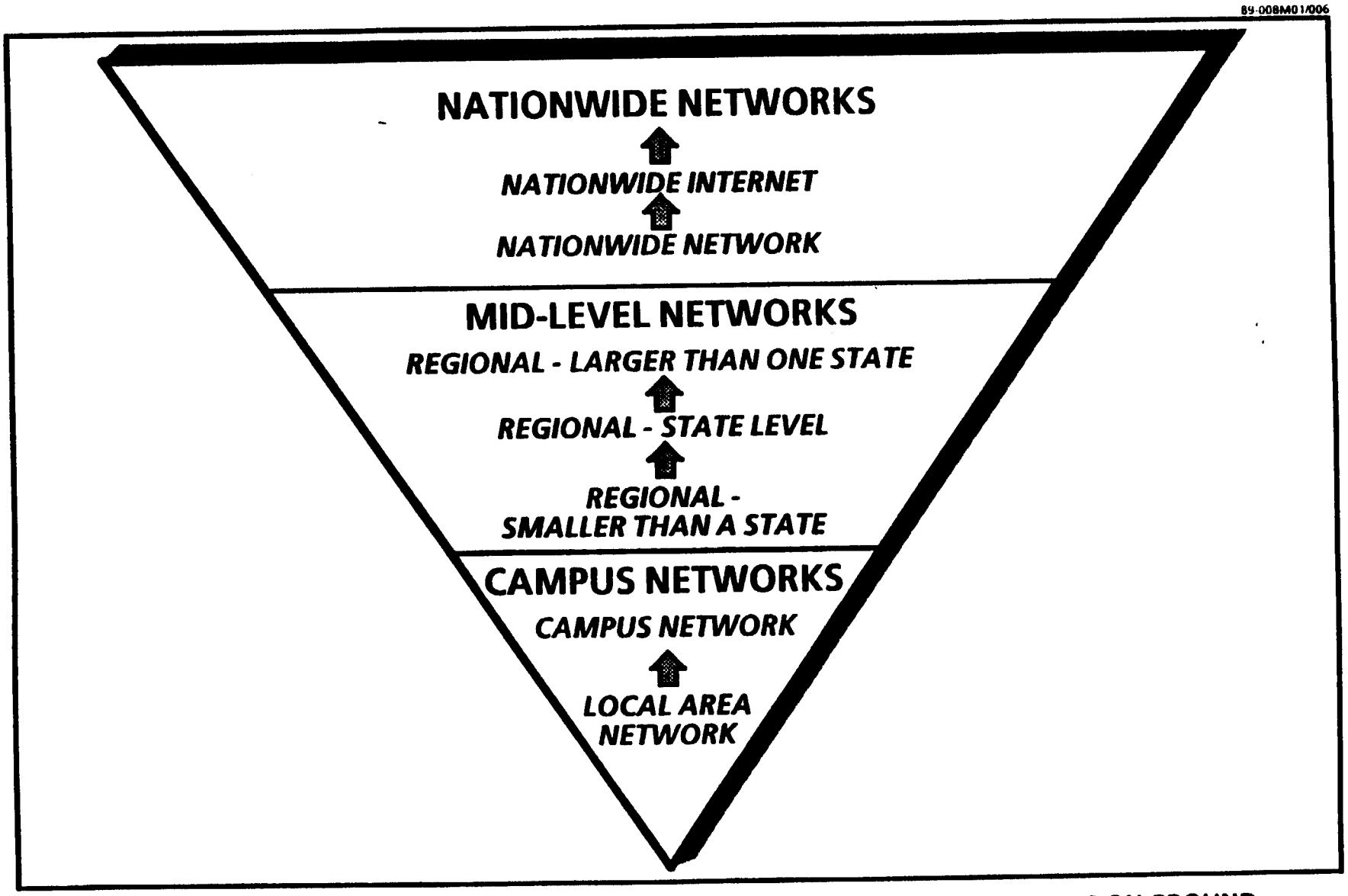


EXHIBIT 1-6. COMPUTER RESEARCH NETWORKS FOR U.S. RESEARCH ACTIVITIES ON GROUND

A "network" uses the same network layer protocols throughout; an "internet" uses several different network layer protocols but all of its constituent networks use the same internet layer protocols; and a "metanet" uses several different network and several different internet layer protocols.

Based on the perspective described above, the results of the analysis of federal agencies' network use, and the information obtained when describing the evolution of the NRN, the following networks were selected for comprehensive examination in this study:

1. Department of Defense (DoD) research networks: Advanced Research Projects Agency (ARPANET), Defense Research Internet (DRI).

2. National Science Foundation Network (NSFNET): three level network including a national backbone, twenty-one mid-level networks, and over 250 campus networks.

3. National Aeronautics and Space Administration (NASA) networks: NASA Science Internet (NSI), NASA Science Network (NSN), Space Physics Analysis Network (SPAN), Numerical Aerodynamics Simulation Network (NASNET), and NASA Communications (NASCOM).

4. Department of Energy research networks: Energy Science Network (ESNET), Magnetic Fusion Energy Network (MFENET), High Energy Physics Network (HEPNET), LEP3NET (A Cern accelerator experiment network), and OPMODEL (An advanced satellite network).

5. BITNET (Because Its Time Network) and CSNET (Computer + Science Network). BITNET and CSNET were included because so many researchers and scientist use these networks.

The results of the examinations of these networks (also outlined in Exhibit 1-7) were used to develop the comprehensive network summaries which are presented in Sections 6-10. These summaries, which were developed using the model outlined in Exhibit 1-2, include the following topics in the following order: history, type of network, purpose and

EXHIBIT 1-7. NETWORKS SELECTED

1. Department of Defense (DOD) research networks:
   - Advanced Research Projects Agency Network (ARPANET)
   - Defense Research Internet (DRI)

2. National Science Foundation Network (NSFNET) - Three level network:
   - National backbone
   - Twenty-one mid-level networks
     - Thirteen Original Backbone and Regional Networks:
       - NORTHWESTNET, BARRNET, SDSCNET, WESTNET, USAN, MIDNET, SESQUINET, NCSNET, MERIT, PSCNET, NYSERNET, JVNCNET, SURANET.
     - Eight New Regional Network:
       - CERFNET, CICNET, LOS NETTOS, MRNET, NEARNET, OARNET, PREPNET, THENET.
   - Over 250 campus networks

3. National Aeronautics & Space Administration (NASA) research networks:
   - NASA Science Internet (NSI)
   - NASA Science Network (NSN)
   - Space Physics Analysis Network (SPAN)
   - Numerical Aerodynamics Simulation Network (NASNET)
   - NASA Communications (NASCOM)

4. Department of Energy (DOE) research networks:
   - Energy Science Network (ESNET)
   - Magnetic Fusion Energy Network (MFENET)
   - High Energy Physics Network (HEPNET)
   - LEP3NET (A Cern Accelerator Experiment Network)
   - OPMODEL

5. BITNET (Because Its Time Network) and
   CSNET (Computer + Science Network)

services, extent and size, topology, computers, media and link speeds, protocols, administration, funding and future.

As a group these selected networks, described in subsequent sections of this report, serve researchers across the United States and have worldwide connections. Individually, these networks are in different states of development (i.e., from initial operation to being replaced), and vary, for example, in size, capacity, protocols and services. The information on these comprehensively examined networks provided, in subsequent subtasks, the data base for sizing a current and projecting a future composite integrated computer research network.

1.3.2 Major Findings: Subtask 2.3 - Current IRN

The major findings obtained from the activities conducted to size the current integrated computer research network are presented in terms of the following: the major access points and their V & H coordinates; the Current IRN links; and the Current IRN topology. These results are presented below and discussed in detail in Section 11.

1.3.2.1 Major Access Points

The major access points for the Current IRN are listed with their state and V & H coordinates in Exhibit 1-8. These access points are: Albuquerque, Austin, Boston, Boulder, Chicago, Cleveland, Columbus, Dallas, Detroit, Houston, Huntsville, Indianapolis, Iowa City, Ithaca, Kansas City, Kennedy Space Center, Lincoln, Livermore, Los Angeles, Madison, Miama, Minneapolis, New York, Norfolk, Oak Ridge, Philadelphia, Pittsburgh, Portland, Princeton, Salt Lake City, San Diego, San Francisco, Seattle, Sate College, Tallahassee, Tucson, Urbana, Wallops Island, Washington, and White Sands.

1.3.2.2 Current IRN Links

The links between pairs of the major access points listed above and the capacity of these links are listed in Exhibit 1-9. For City A and City B the following information is presented: city ID (i.e., major

KEY	CITY	STATE	V	H
AB	ALBUQUERQUE	NM	8549	5887
AU	AUSTIN	TX	9005	3996
BO	BOSTON	MA	4422	1249
BD	BOULDER	CO	7456	5961
CH	CHICAGO	IL	5986	3426
CL	CLEVELAND	OH	5574	2543
CB	COLUMBUS	OH	5972	2555
DL	DALLAS	TX	8436	4034
DT	DETROIT	MI	5536	2828
HU	HOUSTON	TX	8938	3536
HN	HUNTSVILLE	AL	7267	2535
IN	INDIANAPOLIS	IN	6272	2992
IO	IOWA CITY	IA	6315	3971
IT	ITHACA	NY	4798	1990
KS	KANSAS CITY	MO	7249	4210
KN	KENNEDY SPC CTR	FL	7919	0880
LI	LINCOLN	NE	6823	4674
LL	LIVERMORE	CA	8504	8606
LA	LOS ANGELES	CA	9213	7878
MD	MADISON	WI	5890	3798
MI	MIAMI	FL	8351	0527
MP	MINNEAPOLIS	MN	5781	4525
NY	NEW YORK	NY	4997	1406
NF	NORFOLK	VA	5936	1198
OR	OAK RIDGE	TN	6811	2303
PH	PHILADELPHIA	PA	5251	1458
PT	PITTSBURGH	PA	5621	2185
PO	PORTLAND	OR	6799	8914
PR	PRINCETON	NJ	5120	1436
SL	SALT LAKE	UT	7576	7065
SD	SAN DIEGO	CA	9468	7629
SF	SAN FRANCISCO	CA	8492	8719
SE	SEATTLE	WA	6336	8896
SC	STATE COLLEGE	PA	5360	1933
TL	TALLAHASEE	FL	7876	1715
TU	TUCSON	AZ	9342	6480
IL	URBANA	IL	6371	3336
WI	WALLOPS ISLAND	VA	5657	1249
DC	WASHINGTON	DC	5622	1583
WS	WHITE SANDS	NM	9132	5742

EXHIBIT 1-8. Major Access Points

CURRENT IRN TRAFFIC LINKS - SORT CITY - A ID

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1544
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56
AB	LOS ALAMOS	NM	AU	AUSTIN	TX	56
AB	LOS ALAMOS	NM	KS	LAWRENCE	KS	56
AB	LOS ALAMOS	NM	BD	BOULDER	CO	56
AU	AUSTIN	TX	DL	RICHARDSON	TX	1544
BD	BOULDER	CO	MD	MADISON	WI	224
BD	BOULDER	CO	DC	WASHINGTON	DC	224
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	56
BD	BOULDER	CO	DC	WASHINGTON	DC	224
BD	BOULDER	CO	BO	WOODS HOLE	MA	224
BD	BOULDER	CO	MI	MIAMI	FL	224
BD	BOULDER	CO	TU	TUCSON	AZ	56
BD	BOULDER	CO	DT	ANN ARBOR	MI	224
BD	BOULDER	CO	PO	CORVALIS	OR	1544
BD	BOULDER	CO	PO	CORVALLIS	OR	224
BD	DENVER	CO	LA	LOS ANGELES	CA	1544
BO	BOSTON	MA	NY	NEW YORK	NY	1544
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	1544
CH	CHICAGO	IL	SE	SEATTLE	WA	1544
CH	CHICAGO	IL	DT	LANSING	MI	1544
CH	CHICAGO	IL	DT	LITCHFIELD	MI	1544
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	56
CH	CHICAGO	IL	MD	MADISON	WI	1544
CH	CHICAGO	IL	BD	DENVER	CO	1544
CH	CHICAGO	IL	TL	TALLAHASSEE	FL	56
CH	CHICAGO	IL	IL	URBANA	IL	1544
CH	CHICAGO	IL	LI	LINCOLN	NE	1544
CH	CHICAGO	IL	BO	CAMBRIDGE	MA	1544
DC	WASHINGTON	DC	NY	NEW YORK	NY	1544
DC	WASHINGTON	DC	AB	ALBUQUERQUE	NM	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1544
DC	WASHINGTON	DC	CL	CLEVELAND	OH	112
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	168
DC	WASHINGTON	DC	LA	LOS ANGELES	CA	56
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	224
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	56
DC	WASHINGTON	DC	LA	BARSTOW	CA	224

EXHIBIT 1-9. Current IRN Links & Capacity

DC	WASHINGTON	DC	LA	BARSTOW	CA	56
DC	WASHINGTON	DC	BO	CAMBRIDGE	MA	56
DC	WASHINGTON	DC	PR	PRINCETON	NJ	1544
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	1544
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	112
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	224
DC	WASHINGTON	DC	HU	HOUSTON	TX	1544
DC	WASHINGTON	DC	LA	PASADENA	CA	448
DC	WASHINGTON	DC	LA	PASADENA	CA	280
DC	WASHINGTON	DC	LA	LOMPOC	CA	224
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	1544
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	672
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	512
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	2048
DC	WASHINGTON	DC	PH	WILMINGTON	DE	56
DC	WASHINGTON	DC	NF	NORFOLK	VA	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	280
DC	WASHINGTON	DC	NY	NEW YORK	NY	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56
DL	RICHARDSON	TX	TL	TALLAHASSEE	FL	1544
DT	ANN ARBOR	MI	CB	COLUMBUS	OH	1544
DT	ANN ARBOR	MI	PR	PRINCETON	NJ	1544
HN	HUNTSVILLE	AL	KN	CAPE KENNEDY	FL	2048
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	168
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	672
HN	HUNTSVILLE	AL	KN	ORLANDO	FL	56
HN	HUNTSVILLE	AL	MI	MIAMI	FL	56
HU	BRYAN	TX	AU	AUSTIN	TX	1544
HU	HOUSTON	TX	DL	DALLAS	TX	56
HU	HOUSTON	TX	HN	HUNTSVILLE	AL	56
HU	HOUSTON	TX	WS	WHITE SANDS	NM	56
HU	HOUSTON	TX	AU	AUSTIN	TX	1544
HU	HOUSTON	TX	AU	AUSTIN	TX	56
HU	HOUSTON	TX	BD	BOULDER	CO	1544
HU	HOUSTON	TX	AU	AUSTIN	TX	56
HU	HOUSTON	TX	KN	CAPE KENNEDY	FL	1544
IL	URBANA	IL	CH	CHICAGO	IL	1544
IL	URBANA	IL	IN	BLOOMINGTON	IN	1544
IL	URBANA	IL	MD	MILWAUKEE	WI	56
IN	INDIANAPOLIS	IN	CB	COLUMBUS	OH	1544
IO	IOWA CITY	IA	IL	URBANA	IL	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	DC	WASHINGTON	DC	1544
IT	ITHACA	NY	PT	PITTSBURGH	PA	1544
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	56
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	1544
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	1544
LA	LOS ANGELES	CA	AB	LOS ALAMOS	NM	1544
LA	LOS ANGELES	CA	HN	HUNTSVILLE	AL	56

EXHIBIT 1-9. Current IRN Links & Capacity

(Continued)

LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	1544
LA	LOS ANGELES	CA	HU	HOUSTON	TX	56
LA	LOS ANGELES	CA	BD	BOULDER	CO	56
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544
LA	LOS ANGELESO	CA	SF	SAN FRANCISCO	CA	1544
LA	PASADENA	CA	TU	TUCSON	AZ	56
LA	PASADENA	CA	DC	BALTIMORE	MD	56
LA	PASADENA	CA	HU	HOUSTON ISLAND	TX	168
LA	PASADENA	CA	DC	WASHINGTON	DC	672
LI	LINCOLN	NE	IL	URBANA	IL	56
LI	LINCOLN	NE	KS	LAWRENCE	KS	56
LI	LINCOLN	NE	IO	IOWA CITY	IA	56
LI	LINCOLN	NE	BD	BOULDER	CO	1544
LL	LIVERMORE	CA	SF	OAKLAND	CA	56
LL	LIVERMORE	CA	PR	PRINCETON	NJ	1544
LL	LIVERMORE	CA	LA	LOS ANGELES	CA	56
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	1544
MP	MINNEAPOLIS	MN	IO	IOWA CITY	IA	1544
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1544
NF	NORFOLK	VA	TL	TALLAHASSEE	FL	1544
NY	LONG ISLAND	NY	BO	CAMBRIDGE	MA	1544
NY	NEW YORK	NY	IT	ROME	NY	1544
OR	OAK RIDGE	TN	CH	CHICAGO	IL	1544
OR	OAK RIDGE	TN	TL	TALLAHASSEE	FL	1544
PR	PRINCETON	NJ	TU	TUCSON	AZ	1544
PR	PRINCETON	NJ	NF	NORFOLK VA	DC	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	CH	CHICAGO	IL	1544
PR	PRINCETON	NJ	NY	LONG ISLAND	NY	1544
PR	PRINCETON	NJ	BD	BOLDER	CO	1544
PR	PRINCETON	NJ	SC	STATE COLLEGE	PA	1544
PR	PRINCETON	NJ	PH	PHILADELPHIA	PA	1544
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	BO	NEW HAVEN	CT	1544
PR	PRINCETON	NJ	BO	AMHERST	MA	1544
PT	PITTSBURGH	PA	SC	STATE COLLEGE	PA	1544
PT	PITTSBURGH	PA	PR	PRINCETON	NJ	1544
PT	PITTSBURGH	PA	IL	URBANA	IL	1544
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1544
PT	PITTSBURGH	PA	PH	PHILADELPHIA	PA	1544
PT	PITTSBURGH	PA	DC	WASHINGTON	DC	1544
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	LA	RIVERSIDE	CA	56
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	HU	HOUSTON	TX	1544
SD	SAN DIEGO	CA	SF	MENLO PARK	CA	1544
SD	SAN DIEGO	CA	LA	SANTA BARBARA	CA	56

EXHIBIT 1-9. Current IRN Links & Capacity

(Continued)

SD	SAN DIEGO	CA	SE	SEATTLE	WA	56
SD	SAN DIEGO	CA	SF	OAKLAND	CA	56
SD	SAN DIEGO	CA	LA	IRVINE	CA	56
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56
SE	SEATTLE	WA	SD	SAN DIEGO	CA	1544
SE	SEATTLE	WA	SF	MENLO PARK	CA	1544
SE	SEATTLE	WA	PO	PORTLAND	OR	56
SE	SEATTLE	WA	PO	CORVALLIS	OR	56
SE	SEATTLE	WA	PO	EUGENE	OR	56
SF	SAN FRANCISCO	CA	LA	PASADENA	CA	448
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1544
SF	SAN FRANCISCO	CA	BD	BOULDER	CO	56
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	336
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	56
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	56
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	1544
SL	SALT LAKE CITY	UT	SF	MENLO PARK	CA	1544
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	1544
SL	SALT LAKE CITY	UT	CH	CHICAGO	IL	1544
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	1544
WI	WALLOPS ISLAND	VA	MD	MADISON	WI	224
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	224
sum						146824

EXHIBIT 1-9. Current IRN Links & Capacity

(Continued)

access point name), city name, city state, and link speed (i.e., capacity).

1.3.2.3 Current IRN Topology

The Current IRN topology, based on these major access point links, is depicted in Exhibits 1-10. Exhibit 1-10 depicts the major access point T1 connectivity in the Current IRN. The numbers for the various links represent the number of T1s required for the various links. A total of 187 T1s were estimated to be required for the Current IRN.

1.3.3 Major Findings: Subtask 2.4 - Future IRN

The major findings obtained from the activities conducted to size the future integrated computer research network are presented in terms of the IRN city A and city B links and capacities for the future benchmark years and the topology maps showing major access point connectivity for each of the future benchmark years. These results are presented below and discussed in detail in Section 12.

1.3.3.1 1991 IRN Links And Topology

The 1991 IRN links are listed in Exhibit 1-11. The names of the 1991 links are identical to the Current IRN links that were presented in Exhibit 1-9. Again, the ID (i.e., major access point identification), name and state for City A and for City B and the capacity for each City A/City B link are listed. The major change from the Current IRN to the 1991 IRN was the increase in capacity from T1 to T3 on some links. It was assumed that the NSFNET Backbone capacity would increase from T1 to T3 by 1991, and this expected increase was reflected in the 1991 IRN backbone.

The 1991 IRN Topology is depicted in Exhibit 1-12. The 1991 connectivity has not changed from the Current (i.e., 1989) connectivity, but the capacity of the IRN backbone has. Much of the 1991 IRN backbone is projected to have T3 capacity in 1991.

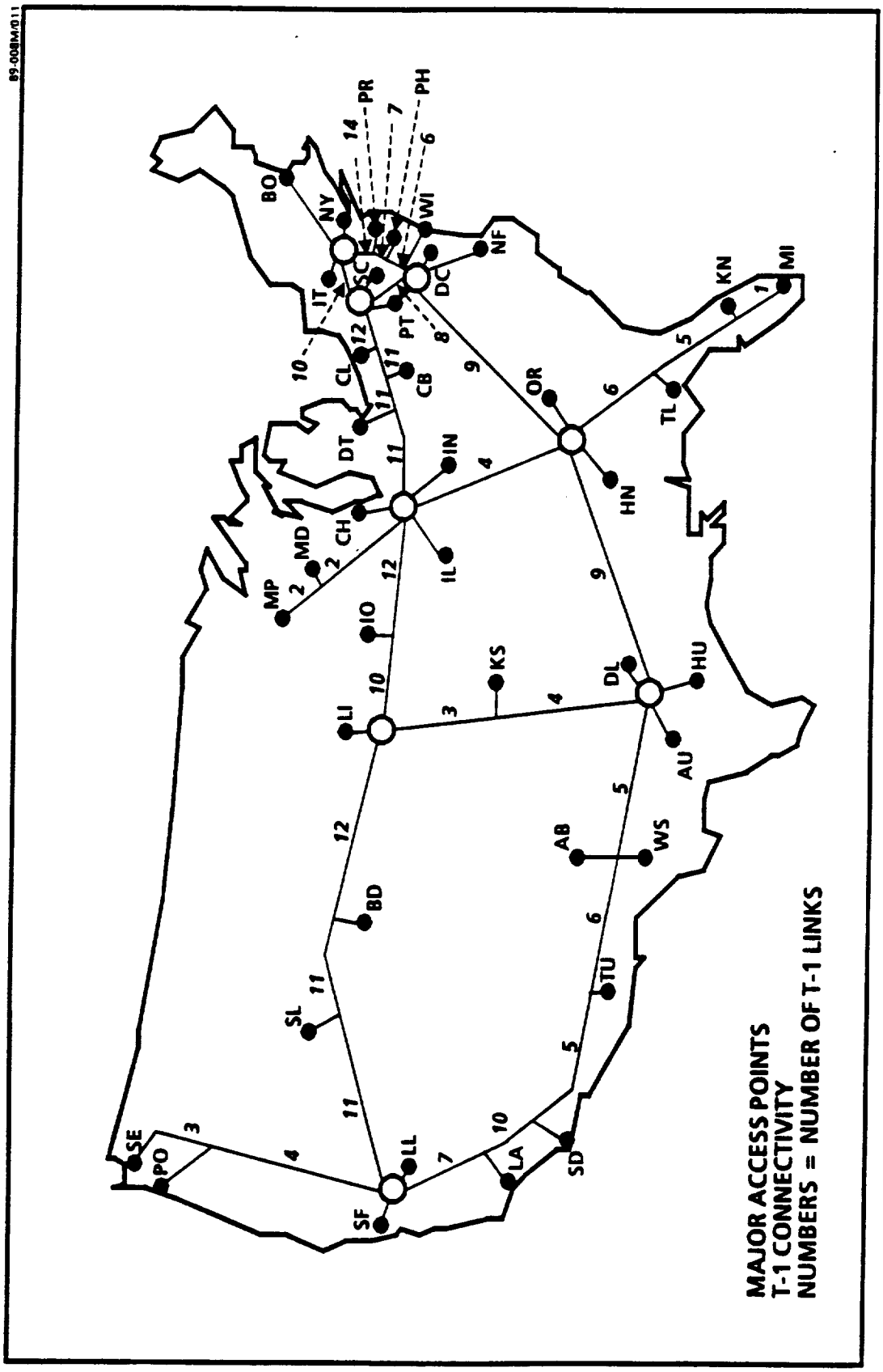


EXHIBIT 1-10. Current IRN Topology

1991 IRN LINKS

ID	CITY - A	ST	ID	CITY	ST	CAPACITY (KB)
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1544
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56
AB	LOS ALAMOS	NM	AU	AUSTIN	TX	56
AB	LOS ALAMOS	NM	KS	LAWRENCE	KS	56
AB	LOS ALAMOS	NM	BD	BOULDER	CO	56
AU	AUSTIN	TX	DL	RICHARDSON	TX	1544
BD	BOULDER	CO	MD	MADISON	WI	224
BD	BOULDER	CO	DC	WASHINGTON	DC	224
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	56
BD	BOULDER	CO	DC	WASHINGTON	DC	224
BD	BOULDER	CO	BO	WOODS HOLE	MA	224
BD	BOULDER	CO	MI	MIAMI	FL	224
BD	BOULDER	CO	TU	TUCSON	AZ	56
BD	BOULDER	CO	DT	ANN ARBOR	MI	224
BD	BOULDER	CO	PO	CORVALIS	OR	1544
BD	BOULDER	CO	PO	CORVALLIS	OR	224
BD	DENVER	CO	LA	LOS ANGELES	CA	1544
BO	BOSTON	MA	NY	NEW YORK	NY	1544
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	1544
CH	CHICAGO	IL	SE	SEATTLE	WA	44M
CH	CHICAGO	IL	DT	LANSING	MI	1544
CH	CHICAGO	IL	DT	LITCHFIELD	MI	1544
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	56
CH	CHICAGO	IL	MD	MADISON	WI	1544
CH	CHICAGO	IL	BD	DENVER	CO	44M
CH	CHICAGO	IL	TL	TALLAHASSEE	FL	56
CH	CHICAGO	IL	IL	URBANA	IL	1544
CH	CHICAGO	IL	LI	LINCOLN	NE	44M
CH	CHICAGO	IL	BO	CAMBRIDGE	MA	1544
DC	WASHINGTON	DC	NY	NEW YORK	NY	1544
DC	WASHINGTON	DC	AB	ALBUQUERQUE	NM	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1544
DC	WASHINGTON	DC	CL	CLEVELAND	OH	112
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	168
DC	WASHINGTON	DC	LA	LOS ANGELES	CA	56
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	224
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	56
DC	WASHINGTON	DC	LA	BARSTOW	CA	224

EXHIBIT 1-11. 1991 IRN Links & Capacity

DC	WASHINGTON	DC	LA	BARSTOW	CA	56
DC	WASHINGTON	DC	BO	CAMBRIDGE	MA	56
DC	WASHINGTON	DC	PR	PRINCETON	NJ	44M
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	1544
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	112
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	224
DC	WASHINGTON	DC	HU	HOUSTON	TX	44M
DC	WASHINGTON	DC	LA	PASADENA	CA	448
DC	WASHINGTON	DC	LA	PASADENA	CA	280
DC	WASHINGTON	DC	LA	LOMPOC	CA	224
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	1544
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	672
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	512
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	2048
DC	WASHINGTON	DC	PH	WILMINGTON	DE	56
DC	WASHINGTON	DC	NF	NORFOLK	VA	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	280
DC	WASHINGTON	DC	NY	NEW YORK	NY	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56
DL	RICHARDSON	TX	TL	TALLAHASSEE	FL	1544
DT	ANN ARBOR	MI	CB	COLUMBUS	OH	1544
DT	ANN ARBOR	MI	PR	PRINCETON	NJ	44M
HN	HUNTSVILLE	AL	KN	CAPE KENNEDY	FL	2048
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	168
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	672
HN	HUNTSVILLE	AL	KN	ORLANDO	FL	56
HN	HUNTSVILLE	AL	MI	MIAMI	FL	56
HU	BRYAN	TX	AU	AUSTIN	TX	1544
HU	HOUSTON	TX	DL	DALLAS	TX	56
HU	HOUSTON	TX	HN	HUNTSVILLE	AL	56
HU	HOUSTON	TX	WS	WHITE SANDS	NM	56
HU	HOUSTON	TX	AU	AUSTIN	TX	1544
HU	HOUSTON	TX	AU	AUSTIN	TX	56
HU	HOUSTON	TX	BD	BOULDER	CO	44M
HU	HOUSTON	TX	AU	AUSTIN	TX	56
HU	HOUSTON	TX	KN	CAPE KENNEDY	FL	1544
IL	URBANA	IL	CH	CHICAGO	IL	1544
IL	URBANA	IL	IN	BLOOMINGTON	IN	1544
IL	URBANA	IL	MD	MILWAUKEE	WI	56
IN	INDIANAPOLIS	IN	CB	COLUMBUS	OH	1544
IO	IOWA CITY	IA	IL	URBANA	IL	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	DC	WASHINGTON	DC	44M
IT	ITHACA	NY	PT	PITTSBURGH	PA	44M
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	56
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	1544
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	1544
LA	LOS ANGELES	CA	AB	LOS ALAMOS	NM	1544
LA	LOS ANGELES	CA	HN	HUNTSVILLE	AL	56

EXHIBIT 1-11. 1991 IRN Links & Capacity

(Contined)

LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	1544
LA	LOS ANGELES	CA	HU	HOUSTON	TX	56
LA	LOS ANGELES	CA	BD	BOULDER	CO	56
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544
LA	LOS ANGELESO	CA	SF	SAN FRANCISCO	CA	1544
LA	PASADENA	CA	TU	TUCSON	AZ	56
LA	PASADENA	CA	DC	BALTIMORE	MD	56
LA	PASADENA	CA	HU	HOUSTON ISLAND	TX	168
LA	PASADENA	CA	DC	WASHINGTON	DC	672
LI	LINCOLN	NE	IL	URBANA	IL	56
LI	LINCOLN	NE	KS	LAWRENCE	KS	56
LI	LINCOLN	NE	IO	IOWA CITY	IA	56
LI	LINCOLN	NE	BD	BOULDER	CO	44M
LL	LIVERMORE	CA	SF	OAKLAND	CA	56
LL	LIVERMORE	CA	PR	PRINCETON	NJ	1544
LL	LIVERMORE	CA	LA	LOS ANGELES	CA	56
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	1544
MP	MINNEAPOLIS	MN	IO	IOWA CITY	IA	1544
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1544
NF	NORFOLK	VA	TL	TALLAHASSEE	FL	1544
NY	LONG ISLAND	NY	BO	CAMBRIDGE	MA	1544
NY	NEW YORK	NY	IT	ROME	NY	1544
OR	OAK RIDGE	TN	CH	CHICAGO	IL	1544
OR	OAK RIDGE	TN	TL	TALLAHASSEE	FL	1544
PR	PRINCETON	NJ	TU	TUCSON	AZ	1544
PR	PRINCETON	NJ	NF	NORFOLK VA	DC	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	CH	CHICAGO	IL	1544
PR	PRINCETON	NJ	NY	LONG ISLAND	NY	1544
PR	PRINCETON	NJ	BD	BOLDER	CO	1544
PR	PRINCETON	NJ	SC	STATE COLLEGE	PA	1544
PR	PRINCETON	NJ	PH	PHILADELPHIA	PA	1544
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	BO	NEW HAVEN	CT	1544
PR	PRINCETON	NJ	BO	AMHERST	MA	1544
PT	PITTSBURGH	PA	SC	STATE COLLEGE	PA	1544
PT	PITTSBURGH	PA	PR	PRINCETON	NJ	44M
PT	PITTSBURGH	PA	IL	URBANA	IL	44M
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1544
PT	PITTSBURGH	PA	PH	PHILADELPHIA	PA	1544
PT	PITTSBURGH	PA	DC	WASHINGTON	DC	1544
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	LA	RIVERSIDE	CA	56
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	HU	HOUSTON	TX	44M
SD	SAN DIEGO	CA	SF	MENLO PARK	CA	44M
SD	SAN DIEGO	CA	LA	SANTA BARBARA	CA	56

EXHIBIT 1-11. 1991 IRN Links & Capacity

(Contined)

SD	SAN DIEGO	CA	SE	SEATTLE	WA	56
SD	SAN DIEGO	CA	SF	OAKLAND	CA	56
SD	SAN DIEGO	CA	LA	IRVINE	CA	56
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56
SE	SEATTLE	WA	SD	SAN DIEGO	CA	44M
SE	SEATTLE	WA	SF	MENLO PARK	CA	44M
SE	SEATTLE	WA	PO	PORTLAND	OR	56
SE	SEATTLE	WA	PO	CORVALLIS	OR	56
SE	SEATTLE	WA	PO	EUGENE	OR	56
SF	SAN FRANCISCO	CA	LA	PASADENA	CA	448
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1544
SF	SAN FRANCISCO	CA	BD	BOULDER	CO	56
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	336
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	56
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	56
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	1544
SL	SALT LAKE CITY	UT	SF	MENLO PARK	CA	44M
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	44M
SL	SALT LAKE CITY	UT	CH	CHICAGO	IL	44M
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	1544
WI	WALLOPS ISLAND	VA	MD	MADISON	WI	224
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	224
sum						

EXHIBIT 1-11. 1991 IRN Links & Capacity

(Contined)

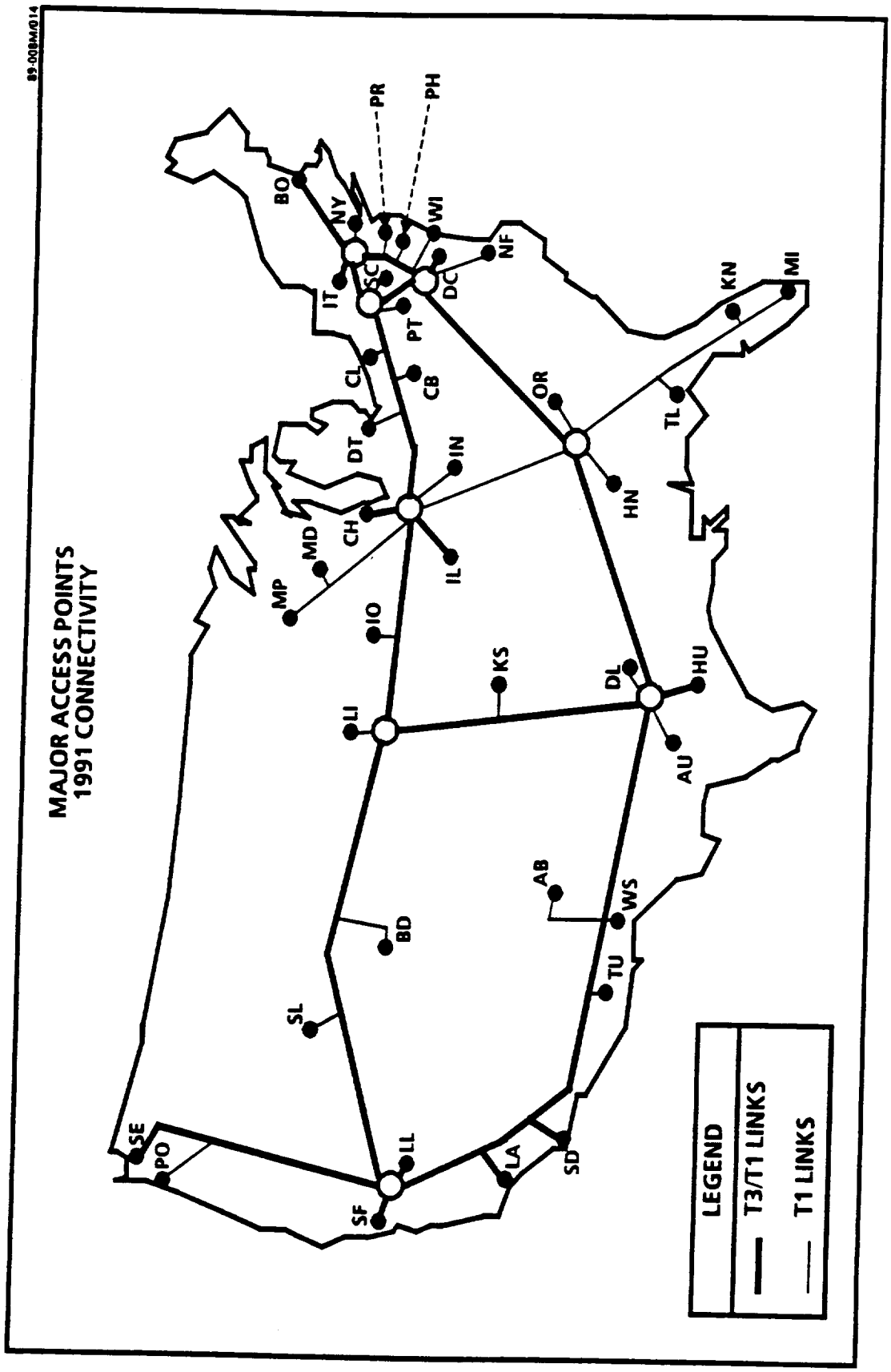


EXHIBIT 1-12. 1991 IRN Topology

1.3.3.2 1996 IRN Links And Topology

For the 1996 IRN, ten new major access points were added, making a total of fifty major access points. These fifty major access points are listed in Exhibit 1-13. The ten new major access points are: Atlanta, Billings, Cheyenne, Columbus, Columbia, Fargo, Helena, Jacksonville, New Orleans, Raleigh and St Louis.

The 1996 IRN links are listed in Exhibit 1-14. As with the Current and 1991 IRN link lists, the ID (i.e., major access point identification), name and state for City A and for City B and the capacity for each City A/City B link are listed. However, even though the number of major access points has increased by ten, the number of links listed has decreased from 177 links in 1991 to 53 links in 1996. This is because only direct links are listed for 1996. For example, in 1996 there are only two links from Seattle (Seattle to Helena and Seattle to San Francisco), while in 1991 there were five. This change in procedure for listing links was made because the 1996 IRN was assumed to be a truly single integrated network, while the 1991 and Current (1989) IRNs were assumed to be composites of many networks with several individual links.

The 1996 IRN topology is depicted in Exhibit 1-15. For the 1996 IRN, the 1991 IRN backbone still exists but its capacity has been increased. Also, the ten new major access points have been connected to this 1991 backbone. The following increases in capacity have been made:

1. Some of the 1991 T3 links have been increased to 1 Gbps links.
2. Some of the 1991 T3 links have been increased to 564/274 Mbps links.
3. All 1991 T1 links have been increased to 564/274 Mbps links.
4. The capacity of each of the links added to connect the ten new major access points was either 90 Mbps or 45 Mbps.

1.3.3.3 2000 IRN Links And Topology

The 2000 IRN links are listed in Exhibit 1-16. The major access points and connectivity for the 2000 IRN are identical to those for the 1996 IRN. The only changes that were made were in the link capacities.

KEY	CITY	STATE	V	H
AB	ALBUQUERQUE	NM	8549	5887
AT	ATLANTA	GA	7243	2092
AU	AUSTIN	TX	9005	3996
BI	BILLINGS	MT	6390	679C
BO	BOSTON	MA	4422	1249
BD	BOULDER	CO	7456	5961
CY	CHEYENNE	WY	7204	5958
CH	CHICAGO	IL	5986	3426
CL	CLEVELAND	OH	5574	2543
CO	COLUMBIA	SC	6902	1587
CB	COLUMBUS	OH	5972	2555
DL	DALLAS	TX	8436	4034
DT	DETROIT	MI	5536	2828
FR	FARGO	ND	5614	5181
HE	HELENA	MT	6339	735C
HU	HOUSTON	TX	8938	3536
HN	HUNTSVILLE	AL	7267	2535
IN	INDIANAPOLIS	IN	6272	2992
IO	IOWA CITY	IA	6315	3971
IT	ITHACA	NY	4798	199C
JK	JACKSONVILLE	FL	7642	1276
KS	KANSAS CITY	MO	7249	4210
KN	KENNEDY SPC CTR	FL	7919	0880
LI	LINCOLN	NE	6823	4674
LL	LIVERMORE	CA	8504	8606
LA	LOS ANGELES	CA	9213	7878
MD	MADISON	WI	5890	3798
MI	MIAMI	FL	8351	0527
MP	MINNEAPOLIS	MN	5781	4525
NO	NEW ORLEANS	LA	8484	2631
NY	NEW YORK	NY	4997	1406
NF	NORFOLK	VA	5936	1198
OR	OAK RIDGE	TN	6811	2303
PH	PHILADELPHIA	PA	5251	1458
PT	PITTSBURGH	PA	5621	2185
PO	PORTLAND	OR	6799	8914
PR	PRINCETON	NJ	5120	1436
RL	RALEIGH	NC	6344	1434
SL	SALT LAKE	UT	7576	7065
SD	SAN DIEGO	CA	9468	7629
SF	SAN FRANCISCO	CA	8492	8719
SE	SEATTLE	WA	6336	8896
ST	ST LOUIS	MO	6807	3483
SC	STATE COLLEGE	PA	5360	1933
TL	TALLAHASEE	FL	7876	1715
TU	TUCSON	AZ	9342	648C
IL	URBANA	IL	6371	3336
WI	WALLOPS ISLAND	VA	5657	1249
DC	WASHINGTON	DC	5622	1583
WS	WHITE SANDS	NM	9132	5742

EXHIBIT 1-13. 1996 IRN Major Access Points

1996 IRN LINKS

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	565M
AT	ATLANTA	GA	CO	COLUMBIA	SC	90M
AT	ATLANTA	GA	TL	TALLAHASEE	FL	90M
AU	AUSTIN	TX	DL	DALLAS	TX	90M
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	90M
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	1G
BI	BILLINGS	MT	CY	CHEYENNE	WY	90M
BI	BILLINGS	MT	FR	FARGO	ND	90M
BO	BOSTON	MA	NY	NEW YORK	NY	1G
CB	COLUMBUS	OH	DT	DETROIT	MI	90M
CH	CHICAGO	IL	IL	URBANA	IL	1G
CH	CHICAGO	IL	OR	OAK RIDGE	TN	565M
CH	CHICAGO	IL	LI	LINCOLN	NE	1G
CH	CHICAGO	IL	DT	DETROIT	MI	90M
CH	CHICAGO	IL	ST	ST LOUIS	MO	90M
CL	CLEVELAND	OH	CB	COLUMBUS	OH	90M
CO	COLUMBIA	SC	RL	RALEIGH	NC	90M
CY	CHEYENNE	WY	BD	BOULDER	CO	90M
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	1G
DC	WASHINGTON	DC	NF	NORFOLK	VA	565M
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	90M
FR	FARGO	ND	MP	MINNEAPOLIS	MN	90M
HE	HELENA	MT	BI	BILLINGS	MT	90M
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	90M
HU	HOUSTON	TX	OR	OAK RIDGE	TN	565M
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	90M
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	90M
IT	ITHACA	NY	NY	NEW YORK	NY	1G
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	90M
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1G
LI	LINCOLN	NE	HU	HOUSTON	TX	1G
LI	LINCOLN	NE	BD	BOULDER	CO	1G
LI	LINCOLN	NE	IO	IOWA CITY	IA	90M
MD	MADISON	WI	CH	CHICAGO	IL	565M
MP	MINNEAPOLIS	MN	MD	MADISON	WI	565M
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	90M
NY	NEW YORK	NY	DC	WASHINGTON	DC	1G
NY	NEW YORK	NY	PT	PITTSBURGH	PA	1G
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	565M
PO	PORTLAND	OR	SE	SEATTLE	WA	90M
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	90M
PT	PITTSBURGH	PA	CH	CHICAGO	IL	1G
RL	RALEIGH	NC	NF	NORFOLK	VA	90M
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	90M
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	565M
SE	SEATTLE	WA	HE	HELENA	MT	90M
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	565M
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1G
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	1G
SL	SALT LAKE	UT	BD	BOULDER	CO	90M
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	90M
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	565M
TU	TUCSON	AZ	WS	WHITE SANDS	NM	90M

EXHIBIT 1-14. 1996 IRN Links & Capacity

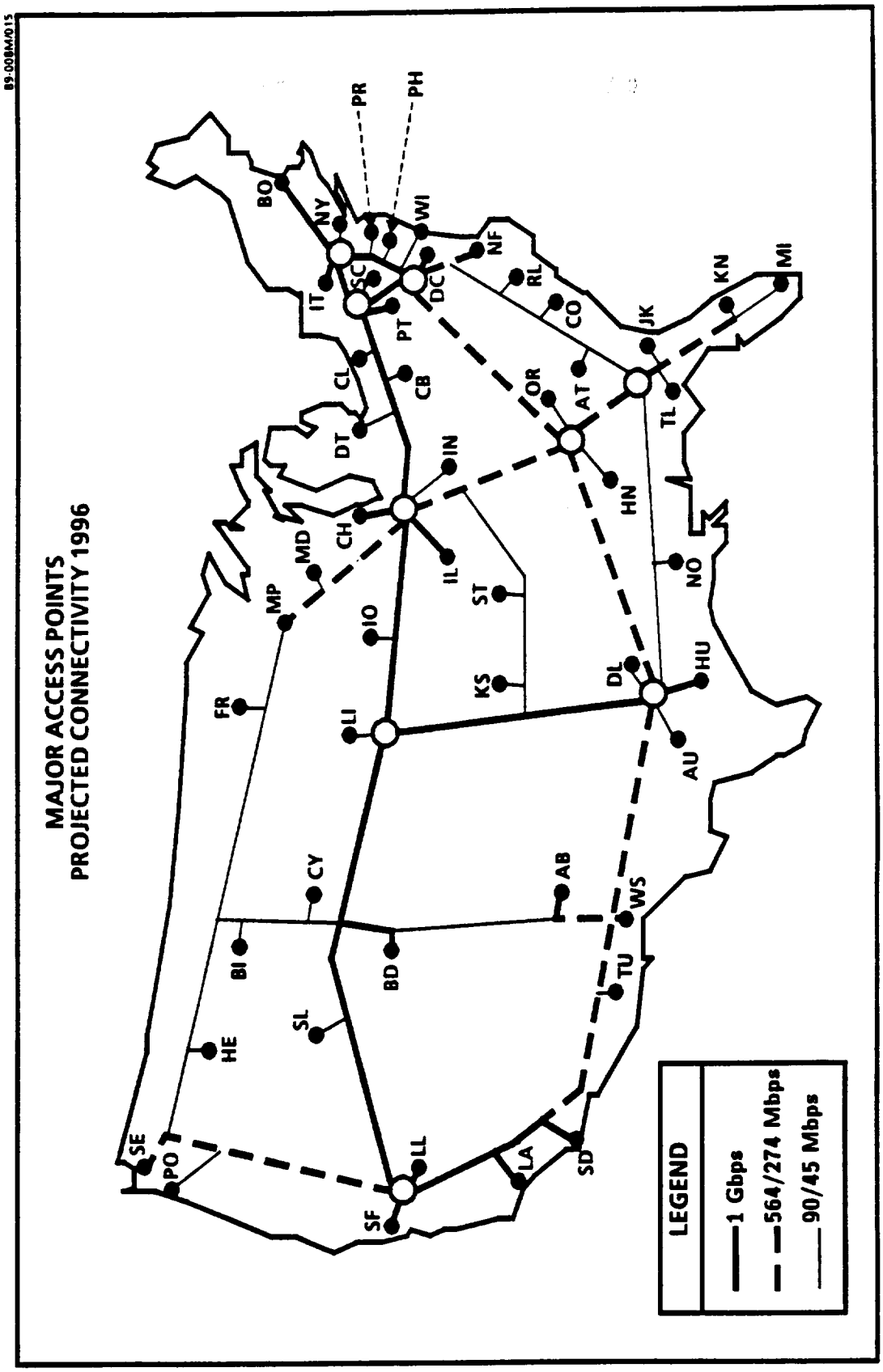


EXHIBIT 1-15. 1996 IRN Topology

YEAR 2000 IRN LINKS

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	1G
AT	ATLANTA	GA	CO	COLUMBIA	SC	565M
AT	ATLANTA	GA	TL	TALLAHASEE	FL	565M
AU	AUSTIN	TX	DL	DALLAS	TX	565M
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	565M
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	5G
BI	BILLINGS	MT	CY	CHEYENNE	WY	565M
BI	BILLINGS	MT	FR	FARGO	ND	565M
BO	BOSTON	MA	NY	NEW YORK	NY	5G
CB	COLUMBUS	OH	DT	DETROIT	MI	565M
CH	CHICAGO	IL	IL	URBANA	IL	5G
CH	CHICAGO	IL	OR	OAK RIDGE	TN	1G
CH	CHICAGO	IL	LI	LINCOLN	NE	5G
CH	CHICAGO	IL	DT	DETROIT	MI	565M
CH	CHICAGO	IL	ST	ST LOUIS	MO	565M
CL	CLEVELAND	OH	CB	COLUMBUS	OH	565M
CO	COLUMBIA	SC	RL	RALEIGH	NC	565M
CY	CHEYENNE	WY	BD	BOULDER	CO	565M
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	5G
DC	WASHINGTON	DC	NF	NORFOLK	VA	1G
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	565M
FR	FARGO	ND	MP	MINNEAPOLIS	MN	565M
HE	HELENA	MT	BI	BILLINGS	MT	565M
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	565M
HU	HOUSTON	TX	OR	OAK RIDGE	TN	1G
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	565M
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	565M
IT	ITHACA	NY	NY	NEW YORK	NY	5G
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	565M
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	5G
LI	LINCOLN	NE	HU	HOUSTON	TX	5G
LI	LINCOLN	NE	BD	BOULDER	CO	5G
LI	LINCOLN	NE	IO	IOWA CITY	IA	565M
MD	MADISON	WI	CH	CHICAGO	IL	1G
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1G
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	565M
NY	NEW YORK	NY	DC	WASHINGTON	DC	5G
NY	NEW YORK	NY	PT	PITTSBURGH	PA	5G
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	1G
PO	PORTLAND	OR	SE	SEATTLE	WA	565M
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	565M
PT	PITTSBURGH	PA	CH	CHICAGO	IL	5G
RL	RALEIGH	NC	NF	NORFOLK	VA	565M
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	565M
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	1G
SE	SEATTLE	WA	HE	HELENA	MT	565M
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	1G
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	5G
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	5G
SL	SALT LAKE	UT	BD	BOULDER	CO	565M
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	565M
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	1G
TU	TUCSON	AZ	WS	WHITE SANDS	NM	565M

EXHIBIT 1-16. 2000 IRN Links & Capacity

The 2000 IRN topology is depicted in Exhibit 1-17. This topology map looks identical to the topology map for the 1996 IRN. However, the link capacities have been increased in the following manner:

1. All 1996 1 Gbps links have been increased to 5 Gbps links.
2. All 1996 564/274 Mbps links have been increased to 1 Gbps links.
3. All 1996 90/45 Mbps links have been increased to 564/274 links.

1.3.3.4 2010 IRN Links And Topology

The 2010 IRN links are listed in Exhibit 1-18. Again, the major access points and connectivity for the 2010 IRN are identical to those for the 2000 IRN. As before, the only changes that were made were in the link capacities.

The 2010 IRN topology is depicted in Exhibt 1-19. This topology map again looks identical to the topology map for the 2000 IRN, and as before, the link capacities have been increased in the following manner:

1. All 2000 5 Gbps links have been increased to 25 Gbps links.
2. All 2000 1 Gbps links have been increased to 5 Gbps links.
3. All 2000 564/274 Mbps links have been increased to 1 Gbps links.

1.3.4 Major Findings: Subtask 2.5 - Current And Future IRN Costs

The major findings obtained from the activities conducted to estimate the current and future circuit costs of the IRN are presented in terms of the link costs and total costs for each of the selected benchmark years. These results are presented below and discussed in detail in Section 13. The costing methodology also is discussed in detail in Section 13. In the following discussion of costs it was assumed that the IRN was not completely integrated in 1989 and 1991, but was so in 1996 and beyond.

1.3.4.1 Current (1989) IRN Circuit Costs

The circuit cost per month for each city-pair link and for the total Current (1989) IRN are shown in Exhibit 1-20. Again, the city-pairs are listed in the same order as they were listed in earlier exhibits listing the Current IRN links.

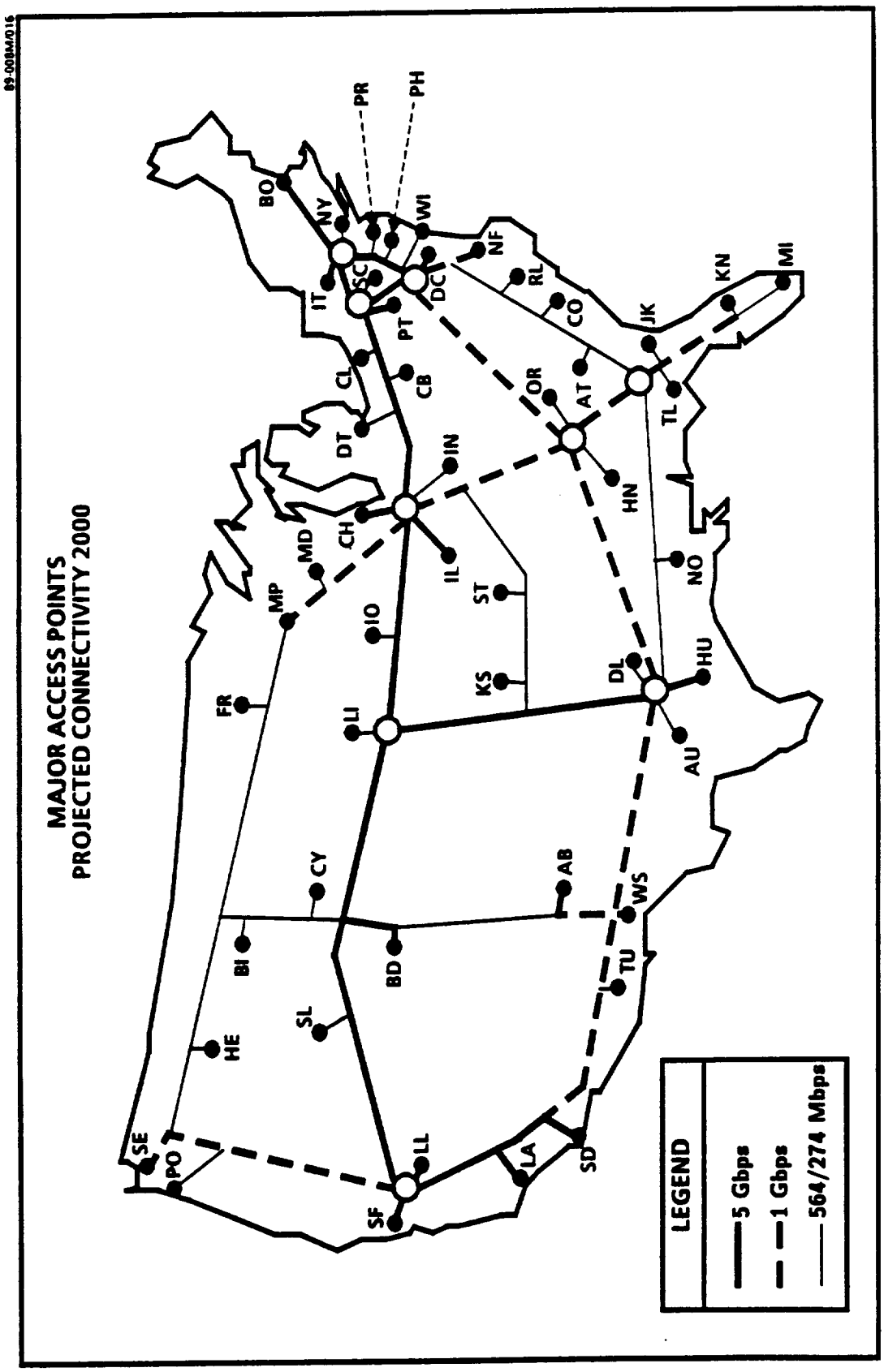


EXHIBIT 1-17. 2000 IRN Topology

YEAR 2010 IRN LINKS

ID	CITY -A	ST	ID	CITY - B	ST	CAPACITY
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	5G
AT	ATLANTA	GA	CO	COLUMBIA	SC	1G
AT	ATLANTA	GA	TL	TALLAHASEE	FL	1G
AU	AUSTIN	TX	DL	DALLAS	TX	1G
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	1G
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	25G
BI	BILLINGS	MT	CY	CHEYENNE	WY	1G
BI	BILLINGS	MT	FR	FARGO	ND	1G
BO	BOSTON	MA	NY	NEW YORK	NY	25G
CB	COLUMBUS	OH	DT	DETROIT	MI	1G
CH	CHICAGO	IL	IL	URBANA	IL	25G
CH	CHICAGO	IL	OR	OAK RIDGE	TN	5G
CH	CHICAGO	IL	LI	LINCOLN	NE	25G
CH	CHICAGO	IL	DT	DETROIT	MI	1G
CH	CHICAGO	IL	ST	ST LOUIS	MO	1G
CL	CLEVELAND	OH	CB	COLUMBUS	OH	1G
CO	COLUMBIA	SC	RL	RALEIGH	NC	1G
CY	CHEYENNE	WY	BD	BOULDER	CO	1G
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	25G
DC	WASHINGTON	DC	NF	NORFOLK	VA	5G
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1G
FR	FARGO	ND	MP	MINNEAPOLIS	MN	1G
HE	HELENA	MT	BI	BILLINGS	MT	1G
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	1G
HU	HOUSTON	TX	OR	OAK RIDGE	TN	5G
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	1G
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	1G
IT	ITHACA	NY	NY	NEW YORK	NY	25G
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	1G
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	25G
LI	LINCOLN	NE	HU	HOUSTON	TX	25G
LI	LINCOLN	NE	BD	BOULDER	CO	25G
LI	LINCOLN	NE	IO	IOWA CITY	IA	1G
MD	MADISON	WI	CH	CHICAGO	IL	5G
MP	MINNEAPOLIS	MN	MD	MADISON	WI	5G
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	1G
NY	NEW YORK	NY	DC	WASHINGTON	DC	25G
NY	NEW YORK	NY	PT	PITTSBURGH	PA	25G
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	5G
PO	PORTLAND	OR	SE	SEATTLE	WA	1G
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1G
PT	PITTSBURGH	PA	CH	CHICAGO	IL	25G
RL	RALEIGH	NC	NF	NORFOLK	VA	1G
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	1G
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	5G
SE	SEATTLE	WA	HE	HELENA	MT	1G
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	5G
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	25G
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	25G
SL	SALT LAKE	UT	BD	BOULDER	CO	1G
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	1G
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	5G
TU	TUCSON	AZ	WS	WHITE SANDS	NM	1G

EXHIBIT 1-18. 2010 IRN Links & Capacity

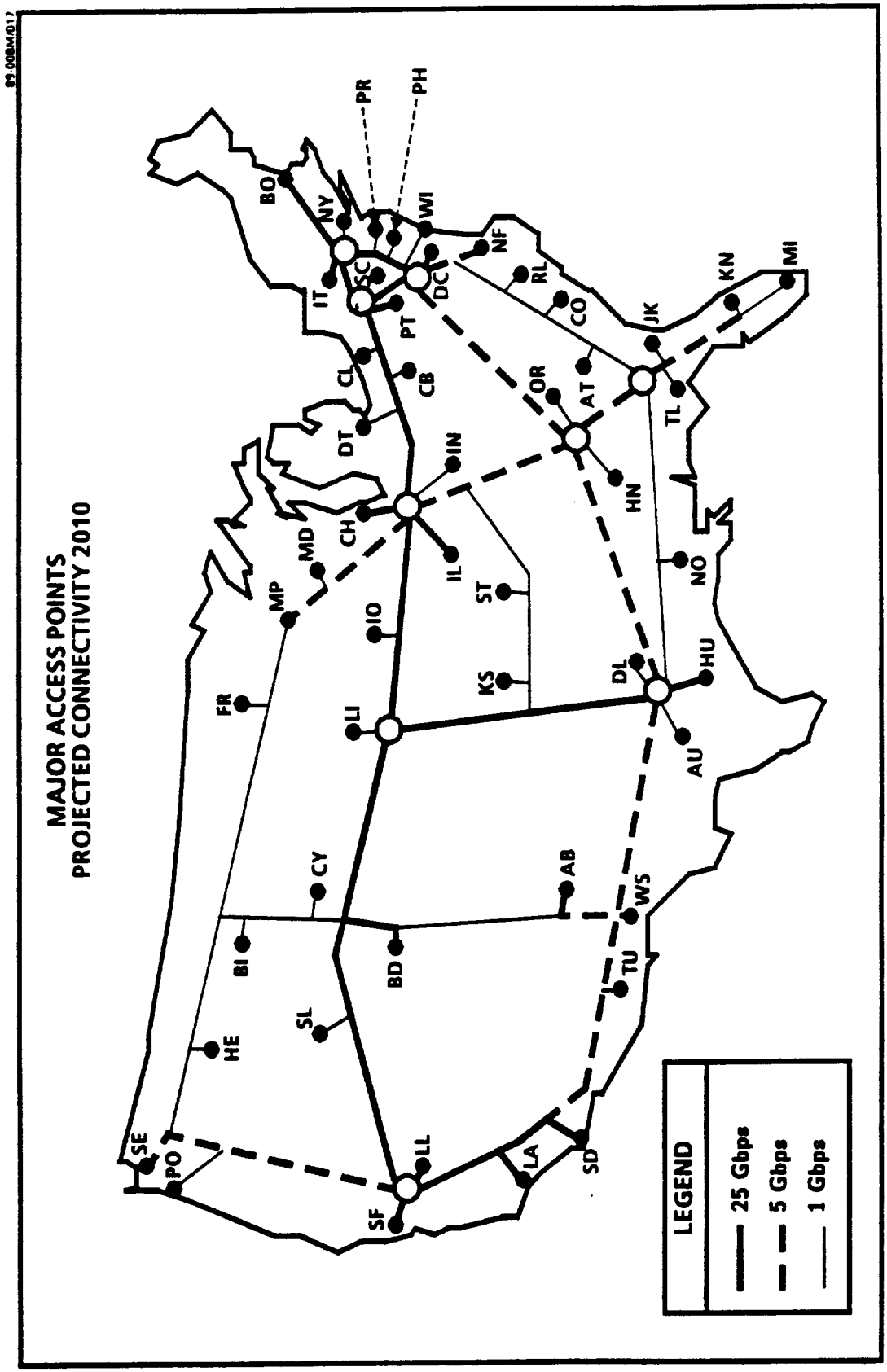


EXHIBIT 1-19. 2010 IRN Topology

COST PER MONTH - CALCULATED BY USING AN ESTIMATED AVERAGE COST PER MILE FOR THE VARIOUS SERVICES

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY	MILES	MM	COST
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56	860	48.16	2,950.00
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1544	860	1,327.84	14,300.00
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2,477.50
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2,477.50
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2,477.50
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56	860	48.16	2,950.00
AB	LOS ALAMOS	NM	AU	AUSTIN	TX	56	615	34.44	2,337.50
AB	LOS ALAMOS	NM	KS	LAWRENCE	KS	56	671	37.58	2,477.50
AB	LOS ALAMOS	NM	BD	BOULDER	CO	56	346	19.38	1,665.00
AU	AUSTIN	TX	DL	RICHARDSON	TX	1544	180	277.92	4,100.00
BD	BOULDER	CO	MD	MADISON	WI	224	844	189.06	9,174.00
BD	BOULDER	CO	DC	WASHINGTON	DC	224	1,501	336.22	14,758.50
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	56	351	19.66	1,677.50
BD	BOULDER	CO	DC	WASHINGTON	DC	224	1,501	336.22	14,758.50
BD	BOULDER	CO	BO	WOODS HOLE	MA	224	1,772	396.93	17,062.00
BD	BOULDER	CO	MI	MIAMI	FL	224	1,742	390.21	16,807.00
BD	BOULDER	CO	TU	TUCSON	AZ	56	619	34.66	2,347.50
BD	BOULDER	CO	DT	ANN ARBOR	MI	224	1,162	260.29	11,877.00
BD	BOULDER	CO	PO	CORVALIS	OR	1544	957	1,477.61	15,755.00
BD	BOULDER	CO	PO	CORVALLIS	OR	224	957	214.37	10,134.50
BD	DENVER	CO	LA	LOS ANGELES	CA	1544	822	1,269.17	13,730.00
BO	BOSTON	MA	NY	NEW YORK	NY	1544	188	290.27	4,220.00
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	1544	229	353.58	4,835.00
CH	CHICAGO	IL	SE	SEATTLE	WA	1544	1,733	2,675.75	27,395.00
CH	CHICAGO	IL	DT	LANSING	MI	1544	237	365.93	4,955.00
CH	CHICAGO	IL	DT	LITCHFIELD	MI	1544	237	365.93	4,955.00
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	56	1,852	103.71	5,430.00
CH	CHICAGO	IL	MD	MADISON	WI	1544	121	186.82	3,215.00
CH	CHICAGO	IL	BD	DENVER	CO	1544	927	1,431.29	15,305.00
CH	CHICAGO	IL	TL	TALLAHASSEE	FL	56	806	45.14	2,815.00
CH	CHICAGO	IL	IL	URBANA	IL	1544	125	193.00	3,275.00
CH	CHICAGO	IL	LI	LINCOLN	NE	1544	475	733.40	8,525.00
CH	CHICAGO	IL	BO	CAMBRIDGE	MA	1544	848	1,309.31	14,120.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	1544	205	316.52	4,475.00
DC	WASHINGTON	DC	AB	ALBUQUERQUE	NM	56	1,646	92.18	4,915.00
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2,401	134.46	6,802.50
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2,401	134.46	6,802.50
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2,401	134.46	6,802.50
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	56	601	33.66	2,302.50
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1,217	68.15	3,842.50
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56	106	5.94	1,065.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1544	106	163.66	2,990.00
DC	WASHINGTON	DC	CL	CLEVELAND	OH	112	304	34.05	2,568.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	168	760	127.68	6,540.00
DC	WASHINGTON	DC	LA	LOS ANGELES	CA	56	2,292	128.35	6,530.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	224	1,572	352.13	15,362.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	56	1,721	96.38	5,102.50
DC	WASHINGTON	DC	LA	BARSTOW	CA	224	2,292	513.41	21,482.00

EXHIBIT 1-20. Current (1989) IRN Circuit Costs

DC	WASHINGTON	DC	LA	BARSTOW	CA	56	2.292	128.35	6.530.00
DC	WASHINGTON	DC	BO	CAMBRIDGE	MA	56	394	22.06	1,785.00
DC	WASHINGTON	DC	PR	PRINCETON	NJ	1544	165	254.76	3,875.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	1544	2.432	3.755.01	37,880.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	112	2.432	272.38	12,144.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	224	2.432	544.77	22,672.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	1544	1.217	1,879.05	19,655.00
DC	WASHINGTON	DC	LA	PASADENA	CA	448	2,292	1,026.82	35,780.00
DC	WASHINGTON	DC	LA	PASADENA	CA	280	2.292	641.76	26,466.00
DC	WASHINGTON	DC	LA	LOMPOC	CA	224	2,292	513.41	21,482.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	1544	601	927.94	10,415.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	672	760	510.72	12,800.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	512	601	307.71	10,415.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1,217	68.15	3,842.50
DC	WASHINGTON	DC	HU	HOUSTON	TX	2048	1,217	2,492.42	29,482.50
DC	WASHINGTON	DC	PH	WILMINGTON	DE	56	124	6.94	1,110.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	56	157	8.79	1,192.50
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1,217	68.15	3,842.50
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	280	760	212.80	10,380.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	56	205	11.48	1,312.50
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56	106	5.94	1,065.00
DL	RICHARDSON	TX	TL	TALLAHASSEE	FL	1544	754	1,164.18	12,710.00
DT	ANN ARBOR	MI	CB	COLUMBUS	OH	1544	163	251.67	3,845.00
DT	ANN ARBOR	MI	PR	PRINCETON	NJ	1544	459	708.70	8,285.00
HN	HUNTSVILLE	AL	KN	CAPE KENNEDY	FL	2048	563	1,153.02	14,767.50
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	168	616	103.49	5,604.00
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	672	601	403.87	10,415.00
HN	HUNTSVILLE	AL	KN	ORLANDO	FL	56	563	31.53	2,207.50
HN	HUNTSVILLE	AL	MI	MIAMI	FL	56	722	40.43	2,605.00
HU	BRYAN	TX	AU	AUSTIN	TX	1544	147	226.97	3,605.00
HU	HOUSTON	TX	DL	DALLAS	TX	56	224	12.54	1,360.00
HU	HOUSTON	TX	HN	HUNTSVILLE	AL	56	616	34.50	2,340.00
HU	HOUSTON	TX	WS	WHITE SANDS	NM	56	700	39.20	2,550.00
HU	HOUSTON	TX	AU	AUSTIN	TX	1544	147	226.97	3,605.00
HU	HOUSTON	TX	AU	AUSTIN	TX	56	147	8.23	1,167.50
HU	HOUSTON	TX	BD	BOULDER	CO	1544	899	1,388.06	14,885.00
HU	HOUSTON	TX	AU	AUSTIN	TX	56	147	8.23	1,167.50
HU	HOUSTON	TX	KN	CAPE KENNEDY	FL	1544	900	1,389.60	14,900.00
IL	URBANA	IL	CH	CHICAGO	IL	1544	125	193.00	3,275.00
IL	URBANA	IL	IN	BLOOMINGTON	IN	1544	113	174.47	3,095.00
IL	URBANA	IL	MD	MILWAUKEE	WI	56	211	11.82	1,327.50
IN	INDIANAPOLIS	IN	CB	COLUMBUS	OH	1544	168	259.39	3,920.00
IO	IOWA CITY	IA	IL	URBANA	IL	1544	202	311.89	4,430.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4,325.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4,325.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4,325.00
IT	ITHACA	NY	DC	WASHINGTON	DC	1544	291	449.30	5,765.00
IT	ITHACA	NY	PT	PITTSBURGH	PA	1544	267	412.25	5,405.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	56	1,446	80.98	4,415.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	1544	1,446	2,232.62	23,090.00
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	1544-	671	1,036.02	11,465.00
LA	LOS ANGELES	CA	AB	LOS ALAMOS	NM	1544	664	1,025.22	11,360.00
LA	LOS ANGELES	CA	HN	HUNTSVILLE	AL	56	1,798	100.69	5,295.00

EXHIBIT 1-20. Current (1989) IRN Circuit Costs

(Continued)

LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56	113	6.33	1,082.50
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56	113	6.33	1,082.50
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	1544	350	540.40	6,650.00
LA	LOS ANGELES	CA	HU	HOUSTON	TX	56	1,376	77.06	4,240.00
LA	LOS ANGELES	CA	BD	BOULDER	CO	56	822	46.03	2,855.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544	113	174.47	3,095.00
LA	LOS ANGELESO	CA	SF	SAN FRANCISCO	CA	1544	350	540.40	6,650.00
LA	PASADENA	CA	TU	TUCSON	AZ	56	444	24.86	1,910.00
LA	PASADENA	CA	DC	BALTIMORE	MD	56	2,292	128.35	6,530.00
LA	PASADENA	CA	HU	HOUSTON ISLAND	TX	168	1,376	231.17	10,544.00
LA	PASADENA	CA	DC	WASHINGTON	DC	672	2,292	1,540.22	35,780.00
LI	LINCOLN	NE	IL	URBANA	IL	56	447	25.03	1,917.50
LI	LINCOLN	NE	KS	LAWRENCE	KS	56	199	11.14	1,297.50
LI	LINCOLN	NE	IO	IOWA CITY	IA	56	274	15.34	1,485.00
LI	LINCOLN	NE	BD	BOULDER	CO	1544	454	700.98	8,210.00
LL	LIVERMORE	CA	SF	OAKLAND	CA	56	36	2.02	890.00
LL	LIVERMORE	CA	PR	PRINCETON	NJ	1544	2,507	3,870.81	39,005.00
LL	LIVERMORE	CA	LA	LOS ANGELES	CA	56	321	17.98	1,602.50
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	1544	860	1,327.84	14,300.00
MP	MINNEAPOLIS	MN	IO	IOWA CITY	IA	1544	243	375.19	5,045.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1544	232	358.21	4,880.00
NF	NORFOLK	VA	TL	TALLAHASSEE	FL	1544	635	980.44	10,925.00
NY	LONG ISLAND	NY	BO	CAMBRIDGE	MA	1544	188	290.27	4,220.00
NY	NEW YORK	NY	IT	ROME	NY	1544	195	301.08	4,325.00
OR	OAK RIDGE	TN	CH	CHICAGO	IL	1544	441	680.90	8,015.00
OR	OAK RIDGE	TN	TL	TALLAHASSEE	FL	1544	385	594.44	7,175.00
PR	PRINCETON	NJ	TU	TUCSON	AZ	1544	2,080	3,211.52	32,600.00
PR	PRINCETON	NJ	NF	NORFOLK VA	DC	1544	269	415.34	5,435.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2,000.00
PR	PRINCETON	NJ	CH	CHICAGO	IL	1544	686	1,059.18	11,690.00
PR	PRINCETON	NJ	NY	LONG ISLAND	NY	1544	40	61.76	2,000.00
PR	PRINCETON	NJ	BD	BOLDER	CO	1544	1,610	2,485.84	25,550.00
PR	PRINCETON	NJ	SC	STATE COLLEGE	PA	1544	175	270.20	4,025.00
PR	PRINCETON	NJ	PH	PHILADELPHIA	PA	1544	42	64.85	2,030.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544	229	353.58	4,835.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544	229	353.58	4,835.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2,000.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2,000.00
PR	PRINCETON	NJ	BO	NEW HAVEN	CT	1544	229	353.58	4,835.00
PR	PRINCETON	NJ	BO	AMHERST	MA	1544	229	353.58	4,835.00
PT	PITTSBURGH	PA	SC	STATE COLLEGE	PA	1544	115	177.56	3,125.00
PT	PITTSBURGH	PA	PR	PRINCETON	NJ	1544	285	440.04	5,675.00
PT	PITTSBURGH	PA	IL	URBANA	IL	1544	434	670.10	7,910.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1544	114	176.02	3,110.00
PT	PITTSBURGH	PA	PH	PHILADELPHIA	PA	1544	258	398.35	5,270.00
PT	PITTSBURGH	PA	DC	WASHINGTON	DC	1544	190	293.36	4,250.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3,095.00
SD	SAN DIEGO	CA	LA	RIVERSIDE	CA	56	113	6.33	1,082.50
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3,095.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3,095.00
SD	SAN DIEGO	CA	HU	HOUSTON	TX	1544	1,305	2,014.92	20,975.00
SD	SAN DIEGO	CA	SF	MENLO PARK	CA	1544	463	714.87	8,345.00
SD	SAN DIEGO	CA	LA	SANTA BARBARA	CA	56	113	6.33	1,082.50

EXHIBIT 1-20. Current (1989) IRN Circuit Costs

(Continued)

SD	SAN DIEGO	CA	SE	SEATTLE	WA	56	1.068	59.81	3,470.00
SD	SAN DIEGO	CA	SF	OAKLAND	CA	56	463	25.93	1,957.50
SD	SAN DIEGO	CA	LA	IRVINE	CA	56	113	6.33	1,082.50
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56	624	34.94	2,360.00
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56	624	34.94	2,360.00
SE	SEATTLE	WA	SD	SAN DIEGO	CA	1544	1.068	1.648.99	17,420.00
SE	SEATTLE	WA	SF	MENLO PARK	CA	1544	684	1.056.10	11,660.00
SE	SEATTLE	WA	PO	PORTLAND	OR	56	147	8.23	1,167.50
SE	SEATTLE	WA	PO	CORVALLIS	OR	56	147	8.23	1,167.50
SE	SEATTLE	WA	PO	EUGENE	OR	56	147	8.23	1,167.50
SF	SAN FRANCISCO	CA	LA	PASADENA	CA	448	350	156.80	6,650.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1544	36	55.58	1,940.00
SF	SAN FRANCISCO	CA	BD	BOULDER	CO	56	932	52.19	3,130.00
SF	SAN FRANCISCO	CA	DC.	WASHINGTON	DC	336	2,432	817.15	33,200.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	56	350	19.60	1,675.00
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	56	2,432	136.19	6,880.00
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	1544	1,852	2,859.49	29,180.00
SL	SALT LAKE CITY	UT	SF	MENLO PARK	CA	1544	598	923.31	10,370.00
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	1544	351	541.94	6,665.00
SL	SALT LAKE CITY	UT	CH	CHICAGO	IL	1544	1,256	1,939.26	20,240.00
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	1544	1,265	1,953.16	20,375.00
WI	WALLOPS ISLAND	VA	MD	MADISON	WI	224	809	181.22	8,876.50
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	224	1,265	283.36	12,752.50
sum						146824	133,734	85,529.58	1,417,122.00

EXHIBIT 1-20. Current (1989) IRN Circuit Costs

(Continued)

The concept of a "Megabit Per Second Mile" (MM) was developed to provide a measure of network efficiency across benchmark years. An MM refers to the movement of one Megabit Per Second of traffic one mile; that is, an MM is a Mbps Mile. The number of MMs is indicated for each city-pair link.

The total Current IRN monthly cost of about 86,000 MMs, was estimated to be about 1.4 million dollars.

1.3.4.2 1991 IRN Circuit Costs

The cost per month for each city-pair link and for the total 1991 IRN are shown in Exhibit 1-21. The city-pairs are listed in the same order as they were listed in earlier exhibits listing the 1991 IRN links and as they were listed in Exhibit 1-20 which showed 1989 IRN costs. City-pair cost changes from 1989 to 1991 occurred only where the increases in the NSFNET backbone link speeds caused IRN city-pair link speed increases, and therefore link cost increases.

The total 1991 IRN monthly cost of about 661,000 MMs, was estimated to be about 2.4 million dollars. That is, compared with 1989, almost eight times as much traffic is expected to be moved in 1991 at less than twice the 1989 cost.

1.3.4.3 1996 IRN Costs

The cost per month for each city-pair link and for the total 1996 IRN are shown in Exhibit 1-22. The city-pairs are listed in the same order as they were listed in earlier exhibits listing the 1996 IRN links.

The total 1996 IRN monthly cost of about eight and one-half million MMs was estimated to be about 6 million dollars. That is, compared with 1991, about thirteen times as much traffic is expected to be moved for only about two and one-half times the 1991 cost.

1991 PROJECTED COST

ID	CITY - A	ID	ID	CITY - B	ST	CAPACITY (KB)	MILES	MM	COST
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56	860	48.16	2,950.00
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1544	860	1,327.84	14,300.00
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2,477.50
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2,477.50
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2,477.50
AB	LOS ALAMOS	NM	LL	LIVERMORE	CA	56	860	48.16	2,950.00
AB	LOS ALAMOS	NM	AU	AUSTIN	TX	56	615	34.44	2,337.50
AB	LOS ALAMOS	NM	KS	LAWRENCE	KS	56	671	37.58	2,477.50
AU	AUSTIN	TX	BD	BOULDER	CO	56	346	19.38	1,665.00
BD	BOULDER	CO	DL	RICHARDSON	TX	1544	180	277.92	4,100.00
BD	BOULDER	CO	MD	MADISON	WI	224	844	189.06	9,174.00
BD	BOULDER	CO	DC	WASHINGTON	DC	224	1,501	336.22	14,758.50
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	56	351	19.66	1,677.50
BD	BOULDER	CO	DC	WASHINGTON	DC	224	1,501	336.22	14,758.50
BD	BOULDER	CO	BO	WOODS HOLE	MA	224	1,772	396.93	17,062.00
BD	BOULDER	CO	MI	MIAMI	FL	224	1,742	390.21	16,807.00
BD	BOULDER	CO	TU	TUCSON	AZ	56	619	34.66	2,347.50
BD	BOULDER	CO	DT	ANN ARBOR	MI	224	1,162	260.29	11,877.00
BD	BOULDER	CO	PO	CORVALIS	OR	1544	957	1,477.61	15,755.00
BD	BOULDER	CO	PO	CORVALLIS	OR	224	957	214.37	10,134.50
BD	DENVER	CO	LA	LOS ANGELES	CA	1544	822	1,269.17	13,730.00
BO	BOSTON	MA	NY	NEW YORK	NY	1544	188	290.27	4,220.00
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	1544	229	353.58	4,835.00
CH	CHICAGO	IL	SE	SEATTLE	WA	44M	1,733	77,527.49	158,970.00
CH	CHICAGO	IL	DT	LANSING	MI	1544	237	365.93	4,955.00
CH	CHICAGO	IL	DT	LITCHFIELD	MI	1544	237	365.93	4,955.00
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	56	1,852	103.71	5,430.00
CH	CHICAGO	IL	MD	MADISON	WI	1544	121	186.82	3,215.00
CH	CHICAGO	IL	BD	DENVER	CO	44M	927	41,470.27	86,430.00
CH	CHICAGO	IL	TL	TALLAHASSEE	FL	56	806	45.14	2,815.00
CH	CHICAGO	IL	IL	URBANA	IL	1544	125	193.00	3,275.00
CH	CHICAGO	IL	LI	LINCOLN	NE	44M	475	21,249.60	45,750.00
CH	CHICAGO	IL	BO	CAMBRIDGE	MA	1544	848	1,309.31	14,120.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	1544	205	316.52	4,475.00
DC	WASHINGTON	DC	AB	ALBUQUERQUE	NM	56	1,646	92.18	4,915.00
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2,401	134.46	6,802.50
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2,401	134.46	6,802.50
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2,401	134.46	6,802.50
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	56	601	33.66	2,302.50
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1,217	68.15	3,842.50
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56	106	5.94	1,065.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1544	106	163.66	2,990.00
DC	WASHINGTON	DC	CL	CLEVELAND	OH	112	304	34.05	2,568.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	168	760	127.58	6,540.00
DC	WASHINGTON	DC	LA	LOS ANGELES	CA	56	2,292	128.35	6,530.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	224	1,572	352.13	15,362.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	56	1,572	88.03	4,730.00
DC	WASHINGTON	DC	LA	BARSTOW	CA	224	2,292	513.41	21,482.00
DC	WASHINGTON	DC	LA	BARSTOW	CA	56	2,292	128.35	6,530.00

EXHIBIT 1-21. 1991 IRN Circuit Costs

DC	WASHINGTON	DC	BO	CAMBRIDGE	MA	56	394	22.06	1,785.00
DC	WASHINGTON	DC	PR	PRINCETON	NJ	44M	165	7,381.44	17,850.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	1544	2,432	3,755.01	37,880.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	112	2,432	272.38	12,144.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	224	2,432	544.77	22,672.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	44M	1,217	54,443.71	112,530.00
DC	WASHINGTON	DC	LA	PASADENA	CA	448	2,292	1,026.82	35,780.00
DC	WASHINGTON	DC	LA	PASADENA	CA	280	2,292	641.76	26,466.00
DC	WASHINGTON	DC	LA	LOMPOC	CA	224	2,292	513.41	21,482.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	1544	601	927.94	10,415.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	672	760	510.72	12,800.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	512	601	307.71	10,415.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1,217	68.15	3,842.50
DC	WASHINGTON	DC	HU	HOUSTON	TX	2048	1,217	2,492.42	29,482.50
DC	WASHINGTON	DC	PH	WILMINGTON	DE	56	124	6.94	1,110.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	56	157	8.79	1,192.50
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1,217	68.15	3,842.50
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	280	760	212.80	10,380.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	56	205	11.48	1,312.50
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56	106	5.94	1,065.00
DL	RICHARDSON	TX	TL	TALLAHASSEE	FL	1544	754	1,164.18	12,710.00
DT	ANN ARBOR	MI	CB	COLUMBUS	OH	1544	163	251.67	3,845.00
DT	ANN ARBOR	MI	PR	PRINCETON	NJ	44M	459	20,533.82	44,310.00
HN	HUNTSVILLE	AL	KN	CAPE KENNEDY	FL	2048	563	1,153.02	14,767.50
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	168	616	103.49	5,604.00
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	672	601	403.87	10,415.00
HN	HUNTSVILLE	AL	KN	ORLANDO	FL	56	563	31.53	2,207.50
HN	HUNTSVILLE	AL	MI	MIAMI	FL	56	722	40.43	2,605.00
HU	BRYAN	TX	AU	AUSTIN	TX	1544	147	226.97	3,605.00
HU	HOUSTON	TX	DL	DALLAS	TX	56	224	12.54	1,360.00
HU	HOUSTON	TX	HN	HUNTSVILLE	AL	56	616	34.50	2,340.00
HU	HOUSTON	TX	WS	WHITE SANDS	NM	56	500	28.00	2,050.00
HU	HOUSTON	TX	AU	AUSTIN	TX	1544	147	226.97	3,605.00
HU	HOUSTON	TX	AU	AUSTIN	TX	56	147	8.23	1,167.50
HU	HOUSTON	TX	BD	BOULDER	CO	44M	899	40,217.66	83,910.00
HU	HOUSTON	TX	AU	AUSTIN	TX	56	147	8.23	1,167.50
HU	HOUSTON	TX	KN	CAPE KENNEDY	FL	1544	900	1,389.60	14,900.00
IL	URBANA	IL	CH	CHICAGO	IL	1544	125	193.00	3,275.00
IL	URBANA	IL	IN	BLOOMINGTON	IN	1544	113	174.47	3,095.00
IL	URBANA	IL	MD	MILWAUKEE	WI	56	211	11.82	1,327.50
IN	INDIANAPOLIS	IN	CB	COLUMBUS	OH	1544	168	259.39	3,920.00
IO	IOWA CITY	IA	IL	URBANA	IL	1544	202	311.89	4,430.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4,325.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4,325.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4,325.00
IT	ITHACA	NY	DC	WASHINGTON	DC	44M	291	13,018.18	29,190.00
IT	ITHACA	NY	PT	PITTSBURGH	PA	44M	267	11,944.51	27,030.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	56	1,446	80.98	4,415.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	1544	1,446	2,232.62	23,090.00
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	1544	671	1,036.02	11,465.00
LA	LOS ANGELES	CA	AB	LOS ALAMOS	NM	1544	564	1,025.22	11,360.00
LA	LOS ANGELES	CA	HN	HUNTSVILLE	AL	56	1,798	100.69	5,295.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56	113	6.33	1,082.50

EXHIBIT 1-21. 1991 IRN Circuit Costs

(Continued)

LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56	113	6.33	1,082.50
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	1544	350	540.40	6,650.00
LA	LOS ANGELES	CA	HU	HOUSTON	TX	56	1,376	77.06	4,240.00
LA	LOS ANGELES	CA	BD	BOULDER	CO	56	822	46.03	2,855.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544	113	174.47	3,095.00
LA	LOS ANGELESO	CA	SF	SAN FRANCISCO	CA	1544	350	540.40	6,650.00
LA	PASADENA	CA	TU	TUCSON	AZ	56	444	24.86	1,910.00
LA	PASADENA	CA	DC	BALTIMORE	MD	56	2,292	128.35	6,530.00
LA	PASADENA	CA	HU	HOUSTON ISLAND	TX	168	1,376	231.17	10,544.00
LA	PASADENA	CA	DC	WASHINGTON	DC	672	2,292	1,540.22	35,780.00
LI	LINCOLN	NE	IL	URBANA	IL	56	447	25.03	1,917.50
LI	LINCOLN	NE	KS	LAWRENCE	KS	56	199	11.14	1,297.50
LI	LINCOLN	NE	IO	IOWA CITY	IA	56	274	15.34	1,485.00
LI	LINCOLN	NE	BD	BOULDER	CO	44M	454	20,310.14	43,860.00
LL	LIVERMORE	CA	SF	OAKLAND	CA	56	36	2.02	890.00
LL	LIVERMORE	CA	PR	PRINCETON	NJ	1544	2,507	3,870.81	39,005.00
LL	LIVERMORE	CA	LA	LOS ANGELES	CA	56	321	17.98	1,602.50
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	1544	860	1,327.84	14,300.00
MP	MINNEAPOLIS	MN	IO	IOWA CITY	IA	1544	243	375.19	5,045.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1544	232	358.21	4,880.00
NF	NORFOLK	VA	TL	TALLAHASSEE	FL	1544	635	980.44	10,925.00
NY	LONG ISLAND	NY	BO	CAMBRIDGE	MA	1544	188	290.27	4,220.00
NY	NEW YORK	NY	IT	ROME	NY	1544	195	301.08	4,325.00
OR	OAK RIDGE	TN	CH	CHICAGO	IL	1544	441	680.90	8,015.00
OR	OAK RIDGE	TN	TL	TALLAHASSEE	FL	1544	385	594.44	7,175.00
PR	PRINCETON	NJ	TU	TUCSON	AZ	1544	2,080	3,211.52	32,600.00
PR	PRINCETON	NJ	NF	NORFOLK VA	DC	1544	269	415.34	5,435.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2,000.00
PR	PRINCETON	NJ	CH	CHICAGO	IL	1544	686	1,059.18	11,690.00
PR	PRINCETON	NJ	NY	LONG ISLAND	NY	1544	40	61.76	2,000.00
PR	PRINCETON	NJ	BD	BOLDER	CO	1544	1,610	2,485.84	25,550.00
PR	PRINCETON	NJ	SC	STATE COLLEGE	PA	1544	175	270.20	4,025.00
PR	PRINCETON	NJ	PH	PHILADELPHIA	PA	1544	42	64.85	2,030.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544	229	353.58	4,835.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544	229	353.58	4,835.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2,000.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2,000.00
PR	PRINCETON	NJ	BO	NEW HAVEN	CT	1544	229	353.58	4,835.00
PR	PRINCETON	NJ	BO	AMHERST	MA	1544	229	353.58	4,835.00
PT	PITTSBURGH	PA	SC	STATE COLLEGE	PA	1544	115	177.56	3,125.00
PT	PITTSBURGH	PA	PR	PRINCETON	NJ	44M	285	12,749.76	28,650.00
PT	PITTSBURGH	PA	IL	URBANA	IL	44M	434	19,415.42	42,060.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1544	114	176.02	3,110.00
PT	PITTSBURGH	PA	PH	PHILADELPHIA	PA	1544	258	398.35	5,270.00
PT	PITTSBURGH	PA	DC	WASHINGTON	DC	1544	190	293.36	4,250.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3,095.00
SD	SAN DIEGO	CA	LA	RIVERSIDE	CA	56	113	6.33	1,082.50
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3,095.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3,095.00
SD	SAN DIEGO	CA	HU	HOUSTON	TX	44M	1,305	58,380.48	120,450.00
SD	SAN DIEGO	CA	SF	MENLO PARK	CA	44M	463	20,712.77	44,670.00
SD	SAN DIEGO	CA	LA	SANTA BARBARA	CA	56	113	6.33	1,082.50
SD	SAN DIEGO	CA	SE	SEATTLE	WA	56	1,068	59.81	3,470.00

EXHIBIT 1-21. 1991 IRN Circuit Costs

(Continued)

SD	SAN DIEGO	CA	SF	OAKLAND	CA	56	463	25.93	1,957.50
SD	SAN DIEGO	CA	LA	IRVINE	CA	56	113	6.33	1,082.50
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56	624	34.94	2,360.00
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56	624	34.94	2,360.00
SE	SEATTLE	WA	SD	SAN DIEGO	CA	44M	1,068	47,778.05	99,120.00
SE	SEATTLE	WA	SF	MENLO PARK	CA	44M	684	30,599.42	64,560.00
SE	SEATTLE	WA	PO	PORTLAND	OR	56	147	8.23	1,167.50
SE	SEATTLE	WA	PO	CORVALLIS	OR	56	147	8.23	1,167.50
SE	SEATTLE	WA	PO	EUGENE	OR	56	147	8.23	1,167.50
SF	SAN FRANCISCO	CA	LA	PASADENA	CA	448	350	156.80	6,650.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1544	36	55.58	1,940.00
SF	SAN FRANCISCO	CA	BD	BOULDER	CO	56	932	52.19	3,130.00
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	336	2,432	817.15	33,200.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	56	350	19.60	1,675.00
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	56	2,432	136.19	6,880.00
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	1544	1,852	2,859.49	29,180.00
SL	SALT LAKE CITY	UT	SF	MENLO PARK	CA	44M	598	26,752.13	56,820.00
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	44M	351	15,702.34	34,590.00
SL	SALT LAKE CITY	UT	CH	CHICAGO	IL	44M	1,256	56,188.42	116,040.00
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	1544	1,265	1,953.16	20,375.00
WI	WALLOPS ISLAND	VA	MD	MADISON	WI	224	809	181.22	8,876.50
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	224	1,265	283.36	12,752.50
sum							133,385	661,302.57	2,446,474.50

EXHIBIT 1-21. 1991 IRN Circuit Costs

(Continued)

1996 PROJECTED COST

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY	MILES	MM	COST
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	565M	754	426,010.00	343,800.00
AT	ATLANTA	GA	CO	COLUMBIA	SC	90M	193	17,408.60	34,766.00
AT	ATLANTA	GA	TL	TALLAHASEE	FL	90M	233	21,016.60	41,246.00
AU	AUSTIN	TX	DL	DALLAS	TX	90M	180	16,236.00	32,660.00
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	90M	346	31,209.20	59,552.00
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	1G	932	1,053,160.00	508,280.00
BI	BILLINGS	MT	CY	CHEYENNE	WY	90M	368	33,193.60	63,116.00
BI	BILLINGS	MT	FR	FARGO	ND	90M	565	50,963.00	95,030.00
BO	BOSTON	MA	NY	NEW YORK	NY	1G	297	335,610.00	165,380.00
CB	COLUMBUS	OH	DT	DETROIT	MI	90M	163	14,702.60	29,906.00
CH	CHICAGO	IL	IL	URBANA	IL	1G	125	141,250.00	72,500.00
CH	CHICAGO	IL	OR	OAK RIDGE	TN	565M	441	249,165.00	202,950.00
CH	CHICAGO	IL	LI	LINCOLN	NE	1G	475	536,750.00	261,500.00
CH	CHICAGO	IL	DT	DETROIT	MI	90M	237	21,377.40	41,894.00
CH	CHICAGO	IL	ST	ST LOUIS	MO	90M	260	23,452.00	45,620.00
CL	CLEVELAND	OH	CB	COLUMBUS	OH	90M	126	11,365.20	23,912.00
CO	COLUMBIA	SC	RL	RALEIGH	NC	90M	183	16,506.60	33,146.00
CY	CHEYENNE	WY	BD	BOULDER	CO	90M	80	7,216.00	16,460.00
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	1G	190	214,700.00	107,600.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	565M	157	88,705.00	75,150.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	90M	106	9,561.20	20,672.00
FR	FARGO	ND	MP	MINNEAPOLIS	MN	90M	214	19,302.80	38,168.00
HE	HELENA	MT	BI	BILLINGS	MT	90M	178	16,055.60	32,336.00
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	90M	162	14,612.40	29,744.00
HU	HOUSTON	TX	OR	OAK RIDGE	TN	565M	777	439,005.00	354,150.00
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	90M	320	28,864.00	55,340.00
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	90M	164	14,792.80	30,068.00
IT	ITHACA	NY	NY	NEW YORK	NY	1G	195	220,350.00	110,300.00
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	90M	176	15,875.20	32,012.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1G	113	127,690.00	66,020.00
LI	LINCOLN	NE	HU	HOUSTON	TX	1G	759	857,670.00	414,860.00
LI	LINCOLN	NE	BD	BOULDER	CO	1G	454	513,020.00	250,160.00
LI	LINCOLN	NE	IO	IOWA CITY	IA	90M	274	24,714.80	47,888.00
MD	MADISON	WI	CH	CHICAGO	IL	565M	121	68,365.00	58,950.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	565M	232	131,080.00	108,900.00
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	90M	348	31,389.60	59,876.00
NY	NEW YORK	NY	DC	WASHINGTON	DC	1G	236	266,680.00	132,440.00
NY	NEW YORK	NY	PT	PITTSBURGH	PA	1G	207	233,910.00	116,780.00
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	565M	385	217,525.00	177,750.00
PO	PORTLAND	OR	SE	SEATTLE	WA	90M	147	13,259.40	27,314.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	90M	114	10,282.80	21,968.00
PT	PITTSBURGH	PA	CH	CHICAGO	IL	1G	409	462,170.00	225,860.00
RL	RALEIGH	NC	NF	NORFOLK	VA	90M	149	13,439.80	27,638.00
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	90M	115	10,373.00	22,130.00
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	565M	623	351,995.00	284,850.00
SE	SEATTLE	WA	HE	HELENA	MT	90M	489	44,107.80	82,718.00
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	565M	684	386,460.00	312,300.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1G	36	40,680.00	24,440.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	1G	350	395,500.00	194,000.00
SL	SALT LAKE	UT	BD	BOULDER	CO	90M	351	31,660.20	60,362.00
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	90M	269	24,263.80	47,078.00
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	565M	264	149,160.00	123,300.00
TU	TUCSON	AZ	WS	WHITE SANDS	NM	90M	440	39,688.00	74,780.00
sum							16,166	8,533,500.00	5,919,620.00

EXHIBIT 1-22. 1996 IRN Circuit Costs

1.3.4.4 2000 IRN Circuit Costs

The circuit costs per month for each city-pair link and for the total 2000 IRN are shown in Exhibit 1-23. The city-pairs are listed in the same order as they were listed in earlier exhibits listing the 2000 IRN links and as they were listed in Exhibit 1-22 which showed 1996 costs.

The total 2000 IRN monthly cost of about 35 million MMs was estimated to be about 16 million dollars. That is, compared with 1996, about four times as much traffic is expected to be moved in 2000 for about two and one-half times the 1996 cost.

1.3.4.5 2010 IRN Costs

The circuit costs per month for each city-pair link and for the total 2010 IRN are shown in Exhibit 1-24. The city-pairs are listed in the same order as they were listed in earlier exhibits listing the 2010 IRN links and as they were listed in Exhibit 1-23 which showed 2000 costs.

The total 2010 IRN monthly cost of about 162 million MMs was estimated to be about 29 million dollars. That is, compared with 2000, about four and one-half times as much traffic is expected to be moved for less than two times the 2000 cost.

1.3.4.6 Summary Of Circuit Costs

The monthly circuit costs and the cost per MM for each benchmark year that were discussed above are summarized in Exhibit 1-25.

In addition to providing a summary of the circuit costs discussed above, Exhibit 1-25 also presents a summary of the circuit costs for the benchmark years 1996, 2000 and 2010, assuming that the IRN does not become integrated. These costs were developed so that the cost implications of not integrating the IRN could be determined. The detailed cost tables for the non-integrated IRN for 1996, 2000 and 2010 are presented in Appendix B. The methodology for developing these cost tables is presented in Section 13.

YEAR 2000 PROJECTED COST

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY	MILES	MM	COST
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	1G	754	852,020.00	412,160.00
AT	ATLANTA	GA	CO	COLUMBIA	SC	565M	193	109,045.00	91,350.00
AT	ATLANTA	GA	TL	TALLAHASEE	FL	565M	233	131,645.00	109,350.00
AU	AUSTIN	TX	DL	DALLAS	TX	565M	180	101,700.00	85,500.00
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	565M	346	195,490.00	160,200.00
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	5G	932	5,055,168.00	2,021,120.00
BI	BILLINGS	MT	CY	CHEYENNE	WY	565M	368	207,920.00	170,100.00
BI	BILLINGS	MT	FR	FARGO	ND	565M	565	319,225.00	258,750.00
BO	BOSTON	MA	NY	NEW YORK	NY	5G	297	1,610,928.00	649,520.00
CB	COLUMBUS	OH	DT	DETROIT	MI	565M	163	92,095.00	77,850.00
CH	CHICAGO	IL	IL	URBANA	IL	5G	125	678,000.00	278,000.00
CH	CHICAGO	IL	OR	OAK RIDGE	TN	1G	441	498,330.00	243,140.00
CH	CHICAGO	IL	LI	LINCOLN	NE	5G	475	2,576,400.00	1,034,000.00
CH	CHICAGO	IL	DT	DETROIT	MI	565M	237	133,905.00	111,150.00
CH	CHICAGO	IL	ST	ST LOUIS	MO	565M	260	146,900.00	121,500.00
CL	CLEVELAND	OH	CB	COLUMBUS	OH	565M	126	71,190.00	61,200.00
CO	COLUMBIA	SC	RL	RALEIGH	NC	565M	183	103,395.00	86,850.00
CY	CHEYENNE	WY	BD	BOULDER	CO	565M	80	45,200.00	40,500.00
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	5G	190	1,030,560.00	418,400.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	1G	157	177,410.00	89,780.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	565M	106	59,890.00	52,200.00
FR	FARGO	ND	MP	MINNEAPOLIS	MN	565M	214	120,910.00	100,800.00
HE	HELENA	MT	BI	BILLINGS	MT	565M	178	100,570.00	84,600.00
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	565M	162	91,530.00	77,400.00
HU	HOUSTON	TX	OR	OAK RIDGE	TN	1G	777	878,010.00	424,580.00
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	565M	320	180,800.00	148,500.00
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	565M	164	92,660.00	78,300.00
IT	ITHACA	NY	NY	NEW YORK	NY	5G	195	1,057,680.00	429,200.00
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	565M	176	99,440.00	83,700.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	5G	113	612,912.00	252,080.00
LI	LINCOLN	NE	HU	HOUSTON	TX	5G	759	4,116,816.00	1,647,440.00
LI	LINCOLN	NE	BD	BOULDER	CO	5G	454	2,462,496.00	988,640.00
LI	LINCOLN	NE	IO	IOWA CITY	IA	565M	274	154,810.00	127,800.00
MD	MADISON	WI	CH	CHICAGO	IL	1G	121	136,730.00	70,340.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1G	232	262,160.00	130,280.00
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	565M	348	196,620.00	161,100.00
NY	NEW YORK	NY	DC	WASHINGTON	DC	5G	236	1,280,064.00	517,760.00
NY	NEW YORK	NY	PT	PITTSBURGH	PA	5G	207	1,122,768.00	455,120.00
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	1G	385	435,050.00	212,900.00
PO	PORTLAND	OR	SE	SEATTLE	WA	565M	147	83,055.00	70,650.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	565M	114	64,410.00	55,800.00
PT	PITTSBURGH	PA	CH	CHICAGO	IL	5G	409	2,218,416.00	891,440.00
RL	RALEIGH	NC	NF	NORFOLK	VA	565M	149	84,185.00	71,550.00
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	565M	115	64,975.00	56,250.00
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	1G	623	703,990.00	341,420.00
SE	SEATTLE	WA	HE	HELENA	MT	565M	489	276,285.00	224,550.00
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	1G	684	772,920.00	374,360.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	5G	36	195,264.00	85,760.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	5G	350	1,898,400.00	764,000.00
SL	SALT LAKE	UT	BD	BOULDER	CO	565M	351	198,315.00	162,450.00
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	565M	269	151,985.00	125,550.00
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	1G	264	298,320.00	147,560.00
TU	TUCSON	AZ	WS	WHITE SANDS	NM	565M	440	248,600.00	202,500.00
sum							16,166	34,857,562.00	16,137,000.00

EXHIBIT 1-23. 2000 IRN Circuit Costs

YEAR 2010 PROJECTED COST

ID	CITY -A	ST	ID	CITY - B	ST	CAPACITY	MILES	MM	COST
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	5G	754	4,089,696.00	1,636,640.00
AT	ATLANTA	GA	CO	COLUMBIA	SC	1G	193	218,090.00	109,220.00
AT	ATLANTA	GA	TL	TALLAHASEE	FL	1G	233	263,290.00	130,820.00
AU	AUSTIN	TX	DL	DALLAS	TX	1G	180	203,400.00	102,200.00
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	1G	346	390,980.00	191,840.00
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	25G	932	25,275,840.00	3,029,680.00
BI	BILLINGS	MT	CY	CHEYENNE	WY	1G	368	415,840.00	203,720.00
BI	BILLINGS	MT	FR	FARGO	ND	1G	565	638,450.00	310,100.00
BO	BOSTON	MA	NY	NEW YORK	NY	25G	297	8,054,640.00	972,280.00
CB	COLUMBUS	OH	DT	DETROIT	MI	1G	163	184,190.00	93,020.00
CH	CHICAGO	IL	IL	URBANA	IL	25G	125	3,390,000.00	415,000.00
CH	CHICAGO	IL	OR	OAK RIDGE	TN	5G	441	2,391,984.00	960,560.00
CH	CHICAGO	IL	LI	LINCOLN	NE	25G	475	12,882,000.00	1,549,000.00
CH	CHICAGO	IL	DT	DETROIT	MI	1G	237	267,810.00	132,980.00
CH	CHICAGO	IL	ST	ST LOUIS	MO	1G	260	293,800.00	145,400.00
CL	CLEVELAND	OH	CB	COLUMBUS	OH	1G	126	142,380.00	73,040.00
CO	COLUMBIA	SC	RL	RALEIGH	NC	1G	183	206,790.00	103,820.00
CY	CHEYENNE	WY	BD	BOULDER	CO	1G	80	90,400.00	48,200.00
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	25G	190	5,152,800.00	625,600.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	5G	157	851,568.00	347,120.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1G	106	119,780.00	62,240.00
FR	FARGO	ND	MP	MINNEAPOLIS	MN	1G	214	241,820.00	120,560.00
HE	HELENA	MT	BI	BILLINGS	MT	1G	178	201,140.00	101,120.00
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	1G	162	183,060.00	92,480.00
HU	HOUSTON	TX	OR	OAK RIDGE	TN	5G	777	4,214,448.00	1,686,320.00
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	1G	320	361,600.00	177,800.00
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	1G	164	185,320.00	93,560.00
IT	ITHACA	NY	NY	NEW YORK	NY	25G	195	5,288,400.00	641,800.00
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	1G	176	198,880.00	100,040.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	25G	113	3,064,560.00	376,120.00
LI	LINCOLN	NE	HU	HOUSTON	TX	25G	759	20,584,080.00	2,469,160.00
LI	LINCOLN	NE	BD	BOULDER	CO	25G	454	12,312,480.00	1,480,960.00
LI	LINCOLN	NE	IO	IOWA CITY	IA	1G	274	309,620.00	152,960.00
MD	MADISON	WI	CH	CHICAGO	IL	5G	121	656,304.00	269,360.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	5G	232	1,258,368.00	509,120.00
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	1G	348	393,240.00	192,920.00
NY	NEW YORK	NY	DC	WASHINGTON	DC	25G	236	6,400,320.00	774,640.00
NY	NEW YORK	NY	PT	PITTSBURGH	PA	25G	207	5,613,840.00	680,680.00
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	5G	385	2,088,240.00	839,600.00
PO	PORTLAND	OR	SE	SEATTLE	WA	1G	147	166,110.00	84,380.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1G	114	128,820.00	66,560.00
PT	PITTSBURGH	PA	CH	CHICAGO	IL	25G	409	11,092,080.00	1,335,160.00
RL	RALEIGH	NC	NF	NORFOLK	VA	1G	149	168,370.00	85,460.00
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	1G	115	129,950.00	67,100.00
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	5G	623	3,379,152.00	1,353,680.00
SE	SEATTLE	WA	HE	HELENA	MT	1G	489	552,570.00	269,060.00
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	5G	684	3,710,016.00	1,485,440.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	25G	36	976,320.00	126,640.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	25G	350	9,492,000.00	1,144,000.00
SL	SALT LAKE	UT	BD	BOULDER	CO	1G	351	396,630.00	194,540.00
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	1G	269	303,970.00	150,260.00
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	5G	264	1,431,936.00	578,240.00
TU	TUCSON	AZ	WS	WHITE SANDS	NM	1G	440	497,200.00	242,600.00
sum							16,166	161,504,572.00	29,184,800.00

EXHIBIT 1-24. 2010 IRN Circuit Costs

89-008M01/008

YEAR	COST/MONTH	MMs	COST/MONTH/MM
Non-Integrated			
1989	$ 1,417,122.00	85,529	$ 16.57
1991	$ 2,446,474.00	661,302	$ 3.70
Integrated (I) vs Non-Integrated (NI)			
1996 - I	$ 5,919,620.00	8,533,500	$ 0.69
- NI	$ 10,604,035.00	9,094,900	$ 1.17
2000 - I	$ 16,137,000.00	34,857,562	$ 0.46
- NI	$ 20,207,500.00	37,104,024	$ 0.81
2010 - I	$ 29,184,800.00	161,504,572	$ 0.18
- NI	$ 88,522,460.00	164,184,932	$ 0.54

EXHIBIT 1-25. Summary Of IRN Circuit Cost Projections

Assuming a non-integrated IRN is 1989 and 1991 and an integrated IRN in 1996 and beyond (i.e, the expected scenario), the IRN monthly circuit cost increases from 1989 to 2010 by about a factor of 20, while the capacity increases by about a factor of 1800. That is, the cost per month per MM in 2010 is only about 1/90 of the cost in 1989. This drop in cost is diagrammed in Exhibit 1-26. The cost per MM drops from about $16.50/MM in 1989 to about $ .18/MM in 2010.

The implications of not integrating the IRN in 1996 and beyond are diagrammed in Exhibits 1-27 and 1-28. Exhibit 1-27 shows that the non-integrated IRN cost per month per MM is about double the integrated IRN cost in 1996. It is tripple the cost in 2010. These cost implications of not integrating the IRN are dramatized even more in Exhibit 1-28. The integrated IRN monthly circuit costs are about five million dollars less than the non-integrated cost in 1996. This difference increases to about sixty million dollars in 2010.

1.4 RECOMMENDATIONS

A consensus of academic, industry, and institutional experts engaged in developing and operating computer research networks is that significantly higher communications capacities will be needed in the years to come to link researchers to enable them to collaborate in cooperative research endeavors regardless of their physical locations. The researchers' needs for communications will encompass accessing large data bases, linking supercomputers in a massively paralleled configuration, and presenting simulation results with ever-increasing resolution and clarity to permit researcher to overcome resource limitations. From that perspective, communications could be viewed as enhancing the effectiveness of research facilities in the same manner as command, control and communications are viewed as force multipliers by the defense community.

NASA needs to address several technology and policy issues in order to translate today's vision into what some experts have called the "Collaboratory" of the future. Some specific recommendations are as

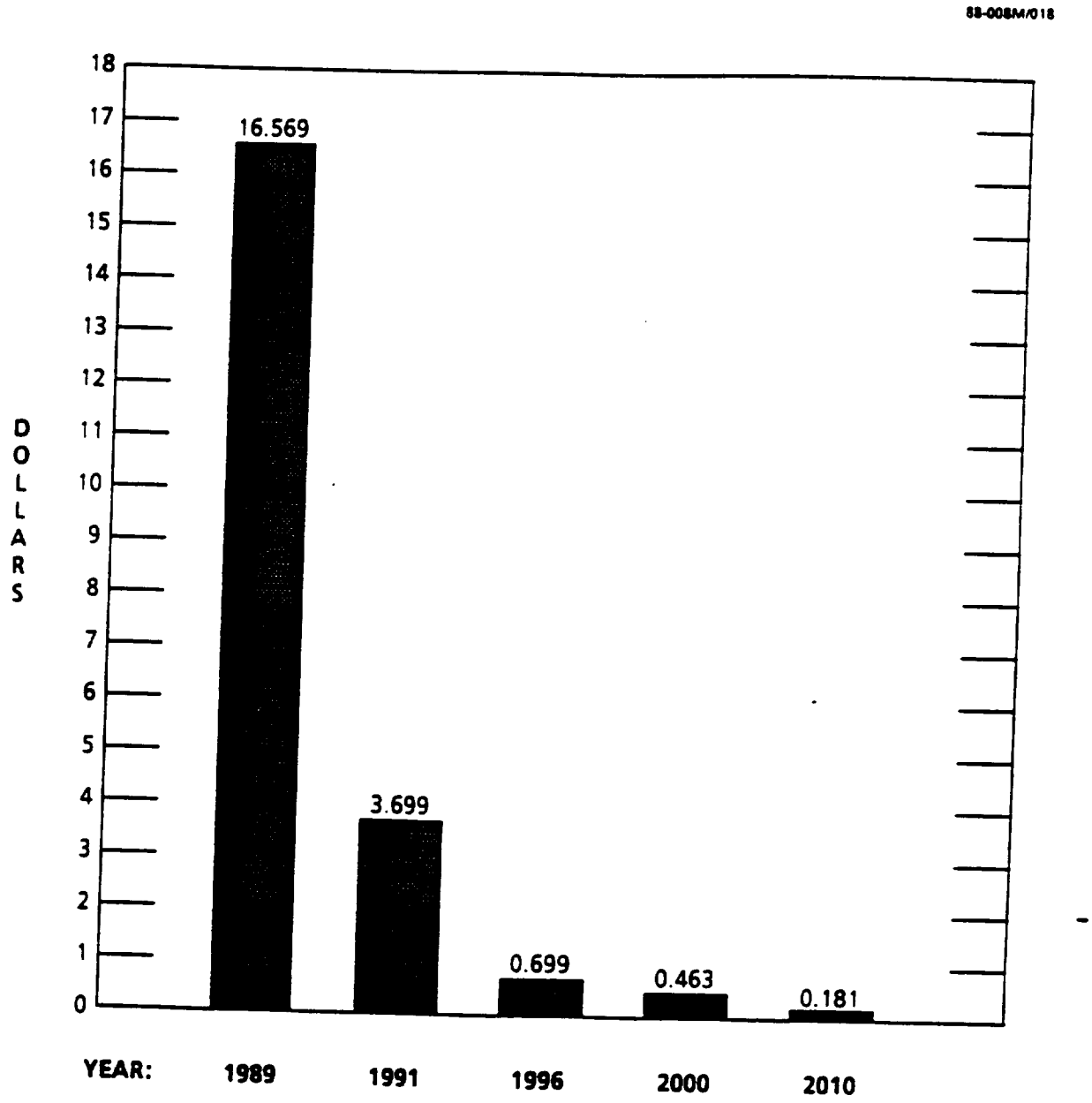


EXHIBIT 1-26. Projections Of Monthly Costs/MM

(Not integrated in 1989 & 1991; Integrated in 1996 and Beyond)

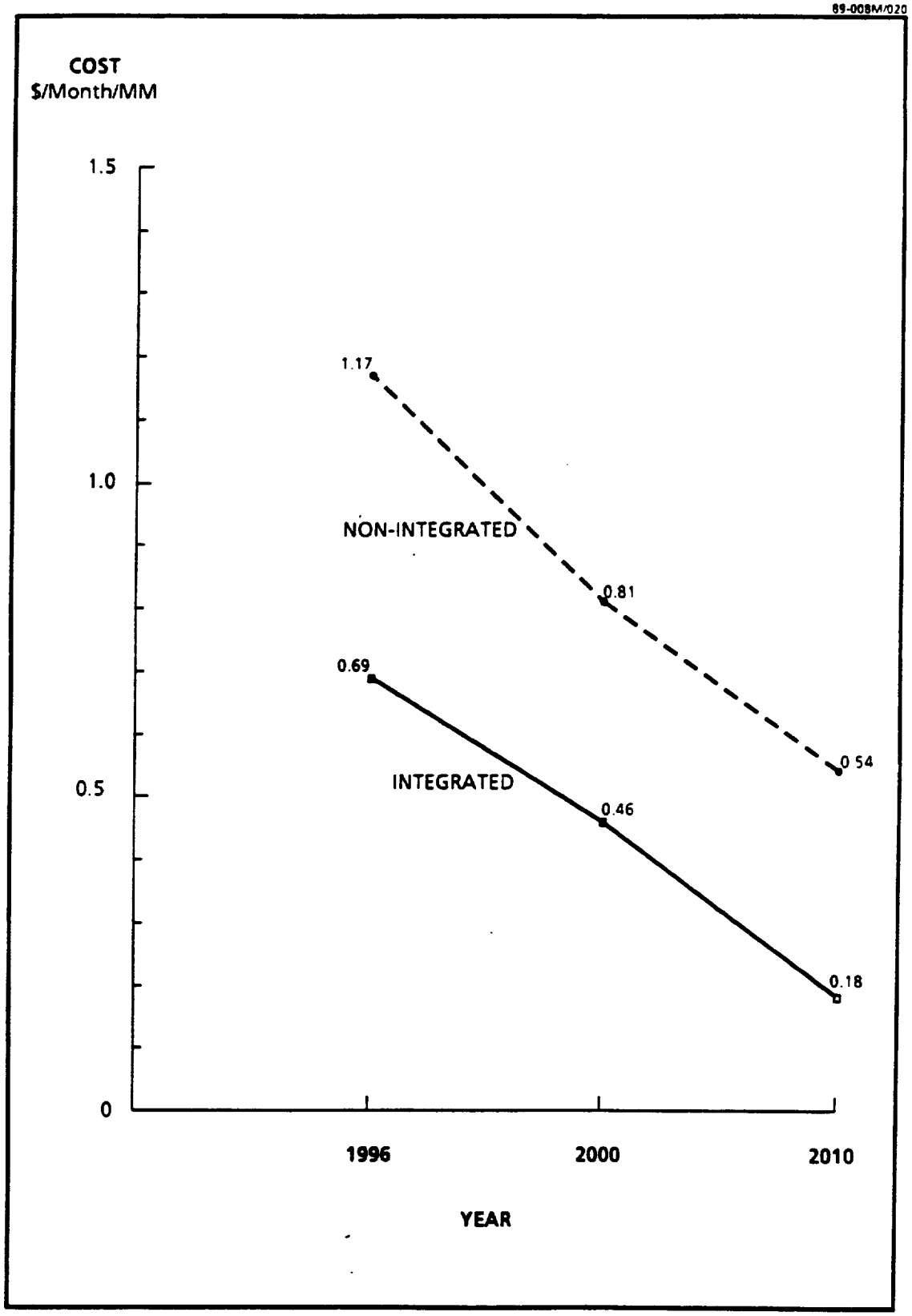


EXHIBIT 1-27. Comparison Of Monthly Cost/MM

Integrated Vs Non-Integrated IRN

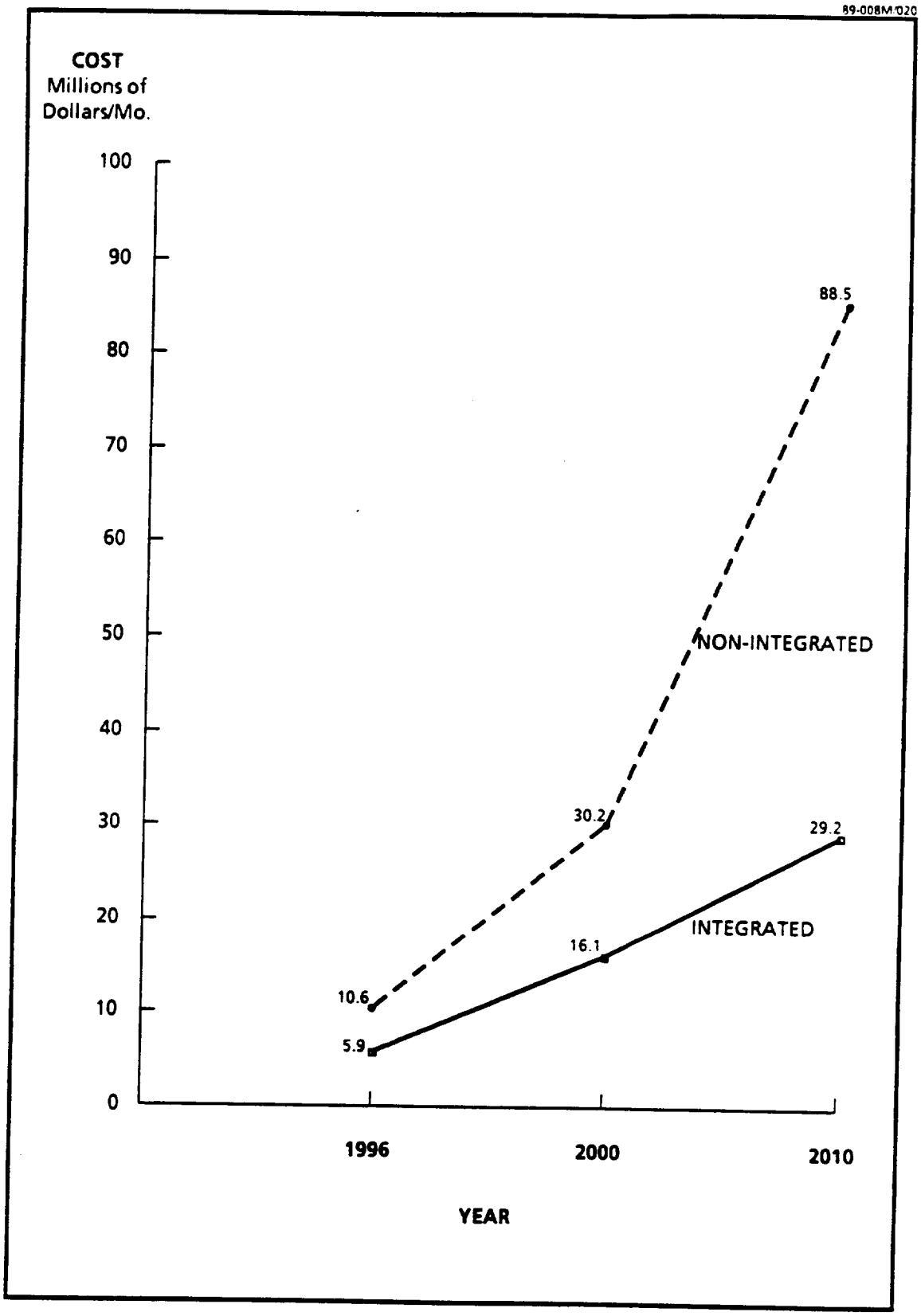


EXHIBIT 1-28. Comparison Of Monthly IRN Circuit Cost

Integrated Vs Non-Integrated IRN

follows:

1. Broaden the scope of the current study to include the communications requirements of ever-increasing international cooperation among researchers.
2. Participate in standards setting committees to actively set the standards for door-to-door delivery of data at rates approaching gigabits and terabits per second.
3. Examine the current and future capacity plans of the commercial communications industry vis-a-vis researchers' needs, and identify communications assets such as satellites or terrestrial systems that are needed to meet researchers' unique requirements.
4. Identify technologies in the areas of computer networking, communications systems, and communications networks management that need to be developed to meet researchers' requirements in the year 1996 and beyond.
5. Identify policy issues that must be resolved to provide communications facilities to researchers in a most cost effective manner. The current approach of implementing several interconnected networks does not take advantage of economies of scale and does not place responsibility on a single organization to integrate requirements into a national level initiative.

1.5 OUTLINE OF REPORT

This Final Report includes the following additional sections:

Section 2: Study Approach.
Section 3: Overview - Computer Research Networks.
Section 4: Overview - A National Research Network.
Section 5: Selected Computer Research Networks.
Section 6: DoD's Research Networks.
Section 7: NSF's NSFNET.
Section 8: NASA's Research Networks.
Section 9: DOE's Research Networks.
Section 10: BITNET and CSNET.

Section 11: Current IRN

Section 12: Future IRN

Section 13: Estimate Of IRN Costs

Section 14: Summary Of Findings

Appendix A: Abbreviations.

Appendix B: Cost Tables - Non-Integrated IRN

SECTION 2

STUDY APPROACH

2.1 OVERVIEW

In this section the general study approach for Task Order 2 and the specific study approaches for Task Order 2 Subtasks are presented. The approach for Task Order 2 was modified several times in response to the findings of the study. Similarly, the original specific approaches for the Subtasks were modified as suggested by the study results. For example, for some subtasks major activities were added and the iteration of the subtask activities was increased.

2.2 TASK ORDER 2 STUDY APPROACH

To accomplish the purpose of Task Order 2, which is to assist NASA in determining the U.S.'s current and future needs for research and development telecommunications networks, the study approach depicted in Exhibit 2-1 was used. Exhibit 2-1 is organized by subtasks; Subtasks 2.1 and 2.2 were conducted simultaneously, with the results being used to conduct Subtask 2.3; Subtask 2.3 fed into Subtask 2.4; and Subtasks 2.3 and 2.4 fed into Subtask 2.5. Subtask 2.6, because it is only the reporting task, is not depicted in this diagram, nor is it discussed in Section 2.3. The milestone schedule for all six subtasks is presented in Exhibit 2-2.

Subtasks 2.1 and 2.2 dealt with identifying, defining and describing computer research networks. The findings from conducting these two subtasks were then used to conduct Subtask 2.3. That is, the descriptions of the current individual research networks, developed in the Subtasks 2.1 and 2.2, were used in Subtask 2.3, to overlay the selected major current computer research networks and to develop the topology of an integrated research network (IRN) representing these selected major current computer research networks. Additional information was collected as needed. After

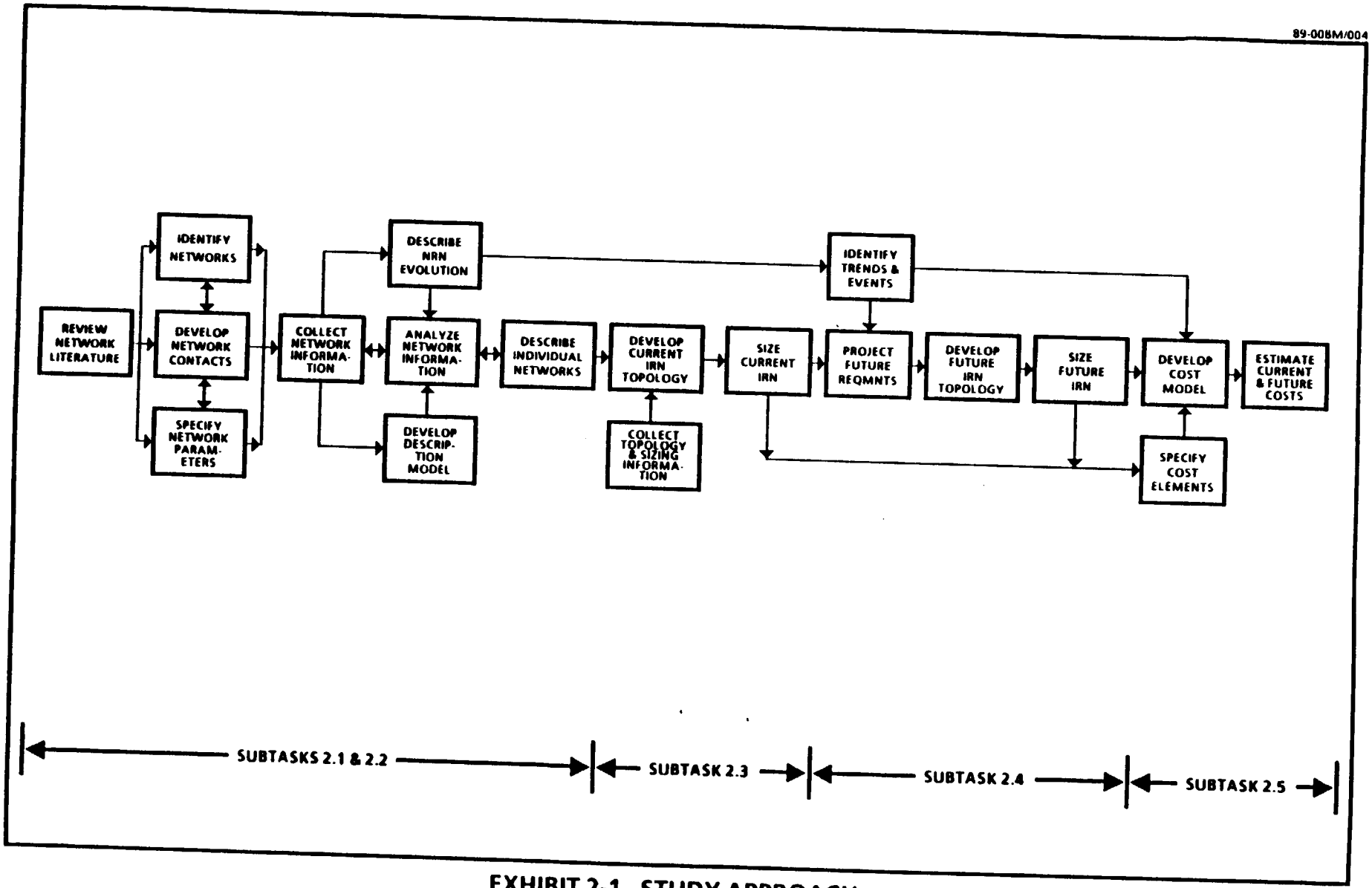


EXHIBIT 2-1. STUDY APPROACH

89-008M/003

EXHIBIT 2-2. MAJOR MILESTONE PROJECT SCHEDULE

SUBTASKS	MAN HOURS	1988 OCT	NOV	DEC	1989 JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
Work Plan - Task 2	----														
2.1 Unique Networks Requirements	500														
2.2 Shared Networks Requirements	500														
2.3 Current IRN	900														
2.4 Future IRN	430														
2.5 Cost Estimates	320														
2.6 Reporting - Reports	300														
- Meetings	250														
Total	3,200														

	SCHED	ACTUAL	SLIP
START	△	▲	
FINISH	▽	▼	

SHEET 1 OF 1

STATUS UPDATED: 10/15/89

PM: DS

PROGRAM: NASA STUDY/NAS3-25083
PROJECT: 8027

the Current IRN topology was determined, the Current IRN was sized.

In Subtask 2.4, trends and events (e.g., technological, economic, and social-political) were identified. Special attention was given to the national research network (NRN) planning efforts. This information was used to develop the Future IRN topology and to size the Future IRN.

In Subtask 2.5 the results, from sizing the Current and Future IRN in Subtasks 2.3 and 2.4, were used to specify cost elements and to develop the cost model for estimating current and future costs of the IRN.

2.3 STUDY APPROACHES FOR SUBTASKS

2.3.1 Subtask 2.1 And 2.2

The purposes of Subtasks 2.1 and 2.2 were very similar, and the activities performed to complete these two subtasks were identical. The only difference between Subtask 2.1 and Subtask 2.2 was that Subtask 2.1 focused on computer research networks unique to a specific federal agency, while Subtask 2.2 focused on those networks that are shared across more than one federal agency. Consequently, these two subtasks were conducted simultaneously. The combined subtask statement, purpose, and activities are outlined below.

2.3.1.1 Subtask 2.1 And 2.2 Statement

Identify, Define And Describe Federal Agency Computer Research Networks

2.3.1.2 Subtask 2.1 And 2.2 Purpose

The purpose of Subtasks 2.1 and 2.2 was to identify, define and describe all major existing federal agency computer research networks.

