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U.S. COMPUTER RESEARCH NETWORKS:

DOMESTIC AND INTERNATIONAL

TELECOMMUNICATIONS

CAPACITY REQUIREMENTS

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PREFACE

This report was prepared by Contel Federal Systems for the NASA Lewis Research Center under Task Order 4 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 dealt with the current and future domestic telecommunications requirements of the United States research community. Task Order 3 identified the legal and regulatory issues related to Direct Broadcast Satellite-Radio. Task Order 4, the results of which are presented in this report and summarized in Section 1, Introduction And Summary, focused on the impact of current and future international telecommunications requirements of the United States research community.

ACKNOWLEDGMENTS

The authors would like to thank members of the Coordinating Committee For Intercontinental Research Networking (CCIRN), the Federal Coordinating Council for Science, Engineering and Technology (FCCSET), the Federal Research Internet Coordinating Committee (the FRICC which now has been replaced by the Federal Networking Council, FNC), and other Federal agency representatives who provided information on their networks.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 in the United States and throughout the world, 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 NASA Project Manager of this study, Mr. James E. Hollansworth, for providing direction and guidance for this study.

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EXECUTIVE SUMMARY

The future telecommunications capacity and connectivity requirements of the United States (US) research and development (R&D) community raise two concerns. First, would there be adequate privately-owned communications capacity to meet the ever-increasing requirements of the US R&D community for domestic and international connectivity? Second, is the method of piecemeal implementation of communications facilities by individual researchers cost effective when viewed from an integrated perspective?

To address the capacity issue, Contel recently completed a study for NASA identifying the current domestic R&D telecommunications capacity and connectivity requirements, and projecting the same to the years 1991, 1996, 2000 and 2010. The work reported here extends the scope of an earlier study by factoring in the impact of international connectivity requirements on capacity and connectivity forecasts.

Most researchers in foreign countries, as is the case with US researchers, rely on regional, national or continent-wide networks to collaborate with each other, and their US counterparts. The US researchers' international connectivity requirements, therefore, stem from the need to link the US domestic research networks to foreign research networks. The number of links and, more importantly, the speeds of links are invariably determined by the characteristics of the networks being linked. The major thrust of this study, therefore, was to identify and characterize the foreign research networks, to quantify the current status of their connectivity to the US networks, and to project growth in the connectivity requirements to years 1991, 1996, 2000, and 2010 so that a composite picture of the US research networks in the same years could be forecasted. Figure A shows the current (1990) US integrated research network, and its connectivity to foreign research networks. As an example of projections, Figure B shows the same for the year 2010.

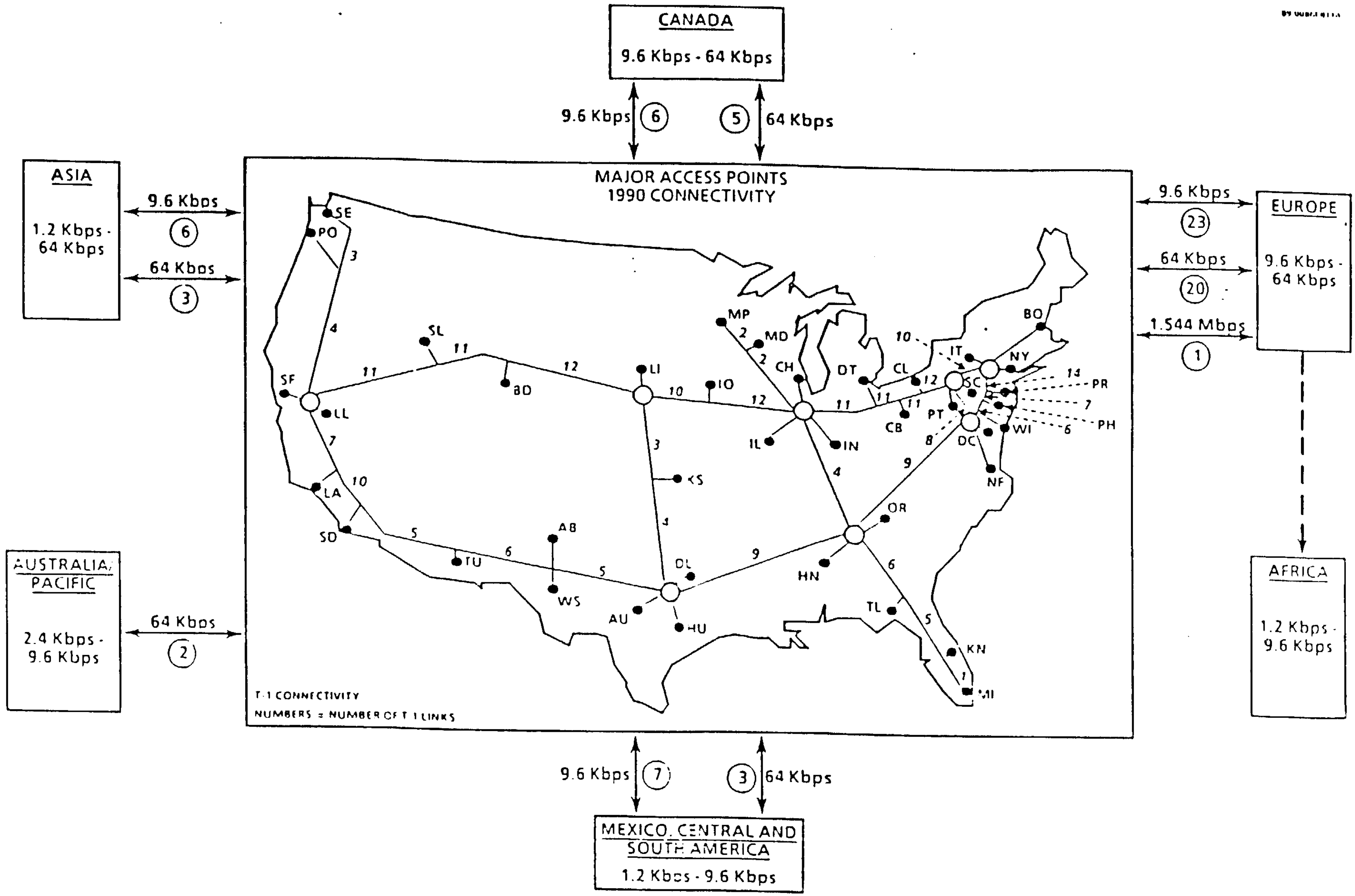

FIGURE A. The Current (1990) U.S. Integrated Research Network With International Links.

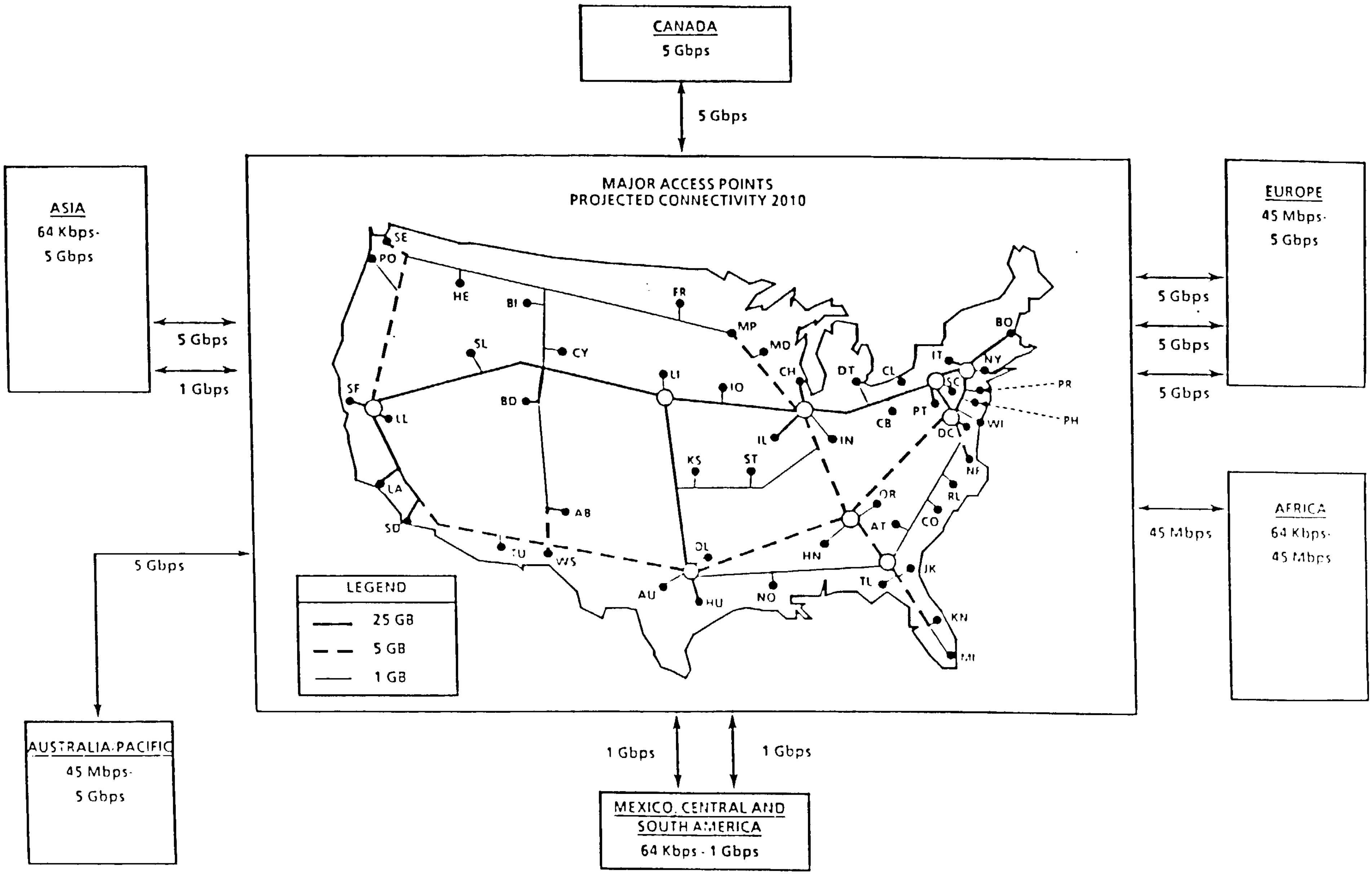

FIGURE B. The 2010 U.S. Integrated Research Network With International Links.

Considerable cost savings can be realized by implementing research networks on an integrated rather than on a piecemeal basis to meet individual researcher's needs. This point was vividly demonstrated in the earlier study, and has the same implications for international connectivity. For example, currently there are 77 links between the US and foreign research networks. We believe that these can be consolidated into 20 links. In the year 1991, and beyond, as the consolidation in the US and abroad progresses, the number of links can be reduced to as few as ten (10). The new links, no doubt would have higher speeds, but would be much more cost efficient due to economies of aggregation.

Major findings of this study are as follows.

INTERNATIONAL RESEARCH NETWORKS

International research networks were identified and described for the following seven areas: Worldwide, North America (excluding the United States), Europe, Asia, Australia/Pacific, Central/South America and Africa. There are a wide variety of research networks throughout these areas. Also, the various nations are at different stages in the development of such networks. A few already have nationwide research networks, while many are just beginning to develop their first research network. Also, a good number of countries have little or no networking activity. The most advanced networks, as expected, are in the more advanced, industrialized countries, e.g., Canada, France, Germany, Japan and the United Kingdom. Asia, Central/South America, and Africa are far behind in network development, but interest is growing in these areas.

Some 84 research networks outside the United States were identified. These networks are listed in Exhibit 1-2. About three-fourths of these are national networks, and about one-fourth are multi-nation, continent-wide or worldwide networks. About half of the networks are in Europe, and the other half are distributed across the other regions. Across all 84 networks, current link speeds range from 1.2 kilobits per second (Kbps) to 1.544 megabits per second (Mbps). When the 84 networks are categorized by link speeds (i.e., 1.2 Kbps to 19.2 Kbps; 48 Kbps to 768 Kbps; and 1544 Kbps or more), about half of the networks fall into the category with the lowest link speeds, and only about ten percent have maximum links speeds of 1544 Kbps or higher. The world-wide networks have the lowest maximum link speed, while networks serving a single nation have the highest maximum link speed. The networks with the highest maximum link speeds are in North America (Canada), Europe (France) and Asia (Japan). The networks with the lowest maximum link speeds are in Central and South America and Africa.

CURRENT INTERNATIONAL TRAFFIC FLOW

An estimate of the current international R&D traffic flow was derived by ascertaining the speeds of the international links between the United States networks and the international networks. Currently, there are 77 United States-international links, and these links connect 22 United States cities to 48 foreign cities in 18 countries. Over half of these links are to Europe, over half originate from two United States cities (i.e., Greenbelt, MD and Princeton, NJ), and about half are NASA network links. The speeds of these international links range from 9.6 Kbps to 1.544 Mbps. Over half of the links are 19.2 Kbps or slower, and there currently is only one 1.544 Mbps link.

FUTURE INTERNATIONAL TRAFFIC FLOW

To estimate the future international traffic flow, the future link speeds of the international networks described above and the future link speeds of the United States-international links were projected. These projections were based on: Coordinating Committee for International Research Networking (CCIRN) drafted policy, Federal

Networking Council Engineering Planning Group (FEPG) proposed policy, CCIRN perspective on worldwide research network requirements, and major factors affecting international network requirements. On the basis of these policies, perspectives and factors guidelines were developed for projecting future link speeds for the international networks and for the international links.

The following is a summary of the projections of future international network link speeds:

1. 1991: about half of the international networks are expected to have only a 9.6 Kbps backbone, about thirty-five percent are expected to have a 64 Kbps backbone, and only about fifteen percent are projected to have a 1.544 Mbps backbone.
2. 1996: about thirty percent of the international networks are expected to have a 64 Kbps backbone, about thirty percent are expected to have a 1.544 Mbps backbone, and about forty percent are projected to have a 45 Mbps backbone.
3. 2000: about thirty percent of the international networks are expected to have a 1.544 Mbps backbone, about thirty percent are expected to have a 45 Mbps backbone, and about forty percent are projected to have a 1 gigabit per second (Gbps) backbone.
4. 2010: about thirty percent of the international networks are expected to have a 45 Mbps backbone, about thirty percent are expected to have a 1 Gbps backbone, and about forty percent are projected to have a 5 Gbps backbone.

To develop the projections of the United States-international links, the current 77 links were consolidated, reducing the number of international links from 77 to 20. It should be pointed out that these 20 links, in a final consolidation, were reduced to 10 links when developing the future integrated research networks (IRNs) which are discussed below. The following is a summary of the projections of the speeds of the United States-international links before this final consolidation:

1. 1991: link speeds of the new **10** international links range from 9.6 Kbps to 1.544 Mbps; about 40 percent of these links are

expected to operate at 1.544 Mbps, about 40 percent at 64/128 Kbps, and about 20 percent at 9.6 Kbps.

2. 1996: link speeds of the new **10** international links range from 64 Kbps to 45 Mbps; about 55 percent of these links are expected to operate at 45 Mbps, 30 percent at 1.544 Mbps, and 15 at 64 Kbps.
3. 2000: link speeds of the new **10** international links range from 1.544 Mbps to 1 Gbps; about 55 percent of these links are expected to operate at 1 Gbps, 30 percent at 45 Mbps, and 15 percent at 1.544 Mbps.
4. 2010: link speeds of the new **10** international links range from 1 Gbps to 5 Gbps; about 55 percent of these links are expected to operate at 5 Gbps, 30 percent at 1 Gbps, and 15 percent at 45 Mbps.

UPDATE OF UNITED STATES RESEARCH NETWORKS

The update of the United States research networks resulted in very few unexpected changes that must be considered when describing the new current and future IRNs. This update was presented in terms of unexpected changes in specific U.S. research networks and in the National Research and Education Network (NREN) plans. The purpose of this update was to determine if the IRN topology maps developed in the previous study had to be modified.

THE NEW INTEGRATED RESEARCH NETWORKS

The New Current Integrated Research Network

The incorporation of the current international research network traffic flow in the new current IRN, resulted in no change in the original current IRN domestic topology map, but suggested a need to consolidate United States-international links. Currently, there are, as noted above, some 77 links connecting the United States research networks to research networks in countries around the world. These links range in speed from 9.6 Kbps to 1.544 Mbps, and they connect a T1 backbone in the United States to research networks that are located around the world and that have link speeds ranging from 1.2 Kbps to 64 Kbps.

The New 1991 Integrated Research Network

An additional consolidation of the 20 United States-international links in 1991 resulted in only 10 links connecting the United States research networks to research networks in countries around the world. This consolidation is possible because of the trend in the US and abroad to consolidate and interconnect networks. Therefore, the US-international connectivity requirement reduces to connecting major US networks to major foreign networks. In 1991, these links are all projected to be 1.544 Mbps links except for the two links to Mexico and Central/South America which are expected to be 128 Kbps links and one of the two links to Asia which is expected to be a 9.6 link. The ten links connect a T3/T1 backbone in the United States to research networks around the world that have link speeds ranging from 9.6 Kbps to 1.544 Mbps.

The New 1996 Integrated Research Network

In 1996, only 10 links are projected (the same as projected for 1991) for connecting the United States research networks to research networks in countries around the world. These links in 1996 are all projected to be 45 Mbps links except for two links to Mexico and Central/South America and one to Asia which are each expected to be 1.544 Mbps links. The ten links connect a backbone, ranging in link speeds from 45 Mbps to 1 Gbps, in the United States to research networks around the world that have link speeds ranging from 9.6 Kbps to 45 Mbps.

The New 2000 Integrated Research Network

In the year 2000, the same 10 links are projected for connecting the United States research networks to research networks in countries around the world. However, these links in year 2000 are all projected to be 1 Gbps links except for two links to Mexico and Central/South America and one to Asia which are each expected to be 45 Mbps links. The ten links connect a backbone, ranging in link speeds from 272 Mbps to 5 Gbps, in the United States to research networks around the world that have link speeds ranging from 9.6 Kbps to 1 Gbps.

The New 2010 Integrated Research Network

In the year 2010, the same 10 links are projected for connecting the United States research networks to research networks in countries around the world. As before, these links are expected to be operating at higher speeds. In year 2010 they are all projected to be 5 Gbps links except for two links to Mexico and Central/South America and one to Asia which are each expected to be 1 Gbps links. The ten links connect, in year 2010, a backbone, ranging in link speeds from 1 Gbps to 25 Gbps, in the United States to research networks around the world that have link speeds ranging from 64 Kbps to 5 Gbps.

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 around the world 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.

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 follows:

1. Support the development of the NREN which will improve network performance and ubiquity for researchers and educators.
2. Support the consolidation of U.S.-international links, thereby increasing network performance and ubiquity worldwide.
3. Support the development of a worldwide research and education network (WREN), thereby improving research and education worldwide.
4. Support the further study of both policy and technical issues related to the implementation of the computer research initiatives already put forth by the White House and Congress.
5. Continue to examine NASA's own computer research network requirements and to work to incorporate these needs in the development of the NREN.
6. Review industry plans for the telecommunications infrastructure growth, and ascertain whether researchers' projected needs can be easily accommodated within the industry expansion plans.

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 communications requirements and trends, 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 Communications 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 re-examination of future telecommunications needs and requirements is necessary to enable NASA to make management decisions in its Communications Program and to ensure that proper technologies and systems are addressed. This re-examination is being accomplished through a series of studies which are helping NASA define the likely communication service needs and requirements of the future, and thereby, ensuring that the most appropriate technology developments are pursued.

The most recent study, in this series of studies, dealt with the domestic telecommunications requirements for the U.S. research and development community. The current study, the results of which are summarized in this volume, extended the scope of this earlier study by focusing on the international telecommunications requirements for the U.S. research and development community.

1.2 METHODOLOGY

The methodology employed in this study is described below in terms of the study purpose, the tasks performed, and the approach used to accomplish the tasks.

1.2.1 Purpose

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

1.2.2 Tasks

This study accomplished its purpose of determining current and future international research communications needs by undertaking the following tasks:

1. Identifying, defining and describing the international research network community.
2. Identifying, defining and describing major research networks outside the U.S..
3. Estimating the current and future international research network traffic flow.
4. Identifying and describing recent unexpected changes in U.S. research networks.

5. Describing new current and future Integrated Research Networks (IRNs).

1.2.3 Approach

To accomplish the purpose of this study, the study approach depicted in Exhibit 1-1 was used. This exhibit shows the interaction of the five major study tasks listed above. The specific approach employed for each of these tasks is summarized below.

1.2.3.1 Identifying, Defining And Describing The International Research Network Community.

The purpose of this task was to describe the international research network community so that the major research networks, which are outside the United States and with which the United States research networks have or may have requirements to interface, could be selected.

The development of the description of the international research network community began with an initial review of the literature on international research networks. Selected books, articles and reports were reviewed to obtain information on the history, development and operation of such networks. This initial review helped structure interviews with leaders in the development of United States research networks. From the initial review and the interviews, preliminary information on international networks was developed, and contacts were identified. These new contacts were telephoned, and additional information on international research networks was obtained.

The information collected through this series of activities was aggregated and analyzed, and provided the basis for describing the international research network community. Included in this description of the international research network community are three major summaries or outlines: a summary of the history of the

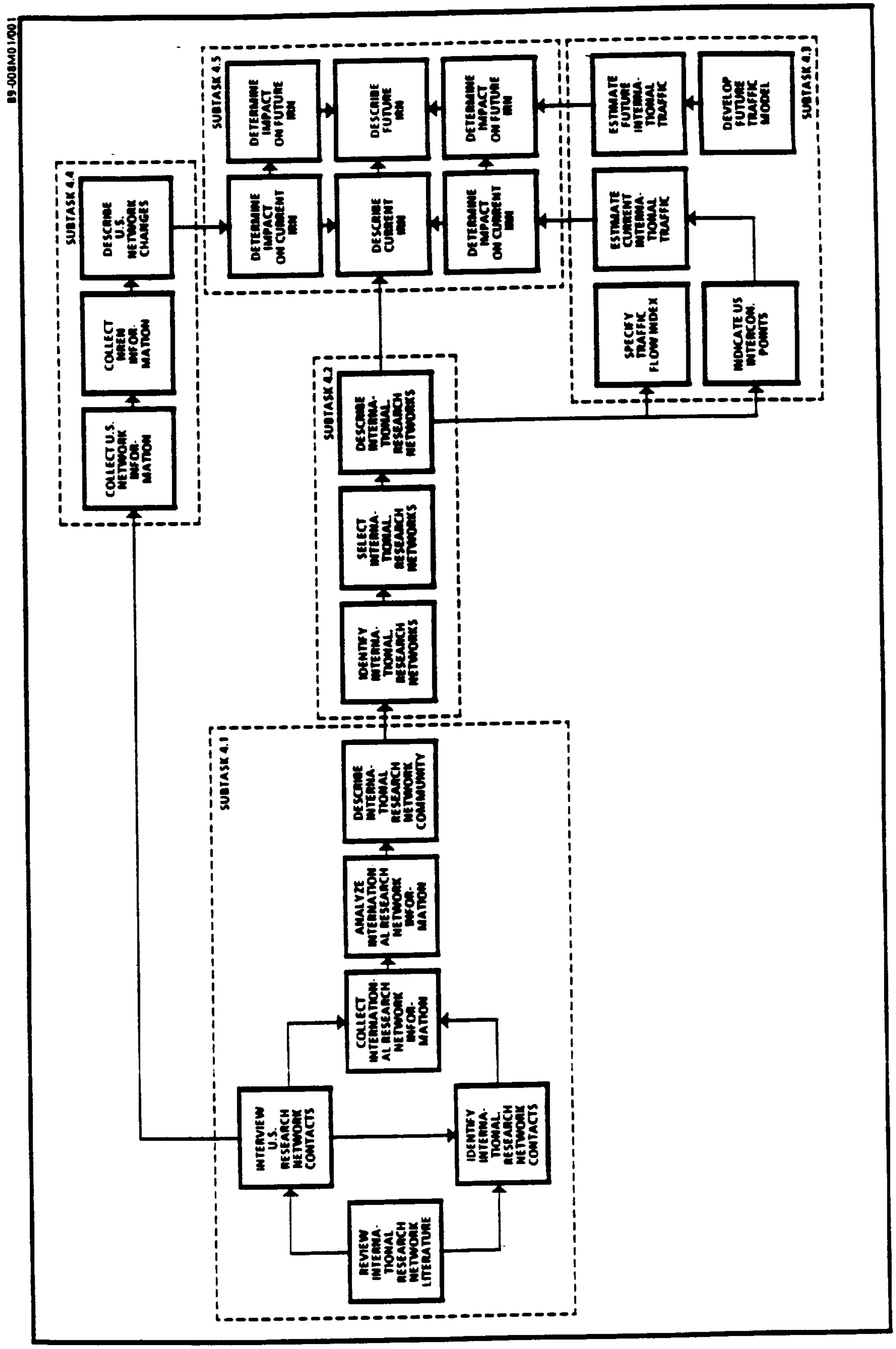

EXHIBIT 1-1. Study Approach

development of the international research networks; a summary of the major organizations involved in the development and coordination of these networks; an outline of all the significant research networks outside the United States, and a summary of the gateways in the United States.