2.3.1.3 Subtasks 2.1 And 2.2 Activities

The major activities for Subtasks 2.1 and 2.2 included:

1. Developing research methodology.
2. Reviewing computer network literature.
3. Identifying agency computer research networks.
4. Specifying responsible agencies and identifying key contacts.
5. Specifying network description parameters.
6. Collecting network information.
7. Describing NRN evolution.
8. Developing Model for describing networks.
9. Analyzing network information.
10. Summarizing federal agency network use.
11. Selecting networks for comprehensive examination.
12. Describing individual research networks.
13. Summarizing procedures and findings.

2.3.1.4 Subtasks 2.1 And 2.2 Study Approach Discussion

Subtasks 2.1 and 2.2 began with a review of network literature. Findings from this review helped to identify networks, develop network contacts and specify network parameters. The development of network contacts, in turn, led to the identification of additional networks, to the specification of additional network parameters and, ultimately, to the collection of additional network information.

Based on information collected, especially from leaders in the field, a model for describing computer research networks (see Section 3) and a summary of the evolution of a national resarch network (see Section 4) were developed. Once this model and summary had been prepared and all major federal agencies had been contacted, a summary of federal agency use of computer research networks was prepared (see Section 5). Then, based on this summary of network use, computer research networks were selected for comprehensive examination. This examination involved the analysis of information on the selected networks, additional interviews with the managers of these networks, and the preparation of comprehensive descriptions of these networks. The development of these descriptions was

based on the model developed for describing these networks. The descriptions of the selected networks are presented in Sections 6-10.

Especially helpful were the in-person and telephone interviews with members of the Federal Coordinating Council for Science, Engineering and Technology (FCCSET), members of the Federal Research Internet Coordinating Committee (FRICC), the directors and managers of major identified research networks, and other industry, academic and government leaders. The information obtained during these interviews proved to be very useful in describing the evolution of the National Research Network, critiquing documents on various networks, and selecting and describing the major research networks.

2.3.2 Subtask 2.3

2.3.2.1 Subtask 2.3 Statement

Size The Current Nationwide Integrated Research Network (IRN).

2.3.2.2 Subtask 2.3 Purpose

The purpose of Subtask 2.3 was to use the information, that was collected in Subtasks 2.1 and 2.2 on the selected computer resarch networks, to size the current nationwide integrated computer research network.

2.3.2.3 Subtask 2.3 Activities

The major activities for Subtask 2.3 included:

1. Plan sizing strategy.
2. Collect current topology data.
3. Develop network database.
4. Identify major access points.
5. Determine major access point connectivity.
7. Determine link capacity between major access points.
8. Iterate activities 3 - 5.
9. Define current IRN.

2.3.2.4 Subtask 2.3 Study Approach Discussion

The topology information initially collected on each of the selected computer research networks in Subtasks 2.1 and 2.2 was six months to a year old when Subtask 2.3 was initiated. Therefore, new and current topology data were collected on each selected network. This information included: current topology maps showing the major nodes and their connectivity; area codes and exchanges; and current speeds of all lines connecting all major nodes and the distances between all pairs of major nodes. The area codes and exchanges were used during the costing subtask to obtain typical link costs for 56 Kbps and T1 services. The new topology information is presented in the descriptions of each network (see Sections 6-10) and in the section on sizing the current IRN (see Section 11).

After this information was collected and organized, a network database was developed, so that the network information could be analyzed when sizing the current IRN. This network database ultimately included the following types of network parameters: network name, network acronym, and subnetwork name; city A name, state, area code and exchange, and major access point identification; city B name, area code and exchange, and major access point identification; and link capacity between city A and city B. It should be pointed out that some of these paramters (e.g., major access point identification) were the products of subsequent activities described below.

This network database then was used to identify major access points. Common hubs and common routes were identified by noting where the various networks overlapped. This overlaying process was iterated several times to identify the major access points. Some of the original network nodes became major access points, some were grouped with other nodes to become a single major access point, and others did not warrant inclusion as a major access point. Once these major access points were selected, their connectivity was determined by reorganizing the original network database in terms of these major access points, resulting in a current network database. The database then was used to note how many links originated from each major access point, what their terminations were and what their

speeds were. This information then was used to specifiy the IRN backbone and the capacity requirements of the various segments of the backbone. The Current IRN was then defined in terms of this IRN backbone and link capacity. It should be pointed out that these major activities were iterated several times, so that the most useful definition of the Current IRN could be presented. This definition and the other results of Subtask 2.3 are presented in Section 11.

2.3.3 Subtask 2.4

2.3.3.1 Subtask 2.4 Statement

Size The Future Nationwide Integrated Research Network (IRN).

2.3.3.2 Subtask 2.4 Purpose

The purpose of Subtask 2.4 was to use the definition of the Current IRN developed in Subtask 2.3 and information on events and trends to develop projections of the size of the IRN at future points in time.

2.3.3.3 Subtask 2.4 Activities

The major activities for Subtask 2.4 included:

1. Review the literature on projections related to an IRN.
2. Identify relevent events and trends.
3. Develop a survey to obtain expert information on events and trends.
4. Collect survey data from experts.
5. Analyze results of literature review and survey.
6. Specify benchmark years.
7. Identify new major access points.
8. Develop a future IRN database.
8. Specify major access point connectivity.
9. Project backbone link speeds.
10. Define IRNs for benchmark years.

2.3.3.4 Subtask 2.4 Study Approach Discussion

Previously collected literature (e.g., national reports, journal articles, and conference summaries) were reviewed to identify strategies for projecting, and actual projections of, the future requirements for an IRN. The results of this review suggested that a combination of qualitative and quantitative factors should be considered when projecting the future requirements for an IRN.

These qualitative and quantitative factors involve:

1. Network Needs And Usage - i.e., the future needs of scientists, usage growth trends, and the addition of new groups of users.
2. Network Development - i.e., the development of new networks and the reconfiguration of existing networks.
3. Federal Government Activity - e.g., legislation and funding support.
4. Private Telecommunications Company Activity - e.g., financial support and research and development participation.
5. NRN Plans - e.g., FRICC, FCCSET and EDUCOM projections,
6. Technological Changes - e.g., advances related to developing a very high speed, i.e., a Gigabit per second (Gbps) network.
7. Economic Pressures - e.g., international competition motivating both federal and private support for an IRN.

These factors were used to develop a guide for surveying leaders in the field of computer research networks. Some fifteen experts were asked to give their opinions, and the basis for them, of when and how a national computer research network might develop in the future. Then, the survey information and the initial literature review findings were analyzed, and the results of the anlysis were used to identify appropriate benchmark years, identify additional major access points, and project link speeds for the future IRNs.

Basesd on the analysis noted above the following guidelines were specified for projecting the future IRN:

1. Benchmark years would be: 1989 (Current), 1991, 1996, 2000, and 2010.
2. Major access points would be the same for 1989 and 1991; new major access points would be added in 1996 and major access points in 2000

and 2010 would be the same as for 1996.

3. For the sake of clarity, only the IRN backbone would be depicted for each benchmark year; while many minor access points will be added yearly, these would not be presented in the projections.
4. Connectivity would be the same for 1989 and 1991; it also would be the same for 1996, 2000 and 2010 with new major access points added for 1996.
5. The IRN link speeds would include DS1 (T1), DS3 (T3), DS4 (T4), and Gbps speeds, and several speeds would be used for each benchmark year.

Given these guidelines, the current network database developed in Subtask 2.3 was used to develop a new future network database, reflecting the changes in major access points, connectivity and link speeds, for each of the four future benchmark years. These databases then were used to develop the definitions of the IRN for four benchmark years. These definitions and the other results of Subtask 2.4 are presented in Section 12.

2.3.4 Subtask 2.5

2.3.4.1 Subtask 2.5 Statement

Estimate Current And Future Costs Of The Nationwide Integrated Research Network (IRN).

2.3.4.2 Subtask 2.5 Purpose

The purpose of Subtask 2.5 was to use the definitions of the Current and Future IRN developed in Subtasks 2.3 and 2.4 to estimate the costs of the IRN for each of the selected benchmark years.

2.3.4.3 Subtask 2.5 Activities

The major activities for Subtask 2.5 included:

1. Convert area code and exchange information to V & H coordinates.
2. Develop average cost per mile for various T1 links.
3. Develop cost model for Current IRN costing.

4. Estimate costs of Current IRN.
5. Develop 1991 IRN Database.
6. Estimate 1991 IRN costs.
7. Develop cost model for 1996, 2000 and 2010 IRN.
8. Estimate cost of IRN for 1996, 2000, and 2010.

2.3.4.4 Subtask 2.5 Study Approach Discussion

First, the approach used to estimate costs for the various benchmark years was developed. The approach used to estimate Current IRN costs and the 1991 IRN costs was different from that used to estimate IRN costs for 1996, 2000 and 2010. The major reason for using different approaches is that it was assumed that in 1989 and 1991, the IRN would not be integrated from a cost point of view, but would be in 1996 and beyond. In 1989 and 1991 the trunking requirements for each of the selected networks were costed individually. For each of the benchmark years, 1996, 2000 and 2010, the trunking requirements of the total IRN were costed.

The first step in estimating current IRN costs was to determine the V (vertical) and H (horizontal) coordinates of each major access point. The V and H coordinates then were used to determine the mileage between any two of the major access points.

Then, a sample of the major access point area codes and exchanges were used to obtain real tariff data from the Network Analysis Center in Great Neck, New York for 56 Kbps and T1 services. This sample of real tariff data was used to develop the average cost per mile for various link distances. **It should be noted that these costs pertain to circuit costs (interexchange carrier and local exchange carrier costs), but do not include costs associated with the end user interface equipment.**

Given the mileage between any two nodes on the Current IRN and the average cost per mile for various 56 Kbps and T1 links, a Current IRN cost database was developed. This cost database reflected the Current IRN definition and included the Current IRN cost model based on current tariff costs and the Current IRN link distances. The database then was used to

calculate the costs of each link on the Current IRN and the total cost for the entire Current IRN.

To estimate the cost of the 1991 IRN, the Current IRN cost database and cost model were modified to reflect the 1991 IRN definition and the costs of T3 links. To estimate the costs of T3 links, it was assumed that carriers would cost future circuit offerings as they had in the past. That is, the increase in cost, for example, from a DS0 to a DS1 link, was used to estimate the increase in cost from DS1 to a DS3 link. The increase in cost from a DS0 to a DS1 which offers 24 times the capacity of a DS0 has been about a factor of six. Therefore, the ratio of capacity increase to cost increase is about four (i.e., 24/6 = 4). That is: New Cost = (Capacity Increase/4) .X Lower Speed Cost. Therefore, the increase in cost from a T1 to a T3 which offers 28 times the capacity of a T1 would be about a factor of seven. Or, T3 Cost = (28/4) X T1 Cost. As calculated for the Current 1989 IRN, the estimated cost of each network in the 1991 IRN and the total cost for the entire 1991 IRN were calculated.

To estimate the future IRN costs for 1996, 2000 and 2010, new cost models and new cost databases were developed. For the new cost models, costs of higher speed links were estimated in the same manner as noted above for estimating the cost of T3 links. Given these estimates of higher speed links, an IRN cost model was developed for each of the benchmark years of 1996, 2000 and 2010. An IRN cost database then was developed for each of these benchmark years using the definitions of the IRNs developed for each of these years and the estimated future costs of the various link speeds and distances. Then, these cost databases were used to estimate the future IRN costs for 1996, 2000, and 2010.

The results of Subtask 2.5 are presented in Section 13. It should be pointed out that the cost estimates presented in Subtask 2.5 were based on estimates of available capacity, rather than on estimates of traffic loads or of peak hour traffic. Estimates of traffic loads or of peak hour traffic were not available for the networks included in this study.

SECTION 3

COMPUTER RESEARCH NETWORKS AN OVERVIEW

3.1 OVERVIEW

Computer research networks are introduced in this section. A computer research network is defined, and then the following computer network topics are discussed: history; types; extent and size; computers, nodes and topologies; media; speed, throughput, and bandwidth; layers and protocols; services; uses; administration; and the future. In subsequent sections of this report, these same topics are used to present the descriptions of the actual networks included in this study. Thus, this section serves two purposes. It provides an introduction to computer research networks, and it introduces the topics and terms used in subsequent sections where the selected research networks are described. The computer research network (CRN) model used for developing these descriptions appears in Exhibit 3-1.

3.2 DEFINITION OF A COMPUTER RESEARCH NETWORK

A computer network exists when independent computers are connected in some way that allows them to exchange information. For the purposes of this study, when such a network is used by scientists for scientific research purposes, it is designated as a computer research network. In a computer network, the computers can range in size from small microcomputers to supercomputers. These computers can be connected by a variety of media, such as optical fiber, microwave, copper, and/or satellites. The common conventions or rules that define how these computers communicate with each other are the communication protocols. Therefore, in this study, what is meant by a computer research network is a network connecting a set of computers used by scientific researchers to exchange scientific data over a variety of communications media using common conventions or protocols.

EXHIBIT 3-1. CRN MODEL FOR DESCRIBING NETWORKS

HISTORY

WHEN STARTED, IMPETUS, MAJOR CHANGES

TYPE OF NETWORK

NETWORK, INTERNET, METANETWORK

PURPOSES & SERVICES

WHY IT WAS DEVELOPED AND FOR WHOM, SERVICES OFFERED

EXTENT & SIZE

GEOGRAPHICAL COVERAGE, #NODES/HOSTS

TOPOLOGY

PICTURE - LOCATION & CONNECTIVITY OF NODES

COMPUTERS

PURPOSE AND SIZE OF COMPUTERS

MEDIA & LINK SPEEDS

TYPE OF MEDIA, SPEEDS IN BITS PER SECOND (BPS)

PROTOCOLS

NAME OF PROTOCOL SUITE (E.G., TCP/IP)

ADMINISTRATION

WHO - POLICY, OPERATION, INFORMATION

FUNDING

WHO PROVIDED SUPPORT

FUTURE

PLANS - TECHNOLOGICAL, POLITICAL

3.3 HISTORY OF COMPUTER NETWORKS

3.3.1 Research And Development

During the last thirty years, significant progress has been made in the research and development (R&D) of computer networks. Research and development initially focused on how to transmit low speed data across a communications medium; then transmitting high speed data across such a medium became the emphasis; and today, we are concerned about providing communications services across a series of interconnected networks. Our computer networking R&D has progressed from signal processing to packet switching to internetwork technologies. Researchers have contributed to this growth of computer networks, by both experimenting with such networks and using them to conduct their scientific research. One of the best early (late 1960s) examples of this involvement by researchers has been the development of ARPANET, which had the original goals of networking research facilities and resource sharing and which was one of the earlier packet switching networks.

3.3.2 Implementation

Significant advances were being made in the implementation of computer networks from the 1960s through the 1980s; additional profound changes are expected through the 1990s. From the early 1960s through the 1980s, computer networks have progressed from simple timesharing systems to worldwide communication networks. During this period, major changes have occurred in all aspects of computer networks: the computers, the media connecting them, the protocols that define how these computers communicate with each other, the users of these networks, and the uses made of these networks. Most significantly, connectivity has progressed from the minimal linkage with a computer involved in timesharing to worldwide connectivity with several thousand hosts on many networks across many nations. Network speeds also have progressed from hundreds of bits per second (bps) to several Kilo bps (Kbps) to Mega bps (Mbps) for backbone networks.

It also is apparent that the technology trends such as increased connectivity and higher transmission speeds will continue to transform these networks during the 1990s and beyond into Giga bps (Gbps) and even Terra bps (Tbps) networks.

3.3.3 Technology, Needs & Funding

On a worldwide scale, technology, user needs, and financial support have worked together to shape the growth of computer networks. In the 1960s, when computers were expensive, remote terminal communications were needed to share their use. In the 1970s, conferencing systems were developed to facilitate and support the sharing of information. Throughout both decades, corporations (e.g., AT&T, DEC, GM, IBM and Xerox), motivated by internal needs and possible markets, invested in the development of their own networking technologies. Throughout the 1960s, the 1970s and the 1980s, technology has been a very potent driving force behind this growth in computer networks. For example, as network speeds and the universality of user interfaces have increased, scientists have discovered new uses for the computer networks. Today, however, even with speeds of 1.544 Mbps and improved connectivity, researchers envison needs that make current United States networking capability too fragmented and a thousand times too slow. The need for improving our current computer networking capability is discussed later under "Overview - A National Research Network." The discussion points out that today, funding might be driving technology which in turn might be driving demand.

Today, there is an international community of computer networking experts who communicate both formally and informally about the latest trends and advances in networking. The consensus among these individuals is that signficant changes will continue to take place in all aspects of computer networking. Technolgoical improvements will make possible services and uses never dreamed of, and such changes likely will influence who the providers will be. The stage is a worldwide arena with various countries vying for leadership roles, and the scientific researcher, wherever he might be, anticipating much greater networking capability.

3.4 TYPES OF COMPUTER NETWORKS

Computer networks, whether used for research or other purposes, are given a variety of names which reflect their structure, approach to communication, and connectivity.

3.4.1 Physical And Logical Networks

The terms physical and logical have been used to denote the structure of a network. A physical computer network is a group of computers which are directly connected to each other via dedicated communications channels and which can communicate over these channels using the common conventions or protocols. A logical computer network is a group of computers which somehow have a way of exchanging data with each other; the user is not concerned with the physical aspects of the communication process. There are many more logical networks than there are physical networks, as logical networks might use part of only one physical network or might cut across several physical networks in numerous possible ways.

The term "virtual" is also used to designate a logical connection. For example, packet networks which typically use the Public Switched Network (PSN) for physical connectivity use two types of virtual circuits. The circuits which are established for the duration of the session are referred to as switched virtual circuits (SVCs), and those which are held permanently for a subscriber are referred to as permanent virtual circuits (PVCs). The SVCs are analogous to dial-up lines and PVCs are analogous to dedicated, i.e., leased lines.

3.4.2 Circuit-Switched And Packet-Switched Computer Networks

Networks also have been given names that reflect their approach to network communication. Two basic types of approaches have been used: circuit-switched and packet-switched networks. Circuit-switched networks operate by forming a dedicated connection or circuit between two points which can be switched to serve any two points. In packet-switched

networks, traffic on the network is divided into small blocks called packets that are transported over SVCs or PVCs and delivered to the specified destination where they are reassembled. Telenet and Tymnet are examples of two packet switched networks available in the United States.

3.4.3 Simple Networks, Internets, & Metanets

Perhaps most frequently, computer networks have been given names based on their connectivity. In a simple network, the same network layer protocol is used throughout. In an internet, which is a logical network, all computers use the same high-level networking protocol but different physical network hardware; that is, different "network layer" protocols may be used across the internet, but all of the constituent networks use the same "internet layer" protocol. However, to the user, the entire internet appears to be part of his local physical network which reaches many computers. A metanetwork is a network of internets; here, protocols at the network, internet and transport levels may be different, and usually are the same only at the highest, or application level.

3.5 COMPUTER NETWORK EXTENT AND SIZE

Both extent and size of a computer network refer to how big the network is. Extent denotes where the users are (i.e., geographical coverage of a network), and size indicates how many users there are and/or how much information they are exchanging.

3.5.1 Computer Network Extent

Specific names have been used to indicate the geographical coverage of a network. A local area network (LAN) typically connects hosts inside a single building or small geographical area. A campus area network (CAN) is a little larger in that it connects hosts on an entire academic or company campus. A metropolitan area network (MAN) connects hosts in an entire city or county. A state network (SN) provides services to hosts across the entire state. A regional network (RN), often acting as a backbone interconnecting these smaller networks, connects hosts across an

entire region. A national network (NN), often built by interconnecting regional networks, provides services across a nation. An international network (IN) connect hosts across national boundaries. When a network crosses many national boundaries it is typically called a worldwide network (WN). The term wide area network (WAN) is also popular. The WAN as the name implies covers a wider area than the LAN and may actually interconnect LANs.

3.5.2 Computer Network Size

A number of indices have been used to indicate the size of a computer network. These measures have included the number of users, the number of hosts, the number of sites, the number of organizations, the number of networks, and how much data or information is exchanged over the network. These indices of size, along with geographical coverage and the type of services provided, are used to determine link speed and bandwidth requirements of a network.

3.6 COMPUTER NETWORK COMPUTERS, NODES AND TOPOLOGIES

A computer network can be diagramed to show the location and connectivity of the computers in the network. In the explanations of these diagrams, the computers and where they are located are given names to reflect their function in the network. While these terms have different precise meanings on different networks, the following definitions are presented for explanatory purposes.

3.6.1 Computer Network Nodes

Each computer in a network is called a network node; a network node is any vertex of a graph representing a network. A computer or node that a person uses directly and that has resources of its own is called a host. Each host may be used by one or more individuals. All hosts are nodes, but all nodes are not hosts; some nodes act as switches. A node which functions as an intermediary agent that makes possible the exchanging of data between dissimilar networks is called a gateway. It is

used to increase the number of computers reachable by a particular computer. In summary, a node is a host; a gateway; a switch; or some combination of the three. Finally, a site is a physical place where network nodes are located.

3.6.2 Computer Network Topologies

A computer network's topology describes its configuration. Network topology is the shape or the physical connectivity of the network. Topologies are selected to maximize connectivity, minimize cost, and maximize the number of users. Network nodes can be organized to have various topologies or configurations. The most common network topologies include: hierarchical, horizontal, star, ring, clique, mesh or some combination of these.

The hierarchical topology is also called a vertical network and often resembles a tree; it is simple but presents potential bottleneck problems. In a horizontal topology often used in LANs, a "bus" permits all stations to receive every transmission; while this typology is simple and control is easy, there is only one communication channel and faults may be difficult to isolate. In the star topology, which has been the most frequently used structure for data communication, all traffic emanates from the hub of the star; while it is easy to control and faults are easy to isolate, it is subject to bottlenecks at the central site. Also, site-to-site communications must pass through the hub causing delays and bottlenecks at the hub.

The ring topology is so named because of the circular aspect of the data flow; it is simple and bottlenecks are uncommon, but it has only one channel tying in all the components of the ring. In a clique topology, every node can talk directly to every other node; this type of configuration is not typically used by itself because it is very expensive. With a mesh topology there is a multiplicity of paths from each node, so traffic can be routed along the most efficient path; it is more immune to bottlenecks and failures but is more expensive than a star topology. Often, configurations include some combination of the generic topologies; for example, there might be a star and a ring within a partial

mesh configuration.

3.7 COMPUTER NETWORK COMMUNICATIONS MEDIA

Computers can be connected by a variety of communications media including optical fiber, microwave, copper and/or satellites. In each case the communications channels either can be dedicated links or can be used through dialup procedures. The merits of each media will not be discussed here, but the important dimensions of channel speed, throughput and bandwidth are discussed in the next section.

3.8 COMPUTER NETWORK SPEED, THROUGHPUT AND BANDWIDTH

The terms speed, throughput and bandwidth are frequently used to describe the capacity of a computer network. While they are very closely related, they are defined differently.

3.8.1 Computer Network Speed

Computer network speed, expressed in the number of bits per second transmitted, describes the speed of a communications channel. When a network has communications channels of variable speeds, the speed of the long haul link is used to indicate the speed of the overall network. Examples of network speed include: 300 bps, 1.544 Mbps (T1), 45 Mbps (DS3) and 1 Gbps.

3.8.2 Computer Network Throughput

The throughput of a computer network is the amount of end-user data that can be transmitted in a given period. This period can be expressed in seconds, minutes, hours, days, weeks or even longer periods of time.

3.8.3 Computer Network Bandwidth

The capacity of a communication channel is directly reflected in

its bandwidth. Bandwidth is the spectral range, expressed in hertz (Hz), carried on a communication line. It is calculated by subtracting the lowest frequency in a signal from the highest frequency in the signal. In short, bandwidth is a limiting factor on transmission capacity within the network. Bandwidth also determines the cost of the communications link. Bandwidth is related to channel speed. For example, to transmit a T-1 (i.e., 1.544 Mbps) channel on a satellite, the bandwidth required is 1.5 MHz. To transmit a 64 Kbps channel, the bandwidth required is approximately 200 KHz.

A variety of models have been used to estimate demand and, hence, bandwidth requirements for a national research network. For example, the kinds and volume of traffic required to support research, ten years into the future, at a representative campus have been estimated using three models. In each model the peak demand was estimated for each type of service. Each model focused on either the type of work (e.g., high-resolution color images), information needs by type and number of user (student, faculty, or research staff), or information flowing at the installation boundary (e.g., data from particle accelerators or supercomputers).

3.9 COMPUTER NETWORK LAYERS AND PROTOCOLS

Today, computer networks are following the concept of layered protocols. Major standards organizations throughout the world are endorsing this concept, and major network vendors are implementing layered networks. The goals of this concept include the decomposition of complex processes, underlying the transport of data, into parts or layers and the standardization of interfaces, so that changes in one part or layer are transparent to other parts or layers.

3.9.1 Computer Network Protocols

Protocols are agreements on how computers are to communicate with each other over a network. They give the algorithms for passing messages, specify the details of message formats, and describe how to handle error

conditions. Protocols allow one to specify communications interfaces without knowing the details of a particular vendor's network hardware.

The network protocols can be very complex, so to facilitate their implementation they are specified in layers or levels, building up from those specifying the hardware to those specifying the applications protocols. There may be one or more protocols in each layer. Interfaces between layers also are defined. In layered protocols, each layer has specific functions, and the intent is for each layer to add a value to the layers above it. The result is that the top layer, which interfaces directly with the end-user application, is provided with the full range of functions offered by the lower layers. Esentially, when a message is sent from an application on one machine to an application on another machine, the message is transferred down through successive layers of protocol software on the sender's machine, transferred across the network, and transferred up through succesive layers of protocol software on the receiver's machine.

A number of protocols currently being used by the various networks. Examples are: TCP/IP (Transmission Control Protocol/Internet Protocol), DECNET protocol and NSP protocols (Non Standard Protocols developed at Livermore and used on MFENET). Since most networks are moving to the International Standards Organization (ISO)/Open Systems Interconnect (OSI) protocols and this section simply introduces the concept of protocols, only the ISO/OSI protocols will be discussed.

3.9.2 ISO/OSI Layered Protocol Model

ISO/OSI model has received worldwide acceptance, is being implemented in many vendor products, and is likely to dominate the field in the near future. This ISO/OSI model, which is supported by the major standards organizations, telecommunications administrations, and trade associations, is presented here to exemplify the layered protocol process. The whole set of protocols that fit this model and that are intended to be used together is referred to as the ISO/OSI protocole suite.

The ISO/OSI model defines layered protocols. The model contains

seven conceptual layers, numbered and named as follows: 1. physical (hardware connection), 2. data link, 3. network, 4. transport, 5. session, 6. presentation, and 7. application. The lower layers are more well developed than the upper layers.

As indicated by the numbering, the physical layer (level 1) is the lowest layer. This layer specifies a physical interface between the data terminal equipment (DTE) and the data communications equipment (DCE). It also contains a mechanism to inform layer 2 of loss of physical connection or electrical power. The most notable level 1 protocols are: RS232C, RS-449, RS-422/RS-423, and V.35.

The data link layer (level 2) is responsible for ensuring error-free data transmission. The protocols for this layer contain recommendations on framing, error control and recovery, link initialization and termination, and message sequence control. An example of a protocol at this level is HDLC (High Level Data Link Control).

The network layer (level 3) is responsible for establishing connections between remote hosts, and switching and routing information. Examples of protocols at level 3 are: X.25 and IP.

The transport layer (level 4) allows end-users to communicate. The most important function it performs is the flow management. An example of a protocol at this level is TCP (Transmission Control Protocol).

The purpose of the session layer (level 5) is to assist in the support of the interactions between user applications on different hosts. It handles functions such as remote log-on/log-off and user authentication, i.e., passwording and recovery from transport layer errors. An example of a session layer protocol is ECMA #75 (European Computer Manufacturers Association #75).

The purpose of the presentation layer (level 6) is to provide the set of services which may be selected by the application layer to enable it to interpret the meaning of the data exchange. It provides for the sytax of data, for the representation of data, but not for the meaning or semantics

of the data. That it, this level is concerned with encoding and decoding data. An example of a protocol at this level is the ISO/OSI abstract syntac notation one (ASN.1) protocol.

The top layer is the application layer (level 7) and includes application programs that use the network. This layer, which is concerned with the semantics of data, provides services to the end users. There are protocols for each service (e.g., electronic mail, X.400 standard).

3.10 COMPUTER NETWORK SERVICES

3.10.1 Supply And Demand Interaction

Scientific researchers have a variety of communication needs many of which can be met by utilizing the services provided by computer research networks. Sometimes the demand for such services has stimulated their supply, and at other times, supply of services has created new demands. Currently, demand is far greter than supply; current connectivity and bandwidth are frequently reported to be inadequate. Demand is expected to grow rapidly, and significant improvements in computer research networks must be made to meet future scientific researchers' needs. In fact, it is expected that as soon as expanded computer research network capability is provided, scientific researchers will utilize all of the new capability, even if they currently do not need such capability; supply will stimulate demand, and new applications will emerge as a result of new capabilities.

3.10.2 Services For Exchanging Messages

Computer research networks currently provide scientific researchers with a variety of services. These services allow users to either exchange messages or to share resources, and in both cases the services can be either batch or interactive. Services that involve exchanging messages in the batch mode are the most widely used and include various ways for users to send messages over the computer network to one or more other users and to receive messages from these same users. The messages are read after a

delay rather than in an interactive mode, and the services are given names like e-mail, mailing lists, and bulletin boards. Services that involve exchanging messages in the interactive mode are not as common. These services, which do not have specific names, can be differentiated in terms of how many people are participating and are similar to telephone interactions and telephone conference calls.

3.10.3 Services For Sharing Resources

The computer research network services which allow scientific researchers to share resources include services which met some of the earliest needs of computer network users. Resource sharing involves using, in either the interactive or batch mode, distant computing resources by means of a computer network. Resource sharing in the interactive mode is more common and includes a variety of services. Remote login allows a user to access, via a network, a remote machine as if he were logged in on it from a local terminal. In file transfer, the user can get a file from a remote host, work on it and put it back. Remote device access allows one to use devices (e.g., printers) on other systems as if they were on the local system. In the distributed computing environment the distinctions between local and remote systems disappear completely.

Batch resource sharing services are of equal importance. These services include remote job entry, which involves submission across a network of a job to be completed, and batch file transfer, where a file travels across a network and the transmission delay is acceptable.

3.11 COMPUTER NETWORK USES & NEEDS

Like the services currently provided by computer research networks, the needs of scientific researchers involve exchanging messages and sharing resources. However, this does not imply, as explained earlier, that current services are meeting current needs. The services noted above are described as generic services, and no reference is made to the specific requirements (e.g., speed or connectivity) of the researcher.

Here, the researchers' needs are summarized first by discipline area and then by generic use. The implications for specific network requirements are discussed in later chapters of this report.

3.11.1 Computer Network Needs

Current and potential needs for computer research network services can be exemplified by noting specific needs in the areas of science and engineering, economics and social sciences, and the arts and humanities. In mathematics, for example, studies of probability theory often require state-of-the-art supercomputing. In physics, instrumentation will increasingly generate complex immages and movies requiring both supercomputing for analysis and wide bandwidth for communicating. In chemistry, scientists need to simulate chemical reactions and model biological units of life, and both often require interactive image transmission. Astronomers often need to conduct computer simulations of three-dimensional images of, for example, blackholes. In the atmospheric sciences, access to huge databases is a frequent need. In engineering, three-dimensional images (e.g., of the space station) often must be developed requiring supercomputing resources.

In the life sciences and medicine, the generation and transmission of complex three-dimensional images (e.g., of living units from molecules to body parts) is key and requires the most sophisticated computer network. In economics and the social sciences supercomputers are often needed to forecast future events using complex models. Finally, in the arts and humanities, access to databases (e.g., a 300 Mbits Thesaurus of Ancient Greek Literature) often facilitates tedious bibliographic searches.

3.11.2 Computer Network Uses

The needs of scientists can be grouped into two categories of uses, those involving a need to share resources and those involving a need to exchange messages. These scientists or researchers need access to high powered remote processing, databanks, existing code, expensive software and specialized devices. They need to share these resources so they can efficiently and effectively conduct complex calculations and three-

dimesnional simulations and create comprehensible visual presentations of their output.

Scientists need to communicate with other scientists in both a batch and interactive mode. They need to exchange high quality graphic data including photographs. They need to be able to simultaneously view and edit documents that combine text, graphics, pictures and voice. Finally, the scientists need to be able to conduct computer conferences in which they interact through both pictures and conversation (e.g., via video teleconferencing). Later sections of this report will analyze and discuss how well these needs are being met, and will be met, by current and future computer research networks.

3.12 ADMINISTRATION

In this report, administration refers to the people, the organizations, and what they do when planning, implementing, funding and operating a computer network. That is, a discussion of computer network administration answers the following specific questions:

1. Who are the sponsors of the network; which people and organizations provided the impetus for its development?
2. What was and what is the major purpose of the network?
3. Who makes policies, and what are the policies, concerning, for example, access, interconnections, growth and funding?
4. Who developed the network?
5. Who operates the network; who installs the hardware and software?
6. Who provides support for the network; who interacts with the end-user when he needs assistance?
7. How is the network funded; by fees, grants or both?

3.13 FUTURE

The future of a computer network refers to its near-term and long-term purposes, users, services, protocols, configuration, size, extent, link speed, and interconnectivity with other networks. Some

computer networks are being phased out and are being replaced by new ones. Others are merging together to better serve their users. Some have plans for significant development in terms of enhanced link speeds and interconnectivity. Finally, others are just in the planning stage and are expected to be operational in the next two to five years.

SECTION 4

A NATIONAL RESEARCH NETWORK AN OVERVIEW

4.1 OVERVIEW

An extensive amount of effort has been, and continues to be, devoted to the development of a National Research Network (NRN). The results of this effort have important implications for the current study. Likewise, it is expected that the results of the current study will be helpful in the development of the NRN. To better understand this relationship between the current study and the development of an NRN, a summary of the activities underlying the development of an NRN and of the organizations responsible for the NRN concept is provided here. First, a brief outline of the history of the National Research Network is presented and then the major activities and events are described in more detail.

4.2 SUMMARY OF NRN HISTORY

The history of the NRN can be best understood by focusing on the interrelationships between four groups of events: the development of major research networks; the pursuit of related legislative agenda; the formation of national-level comittees and offices; and the performance of key national studies. The history summarized here covers the period of 1984 through the present (i.e., 1989) and is diagramed in Exhibit 4-1.

Prior to 1984, a number of networks had already been established. Examples of these networks and their begining dates are: ARPANET, 1969; MFENET, 1975; SPAN, 1980; BITNET, 1981; CSNET, 1981; and HEPNET, 1981. In 1984, the National Science Foundation (NSF) established the Office of Advanced Scientific Computing (OASC). This office initiated programs to develop supercomputer centers and to develop communications networks to enable user to access them. The supercomputer centers were started in 1985, and the network to access them, the NSFnet, was started in 1986.

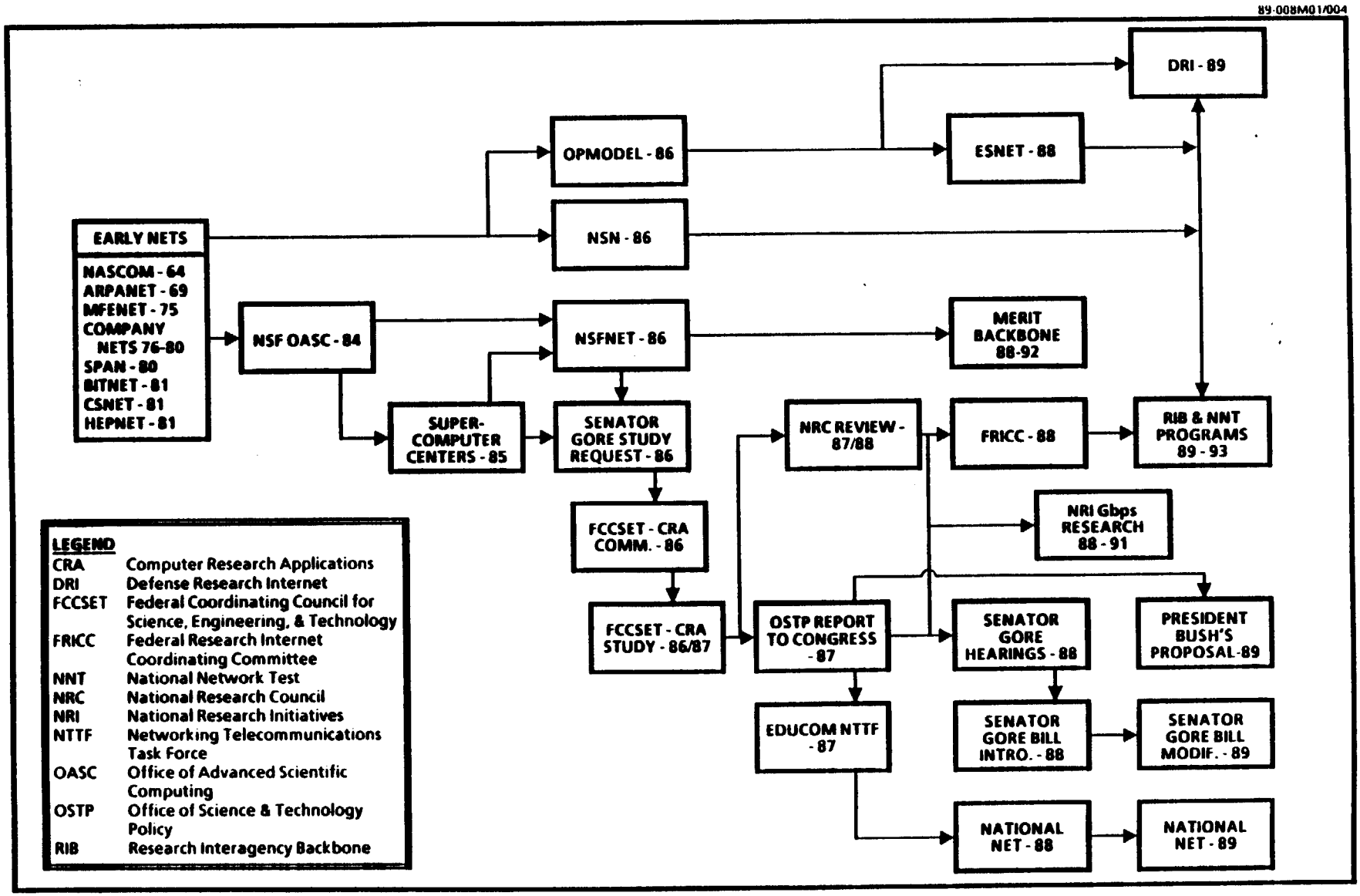


EXHIBIT 4-1. EVOLUTION OF A NATIONAL RESEARCH NETWORK (84-89)

On the legislative side, Senator Gore proposed in 1986, that the White House Office of Science and Technology Policy (OSTP), conduct a supercomputing networking study. This proposal, which was expanded through Senate-House negotiations, led to the OSTP's establishment of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) Committee for Computer Research and Applications CRA). This FCCSET committee, which consists of representatives of federal agencies involved in computer research and applications, conducted studies during 1986 and 1987 and submited their report to the OSTP in August of 1987. The OSTP used this report to prepare their response to Congress, which they submitted in November, 1987.

The FCCSET study report and the OSTP response to Congress led to several major activities. First, the National Research Concil (NRC) was asked by the FCCSET committee to review the FCCSET study report; the NRC conducted their review during 1987 and 1988. Also, the FCCSET report and the OSTP response to Congress encouraged EDUCOM (an ad-hoc group of academic institutions) to establish its Networking and Telecommunications Task Force (NTTF) whose purpose is to provide leadership for networking policy issues. To carry out this mission, NTTF helped sponsor National Net88 to provide a forum for discussion of issues related to research networks, in April, 1988. National Net89, conducted in April, 1989, reviewed progress since National Net88. The OSTP response to Congress and the NRC review of the FCCSET committee report were used in hearings, chaired by Senator Gore in August, 1988. Senator Gore introduced an NRN bill in October, 1988 and plans to hold additional hearings on a modified NRN bill in 1989.

The OSTP response to Congress and the NRC review of the FCCSET committee report encouraged two additional activities. They led to the establishment of the Federal Research Internet Coordinating Committee (FRICC) in 1988 and the funding of the Corporation for National Research Initiatives (NRI) study of Gigabit networks. The FRICC committee efforts have culminated in the Research Interagency Backbone (RIB) program and the National Network Test (NNT) program. The NRI study, begun in late 1988, is an ongoing effort sponsored by NSF and the Defense Advanced Research Projects Agency (DARPA).

While these activities were being conducted, NASA Science Network (NSN, 1986), the MERIT backbone (1988), and the ESNET (1988) were being implemented. The Defense Research Internet (DRI), which will replace ARPANET, is planned for 1989. Segments of each of these networks are expected to use the RIB and to participate in NNT.

To develop a better understanding of the events leading to the development of an NRN concept, the organizations and activities enumerated above are described below in more detail. They include: the FCCSET committee; the NRC review; EDUCOM and its National Nets; FRICC and its RIB and NNT; NRI and its Gigabit network research; and related legislation.

4.3 FCCSET COMMITTEE ON COMPUTER RESEARCH AND APPLICATIONS

4.3.1 The FCCSET Committee

As noted above, in August, 1986 the 99th Congress requested that the OSTP, resident in the Executive Office of the President, study the computer networking requirements of U.S. scientists, engineers and researchers and provide a plan for action by August, 1987. In response, the OSTP established a new interagency group, the FCCSET Committee for Computer Research and Applications. This FCCSET committee on Computer Research and Applications established three subcommittees: a) Science and Engineering Computers, b) Computer Research and Development, and c) Computer Networking Infrastructure and Digital Communications. The subcommittees held a series of workshops involving many scientists, engineers and researchers from academia, industry and government. They examined current resources, current and future needs, technology requirements, and technical problems. The results of their efforts were presented in a report titled, "A Research And Development Strategy For High Permance Computing." In this report, they presented recommendations for developing high performance computers, enhancing software technology and algorithms, developing computer networking, and conducting basic research. The report also dealt with human resources requirements for implementing their recommendations. This report was delivered to the OSTP in August, 1987. While this three-volume report was never made public,

OSTP did send a summary of it to Congress in November, 1987.

4.3.2 Findings And Recommendations

The following are the report's major findings and recommendations concerning networking.

Findings: The report concluded that the U.S. faces serious challenges in networking technology which could become barriers to the advancement and use of computing technology in science and engineering. Specifically, it stated that:

1. Current network technology does not adequately support scientific collaboration or provide access to unique scientific computing resources. At this time, U.S. commercial and government sponsored networks are not coordinated, do not have sufficient capacity, do not interoperate effectively, and do not ensure adequate security.
2. Europe and Japan are aggressively moving ahead of the U.S. in a number of networking areas with the support of concentrated government- and industry-sponsored research and implementation programs.

Recommendations: The report recommended that the U.S. government, industry and universitites coordinate their research and development efforts for implementing a research network to provide a distributed computing capability that would link government, industry, and higher ecucation communities. More specifically, it recommended that a research network be established in the following three-stage approach to upgrade the current facilities and to develop needed new capabilities:

Stage 1 - 1989-1990:

Interconnect and upgrade existing agency networks, adopt common access standards (protocols), and share transmission facilities so that the backbone and major regional networks could operate at 1.544 Mbps (standard T1 rate).

Stage 2, 1991-1996:

Focus developments on gateways, routers, switches, protocols, and architectures. Provide 45 Mbps service for networking selected research facilities and 1.544 Mbps for connecting 200 to 300 research institutions.

Stage 3, 1997-2006:

Establish a vigorous, focused program of network research and development resulting in a network that could deliver 1 to 3 Gbps to selected research facilities, 45 Mbps to about 1000 facilities, and 1.544 Mbps to all other research facilities in the U.S.

4.4 NRC NATIONAL RESEARCH NETWORK REVIEW COMMITTEE

4.4.1 The NRC Committee

The National Research Council, which is administered by the National Academy of Sciences, the National Academy of Engineering and the Institute of Medicine, has a Computer Science and Technology Board (CSTB). The National Research Network Review Committee (NRNRC) was established under the auspices of this board to review proposals developed by the FCCSET Committee on Computer Research and Applications. NRNRC was asked by the FCCSET Subcommittee on Computer Networking to consider issues related to: the technical feasibility of the network proposals; the utility of the proposed network to the research community; and developments in computer technology. Committee members, who were selected for expertise in computer and network technology, network-based services and the conduct of scientific research, represented both academia and industry and began work in September, 1987. They received briefings from FCCSET representatives, deliberated on the OSTP proposals and developed their own views on an NRN. The results of their efforts, which primarily addressed the network proposal section of the OSTP report, are presented in a 1988 report titled, "Toward A National Research Network."

4.4.2 The NRCRC Conclusions

The following are the major conclusions presented by NRNRC:

1. NRN Benefits: The NRNRC strongly supports the concept of an NRN proposed by OSTP. It feels that the U.S. would benefit significantly from the creation of an NRN. The committee points out that such a

network would help create a much needed computer network infrastructure, improve the productivity and quality of research output, lead to commercial spinoffs, and promote U.S. competitiveness in many disciplines.

2. User Needs And Concerns: The NRNRC reported that all potential users (i.e., researchers in science/engineering, economics/social sciences, and arts/humanities) agreed that an NRN is a most worthwhile goal. Specifically, they have needs for high speed, widespread access, user-friendly service, high quality, and high performance. In addition to this concern about needing a good operational network, users want to make certain that federal funding for a research network does not diminsh federal funding for the conduct of research.

3. Technical Considerations: NRNRC pointed out that Phase 1 (requiring coordination) and Phase 2 (requiring network management) of the OSTP plan were efforts to catch-up with the state-of-the-art as opposed to advancing the networking technology. The committee felt that Phase 3 may have to address technical issues in areas such as network control, switching, routing, multiplexing, processor interfaces, protocols, and architectures, particularly, as related to high speed networks.

4. Funding Considerations: NRNRC recommended that incentives be provided to encourage industry to provide existing network technology to the NRN, while the government would provide funding for advanced network development. They also discussed the need for and the problems expected from introducing charges for use.

5. Management Considerations: NRNRC identified the major management concerns as: developing engineering facilities and services to match demand and tuning them to the expressed needs of users; maintaining them in an operational state; and operating them economically. The committee emphasized that a new operating organizational structure is needed to provide the required network facilities and to manage and operate them. That is, this new structure must include a funding mechanism, an oversight committee, day-to-day management, and a feedback loop with the user community.

6. Commercial And Special Network: NRNRC concluded that the NRN must build on existing and anticipated commercial network facilities and network-based services; that the NRN implementors must work with the common carriers and computer vendors; and that NRN long-range planning should allow for the eventual transition of at least portions of the NRN to industry.

4.5 EDUCOM AND NATIONAL NET88/89

4.5.1 EDUCOM Task Force

EDUCOM is a non-profit consortium of colleges, universities and other institutions founded in the early 1960s to facilitate the introduction, use and management of information technology. It is funded by dues, service fees, and grants from foundations, corporations and government agencies. Its networking activities, which are designed to promote the growth and interconnection of computer networks throughout institutions of higher education, include its Networking and Telecommunications Task Force (NTTF) and its BITNET Network Information Center.

4.5.2 National Net88

In April, 1988, EDUCOM, along with the National Association of State Universities and Land Grant Colleges and the New York State Educational and Research Network, sponsored National Net88, which was funded by a support grant from NSF. The purpose of this conference was to begin the process of forging an alliance among government, industry and higher education to create a national instruction and research network that would connect everly college and university and provide a wide array of services including a knowledge management system. The major issues discussed at this conference included: purpose and development of the NRN; its users and uses; its management; and its funding. The importance of the NRN, unsolved problems and possible solutions also were discussed.

4.5.3 National Net88 Observations & Recommendations

As indicated in the summary of the NRN history, this conference grew out of the FCCSET report noted above, and while it supported the major findings of this report, it provided additional insights and added much detail to the definition of problems and the delineation of possible solutions concerning a NRN. The following are some of the major observations and recommendations made by the presenters who represented government, industry and academia. Unlike the findings and recommendations of the OSTP and NRC reports, those presented during the EDUCOM National Net88 conference have not been integrated, and, in fact, often reflect the different views of the various participants. The selected National Net88 observations and recommendations have been grouped under four headings: purpose, users and uses, management and funding.

1. Purpose Of A National Network (NN):

a. We need a NN because technological factors are altering the process of research. Researchers need access to our powerful computers which are becoming both our microscopes and our telescopes. They can help us see what is impossible to see with a lab instrument; simulate places we cannot go; model events that have not occurred; and visualize the results of these possible events.

b. An NN can help us propel scientific research to a new level where we can examine more effectively the great questions of our time. For examples: Will the universe expand forever? How does the brain process information? and What biochemistry underlies disorders like Alzeimer's disease? An NN can also benefit applied science by helping us: track airbone nuclear particles in the event of a nuclear disaster; predict earthquakes; and match patients with organ donors.

c. An NN can be a "workplace without walls," a facility of national and even international scope for education, research, and other scholarly pursuits. It encourages collaborations and resource sharing and thereby speeds the spread of knowledge. It makes accessible the full

range of the nations' educational and intellectual resources: databases, libraries, computers and people.

d. Given that the commerce of ideas is becoming more important to the U.S. than the commerce of things, and that the applications of a NN will be as important to modern research as the telephone was to commerce early in this century, an NN will be critical to U.S. competitiveness.

e. We have a national postal system, a national transportation system, and national broadcast networks; we need a national computer network.

f. We are in an era of internationalization, and scholarship is no exception. We need an NN so our researchers can communicate with each other within the U.S. and across our borders to scholars around the world. Furthermore, future extensions of the NN will go well beyond the boundaries of scientific research to scholarship of all types.

2. Users And Uses Of An NN:

a. The OSTP report failed to focus on the NN as a means for broad access to information and for promotion of collaborative interactions in support of all higher education, not just the research community. Also, the FCCSET committee did not include representatives from academia and industry.

b. We are moving from an era when networks were the province of computer scientists to one when the networks will become an ubiquitous service for all educational endeavors.

c. An NN must be accessible, ultimately, to the public at large. There is no fundamental reason to have networks for research and other uses segregated, than it is necessary to have telephone systems segregated for researchers and non-researchers.

d. An NN must be a public resource, accessible, reasonably secure, and readily available to all segments of our society.

e. The NN must provide for more extensive and productive collaboration among researchers using the most advanced workstations, which have access to the nation's libraries and to unique facilities that enable, for example, the modeling of physical processes in real time.

f. Since library networks foster scholarship across all disciplines, it is imperative that the NN be designed to accomodate the transfer of bibliographic records and other library support data. In the future, and if the obvious legal issues are resolved, the NN should be able to support the exchange of documents themselves, intersystem interlibrary loans, and the full text transfer between a publisher and libraries.

g. Applications (e.g., the updating of color displays from remote computers in real time) of an NN are needed in biotechnology, high energy physics, fluid flow simulation, chemical molecular modeling, and seismic and geological research.

h. In the future, the NN should include a digital library system and custom machines tailored to solve specific problems. With the digital library system, the user at a workstation should be able to gain access to documents with simple language instructions without having to know where the documents are located, or what data base they reside in. Custom machines might be needed, for example, by the physicist exploring the origins of the universe.

3. Management Of An NN:

a. The OSTP failed to provide clear recommendations on management and operation of the NN.

b. The development, operation and management of an NN need a continued partnership among government, industry and higher education.

c. The key issues pertaining to the development, operation and management of an NN involve: structure--need to ensure that the whole process converges on a coherent network that really works for researchers;

bandwidth--need to justify very high bandwidths by providing examples of practical experience and concrete evidence; institutional changes--need to specify which ones are needed; and local area interconnection--need efficient designs for interconnection within the local area, designs that will permit data rates as high as one Gbps to be transmitted to and processed by the workstations.

d. Specific management concerns include: evaluating the effectiveness of the NN; linking network support to ongoing research programs; providing better coupling with industry; adding new technology to the network as it evolves; continuity in management; bringing new ideas about networks to meet future requirements; and giving choices to the researchers.

e. Industry representatives think the U.S. should put the job of moving its most precious commodity (i.e., information) in the hands of experienced networking and information management people, i.e., the industry. They point out that the industry has the bandwidth, the transmission and switching capabilities, and the ability to standardize, and therefore, can create a less expensive, more reliable network.

4. Funding An NN:

a. The costs for research, creation and operation of an NN, as specified in the OSTP report, must be reviewed by potential users to make certain the NN will meet their needs.

b. Universities can help by contributing their intellectual resources; governments by funding development; and industry by contributing funds, equipment and people.

c. Individual scientists are doing their part by learning about and using the networks; academia is doing its part by funding construction and operations of campus area networks; the states are developing state networks; and the federal government must do its part by funding an NN.

d. The federal government funded the national mail system, the continental railroads, and the national highway network; similar funding for an NN will come about in the U.S. in response to worldwide competitive pressures.

e. The bulk of the benefits of an NN accrue to society as a whole. Research and education networks involved in the facilitation of research information and education cannot be self-subsidizing or self-financing and government funding is necessary.

f. The order of magnitude of funding required for an NN is very small compared to the public expenditures the U.S. devotes to the support of research and education. However, the organizations that lobby on behalf of scientific and educational programs do not put networking high among their priorities.

g. The national networking situation can be summarized by saying we have billions of dollars worth of facilities and hundreds of scientists deprived of full use of these facilities for want of relatively sparse investment in linking scientists to facilities. We have billions of dollars expended on research facilities and trivial amounts available for interconnecting people to facilities.

h. We should not shift the cost away from the user to society as a whole, as such a shift would make the NN non-responsive to uers needs and economically inefficient.

i. The funds for network service must go through the hands of the network user; we must transition into a period when data communications is provided as a service.

j. Networking is not mature enough to be treated as a utility. Only after growth, use patterns, and legal impediments are fully understood should an attempt be made to treate an NN as a utility.

k. Funding could be based on user category: the federal government could

support the researcher, the state governments could support the basic needs of educators and students, and individuals could pay for their own use.

4.6 FEDERAL RESEARCH INTERNET COORDINATING COMMITTEE (FRICC)

4.6.1 The FRICC

For several years, a group of representatives from five federal agencies (i.e., the Departments of Defense, Energy and Health and Human Services; the National Aeronautics and Space Administration; and the National Science Foundation) had been meeting informally to discuss common networking problems. After the OSTP report was completed, these representatives chartered themselves as the Federal Research Internet Coordinating Committee. Their goals are: to share networking resources, promote the evolution of internet management techniques, coordinate networking research and development, provide oversight for the development of an NRN, and to coordinate internationalization of the participating agencies' networks. They are working to coordinate the networking plans of the participating agencies and to achieve economies of scale by eliminating duplication.

4.6.2 The Research Interagency Backbone

One of the FRICC's accomplishments is the pooling of funding for a Research Interagency Backbone (RIB). In January, 1989, the National Science Foundation (NSF) released a project solicitation for the development and management of a "Research Interagency Backbone." This project is a joint effort of the five FRICC agencies noted above, and is a response to the OSTP and NRC reports described above. The RIB will be a DS3 (45 Mbps) coast to coast fiber optic high reliability data network. The RIB project, in the short term, will provide a testbed for research in very high speed networks, and will expand the capacity of existing Federal agency research networks. Its long term purpose is to lay the technical groundwork for transition from multiple independent agency networks to an

integrated National Research Network (NRN) offering state of the art capabilities and services.

4.6.3 National Network Test (NNT) Bed

Another similar accomplishment of the FRICC is the National Network Test (NNT) program. The NNT program began in early 1989 and, as planned for the RIB program, is conducting networking experiments using real network data. The NNT program uses six cross-country T1 channels, with three of these T1 channels dedicated to separate, but connected, backbones for DOE, DOD and NASA. A variety of experiments are planned for each of the backbones and for the network formed by the three backbones. Policy based routing and applications using parallel computers are two of the areas that will be examined.

4.7 CORPORATION FOR NATIONAL RESEARCH INITIATIVES: GIGABIT NETWORK RESEARCH

4.7.1 Corporation For National Research Initiatives

The Corporation for National Research Initiatives (NRI) is a non-profit research and development organization formed in 1986 to help focus U.S. strengths in information processing technology. NRI works with industry, government and academia and is engaged in scientific research on the design of experimental infrastructure which can imporve the country's long-range scientific and engineering productivity. Its founder and president is Robert Kahn who has worked at Bell Laboratories, MIT, DARPA and Bolt Beranek and Newman (BBN). At BBN, he was the driving force in the development of ARPANET.

4.7.2 Gigabit Network Research

Currently, NRI is studying the feasibility and utility of wide-area research networks operating at speeds on the order of a gigabit/second or higher. It is hoped that this study effort, which is sponsored by NSF and

DARPA under a grant from NSF, will provide a foundation on which to launch phase three of the NRN as described in the NRC review of the OSTP report to Congress. This study is designed to explore the technology necessasry for the development of a gigabit/second research network and to demonstrate its utility. During the next two or three years it plans to: explore the use of state-of-the-art switching and transmission technologies; determine the applicability of these technologies to network architecture and inter-computing networking; develop protocols and interfaces; evaluate network technology; and design and demonstrate network applications. In its initial effort, NRI has sought, from interested and qualified organizations, information on innovative ideas and/or technology related to a gigabit/second network.

4.8 LEGISLATION: "NATIONAL HIGH PERFORMANCE COMPUTER TECHNOLOGY ACT

As moted earlier, Senator Gore of Tennessee had provided initial impetus for the OSTP FCCSET report. Senator Gore had introduced legislation to explore the use of fiber optics to link supercomputer centers. In negotiations with the House on the fiscal year 1987 NSF Authorization Bill, the proposed study was expanded to project networking needs, critical problems, and current and future options regarding communications networks for all research computers, not just supercomputers, at both academic and federal research facilities. The actual FCCSET committee report went even further; it encompassed all aspects of advancing high performance computuing capabilities, of which networking is only one part.

After this report was submitted to Congress in summary form (November, 1987) and the NRC review of this report was released (April, 1988), Senator Gore held hearings (August, 1988) and introduced a bill, "National High-Performance Computer Technology Act (October, 1988). This bill was to provide for a national plan and coordinated Federal research program to ensure continued U.S. leadership in high performance computing (including a high-capacity national computer research network). There was insufficient time to consider the bill in the Fall of 1988, and it is now

being modified slighlty to reflect new findings. Hearings on the modified bill are planned for Summer or Fall of 1989, and it might be considered on the floor in late 1989 or early 1990.

4.9 SUMMARY - A NATIONAL RESEARCH NETWORK

While it is clear that we need an NRN, it is also equally clear that a number of key questions concerning an NRN remain to be answered and the results of the planning for an NRN had important implications for the current effort.

4.9.1 Key Questions

. The key questions include:

1. What do we mean by research? Is it limited to a miniscule scientific community engaged in advancing frontiers of science, or does it include supporting engineerging and development types of activities. While some have broadened research to include all of education, others expect an NRN to be more limited, especially in the near-term, in its application.

2. Who should use the network? Potential users range from the scientific researcher to the general public.

3. Who should manage the network? Government? Academia? Not-for-profit organizations? Business/Industry? Or, some combination of these groups?

4. Who should pay for the network creation and operation? Suggestions range from treating the NRN as a government investment to a utility. Suggestions also have been made for basing payment on the stage of network development and on the user and usage.

5. What are the network needs and requirements? Will we really need to send giga bits per second (Gbps) traffic door-to-door, and if so, what

requirements will this impose on the backbone network? If we need to send 1 Gbps door-to-door, will we need a backbone that supports data rates on the order of 10 to 100 Gbps?

6. How do we transition from where we are to where we need to be? What research and development steps must be taken? How do we ensure that all stakeholders are represented? What institutional changes are necessary?

7. What are the international implications? What are the implications of the sharing of ideas and resources on an international scale for our NRN requirements, our security, and our economic competitiveness? Should we work towards linking every scholar in the world with every other scholar?

4.9.2 Important Implications

1. An extensive amount of effort has already been spent on planning and developing an NRN, and the current study built upon and supported this effort.

2. This NRN effort had major bearing on all aspects of the current study which benefitted from this effort by carefully examining the results of the specific NRN activities.

3. Plans for the future development of an NRN are being made, and the current study considered these plans when projecting an integrated national computer research network.

4. Since the plans and development of an NRN have changeed rapidly, the current study was designed to be as up-to-date as possible.

5. It is apparent that the current study can be useful to the NRN effort as well as to NASA Lewis.

6. The extensive international links to the NRN and the impact of research in space should be examined.

SECTION 5

SELECTED COMPUTER RESEARCH NETWORKS

5.1 OVERVIEW

All major federal agencies were contacted to identify the major computer research networks sponsored by the federal government. Based on the information obtained from the federal agencies, a brief summary of the computer networks sponsored by and/or used by these agencies was developed. Based on this review and analysis, the computer research networks to be comprehensively examined were selected.

5.2 FEDERAL AGENCY NETWORK SUMMARY

To start this study, an initial list of federal agencies of interest was developed, and is presented in Exhibit 5-1. This list was reviewed to determine which agencies were most likely to have computer research networking requirements and/or interests. Based on this review, a second list was developed of agencies expected to have such requirements and/or interests. This list, which is presented in Exhibit 5-2, includes those agencies which were actually contacted.

Information on the federal agencies' networks was collected through telephone interviews, personal interviews and analysis of existing publications and reports. For each of the agencies contacted, the following information was collected: name, address, telephone number of agency contact person; and type of networks the agency uses (i.e., those managed by and/or funded by them and those that they merely access). This information is presented in Exhibit 5-3.

The majority of the agencies contacted have or use telecommunications networks for operational and administrative purposes. Most of these agencies do not have their own computer research network, but they usually

(Please turn to page 5-14)

EXHIBIT 5-1. INITIAL FEDERAL AGENCY CONTACT LIST

Agency For International Development
Agriculture, Dept. of
Commerce, Dept. of
- National Institute of Standards & Technology (NIST, formally NBS)
- National Oceanic & Atmospheric Administration (NOAA)
- National Telecommunications & Information Administration (NTIA)

Congressional Budget Office (CBO)
Defense, Dept of
- Air Force, Dept. of
- Army, Dept. of
- Defense Advanced Research Projects Agency (DARPA)
- Defense Communications Agency (DCA)
- Navy, Dept. of

Education, Dept. of
Energy, Dept. of
Environmental Protection Agency (EPA)
Executive Office of the President
Export/Import Bank of the U.S.
Federal Communications Commission (FCC)
Federal Emergency Management Agency (FEMA)
Federal Reserve Board
General Accounting Office (GAO)
General Services Administration
Health & Human Services (HHS), Dept. of
- Public Health Service
- Social Security Administration

House of Representatives
Housing & Urban Development, Dept. of
Information Agency, U.S.
Interior, Dept. of
International Trade Commission
Interstate Commerce Commission
Justice, Dept. of
- FBI

Library of Congress
Labor, Dept. of
National Academy of Sciences (NAS)
National Aeronautics & Space Administration (NASA)
National Endowment for the Arts
National Endowment for the Humanities
National Science Foundation
Office of Management & Budget
Peace Corps
Securities & Exchange Commission (SEC)
Small Business Administration (SBA)
State, Dept. of
Transportation, Dept. of
- Federal Aviation Administration (FAA)
- Federal Highway Administration
- U.S. Coast Guard

Treasury, Dept. of
- Internal Revenue Service (IRS)
- U.S. Secret Service

Veterans Administration

EXHIBIT 5-2. FEDERAL AGENCIES CONTACTED

Agriculture, Dept. of
Commerce, Dept. of
- National Institute of Standards & Technology (NIST)
- National Telecommunications & Information Administration (NTIA)
- National Oceanic & Atmospheric Administration (NOAA)

Defense, Dept. of
- Defense Advanced Research Projects Agency (DARPA)
- Defense Communications Agency (DCA)

Education, Dept. of
Energy, Dept. of
Environmental Protection Agency (EPA)
Health & Human Services, Dept of
- National Institutes of Health
- National Library of Medicine

Housing and Urban Development, Dept. of
Interior, Dept. of
- U.S. Geological Survey
- Bureau of Mines
- Office of Surface Mining Reclamation
- Fish & Wildlife Service
- Minerals Management Service

Justice, Dept. of
Library of Congress
National Academy of Sciences
National Aeronautics & Space Administration
National Science Foundation
Nuclear Regulatory Commission
Transportation, Dept. of
- U.S. Coast Guard
- Federal Aviation Administration

Treasury, Dept. of the
Veteran's Administration

EXHIBIT 5-3. FEDERAL AGENCIES' USE OF R&D TELECOMMUNICATIONS NETWORKS

DEPARTMENT	AGENCY	CONTACT	NETWORK	
			INTERNAL - TYPE	EXTERNAL - TYPE
DEPARTMENT OF AGRICULTURE		1. TOM HOWELL, DIRECTOR OF RESEARCH / UTOMATION USDA AGRICULTURAL RESEARCH SERVICE NAL BUILDING, ROOM 013 BELTSVILLE, MARYLAND 20705 2. HERB KUEHNE, DEPNET PROJECT LEADER USDA OFFICE OF INFORMATION RESOURCE MANAGEMENT ROOM 418-W 14TH AND INDEPENDENCE AVE., SW WASHINGTON, DC 20250	• DEPNET - (O&A); X.25 P.S. NETWORK - SUPPORTS ASYNC/SYNC, REMOTE JOB ENTRY, IBM 3270, X.400 - LINKS 15,000 FIELD OFFICES - WILL MIGRATE TO FTS2000 - PROBABLY CARRIES SOME RESEARCH TRAFFIC • AGCOMNET (WAN) - CURRENT PROCUREMENT	• USES BITNET, ARPANET, OTHER DIAL-UP NETS

89-006M/002

EXHIBIT 5-3. FEDERAL AGENCIES' USE OF R&D TELECOMMUNICATIONS NETWORKS

DEPARTMENT	AGENCY	CONTACT	NETWORK	
			INTERNAL - TYPE	EXTERNAL - TYPE
DEPARTMENT OF COMMERCE		1. JEROME GIBBONS (ELECTRONICS ENGINEER) ACTING CHIEF, TELECOMMUNICATIONS MANAGEMENT DIVISION (AS OF 12/30/88) DEPARTMENT OF COMMERCE OFFICE OF THE SECRETARY, ROOM 6625 14TH STREET & CONSTITUTION AVE. NW WASHINGTON, DC 20230 2. THOMAS ZETTY CHIEF, TELECOMMUNICATIONS MANAGEMENT DIVISION DEPARTMENT OF COMMERCE ROOM 6621 14TH STREET BETWEEN CONSTITUTION & E ST. NW WASHINGTON, DC 20230	• VARIOUS FOR OPERATIONAL PURPOSE	
DEPARTMENT OF COMMERCE	NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY	STEVE WHITE CHIEF, COMPUTER SYSTEMS & COMMUNICATIONS DIVISION NIST TECHNOLOGY BUILDING, ROOM A151 GAITHERSBURG, MARYLAND 20899	• TWO T_1 LINES: GAITHERSBURG - BOULDER, CO GAITHERSBURG - UNIV OF MD • (CS)2 CONNECTS 8 LABS; CURRENTLY PLANNED FOR MODERNIZATION ENABLING DIRECT HIGH SPEED LINK BETWEEN WORKSTATIONS AND THE NEW SYSTEMS AND SUPER COMPUTERS [INSTALLED FY 90]	ACCESS ARPANET, NSFNET, BITNET, AND MILNET (56 KBPS OR LOWER) THROUGH LEASE OF WANs

89 008M/002

EXHIBIT 5-3. FEDERAL AGENCIES' USE OF R&D TELECOMMUNICATIONS NETWORKS

DEPARTMENT	AGENCY	CONTACT	NETWORK	
			INTERNAL - TYPE	EXTERNAL - TYPE
DEPARTMENT OF COMMERCE	INSTITUTE OF TELECOMMUNICATION SCIENCES (ITS), NTIA	NEIL SEITZ DEPUTY DIRECTOR SYSTEMS AND NETWORK DEVELOPMENT 325 BROADWAY STREET, BOULDER, CO 80303		• ACCESS TO TELENET PUBLIC NETWORK • HAS NODE ON THE VA NETWORK (VADATS)
DEPARTMENT OF COMMERCE	NOAA	JACK HARPER CHIEF, INFORMATION TECHNOLOGY SCIENCES NOAA ENVIRONMENTAL RESEARCH LABORATORY (MAIL-STOP R-E11) 325 BROADWAY ST. BOULDER, COLORADO 80303	• HAS A PRIVATE NETWORK/ COMMUNICATES WITH NIST IN GAITHERSBURG – NIST MAINTAINS THE NETWORK AND NOAA-ERR SHARES ITS RESOURCES – 9600-56KBPS LEASED CIRCUITS BY NIST (IN '83) • 5 NEW SUPER COMPUTERS: 2 AT METEOROLOGICAL CENTER SUITLAND MD. /2 AT GEOFLUID DYNAMICS LAB, PRINCETON NJ, AND ONE AT NIST	• SCIENCE NET BY OMNET INC - EMAIL - MOST OCEANIC & ATMOSPHERIC RESEARCHERS ARE ON THIS • BITNET & ALL OTHER RESEARCH NETS DEPENDING ON RESEARCHER
DEPARTMENT DEFENSE	DEFENSE ADVANCED RESEARCH AGENCY (DARPA)	J. MARK PULLEN DARPA/ISTO 1400 WILSON BLVD. ARLINGTON, VA 22209	ARPANET DEFENSE RESEARCH INTERNET (SEE DESCRIPTION)	
DEPARTMENT OF EDUCATION		GEORGE SOTOS DEPUTY DIRECTOR OIM US DEPARTMENT OF EDUCATION 400 MARYLAND AVE, 800 ROOM 4682 ROB-3 WASHINGTON DC 20202	• DOES NOT HAVE OWN UNIQUE NETWORK • USES LINKED LINES, DIAL-UP LINES, E.G. DIALCOM	• SOME MAY ACCESS RESEARCH NETS • NO FORMAL TIES WITH EDUCOM

89-0084/002

EXHIBIT 5-3. FEDERAL AGENCIES' USE OF R&D TELECOMMUNICATIONS NETWORKS

DEPARTMENT	AGENCY	CONTACT	NETWORK	
			INTERNAL - TYPE	EXTERNAL - TYPE
DEPARTMENT OF ENERGY	OFFICE OF ENERGY RESEARCH	1. DANIEL A. HITCHCOCK, PH.D. PHYSICIST/MANAGER OF ESNET PROJECT SCIENTIFIC COMPUTING STAFF MSER-7 OFFICE OF ENERGY RESEARCH US DEPARTMENT OF ENERGY WASHINGTON, DC 20545 2. ROBERT WOODS, ER 222 CHIEF, PROGRAM OPERATIONS BRANCH DIVISION OF HIGH ENERGY PHYSICS DEPARTMENT OF ENERGY, WASHINGTON DC 20545	• ESNET • MFENET • HEPNET • LEP3 NET (SEE DESCRIPTIONS)	ACCESS TO NSFNET, BITNET, MILNET, AND ALL OTHER RESEARCH NETS
ENVIRONMENTAL PROTECTION AGENCY (EPA)		BOB DENNY TELECOMMUNICATIONS PROGRAM MANAGER NATIONAL DATA PROCESSING DIVISION ENVIRONMENTAL PROTECTION AGENCY ERC-A-304, MD-34 RESEARCH TRIANGLE PARK, NC 27711		- ACCESS NCAR FACILITIES IN BOULDER, CO - HAS BITNET CONNECTION
DEPARTMENT OF HEALTH AND HUMAN SERVICES	NATIONAL INSTITUTES OF HEALTH	WILLIAM L. RISSO ASSISTANT DIRECTOR DIVISION OF COMPUTER RESEARCH AND TECHNOLOGY (DCRT) HHS, NATIONAL INSTITUTES OF HEALTH 9000 ROCKVILLE PIKE BUILDING 12A, ROOM 3033 BETHESDA, MARYLAND 20892	• IN THE PROCESS OF INSTALLING CAMPUS AREA (300 ACRE) BACKBONE NETWORK USING FIBER OPTIC AND BROADBAND CABLE WITH CAPACITY OF 100 MBPS AND 5 MBPS, RESPECTIVELY • PROTOCOLS SUPPORTED: TCP/IP, XNS, AND DECNET	• T1 LINES CONNECTING TO LIBRARY OF MEDICINE AND THE CANCER INSTITUTE • BITNET AND NSFNET (THRU SURANET) CONNECTIONS

EXHIBIT 5-3. FEDERAL AGENCIES' USE OF R&D TELECOMMUNICATIONS NETWORKS

DEPARTMENT	AGENCY	CONTACT	NETWORK	
			INTERNAL - TYPE	EXTERNAL - TYPE
DEPARTMENT OF HEALTH & HUMAN SERVICES	NATIONAL LIBRARY OF MEDICINE (NLM)	HARRY BENNETT DEPUTY DIRECTOR FOR OPERATIONS, NLM 8600 ROCKVILLE PIKE BETHESDA, MARYLAND 20894	• MEDICAL LIBRARY NETWORK (MLN) CONSISTS OF 4000 LIBRARIES (AT MEDICAL SCHOOL); 7 REGIONAL MEDICAL LIBRARIES (COVERING ALL REGIONS OF U.S.) • MLN PROVIDES LENDING, INFORMATION RETRIEVAL AND OTHER LIBRARY SERVICES • NLM HAS LARGE BIOMEDICAL DATABASES (MEDLARS) AVAILABLE WORLDWIDE THRU TELENET/TYMNET	
DEPARTMENT OF HOUSING & URBAN DEVELOPMENT		BOB SELLERS DIRECTOR, TELECOMMUNICATIONS DIV DEPARTMENT OF HOUSING & URBAN DEV 451 7TH STREET, SW WASHINGTON DC 20410	• HUDNET - (TELEPROCESSING NETWORK; O &A) 1200 TERMINALS LINKED • CHUMS - (COMPUTERIZED MANAGEMENT SYSTEM FOR HOMES UNDERWRITING (O & A)) 800 TERMINALS LINKED • PERSONNEL PAYROLL NETWORK; (O & A) • LOCAL AREA PC NETWORK • HIPS (WILL REPLACE HUDNET, CHUMS, & WILL UPGRADE 2500 PCs) (O &A) - HUD INTEGRATED PROCESSING SERVICE • DOES LEGAL RESEARCH	DOES NOT ACCESS RESEARCH NETS

89-008M/002

EXHIBIT 5-3. FEDERAL AGENCIES' USE OF R&D TELECOMMUNICATIONS NETWORKS

DEPARTMENT	AGENCY	CONTACT	NETWORK	
			INTERNAL - TYPE	EXTERNAL - TYPE
DEPARTMENT OF THE INTERIOR	OFFICE OF THE SECRETARY	WILLIAM HEARN CHIEF, BRANCH OF TELECOM - MGMT DEPARTMENT OF THE INTERIOR 18TH & C STREETS, NW WASHINGTON, DC 20240	SOME BUREAUS WITH DOI CONDUCTING SCIENTIFIC RESEARCH: USES GEONET - USGS - BUREAU OF MINES - FISH AND WILDLIFE SERVICES - MINERALS MANAGEMENT SERVICE - OFFICE OF SURFACE MINING RECLAMATIONS	DOES NOT THINK THE DEPARTMENT OF INTERIOR ACTIVELY ACCESSES OTHER RESEARCH NETS, WITH THE EXCEPTION OF USGS
DEPARTMENT OF THE INTERIOR	U.S. GEOLOGICAL SURVEY	ELAINE STOUT CHIEF, TELECOMMUNICATIONS SERVICES BRANCH USGS (MS-809) 12201 SUNRISE VALLEY DRIVE RESTON, VIRGINIA 22092	• GEONET - SOME RESEARCH - MAINLY OPERATIONAL AND ADMINISTRATIVE (O & A) - 12 MAJOR NODES - 17,000 LEASED TERRESTRIAL LINES - 70,000 CONNECT HOURS/MONTH	RESEARCH NETS UTILIZED: 1. NSFNET; BASICALLY 3 CONNECTIONS: - RESTON (SURANET) - MENLO PARK - DENVER (WESTNET) 2. SPAN - RESTON - GODDARD - MENLO - AMES 3. BITNET - RESTON - GEORGE MASON UNIVERSITY
DEPARTMENT OF THE INTERIOR	BUREAU OF MINES	JOHN BRUBAKER TELECOM MANAGER DIVISION OF PROPERTY AND GENERAL SERVICES DEPARTMENT OF THE INTERIOR, BUREAU OF MINES COLUMBIA PLAZA, 2401 E STREET, NW WASHINGTON, DC 20241	• GEONET - SOME RESEARCH TRAFFIC	UNDETERMINED ACCESS TO OTHER RESEARCH NETS
DEPARTMENT OF INTERIOR	OFFICE OF SURFACE MINING RECLAMATION	DOUGLAS WINK TELECOMMUNICATIONS SPECIALIST ROOM 104, INTERIOR SOUTH BUILDING 1951 CONSTITUTION AVE, NW WASHINGTON, DC	WAN: TYMNET PUBLIC AND PRIVATE SERVICES GEONET: CARRIES SOME RESEARCH DATA	- PROBABLY ACCESSES OTHER RESEARCH NETS BUT MINIMALLY, AS A BUREAU

89 608A/002

EXHIBIT 5-3. FEDERAL AGENCIES' USE OF R&D TELECOMMUNICATIONS NETWORKS

DEPARTMENT	AGENCY	CONTACT	NETWORK	
			INTERNAL - TYPE	EXTERNAL - TYPE
DEPARTMENT OF THE INTERIOR	FISH & WILDLIFE SERVICE	CLAUDE J. CHRISTENSEN CHIEF, BR. OF AUTOMATION TECH DEPARTMENT OF THE INTERIOR, FISH & WILDLIFE SERVICE 18TH & C STREETS, NW WASHINGTON, DC 20240	• GEONET - SOME RESEARCH TRAFFIC	"SPOTTY", NOT DETERMINED ON A REGULAR BASIS
DEPARTMENT OF THE INTERIOR	MINERALS MANAGEMENT SERVICE (MMS)	JAMES D. GREENING BUREAU TELECOMMUNICATIONS MANAGER DEPARTMENT OF THE INTERIOR, MMS 12203 SUNRISE VALLEY DRIVE RESTON, VIRGINIA 22091	• GEONET - SOME RESEARCH TRAFFIC	DOES NOT ACCESS OTHER RESEARCH NETS
DEPARTMENT OF JUSTICE		WAYNE SHIVELEY DEPUTY DIRECTOR FOR COMPUTER TECHNOLOGY & TELECOMS STAFF, DOJ ROOM 4100, CAB BUILDING 4125 I STREET, NW WASHINGTON, DC 20530	• CACN - FBI; - O&A • SAMNET - O&A; FBI; - HQLAN	- DOES NOT ACCESS RESEARCH NETS
LIBRARY OF CONGRESS		DANIEL HANLON ASSISTANT DIRECTOR OF ENGINEERING "THE ARCHITECT OF THE CAPITOL" LIBRARY OF CONGRESS WASHINGTON, DC 20540	• LEGISLATIVE BRANCH TELECOM NETWORK - LEGISLATIVE RESEARCH	• ACCESS PUBLIC DATA NETWORKS AND OUTSIDE DATA BASES
NATIONAL ACADEMY OF SCIENCES		TOM WISNER MANAGER, OPERATIONS & TELECOMMUNICATIONS NATIONAL ACADEMY OF SCIENCES 2101 CONSTITUTION AVE (GR 226) NW WASHINGTON DC 20418	(NOTE: NAS IS A PRIVATE, NON-PROFIT ORGIN)	• USERS BITNET, ARPANET, DIALCOM & OTHER PUBLIC NETS FOR EMAIL AND SPOOL FILES

89 0684/002

EXHIBIT 5-3. FEDERAL AGENCIES' USE OF R&D TELECOMMUNICATIONS NETWORKS

DEPARTMENT	AGENCY	CONTACT	NETWORK	
			INTERNAL - TYPE	EXTERNAL - TYPE
NATIONAL AERONAUTICS & SPACE ADMINISTRATION (NASA)		TONY VILLASENOR NASA HEADQUARTERS 400 MARYLAND AVE, SW WASHINGTON, DC 20546	NASA SCIENCE INTERNET (NSI) NASA SCIENCE NETWORK (NSA) SPACE PHYSICS ANALYSIS NETWORK (SPAN) NUMERICAL AERODYNAMICS SIMULATION NETWORK (NASNET) NASCOM (SEE DESCRIPTIONS)	
NATIONAL SCIENCE FOUNDATION (NSF)		STEVE WOLFF NSF-NCRI 1800 G STREET RM 416 WASHINGTON, DC 20550	NSFNET (SEE DESCRIPTIONS)	• USERS BITNET, ARPANET, DIALCOM & OTHER PUBLIC NETS FOR EMAIL AND SPOOL FILES
NUCLEAR REGULATORY COMMISSION		THOMAS B. KELLAM CHIEF, TELECOMMUNICATIONS BRANCH DISS/IRM/ARM (MS MNBB-8TH FLOOR) NUCLEAR REGULATORY COMMISSION WASHINGTON DC 20555	• HAS OWN AUTO-DIAL NETWORK SERVICE THAT CONNECTS TO ALL 5 NRC REGIONAL OFFICES	• USES NIH COMPUTER FACILITIES ON A TIME-SHARING (DIAL-UP) BASIS • INDIRECTLY USES DOE'S NATIONAL LABORATORIES

89 008M/002

EXHIBIT 5-3. FEDERAL AGENCIES' USE OF R&D TELECOMMUNICATIONS NETWORKS

DEPARTMENT	AGENCY	CONTACT	NETWORK	
			INTERNAL - TYPE	EXTERNAL - TYPE
DEPARTMENT OF TRANSPORTATION	TRANSPORTATION SYSTEM CENTER (TSC) WAS CREATED AS THE RESEARCH DEVELOPMENT CENTER FOR DOT.	ROBERT J. WOODS DIRECTOR, IRM, OFFICE OF THE SECRETARY (M-30) MICHAEL JACOBS CHIEF, SERVICE ASSESSMENT DIVISION US DEPARTMENT OF TRANSPORTATION RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION TRANSPORTATION SYSTEMS CENTER, KENDALL SQUARE CAMBRIDGE, MASS 02142 DICK GAUDET CHIEF, COMPUTER CENTERS DEPARTMENT OF TRANSPORTATION RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION TRANSPORTATION SYSTEMS CENTER, KENDALL SQUARE CAMBRIDGE, MASS 02142		• TERMINAL LINKS TO DDN • PIGGYBACK FAA's (ADTN) ADMINISTRATIVE DATA TRAFFIC NETWORK - ADMIN AND OPERATIONAL
DEPARTMENT OF TRANSPORTATION	UNITED STATES COAST GUARD	MICHAEL SMALLFIELD CHEIF, NETWORK SECTION DOT, UNITED STATESS COAST GUARD 2100 2ND STREET, SW WASHINGTON DC 20593		• USES FAA's ADTN AND TELENET PUBLIC NETWORK FOR O & A PUIIPOSES

89 008M/002

EXHIBIT 5-3. FEDERAL AGENCIES' USE OF R&D TELECOMMUNICATIONS NETWORKS

DEPARTMENT	AGENCY	CONTACT	NETWORK	
			INTERNAL - TYPE	EXTERNAL - TYPE
DEPARTMENT OF THE TREASURY		MARTIN GIZZI ASSISTANT DIRECTOR NETWORKS PROGRAMS, OFFICE OF TELECOMMUNICATIONS MANAGEMENT ROOM 2409-MT DEPARTMENT OF THE TREASURY 1500 PENNSYLVANIA AVE, NW WASHINGTON, DC 20220	• TREASURY CONSOLIDATED DATA NETWORK (CDN) - OPERATIONAL NETWORK FOR TREASURY'S FINANCIAL BUSINESS - X.25 PACKET SWITCH NETWORK SERVING > 3000 LOCATIONS & 20,000 USERS BY EARLY 1990's	
VETERANS ADMINISTRATION		RICHARD GREEN, PH.D. ASST CHIEF MEDICAL DIRECTOR FOR RESEARCH & DEVELOPMENT VETERANS ADMINISTRATION 810 VERMONT AVE; NW WASHINGTON DC 20420	• VADATS - (O&A) LEASED FOR TYMNET CONNECTS ALL 172 HOSPITALS THROUGH A MAIL SYSTEM	• 95 RESEARCH ADMIN OFFICES - SUBSCRIBES TO DIALCOM WHICH LINKS THEM TO THE MAJOR RESEARCH NETS - ARPANET, BITNET, NSFNET, PLUS INTERNATIONAL

89-008M/082

have access to such networks when they need them.

The major computer research networks are sponsored by the following agencies: the Department of Defense (Defense Advanced Research Agency), the Department of Energy, the National Aeronautics & Space Administration, and the National Science Foundation. The National Institute of Standards And Technology (NIST) and the National Institutes of Health (NIH) are planning expansions of their computer research network capabilities. The NIST is in the process of installing its campus-area network that will interconnect with NSFNET and other research networks. The NIH has a modernization plan for direct high-speed links among its laboratories. The National Oceanic & Atmospheric Administration (NOAA) has a private network to communicate with NIST, while the Nuclear Regulatory Commission (NRC) has its own network (involving some research application) that connects its five regional offices.

Unique operational/administrative networks include those of the Department of Agriculture (DEPNET), the Federal Aviation Administration (ATDN), the Department of Interior (GEONET), the Library of Congress (LBNT), the Department of Treasury (CDN), the Department of Housing and Urban Development (HUDNET/HIIPS), the Veterans Administration (VADATS), the Department of Justice (SAMNET; CACN), and the Department of Commerce (connects labs and supercomputers). A number of unique, agency-specific operational/administrative networks carry research traffic to some extent such as the U.S. Geological Survey's GEONET. However, for all of these networks there is no information on the extent to which these networks are used for scientific research purposes, and there is no current effort to develop this information.

5.3 SELECTED COMPUTER RESEARCH NETWORKS

5.3.1 Perspective On Research And Networks

Based on the review and analysis described above and on the information obtained when examining the evolution of the NRN, a

perspective on scientific research and computer research networks was developed. This perspective is depicted in Exhibits 5-4 and 5-5. In Exhibit 5-4, research is divided into "activities on ground" and "activities in space," and in both instances, the activities can be either national or international. A single scientific research effort may involve any of the possible combinations of research activities, i.e., on ground, in space, national or international. Thus far, effort has focused primarily on national (i.e., the United States) research activities on the ground.

The types of United States computer research networks examined in this study are listed in Exhibit 5-5 and include various types of nationwide, mid-level and campus area networks. An inverted triangle is used to depict the various sizes of networks and the relationship of smaller networks to larger ones. The adjectives "smaller" and "larger" are used here to denote geographical areas rather than capacities. The smallest network, a local area network (LAN), is at the bottom of the inverted triangle, and the largest network, a national network (NN), is at the top. LANs are interconnected to form a campus area network (CAN); CANs are interconnected to form a mid-level or regional network (RN) which may serve part of a state, the entire state, or more than one state; the RNs are interconnected to form a nationwide network, which may be termed a network, an internet or a metanetwork, depending upon the variety of protocols used. A "network" uses the same network layer protocols throughout; an "internet" uses several different network layer protocols but all of its constituent networks use the same internet layer protocols; and a "metanet" uses several different network and several different internet layer protocols.

5.3.2 Networks Selected For Comprehensive Examination

Based on the perspective described above, the results of the analysis of federal agencies' network use, and the information obtained when describing the evolution of the NRN, the following networks were selected for comprehensive examination in this study (Please turn to page 5-18):

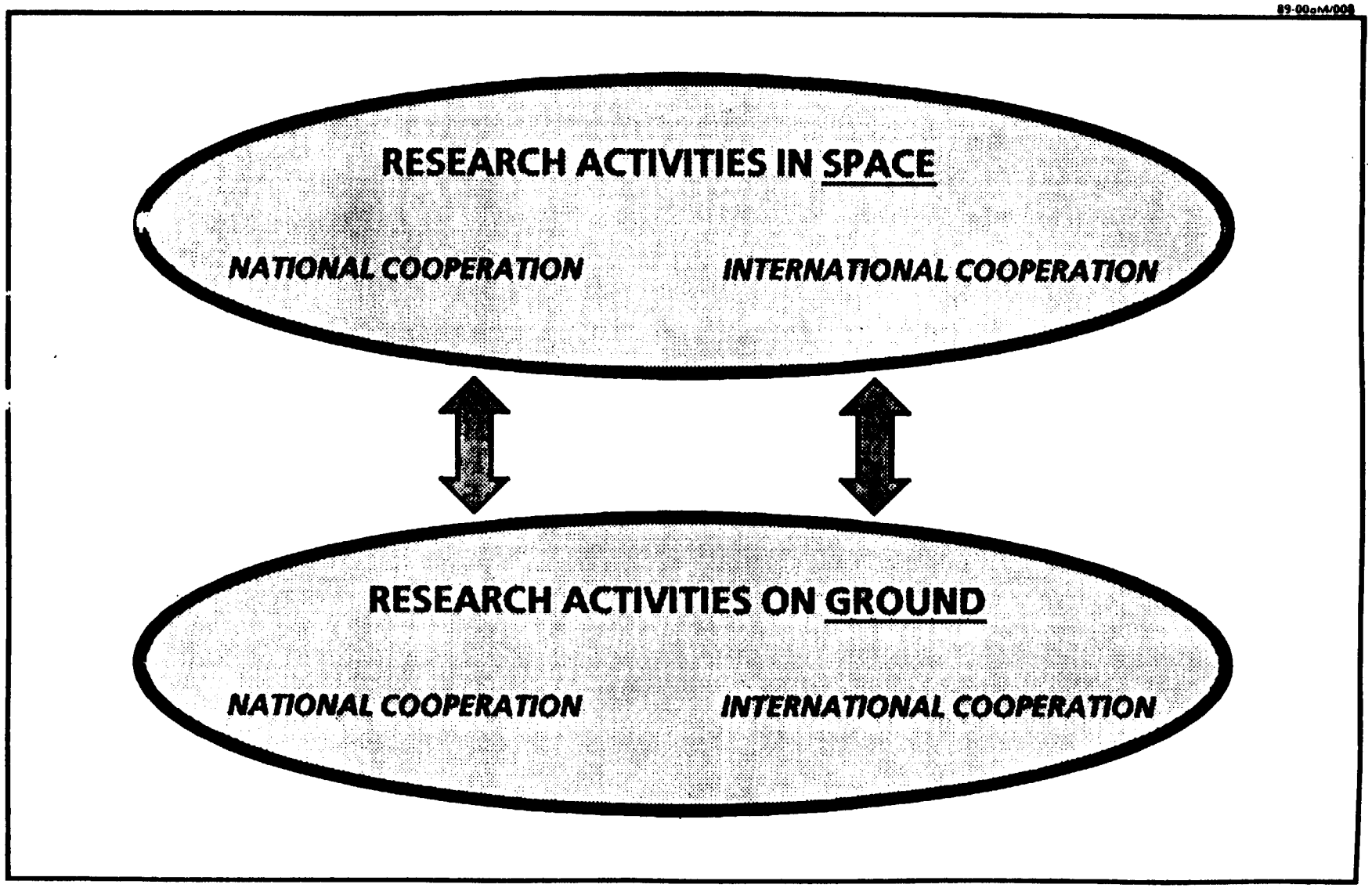


EXHIBIT 5-4. RESEARCH - NATIONAL AND INTERNATIONAL COOPERATION ON GROUND AND IN SPACE

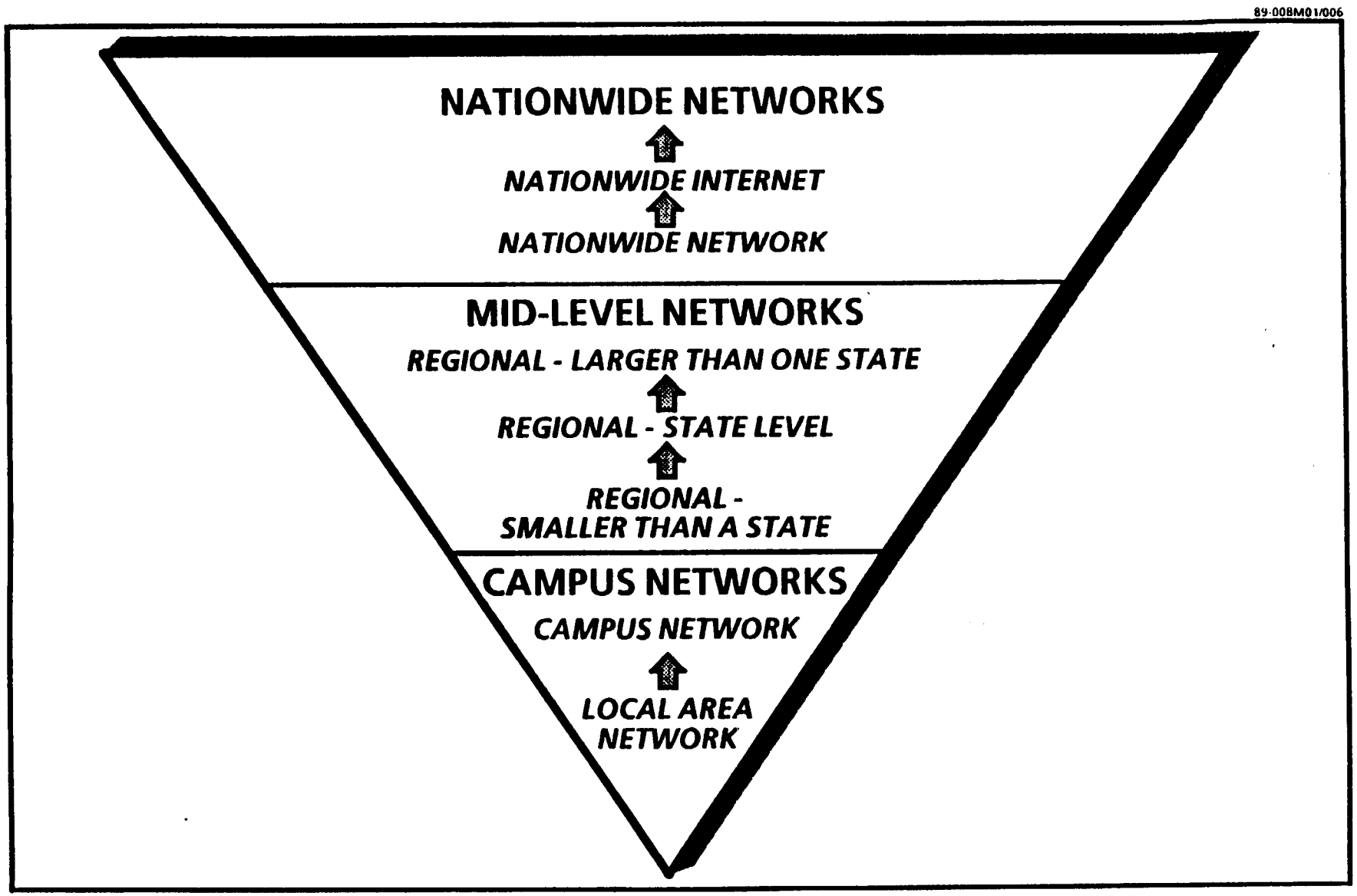


EXHIBIT 5-5. COMPUTER RESEARCH NETWORKS FOR U.S. RESEARCH ACTIVITIES ON GROUND

1. Department of Defense (DoD) research networks: Advanced Research Projects Agency Network (ARPANET), Defense Research Internet (DRI).

2. National Science Foundation Network (NSFNET): three level network including a national backbone, twenty-one mid-level networks, and over 250 campus networks.

3. National Aeronautics and Space Administration (NASA) networks: NASA Science Internet (NSI), NASA Science Network (NSN), Space Physics Analysis Network (SPAN), Numerical Aerodynamics Simulation Network (NASNET), and NASA Communications (NASCOM).

4. Department of Energy research networks: Energy Science Network (ESNET), Magnetic Fusion Energy Network (MFENET), High Energy Physics Network (HEPNET), LEP3NET (A Cern accelerator experiment network), and OPMODEL (An advanced satellite network).

5. BITNET (Before Its Time Network) and CSNET (Computer + Science Network). BITNET and CSNET were included because so many researchers and scientist (e.g., those at NIH) use these networks.

The results of the examinations of these networks (also listed in Exhibit 5-6) were used to develop the comprehensive network summaries which are presented in Sections 6-10. These summaries, which were developed using the model outlined in Exhibit 3-1, include the following topics in the following order: history, type of network, purpose and services, extent and size, topology, computers, media and link speeds, protocols, administration, funding and future.

As a group, these selected networks, described in subsequent sections of this report, serve researchers across the United States and have worldwide connections. Individually, these networks are in different states of development (i.e., from initial operation to being replaced), and vary, for example, in size, capacity, protocols and services. The information on these comprehensively examined networks will provide, in subsequent subtasks, the data base for sizing a current and projecting a future composite integrated computer research network.

EXHIBIT 5-6. NETWORKS SELECTED FOR COMPREHENSIVE EXAMINATION

1. Department of Defense (DOD) research networks:
   - Advanced Research Projects Agency Network (ARPANET)
   - Defense Research Internet (DRI)

2. National Science Foundation Network (NSFNET):
   Three level network:
   - National backbone
   - Twenty-one mid-level networks
   - Over 250 campus networks

3. National Aeronautics and Space Administration (NASA) networks:
   - NASA Science Internet (NSI)
   - NASA Science Network (NSN)
   - Space Physics Analysis Network (SPAN)
   - Numerical Aerodynamics Simulation Network (NASNET)
   - NASA Communications (NASCOM)

4. Department of Energy (DOE) research networks:
   - Energy Science Network (ESNET)
   - Magnetic Fusion Energy Network (MFENET)
   - High Energy Physics Network (HEPNET)
   - LEP3NET (A Cern Accelerator Experiment Network)
   - OPMODEL

5. BITNET (Before Its Time Network) and

   CSNET (Computer + Science Network)

SECTION 6

DEPARTMENT OF DEFENSE RESEARCH NETWORKS

6.1 OVERVIEW

The Department of Defense's (DoD) research networks that will be discussed in this study include the ARPANET (ARPA is the abbreviation for Advanced Research Projects Agency, renamed as the Defense Advanced Research Projects Agency, or DARPA) and DRI or the Defense Research Internet. Since the ARPANET, now being replaced by DRI, has been a part of the Defense Data Network (DDN), which in turn has been a part of the Internet, summary information first will be provided on both the Internet and the DDN. A second reason for providing information on the Internet is that such information will also aid in understanding the development of the other research networks discussed in this study. After the Internet, the DDN and the ARPANET are described, a summary of DRI is presented.

6.2 THE INTERNET

The Internet was formed in 1983 when the Defense Communications Agency (DCA) mandated the use of TCP/IP (Transmission Control Protocol /Internet Protocol) for assessing all hosts connected to either ARPANET or MILNET. The Internet, as its name implies, is an internetwork of many networks all using the TCP/IP protocol suite to access ARPANET or MILNET hosts through gateways. The Internet has been known by several names. Its original name was the ARPA Internet, named after ARPA, which was its original funding agency. When ARPA became DARPA, the Internet was sometimes called DARPA Internet. Since the Internet is now funded and managed by a number of government and private organizations it is sometimes called either the TCP/IP Internet or the Federal Research Internet.

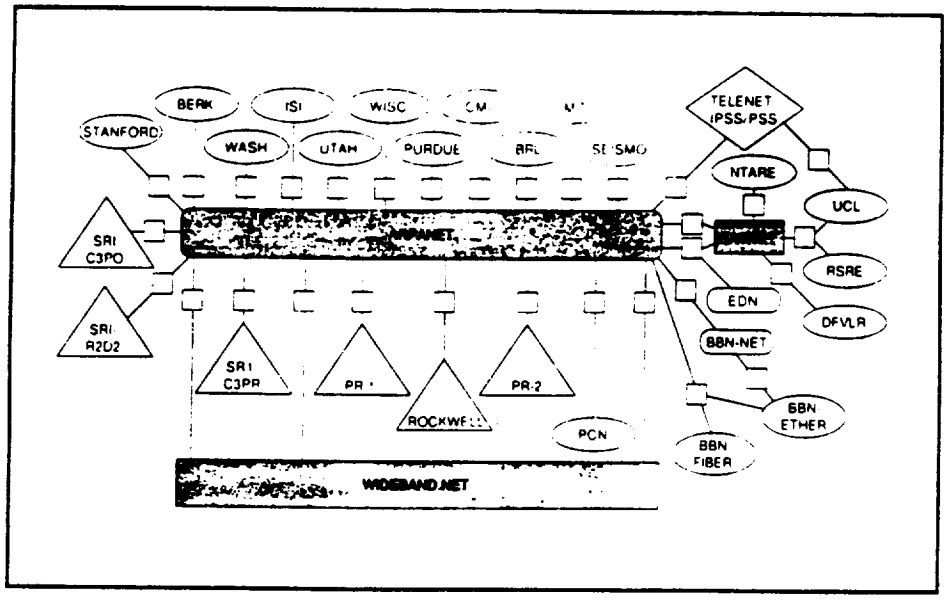
The Internet is primarily a United States network because that is where it began and where most of its networks still are. However, it is

considered a worldwide network, as some of its networks extend to several continents. The Internet includes, as examples: the DDN which includes ARPANET and MILNET; and NSFNET. MILNET and NSFNET are the main backbone networks of the Internet, as the ARPANET is being replaced. Also, numerous companies, schools and government agencies have local networks that are part of the Internet. These local networks include ethernets, token rings, and broadband local area networks. Estimates of the number of hosts on the Internet range from 40,000 to 500,000; estimates of the number of users on the Internet range from 500,000 to more than a million; and estimates of the number of connected networks have exceeded 400. See Exhibit 6-1 which shows the growth of the Internet from 1983 to 1988, as well as the major networks on the Internet.

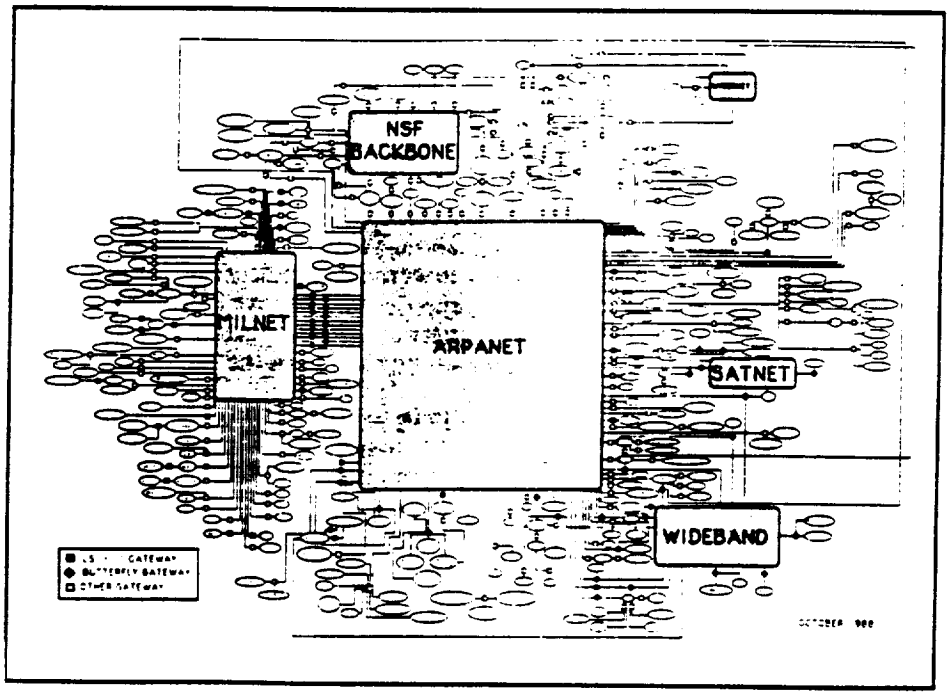
The current purposes of the Internet are to facilitate the sharing of resources, the collaboration among researchers, and the testing of new developments in networking. Some coordination of the entire Internet is provided by the DDN Network Information Center (NIC) at SRI International in Menlo Park, California and the Network Operations Center (NOC) at Bolt, Beranek and Newman (BBN) in Cambridge, Massachusetts. The backbones are funded mostly by government grants and the campus area networks are funded mostly by local organizations. It is expected that as the major networks migrate from TCP/IP to ISO/OSI specified protocols at the network and transport levels, the role of the Internet will be taken over by the National Research Network.

6.3 DEFENSE DATA NETWORK - DDN

The Defense Date Network (DDN) was created in 1982 as a parent or umbrella operational military network made up of serveral existing or planned DOD computer networks. The DDN is composed of several operational, resource sharing, host-to-host networks which are linked by controlled gateways, and which serve DOD facilities and non-DOD research centers in the United States, the Pacific and European areas. It is made up of several networks, and the main ones are the ARPANET, now being replaced by DRI (see discussion below) and MILNET. MILNET is a long-haul military network that was built using the results of the ARPANET



Internet 1983



Internet 1988

EXHIBIT 6-1. Growth Of Internet From 1983 to 1988

research. Interconnection between MILNET and ARPANET is illegal, except through government-approved gateways.

The DDN is a large military common-user data communications internetwork operated for the DoD by the Defense Data Network Program Management Office (DDN/PMO) of the Defense Communications Agency (DCA). It uses the DoD Internet Protocol Suite, including TCP/IP and associated application protocols. Thus, DDN is a TCP/IP internet which is a subset of the Internet, discussed above.

6.4 ARPANET

6.4.1 History

The ARPANET is the oldest of the networks in the Internet, and like the Internet (initially called ARPA Internet), was named after the agency that funded it. In the late 1960's, DARPA administrators, recognizing that their contractors tended to request the same computer resources, decided to develop a network among the contractors that would allow them to share such resources. In 1969, DARPA began a research program designed to advance computer networking, and the experimental packet-switched network that emerged was called ARPANET. The implementation of the ARPANET, which was built by BBN, began in late 1969. It took several years of experimentation before the ARPANET was made useful.

In 1979, the DoD interconnected several DoD long-haul computer networks through a set of internet protocols so that they could share the same backbone of node computers linked by high-speed (at that time) telephone lines. The protocols were tested experimentally for several years on the ARPANET and proved useful for creating the networking environment wanted by DoD. In 1982, a DoD directive, that adopted for the DoD a single set of communication protocols based on the ARPANET protocols was issued. Later in 1982, another directive was issued to create the DDN (discussed above).

By 1983, the ARPANET, still considered an experimental network, had grown to link over 300 computers, and many of these were used for day-to-day operational military purposes as well as for research. Given the growing need for an operational network, the DoD evaluated several network architectures and chose the DARPA Internet architecture as the model for its DDN. In the Fall of 1984 the original ARPANET was split into two separate unclassified networks, a military research and development network (ARPANET) and a military operational communications network (MILNET). The split gave DARPA an unclassified military network able to accomodate the DoD's growing operational needs, as well as a network for experimentation like it had originally. Gateways interconnected the two networks. Since then, the ARPANET has grown rapidly, but this growth has made the network obsolete. By 1988, it was clear that the ARPANET was no longer able to meet its users needs or to serve as a research base. A plan to transfer its users to other more advanced networks and to develop a new network experiment (DRI) was made and this plan now is being implemented.

6.4.2 Type Of Network

The ARPANET began as an experimental research network, built by DARPA and used by the DoD for computer science and networking research. As a subnetwork of the DDN, it evolved into a network that facilitated resource and information sharing in addition to providing a research base. It has now become obsolete and is being replaced.

6.4.3 Purpose And Services

As noted above, the original purposes of the ARPANET were to share resources and to provide a base for networking research. Thus, one of its original goals was to advance the state-of-the-art in computer networking. The designers of the network wanted to demonstrate that computers, made by different manufacturers, of different sizes, and with different operating systems, could communicate with each other across a network. In addition to providing this research base, the network ultimately provided the full range of services for exchanging messages and for sharing resources, including E-mail, file transfer and remote access.

Use of the ARPANET has been limited to users engaged in experimental research for the United States government or government-sponsored research at universities. Because it was not meant to compete with commercial networks, it has not been intended for operational communication needs or use by the general public.

6.4.4 Extent And Size

The ARPANET is a nationwide network. Currently, it has about 50 nodes with multiple hosts attached to each node. There are about 150 ARPANET hosts. These hosts are gradually moving to other networks.

6.4.5 Topology

The ARPANET topology can be depicted by showing the location and connectivity of its major nodes (See Exhibit 6-2). There are about 50 Packet Switched Nodes (PSNs) on the ARPANET. These nodes are dispersed across the continental United States.

6.4.6 Computers

The computers on the ARPANET serve as hosts, links to other nodes, gateways, or some combination of these three uses. Access to supercomputers is available either directly or through other networks in the Internet.

6.4.7 Media And Link Speed

The backbone links which connect the Packet Switched Nodes (PSNs) on the ARPANET are mostly 56 Kbps terrestrial lines. The DRI, which is replacing the ARPANET and which is discussed below, will start with 1.544 Mbps links and will be phased to higher speeds as the demand grows.

6.4.8 Protocols

The ARPANET uses the TCP/IP protocols which were developed and tested

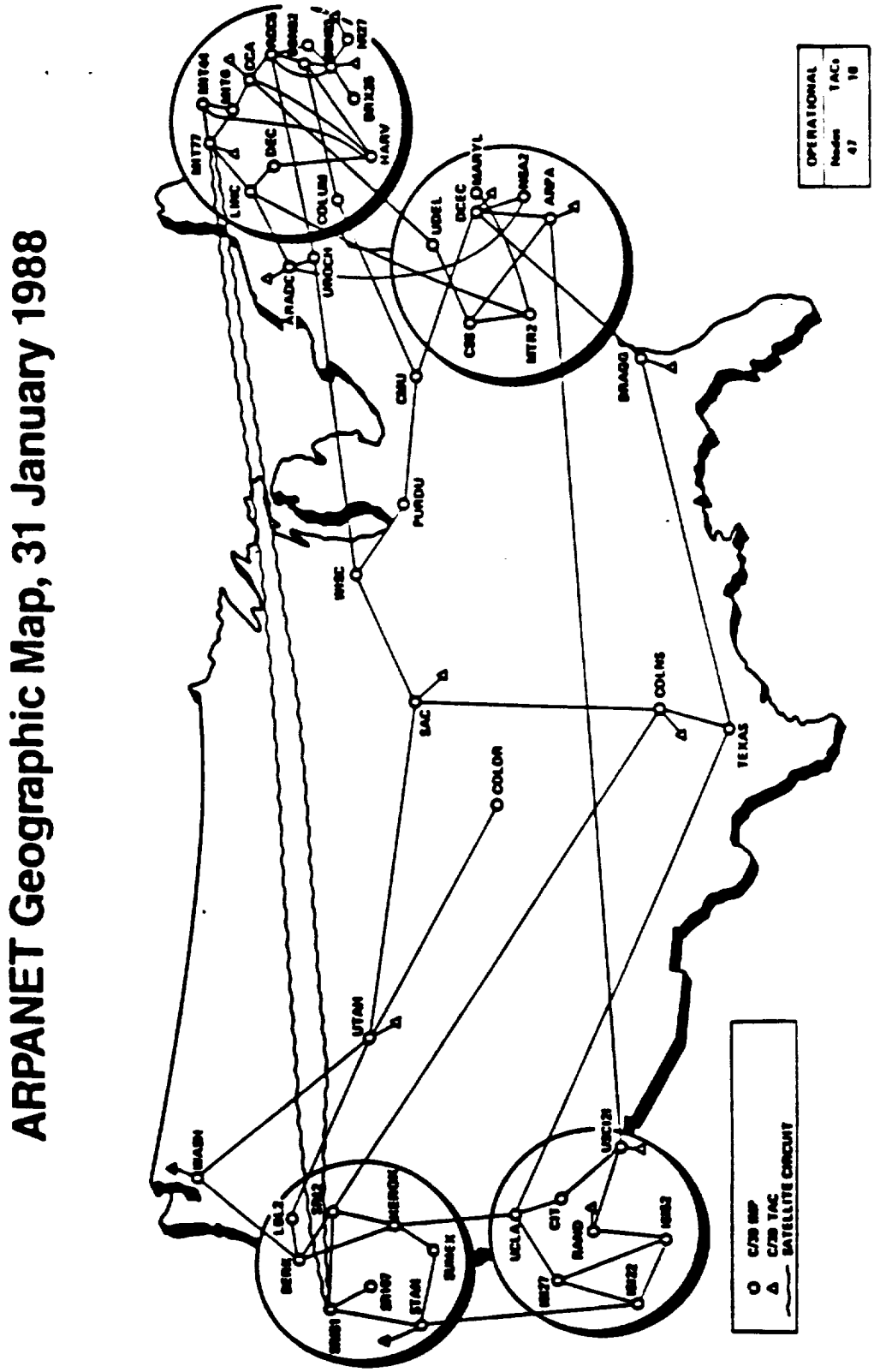


EXHIBIT 6-2. ARPANET Topology (January 31, 1988)

on the ARPANET during the late 1970's and early 1980's. There were several versions of the early NCP (i.e., network control protocols) and several early versions of TCP. Since 1983, the network has used the fourth version of the TCP/IP protocol suite.

6.4.9 Administration

An overview of the management structure for ARPANET is shown in Exhibit 6-3. Policy and access control for the ARPANET are provided by DARPA's Information Processing Techniques Office (IPTO). This has been accomplished within the broad guidelines established for all DDN networks by the Defense Communications Agency's (DCA) DDN Program Management Office (DDN/PMO). Currently, operation and management are provided by the DDN/PMO. From 1969 through 1973, while the ARPANET was developing, DARPA managed and operated the network; after 1973, management and operation was turned over to DCA. A Network Information Center (NIC), located at SRI International in Menlo Park, California, provides user services to ARPANET users via electronic mail, telephone and United States mail.

6.4.10 Funding

As noted in the discussion of ARPANET's history, the ARPANET was initially funded through a research and development program sponsored by DARPA. The building of the ARPANET and development of its protocols was an IPTO program, which evolved into what became known as the Internet Research Program. In addition to funding the ARPANET, the IPTO funds research carried out on the ARPANET.

6.4.11 Future

The ARPANET is being replaced by the DRI (see discussion below). Users are being transferred to other networks (e.g., the NSFNET) and to the DRI.

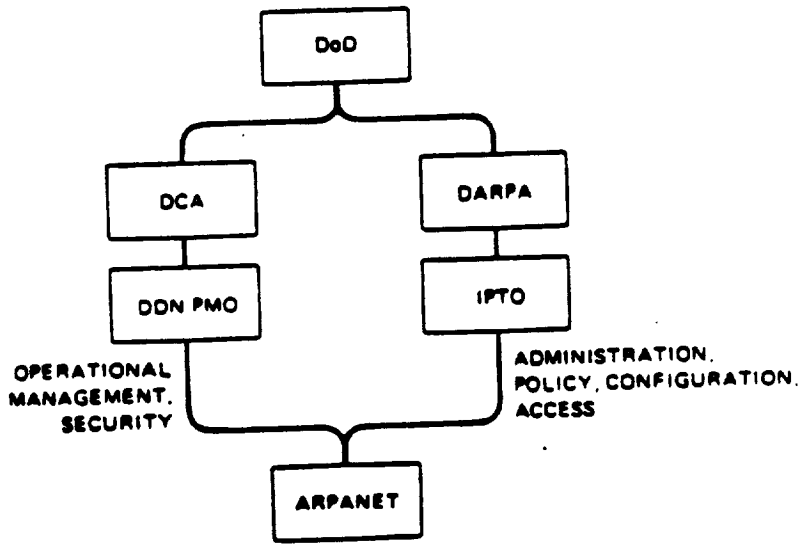


EXHIBIT 6-3. ARPANET Management Structure

6.5 DEFENSE RESEARCH INTERNET - DRI

6.5.1 Impetus For DRI

The impetus for the development of the Defense Research Internet (DRI) was the growing obsolescence of the ARPANET. This obsolescence was indicated by the overloading on the ARPANET, the ARPANET's inability to continue as an adequate research base, and the ARPANET'S use of a significant fraction of DARPA's resarch budget for what is considered a support function. The DoD solved the problem of ARPANET being too slow and too expensive by eliminating the source of the problem, i.e., the ARPANET, and by developing a follow-on network experiment which became known in 1988 as DRI.

6.5.2 DRI And The FCCSET Recommendations

The DRI is key to DARPA's plans for helping to implement the FCCSET recommendations. DARPA's plans by FCCSET phase are as follows:

1. FCCSET Phase 1: ARPANET becomes DRI.
2. FCCSET Phase 2: DRI moves toward DS3.
3. FCCSET Phase 3: Research program in gigabit/second networking.

6.5.3 Purposes And Goals Of DRI

The purposes of DRI are:

1. To advance networking research (ultimately, gigabit/second technology).
2. To support Defense Command, Control and Communication (C3) requirements.
3. To support DARPA wideband research applications; a focus will be on parallel computing.
4. To provide a better model for funding testbeds (e.g., for researching policy based routing).

The DRI performance goals are as follows:

1. Provide megabit/second and above service.

2. Provide easy connection to other government and commercial networks.
3. Make the difference between LANs and WANs (Wide Area Networks) transparent.
4. Support data transfer between local workstation and distant advanced parallel computer servers.

6.5.4 DRI Plans

As presently envisoned, the DRI will:

1. Begin with 1.544 Mbps link speeds and phase to higher and higher speeds with the intent of eventually reaching Gbps performance.
2. Begin with TCP/IP protocols and transition to OSI and more advanced protocols.
3. Internet with other federal agencies:
   a. It will cooperate with FRICC for links (it is participating in the National Network Testbed-NNT and the Research Interagency Backbone-RIB);
   b. It will cooperate with NASA and SDI for competitive acquisitions of gateways (RIG - Research Interagency Gateways).
   c. It will support Gbps network research (It is supporting, with NSF, NRI research)
4. Transition from ARPANET to DRI in the following phases, with the death of ARPANET occurring in FY91:
   a. Phase 1: Rapid restructuring of most costly portions of ARPANET (e.g., by using the NNT program).
   b. Phase 2: Install RIB and use part of it as ARPANET backbone.
   c. Phase 3 and beyond: Support the ARPANET community via the DRI network.
5. The National Network Testbed (NNT), discussed in Section 4 on A National Research Network, will provide some of the initial transmission links for DRI. See Exhibit 6-4 which shows the current NNT backbone topology. Additional NNT sites are: SRI (San Francisco), ISI (Los Angeles), Fort Bend (Chicago), CMU (Pittsburgh), DARPA and DCA (Washington, DC), Rome and CECOM (New York), BBN (Boston). All links are T1. Also, as the Research Interagecny Backbone is developed, it will provide transmission links for DRI.

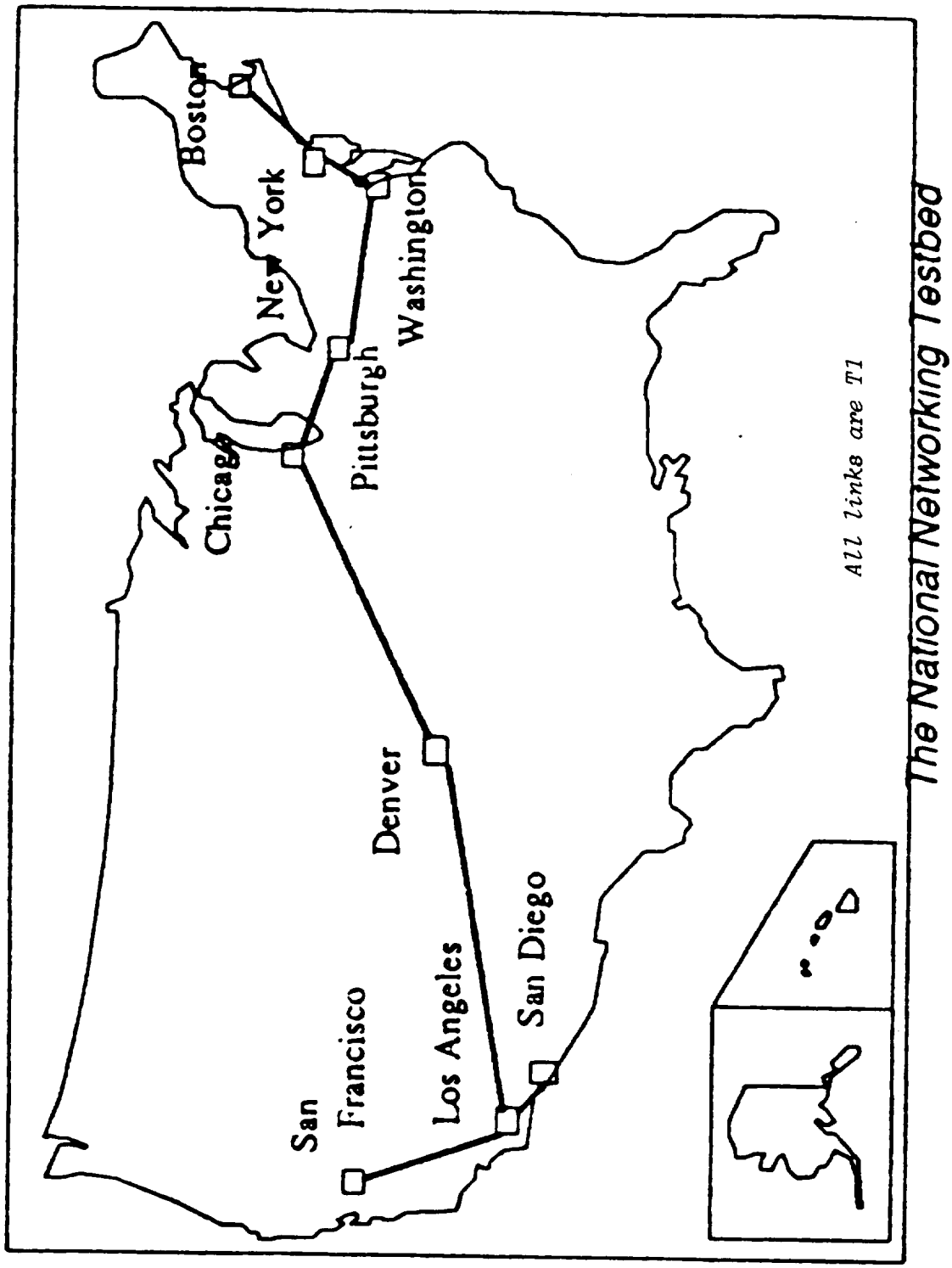


EXHIBIT 6-4. Current NNT Topology

SECTION 7

NATIONAL SICENCE FOUNDATION NETWORK - NSFNET

7.1 OVERVIEW

NSFNET currently is a three-level network which includes a nationwide backbone, twenty-one mid-level networks, and over 250 campus area networks. NSFNET and its mid-level networks are described in detail using the CRN model presented in Section 3. While the mid-level networks are significant networks, they are described together. That is, the NSFNET and the mid-level networks are treated as a single entity when applying the CRN model. For example, the history of NSFNET and the histories of the mid-level networks are discussed in a single section.

7.2 HISTORY

As noted earlier in the section on "A National Research Network," the impetus for the NSFNET came from the 1969 through 1984 development of a number of early academic and research networks and the establishment, in 1984, by the National Science Foundation (NSF) of the Office of Advanced Scientific Computing (OASC). This office initiated programs to develop supercomputer centers and to develop network access to them. The name given to the network that provides this access, as well as access to other centers and networks, is NSFNET.

7.2.1 Initial NSFNET Backbone

The initial NSFNET network became operational in the summer of 1986 and, as a six-node network, interconnected six supercomputer centers. One of these centers was already operating when OASC was established, and the other five were funded in 1985. The six supercomputer centers are:

1. NCAR - The Scientific Computing Division of the National Center for Atmospheric Research at Boulder, Colorado (already operating when OASC was established);

2. JVNC - The John von Neumann Center at Princeton University;
3. NCSA - The National Center for Supercomputer Applications at the University of Illinois;
4. PSCAA - The Pittsburgh Supercomputer Center Academic Affiliates located in Pittsburgh;
5. SDSC - The SanDiego Supercomputer Center at University of California at San Diego; and
6. The Theory Center (A production and experimental supercomputer center at Cornell University).

Also existing at that time and included as NSFNET members were the supercomputer consortia networks associated with the JVNC and the SDSC, the NCAR satellite network sites that made up the University Satellite Network (USAN) and the ARPANET sites.

7.2.2 Evolution To A Three-Level Network

By the fall of 1987, the NSFNET included the six supercomputer centers as backbone sites, six mid-level networks associated with these supercomputer centers, seven mid-level regional or discipline-based networks, and a variety of academic and commercial campus networks connected to the mid-level networks. The following are the names of the networks that, at the time, made up the first two levels of this three level NSFNET internetwork:

<u>NSFNET Backbone Sites</u>:

1. Cornell National Supercomputer Facility;
2. John von Neumann National Supercomputer Center;
3. National Center for Atmospheric Research;
4. National Center for Supercomputing Applications;
5. Pittsburgh Supercomputing Center; and
6. San Diego Supercomputer Center.

<u>Mid-Level Networks</u>:

1. Supercomputer center mid-level networks:
   a. NYSERNET - New York State Education and Research Network (Cornell);
   b. JVNCNET - John von Neumann National Supercomputer Center Network;

c. USAN- University Satellite Network (NCAR);
d. NCSANET - National Center for Supercomputing Applications Network;
e. PSCNET - Pittsburgh Supercomputing Center Network; and
f. SDSCNET - San Diego Supercomputer Center Network.

2. Regional mid-level networks:
   a. BARRNET - Bay Area (No. California) Regional Research Network;
   b. MERIT - Membership consortium of Michigan universities;
   c. MIDNET - Membership consoritum of midwestern universities;
   d. NORTHWESTNET - Membership consortium in Northwest;
   e. SESQUINET - Texas Sesquicentennial Network;
   f. SURANET - Southeastern Universities Research Association Network;
   g. WESTNET - Consortium of five western states: AZ, CO, NM, UT, and WY.

Campus Networks

In the Fall of 1987, over 140 campus networks were connected to these mid-level networks.

7.2.3 New NSFNET Backbone

While the growth in the NSFNET was expected and welcomed, it caused a number of major problems for the network which was fast approaching the limits of its capacity. By the summer of 1987, it was apparent that the NSFNET lacked sufficient trunking speed as well as trunking lines; the three-layer topology model (backbone, mid-level and campus) was incomplete and led to routing difficulties; and there were not enough people, supported and funded, to maintain and operate the current network. Consequently, in June 1987, the NSF issued a solicitation to upgrade, manage and operate the backbone. In November 1987, the NSF awarded a five-year grant to MERIT Inc. to reengineer and manage the NSFNET backbone. MERIT Inc. is a nonprofit membership consortium made up of eight Michigan universities that provides funding and sets policy for the sixteen-year old MERIT Computer Network.

The MERIT plan, which was designed to improve performance of the NSFNET and to accommodate growing numbers of users, included the following

network objectives: greater connectivity; very high bandwidth and very low error rates; the ability to dynamically modify topology and bandwidth; diversity in trunking paths; and a network that is dependable, cost-effective and robust. These objectives are being achieved by MERIT with assistance from its research partners, IBM and MCI. IBM is assisting with the hardware and software needed to implement the packet switching and network management facilities. MCI is playing the key role in providing the transmission backbone. The plan is being implemented in a phased manner. The phases are:

1. Phase 1 : New, primarily fiber optics-based transmission backbone connecting the six supercomputer centers and the seven regional mid-level networks; DS1 point-to-point service with the ability to dynamically vary the traffic flow and the underlying bandwidth of the circuit network; and New Management and Information Services.
2. Phase 2: Upgrade backbone to DS3 point-to-point service; migration from underlying TCP/IP protocols to ISO/OSI standards.

Phase 1 is expected to be completed in 1989 and Phase 2 completion is anticipated to be sometime in the early 1990's.

7.2.4 Current NSFNET

By the Spring of 1989, the following changes had taken place in the three level NSFNET internetwork:

NSFNET Backbone Sites:

The following seven sites had been added to the original six supercomputer sites (These seven sites are associated with the seven regional mid-level networks as noted after the name of each site):

1. Rice University (SESQUINET);
2. Standford University (BARRNET);
3. Univeristy of Maryland (SURANET);
4. University of Michigan (MERIT);
5. University of Nebraska (MIDNET);
6. University of Utah (WESTNET); and
7. University of Washington (NORTHWESTNET).

Mid-Level Networks:

The following eight mid-level networks were added to the thirteen included in 1987:

1. CERFNET - California Education and Research Federation Network.
2. CICNET - Committee on Institutional Cooperation;
3. LOS NETTOS - A Los Angeles LAN.
4. MRNET - Minnesota Regional Network; and
5. NEARNET - New England Academic and Research Network.
6. OARNET - Ohio Academic Resources Network;
7. PREPNET - Pennsylvania Research and Economic Partnership Network.
8. THENET - Texas Higher Education Network.

Campus Networks:

The number of campus networks had increased from over 140 in 1987 to over 240 in 1989.

The names and locations of all the networks making up the three level NSFNET internetwork are presented in a subsequent section on Topology.

7.2.5 Histories Of Mid-Level Networks

The following are brief summaries of the histories of each of the twenty-one mid-level networks currently included in the NSFNET:

The Original Six Supercomputer Center Mid-level Networks

1. JVNCNET: This network, which is a consortium network that serves seven north-east states (New Jersey, Pennsylvania, New York, Connecticut, Rhode Island, Massachusetts, and New Hampshire), Colorado and Arizona, is associated with one of the original NSFNET backbone sites, the John von Neumann Supercomputer Center (JVNC) which was established in 1985.

2. NCSANET: The National Center for Supercomputer Applications Network, which connects universities in the three mid-western states of Illinois, Indiana and Wisconsin, is associated with one of the original NSFNET backbone sites. The supercomputer center, NCSA, was established in 1985, NCSANET was connected to the NSFNET backbone in 1986, and the universities

were connected to each other from 1986 through 1988.

3. NYSERNET: The New York State Education and Research Network (NYSERNET), which is a collaborative effort of a group of universities, the state of New York, several commercial corporations and NSF, was organized in 1985 and is associated with one of the original NSFNET backbone sites, i.e., the supercomputer center at Cronell which was also established in 1985.

4. PSCNET: PSCNET, the Pittsburgh Supercomputing Center (PSC) Academic Affiliates Group Network, serves sites in Pennsylvania, Michigan, Oklahoma and Maryland. This network is associated with one of the original NSFNET backbone sites, the PSC which was established in 1985 and which is a joint project of a private university, a state university and a large corporation.

5. SDSCNET: The San Diego Supercomputer Center Network is associated with the SDSC, one of the original NSFNET backbone sites, and provides services to the six states of California, Arizona, Utah, Washington, Wisconsin, and Maryland. It started with one node in 1986, expanded to nearly two dozen, and then lost several nodes to other mid-level networks of NSFNET.