1.2.3.2 Identifying, Defining And Describing Major Research Networks Outside The U.S..

The major intent of this task was to present a picture of the level of research network development around the world, so that the current and future levels of United States/International research network traffic flow could be estimated. To accomplish this purpose the completion of two major activities was required: selecting the networks and then describing the networks.

Since the major intent was to present a picture of the level of research network development around the world, a comprehensive picture of a wide variety of network efforts had to be developed. Therefore, the criteria used to select the international research networks, had to result in the selection of networks that varied on such elements as size (i.e., extent of coverage), link speed, and connectivity. Consequently, a network was selected if information on the network was accessible and if it met one or more of the following criteria:

1. It is a major worldwide network.
2. It is a major multi-nation network.
3. It is the only multi-nation network serving a region of the world.
4. It is a major national network.
5. It is the only national network for a country.
6. Within a nation, it is an advanced regional network.
7. Within a nation, or among nations, it is, or was, an important experimental network.
8. It has an international link with the United States.

Once the international networks were selected, describing them involved collecting additional information, drafting summaries of each network, and reviewing and modifying the summary descriptions. Information on the selected international networks was collected through interviews and telephone calls with research network leaders and managers. These descriptions of the selected international research networks were used in subsequent tasks to estimate the future topologies of these international networks and to identify current United States/international links.

1.2.3.3 Estimating The Current And Future International Research Network Traffic Flow.

The purpose of this task was to develop estimates of the current and future traffic flows, between the United States research networks described in the previous study on domestic research network requirements and the international research networks (i.e., those outside the United States) selected and described in this study.

Estimating the current and future traffic flows between United States and international research networks included the following activities: selecting the measure of traffic flow; identifying the current international links and specifying their speeds; determining the current link speeds of the selected international networks; estimating the future link speeds of these international networks; and projecting the future link speeds of the international links.

Based on a review of information on the selected international networks and on the international links, it was determined that installed capacity would be the best measure of traffic flow. As with the United States research networks, estimates of traffic loads or of peak hour traffic were not available for the international networks or for the international links.

To identify the current United States-international links three activities were conducted. First, managers of the United States networks described in the previous study were asked to identify all of their links with research networks outside the United States. Next, information on the selected international networks was reviewed to identify links with the United States research networks. Lastly, records of international links were obtained from members of the Coordinating Committee For International Research (CCIRN) and members of the FNC Engineering Planning Group (FEPG). These records served as the basis for the specification of the international links. The findings from the first two activities were used as supportive data.

The current link speeds of the international links were obtained from the records on the international links. The current link speeds of the selected international networks were obtained from the international network descriptions developed in this study.

The future links speeds of the international networks and of the international links were based on the future plans for these networks and these links. The future plans for the networks and the links came from four groups of information: CCIRN drafted policy, FEPG proposed policy, CCIRN perspective on worldwide research network requirements, and major factors affecting international network requirements.

The estimates of research network traffic flows developed in this task were presented under two major topics: the current international research network traffic flow, and the future international research network traffic flow. Estimates of future traffic flow were made for the same benchmark years (i.e., 1991, 1996, 2000, & 2010) used in the previous domestic research network study . These estimates were used in subsequent tasks to describe new current and future integrated research networks (IRNs).

1.2.3.4 Identifying And Describing Recent Unexpected Changes In U.S. Research Networks.

The purpose of this task was to describe any unanticipated changes in United States networks that have taken place, since the completion of the previous study on domestic network requirements, and that might have significant impacts on the current and future Integrated Research Networks (IRNs) defined in this previous study. That is, the intent of this task was to update the information collected, during the previous study, on the United States research networks and on the National Research and Education Network (NREN). The focus was on changes related to the topologies of the United States networks and to the plans for the NREN.

Updating the information on the United States research networks and the NREN included the following activities: collecting information from the managers of each network; collecting information on the NREN from industry leaders; and organizing this information so its impact on the current and future IRNs could be determined.

To collect information on the United States networks, the managers of all the United States networks were contacted by mail and by telephone. Each manager was sent a copy of the narrative description and the topology map prepared during the previous study for his network. He was asked to review this information and to identify any major changes that should be made in either the narrative description or the topology map. This mailing was followed up by telephone calls until the necessary information was obtained. The information then was organized so that the impact of the significant changes could be assessed.

Current information on the NREN plans was obtained by interviewing industry leaders identified in the previous study and by reviewing documents describing current NREN plans. Interviews were conducted in person (e.g., during the EDUCOM National Net'90) and over the telephone. Documents were obtained from the various groups and committees which are involved in the planning of the NREN. Based on the obtained information, the current status and future plans for the NREN were summarized and used in subsequent tasks when describing the new current and future IRNs.

1.2.3.5 Describing New Current And Future Integrated Research Networks (IRNs).

The purpose of this task was to describe, given the findings of the current study, the new current and future Integrated Research Networks (IRNs). That is, the intent was to use the results of Tasks 1-4 to modify the original IRNs developed in the previous study. It was anticipated that the findings from Tasks 1 and 2, which include descriptions of the international research network community and of the major research networks outside of the United States, would provide a worldwide perspective for developing the new IRNs. Then, it was expected that the estimates of the current and future international traffic flows developed in Task 3 and the update of the United States Research networks and the NREN plans prepared in Task 4, along with the current and future IRNs described in the previous study, would be used to develop new current and future IRNs.

To accomplish the aforementioned purpose, the completion of three major activities was required: the assessment of the impact, on the current and future IRNs, of unexpected changes in the United States research networks and in the NREN plans; incorporation of the current international research network traffic flow in the description of the current IRN; and the incorporation of the future international research network traffic flows in the description of the future IRNs.

To determine the impact of the unanticipated changes in United States research networks on the current and future IRNs, each change was reviewed to determine whether or not it would have an impact on the original topology maps developed for the current and future IRNs. That is, if the change required a modification of the major access points, the connectivity, or the link speeds of any of the IRN topology maps, these modifications were made.

In a similar manner, the current NREN plans were reviewed to determine if any unanticipated changes in these plans required modifications in the original projections of future research network requirements. Since this study does not focus on the political and social implications of the NREN, but on its technical network requirements, changes in the planned NREN technical network requirements were given the most attention.

To incorporate the estimates of the current international research network traffic flow in the description of the current IRN, the information depicted on the original current IRN topology map, the current link speeds of the international research networks, and the descriptions of the current United States-international links were summarized and presented in a single diagram. This analysis did not result in the consolidation of United States-international links, as was the case in the analysis of information on the future IRNs. The single diagram that was prepared depicts the new current IRN; it is the new current IRN topology map.

In a similar manner, the estimates of the future international research network traffic flow were incorporated in the description of the future IRNs. That is, the information depicted on the original future IRN topology maps, the future link speeds of the international research networks, and the descriptions of the future United States-international links were summarized and presented in a single diagram for each future benchmark year. As noted in the discussion of Task 3, the same future benchmark years (i.e., 1991, 1996, 2000 & 2010) used in the previous domestic study were used again for this study.

Also, as noted in the discussion of Task 3, the United States-international links initially were consolidated for 1991 and beyond to give each United States city a maximum of one link to any foreign country. When developing the new future IRNs, an additional consolidation of links was made based on an understanding of network requirements between the United States and each foreign country. When making this additional consolidation, it was assumed that continent-wide networks would be developing in selected parts of the world (e.g., Europe), and that the United States would have several links to these continent-wide networks and would not need direct access to every major country. This resulted in a maximum of one United States-international link to each foreign country and only indirect links to some countries.

While it is possible that the United States may desire more than one link to some foreign countries or may desire separate links for special projects, these desires were not reflected in the new future IRN topologies, because these desires would be based more on needs related to security and redundancy than on actual traffic flow.

Four new future topology maps were developed to depict the results of these analyses of the future IRNs. These new IRNs, while still focused on the United States, now include international as well as domestic research network requirements.

1.3 MAJOR FINDINGS

1.3.1 Overview

The major findings of this study are summarized below and focus on:

1. The description of the international research network community.
2. The description of the selected international research networks.
3. The current and future international research network traffic flow.
4. The update of the United States research networks.
5. The new current and future IRNs.

1.3.2 The International Research Network Community.

The international research network community was described in terms of its history, major international organizations, the major international networks, and the United States' terrestrial and satellite international gateways.

The history of the international research network community is similar, in many ways, to the history of research networks in the United States. At the country level, some nations have sponsored experimental networks like the ARPANET in the United States, most nations have had to work to sell the value of research networks, and all are facing similar policy and technological issues. At both the country and the international levels, a variety of networks have been developed, inter-network links have been established as the need arose, and the needs to consolidate and coordinate efforts have resulted.

A number of organizations have been formed to recommend and to implement guidelines for planning, coordinating, and standardizing international networking activities. Some important organizations are: Coordinating Committee For Intercontinental Research Networking (CCIRN), International Standards Organization (ISO), Consultative Committee for International Telephoney and Telegraphy (CCITT), Internet Activities Board (IAB), Federal Networking Council Engineering Planning Group (FEPG), International Collaboration Board (ICB) and the Reseaux Associes pour la Recherche Europeenne (RARE). The general purposes of all of these organizations are to improve services, increase connectivity, and reduce costs related to developing and maintaining research networks throughout the world.

In the description of the international research network community, networks were identified for the following areas: Worldwide, North America, Europe, Asia, Australia/Pacific, Central and South America and Africa. There are a wide variety of research networks throughout these areas. Also, the various nations are at different stages in the development of such networks. A few already have nationwide research networks, while many are just beginning to develop their first research network. Also, a good number of countries have little or no networking activity. Over 80 potentially significant research networks were identified throughout the world. About three-fourths of these are national networks, and about one-fourth are multi-nation, continent-wide or worldwide networks

The most advance networks, as expected, are in the more advanced industrialized countries, e.g., Canada, France, Germany, Japan and the United Kingdom. Asia, Central and South America and Africa are far behind in network development, but interest is growing in these areas.

The United States terrestrial and satellite international gateways include some twelve cable systems and 118 earth stations.

1.3.3 The description of the selected international research networks.

Some eighty-four international research networks, which were selected and described, are briefly described in Exhibits 1-2 and 1-3. The location, network name and link speeds for the eighty-four networks are listed in Exhibit 1-2. These networks are summarized by coverage, major geographical area and link speed in Exhibit 1-3.

Coverage is defined in terms of four groups: worldwide, continent-wide, multi-nation and single nation. About four-fifths of the selected networks serve a single nation. The other one-fifth serve either several nations, an entire continent, or most of the world. The world-wide networks have the lowest maximum link speed, while networks serving a single nation have the highest maximum link speed. Across all groups, link speeds range from 1.2 to 1544 Kbps.

Seven major areas of the world were used to group these networks. These areas are: Worldwide, North America, Europe, Asia, Australia/Pacific, Central/South America, and Africa. About half of the networks are in Europe, and the other half are distributed across the other major areas. The networks with the highest maximum link speeds are in Europe (Germany) and Asia (Japan). The networks with the lowest maximum link speeds are in Central/South America and Africa.