6. USAN: The University Satellite Network connects eight universities, laboratories and institutes in Oregon, Wisconsin, Michigan, Massachusetts, Maryland, Florida, and Mississippi to the National Center for Atmospheric Research in Colorado.

Regional Mid-Level Networks

1. BARRNET: The San Francisco Bay Area Regional Research Network, which serves Northern California, was established in mid-1986 and became operational in mid-1987. It is the logical successor to a San Francisco Bay Area interconnection between Northern California universities, known as the BayBridge created in 1985.

2. MERIT: The MERIT Network, which serves the state of Michigan, began as an interuniversity network in the early 1970s and evolved into a mid-level

NSFNET network. MERIT, Inc., which manages MERIT, was awarded the NSF grant to develop, manage and operate the new NSFNET backbone network.

3. MIDNET: MIDNET, which serves mid-western universities in the states of Nebraska, Iowa, Illinois, Missouri, Kansas, Oklahoma and Arkansas, was conceived in 1985, funded in 1986, and became fully operational in the Fall of 1987. The network connects to the NSFNET backbone at the University of Nebrasks-Lincoln.

4. NORTHWESTNET: NORTHWESTNET, which provides services to the six states of Alaska, Washington, Oregon, Idaho, Montana, and North Dakota, grew from the collaboration of WICHE (Western Interstate Commission for Higher Education), the Northwest Academic Forum, and Boeing Computer Services. This network was connected to the NSFNET and the sites across the six states were interconnected during the 1987-1988 time period.

5. SESQUINET: SESQUINET, which is the Texas Sesquicentennial Network designed to interconnect research campuses in the state of Texas, was initiated at Rice University in 1986, was expanded primarily in the Houston area in 1987 when it was named to honor the state's 150th anniversary, and could eventually serve the entire state.

6. SURANET: SURANET is a project of the Southeastern Universities Research Association (SURA) and serves thirty-five research universities in twelve southeastern states (Maryland, Virginia, West Virginia, Kentucky, Tennessee, Alabama, Mississippi, Louisiana, Florida, Georgia, South Carolina, and North Carolina) and the District of Columbia. Plans for SURANET began in 1983 and the network became operational in 1987.

7. WESTNET: The history of WESTNET, whose member are universities from the five states of Arizona, Colorado, New Mexico, Utah, and Wyoming, began with two state-funded networks: New Mexico Technet established in 1983 and Colorado SuperNet established in 1986. The universities from all five states were connected to the NSFNET backbone during the period from the Fall of 1986 to the Spring of 1988. WESTNET's goal is to evolve into a collection of relatively autonomous state networks.

New Mid-Level Networks

1.CERFNET: The California Education and Research Federation Network (CERFNET) is a communications network linking academic, government and industrial research facilities across California. CERFNET, created for the purpose of advancing science and education in Californai, was organized in early 1988. Its pilot network was operational in late 1988, and all of its 39 sites will be connected by late 1989.

2. CICNET: The Committee on Institutional Cooperation Network, which connects institutions of higher education in the seven midwest states of Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio and Wisconsin, was planned in 1987, funded in 1988 and is expected to be operational in 1989.

3. LOS NETTOS: This is a Los Angeles area network operated by its member organizations which include universities and research laboratories. Five organziations were connected to the network by the Spring of 1989, and seven other organizations are expected to join the network soon.

4. MRNET: The Minnesota Regional Network, which connects organizations such as Control Data, Cray Research, Honeywell, the Minnesota Supercomputer Center, and the University of Minnesota, was organized in 1987 and was operational in 1988.

5. NEARNET: The New England Academic and Research Network (NEARNET), which connects academic and research organizations in New England, became operational in early 1989. It plans to serve the needs of 50 colleges and universities, industrial sites, and other organizations throughout New England by 1993.

6. OARNET: The Ohio Academic Resources Network, which connects most of the academic institutions in the state of Ohio, was established in 1987 to provide statewide access to the Ohio Supercomputer Center. It is now being expanded to provide access to other facilities.

7. PREPNET: The Pennsylvania Research and Economic Partnership Network (PREPNET), which links academic, industrial and public sector researchers

in the state of Pennsylvania, was developed by seven founding universities, Bell of Pennsylvania, and the Commonwealth of Pennsylvania.

8. THENET: The Texas Higher Education Network, which is a state network that serves academic, medical, research and corporate institutions in Texas, evolved out of three main projects: the 1984 linking of the University of Houston and Texas A&M; the 1984 interconnecting of the medical institutions in Texas; and the 1986 creation of the University of Texas System Network.

7.3 TYPE OF NETWORK

While NSFNET began in 1986 as a communication network to facilitate access to NSF supercomputer centers, it has evolved into a general purpose internet for research and scientific information exchange. NSFNET is an interconnected set of campus, regional, consortium and backbone networks. Physically, it comprises a set of networks, lines, and gateway computers. Because all of the NSFNET networks do not use the same internet and transport protocols, NSFNET is actually a metanetwork, or a network of internets.

As suggested above and as noted in the section on "History," the NSFNET is a three level internetwork consisting of a backbone, mid-level networks and campus networks. The backbone is a transcontinental network that connects the mid-level networks and NSF-funded supercomputer centers. The mid-level networks include regional, discipline-based and supercomputer consortium networks. The campus networks, which are connected to the mid-level networks, include both academic and commercial networks.

7.4 PURPOSE AND SERVICES

The general purpose of the NSFNET internet and its networks is to facilitate the sharing of information and resources for research and scientific goals. More specifically, the primary purpose of each of the

six Supercomputer Center Networks is to provide users with access to the supercomputers; a secondary objective is to provide users with access to other networks. Simarily, the objectives of the other fifteen mid-level regional or pilot project networks are to provide users with access to other networks and to the supercomputers. Finally, the objectives of the campus networks are to provide users with access across campus, to other campuses in the network, to other networks and to supercomputer centers.

The NSFNET provides the full range of services for exchanging messages and for sharing resources. For examples it provides such services as: E-mail, remote login, file transfer, remote device access and shared memory.

7.5 EXTENT AND SIZE

NSFNET is a nationwide network (including Alaska and Hawaii). Its national backbone connects seventeen mid-level networks which may be regional networks, consortia networks, or pilot projects. The mid-level networks, each of which connects one or more campus networks or individual resources like national research centers, interconnect over 240 academic and commercial campus networks.

An estimate of the number of users can be made by multiplying the number of organizations on NSFNET by the number of users at each organization. Using the number of networks (i.e., over 240) as a rough count of organizations and 1000 as a conservative estimate of the number of users per organization, an estimate of the number of users on NSFNET would be close to a quarter of a million. This number would be even greater if all users who had indirect access to NSFNET (i.e., users on the Internet but not a part of NSFNET) were included.

7.6 TOPOLOGY

The NSFNET topology can be depicted by showing the location and connectivity of its backbone sites (i.e., its mid-level networks connected

by its backbone) and by showing the location and connectivity of the campus networks that make up each mid-level network.

7.6.1 Overall NSFNET Topology

The overall NSFNET configuration is diagramed in Exhibit 7-1. This exhibit shows the NSFNET backbone, that is, the name, location and connectivity of the six Supercomputer Center Networks and the seven mid-level regional networks. Also indicated, is the T1 link speed for the entire backbone. As noted earlier, the thirteen NSFNET backbone sites associated with these thirteen networks are (from West to East):

1. NORTHWESTNET - University of Washington.
2. BARRNET - Stanford University.
3. SDSCNET - San Diego Supercomputer Center.
4. WESTNET - University of Utah.
5. USAN - National Center for Atmospheric Research.
6. MIDNET - University of Nebraska.
7. SESQUINET - Rice University.
8. NCSANET - National Center for Supercomputing Applications.
9. MERIT - University of Michigan.
10. PSCNET - Pittsburg Supercompter Center.
11. NYSERNET - Cornell National Supercomputer Facility.
12. JVNCNET - John van Neuman National Supercomputer Center.
13. SURANET - University of Maryland.

7.6.2 Topology Of Thirteen Mid-Level Netowrks

The topologies of the thirteen mid-level networks are presented in Exhibits 7-2 through 7-14 as listed below. The names of the major nodes (For node abbreviations see Exhibit 7-23), the connectivity and the link speeds are indicated for each network.

1. NORTHWESTNET - Exhibit 7-2.
2. BARRNET - Exhibit 7-3
3. SDSCNET - Exhibit 7-4.
4. WESTNET - Exhibit 7-5.
5. USAN - Exhibit 7-6.
6. MIDNET - Exhibit 7-7.
7. SESQUINET - Exhibit 7-8.
8. NCSANET - Exhibit 7-9.
9. MERIT - Exhibit 7-10.
10. PSCNET - Exhibit 7-11.
11. NYSERNET - Exhibit 7-12.
12. JVNCNET - Exhibit 7-13.
13. SURANET - Exhibit 7-14.

(Please turn to page 7-26)

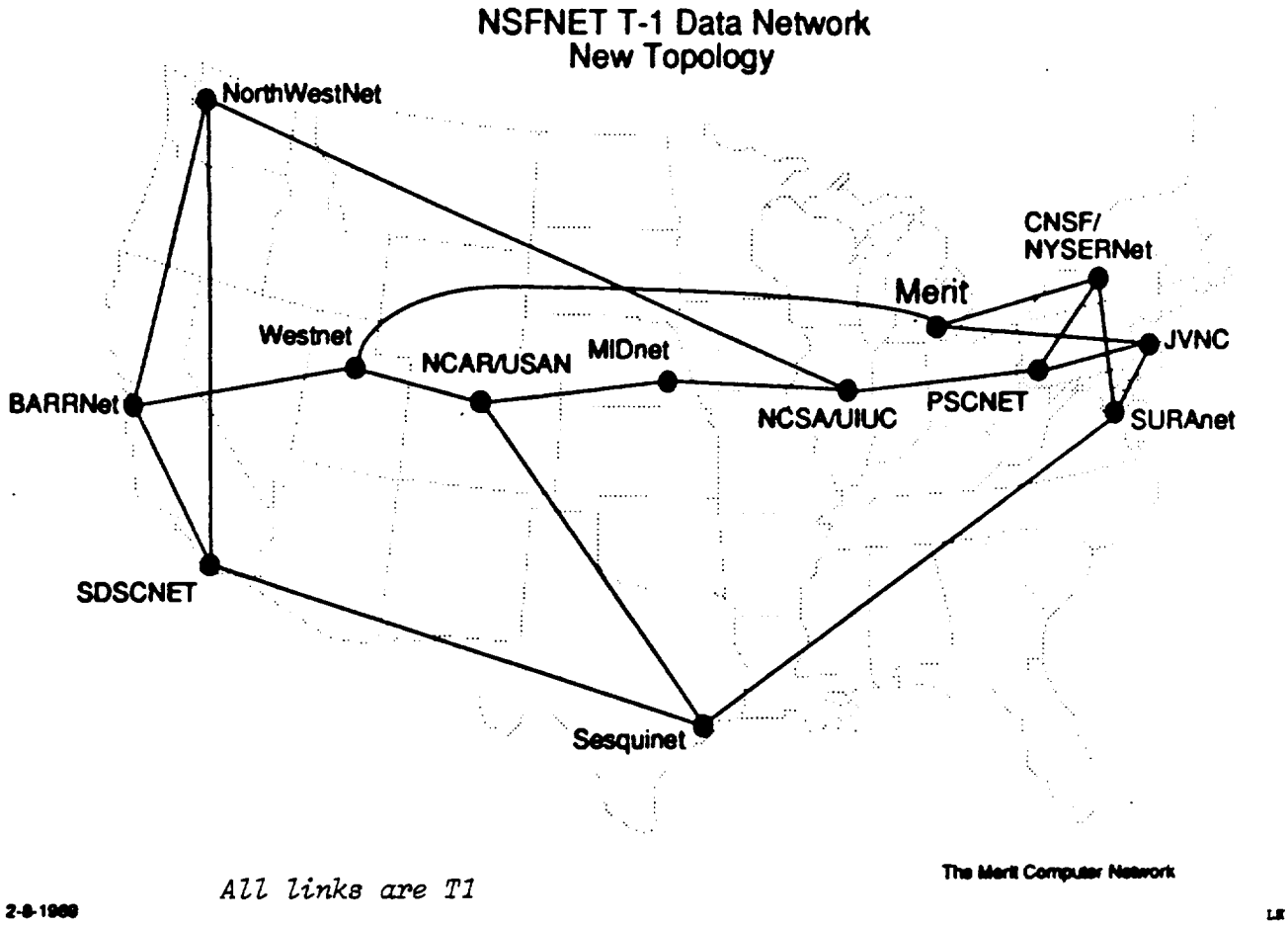


EXHIBIT 7-1. Overall NSFNET Topology.

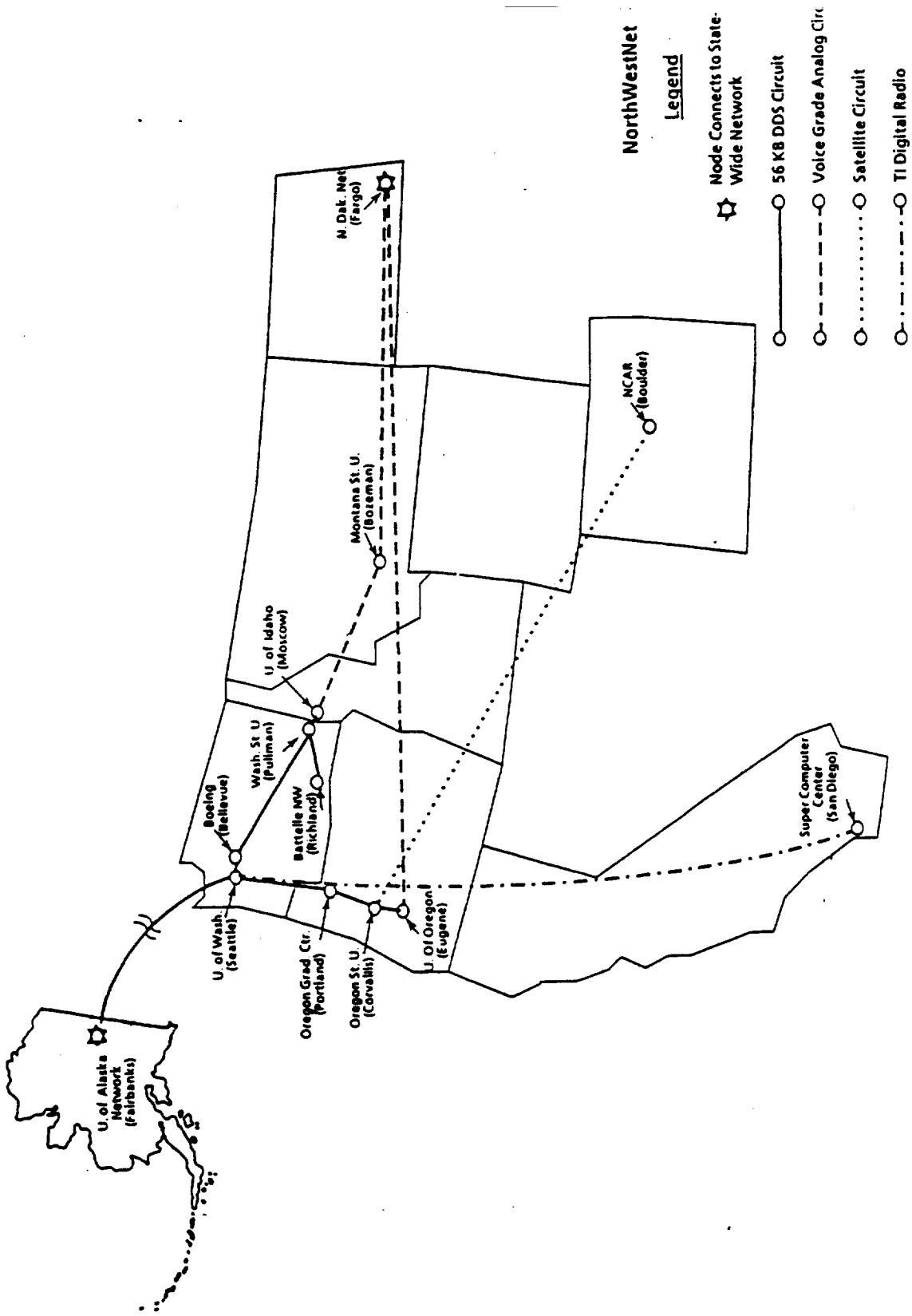


EXHIBIT 7-2. NORTHWESTNET Topology.

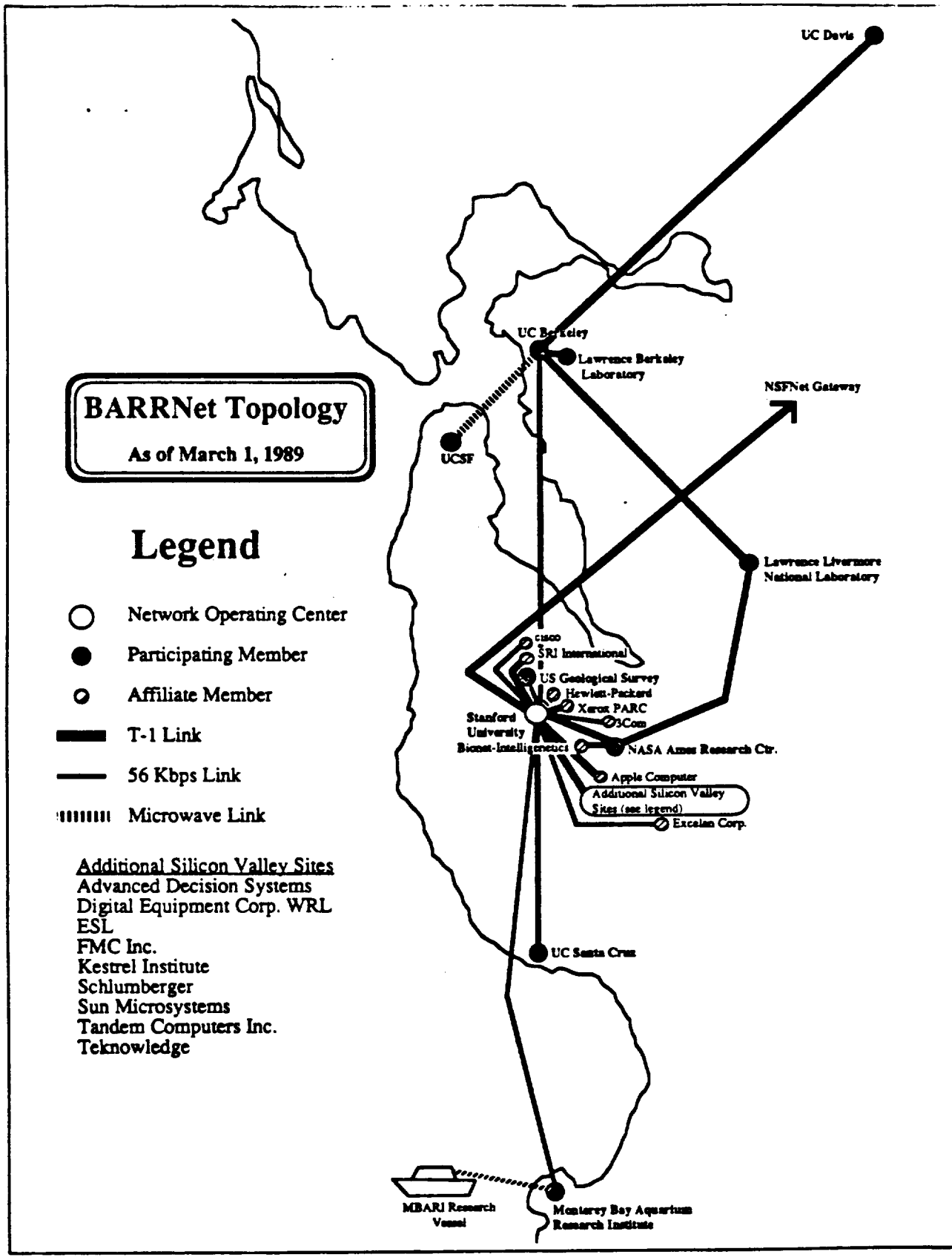


EXHIBIT 7-3. BARRNET Topology.

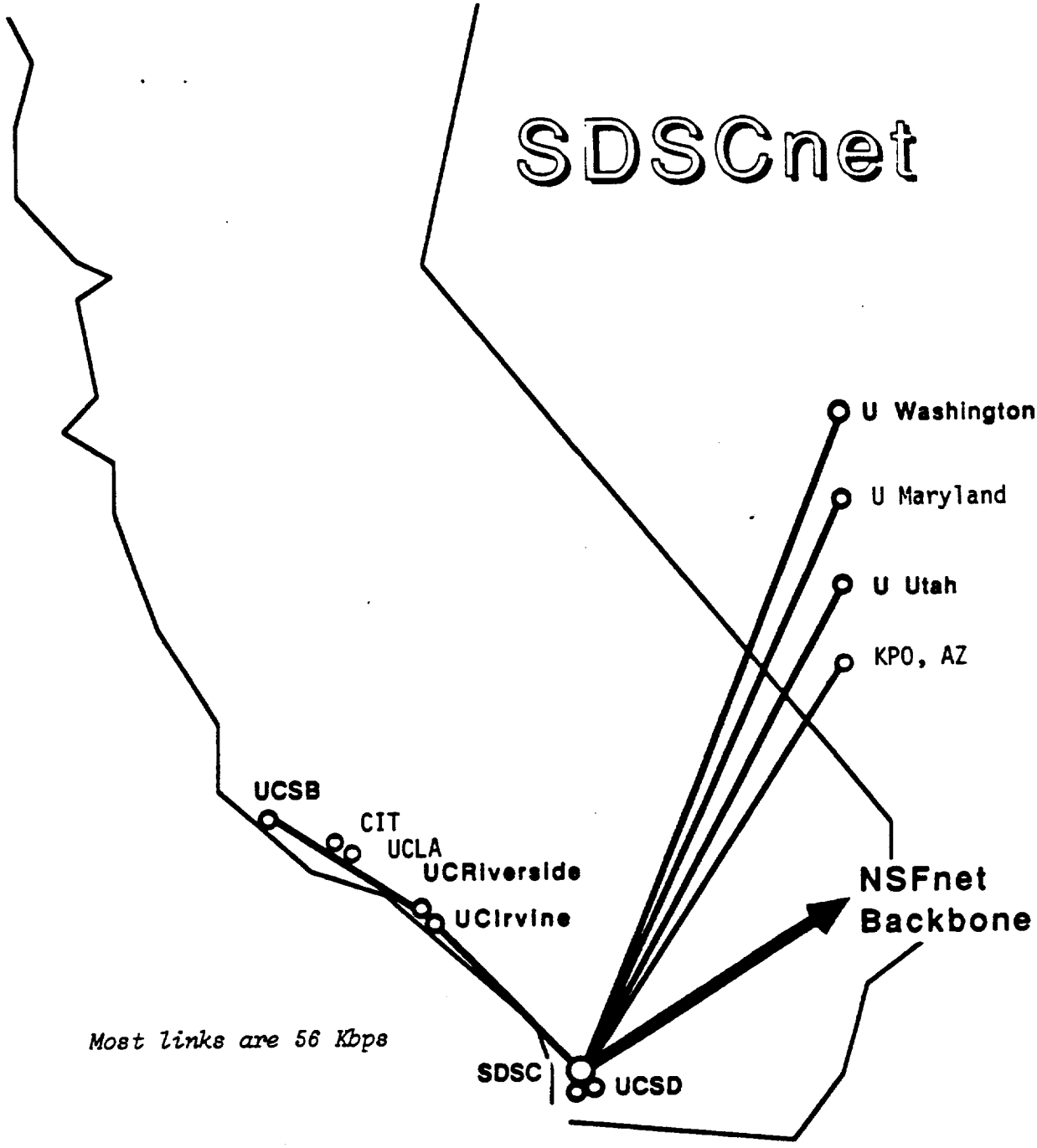
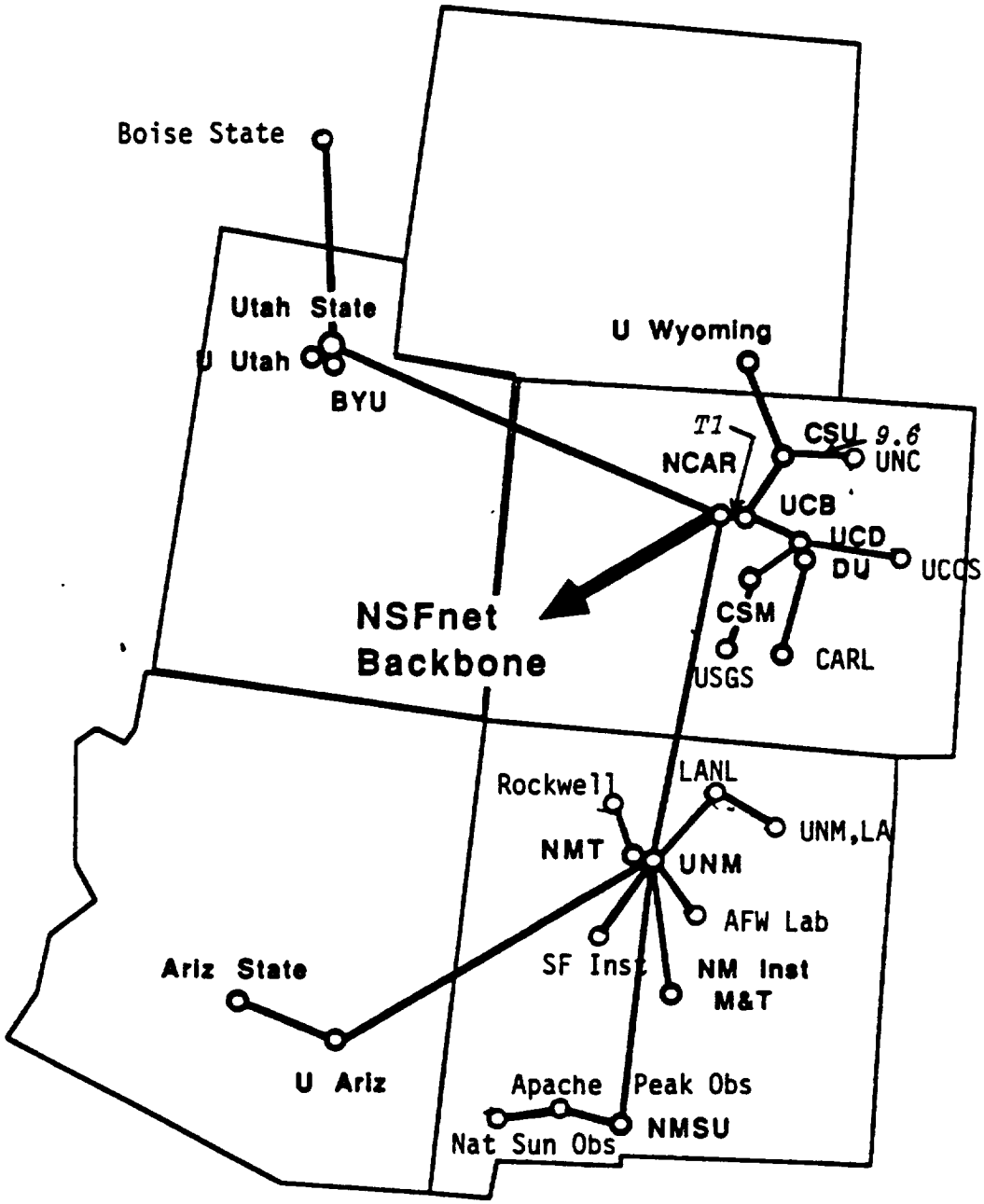


EXHIBIT 7-4. SDSCNET Topology.

WestNet



All links are 56 Kbps, except as noted

EXHIBIT 7-5. WESTNET Topology.

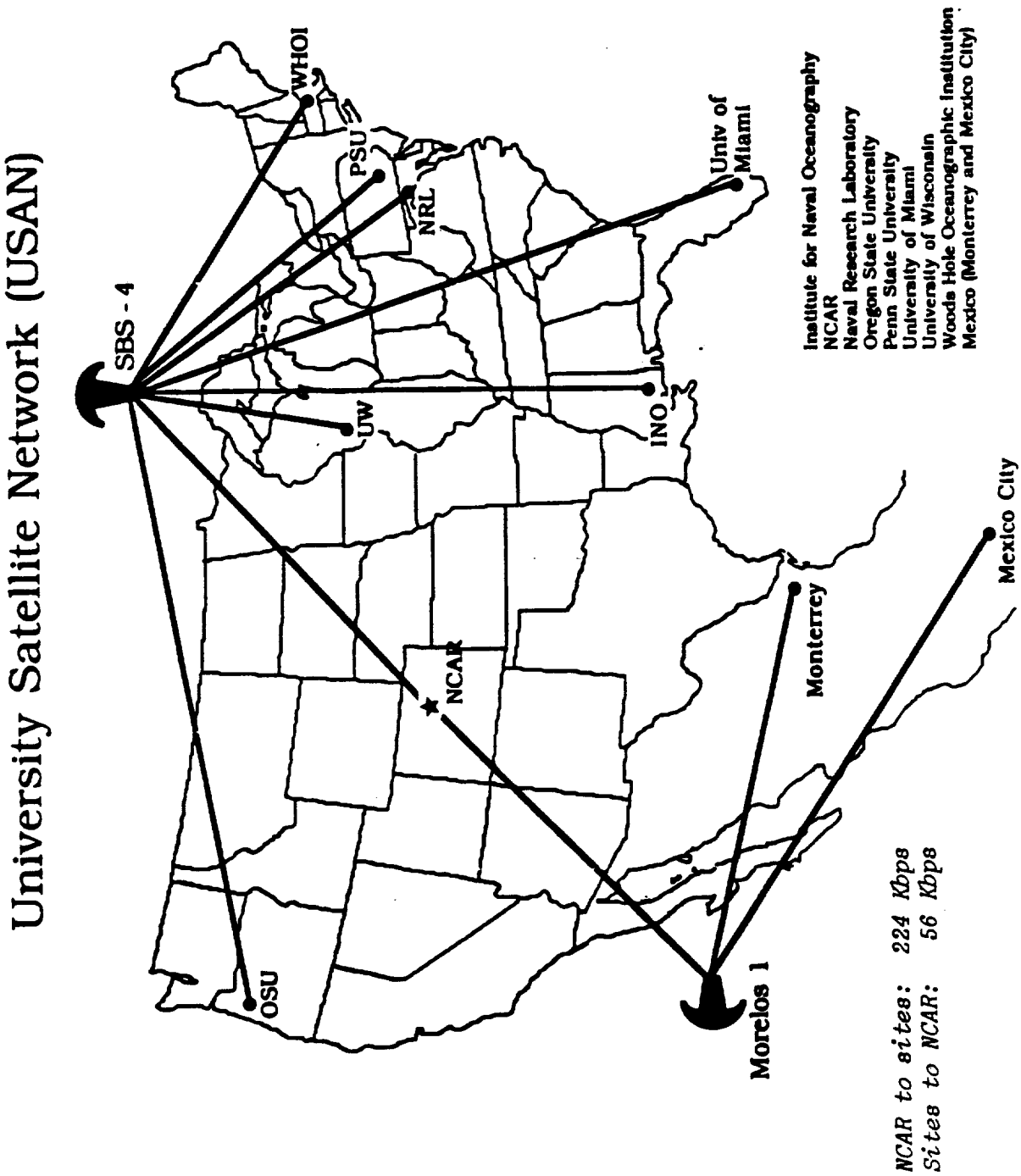


EXHIBIT 7-6. USAN Topology.

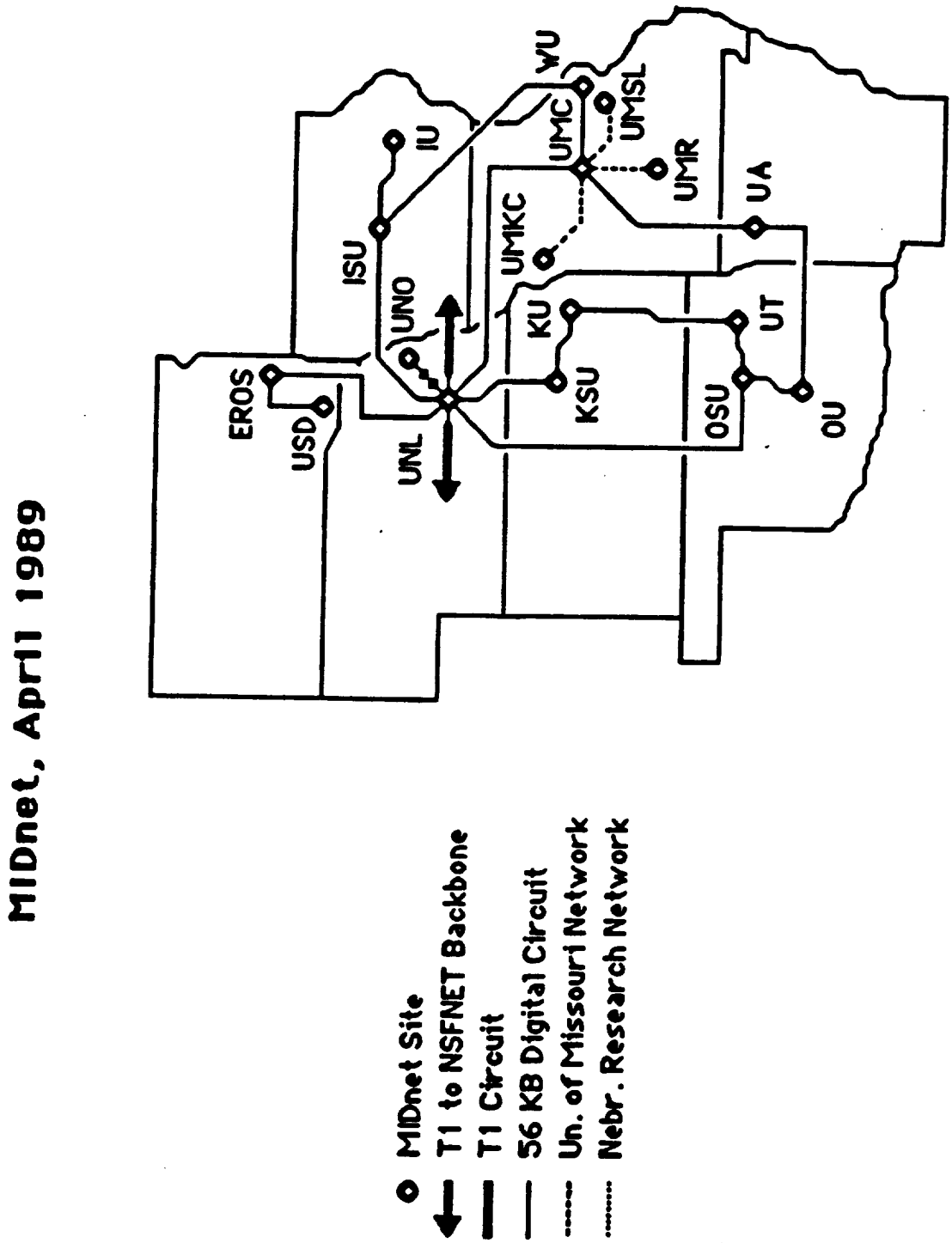


EXHIBIT 7-7. MIDNET Topology.

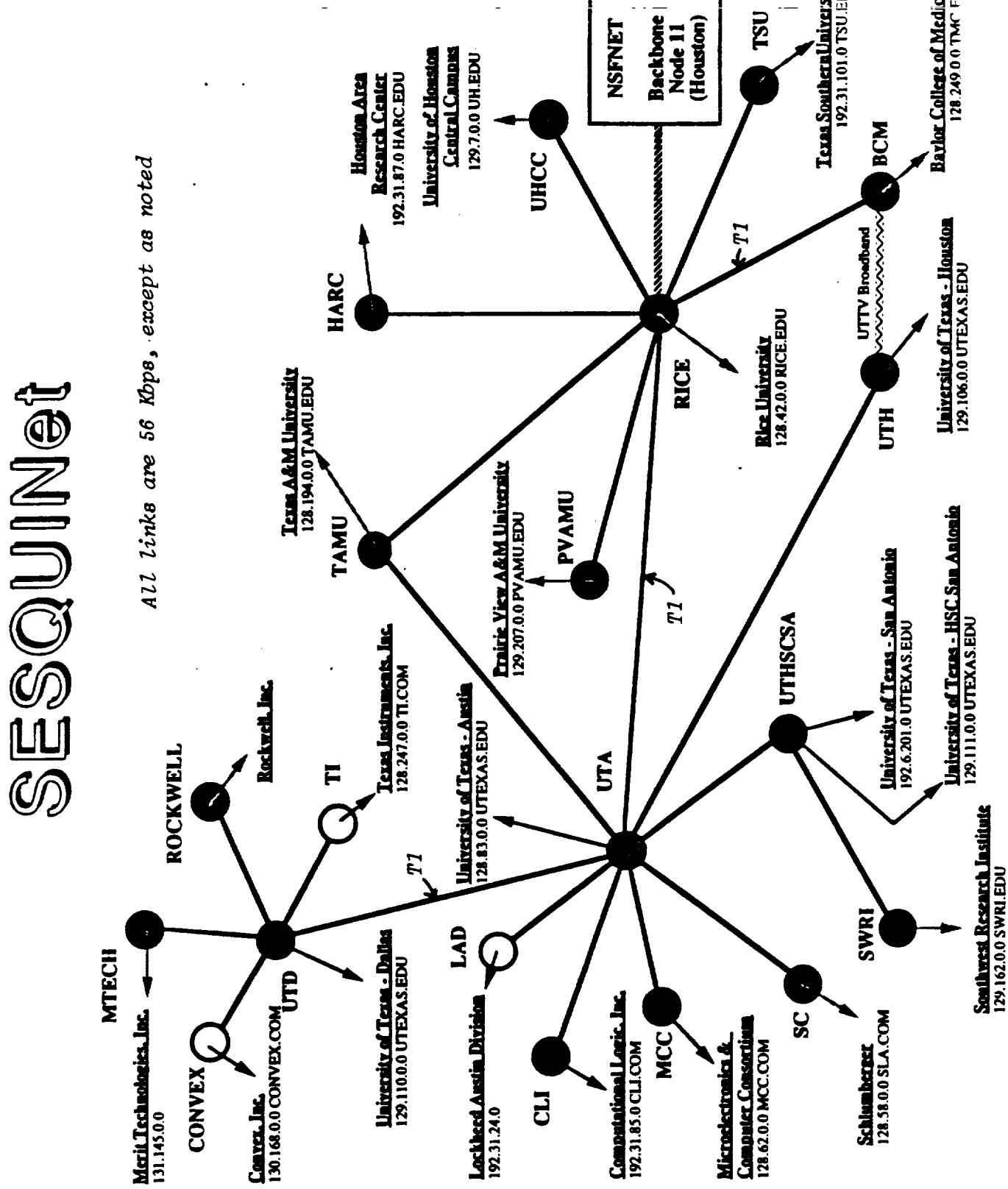


EXHIBIT 7-8. SESQUINET Topology.

NCSAnet

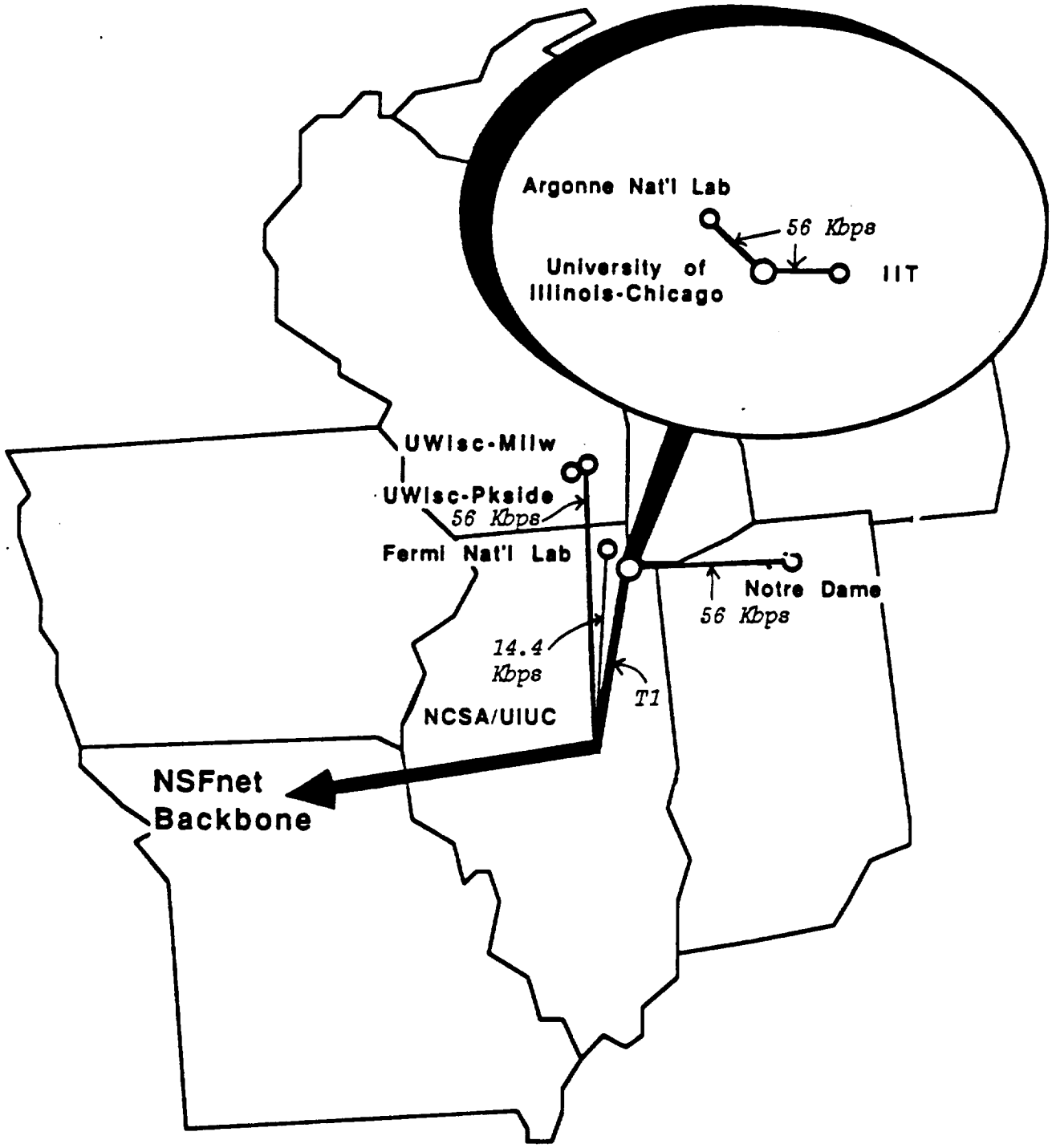


EXHIBIT 7-9. NCSNET Topology.

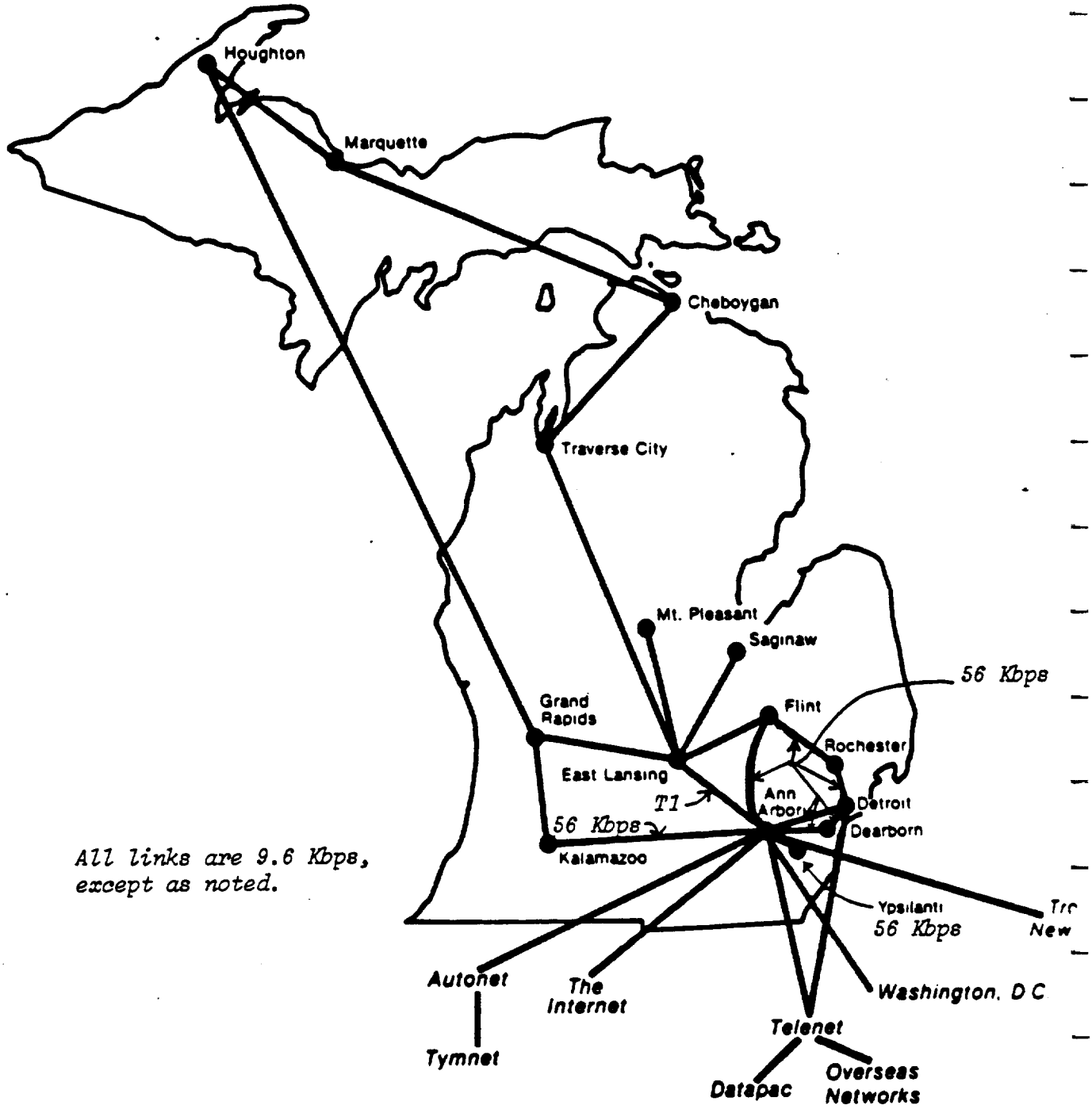


EXHIBIT 7-10. MERIT Topology.

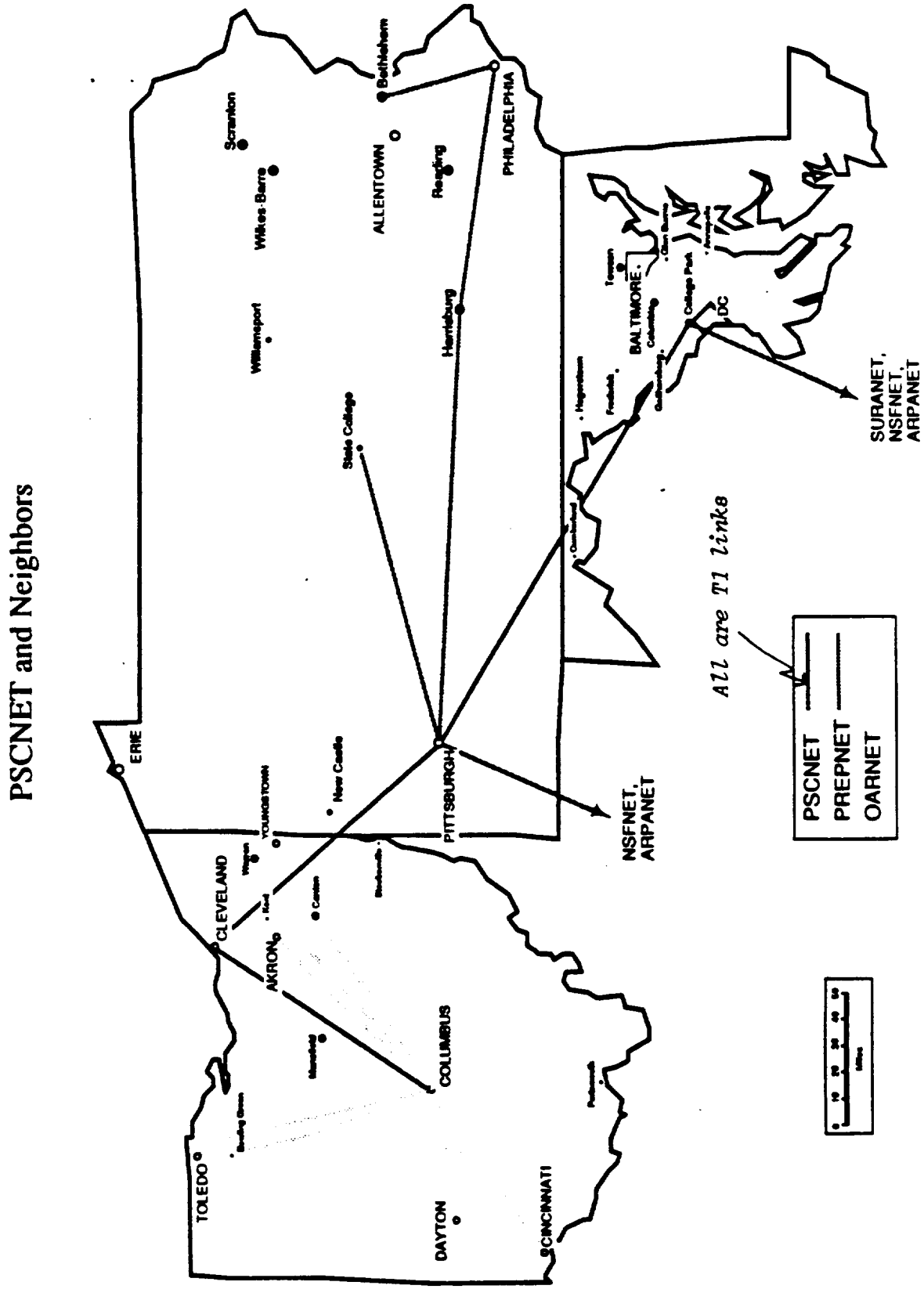


EXHIBIT 7-11. PSCNET Topology.

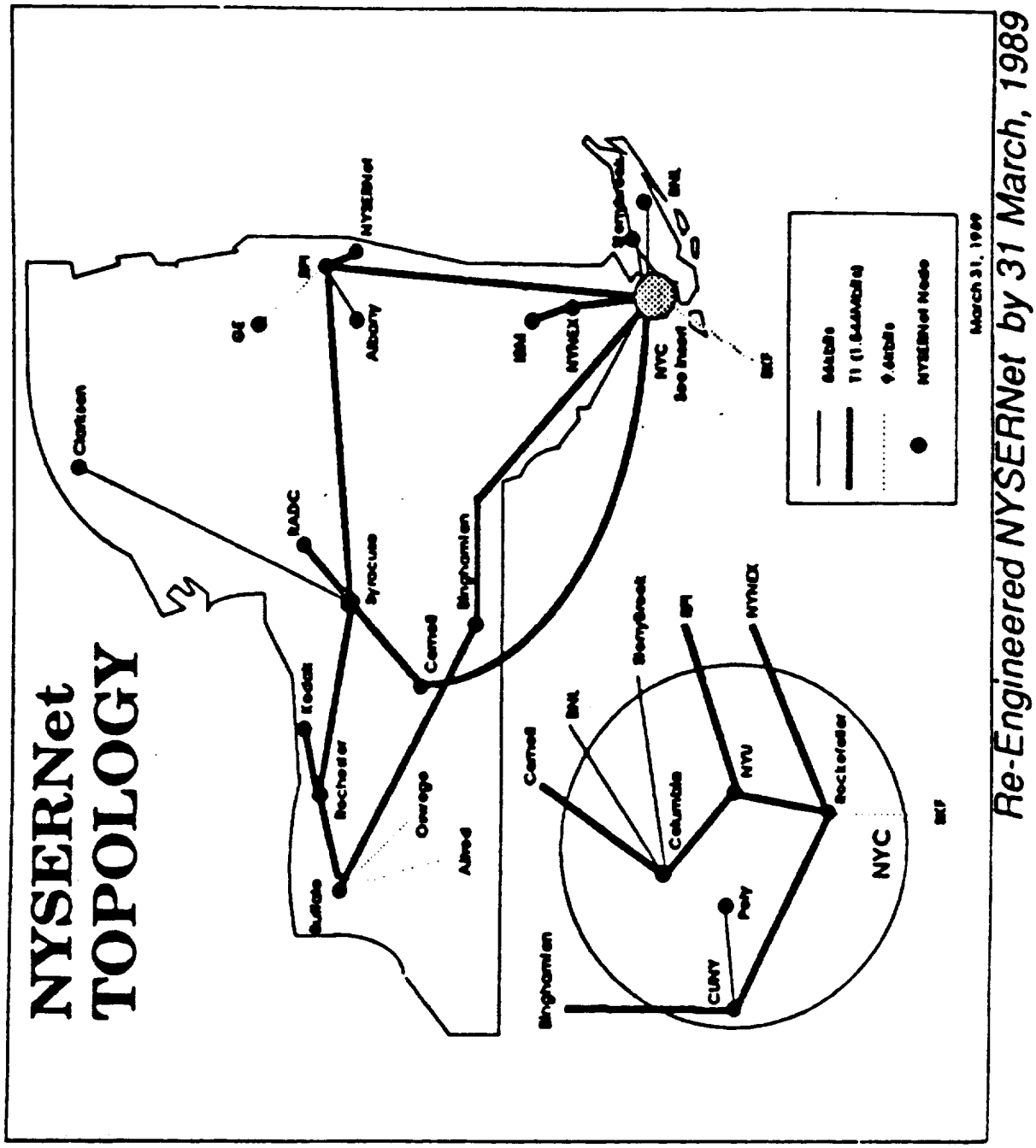


EXHIBIT 7-12. NYSERNET Topology.

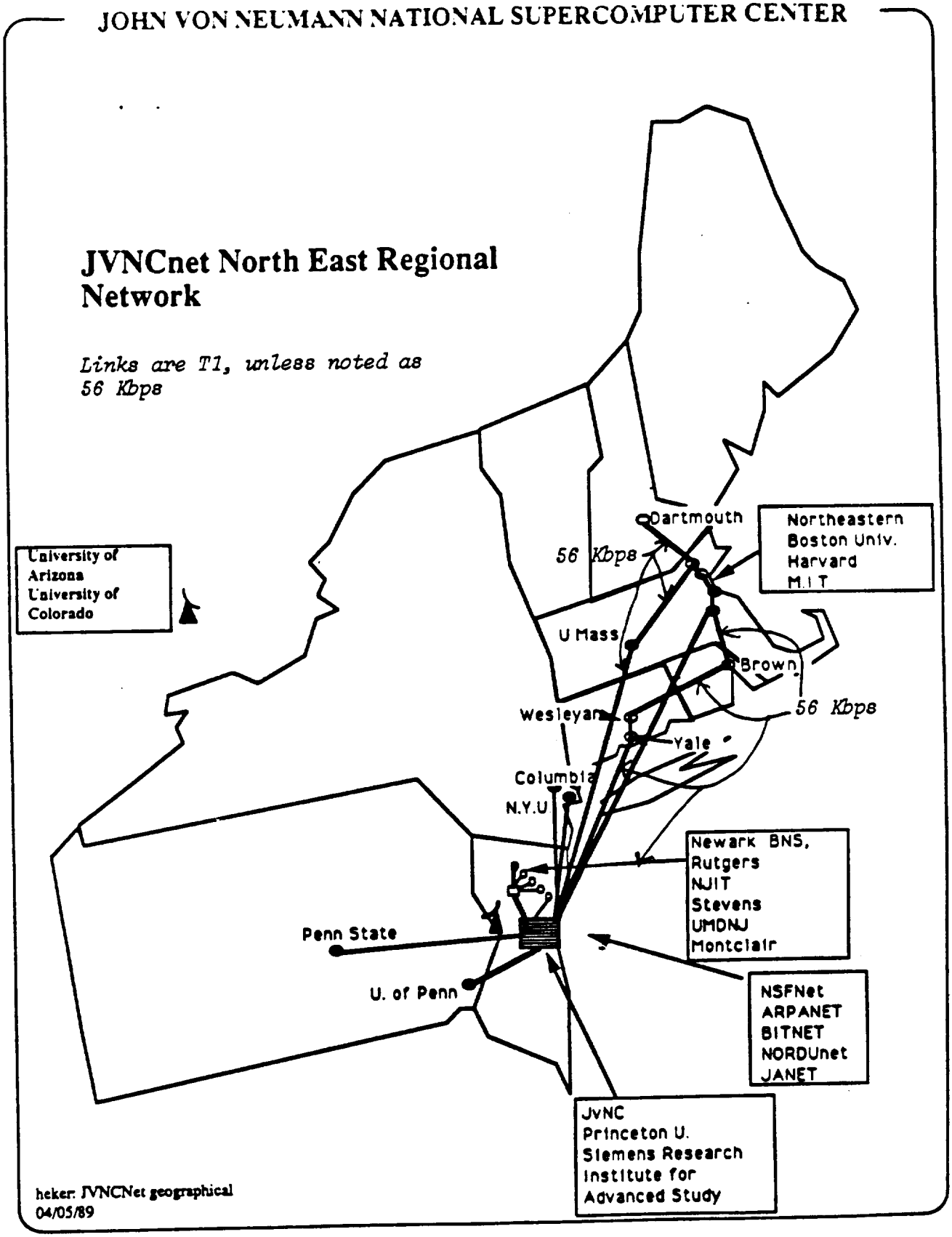


EXHIBIT 7-13. JVNCNET Topology.

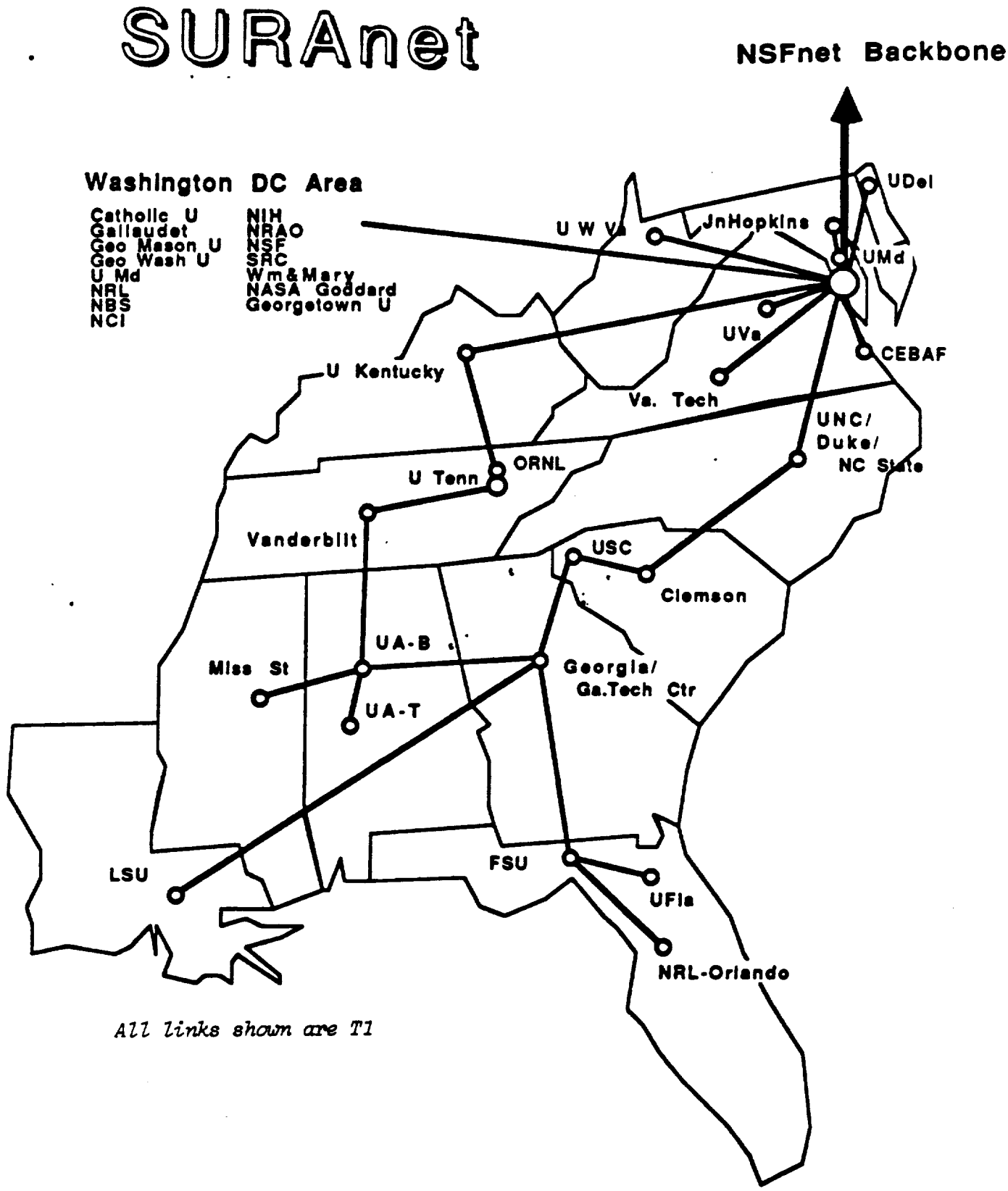


EXHIBIT 7-14. SURANET Topology.

7.6.3 Topology Of Eight New Mid-Level Netowrks

The topologies of the eight new mid-level networks are presented in Exhibits 7-15 through 7-22. The names (For node abbreviations see Exhibit 7-23) of the major nodes, the connectivity and the link speeds are indicated for each network. The networks and their topologies are presented as follows:

1. CERFNET - Exhibit 7-15.
2. CICNET - Exhibit 7-16.
3. LOS NETTOS - Exhibit 7-17.
4. MRNET - EXHIBIT 7-18.
5. NEARNET - Exhibit 7-19.
6. OARNET - Exhibit 7-20.
7. PREPNET - Exhibit 7-21.
8. THENET - Exhibit 7-22.

7.6.4 Campus Area Networks

The current list of campus area networks, by mid-level network, appears in Exhibit 7-23.

7.7 COMPUTERS

The computers in NSFNET serve as hosts, links to other nodes, gateways or some combination of these three uses. They range in size from small microcomputers to supercomputers. The supercomputers at the six supercomputer centers are described below.

1. Cornell Theory Center: The Center's current configuration is an IBM 3090 600/E with six vector processors and five attached FPS 264 scientific computers, connected by high-speed bus for parallel processing. The system offers 256 Mbytes of memory, 512 Mbytes of storage, 115 Gbytes of disk storage, and a peak throughput of 886 Mflops. In addition, an IBM 4381 and two FPS 164 processors provide a development environment.

(Please turn to page 7-39)

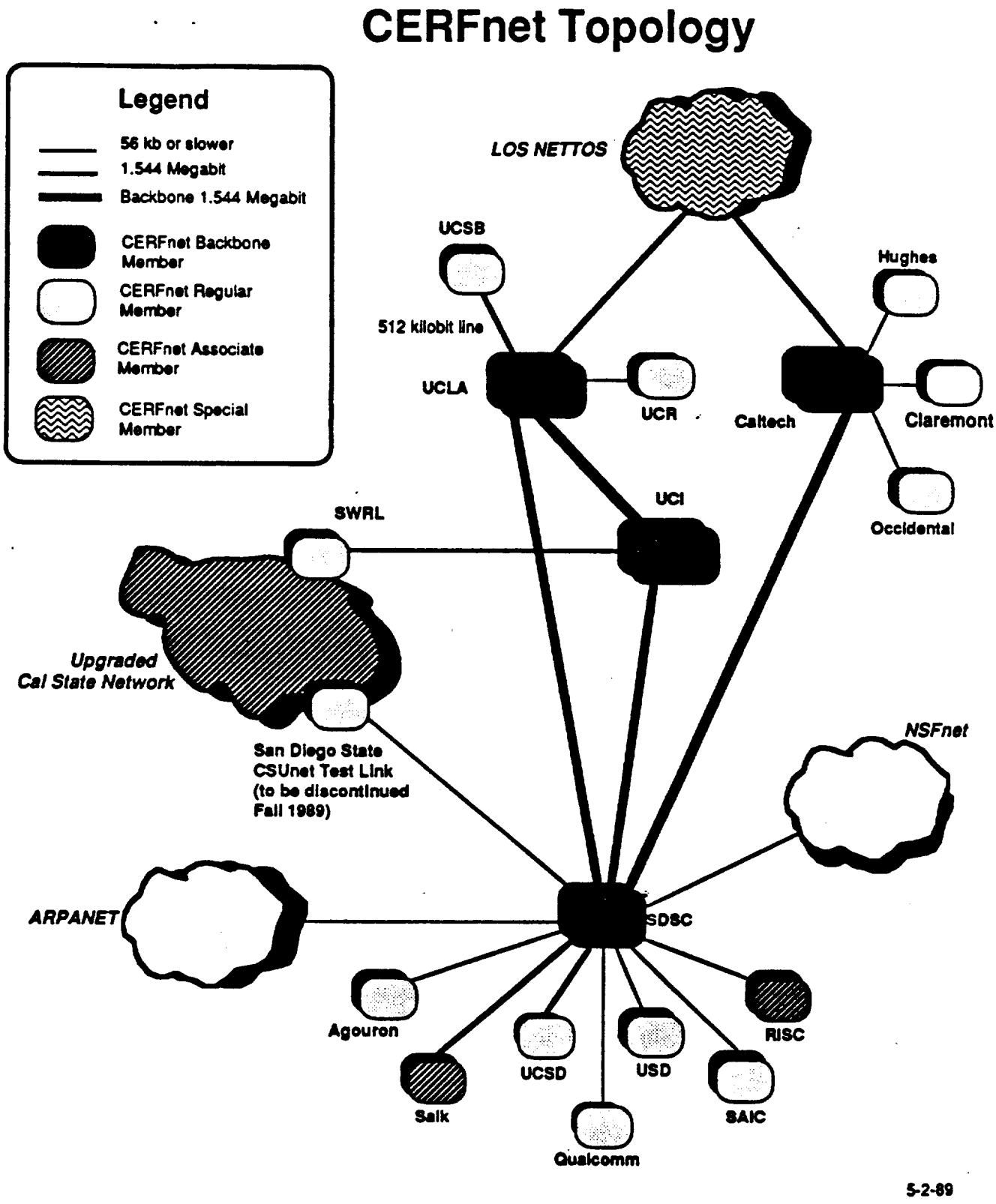


EXHIBIT 7-15. CERFNET Topology.

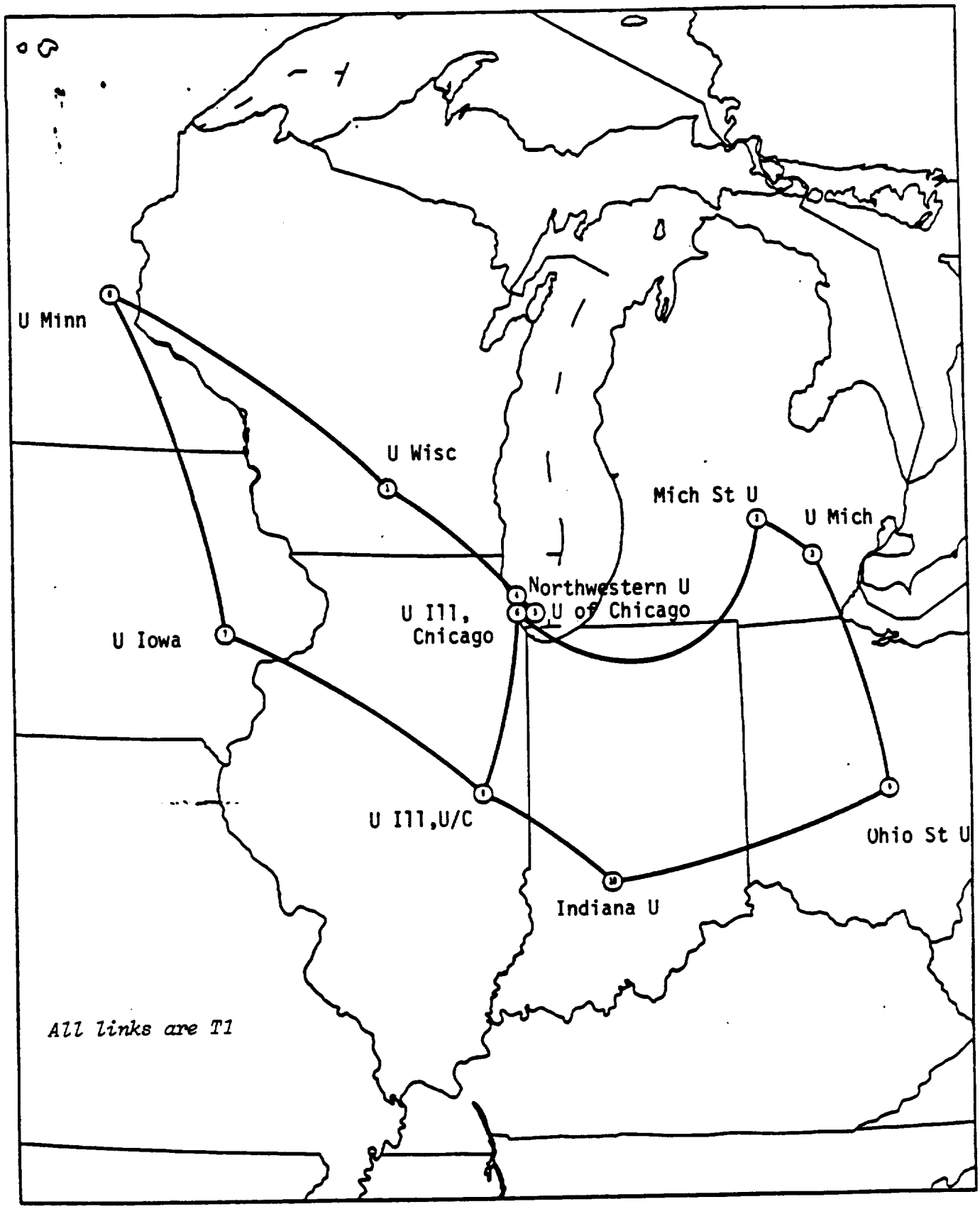


EXHIBIT 7-16. CICNET Topology.

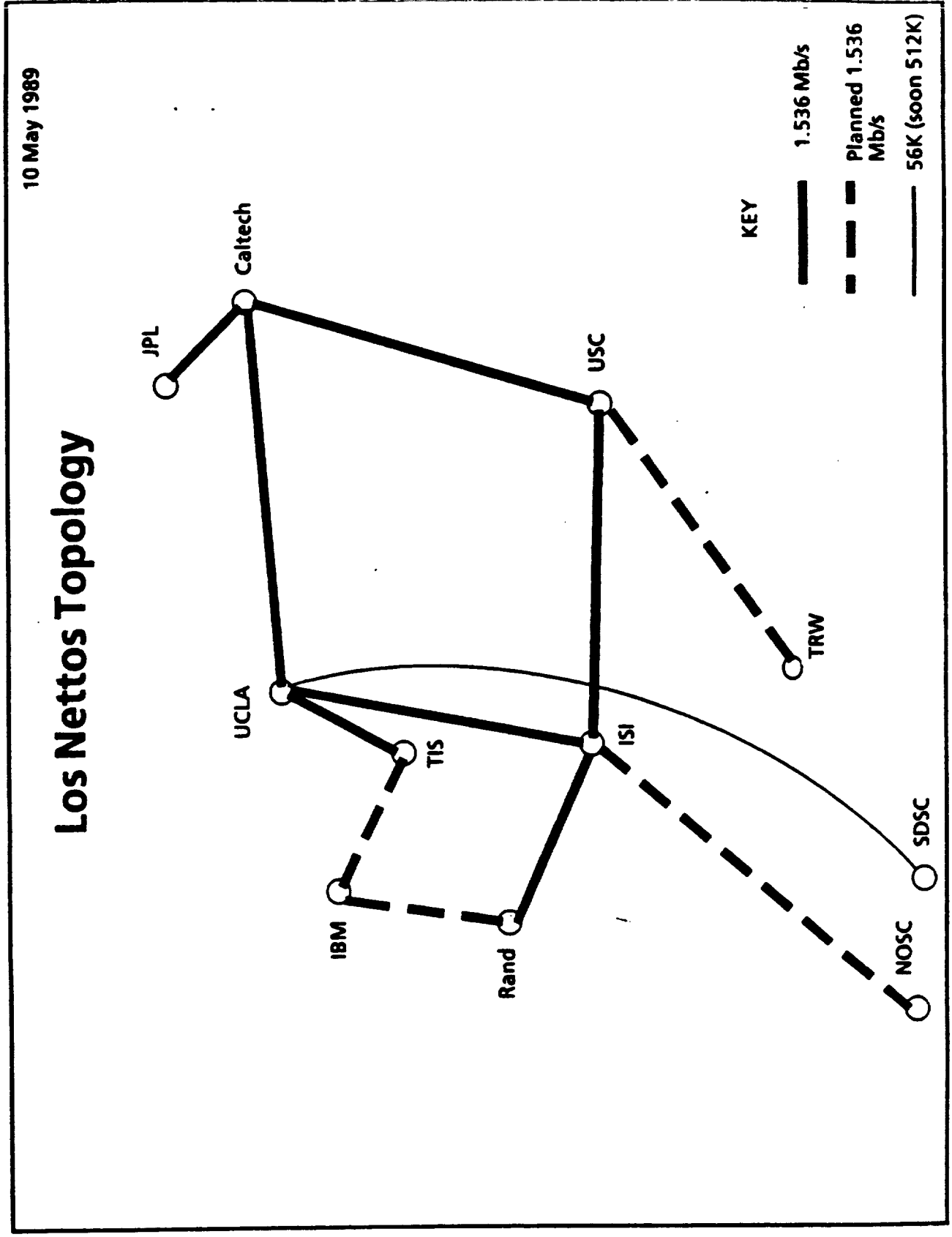
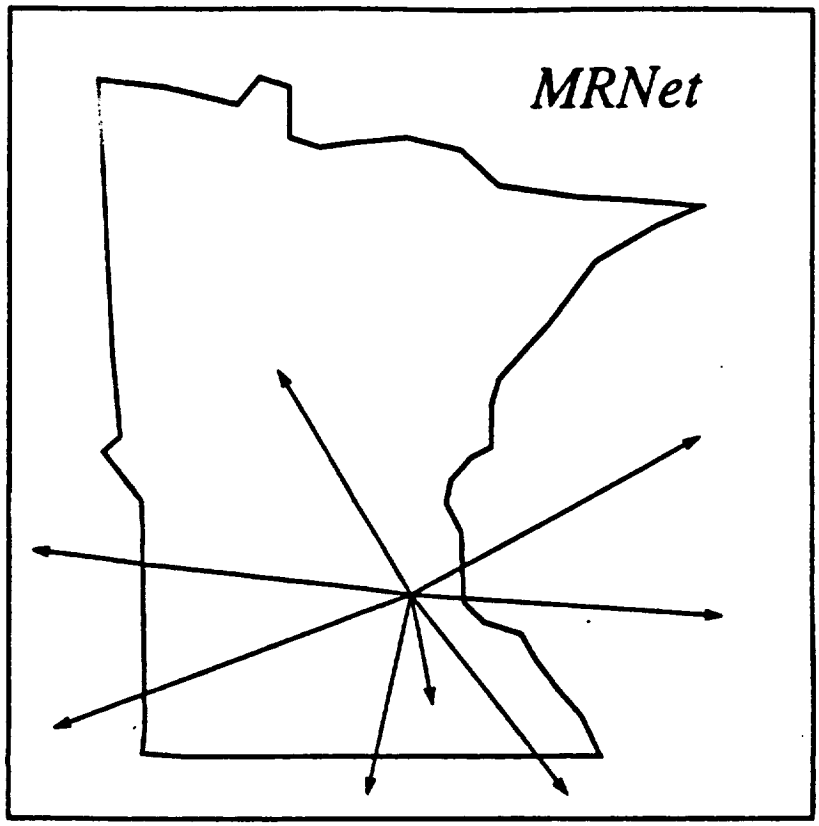
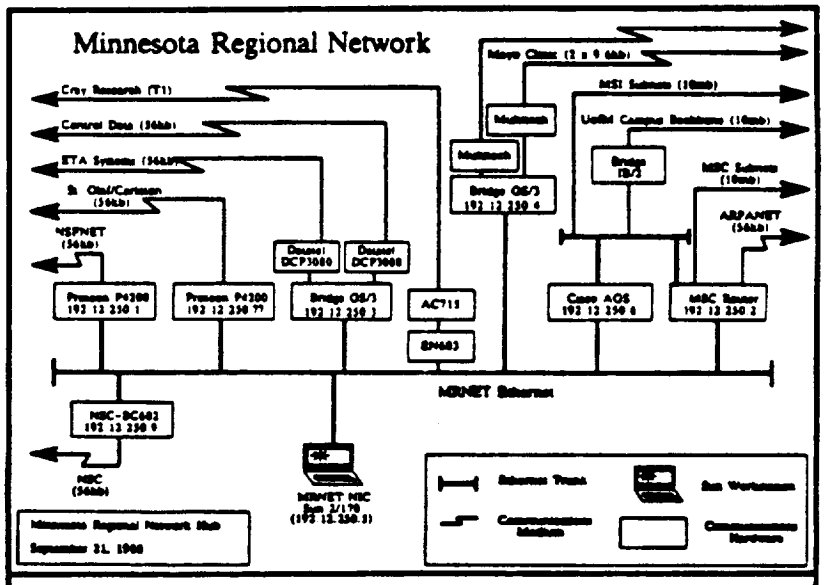


EXHIBIT 7-17. LOS NETTOS Topology.





Topology of the MRNet network. Currently, members are responsible for providing their own communication lines and equipment to connect to the hub. Various connection schemes are pos-

EXHIBIT 7-18. MRNET Topology.

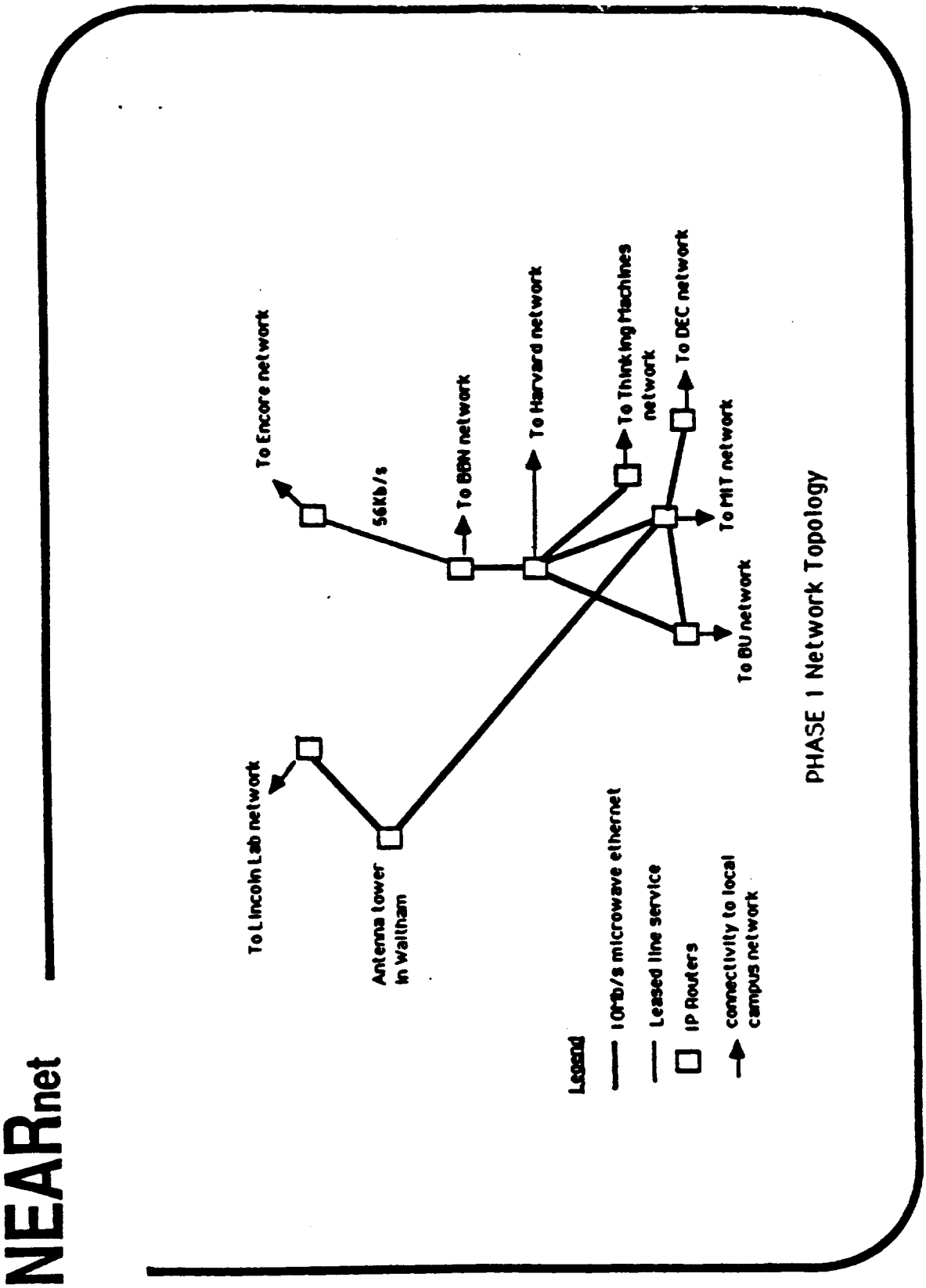


EXHIBIT 7-19. NEARNET Topology.

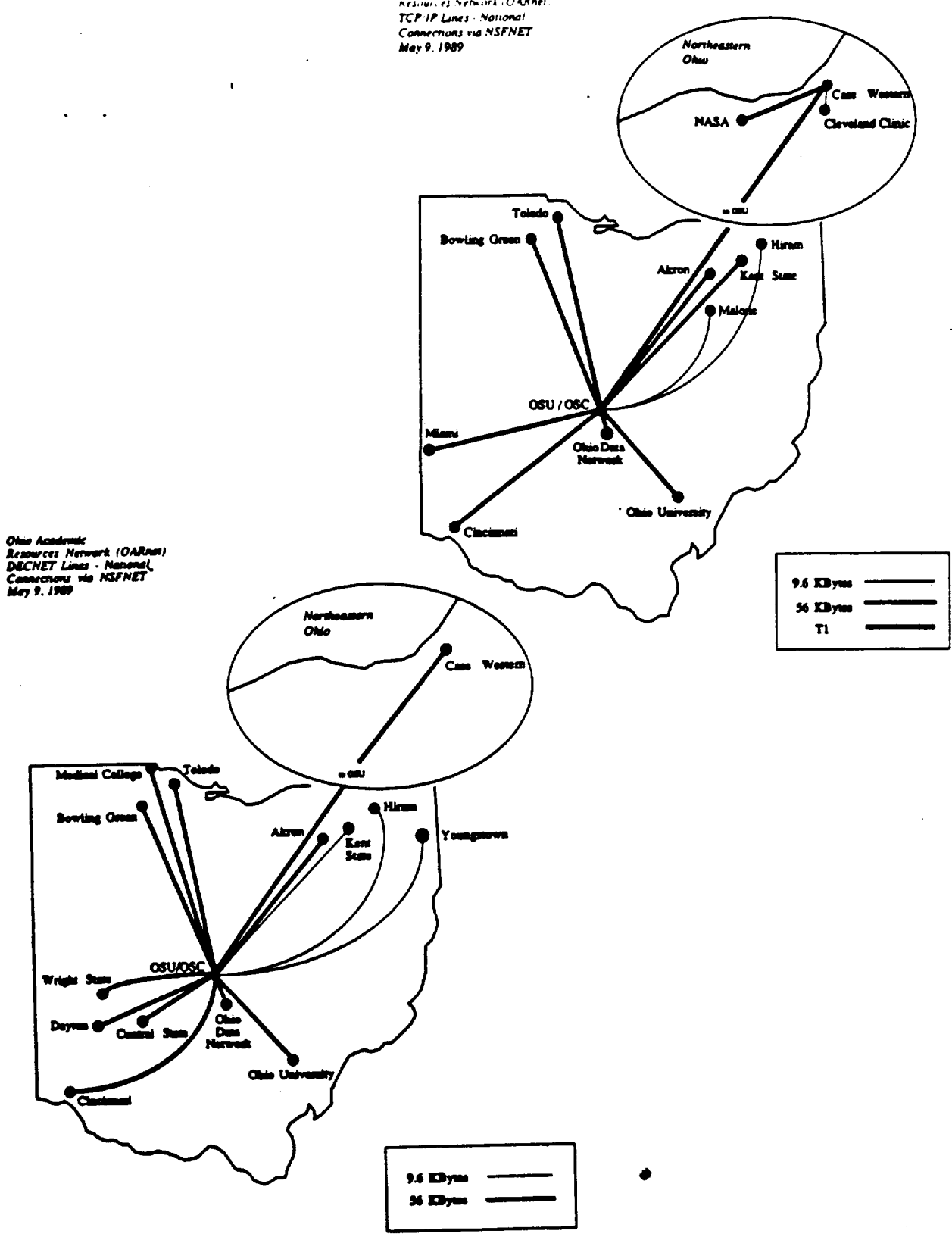


EXHIBIT 7-20. OARNET Topology.

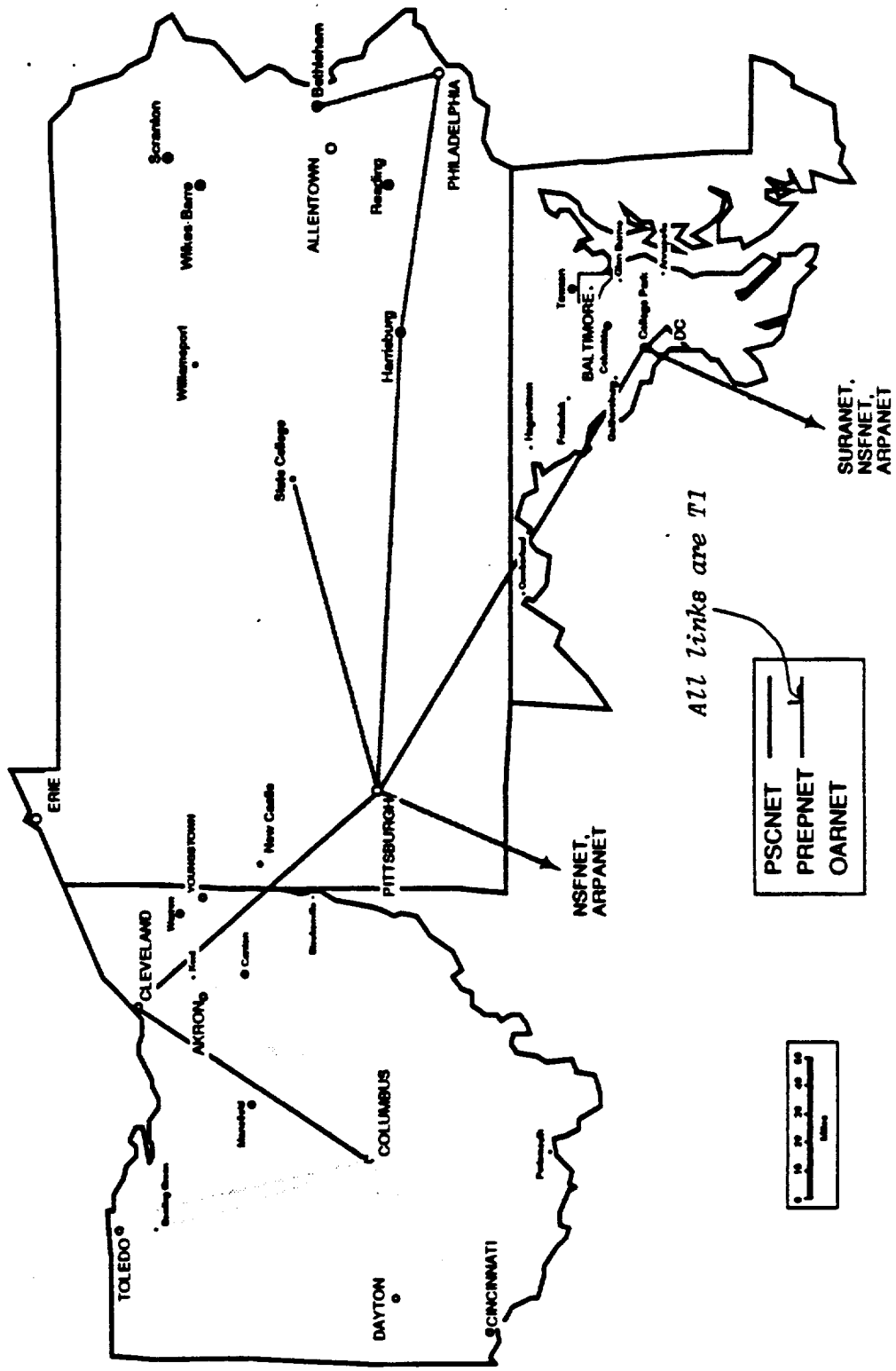
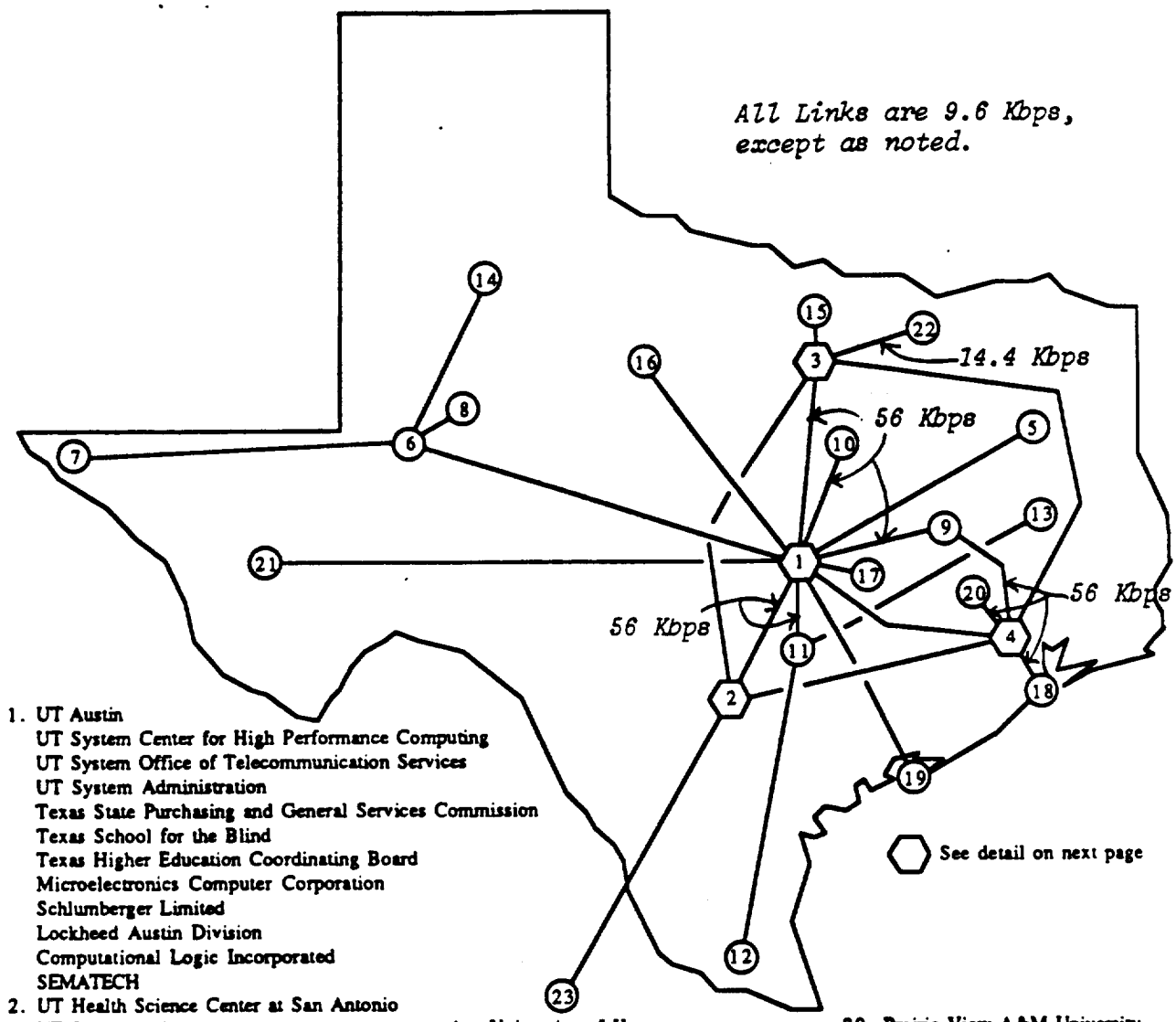


EXHIBIT 7-21. PREPNET Topology.

Texas Higher Education Network (THEnet)



1. UT Austin
   UT System Center for High Performance Computing
   UT System Office of Telecommunication Services
   UT System Administration
   Texas State Purchasing and General Services Commission
   Texas School for the Blind
   Texas Higher Education Coordinating Board
   Microelectronics Computer Corporation
   Schlumberger Limited
   Lockheed Austin Division
   Computational Logic Incorporated
   SEMATECH
2. UT Health Science Center at San Antonio
   UT San Antonio
   Wilford Hall Medical Center
   Brooke Army Medical Center
   Brooks School of Aerospace Medicine
   Southwest Research Institute
   St. Mary's University
3. UT Dallas
   UT Southwestern Medical Center at Dallas
   UT Arlington
   Texas Christian University
   Merit Technology Incorporated
   Texas Instruments Incorporated
   Rockwell International
   Convex Computer Corporation
4. UT Health Science Center at Houston
   UT M.D. Anderson Cancer Center
   Texas Cancer Data Center
   Houston Area Research Center
4. University of Houston
   Rice University
5. UT Health Center at Tyler
   UT Tyler
6. UT Permian Basin
7. UT El Paso
8. UT West Texas Lands Management
9. Texas A&M University
10. Baylor University
11. Southwest Texas State University
12. Pan American University
13. Sam Houston State University
14. Texas Tech University
15. Univerisity of North Texas
16. Abilene Christian University
17. UT M.D. Anderson Cancer Center Science Park
18. UT Medical Branch Galveston
19. UT Marine Science Institute
20. Prairie View A&M University
21. UT McDonald Observatory
22. East Texas State University
23. Instituto Tecnológico y de Estudios Superiores de Monterrey

890309

EXHIBIT 7-22. THENET Topology.

EXHIBIT 7-23. Campus Area Networks

NORTHWESTNET
Alaska, University System
Battelle (Richland)
Boeing Computer System
Idaho, U of
Montana State U
N. Dakota Higher Educ.
Oregon, U of
Oregon, Graduate Center
Oregon State U
Washington, U of
Washington State U

BARRNET
Advanced Decision Systems
Apple Computer Corp.
Bionet/Intelligenetics
Cal State Sacramento
CA, U of, Berkeley
CA, U of, Davis
CA, U of, San Francisco
CA, U of, Santa Cruz
cisco Systems, Inc.
ESL (TRW)
Excelen
FMC Inc.
Hewlett Packward Labs
Kestrel Institute
Lawrence Berkeley Lab
Lawrence LIvermore Nat'l Lab
Monterey Bay Research
NASA Ames Research Center
SRI Internat.
Stanford U
Sun Microsystems
Tandem Computers Inc.
Teknowledge
US Geological Survey
Xerox PARC
3Com

SDSCNET
Agoron Institute
Calif. Institute of Tech
CA. U of, Irvine
CA, U of, Riverside
CA, U of, Santa Barbara
CA, U of, San Diego
CA, U of, Los Angeles
Hughes Network Systems
Kit Peak Observatory, AZ
Maryland, U of
San Diego Supercomputer Center
San Diego State University

SDSCNET (Cont.)
Scripps Institute
Utah, U of
Washington, U of

WESTNET
Air Force Weapons Lab
Apache Point Observatory
Arizona, U of
Arizona State U
Boise State U
Brigham Young U
Colorado Alliance of Res Lib.
Colorado, U of, Boulder
Colorado, U of, Col Spr
Colorado, U of, Denver
Colorado, U of No.
Colorado School of Mines
Colorado State U
Denver U
Ford Aerospace
Los Alamos Nat Lab
NCAR
Nat Sunspot Observatory
New Mexico Institute of Min/Tech
New Mexico Technet
New Mexico, U of
New Mexico, U of, Los Alamos
New Mexico State U
Rockwell International
Sante Fe Institute
Utah, U of
Utah State U
U.S. Geological Survey
Wyoming, U of

USAN
Institute for Naval Ocean.
Miami, U of
NCAR
Naval Res Lab
Oregon State U
Penn State U
Wisconsin, U of
Woods Hole Ocean. Institution

MIDNET
Arkansas, U of
EROS Data Center
Iowa State U
Iowa, U of
Kansas State U
Kansas, U of
Missouri, U of, Columbia

EXHIBIT 7-23. Campus Area Networks

(Continued)

MIDNET (Cont.)
Missouri, U of, Kansas City
Missouri, U of, Rolla
Missouri, U of, St Louis
Nebrasks, U of, Lincoln
Nebrasks, U of, Omaha
Oklahoma State U
Oklahoma, U of
South Dakota, U of
Tulsa, U of
Washington U

SESQUINET
Baylor College of Medicine
Computational Logic, Inc
Convex, Inc
Houston Area Research Center
Houston, U of
Lockhead Austin Div
Merit Technologies
Microelectronics & Computer Cons.
Prairie View A&M U
Rice U
Rockwell, Inc.
Schlumberger
Southwest Research Institute
Texas A & M U
Texas Southern U
Texas, U of, Austin
Texas, U of, Dallas
Texas, U of, HSC San Antonio
Texas, U of, Houston
Texas, U of, San Antonio
Texas Instruments

NCSANET
Argone Nat'l Lab
Fermi Nat'l Lab
Ill, U of, Chicago
NCSA/U of Ill
Notre Dame U
Wisc, U of, Milwaukee
Wisc, U of, Parkside

MERIT
Ann Arbor
Cheboygen
Dearborn
Detroit
East Lansing
Flint
Grand Rapids
Houghton

MERIT (Cont.)
Kalamazoo
Marquett
Mt Pleasant
Rochester
Saginaw
Telenet
Traverse City
Troy, NY
Tymnet
Washington, DC
Ypsilanti

PSCNET
Maryland, U of
NASA Lewis
Ohio State U
Pittsburgh Supercomputer Center

NYSERNET
Alfred U
Brookhave Nat Lab
City U of NY
Clarkson U
Columbia U
Cornell U
Eastman Kodak
General Electric
Hartford Grad Center
IBM
New York U
NYNEX Sci & Tech
Polytechnic U
Rensselaer Polytechnic Inst.
Rochester, U of
Rockfeller U
Rome Air Devop Center
SmithKline & French
SUNY Albany
SUNY Binghamton
SUNY Buffalo
SUNY Oswego
SUNY Stony Brook
Syracuse U

JVNCNET
Arizona, U of
Bellcore
Bell Labs
Boston U
Brown U
Colorado U
Columbia U

EXHIBIT 7-23. Campus Area Networks

(Continued)

JVNCNET(Cont.)
Dartmouth U
Harvard U
Massachusetts, U of
MIT
New York U
NJIT
Northeastern U
Penn State U
Penn, U of
Princeton U
Rutgers U
Siemens Corp
Stevens Inst. of Tech
Wesleyan U
Yale U

SURANET
Alabama, U of, Birmingham
Alabama, U of, Tuscaloosa
Catholic U
Clemson U
Continuous Elec Beam Accel Fac
Delaware, U of
Florida State U
Florida, U of
Gallaudet U
George Mason U
George Washington U
Georgetown U
Georgia, U of
Georgia Institute of Tech
John Hopkins U
Kentucky, U of
Louisiana State U
Maryland, U of
Miss State U
Naval Research Lab, DC
Naval Research Lab, Orlando
NASA Goddard
NASA Langley
National Bureau of Standards
National Cancer Institute
Nat Inst of Env Health Sciences
Nat Inst of Health
Nat Radio Astronlmy Observ
Nat Science Found
Oak Ridge Nat Labs
Old Dominion U
South Carolina, U of
Supercomputer Res Center
Tenn, U of
Triangle U Computation Center

SURANET(Cont.)
Duke U
North Carolina, U of
North Carolina State U
US Geological Survey
Vanderbilt U
Virginia, U of
Virginia Commonwealth U
West Virginia U
Virginia Polytechnic U
William & Mary College

CERFNET
Agouron Institute
Calif Institute of Tech
Calif State U Network
CA, U of, Los Angeles
CA, U of, Riverside
CA, U of, San Diego
CA, U of, Santa Barbara
Claremont Colleges
Hughes Aircraft
Occidental College
Qualcomm Inc
Research Institute of Scripps
Salk Institute
San Diego Supercomputer Center
San Diego, U of
Science Applications Inf Corp
South West Research Labs

CICNET
Chicago, U of
Ill, U of, Chicago
Ill, U of, Urbana/Carb
Indiana U
Iowa, U of
Minnesota, U of
Michigan, U of
Michigan State U
Northwestern U
Ohio State U
Wisconsin, U of, Madison

LOS NETTOS
Calif Institute of Tech
CA, U of, Los Angeles
IBM
ISI (Stanford)
JPL
NOSC
Rand
San Diego Supercomputer Center

EXHIBIT 7-23. Campus Area Networks

(Continued)

LOS NETTOS (Cont.)
TRW
TIS
University of So. CA

MRNET
Carleton College
Minn Supercomputer Center
Network Systems Corp
Control Data Corp
Cray Research
Honeywell
Mayo Foundation
St Olaf College
3M Company
Minn, U of

NEARNET
BBN, Inc
Boston U
DEC
Encore Computer Corp
Harvard U
MIT
MIT Lincoln Lab
Thinking Machines Corp

OARNET
Akron, U of
Bowling Green State U
Case Western U
Central State U
Cincinnati, U of
Cleveland Clinic
Dayton
Hiram U
Kent State U
Malone U
Medical College
Miami, U of
NASA Lewis
Ohio Data Network
Ohio U
Ohio State U
Toledo, U of
Wright State
Yougstown

PREPNET
Carnegie Mellon U
Drexel U
Lehigh U
PA, U of

PREPNETCont.)
PA State U
Pittsburgh Supercomputer Center
Pittsburgh, U of
Temple U

THENET
Abilene Christian U
Baylor U
East Texas State U
Houston, U of
Pan American U
Prarie View A&M
Rice U
Sam Houston State U
Southwest TX State U
TX, U of, Austin
11 sites
TX, U of, Dallas
7 sites
TX, U of, El Paso
TX, U of, Health Sci,
Houston, 3 sites
TX, U of, Health Sci,
San Antonio, 6 sites
TX, U of, Health Center
Tyler
TX, U of, MD Adersen Cancer
TX, U of, Marine Sci Inst
TX, U of, McDonald Obser
TX, U of, Medical, Galveston
TX, U of, Permian Basin
TX, U of, West TX Lands Mgmt
Texas A&M
Texas Tech U
U of North TX

2. John von Neumann Supercomputer Center: The center maintains two CYBER 205 supercomputers and plans to enhance its facilities by adding the ETA-10 Class VII supercomputer, which will be the fastest nonclassified supercomputer in the world. The ETA-10 will have eight processors and 256 Mbytes of memory.

3. National Center for Atmospheric Research: The center has a Cray X-MP/48 supercomputer with four processors and eight million 64-bit words (64 Mbytes) of memory, and 256 million words of storage. It also has a Cray-1A supercomputer with one processor, one million 64-bit words of memory, and four Gbits of disk storage. The center has some of the most comprehensive data archives in the world.

4. National Center for Supercomputer Applications: NCSA operates a Cray X-MP/48 supercomputer running the Cray Time Sharing System (CTSS). It has four CPUs, eight million 64-bit words of memory and 21 Gbytes of on-line disk capacity. NCSA also operates a Cray 2S/4-128 running UNICOS operating system.

5. Pittsburgh Supercomputer Center: The equipment in the PSC ranges from the Cray X-MP/48 through the VAX 8650 front-ends to high-function engineering workstations, personal computers and special-purpose graphics devices.

6. San Diego Supercomputer Center: The supercomputer at SDSC is a Cray X-MP/48 running the Cray Time Sharing System (CTSS) interactive operating system. It has four CPUs, eight million 64-bit words of memory, a peak speed of 840 Mflops, and 14.4 Gbytes of disk storage.

7.8 MEDIA AND LINK SPEED

The media and link speeds for NSFNET are described in this section for each level of NSFNET's three level internetwork: its backbone, its mid-level networks, and its campus networks.

7.8.1 Backbone

The initial backbone, which became operational in 1986, was composed of 56 Kbps links between six supercompueter centers. In early 1988, the NSFNET backbone was expanded to connect thirteen network hubs and an upgrade to T1 links (i.e., 1.544 Mbps) was begun. The full upgrade to T1 speeds was completed in 1989 (As noted earlier in Exhibit 7-1) and the move to 45 Mbps is projected for the early 1990s.

The NSFNET backbone uses MCI's fiber-optic network which incorporates advanced switching technologies. Hardware and software from IBM comprising the Nodal Switching Subsystems (NSS) are used for routing and packetizing data for transmission over the MCI network. One NSS is located at each of the thirteen hub sites. Each NSS is composed of nine IBM RT/PCs, each connected to two token ring networks for redundancy. There is a Routing Control Processor (RCP) within each NSS which mediates routing information between NSSes. These advanced technologies will make it possible to dynamically vary the traffic flow and the underlying bandwidth of the circuit network.

7.8.2 Thirteen Original Mid-Level Networks

The media and link speeds for each of the thirteen original mid-level networks are discussed below. As noted earlier, these link speeds are indicated on the network topologies in Exhibits 7-2 through 7-14. The network link speed discussions are presented in the same order as those for mid-level topologies, i.e., from West to East.

1. NORTHWESTNET: This network is a ring of land circuits with a satellite spur to Alaska. On the northwestern segment, 56 Kbps circuits connect the University of Oregon, Oregon State University, the Oregon Graduate Center, Boeing Computer Services, the University of Washington, Washington State University, and the University of Idaho. On the reamining segment, 9.6 Kbps circuits (running at 19.2 Kbps with Fujitsu modems) complete the ring, connecting the University of Idaho, Montana State University, North Dakota State University, and the University of Oregon. The University of Washington is connected to the University of

Alaska (Fairbanks) via a 56 Kbps satellite link. The Alaska and North Dakota nodes connect statewide networks to NORTHWESTNET. NORTHWESTNET routes traffic to the NSFNET backbone via T1 cicuits from the Nodal Switching Subsystem at the University of Washington to the San Diego Supercomputer Center, and by satellite from Oregon State University to the National Center for Atmospheric Research.

2. BARRNET: BARRNET was the first to operate entirely with T-1 interconnection, 1.544 Mbps speeds, between connected campus networks. Recently, however, some business sites have connected with a link speed of 56 Kbps. BARRNET It is connected to the NSFNET backbone through a T1 link from Stanford.

3. SDSCNET: This consortium network of the SDSC is modeled after MFENET (discussed under ESNET in a susbsequent section). It uses mostly 56 Kbps terrestrial and satellite links centered on SDSC which is tied to the NSFNET backbone. There are a few T1 links, e.g., to NCAR and to the University of Washington.

4. WESTNET: Long-haul links in WESTNET are mostly 56 Kbps links. Currently, it has two plugs into the NSFNET backbone: the Network Switching Subsystem (NSS) at the NCAR and the NSS at the University of Utah (UU). Arizona, Colorado, New Mexico and Utah have direct circuits into the gateways at NCAR and UU. Plans for upgrading selected circuits to T1 speeds will be considered after the NSFNET backbone stabilizes.

5. USAN: The University Satellite Network connects seven United States sites to the NCAR via Ku-band satellite links that use Very Small Aperture Terminal (VSAT) technology. The nominal speeds are 56 Kbps to NCAR and 224 Kbps in the broadcasts to each of the sites. File transfers from NCAR to the remote sites have been measured at up to 70 Kbps, and transfers from the remote sites to NCAR have been measured at up to 45 Kbps.

6. MIDNET: Midnet is arranged in a ring connecting sites in seven states. The links connecting these sites are all 56 Kbps leased

lines. It connects via a T1 link to the NSFNET backbone at the University of Nebraska.

7. SESQUINET: In this network the connections from Baylor College of Medicine to Rice University to University of Texas (UT) at Austin to UT at Dallas are T1 links. All other nodes are connected via 56 Kbps links. The networks' connection to the NSFNET backbone is from Rice University to NCAR. Plans have been made to add members and to upgrade the most important lines to T1 speeds.

8. NCSANET: This network has two hubs, one at NCSA and the other at the University of Illinois (Chicago); a T1 line links these two hubs. The hubs and the direct links to them appear as Ethernets. The NCSA hub has a T1 link to CICNET, a 56 Kbps leased line to the University of Wisconsin (Milwaukee), and a 14.4 Kbps link to the Fermi National Lab. The Chicago hub has T1 link to CICNET, and 56 Kbps links to Argonne National Lab, Illinois Institute of Technology, and the University of Notre Dame. The NSFNET backbone connection is at the NCSA/UIUC (University of Illinois/Urbana-Champaign).

9. MERIT: MERIT has grown to over 300 nodes, and most long distance lines run at 9.6 Kbps, although a few digital lines are 56 Kbps links. The NSFNET backbone connection is at Ann Arbor, which is also the location of MERIT's facilities for management of NSFNET. There is currently one T1 link from East Lansing to Ann Arbor.

10. PSCNET: This network uses primarily T1 lines, but there are a few 56 Kpbs lines. The NSFNET connection is at the Pittsburgh Supercomputer Center.

11. NYSERNET: This network currently covers the state of New York with a T1 backbone structure and reaches some neighboring states with 9.6 Kbps and 56 Kbps links.

12. JVNCNET: This network includes 9 T1 links with speeds of 1.544 Mbps. It also has 12 other 56 Kbps dedicated lines, some terrestrial and some via satellite. The satellite network currently consists of three

nodes with the hub at the JVNC.

13. SURANET: This network includes a combination of 56 Kbps, T-1, and ethernet lines. The NSFNET connection is at the University of Maryland.

7.8.3 Eight New Mid-Level Networks

The media and link speeds for each of the eight new mid-level networks are discussed below. As noted earlier, these link speeds are indicated on the network topologies in Exhibits 7-15 through 7-22.

1. CERFNET: This network has a T1 backbone, T1 links from the backbone to several nodes and 56 Kbps links from the backbone to several nodes.

2. CICNET: This network is a T1 backbone network connecting institutions of higher education in seven midwest sates.

3. LOS NETTOS: This network is primarily a T1 network. There is one 56Kbps link to the San Diego Supercomputer Center.

4. MRNET: For this network link speeds range from 9.6 Kbps to 56 Kbps to 1.544 Mbps to the 10 Mbps Ethernet links that connect the Minnesota Supercomputer Center (MSC) and the University of Minnesota. It has a 56 Kbps link to the NSFNET backbone via the University of Illinios at Urbana/Champaign.

5 NEARNET: This network has a 10 Mbps ethernet backbone with 9.6 Kbps to 56 Kbps links to nodes not on the backbone.

6. OARNET: This network's links speeds range from 9.78 Kbps to 56 Kbps to 1.544 Mbps. Most links are 56 Kbps.

7. PREPNET: The link speeds for this network are all T1s.

8. THENET: This state network currently connects over 800 computers at 35

academic and research institutions. Its link speeds range from 9.6 Kbps to 56 Kbps to 1.544 Mbps. Most are 9.6 Kbps or 56 Kbps links.

7.8.4 Campus Networks

The speeds of the over 240 NSFNET campus networks cover the entire range from 9.6 Kbps to 100 Mbps. Researchers' Local Area Networks (LANs) typically operate at speeds up to 10 Mbps, and Campus Area Networks, which connect the LANs, typically operate at speeds up to 100 Mbps.

7.9 PROTOCOLS

The TCP/IP (Transmission Control Protocol/Internet Protocol) protocols are used on the backbone and on most of the mid-level and campus networks. Some of the NSFNET networks use internet and trasnport protocols other than, or in addition to, IP and TCP; these are: MERIT (locally developed protocols); MIDNET (TCP/IP, DECNET, and SNA protocols); NYSERNET (TCP/IP and electronic library acess protocols); OARNET (TCP/IP and DECNET); SDSCNET (MFENET NSP, TCP/IP, and DECNET protocols); THENET (TCP/IP and DECNET); and WESTNET (combination of TCP/IP and DECNET protocols).

It is expected that the NSFNET will gradually move to the International Standards Organization (ISO) reference model of Open Systems Interconnection (OSI). That is, the ISO/OSI protocol gradually will come into use to augment, and eventually supplant, the current TCP/IP protocols. Many of the mid-level networks are planning and anticipating a similar change in protocols.

7.10 ADMINISTRATION

There is no single administrative entity for the three levels of the NSFNET internetwork. The backbone has an administration and the mid-level networks have a variety of administrations, as do the campus networks.

7.10.1 Backbone Administration

Administration of the NSFNET backbone is divided functionally among several entities. The NSF Division of Network and Communications Research and Infrastructure is responsible for policy. MERIT, Inc., the non-profit membership consortium of Michigan universities, located in Ann Arbor, Michigan is responsible for management and operation. The Network Information Center (NIC), a part of the NSF Newtowrk Service Center (NNSC) at BBN systems and Technologies Corporation in Cambridge, Massachusetts, provides end user support to the research community. Thus, day-to-day management of the network is based in Ann Arbor, where the MERIT central staff is headquartered. In addition, a Network Operations Center (NOC) in the University of Michigan's Computing Center is the focus of daily operations. Some 30 engineers, technicians, operators and technical support specialists monitor and maintain the hardware and software comprising the NSFNET backbone.

7.10.2 Mid-Level And Campus Network Administration

Administration of the mid-level networks and the campus networks making up the mid-level networks varies from informal committees to corporations. The following are examples of the types of groups that are carrying out administrative functions for mid-level networks: Boeing Computer Center (NORTHWESTNET), consortium charters with administration at the site (BARRNET), state level focus (WESTNET), formal board (MIDNET), steering committee (SESQUINET), supercomputer center administration (NCSANET), non-profit corporation (MERIT), network committee (NYSERNET), and a state office of telecommunications services (THENET). The variation is similar at the campus level.

7.11 FUNDING

As noted under the section on "History," funding for NSFNET began with the NSF funding of the supercomputer centers and network access to them. The current NSFNET backbone is the result of cooperative efforts by the NSF, MERIT, IBM Corporation, MCI Telecommunications Corporation, and the

mid-level networks. Many of the mid-level networks received start-up funding from NSF or other federal sources. Currently, funding comes from various combinations of the following sources: federal government, higher education, business partners, and fees. Many of the mid-level networks are making plans to become self-sustaining through some type of fee for membership and service program.

7.12 FUTURE

The future of NSFNET can be described in technological and political terms. Technologicallly, the following changes are possible: upgrading the backbone to DS3 speeds; migrating from TCP/IP to ISO/OSI; and continued experimentation. Politically, NSFNET likely will play a key role in the development of a NRN. Its exact role will be a function of how it interfaces with other national efforts like RIB (the Research Interagency Backbone) and the NRI (National Research Initiatives) Gigabit network research.

SECTION 8

NASA RESEARCH NETWORKS

8.1 OVERVIEW

To understand the National Aeronautics and Space Administration's (NASA's) research networks, one needs to understand the purposes and realtionships among NASA Science Internet (NSI), NASA Science Network (NSN), Space Physics Analysis Network (SPAN), the Numerical Aerodynamics Simulation Network (NASNET), and NASA Communications (NASCOM). To provide a background for this understanding, a brief summary of NASA's networking organization is presented. Then NSI is described in terms of its purpose, function and relationship to NSN, SPAN, NASNET and NASCOM. In the last four sections, descriptions of NSN, SPAN, NASNET and NASCOM are presented and include, in each case, discussions of all of the major network topics.

8.2 NASA NETWORKING ORGANIZATION

Five of NASA's seventeen centers and its headquarters are responsible for most of the NASA networking activities. The centers and their roles are:

1. Ames Research Center (ARC) at Moffett Field, CA: Was involved with the ARPANET since 1970; currently is the location for administration of NSI, NSN, and NASNET.
2. Goddard Space Flight Center (GSFC) in Greenbelt, MD: Has been responsible for networks for collection and dissemination of NASA-wide data (NASCOM); is location for the National Space Science Data Center and the NASA Space and Earth Science Computer center and for the administration of SPAN.
3. Jet Propulsion Laboratory (JPL) in Pasadena, CA: Developed a tracking network for planetary missions.
4. Johnson Space Center (JSC) in Houston, TX: This center has a 9.6 Kbps SNA network, called NASAnet, for administrative computing.

5. Marshall Space Flight Center (MSFC) in Huntsville, AL: Operates and manages administrative networks (PSCN-Program Support Communications Network).
6. Headquarters in Washington, D.C.: is responsible for policy decisions, interagency agreements (e.g., FRICC) and funding.

8.3 NASA SCIENCE INTERNET - NSI

8.3.1 Purpose

NASA Science Internet (NSI) is a communications technology program, rather than a communications network, within NASA's Office of Space Science and Application (OSSA). It was created in 1986 as a management tool to analyze and control network communications costs. It was designed as a mechanism to examine and consolidate user requirements into fewer circuits, to use new technology for sharing circuits and equipment, and to take advantage of existing computer networks.

8.3.2 Function

NSI works with OSSA scientists to analyze their access requirements and evaluate alternate network solutions. In general, these requirements include providing scientists with improved access to data, computing services, and to each other for collaborative research. Given these requirements, NSI works with Marshall Space Flight Center's PSCN (Program Suppport Communications Network) engineers, the PSCN coordinators at each NASA Center, and with other agencies to implement the most cost-effective communications network using PSCN or other communications systems.

8.3.3 Relationship With NSN, SPAN And NASNET

The NSI Project Office is in the Communications Division at the Ames Research Center. As the management structure that coordinates all of OSSA's networking requirements, NSI represents both NSN (NASA Science Network) and SPAN (Space Physics Analysis Network). NSI does not manage

NSN or SPAN, but it does oversee both networks so that it can coordinate and consolidate circuit requirements, maintain the requirements and cost database, monitor circuit usage, evaluate new technologies, and provide both technical and user support services. While NASNET, like NSI and NSN, is administered at ARC, NASNET is run by the Office of Aerodynamics and Space Technology (in contrast to NSI and NSN which are a part of OSSA, as noted above).

8.4 NASA SCIENCE NETWORK - NSN

8.4.1 History

NSN was conceived in 1985 as a means of addressing science needs for a vendor-independent network. Its creation was driven by OSSA scientists who wanted a vendor-independent computer network that offered a variety of services between heterogeneous computers, databases and collaborating colleagues located worldwide. It began operating in 1987.

8.4.2 Type Of Network

NSN, whose focus is to connect universitites and science institutes, is an internet that supports NASA research communities within the United States and internationally.

8.4.3 Purpose And Services

As a supporter of NASA research communities worldwide, NSN's general purpose is to facilitate the sharing of information and resources for research and scientific goals. It provides the full range of services for exchanging messages and for sharing resources, such as: remote login, file transfer, and electronic mail. It supports, as examples, astronomy, earth science and planetary science investigators and their data sources and computational facilities.

8.4.4 Extent And Size

As indicated above, NSN is a nationwide network with worldwide connections. In connects to more than 1000 networks or subnetworks, each of which may connect many computers. In the Fall of 1988 it served about 25 backbone hosts. It connects an estimated 2500 nodes at the NASA centers.

8.4.5 Topology

The NSN topology can be depicted by showing the location and connectivity of its major and secondary nodes (See Exhibits 8-1 and 8-2). Exhibit 8-1 shows the names and connectivity of the major NSN nodes. Exhibit 8-2 shows the speeds for each of the NSN links. Most of the link speeds are 56 Kbps, but there are a few slower links at 9.6 Kbps and several faster links with speeds up to 1.544 Mbps.

Common to both NSN and SPAN is a NASA circuit backbone called the Program Support Communications Network (PSCN), managed by the Boeing Company at the Marshall Space Flight Center (MSFC). This network backbone connects five main routing centers: NASA's Johnson Space Center (JSC - Houston, TX), NASA and California Institute of Technology's Jet Propulsion Lab (JPL - Pasadena, CA), NASA's Marshall Space Flight Center (MSFC - Huntsville, AL), NASA's Goddard Space Flight Center (GSFC - Greenbelt, MD), and NASA's Ames Research Center (ARC - Moffett Field, CA). Since the primary focus for PSCN has been and will continue to be administrative traffic between NASA Centers, NSI will coordinate NSN network development to achieve the required connectivity, by making use of communications services provided by a variety of sources, only one of which is PSCN.

While a discussion of SPAN will show that several sites have both NSN and SPAN connectivity, the physical links between the NASA sites are separate. Science requirements for internet connectivity and interoperability at the same geographic locations among homogeneous and nonhomogeneous data systems have encouraged the development of new technology that enables different network communications protocols to operate on the same circuit, and NASA intends to use this new technology to permit sharing of circuits

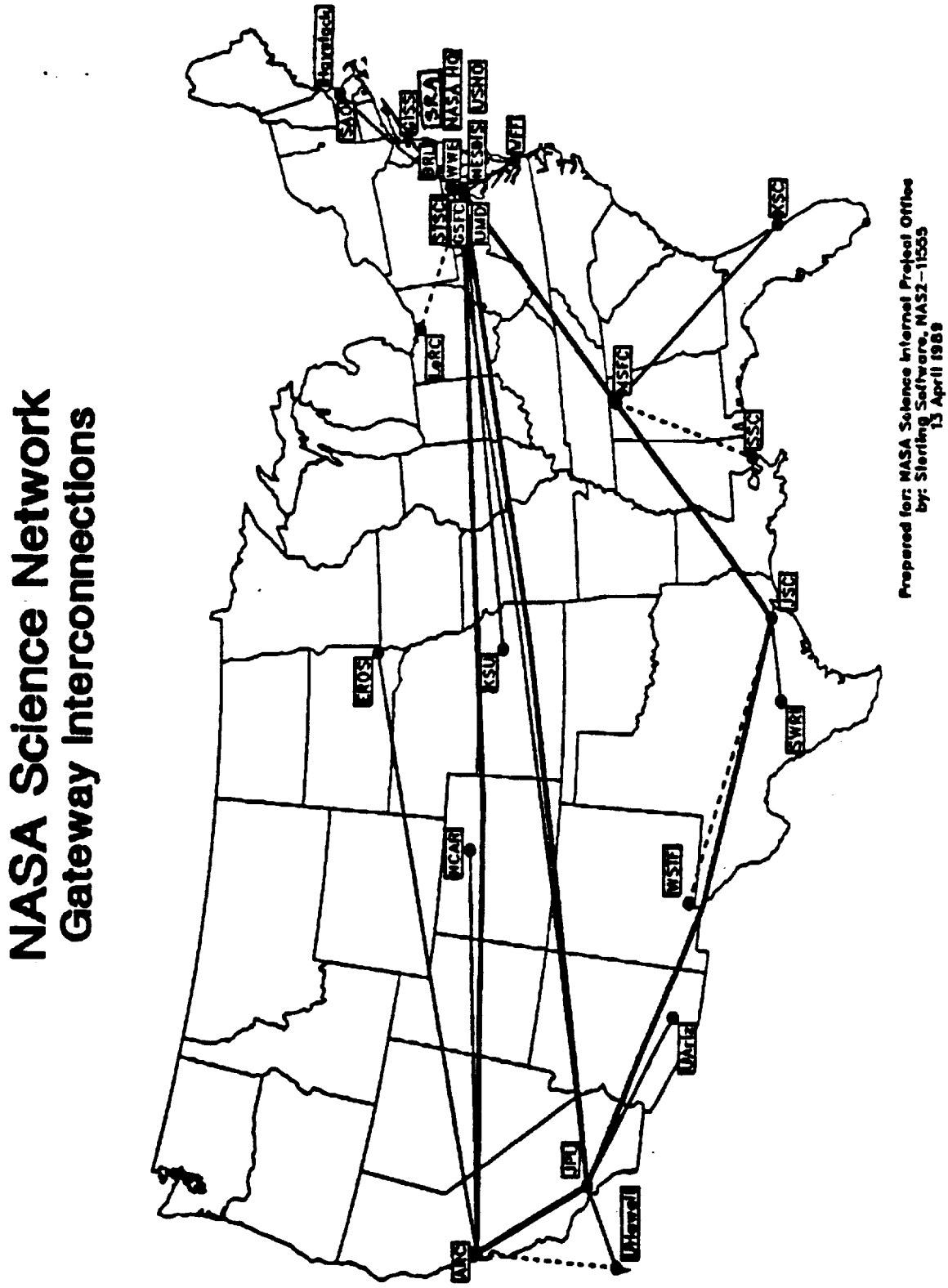


EXHIBIT 8-1. NSN Topology.

NASA Science Network

Line Speed between Sites

From	To	Line Speed	
ARC	EROS	9.6 Kbps	
ARC	GSFC	336 Kbps	
ARC	JPL	448 Kbps	
ARC	NCAR	56 Kbps	
GSFC	GISS	56 Kbps	
GSFC	KSU	9.6 Kbps	
GSFC	NESDIS	9.6 Kbps	
GSFC	SAO	56 Kbps	
GSFC	SRA	14 Kbps	
GSFC	STSCI	56 Kbps	
GSFC	UMD	1544 Kbps	
GSFC	USNO	56 Kbps	
GSFC	WFF	56 Kbps	
GSFC	WWB	56 Kbps	
JPL	JSC	168 Kbps	
JPL	STSCI	56 Kbps	
JPL	UAZ	56 Kbps	
JPL	UHAWAII	56 Kbps	
JPL	GSFC	672 Kbps	
JSC	SWRI	56 Kbps	
MSFC	KSC	56 Kbps	
MSFC	GSFC	672 Kbps	
MSFC	JSC	168 Kbps	
SAO	HAYSTACK	56 Kbps	
STSCI	BRL	56 Kbps	
UHAWAII	UWAIKATO	56 Kbps	Hawaii to New Zealand
* ARC	UHAWAII	512 Kbps	
* JSC	WSTF	56 Kbps	
* GSFC	LeRC	112 Kbps	
* GSFC	NASAHQ	56 Kbps	
* MSFC	SSC	56 Kbps	

* These are speeds of imminent sites

EXHIBIT 8-2. NSN Link Speeeds.

between NSN and SPAN.

8.4.6 Computers

The computers in NSN serve as hosts, links to other nodes, gateways or some combinations of these three uses. They range in size from small microcomputers to supercomputers. Two of the supercomputer sites to which NSN offers access are the ones at Goddard and at the National Center for Atmospheric Research.

The NASA Space and Earth Sciences Computing Center (NSECC) at Goddard and funded by the OSSA, is a supercomputer center that offers large-scale computational resources to researchers at Goddard, other NASA centers and the general university community for conducting NASA-funded research. It was formed in 1984 by combining two existing facilities at the Goddard Space Flight Center, and provides NASA-sponsored researchers with mainframe data handling capabilities to 400 megaflops on a Class VI supercomputer. Currently its IBM 3081, which performs its data handling and mainframe processing, can access 48 Mbytes of shared main memory and 24 data channels; its Cyber 205, which supports the more intensive computations, has 32 Mbytes of main memory, 10 Gbytes of disk storage and 10 input/output channels. A total of almost 400 Gbytes of online storage are available to NSESCC users through a combination of disk drives and mass storage devices.

The National Center for Atmospheric Research (NCAR), discussed as one of the supercomputer sites for NSFNET, actually also is a part of NSN. The Scientific Computing Division (SCD) of NCAR provides supercomputing resources and services that support research in the atmospheric, oceanographic and related sciences. Through the partnership between NCAR and universities, SCD provides these resources to both universities and NCAR scientists. In addition, and as noted in the discussion on Topology, NSN users have access to the supercomputers on the other major research networks.

8.4.7 Media And Link Speed

The PSCN backbone connects the major NASA routing centers by means of a variety of transmission media (e.g., fiber optics, microwave, copper and satellites). The Boeing Company which manages this backbone leases lines from various common carriers on an as needed basis and then provides them to NASA on either a dedicated or switched basis; modem to modem connections are provided. While both terrestrial and satellite links are available, NSN uses only terrestrial media on this backbone. As noted earlier, NSN link speeds are indicated in Exhibit 8-2. NSN is in the process of upgrading its backbone, so it will have links with speeds of 56Kbps, 1/4 T-1, 1/2 T-1 and a full T-1.

8.4.8 Protocols

NSN is based on the TCP/IP (Transmission Control Protocol/Internet Protocol), in contrast to SPAN which is based on the proprietary DECNET protocol suite. As noted earlier, one of the drivers in the development of NSN was the need for a vendor-independent network that could connect heterogeneous computers, databases and users. While many of these users could be connected via SPAN, many others could not because of incompatible equipment. Because of this and because NSF was standardizing on TCP/IP and NASA's and NSF's science communities largely overlap, TCP/IP was adopted for NSN. It is expected that NSN will migrate towards ISO standard protocols as they become available.

8.4.9 Administration

As noted above, NSI oversees but does not manage NSN. NSN management and operations personnel are colocated with NSI at the Ames Research Center. Its client working group is called the NSN Users Working Group for TCP/IP.

8.4.10 Funding

The NASA Office of Space Science and Applications has provided all the funding for NSN.

8.4.11 Future

Like NSFNET, the future of NSN can be described in technological and political terms. Technologically, the following changes are anticipated: upgrading of its link sppeds, migrating from TCP/IP to ISO/OSI, and continued experimentation. Politically, NSN, via NSI, likely will play a key role in the development of a NRN. Also, like NSFNET, this role will be a function of how it interfaces with other national efforts like RIB and the NRI Gigabit network research.