Networks were also grouped by maximum link speed. The three

EXHIBIT 1-2. International Research Networks

Location	Network	Link Speeds (Kbps)
WORLDWIDE	BITNET	9.6
	CSNET	9.6
	USENET	11
	UUCP	1.2 - 11
	UUNET	1.2 - 11
	FIDONET	1.2 - 9.6
NORTH AMERICA		
CANADA	DREnet	1.2 - 64
	CDNnet	1.2 - 19.2
	NetNorth	2.4 - 9.6
	CA'net	56 - 1544
	AHEN	2.4 - 9.6
	BCnet	9.6 - 1544
	CRIM	56
	Onet	19.2 - 56
MEXICO	ITESM	9.6 - 64
	UNAM	9.6 - 64
EUROPE		
CONTINENT-WIDE	EUnet	2.4 - 64
	EARN	2.4 - 64
	HEPnet	64
	Ean	9.6
	RIPE	1544
MULTI-NATION	IASnet	2.4 - 11
	NORDUnet	64 - 2000
FRANCE	CYCLADES	4.8 - 19.2
	FNET	4.8
	ARISTOTE	4.8 - 64
	SMARTIX	4.8 - 64
	PHYNET	64
	REUNIR	4.8 - 2000
GERMANY	HMI-NET	9.6
	DFN	9.6 - 64
	AGFNET	64
	BERNET	64
UNITED KINGDOM	NPL	2.4 - 9.6
	SERCnet	9.6
	JANET	9.6 - 64
	Starlink	9.6
	UKnet	1.2 - 19.2
OTHER EUROPE		
AUSTRIA	ACONET	2.4 - 19.2

EXHIBIT 1-3. International Research Networks
Summary By Coverage , Major Area & Link Speed

Summary Groups	# Of Networks	Link Speeds (Kbps)
BY COVERAGE		
Worldwide	6	1.2 - 11
Continent-Wide	5	2.4 - 1544
Multi-Nation	7	1.2 - 2000
Single Nation	66	1.2 - 1544
BY MAJOR GEOGRAPHICAL AREA		
Worldwide	6	1.2 - 11
North America	8	1.2 - 1544
Europe	40	1.2 - 1544
Asia	15	1.2 - 1544
Australia/Pacific	8	2.4 - 512
Central & South America	4	1.2 - 64
Africa	3	1.2 - 9.6
BY MAXIMUM LINK SPEED (Kbps)		
1.2 - 19.2	41	
48 - 768	30	
1544 or more	9	
N/A	4	

groups of link speeds are: 1.2 Kbps to 19.2 Kbps; 48 Kbps to 768 Kbps; and 1544 Kbps or more. About half of the networks fall into the category with the lowest link speeds. Only about ten percent have maximum links speeds of 1544 Kbps or higher.

1.3.4 The Current And Future International Research Network Traffic Flow.

1.3.4.1 Current Traffic Flow

The current traffic flow was estimated by determining the installed capacity of the international links between the United States networks described in the previous study and the international networks described in this study. That is, the current installed capacity of the international links (see Exhibit 1-4 below), along with the current link capacity of the selected international networks (see Exhibit 1-3 above), was used to develop a picture of the current international traffic flow.

There currently are 77 United States-international links that connect 22 United States cities to 48 foreign cities in 18 countries. Over half of these links are to Europe, over half originate from two United States cities (i.e., Greenbelt, MD and Princeton, NJ), and about half are NASA network links. The speeds of these international links range from 9.6 Kbps to 1.544 Mbps. Over half of the links are 19.2 Kbps or slower, and there currently is only one 1.544 Mbps link.

1.3.4.2 Future Traffic Flow

To estimate the future international traffic flow, the future link speeds of the international networks and the future link speeds of the United States-international links were projected. These projections were based on: CCIRN drafted policy, FEPG proposed policy, CCIRN perspective on worldwide research network requirements, and major factors affecting international network requirements

EXHIBIT 1-2. International Research Networks
(Continued)

Location	Network	Link Speeds (Kbps)
DENMARK	DENet	64 - 128
FINLAND	FUNET	14 - 64
ICELAND	EUNET	1.2 - 9.6
IRELAND	HEANET	1.2 - 64
	EuroKom	1.2 - 64
ITALY	INFNET	9.6 - 48
NETHERLANDS	SURFnet	9.6 - 64
NORWAY	UNINETT	64
SOVIET UNION	Academnet	---
	Adonis	---
	ANAS	---
SPAIN	Enet	9.6
	Ean	9.6 - 64
SWEDEN	SUNET	64
SWITZERLAND	SWITCH	64
YUGOSLAVIA	SIS	1.2 - 19.2
ASIA		
MULTI-NATION	AUSEAnet	1.2
	GULFnet	1.2 - 9.6
	PACNET	2.4
JAPAN	N-1	4.8 - 48
	NACSIS	48 - 768
	JUNET	2.4 - 1544
Hong Kong	HARNET	1.2 - 9.6
INDIA	NICNET	1.2 - 9.6
INDONESIA	UNInet	---
ISRAEL	ILAN	9.6
KOREA	KREONet	56

EXHIBIT 1-2. International Research Networks
(Continued)

Location	Network	Link Speeds (Kbps)
ASIA - Continued		
MALAYSIA	RangKom	4.8 - 9.6
THAILAND	TCSnet	1.2 - 2.4
AUSTRALIA/PACIFIC		
MULTI-NATION	PACCOM	19.2 - 512
	SPEARNET	2.4 - 9.6
AUSTRALIA	ACSnet	2.4
	ABN	2.4 - 9.6
	QTInet	2.4 - 9.6
	VICNET	2.4 - 9.6
	AARNet	48
NEW ZEALAND	DSIRnet	2.4
CENTRAL & SOUTH AMERICA		
MULTI-NATION	CARINET	1.2
	CATIENET	1.2 - 2.4
AFRICA		
MULTI-NATION	CGNET	1.2 - 2.4
EGYPT	ENTSTINET	9.6
TUNISIA	Afrimail	1.2 - 2.4

EXHIBIT 1-4. US-INTERNATIONAL LINKS
(Organized By Foreign Country)

FOREIGN CITY	US CITY	US NET./PURPOSE	LINK SPEED (Kbps)
NORTH AMERICA			
CANADA			
Edmonton, BC	Princeton, NJ	BITNET, Acad Res	9.6
Montreal, QB	Princeton (JVNC), NJ	NSFNET, Research	56
Montreal, QB	Princeton, NJ	BITNET, Acad Res	9.6
Ottawa, QB	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Ottawa, QB	Rochester, NY	NSFNET, Research	56
Ottawa, QB	Princeton, NJ	BITNET, Acad Res	9.6
Toronto, ON	Chicago (FNAL), IL	ESNET/DOE HEP	56
Toronto, ON	Ithaca (CNSC), NY	NSFNET, Research	56
Toronto, ON	Princeton, NJ	BITNET, Acad Res	9.6
Vancover,BC	Seattle (UofW), WA	NSFNET, Research	19.2 (56)
Vancover,BC	Seattle (UofW), WA	BITNET, Acad Res	9.6
MEXICO			
Mexico City (UNAM)	Boulder (NCAR), CO	USAN Acad Research	64/128
Antizapan (ITESM)	Boulder (NCAR), CO	USAN Acad Research	64/128
Monterrey	San Antonio, TX	NSFNET, Acad Res	9.6
Monterrey	San Antonio, TX	BITNET, Acad Res	9.6
EUROPE			
FRANCE			
Sophia	Princeton, NJ	NSFNET, Research	64
Montepellier	Ithaca, NY	NSFNET, Supercomput.	56
Montepellier	New York (CUNY), NY	BITNET, Acad Res	56
Paris	Greenbelt (GSFC), MD	SPAN/NSN Research	9.6
Paris	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Toulouse	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Toulouse	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Moudon (Paris Obs)	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Moudon (Paris Obs)	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6 (1995)
Moudon (Paris Obs)	Greenbelt (GSFC), MD	SPAN/NASA Research	56 (1996)
Strasburg	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
GERMANY			
Bonn	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Bonn	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Bonn	Princeton, NJ	BITNET, Acad Res	9.6
Darmstadt	Greenbelt (GSFC), MD	SPAN/NASA Research	19.2
Darmstadt	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Garching	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Garching	Chicago (FNAL), IL	ESNET/DOE Research	64
Garching	Greenbelt (GSFC), MD	SPAN/NSN Research	9.6
Heidelberg	Greenbelt (GSFC), MD	SPAN/NSN Research	9.6
Max Plank	Greenbelt (GSFC), MD	SPAN/NSN Research	9.6
Max Plank	Greenbelt (GSFC), MD	SPAN/NSN Research	9.6
Oberfaf	Greenbelt (GSFC), MD	SPAN/NASA Research	56 (1995)
Oberfaf	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6

EXHIBIT 1-4. US-INTERNATIONAL LINKS
(Organized By Foreign Country - Continued)

FOREIGN CITY	US CITY	US NET./PURPOSE	LINK SPEED (Kbps)
UNITED KINGDOM			
Abingdon	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Bristol	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
London	Princeton (JVNC), NJ	NSFNET, Acad Res	56
Malvern	Cambridge (BBN), MA	DRI/DARPA Research	64
Oxford	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Oxford	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
OTHER EUROPE			
ITALY			
Bologona	Chicago (FNAL), IL	ESNET/DOE HEP	9.6
Bologona	Chicago (FNAL), IL	ESNET/DOE HEP	64
Citta	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Frascati	Chicago (FNAL), IL	ESNET/DOE HEP	64
Frascati	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Frascati	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Pisa	Arlington (DARPA),VA	DRI/DARPA Research	64
NETHERLANDS			
Hague	Greenbelt (GSFC), MD	SPAN/NASA Research	19.2
Noordwijk	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Amsterdam	Falls Church, VA	EUNET, UNET	64
NORWAY			
Oslo	Seismo, Washington,DC	DRI/DARPA Research	64
SWEDEN			
Stockholm	Princeton (JVNC), NJ	NSFNET, Acad. Res.	64
SWITZERLAND			
Cern	Ithaca, NY	NSFNET, Supercomput	1544
Geneva	Cambridge (MIT), MA	ESNET/DOE HEP	256
Geneva	Chicago (FNAL), IL	ESNET/DOE HEP	64
ASIA			
JAPAN			
Jaeri	Lawrence (LLNL), CA	ESNET/DOE HEP	9.6
Nagoya	Lawrence (LLNL), CA	ESNET/DOE HEP	9.6
Tokyo	Berkeley (LBL), CA	ESNET/DOE HEP	56
Tokyo	Washington, DC (NSF)	NSFNET Acad Res	14.4
Tokyo	Honolulu, HA	NSN/NASA Research	64
Tokyo	Honolulu, HA	NSN/NASA Research	64
Tokyo	Princeton, NJ	BITNET, Acad Res	9.6
MALAYSIA			
Singapore	Princeton, NJ	BITNET, Acad Res	9.6
SAUDI ARABIA			
Riyadh	Princeton, NJ	BITNET, Acad Res	9.6

EXHIBIT 1-4. US-INTERNATIONAL LINKS
(Organized By Foreign Country - Continued)

FOREIGN CITY	US CITY	US NET./PURPOSE	LINK SPEED (Kbps)
AUSTRALIA/PACIFIC			
AUSTRALIA			
Melbourne	Honolulu, HI	NSN/NASA Research	64
NEW ZEALAND			
Hamilton	Honolulu, HI	NSN/NASA Research	64
CENTRAL & SOUTH AMERICA			
BRAZIL			
Rio De Janeiro	Los Angeles, CA	BITNET, Acad Res	9.6
Rio De Janeiro	Princeton, NJ	BITNET, Acad Res	9.6
Sao Paulo	Princeton, NJ	BITNET, Acad Res	9.6
CHILE			
La Serena	Huntsville, AL	SPAN/NASA Research	56
Santiago	Princeton, NJ	BITNET, Acad Res	9.6
PUERTO RICO			
San Juan	Tampa, FL	BITNET, Acad Res	9.6

These policies, perspectives and factors were summarized in terms of the following expectations:

1. International organizations like the CCIRN will encourage worldwide network development and coordination.
2. World events are leading to an increase in multi-nation and even global cooperative research efforts which will require increased connectivity.
3. Specific research in the areas of the environment, energy, medicine and space are demanding more advanced network functions and new network applications.
4. Network technology research and development will encourage and facilitate network development worldwide.

On the basis of these expectations, guidelines were developed for projecting future link speeds for the international networks and for the international links. The guidelines for projecting international network link speeds were: all foreign countries would move toward developing a nationwide research network; the link speeds of the backbones of these networks would increase to speeds as high as 5 Gbps; only the backbone of these nationwide networks would be projected; and networks that might be developed in the future would be considered when developing the new IRNs, but not when making these projections. The guidelines for projecting the speeds of the United States-international links were: these links would be consolidated in 1991; the speeds of these links would increase to speeds as high as 5 Gbps; only the consolidated links would be projected; new links that might be required in the future would be considered when developing the new IRNs, but not when making these projections. In both instances, projections would be developed for 1991, 1996, 2000, and 2010.

The projections of international network link speeds are listed and summarized in Exhibits 1-5 through 1-12. The following is a summary of these projections:

1. 1991: about half of the international networks are expected to have only a 9.6 Kbps backbone, about thirty-five percent are

EXHIBIT 1-5. 1991 Projected Link Speeds
International Research Networks

Location	Link Speeds
WORLDWIDE Networks	9.6 Kbps
NORTH AMERICA	
Canada	64 Kbps
Mexico	64 Kbps
EUROPE	
Continent-Wide Nets.	1.544 Mbps
Multi-Nation Nets.	1.544 Mbps
France	64 Kbps
Germany	64 Kbps
United Kingdom	64 Kbps
OTHER EUROPE	
Austria	9.6 Kbps
Denmark	64 Kbps
Finland	64 Kbps
Iceland	9.6 Kbps
Ireland	64 Kbps
Italy	64 Kbps
Netherlands	64 Kbps
Norway	64 Kbps
Soviet Union	9.6 Kbps
Spain	9.6 Kbps
Sweden	64 Kbps
Switzerland	64 Kbps
Yugoslavia	9.6 Kbps
ASIA	
Multi-Nation Nets.	9.6 Kbps

EXHIBIT 1-5. 1991 Projected Link Speeds

International Research Networks
(Continued)

Location	Link Speeds
ASIA (Continued)	
Japan	1.544 Mbps
Hong Kong	9.6 Kbps
India	9.6 Kbps
Indonesia	9.6 Kbps
Israel	9.6 Kbps
Korea	1.544 Mbps
Malaysia	9.6 Kbps
Thailand	9.6 Kbps
AUSTRALIA/PACIFIC	
Multi-Nation Nets.	1.544 Mbps
Australia	9.6 Kbps
New Zealand	9.6 Kbps
CENTRAL & SOUTH AMERICA	
Multi-Nation Nets.	9.6 Kbps
AFRICA	
Multi-Nation Nets.	9.6 Kbps
Egypt	9.6 Kbps
Tunisia	9.6 Kbps

EXHIBIT 1-6. Summary-1991 Link Speeds
International Research Networks

Summary Groups	# Of Networks	Link Speeds
BY COVERAGE		
Worldwide	1	9.6 Kbps
Continent-Wide	1	1.544 Mbps
Multi-Nation	5	9.6 Kbps - 1.544 Mbps
Single Nation	29	9.6 Kbps - 1.544 Mbps
BY MAJOR GEOGRAPHICAL AREA		
Worldwide	1	9.6 Kbps
North America	2	64 Kbps
Europe	18	9.6 Kbps - 1.544 Mbps
Asia	8	9.6 Kbps - 1.544 Mbps
Australia/Pacific	3	9.6 Kbps - 1.544 Mbps
Central & South America	1	9.6 Kbps
Africa	3	9.6 Kbps
BY LINK SPEED		
9.6 Kbps	18	
64 Kbps	13	
1.544 Mbps	5	

EXHIBIT 1-7. 1996 Projected Link Speeds
International Research Networks

Location	Link Speeds
WORLDWIDE Networks	1.544 Mbps
NORTH AMERICA	
Canada	45 Mbps
Mexico	1.544 Mbps
EUROPE	
Continent-Wide Nets.	45 Mbps
Multi-Nation Nets.	45 Mbps
France	45 Mbps
Germany	45 Mbps
United Kingdom	45 Mbps
OTHER EUROPE	
Austria	1.544 Mbps
Denmark	45 Mbps
Finland	1.544 Mbps
Iceland	1.544 Mbps
Ireland	1.544 Mbps
Italy	45 Mbps
Netherlands	45 Mbps
Norway	45 Mbps
Soviet Union	1.544 Mbps
Spain	1.544 Mbps
Sweden	45 Mbps
Switzerland	45 Mbps
Yugoslavia	64 Kbps
ASIA	
Multi-Nation Nets.	64 Kbps

EXHIBIT 1-7. 1996 Projected Link Speeds

International Research Networks
(Continued)

Location	Link Speeds
ASIA (Continued)	
Japan	45 Mbps
Hong Kong	64 Kbps
India	64 Kbps
Indonesia	64 Kbps
Israel	64 Kbps
Korea	1.544 Mbps
Malaysia	64 Kbps
Thailand	64 Kbps
AUSTRALIA/PACIFIC	
Multi-Nation Nets.	45 Mbps
Australia	1.544 Mbps
New Zealand	1.544 Mbps
CENTRAL & SOUTH AMERICA	
Multi-Nation Nets.	64 Kbps
AFRICA	
Multi-Nation Nets.	64 Kbps
Egypt	64 Kbps
Tunisia	64 Kbps

EXHIBIT 1-8. Summary-1996 Link Speeds
International Research Networks

Summary Groups	# Of Networks	Link Speeds
BY COVERAGE		
Worldwide	1	1.544 Mbps
Continent-Wide	1	45 Mbps
Multi-Nation	5	64 Kbps - 45 Mbps
Single Nation	29	64 Kbps - 45 Mbps
BY MAJOR GEOGRAPHICAL AREA		
Worldwide	1	1.544 Mbps
North America	2	1.544 Mbps - 45 Mbps
Europe	18	64 Kbps - 45 Mbps
Asia	8	64 Kbps - 45 Mbps
Australia/Pacific	3	1.544 Mbps - 45 Mbps
Central & South America	1	64 Kbps
Africa	3	64 Kbps
BY LINK SPEED		
64 Kbps	11	
1.544 Mbps	11	
45 Mbps	14	

EXHIBIT 1-9. 2000 Projected Link Speeds

International Research Networks

Location	Link Speeds
WORLDWIDE Networks	45 Mbps
NORTH AMERICA	
Canada	1 Gbps
Mexico	45 Mbps
EUROPE	
Continent-Wide Nets.	1 Gbps
Multi-Nation Nets.	1 Gbps
France	1 Gbps
Germany	1 Gbps
United Kingdom	1 Gbps
OTHER EUROPE	
Austria	45 Mbps
Denmark	1 Gbps
Finland	45 Mbps
Iceland	45 Mbps
Ireland	45 Mbps
Italy	1 Gbps
Netherlands	1 Gbps
Norway	1 Gbps
Soviet Union	45 Mbps
Spain	45 Mbps
Sweden	1 Gbps
Switzerland	1 Gbps
Yugoslavia	1.544 Mbps
ASIA	
Multi-Nation Nets.	1.544 Mbps

EXHIBIT 1-9. 2000 Projected Link Speeds

International Research Networks

(Continued)

Location	Link Speeds
ASIA (Continued)	
Japan	1 Gbps
Hong Kong	1.544 Mbps
India	1.544 Mbps
Indonesia	1.544 Mbps
Israel	1.544 Mbps
Korea	45 Mbps
Malaysia	1.544 Mbps
Thailand	1.544 Mbps
AUSTRALIA/PACIFIC	
Multi-Nation Nets.	1 Gbps
Australia	45 Mbps
New Zealand	45 Mbps
CENTRAL & SOUTH AMERICA	
Multi-Nation Nets.	1.544 Mbps
AFRICA	
Multi-Nation Nets.	1.544 Mbps
Egypt	1.544 Mbps
Tunisia	1.544 Mbps

EXHIBIT 1-10. Summary-2000 Link Speeds

International Research Networks

Summary Groups	# Of Networks	Link Speeds
BY COVERAGE		
Worldwide	1	45 Mbps
Continent-Wide	1	1 Gbps
Multi-Nation	5	1.544 Mbps - 1 Gbps
Single Nation	29	1.544 Mbps - 1 Gbps
BY MAJOR GEOGRAPHICAL AREA		
Worldwide	1	45 Mbps
North America	2	45 Mbps - 1 Gbps
Europe	18	1.544 Mbps - 1 Gbps
Asia	8	1.544 Mbps - 1 Gbps
Australia/Pacific	3	45 Mbps - 1 Gbps
Central & South America	1	1.544 Mbps
Africa	3	1.544 Kbps
BY LINK SPEED		
1.544 Mbps	11	
45 Mbps	11	
1 Gbps	14	

EXHIBIT 1-11. 2010 Projected Link Speeds
International Research Networks

Location	Link Speeds
WORLDWIDE Networks	1 Gbps
NORTH AMERICA	
Canada	5 Gbps
Mexico	1 Gbps
EUROPE	
Continent-Wide Nets.	5 Gbps
Multi-Nation Nets.	5 Gbps
France	5 Gbps
Germany	5 Gbps
United Kingdom	5 Gbps
OTHER EUROPE	
Austria	1 Gbps
Denmark	5 Gbps
Finland	1 Gbps
Iceland	1 Gbps
Ireland	1 Gbps
Italy	5 Gbps
Netherlands	5 Gbps
Norway	5 Gbps
Soviet Union	1 Gbps
Spain	1 Gbps
Sweden	5 Gbps
Switzerland	5 Gbps
Yugoslavia	45 Mbps
ASIA	
Multi-Nation Nets.	45 Mbps

EXHIBIT 1-11. 2010 Projected Link Speeds

International Research Networks
(Continued)

Location	Link Speeds
ASIA (Continued)	
Japan	5 Gbps
Hong Kong	45 Mbps
India	45 Mbps
Indonesia	45 Mbps
Israel	45 Mbps
Korea	1 Gbps
Malaysia	45 Mbps
Thailand	45 Mbps
AUSTRALIA/PACIFIC	
Multi-Nation Nets.	5 Gbps
Australia	1 Gbps
New Zealand	1 Gbps
CENTRAL & SOUTH AMERICA	
Multi-Nation Nets.	45 Mbps
AFRICA	
Multi-Nation Nets.	45 Mbps
Egypt	45 Mbps
Tunisia	45 Mbps

EXHIBIT 1-12. Summary-2010 Link Speeds

International Research Networks

Summary Groups	# Of Networks	Link Speeds
BY COVERAGE		
Worldwide	1	1 Gbps
Continent-Wide	1	5 Gbps
Multi-Nation	5	45 Mbps - 5 Gbps
Single Nation	29	45 Mbps - 5 Gbps
BY MAJOR GEOGRAPHICAL AREA		
Worldwide	1	1 Gbps
North America	2	1 Gbps - 5 Gbps
Europe	18	45 Mbps - 5 Gbps
Asia	8	45 Mbps - 5 Gbps
Australia/Pacific	3	1 Gbps - 5 Gbps
Central & South America	1	45 Mbps
Africa	3	45 mbps
BY LINK SPEED		
45 Mbps	11	
1 Gbps	11	
5 Gbps	14	

expected to have a 64 Kbps backbone, and only about fifteen percent are projected to have a 1.544 Mbps backbone.

2. 1996: about thirty percent of the international networks are expected to have a 64 Kbps backbone, about thirty percent are expected to have a 1.544 Mbps backbone, and about forty percent are projected to have a 45 Mbps backbone.
3. 2000: about thirty percent of the international networks are expected to have a 1.544 Mbps backbone, about thirty percent are expected to have a 45 Mbps backbone, and about forty percent are projected to have a 1 Gbps backbone.
4. 2010: about thirty percent the international networks are expected to have a 45 Mbps backbone, about thirty percent are expected to have a 1 Gbps backbone, and about forty percent are projected to have a 5 Gbps backbone.

To develop the projections of the United States-international links, the current 77 links were consolidated. This process reduced the number of international links, and therefore number of United States cities and foreign cities directly linked. The only constant was the number of foreign countries. The number of international links was reduced from 77 to 20. The number of United States cities was reduced from 22 to seven. The number of foreign cities was reduced from 48 to 20.

In addition to the guidelines noted above, the projections of the speeds of the international links were based, each year, on the following: the number and speeds of links to each foreign country during the previous benchmark year; the projected link speed of the backbone of the network in each foreign country during the same benchmark year; and the policies proposed by various organizations concerned with international traffic.