8.5 SPACE PHYSICS ANALYSIS NETWORK - SPAN

8.5.1 History

The Sapce Physics Analysis Network (SPAN), which grew out of a pilot project at Marshall Space Flight Center, was conceptualized in 1980 and became operational in 1981. It developed as a "grass roots" effort by scientists to exploit low-cost computer communications technology esisting in the early 1980's among vendor-specific computer systems. While it was originally oriented toward researchers in Solar, Terrestrial and Interplanetary Physics, it now continues to grow to meet the increasing needs of multi-disciplinary research.

8.5.2 Type Of Network

SPAN, while sometimes used to support specific missions, is a multimission, general purpose, operational internet that supports NASA research communities within the United States and internationally.

8.5.3 Purpose And Services

SPAN's purpose has been to address the problem of exchanging data (raw and processed), analysis software, graphic images and correspondence between researchers in geographically disparate locations. Today, SPAN supports research in numerous disciplines including: Solar-Terrestrial,

Interplanetary and Planetary Physics, Astrophysics, Atmospheric, Oceans, Climate, Earth Science and Space Lab/Space Station. Its main purpose is to provide NASA centers, researchers at Universities, industrual organizations and other government agencies involved in NASA activities a common communication system. It provides the full range of services for exchanging messages and for sharing resources, such as: remote login, file transfer, and electronic mail.

8.5.4 Extent And Size

SPAN is a worldwide network that connects computers throughout the United States and in Canada, Europe, Japan and South America. In the Fall of 1988 there were over 2000 hosts on SPAN, and about three-fourths of these were in the United States. Throughg gateways to many other networks and by being interconnected to other networks, SPAN is internetworked with over 6000 nodes in the United States, Canada, Europe, Japan and South America.

8.5.5 Topology

The SPAN topology can be depicted by showing the location and connectivity of its major and secondary nodes (See Exhibits 8-3, 8-4 and 8-5). Exhibit 8-3 shows the names and connectivity of the major SPAN nodes. Exhibit 8-4 shows the SPAN backbone configuration. The speeds of each of the major SPAN links are indicated in Exhibit 8-5. While the SPAN backbone consists of 56 Kbps links and there are a few tail links with speeds of 56 Kbps, most of the links have speeds of 9.6 Kbps.

As noted in the discussion of NSN, common to both SPAN and NSN is a NASA circuit backbone called the Program Support Communications Network (PSCN), managed by the Boeing Company at the Marshall Space Flight Center (MSFC). This PSCN network backbone connects five main routing centers: NASA's Johnson Space Center (JSC - Houston, TX), NASA and California Institute of Technology's Jet Propulsion Lab (JPL - Pasadena, CA), NASA's Marshall Space Flight Center (MSFC - Huntsville, AL), NASA's Goddard Space Flight Center (GSFC - Greenbelt, MD), and NASA's Amers Research Center (ARC - Moffett Field, CA).

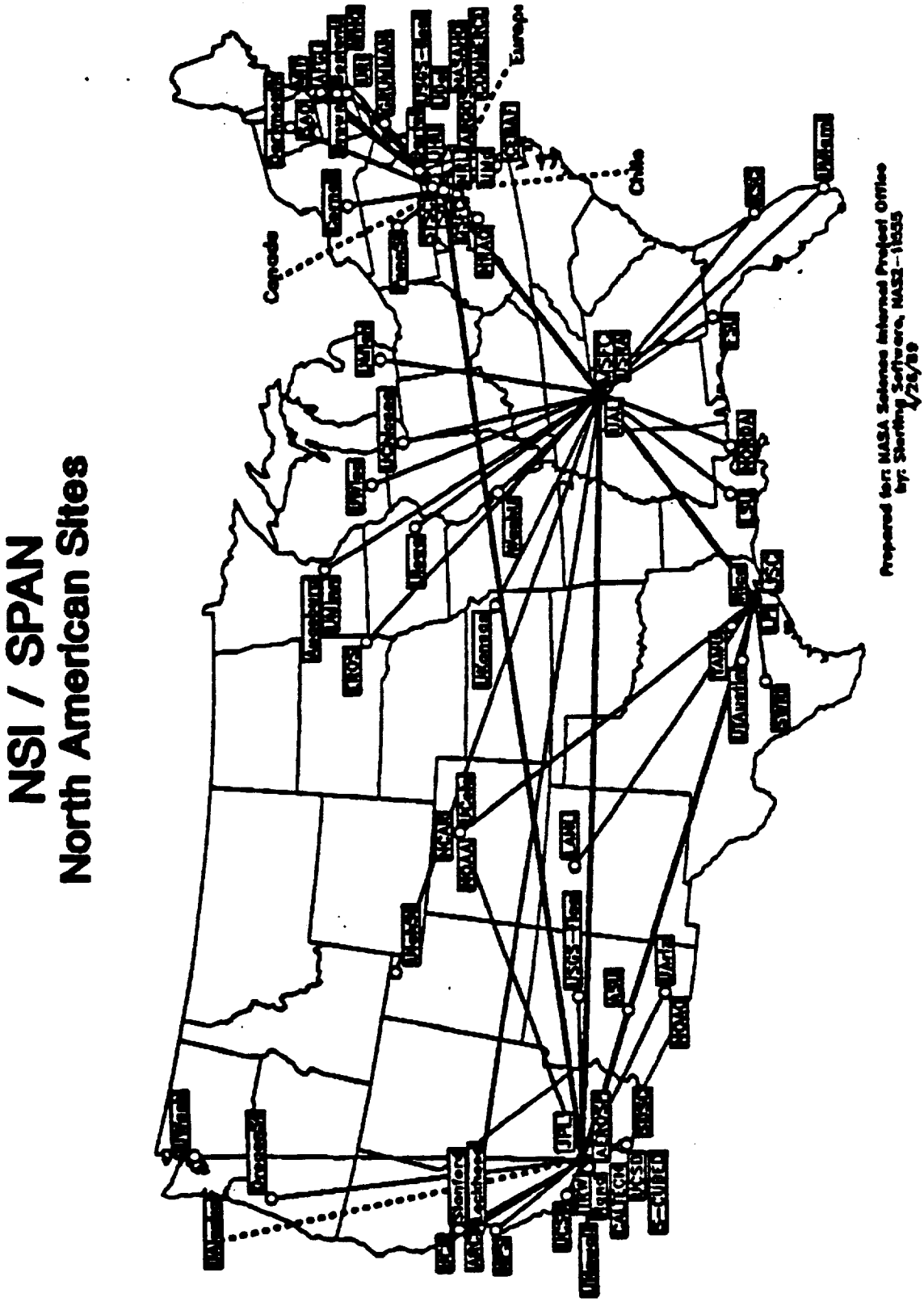


EXHIBIT 8-3. SPAN Topology.

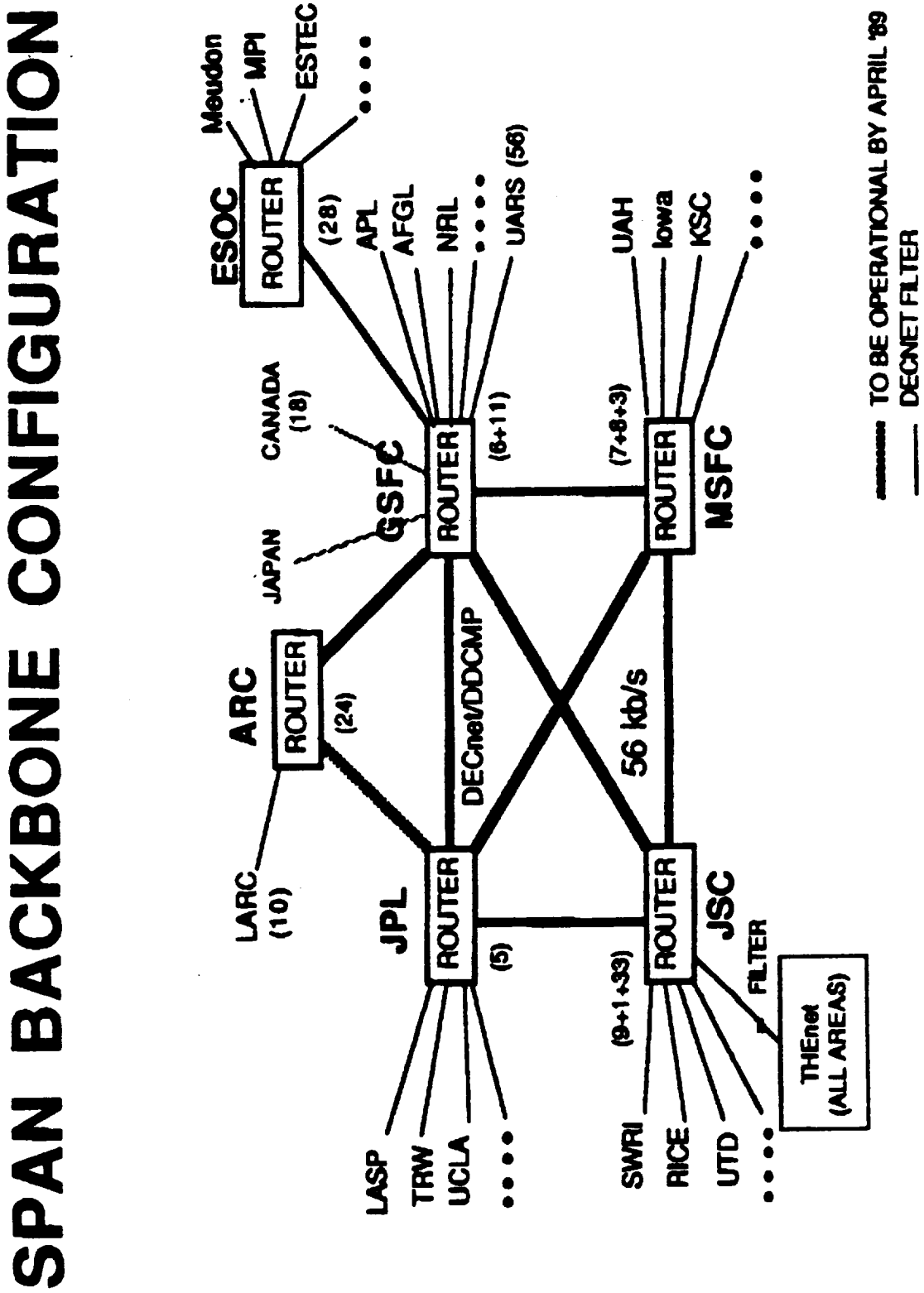


EXHIBIT 8-4. SPAN Backbone Configuration.

GSFC ROUTING CENTER

NODE-LOCATION	SPEED	TELEPHONE #	INSTITUTION
AFGL - HANSCOM AFB, MA	9.6	(617) 377	GEOPHYSICS LAB
SCIVAX - BALTIMORE, MD	9.6	(301) 338	SPACE TELESCOPE INSTITUTION
BARTOL - NEWARK, DE	9.6	(302) 451	UNIV. OF DELAWARE
POLLUX - WASH., DC	9.6	(202) 453	NASA HQ - RESTON, VA
CUSPIF - ITHACA, NY	9.6	(607) 255	CORNELL UNIV.
CFA2 - CAMBRIDGE, MA	9.6	(617) 495	SAO
NRLDR1 - WASH., DC	9.6	(202) 767	NAVAL RESEARCH LAB
BUASTA - BOSTON, MA	9.6	(617) 353	BOSTON UNIV.
T1 - HANOVER, NH	9.6	(603) 646	DARTMOUTH COLLEGE
UMDSW - COLLEGE PARK, MD	9.6	(301) 454	UNIV. OF MARYLAND
PSUNWP - UNIV. PARK, PA	9.6	(814) 863	PENN. STATE
ISDRES - RESTON, VA	9.6	(301) 648	USGS RESTON, VA
YSOLAR - NEW HAVEN, CT	9.6	(203) 432	YALE UNIV.
UNHROC - UNIV. OF NEW HAMPSHIRE	9.6	(603) 862	UNIV. OF NEW HAMPHIRE
APLSP - LAUREL, MD	9.6	(301) 953	JOHN HOPKINS
CEBAF1 - NEWPORT NEW, VA	9.6	(804) 249	CEBAF NEWPORT NEWS, VA
CMPO - CAMBRIDGE, MA	9.6	(617) 253	MIT
NODC - WASH., DC	9.6	(202) 673	NOAA/WDC
NRAO - CHARLOTTESVILLE, VA	9.6	(505) 835	NATL RADIO ASTRON SOCORRO, NM
DELOCN - LEWES, DE	9.6	(302) 645	UNIV. OF DELAWARE MARINE STUDIES
RED - WOODS HOLE, MA	9.6	(617) 548	WOODS HOLE (WHOI)
URI - NARRAGANSETT, RI	9.6	(401) 792	UNIV. OF RHODE ISLAND
MORRIS - HUNTSVILLE, AL	56	(205) 544	MSFC
JSCRT2 - HOUSTON, TX	56	(713) 483	JSC
JPLRT1 - PASADENA, CA	56	(818) 354	JPL
ECD1 - DARMSTADT, WG	19.2	49-6151-886-659	EUROPEAN SPACE OPERATIONS CTR.
RS2 - GSFC BLDG 23/RM N410	56 (ROLM)	(301) 286	GSFC
CANOT - OTTAWA, ONTARIO, CA	X.25	(613) 990	NATL RES. COUNCIL OF CANADA
KYOTO - KYOTO, JAPAN	X.25	81-75-722-0865	KYOTO UNIV.
CTIOV1 - SANTIAGO, CHILE	X.25	011-56-51-213-352	CERRO TOLOLO INTER-AMERICAN OBS.
CTIOV2 - SANTIAGO, CHILE	X.25	011-56-51-213-352	

JSC ROUTING CENTER

NODE-LOCATION	SPEED	TELEPHONE #	INSTITUTION
ESSDP1 - LOS ALAMOS, NM	9.6	(505) 667	LOS ALAMOS NATL LAB
LPI - HOUSTON, TX	250K	(713) 486	JSC
MORRIS - HUNTSVILLE, AL	56	(205) 544	MSFC
NCFTR3 - GREENBELT, MD	56	(301) 286	GSFC
JPLRT1 - PASADENA, CA	56	(818) 354	JPL
SPAN3 - AUSTIN, TX	56	(512) 471	UNIV. OF TEXAS
UCERTO - BOULDER, CO	9.6	(303) 492	UNIV. OF COLORADO
ACDURS - BOULDER, CO	9.6	(303) 497	NCAR
RICE - HOUSTON, TX	9.6	(703) 527	RICE UNIV.
CRYDEL - BOULDER, CO	9.6	(303) 497	NATL BUREAU OF STANDARDS
SWRI - SAN ANTONIO, TX	9.6	(512) 522	SW RESEARCH INST.

EXHIBIT 8-5. SPAN Link Speeds.

NODE-LOCATION	SPEED	TELEPHONE #	INSTITUTION
NCFRT3 - GREENBELT, MD	56	(301) 286	GSFC
JPLRT1 - PASADENA, CA	56	(818) 354	JPL
JSCRT1 - HOUSTON, TX	56	(713) 483	JSC
KSCRTR - KSC	9.6	(305) 867	KSC
IOWAGL - IOWA CITY, IA	9.6	(319) 335	UNIV. OF IOWA
STAR - STANFORD, CA	9.6	(415) 723	STANFORD UNIV.
PLUTO - MIAMI, FL	56	(305) 361	RSMAS
A36 - SSC, MS (NORDA)	56	(601) 688	NORDA
JSPARC - HUNTSVILLE, AL	56	(205) 895	UNIV. OF ALABAMA
USU - LOGAN, UT	9.6	(801) 750	UTAH STATE UNVI.
MADRAF - MADISON, WI	9.6	(608) 262	UNIV. OF WISCONSIN
WURST - ST. LOUIS, MO	9.6	(314) 889	WASHINGTON UNIV.
METDAT - TALLAHASSEE, FL	9.6	(904) 644	FLORIDA STATE UNIV.
KUPHSX - LAWRENCE, KS	9.6	(913) 864	UNIV. OF KANSAS
SPRLB - ANN ARBOR, MI	9.6	(313) 747	UNIV. OF MICHIGAN
LASR - CHICAGO, IL	9.6	(312) 702	UNIV. OF CHICAGO
EROSA - SIOUX FALLS, SD	9.6	(605) 594	USGS/EROS DATA CENTER
A32 - SSC, MS (NORDA BACKUP)	9.6	(601) 688	NORDA
WAVES - MINNEAPOLIS, MN	9.6	(612) 624	UNIV. OF MINNESOTA
LSU1VX - BATON ROUGE, LA	9.6	(504) 388	LOUISIANA STATE UNIV.
AUGGIE - MINNEAPOLIS, MN	9.6	(612) 330	AUGSBURG COLLEGE
LAMPS - HUNTSVILLE, AL	9.6	(205) 895	UNIV. SPACE RES. ASSOC.
MAGRPH - HUNTSVILLE, AL	9.6	(205) 544	MSFC

JPL ROUTING CENTER

NODE-LOCATION	SPEED	TELEPHONE #	INSTITUTION
NCFRT1 - GREENBELT, MD	56	(301) 286	GSFC
RT4 - ARC	9.6	(414) 694	ARC
UCBRTO - BOULDER, CO	56	(303) 497	UNIV. OF COLORADO
ROMEO - PASADENA, CA	9.6	(818) 354	CALTECH CAMPUS COMPUTING ORG.
JSCRT2 - HOUSTON, TX	56	(713) 483	JSC
PSIKEY - TUCSON, AZ	9.6	(602) 881	UNIV. OF ARIZONA
LOONEY - TUCSON, AZ	9.6	(602) 621	UNIV. OF ARIZONA
HYRAX - SANTA MONICA	9.6	(213) 393	THE RAND CORPORATION
TRWATD - REDONDO BEACH	56	(213) 535	TRW, INC.
DRACO - TUCSON, AZ	9.6	(602) 325	NRAO
HAWAII - HONOLULU, HI	9.6	(808) 948	UNIV. OF HAWAII
UCLASO - LOS ANGELES, CA	56	(213) 825	UCLA
BRNPSG - PROVIDENCE, RI	9.6	(401) 863	BROWN UNIV.
ASUIPF - TEMPE, AZ	56	(602) 965	ARIZONA STATE UNIV.
ASTROG - FLAGSTAFF, AZ	9.6	(602) 527	U.S. GEOLOGICAL SURVEY
UCBSP - BERKELEY, CA	9.6	(415) 642	UNIV. CALF. @ BERKELEY
FRED - FAIRBANKS, AL	9.6	(907) 474	UNIV. OF ALASKA
MOTHRA - SEATTLE, WA	9.6	(206) 543	UNIV. OF WASHINGTON
DIRAC2 - EL SEGUNDO, CA	9.6	(213) [illegible]	THE AEROSPACE CORPORATION
LOCKHD - PALO ALTO CA	9.6	(415) 424	LOCKHEED PALO ALTO RES. LAB

EXHIBIT 8-5. SPAN Link Speeds.

(Continued)

OSUVAX CORVALLIS, OR	9.6	(408)	646	OREGON STATE UNIV.
MORRIS - HUNTSVILLE, AL	56	(205)	544	MSFC
NPSLAB - MONTEREY, CA	9.6	(408)	646	NAVAL POST GRAD. SCH.
GUAM - PASADENA, CA	19.2	(818)	354	JPL
JPLRT2 - PASADENA, CA	56	(818)	354	JPL
ROTO - HUNTSVILLE, AL	56	(205)	895	MSFC
JPLRT9 - PASADENA, CA	56	(818)	354	JPL
PANCHO - SAN DIEGO, CA	56	(619)	534	JPL
ISSAC - PASADENA, CA	19.2	(818)	354	JPL
GODEL - SDSC/SCRIPPS	56	(619)	534	SDSC

EXHIBIT 8-5. SPAN Link Speeds.

(Continued)

SPAN has connections between all five routing centers. The connections between JSC, JPL, MSFC, and GSFC form a complete mesh network. ARC has connections to JPL and GSFC. Tail circuits connect SPAN member institutions to the closest routing center, in most cases with leased lines.

Also, as noted in the discussion of NSN, there are several sites that have both SPAN and NSN connectivity, but the physical links between the NASA sites are separate and NASA intends to use new technology to permit sharing of circuits.

8.5.6 Computers

The computers in SPAN serve as hosts, links to other nodes, gateways or some combinations of these three uses. They range in size from small microcomputers to supercomputers. While SPAN was not created to access supercomputers, supercomputers like those at the NASA Space and Earth Science Computing Center (NSECC) and the National Center for Atmospheric Research (NCAR) are becoming more assessible through it. These two centers were discussed in the NSN presentation.

8.5.7 Media And Link Speed

As noted in the NSN discussion, the PSCN backbone connects the major NASA routing centers by means of a variety of transmission media (e.g., fiber optics, microwave, copper and satellites). The Boeing Company which manages this backbone leases lines from various common carriers and provides them to NASA on either a dedicated or switched basis; modem to modem connections are provided. The actual SPAN backbone has link speeds of 56 Kbps. Most tails are 9.6 Kbps with a few at 56 Kbps.

8.5.8 Protocols

SPAN is based on the proprietary DECNET protocol suite. It is expected that SPAN will migrate towards ISO standard protocols as they become available.

8.5.9 Administration

As with NSN, SPAN is overseen but is not managed by NSI. SPAN has its own autonomous network management structure. It is managed by the National Space Science Data Center at the Goddard Space Flight Center. Direct administration is done by project managers, network managers and routing center managers. Guidance for the network is provided by the users through the Data Systems Users Workers Group (DSUWG---Informal group of users of DECNET) for DECNET.

8.5.10 Funding

NASA sponsors SPAN. Various offices of NASA provide funds for the SPAN backbone and tail circuits in the United States. Other participating organizations pay for their own host computers and network interfaces. Much of the original hardware, such as the routing center computers, came from NASA.

8.5.11 Future

Like NSN, the future of SPAN can be described in technological and political terms. Technologically, the following changes are anticipated: upgrading of its link speeds, sharing circuits with NSN, merging study groups with NSN, and migrating from DECNET to ISO/OSI. Politically, SPAN, via NSI, likely will play a key role in the development of a NRN, and this role will be a function of how it interfaces with other national efforts like RIB and the NRI Gigabit network research.

8.6 NUMERICAL AERODYNAMICS SIMULATION NETWORK - NASNET

8.6.1 History

The concept of a Numerical Aerodynamics Simulation Network (NASNET) began in the Spring of 1984. A prototype of the network became operational in the Summer of 1985, and experiments and tests were

conducted during 1985 and 1986. The prototype became the basis for the design of the NASNET system which became fully funtional in 1987. Since 1987, additonal sites have been added to the network.

8.6.2 Type Of Network

NASNET is an internet (Uses different network layer protocols, but same internet layer protocols).

8.6.3 Purpose And Services

NASNET was designed to provide a high-speed link between the remote workstations of individuals involved in the Numerical Aerodynamic Simulation Program (NASP) and the computers at NASP, ARC. NASNET provides the full range of services for exchanging messages and for sharing resosurces, including E-mail, remote login and file transfer. Its users are from academia, government and industry.

8.6.4 Extent And Size

NASNET is a nationwide network with some 26 sites interconnected.

8.6.5 Topology

The NASNET topology can be depicted by showing the location and connectivity of its 26 sites. Exhibit 8-6 show the NASNET topology and the speeds of the NASNET links. As suggested by Exhibit 8-6, the original topology was a star with each site connected to NAS, ARC, but this topology is now being modified somewhat, with a few sites being indirectly connected to NASP, ARC.

8.6.6 Computers

The computers in NASNET serve as hosts, links to other nodes, gateways or some combination of these three uses. They range in size from small microcomputers to supercomputers. A major purpose of NASNET is to provide fast interactive access to several supercomputers including a Cray

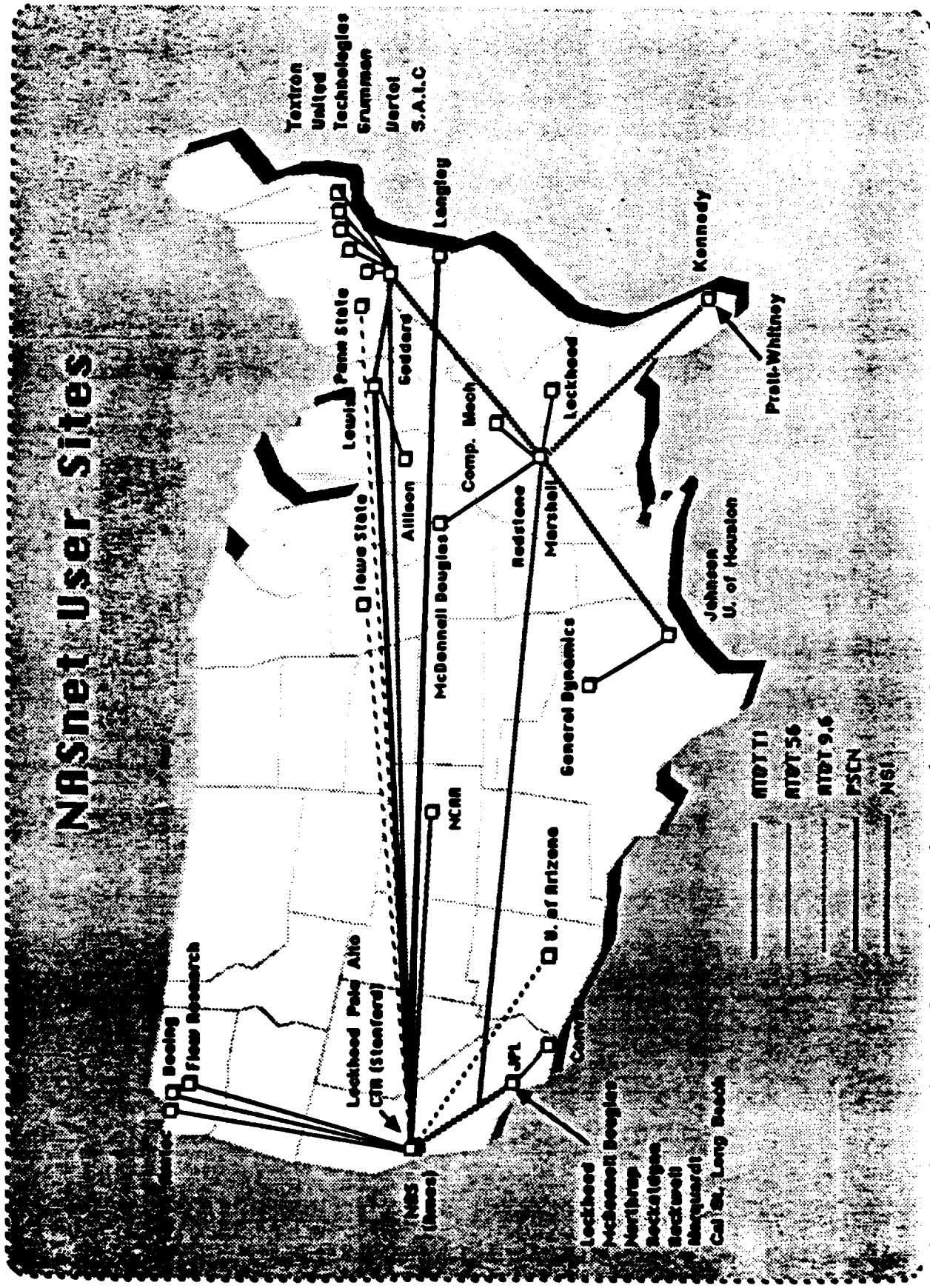


EXHIBIT 8-6. NASNET Topology & Link Speeds.

Y-MP, two Cray 2s and an ETA-10.

8.6.7 Media And Link Speeds

While both satellite and terrestrial links are used, most of the links are terrestrial links. As noted in Exhibit 8-6, link speeds vary from 9.6 Kbps to 1.544 Mbps. Each remote site on NASNET is equipped with DEC and Vitalink equipment provided by the NAS program. The Vitalink equipment is attached to an Ethernet at the user site and any computer attached to the user-site Ethernet can potentially communicate with all computers at NASP, ARC, including the supercomputer.

8.6.8 Protocols

The TCP/IP protocol suite is used.

8.6.9 Administration

While the ARC, where the supercomputers and network operations center for the network are located, administers NASNET, circuit management occurs at the Marshall Space Flight Center Program Support Communications Network. A NAS User Interface Group (UIG) provides a forum for organizational representatives to give feedback and new ideas for establishing the future direction of NAS.

8.6.10 Funding

The Office of Aeronautics and Space Technology of NASA funds NASNET. However, there are some joint agreements with other organizations (e.g., universities or businesses).

8.6.11 Future

Technologically, the following changes are anticipated: increasing link speeds and migrating to ISO/OSI. Politically, NASNET will participate in the development of a national research network by being involved in national interagency efforts like the RIB.

8.7. NASCOM NETWORK

The term "NASCOM" is an acronym for NASA Communications and refers to a collection of personnel, network facilities and methods organized by NASA. The term "NASCOM Network" refers to the circuits and facilities operated by NASA to support all NASA projects. Each year the NASCOM network is thoroughly described in the NASCOM System Development Plan and in the NASCOM Long-Term Plan prepared by the NASA Communications Division at Goddard Space Flight Center (GSFC). This discussion of the NASCOM Network is based on these reports and on interviews with NASA personnel.

8.7.1 History

The origin of the NASCOM Network can be traced back to the late 1950s when the United States placed into orbit, tracked and acquired data from the first U.S. artificial earth satellite. The Minitrack Network was established by the Naval Research Laboratory in Washington, D.C. for this purpose and this network was the predecessor of the Satellite Tracking and Data Acquisition Network (STADAN). The communication functions related to the Minitrack Network became designated as SPACECOMM and became the responsibility of GSFC. Also about this time (i.e., 1959), communications developed and used by the Deep Space Network (DSN) of the Jet Propulsion Laboratory (JPL) was brought into the SPACECOMM system to time-share circuits. In 1960 the Project Mercury Network of radar tracking, telemetry and command stations was established at Langley Research Center (LaRC). After implementation, this network was transferred to GSFC management and it evolved to the Manned Space Flight Network (MSFN).

Thus, after the inception of NASA in 1958, three primary tracking and data acquisition networks (i.e., STADAN, DSN, and MSFN) developed as separate systems for earth orbiting science, planetary and manned space missions. NASA, while understanding the unique and varied requirements of its missions, recognized the need for unified communications management control and, therefore, in 1964, integrated all NASA operational longline communications operated by NASA under NASCOM. NASCOM became part of the National Communications System (NCS). The STADAN and MSFN Networks were unified under a single management organization at GSFC in 1971 under the

Spaceflight Tracking and Data Network (STDN). The DSN continued as a separately (JPL) managed network, but its long-haul communications now are obtained from the common user NASCOM system. The NASA Communications Division at GSFC now is chartered to provide operational ground communications support service to all NASA missions.

8.7.2 Type Of Network

The NASCOM Network refers collectively to a domestic and/or overseas interconnection of circuits, switching, and terminal facilities established and operated by NASA to provide operational support for all NASA projects. The major requirements of the NASCOM Network are: low speed data, high speed data, voice, and video.

8.7.3 Purposes And Services

NASCOM is the operational network of the NASA Telecommunications System, while the Program Support Communications Network (PSCN) at MSFC is the administrative network. The primary purpose of the NASCOM Network is to interconnect domestic and overseas tracking and telemetry stations and sites, all launch areas, the mission and project/payload operations control centers, science data capture facilities, and network control centers.

More specifically, the NASCOM Network's functions are related to providing the circuits and facilities for:

1. Transporting spacecraft telemetered data, air-to-ground voice and video for command, control, tracking, orbit determination and data acquisition.
2. Spacecraft prelaunch compatibility and simulated mission readiness testing.
3. Scheduling, maintenance, control and coordination for all Office of Space Operations (OSO) space and ground tracking network elements.
4. Monitoring and controling an instrument, experiment or payload.

The NASCOM Network's functions do not include:

1. Administrative network functions or internetworking with other established value-added networks like TELENET or ARPANET.
2. The distribution of nonoperational, nonreal time science data products after they have been processed by the data capture facilities.
3. The operational telecommunictions between mission spacecraft and the ground.

The NASCOM Network capabilities include:

1. Providing all NASA mission control centers with real-time communications access to spacecraft via launch sites and remote T&DA stations.
2. Providing communication support to spacecraft development contractor's test facilities.
3. Providing for the transport and delivery of spacecraft telemetry housekeeping and experiment data to control centers and data processing centers.
4. Providing the science data transport to support data capture functions.
5. Providing the data transport of experiment and science data to science support centers and experimenters.
6. Providing data transport support for testing aircraft.
7. Provide the communications link for agencies or organizations that support the NASA spaceflight program.

The NASCOM Network services include:

1. Voice services: analog voice; digital voice.
2. Data services: low speed (up to 1200 baud), median speed (up to 9.6 Kbps), high speed (up to 50 Mbps).
3. Specialized data services: Baseline Data System (BDS-10 bps up to 2 Mbps) for the Space Network (SN), High Data Rate System (HDRS-above 2 Mbps) for SN, and the Data Distribution and Command System.
4. Video services: Video transponder service, video teleconferencing (1.544 Mbps on NASCOM/TDMA Network), occasional use TV, and closed circuit TV.

5. Integrated communications services: secure communications systems, NASCOM/TDMA Network, other intergrated services.

8.7.4 Extent And Size

The NASCOM Network is a global network which interconnects various communications systems by a diversity of domestic and overseas circuit facilities that are operationally controlled from the GSFC Primary Nascom Control Center.

8.7.5 Topology

The network's basic configuration is shown in Exhibit 8-7, which indicates that the network is a star network arrangement showing the switching and routing elements, the access relationships, and the variety of user elements.

The NASCOM Network consists of the array of circuit facilities controlled by the GSFC primary NASCOM control and switching center to interconnect the various switching centers and user terminals with the supporting NASCOM system. The systems that do not interconnect with the GSFC primary NASCOM control and switching center also are considered in the network when NASCOM is responsible for the system. The NASCOM Network includes the following elements:

1. Circuit facilities: About 875 leased communications satellite and terrestrial communications circuits with over 2.5 million circuit miles of diversely routed voice, low-speed data, medium speed data, and high-speed data communications channels.
2. GSFC Primary NASCOM Control and Switching Center: Provides centralized technical control and switching capabilities under direct NASCOM control.
3. Intermediate Switching Centers: Provide flexible circuit sharing on overseas channels.
4. User Terminals At: Remote tracking and data acquisition stations (STDN & DSN); project or mission operations control centers; computation and data processing centers; network scheduling and operations control centers; launch operations centers; other remote terminal.

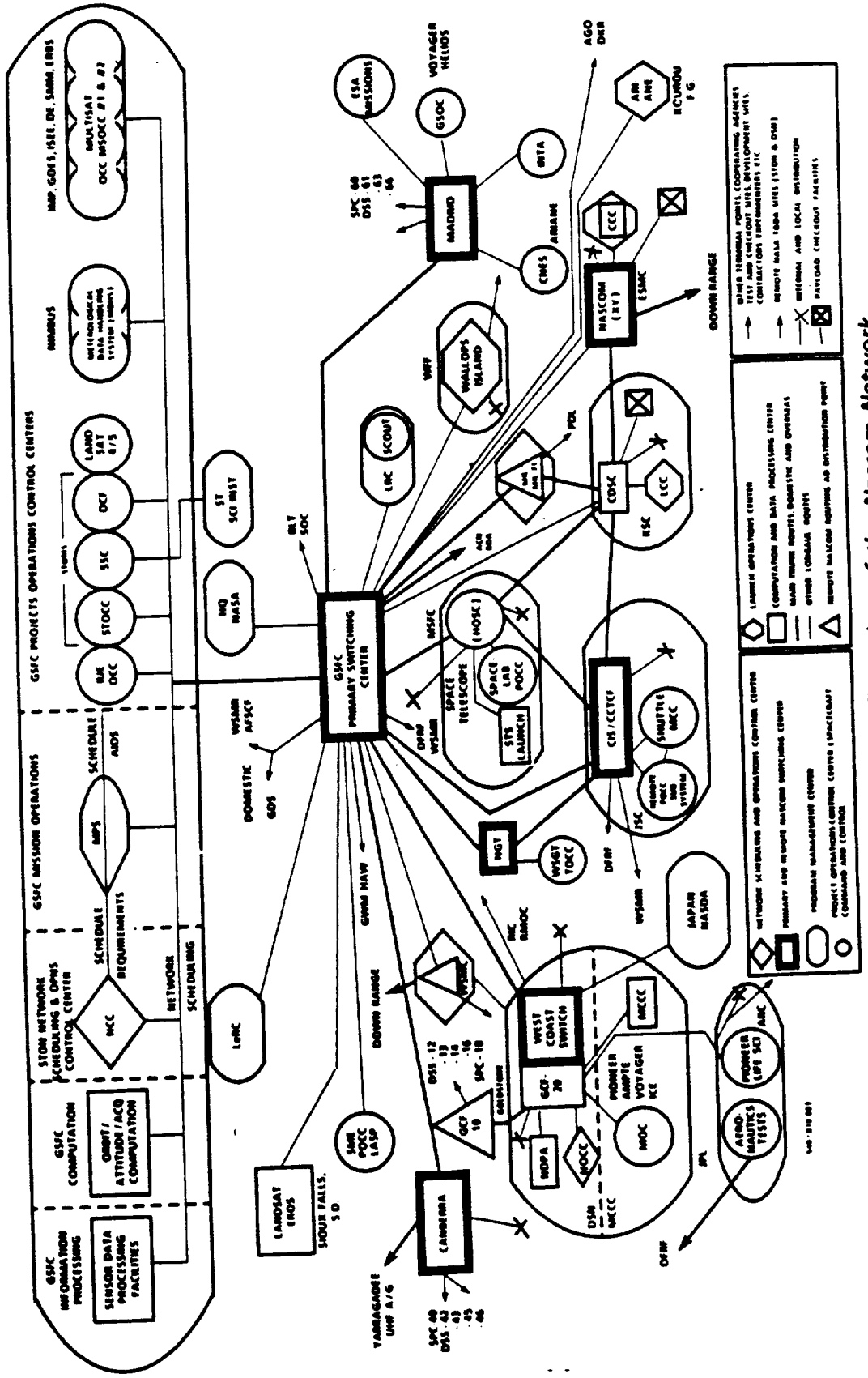


Figure 3-1. Basic Configuration of the Nascom Network

EXHIBIT 8-7. NASCOM Network Configuration.

5. NASCOM Ground Communications Support (GCS) Systems: Provides support for user terminals.

The overview network configuration of circuits in the high speed data system is shown in Exhibit 8-8. The high speed data services range from 56 Kbps up to 50 Mbps. The functional configuration and the system configuration of the High Data Rate System (HDRS) are shown, respectively, in Exhibits 8-9 and 8-10. The system configuration of the Common Carrier Domestic Satellite Transponder Service (CCDTS-main system element of HDRS) is shown in Exhibit 8-11. The HDRS provides a 50 Mbps data transport service with up to 48 Mbps composite data throughput capability. The NASCOM TDMA Network system configuration and node location are presented, respectively in Exhibits 8-12 and 8-13. The satellite network provides for the integration of a wide range of voice, data and video services; interconnects 14 NASA sites; and provides data rates up to 15 Mbps.

8.7.6 Computers

Computers used in the NASCOM Network range from small personal computers to very large supercomputers.

8.7.7 Media And Link Speeds

As indicated above, the NASCOM Network uses both satellite and terrestrial media, and the link speeds vary from a very slow speed of 10 bps to a relatively high speed of 50 Mbps.

8.7.8 Protocols

The NASCOM Network uses the NASCOM 4800 Bit Block Protocol developed specifically for the network by the NASA Communiations Division. The network also uses, on a very limited bases, the X.25 Protocol.

8.7.9 Administration

The Associate Administrator for Space Operations at NASA Headquarters is charged with overall management responsiblity for all NASA operational

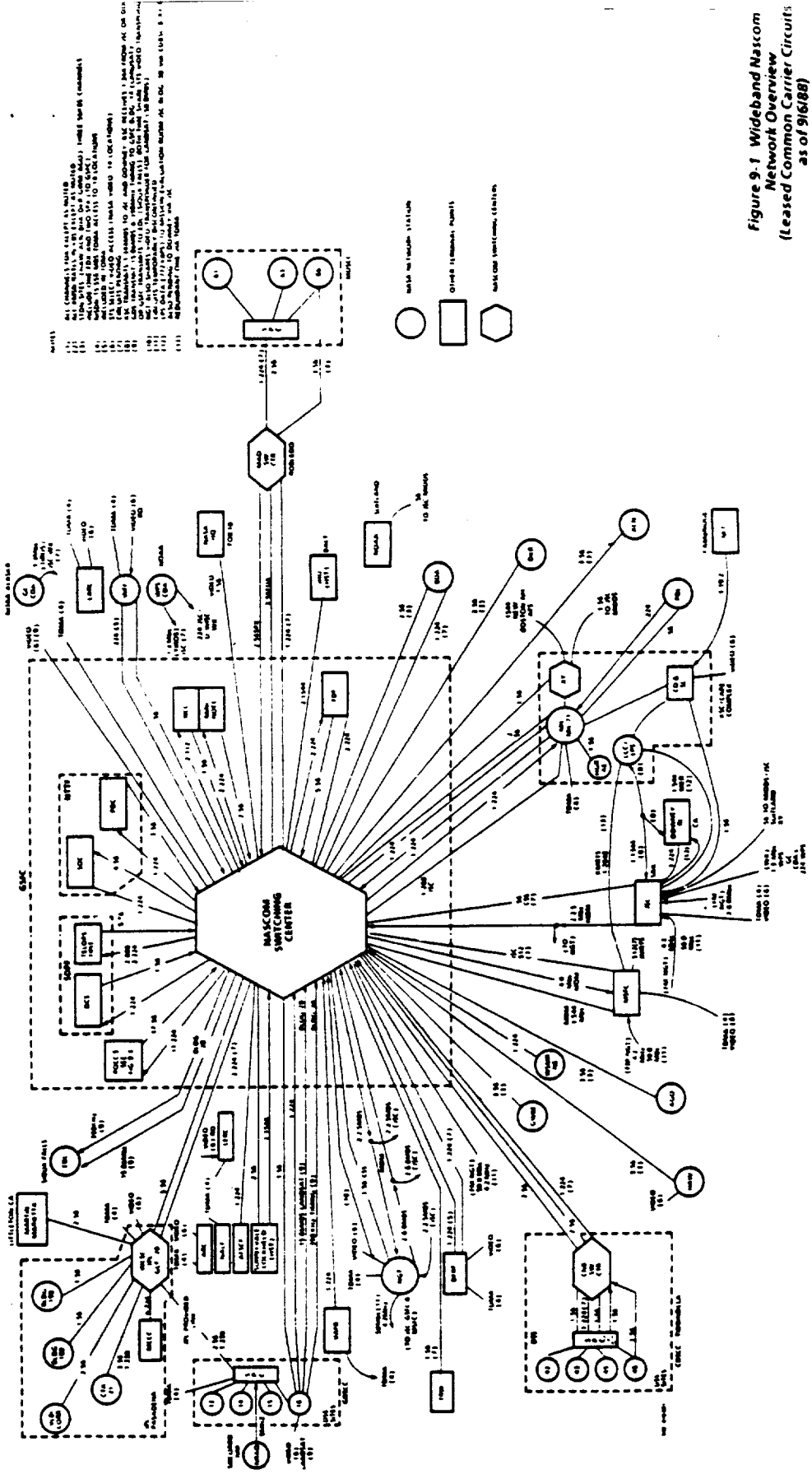


EXHIBIT 8-8. Wideband Data Configuration.

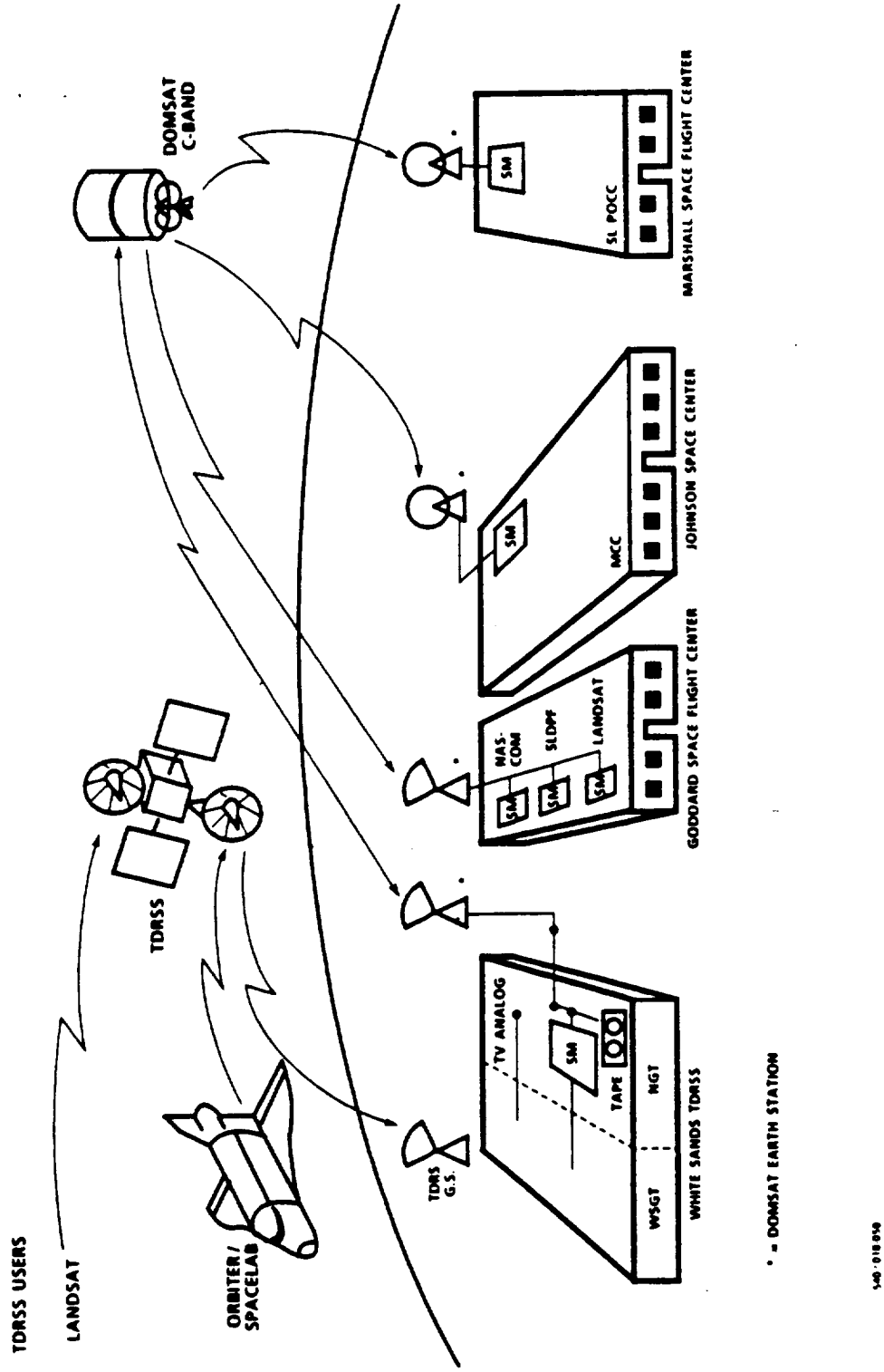


Figure 12-1. Functional Configuration of HDRS as a Nascom Data Transport System

EXHIBIT 8-9. HDRS Functional Configuration.

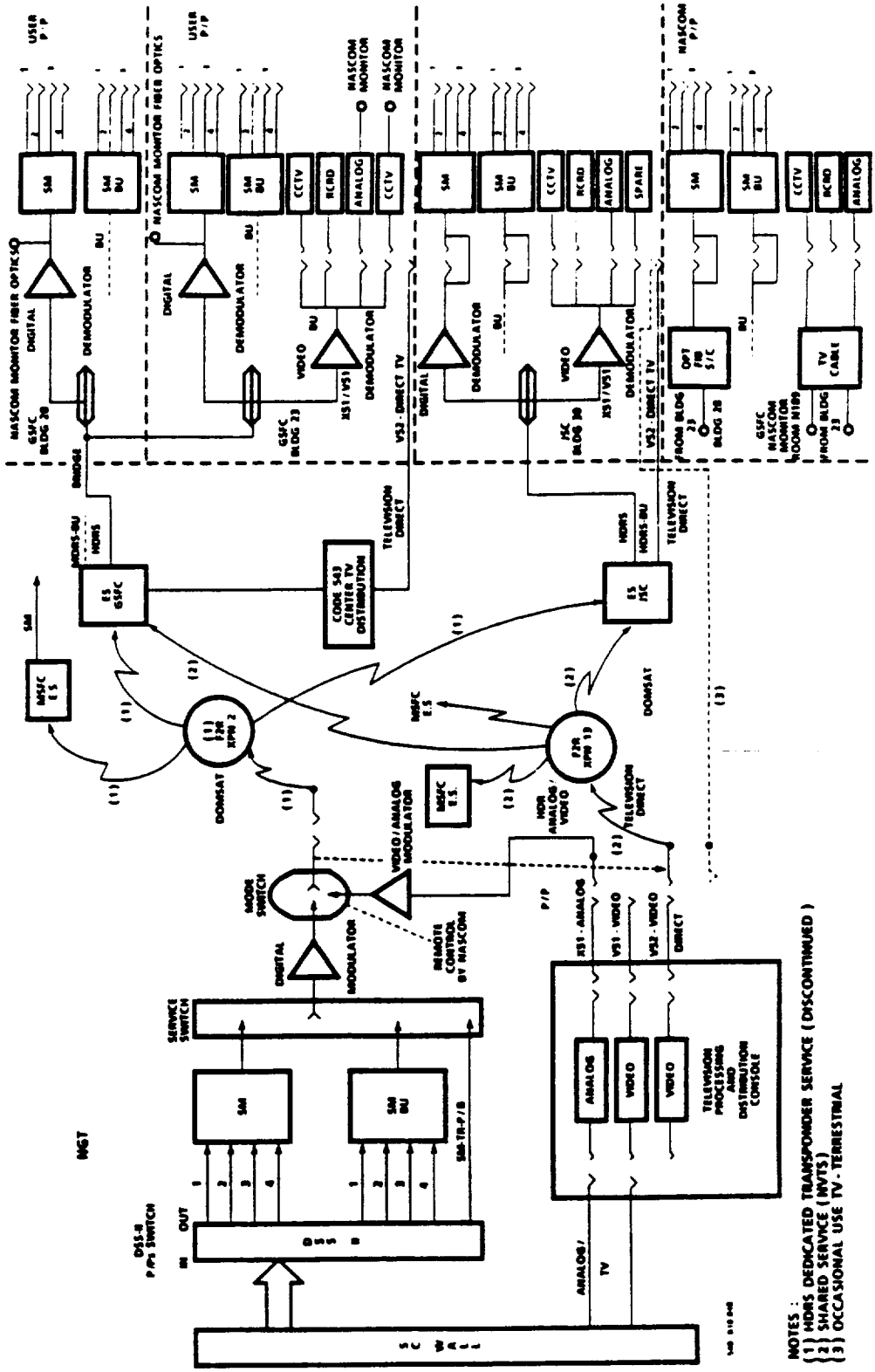
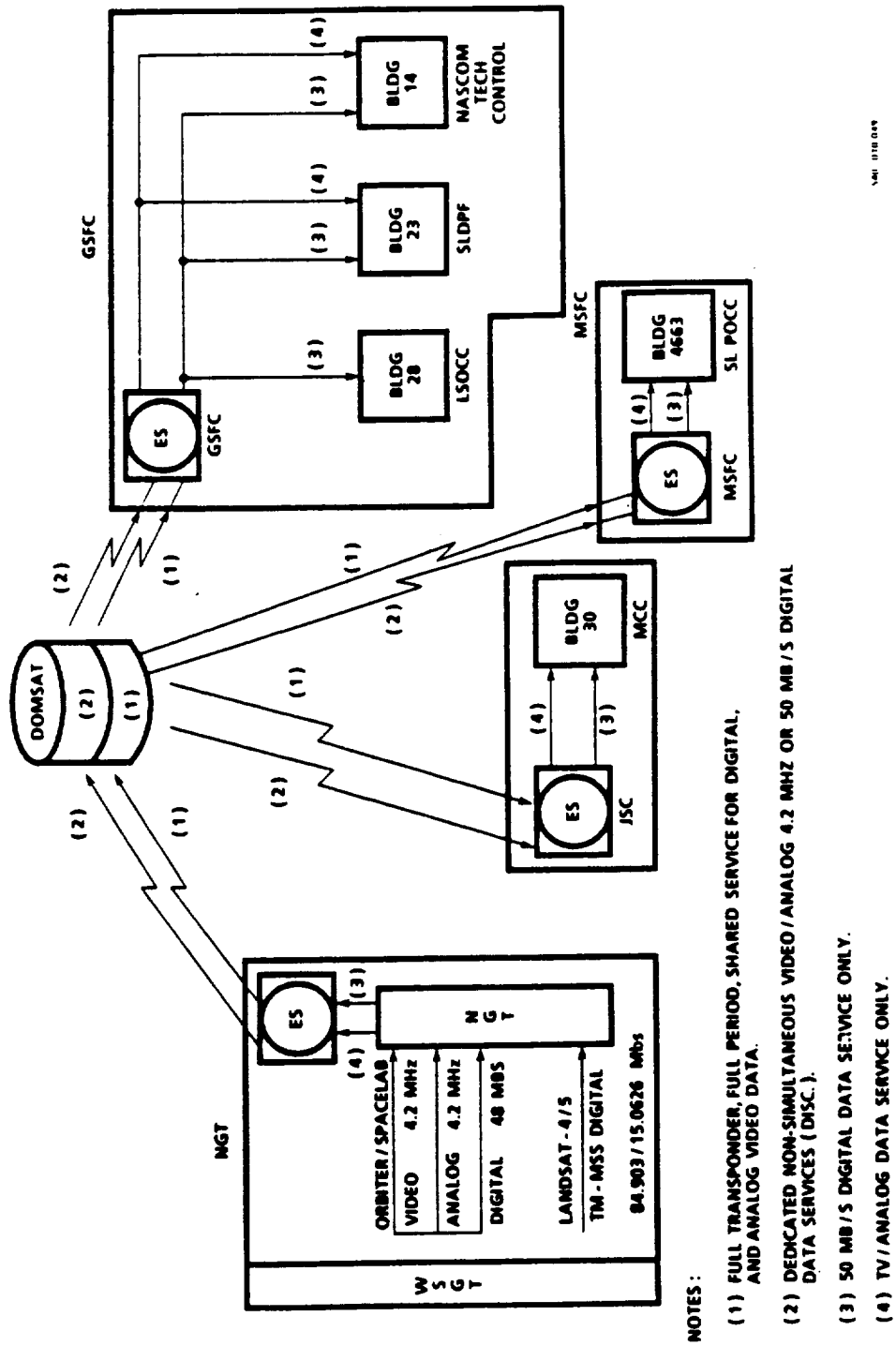


EXHIBIT 8-10. HDRS System Configuration.



NOTES:

(1) FULL TRANSPONDER, FULL PERIOD, SHARED SERVICE FOR DIGITAL, AND ANALOG VIDEO DATA.

(2) DEDICATED NON-SIMULTANEOUS VIDEO/ANALOG 4.2 MHZ OR 50 MB/S DIGITAL DATA SERVICES (DISC.).

(3) 50 MB/S DIGITAL DATA SERVICE ONLY.

(4) TV/ANALOG DATA SERVICE ONLY.

EXHIBIT 8-11. CCDTS System Configuration.

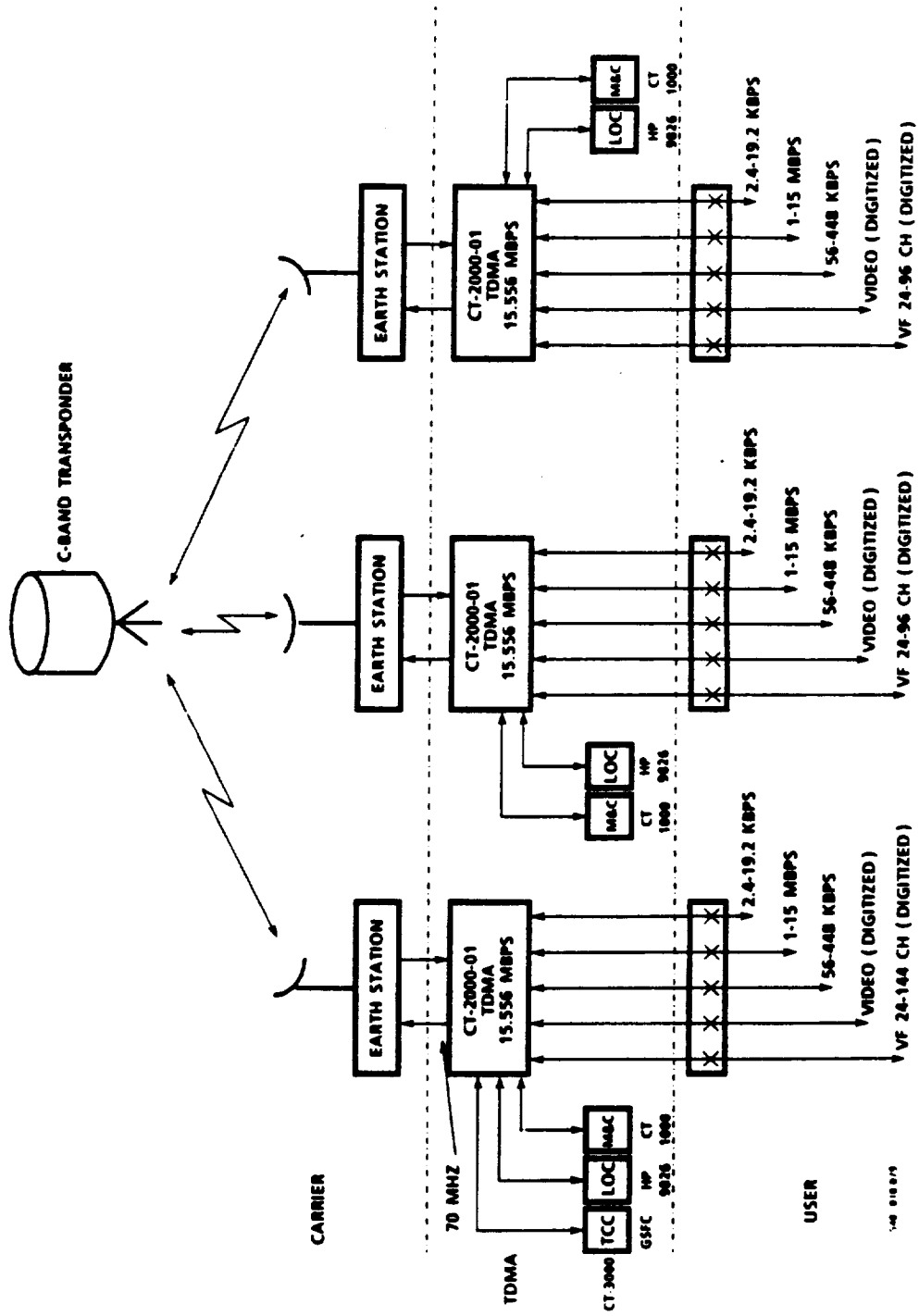
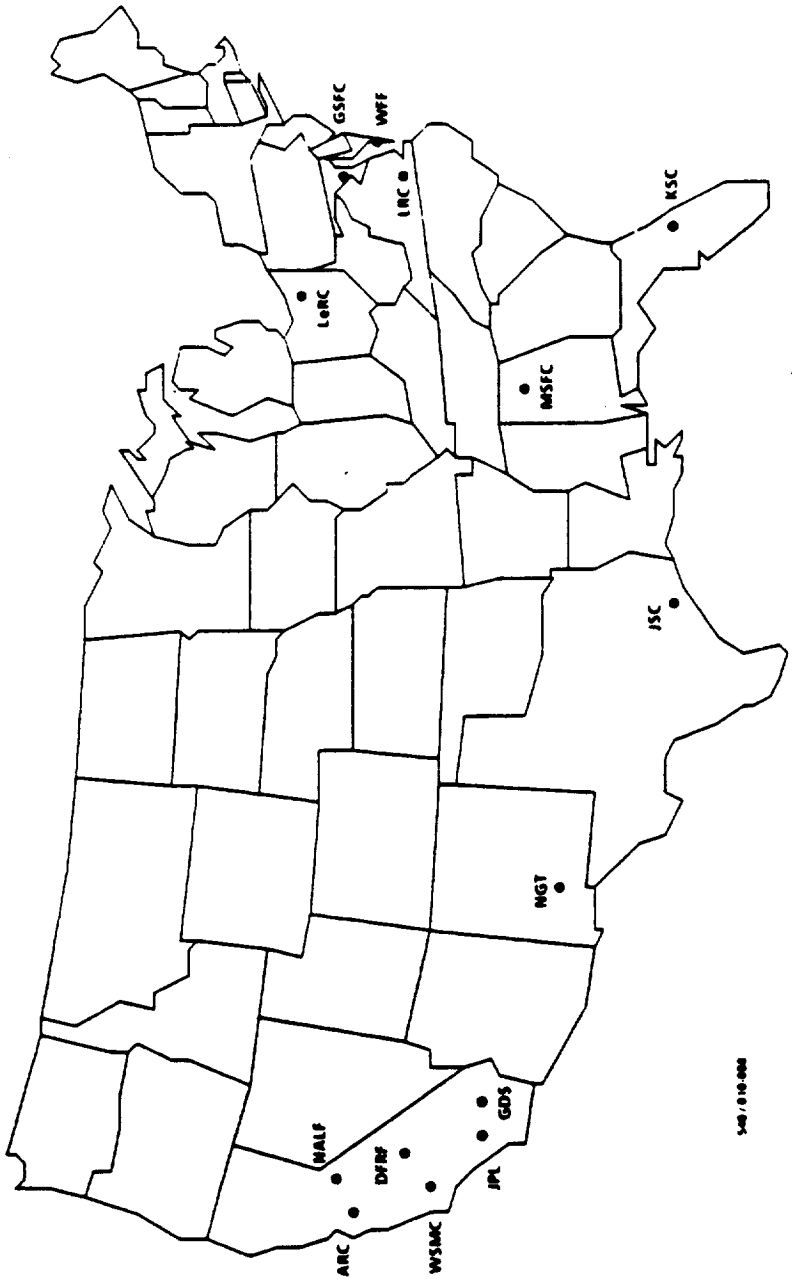


EXHIBIT 8-12. TDMA System Configuration.



- NASCOM / TDMA LOCATIONS

1. GODDARD SPACE FLIGHT CENTER (GSFC)
2. JOHNSON SPACE CENTER (JSC)
3. AMES RESEARCH CENTER (ARC)
4. WESTERN SPACE AND MISSLE CENTER (WSMC)
5. KENNEDY SPACE CENTER (KSC)
6. JET PROPULSION LABS (JPL)
7. DRYDEN FLIGHT RESEARCH FACILITY (DFRF)
8. MARSHALL SPACE FLIGHT CENTER (MSFC)
9. LEWIS RESEARCH CENTER (LeRC)
10. NASA GROUND TERMINAL (NGT)
11. GOLDSTONE (GDS)
12. LANGLEY RESEARCH CENTER (LRC)
13. WALLOPS FLIGHT FACILITY (WFF)
14. NAVAL AUXILLARY LANDING FIELD (NALF)

EXHIBIT 8-13. TDMA Node Location.

long-line communications. The GSFC has been assigned the overall responsibility for the technical management of the NASCOM Network. At GSFC this responsibility is assigned to the NASA Communications Division. In some instances, management responsibilities have been delegated by GSFC to other NASA field installations.

8.7.10 Funding

The NASCOM Network is funded by the NASA Communications Division of GSFC.

8.7.11 Future

The following are examples of recent upgrades made in the NASCOM Network:

1. A 50 Mbps, one-way broadcast satellite link for Landsat and Spacelab support.
2. A 14 node TDMA-based system utilizing a leased transponder and leased earth station DOMSAT network (as noted above).
3. A multi-accessed (from 12 nodes), time-shared full period, full transponder video broadcast (to 16 nodes) service.
4. Overseas wideband leased digital data services up to 224 Kbps.
5. A packet switching system using X.25 protocols.

The future of the NASCOM Network will be affected by both internal and external drivers. External drivers include: space station requirements, higher data rate needs, technological changes, and budgets. Internal drivers include: management of interagency coordination, R&D, and personnel. A variety of network upgrades and network augmentations are being planned in anticipation of future requirements.

SECTION 9

DEPARTMENT OF ENERGY RESEARCH NETWORKS

9.1 OVERVIEW

The Department of Energy's research networks include the Energy Science Network (ESNET), the Magnetic Fusion Energy Network (MFENET), the High Energy Physics Network (HEPNET), LEP3NET, and OPMODEL Network.

9.2 ENERGY SCIENCE NETWORK - ESNET

9.2.1 History

In 1985, the Scientific Computing Staff (SCS) of the Office of Energy Research (ER), Department of Energy (DOE), surveyed the status of and the requirements for computer networking throughout all ER programs. The SCS concluded that there was an urgent need for improved computer networking to facilitate collaboration among all ER programs and to provide improved access to unique ER and other supercomputer facilities. Based on these findings, a general purpose computer network concept for ER across program support emerged for consideration in early 1986. The concept was reviewed by an interagency working group and was determined to be a major step toward an interagency internet capability. This ESNET concept, approved in late 1986, included the formation of the ESNET Steering Committee, the use of a new MFENET design and facilities as the basis for ESNET facilities, an evolutionary operational model, and a phased approach to addressing long term computer network requirements.

A comprehensive ESNET plan was approved and published in mid-1987. Subsequent changes to this plan have been made based on the results of initial implementation and on the needs of the other ER networks. The most significant change is that it now appears that ESNET will provide backbone services to the other ER networks but will replace only MFENET over time, and that this ESNET backbone may eventually become part of the

National Research Network backbone.

9.2.2 Type Of Network

ESNET currently is being installed by the DOE and will be the network backbone for all DOE Energy Research programs. As ESNET is developing, users from the other DOE Energy Research networks are beginning to use the ESNET backbone. Since ESNET supports a number of high level protocols used on these other networks, ESNET is a metanetwork. The ESNET architectural model described in the 1987 plan is presented in Exhibit 9-1.

9.2.3 Purpose And Services

As noted above, the ESNET initially was intended to bring together (i.e., make into a single coherent effort) the various data communications efforts of the different research programs funded by the OER of DOE. The major purpose was to improve the networking capabilities of these programs, and at the same time, to reduce costs associated with redundant data communications projects. This major purpose still exists, as it will provide increased connectivity and bandwidth in support of all the Energy Research Programs. However, ESNET will replace only MFENET and will provide, for the other ER networks, services and management at the backbone level only.

The DOE Energy Research programs include: High Energy Physics, Nuclear Physics, Materials Sciences, Chemical Sciences, Carbon Dioxide Research, Engineering and Geosciences, Heavy Ion Fusion, Applied Plasma Physics, and Health and Environmental Research. The ER headquarters program organizations are: Applied Mathematical Sciences, Basic Energy Sciences (BES), Fusion Energy (FE), High Energy and Nuclear Physics (HENP), and Health & Environmental Research (HER). These programs need the most sophisticated computer research network capabilities (e.g. distributed computing and network-wide file management systems) in addition to the more traditional capabilities (e.g., e-mail and file transfer).

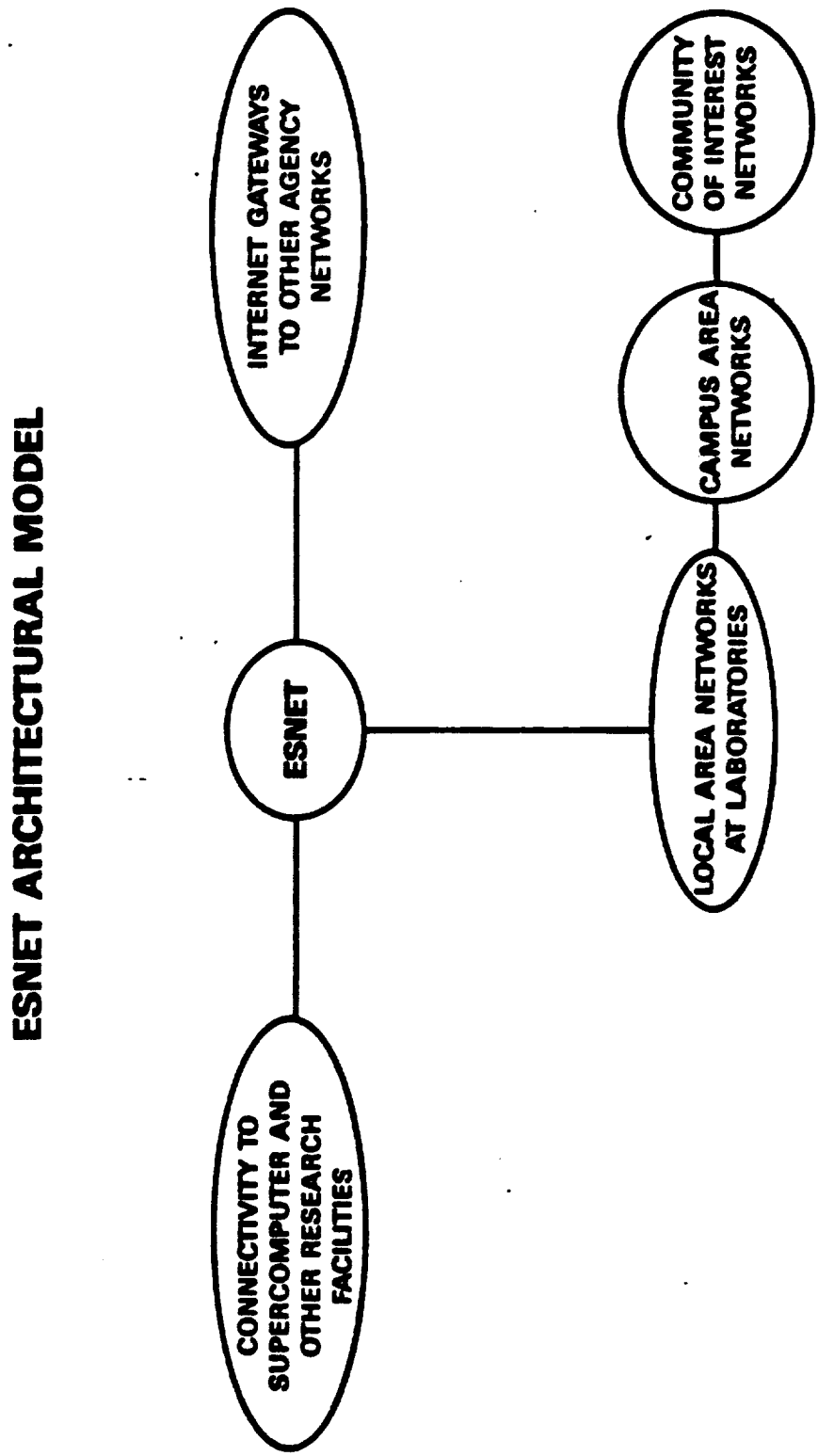


EXHIBIT 9-1. ESNET Architectural Model.

The intent is to enable a scientist at even a small university to share resources and information in the most sophisticated manner possible. For example, given a low cost, high performance workstation, he should be able to have one workstation window opened to a supercomputer application, which is executing 2000 miles away, programmed to analyze data for an experiment via another workstation window where this experiment is running at a third installation distant from both the scientist and the supercomputer facility. Collaborators of the scientist also should be able to view, by multicast technology, these events at still other geographic locations while electronically communicating with the scientist. In summary, it is expected that ESNET will provide the full range of services for exchanging messages and for sharing resources (e.g., e-mail, remote login, file transfer), and its use will be restricted to DOE sponsored projects.

Since the DOE Energy Research programs are experiencing a phenomenal growth in international requirements, as large scientific collaborations have become increasingly international in scope, ESNET is being designed to meet these foreign requirements.

9.2.4 Extent And Size

ESNET, ultimately, will be a nationwide network with worldwide connectivity. It will provide access to all major laboratories and many smaller sites with projects supported by the DOE Office of Energy Research (See descriptions of HEPNET and MFENET for names of sites). Currently, there are about 30 hosts on ESNET.

ESNET's extent and size will continue to grow as it is being implemented. It is being implemented in the following phases:

1. Phase 0 - completed in 1988: X.25 links to several laboratories and universities and one foreign site.
2. Phase I - completed in 1988: 56 Kbps leased line IP (Internet Protocol) backbone connecting various labs and universities.
3. Phase II - completed in 1988: More sites added to high speed backbone; some of these were MFSNET sites.

4. Phase III - 1989 and beyond: More sites will be disconnected from MFENET and connected to the ESNET backbone and other new sites, including international ones, will be added.

9.2.5 Topology

The ESNET Steering Committee presented in their 1987 plan the ESNET backbone configuration shown in Exhibit 9-2 and the list of desirable geographic locations shown in Exhibit 9-3. In addition, a number of foreign communications links were also planned. However, since most of the locations overlap existing or planned network installations for other federal agencies, especially NSF, an effort is being made to minimize redundancies.

The current ESNET topology is shown in Exhibit 9-4. The initial backbone which became operational in the Fall of 1988 connects the MFECC, Lawrence Berkeley Laboratory (LBL), Argonne National Laboratory (ANL), Princeton Plasma Physics Laboratory (PPPL or PL), Supercomputer Computations Research Institute at Florida State University (FSU), University of Texas at Austin (UT or UTA), and General Atomics (San Diego). Subsequent extensions have been made to the California Institute of Technology (CIT), the Continuous Electron Beam Accelerator Facility (CEBAF), Fermi Naional Accelerator Laboratory (FNAL), Los Alamos National Laboratory (LASL), Massachusetts Institute of Technology (MIT), Brookhaven National Laboratory (BNL), Oak Ridge National Labs (ORNL), Stanford Linear Accelerator (SLAC), the Superconducting Super Collidor (SSC) - in Dallas, UCLA, and several foreign sites (e.g., Cern and FRG).

9.2.6 Computers

The computers in ESNET will serve as hosts, links to other nodes, gateways or some combination of these three uses. They range in size from small microcomputers to supercomputers. The specific supercomputers are described in the presentation of MFENET.

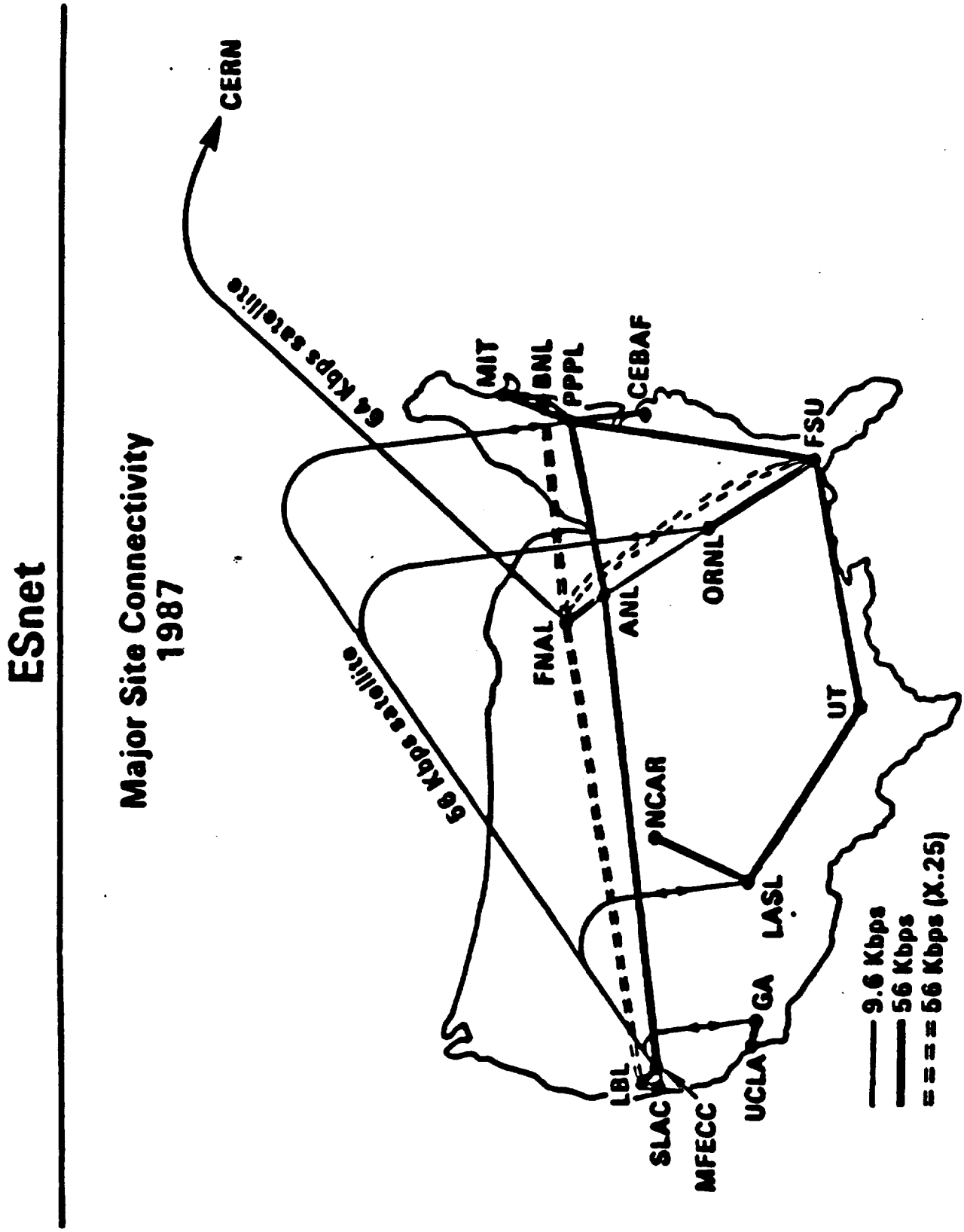


EXHIBIT 9-2. ESNET Backbone Configuration.

GEOGRAPHIC LOCATIONS

This list of geographic locations has been compiled from ER program individual requirements documents. The locations are footnoted to designate 1.) that connectivity to this location is required by more than one ER program, 2.) that there are already multiple ER funded computer network links to the location, and 3.) that the location is serviced by or is part of a computer network funded by another agency, such as NSF, DARPA, etc.

ABILENE CHRISTIAN
ALABAMA 3
AMES LABORATORY 1, 2, 3
ARGONNE NATIONAL LABORATORY 1, 2, 3
ARIZONA 1, 3
ARIZONA STATE 3
ARKANSAS 3
ATLANTA
AUBURN
BALL STATE
BATTELLE PACIFIC NORTHWEST LABORATORY
BOSTON 1, 3
BPA-PORTLAND
BRANDEIS
BRIGHAM YOUNG UNIVERSITY 1
BROOKHAVEN NATIONAL LABORATORY 1, 2, 3
BROOKLYN COLLEGE
BROWN 3
CALIFORNIA/BERKELEY 2, 3
CALIFORNIA/DAVIS 1, 3
CALIFORNIA INST OF TECH 1, 2, 3
CALIFORNIA/LOS ANGELES 1, 2, 3
CALIFORNIA POLYTECHNIC STATE
CALIFORNIA/RIVERSIDE 1
CALIFORNIA/SAN DIEGO 3
CALIFORNIA/SANTA BARBARA 1, 3
CALIFORNIA/SANTA CRUZ 3
CARNEGIE-MELLON 1, 3
CEBAF
CHICAGO 1
CINCINNATI 1
CLARK
CLARKSON
COLORADO 3
COLORADO STATE 3
COLUMBIA 1, 3
CONNECTICUT 3
CORNELL 1, 3

EXHIBIT 9-3. Desired Locations Of ESNET Nodes.

DENVER 3
DEPT OF ENERGY-GTN 1, 2
DEPT OF INTERIOR-DENVER
DREXEL
DUKE 1, 3
ELMHURST
EMORY
ENVIRONMENTAL MEASUREMENT LAB-NY
FERMI NATIONAL ACCELERATOR LABORATORY 1, 2, 3
FLORIDA 3
FLORIDA STATE 1, 2, 3
FLOW RESEARCH
FRANKLIN/MARSHAL COLLEGE
GA TECHNOLOGIES 1
GEORGE MASON
GEORGE WASHINGTON 3
GEORGIA 3
GEORGIA TECH 3
GRUMMAN AERO
HANFORD 1, 2
HARVARD 1, 2, 3
HOUSTON 1, 3
IDAHO
IDAHO NATIONAL ENGINEERING LABORATORY 3
ILLINOIS-CHAM 1, 3
ILLINOIS-CHI 1, 3
ILLINOIS STATE 3
INDIANA 1
INHALATION TOXICOLOGY RES INST-ALBUQUERQUE
INST MINING & TECH-SOCORRO/NM
IOWA 1, 3
IOWA STATE 1, 3
JOHNS-HOPKINS 1, 2, 3
KANSAS 1, 3
KANSAS STATE 1, 3
KENT STATE
KENTUCKY 1, 3
LAWRENCE BERKELEY LABORATORY 1, 2, 3
LAWRENCE LIVERMORE NATIONAL LABORATORY 1, 2, 3
LEHIGH 1, 3
LOS ALAMOS NATIONAL LABORATORY 1, 2, 3
LOUISIANA STATE 1, 3
LOUISVILLE 3
MARYLAND 1, 2, 3
MASSACHUSETTS INST OF TECH 1, 2, 3
MCDONNELL DOUGLAS
MICHIGAN 1, 3
MICHIGAN STATE 1, 3
MINNESOTA 1, 3
MISSISSIPPI 3
MISSOURI 3
MONTANA

EXHIBIT 9-3. Desired Locations Of ESNET Nodes.

(CONTINUED)

NASA/LEWIS RESEARCH CENTER
NATIONAL BUREAU OF STANDARDS-JILA
NCAR 1, 3
NEBRASKA 3
NEW HAMPSHIRE 1
NEW MEXICO 1
NEW MEXICO IMT
NEW MEXICO STATE
NEW YORK 1, 2, 3
NEW YORK MEDICAL CENTER 1
NEW YORK, STATE UNIV/STONY BROOK 1, 2, 3
NORTH CAROLINA/CHAPEL HILL 1, 3
NORTH CAROLINA STATE 1, 3
NORTHEASTERN 3
NORTHRIDGE
NORTHWESTERN 1
NOTRE DAME
OAK RIDGE NATIONAL LABORATORY 1, 2, 3
OHIO 1
OHIO STATE 1, 3
OKLAHOMA 3
OREGON
PACIFIC NORTHWEST LABORATORY 1, 2
PENN 1, 3
PENN STATE 1, 3
PHILADELPHIA
PITTSBURGH 3
PRINCETON 1, 3
PRINCETON PLASMA PHYSICS LABORATORY 1, 2
PURDUE 1, 3
RENSSELAER POLYTECHNIC INSTITUTE
RICE 1, 3
ROCHESTER 3
ROCKWELL HANFORD
RUTGERS 1, 3
SANDIA NATIONAL LABORATORY 1, 2, 3
SAN FRANCISCO STATE
SCIENCE APPLICATIONS, INC 1, 2, 3
SCRIPPS INSTITUTION OF OCEANOGRAPHY
SKIDAWAY INST OF OCEANOGRAPHY
SOLAR ENERGY RESEARCH INST
SOUDAN
SOUTH CAROLINA
SOUTHEASTERN
SOUTHWEST RESEARCH INSTITUTE
ST. LOUIS
STANFORD 1, 3
STANFORD LINEAR ACCELERATOR CENTER 1, 2, 3
SYRACUSE 1, 3
TEMPLE
TENNESSEE 3
TEXAS 1, 2, 3
TEXAS A&M 1, 3

EXHIBIT 9-3. Desired Locations Of ESNET Nodes.

(CONTINUED)

TEXAS ACCELERATOR CENTER 1, 3
TEXAS TECH 3
TOLEDO
TRW INC
U.S. AIR FORCE ACADEMY
U.S. NAVAL ACADEMY
UTAH
UTAH STATE
VALPARAISO
VANDERBILT 3
VASSAR
VIRGINIA 3
VIRGINIA POLY INST 3
VIRGINIA STATE
WASHINGTON 3
WASHINGTON STATE
WILLIAM & MARY
WISCONSIN 3
WORCESTER POLYTECHNIC INSTITUTE
WYOMING
YALE 3

EXHIBIT 9-3. Desired Locations Of ESNET Nodes.

(CONTINUED)

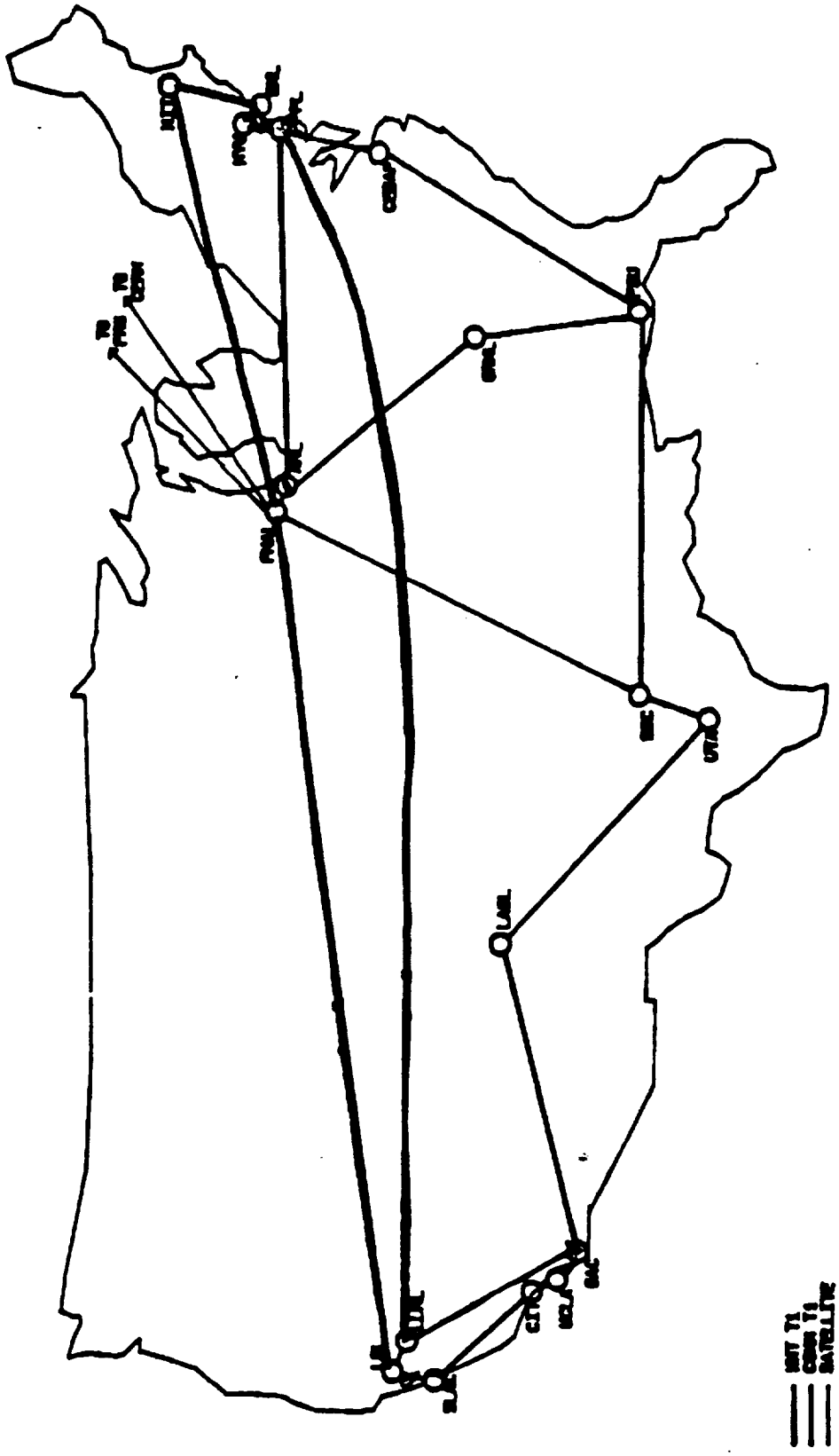


EXHIBIT 9-4. Current ESNET Topology.

9.2.7 Media And Link Speeds

While it was planned that ESNET would use a mixture of terrestrial and satellite communications links, most of its links are now terrestrial and eventually all will be fiber links. The initial backbone is a loop of 56 Kbps and 1.544 Mbps links. Upgrades to T1 speeds on all links is anticipated. See Exhibit 9-4 for backbone link speeds.

9.2.8 Protocols

The ESNET will support the higher level DECNET and NSP protocols (Non Standard Protocols) used by HEPNET and MFENET, as well as TCP/IP.

9.2.9 Administration

ESNET management is distribute over DOE hadquarters, MFECC and the ESNET sites. The SCS coordinates requirements and develops plans and budgets. the National MFE Computer Center (NMFECC) of Lawrence Livermore National Laboratory (LLNL) installs and operates ESNET. Representatives from each of the DOE Energy Research programs are appointed by the DOE Office of Scientific Computing to the ESNET Steering Committee which handles policy issues. The ESNET Site Access Committee, DECNET Working Group and Site Coordinating Committee provide site support and representation.

9.2.10 Funding

ESNET is funded by the DOE.

9.2.11 Future

The future of ESNET can be described in technological and political terms. Technologically, the following changes are expected: upgrading the backbone to 1.544 Mbps, migrating to ISO/OSI, and integrating access internally and externally with other networks. Politically, ESNET will play a key role in the development of a national research network, with

this role being a function of how it interfaces with national efforts like the RIB and the NRI Gigabit network research.

9.3 MAGNETIC FUSION ENERGY NETWORK - MFENET

9.3.1 History

MFENET was created in 1976 to provide access to the National MFE Computer Center (NMFECC) located at Lawrence Livermore National Laboratory. Since then, it has grown, using several underlying network and transport protocols, to support access to more supercomputers.

9.3.2 Type Of Network

MFENET is an internet.

9.3.3 Purpose And Services

The original purpose of MFENET was to connect physics departments doing research in nuclear fusion, specifically in Magnetic Fusion energy (MFE). However, the DOE has expanded it to reach all the DOE Energy Research Programs. That is, its primary users are the national laboratories and DOE Energy Research programs. Services provided include E-mail, remote login, file transport, and remote command execution. Access is restricted to DOE-funded researchers.

9.3.4 Extent And Size

MFENET is a nationwide network with currently about 120 hosts in the continental United States.

9.3.5 Topology

The United States MFENET topology in 1986 is shown in Exhibit 9-5,

and a list of user sites is shown in Exhibit 9-6. While MFENET reached, at its most advanced stage, all the national laboratories, several universities, the Supercomputer Computations Research Institute at Florida State University and other institutions, it is now being replaced by ESNET. Exhibit 7 presents a conceptual diagram of the MSFNET II architecture, which is the ESNET architecture. Exhibit 9-8 shows the originally planned full backbone configuration for MFENET II (i.e., ESNET).

9.3.6 Computers

The computers in MFENET serve as hosts, links to other nodes, gateways or some combination of these three uses. They range in size from small microcomputers to supercomputers. Five supercomputers are reachable: a Cray 1s, a Cray X-MP/2, two Cray 2s, and a Cyber 205.

9.3.7 Media And Link Speeds

MFENET uses a mixture of terrestrial and satellite communications links. The existing links range from 9.6 Kbps to 56 Kbps lines to 112 Kbps satellite links. While the speed between any two hosts depends greatly on the intervening links, reliability is high and there are gateways to other networks.

9.3.8 Protocols

MFENET uses its own special purpose link protocols developed at the Lawrence Livermore National Laboratory and called NSP. These protocols are implemented for VAX/VMS and the Cray Time Sharing System (CTSS) operating system used on the NMFECC Cray Supercomputers. Because the use of non-standard protocols has led to interoperability problems with other networks, MFENET will be using the NSP suite over the IP protocol, and will eventually move to the ISO/OSI protocols. As noted earlier, this change is part of the replacement of MFENET by MFENET II.

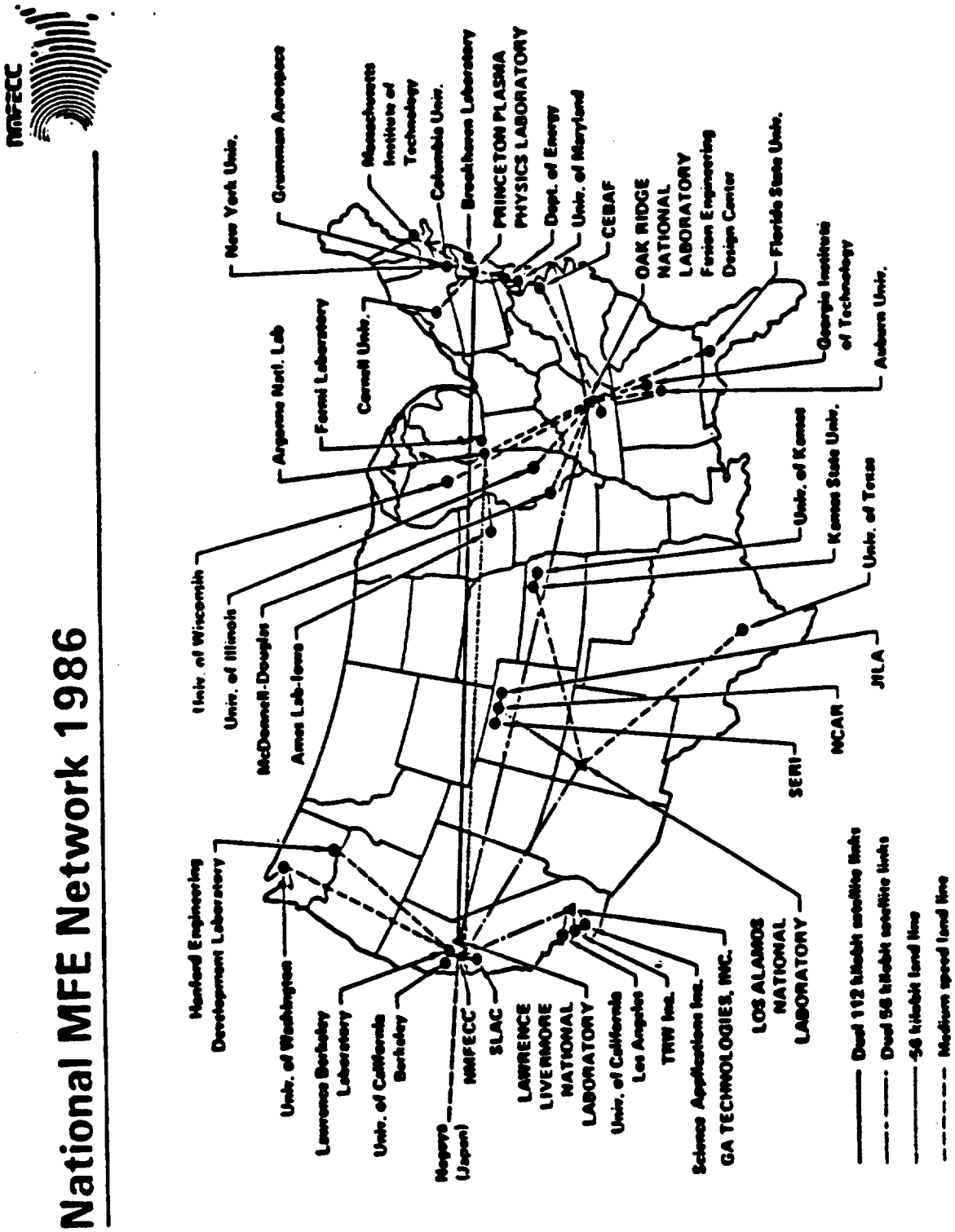


EXHIBIT 9-5. 1986 MFENET Topology.

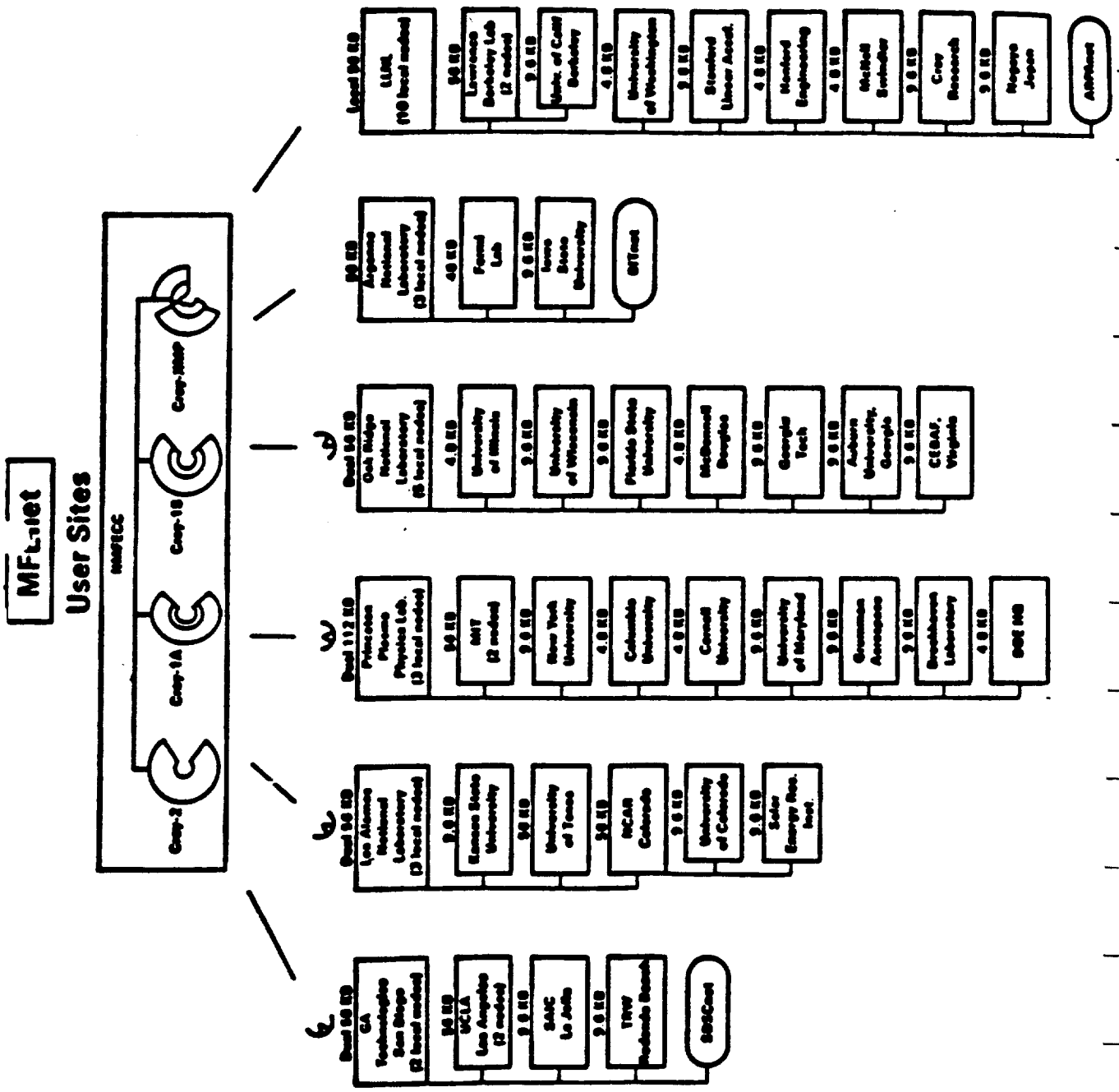


EXHIBIT 9-6. MFENET User Sites.

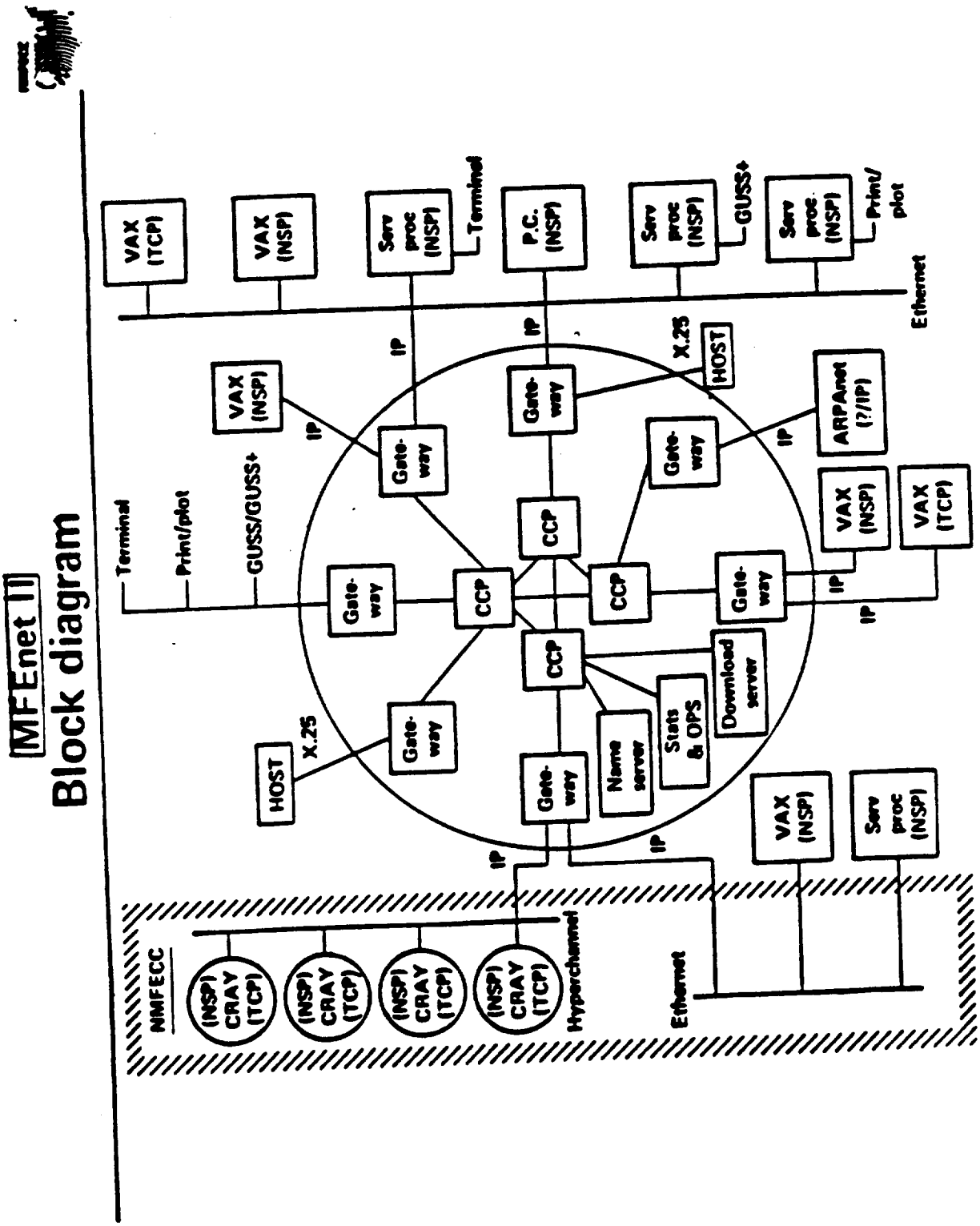


EXHIBIT 9-7. MFENET II Architecture.

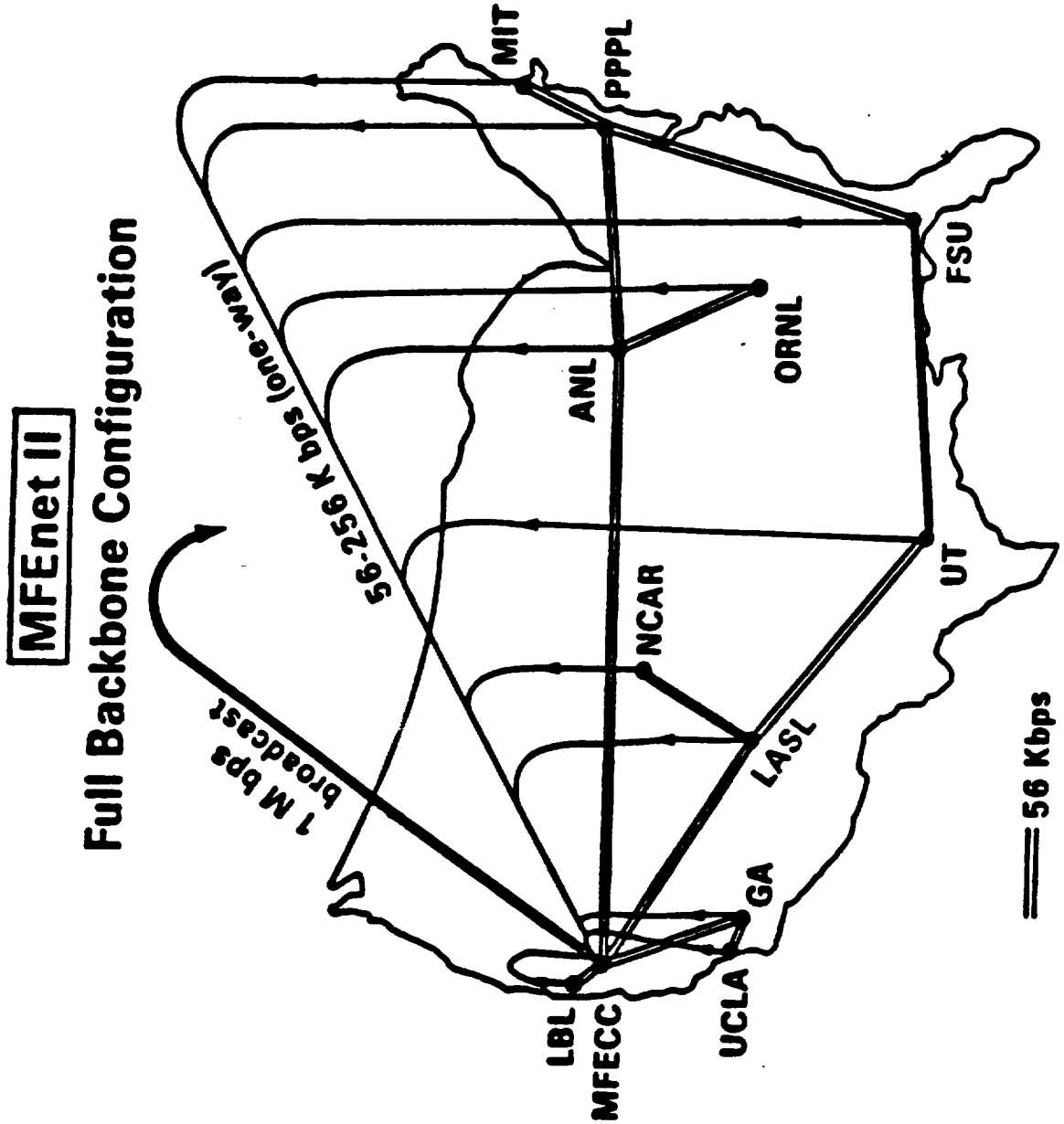


EXHIBIT 9-8. MFENET II Backbone Configuration.

9.3.9 Administration

MFENET is administered by the United States DOE and is managed from the National MFE Computer Center of Lawrence Livermore National Laboratory (LLNL). That is, the LLNL installs and operates MFENET.

9.3.10 Funding

MFENET is funded by the DOE.

9.3.11 Future

It is expected that MFENET will increasingly use the ESNET backbone, gradually increase the speed of its tail links and eventually migrate to ISO/OSI. Its impact on the national research network will be through the ESNET.

9.4 HIGH ENERGY PHYSICS NETWORK - HEPNET

9.4.1 History

High Energy Physics (HEP), also known as Elementary Particle Physics, is a branch of physics research which explores the underlying physics of the universe. HEP uses techniques involving large accelerators which permit the investigation of matter on a minute, sub-nuclear, sub-nucleon scale. The size of the experiments, the scale of accelerators and the cost of the efforts have led, over the last forty years, to the concentration of the experimental sites at relatively few laboratories worldwide. The typical experimental collaboration today encompasses from 100 to 400 physicists, who come from 10 to 40 institutions, in as many as a dozen countries.

The original growth of networking for HEP began in the late 1970's. Then, in 1984, the HEP Advisory Panel (HEPAP) formed a sub-panel to study the computer needs of HEP for the next decade. This panel produced a

report,and a response by the community to that report resulted in a prospectus for a HEP Network in 1986. In 1987 the HEPNET Review Committee (HRC) was formed to review the plans for networking in HEP, and this committee has met several times up to the present. Thus, HEPNET, as an extensive network, developed during the last decade. Finally, and as noted in the initial overview, HEPNET has been using the backbone services provided by ESNET.

9.4.2 Type Of Network

HEPNET is a the collection of lines and switches leased through HEP and provides the management of networking protocols and services for HEP use. It is a collection of networks used to support the HEP community. It includes HEPNET Data Switch Networks, HEPNET DECNET, and HEPNET LEP3NET (Discussed separately, below). As such, HEPNET is not a specific physical network.

In the Data Switch Networks leased lines are used to connect terminals and printers at home institutions with the switches and computers at the laboratories. The HEPNET DECNET developed as a set of smaller networks for individual collaborations and now these networks have been connected into a single network. HEPNET DECNET consists of a number of leased lines from about 50 universities to the laboratories, includes many international sites, and uses the DEC networking software to connect DEC computers which are widely used by the HEP community. As indicated above, HEPNET LEP3NET is discussed later as a single network.

9.4.3 Purpose And Services

The primary purpose of HEPNET is to facilitate the geographically dispersed collaborations typical of HEP research projects. HEPNET, as a collection of networks, supports the full range of services for exchanging messages and for sharing resources (e.g., E-mail, remote login, file transfer).

9.4.4 Extent And Size

While HEPNET originated in the United States, it has spread to most places where high energy physics is conducted. The HEPNET community is an international community; HEPNET is also a major continental European network and extends to Canada and to Japan. The network currently has over 6000 nodes.

9.4.5 Topology

The core facilities of HEPNET are the major High Energy Physics laboratories: Argonnne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Fermi National Accelerator Laboratory (FNAL), Lawrence Berkeley Laboratory (LBL), and the Stanford Linear Accelerator (SLAC). The links among these facilities form the backbone of the network. Additionally, as suggested earlier, several European research organizations are connected to HEPNET. Also, there are gateways to other major research networks including: ESNET, MFENET, BITNET, and NSFNET. See Exhibit 9-9 for a diagram of the Data Switch component of HEPNET, and Exhibit 9-10 for the DECNET component of HEPNET. Since BITNET has been so widely used by HEP users, the portion of BITNET involved in HEP activities is presented in Exhibit 9-11.

9.4.6 Computers

The computers in HEPNET serve as hosts, links to other nodes, gateways or some combination of these three uses. The main purpose of HEPNET has been to provide access the the accelerator centers, and access to supercomputers (increasingly needed for theoretical work by HEP users) has been via MFENET.

9.4.7 Media And Link Speed

The links between the major facilities and those connecting universities to these facilities are primarily 9.6 Kbps and 56 Kbps leased lines. As the ESNET backbone is developed and used for HEP activities, the speed of the links connecting the major HEPNET nodes will increase to

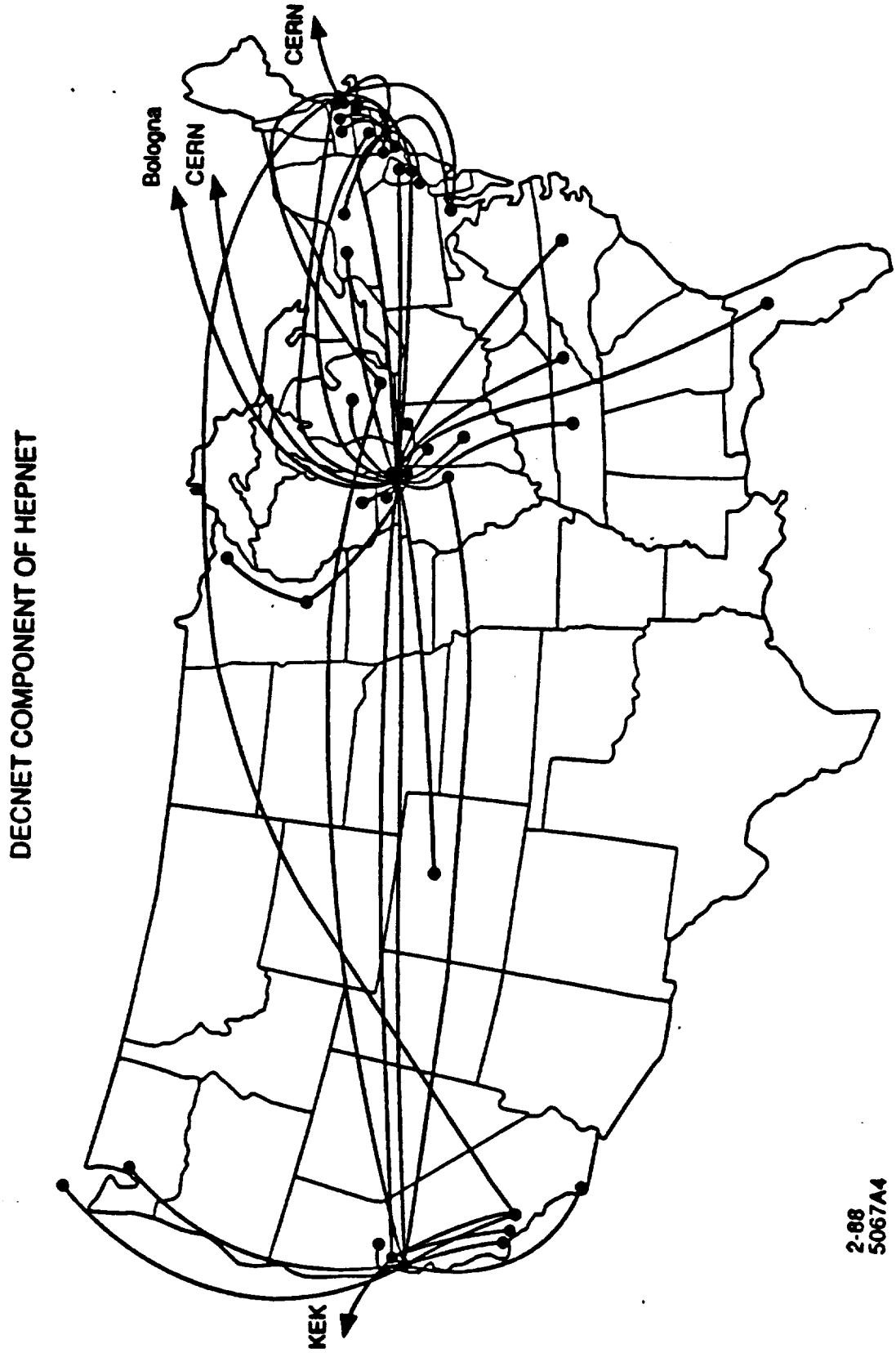


EXHIBIT 9-10. HEPNET Topology, DECNET Component.

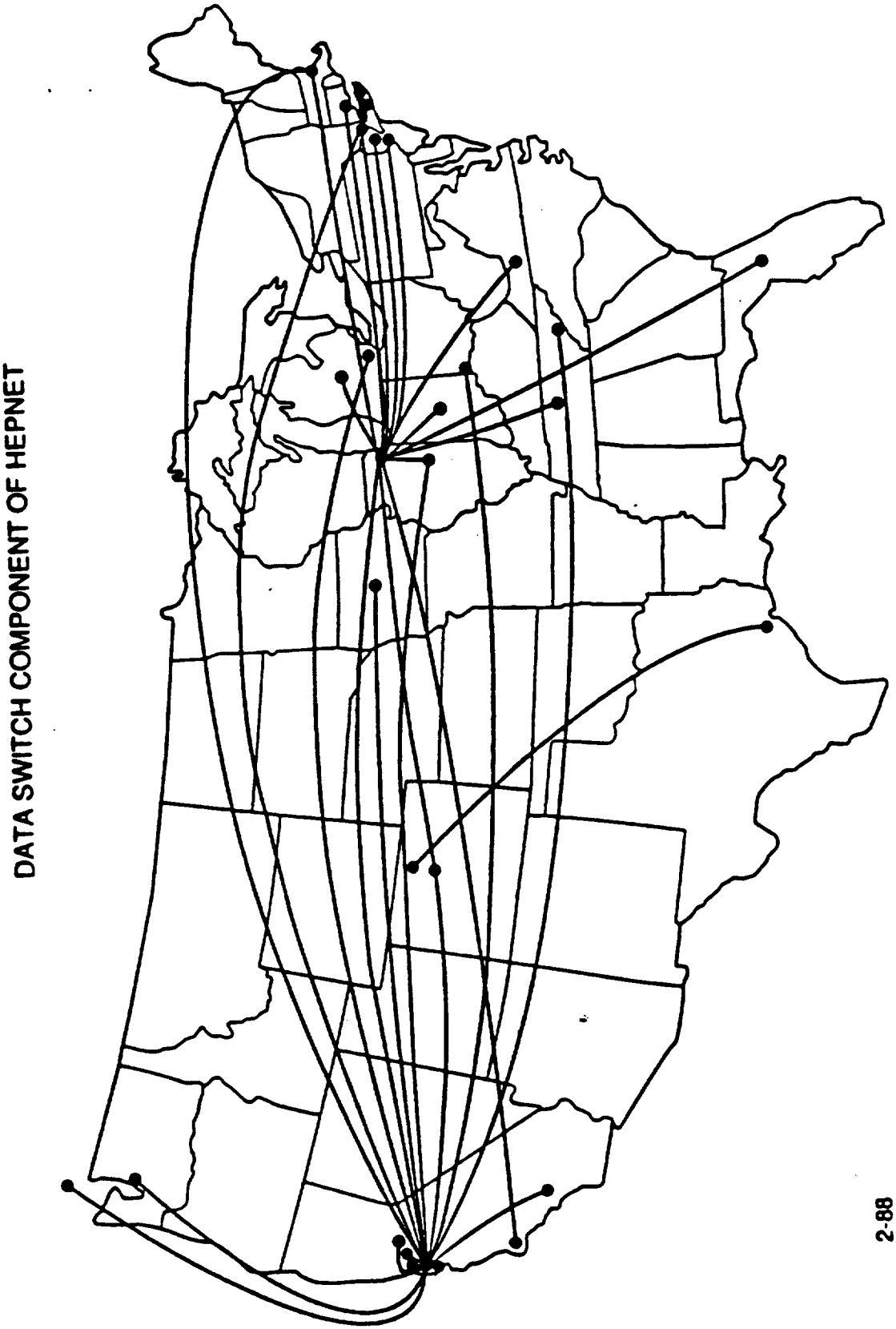


EXHIBIT 9-9. HEPNET Topology, Data Switch Component.

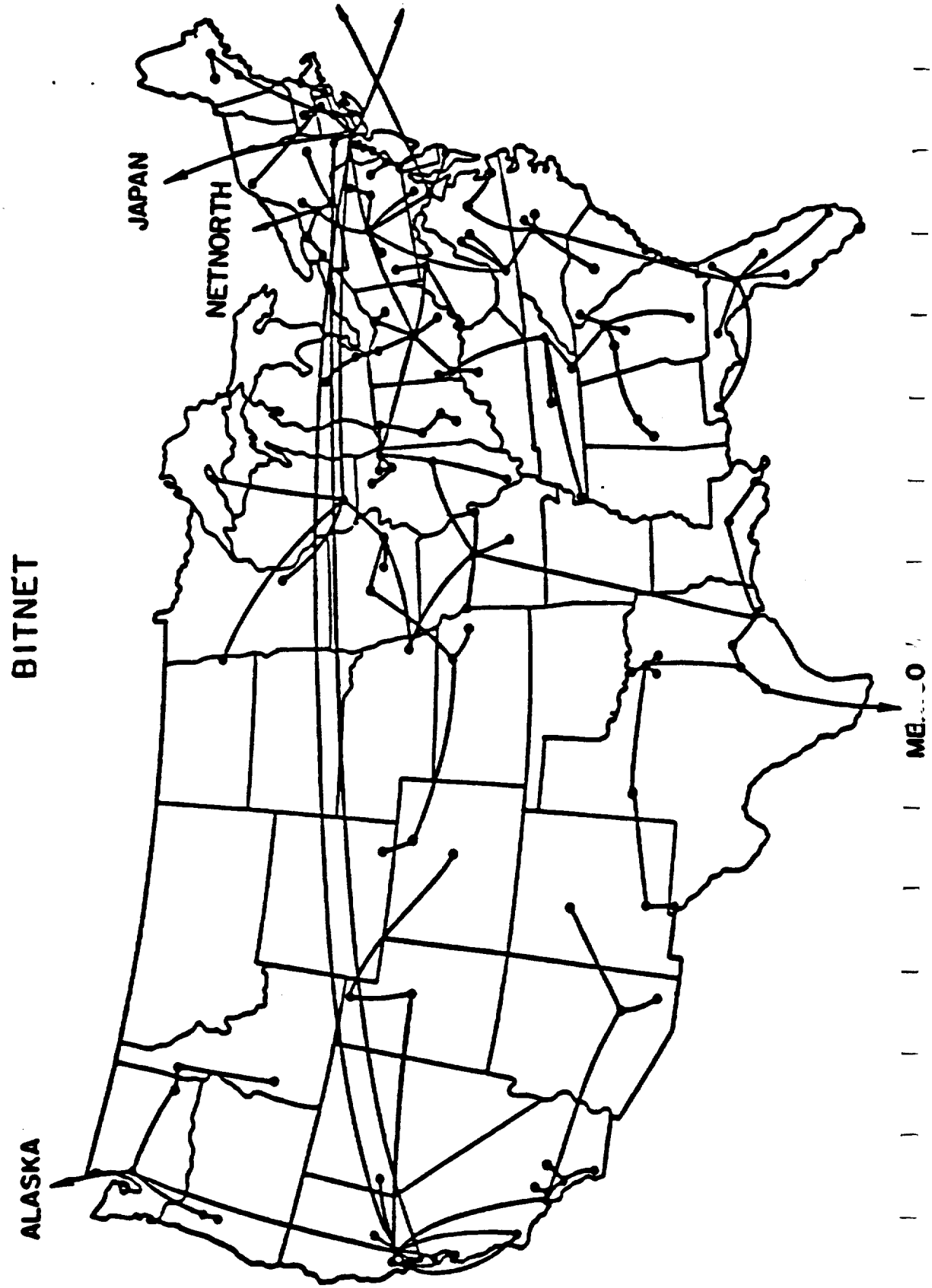


EXHIBIT 9-11. HEPNET Topology, BITNET Component.

1.544 Mbps. Also, it is expected that the speeds of the tail circuits will have to be increased.

9.4.8 Protocols

The DECNET protocols are used for the following reasons: DEC equipment is widely used by physicists; DECNET services have been considered satisfactory by physicists; DECNET protocols are compatible with Ethernet and X.25 protocol which is important in Europe. TCP/IP was not used because the huge files physicists often exchange made use of the early ARPANET and Internet impractical. It is expected that DECNET Phase 5, which will be compatible with ISO/OSI, will be used by HEPNET.

9.4.9 Administration

The day to day operation of the network is the responsibility of the local management at each of the nodes and access points. Because this has proven inpractical, plans are being made for a more centralized administration. Currently, some coordination is provided through the HEPNET Technical Coordinating Committee (HTCC). The committee was formed at the request of the DHEP program office in DOE and includes representatives of the HEP laboratories (ANL, BNL, FNAL, LBL, and SLAC) and of the L3 collaboration. However, there have been recent recommendations for a more centralized management to meet the new and growing needs of the HEP users.

9.4.10 Funding

HEPNET has evolved to its current state with little coordination or planning, and thus has been funded from a variety of sources. Funding for HEPNET has come primarily from DOE and NSF, but other sources (e.g., universities and BITNET) also have contributed to the HEPNET.

9.4.11 Future

As noted above, ESNET will support HEPNET, but the actual amount of integration that will take place between the two networks remains to be

determined. The following are expected: increased backbone speeds (to T1), upgraded foreign links, upgraded tail links in the United States, migration to DECNET Phase 5 protocol, and a more centralized administration.

9.5 LEP3NET

9.5.1 History

L3 is the name given to one of four experiments in new high energy physics at the LEP accelerator at the Cern Laboratory in Switzerland. It is a multi-nation project costing about $100 million, with the United States contribution being about $25 million. The experiment involves over 400 international physicists who need to communicate with each other. To make this international communication possible, LEP3NET was built. "LEP" refers to the name of the accelerator at Cern, and "3" refers to the number of the experiment. LEP3NET has been operating for about four years and will exist as long as the Cern experiment continues, which will be for an additional five to ten years.

9.5.2 Type Of Network

As noted above, LEP3NET is often considered one of the components of HEPNET. Standing alone it is considered to be an internet.

9.5.3 Purpose And Services

As noted above, the purpose of LEP3NET is to support the L3 experiment at the Cern Laboratory in Switzerland. Services include the full range of services for exchanging messages and for sharing resources, including e-mail, remote login, and file transfer.

9.5.4 Extent And Size

LEP3NET is an international internet covering some twenty-one

countries including European countries (e.g., France, Italy, Netherlands, Spain, Sweden, Switzerland the center, West Germany), Soviet Union, China and the United States. In the United States, nine institutions and 20 hosts are connected to the network.

9.5.5 Topology

In the United States, LEP3NET connects all United States research institutions involved in the project including the following universities: California Institute of Technology, Carnegie Mellon, Harvard, John Hopkins, Massachusetts Institute of Technology, Michigan, Northeastern, Princeton and Rutgers. See Exhibit 9-12 which shows the location and connectivity of the LEP3NET nodes. LEP3NET also interconnects with other networks, e.g., HEPNET, BITNET.

9.5.6 Computers

The computers in LEP3NET serve as hosts, links to other nodes, gateways or some combination of these three uses. There are no supercomputers on this network, but indirect access to supercomputers is available.

9.5.7 Media And Link Speed

LEP3NET uses only terrestrial media; satellite service is not used because of the delay factor. In the United States, lines are leased from common carriers, and link speeds are 9.6 Kbps and 19.2 Kbps. Since these links are often saturated, higher link speeds (e.g., 56 Kbps and 1.544 Mbps) are being evaluated. This upgrading could involve sharing with ESNET.

9.5.8 Protocols

LEP3NET is based on X.25 switches which makes the network fully compatible with the simultaneous use of higher level protocol suites including DECNET, the COLOURED BOOKS, and ISO standard protocols.

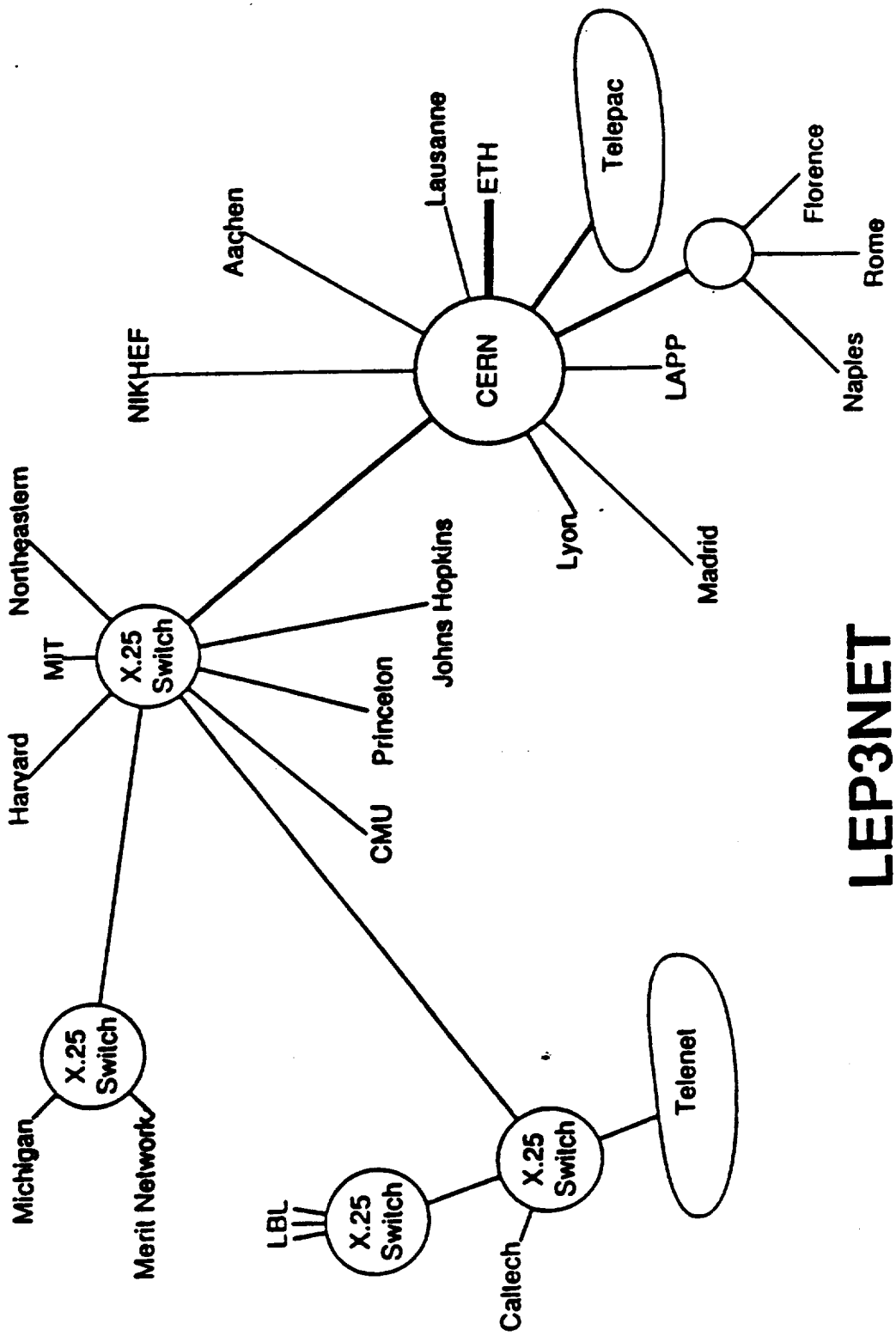


EXHIBIT 9-12. LEP3NET Topology.

9.5.9 Administration

In the United States, LEP3NET is administered, on a day to day basis, at each of the sites involved in the L3 experiment. Major operation, maintenance, training and support concerns are directed to the California Institute of Technology.