The projections of the speeds of the United States-international links are presented in Exhibit 1-13 through 1-16. The following is a summary of these projections:

1. 1991: link speeds of the new 20 international links range from

EXHIBIT 1-13. 1991 Projected Link Speeds

U.S.-International Links

U.S. City	Foreign City/Country	Link Speed
Chicago, IL	Toronto, Canada	1.544 Mbps
Ithaca, NY	Montpellier, France	1.544 Mbps
	Cern, Switzerland	1.544 Mbps
Princeton, NJ	Bonn, Germany	1.544 Mbps
	Stockholm, Sweden	64 Kbps
	Rio De Janeiro, Brazil	64 Kbps
	La Serena, Chile	64 Kbps
	Singapore, Malaysia	9.6 Kbps
	Riyadh, Saudi Arabia	9.6 Kbps
Greenbelt, MD	Ottawa, Canada	1.544 Mbps
	Oxford, United Kingdom	1.544 Mbps
	Franscati, Italy	1.544 Mbps
	Amsterdam, Netherlands	64 Kbps
	Oslo, Norway	64 Kbps
Boulder, CO	Mexico City, Mexico	128 Kbps
Austin, TX	Monterrey, Mexico	9.6 Kbps
	San Juan, Puerto Rico	9.6 Kbps
Honolulu	Tokyo, Japan	1.544 Mbps
	Melbourne, Australia	64 Kbps
	Hamilton, New Zealand	64 Kbps

EXHIBIT 1-14. 1996 Projected Link Speeds

U.S.-International Links

U.S. City	Foreign City/Country	Link Speed
Chicago, IL	Toronto, Canada	45 Mbps
Ithaca, NY	Montpellier, France	45 Mbps
	Cern, Switzerland	45 Mbps
Princeton, NJ	Bonn, Germany	45 Mbps
	Stockholm, Sweden	45 Mbps
	Rio De Janeiro, Brazil	1.544 Mbps
	La Serena, Chile	1.544 Mbps
	Singapore, Malaysia	64 Kbps
	Riyadh, Saudi Arabia	64 Kbps
Greenbelt, MD	Ottawa, Canada	45 Mbps
	Oxford, United Kingdom	45 Mbps
	Franscati, Italy	45 Mbps
	Amsterdam, Netherlands	45 Mbps
	Oslo, Norway	45 Mbps
Boulder, CO	Mexico City, Mexico	1.544 Mbps
Austin, TX	Monterrey, Mexico	1.544 Mbps
	San Juan, Puerto Rico	64 Kbps
Honolulu	Tokyo, Japan	45 Mbps
	Melbourne, Australia	1.544 Mbps
	Hamilton, New Zealand	1.544 Mbps

EXHIBIT 1-15. 2000 Projected Link Speeds

U.S.-International Links

U.S. City	Foreign City/Country	Link Speed
Chicago, IL	Toronto, Canada	1 Gbps
Ithaca, NY	Montpellier, France	1 Gbps
	Cern, Switzerland	1 Gbps
Princeton, NJ	Bonn, Germany	1 Gbps
	Stockholm, Sweden	1 Gbps
	Rio De Janeiro, Brazil	45 Mbps
	La Serena, Chile	45 Mbps
	Singapore, Malaysia	1.544 Mbps
	Riyadh, Saudi Arabia	1.544 Mbps
Greenbelt, MD	Ottawa, Canada	1 Gbps
	Oxford, United Kingdom	1 Gbps
	Franscati, Italy	1 Gbps
	Amsterdam, Netherlands	1 Gbps
	Oslo, Norway	1 Gbps
Boulder, CO	Mexico City, Mexico	45 Mbps
Austin, TX	Monterrey, Mexico	45 Mbps
	San Juan, Puerto Rico	1.544 Mbps
Honolulu	Tokyo, Japan	1 Gbps
	Melbourne, Australia	45 Mbps
	Hamilton, New Zealand	45 Mbps

EXHIBIT 1-16. 2010 Projected Link Speeds

U.S.-International Links

U.S. City	Foreign City/Country	Link Speed
Chicago, IL	Toronto, Canada	5 Gbps
Ithaca, NY	Montpellier, France	5 Gbps
	Cern, Switzerland	5 Gbps
Princeton, NJ	Bonn, Germany	5 Gbps
	Stockholm, Sweden	5 Gbps
	Rio De Janeiro, Brazil	1 Gbps
	La Serena, Chile	1 Gbps
	Singapore, Malaysia	45 Mbps
	Riyadh, Saudi Arabia	45 Mbps
Greenbelt, MD	Ottawa, Canada	5 Gbps
	Oxford, United Kingdom	5 Gbps
	Franscati, Italy	5 Gbps
	Amsterdam, Netherlands	5 Gbps
	Oslo, Norway	5 Gbps
Boulder, CO	Mexico City, Mexico	1 Gbps
Austin, TX	Monterrey, Mexico	1 Gbps
	San Juan, Puerto Rico	45 Mbps
Honolulu	Tokyo, Japan	5 Gbps
	Melbourne, Australia	1 Gbps
	Hamilton, New Zealand	1 Gbps

9.6 Kbps to 1.544 Mbps; about 40 percent of these links are expected to operate at 1.544 Mbps, about 40 percent at 64/128 Kbps, and about 20 percent at 9.6 Kbps.

2. 1996: link speeds of the new 20 international links range from 64 Kbps to 45 Mbps; about 55 percent of these links are expected to operate at 45 Mbps, 30 percent at 1.544 Mbps, and 15 at 64 Kbps.
3. 2000: link speeds of the new 20 international links range from 1.544 Mbps to 1 Gbps; about 55 percent of these links are expected to operate at 1 Gbps, 30 percent at 45 Mbps, and 15 percent at 1.544 Mbps.
4. 2010: link speeds of the new 20 international links range from 1 Gbps to 5 Gbps; about 55 percent of these links are expected to operate at 5 Gbps, 30 percent at 1 Gbps, and 15 percent at 45 Mbps.

1.3.5 The Update Of The United States Research Networks.

The update of the United States research networks was described in terms of changes in the United States research networks and changes in NREN plans.

There have been very few unexpected changes in the United States Research Networks, since the completion of the previous study, that must be considered when describing the new current and future IRNs. The most important changes, those involving growth of the various networks, were anticipated. Examples of unanticipated changes included: one of the cities of a city pair was changed; a site was dropped; and a network with slower link speeds increased its backbone link speed from 56 Kbps to 1.544 Mbps several months earlier than anticipated.

Since the completion of the previous study, NREN plans have become more clearly delineated. The description of the NREN, in terms of its goal, objectives, benefits, access, services, network structure, management and funding, has been discussed and presented many times. The NREN implementation plans are being implemented on schedule. Connectivity expectations have been well specified, the NREN is in the second of three R&D stages, and the NREN testbed program is equally well planned. Finally, a number of recent federal agency, legislative and network development activities are directly impacting the NREN and are helping to clarify major NREN issues related to ubiquity, performance, funding and management.

In summary, there have been very few unexpected changes in the United States Research Networks, since the completion of the previous study, that must be considered when describing the new current and future IRNs.

1.3.6 The New Current And Future IRNs.

To describe the new current and future IRNs, the results of Tasks 1-4 were used to modify the original IRNs developed in the previous study. First, the impact, on the current and future IRNs, of unexpected changes in the United States research networks and in the NREN plans was assessed and summarized. Then, the current international research network traffic flow was incorporated in the description of the new current IRN. Lastly, and in a similar manner, the future international research network traffic flow was incorporated in the descriptions of the new future IRNs.

The update of the United States research networks and the NREN plans suggested that the original topology maps, developed in the previous study for the current and future IRNs, appropriately reflect expected domestic research network requirements. Therefore, it was concluded that these original topology maps could be used as they were presented in the previous study, along with information on the networks outside of the United States and on the United States-international links, to develop the new current and future IRNs. Hence, it followed that changes would be made in these original topology maps only if the information on the international networks and the United States-international links indicate changes were necessary.

The incorporation of the current international research network traffic flow in the description of the new current IRN, resulted in no change in the original current IRN domestic topology map, but suggested a need to consolidate and improve the performance of United States-international links (see Exhibit 1-17). Currently, there are some 77 links connecting the United States research networks to research networks in countries around the world. These links range from 9.6 Kbps to 1.544 Mbps, and they connect a T1 backbone in the United States to research networks taround the world that have link speeds ranging from 1.2 Kbps to 64 Kbps. Currently, there are no direct United States links to Africa.

Thus, the current integrated domestic United States research network has a backbone link speed that is higher than the backbone link speed of the various networks in other parts of the world. Also, it is higher than the typical link speed of links connecting the United States to other parts of the world. Therefore, it was concluded that the original current IRN topology map did not have to be altered to incorporate current international network requirements. Because there are a large number of international links, it was suggested that consolidating the international links would save money just as integrating the networks in the United States would save money.

In summary, the new current IRN topology map includes the following: the original current domestic topology map developed in the previous study; the 77 international links to six major areas of the world; and the range of the typical link speeds of the backbones of the research networks in the countries in the six major areas.

The incorporation of the future international research network traffic flows in the descriptions of the new future IRNs, resulted in no changes in the original future IRN domestic topology maps, but, as for the new current IRN, suggested a need to consolidate and improve the performance of United States-international links for each benchmark year.

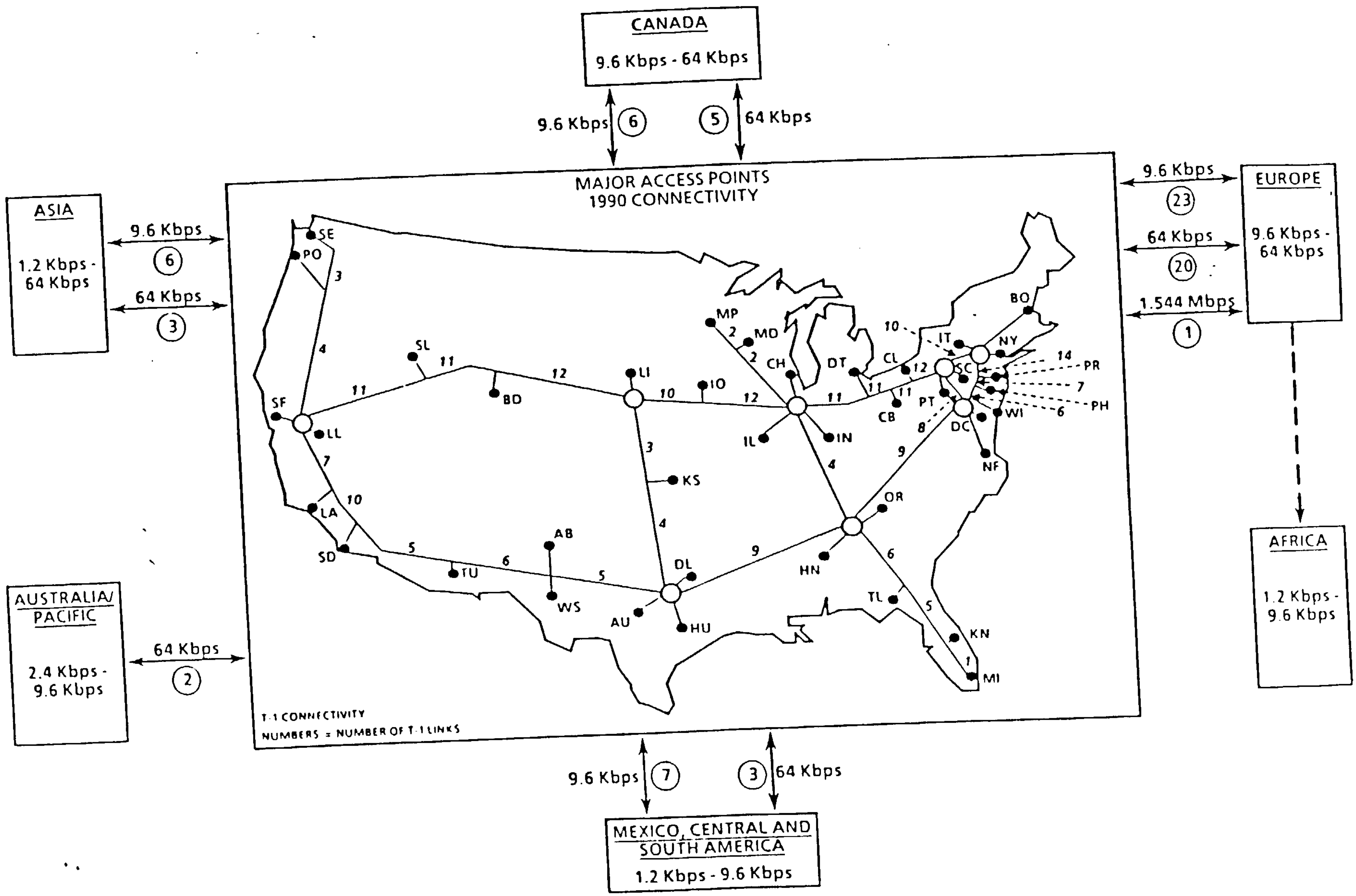

EXHIBIT 1-17. The Current (1990) U.S. Integrated Research Network With International Links.

A Consolidation of the United States-international links in 1991 resulted in only 10 links connecting the United States research networks to research networks in countries around the world (see Exhibit 1-18). In 1991, these links are all projected to be 1.544 Mbps links except for the two links to Mexico and Central/South America which are expected to be 128 Kbps links and one of the two links to Asia which is expected to be a 9.6 link. The ten links connect a T3/T1 backbone in the United States to research networks around the world that have link speeds ranging from 9.6 Kbps to 1.544 Mbps.

Thus, the 1991 United States research network has a backbone link speed that is still higher than the backbone link speed of the various networks in other parts of the world. Also, it is higher than the typical link speed of projected links for connecting the United States to other parts of the world. It was therefore concluded that the original 1991 topology map does not have to be altered to incorporate international research network requirements. However, it was also suggested that continual improvements are needed in the United States-international links to make certain the United States research networks have adequate connectivity with research networks around the world. These improvements were indicated by the increase, noted above, in the speeds of the United States-international links.

In summary, the new 1991 IRN topology map includes the following: the original 1991 domestic topology map developed in the previous study; the 10 1991 consolidated international links to six major areas of the world; and the range of the typical 1991 link speeds of the backbones of the research networks in the countries in the six major areas.

In 1996, only 10 links are projected (the same as projected for 1991) for connecting the United States research networks to research networks in countries around the world (see Exhibit 1-19). These links in 1996 are all projected to be 45 Mbps links except for two links to Mexico and Central/South America and one to Asia which are each expected to be 1.544 Mbps links. The ten links connect a

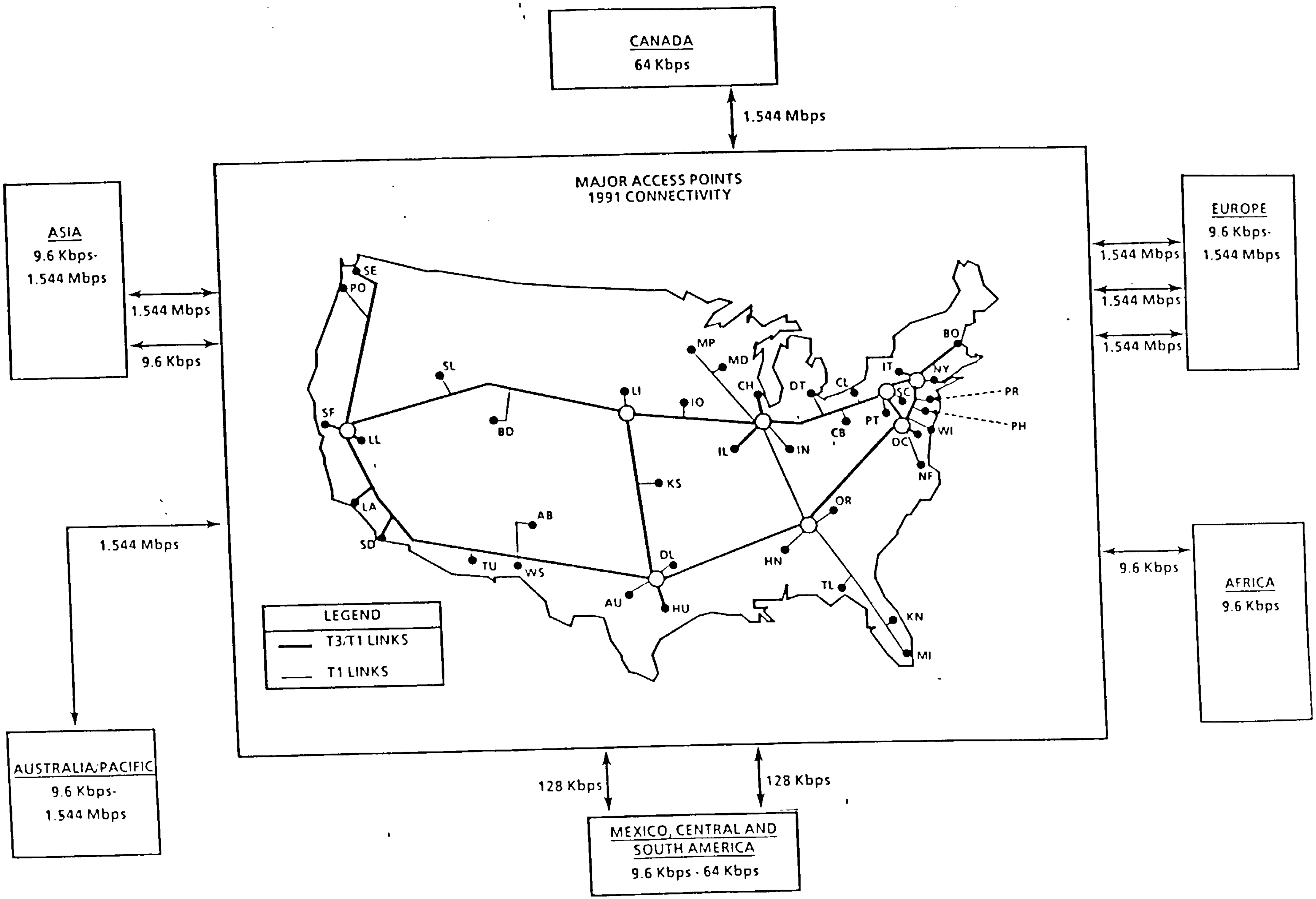

EXHIBIT 1-18. The 1991 U.S. Integrated Research Network With International Links

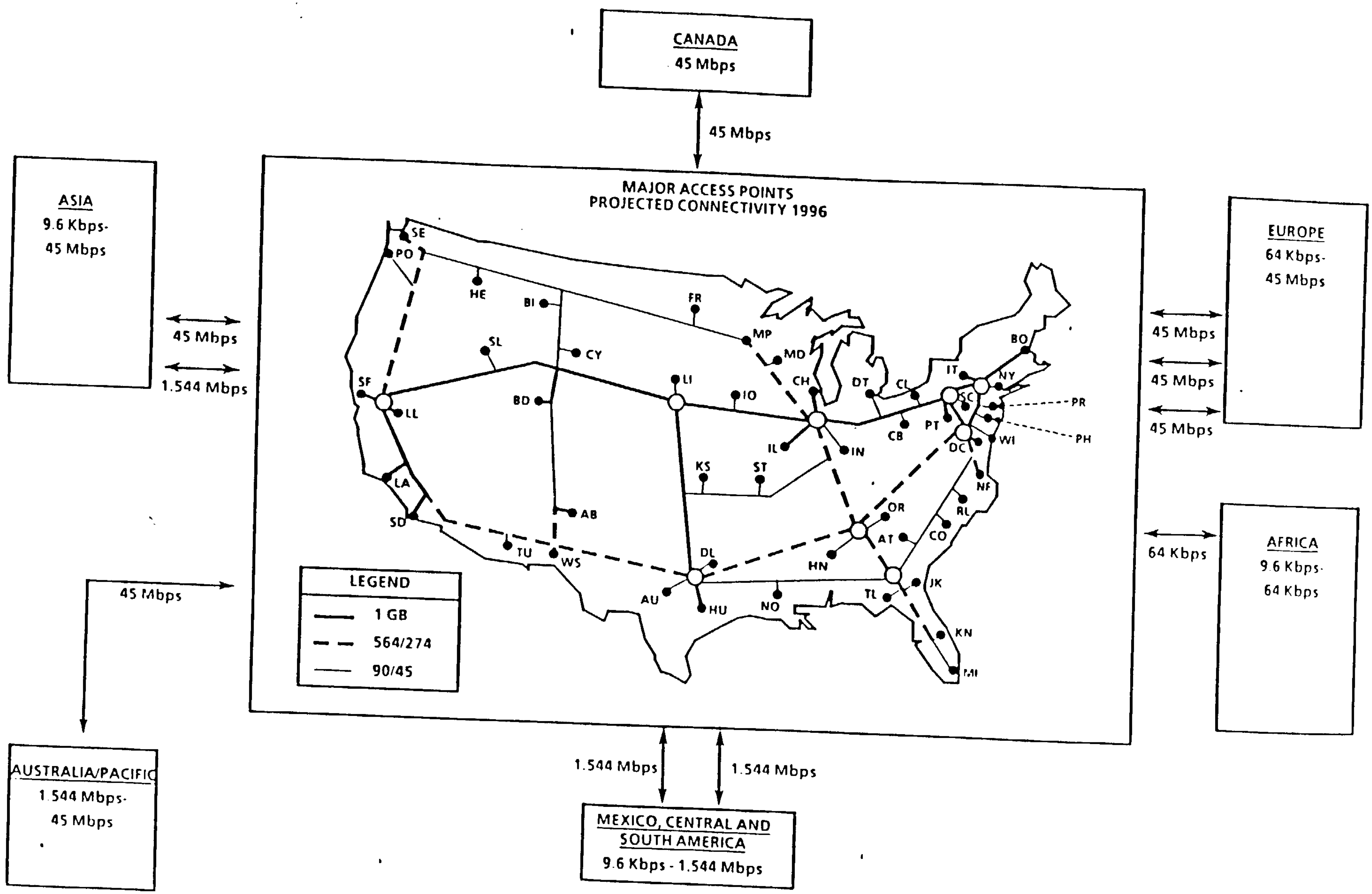

EXHIBIT 1-19. The 1996 U.S. Integrated Research Network With International Links

backbone, ranging in link speeds from 45 Mbps to 1 Gbps, in the United States to research networks around the world that have link speeds ranging from 9.6 Kbps to 45 Mbps.

Thus, the 1996 United States research network has a backbone link speed that is still higher than the backbone link speed of the various networks in other parts of the world. Also, it is higher than the typical link speed of links connecting the United States to other parts of the world. Therefore, as before for 1991, it was concluded that the original 1996 topology map does not have to be altered to incorporate international research network requirements. Again, however, it was also suggested that continual improvements are needed in the United States-international links to make certain the United States research networks have adequate connectivity with research networks around the world. And again, these improvements were indicated by the increase, noted above, in the speeds of the United States-international links.

In summary, the new 1996 IRN topology map includes the following: the original 1996 domestic topology map developed in the previous study; the 10 1996 consolidated international links to six major areas of the world; and the range of the typical 1996 link speeds of the backbones of the research networks in the countries in the six major areas.

In the year 2000, the same 10 links are projected for connecting the United States research networks to research networks in countries around the world (see Exhibit 1-20). However, these links in year 2000 are all projected to be 1 Gbps links except for two links to Mexico and Central/South America and one to Asia which are each expected to be 45 Mbps links. The ten links connect a backbone, ranging in link speeds from 272 Mbps to 5 Gbps, in the United States to research networks around the world that have link speeds ranging from 9.6 Kbps to 1 Gbps.