9.5.10 Funding

Funding has been provided primarily by Division of High Energy Physics, DOE. Other sources of support have included the NSF and the universities involved in the L3 experiment.

9.5.11 Future

LEP3NET will continue as long as the L3 experiment is being conducted. The future nature of this network will be a function of how it is integrated with ESNET. Probably, LEP3NET will use the ESNET backbone, but will not actually become a part of ESNET.

9.6 OPMODEL NETWORK

9.6.1 History

The DOE released a request for proposal for the development and implementation of the OPMODEL (i.e., Operational Model) network in late 1981. The contract was awarded to the Government Networks Division of Contel Federal Systems, McLean, Virginia. The network, which is a Time Division Multiple Access (TDMA)/Demand Assigned Multiple Access (DAMA) wideband satellite network, is being installed in phases. In Phase 1, completed in late 1985, four nodes were operational and the burst bit rate was 15 Mbps. Cut-over to full service at the four nodes occurred in the Spring of 1986. In Phase 2, which will be completed in early 1990, two nodes are being added, the burst rate is being increased to 60 Mbps, and new features are being added.

9.6.2 Type

The DOE OPMODEL network is a nationwide network. Since the network is not protocol sensitive and since the DOE does not disclose it use of protocols, whether the network is a simple network, an internet or a metanet cannot be determined.

9.6.3 Purposes & Services

The DOE OPMODEL network is designed to provide the DOE with an integrated dedicated telecommunications network with wideband connectivity to meet its mission needs. Since privacy is a major concern, data is encrypted using the DES (Data Encryption Standards) algorithm. Services include secure and non-secure, switched and dedicated digital data services; computer to computer interchange (analog data); computer aided design/computer aided manufacturing (CAD/CAM); voice services; and specialized services, including video teleconferencing and document distribution.

9.6.4 Extent & Size

This network is a nationwide network which is used primarily by the DOE and its contractors.

9.6.5 Topology

The DOE OPMDOEL network topology is depicted in Exhibit 9-13. When Phase 2 is completed the six nodes of the network will include the four original nodes at Germantown, MD, Kansas City, MO, Albuquerque, NM and Livermore, CA, and the two new nodes at Oak Ridge, TN and Mercury, NV. The network is dynamically reconfigurable. As user needs change during the hour, day or week, system capacity can be restructured to give bandwidth to meet the changing load demands.

9.6.6 Computers

All types and sizes of computers are used on this network. The exact types and sizes have not been disclosed by the DOE.

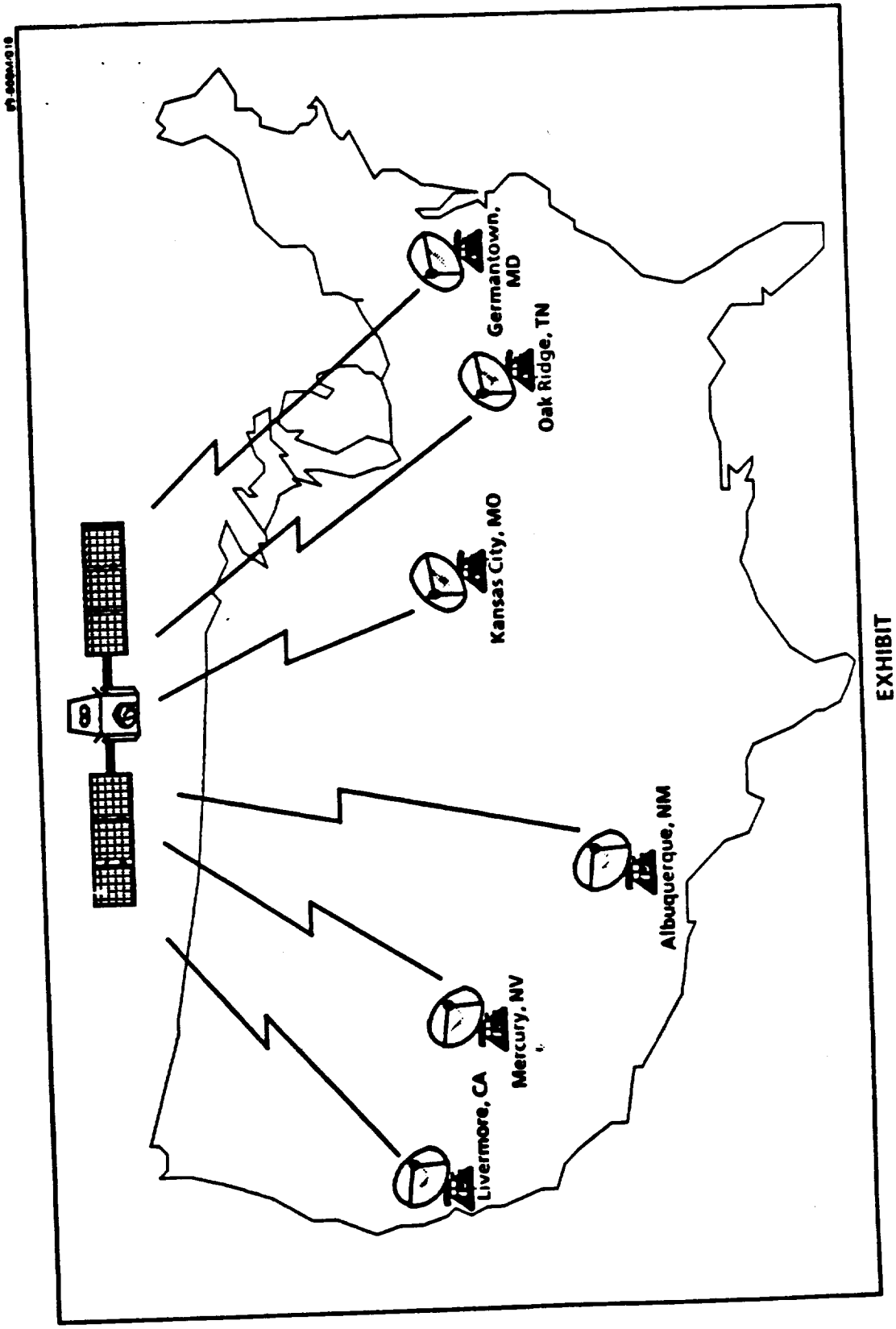


EXHIBIT 9-13. DOE OPMODEL Topology.

9.6.7 Media & Link Speed

The DOE OPMODEL Network, as a TDMA/DAMA wideband satellite network with on-demand connectivity, has a burst bit rate up to 60 Mbps. Port bit rates are up to 2.048 Mbps. Individual communications circuits enter this wideband channel via TDMA/DAMA interfaces. The nodal processor controlling the system access operates in a burst mode so that all nodes can transmit addressed data onto the wideband channel in a time shared access arrangement. Because data privacy is a major concern, bulk DES encryption is provided for data paths up to 60 Mbps. The system supports data rates from 2.4 Kbps to 1.544 Mbps. 64 Kbps digital voice is also provided via the DAMA system. Total throughput of each node is currently about 5 Mbps.

9.6.8 Protocols

As noted earlier, the DOE OPMODEL Network is not protocol sensitive. That is, circuits can be configured to accommodate most kinds of protocols. Since the DOE does not disclose the protocols they use, they cannot be discussed here.

9.6.9 Administration

The Contel Federal Systems' Government Networks Division, along with its subcontractors, has procured, installed and tested this network, and continues to provide services to expand the network. Another DOE contractor, CDSI, operates the network from the Government Network Control Center at Germantown, MD. DOE personnel oversee these efforts.

9.6.10 Funding

The DOE has funded this network.

9.6.11 Future

In the future, new nodes may be added and satellite hoping may be incorporated to increase capacity. Because this is a secure DOE network, it probably will note be integrated into the NRN.

SECTION 10

BITNET - BECAUSE ITS TIME NETWORK AND CSNET - COMPUTER + SCIENCE NETWORK

10.1 OVERVIEW

Both BITNET (Because Its Time Network) and CSNET (Computer + Science Network) emerged in the early 1980's as distinct networks. However, since these two networks have agreed to merge, they will be discussed together. The premise for the merger is that the combination of the resources of BITNET and CSNET will provide the research community with more reliable, consistent and widespread networking resources. It will take the research community a step closer to having a single national network for academic and industrial organizations. The goals of the merged organization include supporting a range of services to national and international groups in academic, government and industry, and providing a voice for the community it serves. The new network will be open to all academic users, to research, development and engineering staff in industry, and to government and non-profit research and scholarly organizations.

10.2 BITNET - BECAUSE ITS TIME NETWORK

10.2.1 History

BITNET was the first major network based on the interest and belief that computer-based networking could improve higher education, rather than on networking research or a disciplinary specialty. It began in 1981 when two sites, City University of New York and Yale University, were connected; two modems sent data flowing over a leased telephone circuit between the computing centers of these two schools. BITNET started as a

network of IBM hosts, but today there are many non-IBM hosts on the network.

BITNET is a cooperative network. From its start, BITNET's philosophy has been that each institution would pay for its own communications link to the network and provide facilities for at least one new member to connect. Consequently, new members expanded the geographic penetration of the network. Each new node on the network contributed communications, intermediate storage, and the computer processing necessary to make its part of the network function. Each member agreed to pass traffic bound for other members without charge, and the network grew in a vine-like manner throughout the United States.

Volunteer efforts and improved end user programs facilitated growth, but growth, itself, created a need for centralized information and services. In 1984 information and operation centers were established, and an executive committee was formed to provide policy and supervision. In 1987, BITNET underwent a major reorganization; it became incorporated and governed by a Board of Trustees.

10.2.2 Type Of Network

BITNET is a cooperative store and forward network. Information transmitted from one node is received by intermediate nodes and forwarded to its destination. The network serves as a communication link between universities and research centers with few restrictions.

10.2.3 Purpose And Services

The premise for establishing BITNET was that it could provide a communications network among universities with no special requirments or restrictions. The network has played a major role in fostering the use of digital electronic communications networks for scholarly and administrative communication within the academic community. Today, students, faculty and administrators are transcending geographical boundaries to form partnerships based on discipline, interest and mutual concern.

BITNET is chartered for the purpose of facilitating non-commercial exchange of information consistent with the academic purposes of its members. Services available on the network include electronic mail, file transfer, real-time terminal messages, and access to BITNET server machines which provide information retrieval services. The network does not support remote login and general file transfer.

10.2.4 Extent And Size

BITNET is a worldwide network. It serves hundreds of sites in 32 countries. In the United States it serves over 400 institutions and over 2500 nodes encompassing all 50 states; virtually all major research institutions are connected and growing numbers of smaller institutions are joining.

BITNET in the United States is complemented by a worldwide network that uses the same networking software and that includes sites in Europe and the Middle East (EARN - the European Academic Research Network), Canada (NetNorth), Singapore, Taiwan, Japan, Korea, Mexico, Chile and Brazil. BITNET, EARN AND NetNorth form one topologically interconnected logical network, even though political and funding considerations have enforced their separate administration and distinct policies. They are fully interconnected, permitting scholars and researchers to communicate and share information in a cooperating network of computers that transcends political and geographic boundaries.

In addition, gateways exist from BITNET to many other networks (e.g., NSFNET, CSNET, and various specialized networks throughout the world).

10.2.5 Topology

The BITNET topology in the United States can be depicted by showing the location and connectivity of its nodes (See Exhibit 10-1). Exhibit 10-1 indicates that the BITNET nodes are distributed throughout the Unite States, and that this distribution reflects the population distribution of the United States. Also, the geographic map of the network suggests that

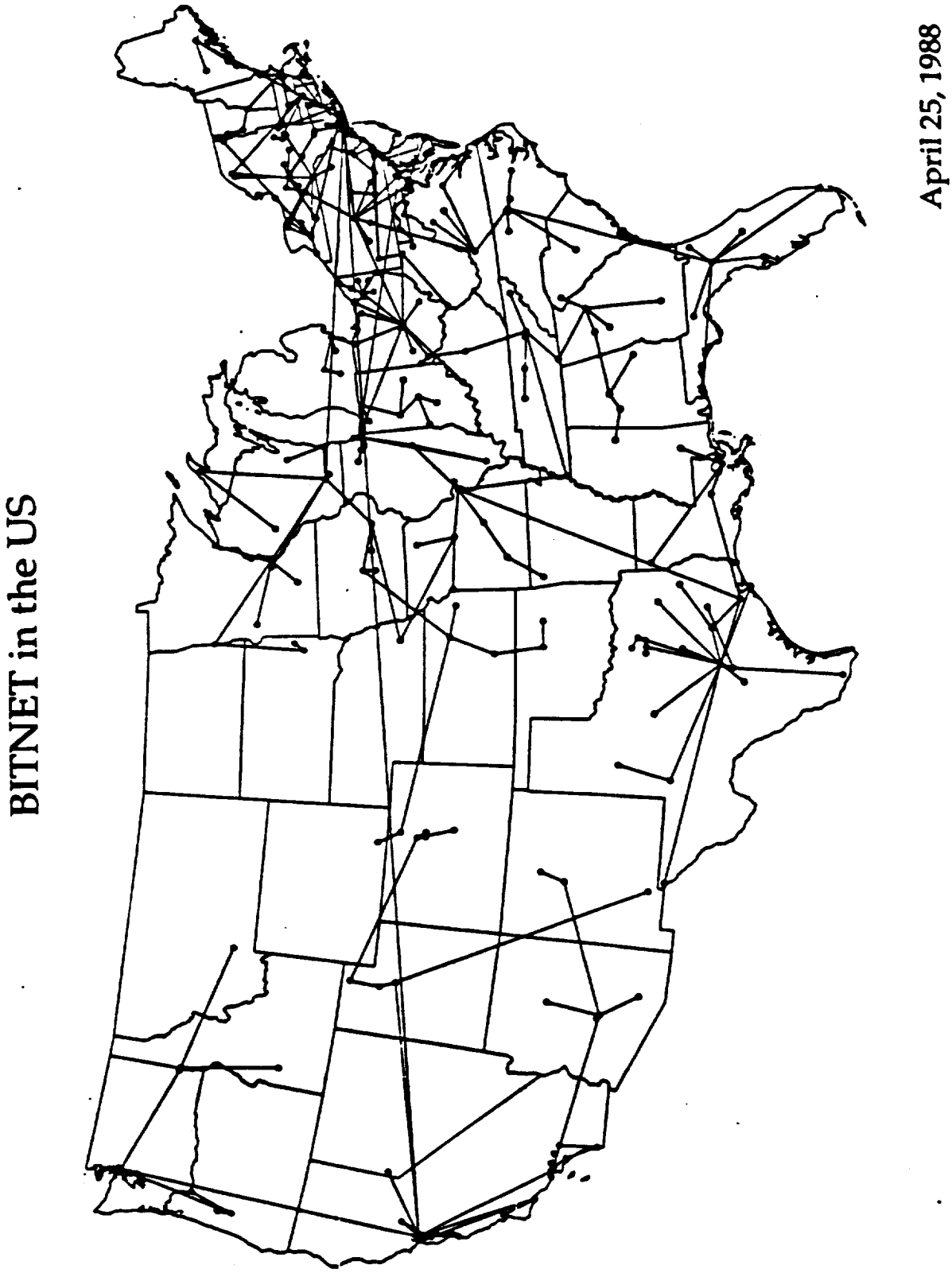


EXHIBIT 10-1. BITNET Topology.

the network is a tree network rooted at the City University of New York where it began; this means that the nodes near the root of the tree are more important.

10.2.6 Computers

While BITNET started as a network of IBM hosts and most of its hosts still communicate using an IBM communication environment, there are many non-IBM hosts using emulation software to provide the appropriate protocols for the DEC and Sperry environments. This emulation software has allowed the network to become quite heterogeneous in terms of machine type and operating system.

10.2.7 Media And Link Speed

BITNET nodes are commonly interconnected by 9.6 Kbps leased phone lines. However, the increasing use of other networking protocols as the trasnport mechanism has allowed for line speeds of as mush as 1.544 Mbps.

10.2.8 Protocols

Usually, computers on BITNET communicate with each other using software implementing IBM's SNA protocols. Recently, there has been increasing use of other networking protocols (e.g., DECNET and TCP/IP). BITNET is developing a BITNET prototype to utilize the TCP/IP protocol of the Internet, so that BITNET users will have full acccess to NSFNET. Also, the development of software and gateways that will allow BITNET to coexist with international networks using international protocol standard such as X.400 is anticipated. As with other research networks, the eventual migration to ISO/OSI protocols is expected. Currently, this migration is at different stages throughout the world in the BITNET.

10.2.9 Administration

BITNET started as a cooperative network with no formal administrative

structure. Its computer center directors held informal meetings to discuss issues and policies. In 1984, this Board of Directors formed an Executive Committee composed of representatives from the major hub nodes on the network and made it responsible for policy and planning. In 1987, the network became an incorporated body governed by a Board of Trustees elected by and of its membership. Daily operations and user support for BITNET is provided by the BITNET Network Information Center (BITNIT) in Princeton, NJ.

10.2.10 Funding

There was no formal support structure for BITNET until the 1984-86 IBM grant funding the establishment of an information and operations support center. Since 1987, BITNET and the BITNET Network Information Center have been supported by membership dues. The network's fee structure is based on members' annual operating budgets and their functions (i.e., academic, commercial, government, or non-profit). As mentioned above, NSF recently has funded some protocol development that will enable users to access NSFNET.

10.2.11 Future

New technologies, protocols, and applications and a new administrative structure are expected in BITNET's future. By 1991 there will be a new corporation in place to manage the new network resulting from the merger of BITNET with CSNET. As noted earlier, the gradual migration to TCP/IP and ultimately to ISO/OSI is taking place. Also, BITNET Board members and staff are working with other network leaders on the national and international planning that is required to ensure the development of standards and networks and their application and utilization for BITNET.

10.3 CSNET - COMPUTER + SCIENCE NETWORK

10.3.1 History

CSNET was established in 1981, but its history began in mid-1979 when discussions, at the University of Wisconsin on the feasibility of a establishing a computer science department research computer network, were initiated; participants included NSF, DARPA and other institutions. In late 1979 an initial proposal to NSF for establishing a network was deferred in favor of funding further study. In 1980 a planning group of representatives from universities, EDUCOM, and the Rand Corporation prepared a new proposal and submitted in to NSF. This proposal, which was approved by NSF and which provided funding for the 1981 through 1985 time period, was to develop a computer science research network to link any university, commercial or government organizations involved in research and advance development in computer science and computer engineering.

10.3.2 Type Of Network

Today, CSNET is a metanetwork including several physical networks using different protocols but serving a single community of users. That is, it is a single logical network that connects many computers on six networks. These networks, which vary in services offered, lower-level protocols used, and speed and reliability, include: PhoneNet, X25Net, ARPANET, Cypress, Leased Lines and Dial-up IP. They are described briefly as follows:

1. PhoneNet: This is a store-and-forward electronic mail network that allows CSNET users to exchange messages with each other and with the DARPA Internet through a central relay host. PhoneNet sites run MMDF, PMDF or CMDF software and utilize modems for dial-up access to the CSNET relay over public telephone lines. In the Fall of 1988 there were 89 active sites, eleven international affiliates were acting as gateways to foreign countries, and four other organizations were international members.
2. X25Net: This component network uses TCP/IP on top of X.25, is part of

the Internet, and was designed to allow full TCP/IP services (e.g., file transfer and remote login) for subscribers without a direct ARPANET connection. It is now a common method for international members to connect to CSNET.

3. ARPANET: Some sites have joined CSNET to increase the availability of a pre-existing ARPANET connection. CSNET has had permission from DARPA to allow researchers who are not working directly on government contracts to access the ARPANET.
4. Cypress: This network, which is built from the Cypress leased-line protocol and uses UNIX systems as switching nodes, has provided Internet access through gateways at Purdue University since 1985.
5. Leased Lines: Leased Lines provide full Internet connectivity to a number of CSNET sites, primarily in the greater Boston area. TCP/IP is supported by a number of link level protocols.
6. Dial-up IP: This is an implementation of Serial Line IP (SLIP) which allows users to establish an IP connection to a central CSNET router over public telephone lines. All of the usual TCP/IP services are supported above IP, and users have the same services as X25Net sites. This type of connection uses 9.6 Kbps modems, and it is expected that many PhoneNet sites will convert to Dial-up IP.

CSNET also is considered as a NSFNET mid-level network, even though it is not directly connected to the NSFNET backbone.

10.3.3 Purpose And Services

CSNET's original purpose was to facilitate research and advanced development in computer science or engineering by providing a means of increased collaboration among those working in the field. Over time, its membership became more general and included industrial, academic, government or non-profit institutions engaged in computer-related research or advanced development in science or engineering. With its merger with BITNET, its membership will be even broader; as noted in the Overview, the new network will be open to all academic users, to research, development and engineering staff in industry and to government and non-profit research and scholarly organizations.

The services that have been provided by CSNET through its component networks have included E-mail, remote login, and file transfer. Mail delivery has been a major CSNET service from its beginning, and mail is the only service supported on all of the CSNET component networks. Its Info-Server Program provides distribution of requested documents in response to requests. Its User Name Server provides information such as name, address, telephone numbers and electronic mail addredsses for CSNET sites and users. In general, PhoneNet provides electronic mail service using dial-up connections, Dial-up IP provides remote login, electronic mail, and file transfer services using telephone connections, and X25Net or Leased-Lines provide full-time interactive communication with the Internet.

10.3.4 Extent And Size

While CSNET is primarily in the United States and Canada, it has links to international members and affiliates throughout the world including the following countries: Australia, Finland, France, Germany, Israel, Japan, Korea, New Zealand, People's Republic of China, Sweden, Switzerland, and the United Kingdom. There are over 200 hosts in all, and many of them serve as gateways into internal company networks or national networks. That is, CSNET provides gateways to other networks in the United States, Canada, Europe and Asia, and foreign academic organizations may connect to CSNET via gateways established by its international affiliates.

10.3.5 Topology

The CSNETT topology in the United States can be depicted by showing the location and connectivity of its nodes (See Exhibit 10-2). Exhibit 10-2 indicates that the CSNET nodes are distributed throughout the United States and that this distribution reflects the population distribution of the United States as well as the concentration of research centers and institutions of higher learning.

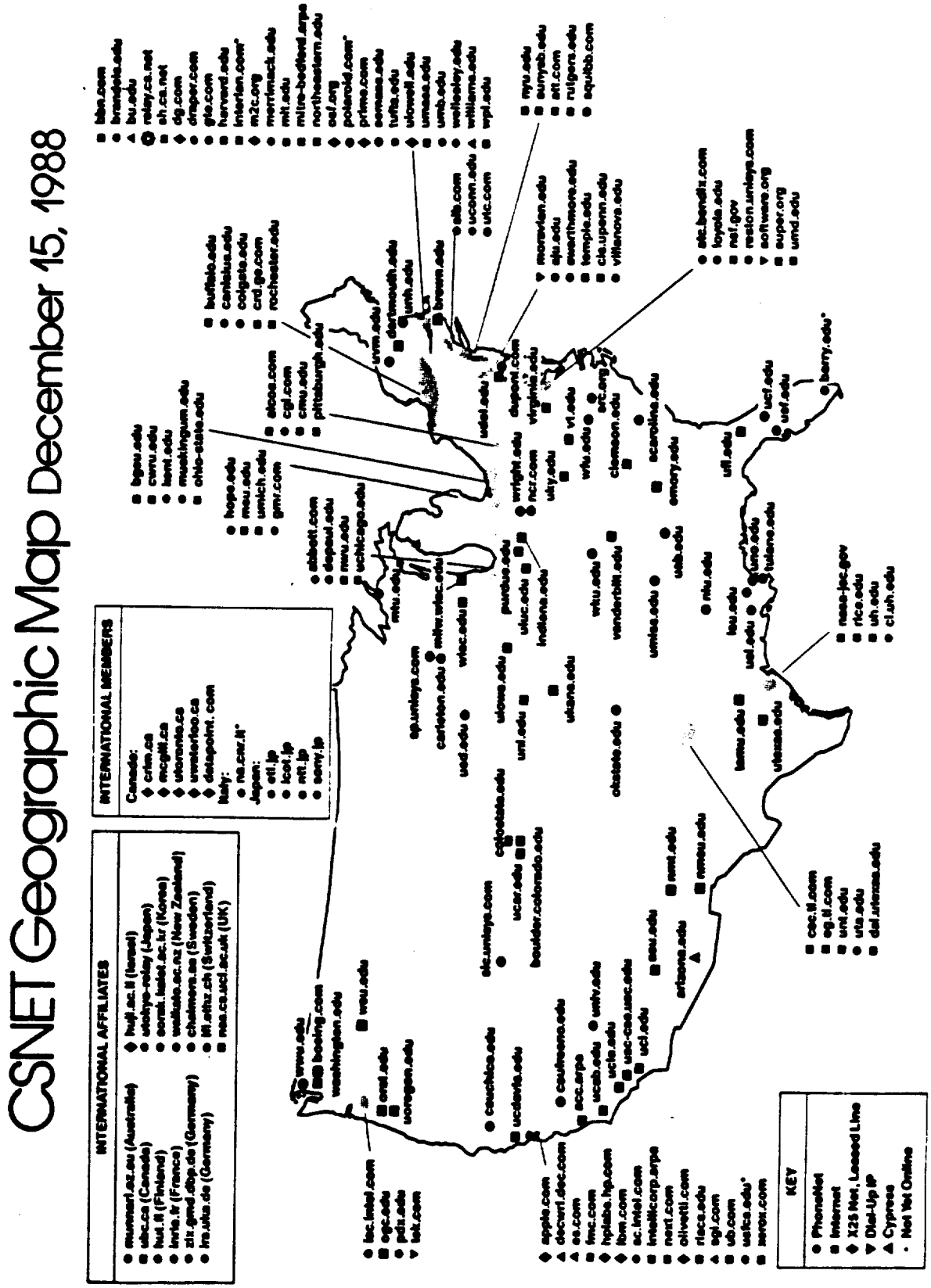


EXHIBIT 10-2. CSNET Topology.

10.3.6 Computers

Because CSNET link speeds are relatively slow, its computers are relatively small; i.e., it does not have direct access to supercomputers. While it anticipates direct access to NSFNET and DRI, it does not anticipate providing high speed links to supercomputers for its users.

10.3.7 Media And Link Speed

CSNET nodes are interconnected by public phone lines, leased phone iines, or public X25 connections purchased from Telenet. The speeds on these lines vary from 1.2 Kbps to 56 Kbps, with most of the link speeds being at 9.6 Kbps. CSNET does not anticipate increasisng these link speeds significantly; they plan are being a relatively low-speed network.

10.3.8 Protocols

As noted above, CSNET is a metanetwork with varying protocols, especially at the lower levels. Its two main protocols are PhoneNet, a special dial-up and electronic mail protocol, and TCP/IP. An example of a lower level protocol that is used by only one of the component networks is the Cypress leased line protocol. Its transition to ISO/OSI is not clear at this time.

10.3.9 Administration

CSNET is a project of the University Corporation for Atmospheric Research (UCAR), Boulder, Colorado, under contract to the NSF. Bolt, Beranek and Newman (BBN) in Cambridge, Massachusetts, has a sub-contract with UCAR to provide the CSNET operations and user services. BBN does this through a Coordination and Information Center (CIC). The CIC provides technical, operational, administrative and end user support. UCAR, with advice from the CSNET Executive Committee which consists of representatives from member organizations, oversees BBN's operation of the CIC.

10.3.10 Funding

As noted above, NSF provided initial funding for the development of CSNET. NSF funds supported the network from 1981 through 1985, and CSNET has been self-supporting since them. The CSNET CIC operates with a no-cost contract with NSF. Member organizations pay annual dues based on several classifications (e.g., academic or industrial) and pay for hardware and communication costs. Recently, CSNET received a grant from the NSF to support the further development of TCP/IP services and improvement to the CSNET User Name Server.

10.3.11 Future

As noted earlier, CSNET plans to merge with BITNET. This merger has been approved and plans for implementation are underway. It will expand CSNET's purpose, the number of its users, and the number of services it provides. Also, the merger will make possible unified representation for the user community. While it is expected that the new network will be interconnected with other national network, it plans to remain a relatively low-speed network. While representatives of both CSNET and BITNET are participating in the planning of a national research network, it is not clear how the new combined network will interface with a national research network.

SECTION 11

CURRENT INTEGRATED RESEARCH NETWORK

11.1 OVERVIEW

Once the selected computer research networks were identified, defined and described, as documented in Sections 3-10, the next task was to size the current nationwide integrated computer research network. The descriptions of the current individual research networks were used to overlay these networks and to develop the topology and definition of a current integrated research network (IRN) representing these selected networks.

11.2 METHODOLOGY

As noted earlier in Section 2, the major activities conducted to size and define the current integrated research network included:

1. Planned sizing strategy.
2. Collected current topology data.
3. Developed network database.
4. Identified major access points.
5. Determined major access point connectivity.
7. Determined link capacity between major access points.
8. Iterated activities 3 - 5.
9. Defined current IRN.

The first step taken to size the current integrated computer research network was the collection of new and current topology data on each selected network. This information included: current topology maps showing the major nodes and their connectivity; area codes and exchanges; and current speeds of all lines connecting all major nodes and the distances between all pairs of major nodes. The area codes and exchanges were used during the costing subtask to obtain typical link costs for 56 Kbps and T1 services. The new topology information was presented in the

descriptions of each network (see Sections 6-10) and later in this section (see Section 11.3.2).

After this information was collected and organized, a main network database was developed, so that the network information could be analyzed when sizing the current IRN. This main network database ultimately included the following types of network parameters: network name, network acronym, and subnetwork name; city A name, state, area code and exchange, and major access point identification; city B name, area code and exchange, and major access point identification; and link capacity and distance between city A and city B. It should be pointed out that some of these paramters (e.g., major access point identification and distance between cities) were the products of subsequent activities noted below.

This main network database then was used to identify major access points. Common hubs and common routes were identified by noting where the various networks overlapped. This overlaying process was iterated several times to identify the major access points. Some of the original network nodes became access points, some were grouped with other nodes to become a single access point, and others did not warrant inclusion as a major access point.

Once these major access points were selected, their connectivity was determined by reorganizing the original main network database in terms of these major access points, resulting in a current network database. The database then was used to note how many links originated from each major access point, what their terminations were and what their speeds were. This information then was used to specifiy the IRN backbone and the capacity requirements of the various segments of the backbone. The Current IRN was then defined in terms of this IRN backbone and link capacity. It should be pointed out that these major activities were iterated several times.

11.3 FINDINGS

The findings obtained from the activities conducted to size the

Current computer research network are presented in terms of the following: the current topology maps on each selected network; the primary network database; the major access points and their V & H coordinates; City A and City B links sorted by City A and City B identifications (i.e., major access points), and the Current IRN topology. These results are presented below.

11.3.1 Current Topology Maps

A list of the networks selected in this study is presented in Exhibit 11-1. The current topology maps of all these selected networks are presented in Exhibits 11-2 through 11-53. These maps, which depict network nodes, connectivity and link speeds, represent the raw data which served as the basis for all subsequent analyses conducted to size the Current IRN.

11.3.2 Primary Network Database

The primary network database is presented in Exhibit 11-54 (see page 11-57). This database includes the following types of network parameters: network name, network acronym, and subnetwork name; city A name, state, area code and exchange, and major access point identification; city B name, area code and exchange, and major access point identification; and link capacity between city A and city B. This primary database was used to identify major access points for the Current IRN.

11.3.3 Major Access Points

The major access points for the Current IRN are listed with their state and V & H coordinates in Exhibit 11-55. These major access points are: Albuquerque, Austin, Boston, Boulder, Chicago, Cleveland, Columbus, Dallas, Detroit, Houston, Huntsville, Indianapolis, Iowa City, Ithaca, Kansas City, Kennedy Space Center, Lincoln, Livermore, Los Angeles, Madison, Miama, Minneapolis, New York, Norfolk, Oak Ridge, Philadelphia, Pittsburgh, Portland, Princeton, Salt Lake City, San Diego, San Francisco, Seattle, Sate College, Tallahassee, Tucson, Urbana, Wallops Island, Washington, and White Sands. **(Next text on Page 71)**

EXHIBIT 11-1. NETWORKS SELECTED

1. Department of Defense (DOD) research networks:
   - Advanced Research Projects Agency Network (ARPANET)
   - Defense Research Internet (DRI)

2. National Science Foundation Network (NSFNET) - Three level network:
   - National backbone
   - Twenty-one mid-level networks
     - Thirteen Original Backbone and Regional Networks:
       - NORTHWESTNET, BARRNET, SDSCNET, WESTNET, USAN, MIDNET, SESQUINET, NCSNET, MERIT, PSCNET, NYSERNET, JVNCNET, SURANET.
     - Eight New Regional Network:
       - CERFNET, CICNET, LOS NETTOS, MRNET, NEARNET, OARNET, PREPNET, THENET.
   - Over 250 campus networks

3. National Aeronautics & Space Administration (NASA) research networks:
   - NASA Science Internet (NSI)
   - NASA Science Network (NSN)
   - Space Physics Analysis Network (SPAN)
   - Numerical Aerodynamics Simulation Network (NASNET)
   - NASA Communications (NASCOM)

4. Department of Energy (DOE) research networks:
   - Energy Science Network (ESNET)
   - Magnetic Fusion Energy Network (MFENET)
   - High Energy Physics Network (HEPNET)
   - LEP3NET (A Cern Accelerator Experiment Network)
   - OPMODEL

5. BITNET (Before Its Time Network) and
   CSNET (Computer + Science Network)

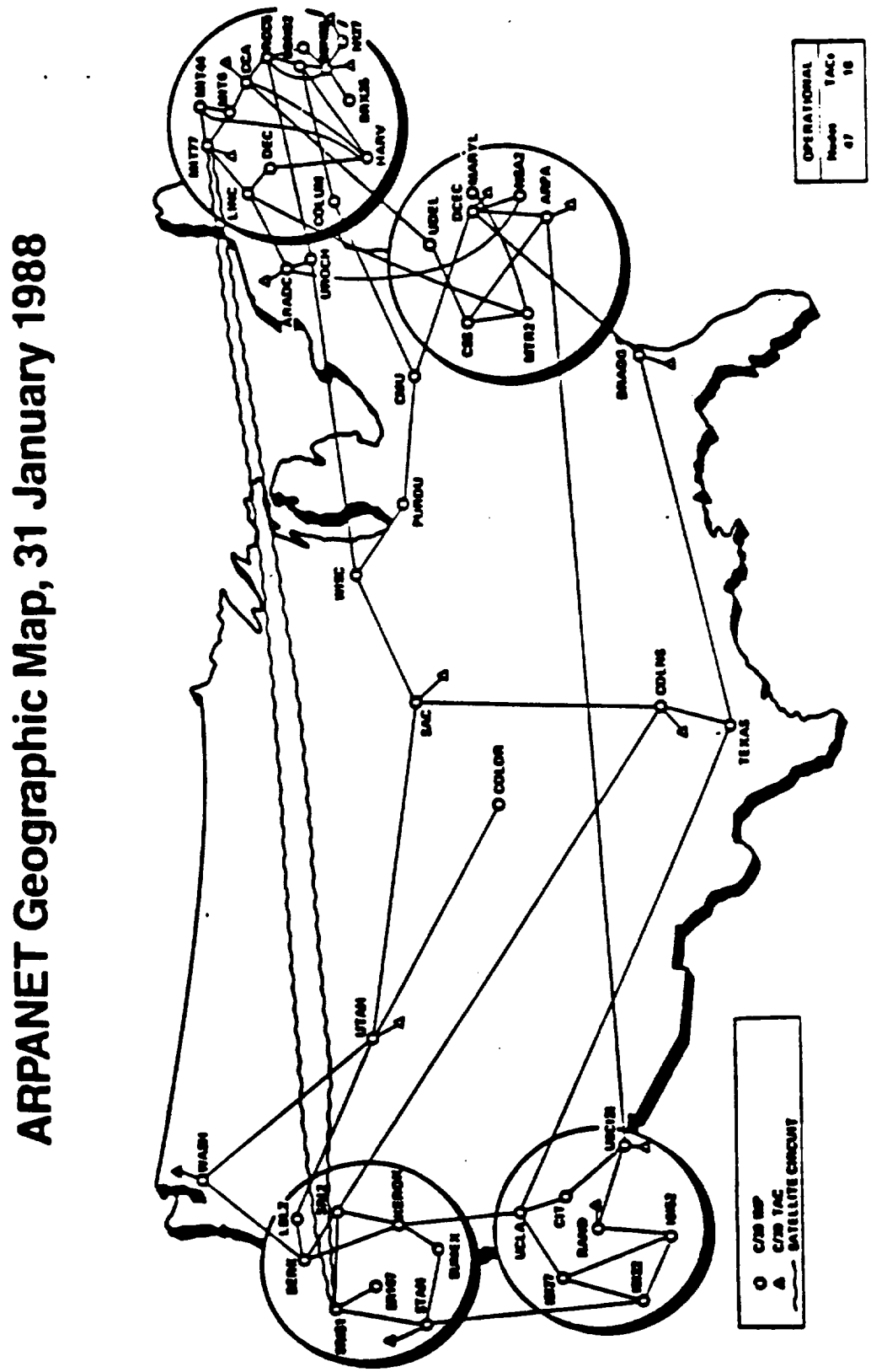


EXHIBIT 11-2. ARPANET Topology (January 31, 1988)

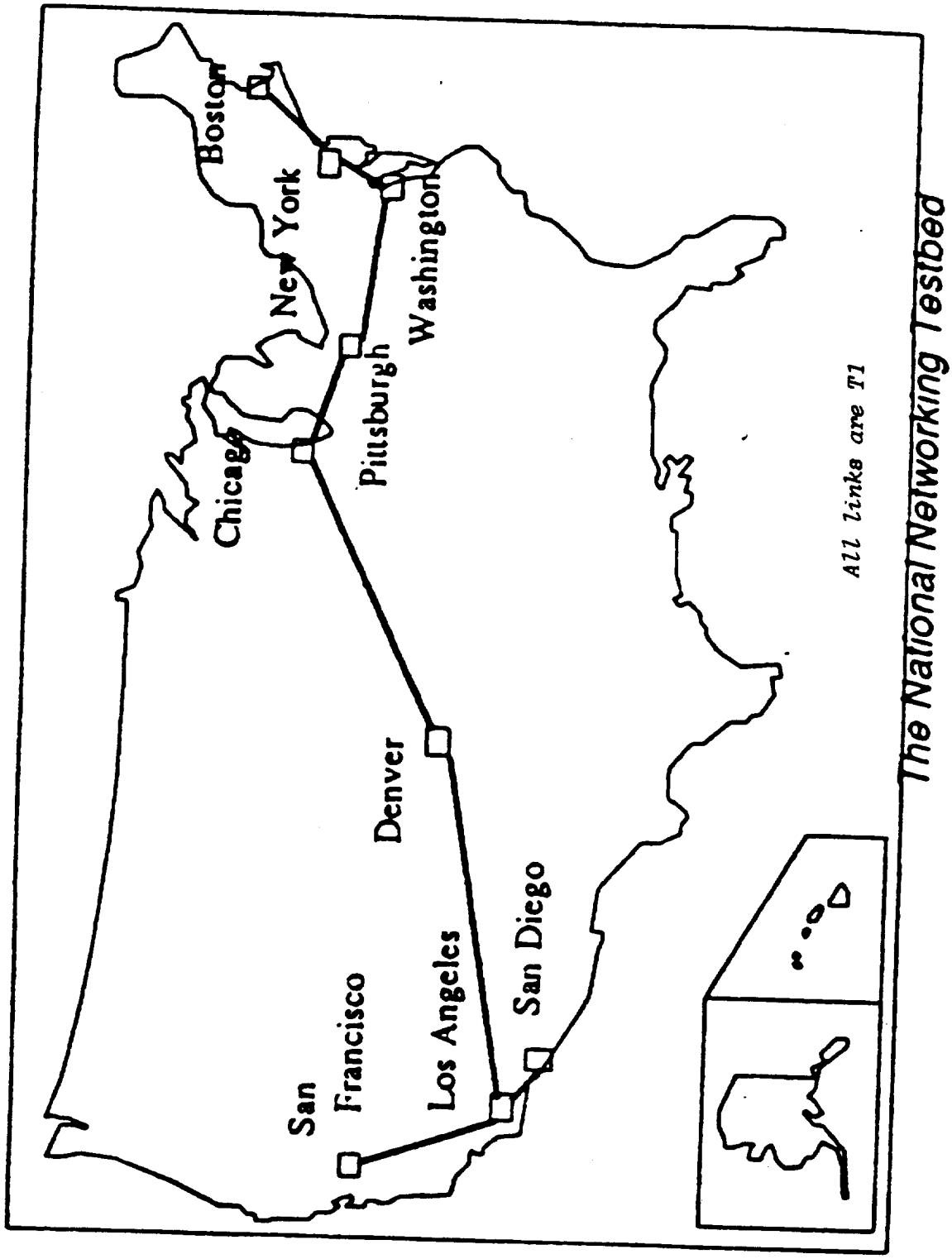


EXHIBIT 11-3. Current NNT Topology

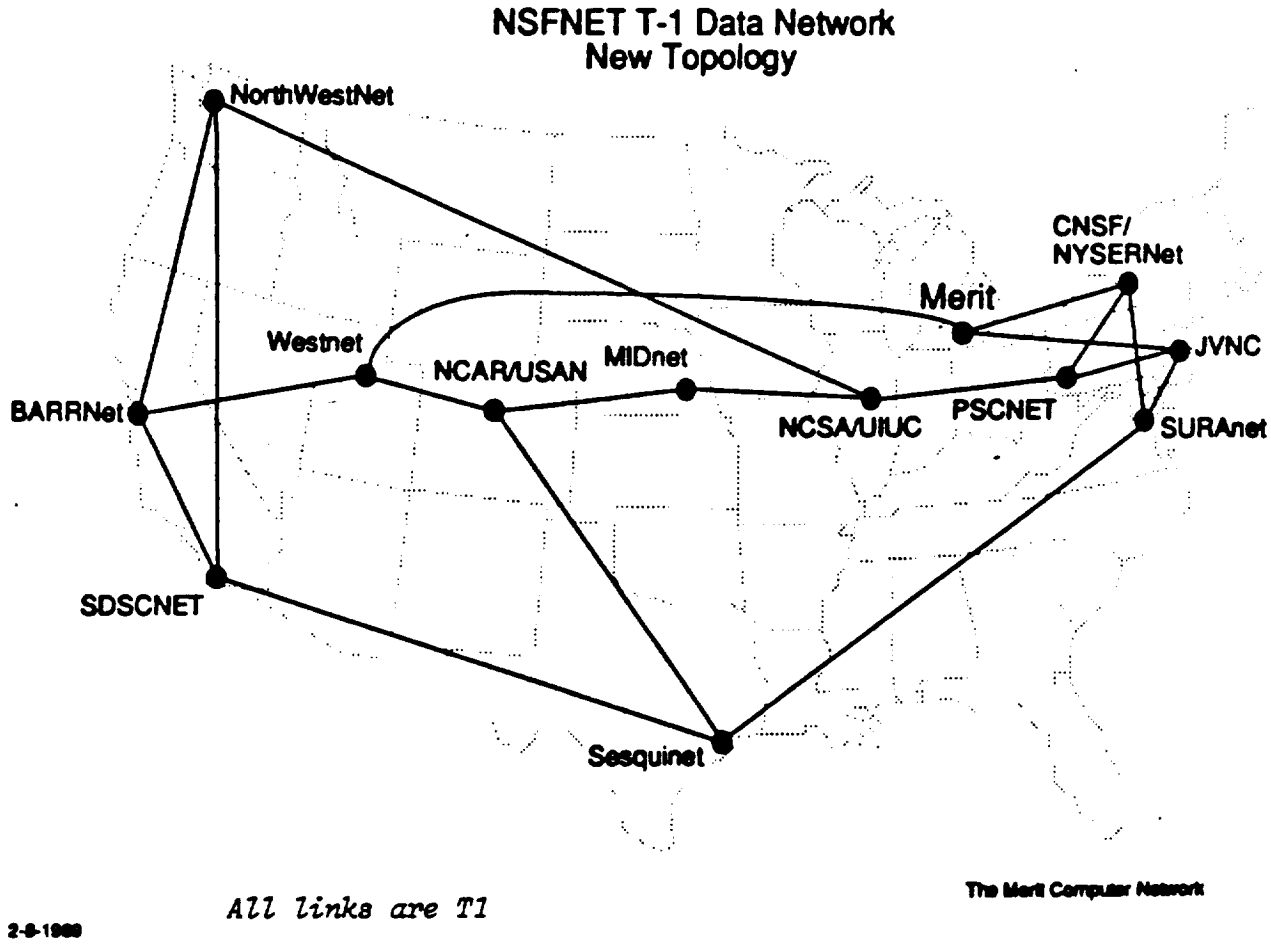


EXHIBIT 11-4. Overall NSFNET Topology

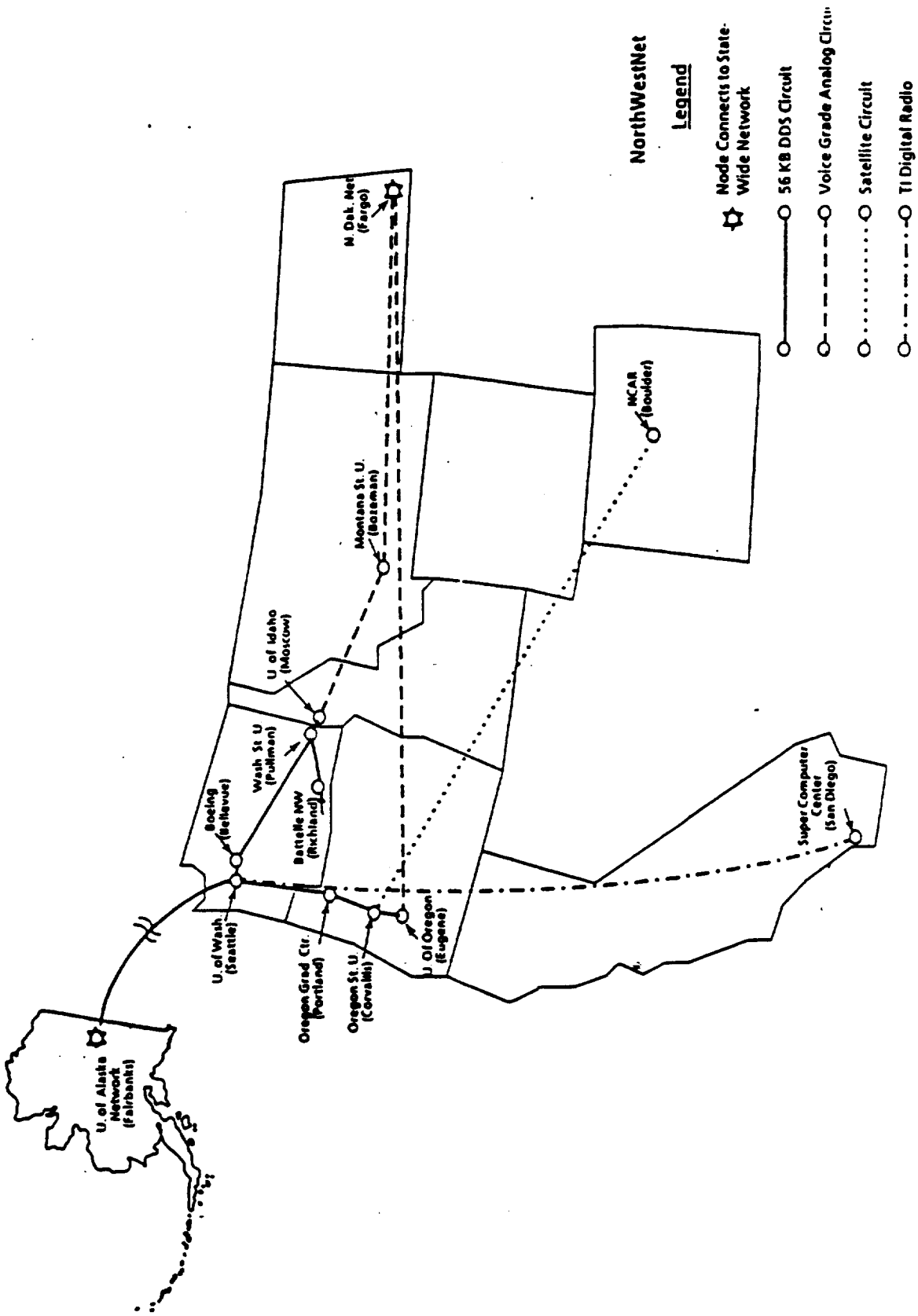


EXHIBIT 11-5. NORTHWESTNET Topology

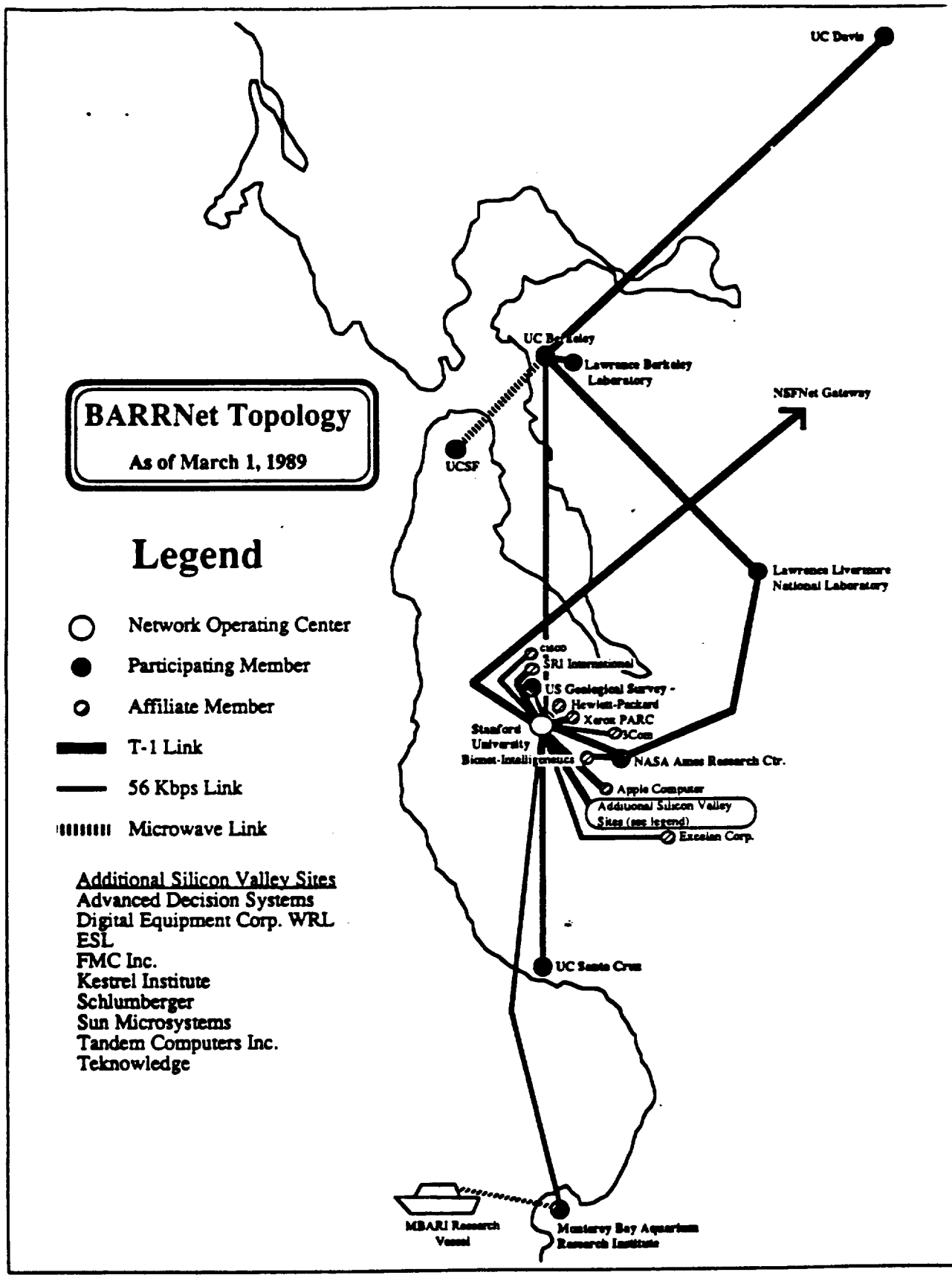


EXHIBIT 11-6. BARRNET Topology

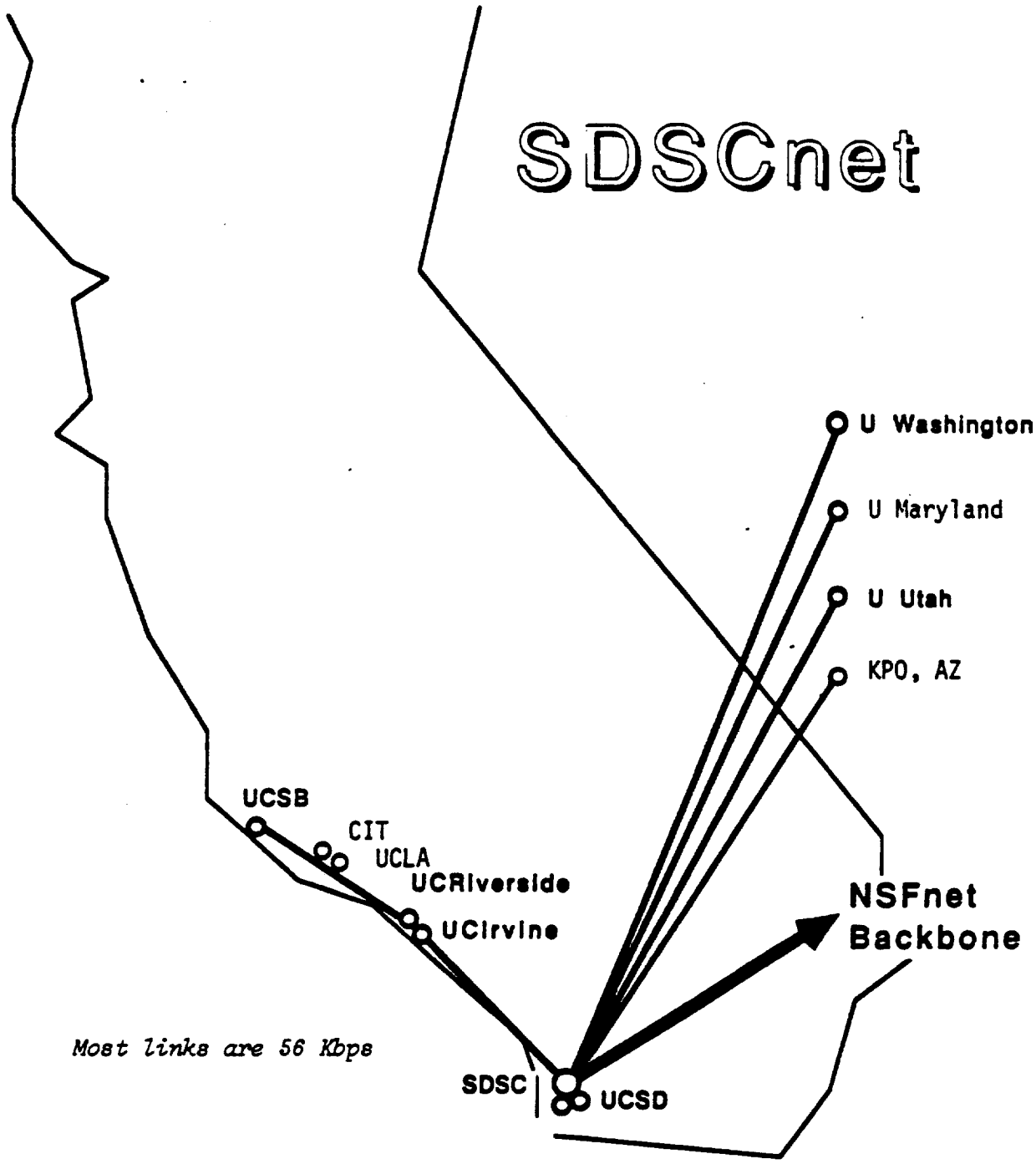
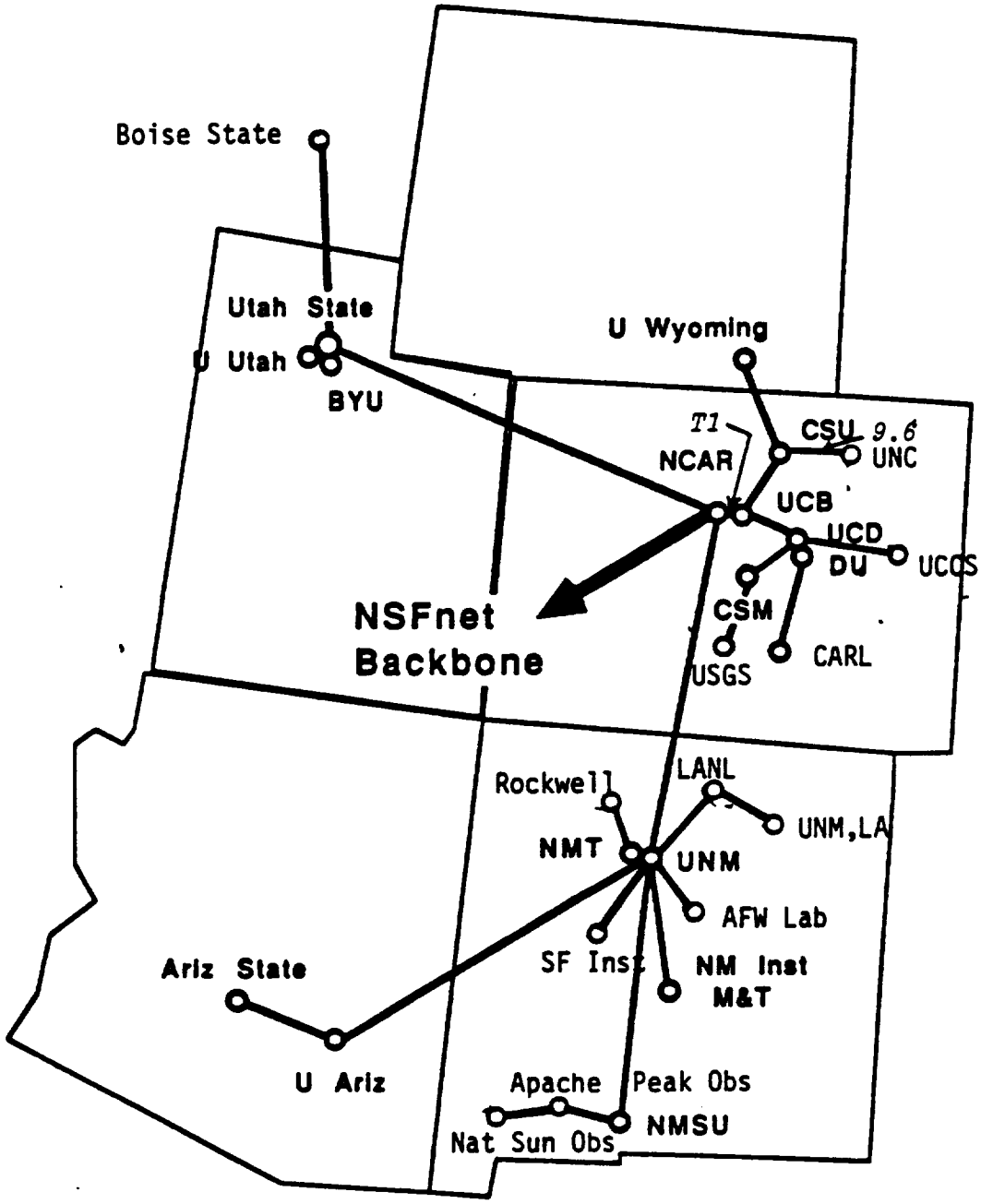


EXHIBIT 11-7. SDSCNET Topology

WestNet



All links are 56 Kbps, except as noted

EXHIBIT 11-8. WESTNET Topology

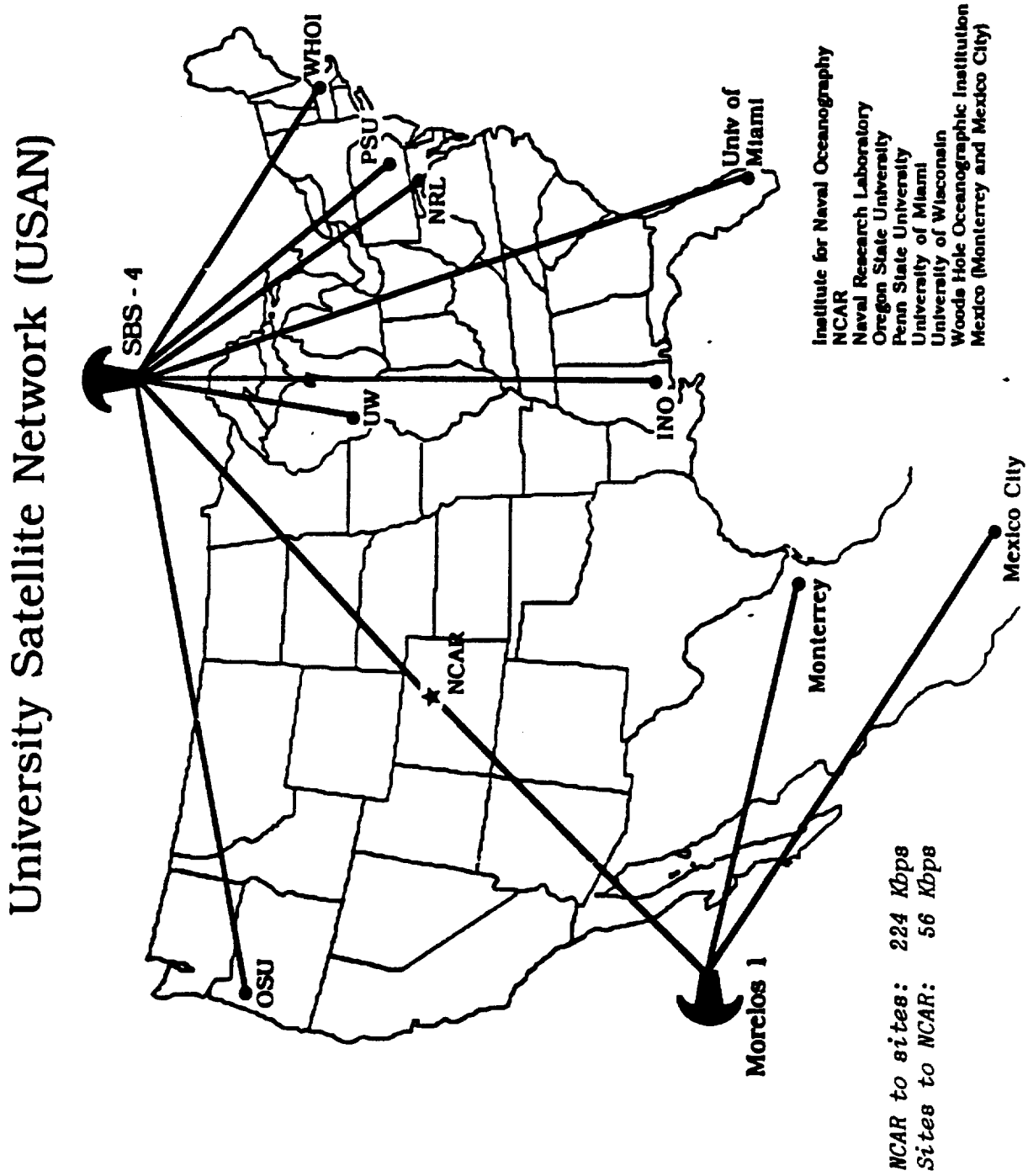


EXHIBIT 11-9. USAN Topology

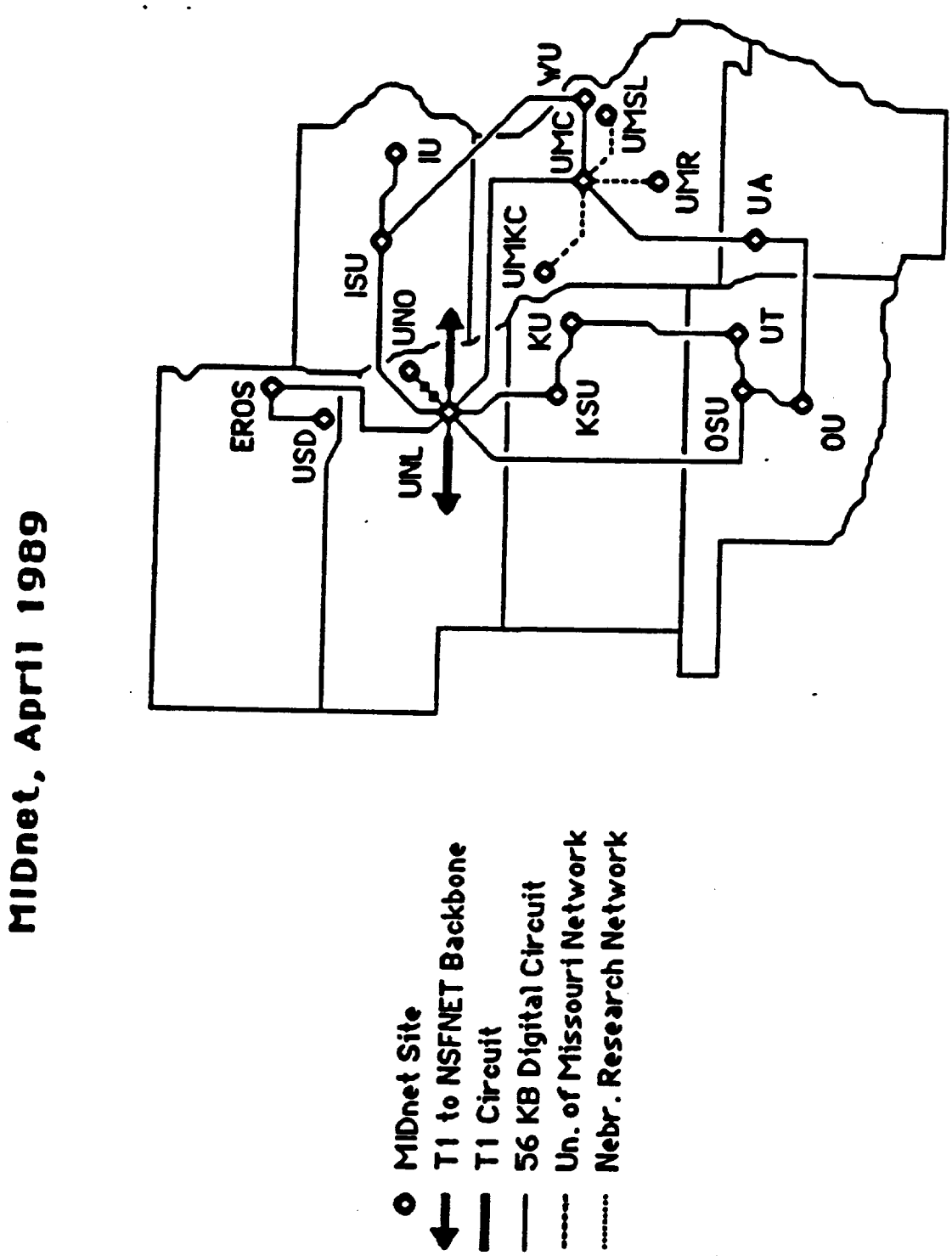


EXHIBIT 11-10. MIDNET Topology

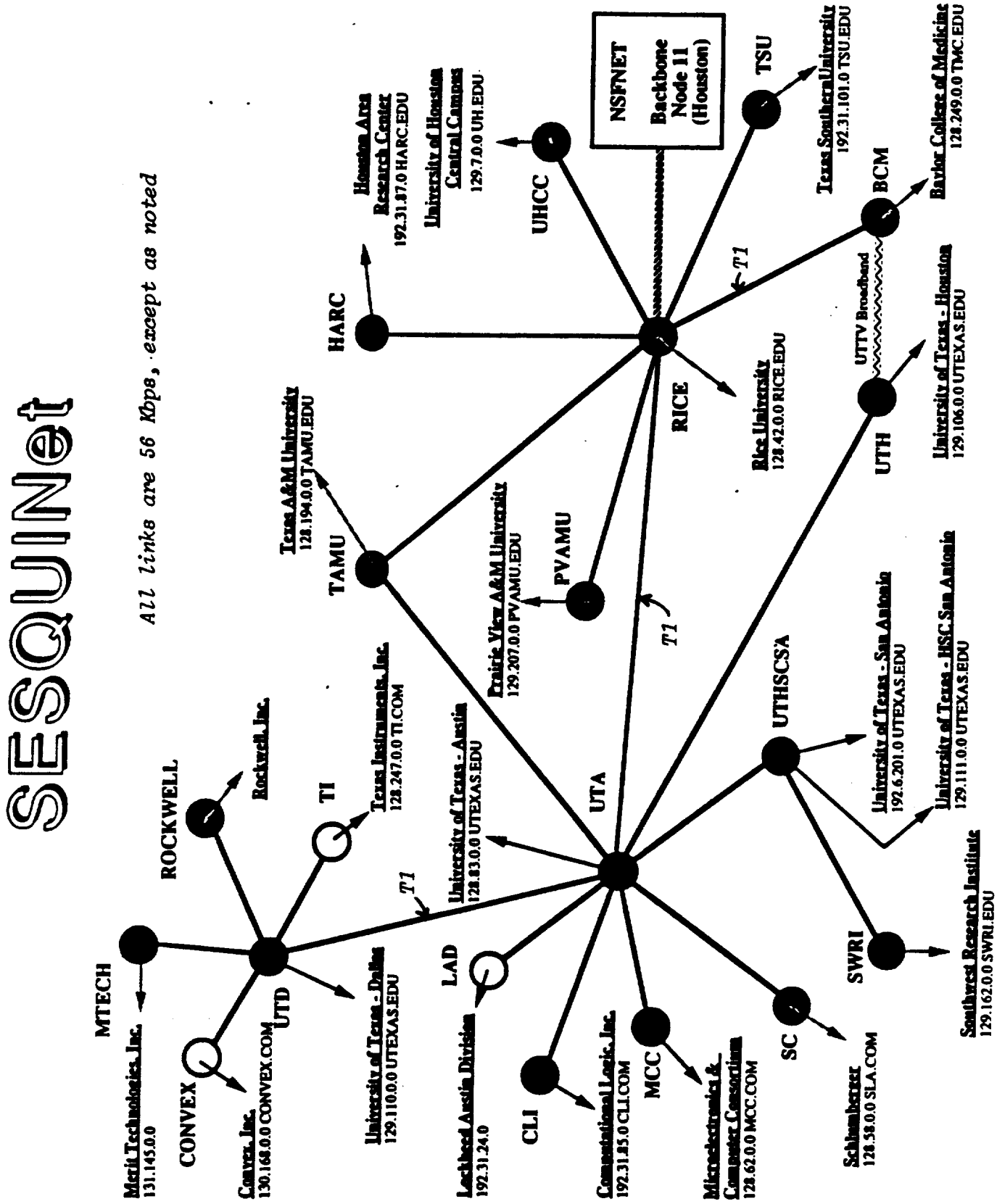


EXHIBIT 11-11. SESQUINET Topology

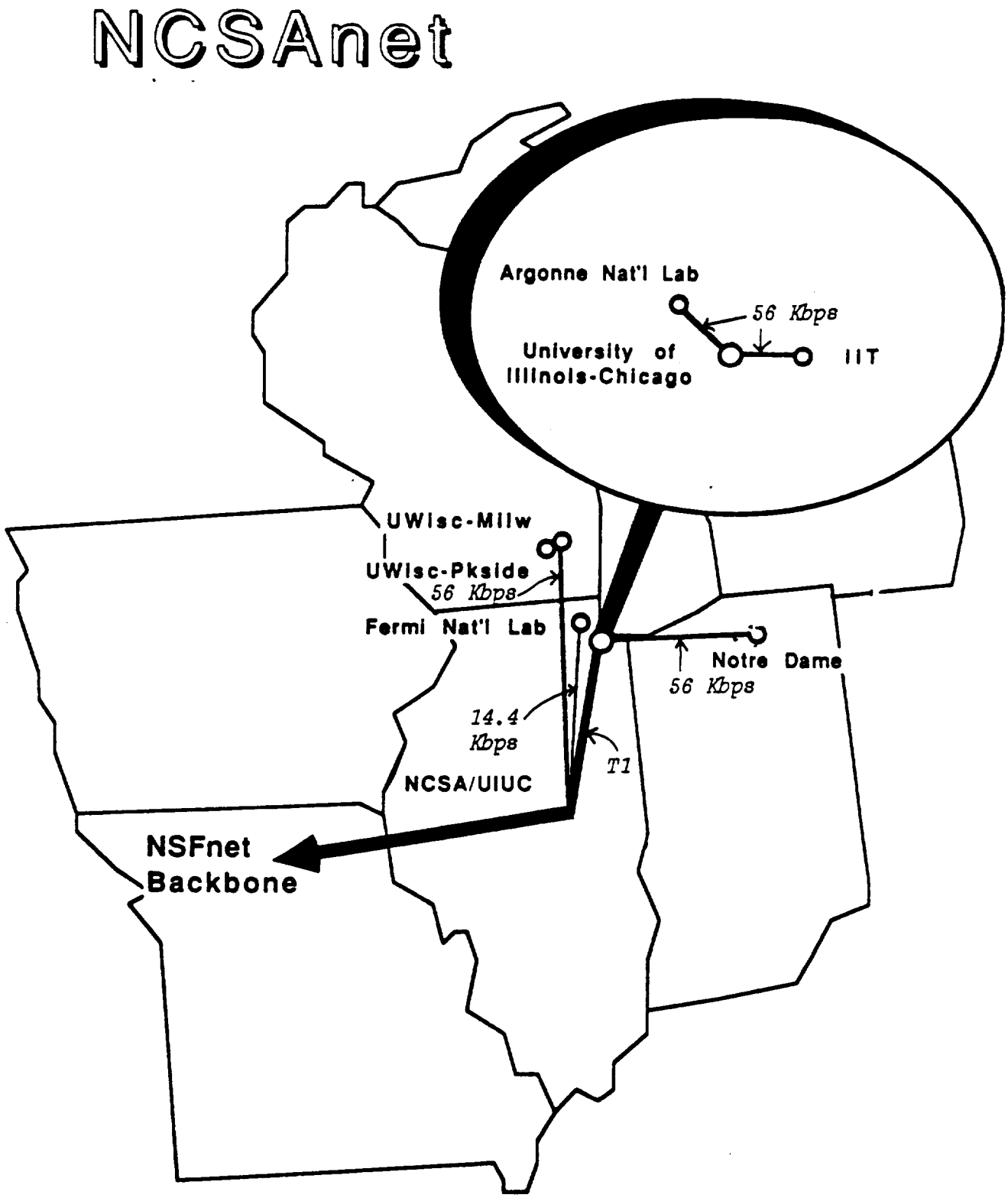
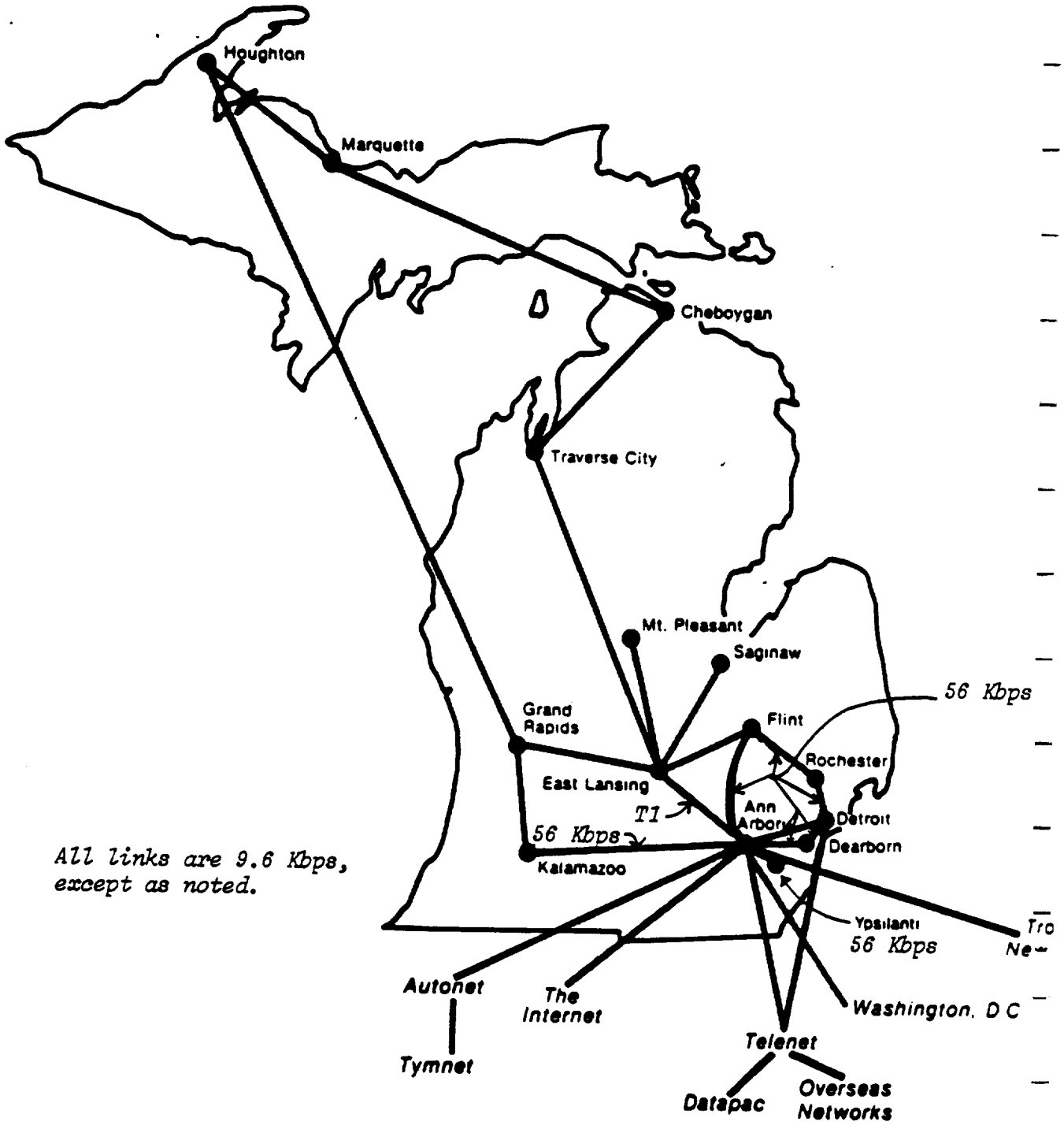


EXHIBIT 11-12. NCSNET Topology



All links are 9.6 Kbps, except as noted.

EXHIBIT 11-13. MERIT Topology

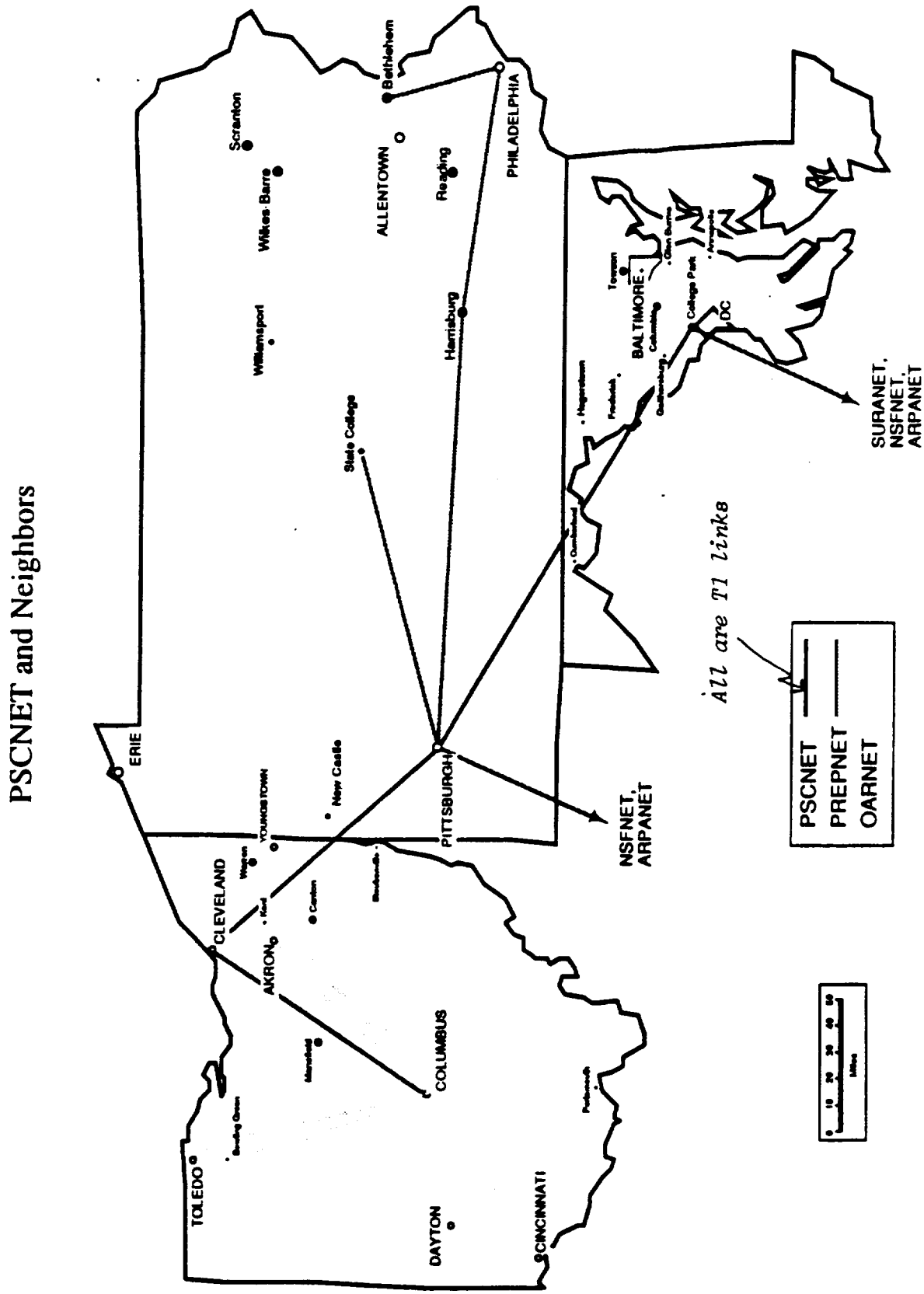


EXHIBIT 11-14. PSCNET Topology

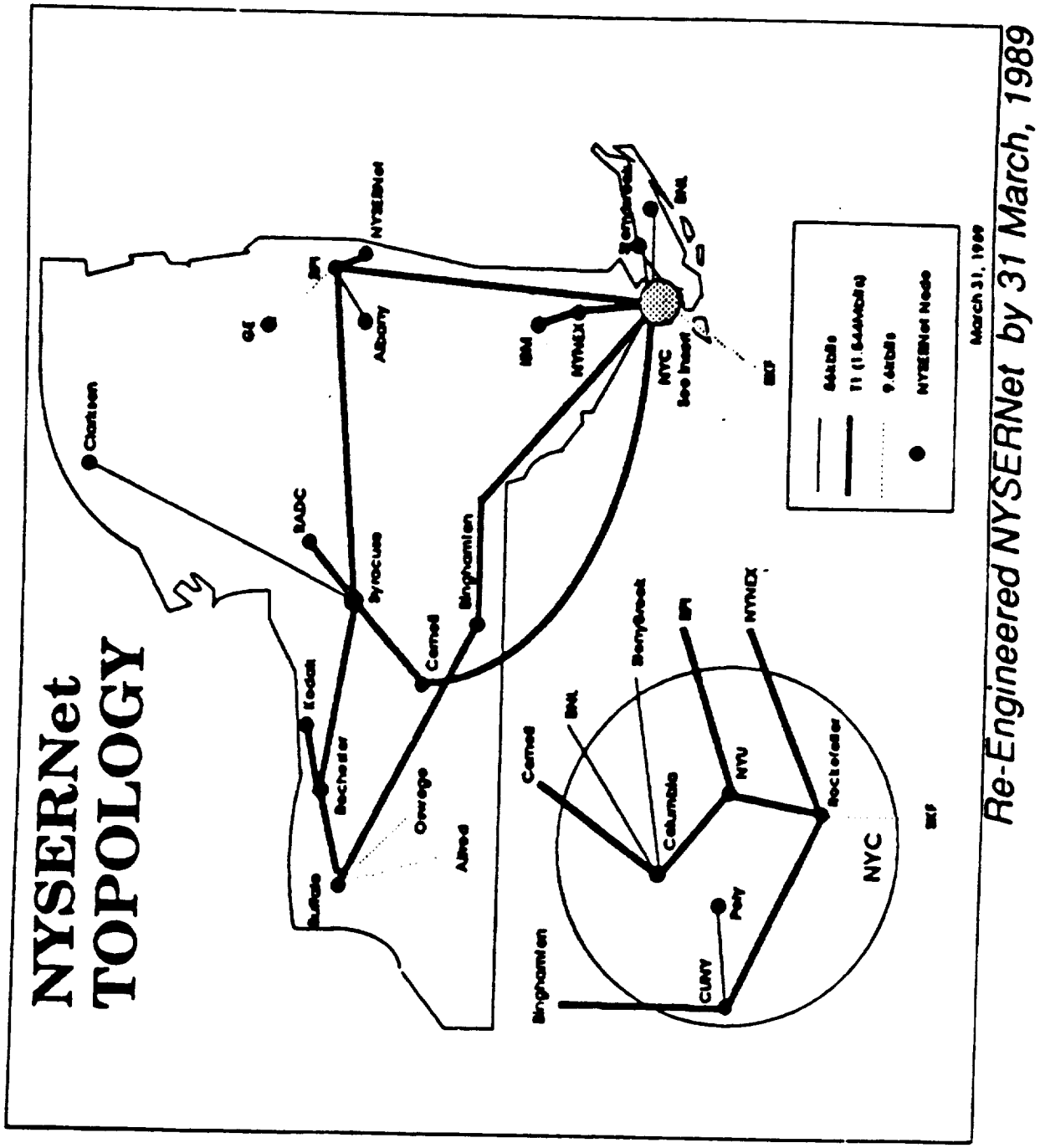


EXHIBIT 11-15. NYSERNET Topology

C-4

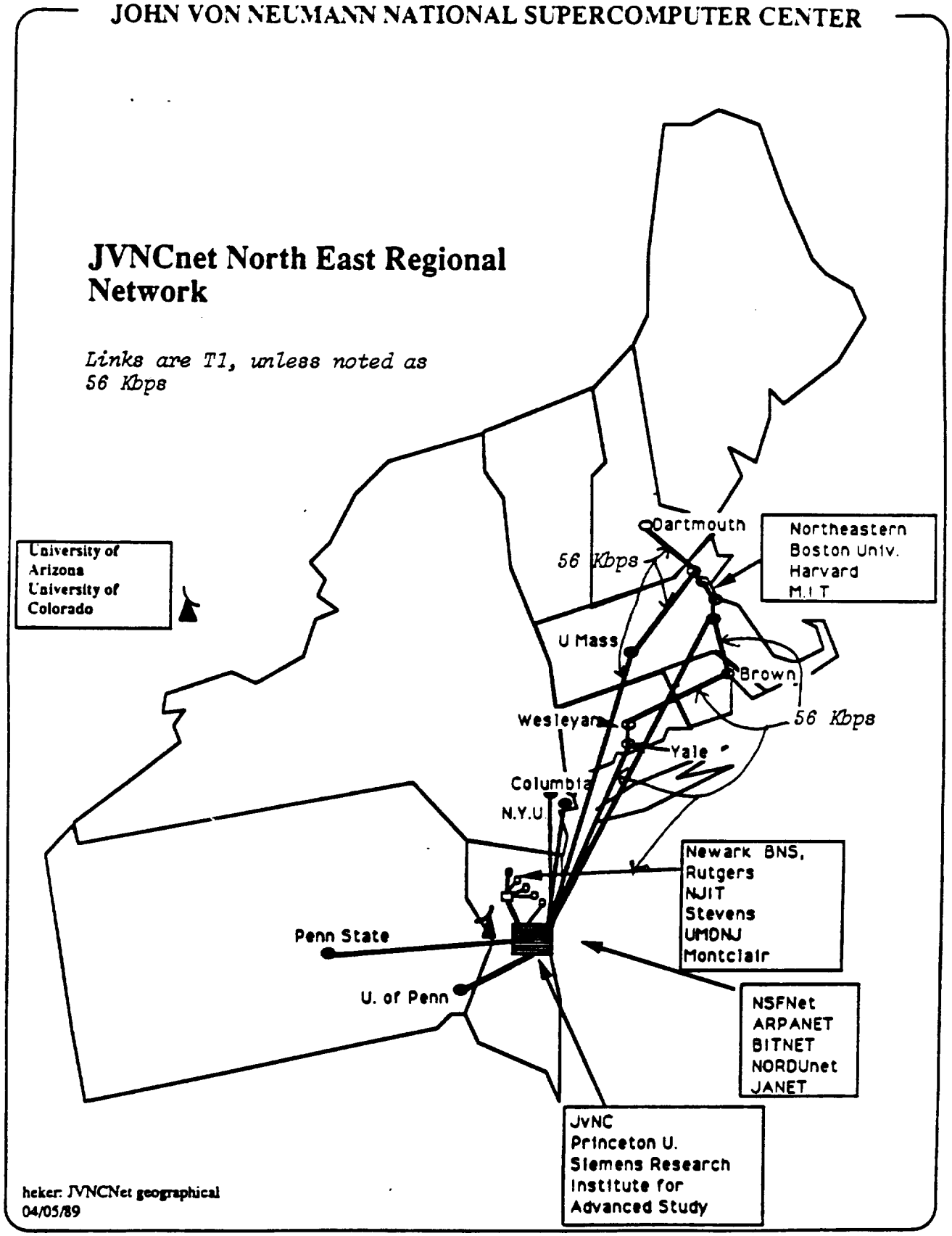


EXHIBIT 11-16. JVNCNET Topology

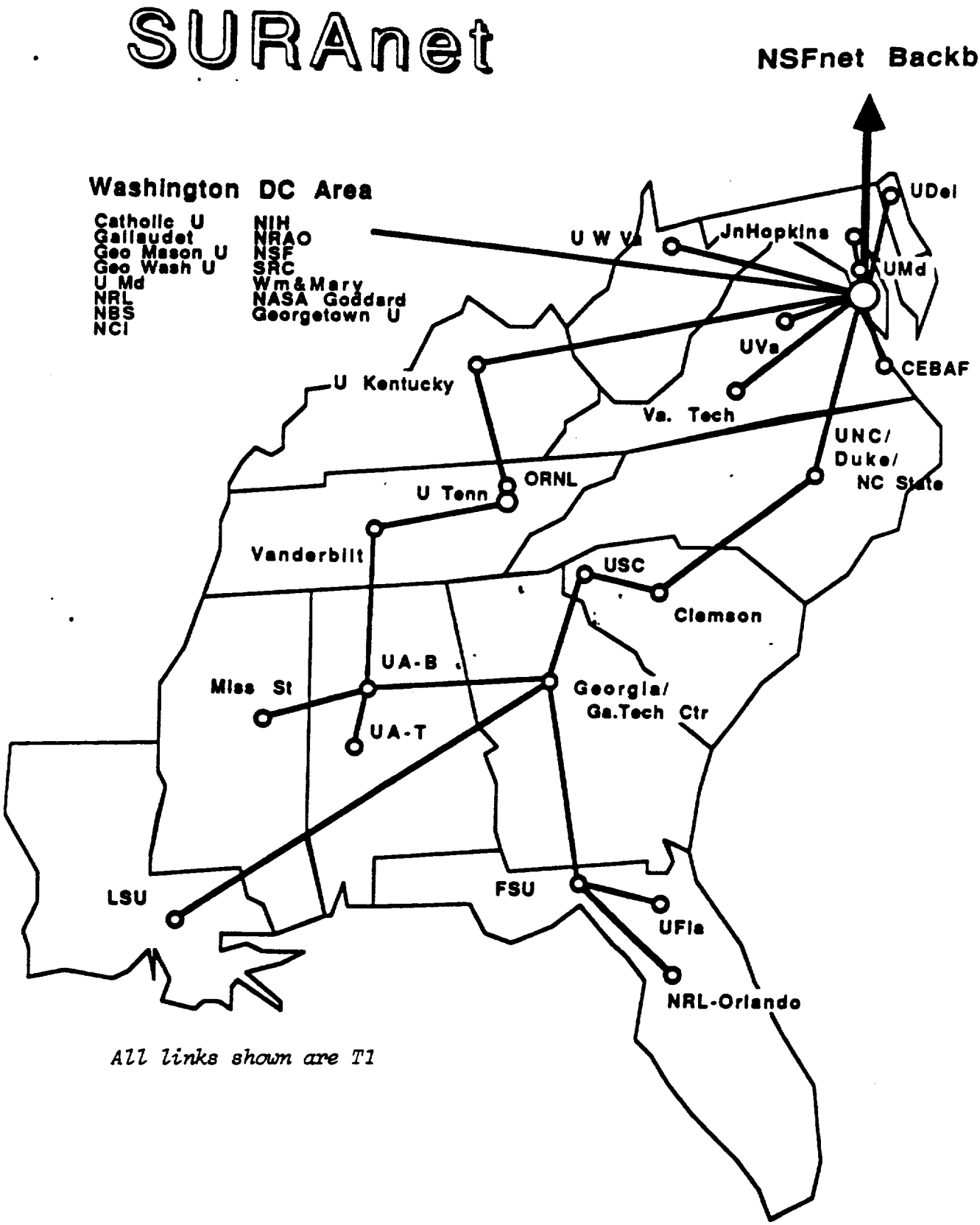


EXHIBIT 11-17. SURANET Topology

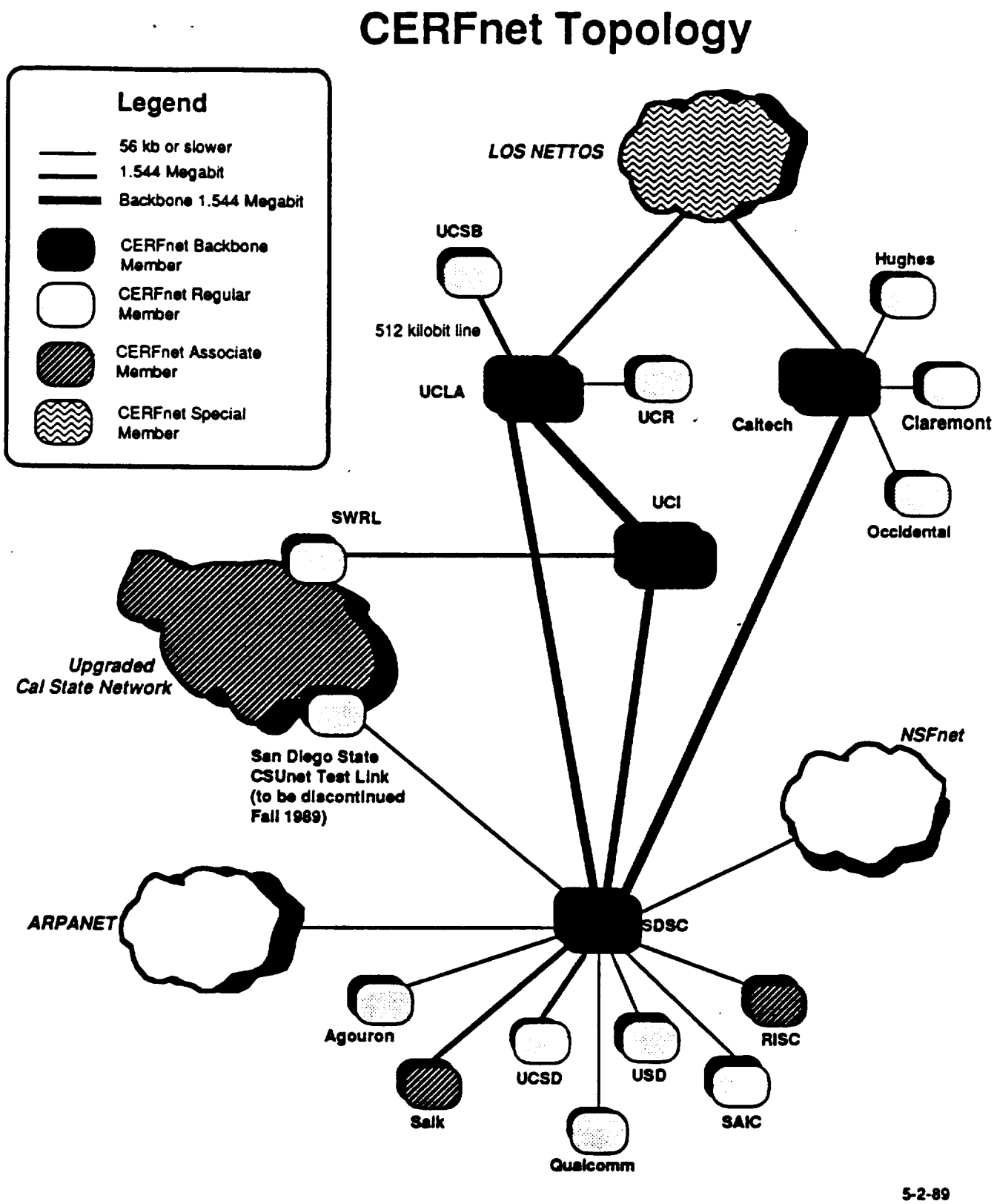


EXHIBIT 11-18. CERFNET Topology

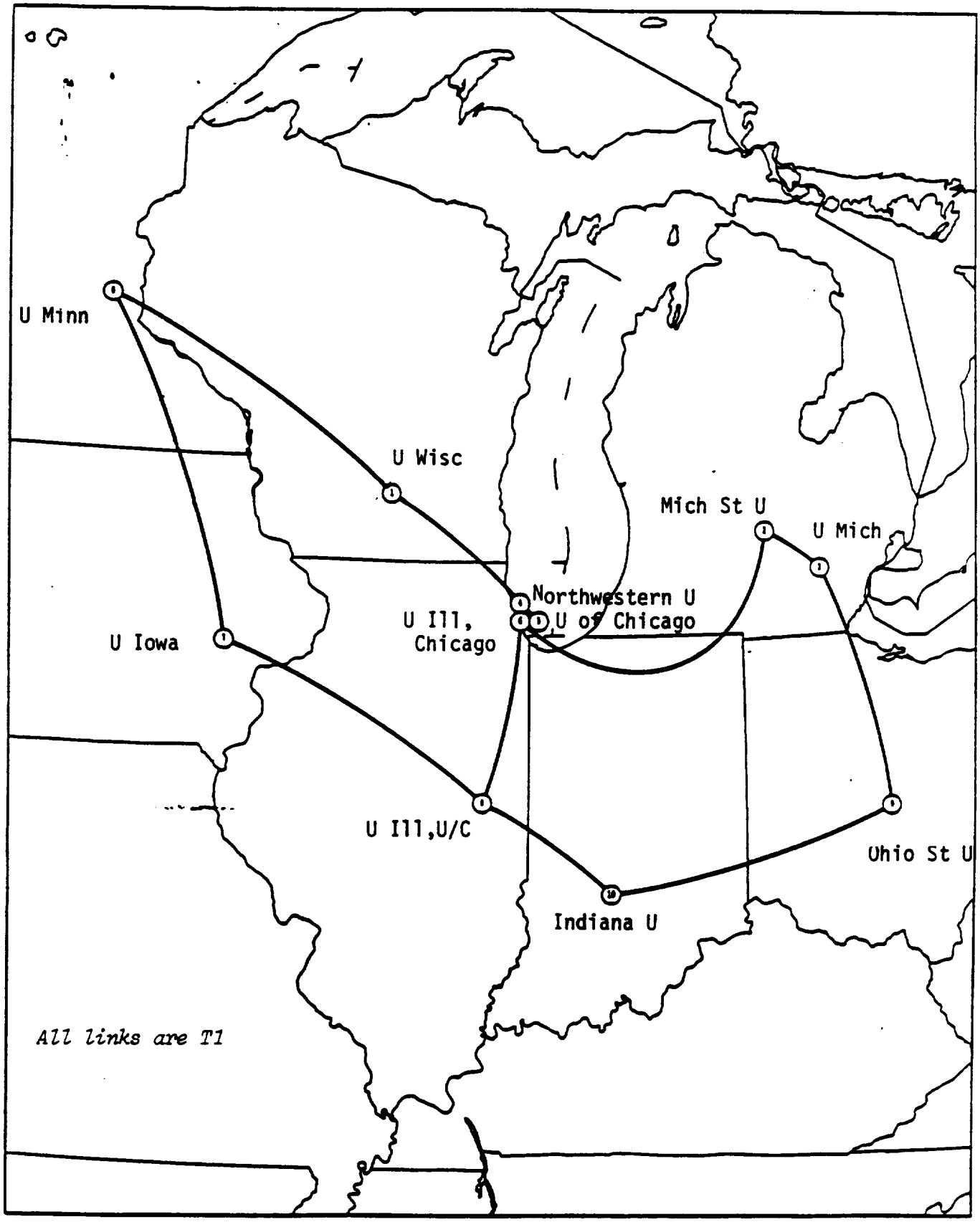


EXHIBIT 11-19. CICNET Topology

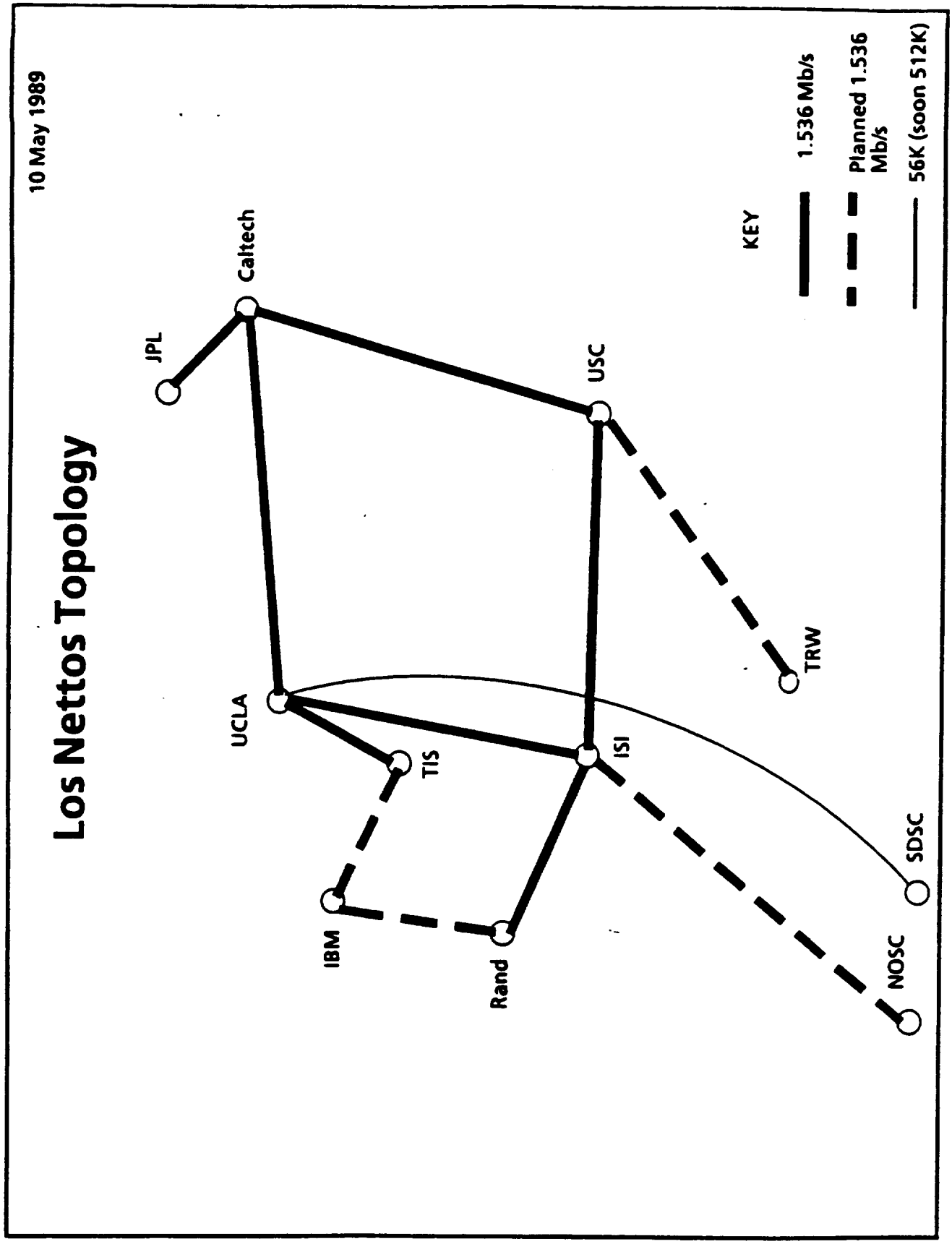
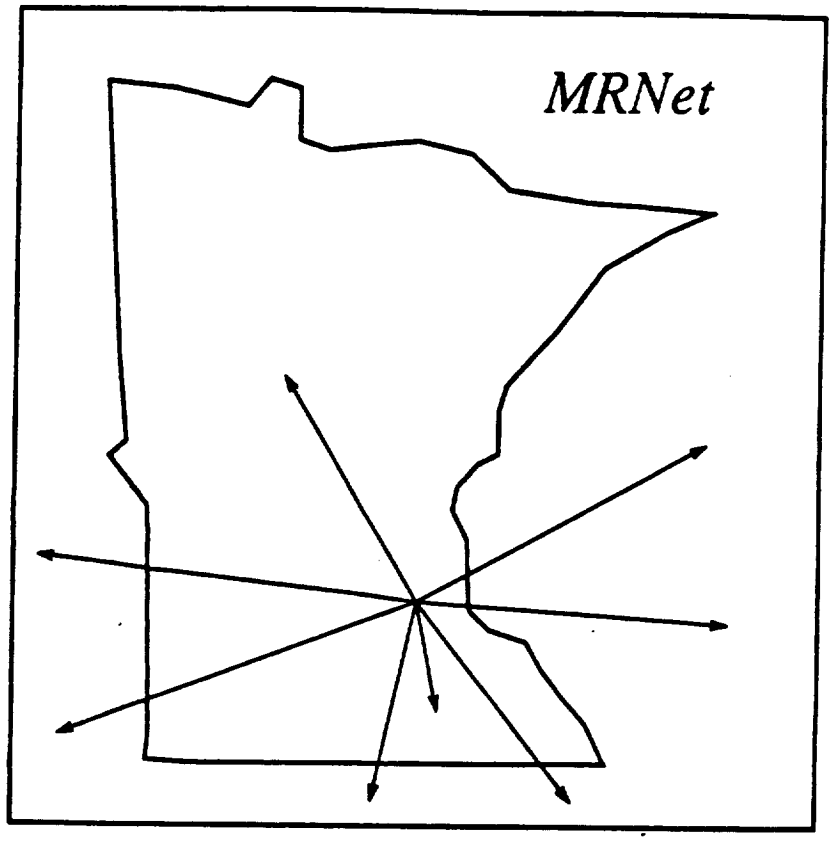
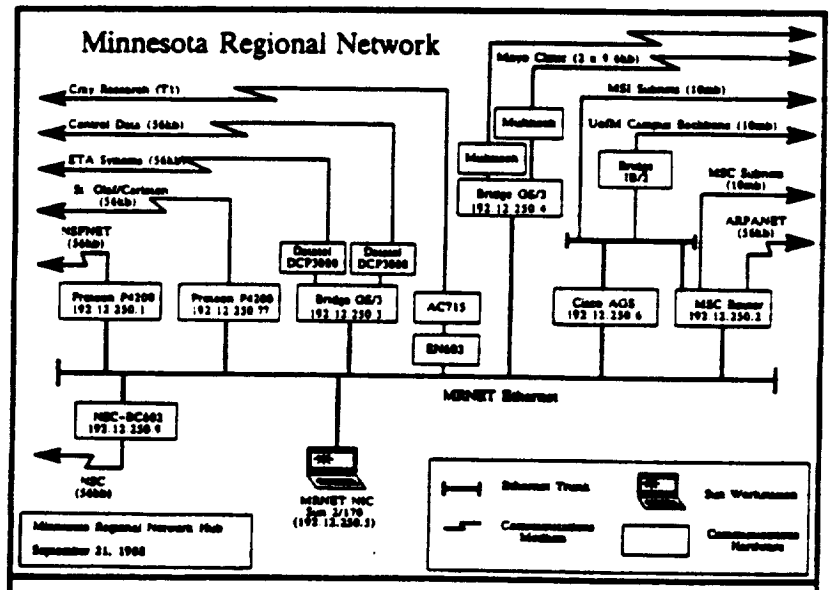


EXHIBIT 11-20. LOS NETTOS Topology





Topology of the MRNet network. Currently, members are responsible for providing their own communication lines and equipment to connect to the hub. Various connection schemes are pos-

EXHIBIT 11-21. MRNET Topology

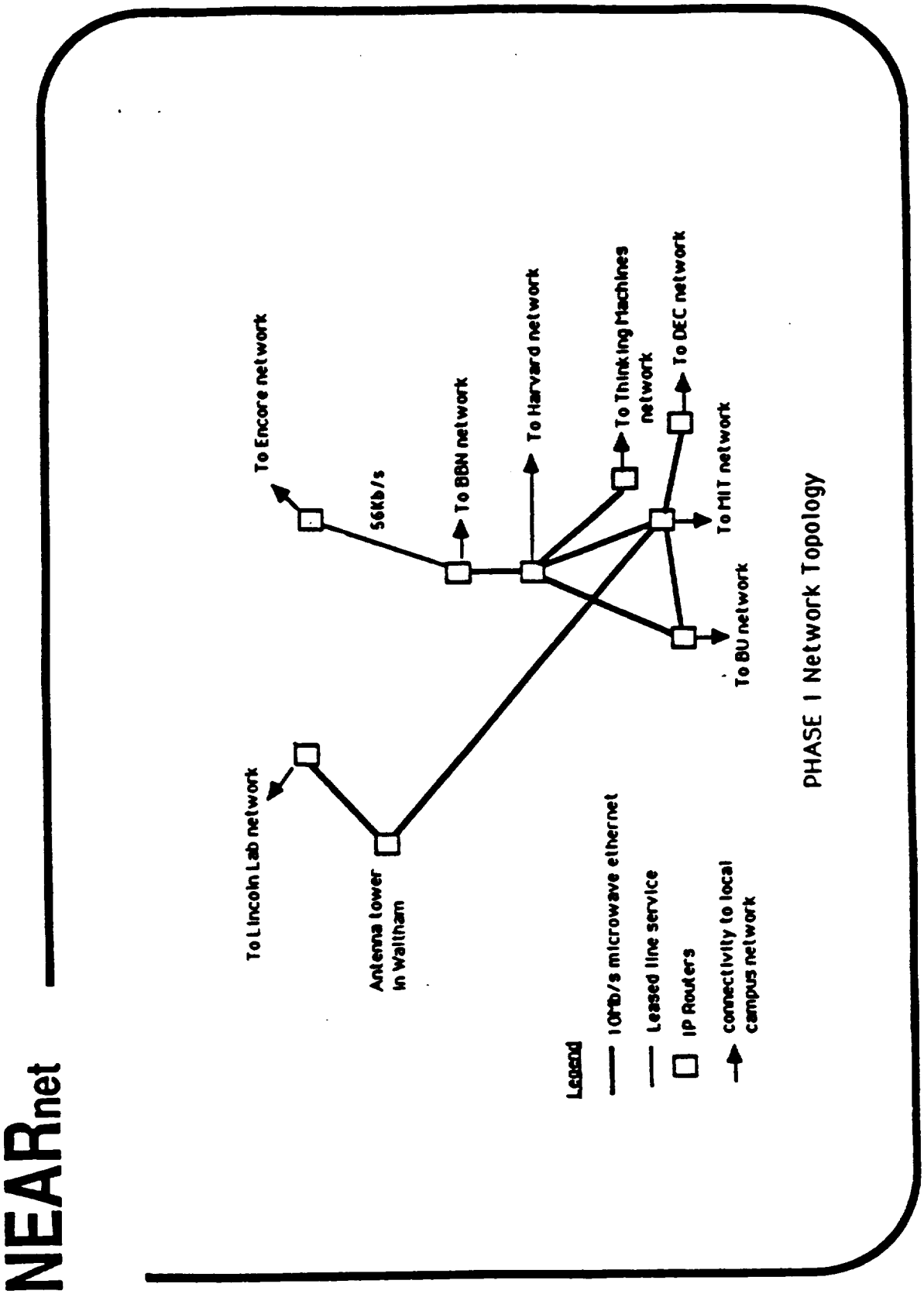


EXHIBIT 11-22. NEARNET Topology

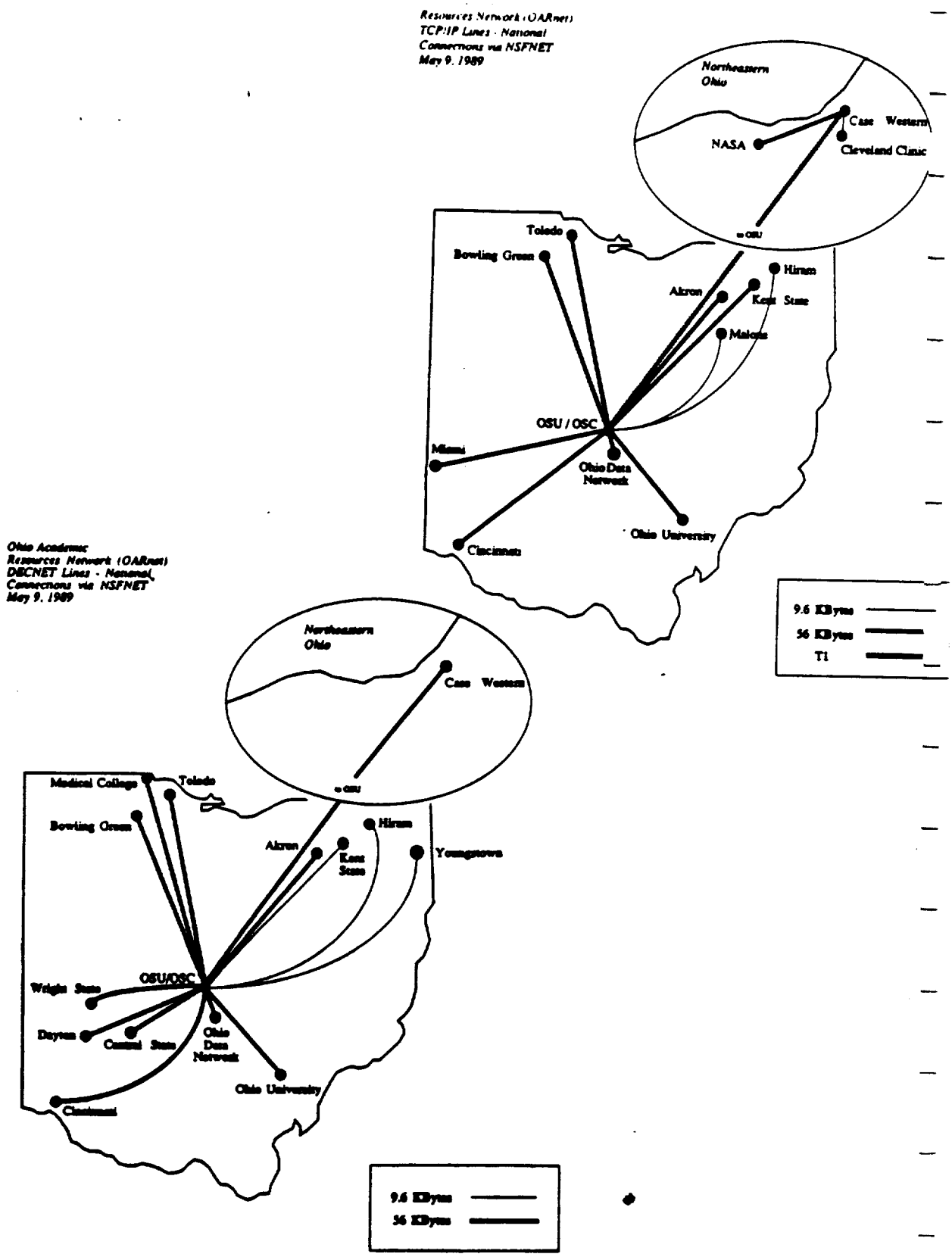


EXHIBIT 11-23. OARNET Topology

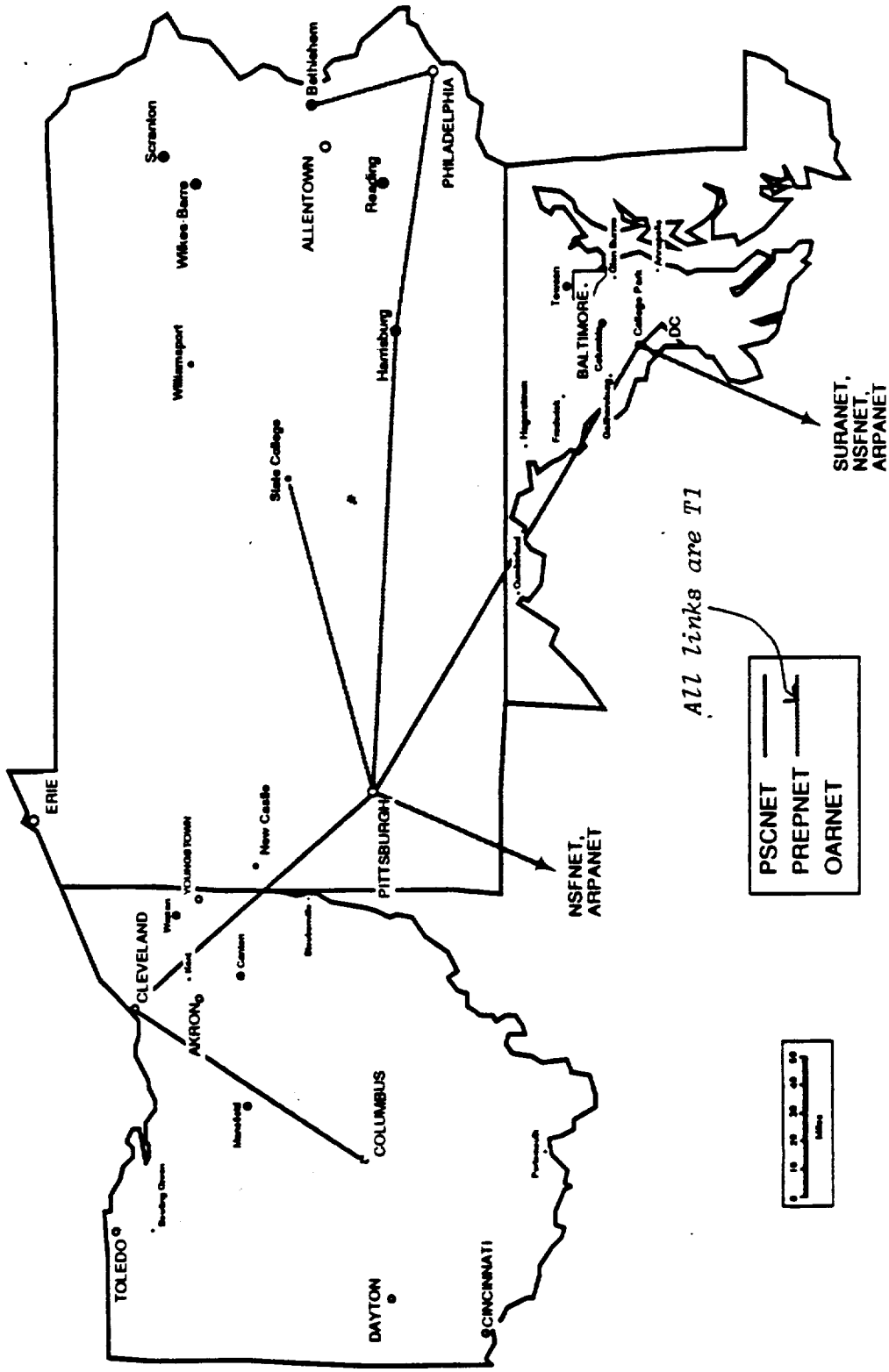
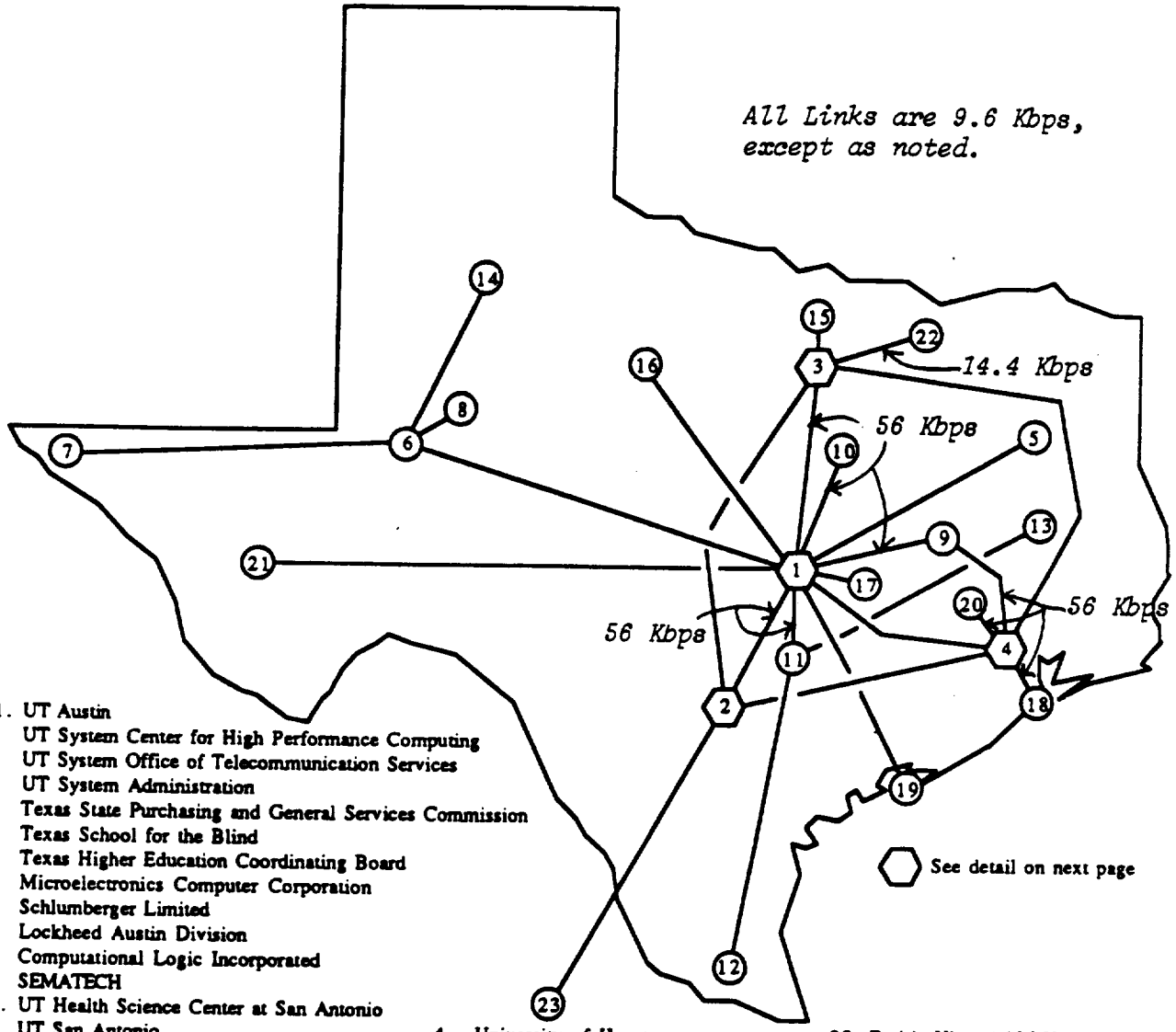


EXHIBIT 11-24. PREPNET Topology

Texas Higher Education Network (THEnet)



1. UT Austin
   UT System Center for High Performance Computing
   UT System Office of Telecommunication Services
   UT System Administration
   Texas State Purchasing and General Services Commission
   Texas School for the Blind
   Texas Higher Education Coordinating Board
   Microelectronics Computer Corporation
   Schlumberger Limited
   Lockheed Austin Division
   Computational Logic Incorporated
   SEMATECH
2. UT Health Science Center at San Antonio
   UT San Antonio
   Wilford Hall Medical Center
   Brooke Army Medical Center
   Brooks School of Aerospace Medicine
   Southwest Research Institute
   St. Mary's University
3. UT Dallas
   UT Southwestern Medical Center at Dallas
   UT Arlington
   Texas Christian University
   Merit Technology Incorporated
   Texas Instruments Incorporated
   Rockwell International
   Convex Computer Corporation
4. UT Health Science Center at Houston
   UT M.D. Anderson Cancer Center
   Texas Cancer Data Center
   Houston Area Research Center
4. University of Houston
   Rice University
5. UT Health Center at Tyler
   UT Tyler
6. UT Permian Basin
7. UT El Paso
8. UT West Texas Lands Management
9. Texas A&M University
10. Baylor University
11. Southwest Texas State University
12. Pan American University
13. Sam Houston State University
14. Texas Tech University
15. Univerisity of North Texas
16. Abilene Christian University
17. UT M.D. Anderson Cancer Center Science Park
18. UT Medical Branch Galveston
19. UT Marine Science Institute
20. Prairie View A&M University
21. UT McDonald Observatory
22. East Texas State University
23. Instituto Tecnológico y de Estudios Superiores de Monterrey

890309

EXHIBIT 11-27. THENET Topology

EXHIBIT 11-26. Campus Area Networks

NORTHWESTNET
Alaska, University System
Battelle (Richland)
Boeing Computer System
Idaho, U of
Montana State U
N. Dakota Higher Educ.
Oregon, U of
Oregon, Graduate Center
Oregon State U
Washington, U of
Washington State U

BARRNET
Advanced Decision Systems
Apple Computer Corp.
Bionet/Intelligenetics
Cal State Sacramento
CA, U of, Berkeley
CA, U of, Davis
CA, U of, San Francisco
CA, U of, Santa Cruz
cisco Systems, Inc.
ESL (TRW)
Excelen
FMC Inc.
Hewlett Packward Labs
Kestrel Institute
Lawrence Berkeley Lab
Lawrence LIvermore Nat'l Lab
Monterey Bay Research
NASA Ames Research Center
SRI Internat.
Stanford U
Sun Microsystems
Tandem Computers Inc.
Teknowledge
US Geological Survey
Xerox PARC
3Com

SDSCNET
Agoron Institute
Calif. Institute of Tech
CA. U of, Irvine
CA, U of, Riverside
CA, U of, Santa Barbara
CA, U of, San Diego
CA, U of, Los Angeles
Hughes Network Systems
Kit Peak Observatory, AZ
Maryland, U of
San Diego Supercomputer Center
San Diego State University

SDSCNET (Cont.)
Scripps Institute
Utah, U of
Washington, U of

WESTNET
Air Force Weapons Lab
Apache Point Observatory
Arizona, U of
Arizona State U
Boise State U
Brigham Young U
Colorado Alliance of Res Lib.
Colorado, U of, Boulder
Colorado, U of, Col Spr
Colorado, U of, Denver
Colorado, U of No.
Colorado School of Mines
Colorado State U
Denver U
Ford Aerospace
Los Alamos Nat Lab
NCAR
Nat Sunspot Observatory
New Mexico Institute of Min/Tech
New Mexico Technet
New Mexico, U of
New Mexico, U of, Los Alamos
New Mexico State U
Rockwell International
Sante Fe Institute
Utah, U of
Utah State U
U.S. Geological Survey
Wyoming, U of

USAN
Institute for Naval Ocean.
Miami, U of
NCAR
Naval Res Lab
Oregon State U
Penn State U
Wisconsin, U of
Woods Hole Ocean. Institution

MIDNET
Arkansas, U of
EROS Data Center
Iowa State U
Iowa, U of
Kansas State U
Kansas, U of
Missouri, U of, Columbia

EXHIBIT 11-26. Campus Area Networks

(Continued)

MIDNET (Cont.)
Missouri, U of, Kansas City
Missouri, U of, Rolla
Missouri, U of, St Louis
Nebrasks, U of, Lincoln
Nebrasks, U of, Omaha
Oklahoma State U
Oklahoma, U of
South Dakota, U of
Tulsa, U of
Washington U

SESQUINET
Baylor College of Medicine
Computational Logic, Inc
Convex, Inc
Houston Area Research Center
Houston, U of
Lockhead Austin Div
Merit Technologies
Microelectronics & Computer Cons.
Prairie View A&M U
Rice U
Rockwell, Inc.
Schlumberger
Southwest Research Institute
Texas A & M U
Texas Southern U
Texas, U of, Austin
Texas, U of, Dallas
Texas, U of, HSC San Antonio
Texas, U of, Houston
Texas, U of, San Antonio
Texas Instruments

NCSANET
Argone Nat'l Lab
Fermi Nat'l Lab
Ill, U of, Chicago
NCSA/U of Ill
Notre Dame U
Wisc, U of, Milwaukee
Wisc, U of, Parkside

MERIT
Ann Arbor
Cheboygen
Dearborn
Detroit
East Lansing
Flint
Grand Rapids
Houghton

MERIT (Cont.)
Kalamazoo
Marquett
Mt Pleasant
Rochester
Saginaw
Telenet
Traverse City
Troy, NY
Tymnet
Washington, DC
Ypsilanti

PSCNET
Maryland, U of
NASA Lewis
Ohio State U
Pittsburgh Supercomputer Center

NYSERNET
Alfred U
Brookhave Nat Lab
City U of NY
Clarkson U
Columbia U
Cornell U
Eastman Kodak
General Electric
Hartford Grad Center
IBM
New York U
NYNEX Sci & Tech
Polytechnic U
Rensselaer Polytechnic Inst.
Rochester, U of
Rockfeller U
Rome Air Devop Center
SmithKline & French
SUNY Albany
SUNY Binghamton
SUNY Buffalo
SUNY Oswego
SUNY Stony Brook
Syracuse U

JVNCNET
Arizona, U of
Bellcore
Bell Labs
Boston U
Brown U
Colorado U
Columbia U

EXHIBIT 11-26. Campus Area Networks

(Continued)

JVNCNET(Cont.)
Dartmouth U
Harvard U
Massachusetts, U of
MIT
New York U
NJIT
Northeastern U
Penn State U
Penn, U of
Princeton U
Rutgers U
Siemens Corp
Stevens Inst. of Tech
Wesleyan U
Yale U

SURANET
Alabama, U of, Birmingham
Alabama, U of, Tuscaloosa
Catholic U
Clemson U
Continuous Elec Beam Accel Fac
Delaware, U of
Florida State U
Florida, U of
Gallaudet U
George Mason U
George Washington U
Georgetown U
Georgia, U of
Georgia Institute of Tech
John Hopkins U
Kentucky, U of
Louisiana State U
Maryland, U of
Miss State U
Naval Research Lab, DC
Naval Research Lab, Orlando
NASA Goddard
NASA Langley
National Bureau of Standards
National Cancer Institute
Nat Inst of Env Health Sciences
Nat Inst of Health
Nat Radio Astronlmy Observ
Nat Science Found
Oak Ridge Nat Labs
Old Dominion U
South Carolina, U of
Supercomputer Res Center
Tenn, U of
Triangle U Computation Center

SURANET(Cont.)
Duke U
North Carolina, U of
North Carolina State U
US Geological Survey
Vanderbilt U
Virginia, U of
Virginia Commonwealth U
West Virginia U
Virginia Polytechnic U
William & Mary College

CERFNET
Agouron Institute
Calif Institute of Tech
Calif State U Network
CA, U of, Los Angeles
CA, U of, Riverside
CA, U of, San Diego
CA, U of, Santa Barbara
Claremont Colleges
Hughes Aircraft
Occidental College
Qualcomm Inc
Research Institute of Scripps
Salk Institute
San Diego Supercomputer Center
San Diego, U of
Science Applications Inf Corp
South West Research Labs

CICNET
Chicago, U of
Ill, U of, Chicago
Ill, U of, Urbana/Carb
Indiana U
Iowa, U of
Minnesota, U of
Michigan, U of
Michigan State U
Northwestern U
Ohio State U
Wisconsin, U of, Madison

LOS NETTOS
Calif Institute of Tech
CA, U of, Los Angeles
IBM
ISI (Stanford)
JPL
NOSC
Rand
San Diego Supercomputer Center

EXHIBIT 11-26. Campus Area Networks

(Continued)

LOS NETTOS (Cont.)
TRW
TIS
University of So. CA

MRNET
Carleton College
Minn Supercomputer Center
Network Systems Corp
Control Data Corp
Cray Research
Honeywell
Mayo Foundation
St Olaf College
3M Company
Minn, U of

NEARNET
BBN, Inc
Boston U
DEC
Encore Computer Corp
Harvard U
MIT
MIT Lincoln Lab
Thinking Machines Corp

OARNET
Akron, U of
Bowling Green State U
Case Western U
Central State U
Cincinnati, U of
Cleveland Clinic
Dayton
Hiram U
Kent State U
Malone U
Medical College
Miami, U of
NASA Lewis
Ohio Data Network
Ohio U
Ohio State U
Toledo, U of
Wright State
Yougstown

PREPNET
Carnegie Mellon U
Drexel U
Lehigh U
PA, U of

PREPNETCont.)
PA State U
Pittsburgh Supercomputer Center
Pittsburgh, U of
Temple U

THENET
Abilene Christian U
Baylor U
East Texas State U
Houston, U of
Pan American U
Prarie View A&M
Rice U
Sam Houston State U
Southwest TX State U
TX, U of, Austin
11 sites
TX, U of, Dallas
7 sites
TX, U of, El Paso
TX, U of, Health Sci,
Houston, 3 sites
TX, U of, Health Sci,
San Antonio, 6 sites
TX, U of, Health Center
Tyler
TX, U of, MD Adersen Cancer
TX, U of, Marine Sci Inst
TX, U of, McDonald Obser
TX, U of, Medical, Galveston
TX, U of, Permian Basin
TX, U of, West TX Lands Mgmt
Texas A&M
Texas Tech U
U of North TX

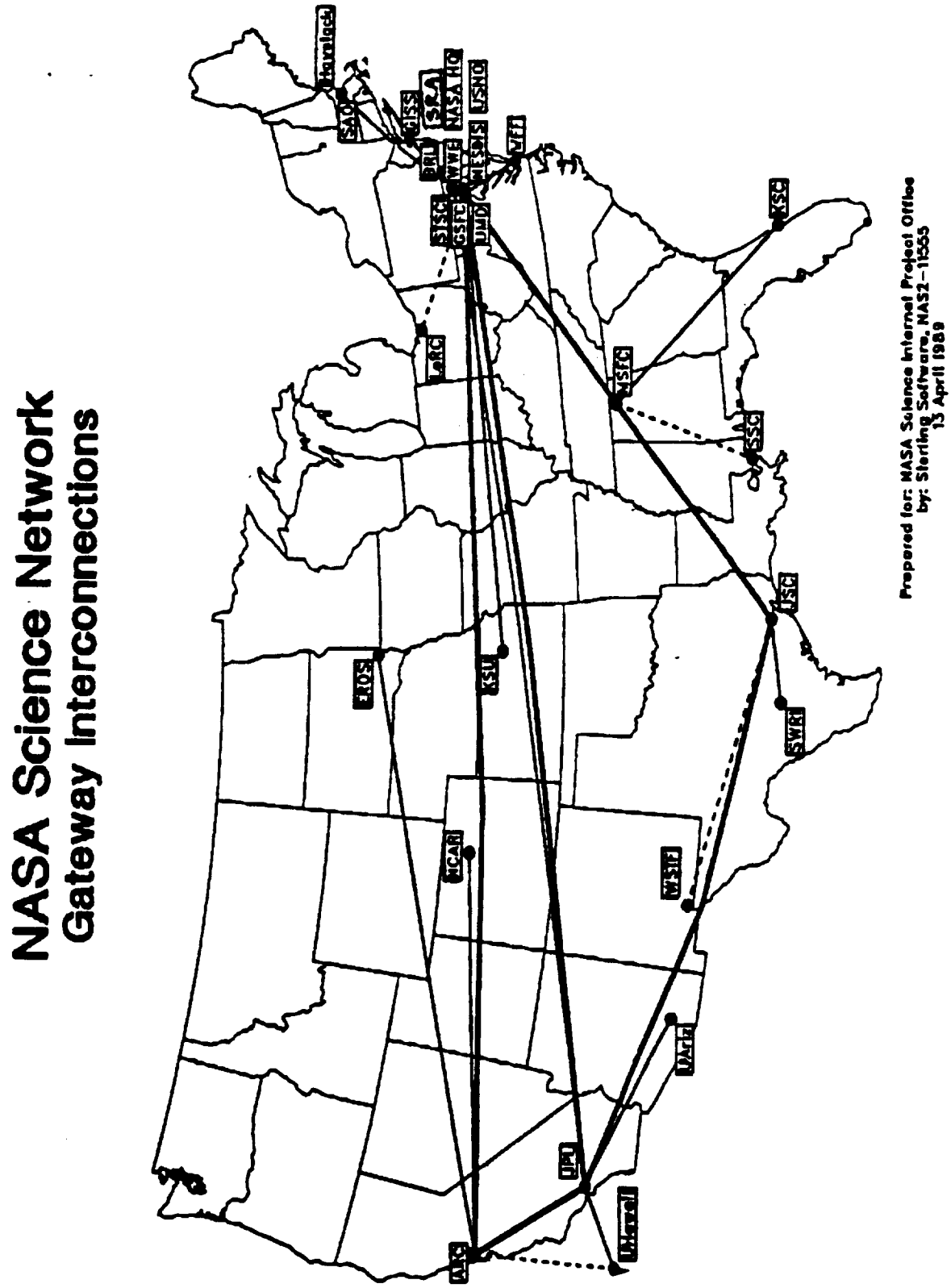


EXHIBIT 11-27. NSN Topology

NASA Science Network

Line Speed between Sites

From	To	Line Speed	
ARC	EROS	9.6 Kbps	
ARC	GSFC	336 Kbps	
ARC	JPL	448 Kbps	
ARC	NCAR	56 Kbps	
GSFC	GISS	56 Kbps	
GSFC	KSU	9.6 Kbps	
GSFC	NESDIS	9.6 Kbps	
GSFC	SAO	56 Kbps	
GSFC	SRA	14 Kbps	
GSFC	STSCI	56 Kbps	
GSFC	UMD	1544 Kbps	
GSFC	USNO	56 Kbps	
GSFC	WFF	56 Kbps	
GSFC	WWB	56 Kbps	
JPL	JSC	168 Kbps	
JPL	STSCI	56 Kbps	
JPL	UAZ	56 Kbps	
JPL	UHAWAII	56 Kbps	
JPL	GSFC	672 Kbps	
JSC	SWRI	56 Kbps	
MSFC	KSC	56 Kbps	
MSFC	GSFC	672 Kbps	
MSFC	JSC	168 Kbps	
SAO	HAYSTACK	56 Kbps	
STSCI	BRL	56 Kbps	
UHAWAII	UWAIKATO	56 Kbps	Hawaii to New Zealand
* ARC	UHAWAII	512 Kbps	
* JSC	WSTF	56 Kbps	
* GSFC	LeRC	112 Kbps	
* GSFC	NASAHQ	56 Kbps	
* MSFC	SSC	56 Kbps	

* These are speeds of imminent sites

EXHIBIT 11-28. NSN Link Speeds

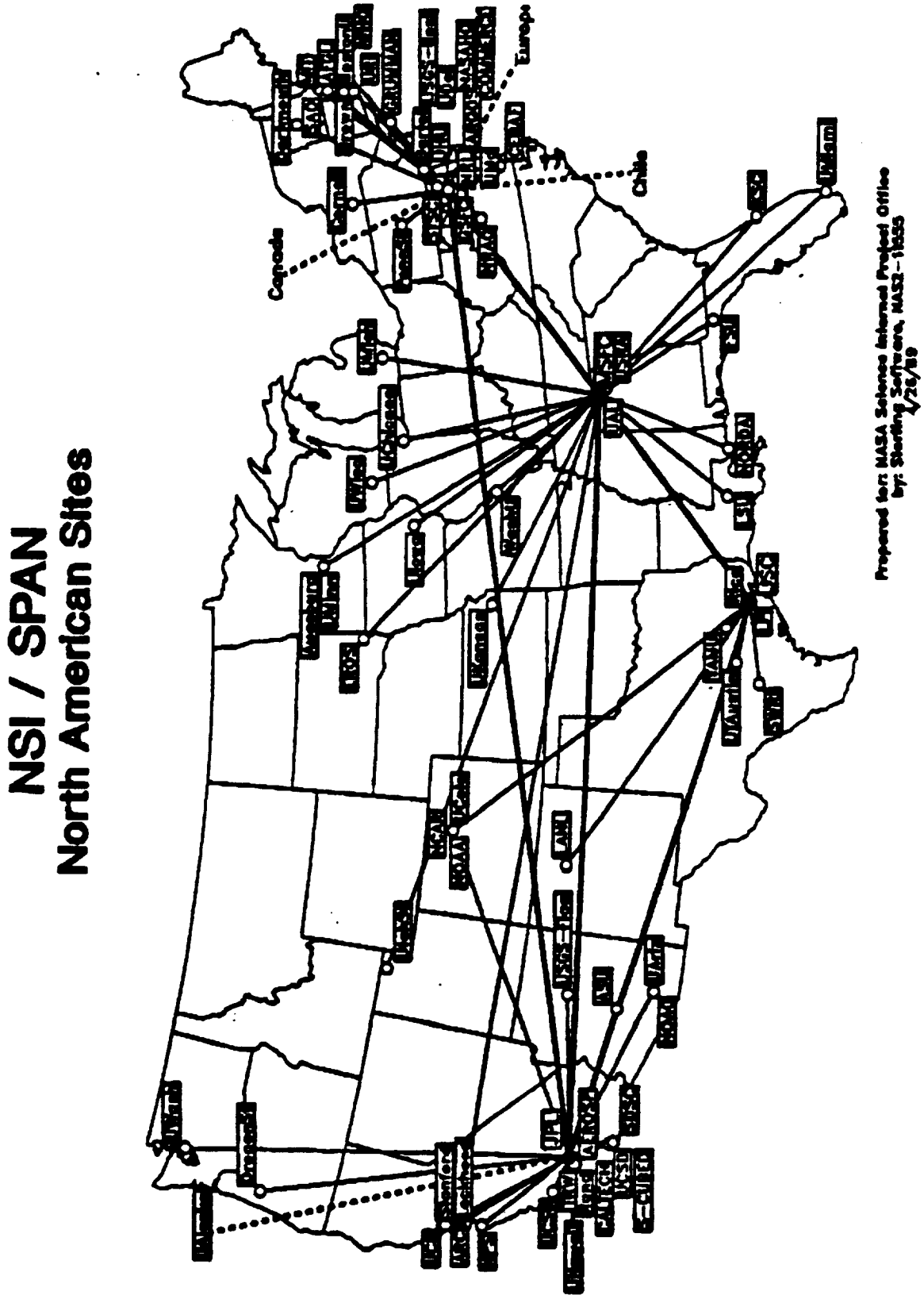


EXHIBIT 11-29. SPAN Topology

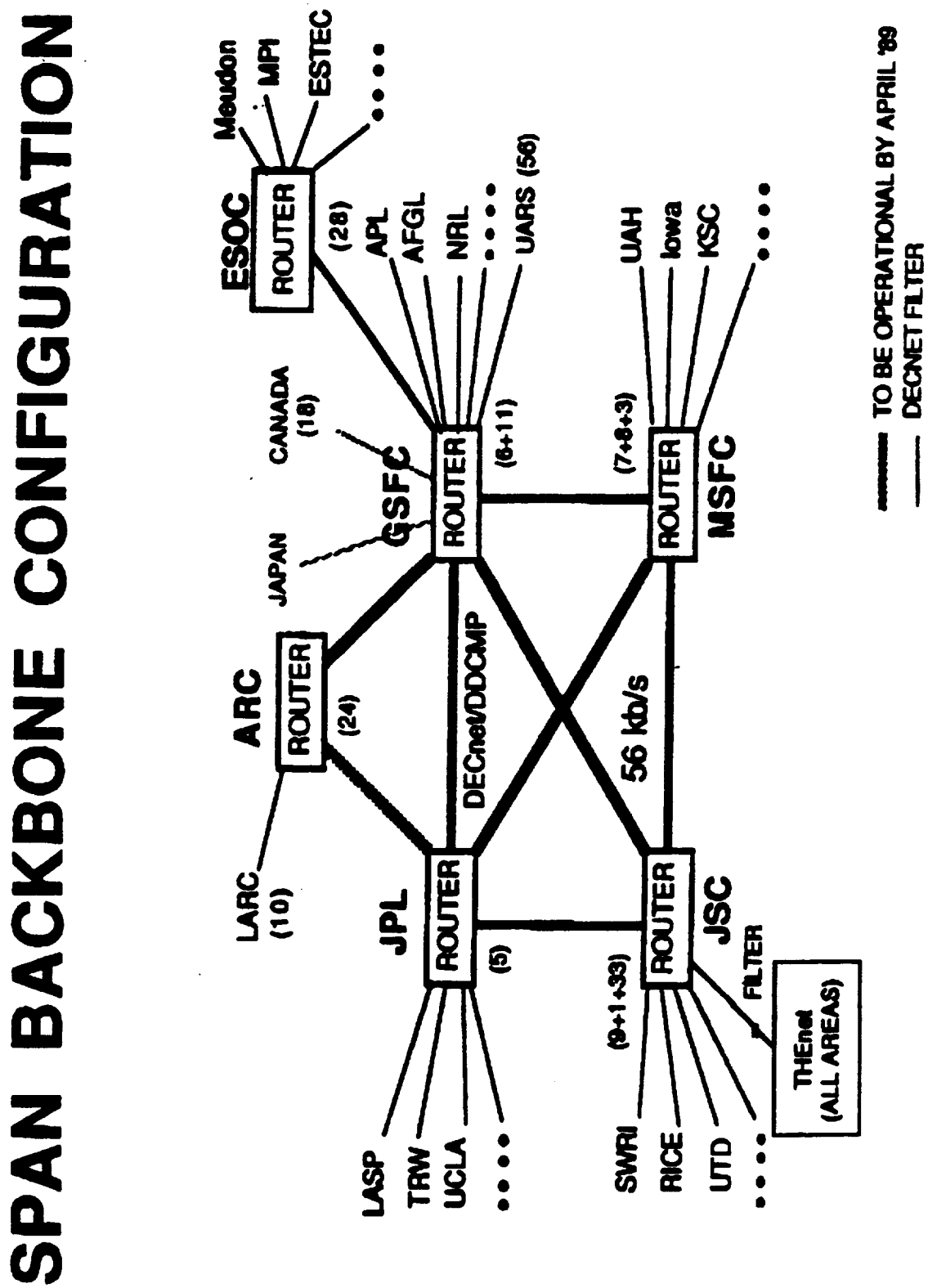


EXHIBIT 11-30. SPAN Backbone Configuration

SPAN CONFIGURATION

GSFC ROUTING CENTER

NODE-LOCATION	SPEED	TELEPHONE #	INSTITUTION
AFGL - HANSCOM AFB, MA	9.6	(617) 377	GEOPHYSICS LAB
SCIVAX - BALTIMORE, MD	9.6	(301) 338	SPACE TELESCOPE INSTITUTION
BARTOL - NEWARK, DE	9.6	(302) 451	UNIV. OF DELAWARE
POLLUX - WASH., DC	9.6	(202) 453	NASA HQ - RESTON, VA
CUSPIP - ITHACA, NY	9.6	(607) 255	CORNELL UNIV.
CFA2 - CAMBRIDGE, MA	9.6	(617) 495	SAO
NRLDR1 - WASH., DC	9.6	(202) 767	NAVAL RESEARCH LAB
BUASTA - BOSTON, MA	9.6	(617) 353	BOSTON UNIV.
T1 - HANOVER, NH	9.6	(603) 646	DARTMOUTH COLLEGE
UMDSW - COLLEGE PARK, MD	9.6	(301) 454	UNIV. OF MARYLAND
PSUNWP - UNIV. PARK, PA	9.6	(814) 863	PENN. STATE
USDRES - RESTON, VA	9.6	(301) 648	USGS RESTON, VA
YSOLAR - NEW HAVEN, CT	9.6	(203) 432	YALE UNIV.
UNHROC - UNIV. OF NEW HAMPSHIRE	9.6	(603) 862	UNIV. OF NEW HAMPHIRE
APLSP - LAUREL, MD	9.6	(301) 953	JOHN HOPKINS
CEBAF1 - NEWPORT NEW, VA	9.6	(804) 249	CEBAF NEWPORT NEWS, VA
CMPO - CAMBRIDGE, MA	9.6	(617) 253	MIT
NODC - WASH., DC	9.6	(202) 673	NOAA/WDC
NRAO - CHARLOTTESVILLE, VA	9.6	(505) 835	NATL RADIO ASTRON SOCORRO, NM
DELOCN - LEWES, DE	9.6	(302) 645	UNIV. OF DELAWARE MARINE STUDIES
RED - WOODS HOLE, MA	9.6	(617) 548	WOODS HOLE (WHOI)
URI - NARRAGANSETT, RI	9.6	(401) 792	UNIV. OF RHODE ISLAND
MORRIS - HUNTSVILLE, AL	56	(205) 544	MSFC
JSORT2 - HOUSTON, TX	56	(713) 483	JSC
JPLRT1 - PASADENA, CA	56	(818) 354	JPL
ECD1 - DARMSTADT, WG	19.2	49-6151-886-659	EUROPEAN SPACE OPERATIONS CTR.
RS2 - GSFC BLDG 23/RM N410	56 (ROLM)	(301) 286	GSFC
CANOT - OTTAWA, ONTARIO, CA	X.25	(613) 990	NATL RES. COUNCIL OF CANADA
KYOTO - KYOTO, JAPAN	X.25	81-75-722-0865	KYOTO UNIV.
CTIOV1 - SANTIAGO, CHILE	X.25	011-56-51-213-352	CERRO TOLOLO INTER-AMERICAN OBSER
CTIOV2 - SANTIAGO, CHILE	X.25	011-56-51-213-352	

JSC ROUTING CENTER

NODE-LOCATION	SPEED	TELEPHONE #	INSTITUTION
ESSDP1 - LOS ALAMOS, NM	9.6	(505) 667	LOS ALAMOS NATL LAB
LPI - HOUSTON, TX	250K	(713) 486	JSC
MORRIS - HUNTSVILLE, AL	56	(205) 544	MSFC
NCFTR3 - GREENBELT, MD	56	(301) 286	GSFC
JPLRT1 - PASADENA, CA	56	(818) 354	JPL
SPAN3 - AUSTIN, TX	56	(512) 471	UNIV. OF TEXAS
UCBRTO - BOULDER, CO	9.6	(303) 492	UNIV. OF COLORADO
ACDURS - BOULDER, CO	9.6	(303) 497	NCAR
RICE - HOUSTON, TX	9.6	(703) 527	RICE UNIV.
CRYDEL - BOULDER, CO	9.6	(303) 497	NATL BUREAU OF STANDARDS
SWRI - SAN ANTONIO, TX	9.6	(512) 522	SW RESEARCH INST.

EXHIBIT 11-31. SPAN Link Speeds

NODE-LOCATION	SPEED	TELEPHONE #	INSTITUTION
NCFRT3 - GREENBELT, MD	56	(301) 286	GSFC
JPLRT1 - PASADENA, CA	56	(818) 354	JPL
JSCRT1 - HOUSTON, TX	56	(713) 483	JSC
KSCRTR - KSC	9.6	(305) 867	KSC
IOWAGL - IOWA CITY, IA	9.6	(319) 335	UNIV. OF IOWA
STAR - STANFORD, CA	9.6	(415) 723	STANFORD UNIV.
PLUTO - MIAMI, FL	56	(305) 361	RSMAS
A36 - SSC, MS (NORDA)	56	(601) 688	NORDA
SPARC - HUNTSVILLE, AL	56	(205) 895	UNIV. OF ALABAMA
USU - LOGAN, UT	9.6	(801) 750	UTAH STATE UNVI.
MADRAF - MADISON, WI	9.6	(608) 262	UNIV. OF WISCONSIN
WURST - ST. LOUIS, MO	9.6	(314) 889	WASHINGTON UNIV.
METDAT - TALLAHASSEE, FL	9.6	(904) 644	FLORIDA STATE UNIV.
KUPHSX - LAWRENCE, KS	9.6	(913) 864	UNIV. OF KANSAS
SPRLB - ANN ARBOR, MI	9.6	(313) 747	UNIV. OF MICHIGAN
LASR - CHICAGO, IL	9.6	(312) 702	UNIV. OF CHICAGO
EROSA - SIOUX FALLS, SD	9.6	(605) 594	USGS/EROS DATA CENTER
A32 - SSC, MS (NORDA BACKUP)	9.6	(601) 688	NORDA
WAVES - MINNEAPOLIS, MN	9.6	(612) 624	UNIV. OF MINNESOTA
LSU1VX - BATON ROUGE, LA	9.6	(504) 388	LOUISIANA STATE UNIV.
AUGGIE - MINNEAPOLIS, MN	9.6	(612) 330	AUGSBURG COLLEGE
LAMPS - HUNTSVILLE, AL	9.6	(205) 895	UNIV. SPACE RES. ASSOC.
MAGRPH - HUNTSVILLE, AL	9.6	(205) 544	MSFC

JPL ROUTING CENTER

NODE-LOCATION	SPEED	TELEPHONE #	INSTITUTION
NCFRT1 - GREENBELT, MD	56	(301) 286	GSFC
RT4 - ARC	9.6	(414) 694	ARC
UCBRTO - BOULDER, CO	56	(303) 497	UNIV. OF COLORADO
ROMEO - PASADENA, CA	9.6	(818) 354	CALTECH CAMPUS COMPUTING ORG.
JSCRT2 - HOUSTON, TX	56	(713) 483	JSC
PSIKEY - TUCSON, AZ	9.6	(602) 881	UNIV. OF ARIZONA
LOONEY - TUCSON, AZ	9.6	(602) 621	UNIV. OF ARIZONA
HYRAX - SANTA MONICA	9.6	(213) 393	THE RAND CORPORATION
TRWATD - REDONDO BEACH	56	(213) 535	TRW, INC.
DRACO - TUCSON, AZ	9.6	(602) 325	NRAO
HAWAII - HONOLULU, HI	9.6	(808) 948	UNIV. OF HAWAII
UCLASO - LOS ANGELES, CA	56	(213) 825	UCLA
BRNPSG - PROVIDENCE, RI	9.6	(401) 863	BROWN UNIV.
ASUIPF - TEMPE, AZ	56	(602) 965	ARIZONA STATE UNIV.
ASTROG - FLAGSTAFF, AZ	9.6	(602) 527	U.S. GEOLOGICAL SURVEY
UCBSP - BERKELEY, CA	9.6	(415) 642	UNIV. CALF. @ BERKELEY
FRED - FAIRBANKS, AL	9.6	(907) 474	UNIV. OF ALASKA
MOTHRA - SEATTLE, WA	9.6	(206) 543	UNIV. OF WASHINGTON
DIRAC2 - EL SEGUNDO, CA	9.6	(213) [illegible]	THE AEROSPACE CORPORATION
LOCKHD - PALO ALTO CA	9.6	(415) 424	LOCKHEED PALO ALTO RES. LAB

EXHIBIT 11-31. SPAN Link Speeds

(Continued)

OSUVAX	CORVALLIS, OR	9.6	(408) 646	OREGON STATE UNIV.
MORRIS -	HUNTSVILLE, AL	56	(205) 544	MSFC
NPSLAB -	MONTEREY, CA	9.6	(408) 646	NAVAL POST GRAD. SCH.
GUAM -	PASADENA, CA	19.2	(818) 354	JPL
JPLRT2 -	PASADENA, CA	56	(818) 354	JPL
ROTO -	HUNTSVILLE, AL	56	(205) 895	MSFC
JPLRT9 -	PASADENA, CA	56	(818) 354	JPL
PANCHO -	SAN DIEGO, CA	56	(619) 534	JPL
ISSAC -	PASADENA, CA	19.2	(818) 354	JPL
GODEL -	SDSC/SCRIPPS	56	(619) 534	SDSC

EXHIBIT 11-31. SPAN Link Speeds

(Continued)

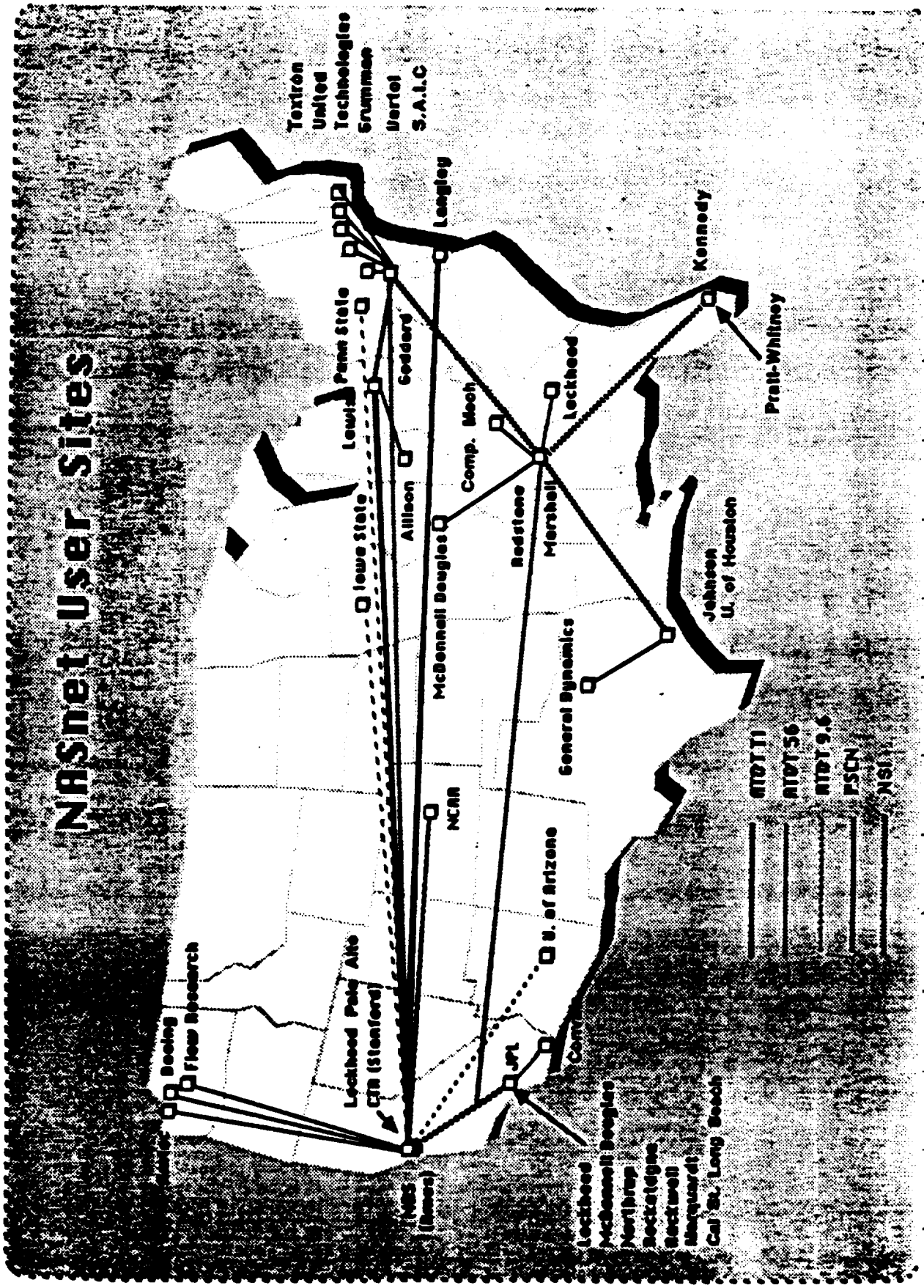


EXHIBIT 11-32. NASNET Topology & Link Speeds

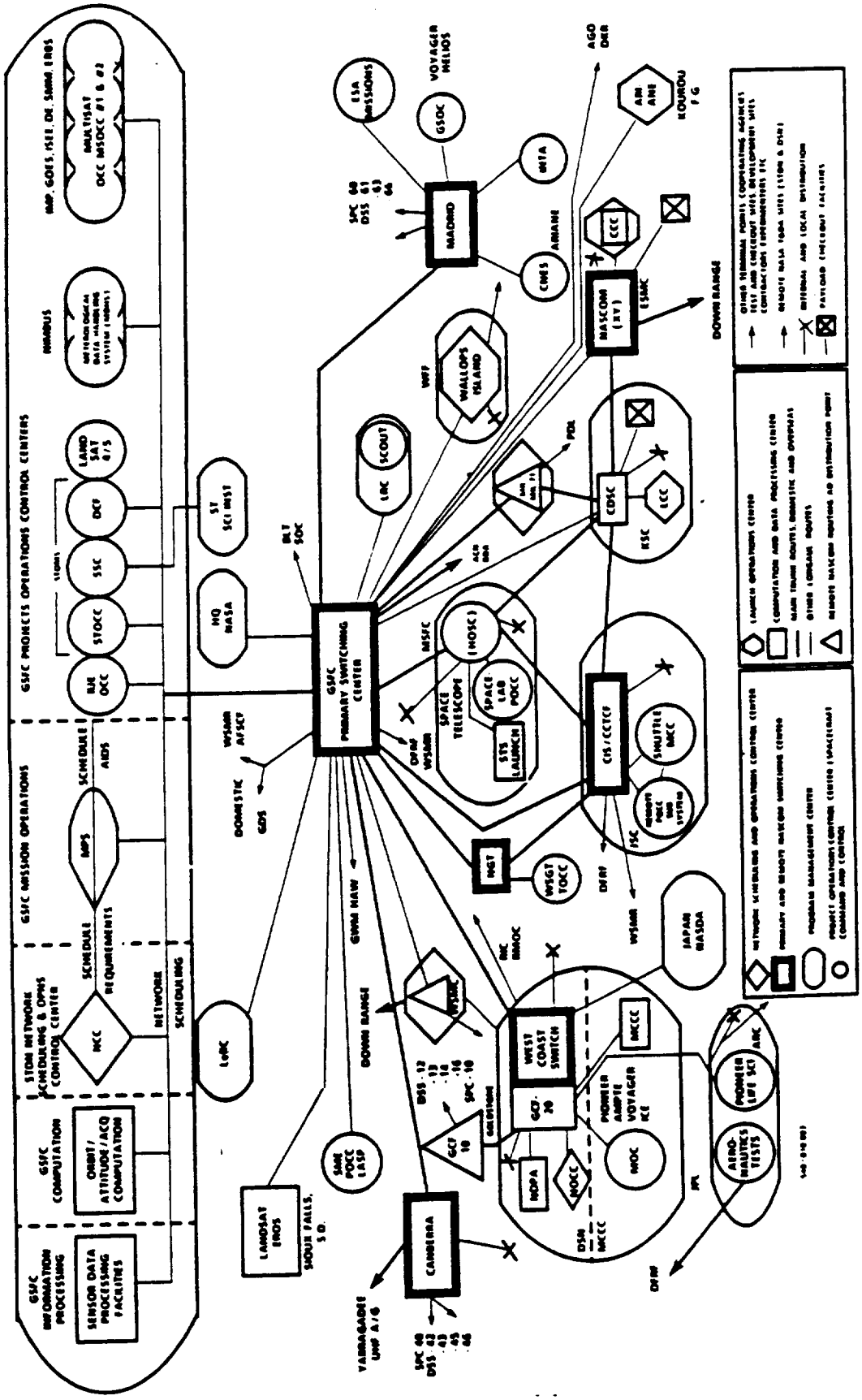


EXHIBIT 11-33. NASCOM Network Configuration

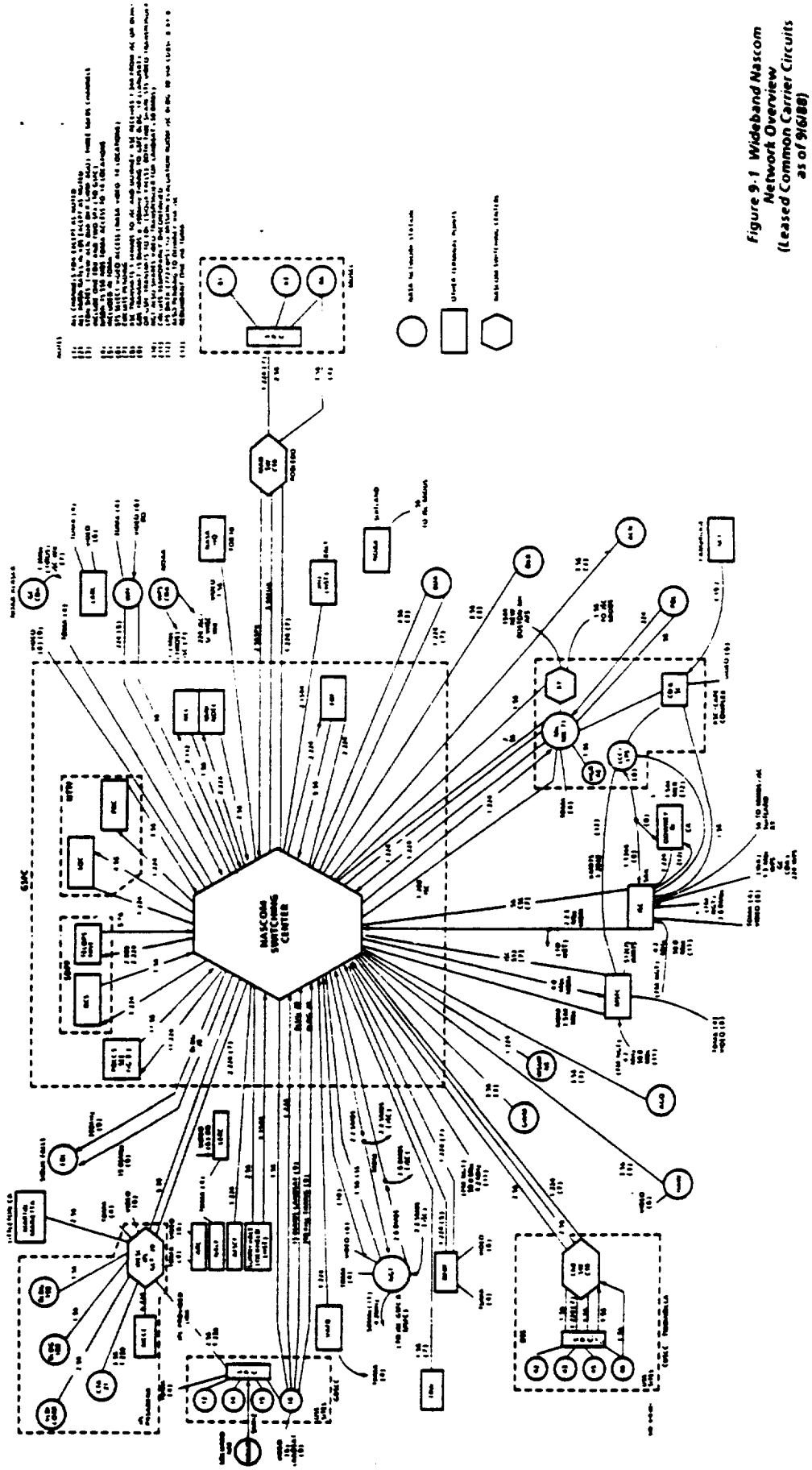


EXHIBIT 11-34. Wideband Data Configuration

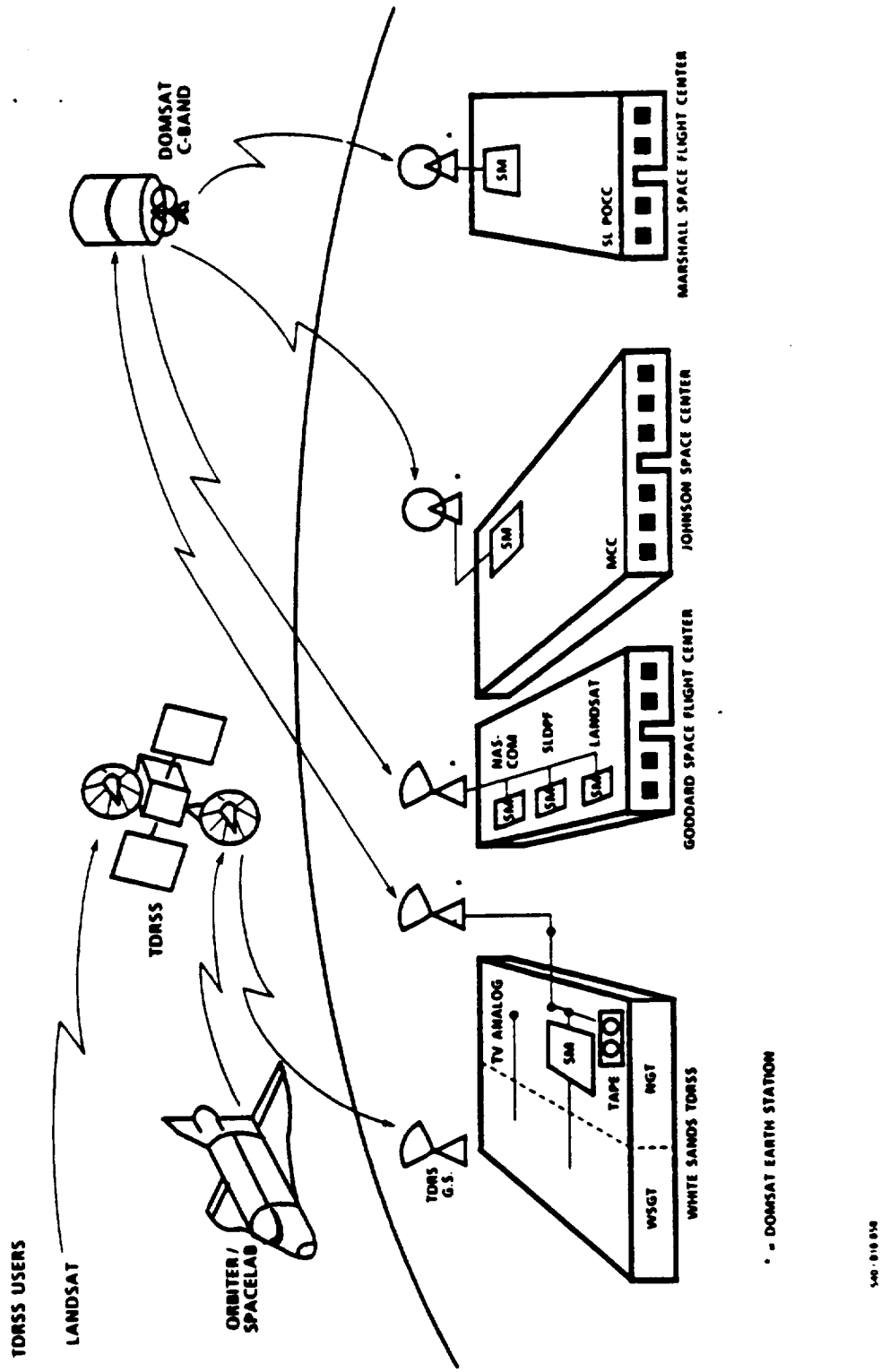
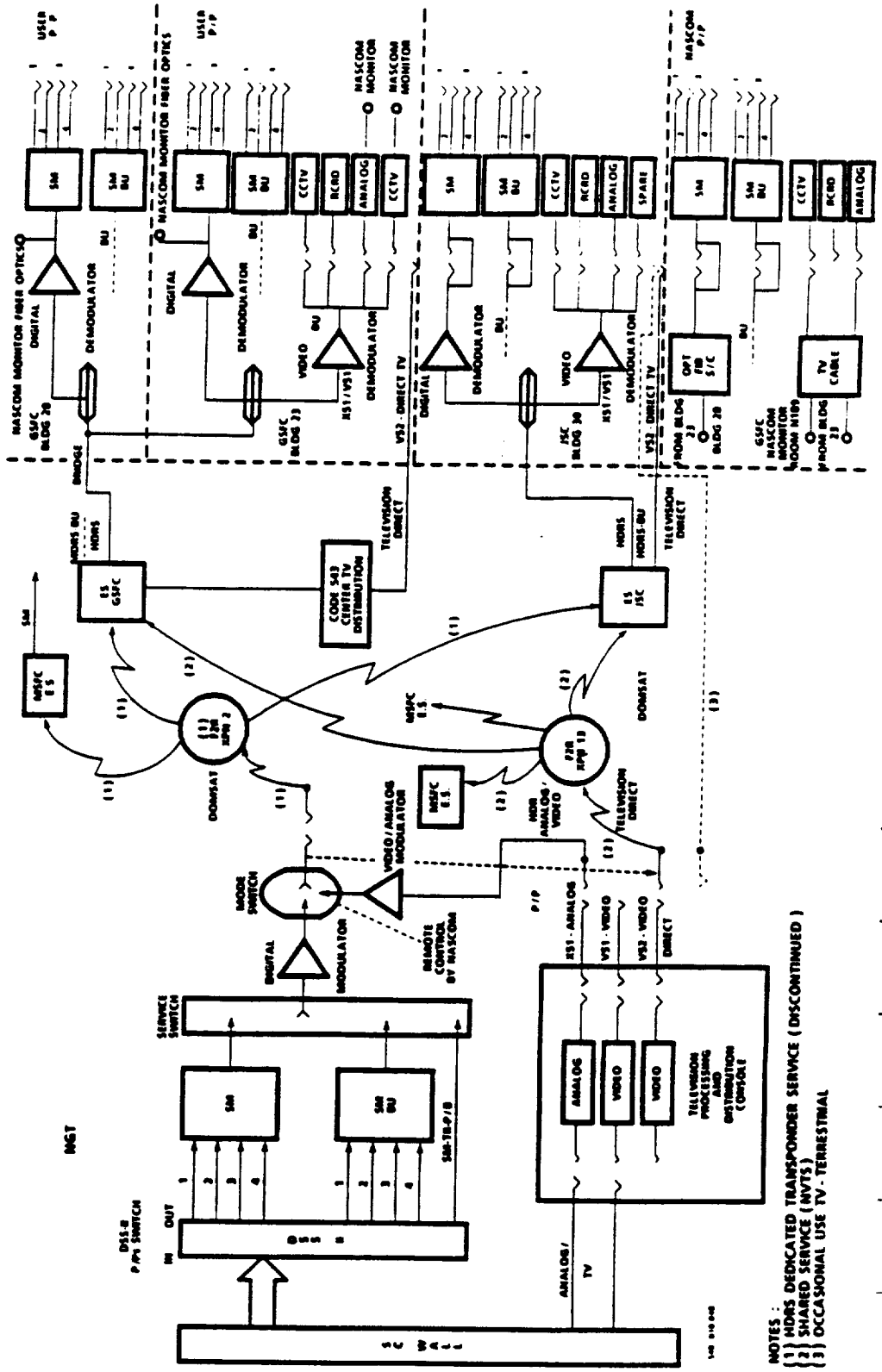


Figure 12-1. Functional Configuration of HDRS as a Nascom Data Transport System

EXHIBIT 11-35. HDRS Functional Configuration



HIGH DATA RATE SYSTEM 12-3

EXHIBIT 11-36. HDRS System Configuration

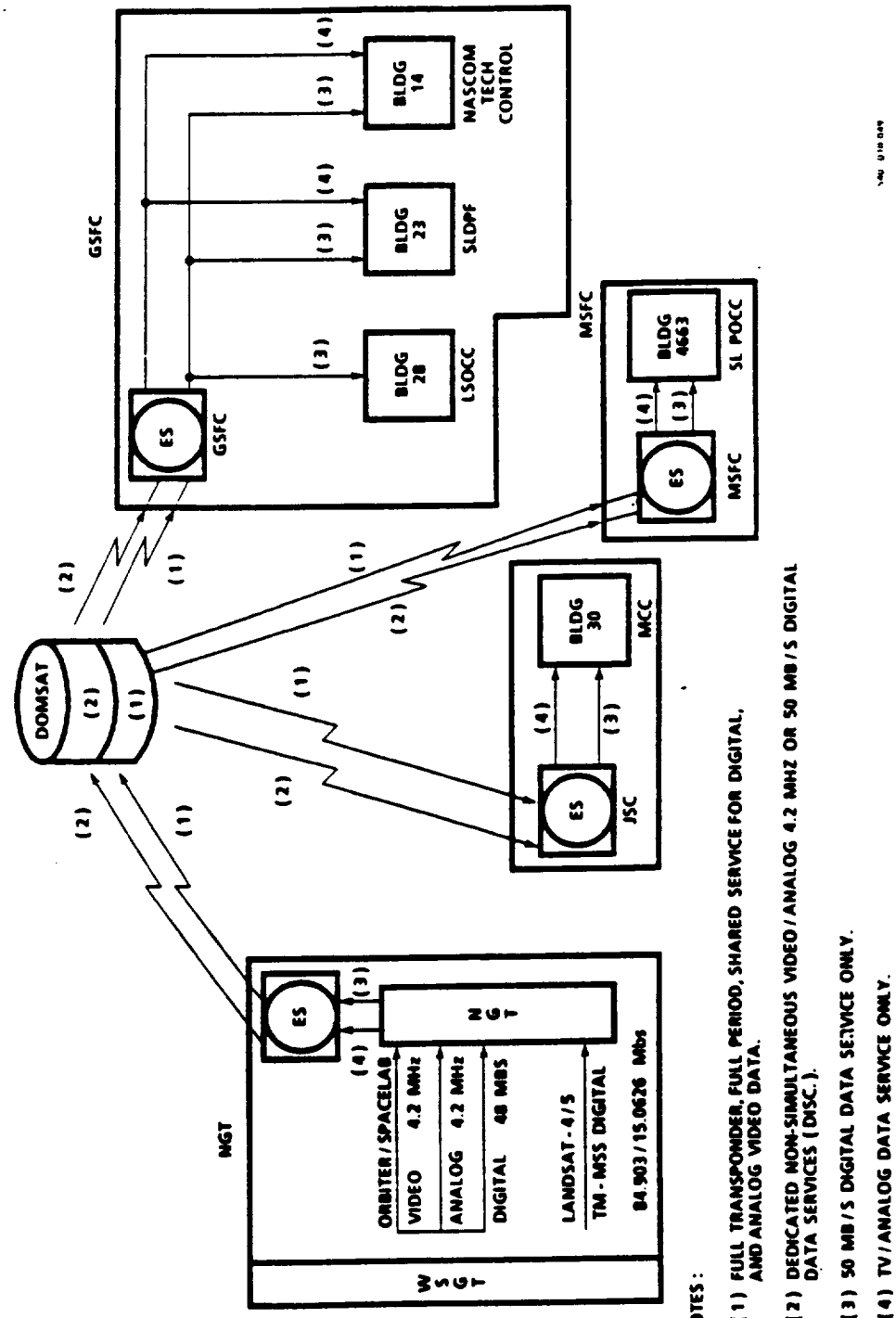


EXHIBIT 11-37. CCDTS System Configuration

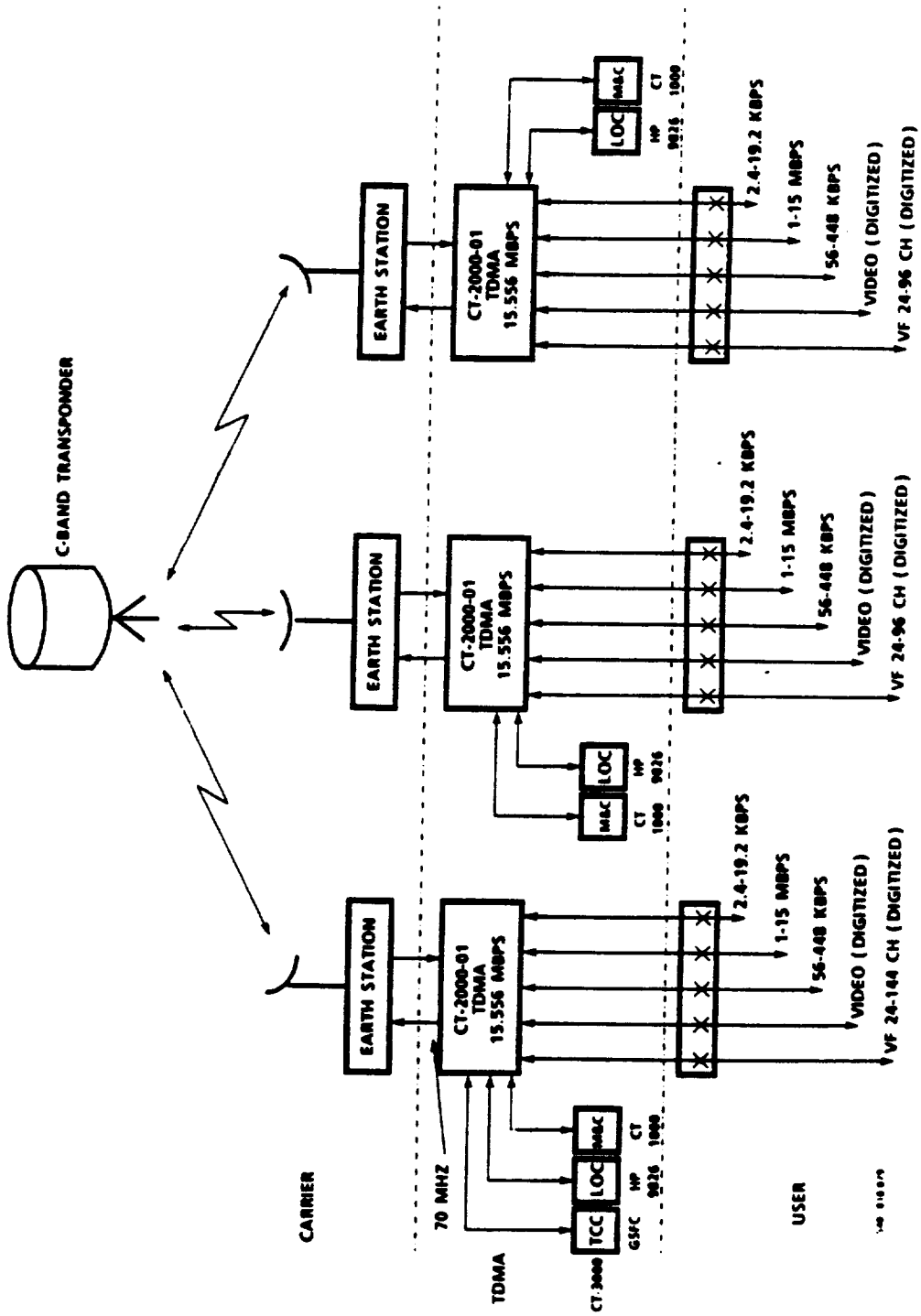


EXHIBIT 11-38. TDMA System Configuration

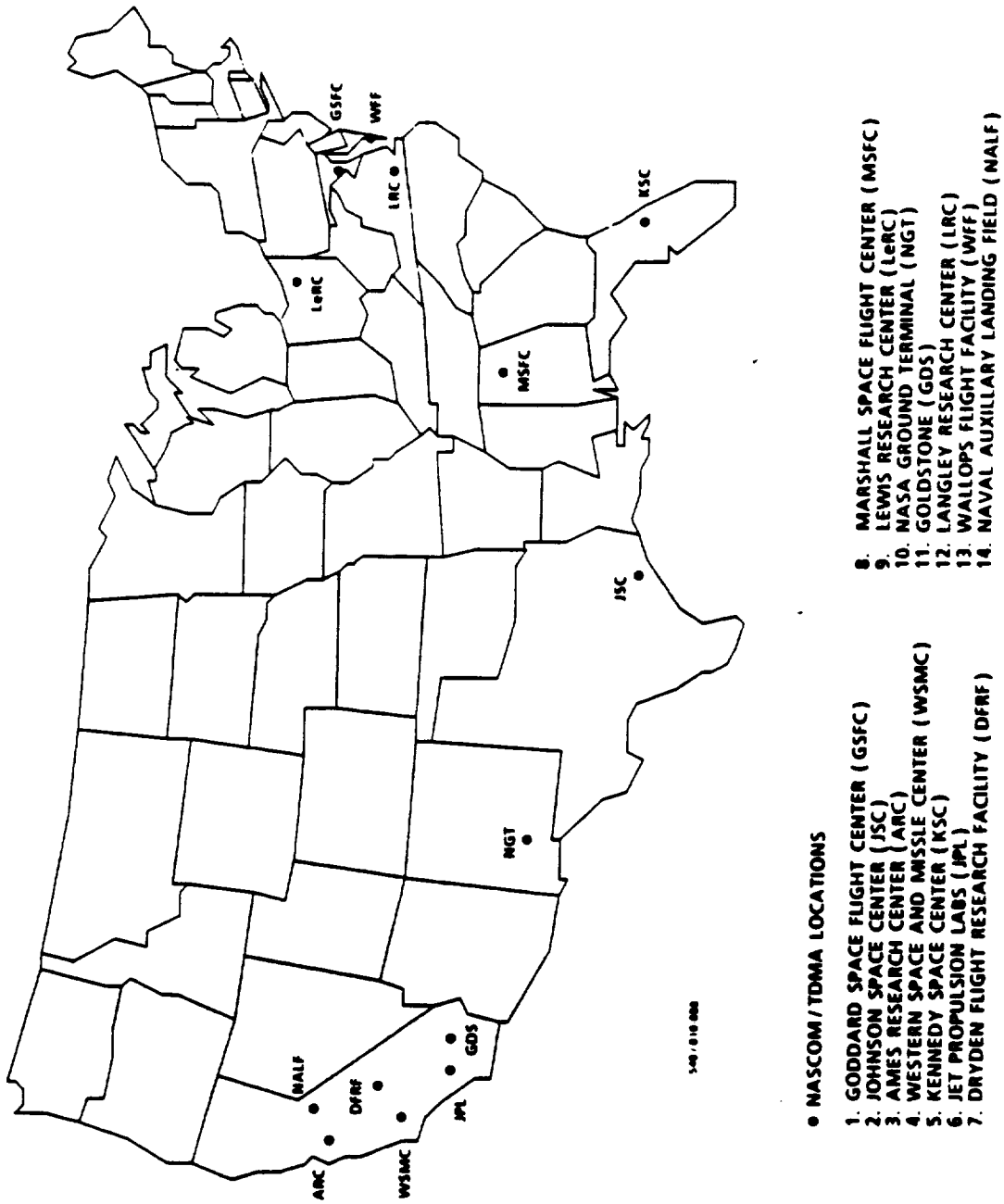


EXHIBIT 11-39. TDMA Node Location

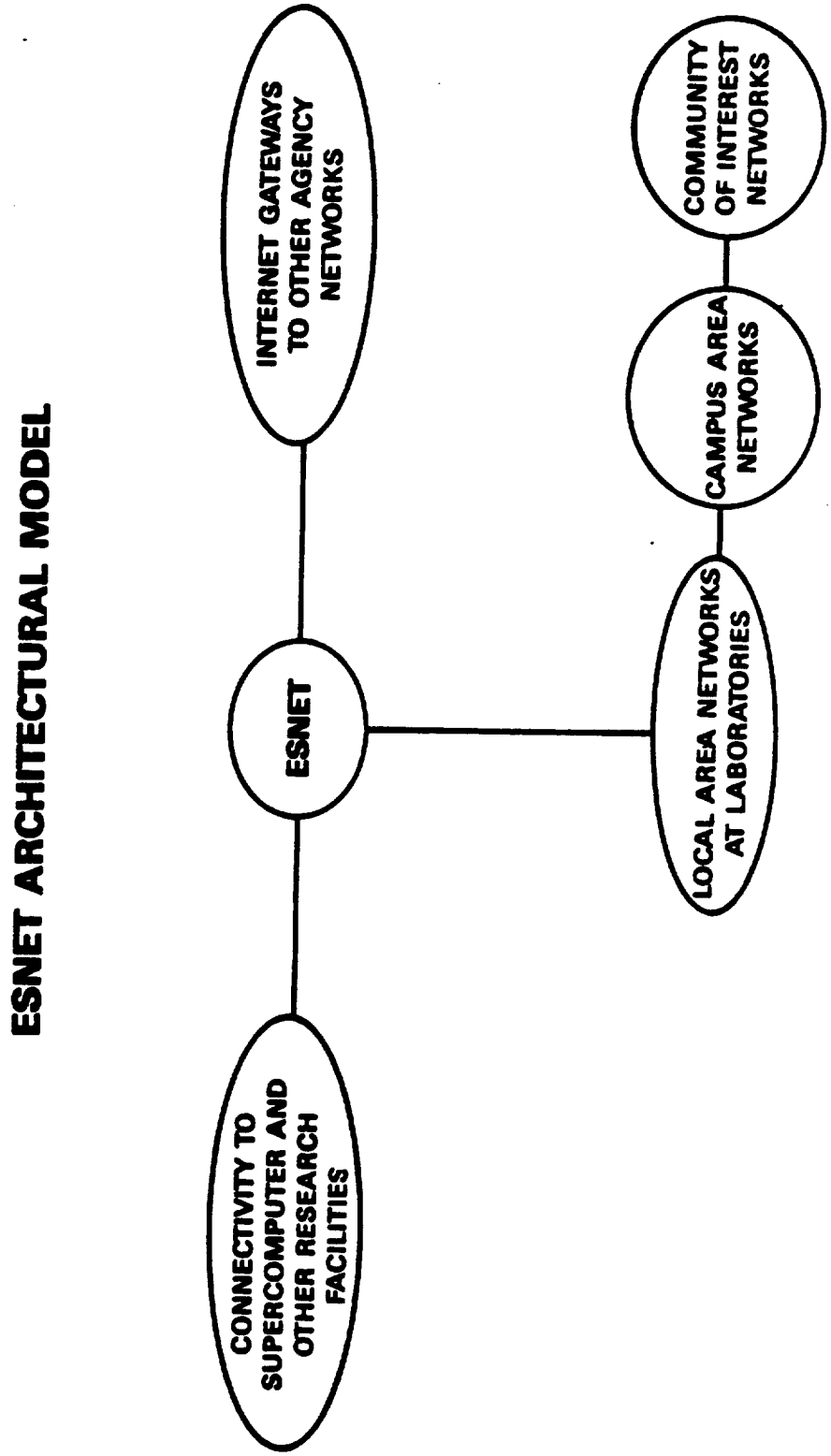


EXHIBIT 11-40. ESNET Architectural Model

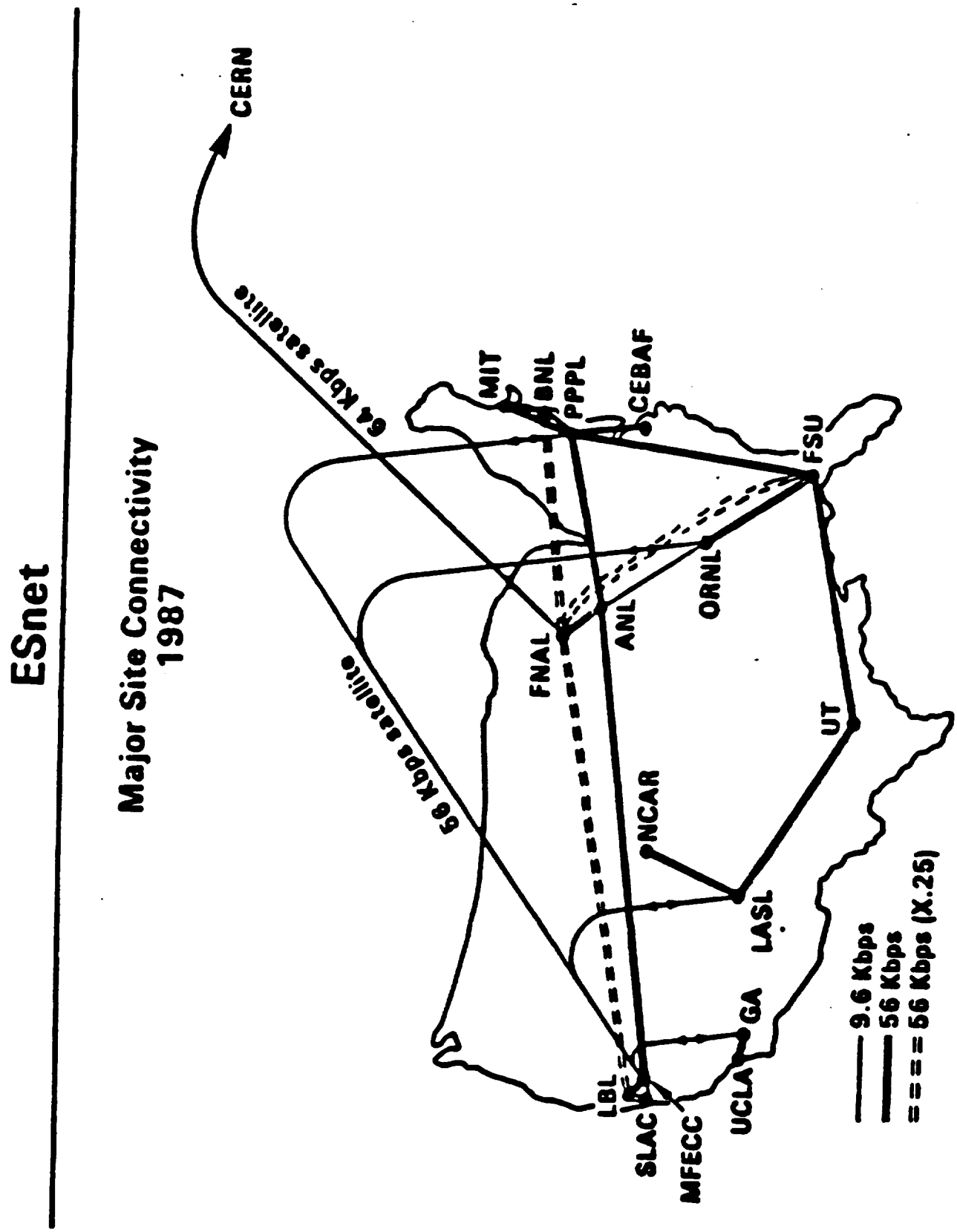


EXHIBIT 11-41. ESNET Backbone Configuration

CONNECTIVITY REQUIREMENT FOR ER COMPUTER NETWORK

GEOGRAPHIC LOCATIONS

This list of geographic locations has been compiled from ER program individual requirements documents. The locations are footnoted to designate 1.) that connectivity to this location is required by more than one ER program, 2.) that there are already multiple ER funded computer network links to the location, and 3.) that the location is serviced by or is part of a computer network funded by another agency, such as NSF, DARPA, etc.

ABILENE CHRISTIAN
ALABAMA 3
AMES LABORATORY 1, 2, 3
ARGONNE NATIONAL LABORATORY 1, 2, 3
ARIZONA 1, 3
ARIZONA STATE 3
ARKANSAS 3
ATLANTA
AUBURN
BALL STATE
BATTELLE PACIFIC NORTHWEST LABORATORY
BOSTON 1, 3
BPA-PORTLAND
BRANDEIS
BRIGHAM YOUNG UNIVERSITY 1
BROOKHAVEN NATIONAL LABORATORY 1, 2, 3
BROOKLYN COLLEGE
BROWN 3
CALIFORNIA/BERKELEY 2, 3
CALIFORNIA/DAVIS 1, 3
CALIFORNIA INST OF TECH 1, 2, 3
CALIFORNIA/LOS ANGELES 1, 2, 3
CALIFORNIA POLYTECHNIC STATE
CALIFORNIA/RIVERSIDE 1
CALIFORNIA/SAN DIEGO 3
CALIFORNIA/SANTA BARBARA 1, 3
CALIFORNIA/SANTA CRUZ 3
CARNEGIE-MELLON 1, 3
CEBAF
CHICAGO 1
CINCINNATI 1
CLARK
CLARKSON
COLORADO 3
COLORADO STATE 3
COLUMBIA 1, 3
CONNECTICUT 3
CORNELL 1, 3

EXHIBIT 11-42. Desired Locations of ESNET Nodes

DENVER 3
DEPT OF ENERGY-GTN 1, 2
DEPT OF INTERIOR-DENVER
DREXEL
DUKE 1, 3
ELMHURST
EMORY
ENVIRONMENTAL MEASUREMENT LAB-NY
FERMI NATIONAL ACCELERATOR LABORATORY 1, 2, 3
FLORIDA 3
FLORIDA STATE 1, 2, 3
FLOW RESEARCH
FRANKLIN/MARSHAL COLLEGE
GA TECHNOLOGIES 1
GEORGE MASON
GEORGE WASHINGTON 3
GEORGIA 3
GEORGIA TECH 3
GRUMMAN AERO
HANFORD 1, 2
HARVARD 1, 2, 3
HOUSTON 1, 3
IDAHO
IDAHO NATIONAL ENGINEERING LABORATORY 3
ILLINOIS-CHAM 1, 3
ILLINOIS-CHI 1, 3
ILLINOIS STATE 3
INDIANA 1
INHALATION TOXICOLOGY RES INST-ALBUQUERQUE
INST MINING & TECH-SOCORRO/NM
IOWA 1, 3
IOWA STATE 1, 3
JOHNS-HOPKINS 1, 2, 3
KANSAS 1, 3
KANSAS STATE 1, 3
KENT STATE
KENTUCKY 1, 3
LAWRENCE BERKELEY LABORATORY 1, 2, 3
LAWRENCE LIVERMORE NATIONAL LABORATORY 1, 2, 3
LEHIGH 1, 3
LOS ALAMOS NATIONAL LABORATORY 1, 2, 3
LOUISIANA STATE 1, 3
LOUISVILLE 3
MARYLAND 1, 2, 3
MASSACHUSETTS INST OF TECH 1, 2, 3
MCDONNELL DOUGLAS
MICHIGAN 1, 3
MICHIGAN STATE 1, 3
MINNESOTA 1, 3
MISSISSIPPI 3
MISSOURI 3
MONTANA

EXHIBIT 11-42. Desired Locations of ESNET Nodes

(Continued)

NASA/LEWIS RESEARCH CENTER
NATIONAL BUREAU OF STANDARDS-JILA
NCAR 1, 3
NEBRASKA 3
NEW HAMPSHIRE 1
NEW MEXICO 1
NEW MEXICO IMT
NEW MEXICO STATE
NEW YORK 1, 2, 3
NEW YORK MEDICAL CENTER 1
NEW YORK, STATE UNIV/STONY BROOK 1, 2, 3
NORTH CAROLINA/CHAPEL HILL 1, 3
NORTH CAROLINA STATE 1, 3
NORTHEASTERN 3
NORTHRIDGE
NORTHWESTERN 1
NOTRE DAME
OAK RIDGE NATIONAL LABORATORY 1, 2, 3
OHIO 1
OHIO STATE 1, 3
OKLAHOMA 3
OREGON
PACIFIC NORTHWEST LABORATORY 1, 2
PENN 1, 3
PENN STATE 1, 3
PHILADELPHIA
PITTSBURGH 3
PRINCETON 1, 3
PRINCETON PLASMA PHYSICS LABORATORY 1, 2
PURDUE 1, 3
RENSSELAER POLYTECHNIC INSTITUTE
RICE 1, 3
ROCHESTER 3
ROCKWELL HANFORD
RUTGERS 1, 3
SANDIA NATIONAL LABORATORY 1, 2, 3
SAN FRANCISCO STATE
SCIENCE APPLICATIONS, INC 1, 2, 3
SCRIPPS INSTITUTION OF OCEANOGRAPHY
SKIDAWAY INST OF OCEANOGRAPHY
SOLAR ENERGY RESEARCH INST
SOUDAN
SOUTH CAROLINA
SOUTHEASTERN
SOUTHWEST RESEARCH INSTITUTE
ST. LOUIS
STANFORD 1, 3
STANFORD LINEAR ACCELERATOR CENTER 1, 2, 3
SYRACUSE 1, 3
TEMPLE
TENNESSEE 3
TEXAS 1, 2, 3
TEXAS A&M 1, 3

EXHIBIT 11-42. Desired Locations of ESNET Nodes

(Continued)

TEXAS ACCELERATOR CENTER 1, 3
TEXAS TECH 3
TOLEDO
TRW INC
U.S. AIR FORCE ACADEMY
U.S. NAVAL ACADEMY
UTAH
UTAH STATE
VALPARAISO
VANDERBILT 3
VASSAR
VIRGINIA 3
VIRGINIA POLY INST 3
VIRGINIA STATE
WASHINGTON 3
WASHINGTON STATE
WILLIAM & MARY
WISCONSIN 3
WORCESTER POLYTECHNIC INSTITUTE
WYOMING
YALE 3

EXHIBIT 11-42. Desired Locations of ESNET Nodes

(Continued)

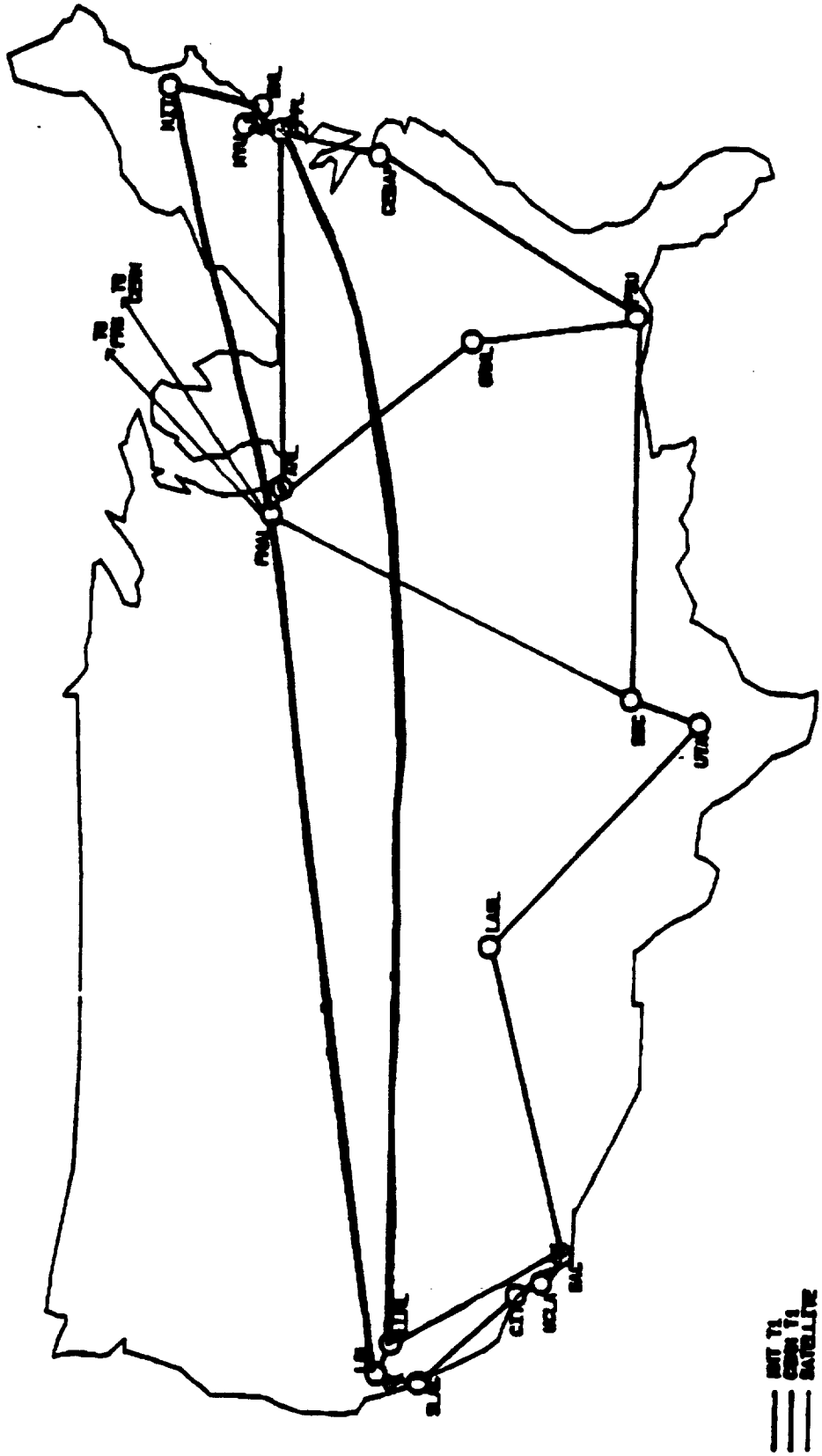


EXHIBIT 11-43. Current ESNET Topology

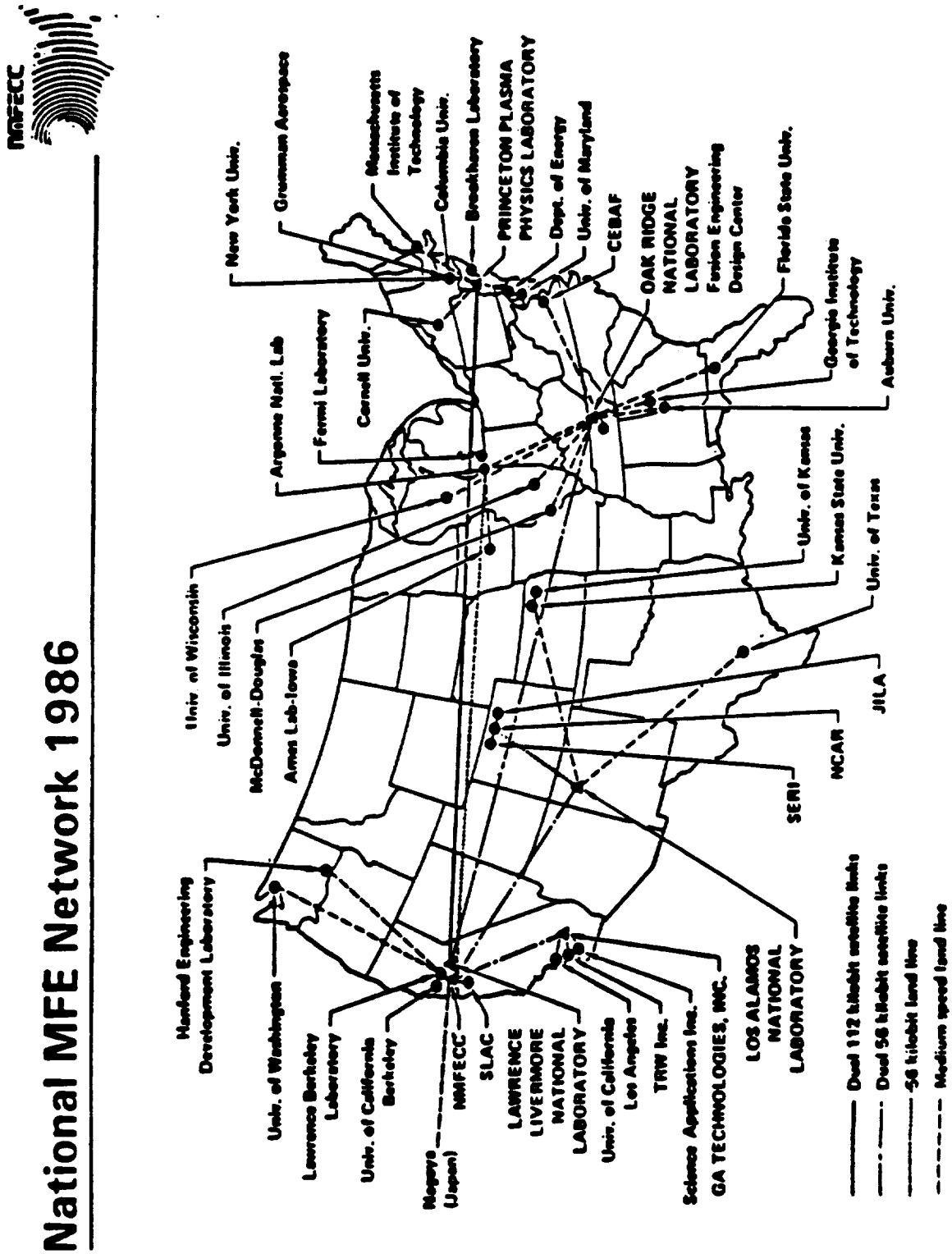


EXHIBIT 11-44. 1986 MFENET Topology

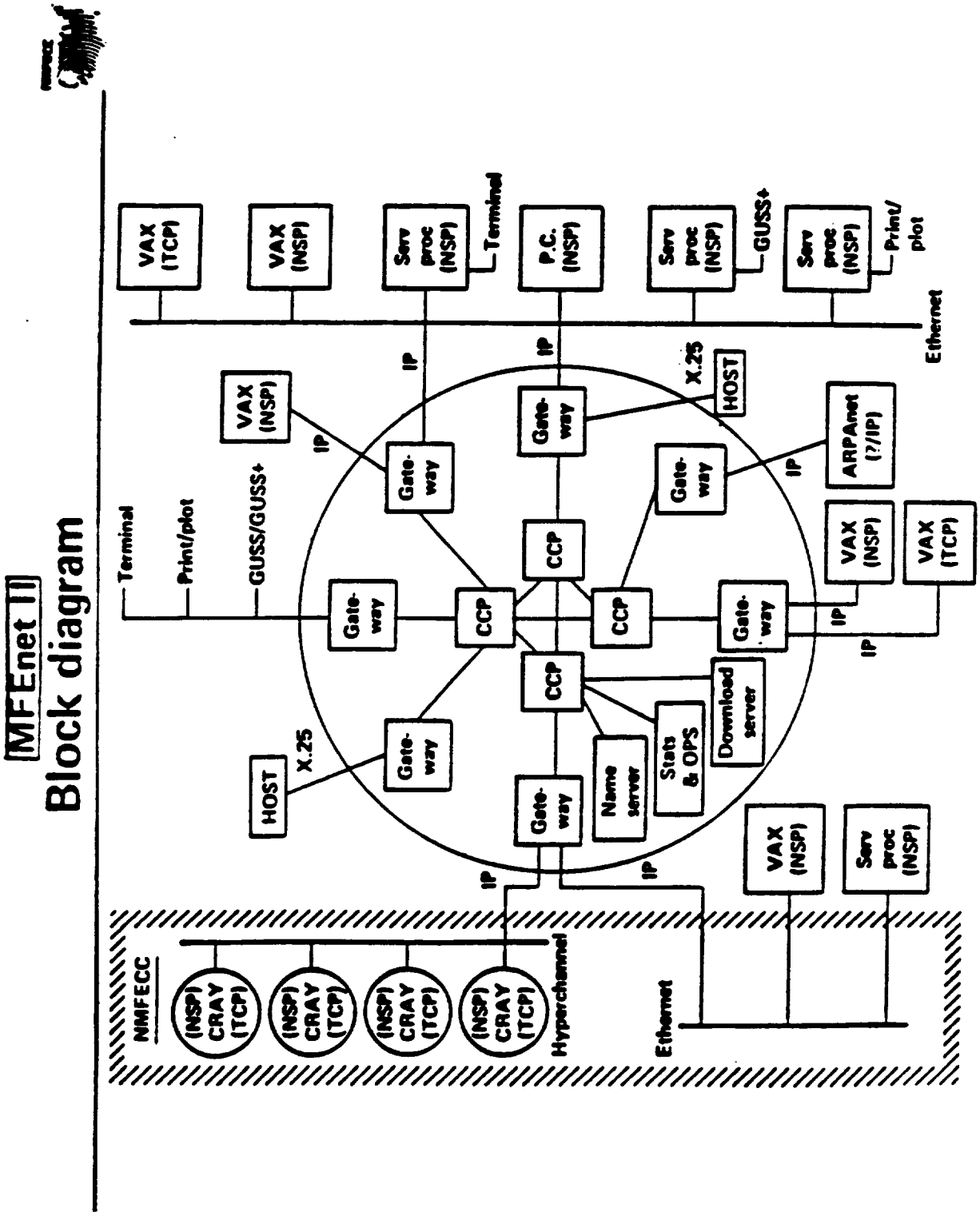


EXHIBIT 11-45. MFENET II Architecture

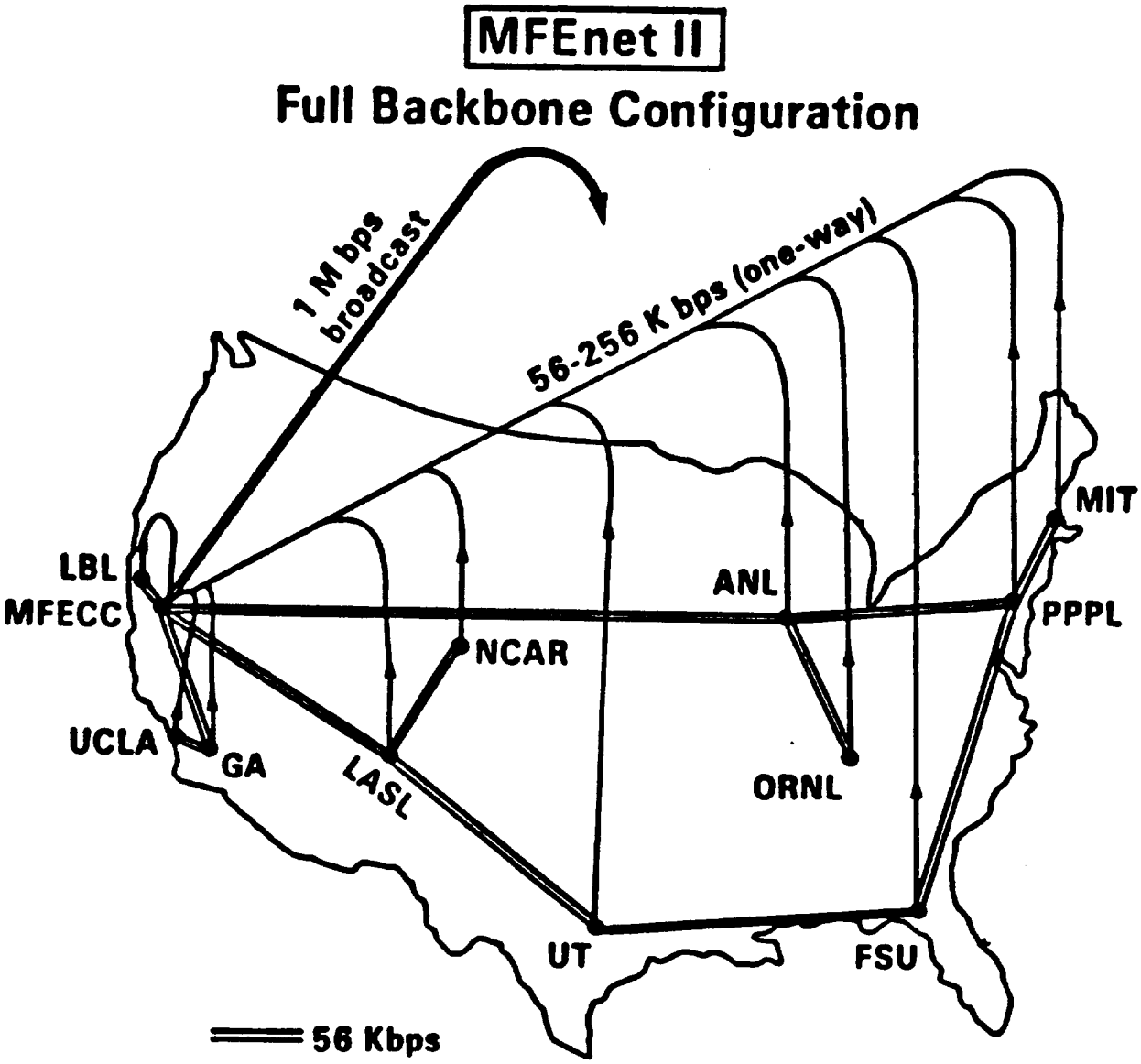


EXHIBIT 11-46. MFENET II Backbone Configuration

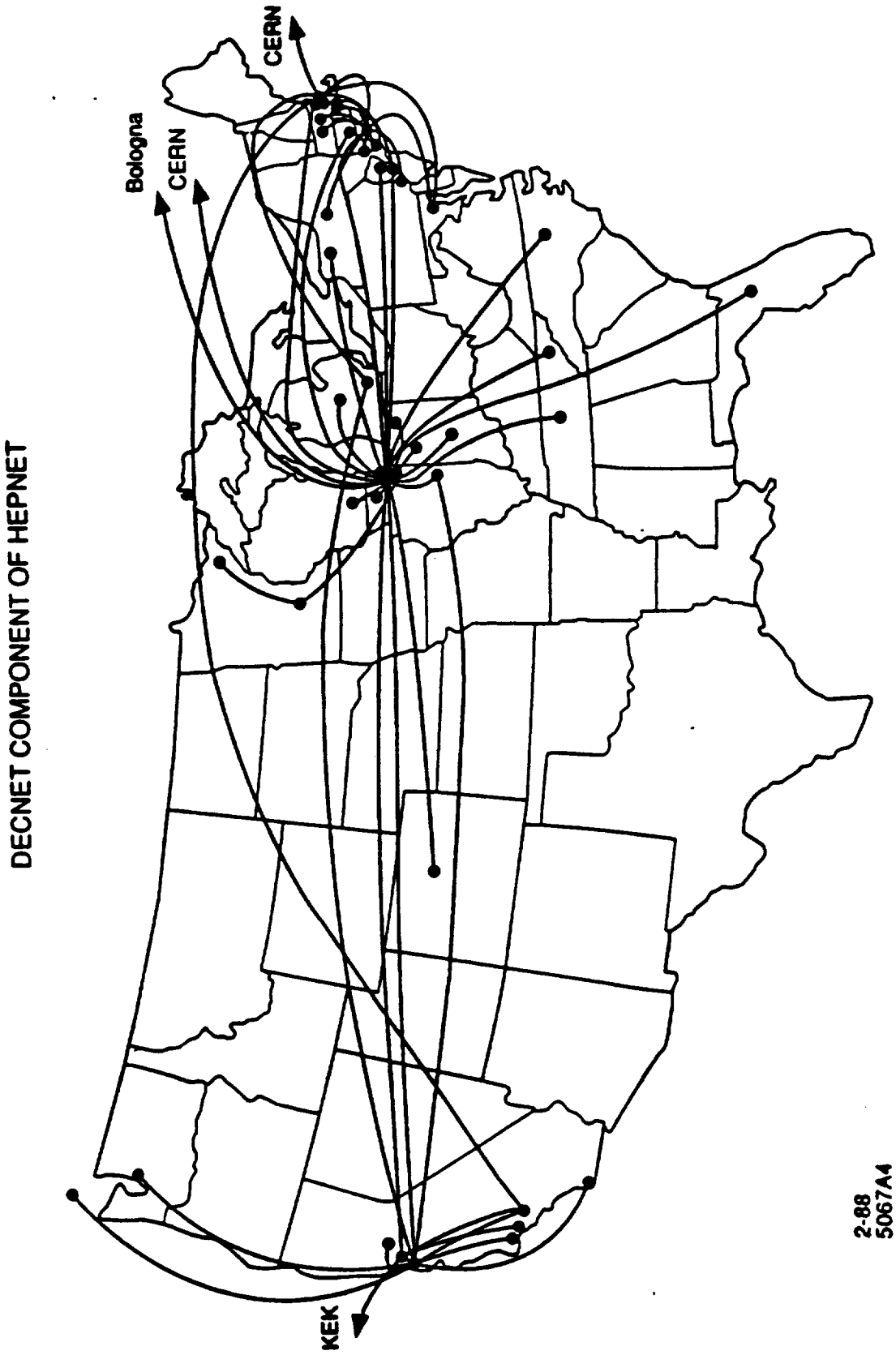


EXHIBIT 11-47. HEPNET Topology, DECNET Component

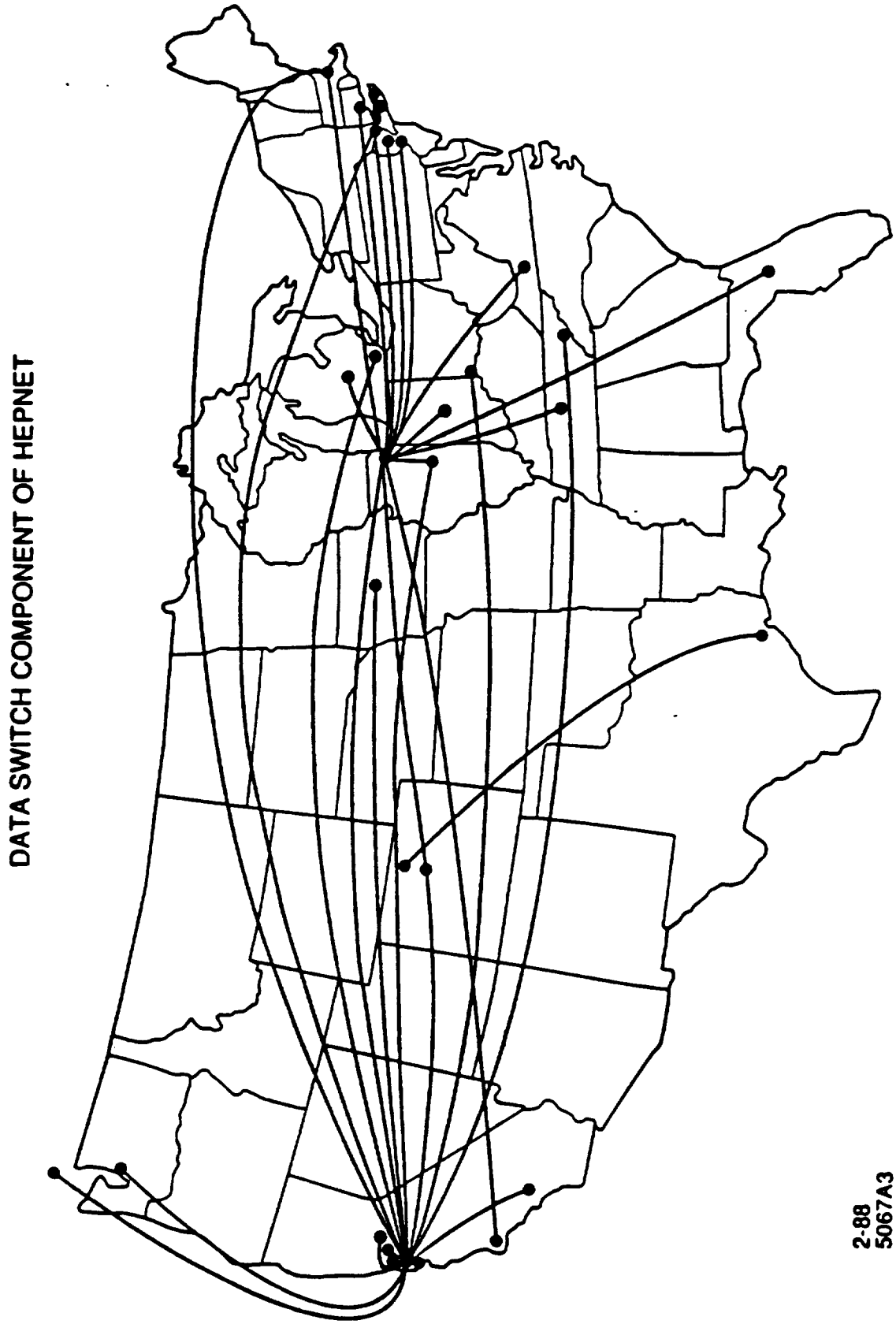


EXHIBIT 11-48. HEPNET Topology, Data Switch Component

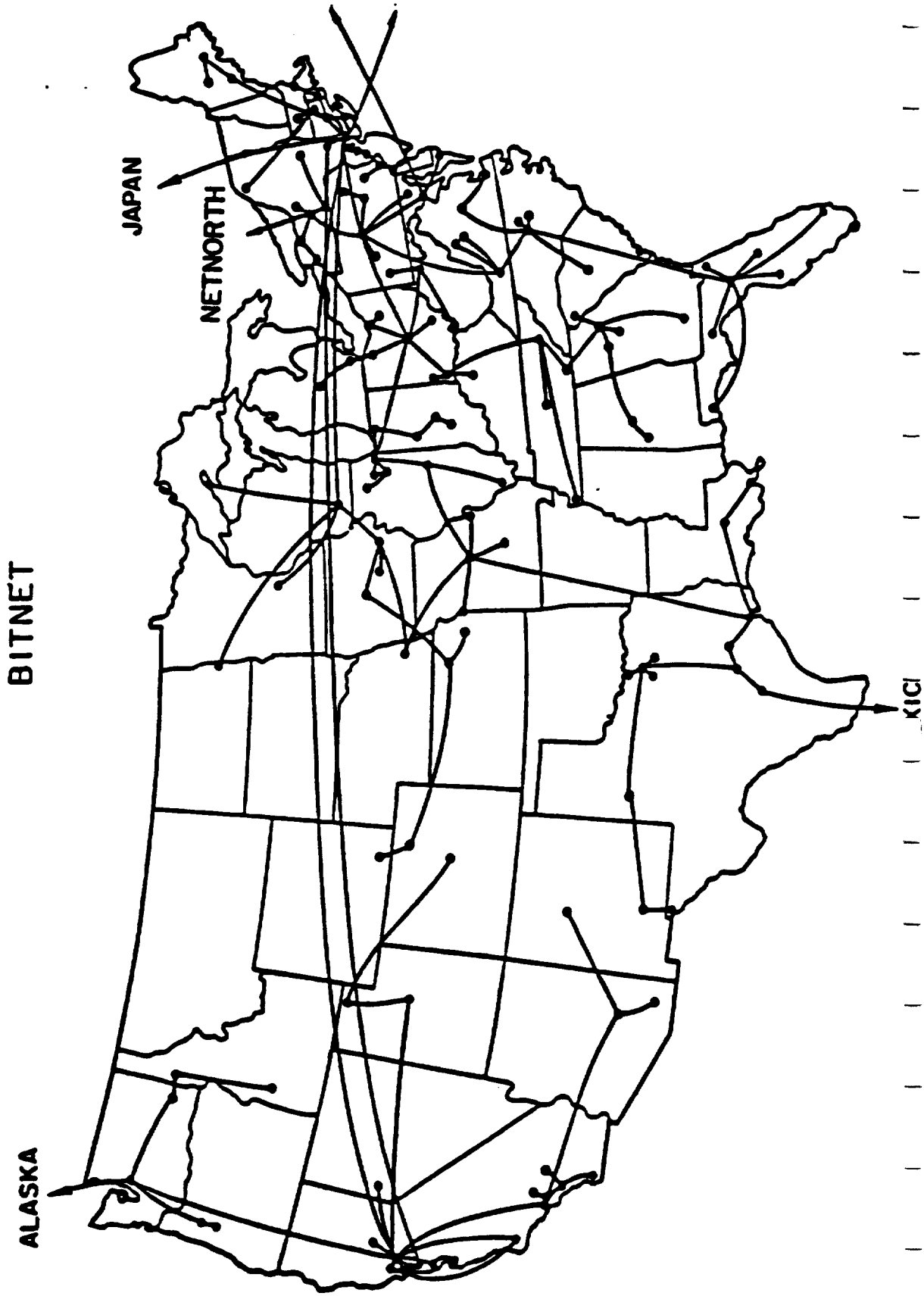


EXHIBIT 11-49. HEPNET Topology, BITNET Component

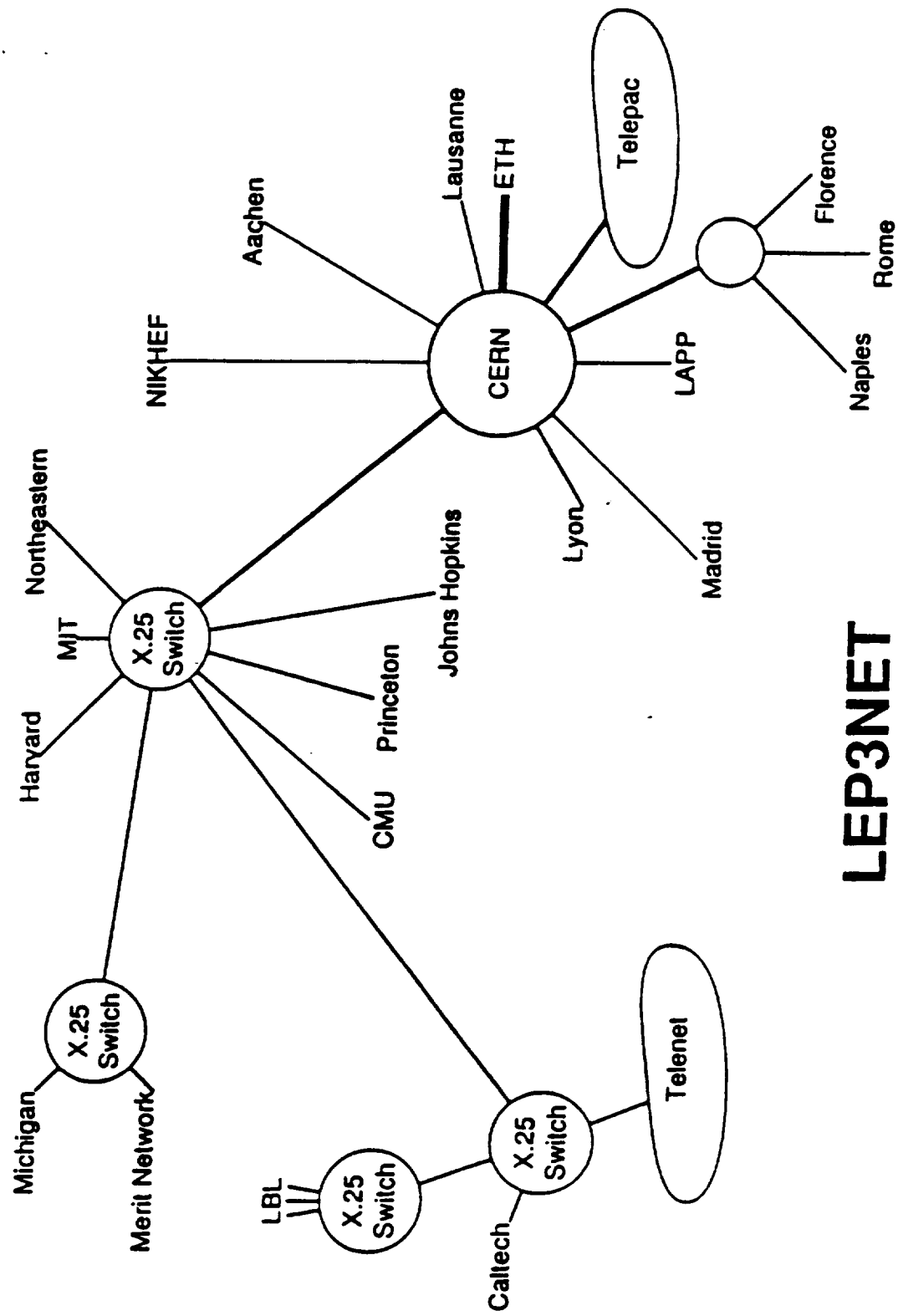


EXHIBIT 11-50. LEP3NET Topology

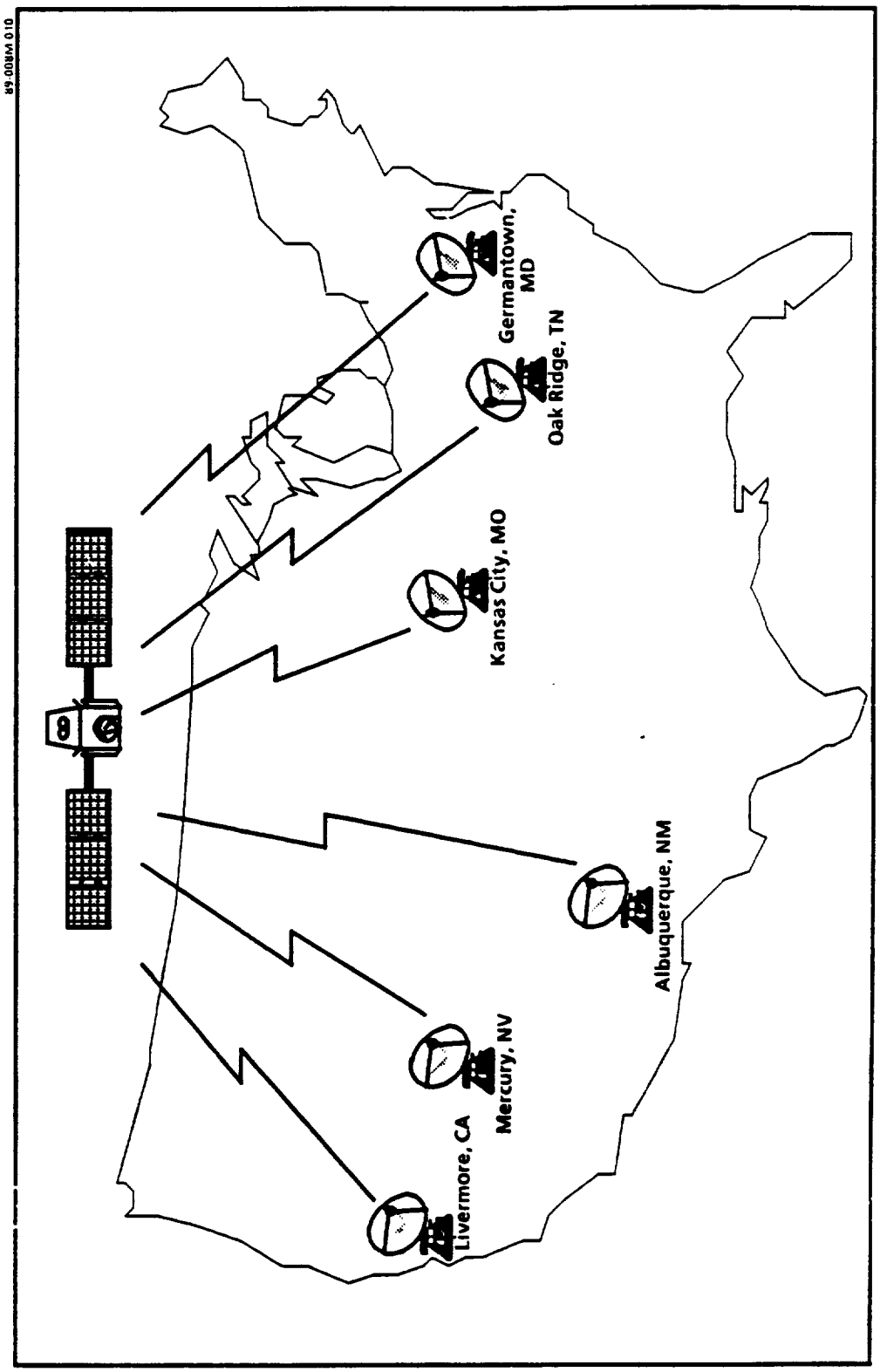


EXHIBIT 11-51. OPMODEL Topology

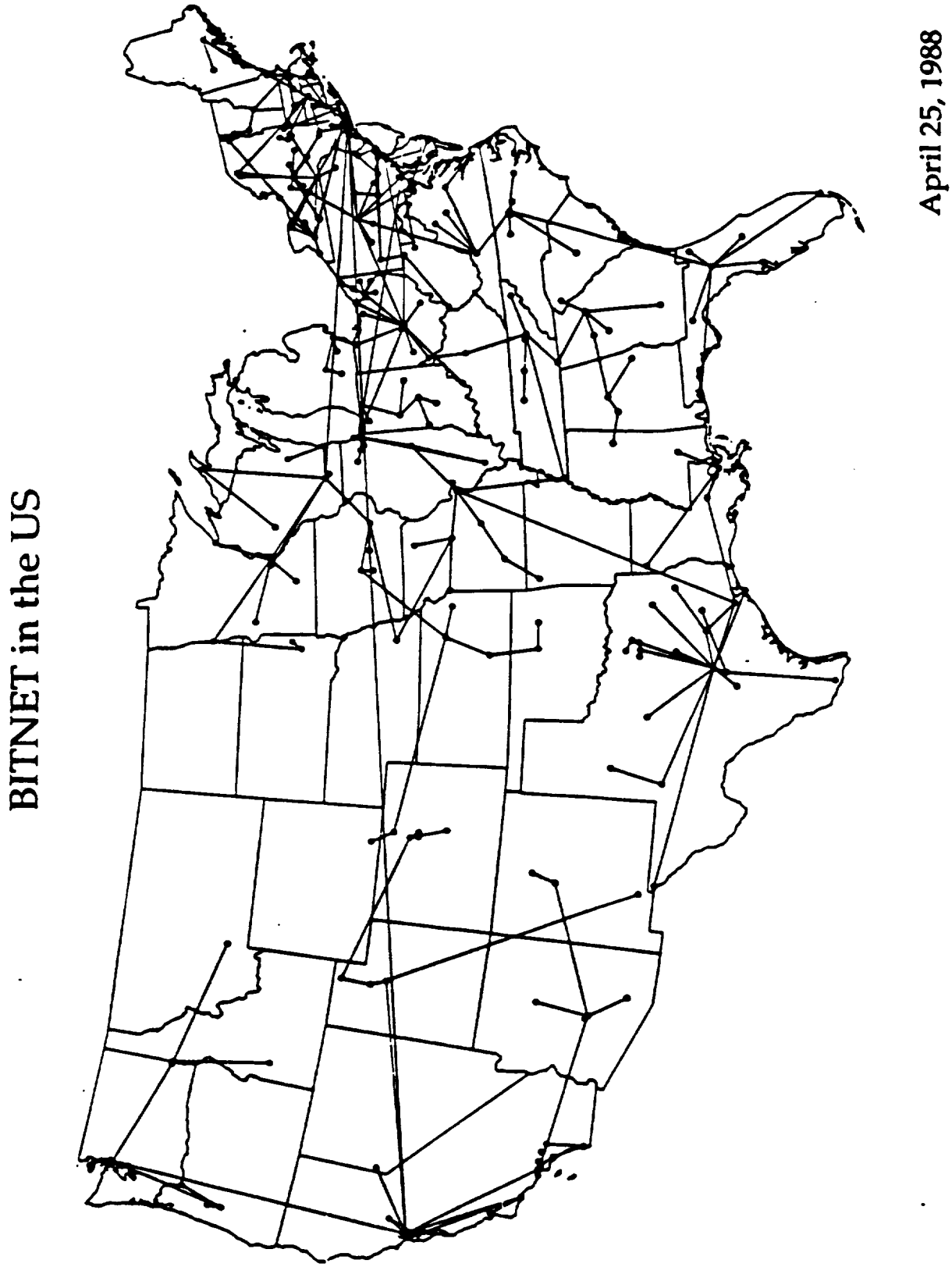


EXHIBIT 11-52. BITNET Topology

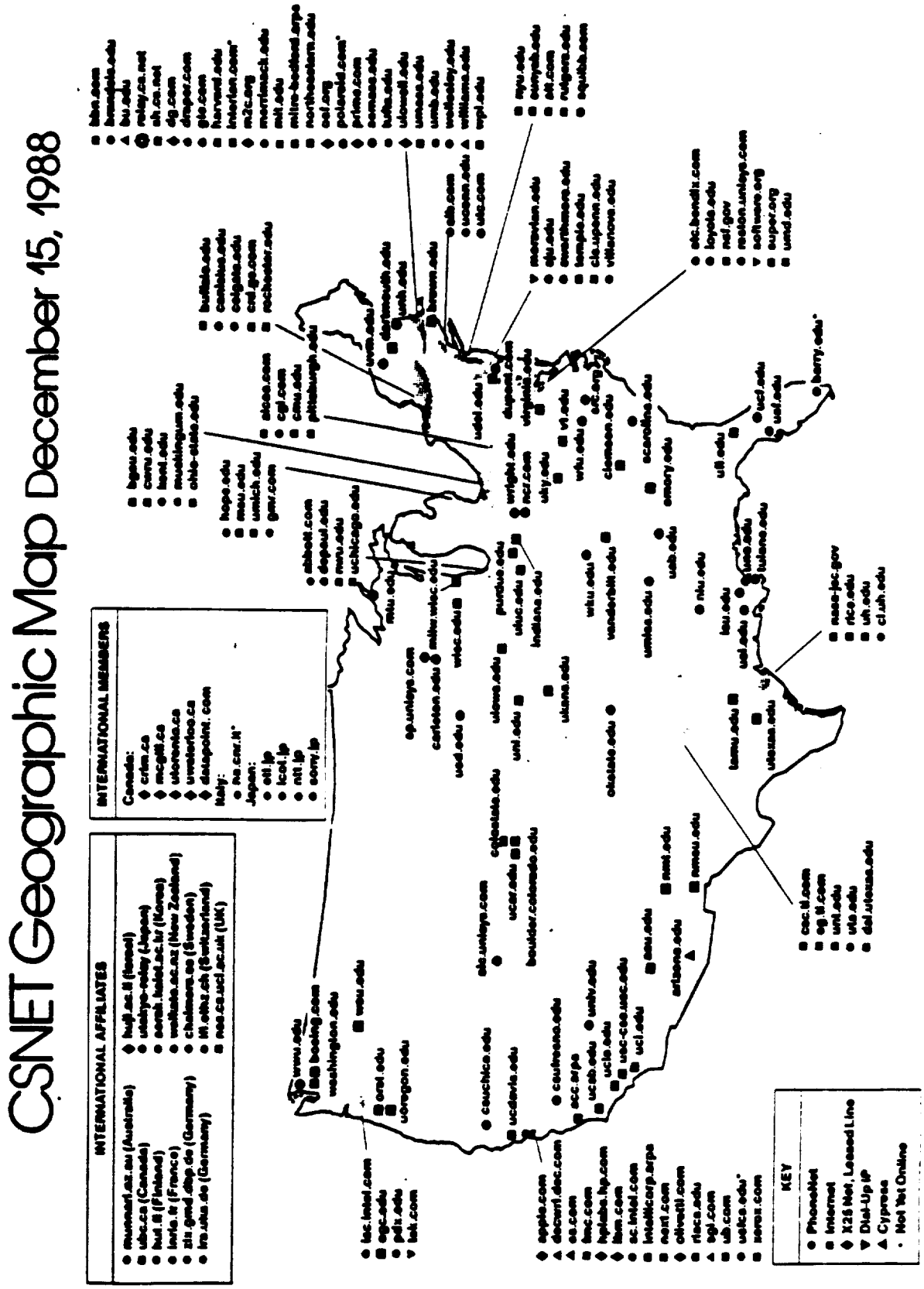


EXHIBIT 11-53. CSNET Topology

PRIMARY FILE - LIST OF KEY FIELDS

NETWORK	ACRONYM	SUBNETWORK	CAPACITY	ID	CITY - A	ST	ACEX	ID	CITY - B	ST	ACEX
CALIF EDUCATION NET	CERFNET	BACKBONE	1544	SD	SAN DIEGO	CA	619-534	LA	LOS ANGELES	CA	213-825
CALIF EDUCATION NET	CERFNET	BACKBONE	1544	SD	SAN DIEGO	CA	619-534	LA	LOS ANGELES	CA	818-356
CALIF EDUCATION NET	CERFNET	BACKBONE	1544	SD	SAN DIEGO	CA	619-534	LA	LOS ANGELES	CA	213-419
DEFENSE RES INTERNET	DRI		1544		BOSTON	MA	617-236		BOSTON	MA	617-813
DEFENSE RES INTERNET	DRI		1544		NEW YORK	NY	212-524		EATON	NJ	201-532
DEFENSE RES INTERNET	DRI		1544	DC	WASHINGTON	DC	202-545	NY	NEW YORK	NY	212-524
DEFENSE RES INTERNET	DRI		1544	NY	NEW YORK	NY	212-524	IT	ROME	NY	315-330
DEFENSE RES INTERNET	DRI		1544	CH	CHICAGO	IL	312-565	BD	DENVER	CO	303-572
DEFENSE RES INTERNET	DRI		1544	BD	DENVER	CO	303-572	LA	LOS ANGELES	CA	213-622
DEFENSE RES INTERNET	DRI		1544	LA	LOS ANGELES	CA	213-622	SD	SAN DIEGO	CA	619-553
DEFENSE RES INTERNET	DRI		1544		LOS ANGELES	CA	213-622		LOS ANGELES	CA	213-822
DEFENSE RES INTERNET	DRI		1544	CH	CHICAGO	IL	312-565	DT	LITCHFIELD	MI	517-542
DEFENSE RES INTERNET	DRI		1544		WASHINGTON	DC	202-545		ARLINGTON	VA	703-521
DEFENSE RES INTERNET	DRI		1544		WASHINGTON	DC	202-545		RESTON	VA	703-437
DEFENSE RES INTERNET	DRI		1544		PITTSBURGH	PA	412-621		PITTSBURGH	PA	412-628
DEFENSE RES INTERNET	DRI		1544	BO	BOSTON	MA	617-236	NY	NEW YORK	NY	212-524
DEFENSE RES INTERNET	DRI		1544	LA	LOS ANGELESO	CA	213-622	SF	SAN FRANCISCO	CA	415-859
DOE OPMODEL	OPMODEL		1544	AB	ALBUQUERQUE	NM	505-846	LL	LIVERMORE	CA	415-443
DOE OPMODEL	OPMODEL		1544	KS	KANSAS CITY	KS	816-363	LL	LIVERMORE	CA	415-443
DOE OPMODEL	OPMODEL		1544	KS	KANSAS CITY	KS	816-363	AB	ALBUQUERQUE	NM	505-846
DOE OPMODEL	OPMODEL		56	AB	ALBUQUERQUE	NM	505-846	KS	KANSAS CITY	KS	816-363
DOE OPMODEL	OPMODEL		56	AB	ALBUQUERQUE	NM	505-846	KS	KANSAS CITY	KS	816-363
DOE OPMODEL	OPMODEL		56	AB	ALBUQUERQUE	NM	505-846	KS	KANSAS CITY	KS	816-363
DOE OPMODEL	OPMODEL		56	AB	ALBUQUERQUE	NM	505-846	LL	LIVERMORE	CA	415-443
DOE OPMODEL	OPMODEL		56	AB	ALBUQUERQUE	NM	505-846	LL	LIVERMORE	CA	415-443
DOE OPMODEL	OPMODEL		56	KS	KANSAS CITY	KS	816-363	LL	LIVERMORE	CA	415-443
DOE OPMODEL	OPMODEL		56	DC	WASHINGTON	DC	301-428	LL	LIVERMORE	CA	415-443
DOE OPMODEL	OPMODEL		56	DC	WASHINGTON	DC	301-428	LL	LIVERMORE	CA	415-443
DOE OPMODEL	OPMODEL		56	DC	WASHINGTON	DC	301-428	LL	LIVERMORE	CA	415-443
DOE OPMODEL	OPMODEL		56	DC	WASHINGTON	DC	301-428	AB	ALBUQUERQUE	NM	505-846
DOE OPMODEL	OPMODEL		1544	LL	LIVERMORE	CA	415-443	AB	ALBUQUERQUE	NM	505-846
ENERGY SCIENCE	ESNET		1544	LA	LOS ANGELES	CA	213-825	SF	SAN FRANCISCO	CA	415-723
ENERGY SCIENCE	ESNET		1544	LA	LOS ANGELES	CA	619-955	AB	LOS ALAMOS	NM	505-667
ENERGY SCIENCE	ESNET		1544	PR	PRINCETON	NJ	609-243	NY	LONG ISLAND	NY	516-282
ENERGY SCIENCE	ESNET		1544	AU	AUSTIN	TX	512-471	DL	RICHARDSON	TX	214-690
ENERGY SCIENCE	ESNET		1544	DL	RICHARDSON	TX	214-690	TL	TALLAHASSEE	FL	904-644
ENERGY SCIENCE	ESNET		1544	NF	NORFOLK	VA	804-543	TL	TALLAHASSEE	FL	904-644
ENERGY SCIENCE	ESNET		1544	PR	PRINCETON	NJ	609-243	NF	NORFOLK VA	DC	804-543
ENERGY SCIENCE	ESNET		1544	PR	PRINCETON	NJ	609-243	CH	CHICAGO	IL	312-972
ENERGY SCIENCE	ESNET		1544	PR	PRINCETON	NJ	609-243	NY	NEW YORK	NY	212-460
ENERGY SCIENCE	ESNET		1544	NY	LONG ISLAND	NY	516-282	BO	CAMBRIDGE	MA	617-253
ENERGY SCIENCE	ESNET		1544	CH	CHICAGO	IL	312-840	BO	CAMBRIDGE	MA	617-253
ENERGY SCIENCE	ESNET		1544	LL	LIVERMORE	CA	415-422	PR	PRINCETON	NJ	609-243
ENERGY SCIENCE	ESNET		1544	SF	SAN FRANCISCO	CA	415-486	CH	CHICAGO	IL	312-840
ENERGY SCIENCE	ESNET		1544	OR	OAK RIDGE	TN	615-624	CH	CHICAGO	IL	312-972
ENERGY SCIENCE	ESNET		1544	OR	OAK RIDGE	TN	615-624	TL	TALLAHASSEE	FL	904-644
ENERGY SCIENCE	ESNET		56	AB	LOS ALAMOS	NM	505-667	AU	AUSTIN	TX	512-471
ENERGY SCIENCE	ESNET		56	AB	LOS ALAMOS	NM	505-667	KS	LAWRENCE	KS	913-842
ENERGY SCIENCE	ESNET		56	AB	LOS ALAMOS	NM	505-667	BD	BOULDER	CO	303-497

EXHIBIT 11-54. Primary Network Database

EXHIBIT 11-54. Primary Network Database

(Continued)

ENERGY SCIENCE	ESNET	56	LL	LIVERMORE	CA 415-422	SF	OAKLAND	CA 415-723
ENERGY SCIENCE	ESNET	56	LL	LIVERMORE	CA 415-422	LA	LOS ANGELES	CA 619-455
ENERGY SCIENCE	ESNET	1544	BO	CAMBRIDGE	MA 617-253	PR	PRINCETON	NJ 609-243
ENERGY SCIENCE	ESNET	56	CH	CHICAGO	IL 312-840	SF	SAN FRANCISCO	CA 415-486
ENERGY SCIENCE	ESNET	56	CH	CHICAGO	IL 312-840	TL	TALLAHASSEE	FL 904-644
NASA COMM NET	NASCOM	1544	DC	WASHINGTON	DC 301-286	WI	WALLOPS ISLAND	VA 804-336
NASA COMM NET	NASCOM	224	DC	WASHINGTON	DC 301-286	WS	WHITE SANDS	NM 505-524
NASA COMM NET	NASCOM	56	DC	WASHINGTON	DC 301-286	WS	WHITE SANDS	NM 505-524
NASA COMM NET	NASCOM	112		PASADENA	CA 818-354		BARSTOW	CA 619-255
NASA COMM NET	NASCOM	224	DC	WASHINGTON	DC 301-286	LA	BARSTOW	CA 619-255
NASA COMM NET	NASCOM	56	DC	WASHINGTON	DC 301-286	LA	BARSTOW	CA 619-255
NASA COMM NET	NASCOM	1544	DC	WASHINGTON	DC 301-286	SF	SAN FRANCISCO	CA 415-694
NASA COMM NET	NASCOM	112	DC	WASHINGTON	DC 301-286	SF	SAN FRANCISCO	CA 415-694
NASA COMM NET	NASCOM	224	DC	WASHINGTON	DC 301-286	SF	SAN FRANCISCO	CA 415-694
NASA COMM NET	NASCOM	448	DC	WASHINGTON	DC 301-286	LA	PASADENA	CA 818-354
NASA COMM NET	NASCOM	280	DC	WASHINGTON	DC 301-286	LA	PASADENA	CA 818-354
NASA COMM NET	NASCOM	224	DC	WASHINGTON	DC 301-286	LA	LOMPOC	CA 805-000
NASA COMM NET	NASCOM	1544	DC	WASHINGTON	DC 301-286	HN	HUNTSVILLE	AL 205-544
NASA COMM NET	NASCOM	512	DC	WASHINGTON	DC 301-286	HN	HUNTSVILLE	AL 205-544
NASA COMM NET	NASCOM	56	DC	WASHINGTON	DC 301-286	HU	HOUSTON	TX 713-486
NASA COMM NET	NASCOM	2048	DC	WASHINGTON	DC 301-286	HU	HOUSTON	TX 713-486
NASA COMM NET	NASCOM	1544	HU	HOUSTON	TX 713-486	KN	CAPE KENNEDY	FL 407-867
NASA COMM NET	NASCOM	2048	HN	HUNTSVILLE	AL 205-544	KN	CAPE KENNEDY	FL 407-867
NASA COMM NET	NASCOM	672	DC	WASHINGTON	DC 301-286	KN	CAPE KENNEDY	FL 407-867
NASA COMM NET	NASCOM	168	DC	WASHINGTON	DC 301-286	KN	CAPE KENNEDY	FL 407-867
NASA COMM NET	NASCOM	280	DC	WASHINGTON	DC 301-286	KN	CAPE KENNEDY	FL 407-867
NASA COMM NET	NASCOM	56	DC	WASHINGTON	DC 301-763	HU	HOUSTON	TX 713-486
NASA COMM NET	NASCOM	224	WI	WALLOPS ISLAND	VA 804-336	HU	HOUSTON	TX 713-486
NASA COMM NET	NASCOM	224	WI	WALLOPS ISLAND	VA 804-336	MD	MADISON	WI 608-262
NASA COMM NET	NASCOM	1544	WI	WALLOPS ISLAND	VA 804-336	HU	HOUSTON	TX 713-486
NASA COMM NET	NASCOM	56	DC	WASHINGTON	DC 301-286	WI	WALLOPS ISLAND	VA 804-336
NASA SCI INTERNET	NSI	56	LA	LOS ANGELES	CA 818-354	SD	SAN DIEGO	CA 619-534
NASA SCI INTERNET	NSI	56	LA	LOS ANGELES	CA 818-354	SD	SAN DIEGO	CA 619-534
NASA SCI INTERNET	NSI	56		LOS ANGELES	CA 818-354		LOS ANGELES	CA 213-535
NASA SCI INTERNET	NSI	56	LA	LOS ANGELES	CA 818-354	BD	BOULDER	CO 303-497
NASA SCI INTERNET	NSI	56		HUNTSVILLE	AL 205-544		BAY SAINT LOUIS	MS 601-688
NASA SCI INTERNET	NSI	56	HN	HUNTSVILLE	AL 205-544	MI	MIAMI	FL 305-361
NASA SCI INTERNET	NSI/SPAN BACKBONE	56	HU	HOUSTON	TX 713-486	AU	AUSTIN	TX 512-471
NASA SCI INTERNET	NSI/SPAN BACKBONE	56	DC	WASHINGTON	DC 301-286	LA	LOS ANGELES	CA 818-354
NASA SCI INTERNET	NSI/SPAN BACKBONE	56	SF	SAN FRANCISCO	CA 415-694	DC	WASHINGTON	DC 301-286
NASA SCI INTERNET	NSI/SPAN BACKBONE	56	SF	SAN FRANCISCO	CA 415-694	LA	LOS ANGELES	CA 818-354
NASA SCI INTERNET	NSI/SPAN BACKBONE	56	DC	WASHINGTON	DC 301-286	HN	HUNTSVILLE	AL 205-544
NASA SCI INTERNET	NSI/SPAN BACKBONE	56	LA	LOS ANGELES	CA 818-354	HN	HUNTSVILLE	AL 205-544
NASA SCI INTERNET	NSI/SPAN BACKBONE	56	LA	LOS ANGELES	CA 818-354	HU	HOUSTON	TX 713-486
NASA SCIENCE NETWORK	NSNET	168	DC	WASHINGTON	DC 301-286	HU	HOUSTON	TX 713-486
NASA SCIENCE NETWORK	NSNET	56	HU	HOUSTON	TX 713-486	HN	HUNTSVILLE	AL 205-544
NASA SCIENCE NETWORK	NSNET	56	LA	PASADENA	CA 818-354	HU	HOUSTON ISLAND	TX 713-486
NASA SCIENCE NETWORK	NSNET	56	LA	PASADENA	CA 818-354	DC	BALTIMORE	MD 301-338
NASA SCIENCE NETWORK	NSNET	56	LA	PASADENA	CA 818-354	TU	TUCSON	AZ 602-965
NASA SCIENCE NETWORK	NSNET	56	DC	WASHINGTON	DC 301-286	WI	WALLOPS ISLAND	VA 804-336
NASA SCIENCE NETWORK	NSNET	56	DC	WASHINGTON	DC 301-286	BO	CAMBRIDGE	MA 617-495
NASA SCIENCE NETWORK	NSNET	1544		WASHINGTON	DC 301-286		BALTIMORE	MD 301-338
				WASHINGTON	DC 301-286		WASHINGTON	DC 301-454

NASA SCIENCE NETWORK	NSNET		56		PASADENA	CA	818-354		HONOLULU	HI	808-949
NASA SCIENCE NETWORK	NSNET		168	HN	HUNTSVILLE	AL	205-544	HU	HOUSTON	TX	713-486
NASA SCIENCE NETWORK	NSNET		56	HU	HOUSTON	TX	713-486	WS	WHITE SANDS	NM	505-524
NASA SCIENCE NETWORK	NSNET		112	DC	WASHINGTON	DC	301-286	CL	CLEVELAND	OH	216-433
NASA SCIENCE NETWORK	NSNET		672	HN	HUNTSVILLE	AL	205-544	DC	WASHINGTON	DC	301-286
NASA SCIENCE NETWORK	NSNET		672	LA	PASADENA	CA	818-354	DC	WASHINGTON	DC	301-286
NASA SCIENCE NETWORK	NSNET		56		HOUSTON	TX	713-486		SAN ANTONIO	TX	512-522
NASA SCIENCE NETWORK	NSNET		56	HN	HUNTSVILLE	AL	205-544	KN	ORLANDO	FL	407-867
NASA SCIENCE NETWORK	NSNET		56	DC	WASHINGTON	DC	301-286	NY	NEW YORK	NY	212-678
NASA SCIENCE NETWORK	NSNET		56		HUNTSVILLE	AL	205-544		GULFPORT	MS	601-688
NASA SCIENCE NETWORK	NSNET		336	SF	SAN FRANCISCO	CA	415-694	DC	WASHINGTON	DC	301-286
NASA SCIENCE NETWORK	NSNET		56	SF	SAN FRANCISCO	CA	415-694	BD	BOULDER	CO	303-497
NASA SCIENCE NETWORK	NSNET		448	SF	SAN FRANCISCO	CA	415-694	LA	PASADENA	CA	818-354
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	IT	ITHACA	NY	607-255	DC	WASHINGTON	DC	301-454
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	SL	SALT LAKE CITY	UT	801-581	CH	CHICAGO	IL	312-996
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	SL	SALT LAKE CITY	UT	801-581	SF	MENLO PARK	CA	415-723
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	SL	SALT LAKE CITY	UT	801-581	BD	BOULDER	CO	303-497
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	HU	HOUSTON	TX	713-792	BD	BOULDER	CO	303-497
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	LI	LINCOLN	NE	402-472	BD	BOULDER	CO	303-497
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	SD	SAN DIEGO	CA	619-265	SF	MENLO PARK	CA	415-723
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	SD	SAN DIEGO	CA	619-265	HU	HOUSTON	TX	713-792
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	SE	SEATTLE	WA	206-543	SF	MENLO PARK	CA	415-723
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	SE	SEATTLE	WA	206-543	SD	SAN DIEGO	CA	619-265
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	CH	CHICAGO	IL	312-996	LI	LINCOLN	NE	402-472
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	CH	CHICAGO	IL	312-996	SE	SEATTLE	WA	206-543
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	DT	ANN ARBOR	MI	313-763	PR	PRINCETON	NJ	609-520
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	DC	WASHINGTON	DC	301-000	PR	PRINCETON	NJ	609-520
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	DC	WASHINGTON	DC	301-000	HU	HOUSTON	TX	713-792
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	PT	PITTSBURGH	PA	412-268	IL	URBANA	IL	217-333
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	PT	PITTSBURGH	PA	412-268	PR	PRINCETON	NJ	609-520
NAT SCIENCE FNDTN	NSFNET	BACKBONE	1544	IT	ITHACA	NY	607-255	PT	PITTSBURGH	PA	412-268
NAT SCIENCE FNDTN	NSFNET	BARRNET	1544		OAKLAND	CA	415-723		DAVIS	CA	916-752
NAT SCIENCE FNDTN	NSFNET	BARRNET	1544		SAN FRANCISCO	CA	415-723		MOFFETT FIELD	CA	415-694
NAT SCIENCE FNDTN	NSFNET	BARRNET	56		SAN FRANCISCO	CA	415-723		MONTEREY	CA	408-647
NAT SCIENCE FNDTN	NSFNET	BARRNET	1544		SAN FRANCISCO	CA	415-723		SANTA CRUZ	CA	408-429
NAT SCIENCE FNDTN	NSFNET	BARRNET	1544	SF	SAN FRANCISCO	CA	415-723	LL	LIVERMORE	CA	415-422
NAT SCIENCE FNDTN	NSFNET	CICNET	1544	CH	CHICAGO	IL	312-491	MD	MADISON	WI	608-262
NAT SCIENCE FNDTN	NSFNET	CICNET	1544		ANN ARBOR	MI	313-763		LANSING	MI	512-355
NAT SCIENCE FNDTN	NSFNET	CICNET	1544	DT	ANN ARBOR	MI	313-763	CB	COLUMBUS	OH	614-292
NAT SCIENCE FNDTN	NSFNET	CICNET	1544	IN	INDIANAPOLIS	IN	812-335	CB	COLUMBUS	OH	614-292
NAT SCIENCE FNDTN	NSFNET	CICNET	1544	CH	CHICAGO	IL	312-491	IL	URBANA	IL	217-244
NAT SCIENCE FNDTN	NSFNET	CICNET	1544	IL	URBANA	IL	217-333	IN	BLOOMINGTON	IN	812-335
NAT SCIENCE FNDTN	NSFNET	CICNET	1544	IO	IOWA CITY	IA	319-337	IL	URBANA	IL	217-244
NAT SCIENCE FNDTN	NSFNET	CICNET	1544	MP	MINNEAPOLIS	MN	612-625	IO	IOWA CITY	IA	515-294
NAT SCIENCE FNDTN	NSFNET	CICNET	1544	MP	MINNEAPOLIS	MN	612-625	MD	MADISON	WI	608-262
NAT SCIENCE FNDTN	NSFNET	JVNCNET	1544	PR	PRINCETON	NJ	609-520	BO	CAMBRIDGE	MA	617-253
NAT SCIENCE FNDTN	NSFNET	JVNCNET	1544	PR	PRINCETON	NJ	609-520	BD	BOLDER	CO	303-492
NAT SCIENCE FNDTN	NSFNET	JVNCNET	1544	PR	PRINCETON	NJ	609-520	BO	CAMBRIDGE	MA	617-495
NAT SCIENCE FNDTN	NSFNET	JVNCNET	1544	PR	PRINCETON	NJ	609-520	BO	AMHERST	MA	413-545
NAT SCIENCE FNDTN	NSFNET	JVNCNET	1544	PR	PRINCETON	NJ	609-520	BO	NEW HAVEN	CT	203-432
NAT SCIENCE FNDTN	NSFNET	JVNCNET	1544	PR	PRINCETON	NJ	609-520	NY	NEW YORK	NY	212-460
NAT SCIENCE FNDTN	NSFNET	JVNCNET	1544	PR	PRINCETON	NJ	609-520	NY	NEW YORK	NY	212-280
NAT SCIENCE FNDTN	NSFNET	JVNCNET	1544	PR	PRINCETON	NJ	609-520	TU	TUCSON	AZ	602-261

EXHIBIT 11-54. Primary Network Database

(Continued)

NAT	SCIENCE	FNDTN	NSFNET	JVNCNET	1544		PRINCETON	NJ	609-520		NEW BRUNSWICK	NJ	201-932
NAT	SCIENCE	FNDTN	NSFNET	JVNCNET	1544	PR	PRINCETON	NJ	609-520	SC	STATE COLLEGE	PA	814-863
NAT	SCIENCE	FNDTN	NSFNET	JVNCNET	1544	PR	PRINCETON	NJ	609-520	PH	PHILADELPHIA	PA	215-898
NAT	SCIENCE	FNDTN	NSFNET	JVNCNET	1544		PRINCETON	NJ	609-520		PRINCETON	NJ	609-452
NAT	SCIENCE	FNDTN	NSFNET	MIDNET	56	LI	LINCOLN	NE	402-472	IO	IOWA CITY	IA	515-294
NAT	SCIENCE	FNDTN	NSFNET	MIDNET	56	LI	LINCOLN	NE	402-472	KS	LAWRENCE	KS	913-532
NAT	SCIENCE	FNDTN	NSFNET	MIDNET	56		LINCOLN	NE	402-472		NORMAN	OK	405-744
NAT	SCIENCE	FNDTN	NSFNET	MIDNET	56		LINCOLN	NE	402-472		FAYETTEVILLE	AR	501-575
NAT	SCIENCE	FNDTN	NSFNET	MIDNET	56		LINCOLN	NE	402-472		COLUMBIA	MO	314-882
NAT	SCIENCE	FNDTN	NSFNET	MIDNET	56	LI	LINCOLN	NE	402-472	IL	URBANA	IL	217-333
NAT	SCIENCE	FNDTN	NSFNET	NCSANET	1544	IL	URBANA	IL	217-333	CH	CHICAGO	IL	312-996
NAT	SCIENCE	FNDTN	NSFNET	NCSANET	56	IL	URBANA	IL	217-333	MD	MILWAUKEE	WI	414-229
NAT	SCIENCE	FNDTN	NSFNET	NCSANET	14.4		URBANA	IL	217-333		CHICAGO	IL	312-840
NAT	SCIENCE	FNDTN	NSFNET	NCSANET	56		CHICAGO	IL	312-996		SOUTH BEND	IL	219-239
NAT	SCIENCE	FNDTN	NSFNET	NCSANET	1544	CH	CHICAGO	IL	312-996	DT	LANSING	MI	517-355
NAT	SCIENCE	FNDTN	NSFNET	NWNET	56		SEATTLE	WA	206-543		SEATTLE	WA	206-865
NAT	SCIENCE	FNDTN	NSFNET	NWNET	1544	BD	BOULDER	CO	303-497	PO	CORVALIS	OR	503-767
NAT	SCIENCE	FNDTN	NSFNET	NWNET	56		SEATTLE	WA	206-543		FAIRBANKS	AK	907-786
NAT	SCIENCE	FNDTN	NSFNET	NWNET	19.2		SEATTLE	WA	206-543		SAN DIEGO	CA	619-534
NAT	SCIENCE	FNDTN	NSFNET	NWNET	19.2		SEATTLE	WA	206-543		FARGO	ND	701-237
NAT	SCIENCE	FNDTN	NSFNET	NWNET	56		SEATTLE	WA	206-543		MOSCOW	ID	208-885
NAT	SCIENCE	FNDTN	NSFNET	NWNET	56	SE	SEATTLE	WA	206-543	PO	EUGENE	OR	503-686
NAT	SCIENCE	FNDTN	NSFNET	NWNET	56	SE	SEATTLE	WA	206-543	PO	CORVALLIS	OR	503-767
NAT	SCIENCE	FNDTN	NSFNET	NWNET	56	SE	SEATTLE	WA	206-543	PO	PORTLAND	OR	503-690
NAT	SCIENCE	FNDTN	NSFNET	NYSERNET	1544		ITHACA	NY	607-255		ROCHESTER	NY	716-275
NAT	SCIENCE	FNDTN	NSFNET	NYSERNET	1544	IT	ITHACA	NY	607-255	NY	NEW YORK	NY	212-903
NAT	SCIENCE	FNDTN	NSFNET	NYSERNET	1544	IT	ITHACA	NY	607-255	NY	NEW YORK	NY	212-998
NAT	SCIENCE	FNDTN	NSFNET	NYSERNET	1544	IT	ITHACA	NY	607-255	NY	NEW YORK	NY	212-854
NAT	SCIENCE	FNDTN	NSFNET	NYSERNET	1544		ITHACA	NY	607-255		ALBANY	NY	518-442
NAT	SCIENCE	FNDTN	NSFNET	NYSERNET	1544		ITHACA	NY	607-255		SYRACUSE	NY	315-443
NAT	SCIENCE	FNDTN	NSFNET	PREPNET	1544	PT	PITTSBURGH	PA	412-268	PH	PHILADELPHIA	PA	215-898
NAT	SCIENCE	FNDTN	NSFNET	PREPNET	1544		PHILADELPHIA	PA	215-898		LEHIGH	PA	215-758
NAT	SCIENCE	FNDTN	NSFNET	PSCNET	1544	PT	PITTSBURGH	PA	412-268	DC	WASHINGTON	DC	301-454
NAT	SCIENCE	FNDTN	NSFNET	PSCNET	1544	PT	PITTSBURGH	PA	412-268	CL	CLEVELAND	OH	216-368
NAT	SCIENCE	FNDTN	NSFNET	PSCNET	1544	PT	PITTSBURGH	PA	412-268	SC	STATE COLLEGE	PA	814-865
NAT	SCIENCE	FNDTN	NSFNET	SDSCNET	56	SD	SAN DIEGO	CA	619-265	SL	SALT LAKE CITY	UT	801-581
NAT	SCIENCE	FNDTN	NSFNET	SDSCNET	56	SD	SAN DIEGO	CA	619-265	LA	IRVINE	CA	714-856
NAT	SCIENCE	FNDTN	NSFNET	SDSCNET	56	SD	SAN DIEGO	CA	619-265	SF	OAKLAND	CA	415-642
NAT	SCIENCE	FNDTN	NSFNET	SDSCNET	56	SD	SAN DIEGO	CA	619-652	LA	SANTA BARBARA	CA	805-961
NAT	SCIENCE	FNDTN	NSFNET	SDSCNET	56	SD	SAN DIEGO	CA	619-652	LA	RIVERSIDE	CA	714-787
NAT	SCIENCE	FNDTN	NSFNET	SDSCNET	56	SD	SAN DIEGO	CA	619-265	SL	SALT LAKE CITY	UT	801-378
NAT	SCIENCE	FNDTN	NSFNET	SDSCNET	56	SD	SAN DIEGO	CA	619-265	SE	SEATTLE	WA	206-543
NAT	SCIENCE	FNDTN	NSFNET	SESQUINET	56		HOUSTON	TX	713-792		HOUSTON	TX	713-798
NAT	SCIENCE	FNDTN	NSFNET	SESQUINET	56		HOUSTON	TX	713-792		HOUSTON	TX	713-527
NAT	SCIENCE	FNDTN	NSFNET	SESQUINET	1544		HOUSTON	TX	713-792		BYRAN	TX	409-845
NAT	SCIENCE	FNDTN	NSFNET	SESQUINET	1544	HU	HOUSTON	TX	713-792	AU	AUSTIN	TX	512-471
NAT	SCIENCE	FNDTN	NSFNET	SESQUINET	1544	HU	BRYAN	TX	409-845	AU	AUSTIN	TX	512-471
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		ATLANTA	GA	404-894		BATON ROUGE	LA	504-388
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		ATLANTA	GA	404-894		BIRMINGHAM	AL	205-934
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		NASHVILLE	TN	615-343		OAK RIDGE	TN	615-574
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		OAK RIDGE	TN	615-576		OAK RIDGE	TN	615-574
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		OAK RIDGE	TN	615-576		LEXINGTON	KY	606-257
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		NASHVILLE	TN	615-343		BIRMINGHAM	AL	205-934

NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		ATLANTA	GA	404-894		TALLAHASSEE	FL 904-644
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		ATLANTA	GA	404-894		COLUMBIA	SC 803-656
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		CLEMSON	SC	803-656		COLUMBIA	SC 803-656
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56	DC	WASHINGTON	DC	301-454	PH	WILMINGTON	DE 302-451
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		WASHINGTON	DC	301-454		BALTIMORE	MD 301-338
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		WASHINGTON	DC	301-454		WASHINGTON	DC 301-454
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56	DC	WASHINGTON	DC	301-454	NF	NORFOLK	VA 804-249
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		WASHINGTON	DC	301-454		BLACKSBURG	VA 703-961
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		WASHINGTON	DC	301-454		CHARLOTTESVILLE	VA 804-924
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		WASHINGTON	DC	301-454		MORGANTOWN	WV 304-293
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		WASHINGTON	DC	301-454		GAITHERSBURG	MD 202-975
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		WASHINGTON	DC	301-454		WASHINGTON	DC 202-357
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		WASHINGTON	DC	301-454		HYATTSVILLE	MD 301-731
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		WASHINGTON	DC	301-454		WILLIAMSBURG	VA 804-253
NAT	SCIENCE	FNDTN	NSFNET	SURANET	1544		WASHINGTON	DC	301-454		WASHINGTON	DC 301-286
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		WASHINGTON	DC	301-454		LEXINGTON	KY 606-257
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		STARKVILLE	MS	601-325		BIRMINGHAM	AL 205-934
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		TUSCALOOSA	AL	205-348		BIRMINGHAM	AL 205-934
NAT	SCIENCE	FNDTN	NSFNET	SURANET	56		CLEMSON	SC	803-656		CHARLOTTE	NC 504-286
NAT	SCIENCE	FNDTN	NSFNET	THENET	56		HOUSTON	TX	713-792		BRYAN	TX 409-845
NAT	SCIENCE	FNDTN	NSFNET	THENET	56	HU	HOUSTON	TX	713-792	DL	DALLAS	TX 214-690
NAT	SCIENCE	FNDTN	NSFNET	THENET	56		HOUSTON	TX	713-792		SAN ANTONIO	TX 512-691
NAT	SCIENCE	FNDTN	NSFNET	THENET	56	HU	HOUSTON	TX	713-792	AU	AUSTIN	TX 512-471
NAT	SCIENCE	FNDTN	NSFNET	THENET	56		HOUSTON	TX	713-792		PRAIRIE VIEW	TX 409-857
NAT	SCIENCE	FNDTN	NSFNET	USAN	224	BD	BOULDER	CO	303-497	BO	WOODS HOLE	MA 508-548
NAT	SCIENCE	FNDTN	NSFNET	USAN	224	BD	BOULDER	CO	303-497	DC	WASHINGTON	DC 301-454
NAT	SCIENCE	FNDTN	NSFNET	USAN	224	BD	BOULDER	CO	303-497	DC	WASHINGTON	DC 202-767
NAT	SCIENCE	FNDTN	NSFNET	USAN	224	BD	BOULDER	CO	303-497	MI	MIAMI	FL 305-361
NAT	SCIENCE	FNDTN	NSFNET	USAN	224		BOULDER	CO	303-497		BAY ST LOUIS	MS 601-688
NAT	SCIENCE	FNDTN	NSFNET	USAN	224	BD	BOULDER	CO	303-497	DT	ANN ARBOR	MI 313-763
NAT	SCIENCE	FNDTN	NSFNET	USAN	224	BD	BOULDER	CO	303-497	MD	MADISON	WI 608-262
NAT	SCIENCE	FNDTN	NSFNET	USAN	224	BD	BOULDER	CO	303-497	PO	CORVALLIS	OR 503-767
NAT	SCIENCE	FNDTN	NSFNET	WESTNET	56	BD	BOULDER	CO	303-497	SL	SALT LAKE CITY	UT 801-581
NAT	SCIENCE	FNDTN	NSFNET	WESTNET	56	BD	BOULDER	CO	303-497	TU	TUCSON	AZ 602-261
NAT	SCIENCE	FNDTN	NSFNET	WESTNET	56		BOULDER	CO	303-497		LAS CRUCES	NM 505-646
NAT	SCIENCE	FNDTN	NSFNET	WESTNET	56		BOULDER	CO	303-497		DENVER	CO 303-556
NAT	SCIENCE	FNDTN	NSFNET	WESTNET	56		BOULDER	CO	303-497		COLORADO SPRS	CO 719-593
NAT	SCIENCE	FNDTN	NSFNET	WESTNET	56		BOULDER	CO	303-497		FT COLLINS	CO 303-491
NAT	SCIENCE	FNDTN	NSFNET	WESTNET	56		BOULDER	CO	303-497		LARAME	WY 307-766

EXHIBIT 11-54. Primary Network Database

(Continued)

KEY	CITY	STATE	V	H
AB	ALBUQUERQUE	NM	8549	5887
AU	AUSTIN	TX	9005	3996
BO	BOSTON	MA	4422	1249
BD	BOULDER	CO	7456	5961
CH	CHICAGO	IL	5986	3426
CL	CLEVELAND	OH	5574	2543
CB	COLUMBUS	OH	5972	2555
DL	DALLAS	TX	8436	4034
DT	DETROIT	MI	5536	2828
HU	HOUSTON	TX	8938	3536
HN	HUNTSVILLE	AL	7267	2535
IN	INDIANAPOLIS	IN	6272	2992
IO	IOWA CITY	IA	6315	3971
IT	ITHACA	NY	4798	1990
KS	KANSAS CITY	MO	7249	4210
KN	KENNEDY SPC CTR	FL	7919	0880
LI	LINCOLN	NE	6823	4674
LL	LIVERMORE	CA	8504	8606
LA	LOS ANGELES	CA	9213	7878
MD	MADISON	WI	5890	3798
MI	MIAMI	FL	8351	0527
MP	MINNEAPOLIS	MN	5781	4525
NY	NEW YORK	NY	4997	1406
NF	NORFOLK	VA	5936	1198
OR	OAK RIDGE	TN	6811	2303
PH	PHILADELPHIA	PA	5251	1458
PT	PITTSBURGH	PA	5621	2185
PO	PORTLAND	OR	6799	8914
PR	PRINCETON	NJ	5120	1436
SL	SALT LAKE	UT	7576	7065
SD	SAN DIEGO	CA	9468	7629
SF	SAN FRANCISCO	CA	8492	8719
SE	SEATTLE	WA	6336	8896
SC	STATE COLLEGE	PA	5360	1933
TL	TALLAHASEE	FL	7876	1715
TU	TUCSON	AZ	9342	648C
IL	URBANA	IL	6371	3336
WI	WALLOPS ISLAND	VA	5657	1249
DC	WASHINGTON	DC	5622	1583
WS	WHITE SANDS	NM	9132	5742

EXHIBIT 11-55. Major Access Points - Current IRN

11.3.4 Sorts By City Identifcation

City A and City B links sorted by City A and City B identifications (i.e., major access points) are presented in Exhibits 11-56 and 11-57. As noted earlier, these sorts were used to determine major access point connectivity and link capacity requirements (in Kbps).

11.3.5 Current IRN Links And Topology

The Current IRN links are listed in Exhibit 1-58 (Capacity is in Kbps). The Current IRN topology, based on these links, is depicted in Exhibits 11-59 through 11-61. Exhibit 11-59 simply shows the location of the 40 major access points. Exhibit 11-60 shows the number of T1s terminating in each major access point. Exhibit 11-61 depicts the major access point T1 connectivity in the current IRN. The numbers for the various links represent the number of T1s required for the various links. A total of 187 T1s were estimated to be required for the Current IRN.

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SORTED BY CITY-A IDS

ID	CITY- A	ST	ID	CITY - B	ST	CAPACITY	MILES	NETWORK	SUBNETWORK
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56	860	OPMODEL	
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1544	860	OPMOD	
AB	LOS ALAMOS	NM	BD	BOULDER	CO	56	346	ESNET	
AB	LOS ALAMOS	NM	KS	LAWRENCE	KS	56	671	ESNET	
AB	LOS ALAMOS	NM	AU	AUSTIN	TX	56	615	ESNET	
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56	860	OPMODEL	
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	OPMODEL	
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	OPMODEL	
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	OPMOD	
AU	AUSTIN	TX	DL	RICHARDSON	TX	1544	180	ESN	
BD	DENVER	CO	LA	LOS ANGELES	CA	1544	822	DRI	
BD	BOULDER	CO	DC	WASHINGTON	DC	224	1,501	NSFNET	USAN
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	56	351	NSFNET	WEST
BD	BOULDER	CO	DC	WASHINGTON	DC	224	1,501	NSFNET	USAN
BD	BOULDER	CO	BO	WOODS HOLE	MA	224	1,772	NSFNET	USAN
BD	BOULDER	CO	MI	MIAMI	FL	224	1,742	NSFNET	USAN
BD	BOULDER	CO	TU	TUCSON	AZ	56	619	NSFNET	WEST
BD	BOULDER	CO	DT	ANN ARBOR	MI	224	1,162	NSFNET	USAN
BD	BOULDER	CO	PO	CORVALIS	OR	1544	957	NSFNET	NWNE
BD	BOULDER	CO	PO	CORVALLIS	OR	224	957	NSFNET	USAN
BD	BOULDER	CO	MD	MADISON	WI	224	844	NSFNE	
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	1544	229	ESN	
BO	BOSTON	MA	NY	NEW YORK	NY	1544	188	DRI	
CH	CHICAGO	IL	SE	SEATTLE	WA	1544	1,733	NSFNET	BACKBON
CH	CHICAGO	IL	DT	LANSING	MI	1544	237	NSF	
CH	CHICAGO	IL	DT	LITCHFIELD	MI	1544	237	DRI	
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	56	1,852	ESNET	
CH	CHICAGO	IL	MD	MADISON	WI	1544	121	NSF	
CH	CHICAGO	IL	BD	DENVER	CO	1544	927	DRI	
CH	CHICAGO	IL	TL	TALLAHASSEE	FL	56	806	ESNET	
CH	CHICAGO	IL	IL	URBANA	IL	1544	125	NSFNET	CICNET
CH	CHICAGO	IL	LI	LINCOLN	NE	1544	475	NSFNE	
CH	CHICAGO	IL	BO	CAMBRIDGE	MA	1544	848	ESN	
DC	WASHINGTON	DC	NY	NEW YORK	NY	1544	205	DRI	
DC	WASHINGTON	DC	AB	ALBUQUERQUE	NM	56	1,646	OPMODEL	
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2,401	OPMODEL	
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2,401	OPMODEL	
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2,401	OPMODEL	
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	56	601	NSI/SPAN	BACKBONE
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1,217	NSI/SP	
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56	106	NASCOM	
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1544	106	NASCC	
DC	WASHINGTON	DC	CL	CLEVELAND	OH	112	304	NSNET	
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	168	760	NASCOM	
DC	WASHINGTON	DC	LA	LOS ANGELES	CA	56	2,292	NSI/SP	
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	224	1,572	NASCOM	

EXHIBIT 11-56. Major Access Point Sort - City A

DC	WASHINGTON	DC	WS	WHITE SANDS	NM	56	1,721	NASCOM	
DC	WASHINGTON	DC	LA	BARSTOW	CA	224	2,292	NASCOM	
DC	WASHINGTON	DC	LA	BARSTOW	CA	56	2,292	NASCC	
DC	WASHINGTON	DC	BO	CAMBRIDGE	MA	56	394	NSNET	
DC	WASHINGTON	DC	PR	PRINCETON	NJ	1544	165	NSFNET	
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	1544	2,432	NASCOM	
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	112	2,432	NASCOM	
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	224	2,432	NASCOM	
DC	WASHINGTON	DC	HU	HOUSTON	TX	1544	1,217	NSFNET	
DC	WASHINGTON	DC	LA	PASADENA	CA	448	2,292	NASCOM	
DC	WASHINGTON	DC	LA	PASADENA	CA	280	2,292	NASCOM	
DC	WASHINGTON	DC	LA	LOMPOC	CA	224	2,292	NASCOM	
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	1544	601	NASCOM	
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	672	760	NASCOM	
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	512	601	NASCOM	
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1,217	NASCOM	
DC	WASHINGTON	DC	HU	HOUSTON	TX	2048	1,217	NASCOM	
DC	WASHINGTON	DC	PH	WILMINGTON	DE	56	124	NSFNET	SURANET
DC	WASHINGTON	DC	NF	NORFOLK	VA	56	157	NSFNET	
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1,217	NASCOM	
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	280	760	NASCC	
DC	WASHINGTON	DC	NY	NEW YORK	NY	56	205	NSNET	
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56	106	NSNET	
DL	RICHARDSON	TX	TL	TALLAHASSEE	FL	1544	754	ESNET	
DT	ANN ARBOR	MI	CB	COLUMBUS	OH	1544	163	NSFNET	CICNET
DT	ANN ARBOR	MI	PR	PRINCETON	NJ	1544	459	NSFNET	
HN	HUNTSVILLE	AL	KN	CAPE KENNEDY	FL	2048	563	NASCC	
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	168	616	NSNET	
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	672	601	NSNET	
HN	HUNTSVILLE	AL	KN	ORLANDO	FL	56	563	NSN	
HN	HUNTSVILLE	AL	MI	MIAMI	FL	56	722	NSI	
HU	HOUSTON	TX	AU	AUSTIN	TX	56	147	NSFNET	THENET
HU	HOUSTON	TX	DL	DALLAS	TX	56	224	NSFNET	THENET
HU	HOUSTON	TX	HN	HUNTSVILLE	AL	56	616	NSI/S	
HU	HOUSTON	TX	WS	WHITE SANDS	NM	56	700	NSNET	
HU	HOUSTON	TX	AU	AUSTIN	TX	1544	147	NSFNET	SESQUINET
HU	BRYAN	TX	AU	AUSTIN	TX	1544	147	NSFNET	SESQUINE
HU	HOUSTON	TX	BD	BOULDER	CO	1544	899	NSF	
HU	HOUSTON	TX	AU	AUSTIN	TX	56	147	NSI	
HU	HOUSTON	TX	KN	CAPE KENNEDY	FL	1544	900	NASCOM	
IL	URBANA	IL	CH	CHICAGO	IL	1544	125	NSFNET	NCSANE
IL	URBANA	IL	IN	BLOOMINGTON	IN	1544	113	NSFNET	CICNET
IL	URBANA	IL	MD	MILWAUKEE	WI	56	211	NSFNET	NCSANE
IN	INDIANAPOLIS	IN	CB	COLUMBUS	OH	1544	168	NSFNET	CICNET
IO	IOWA CITY	IA	IL	URBANA	IL	1544	202	NSFNET	CICNET
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	NSFNET	NYSERNET
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	NSFNET	NYSERNET
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	NSFNET	NYSERNET
IT	ITHACA	NY	DC	WASHINGTON	DC	1544	291	NSFNET	BACKBONE
IT	ITHACA	NY	PT	PITTSBURGH	PA	1544	267	NSFNET	
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	56	1,446	OPMODEL	
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	1544	1,446	OPMODEL	
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	1544	671	OPMOD	

EXHIBIT 11-56. Major Access Point Sort - City A

(Continued)

LA	LOS ANGELES	CA	AB	LOS ALAMOS	NM	1544	664	ESNET	
LA	PASADENA	CA	DC	WASHINGTON	DC	672	2,292	NSN	
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56	113	NSI	
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56	113	NSI	
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	1544	350	ESNET	
LA	PASADENA	CA	HU	HOUSTON ISLAND	TX	168	1,376	NSNET	
LA	PASADENA	CA	DC	BALTIMORE	MD	56	2,292	NSNET	
LA	PASADENA	CA	TU	TUCSON	AZ	56	444	NSN	
LA	LOS ANGELESO	CA	SF	SAN FRANCISCO	CA	1544	350	DRI	
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544	113	DRI	
LA	LOS ANGELES	CA	BD	BOULDER	CO	56	822	NSI	
LA	LOS ANGELES	CA	HU	HOUSTON	TX	56	1,376	NSI/SPAN	BACKBONE
LA	LOS ANGELES	CA	HN	HUNTSVILLE	AL	56	1,798	NSI/SPAN	BACKBC
LI	LINCOLN	NE	IL	URBANA	IL	56	447	NSFNET	MIDNET
LI	LINCOLN	NE	KS	LAWRENCE	KS	56	199	NSFNET	MIDNET
LI	LINCOLN	NE	IO	IOWA CITY	IA	56	274	NSFNET	MIDNET
LI	LINCOLN	NE	BD	BOULDER	CO	1544	454	NSFNE	
LL	LIVERMORE	CA	SF	OAKLAND	CA	56	36	ESNET	
LL	LIVERMORE	CA	PR	PRINCETON	NJ	1544	2,507	ESNET	
LL	LIVERMORE	CA	LA	LOS ANGELES	CA	56	321	ESNET	
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	1544	860	OPMODEL	
MP	MINNEAPOLIS	MN	IO	IOWA CITY	IA	1544	243	NSFNET	CICNET
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1544	232	NSFNE	
NF	NORFOLK	VA	TL	TALLAHASSEE	FL	1544	635	ESN	
NY	NEW YORK	NY	IT	ROME	NY	1544	195	DRI	
NY	LONG ISLAND	NY	BO	CAMBRIDGE	MA	1544	188	ESNET	
OR	OAK RIDGE	TN	CH	CHICAGO	IL	1544	441	ESNET	
OR	OAK RIDGE	TN	TL	TALLAHASSEE	FL	1544	385	ESNET	
PR	PRINCETON	NJ	TU	TUCSON	AZ	1544	2,080	NSFNE	
PR	PRINCETON	NJ	NF	NORFOLK VA	DC	1544	269	ESNET	
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	ESNET	
PR	PRINCETON	NJ	CH	CHICAGO	IL	1544	686	ESNET	
PR	PRINCETON	NJ	NY	LONG ISLAND	NY	1544	40	ESNET	
PR	PRINCETON	NJ	BD	BOLDER	CO	1544	1,610	NSFNET	JVNCNET
PR	PRINCETON	NJ	SC	STATE COLLEGE	PA	1544	175	NSFNET	JVNCNET
PR	PRINCETON	NJ	PH	PHILADELPHIA	PA	1544	42	NSFNET	JVNCNET
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544	229	NSFNET	JVNCNET
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544	229	NSFNET	JVNCNET
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	NSFNET	JVNCNET
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	NSFNET	JVNCNET
PR	PRINCETON	NJ	BO	NEW HAVEN	CT	1544	229	NSFNET	JVNCNET
PR	PRINCETON	NJ	BO	AMHERST	MA	1544	229	NSFNET	JVNCNE
PT	PITTSBURGH	PA	SC	STATE COLLEGE	PA	1544	115	NSFNET	PSCNET
PT	PITTSBURGH	PA	PR	PRINCETON	NJ	1544	285	NSFNET	BACKBONE
PT	PITTSBURGH	PA	IL	URBANA	IL	1544	434	NSFNET	BACKBC
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1544	114	NSFNET	PSCNET
PT	PITTSBURGH	PA	PH	PHILADELPHIA	PA	1544	258	NSFNET	PREPNE
PT	PITTSBURGH	PA	DC	WASHINGTON	DC	1544	190	NSFNET	PSCNET
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	CERFNET	BACKBON
SD	SAN DIEGO	CA	LA	RIVERSIDE	CA	56	113	NSFNET	SDSCNET
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	CERFNET	BACKBONE
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	CERFNET	BACKBONE
SD	SAN DIEGO	CA	HU	HOUSTON	TX	1544	1,305	NSFNET	BACKBONE

EXHIBIT 11-56. Major Access Point Sort - City A

(Continued)

SD	SAN DIEGO	CA	SF	MENLO PARK	CA	1544	463	NSFNET	BACKBON
SD	SAN DIEGO	CA	LA	SANTA BARBARA	CA	56	113	NSFNET	SDSCNET
SD	SAN DIEGO	CA	SE	SEATTLE	WA	56	1.068	NSFNET	SDSCNET
SD	SAN DIEGO	CA	SF	OAKLAND	CA	56	463	NSFNET	SDSCNET
SD	SAN DIEGO	CA	LA	IRVINE	CA	56	113	NSFNET	SDSCNET
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56	624	NSFNET	SDSCNET
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56	624	NSFNET	SDSCNET
SE	SEATTLE	WA	SD	SAN DIEGO	CA	1544	1.068	NSFNET	BACKBONE
SE	SEATTLE	WA	SF	MENLO PARK	CA	1544	684	NSFNET	BACKB
SE	SEATTLE	WA	PO	PORTLAND	OR	56	147	NSFNET	NWNET
SE	SEATTLE	WA	PO	CORVALLIS	OR	56	147	NSFNET	NWNET
SE	SEATTLE	WA	PO	EUGENE	OR	56	147	NSFNE	
SF	SAN FRANCISCO	CA	LA	PASADENA	CA	448	350	NSNET	
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1544	36	NSFNE	
SF	SAN FRANCISCO	CA	BD	BOULDER	CO	56	932	NSNET	
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	336	2.432	NSNET	
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	56	350	NSI/SPAN	BACKBONE
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	56	2.432	NSI/S	
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	1544	1.852	ESNET	
SL	SALT LAKE CITY	UT	SF	MENLO PARK	CA	1544	598	NSFNET	BACKBONE
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	1544	351	NSFNET	BACKBONE
SL	SALT LAKE CITY	UT	CH	CHICAGO	IL	1544	1.256	NSFNET	
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	1544	1.265	NASCOM	
WI	WALLOPS ISLAND	VA	MD	MADISON	WI	224	809	NASCOM	
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	224	1.265	NASCOM	
sum						146824	133.734		

EXHIBIT 11-56. Major Access Point Sort - City A

(Continued)

SORTED BY CITY-B IDs

ID	CITY - B	ST	ID	CITY - A	ST	CAPACITY	MILES	NETWORK	SUBNETWORK
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1544	860	OPMODEL	
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	1544	671	OPMODEL	
AB	ALBUQUERQUE	NM	DC	WASHINGTON	DC	56	1,646	OPMOD	
AB	LOS ALAMOS	NM	LA	LOS ANGELES	CA	1544	664	ESNET	
AU	AUSTIN	TX	AB	LOS ALAMOS	NM	56	615	ESNET	
AU	AUSTIN	TX	HU	HOUSTON	TX	1544	147	NSF	
AU	AUSTIN	TX	HU	HOUSTON	TX	56	147	NSI	
AU	AUSTIN	TX	HU	BRYAN	TX	1544	147	NSFNET	SESQUI
AU	AUSTIN	TX	HU	HOUSTON	TX	56	147	NSFNET	THENET
BD	BOLDER	CO	PR	PRINCETON	NJ	1544	1,610	NSF	
BD	BOULDER	CO	LA	LOS ANGELES	CA	56	822	NSI	
BD	BOULDER	CO	AB	LOS ALAMOS	NM	56	346	ESNET	
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	56	932	NSNET	
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	1544	351	NSFNET	BACKBONE
BD	BOULDER	CO	HU	HOUSTON	TX	1544	899	NSFNET	BACKBONE
BD	BOULDER	CO	LI	LINCOLN	NE	1544	454	NSF	
BD	DENVER	CO	CH	CHICAGO	IL	1544	927	DRI	
BO	AMHERST	MA	PR	PRINCETON	NJ	1544	229	NSFNE	
BO	CAMBRIDGE	MA	CH	CHICAGO	IL	1544	848	ESNET	
BO	CAMBRIDGE	MA	NY	LONG ISLAND	NY	1544	188	ESNET	
BO	CAMBRIDGE	MA	DC	WASHINGTON	DC	56	394	NSNET	
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	1544	229	NSFNET	JVNCNET
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	1544	229	NSFNET	JVNCNET
BO	NEW HAVEN	CT	PR	PRINCETON	NJ	1544	229	NSFNET	JVNC
BO	WOODS HOLE	MA	BD	BOULDER	CO	224	1,772	NSFNET	USAN
CB	COLUMBUS	OH	IN	INDIANAPOLIS	IN	1544	168	NSFNET	CICNET
CB	COLUMBUS	OH	DT	ANN ARBOR	MI	1544	163	NSFNE	
CH	CHICAGO	IL	PR	PRINCETON	NJ	1544	686	ESNET	
CH	CHICAGO	IL	SL	SALT LAKE CITY	UT	1544	1,256	NSFNE	
CH	CHICAGO	IL	OR	OAK RIDGE	TN	1544	441	ESNET	
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	1544	1,852	ESNET	
CH	CHICAGO	IL	IL	URBANA	IL	1544	125	NSFNE	
CL	CLEVELAND	OH	DC	WASHINGTON	DC	112	304	NSNET	
CL	CLEVELAND	OH	PT	PITTSBURGH	PA	1544	114	NSFNE	
DC	BALTIMORE	MD	LA	PASADENA	CA	56	2,292	NSNET	
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	336	2,432	NSNET	
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	1544	190	NSFNET	PSCNET
DC	WASHINGTON	DC	IT	ITHACA	NY	1544	291	NSFNET	BACK
DC	WASHINGTON	DC	BD	BOULDER	CO	224	1,501	NSFNET	USAN
DC	WASHINGTON	DC	BD	BOULDER	CO	224	1,501	NSFNE	
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	672	601	NSNET	
DC	WASHINGTON	DC	LA	PASADENA	CA	672	2,292	NSNET	
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	56	2,432	NSI/SPAN	BACKBC
DL	DALLAS	TX	HU	HOUSTON	TX	56	224	NSFNE	
DL	RICHARDSON	TX	AU	AUSTIN	TX	1544	180	ESNET	
DT	ANN ARBOR	MI	BD	BOULDER	CO	224	1,162	NSFNET	USAN
DT	LANSING	MI	CH	CHICAGO	IL	1544	237	NSF	

EXHIBIT 11-57. Major Access Point Sort - City B

DT	LITCHFIELD	MI	CH	CHICAGO	IL	1544	237	DRI	
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	512	601	NASCOM	
HN	HUNTSVILLE	AL	LA	LOS ANGELES	CA	56	1,798	NSI/SPAN	BACKBONE
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	56	616	NSI/SP	
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	1544	601	NASCOM	
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	56	601	NSI/SPAN	BACKBONE
HU	HOUSTON	TX	DC	WASHINGTON	DC	56	1,217	NSI/SPAN	BACKBONE
HU	HOUSTON	TX	DC	WASHINGTON	DC	1544	1,217	NSFNET	BACKBONE
HU	HOUSTON	TX	SD	SAN DIEGO	CA	1544	1,305	NSFNET	BACKBONE
HU	HOUSTON	TX	LA	LOS ANGELES	CA	56	1,376	NSI/SP	
HU	HOUSTON	TX	DC	WASHINGTON	DC	56	1,217	NASCOM	
HU	HOUSTON	TX	DC	WASHINGTON	DC	56	1,217	NASCOM	
HU	HOUSTON	TX	WI	WALLOPS ISLAND	VA	224	1,265	NASCOM	
HU	HOUSTON	TX	WI	WALLOPS ISLAND	VA	1544	1,265	NASCOM	
HU	HOUSTON	TX	DC	WASHINGTON	DC	2048	1,217	NASCC	
HU	HOUSTON	TX	HN	HUNTSVILLE	AL	168	616	NSNET	
HU	HOUSTON ISLAND	TX	LA	PASADENA	CA	168	1,376	NSNET	
IL	URBANA	IL	LI	LINCOLN	NE	56	447	NSFNET	MIDNET
IL	URBANA	IL	CH	CHICAGO	IL	1544	125	NSFNET	CICNET
IL	URBANA	IL	IO	IOWA CITY	IA	1544	202	NSFNET	CICNET
IL	URBANA	IL	PT	PITTSBURGH	PA	1544	434	NSFNET	BACKBC
IN	BLOOMINGTON	IN	IL	URBANA	IL	1544	113	NSFNET	CICNET
IO	IOWA CITY	IA	LI	LINCOLN	NE	56	274	NSFNET	MIDNET
IO	IOWA CITY	IA	MP	MINNEAPOLIS	MN	1544	243	NSF	
IT	ROME	NY	NY	NEW YORK	NY	1544	195	DRI	
KN	CAPE KENNEDY	FL	DC	WASHINGTON	DC	280	760	NASCOM	
KN	CAPE KENNEDY	FL	DC	WASHINGTON	DC	168	760	NASCOM	
KN	CAPE KENNEDY	FL	DC	WASHINGTON	DC	672	760	NASCOM	
KN	CAPE KENNEDY	FL	HU	HOUSTON	TX	1544	900	NASCOM	
KN	CAPE KENNEDY	FL	HN	HUNTSVILLE	AL	2048	563	NASCC	
KN	ORLANDO	FL	HN	HUNTSVILLE	AL	56	563	NSNET	
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	56	671	OPMODEL	
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	56	671	OPMODEL	
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	56	671	OPMODEL	
KS	LAWRENCE	KS	LI	LINCOLN	NE	56	199	NSFNE	
KS	LAWRENCE	KS	AB	LOS ALAMOS	NM	56	671	ESNET	
LA	BARSTOW	CA	DC	WASHINGTON	DC	224	2,292	NASCOM	
LA	BARSTOW	CA	DC	WASHINGTON	DC	56	2,292	NASCOM	
LA	IRVINE	CA	SD	SAN DIEGO	CA	56	113	NSFNET	
LA	LOMPOC	CA	DC	WASHINGTON	DC	224	2,292	NASCC	
LA	LOS ANGELES	CA	LL	LIVERMORE	CA	56	321	ESN	
LA	LOS ANGELES	CA	BD	DENVER	CO	1544	822	DRI	
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	56	350	NSI/SPAN	BACKBONE
LA	LOS ANGELES	CA	DC	WASHINGTON	DC	56	2,292	NSI/SPAN	BACKBONE
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544	113	CERFNET	BACKBONE
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544	113	CERFNET	BACKBONE
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544	113	CERFNE	
LA	PASADENA	CA	DC	WASHINGTON	DC	280	2,292	NASCC	
LA	PASADENA	CA	SF	SAN FRANCISCO	CA	448	350	NSNET	
LA	PASADENA	CA	DC	WASHINGTON	DC	448	2,292	NASCOM	
LA	RIVERSIDE	CA	SD	SAN DIEGO	CA	56	113	NSFNET	SDSCNET
LA	SANTA BARBARA	CA	SD	SAN DIEGO	CA	56	113	NSFNET	SDSCNET
LI	LINCOLN	NE	CH	CHICAGO	IL	1544	475	NSFNET	

EXHIBIT 11-57. Major Access Point Sort - City B

(Continued)

LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	1544	860	OPMODEL	
LL	LIVERMORE	CA	SF	SAN FRANCISCO	CA	1544	36	NSFNET	
LL	LIVERMORE	CA	KS	KANSAS CITY	KS	1544	1,446	OPMODEL	
LL.	LIVERMORE	CA	DC	WASHINGTON	DC	56	2,401	OPMODEL	
LL	LIVERMORE	CA	DC	WASHINGTON	DC	56	2,401	OPMODEL	
LL	LIVERMORE	CA	DC	WASHINGTON	DC	56	2,401	OPMODEL	
LL	LIVERMORE	CA	KS	KANSAS CITY	KS	56	1,446	OPMODEL	
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	56	860	OPMODEL	
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	56	860	OPMODE	
MD	MADISON	WI	WI	WALLOPS ISLAND	VA	224	809	NASCOM	
MD	MADISON	WI	MP	MINNEAPOLIS	MN	1544	232	NSFNET	CICN
MD	MADISON	WI	BD	BOULDER	CO	224	844	NSFNET	USAN
MD	MADISON	WI	CH	CHICAGO	IL	1544	121	NSFNET	CICNET
MD	MILWAUKEE	WI	IL	URBANA	IL	56	211	NSF	
MI	MIAMI	FL	HN	HUNTSVILLE	AL	56	722	NSI	
MI	MIAMI	FL	BD	BOULDER	CO	224	1,742	NSFNET	USAN
NF	NORFOLK	VA	DC	WASHINGTON	DC	56	157	NSFNE	
NF	NORFOLK VA	DC	PR	PRINCETON	NJ	1544	269	ESNET	
NY	LONG ISLAND	NY	PR	PRINCETON	NJ	1544	40	ESNET	
NY	NEW YORK	NY	IT	ITHACA	NY	1544	195	NSFNET	NYSERNET
NY	NEW YORK	NY	IT	ITHACA	NY	1544	195	NSFNET	NYSERNE
NY	NEW YORK	NY	PR	PRINCETON	NJ	1544	40	NSFNET	JVNCNET
NY	NEW YORK	NY	IT	ITHACA	NY	1544	195	NSFNET	NYSERNE
NY	NEW YORK	NY	PR	PRINCETON	NJ	1544	40	NSF	
NY	NEW YORK	NY	DC	WASHINGTON	DC	1544	205	DRI	
NY	NEW YORK	NY	BO	BOSTON	MA	1544	188	DRI	
NY	NEW YORK	NY	DC	WASHINGTON	DC	56	205	NSNET	
NY	NEW YORK	NY	PR	PRINCETON	NJ	1544	40	ESNET	
PH	PHILADELPHIA	PA	PT	PITTSBURGH	PA	1544	258	NSFNET	PREPNET
PH	PHILADELPHIA	PA	PR	PRINCETON	NJ	1544	42	NSFNET	JVNCNET
PH	WILMINGTON	DE	DC	WASHINGTON	DC	56	124	NSFNET	SURAN
PO	CORVALIS	OR	BD	BOULDER	CO	1544	957	NSFNET	NWNE
PO	CORVALLIS	OR	BD	BOULDER	CO	224	957	NSFNET	USAN
PO	CORVALLIS	OR	SE	SEATTLE	WA	56	147	NSFNET	NWNET
PO	EUGENE	OR	SE	SEATTLE	WA	56	147	NSFNET	NWNET
PO	PORTLAND	OR	SE	SEATTLE	WA	56	147	NSFNE	
PR	PRINCETON	NJ	LL	LIVERMORE	CA	1544	2,507	ESNET	
PR	PRINCETON	NJ	PT	PITTSBURGH	PA	1544	285	NSFNET	BACKBONE
PR	PRINCETON	NJ	DT	ANN ARBOR	MI	1544	459	NSFNE	
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544	229	ESNET	
PR	PRINCETON	NJ	DC	WASHINGTON	DC	1544	165	NSFNET	BACKBONE
PT	PITTSBURGH	PA	IT	ITHACA	NY	1544	267	NSFNET	BACKBC
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	1544	115	NSFNET	PSCNET
SC	STATE COLLEGE	PA	PR	PRINCETON	NJ	1544	175	NSFNET	JVNCNET
SD	SAN DIEGO	CA	SE	SEATTLE	WA	1544	1,068	NSF	
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	56	113	NSI	
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	56	113	NSI	
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	DRI	
SE	SEATTLE	WA	CH	CHICAGO	IL	1544	1,733	NSFNET	BACKBON
SE	SEATTLE	WA	SD	SAN DIEGO	CA	56	1,068	NSFNET	SDSCNET
SF	MENLO PARK	CA	SE	SEATTLE	WA	1544	684	NSFNET	BACKBONE
SF	MENLO PARK	CA	SL	SALT LAKE CITY	UT	1544	598	NSFNET	BACKBONE
SF	MENLO PARK	CA	SD	SAN DIEGO	CA	1544	463	NSFNE	

EXHIBIT 11-57. Major Access Point Sort - City B

(Continued)

SF	OAKLAND	CA	LL	LIVERMORE	CA	56	36	ESNET	
SF	OAKLAND	CA	SD	SAN DIEGO	CA	56	463	NSFNE	
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	1544	350	ESNET	
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	56	1,852	ESNET	
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	112	2,432	NAS	
SF	SAN FRANCISCO	CA	LA	LOS ANGELESO	CA	1544	350	DRI	
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	1544	2,432	NASCOM	
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	224	2,432	NASCOM	
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	56	351	NSFNET	WESTNET
SL	SALT LAKE CITY	UT	SD	SAN DIEGO	CA	56	624	NSFNET	SDSCNET
SL	SALT LAKE CITY	UT	SD	SAN DIEGO	CA	56	624	NSFNE	
TL	TALLAHASSEE	FL	NF	NORFOLK	VA	1544	635	ESNET	
TL	TALLAHASSEE	FL	DL	RICHARDSON	TX	1544	754	ESNET	
TL	TALLAHASSEE	FL	OR	OAK RIDGE	TN	1544	385	ESNET	
TL	TALLAHASSEE	FL	CH	CHICAGO	IL	56	806	ESNET	
TU	TUCSON	AZ	LA	PASADENA	CA	56	444	NSNET	
TU	TUCSON	AZ	PR	PRINCETON	NJ	1544	2,080	NSFNET	JVNCNET
TU	TUCSON	AZ	BD	BOULDER	CO	56	619	NSFNET	
WI	WALLOPS ISLAND	VA	DC	WASHINGTON	DC	56	106	NASCOM	
WI	WALLOPS ISLAND	VA	DC	WASHINGTON	DC	1544	106	NASCC	
WI	WALLOPS ISLAND	VA	DC	WASHINGTON	DC	56	106	NSNET	
WS	WHITE SANDS	NM	DC	WASHINGTON	DC	56	1,721	NASCC	
WS	WHITE SANDS	NM	HU	HOUSTON	TX	56	700	NSNET	
WS	WHITE SANDS	NM	DC	WASHINGTON	DC	224	1,572	NASCOM	
sum						146824	133,734		

EXHIBIT 11-57. Major Access Point Sort - City B

(Continued)

CURRENT IRN TRAFFIC LINKS - SORT CITY - A ID

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1544
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56
AB	LOS ALAMOS	NM	AU	AUSTIN	TX	56
AB	LOS ALAMOS	NM	KS	LAWRENCE	KS	56
AB	LOS ALAMOS	NM	BD	BOULDER	CO	56
AU	AUSTIN	TX	DL	RICHARDSON	TX	1544
BD	BOULDER	CO	MD	MADISON	WI	224
BD	BOULDER	CO	DC	WASHINGTON	DC	224
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	56
BD	BOULDER	CO	DC	WASHINGTON	DC	224
BD	BOULDER	CO	BO	WOODS HOLE	MA	224
BD	BOULDER	CO	MI	MIAMI	FL	224
BD	BOULDER	CO	TU	TUCSON	AZ	56
BD	BOULDER	CO	DT	ANN ARBOR	MI	224
BD	BOULDER	CO	PO	CORVALIS	OR	1544
BD	BOULDER	CO	PO	CORVALLIS	OR	224
BD	DENVER	CO	LA	LOS ANGELES	CA	1544
BO	BOSTON	MA	NY	NEW YORK	NY	1544
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	1544
CH	CHICAGO	IL	SE	SEATTLE	WA	1544
CH	CHICAGO	IL	DT	LANSING	MI	1544
CH	CHICAGO	IL	DT	LITCHFIELD	MI	1544
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	56
CH	CHICAGO	IL	MD	MADISON	WI	1544
CH	CHICAGO	IL	BD	DENVER	CO	1544
CH	CHICAGO	IL	TL	TALLAHASSEE	FL	56
CH	CHICAGO	IL	IL	URBANA	IL	1544
CH	CHICAGO	IL	LI	LINCOLN	NE	1544
CH	CHICAGO	IL	BO	CAMBRIDGE	MA	1544
DC	WASHINGTON	DC	NY	NEW YORK	NY	1544
DC	WASHINGTON	DC	AB	ALBUQUERQUE	NM	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1544
DC	WASHINGTON	DC	CL	CLEVELAND	OH	112
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	168
DC	WASHINGTON	DC	LA	LOS ANGELES	CA	56
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	224
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	56
DC	WASHINGTON	DC	LA	BARSTOW	CA	224

EXHIBIT 11-58. Current (1989) IRN Links & Capacity

DC	WASHINGTON	DC	LA	BARSTOW	CA	56
DC	WASHINGTON	DC	BO	CAMBRIDGE	MA	56
DC	WASHINGTON	DC	PR	PRINCETON	NJ	1544
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	1544
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	112
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	224
DC	WASHINGTON	DC	HU	HOUSTON	TX	1544
DC	WASHINGTON	DC	LA	PASADENA	CA	448
DC	WASHINGTON	DC	LA	PASADENA	CA	280
DC	WASHINGTON	DC	LA	LOMPOC	CA	224
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	1544
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	672
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	512
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	2048
DC	WASHINGTON	DC	PH	WILMINGTON	DE	56
DC	WASHINGTON	DC	NF	NORFOLK	VA	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	280
DC	WASHINGTON	DC	NY	NEW YORK	NY	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56
DL	RICHARDSON	TX	TL	TALLAHASSEE	FL	1544
DT	ANN ARBOR	MI	CB	COLUMBUS	OH	1544
DT	ANN ARBOR	MI	PR	PRINCETON	NJ	1544
HN	HUNTSVILLE	AL	KN	CAPE KENNEDY	FL	2048
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	168
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	672
HN	HUNTSVILLE	AL	KN	ORLANDO	FL	56
HN	HUNTSVILLE	AL	MI	MIAMI	FL	56
HU	BRYAN	TX	AU	AUSTIN	TX	1544
HU	HOUSTON	TX	DL	DALLAS	TX	56
HU	HOUSTON	TX	HN	HUNTSVILLE	AL	56
HU	HOUSTON	TX	WS	WHITE SANDS	NM	56
HU	HOUSTON	TX	AU	AUSTIN	TX	1544
HU	HOUSTON	TX	AU	AUSTIN	TX	56
HU	HOUSTON	TX	BD	BOULDER	CO	1544
HU	HOUSTON	TX	AU	AUSTIN	TX	56
HU	HOUSTON	TX	KN	CAPE KENNEDY	FL	1544
IL	URBANA	IL	CH	CHICAGO	IL	1544
IL	URBANA	IL	IN	BLOOMINGTON	IN	1544
IL	URBANA	IL	MD	MILWAUKEE	WI	56
IN	INDIANAPOLIS	IN	CB	COLUMBUS	OH	1544
IO	IOWA CITY	IA	IL	URBANA	IL	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	DC	WASHINGTON	DC	1544
IT	ITHACA	NY	PT	PITTSBURGH	PA	1544
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	56
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	1544
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	1544
LA	LOS ANGELES	CA	AB	LOS ALAMOS	NM	1544
LA	LOS ANGELES	CA	HN	HUNTSVILLE	AL	56

EXHIBIT 11-58. Current (1989) IRN Links & Capacity

(Continued)

LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	1544
LA	LOS ANGELES	CA	HU	HOUSTON	TX	56
LA	LOS ANGELES	CA	BD	BOULDER	CO	56
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544
LA	LOS ANGELESO	CA	SF	SAN FRANCISCO	CA	1544
LA	PASADENA	CA	TU	TUCSON	AZ	56
LA	PASADENA	CA	DC	BALTIMORE	MD	56
LA	PASADENA	CA	HU	HOUSTON ISLAND	TX	168
LA	PASADENA	CA	DC	WASHINGTON	DC	672
LI	LINCOLN	NE	IL	URBANA	IL	56
LI	LINCOLN	NE	KS	LAWRENCE	KS	56
LI	LINCOLN	NE	IO	IOWA CITY	IA	56
LI	LINCOLN	NE	BD	BOULDER	CO	1544
LL	LIVERMORE	CA	SF	OAKLAND	CA	56
LL	LIVERMORE	CA	PR	PRINCETON	NJ	1544
LL	LIVERMORE	CA	LA	LOS ANGELES	CA	56
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	1544
MP	MINNEAPOLIS	MN	IO	IOWA CITY	IA	1544
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1544
NF	NORFOLK	VA	TL	TALLAHASSEE	FL	1544
NY	LONG ISLAND	NY	BO	CAMBRIDGE	MA	1544
NY	NEW YORK	NY	IT	ROME	NY	1544
OR	OAK RIDGE	TN	CH	CHICAGO	IL	1544
OR	OAK RIDGE	TN	TL	TALLAHASSEE	FL	1544
PR	PRINCETON	NJ	TU	TUCSON	AZ	1544
PR	PRINCETON	NJ	NF	NORFOLK VA	DC	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	CH	CHICAGO	IL	1544
PR	PRINCETON	NJ	NY	LONG ISLAND	NY	1544
PR	PRINCETON	NJ	BD	BOLDER	CO	1544
PR	PRINCETON	NJ	SC	STATE COLLEGE	PA	1544
PR	PRINCETON	NJ	PH	PHILADELPHIA	PA	1544
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	BO	NEW HAVEN	CT	1544
PR	PRINCETON	NJ	BO	AMHERST	MA	1544
PT	PITTSBURGH	PA	SC	STATE COLLEGE	PA	1544
PT	PITTSBURGH	PA	PR	PRINCETON	NJ	1544
PT	PITTSBURGH	PA	IL	URBANA	IL	1544
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1544
PT	PITTSBURGH	PA	PH	PHILADELPHIA	PA	1544
PT	PITTSBURGH	PA	DC	WASHINGTON	DC	1544
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	LA	RIVERSIDE	CA	56
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	HU	HOUSTON	TX	1544
SD	SAN DIEGO	CA	SF	MENLO PARK	CA	1544
SD	SAN DIEGO	CA	LA	SANTA BARBARA	CA	56

EXHIBIT 11-58. Current (1989) IRN Links & Capacity

(Continued)

SD	SAN DIEGO	CA	SE	SEATTLE	WA	56
SD	SAN DIEGO	CA	SF	OAKLAND	CA	56
SD	SAN DIEGO	CA	LA	IRVINE	CA	56
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56
SE	SEATTLE	WA	SD	SAN DIEGO	CA	1544
SE	SEATTLE	WA	SF	MENLO PARK	CA	1544
SE	SEATTLE	WA	PO	PORTLAND	OR	56
SE	SEATTLE	WA	PO	CORVALLIS	OR	56
SE	SEATTLE	WA	PO	EUGENE	OR	56
SF	SAN FRANCISCO	CA	LA	PASADENA	CA	448
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1544
SF	SAN FRANCISCO	CA	BD	BOULDER	CO	56
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	336
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	56
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	56
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	1544
SL	SALT LAKE CITY	UT	SF	MENLO PARK	CA	1544
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	1544
SL	SALT LAKE CITY	UT	CH	CHICAGO	IL	1544
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	1544
WI	WALLOPS ISLAND	VA	MD	MADISON	WI	224
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	224
sum						146824

EXHIBIT 11-58. Current (1989) IRN Links & Capacity

(Continued)

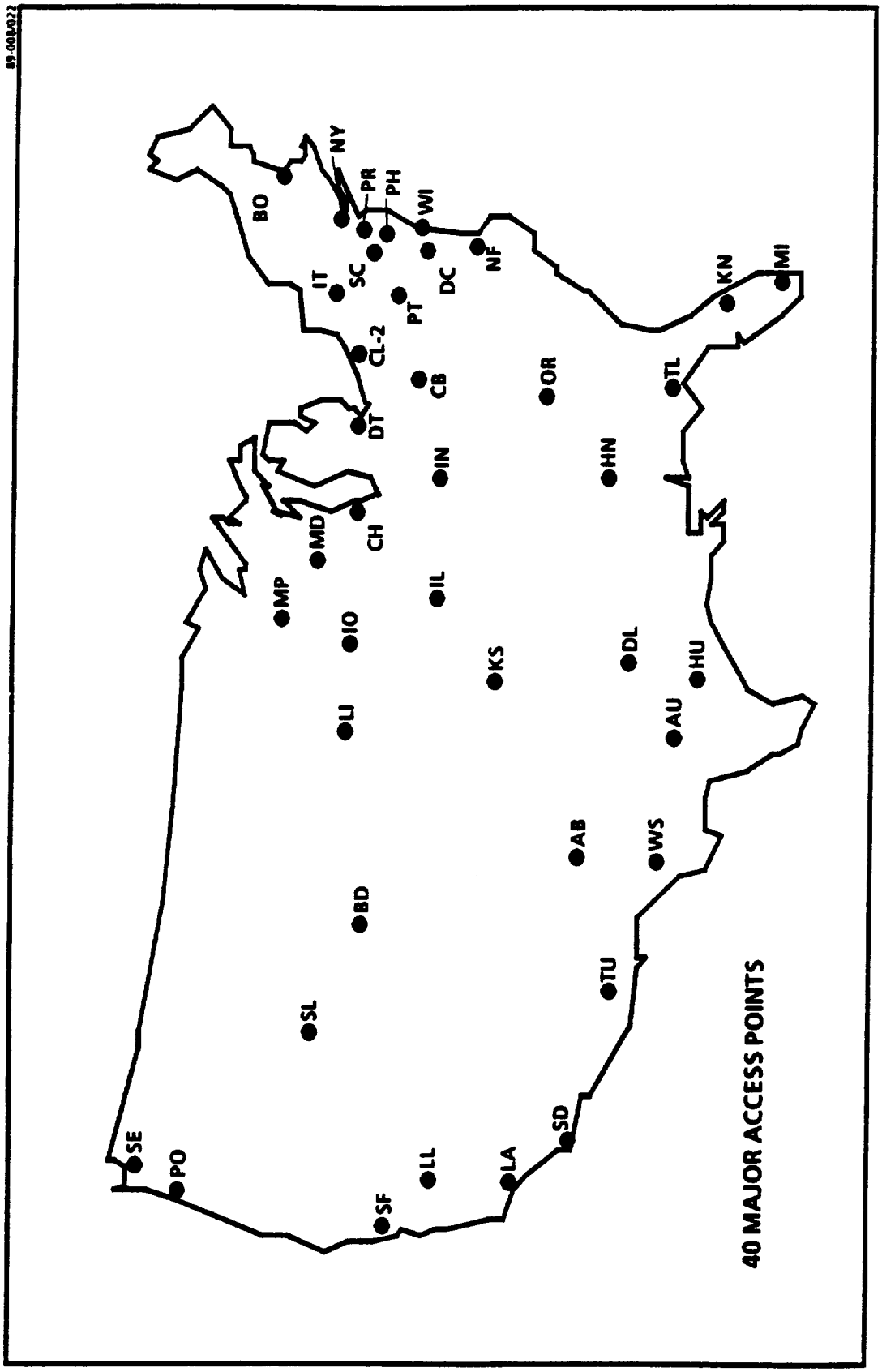

EXHIBIT 11-59. Current IRN - Location Of 40 Major Access Points

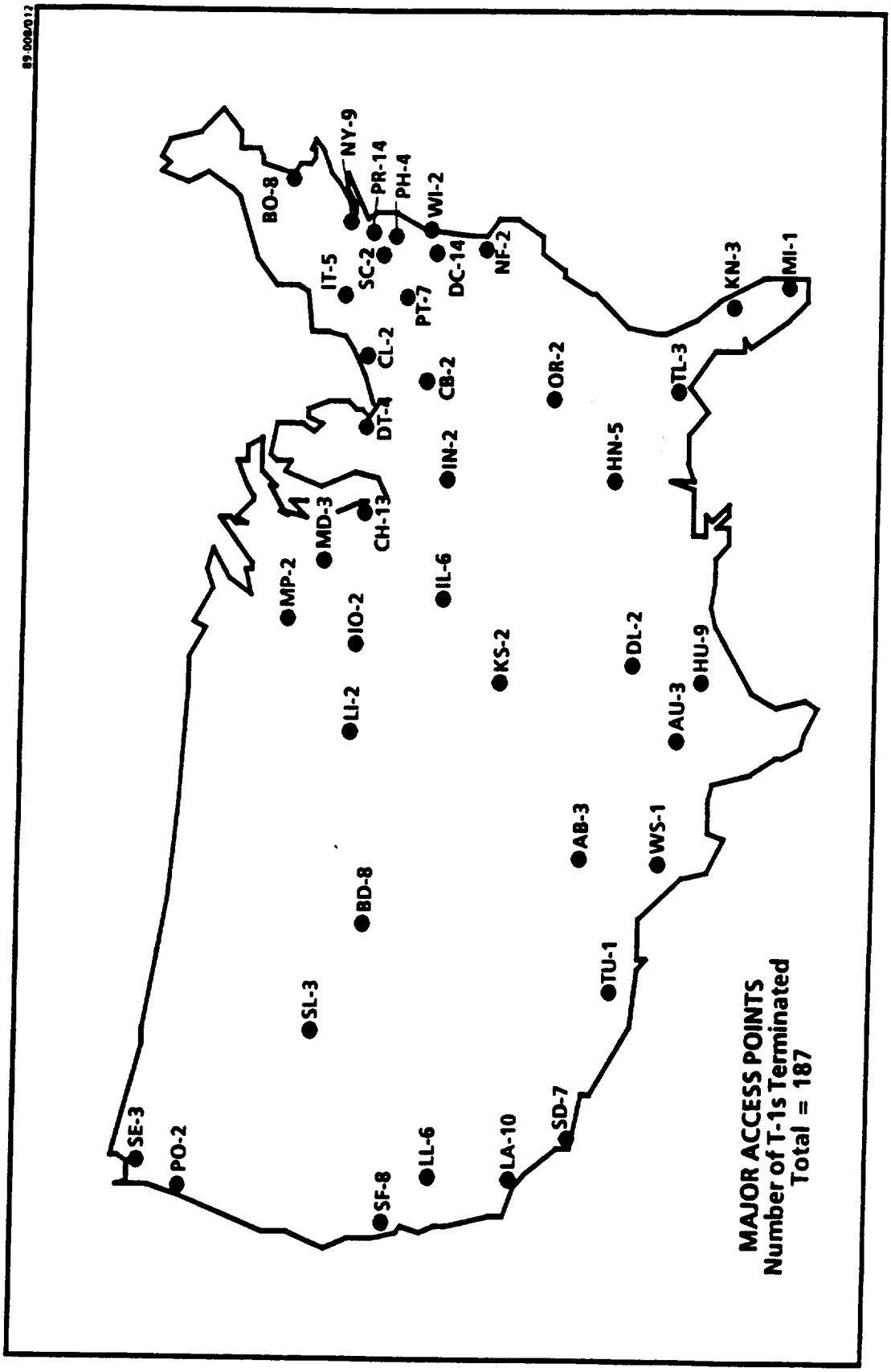

EXHIBIT 11-60. Current IRN - Number of T1s Terminated

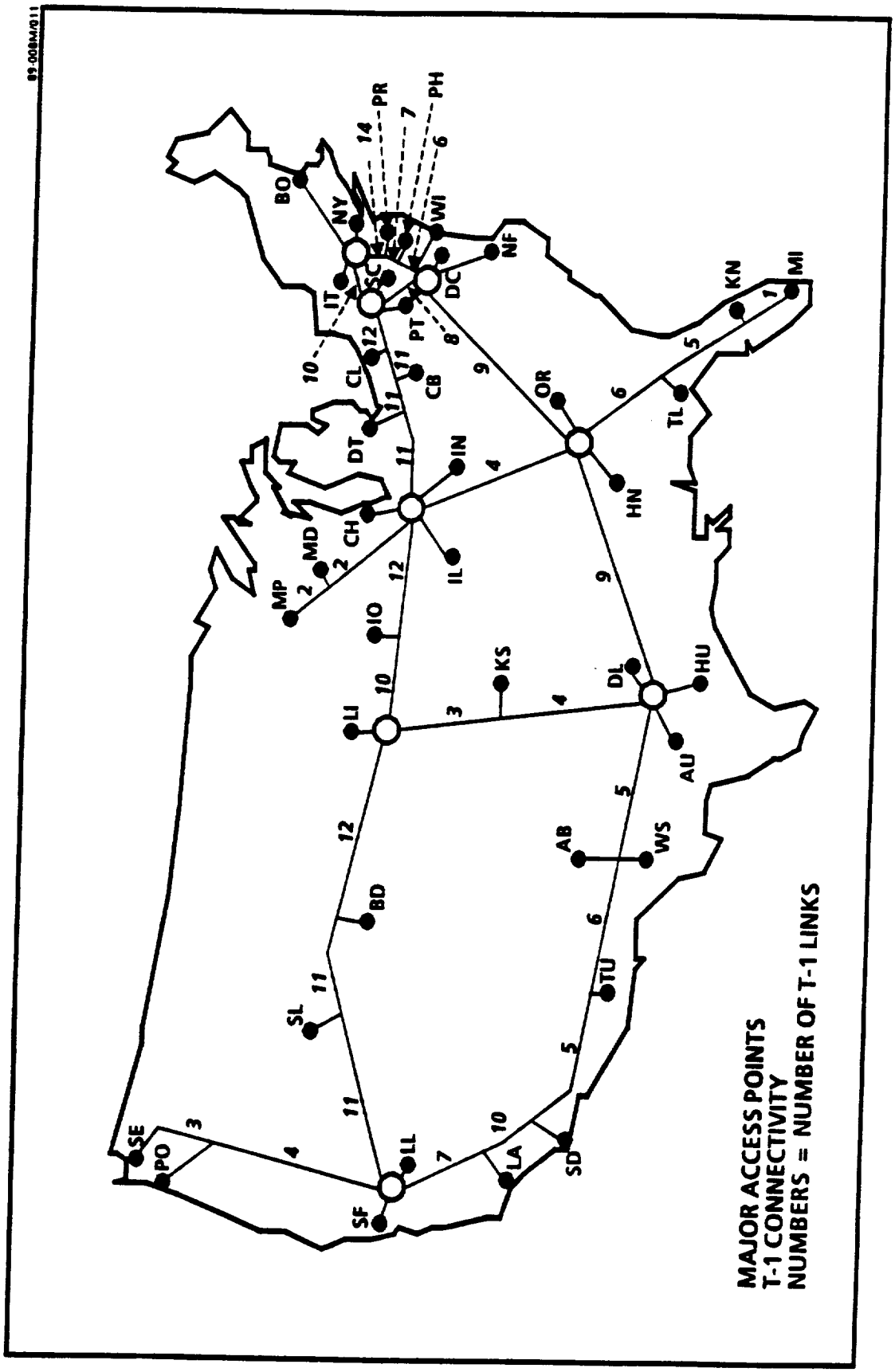

EXHIBIT 11-61. Current IRN - T1 Connectivity

SECTION 12

FUTURE INTEGRATED RESEARCH NETWORK

12.1 OVERVIEW

Given the definition of the current IRN described in Section 11, information on events and trends expected to impact future development of the IRN was collected and analyzed. Then the definition of the current IRN and the results of this analysis of events and trends were used to develop projections of the size of the IRN at future points in time.

12.2 METHODOLOGY

As noted earlier in Section 2, the major activities conducted to size and define the future integrated research network included:

1. Review the literature on projections related to an IRN.
2. Identify relevent events and trends.
3. Develop a survey to obtain expert information on events and trends.
4. Collect survey data from experts.
5. Analyze results of literature review and survey.
6. Specify benchmark years.
7. Identify new major access points.
8. Develop a future IRN database.
8. Specify major access point connectivity.
9. Project backbone link speeds.
10. Define IRNs for benchmark years.

Previously collected literature (e.g., national reports, journal articles, and conference summaries) were reviewed to identify strategies for projecting, and actual projections of, the future requirements for an IRN. The results of this review suggested that a combination of qualitative and quantitative factors should be considered when projecting the future requirements for an IRN.

These qualitative and quantitative factors involve:

1. Network Needs And Usage - i.e., the future needs of scientists, usage growth trends, and the addition of new groups of users.
2. Network Development - i.e., the development of new networks and the reconfiguration of existing networks.
3. Federal Government Activity - e.g., legislation and funding support.
4. Private Telecommunications Company Activity - e.g., financial support and research and development participation.
5. NRN Plans - e.g., FRICC, FCCSET and EDUCOM projections,
6. Technological Changes - e.g., advances related to developing a Gbps network.
7. Economic Pressures - e.g., international competition motivating both federal and private support for an IRN.

These factors were used to develop a brief guide for surveying leaders in the field of computer research networks. Some fifteen experts were asked to give their opinions, and the basis for them, of when and how a national computer research network might develop in the future. Then, the survey information and the initial literature review findings were analyzed, and the results of the anlysis were used to identify appropriate benchmark years, identify additional major access points, and project link speeds for the future IRNs.

Basesd on the analysis noted above the following guidelines were specified for projecting the future IRN:

1. Benchmark years would be: 1989 (Current), 1991, 1996, 2000, and 2010.
2. Major access points would be the same for 1989 and 1991; new major access points would be added in 1996. Major access points in 2000 and 2010 would be the same as for 1996.
3. For the sake of clarity, only the IRN backbone would be depicted for each benchmark year topology maps. While many other access points may be added yearly, these would not be presented in the projections.
4. Connectivity would be the same for 1989 and 1991; it also would be the same for 1996, 2000 and 2010 with new access points added for 1996.
5. The IRN link speeds would include DS1 (T1), DS3 (T3), DS4 (T4), & Gbps speeds; several speeds would be used for each benchmark year; and the magnitude of speed increases would reflect technology/use projections.

Given these guidelines, the current network database developed in Subtask 2.3 was used to develop a new future network database, reflecting the changes in major access points, connectivity and link speeds, for each of the four future benchmark years. These databases then were used to develop the definitions of the IRN for four benchmark years.

12.3 FINDINGS

The findings obtained from the activities conducted to size the future integrated computer research network are presented in terms of the IRN city A and city B links and capacities for each of the benchmark years and the topology maps showing major access point connectivity for each of the benchmark years. These results are presented below.

12.3.1 Current IRN Links and Topology

The Current IRN links and the Current IRN topology map, which were discussed in Section 11, are presented again here so that they can be compared easily with the links and maps for the future benchmark years. The Current IRN traffic links are listed in Exhibit 12-1. The ID (i.e., major access point identification), name and state for City A and for City B and the capacity (in Kbps) for each City A/City B link are listed.

The Current IRN topology is depicted in Exhibit 12-2. In this exhibit, City A/City B links have been grouped to form T1 capacity requirements for the various segments of the Current IRN backbone. As noted earlier, the total number of T1 links on this backbone is 187.

12.3.2 1991 IRN Links And Topology

The 1991 IRN links are listed in Exhibit 12-3. The names of the 1991 links are identical to the Current IRN links that were presented in Exhibit 12-1. Again, the ID (i.e., major access point identification), name and state for City A and for City B and the capacity (in Kbps unless followed by an M which denotes Mbps) for each City A/City B link are

(Next text, Page 12-13)

CURRENT IRN TRAFFIC LINKS - SORT CITY - A ID

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1544
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56
AB	LOS ALAMOS	NM	AU	AUSTIN	TX	56
AB	LOS ALAMOS	NM	KS	LAWRENCE	KS	56
AB	LOS ALAMOS	NM	BD	BOULDER	CO	56
AU	AUSTIN	TX	DL	RICHARDSON	TX	1544
BD	BOULDER	CO	MD	MADISON	WI	224
BD	BOULDER	CO	DC	WASHINGTON	DC	224
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	56
BD	BOULDER	CO	DC	WASHINGTON	DC	224
BD	BOULDER	CO	BO	WOODS HOLE	MA	224
BD	BOULDER	CO	MI	MIAMI	FL	224
BD	BOULDER	CO	TU	TUCSON	AZ	56
BD	BOULDER	CO	DT	ANN ARBOR	MI	224
BD	BOULDER	CO	PO	CORVALIS	OR	1544
BD	BOULDER	CO	PO	CORVALLIS	OR	224
BD	DENVER	CO	LA	LOS ANGELES	CA	1544
BO	BOSTON	MA	NY	NEW YORK	NY	1544
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	1544
CH	CHICAGO	IL	SE	SEATTLE	WA	1544
CH	CHICAGO	IL	DT	LANSING	MI	1544
CH	CHICAGO	IL	DT	LITCHFIELD	MI	1544
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	56
CH	CHICAGO	IL	MD	MADISON	WI	1544
CH	CHICAGO	IL	BD	DENVER	CO	1544
CH	CHICAGO	IL	TL	TALLAHASSEE	FL	56
CH	CHICAGO	IL	IL	URBANA	IL	1544
CH	CHICAGO	IL	LI	LINCOLN	NE	1544
CH	CHICAGO	IL	BO	CAMBRIDGE	MA	1544
DC	WASHINGTON	DC	NY	NEW YORK	NY	1544
DC	WASHINGTON	DC	AB	ALBUQUERQUE	NM	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1544
DC	WASHINGTON	DC	CL	CLEVELAND	OH	112
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	168
DC	WASHINGTON	DC	LA	LOS ANGELES	CA	56
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	224
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	56
DC	WASHINGTON	DC	LA	BARSTOW	CA	224

EXHIBIT 12-1. Current IRN Links & Capacity

DC	WASHINGTON	DC	LA	BARSTOW	CA	56
DC	WASHINGTON	DC	BO	CAMBRIDGE	MA	56
DC	WASHINGTON	DC	PR	PRINCETON	NJ	1544
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	1544
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	112
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	224
DC	WASHINGTON	DC	HU	HOUSTON	TX	1544
DC	WASHINGTON	DC	LA	PASADENA	CA	448
DC	WASHINGTON	DC	LA	PASADENA	CA	280
DC	WASHINGTON	DC	LA	LOMPOC	CA	224
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	1544
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	672
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	512
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	2048
DC	WASHINGTON	DC	PH	WILMINGTON	DE	56
DC	WASHINGTON	DC	NF	NORFOLK	VA	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	280
DC	WASHINGTON	DC	NY	NEW YORK	NY	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56
DL	RICHARDSON	TX	TL	TALLAHASSEE	FL	1544
DT	ANN ARBOR	MI	CB	COLUMBUS	OH	1544
DT	ANN ARBOR	MI	PR	PRINCETON	NJ	1544
HN	HUNTSVILLE	AL	KN	CAPE KENNEDY	FL	2048
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	168
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	672
HN	HUNTSVILLE	AL	KN	ORLANDO	FL	56
HN	HUNTSVILLE	AL	MI	MIAMI	FL	56
HU	BRYAN	TX	AU	AUSTIN	TX	1544
HU	HOUSTON	TX	DL	DALLAS	TX	56
HU	HOUSTON	TX	HN	HUNTSVILLE	AL	56
HU	HOUSTON	TX	WS	WHITE SANDS	NM	56
HU	HOUSTON	TX	AU	AUSTIN	TX	1544
HU	HOUSTON	TX	AU	AUSTIN	TX	56
HU	HOUSTON	TX	BD	BOULDER	CO	1544
HU	HOUSTON	TX	AU	AUSTIN	TX	56
HU	HOUSTON	TX	KN	CAPE KENNEDY	FL	1544
IL	URBANA	IL	CH	CHICAGO	IL	1544
IL	URBANA	IL	IN	BLOOMINGTON	IN	1544
IL	URBANA	IL	MD	MILWAUKEE	WI	56
IN	INDIANAPOLIS	IN	CB	COLUMBUS	OH	1544
IO	IOWA CITY	IA	IL	URBANA	IL	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	DC	WASHINGTON	DC	1544
IT	ITHACA	NY	PT	PITTSBURGH	PA	1544
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	56
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	1544
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	1544
LA	LOS ANGELES	CA	AB	LOS ALAMOS	NM	1544
LA	LOS ANGELES	CA	HN	HUNTSVILLE	AL	56

EXHIBIT 12-1. Current IRN Links & Capacity

(Continued)

LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	1544
LA	LOS ANGELES	CA	HU	HOUSTON	TX	56
LA	LOS ANGELES	CA	BD	BOULDER	CO	56
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544
LA	LOS ANGELESO	CA	SF	SAN FRANCISCO	CA	1544
LA	PASADENA	CA	TU	TUCSON	AZ	56
LA	PASADENA	CA	DC	BALTIMORE	MD	56
LA	PASADENA	CA	HU	HOUSTON ISLAND	TX	168
LA	PASADENA	CA	DC	WASHINGTON	DC	672
LI	LINCOLN	NE	IL	URBANA	IL	56
LI	LINCOLN	NE	KS	LAWRENCE	KS	56
LI	LINCOLN	NE	IO	IOWA CITY	IA	56
LI	LINCOLN	NE	BD	BOULDER	CO	1544
LL	LIVERMORE	CA	SF	OAKLAND	CA	56
LL	LIVERMORE	CA	PR	PRINCETON	NJ	1544
LL	LIVERMORE	CA	LA	LOS ANGELES	CA	56
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	1544
MP	MINNEAPOLIS	MN	IO	IOWA CITY	IA	1544
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1544
NF	NORFOLK	VA	TL	TALLAHASSEE	FL	1544
NY	LONG ISLAND	NY	BO	CAMBRIDGE	MA	1544
NY	NEW YORK	NY	IT	ROME	NY	1544
OR	OAK RIDGE	TN	CH	CHICAGO	IL	1544
OR	OAK RIDGE	TN	TL	TALLAHASSEE	FL	1544
PR	PRINCETON	NJ	TU	TUCSON	AZ	1544
PR	PRINCETON	NJ	NF	NORFOLK VA	DC	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	CH	CHICAGO	IL	1544
PR	PRINCETON	NJ	NY	LONG ISLAND	NY	1544
PR	PRINCETON	NJ	BD	BOLDER	CO	1544
PR	PRINCETON	NJ	SC	STATE COLLEGE	PA	1544
PR	PRINCETON	NJ	PH	PHILADELPHIA	PA	1544
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	BO	NEW HAVEN	CT	1544
PR	PRINCETON	NJ	BO	AMHERST	MA	1544
PT	PITTSBURGH	PA	SC	STATE COLLEGE	PA	1544
PT	PITTSBURGH	PA	PR	PRINCETON	NJ	1544
PT	PITTSBURGH	PA	IL	URBANA	IL	1544
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1544
PT	PITTSBURGH	PA	PH	PHILADELPHIA	PA	1544
PT	PITTSBURGH	PA	DC	WASHINGTON	DC	1544
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	LA	RIVERSIDE	CA	56
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	HU	HOUSTON	TX	1544
SD	SAN DIEGO	CA	SF	MENLO PARK	CA	1544
SD	SAN DIEGO	CA	LA	SANTA BARBARA	CA	56

EXHIBIT 12-1. Current IRN Links & Capacity

(Continued)

SD	SAN DIEGO	CA	SE	SEATTLE	WA	56
SD	SAN DIEGO	CA	SF	OAKLAND	CA	56
SD	SAN DIEGO	CA	LA	IRVINE	CA	56
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56
SE	SEATTLE	WA	SD	SAN DIEGO	CA	1544
SE	SEATTLE	WA	SF	MENLO PARK	CA	1544
SE	SEATTLE	WA	PO	PORTLAND	OR	56
SE	SEATTLE	WA	PO	CORVALLIS	OR	56
SE	SEATTLE	WA	PO	EUGENE	OR	56
SF	SAN FRANCISCO	CA	LA	PASADENA	CA	448
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1544
SF	SAN FRANCISCO	CA	BD	BOULDER	CO	56
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	336
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	56
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	56
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	1544
SL	SALT LAKE CITY	UT	SF	MENLO PARK	CA	1544
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	1544
SL	SALT LAKE CITY	UT	CH	CHICAGO	IL	1544
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	1544
WI	WALLOPS ISLAND	VA	MD	MADISON	WI	224
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	224
sum						146824

EXHIBIT 12-1. Current IRN Links & Capacity

(Continued)

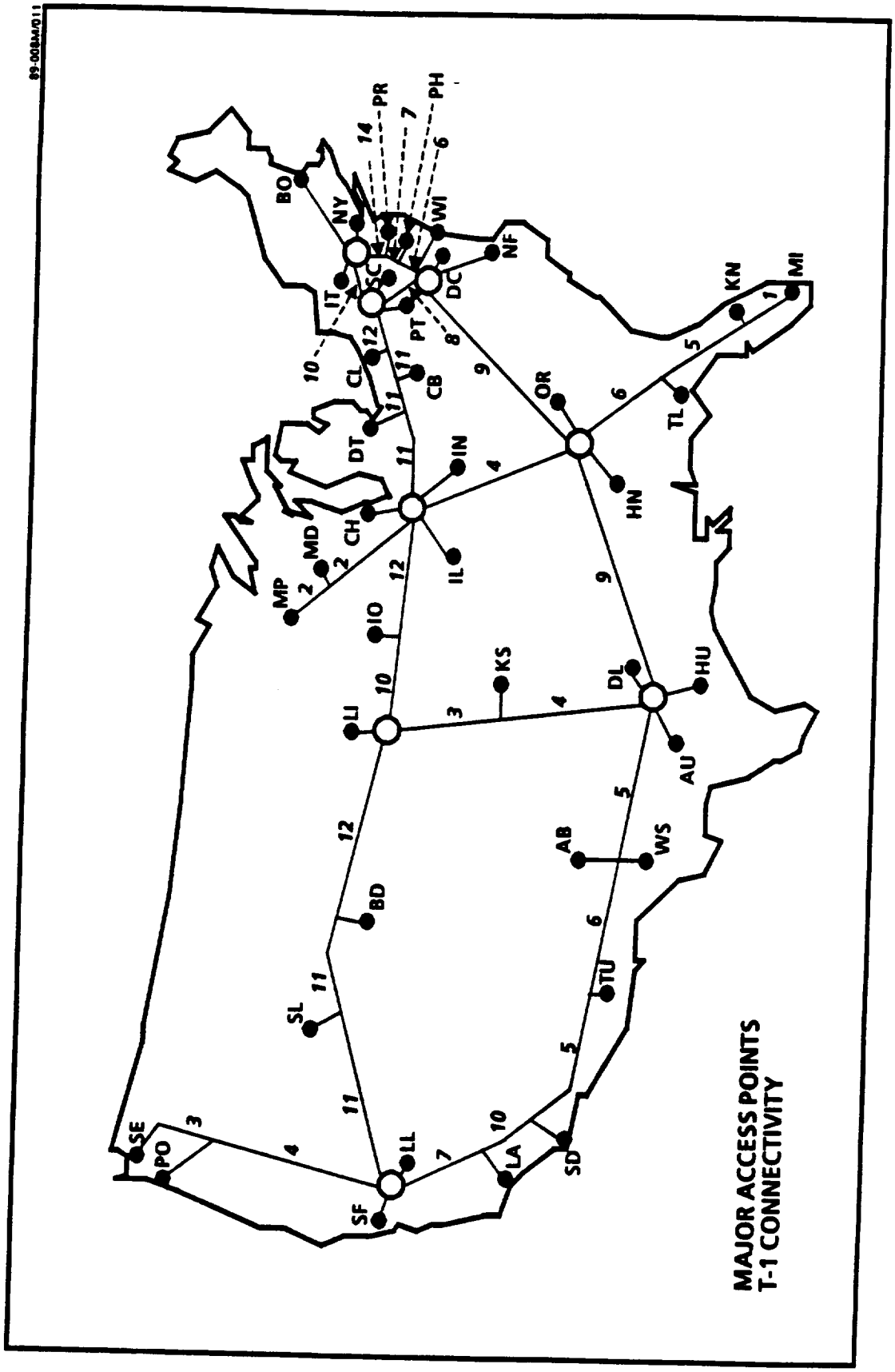

EXHIBIT 12-2. Current IRN Topology

1991 IRN LINKS

ID	CITY - A	ST	ID	CITY	ST	CAPACITY (KB)
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1544
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56
AB	LOS ALAMOS	NM	AU	AUSTIN	TX	56
AB	LOS ALAMOS	NM	KS	LAWRENCE	KS	56
AB	LOS ALAMOS	NM	BD	BOULDER	CO	56
AU	AUSTIN	TX	DL	RICHARDSON	TX	1544
BD	BOULDER	CO	MD	MADISON	WI	224
BD	BOULDER	CO	DC	WASHINGTON	DC	224
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	56
BD	BOULDER	CO	DC	WASHINGTON	DC	224
BD	BOULDER	CO	BO	WOODS HOLE	MA	224
BD	BOULDER	CO	MI	MIAMI	FL	224
BD	BOULDER	CO	TU	TUCSON	AZ	56
BD	BOULDER	CO	DT	ANN ARBOR	MI	224
BD	BOULDER	CO	PO	CORVALIS	OR	1544
BD	BOULDER	CO	PO	CORVALLIS	OR	224
BD	DENVER	CO	LA	LOS ANGELES	CA	1544
BO	BOSTON	MA	NY	NEW YORK	NY	1544
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	1544
CH	CHICAGO	IL	SE	SEATTLE	WA	44M
CH	CHICAGO	IL	DT	LANSING	MI	1544
CH	CHICAGO	IL	DT	LITCHFIELD	MI	1544
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	56
CH	CHICAGO	IL	MD	MADISON	WI	1544
CH	CHICAGO	IL	BD	DENVER	CO	44M
CH	CHICAGO	IL	TL	TALLAHASSEE	FL	56
CH	CHICAGO	IL	IL	URBANA	IL	1544
CH	CHICAGO	IL	LI	LINCOLN	NE	44M
CH	CHICAGO	IL	BO	CAMBRIDGE	MA	1544
DC	WASHINGTON	DC	NY	NEW YORK	NY	1544
DC	WASHINGTON	DC	AB	ALBUQUERQUE	NM	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1544
DC	WASHINGTON	DC	CL	CLEVELAND	OH	112
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	168
DC	WASHINGTON	DC	LA	LOS ANGELES	CA	56
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	224
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	56
DC	WASHINGTON	DC	LA	BARSTOW	CA	224

EXHIBIT 12-3. 1991 IRN Links & Capacity

DC	WASHINGTON	DC	LA	BARSTOW	CA	56
DC	WASHINGTON	DC	BO	CAMBRIDGE	MA	56
DC	WASHINGTON	DC	PR	PRINCETON	NJ	44M
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	1544
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	112
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	224
DC	WASHINGTON	DC	HU	HOUSTON	TX	44M
DC	WASHINGTON	DC	LA	PASADENA	CA	448
DC	WASHINGTON	DC	LA	PASADENA	CA	280
DC	WASHINGTON	DC	LA	LOMPOC	CA	224
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	1544
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	672
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	512
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	2048
DC	WASHINGTON	DC	PH	WILMINGTON	DE	56
DC	WASHINGTON	DC	NF	NORFOLK	VA	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	280
DC	WASHINGTON	DC	NY	NEW YORK	NY	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56
DL	RICHARDSON	TX	TL	TALLAHASSEE	FL	1544
DT	ANN ARBOR	MI	CB	COLUMBUS	OH	1544
DT	ANN ARBOR	MI	PR	PRINCETON	NJ	44M
HN	HUNTSVILLE	AL	KN	CAPE KENNEDY	FL	2048
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	168
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	672
HN	HUNTSVILLE	AL	KN	ORLANDO	FL	56
HN	HUNTSVILLE	AL	MI	MIAMI	FL	56
HU	BRYAN	TX	AU	AUSTIN	TX	1544
HU	HOUSTON	TX	DL	DALLAS	TX	56
HU	HOUSTON	TX	HN	HUNTSVILLE	AL	56
HU	HOUSTON	TX	WS	WHITE SANDS	NM	56
HU	HOUSTON	TX	AU	AUSTIN	TX	1544
HU	HOUSTON	TX	AU	AUSTIN	TX	56
HU	HOUSTON	TX	BD	BOULDER	CO	44M
HU	HOUSTON	TX	AU	AUSTIN	TX	56
HU	HOUSTON	TX	KN	CAPE KENNEDY	FL	1544
IL	URBANA	IL	CH	CHICAGO	IL	1544
IL	URBANA	IL	IN	BLOOMINGTON	IN	1544
IL	URBANA	IL	MD	MILWAUKEE	WI	56
IN	INDIANAPOLIS	IN	CB	COLUMBUS	OH	1544
IO	IOWA CITY	IA	IL	URBANA	IL	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	DC	WASHINGTON	DC	44M
IT	ITHACA	NY	PT	PITTSBURGH	PA	44M
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	56
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	1544
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	1544
LA	LOS ANGELES	CA	AB	LOS ALAMOS	NM	1544
LA	LOS ANGELES	CA	HN	HUNTSVILLE	AL	56

EXHIBIT 12-3. 1991 IRN Links & Capacity

(Contined)

LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	1544
LA	LOS ANGELES	CA	HU	HOUSTON	TX	56
LA	LOS ANGELES	CA	BD	BOULDER	CO	56
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544
LA	LOS ANGELESO	CA	SF	SAN FRANCISCO	CA	1544
LA	PASADENA	CA	TU	TUCSON	AZ	56
LA	PASADENA	CA	DC	BALTIMORE	MD	56
LA	PASADENA	CA	HU	HOUSTON ISLAND	TX	168
LA	PASADENA	CA	DC	WASHINGTON	DC	672
LI	LINCOLN	NE	IL	URBANA	IL	56
LI	LINCOLN	NE	KS	LAWRENCE	KS	56
LI	LINCOLN	NE	IO	IOWA CITY	IA	56
LI	LINCOLN	NE	BD	BOULDER	CO	44M
LL	LIVERMORE	CA	SF	OAKLAND	CA	56
LL	LIVERMORE	CA	PR	PRINCETON	NJ	1544
LL	LIVERMORE	CA	LA	LOS ANGELES	CA	56
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	1544
MP	MINNEAPOLIS	MN	IO	IOWA CITY	IA	1544
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1544
NF	NORFOLK	VA	TL	TALLAHASSEE	FL	1544
NY	LONG ISLAND	NY	BO	CAMBRIDGE	MA	1544
NY	NEW YORK	NY	IT	ROME	NY	1544
OR	OAK RIDGE	TN	CH	CHICAGO	IL	1544
OR	OAK RIDGE	TN	TL	TALLAHASSEE	FL	1544
PR	PRINCETON	NJ	TU	TUCSON	AZ	1544
PR	PRINCETON	NJ	NF	NORFOLK VA	DC	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	CH	CHICAGO	IL	1544
PR	PRINCETON	NJ	NY	LONG ISLAND	NY	1544
PR	PRINCETON	NJ	BD	BOLDER	CO	1544
PR	PRINCETON	NJ	SC	STATE COLLEGE	PA	1544
PR	PRINCETON	NJ	PH	PHILADELPHIA	PA	1544
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	BO	NEW HAVEN	CT	1544
PR	PRINCETON	NJ	BO	AMHERST	MA	1544
PT	PITTSBURGH	PA	SC	STATE COLLEGE	PA	1544
PT	PITTSBURGH	PA	PR	PRINCETON	NJ	44M
PT	PITTSBURGH	PA	IL	URBANA	IL	44M
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1544
PT	PITTSBURGH	PA	PH	PHILADELPHIA	PA	1544
PT	PITTSBURGH	PA	DC	WASHINGTON	DC	1544
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	LA	RIVERSIDE	CA	56
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	HU	HOUSTON	TX	44M
SD	SAN DIEGO	CA	SF	MENLO PARK	CA	44M
SD	SAN DIEGO	CA	LA	SANTA BARBARA	CA	56

EXHIBIT 12-3. 1991 IRN Links & Capacity

(Contined)

SD	SAN DIEGO	CA	SE	SEATTLE	WA	56
SD	SAN DIEGO	CA	SF	OAKLAND	CA	56
SD	SAN DIEGO	CA	LA	IRVINE	CA	56
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56
SE	SEATTLE	WA	SD	SAN DIEGO	CA	44M
SE	SEATTLE	WA	SF	MENLO PARK	CA	44M
SE	SEATTLE	WA	PO	PORTLAND	OR	56
SE	SEATTLE	WA	PO	CORVALLIS	OR	56
SE	SEATTLE	WA	PO	EUGENE	OR	56
SF	SAN FRANCISCO	CA	LA	PASADENA	CA	448
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1544
SF	SAN FRANCISCO	CA	BD	BOULDER	CO	56
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	336
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	56
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	56
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	1544
SL	SALT LAKE CITY	UT	SF	MENLO PARK	CA	44M
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	44M
SL	SALT LAKE CITY	UT	CH	CHICAGO	IL	44M
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	1544
WI	WALLOPS ISLAND	VA	MD	MADISON	WI	224
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	224
sum						

EXHIBIT 12-3. 1991 IRN Links & Capacity

(Contined)

listed. The major change from the Current IRN to the 1991 IRN was the increase in capacity from T1 to T3 on some links. It was assumed that the NSFNET Backbone capacity would increase from T1 to T3 by 1991, and this expected increase was reflected in the 1991 IRN backbone.

The 1991 IRN Topology is depicted in Exhibit 12-4. The 1991 connectivity has not changed from the Current (i.e., 1989) connectivity, but the capacity of the IRN backbone has. Much of the 1991 IRN backbone now has T3 capacity.

12.3.3 1996 IRN Links And Topology

For the 1996 IRN, ten new major access points were added, making a total of fifty major access points. These fifty major access points are listed in Exhibit 12-5. The ten new major access points are: Atlanta, Billings, Cheyenne, Columbus, Columbia, Fargo, Helena, Jacksonville, New Orleans, Raleigh and St Louis.

The 1996 IRN links are listed in Exhibit 12-6. As with the Current and 1991 IRN link lists, the ID (i.e., major access point identification), name and state for City A and for City B and the capacity (in Mbps denoted by an M or in Gbps denoted by a G) for each City A/City B link are listed. However, even though the number of major access points has increased by ten, the number of links listed has decreased from 177 links in 1991 to 53 links in 1996. This is because only direct links are listed for 1996. For example, in 1996 there are only two links from Seattle (Seattle to Helena and Seattle to San Francisco), while in 1991 there were five. This change in procedure for listing links was made because the 1996 IRN was assumed to be a truly single integrated network, while the 1991 and Current (1989) IRNs were assumed to be composites of many networks whose individual links were considered separatelt.

The 1996 IRN topology is depicted in Exhibit 12-7. For the 1996 IRN, the 1991 IRN backbone still exists but its capacity has been increased. Also, the ten new major access points have been connected to this 1991 backbone. The following increases in capacity have been made:

1. Some of the 1991 T3 links have been increased to 1 Gbps links.

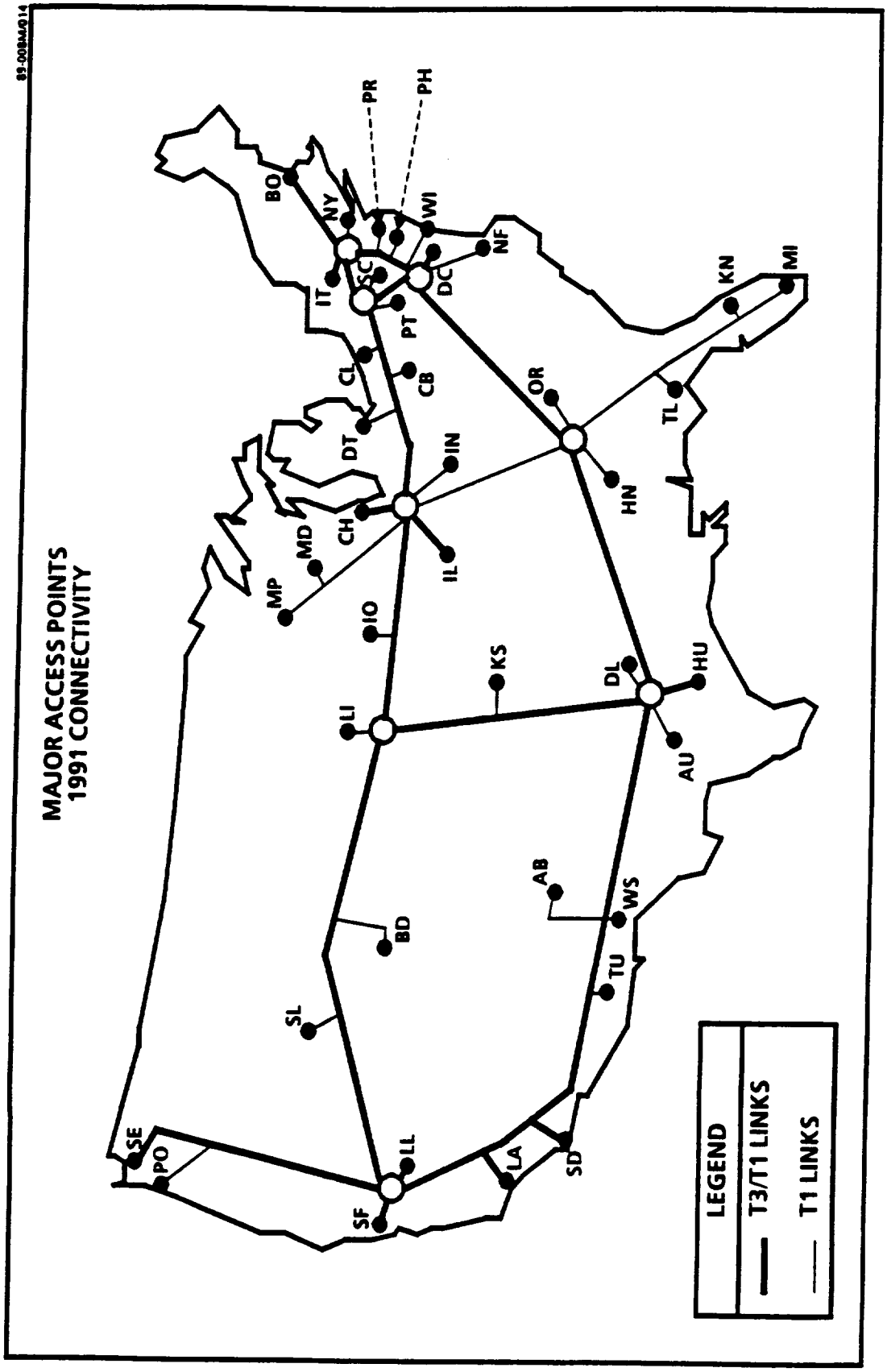

EXHIBIT 12-4. 1991 IRN Topology

KEY	CITY	STATE	V	H
AB	ALBUQUERQUE	NM	8549	5887
AT	ATLANTA	GA	7243	2092
AU	AUSTIN	TX	9005	3996
BI	BILLINGS	MT	6390	679C
BO	BOSTON	MA	4422	1249
BD	BOULDER	CO	7456	5961
CY	CHEYENNE	WY	7204	5958
CH	CHICAGO	IL	5986	3426
CL	CLEVELAND	OH	5574	2543
CO	COLUMBIA	SC	6902	1587
CB	COLUMBUS	OH	5972	2555
DL	DALLAS	TX	8436	4034
DT	DETROIT	MI	5536	2828
FR	FARGO	ND	5614	5181
HE	HELENA	MT	6339	735C
HU	HOUSTON	TX	8938	3536
HN	HUNTSVILLE	AL	7267	2535
IN	INDIANAPOLIS	IN	6272	2992
IO	IOWA CITY	IA	6315	3971
IT	ITHACA	NY	4798	199C
JK	JACKSONVILLE	FL	7642	1276
KS	KANSAS CITY	MO	7249	4210
KN	KENNEDY SPC CTR	FL	7919	0880
LI	LINCOLN	NE	6823	4674
LL	LIVERMORE	CA	8504	8606
LA	LOS ANGELES	CA	9213	7878
MD	MADISON	WI	5890	3798
MI	MIAMI	FL	8351	0527
MP	MINNEAPOLIS	MN	5781	4525
NO	NEW ORLEANS	LA	8484	2631
NY	NEW YORK	NY	4997	1406
NF	NORFOLK	VA	5936	1198
OR	OAK RIDGE	TN	6811	2303
PH	PHILADELPHIA	PA	5251	1458
PT	PITTSBURGH	PA	5621	2185
PO	PORTLAND	OR	6799	8914
PR	PRINCETON	NJ	5120	1436
RL	RALEIGH	NC	6344	1434
SL	SALT LAKE	UT	7576	7065
SD	SAN DIEGO	CA	9468	7629
SF	SAN FRANCISCO	CA	8492	8719
SE	SEATTLE	WA	6336	8896
ST	ST LOUIS	MO	6807	3483
SC	STATE COLLEGE	PA	5360	1933
TL	TALLAHASEE	FL	7876	1715
TU	TUCSON	AZ	9342	648C
IL	URBANA	IL	6371	3336
WI	WALLOPS ISLAND	VA	5657	1249
DC	WASHINGTON	DC	5622	1583
WS	WHITE SANDS	NM	9132	5742

EXHIBIT 12-5. 1996 IRN Major Access Points

1996 IRN LINKS

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	565M
AT	ATLANTA	GA	CO	COLUMBIA	SC	90M
AT	ATLANTA	GA	TL	TALLAHASEE	FL	90M
AU	AUSTIN	TX	DL	DALLAS	TX	90M
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	90M
BD	BOULDER	CO	SF	SAN FPANCISCO	CA	1G
BI	BILLINGS	MT	CY	CHEYENNE	WY	90M
BI	BILLINGS	MT	FR	FARGO	ND	90M
BO	BOSTON	MA	NY	NEW YORK	NY	1G
CB	COLUMBUS	OH	DT	DETROIT	MI	90M
CH	CHICAGO	IL	IL	URBANA	IL	1G
CH	CHICAGO	IL	OR	OAK RIDGE	TN	565M
CH	CHICAGO	IL	LI	LINCOLN	NE	1G
CH	CHICAGO	IL	DT	DETROIT	MI	90M
CH	CHICAGO	IL	ST	ST LOUIS	MO	90M
CL	CLEVELAND	OH	CB	COLUMBUS	OH	90M
CO	COLUMBIA	SC	RL	RALEIGH	NC	90M
CY	CHEYENNE	WY	BD	BOULDER	CO	90M
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	1G
DC	WASHINGTON	DC	NF	NORFOLK	VA	565M
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	90M
FR	FARGO	ND	MP	MINNEAPOLIS	MN	90M
HE	HELENA	MT	BI	BILLINGS	MT	90M
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	90M
HU	HOUSTON	TX	OR	OAK RIDGE	TN	565M
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	90M
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	90M
IT	ITHACA	NY	NY	NEW YORK	NY	1G
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	90M
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1G
LI	LINCOLN	NE	HU	HOUSTON	TX	1G
LI	LINCOLN	NE	BD	BOULDER	CO	1G
LI	LINCOLN	NE	IO	IOWA CITY	IA	90M
MD	MADISON	WI	CH	CHICAGO	IL	565M
MP	MINNEAPOLIS	MN	MD	MADISON	WI	565M
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	90M
NY	NEW YORK	NY	DC	WASHINGTON	DC	1G
NY	NEW YORK	NY	PT	PITTSBURGH	PA	1G
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	565M
PO	PORTLAND	OR	SE	SEATTLE	WA	90M
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	90M
PT	PITTSBURGH	PA	CH	CHICAGO	IL	1G
RL	RALEIGH	NC	NF	NORFOLK	VA	90M
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	90M
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	565M
SE	SEATTLE	WA	HE	HELENA	MT	90M
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	565M
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1G
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	1G
SL	SALT LAKE	UT	BD	BOULDER	CO	90M
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	90M
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	565M
TU	TUCSON	AZ	WS	WHITE SANDS	NM	90M

EXHIBIT 12-6. 1996 IRN Links & Capacity

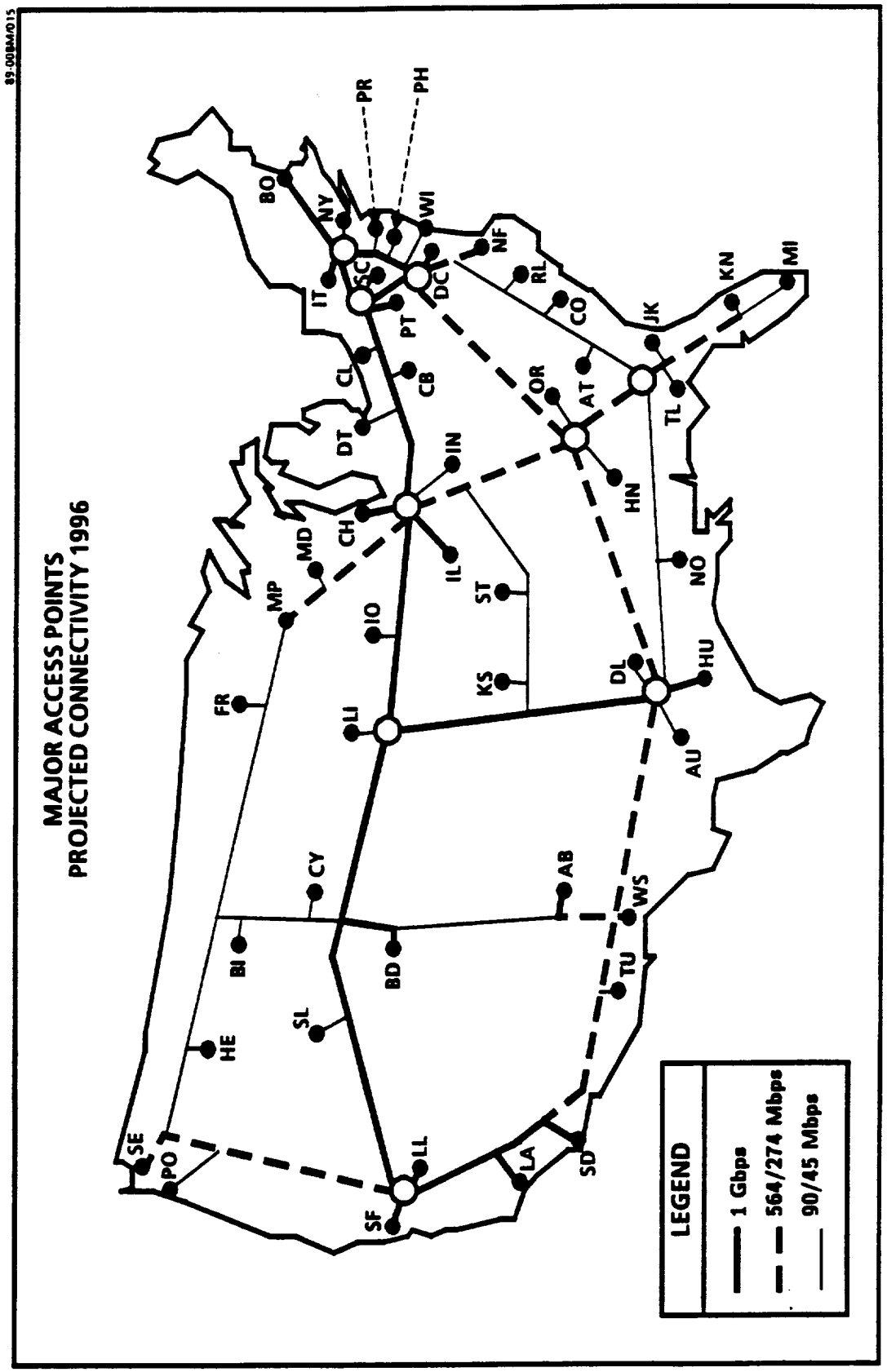

EXHIBIT 12-7. 1996 IRN Topology

2. Some of the 1991 T3 links have been increased to 564/274 Mbps links.
3. All 1991 T1 links have been increased to 564/274 Mbps links.
4. The capacity of all links added to connect the ten new major access points was either 90 Mbps or 45 Mbps.

12.3.4 2000 IRN Links And Topology

The 2000 IRN links are listed in Exhibit 12-8. The major access points and connectivity for the 2000 IRN are identical to those for the 1996 IRN. The only changes that were made were in the link capacities (again denoted by M or G for Mbps and Gbps respectively).

The 2000 IRN topology is depicted in Exhibt 12-9. This topology map looks identical to the topology map for the 1996 IRN. However, the link capacities have been increased in the following manner:

1. All 1996 1 Gbps links have been increased to 5 Gbps links.
2. All 1996 564/274 Mbps links have been increased to 1 Gbps links.
3. All 1996 90/45 Mbps links have been increased to 564/274 Mbps links.

12.3.5 2010 IRN Links And Topology

The 2010 IRN links are listed in Exhibit 12-10. Again, the major access points and connectivity for the 2010 IRN are identical to those for the 2000 IRN. As before, the only changes that were made were in the link capacities (again denoted by M or G for Mbps and Gbps respectively).

The 2010 IRN topology is depicted in Exhibt 12-11. This topology map again looks identical to the topology map for the 2000 IRN, and as before, the link capacities have been increased in the following manner:

1. All 2000 5 Gbps links have been increased to 25 Gbps links.
2. All 2000 1 Gbps links have been increased to 5 Gbps links.
3. All 2000 564/274 Mbps links have been increased to 1 Gbps links.

YEAR 2000 IRN LINKS

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	1G
AT	ATLANTA	GA	CO	COLUMBIA	SC	565M
AT	ATLANTA	GA	TL	TALLAHASEE	FL	565M
AU	AUSTIN	TX	DL	DALLAS	TX	565M
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	565M
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	5G
BI	BILLINGS	MT	CY	CHEYENNE	WY	565M
BI	BILLINGS	MT	FR	FARGO	ND	565M
BO	BOSTON	MA	NY	NEW YORK	NY	5G
CB	COLUMBUS	OH	DT	DETROIT	MI	565M
CH	CHICAGO	IL	IL	URBANA	IL	5G
CH	CHICAGO	IL	OR	OAK RIDGE	TN	1G
CH	CHICAGO	IL	LI	LINCOLN	NE	5G
CH	CHICAGO	IL	DT	DETROIT	MI	565M
CH	CHICAGO	IL	ST	ST LOUIS	MO	565M
CL	CLEVELAND	OH	CB	COLUMBUS	OH	565M
CO	COLUMBIA	SC	RL	RALEIGH	NC	565M
CY	CHEYENNE	WY	BD	BOULDER	CO	565M
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	5G
DC	WASHINGTON	DC	NF	NORFOLK	VA	1G
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	565M
FR	FARGO	ND	MP	MINNEAPOLIS	MN	565M
HE	HELENA	MT	BI	BILLINGS	MT	565M
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	565M
HU	HOUSTON	TX	OR	OAK RIDGE	TN	1G
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	565M
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	565M
IT	ITHACA	NY	NY	NEW YORK	NY	5G
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	565M
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	5G
LI	LINCOLN	NE	HU	HOUSTON	TX	5G
LI	LINCOLN	NE	BD	BOULDER	CO	5G
LI	LINCOLN	NE	IO	IOWA CITY	IA	565M
MD	MADISON	WI	CH	CHICAGO	IL	1G
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1G
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	565M
NY	NEW YORK	NY	DC	WASHINGTON	DC	5G
NY	NEW YORK	NY	PT	PITTSBURGH	PA	5G
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	1G
PO	PORTLAND	OR	SE	SEATTLE	WA	565M
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	565M
PT	PITTSBURGH	PA	CH	CHICAGO	IL	5G
RL	RALEIGH	NC	NF	NORFOLK	VA	565M
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	565M
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	1G
SE	SEATTLE	WA	HE	HELENA	MT	565M
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	1G
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	5G
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	5G
SL	SALT LAKE	UT	BD	BOULDER	CO	565M
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	565M
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	1G
TU	TUCSON	AZ	WS	WHITE SANDS	NM	565M

EXHIBIT 12-8. 2000 IRN Links & Capacity

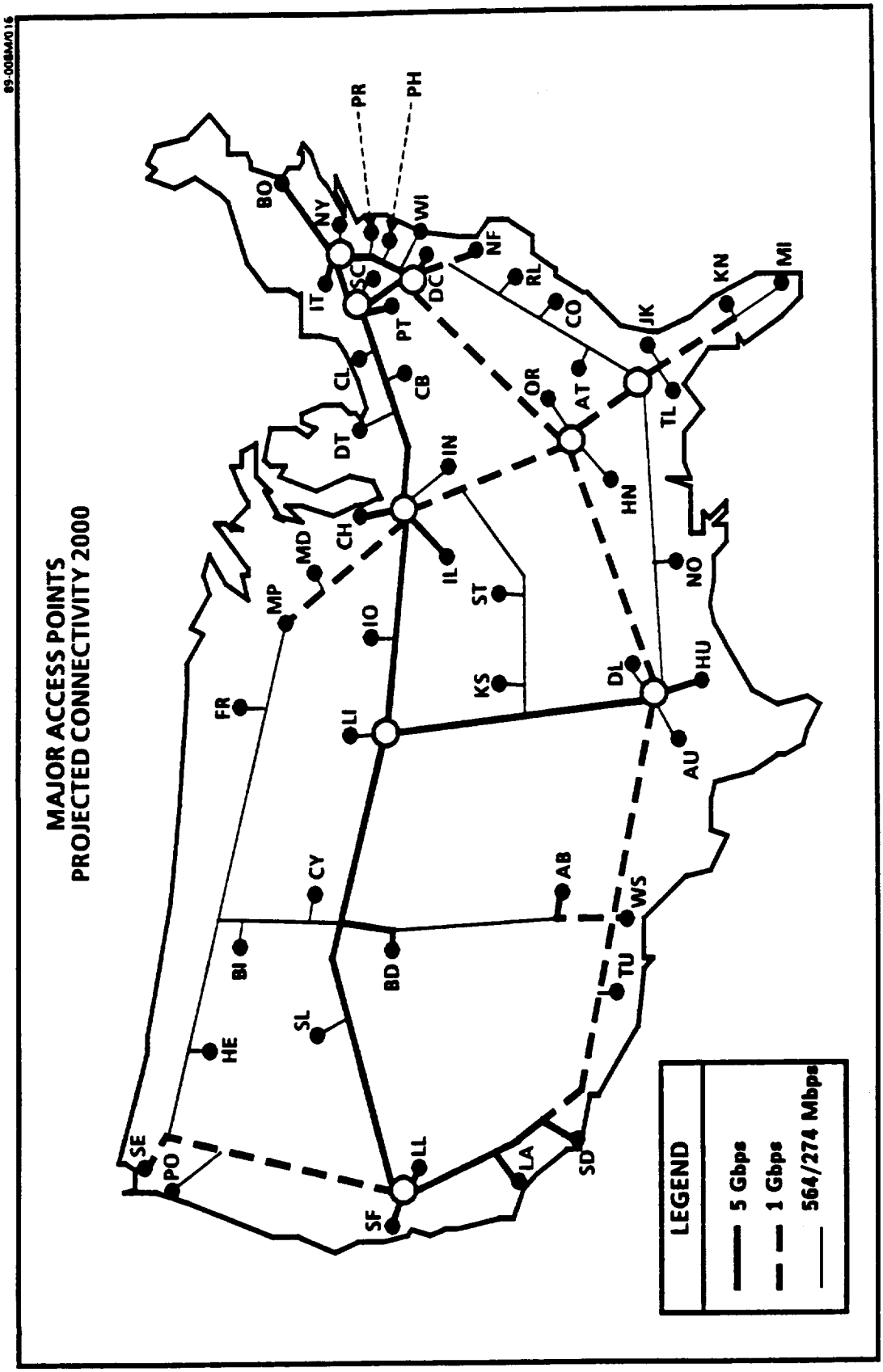

EXHIBIT 12-9. 2000 IRN Topology

YEAR 2010 IRN LINKS

ID	CITY -A	ST	ID	CITY - B	ST	CAPACITY
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	5G
AT	ATLANTA	GA	CO	COLUMBIA	SC	1G
AT	ATLANTA	GA	TL	TALLAHASEE	FL	1G
AU	AUSTIN	TX	DL	DALLAS	TX	1G
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	1G
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	25G
BI	BILLINGS	MT	CY	CHEYENNE	WY	1G
BI	BILLINGS	MT	FR	FARGO	ND	1G
BO	BOSTON	MA	NY	NEW YORK	NY	25G
CB	COLUMBUS	OH	DT	DETROIT	MI	1G
CH	CHICAGO	IL	IL	URBANA	IL	25G
CH	CHICAGO	IL	OR	OAK RIDGE	TN	5G
CH	CHICAGO	IL	LI	LINCOLN	NE	25G
CH	CHICAGO	IL	DT	DETROIT	MI	1G
CH	CHICAGO	IL	ST	ST LOUIS	MO	1G
CL	CLEVELAND	OH	CB	COLUMBUS	OH	1G
CO	COLUMBIA	SC	RL	RALEIGH	NC	1G
CY	CHEYENNE	WY	BD	BOULDER	CO	1G
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	25G
DC	WASHINGTON	DC	NF	NORFOLK	VA	5G
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1G
FR	FARGO	ND	MP	MINNEAPOLIS	MN	1G
HE	HELENA	MT	BI	BILLINGS	MT	1G
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	1G
HU	HOUSTON	TX	OR	OAK RIDGE	TN	5G
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	1G
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	1G
IT	ITHACA	NY	NY	NEW YORK	NY	25G
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	1G
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	25G
LI	LINCOLN	NE	HU	HOUSTON	TX	25G
LI	LINCOLN	NE	BD	BOULDER	CO	25G
LI	LINCOLN	NE	IO	IOWA CITY	IA	1G
MD	MADISON	WI	CH	CHICAGO	IL	5G
MP	MINNEAPOLIS	MN	MD	MADISON	WI	5G
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	1G
NY	NEW YORK	NY	DC	WASHINGTON	DC	25G
NY	NEW YORK	NY	PT	PITTSBURGH	PA	25G
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	5G
PO	PORTLAND	OR	SE	SEATTLE	WA	1G
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1G
PT	PITTSBURGH	PA	CH	CHICAGO	IL	25G
RL	RALEIGH	NC	NF	NORFOLK	VA	1G
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	1G
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	5G
SE	SEATTLE	WA	HE	HELENA	MT	1G
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	5G
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	25G
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	25G
SL	SALT LAKE	UT	BD	BOULDER	CO	1G
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	1G
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	5G
TU	TUCSON	AZ	WS	WHITE SANDS	NM	1G

EXHIBIT 12-10. 2010 IRN Links & Capacity

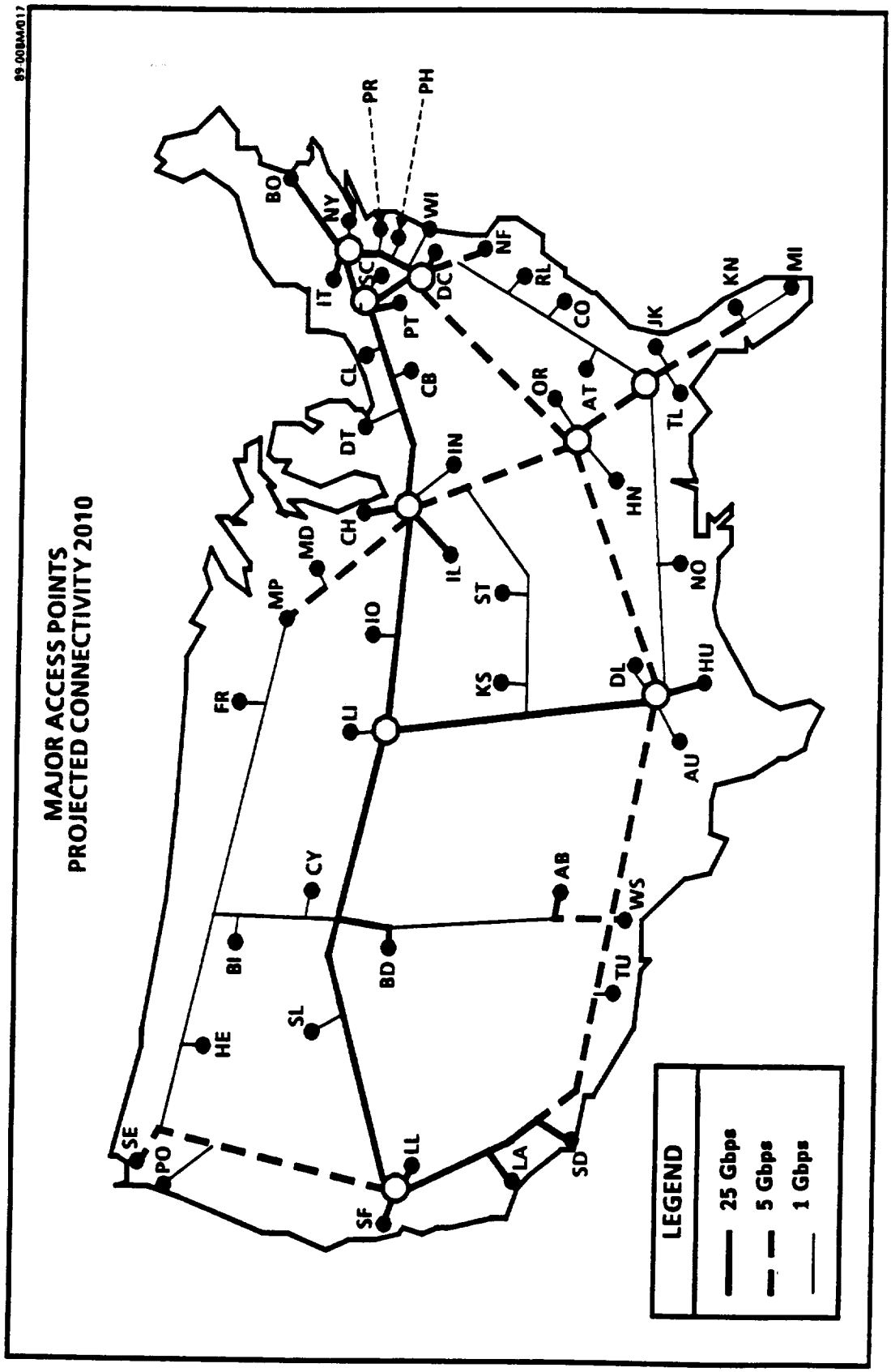

EXHIBIT 12-11. 2010 IRN Topology

SECTION 13

ESTIMATES OF CURRENT AND FUTURE IRN COSTS

13.1 OVERVIEW

Once the definitions of the current and future nationwide integrated computer research networks were developed, it was possible to estimate the current and future circuit costs of the IRN. The definitions of the IRN, along with current and future cost models and databases, were used to estimate circuit costs for each of the benchmark years.

13.2 METHODOLOGY

As noted earlier in Section 2, the major activities conducted to estimate the current and future costs of the IRN included:

1. Convert area code and exchange information to V & H coordinates.
2. Develop average cost per mile for various T1 links.
3. Develop cost model for current IRN costing.
4. Estimate circuit costs of current IRN.
5. Develop 1991 IRN Database.
6. Estimate 1991 IRN circuit costs.
7. Develop cost model for 1996, 2000 and 2010 IRN.
8. Estimate circuit cost of IRN for 1996, 2000, and 2010.

First, the approach used to estimate circuit costs for the various benchmark years was developed. The approach used to estimate current IRN costs and the 1991 IRN costs was different from that used to estimate IRN costs for 1996, 2000 and 2010. The major reason for using different approaches is that it was assumed that in 1989 and 1991 the IRN would not be integrated from a cost point of view, but would be in 1996 and beyond. In 1989 and 1991 the trunking requirements for each of the selected networks were costed individually. For each of the benchmark years, 1996,

2000 and 2010, the trunking requirements of the total IRN were costed.

The first step in estimating Current IRN circuit costs was to determine the V (vertical) and H (horizontal) coordinates of each major access point. The V and H coordinates then were used to determine the mileage between any two of the access points.

Next, a sample of the major access point area codes and exchanges were used to obtain real tariff data from the Network Analysis Center in Great Neck, New York for 56 Kbps and T1 services. This sample of real tariff data was used to develop the average circuit cost per mile for various link distances. It should be emphasized that these costs pertain to circuit costs and do not include costs associated with the end user interface equipment.

Given the mileage between any two access points on the Current IRN and the average cost per mile for various 56 Kbps and T1 links, a Current IRN cost database was developed. This cost database reflected the Current IRN definition and included the Current IRN cost model that was based on current tariff costs and IRN link distances. The database then was used to calculate the current costs of each link on the IRN and the total cost for the entire Current IRN.

To estimate the circuit cost of the 1991 IRN, the Current IRN cost database and cost model were modified to reflect the 1991 IRN definition and the costs of T3 links. To estimate the costs of T3 links, it was assumed that carriers would price future circuit offerings as they had done in the past. That is, the increase in price, for example, from a DS0 to a DS1, was used to estimate the increase in price from DS1 to a DS3. The increase in price from a DS0 to a DS1 which offers 24 times the capacity of a DS0 has been about a factor of six. Therefore, the ratio of capacity increase to cost increase is about four (i.e., 24/6 = 4). That is: New Price = (Capacity Increase/4) X Lower Speed Price. Therefore, the increase in cost from a T1 to a T3 which offers 28 times the capacity of a T1 would be about a factor of seven. Or, T3 Price = (28/4) X T1 Price. The estimated circuit costs of each network in the 1991 IRN and the total cost for the entire 1991 IRN were then calculated as done for 1989.

To estimate the future IRN circuit costs for 1996, 2000 and 2010, new price models and new price databases were developed. For the new price models, prices of higher speed links were estimated in the same manner as noted above for estimating the price of T3 links from T1 link prices. Given these estimates of higher speed links, an IRN cost model was developed for each of the benchmark years of 1996, 2000 and 2010. An IRN price database then was developed for each of these benchmark years using the definitions of the IRNs developed for each of these years and the estimated future circuit prices of the various link speeds and distances. Then, these price databases were used to estimate the IRN costs for 1996, 2000, and 2010.

13.3 FINDINGS

The findings obtained from the activities conducted to estimate the current and future circuit costs of the IRN are presented in terms of the link costs and total costs for each of the selected benchmark years. These results are presented below.

13.3.1 Current (1989) IRN Circuit Costs

The V & H coordinates for each city and the mileage between each city-pair for the Current IRN are shown in Exhibit 13-1. The city-pairs are listed in the same order as they were listed in earlier exhibits listing the Current IRN links.

The circuit cost per month for each city-pair link and for the total Current (1989) IRN are shown in Exhibit 13-2. Again, the city-pairs are listed in the same order as they were listed in earlier exhibits listing the Current IRN links.

The concept of a "Megabit Per Second Mile" (MM) was developed to provide a measure of network efficiency across benchmark years. An MM refers to the movement of one Megabit Per Second of traffic one mile; that is, an MM is a Mbps Mile. The number of MMs is indicated for each city-pair link. For Example, in Exhibit 13-2, for the first entry, (capacity = .056 Mb) * (miles = 860) = 48.16 MMs.

MILEAGE REPORT USING V & H COORDINATES

ID	CITY - A	ST	V1	H1	ID	CITY - B	ST	V2	H2	MILES	CAPACITY
AB	ALBUQUERQUE	NM	8,549	5,887	LL	LIVERMORE	CA	8,504	8,606	860	56
AB	ALBUQUERQUE	NM	8,549	5,887	LL	LIVERMORE	CA	8,504	8,606	860	1544
AB	ALBUQUERQUE	NM	8,549	5,887	KS	KANSAS CITY	KS	7,249	4,210	671	56
AB	ALBUQUERQUE	NM	8,549	5,887	KS	KANSAS CITY	KS	7,249	4,210	671	56
AB	ALBUQUERQUE	NM	8,549	5,887	KS	KANSAS CITY	KS	7,249	4,210	671	56
AB	ALBUQUERQUE	NM	8,549	5,887	LL	LIVERMORE	CA	8,504	8,606	860	56
AB	LOS ALAMOS	NM	8,549	5,887	AU	AUSTIN	TX	9,005	3,996	615	56
AB	LOS ALAMOS	NM	8,549	5,887	KS	LAWRENCE	KS	7,249	4,210	671	56
AB	LOS ALAMOS	NM	8,549	5,887	BD	BOULDER	CO	7,456	5,961	346	56
AU	AUSTIN	TX	9,005	3,996	DL	RICHARDSON	TX	8,436	4,034	180	1544
BD	BOULDER	CO	7,456	5,961	MD	MADISON	WI	5,890	3,798	844	224
BD	BOULDER	CO	7,456	5,961	DC	WASHINGTON	DC	5,622	1,583	1,501	224
BD	BOULDER	CO	7,456	5,961	SL	SALT LAKE CITY	UT	7,576	7,065	351	56
BD	BOULDER	CO	7,456	5,961	DC	WASHINGTON	DC	5,622	1,583	1,501	224
BD	BOULDER	CO	7,456	5,961	BO	WOODS HOLE	MA	4,422	1,249	1,772	224
BD	BOULDER	CO	7,456	5,961	MI	MIAMI	FL	8,351	527	1,742	224
BD	BOULDER	CO	7,456	5,961	TU	TUCSON	AZ	9,342	6,480	619	56
BD	BOULDER	CO	7,456	5,961	DT	ANN ARBOR	MI	5,536	2,828	1,162	224
BD	BOULDER	CO	7,456	5,961	PO	CORVALIS	OR	6,799	8,914	957	1544
BD	DENVER	CO	7,456	5,961	PO	CORVALLIS	OR	6,799	8,914	957	224
BO	BOSTON	MA	4,422	1,249	LA	LOS ANGELES	CA	9,213	7,878	822	1544
BO	CAMBRIDGE	MA	4,422	1,249	NY	NEW YORK	NY	4,997	1,406	188	1544
CH	CHICAGO	IL	5,986	3,426	PR	PRINCETON	NJ	5,120	1,436	229	1544
CH	CHICAGO	IL	5,986	3,426	SE	SEATTLE	WA	6,336	8,896	1,733	1544
CH	CHICAGO	IL	5,986	3,426	DT	LANSING	MI	5,536	2,828	237	1544
CH	CHICAGO	IL	5,986	3,426	DT	LITCHFIELD	MI	5,536	2,828	237	1544
CH	CHICAGO	IL	5,986	3,426	SF	SAN FRANCISCO	CA	8,492	8,719	1,852	56
CH	CHICAGO	IL	5,986	3,426	MD	MADISON	WI	5,890	3,798	121	1544
CH	CHICAGO	IL	5,986	3,426	BD	DENVER	CO	7,456	5,961	927	1544
CH	CHICAGO	IL	5,986	3,426	TL	TALLAHASSEE	FL	7,876	1,715	806	56
CH	CHICAGO	IL	5,986	3,426	IL	URBANA	IL	6,371	3,336	125	1544
CH	CHICAGO	IL	5,986	3,426	LI	LINCOLN	NE	6,823	4,674	475	1544
DC	WASHINGTON	DC	5,622	1,583	BO	CAMBRIDGE	MA	4,422	1,249	848	1544
DC	WASHINGTON	DC	5,622	1,583	NY	NEW YORK	NY	4,997	1,406	205	1544
DC	WASHINGTON	DC	5,622	1,583	AB	ALBUQUERQUE	NM	8,549	5,887	1,646	56
DC	WASHINGTON	DC	5,622	1,583	LL	LIVERMORE	CA	8,504	8,606	2,401	56
DC	WASHINGTON	DC	5,622	1,583	LL	LIVERMORE	CA	8,504	8,606	2,401	56
DC	WASHINGTON	DC	5,622	1,583	LL	LIVERMORE	CA	8,504	8,606	2,401	56
DC	WASHINGTON	DC	5,622	1,583	HN	HUNTSVILLE	AL	7,267	2,535	601	56
DC	WASHINGTON	DC	5,622	1,583	HU	HOUSTON	TX	8,938	3,536	1,217	56
DC	WASHINGTON	DC	5,622	1,583	WI	WALLOPS ISLAND	VA	5,657	1,249	106	56
DC	WASHINGTON	DC	5,622	1,583	WI	WALLOPS ISLAND	VA	5,657	1,249	106	1544
DC	WASHINGTON	DC	5,622	1,583	CL	CLEVELAND	OH	5,574	2,543	304	112
DC	WASHINGTON	DC	5,622	1,583	KN	CAPE KENNEDY	FL	7,919	880	760	168
DC	WASHINGTON	DC	5,622	1,583	LA	LOS ANGELES	CA	9,213	7,878	2,292	56
DC	WASHINGTON	DC	5,622	1,583	WS	WHITE SANDS	NM	9,132	5,742	1,572	224
DC	WASHINGTON	DC	5,622	1,583	WS	WHITE SANDS	NM	9,132	5,742	1,721	56
DC	WASHINGTON	DC	5,622	1,583	LA	BARSTOW	CA	9,213	7,878	2,292	224

EXHIBIT 13-1. Current (1989) IRN Mileage Report

DC	WASHINGTON	DC	5,622	1,583	LA	BARSTOW	CA	9,213	7,878	2,292	56
DC	WASHINGTON	DC	5,622	1,583	BO	CAMBRIDGE	MA	4,422	1,249	394	56
DC	WASHINGTON	DC	5,622	1,583	PR	PRINCETON	NJ	5,120	1,436	165	1544
DC	WASHINGTON	DC	5,622	1,583	SF	SAN FRANCISCO	CA	8,492	8,719	2,432	1544
DC	WASHINGTON	DC	5,622	1,583	SF	SAN FRANCISCO	CA	8,492	8,719	2,432	112
DC	WASHINGTON	DC	5,622	1,583	SF	SAN FRANCISCO	CA	8,492	8,719	2,432	224
DC	WASHINGTON	DC	5,622	1,583	HU	HOUSTON	TX	8,938	3,536	1,217	1544
DC	WASHINGTON	DC	5,622	1,583	LA	PASADENA	CA	9,213	7,878	2,292	448
DC	WASHINGTON	DC	5,622	1,583	LA	PASADENA	CA	9,213	7,878	2,292	280
DC	WASHINGTON	DC	5,622	1,583	LA	LOMPOC	CA	9,213	7,878	2,292	224
DC	WASHINGTON	DC	5,622	1,583	HN	HUNTSVILLE	AL	7,267	2,535	601	1544
DC	WASHINGTON	DC	5,622	1,583	KN	CAPE KENNEDY	FL	7,919	880	760	672
DC	WASHINGTON	DC	5,622	1,583	HN	HUNTSVILLE	AL	7,267	2,535	601	512
DC	WASHINGTON	DC	5,622	1,583	HU	HOUSTON	TX	8,938	3,536	1,217	56
DC	WASHINGTON	DC	5,622	1,583	HU	HOUSTON	TX	8,938	3,536	1,217	2048
DC	WASHINGTON	DC	5,622	1,583	PH	WILMINGTON	DE	5,251	1,458	124	56
DC	WASHINGTON	DC	5,622	1,583	NF	NORFOLK	VA	5,936	1,198	157	56
DC	WASHINGTON	DC	5,622	1,583	HU	HOUSTON	TX	8,938	3,536	1,217	56
DC	WASHINGTON	DC	5,622	1,583	KN	CAPE KENNEDY	FL	7,919	880	760	280
DC	WASHINGTON	DC	5,622	1,583	NY	NEW YORK	NY	4,997	1,406	205	56
DC	WASHINGTON	DC	5,622	1,583	WI	WALLOPS ISLAND	VA	5,657	1,249	106	56
DL	RICHARDSON	TX	8,436	4,034	TL	TALLAHASSEE	FL	7,876	1,715	754	1544
DT	ANN ARBOR	MI	5,536	2,828	CB	COLUMBUS	OH	5,972	2,555	163	1544
DT	ANN ARBOR	MI	5,536	2,828	PR	PRINCETON	NJ	5,120	1,436	459	1544
HN	HUNTSVILLE	AL	7,267	2,535	KN	CAPE KENNEDY	FL	7,919	880	563	2048
HN	HUNTSVILLE	AL	7,267	2,535	HU	HOUSTON	TX	8,938	3,536	616	168
HN	HUNTSVILLE	AL	7,267	2,535	DC	WASHINGTON	DC	5,622	1,583	601	672
HN	HUNTSVILLE	AL	7,267	2,535	KN	ORLANDO	FL	7,919	880	563	56
HN	HUNTSVILLE	AL	7,267	2,535	MI	MIAMI	FL	8,351	527	722	56
HU	BRYAN	TX	8,938	3,536	AU	AUSTIN	TX	9,005	3,996	147	1544
HU	HOUSTON	TX	8,938	3,536	DL	DALLAS	TX	8,436	4,034	224	56
HU	HOUSTON	TX	8,938	3,536	HN	HUNTSVILLE	AL	7,267	2,535	616	56
HU	HOUSTON	TX	8,938	3,536	WS	WHITE SANDS	NM	9,132	5,742	700	56
HU	HOUSTON	TX	8,938	3,536	AU	AUSTIN	TX	9,005	3,996	147	1544
HU	HOUSTON	TX	8,938	3,536	AU	AUSTIN	TX	9,005	3,996	147	56
HU	HOUSTON	TX	8,938	3,536	BD	BOULDER	CO	7,456	5,961	899	1544
HU	HOUSTON	TX	8,938	3,536	AU	AUSTIN	TX	9,005	3,996	147	56
HU	HOUSTON	TX	8,938	3,536	KN	CAPE KENNEDY	FL	7,919	880	900	1544
IL	URBANA	IL	6,371	3,336	CH	CHICAGO	IL	5,986	3,426	125	1544
IL	URBANA	IL	6,371	3,336	IN	BLOOMINGTON	IN	6,272	2,992	113	1544
IL	URBANA	IL	6,371	3,336	MD	MILWAUKEE	WI	5,890	3,798	211	56
IN	INDIANAPOLIS	IN	6,272	2,992	CB	COLUMBUS	OH	5,972	2,555	168	1544
IO	IOWA CITY	IA	6,315	3,971	IL	URBANA	IL	6,371	3,336	202	1544
IT	ITHACA	NY	4,798	1,990	NY	NEW YORK	NY	4,997	1,406	195	1544
IT	ITHACA	NY	4,798	1,990	NY	NEW YORK	NY	4,997	1,406	195	1544
IT	ITHACA	NY	4,798	1,990	NY	NEW YORK	NY	4,997	1,406	195	1544
IT	ITHACA	NY	4,798	1,990	DC	WASHINGTON	DC	5,622	1,583	291	1544
IT	ITHACA	NY	4,798	1,990	PT	PITTSBURGH	PA	5,621	2,185	267	1544
KS	KANSAS CITY	KS	7,249	4,210	LL	LIVERMORE	CA	8,504	8,606	1,446	56
KS	KANSAS CITY	KS	7,249	4,210	LL	LIVERMORE	CA	8,504	8,606	1,446	1544
KS	KANSAS CITY	KS	7,249	4,210	AB	ALBUQUERQUE	NM	8,549	5,887	671	1544
LA	LOS ANGELES	CA	9,213	7,878	AB	LOS ALAMOS	NM	8,549	5,887	664	1544
LA	LOS ANGELES	CA	9,213	7,878	HN	HUNTSVILLE	AL	7,267	2,535	1,798	56

EXHIBIT 13-1. Current (1989) IRN Mileage Report

(Continued)

LA	LOS ANGELES	CA	9,213	7,878	SD	SAN DIEGO	CA	9,468	7,629	113	56
LA	LOS ANGELES	CA	9,213	7,878	SD	SAN DIEGO	CA	9,468	7,629	113	56
LA	LOS ANGELES	CA	9,213	7,878	SF	SAN FRANCISCO	CA	8,492	8,719	350	1544
LA	LOS ANGELES	CA	9,213	7,878	HU	HOUSTON	TX	8,938	3,536	1,376	56
LA	LOS ANGELES	CA	9,213	7,878	BD	BOULDER	CO	7,456	5,961	822	56
LA	LOS ANGELES	CA	9,213	7,878	SD	SAN DIEGO	CA	9,468	7,629	113	1544
LA	LOS ANGELESO	CA	9,213	7,878	SF	SAN FRANCISCO	CA	8,492	8,719	350	1544
LA	PASADENA	CA	9,213	7,878	TU	TUCSON	AZ	9,342	6,480	444	56
LA	PASADENA	CA	9,213	7,878	DC	BALTIMORE	MD	5,622	1,583	2,292	56
LA	PASADENA	CA	9,213	7,878	HU	HOUSTON ISLAND	TX	8,938	3,536	1,376	168
LA	PASADENA	CA	9,213	7,878	DC	WASHINGTON	DC	5,622	1,583	2,292	672
LI	LINCOLN	NE	6,823	4,674	IL	URBANA	IL	6,371	3,336	447	56
LI	LINCOLN	NE	6,823	4,674	KS	LAWRENCE	KS	7,249	4,210	199	56
LI	LINCOLN	NE	6,823	4,674	IO	IOWA CITY	IA	6,315	3,971	274	56
LI	LINCOLN	NE	6,823	4,674	BD	BOULDER	CO	7,456	5,961	454	1544
LL	LIVERMORE	CA	8,504	8,606	SF	OAKLAND	CA	8,492	8,719	36	56
LL	LIVERMORE	CA	8,504	8,606	PR	PRINCETON	NJ	5,120	1,436	2,507	1544
LL	LIVERMORE	CA	8,504	8,606	LA	LOS ANGELES	CA	9,213	7,878	321	56
LL	LIVERMORE	CA	8,504	8,606	AB	ALBUQUERQUE	NM	8,549	5,887	860	1544
MP	MINNEAPOLIS	MN	5,781	4,525	IO	IOWA CITY	IA	6,315	3,971	243	1544
MP	MINNEAPOLIS	MN	5,781	4,525	MD	MADISON	WI	5,890	3,798	232	1544
NF	NORFOLK	VA	5,936	1,198	TL	TALLAHASSEE	FL	7,876	1,715	635	1544
NY	LONG ISLAND	NY	4,997	1,406	BO	CAMBRIDGE	MA	4,422	1,249	188	1544
NY	NEW YORK	NY	4,997	1,406	IT	ROME	NY	4,798	1,990	195	1544
OR	OAK RIDGE	TN	6,811	2,303	CH	CHICAGO	IL	5,986	3,426	441	1544
OR	OAK RIDGE	TN	6,811	2,303	TL	TALLAHASSEE	FL	7,876	1,715	385	1544
PR	PRINCETON	NJ	5,120	1,436	TU	TUCSON	AZ	9,342	6,480	2,080	1544
PR	PRINCETON	NJ	5,120	1,436	NF	NORFOLK VA	DC	5,936	1,198	269	1544
PR	PRINCETON	NJ	5,120	1,436	NY	NEW YORK	NY	4,997	1,406	40	1544
PR	PRINCETON	NJ	5,120	1,436	CH	CHICAGO	IL	5,986	3,426	686	1544
PR	PRINCETON	NJ	5,120	1,436	NY	LONG ISLAND	NY	4,997	1,406	40	1544
PR	PRINCETON	NJ	5,120	1,436	BD	BOLDER	CO	7,456	5,961	1,610	1544
PR	PRINCETON	NJ	5,120	1,436	SC	STATE COLLEGE	PA	5,360	1,933	175	1544
PR	PRINCETON	NJ	5,120	1,436	PH	PHILADELPHIA	PA	5,251	1,458	42	1544
PR	PRINCETON	NJ	5,120	1,436	BO	CAMBRIDGE	MA	4,422	1,249	229	1544
PR	PRINCETON	NJ	5,120	1,436	BO	CAMBRIDGE	MA	4,422	1,249	229	1544
PR	PRINCETON	NJ	5,120	1,436	NY	NEW YORK	NY	4,997	1,406	40	1544
PR	PRINCETON	NJ	5,120	1,436	NY	NEW YORK	NY	4,997	1,406	40	1544
PR	PRINCETON	NJ	5,120	1,436	BO	NEW HAVEN	CT	4,422	1,249	229	1544
PR	PRINCETON	NJ	5,120	1,436	BO	AMHERST	MA	4,422	1,249	229	1544
PT	PITTSBURGH	PA	5,621	2,185	SC	STATE COLLEGE	PA	5,360	1,933	115	1544
PT	PITTSBURGH	PA	5,621	2,185	PR	PRINCETON	NJ	5,120	1,436	285	1544
PT	PITTSBURGH	PA	5,621	2,185	IL	URBANA	IL	6,371	3,336	434	1544
PT	PITTSBURGH	PA	5,621	2,185	CL	CLEVELAND	OH	5,574	2,543	114	1544
PT	PITTSBURGH	PA	5,621	2,185	PH	PHILADELPHIA	PA	5,251	1,458	258	1544
PT	PITTSBURGH	PA	5,621	2,185	DC	WASHINGTON	DC	5,622	1,583	190	1544
SD	SAN DIEGO	CA	9,468	7,629	LA	LOS ANGELES	CA	9,213	7,878	113	1544
SD	SAN DIEGO	CA	9,468	7,629	LA	RIVERSIDE	CA	9,213	7,878	113	56
SD	SAN DIEGO	CA	9,468	7,629	LA	LOS ANGELES	CA	9,213	7,878	113	1544
SD	SAN DIEGO	CA	9,468	7,629	LA	LOS ANGELES	CA	9,213	7,878	113	1544
SD	SAN DIEGO	CA	9,468	7,629	HU	HOUSTON	TX	8,938	3,536	1,305	1544
SD	SAN DIEGO	CA	9,468	7,629	SF	MENLO PARK	CA	8,492	8,719	463	1544
SD	SAN DIEGO	CA	9,468	7,629	LA	SANTA BARBARA	CA	9,213	7,878	113	56

EXHIBIT 13-1. Current (1989) IRN Mileage Report

(Continued)

SD	SAN DIEGO	CA	9,468	7,629	SE	SEATTLE	WA	6,336	8,896	1,068	56
SD	SAN DIEGO	CA	9,468	7,629	SF	OAKLAND	CA	8,492	8,719	463	56
SD	SAN DIEGO	CA	9,468	7,629	LA	IRVINE	CA	9,213	7,878	113	56
SD	SAN DIEGO	CA	9,468	7,629	SL	SALT LAKE CITY	UT	7,576	7,065	624	56
SD	SAN DIEGO	CA	9,468	7,629	SL	SALT LAKE CITY	UT	7,576	7,065	624	56
SE	SEATTLE	WA	6,336	8,896	SD	SAN DIEGO	CA	9,468	7,629	1,068	1544
SE	SEATTLE	WA	6,336	8,896	SF	MENLO PARK	CA	8,492	8,719	684	1544
SE	SEATTLE	WA	6,336	8,896	PO	PORTLAND	OR	6,799	8,914	147	56
SE	SEATTLE	WA	6,336	8,896	PO	CORVALLIS	OR	6,799	8,914	147	56
SE	SEATTLE	WA	6,336	8,896	PO	EUGENE	OR	6,799	8,914	147	56
SF	SAN FRANCISCO	CA	8,492	8,719	LA	PASADENA	CA	9,213	7,878	350	448
SF	SAN FRANCISCO	CA	8,492	8,719	LL	LIVERMORE	CA	8,504	8,606	36	1544
SF	SAN FRANCISCO	CA	8,492	8,719	BD	BOULDER	CO	7,456	5,961	932	56
SF	SAN FRANCISCO	CA	8,492	8,719	DC	WASHINGTON	DC	5,622	1,583	2,432	336
SF	SAN FRANCISCO	CA	8,492	8,719	LA	LOS ANGELES	CA	9,213	7,878	350	56
SF	SAN FRANCISCO	CA	8,492	8,719	DC	WASHINGTON	DC	5,622	1,583	2,432	56
SF	SAN FRANCISCO	CA	8,492	8,719	CH	CHICAGO	IL	5,986	3,426	1,852	1544
SL	SALT LAKE CITY	UT	7,576	7,065	SF	MENLO PARK	CA	8,492	8,719	598	1544
SL	SALT LAKE CITY	UT	7,576	7,065	BD	BOULDER	CO	7,456	5,961	351	1544
SL	SALT LAKE CITY	UT	7,576	7,065	CH	CHICAGO	IL	5,986	3,426	1,256	1544
WI	WALLOPS ISLAND	VA	5,657	1,249	HU	HOUSTON	TX	8,938	3,536	1,265	1544
WI	WALLOPS ISLAND	VA	5,657	1,249	MD	MADISON	WI	5,890	3,798	809	224
WI	WALLOPS ISLAND	VA	5,657	1,249	HU	HOUSTON	TX	8,938	3,536	1,265	224

EXHIBIT 13-1. Current (1989) IRN Mileage Report

(Continued)

COST PER MONTH - CALCULATED BY USING AN ESTIMATED AVERAGE COST PER MILE FOR THE VARIOUS SERVICES

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY	MILES	MM	COST
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56	860	48.16	2,950.00
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1544	860	1,327.84	14,300.00
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2,477.50
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2,477.50
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2,477.50
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56	860	48.16	2,950.00
AB	LOS ALAMOS	NM	AU	AUSTIN	TX	56	615	34.44	2,337.50
AB	LOS ALAMOS	NM	KS	LAWRENCE	KS	56	671	37.58	2,477.50
AB	LOS ALAMOS	NM	BD	BOULDER	CO	56	346	19.38	1,665.00
AU	AUSTIN	TX	DL	RICHARDSON	TX	1544	180	277.92	4,100.00
BD	BOULDER	CO	MD	MADISON	WI	224	844	189.06	9,174.00
BD	BOULDER	CO	DC	WASHINGTON	DC	224	1,501	336.22	14,758.50
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	56	351	19.66	1,677.50
BD	BOULDER	CO	DC	WASHINGTON	DC	224	1,501	336.22	14,758.50
BD	BOULDER	CO	BO	WOODS HOLE	MA	224	1,772	396.93	17,062.00
BD	BOULDER	CO	MI	MIAMI	FL	224	1,742	390.21	16,807.00
BD	BOULDER	CO	TU	TUCSON	AZ	56	619	34.66	2,347.50
BD	BOULDER	CO	DT	ANN ARBOR	MI	224	1,162	260.29	11,877.00
BD	BOULDER	CO	PO	CORVALIS	OR	1544	957	1,477.61	15,755.00
BD	BOULDER	CO	PO	CORVALLIS	OR	224	957	214.37	10,134.50
BD	DENVER	CO	LA	LOS ANGELES	CA	1544	822	1,269.17	13,730.00
BO	BOSTON	MA	NY	NEW YORK	NY	1544	188	290.27	4,220.00
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	1544	229	353.58	4,835.00
CH	CHICAGO	IL	SE	SEATTLE	WA	1544	1,733	2,675.75	27,395.00
CH	CHICAGO	IL	DT	LANSING	MI	1544	237	365.93	4,955.00
CH	CHICAGO	IL	DT	LITCHFIELD	MI	1544	237	365.93	4,955.00
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	56	1,852	103.71	5,430.00
CH	CHICAGO	IL	MD	MADISON	WI	1544	121	186.82	3,215.00
CH	CHICAGO	IL	BD	DENVER	CO	1544	927	1,431.29	15,305.00
CH	CHICAGO	IL	TL	TALLAHASSEE	FL	56	806	45.14	2,815.00
CH	CHICAGO	IL	IL	URBANA	IL	1544	125	193.00	3,275.00
CH	CHICAGO	IL	LI	LINCOLN	NE	1544	475	733.40	8,525.00
CH	CHICAGO	IL	BO	CAMBRIDGE	MA	1544	848	1,309.31	14,120.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	1544	205	316.52	4,475.00
DC	WASHINGTON	DC	AB	ALBUQUERQUE	NM	56	1,646	92.18	4,915.00
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2,401	134.46	6,802.50
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2,401	134.46	6,802.50
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2,401	134.46	6,802.50
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	56	601	33.66	2,302.50
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1,217	68.15	3,842.50
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56	106	5.94	1,065.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1544	106	163.66	2,990.00
DC	WASHINGTON	DC	CL	CLEVELAND	OH	112	304	34.05	2,568.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	168	760	127.68	6,540.00
DC	WASHINGTON	DC	LA	LOS ANGELES	CA	56	2,292	128.35	6,530.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	224	1,572	352.13	15,362.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	56	1,721	96.38	5,102.50
DC	WASHINGTON	DC	LA	BARSTOW	CA	224	2,292	513.41	21,482.00

EXHIBIT 13-2. Current (1989) IRN Circuit Costs

DC	WASHINGTON	DC	LA	BARSTOW	CA	56	2.292	128.35	6.530.00
DC	WASHINGTON	DC	BO	CAMBRIDGE	MA	56	394	22.06	1.785.00
DC	WASHINGTON	DC	PR	PRINCETON	NJ	1544	165	254.76	3.875.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	1544	2.432	3.755.01	37.880.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	112	2.432	272.38	12.144.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	224	2.432	544.77	22.672.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	1544	1.217	1.879.05	19.655.00
DC	WASHINGTON	DC	LA	PASADENA	CA	448	2.292	1.026.82	35.780.00
DC	WASHINGTON	DC	LA	PASADENA	CA	280	2.292	641.76	26.466.00
DC	WASHINGTON	DC	LA	LOMPOC	CA	224	2.292	513.41	21.482.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	1544	601	927.94	10.415.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	672	760	510.72	12.800.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	512	601	307.71	10.415.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1.217	68.15	3.842.50
DC	WASHINGTON	DC	HU	HOUSTON	TX	2048	1.217	2.492.42	29.482.50
DC	WASHINGTON	DC	PH	WILMINGTON	DE	56	124	6.94	1.110.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	56	157	8.79	1.192.50
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1.217	68.15	3.842.50
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	280	760	212.80	10.380.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	56	205	11.48	1.312.50
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56	106	5.94	1.065.00
DL	RICHARDSON	TX	TL	TALLAHASSEE	FL	1544	754	1.164.18	12.710.00
DT	ANN ARBOR	MI	CB	COLUMBUS	OH	1544	163	251.67	3.845.00
DT	ANN ARBOR	MI	PR	PRINCETON	NJ	1544	459	708.70	8.285.00
HN	HUNTSVILLE	AL	KN	CAPE KENNEDY	FL	2048	563	1.153.02	14.767.50
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	168	616	103.49	5.604.00
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	672	601	403.87	10.415.00
HN	HUNTSVILLE	AL	KN	ORLANDO	FL	56	563	31.53	2.207.50
HN	HUNTSVILLE	AL	MI	MIAMI	FL	56	722	40.43	2.605.00
HU	BRYAN	TX	AU	AUSTIN	TX	1544	147	226.97	3.605.00
HU	HOUSTON	TX	DL	DALLAS	TX	56	224	12.54	1.360.00
HU	HOUSTON	TX	HN	HUNTSVILLE	AL	56	616	34.50	2.340.00
HU	HOUSTON	TX	WS	WHITE SANDS	NM	56	700	39.20	2.550.00
HU	HOUSTON	TX	AU	AUSTIN	TX	1544	147	226.97	3.605.00
HU	HOUSTON	TX	AU	AUSTIN	TX	56	147	8.23	1.167.50
HU	HOUSTON	TX	BD	BOULDER	CO	1544	899	1.388.06	14.885.00
HU	HOUSTON	TX	AU	AUSTIN	TX	56	147	8.23	1.167.50
HU	HOUSTON	TX	KN	CAPE KENNEDY	FL	1544	900	1.389.60	14.900.00
IL	URBANA	IL	CH	CHICAGO	IL	1544	125	193.00	3.275.00
IL	URBANA	IL	IN	BLOOMINGTON	IN	1544	113	174.47	3.095.00
IL	URBANA	IL	MD	MILWAUKEE	WI	56	211	11.82	1.327.50
IN	INDIANAPOLIS	IN	CB	COLUMBUS	OH	1544	168	259.39	3.920.00
IO	IOWA CITY	IA	IL	URBANA	IL	1544	202	311.89	4.430.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4.325.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4.325.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4.325.00
IT	ITHACA	NY	DC	WASHINGTON	DC	1544	291	449.30	5.765.00
IT	ITHACA	NY	PT	PITTSBURGH	PA	1544	267	412.25	5.405.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	56	1.446	80.98	4.415.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	1544	1.446	2.232.62	23.090.00
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	1544	671	1.036.02	11.465.00
LA	LOS ANGELES	CA	AB	LOS ALAMOS	NM	1544	664	1.025.22	11.360.00
LA	LOS ANGELES	CA	HN	HUNTSVILLE	AL	56	1.798	100.69	5.295.00

EXHIBIT 13-2. Current (1989) IRN Circuit Costs

(Continued)

LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56	113	6.33	1,082.50
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56	113	6.33	1,082.50
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	1544	350	540.40	6,650.00
LA	LOS ANGELES	CA	HU	HOUSTON	TX	56	1,376	77.06	4,240.00
LA	LOS ANGELES	CA	BD	BOULDER	CO	56	822	46.03	2,855.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544	113	174.47	3,095.00
LA	LOS ANGELESO	CA	SF	SAN FRANCISCO	CA	1544	350	540.40	6,650.00
LA	PASADENA	CA	TU	TUCSON	AZ	56	444	24.86	1,910.00
LA	PASADENA	CA	DC	BALTIMORE	MD	56	2,292	128.35	6,530.00
LA	PASADENA	CA	HU	HOUSTON ISLAND	TX	168	1,376	231.17	10,544.00
LA	PASADENA	CA	DC	WASHINGTON	DC	672	2,292	1,540.22	35,780.00
LI	LINCOLN	NE	IL	URBANA	IL	56	447	25.03	1,917.50
LI	LINCOLN	NE	KS	LAWRENCE	KS	56	199	11.14	1,297.50
LI	LINCOLN	NE	IO	IOWA CITY	IA	56	274	15.34	1,485.00
LI	LINCOLN	NE	BD	BOULDER	CO	1544	454	700.98	8,210.00
LL	LIVERMORE	CA	SF	OAKLAND	CA	56	36	2.02	890.00
LL	LIVERMORE	CA	PR	PRINCETON	NJ	1544	2,507	3,870.81	39,005.00
LL	LIVERMORE	CA	LA	LOS ANGELES	CA	56	321	17.98	1,602.50
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	1544	860	1,327.84	14,300.00
MP	MINNEAPOLIS	MN	IO	IOWA CITY	IA	1544	243	375.19	5,045.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1544	232	358.21	4,880.00
NF	NORFOLK	VA	TL	TALLAHASSEE	FL	1544	635	980.44	10,925.00
NY	LONG ISLAND	NY	BO	CAMBRIDGE	MA	1544	188	290.27	4,220.00
NY	NEW YORK	NY	IT	ROME	NY	1544	195	301.08	4,325.00
OR	OAK RIDGE	TN	CH	CHICAGO	IL	1544	441	680.90	8,015.00
OR	OAK RIDGE	TN	TL	TALLAHASSEE	FL	1544	385	594.44	7,175.00
PR	PRINCETON	NJ	TU	TUCSON	AZ	1544	2,080	3,211.52	32,600.00
PR	PRINCETON	NJ	NF	NORFOLK VA	DC	1544	269	415.34	5,435.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2,000.00
PR	PRINCETON	NJ	CH	CHICAGO	IL	1544	686	1,059.18	11,690.00
PR	PRINCETON	NJ	NY	LONG ISLAND	NY	1544	40	61.76	2,000.00
PR	PRINCETON	NJ	BD	BOLDER	CO	1544	1,610	2,485.84	25,550.00
PR	PRINCETON	NJ	SC	STATE COLLEGE	PA	1544	175	270.20	4,025.00
PR	PRINCETON	NJ	PH	PHILADELPHIA	PA	1544	42	64.85	2,030.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544	229	353.58	4,835.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544	229	353.58	4,835.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2,000.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2,000.00
PR	PRINCETON	NJ	BO	NEW HAVEN	CT	1544	229	353.58	4,835.00
PR	PRINCETON	NJ	BO	AMHERST	MA	1544	229	353.58	4,835.00
PT	PITTSBURGH	PA	SC	STATE COLLEGE	PA	1544	115	177.56	3,125.00
PT	PITTSBURGH	PA	PR	PRINCETON	NJ	1544	285	440.04	5,675.00
PT	PITTSBURGH	PA	IL	URBANA	IL	1544	434	670.10	7,910.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1544	114	176.02	3,110.00
PT	PITTSBURGH	PA	PH	PHILADELPHIA	PA	1544	258	398.35	5,270.00
PT	PITTSBURGH	PA	DC	WASHINGTON	DC	1544	190	293.36	4,250.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3,095.00
SD	SAN DIEGO	CA	LA	RIVERSIDE	CA	56	113	6.33	1,082.50
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3,095.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3,095.00
SD	SAN DIEGO	CA	HU	HOUSTON	TX	1544	1,305	2,014.92	20,975.00
SD	SAN DIEGO	CA	SF	MENLO PARK	CA	1544	463	714.87	8,345.00
SD	SAN DIEGO	CA	LA	SANTA BARBARA	CA	56	113	6.33	1,082.50

EXHIBIT 13-2. Current (1989) IRN Circuit Costs

(Continued)

SD	SAN DIEGO	CA	SE	SEATTLE	WA	56	1.068	59.81	3,470.00
SD	SAN DIEGO	CA	SF	OAKLAND	CA	56	463	25.93	1,957.50
SD	SAN DIEGO	CA	LA	IRVINE	CA	56	113	6.33	1,082.50
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56	624	34.94	2,360.00
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56	624	34.94	2,360.00
SE	SEATTLE	WA	SD	SAN DIEGO	CA	1544	1.068	1,648.99	17,420.00
SE	SEATTLE	WA	SF	MENLO PARK	CA	1544	684	1,056.10	11,660.00
SE	SEATTLE	WA	PO	PORTLAND	OR	56	147	8.23	1,167.50
SE	SEATTLE	WA	PO	CORVALLIS	OR	56	147	8.23	1,167.50
SE	SEATTLE	WA	PO	EUGENE	OR	56	147	8.23	1,167.50
SF	SAN FRANCISCO	CA	LA	PASADENA	CA	448	350	156.80	6,650.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1544	36	55.58	1,940.00
SF	SAN FRANCISCO	CA	BD	BOULDER	CO	56	932	52.19	3,130.00
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	336	2,432	817.15	33,200.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	56	350	19.60	1,675.00
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	56	2,432	136.19	6,880.00
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	1544	1,852	2,859.49	29,180.00
SL	SALT LAKE CITY	UT	SF	MENLO PARK	CA	1544	598	923.31	10,370.00
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	1544	351	541.94	6,665.00
SL	SALT LAKE CITY	UT	CH	CHICAGO	IL	1544	1,256	1,939.26	20,240.00
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	1544	1,265	1,953.16	20,375.00
WI	WALLOPS ISLAND	VA	MD	MADISON	WI	224	809	181.22	8,876.50
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	224	1,265	283.36	12,752.50
sum						146824	133,734	85,529.58	1,417,122.00

EXHIBIT 13-2. Current (1989) IRN Circuit Costs

(Continued)

The total Current IRN monthly cost of about 86,000 MMs, was estimated to be about 1.4 million dollars.

13.3.2 1991 IRN Circuit Costs

The circuit cost per month for each city-pair link and for the total 1991 IRN are shown in Exhibit 13-3. The city-pairs are listed in the same order as they were listed in earlier exhibits listing the 1991 IRN links and as they were listed in Exhibit 13-2 which showed 1989 IRN costs. City-pair circuit cost changes, from 1989 to 1991, occurred only where the increases in the NSFNET backbone link speeds caused IRN city-pair link speed increases, and therefore link cost increases.

The total 1991 IRN monthly cost of about 661,000 MMs, was estimated to be about 2.4 million dollars. That is, compared with 1989, almost eight times as much traffic is expected to be moved in 1991 at less than twice the 1989 cost.

13.3.3 1996 IRN Circuit Costs

The circuit cost per month for each city-pair link and for the total 1996 IRN are shown in Exhibit 13-4. The city-pairs are listed in the same order as they were listed in earlier exhibits listing the 1996 IRN links.

The total 1996 IRN monthly cost of about eight and one-half million MMs was estimated to be about 6 million dollars. That is, compared with 1991, about thirteen times as much traffic is expected to be moved in 1996 for only about two and one-half times the 1991 cost.

13.3.4 2000 IRN Circuit Costs

The circuit cost per month for each city-pair link and for the total 2000 IRN are shown in Exhibit 13-5. The city-pairs are listed in the same order as they were listed in earlier exhibits listing the 2000 IRN links and as they were listed in 13-4 which showed 1996 costs.

The total 2000 IRN monthly cost of about 35 million MMs was estimated

1991 PROJECTED COST

ID	CITY - A	ID	ID	CITY - B	ST	CAPACITY (KB)	MILES	MM	COST
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56	860	48.16	2,950.00
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1544	860	1,327.84	14,300.00
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2,477.50
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2,477.50
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2,477.50
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56	860	48.16	2,950.00
AB	LOS ALAMOS	NM	AU	AUSTIN	TX	56	615	34.44	2,337.50
AB	LOS ALAMOS	NM	KS	LAWRENCE	KS	56	671	37.58	2,477.50
AB	LOS ALAMOS	NM	BD	BOULDER	CO	56	346	19.38	1,665.00
AU	AUSTIN	TX	DL	RICHARDSON	TX	1544	180	277.92	4,100.00
BD	BOULDER	CO	MD	MADISON	WI	224	844	189.06	9,174.00
BD	BOULDER	CO	DC	WASHINGTON	DC	224	1,501	336.22	14,758.50
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	56	351	19.66	1,677.50
BD	BOULDER	CO	DC	WASHINGTON	DC	224	1,501	336.22	14,758.50
BD	BOULDER	CO	BO	WOODS HOLE	MA	224	1,772	396.93	17,062.00
BD	BOULDER	CO	MI	MIAMI	FL	224	1,742	390.21	16,807.00
BD	BOULDER	CO	TU	TUCSON	AZ	56	619	34.66	2,347.50
BD	BOULDER	CO	DT	ANN ARBOR	MI	224	1,162	260.29	11,877.00
BD	BOULDER	CO	PO	CORVALIS	OR	1544	957	1,477.61	15,755.00
BD	BOULDER	CO	PO	CORVALLIS	OR	224	957	214.37	10,134.50
BD	DENVER	CO	LA	LOS ANGELES	CA	1544	822	1,269.17	13,730.00
BO	BOSTON	MA	NY	NEW YORK	NY	1544	188	290.27	4,220.00
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	1544	229	353.58	4,835.00
CH	CHICAGO	IL	SE	SEATTLE	WA	44M	1,733	77,527.49	158,970.00
CH	CHICAGO	IL	DT	LANSING	MI	1544	237	365.93	4,955.00
CH	CHICAGO	IL	DT	LITCHFIELD	MI	1544	237	365.93	4,955.00
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	56	1,852	103.71	5,430.00
CH	CHICAGO	IL	MD	MADISON	WI	1544	121	186.82	3,215.00
CH	CHICAGO	IL	BD	DENVER	CO	44M	927	41,470.27	86,430.00
CH	CHICAGO	IL	TL	TALLAHASSEE	FL	56	806	45.14	2,815.00
CH	CHICAGO	IL	IL	URBANA	IL	1544	125	193.00	3,275.00
CH	CHICAGO	IL	LI	LINCOLN	NE	44M	475	21,249.60	45,750.00
CH	CHICAGO	IL	BO	CAMBRIDGE	MA	1544	848	1,309.31	14,120.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	1544	205	316.52	4,475.00
DC	WASHINGTON	DC	AB	ALBUQUERQUE	NM	56	1,646	92.18	4,915.00
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2,401	134.46	6,802.50
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2,401	134.46	6,802.50
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2,401	134.46	6,802.50
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	56	601	33.66	2,302.50
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1,217	68.15	3,842.50
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56	106	5.94	1,065.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1544	106	163.66	2,990.00
DC	WASHINGTON	DC	CL	CLEVELAND	OH	112	304	34.05	2,568.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	168	750	127.68	6,540.00
DC	WASHINGTON	DC	LA	LOS ANGELES	CA	56	2,292	128.35	6,530.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	224	1,572	352.13	15,362.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	56	1,572	88.03	4,730.00
DC	WASHINGTON	DC	LA	BARSTOW	CA	224	2,292	513.41	21,482.00
DC	WASHINGTON	DC	LA	BARSTOW	CA	56	2,292	128.35	6,530.00

EXHIBIT 13-3. 1991 IRN Circuit Costs

DC	WASHINGTON	DC	BO	CAMBRIDGE	MA	56	394	22.06	1,785.00
DC	WASHINGTON	DC	PR	PRINCETON	NJ	44M	165	7,381.44	17,850.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	1544	2,432	3,755.01	37,880.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	112	2,432	272.38	12,144.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	224	2,432	544.77	22,672.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	44M	1,217	54,443.71	112,530.00
DC	WASHINGTON	DC	LA	PASADENA	CA	448	2,292	1,026.82	35,780.00
DC	WASHINGTON	DC	LA	PASADENA	CA	280	2,292	641.76	26,466.00
DC	WASHINGTON	DC	LA	LOMPOC	CA	224	2,292	513.41	21,482.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	1544	601	927.94	10,415.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	672	760	510.72	12,800.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	512	601	307.71	10,415.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1,217	68.15	3,842.50
DC	WASHINGTON	DC	HU	HOUSTON	TX	2048	1,217	2,492.42	29,482.50
DC	WASHINGTON	DC	PH	WILMINGTON	DE	56	124	6.94	1,110.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	56	157	8.79	1,192.50
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1,217	68.15	3,842.50
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	280	760	212.80	10,380.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	56	205	11.48	1,312.50
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56	106	5.94	1,065.00
DL	RICHARDSON	TX	TL	TALLAHASSEE	FL	1544	754	1,164.18	12,710.00
DT	ANN ARBOR	MI	CB	COLUMBUS	OH	1544	163	251.67	3,845.00
DT	ANN ARBOR	MI	PR	PRINCETON	NJ	44M	459	20,533.82	44,310.00
HN	HUNTSVILLE	AL	KN	CAPE KENNEDY	FL	2048	563	1,153.02	14,767.50
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	168	616	103.49	5,604.00
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	672	601	403.87	10,415.00
HN	HUNTSVILLE	AL	KN	ORLANDO	FL	56	563	31.53	2,207.50
HN	HUNTSVILLE	AL	MI	MIAMI	FL	56	722	40.43	2,605.00
HU	BRYAN	TX	AU	AUSTIN	TX	1544	147	226.97	3,605.00
HU	HOUSTON	TX	DL	DALLAS	TX	56	224	12.54	1,360.00
HU	HOUSTON	TX	HN	HUNTSVILLE	AL	56	616	34.50	2,340.00
HU	HOUSTON	TX	WS	WHITE SANDS	NM	56	500	28.00	2,050.00
HU	HOUSTON	TX	AU	AUSTIN	TX	1544	147	226.97	3,605.00
HU	HOUSTON	TX	AU	AUSTIN	TX	56	147	8.23	1,167.50
HU	HOUSTON	TX	BD	BOULDER	CO	44M	899	40,217.66	83,910.00
HU	HOUSTON	TX	AU	AUSTIN	TX	56	147	8.23	1,167.50
HU	HOUSTON	TX	KN	CAPE KENNEDY	FL	1544	900	1,389.60	14,900.00
IL	URBANA	IL	CH	CHICAGO	IL	1544	125	193.00	3,275.00
IL	URBANA	IL	IN	BLOOMINGTON	IN	1544	113	174.47	3,095.00
IL	URBANA	IL	MD	MILWAUKEE	WI	56	211	11.82	1,327.50
IN	INDIANAPOLIS	IN	CB	COLUMBUS	OH	1544	168	259.39	3,920.00
IO	IOWA CITY	IA	IL	URBANA	IL	1544	202	311.89	4,430.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4,325.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4,325.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4,325.00
IT	ITHACA	NY	DC	WASHINGTON	DC	44M	291	13,018.18	29,190.00
IT	ITHACA	NY	PT	PITTSBURGH	PA	44M	267	11,944.51	27,030.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	56	1,446	80.98	4,415.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	1544	1,446	2,232.62	23,090.00
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	1544	671	1,036.02	11,465.00
LA	LOS ANGELES	CA	AB	LOS ALAMOS	NM	1544	564	1,025.22	11,360.00
LA	LOS ANGELES	CA	HN	HUNTSVILLE	AL	56	1,798	100.69	5,295.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56	113	6.33	1,082.50

EXHIBIT 13-3. 1991 IRN Circuit Costs

(Continued)

LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56	113	6.33	1,082.50
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	1544	350	540.40	6,650.00
LA	LOS ANGELES	CA	HU	HOUSTON	TX	56	1,376	77.06	4,240.00
LA	LOS ANGELES	CA	BD	BOULDER	CO	56	822	46.03	2,855.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544	113	174.47	3,095.00
LA	LOS ANGELESO	CA	SF	SAN FRANCISCO	CA	1544	350	540.40	6,650.00
LA	PASADENA	CA	TU	TUCSON	AZ	56	444	24.86	1,910.00
LA	PASADENA	CA	DC	BALTIMORE	MD	56	2,292	128.35	6,530.00
LA	PASADENA	CA	HU	HOUSTON ISLAND	TX	168	1,376	231.17	10,544.00
LA	PASADENA	CA	DC	WASHINGTON	DC	672	2,292	1,540.22	35,780.00
LI	LINCOLN	NE	IL	URBANA	IL	56	447	25.03	1,917.50
LI	LINCOLN	NE	KS	LAWRENCE	KS	56	199	11.14	1,297.50
LI	LINCOLN	NE	IO	IOWA CITY	IA	56	274	15.34	1,485.00
LI	LINCOLN	NE	BD	BOULDER	CO	44M	454	20,310.14	43,860.00
LL	LIVERMORE	CA	SF	OAKLAND	CA	56	36	2.02	890.00
LL	LIVERMORE	CA	PR	PRINCETON	NJ	1544	2,507	3,870.81	39,005.00
LL	LIVERMORE	CA	LA	LOS ANGELES	CA	56	321	17.98	1,602.50
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	1544	860	1,327.84	14,300.00
MP	MINNEAPOLIS	MN	IO	IOWA CITY	IA	1544	243	375.19	5,045.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1544	232	358.21	4,880.00
NF	NORFOLK	VA	TL	TALLAHASSEE	FL	1544	635	980.44	10,925.00
NY	LONG ISLAND	NY	BO	CAMBRIDGE	MA	1544	188	290.27	4,220.00
NY	NEW YORK	NY	IT	ROME	NY	1544	195	301.08	4,325.00
OR	OAK RIDGE	TN	CH	CHICAGO	IL	1544	441	680.90	8,015.00
OR	OAK RIDGE	TN	TL	TALLAHASSEE	FL	1544	385	594.44	7,175.00
PR	PRINCETON	NJ	TU	TUCSON	AZ	1544	2,080	3,211.52	32,600.00
PR	PRINCETON	NJ	NF	NORFOLK VA	DC	1544	269	415.34	5,435.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2,000.00
PR	PRINCETON	NJ	CH	CHICAGO	IL	1544	686	1,059.18	11,690.00
PR	PRINCETON	NJ	NY	LONG ISLAND	NY	1544	40	61.76	2,000.00
PR	PRINCETON	NJ	BD	BOLDER	CO	1544	1,610	2,485.84	25,550.00
PR	PRINCETON	NJ	SC	STATE COLLEGE	PA	1544	175	270.20	4,025.00
PR	PRINCETON	NJ	PH	PHILADELPHIA	PA	1544	42	64.85	2,030.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544	229	353.58	4,835.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544	229	353.58	4,835.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2,000.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2,000.00
PR	PRINCETON	NJ	BO	NEW HAVEN	CT	1544	229	353.58	4,835.00
PR	PRINCETON	NJ	BO	AMHERST	MA	1544	229	353.58	4,835.00
PT	PITTSBURGH	PA	SC	STATE COLLEGE	PA	1544	115	177.56	3,125.00
PT	PITTSBURGH	PA	PR	PRINCETON	NJ	44M	285	12,749.76	28,650.00
PT	PITTSBURGH	PA	IL	URBANA	IL	44M	434	19,415.42	42,060.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1544	114	176.02	3,110.00
PT	PITTSBURGH	PA	PH	PHILADELPHIA	PA	1544	258	398.35	5,270.00
PT	PITTSBURGH	PA	DC	WASHINGTON	DC	1544	190	293.36	4,250.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3,095.00
SD	SAN DIEGO	CA	LA	RIVERSIDE	CA	56	113	6.33	1,082.50
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3,095.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3,095.00
SD	SAN DIEGO	CA	HU	HOUSTON	TX	44M	1,305	58,380.48	120,450.00
SD	SAN DIEGO	CA	SF	MENLO PARK	CA	44M	463	20,712.77	44,670.00
SD	SAN DIEGO	CA	LA	SANTA BARBARA	CA	56	113	6.33	1,082.50
SD	SAN DIEGO	CA	SE	SEATTLE	WA	56	1,068	59.81	3,470.00

EXHIBIT 13-3. 1991 IRN Circuit Costs

(Continued)

SD	SAN DIEGO	CA	SF	OAKLAND	CA	56	463	25.93	1,957.50
SD	SAN DIEGO	CA	LA	IRVINE	CA	56	113	6.33	1,082.50
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56	624	34.94	2,360.00
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56	624	34.94	2,360.00
SE	SEATTLE	WA	SD	SAN DIEGO	CA	44M	1,068	47,778.05	99,120.00
SE	SEATTLE	WA	SF	MENLO PARK	CA	44M	684	30,599.42	64,560.00
SE	SEATTLE	WA	PO	PORTLAND	OR	56	147	8.23	1,167.50
SE	SEATTLE	WA	PO	CORVALLIS	OR	56	147	8.23	1,167.50
SE	SEATTLE	WA	PO	EUGENE	OR	56	147	8.23	1,167.50
SF	SAN FRANCISCO	CA	LA	PASADENA	CA	448	350	156.80	6,650.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1544	36	55.58	1,940.00
SF	SAN FRANCISCO	CA	BD	BOULDER	CO	56	932	52.19	3,130.00
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	336	2,432	817.15	33,200.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	56	350	19.60	1,675.00
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	56	2,432	136.19	6,880.00
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	1544	1,852	2,859.49	29,180.00
SL	SALT LAKE CITY	UT	SF	MENLO PARK	CA	44M	598	26,752.13	56,820.00
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	44M	351	15,702.34	34,590.00
SL	SALT LAKE CITY	UT	CH	CHICAGO	IL	44M	1,256	56,188.42	116,040.00
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	1544	1,265	1,953.16	20,375.00
WI	WALLOPS ISLAND	VA	MD	MADISON	WI	224	809	181.22	8,876.50
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	224	1,265	283.36	12,752.50
sum							133,385	661,302.57	2,446,474.50

EXHIBIT 13-3. 1991 IRN Circuit Costs

(Continued)

1996 PROJECTED COST

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY	MILES	MM	COST
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	565M	754	426,010.00	343,800.00
AT	ATLANTA	GA	CO	COLUMBIA	SC	90M	193	17,408.60	34,766.00
AT	ATLANTA	GA	TL	TALLAHASEE	FL	90M	233	21,016.60	41,246.00
AU	AUSTIN	TX	DL	DALLAS	TX	90M	180	16,236.00	32,660.00
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	90M	346	31,209.20	59,552.00
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	1G	932	1,053,160.00	508,280.00
BI	BILLINGS	MT	CY	CHEYENNE	WY	90M	368	33,193.60	63,116.00
BI	BILLINGS	MT	FR	FARGO	ND	90M	565	50,963.00	95,030.00
BO	BOSTON	MA	NY	NEW YORK	NY	1G	297	335,610.00	165,380.00
CB	COLUMBUS	OH	DT	DETROIT	MI	90M	163	14,702.60	29,906.00
CH	CHICAGO	IL	IL	URBANA	IL	1G	125	141,250.00	72,500.00
CH	CHICAGO	IL	OR	OAK RIDGE	TN	565M	441	249,165.00	202,950.00
CH	CHICAGO	IL	LI	LINCOLN	NE	1G	475	536,750.00	261,500.00
CH	CHICAGO	IL	DT	DETROIT	MI	90M	237	21,377.40	41,894.00
CH	CHICAGO	IL	ST	ST LOUIS	MO	90M	260	23,452.00	45,620.00
CL	CLEVELAND	OH	CB	COLUMBUS	OH	90M	126	11,365.20	23,912.00
CO	COLUMBIA	SC	RL	RALEIGH	NC	90M	183	16,506.60	33,146.00
CY	CHEYENNE	WY	BD	BOULDER	CO	90M	80	7,216.00	16,460.00
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	1G	190	214,700.00	107,600.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	565M	157	88,705.00	75,150.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	90M	106	9,561.20	20,672.00
FR	FARGO	ND	MP	MINNEAPOLIS	MN	90M	214	19,302.80	38,168.00
HE	HELENA	MT	BI	BILLINGS	MT	90M	178	16,055.60	32,336.00
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	90M	162	14,612.40	29,744.00
HU	HOUSTON	TX	OR	OAK RIDGE	TN	565M	777	439,005.00	354,150.00
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	90M	320	28,864.00	55,340.00
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	90M	164	14,792.80	30,068.00
IT	ITHACA	NY	NY	NEW YORK	NY	1G	195	220,350.00	110,300.00
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	90M	176	15,875.20	32,012.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1G	113	127,690.00	66,020.00
LI	LINCOLN	NE	HU	HOUSTON	TX	1G	759	857,670.00	414,860.00
LI	LINCOLN	NE	BD	BOULDER	CO	1G	454	513,020.00	250,160.00
LI	LINCOLN	NE	IO	IOWA CITY	IA	90M	274	24,714.80	47,888.00
MD	MADISON	WI	CH	CHICAGO	IL	565M	121	68,365.00	58,950.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	565M	232	131,080.00	108,900.00
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	90M	348	31,389.60	59,876.00
NY	NEW YORK	NY	DC	WASHINGTON	DC	1G	236	266,680.00	132,440.00
NY	NEW YORK	NY	PT	PITTSBURGH	PA	1G	207	233,910.00	116,780.00
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	565M	385	217,525.00	177,750.00
PO	PORTLAND	OR	SE	SEATTLE	WA	90M	147	13,259.40	27,314.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	90M	114	10,282.80	21,968.00
PT	PITTSBURGH	PA	CH	CHICAGO	IL	1G	409	462,170.00	225,860.00
RL	RALEIGH	NC	NF	NORFOLK	VA	90M	149	13,439.80	27,638.00
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	90M	115	10,373.00	22,130.00
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	565M	623	351,995.00	284,850.00
SE	SEATTLE	WA	HE	HELENA	MT	90M	489*	44,107.80	82,718.00
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	565M	684	386,460.00	312,300.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1G	36	40,680.00	24,440.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	1G	350	395,500.00	194,000.00
SL	SALT LAKE	UT	BD	BOULDER	CO	90M	351	31,660.20	60,362.00
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	90M	269	24,263.80	47,078.00
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	565M	264	149,160.00	123,300.00
TU	TUCSON	AZ	WS	WHITE SANDS	NM	90M	440	39,688.00	74,780.00
sum							16,166	8,533,500.00	5,919,620.00

EXHIBIT 13-4. 1996 IRN Circuit Costs

YEAR 2000 PROJECTED COST

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY	MILES	MM	COST
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	1G	754	852,020.00	412,160.00
AT	ATLANTA	GA	CO	COLUMBIA	SC	565M	193	109,045.00	91,350.00
AT	ATLANTA	GA	TL	TALLAHASEE	FL	565M	233	131,645.00	109,350.00
AU	AUSTIN	TX	DL	DALLAS	TX	565M	180	101,700.00	85,500.00
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	565M	346	195,490.00	160,200.00
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	5G	932	5,055,168.00	2,021,120.00
BI	BILLINGS	MT	CY	CHEYENNE	WY	565M	368	207,920.00	170,100.00
BI	BILLINGS	MT	FR	FARGO	ND	565M	565	319,225.00	258,750.00
BO	BOSTON	MA	NY	NEW YORK	NY	5G	297	1,610,928.00	649,520.00
CB	COLUMBUS	OH	DT	DETROIT	MI	565M	163	92,095.00	77,850.00
CH	CHICAGO	IL	IL	URBANA	IL	5G	125	678,000.00	278,000.00
CH	CHICAGO	IL	OR	OAK RIDGE	TN	1G	441	498,330.00	243,140.00
CH	CHICAGO	IL	LI	LINCOLN	NE	5G	475	2,576,400.00	1,034,000.00
CH	CHICAGO	IL	DT	DETROIT	MI	565M	237	133,905.00	111,150.00
CH	CHICAGO	IL	ST	ST LOUIS	MO	565M	260	146,900.00	121,500.00
CL	CLEVELAND	OH	CB	COLUMBUS	OH	565M	126	71,190.00	61,200.00
CO	COLUMBIA	SC	RL	RALEIGH	NC	565M	183	103,395.00	86,850.00
CY	CHEYENNE	WY	BD	BOULDER	CO	565M	80	45,200.00	40,500.00
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	5G	190	1,030,560.00	418,400.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	1G	157	177,410.00	89,780.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	565M	106	59,890.00	52,200.00
FR	FARGO	ND	MP	MINNEAPOLIS	MN	565M	214	120,910.00	100,800.00
HE	HELENA	MT	BI	BILLINGS	MT	565M	178	100,570.00	84,600.00
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	565M	162	91,530.00	77,400.00
HU	HOUSTON	TX	OR	OAK RIDGE	TN	1G	777	878,010.00	424,580.00
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	565M	320	180,800.00	148,500.00
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	565M	164	92,660.00	78,300.00
IT	ITHACA	NY	NY	NEW YORK	NY	5G	195	1,057,680.00	429,200.00
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	565M	176	99,440.00	83,700.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	5G	113	612,912.00	252,080.00
LI	LINCOLN	NE	HU	HOUSTON	TX	5G	759	4,116,816.00	1,647,440.00
LI	LINCOLN	NE	BD	BOULDER	CO	5G	454	2,462,496.00	988,640.00
LI	LINCOLN	NE	IO	IOWA CITY	IA	565M	274	154,810.00	127,800.00
MD	MADISON	WI	CH	CHICAGO	IL	1G	121	136,730.00	70,340.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1G	232	262,160.00	130,280.00
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	565M	348	196,620.00	161,100.00
NY	NEW YORK	NY	DC	WASHINGTON	DC	5G	236	1,280,064.00	517,760.00
NY	NEW YORK	NY	PT	PITTSBURGH	PA	5G	207	1,122,768.00	455,120.00
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	1G	385	435,050.00	212,900.00
PO	PORTLAND	OR	SE	SEATTLE	WA	565M	147	83,055.00	70,650.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	565M	114	64,410.00	55,800.00
PT	PITTSBURGH	PA	CH	CHICAGO	IL	5G	409	2,218,416.00	891,440.00
RL	RALEIGH	NC	NF	NORFOLK	VA	565M	149	84,185.00	71,550.00
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	565M	115	64,975.00	56,250.00
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	1G	623	703,990.00	341,420.00
SE	SEATTLE	WA	HE	HELENA	MT	565M	489	276,285.00	224,550.00
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	1G	684	772,920.00	374,360.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	5G	36	195,264.00	85,760.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	5G	350	1,898,400.00	764,000.00
SL	SALT LAKE	UT	BD	BOULDER	CO	565M	351	198,315.00	162,450.00
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	565M	269	151,985.00	125,550.00
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	1G	264	298,320.00	147,560.00
TU	TUCSON	AZ	WS	WHITE SANDS	NM	565M	440	248,600.00	202,500.00
sum							16,166	34,857,562.00	16,137,000.00

EXHIBIT 13-5. 2000 IRN Circuit Costs

to be about 16 million dollars. That is, compared with 1996, about four times as much traffic is expected to be moved in 2000 for about two and one-half times the 1996 cost.

13.3.5 2010 IRN Costs

The circuit cost per month for each city-pair link and for the total 2010 IRN are inidcated in Exhibit 13-6. The city-pairs are listed in the same order as they were listed in earlier exhibits listing the 2010 IRN links and as they were listed in 13-5 which showed 2000 costs.

The total 2010 IRN monthly cost of about 162 million MMs was estimated to be about 29 million dollars. That is, compared with 2000, about four and one-half times as much traffic is expected to be moved in 2010 for less than two times the 2000 cost.

13.3.6 Summary Of Circuit Costs

The monthly circuit costs and the cost per MM for each benchmark year, as discussed above, are summarized in Exhibit 13-7.

In addition to providing a summary of the circuit costs discussed above, Exhibit 13-7 also presents a summary of the monthly circuit costs for the benchmark years 1996, 2000 and 2010, assuming that the IRN does not become integrated. These costs were developed so that the cost implications of not integrating the IRN could be determined. The detailed cost tables for the non-integrated IRN for 1996, 2000 and 2010 are presented in Appendix B. These cost tables were developed by first applying growth rates to the individual network links in the 1991 IRN. That is, the same network links that were costed for 1989 and 1991 were costed for 1996, 2000 and 2010. For each benckmark year, a link's capacity was increased to a capacity one step above its capacity for the previous benchmark year, using the following step increases in capacity: 56 Kbps, 1.544 Mbps, 45 Mbps, 565 Mbps, 1 Gbps, and 5 Gbps. These growth projections resulted in non-integrated IRNs for 1996, 2000 and 2010 with total capacities about equal to the capacities of the integrated IRNs for 1996, 2000, and 2010.

YEAR 2010 PROJECTED COST

ID	CITY -A	ST	ID	CITY - B	ST	CAPACITY	MILES	MM	COST
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	5G	754	4,089,696.00	1,636,640.00
AT	ATLANTA	GA	CO	COLUMBIA	SC	1G	193	218,090.00	109,220.00
AT	ATLANTA	GA	TL	TALLAHASEE	FL	1G	233	263,290.00	130,820.00
AU	AUSTIN	TX	DL	DALLAS	TX	1G	180	203,400.00	102,200.00
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	1G	346	390,980.00	191,840.00
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	25G	932	25,275,840.00	3,029,680.00
BI	BILLINGS	MT	CY	CHEYENNE	WY	1G	368	415,840.00	203,720.00
BI	BILLINGS	MT	FR	FARGO	ND	1G	565	638,450.00	310,100.00
BO	BOSTON	MA	NY	NEW YORK	NY	25G	297	8,054,640.00	972,280.00
CB	COLUMBUS	OH	DT	DETROIT	MI	1G	163	184,190.00	93,020.00
CH	CHICAGO	IL	IL	URBANA	IL	25G	125	3,390,000.00	415,000.00
CH	CHICAGO	IL	OR	OAK RIDGE	TN	5G	441	2,391,984.00	960,560.00
CH	CHICAGO	IL	LI	LINCOLN	NE	25G	475	12,882,000.00	1,549,000.00
CH	CHICAGO	IL	DT	DETROIT	MI	1G	237	267,810.00	132,980.00
CH	CHICAGO	IL	ST	ST LOUIS	MO	1G	260	293,800.00	145,400.00
CL	CLEVELAND	OH	CB	COLUMBUS	OH	1G	126	142,380.00	73,040.00
CO	COLUMBIA	SC	RL	RALEIGH	NC	1G	183	206,790.00	103,820.00
CY	CHEYENNE	WY	BD	BOULDER	CO	1G	80	90,400.00	48,200.00
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	25G	190	5,152,800.00	625,600.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	5G	157	851,568.00	347,120.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1G	106	119,780.00	62,240.00
FR	FARGO	ND	MP	MINNEAPOLIS	MN	1G	214	241,820.00	120,560.00
HE	HELENA	MT	BI	BILLINGS	MT	1G	178	201,140.00	101,120.00
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	1G	162	183,060.00	92,480.00
HU	HOUSTON	TX	OR	OAK RIDGE	TN	5G	777	4,214,448.00	1,686,320.00
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	1G	320	361,600.00	177,800.00
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	1G	164	185,320.00	93,560.00
IT	ITHACA	NY	NY	NEW YORK	NY	25G	195	5,288,400.00	641,800.00
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	1G	176	198,880.00	100,040.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	25G	113	3,064,560.00	376,120.00
LI	LINCOLN	NE	HU	HOUSTON	TX	25G	759	20,584,080.00	2,469,160.00
LI	LINCOLN	NE	BD	BOULDER	CO	25G	454	12,312,480.00	1,480,960.00
LI	LINCOLN	NE	IO	IOWA CITY	IA	1G	274	309,620.00	152,960.00
MD	MADISON	WI	CH	CHICAGO	IL	5G	121	656,304.00	269,360.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	5G	232	1,258,368.00	509,120.00
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	1G	348	393,240.00	192,920.00
NY	NEW YORK	NY	DC	WASHINGTON	DC	25G	236	6,400,320.00	774,640.00
NY	NEW YORK	NY	PT	PITTSBURGH	PA	25G	207	5,613,840.00	680,680.00
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	5G	385	2,088,240.00	839,600.00
PO	PORTLAND	OR	SE	SEATTLE	WA	1G	147	166,110.00	84,380.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1G	114	128,820.00	66,560.00
PT	PITTSBURGH	PA	CH	CHICAGO	IL	25G	409	11,092,080.00	1,335,160.00
RL	RALEIGH	NC	NF	NORFOLK	VA	1G	149	168,370.00	85,460.00
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	1G	115	129,950.00	67,100.00
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	5G	623	3,379,152.00	1,353,680.00
SE	SEATTLE	WA	HE	HELENA	MT	1G	489	552,570.00	269,060.00
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	5G	684	3,710,016.00	1,485,440.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	25G	36	976,320.00	126,640.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	25G	350	9,492,000.00	1,144,000.00
SL	SALT LAKE	UT	BD	BOULDER	CO	1G	351	396,630.00	194,540.00
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	1G	269	303,970.00	150,260.00
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	5G	264	1,431,936.00	578,240.00
TU	TUCSON	AZ	WS	WHITE SANDS	NM	1G	440	497,200.00	242,600.00
sum							16,166	161,504,572.00	29,184,800.00

EXHIBIT 13-6. 2010 IRN Circuit Costs

YEAR	COST/MONTH	MMs	COST/MONTH/MM
Non-Integrated			
1989	$ 1,417,122.00	85,529	$ 16.57
1991	$ 2,446,474.00	661,302	$ 3.70
Integrated (I) vs Non-Integrated (NI)			
1996 – I	$ 5,919,620.00	8,533,500	$ 0.69
– NI	$ 10,604,035.00	9,094,900	$ 1.17
2000 – I	$ 16,137,000.00	34,857,562	$ 0.46
– NI	$ 20,207,500.00	37,104,024	$ 0.81
2010 – I	$ 29,184,800.00	161,504,572	$ 0.18
– NI	$ 88,522,460.00	164,184,932	$ 0.54

EXHIBIT 13-7. Summary of IRN Circuit Cost Projections

Assuming a non-integrated IRN is 1989 and 1991 and an integrated IRN in 1996 and beyond (i.e, the expected scenario), the IRN monthly circuit cost increases from 1989 to 2010 by about a factor of 20, while the capacity increases by about a factor of 1800. That is, the cost per month per MM in 2010 is only about 1/90 of the cost in 1989. This drop in cost is diagrammed in Exhibit 13-8. The cost per MM drops from about $16.50/MM in 1989 to about $ .18/MM in 2010.

The implications of not integrating the IRN in 1996 and beyond are diagrammed in Exhibits 13-9 and 13-10. Exhibit 13-9 shows that the non-integrated IRN cost per month per MM is about double the integrated IRN cost in 1996. It is triple the cost in 2010. These cost implications of not integrating the IRN are dramatized even more in Exhibit 13-10. The integrated IRN monthly circuit costs are about five million dollars less than the non-integrated cost in 1996. This difference increases to about sixty million dollars in 2010.

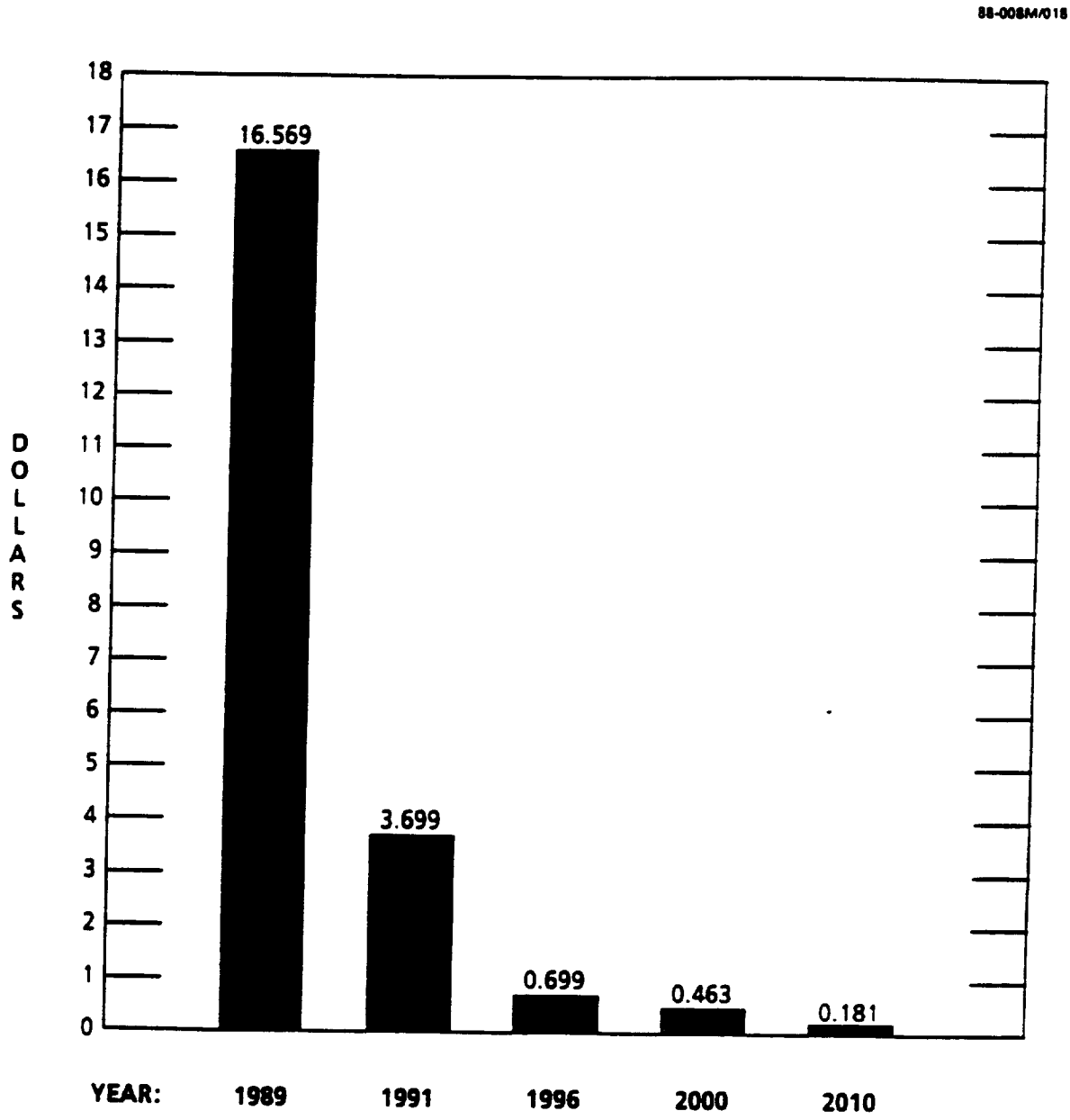

EXHIBIT 13-8. Projections Of Monthly Costs/MM

(Not integrated in 1989 & 1991; Integrated in 1996 and Beyond)

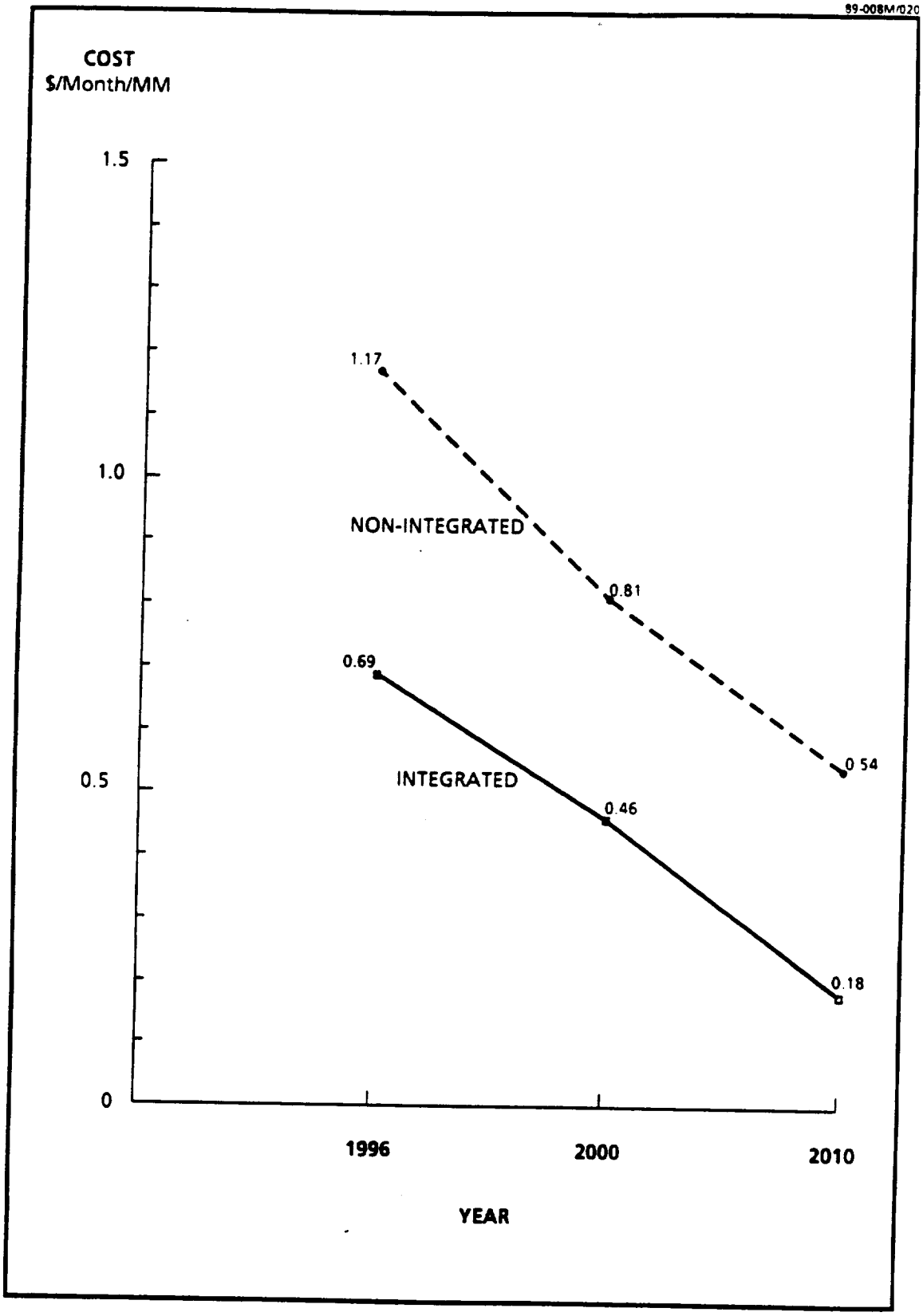

EXHIBIT 13-9. Comparison Of Monthly Cost/MM

Integrated Vs Non-Integrated IRN

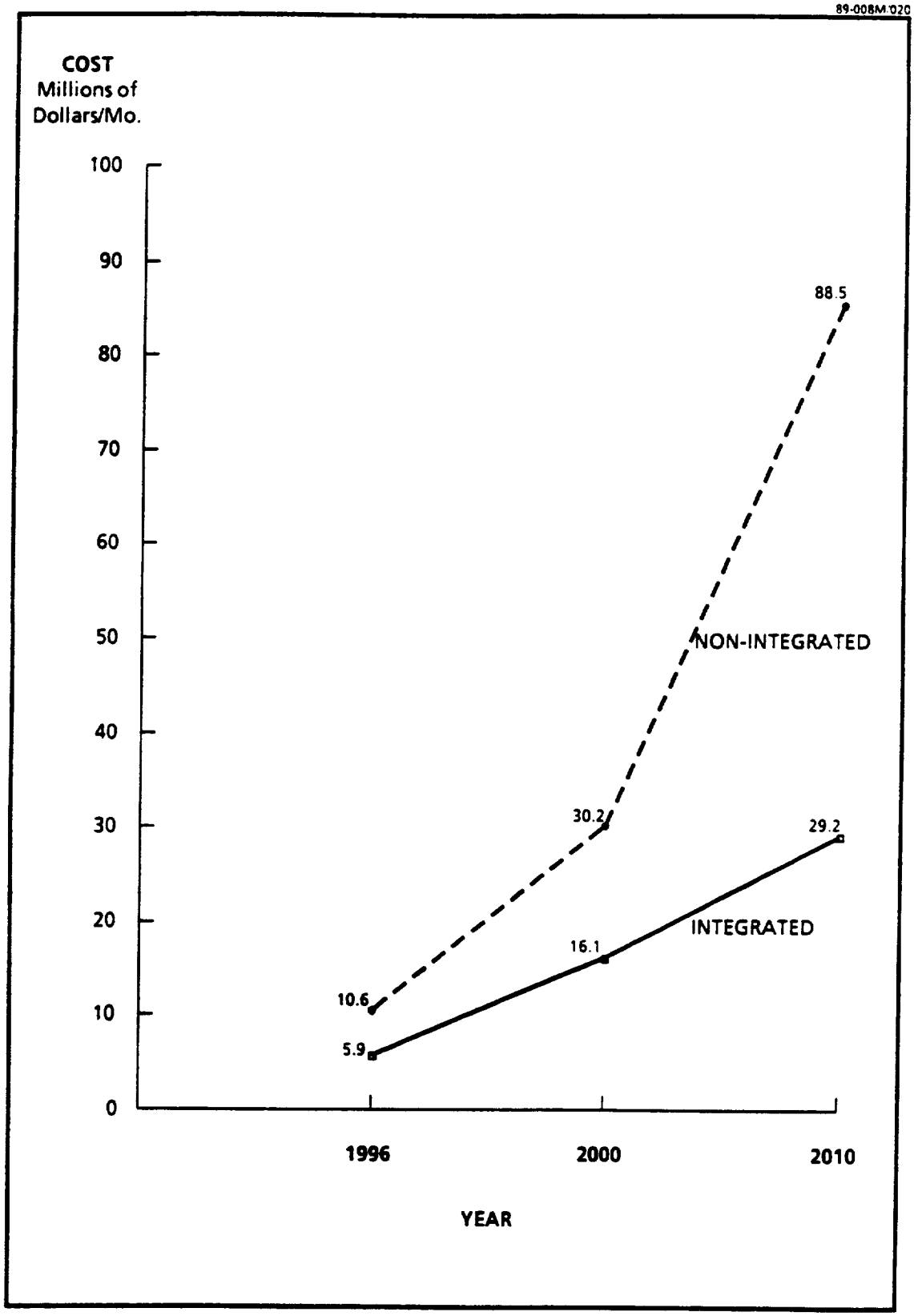

EXHIBIT 13-10. Comparison Of Monthly IRN Circuit Cost

Integrated Vs Non-Integrated IRN

APPENDIX A

LIST OF ABBREVIATIONS

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LIST OF ABBREVIATIONS

All abbreviations are defined when they first appear in the text. Those abbreviations that are used more than once in the text are listed and defined here.

ABBREVIATION	MEANING
ARC	Ames Research Center
ARPANET	Advanced Research Projects Agency Network
BARRNET	Bay Area (No. California) Regional Research Network
BBN	Bolt, Baranek and Newman
BITNET	Before Its Time Network
CAN	Campus Area Network
CICNET	Committee on Institutional Cooperation Network
CRA	Computer Research Applications
CRN	Computer Research Network
CSNET	Computer + Science Network
CTSS	Cray Time Sharing System
DARPA	Defense Advanced Research Projects Agency
DCA	Defense Communications Agency
DDN	Defense Data Network
DDN/PMO	DDN Program Management Office
DECNET	Digital Equipment Corporation (DEC) Communications Software Products
DOD	Department of Defense
DOE	Department of Energy
DRI	Defense Research Internet
EDUCOM	Non-profit consortium of institutions of higher education.
ER	Energy Research
ESNET	Energy Science Network
FCCSET	Federal Coordinating Council for Science, Engineering & Technology
FRICC	Federal Research Internet Coordinating Committee
GSFC	Goddard Space Flight Center

LIST OF ABBREVIATIONS
(CONTINUED)

ABBREVIATION	MEANING
HEP	High Energy Physics
HEPNET	High Energy Physics Network
IN	International Network
IPTO	Information Processing Techniques Office
IRN	Integrated Research Network
ISO	International Standards Organization
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
JVNC	John von Neumann Center
JVNCNET	John von Neumann National Supercomputer Center Network
KSP	Kennedy Space Center
LAN	Local Area Network
LEP3NET	LEP = an accelerator at Cern, 3 = experiment number
MAN	Metropolitan Area Network
MERIT	Membership consortium of Michigan universities
MFE	Magnetic Fusion Energy
MFENET	Magnetic Fusion Energy Network
MIDNET	Membership consoritum of midwestern universities
MM	Megabits Per Second Mile - The movement of one megabit per second one mile
MRNET	Minnesota Regional Network
MSFC	Marshall Space Flight Center
NASA	National Aeronautics & Space Administration
NASCOM	NASA's communication network (Goddard)
NASNET	Numerical Aerodynamics Simulation Network
NCAR	National Center for Atmospheric Research
NCSA	National Center for Supercomputer Applications
NCSANET	National Center for Supercomputing Applications Network
NIC	Network Information Center
NIH	National Institutes of Health
NIST	National Institute of Standards & Technology
NJE/NJI	Network Job Entry/Network Job Interface

LIST OF ABBREVIATIONS
(CONTINUED)

ABBREVIATION	MEANING
NMFECC	National Magnetic Fusion Energy Computer Center
NN	National Network
NNT	National Network Test Bed
NOAA	National Oceanic & Atmospheric Administration
NOC	Network Operations Center
NORTHWESTNET	Membership consortium in Northwest
NRC	National Research Council
NRI	National Research Initiatives
NRN	National Research Network
NRNRC	National Research Network Review Committee
NSECC	NASA Space & Earth Sciences Computing Center
NSF	National Science Foundation
NSFNET	National Science Foundation Network
NSI	NASA Science Internet
NSN	NASA Science Network
NSP	Non Standard Protocols
NTIA	National Telecommunications & Information Administration
NTTF	Networking & Telecommunications Task Force (EDUCOM)
NYSERNET	New York State Education and Research Network (Cornell)
OARNET	Ohio Academic Resources Network
OASC	Office of Advance Scientific Computing (NSF)
OPMODEL	DOE Operational Model Network
OSI	Open Systems Interconnect
OSSA	Office of Space Science & Applications
OSTP	Office of Science & Technology Policy (White House)
PSCAA	Pittsburgh Supercomputer Center Academic Affiliates
PSCN	Program Support Communications Network (MSFC)
PSCNET	Pittsburgh Supercomputing Center Network
PSN	Public Switched Network
RIB	Research Interagency Backbone
RIG	Research Interagency Gateways
RN	Regional Network

LIST OF ABBREVIATIONS
(CONTINUED)

ABBREVIATION	MEANING
SCD	Scientific Computing Disvision (NCAR)
SCS	Scientific Computing Staff (DOE/Office Of Energy Research)
SDCS	San Diego Supercomputer Center
SDSCNET	San Diego Supercomputer Center Network
SESQUINET	Texas Sesquicentennial Network
SN	State Network
SPAN	Space Physics Analysis Network
SURANET	Southeastern Universities Research Association Network
TCP/IP	Transmission Control Protocol/Internet Protocol
THENET	Texas Higher Education Network
USAN	University Satellite Network
WESTNET	Network of five western states: AZ, CO, NM, UT, and WY
WN	Worldwide Network

APPENDIX B

COST TABLES: NON-INTEGRATED IRN: 1996, 2000, 2010

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1996 PROJECTED COST - NETWORKS NOT INTEGRATED

ID	CITY - A	ID	ID	CITY - B	ST	CAPACITY	MILES	MM	COST
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1544	860	1,327.84	14,300.00
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	44M	860	38,472.96	80,400.00
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	1544	671	1,036.02	11,465.00
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	1544	671	1,036.02	11,465.00
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	1544	671	1,036.02	11,465.00
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1544	860	1,327.84	14,300.00
AB	LOS ALAMOS	NM	AU	AUSTIN	TX	1544	615	949.56	10,625.00
AB	LOS ALAMOS	NM	KS	LAWRENCE	KS	1544	671	1,036.02	11,465.00
AB	LOS ALAMOS	NM	BD	BOULDER	CO	1544	346	534.22	6,590.00
AU	AUSTIN	TX	DL	RICHARDSON	TX	44M	180	8,052.48	19,200.00
BD	BOULDER	CO	MD	MADISON	WI	1544	844	1,303.14	14,060.00
BD	BOULDER	CO	DC	WASHINGTON	DC	1544	1,501	2,317.54	23,915.00
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	1544	351	541.94	6,665.00
BD	BOULDER	CO	DC	WASHINGTON	DC	1544	1,501	2,317.54	23,915.00
BD	BOULDER	CO	BO	WOODS HOLE	MA	1544	1,772	2,735.97	27,980.00
BD	BOULDER	CO	MI	MIAMI	FL	1544	1,742	2,689.65	27,530.00
BD	BOULDER	CO	TU	TUCSON	AZ	1544	619	955.74	10,685.00
BD	BOULDER	CO	DT	ANN ARBOR	MI	1544	1,162	1,794.13	18,830.00
BD	BOULDER	CO	PO	CORVALIS	OR	44M	957	42,812.35	89,130.00
BD	BOULDER	CO	PO	CORVALLIS	OR	1544	957	1,477.61	15,755.00
BD	DENVER	CO	LA	LOS ANGELES	CA	44M	822	36,772.99	76,980.00
BO	BOSTON	MA	NY	NEW YORK	NY	44M	188	8,410.37	19,920.00
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	44M	229	10,244.54	23,610.00
CH	CHICAGO	IL	SE	SEATTLE	WA	565M	1,733	979,145.00	784,350.00
CH	CHICAGO	IL	DT	LANSING	MI	44M	237	10,602.43	24,330.00
CH	CHICAGO	IL	DT	LITCHFIELD	MI	44M	237	10,602.43	24,330.00
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	1544	1,852	2,859.49	29,180.00
CH	CHICAGO	IL	MD	MADISON	WI	44M	121	5,413.06	13,890.00
CH	CHICAGO	IL	BD	DENVER	CO	565M	927	523,755.00	421,650.00
CH	CHICAGO	IL	TL	TALLAHASSEE	FL	1544	806	1,244.46	13,490.00
CH	CHICAGO	IL	IL	URBANA	IL	44M	125	5,592.00	14,250.00
CH	CHICAGO	IL	LI	LINCOLN	NE	565M	475	268,375.00	218,250.00
CH	CHICAGO	IL	BO	CAMBRIDGE	MA	44M	848	37,936.13	79,320.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	44M	205	9,170.88	21,450.00
DC	WASHINGTON	DC	AB	ALBUQUERQUE	NM	1544	1,646	2,541.42	26,090.00
DC	WASHINGTON	DC	LL	LIVERMORE	CA	1544	2,401	3,707.14	37,415.00
DC	WASHINGTON	DC	LL	LIVERMORE	CA	1544	2,401	3,707.14	37,415.00
DC	WASHINGTON	DC	LL	LIVERMORE	CA	1544	2,401	3,707.14	37,415.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	1544	601	927.94	10,415.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	1544	1,217	1,879.05	19,655.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1544	106	163.66	2,990.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	44M	106	4,742.02	12,540.00
DC	WASHINGTON	DC	CL	CLEVELAND	OH	1544	304	469.38	5,960.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	1544	760	1,173.44	12,800.00
DC	WASHINGTON	DC	LA	LOS ANGELES	CA	1544	2,292	3,538.85	35,780.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	1544	1,572	2,427.17	24,980.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	1544	1,572	2,427.17	24,980.00
DC	WASHINGTON	DC	LA	BARSTOW	CA	1544	2,292	3,538.85	35,780.00
DC	WASHINGTON	DC	LA	BARSTOW	CA	1544	2,292	3,538.85	35,780.00

EXHIBIT B-1. 1996 IRN Circuit Costs

(Non-Integrated)

DC	WASHINGTON	DC	BO	CAMBRIDGE	MA	1544	394	608.34	7,310.00
DC	WASHINGTON	DC	PR	PRINCETON	NJ	565M	165	93,225.00	78,750.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	44M	2,432	108,797.95	221,880.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	1544	2,432	3,755.01	37,880.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	1544	2,432	3,755.01	37,880.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	565M	1,217	687,605.00	552,150.00
DC	WASHINGTON	DC	LA	PASADENA	CA	1544	2,292	3,538.85	35,780.00
DC	WASHINGTON	DC	LA	PASADENA	CA	1544	2,292	3,538.85	35,780.00
DC	WASHINGTON	DC	LA	LOMPOC	CA	1544	2,292	3,538.85	35,780.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	1544	601	927.94	10,415.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	1544	760	1,173.44	12,800.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	1544	601	927.94	10,415.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	1544	1,217	1,879.05	19,655.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	44M	1,217	54,443.71	112,530.00
DC	WASHINGTON	DC	PH	WILMINGTON	DE	1544	124	191.46	3,260.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	1544	157	242.41	3,755.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	1544	1,217	1,879.05	19,655.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	1544	760	1,173.44	12,800.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	1544	205	316.52	4,475.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1544	106	163.66	2,990.00
DL	RICHARDSON	TX	TL	TALLAHASSEE	FL	44M	754	33,730.94	70,860.00
DT	ANN ARBOR	MI	CB	COLUMBUS	OH	44M	163	7,291.97	17,670.00
DT	ANN ARBOR	MI	PR	PRINCETON	NJ	565M	459	259,335.00	211,050.00
HN	HUNTSVILLE	AL	KN	CAPE KENNEDY	FL	44M	563	25,186.37	53,670.00
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	1544	616	951.10	10,640.00
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	1544	601	927.94	10,415.00
HN	HUNTSVILLE	AL	KN	ORLANDO	FL	1544	563	869.27	9,845.00
HN	HUNTSVILLE	AL	MI	MIAMI	FL	1544	722	1,114.77	12,230.00
HU	BRYAN	TX	AU	AUSTIN	TX	44M	147	6,576.19	16,230.00
HU	HOUSTON	TX	DL	DALLAS	TX	1544	224	345.86	4,760.00
HU	HOUSTON	TX	HN	HUNTSVILLE	AL	1544	616	951.10	10,640.00
HU	HOUSTON	TX	WS	WHITE SANDS	NM	1544	500	772.00	8,900.00
HU	HOUSTON	TX	AU	AUSTIN	TX	44M	147	6,576.19	16,230.00
HU	HOUSTON	TX	AU	AUSTIN	TX	1544	147	226.97	3,605.00
HU	HOUSTON	TX	BD	BOULDER	CO	565M	899	507,935.00	409,050.00
HU	HOUSTON	TX	AU	AUSTIN	TX	1544	147	226.97	3,605.00
HU	HOUSTON	TX	KN	CAPE KENNEDY	FL	44M	900	40,262.40	84,000.00
IL	URBANA	IL	CH	CHICAGO	IL	1544	125	193.00	3,275.00
IL	URBANA	IL	IN	BLOOMINGTON	IN	44M	113	5,055.17	13,170.00
IL	URBANA	IL	MD	MILWAUKEE	WI	1544	211	325.78	4,565.00
IN	INDIANAPOLIS	IN	CB	COLUMBUS	OH	44M	168	7,515.65	18,120.00
IO	IOWA CITY	IA	IL	URBANA	IL	44M	202	9,036.67	21,180.00
IT	ITHACA	NY	NY	NEW YORK	NY	44M	195	8,723.52	20,550.00
IT	ITHACA	NY	NY	NEW YORK	NY	44M	195	8,723.52	20,550.00
IT	ITHACA	NY	NY	NEW YORK	NY	44M	195	8,723.52	20,550.00
IT	ITHACA	NY	DC	WASHINGTON	DC	565M	291	164,415.00	135,450.00
IT	ITHACA	NY	PT	PITTSBURGH	PA	565M	267	150,855.00	124,650.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	1544	1,446	2,232.62	23,090.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	44M	1,446	64,688.26	133,140.00
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	44M	671	30,017.86	63,390.00
LA	LOS ANGELES	CA	AB	LOS ALAMOS	NM	44M	.664	29,704.70	62,760.00
LA	LOS ANGELES	CA	HN	HUNTSVILLE	AL	1544	1,798	2,776.11	28,370.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544	113	174.47	3,095.00

EXHIBIT B-1. 1996 IRN Circuit Costs

(Non-Integrated - Continued)

LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544	113	174.47	3,095.00
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	44M	350	15,657.60	34,500.00
LA	LOS ANGELES	CA	HU	HOUSTON	TX	1544	1,376	2,124.54	22,040.00
LA	LOS ANGELES	CA	BD	BOULDER	CO	1544	822	1,269.17	13,730.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	44M	113	5,055.17	13,170.00
LA	LOS ANGELESO	CA	SF	SAN FRANCISCO	CA	44M	350	15,657.60	34,500.00
LA	PASADENA	CA	TU	TUCSON	AZ	1544	444	685.54	8,060.00
LA	PASADENA	CA	DC	BALTIMORE	MD	1544	2,292	3,538.85	35,780.00
LA	PASADENA	CA	HU	HOUSTON ISLAND	TX	1544	1,376	2,124.54	22,040.00
LA	PASADENA	CA	DC	WASHINGTON	DC	1544	2,292	3,538.85	35,780.00
LI	LINCOLN	NE	IL	URBANA	IL	1544	447	690.17	8,105.00
LI	LINCOLN	NE	KS	LAWRENCE	KS	1544	199	307.26	4,385.00
LI	LINCOLN	NE	IO	IOWA CITY	IA	1544	274	423.06	5,510.00
LI	LINCOLN	NE	BD	BOULDER	CO	565M	454	256,510.00	208,800.00
LL	LIVERMORE	CA	SF	OAKLAND	CA	1544	36	55.58	1,940.00
LL	LIVERMORE	CA	PR	PRINCETON	NJ	44M	2,507	112,153.15	228,630.00
LL	LIVERMORE	CA	LA	LOS ANGELES	CA	1544	321	495.62	6,215.00
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	44M	860	38,472.96	80,400.00
MP	MINNEAPOLIS	MN	IO	IOWA CITY	IA	44M	243	10,870.85	24,870.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	44M	232	10,378.75	23,880.00
NF	NORFOLK	VA	TL	TALLAHASSEE	FL	44M	635	28,407.36	60,150.00
NY	LONG ISLAND	NY	BO	CAMBRIDGE	MA	44M	188	8,410.37	19,920.00
NY	NEW YORK	NY	IT	ROME	NY	44M	195	8,723.52	20,550.00
OR	OAK RIDGE	TN	CH	CHICAGO	IL	44M	441	19,728.58	42,690.00
OR	OAK RIDGE	TN	TL	TALLAHASSEE	FL	44M	385	17,223.36	37,650.00
PR	PRINCETON	NJ	TU	TUCSON	AZ	44M	2,080	93,050.88	190,200.00
PR	PRINCETON	NJ	NF	NORFOLK VA	DC	44M	269	12,033.98	27,210.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	44M	40	1,789.44	6,600.00
PR	PRINCETON	NJ	CH	CHICAGO	IL	44M	686	30,688.90	64,740.00
PR	PRINCETON	NJ	NY	LONG ISLAND	NY	44M	40	1,789.44	6,600.00
PR	PRINCETON	NJ	BD	BOLDER	CO	44M	1,610	72,024.96	147,900.00
PR	PRINCETON	NJ	SC	STATE COLLEGE	PA	44M	175	7,828.80	18,750.00
PR	PRINCETON	NJ	PH	PHILADELPHIA	PA	44M	42	1,878.91	6,780.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	44M	229	10,244.54	23,610.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	44M	229	10,244.54	23,610.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	44M	40	1,789.44	6,600.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	44M	40	1,789.44	6,600.00
PR	PRINCETON	NJ	BO	NEW HAVEN	CT	44M	229	10,244.54	23,610.00
PR	PRINCETON	NJ	BO	AMHERST	MA	44M	229	10,244.54	23,610.00
PT	PITTSBURGH	PA	SC	STATE COLLEGE	PA	44M	115	5,144.64	13,350.00
PT	PITTSBURGH	PA	PR	PRINCETON	NJ	565M	285	161,025.00	132,750.00
PT	PITTSBURGH	PA	IL	URBANA	IL	565M	434	245,210.00	199,800.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	44M	114	5,099.90	13,260.00
PT	PITTSBURGH	PA	PH	PHILADELPHIA	PA	44M	258	11,541.89	26,220.00
PT	PITTSBURGH	PA	DC	WASHINGTON	DC	44M	190	8,499.84	20,100.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	44M	113	5,055.17	13,170.00
SD	SAN DIEGO	CA	LA	RIVERSIDE	CA	1544	113	174.47	3,095.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	44M	113	5,055.17	13,170.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	44M	113	5,055.17	13,170.00
SD	SAN DIEGO	CA	HU	HOUSTON	TX	565M	1,305	737,325.00	591,750.00
SD	SAN DIEGO	CA	SF	MENLO PARK	CA	565M	463	261,595.00	212,850.00
SD	SAN DIEGO	CA	LA	SANTA BARBARA	CA	1544	113	174.47	3,095.00
SD	SAN DIEGO	CA	SE	SEATTLE	WA	1544	1,068	1,648.99	17,420.00

EXHIBIT B-1. 1996 IRN Circuit Costs

(Non-Integrated - Continued)

SD	SAN DIEGO	CA	SF	OAKLAND	CA	1544	463	714.87	8,345.00
SD	SAN DIEGO	CA	LA	IRVINE	CA	1544	113	174.47	3,095.00
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	1544	624	963.46	10,760.00
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	1544	624	963.46	10,760.00
SE	SEATTLE	WA	SD	SAN DIEGO	CA	565M	1,068	603,420.00	485,100.00
SE	SEATTLE	WA	SF	MENLO PARK	CA	565M	684	386,460.00	312,300.00
SE	SEATTLE	WA	PO	PORTLAND	OR	1544	147	226.97	3,605.00
SE	SEATTLE	WA	PO	CORVALLIS	OR	1544	147	226.97	3,605.00
SE	SEATTLE	WA	PO	EUGENE	OR	1544	147	226.97	3,605.00
SF	SAN FRANCISCO	CA	LA	PASADENA	CA	1544	350	540.40	6,650.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	44M	36	1,610.50	6,240.00
SF	SAN FRANCISCO	CA	BD	BOULDER	CO	1544	932	1,439.01	15,380.00
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	1544	2,432	3,755.01	37,880.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	1544	350	540.40	6,650.00
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	1544	2,432	3,755.01	37,880.00
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	44M	1,852	82,851.07	169,680.00
SL	SALT LAKE CITY	UT	SF	MENLO PARK	CA	565M	598	337,870.00	273,600.00
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	565M	351	198,315.00	162,450.00
SL	SALT LAKE CITY	UT	CH	CHICAGO	IL	565M	1,256	709,640.00	569,700.00
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	44M	1,265	56,591.04	116,850.00
WI	WALLOPS ISLAND	VA	MD	MADISON	WI	1544	809	1,249.10	13,535.00
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	1544	1,265	1,953.16	20,375.00
sum							133,385	9,094,900.81	10,604,035.00

EXHIBIT B-1. 1996 IRN Circuit Costs

(Non-Integrated - Continued)

2000 PROJECTED COST - NETWORKS NOT INTEGRATED

ID	CITY - A	ID	ID	CITY - B	ST	CAPACITY	MILES	MM	COST
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	44M	860	38,473.0	80,400.00
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	565M	860	485,900.0	391,500.00
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	44M	671	30,017.9	63,390.00
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	44M	671	30,017.9	63,390.00
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	44M	671	30,017.9	63,390.00
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	44M	860	38,473.0	80,400.00
AB	LOS ALAMOS	NM	AU	AUSTIN	TX	44M	615	27,512.6	58,350.00
AB	LOS ALAMOS	NM	KS	LAWRENCE	KS	44M	671	30,017.9	63,390.00
AB	LOS ALAMOS	NM	BD	BOULDER	CO	44M	346	15,478.7	34,140.00
AU	AUSTIN	TX	DL	RICHARDSON	TX	565M	180	101,700.0	85,500.00
BD	BOULDER	CO	MD	MADISON	WI	44M	844	37,757.2	78,960.00
BD	BOULDER	CO	DC	WASHINGTON	DC	44M	1,501	67,148.7	138,090.00
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	44M	351	15,702.3	34,590.00
BD	BOULDER	CO	DC	WASHINGTON	DC	44M	1,501	67,148.7	138,090.00
BD	BOULDER	CO	BO	WOODS HOLE	MA	44M	1,772	79,272.2	162,480.00
BD	BOULDER	CO	MI	MIAMI	FL	44M	1,742	77,930.1	159,780.00
BD	BOULDER	CO	TU	TUCSON	AZ	44M	619	27,691.6	58,710.00
BD	BOULDER	CO	DT	ANN ARBOR	MI	44M	1,162	51,983.2	107,580.00
BD	BOULDER	CO	PO	CORVALIS	OR	565M	957	540,705.0	435,150.00
BD	BOULDER	CO	PO	CORVALLIS	OR	44M	957	42,812.3	89,130.00
BD	DENVER	CO	LA	LOS ANGELES	CA	565M	822	464,430.0	374,400.00
BO	BOSTON	MA	NY	NEW YORK	NY	565M	188	106,220.0	89,100.00
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	565M	229	129,385.0	107,550.00
CH	CHICAGO	IL	SE	SEATTLE	WA	1G	1,733	1,958,290.0	940,820.00
CH	CHICAGO	IL	DT	LANSING	MI	565M	237	133,905.0	111,150.00
CH	CHICAGO	IL	DT	LITCHFIELD	MI	565M	237	133,905.0	111,150.00
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	44M	1,852	82,851.1	169,680.00
CH	CHICAGO	IL	MD	MADISON	WI	565M	121	68,365.0	58,950.00
CH	CHICAGO	IL	BD	DENVER	CO	1G	927	1,047,510.0	505,580.00
CH	CHICAGO	IL	TL	TALLAHASSEE	FL	44M	806	36,057.2	75,540.00
CH	CHICAGO	IL	IL	URBANA	IL	565M	125	70,625.0	60,750.00
CH	CHICAGO	IL	LI	LINCOLN	NE	1G	475	536,750.0	261,500.00
CH	CHICAGO	IL	BO	CAMBRIDGE	MA	565M	848	479,120.0	386,100.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	565M	205	115,825.0	96,750.00
DC	WASHINGTON	DC	AB	ALBUQUERQUE	NM	44M	1,646	73,635.5	151,140.00
DC	WASHINGTON	DC	LL	LIVERMORE	CA	44M	2,401	107,411.1	219,090.00
DC	WASHINGTON	DC	LL	LIVERMORE	CA	44M	2,401	107,411.1	219,090.00
DC	WASHINGTON	DC	LL	LIVERMORE	CA	44M	2,401	107,411.1	219,090.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	44M	601	26,886.3	57,090.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	44M	1,217	54,443.7	112,530.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	44M	106	4,742.0	12,540.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	565M	106	59,890.0	52,200.00
DC	WASHINGTON	DC	CL	CLEVELAND	OH	44M	304	13,599.7	30,360.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	44M	760	33,999.4	71,400.00
DC	WASHINGTON	DC	LA	LOS ANGELES	CA	44M	2,292	102,534.9	209,280.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	44M	1,572	70,325.0	144,480.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	44M	1,572	70,325.0	144,480.00
DC	WASHINGTON	DC	LA	BARSTOW	CA	44M	2,292	102,534.9	209,280.00
DC	WASHINGTON	DC	LA	BARSTOW	CA	44M	2,292	102,534.9	209,280.00

EXHIBIT B-2. 2000 IRN Circuit Costs

(Non-Integrated)

DC	WASHINGTON	DC	BO	CAMBRIDGE	MA	44M	394	17.626.0	38.460.00
DC	WASHINGTON	DC	PR	PRINCETON	NJ	1G	165	186.450.0	94.100.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	565M	2.432	1.274.080.0	1.098.900.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	44M	2.432	108.797.9	221.880.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	44M	2.432	108.797.9	221.880.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	1G	1.217	1.375.210.0	662.180.00
DC	WASHINGTON	DC	LA	PASADENA	CA	44M	2.292	102.534.9	209.280.00
DC	WASHINGTON	DC	LA	PASADENA	CA	44M	2.292	102.534.9	209.280.00
DC	WASHINGTON	DC	LA	LOMPOC	CA	44M	2.292	102.534.9	209.280.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	44M	601	26.886.3	57.090.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	44M	760	33.999.4	71.400.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	44M	601	26.886.3	57.090.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	44M	1.217	54.443.7	112.530.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	565M	1.217	687.605.0	552.150.00
DC	WASHINGTON	DC	PH	WILMINGTON	DE	44M	124	5.547.3	14.160.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	44M	157	7.023.5	17.130.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	44M	1.217	54.443.7	112.530.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	44M	760	33.999.4	71.400.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	44M	205	9.170.9	21.450.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	44M	106	4.742.0	12.540.00
DL	RICHARDSON	TX	TL	TALLAHASSEE	FL	565M	754	426.010.0	343.800.00
DT	ANN ARBOR	MI	CB	COLUMBUS	OH	565M	163	92.095.0	77.850.00
DT	ANN ARBOR	MI	PR	PRINCETON	NJ	1G	459	518.670.0	252.860.00
HN	HUNTSVILLE	AL	KN	CAPE KENNEDY	FL	565M	563	318.095.0	257.850.00
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	44M	616	27.557.4	58.440.00
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	44M	601	26.886.3	57.090.00
HN	HUNTSVILLE	AL	KN	ORLANDO	FL	44M	563	25.186.4	53.670.00
HN	HUNTSVILLE	AL	MI	MIAMI	FL	44M	722	32.299.4	67.980.00
HU	BRYAN	TX	AU	AUSTIN	TX	565M	147	83.055.0	70.650.00
HU	HOUSTON	TX	DL	DALLAS	TX	44M	224	10.020.9	23.160.00
HU	HOUSTON	TX	HN	HUNTSVILLE	AL	44M	616	27.557.4	58.440.00
HU	HOUSTON	TX	WS	WHITE SANDS	NM	44M	500	22.368.0	48.000.00
HU	HOUSTON	TX	AU	AUSTIN	TX	565M	147	83.055.0	70.650.00
HU	HOUSTON	TX	AU	AUSTIN	TX	44M	147	6.576.2	16.230.00
HU	HOUSTON	TX	BD	BOULDER	CO	1G	899	1.015.870.0	490.460.00
HU	HOUSTON	TX	AU	AUSTIN	TX	44M	147	6.576.2	16.230.00
HU	HOUSTON	TX	KN	CAPE KENNEDY	FL	565M	900	508.500.0	409.500.00
IL	URBANA	IL	CH	CHICAGO	IL	44M	125	5.592.0	14.250.00
IL	URBANA	IL	IN	BLOOMINGTON	IN	565M	113	63.845.0	55.350.00
IL	URBANA	IL	MD	MILWAUKEE	WI	44M	211	9.439.3	21.990.00
IN	INDIANAPOLIS	IN	CB	COLUMBUS	OH	565M	168	94.920.0	80.100.00
IO	IOWA CITY	IA	IL	URBANA	IL	565M	202	114.130.0	95.400.00
IT	ITHACA	NY	NY	NEW YORK	NY	565M	195	110.175.0	92.250.00
IT	ITHACA	NY	NY	NEW YORK	NY	565M	195	110.175.0	92.250.00
IT	ITHACA	NY	NY	NEW YORK	NY	565M	195	110.175.0	92.250.00
IT	ITHACA	NY	DC	WASHINGTON	DC	1G	291	328.830.0	162.140.00
IT	ITHACA	NY	PT	PITTSBURGH	PA	1G	267	301.710.0	149.180.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	44M	1.446	64.688.3	133.140.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	565M	1.446	816.990.0	655.200.00
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	565M	671	379.115.0	306.450.00
LA	LOS ANGELES	CA	AB	LOS ALAMOS	NM	565M	664	375.160.0	303.300.00
LA	LOS ANGELES	CA	HN	HUNTSVILLE	AL	44M	1.798	80.435.3	164.820.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	44M	113	5.055.2	13.170.00

EXHIBIT B-2. 2000 IRN Circuit Costs

(Non-Integrated - Continued)

LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	44M	113	5,055.2	13,170.00
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	565M	350	197,750.0	162,000.00
LA	LOS ANGELES	CA	HU	HOUSTON	TX	44M	1,376	61,556.7	126,840.00
LA	LOS ANGELES	CA	BD	BOULDER	CO	44M	822	36,773.0	76,980.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	565M	113	63,845.0	55,350.00
LA	LOS ANGELESO	CA	SF	SAN FRANCISCO	CA	565M	350	197,750.0	162,000.00
LA	PASADENA	CA	TU	TUCSON	AZ	44M	444	19,862.8	42,960.00
LA	PASADENA	CA	DC	BALTIMORE	MD	44M	2,292	102,534.9	209,280.00
LA	PASADENA	CA	HU	HOUSTON ISLAND	TX	44M	1,376	61,556.7	126,840.00
LA	PASADENA	CA	DC	WASHINGTON	DC	44M	2,292	102,534.9	209,280.00
LI	LINCOLN	NE	IL	URBANA	IL	44M	447	19,997.0	43,230.00
LI	LINCOLN	NE	KS	LAWRENCE	KS	44M	199	8,902.5	20,910.00
LI	LINCOLN	NE	IO	IOWA CITY	IA	44M	274	12,257.7	27,660.00
LI	LINCOLN	NE	BD	BOULDER	CO	1G	454	513,020.0	250,160.00
LL	LIVERMORE	CA	SF	OAKLAND	CA	44M	36	1,610.5	6,240.00
LL	LIVERMORE	CA	PR	PRINCETON	NJ	565M	2,507	1,416,455.0	1,132,650.00
LL	LIVERMORE	CA	LA	LOS ANGELES	CA	44M	321	14,360.3	31,890.00
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	565M	860	485,900.0	391,500.00
MP	MINNEAPOLIS	MN	IO	IOWA CITY	IA	565M	243	137,295.0	113,850.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	565M	232	131,080.0	108,900.00
NF	NORFOLK	VA	TL	TALLAHASSEE	FL	565M	635	358,775.0	290,250.00
NY	LONG ISLAND	NY	BO	CAMBRIDGE	MA	565M	188	106,220.0	89,100.00
NY	NEW YORK	NY	IT	ROME	NY	565M	195	110,175.0	92,250.00
OR	OAK RIDGE	TN	CH	CHICAGO	IL	565M	441	249,165.0	202,950.00
OR	OAK RIDGE	TN	TL	TALLAHASSEE	FL	565M	385	217,525.0	177,750.00
PR	PRINCETON	NJ	TU	TUCSON	AZ	565M	2,080	1,175,200.0	940,500.00
PR	PRINCETON	NJ	NF	NORFOLK VA	DC	565M	269	151,985.0	125,550.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	565M	40	22,600.0	22,500.00
PR	PRINCETON	NJ	CH	CHICAGO	IL	565M	686	387,590.0	313,200.00
PR	PRINCETON	NJ	NY	LONG ISLAND	NY	565M	40	22,600.0	22,500.00
PR	PRINCETON	NJ	BD	BOLDER	CO	565M	1,610	909,650.0	729,000.00
PR	PRINCETON	NJ	SC	STATE COLLEGE	PA	565M	175	98,875.0	83,250.00
PR	PRINCETON	NJ	PH	PHILADELPHIA	PA	565M	42	23,730.0	23,400.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	565M	229	129,385.0	107,550.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	565M	229	129,385.0	107,550.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	565M	40	22,600.0	22,500.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	565M	40	22,600.0	22,500.00
PR	PRINCETON	NJ	BO	NEW HAVEN	CT	565M	229	129,385.0	107,550.00
PR	PRINCETON	NJ	BO	AMHERST	MA	565M	229	129,385.0	107,550.00
PT	PITTSBURGH	PA	SC	STATE COLLEGE	PA	565M	115	64,975.0	56,250.00
PT	PITTSBURGH	PA	PR	PRINCETON	NJ	1G	285	322,050.0	158,900.00
PT	PITTSBURGH	PA	IL	URBANA	IL	1G	434	490,420.0	239,360.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	565M	114	64,410.0	55,800.00
PT	PITTSBURGH	PA	PH	PHILADELPHIA	PA	565M	258	145,770.0	120,600.00
PT	PITTSBURGH	PA	DC	WASHINGTON	DC	565M	190	107,350.0	90,000.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	565M	113	63,845.0	55,350.00
SD	SAN DIEGO	CA	LA	RIVERSIDE	CA	44M	113	5,055.2	13,170.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	565M	113	63,845.0	55,350.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	565M	113	63,845.0	55,350.00
SD	SAN DIEGO	CA	HU	HOUSTON	TX	1G	1,305	1,474,650.0	709,700.00
SD	SAN DIEGO	CA	SF	MENLO PARK	CA	1G	463	523,190.0	255,020.00
SD	SAN DIEGO	CA	LA	SANTA BARBARA	CA	44M	113	5,055.2	13,170.00
SD	SAN DIEGO	CA	SE	SEATTLE	WA	44M	1,068	47,778.0	99,120.00

EXHIBIT B-2. 2000 IRN Circuit Costs

(Non-Integrated - Continued)

SD	SAN DIEGO	CA	SF	OAKLAND	CA	44M	463	20,712.8	44,670.00
SD	SAN DIEGO	CA	LA	IRVINE	CA	44M	113	5,055.2	13,170.00
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	44M	624	27,915.3	59,160.00
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	44M	624	27,915.3	59,160.00
SE	SEATTLE	WA	SD	SAN DIEGO	CA	1G	1,068	1,206,840.0	581,720.00
SE	SEATTLE	WA	SF	MENLO PARK	CA	1G	684	772,920.0	374,360.00
SE	SEATTLE	WA	PO	PORTLAND	OR	565M	147	83,055.0	70,650.00
SE	SEATTLE	WA	PO	CORVALLIS	OR	44M	147	6,576.2	16,230.00
SE	SEATTLE	WA	PO	EUGENE	OR	44M	147	6,576.2	16,230.00
SF	SAN FRANCISCO	CA	LA	PASADENA	CA	44M	350	15,657.6	34,500.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	565M	36	20,340.0	20,700.00
SF	SAN FRANCISCO	CA	BD	BOULDER	CO	44M	932	41,693.9	86,880.00
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	44M	2,432	108,797.9	221,880.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	44M	350	15,657.6	34,500.00
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	44M	2,432	108,797.9	221,880.00
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	565M	1,852	1,046,380.0	837,900.00
SL	SALT LAKE CITY	UT	SF	MENLO PARK	CA	1G	598	675,740.0	327,920.00
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	1G	351	396,630.0	194,540.00
SL	SALT LAKE CITY	UT	CH	CHICAGO	IL	1G	1,256	1,419,280.0	683,240.00
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	565M	1,265	714,725.0	573,750.00
WI	WALLOPS ISLAND	VA	MD	MADISON	WI	44M	809	36,191.4	75,810.00
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	44M	1,265	56,591.0	116,850.00
SUB							133,385	37,104,024.3	30,207,500.00

EXHIBIT B-2. 2000 IRN Circuit Costs

(Non-Integrated - Continued)

2010 PROJECTED COST - NETWORKS NOT INTEGRATED

ID	CITY - A	ID	ID	CITY - B	ST	CAPACITY	MILES	MM	COST
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	565M	860	485,900.0	391,500.00
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1G	860	971,800.0	469,400.00
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	565M	671	379,115.0	306,450.00
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	565M	671	379,115.0	306,450.00
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	565M	671	379,115.0	306,450.00
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	565M	860	485,900.0	391,500.00
AB	LOS ALAMOS	NM	AU	AUSTIN	TX	565M	615	347,475.0	281,250.00
AB	LOS ALAMOS	NM	KS	LAWRENCE	KS	565M	671	379,115.0	306,450.00
AB	LOS ALAMOS	NM	BD	BOULDER	CO	565M	346	195,490.0	160,200.00
AU	AUSTIN	TX	DL	RICHARDSON	TX	1G	180	203,400.0	102,200.00
BD	BOULDER	CO	MD	MADISON	WI	565M	844	476,860.0	384,300.00
BD	BOULDER	CO	DC	WASHINGTON	DC	565M	1,501	848,065.0	679,950.00
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	565M	351	198,315.0	162,450.00
BD	BOULDER	CO	DC	WASHINGTON	DC	565M	1,501	848,065.0	679,950.00
BD	BOULDER	CO	BO	WOODS HOLE	MA	565M	1,772	1,001,180.0	801,900.00
BD	BOULDER	CO	MI	MIAMI	FL	565M	1,742	984,230.0	788,400.00
BD	BOULDER	CO	TU	TUCSON	AZ	565M	619	349,735.0	283,050.00
BD	BOULDER	CO	DT	ANN ARBOR	MI	565M	1,162	656,530.0	527,400.00
BD	BOULDER	CO	PO	CORVALIS	OR	1G	957	1,081,410.0	521,780.00
BD	BOULDER	CO	PO	CORVALLIS	OR	565M	957	540,705.0	435,150.00
BD	DENVER	CO	LA	LOS ANGELES	CA	1G	822	928,860.0	448,880.00
BO	BOSTON	MA	NY	NEW YORK	NY	1G	188	212,440.0	106,520.00
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	1G	229	258,770.0	128,660.00
CH	CHICAGO	IL	SE	SEATTLE	WA	5G	1,723	9,399,792.0	3,751,280.00
CH	CHICAGO	IL	DT	LANSING	MI	1G	237	267,810.0	132,980.00
CH	CHICAGO	IL	DT	LITCHFIELD	MI	1G	237	267,810.0	132,980.00
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	1G	1,852	2,092,760.0	1,005,080.00
CH	CHICAGO	IL	MD	MADISON	WI	1G	121	136,730.0	70,340.00
CH	CHICAGO	IL	BD	DENVER	CO	5G	927	5,028,048.0	2,010,320.00
CH	CHICAGO	IL	TL	TALLAHASSEE	FL	1G	806	910,780.0	440,240.00
CH	CHICAGO	IL	IL	URBANA	IL	1G	125	141,250.0	72,500.00
CH	CHICAGO	IL	LI	LINCOLN	NE	5G	475	2,576,400.0	1,034,000.00
CH	CHICAGO	IL	BO	CAMBRIDGE	MA	1G	848	958,240.0	462,920.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	1G	205	231,650.0	115,700.00
DC	WASHINGTON	DC	AB	ALBUQUERQUE	NM	565M	1,646	929,990.0	745,200.00
DC	WASHINGTON	DC	LL	LIVERMORE	CA	565M	2,401	1,356,565.0	1,084,950.00
DC	WASHINGTON	DC	LL	LIVERMORE	CA	565M	2,401	1,356,565.0	1,084,950.00
DC	WASHINGTON	DC	LL	LIVERMORE	CA	565M	2,401	1,356,565.0	1,084,950.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	565M	601	339,565.0	274,950.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	565M	1,217	687,605.0	552,150.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	565M	106	59,890.0	52,200.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1G	106	119,780.0	62,240.00
DC	WASHINGTON	DC	CL	CLEVELAND	OH	565M	304	171,760.0	141,300.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	565M	760	429,400.0	346,500.00
DC	WASHINGTON	DC	LA	LOS ANGELES	CA	565M	2,292	1,294,980.0	1,035,900.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	565M	1,572	888,180.0	711,900.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	565M	1,572	888,180.0	711,900.00
DC	WASHINGTON	DC	LA	BARSTOW	CA	565M	2,292	1,294,980.0	1,035,900.00
DC	WASHINGTON	DC	LA	BARSTOW	CA	565M	2,292	1,294,980.0	1,035,900.00

EXHIBIT B-3. 2010 IRN Circuit Costs

(Non-Integrated)

DC	WASHINGTON	DC	BO	CAMBRIDGE	MA	565M	394	222.610.0	181.800.00
DC	WASHINGTON	DC	PR	PRINCETON	NJ	5G	165	894.960.0	364.400.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	1G	2.432	2.748.160.0	1.318.280.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	565M	2.432	1.374.080.0	1.098.900.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	565M	2.432	1.374.080.0	1.098.900.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	5G	1.217	6.601.008.0	2.636.720.00
DC	WASHINGTON	DC	LA	PASADENA	CA	565M	2.292	1.294.980.0	1.035.900.00
DC	WASHINGTON	DC	LA	PASADENA	CA	565M	2.292	1.294.980.0	1.035.900.00
DC	WASHINGTON	DC	LA	LOMPOC	CA	565M	2.292	1.294.980.0	1.035.900.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	565M	601	339.565.0	274.950.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	565M	760	429.400.0	346.500.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	565M	601	339.565.0	274.950.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	565M	1.217	687.605.0	552.150.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	5G	1.217	6.601.008.0	2.636.720.00
DC	WASHINGTON	DC	PH	WILMINGTON	DE	565M	124	70.060.0	60.300.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	565M	157	88.705.0	75.150.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	565M	1.217	687.605.0	552.150.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	565M	760	429.400.0	346.500.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	565M	205	115.825.0	96.750.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	565M	106	59.890.0	52.200.00
DL	RICHARDSON	TX	TL	TALLAHASSEE	FL	1G	754	852.020.0	412.160.00
DT	ANN ARBOR	MI	CB	COLUMBUS	OH	1G	163	184.190.0	93.020.00
DT	ANN ARBOR	MI	PR	PRINCETON	NJ	5G	459	2.489.616.0	999.440.00
HN	HUNTSVILLE	AL	KN	CAPE KENNEDY	FL	1G	563	636.190.0	309.020.00
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	565M	616	348.040.0	281.700.00
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	565M	601	339.565.0	274.950.00
HN	HUNTSVILLE	AL	KN	ORLANDO	FL	565M	563	318.095.0	257.850.00
HN	HUNTSVILLE	AL	MI	MIAMI	FL	565M	722	407.930.0	329.400.00
HU	BRYAN	TX	AU	AUSTIN	TX	1G	147	166.110.0	84.380.00
HU	HOUSTON	TX	DL	DALLAS	TX	565M	224	126.560.0	105.300.00
HU	HOUSTON	TX	HN	HUNTSVILLE	AL	565M	616	348.040.0	281.700.00
HU	HOUSTON	TX	WS	WHITE SANDS	NM	565M	500	282.500.0	229.500.00
HU	HOUSTON	TX	AU	AUSTIN	TX	1G	147	166.110.0	84.380.00
HU	HOUSTON	TX	AU	AUSTIN	TX	565M	147	83.055.0	70.650.00
HU	HOUSTON	TX	BD	BOULDER	CO	5G	899	4.876.176.0	1.949.840.00
HU	HOUSTON	TX	AU	AUSTIN	TX	565M	147	83.055.0	70.650.00
HU	HOUSTON	TX	KN	CAPE KENNEDY	FL	1G	900	1.017.000.0	491.000.00
IL	URBANA	IL	CH	CHICAGO	IL	565M	125	70.625.0	60.750.00
IL	URBANA	IL	IN	BLOOMINGTON	IN	565M	113	63.845.0	55.350.00
IL	URBANA	IL	MD	MILWAUKEE	WI	565M	211	119.215.0	99.450.00
IN	INDIANAPOLIS	IN	CB	COLUMBUS	OH	1G	168	189.840.0	95.720.00
IO	IOWA CITY	IA	IL	URBANA	IL	1G	202	228.260.0	114.080.00
IT	ITHACA	NY	NY	NEW YORK	NY	1G	195	220.350.0	110.300.00
IT	ITHACA	NY	NY	NEW YORK	NY	1G	195	220.350.0	110.300.00
IT	ITHACA	NY	NY	NEW YORK	NY	1G	195	220.350.0	110.300.00
IT	ITHACA	NY	DC	WASHINGTON	DC	5G	291	1.578.384.0	636.560.00
IT	ITHACA	NY	PT	PITTSBURGH	PA	5G	267	1.448.208.0	584.720.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	565M	1.446	816.990.0	655.200.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	1G	1.446	1.633.980.0	785.840.00
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	1G	671	758.230.0	367.340.00
LA	LOS ANGELES	CA	AB	LOS ALAMOS	NM	1G	664	750.320.0	363.560.00
LA	LOS ANGELES	CA	HN	HUNTSVILLE	AL	565M	1.798	1.015.870.0	813.600.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	565M	113	63.845.0	55.350.00

EXHIBIT B-3. 2010 IRN Circuit Costs

(Non-Integrated - Continued)

LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	565M	113	63.845.0	55,350.00
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	1G	350	395.500.0	194,000.00
LA	LOS ANGELES	CA	HU	HOUSTON	TX	565M	1.376	777.440.0	623,700.00
LA	LOS ANGELES	CA	BD	BOULDER	CO	565M	822	464.430.0	374,400.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1G	113	127.690.0	66,020.00
LA	LOS ANGELESO	CA	SF	SAN FRANCISCO	CA	1G	350	395.500.0	194,000.00
LA	PASADENA	CA	TU	TUCSON	AZ	565M	444	250.860.0	204,300.00
LA	PASADENA	CA	DC	BALTIMORE	MD	565M	2.292	1.294.980.0	1.035,900.00
LA	PASADENA	CA	HU	HOUSTON ISLAND	TX	565M	1.376	777.440.0	623,700.00
LA	PASADENA	CA	DC	WASHINGTON	DC	565M	2.292	1.294.980.0	1.035,900.00
LI	LINCOLN	NE	IL	URBANA	IL	565	447	0.0	0.00
LI	LINCOLN	NE	KS	LAWRENCE	KS	565M	199	112.435.0	94,050.00
LI	LINCOLN	NE	IO	IOWA CITY	IA	565M	274	154.810.0	127,800.00
LI	LINCOLN	NE	BD	BOULDER	CO	5G	454	2,462.496.0	988,640.00
LL	LIVERMORE	CA	SF	OAKLAND	CA	565M	36	20.340.0	20,700.00
LL	LIVERMORE	CA	PR	PRINCETON	NJ	1G	2.507	2,832.910.0	1.358,780.00
LL	LIVERMORE	CA	LA	LOS ANGELES	CA	565M	321	181.365.0	148,950.00
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	1G	860	971.800.0	469,400.00
MP	MINNEAPOLIS	MN	IO	IOWA CITY	IA	1G	243	274.590.0	136,220.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1G	232	262.160.0	130,280.00
NF	NORFOLK	VA	TL	TALLAHASSEE	FL	1G	635	717.550.0	347,900.00
NY	LONG ISLAND	NY	BO	CAMBRIDGE	MA	1G	188	212.440.0	106,520.00
NY	NEW YORK	NY	IT	ROME	NY	1G	195	220.350.0	110,300.00
OR	OAK RIDGE	TN	CH	CHICAGO	IL	565M	441	249.165.0	202,950.00
OR	OAK RIDGE	TN	TL	TALLAHASSEE	FL	565M	385	217.525.0	177,750.00
PR	PRINCETON	NJ	TU	TUCSON	AZ	1G	2,080	2,350.400.0	1,128,200.00
PR	PRINCETON	NJ	NF	NORFOLK VA	DC	1G	269	303.970.0	150,260.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1G	40	45,200.0	26,600.00
PR	PRINCETON	NJ	CH	CHICAGO	IL	1G	686	775.180.0	375,440.00
PR	PRINCETON	NJ	NY	LONG ISLAND	NY	1G	40	45,200.0	26,600.00
PR	PRINCETON	NJ	BD	BOLDER	CO	1G	1,610	1,819.300.0	874,400.00
PR	PRINCETON	NJ	SC	STATE COLLEGE	PA	1G	175	197,750.0	99,500.00
PR	PRINCETON	NJ	PH	PHILADELPHIA	PA	1G	42	47,460.0	27,680.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1G	229	258,770.0	128,660.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1G	229	258,770.0	128,660.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1G	40	45,200.0	26,600.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1G	40	45,200.0	26,600.00
PR	PRINCETON	NJ	BO	NEW HAVEN	CT	1G	229	258.770.0	128,660.00
PR	PRINCETON	NJ	BO	AMHERST	MA	1G	229	258.770.0	128,660.00
PT	PITTSBURGH	PA	SC	STATE COLLEGE	PA	1G	115	129.950.0	67,100.00
PT	PITTSBURGH	PA	PR	PRINCETON	NJ	5G	285	1,545,840.0	623,600.00
PT	PITTSBURGH	PA	IL	URBANA	IL	5G	434	2,354.016.0	945,440.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1G	114	128.820.0	66,560.00
PT	PITTSBURGH	PA	PH	PHILADELPHIA	PA	1G	258	291.540.0	144,320.00
PT	PITTSBURGH	PA	DC	WASHINGTON	DC	1G	190	214,700.0	107,600.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1G	113	127,690.0	66,020.00
SD	SAN DIEGO	CA	LA	RIVERSIDE	CA	565M	113	63,845.0	55,350.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1G	113	127.690.0	66,020.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1G	113	127.690.0	66,020.00
SD	SAN DIEGO	CA	HU	HOUSTON	TX	5G	1,305	7,078.320.0	2,826,800.00
SD	SAN DIEGO	CA	SF	MENLO PARK	CA	5G	463	2,511.312.0	1,008,080.00
SD	SAN DIEGO	CA	LA	SANTA BARBARA	CA	565M	113	63.845.0	55,350.00
SD	SAN DIEGO	CA	SE	SEATTLE	WA	565M	1,068	603.420.0	485,100.00

EXHIBIT B-3. 2010 IRN Circuit Costs

(Non-Integrated - Continued)

SD	SAN DIEGO	CA	SF	OAKLAND	CA	565M	463	261,595.0	212,850.00
SD	SAN DIEGO	CA	LA	IRVINE	CA	565M	113	63,845.0	55,350.00
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	565M	624	352,560.0	285,300.00
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	565M	624	352,560.0	285,300.00
SE	SEATTLE	WA	SD	SAN DIEGO	CA	5G	1,068	5,792,832.0	2,314,880.00
SE	SEATTLE	WA	SF	MENLO PARK	CA	5G	684	3,710,016.0	1,485,440.00
SE	SEATTLE	WA	PO	PORTLAND	OR	1G	147	166,110.0	84,380.00
SE	SEATTLE	WA	PO	CORVALLIS	OR	565M	147	83,055.0	70,650.00
SE	SEATTLE	WA	PO	EUGENE	OR	565M	147	83,055.0	70,650.00
SF	SAN FRANCISCO	CA	LA	PASADENA	CA	565M	350	197,750.0	162,000.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1G	36	40,680.0	24,440.00
SF	SAN FRANCISCO	CA	BD	BOULDER	CO	565M	932	526,580.0	423,900.00
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	565M	2,432	1,374,080.0	1,098,900.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	565M	350	197,750.0	162,000.00
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	565M	2,432	1,374,080.0	1,098,900.00
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	1G	1,852	2,092,760.0	1,005,080.00
SL	SALT LAKE CITY	UT	SF	MENLO PARK	CA	5G	598	3,243,552.0	1,299,680.00
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	5G	351	1,903,824.0	766,160.00
SL	SALT LAKE CITY	UT	CH	CHICAGO	IL	5G	1,256	6,812,544.0	2,720,960.00
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	1G	1,265	1,429,450.0	688,100.00
WI	WALLOPS ISLAND	VA	MD	MADISON	WI	565M	809	457,085.0	368,550.00
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	565M	1,265	714,725.0	573,750.00
SUM							133,385	164,184,932.0	88,522,460.00

EXHIBIT B-3. 2010 IRN Circuit Costs

(Non-Integrated - Continued)

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13. ABSTRACT (*Maximum 200 words*)

The main report of current and future telecommunications capacity and connectivity requirements of the United States domestic research and development (R & D) community are identified. Starting with 1989 as the base year, projections are made for the years 1996, 2000, and 2010. It is shown that it is much more cost effective to implement researchers requirements as an integrated network rather than on a piece-meal basis, as is the case today.

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