Thus, the 2000 United States research network has a backbone

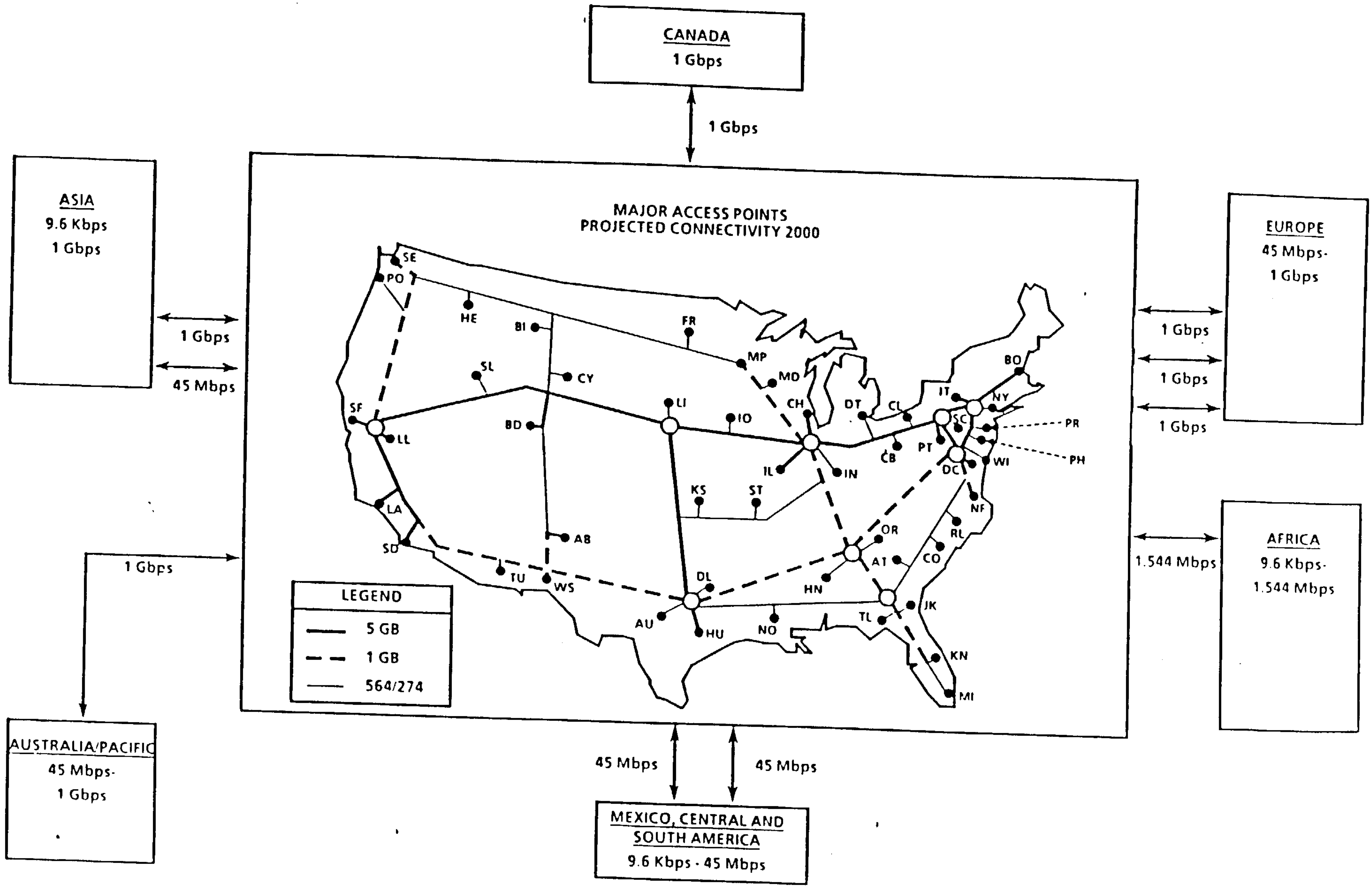

EXHIBIT 1-20. The Year 2000 U.S. Integrated Research Network With International Links.

link speed that is still higher than the backbone link speed of the various networks in other parts of the world. Also, it is higher than the typical link speed of links connecting the United States to other parts of the world. Therefore, as before for 1996, it was concluded that the original year 2000 topology map does not have to be altered to incorporate international research network requirements. Again, it was also suggested that continual improvements are needed in the United States-international links to make certain the United States research networks have adequate connectivity with research networks around the world. And again, these improvements were indicated by the increase, noted above, in the speeds of the United States-international links.

In summary, the new year 2000 IRN topology map includes the following: the original year 2000 domestic topology map developed in the previous study; the 10 consolidated international links to six major areas of the world; and the range of the typical year 2000 link speeds of the backbones of the research networks in the countries in the six major areas.

In year 2010, the same 10 links are projected for connecting the United States research networks to research networks in countries around the world (see Exhibit 1-21). As before, these links are expected to be operating at higher speeds. In year 2010 they are all projected to be 5 Gbps links except for two links to Mexico and Central/South America and one to Asia which are each expected to be 1 Gbps links. The ten links connect, in year 2010, a backbone, ranging in link speeds from 1 Gbps to 25 Gbps, in the United States to research networks around the world that have link speeds ranging from 64 Kbps to 5 Gbps.

Hence, the year 2010 United States research network has a backbone link speed that is still higher than the backbone link speed of the various networks in other parts of the world. Also, it is higher than the typical link speed of links connecting the United States to other parts of the world. Therefore, as before for year

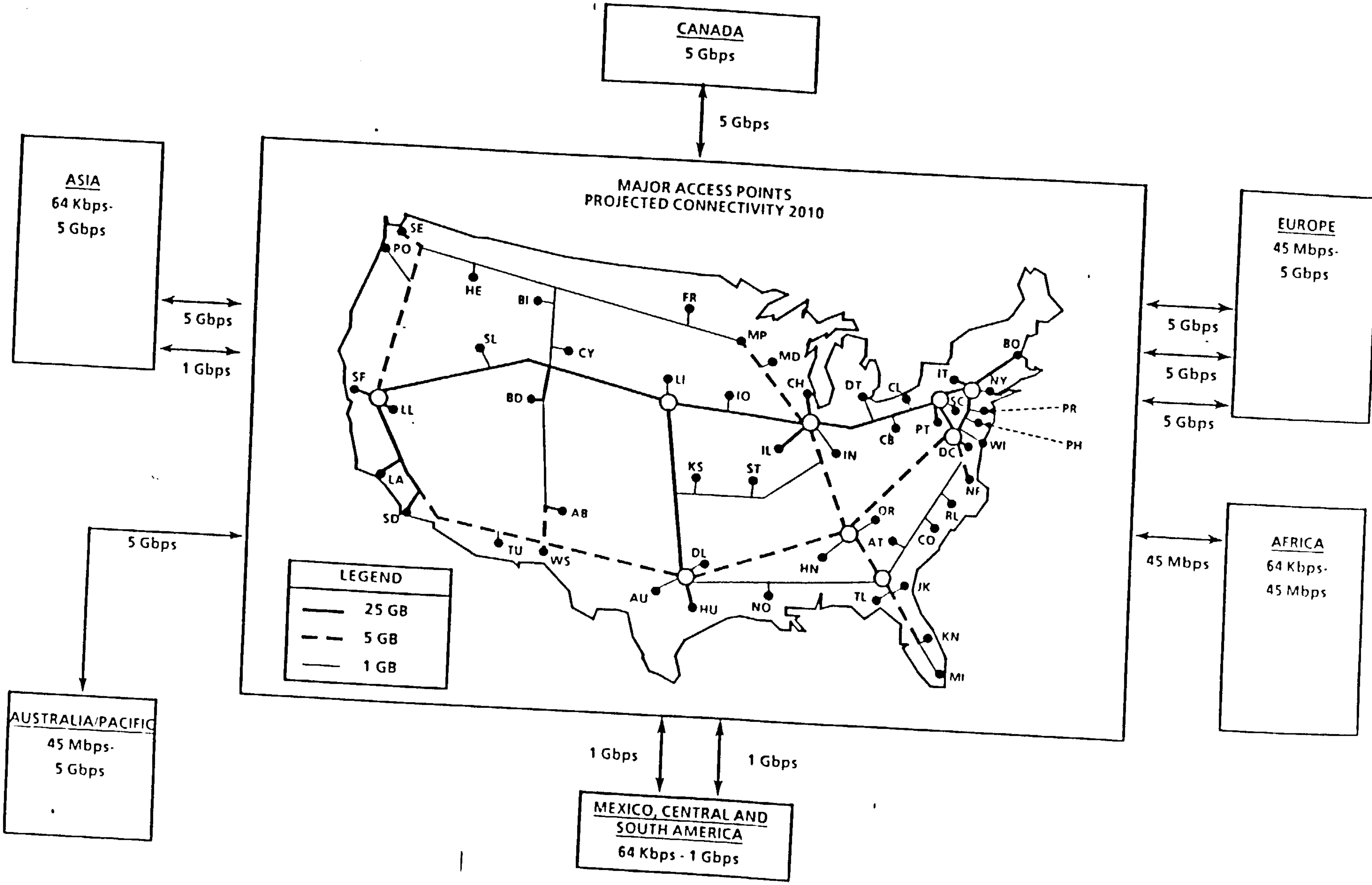

EXHIBIT 1-21. The 2010 U.S. Integrated Research Network With International Links.

2000, it was concluded that the original year 2010 topology map does not have to be altered to incorporate international research network requirements. Again, it was also suggested that continual improvements are needed in the United States-international links to make certain the United States research networks have adequate connectivity with research networks around the world. And again, these improvements were indicated by the increase, noted above, in the speeds of the United States-international links.

In summary, the new year 2010 IRN topology map includes the following: the original year 2010 domestic topology map developed in the previous study; the 10 consolidated international links to six major areas of the world; and the range of the typical year 2010 link speeds of the backbones of the research networks in the countries in the six major areas.

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 around the world 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.

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 follows:

1. Support the development of the NREN which will improve network performance and ubiquity for researchers and educatiors.

2. Support the consolidation of U.S.-international links, thereby increasing network performance and ubiquity worldwide.
3. Support the development of a worldwide research and education network (WREN), thereby improving research and education worldwide.
4. Support the further study of both policy and technical issues related to the implementing of the computer research initiatives already put forth by the White House and Congress.
5. Continue to examine its own computer research network requirements and to work to incorporate these needs in the development of the NREN.

SECTION 2

THE INTERNATIONAL RESEARCH NETWORK COMMUNITY

2.1 OVERVIEW

2.1.1 Purpose

In this section the international research network community is described. This description was developed so that the major research networks, which are outside the United States and with which the United States research networks have or may have requirements to interface, could be selected. Included in this desciption of the international research network community are three major summaries or outlines: a summary of the history of the development of the international research networks; a summary of the major organizations involved in the development and coordination of these networks; an outline of all the significant research networks outside the United States, and a summary of the gateways in the United States.

2.1.2 Approach

The development of the description of the international research network community began with an initial review of the literature on international research networks. Selected books, articles and reports were reviewed to obtain information on the history, development and operation of such networks. This initial review helped structure interviews with leaders in the development of United States research networks. From the initial review and the interviews, preliminary information on international networks was developed, and contacts were identified. These new contacts were telephoned, and additional information on international research networks was obtained.

This information was aggregated and analyzed, and provides the basis for describing the international research network community.

2.2 HISTORY OF INTERNATIONAL RESEARCH NETWORK COMMUNITY

The history of the development of research networks outside the United States is summarized in this section. First, the similarity of the development of research networks in the United States with that in other countries is noted. Next, the similarity of the United States development with that taking place on a multi-nation or worldwide basis is discussed. Then, an overview of the early network development in countries, which today are leaders in research networking, is presented.

2.2.1 Network Development: United States & Other Countries

Many of the events that occurred in the development of research networks in the United States, have occurred or are occurring in the development of research networks outside the United States. In some countries, the events occurred in the same time frame as in the United States; in other cases, the events just now are taking place.

For example, some countries have sponsored experimental networks, like ARPANET, whose initial purpose was to develop networking technology, but whose development and use led to the development of much larger general purpose research networks. In some cases, this sponsorship occurred about the same time as the ARPANET sponsorship in the United States, while in other countries such sponsorship is still in the planning stages.

Another example of the similarity in the development of research networks in the United States and in other countries pertains to the initial selling of the value of such networks. All countries have worked to convince, or are in the process of trying to convince, potential sponsors and users of the immediate and long-range value of developing research networks.

Also, in some countries the proliferation of small networks followed by the need to consolidate networks has mirrored events in the United States. Once interest and need were obvious, networks developed to meet researchers' needs in a geographically limited area merged with and overlapped other networks. These events, as in the United States, were stimulated by major technological advances and funding concerns, all of which lead to the need to consolidate research networks for reasons related to efficiency and effectiveness.

The same policy and technological issues faced in the United States also have been, or are being, faced in other countries. As examples, issues related to access, coordination, funding, and standards have been problems for users and managers in other countries just as they have been in the United States. While the issues often have been similar, the responses and approaches to resolving the issues have varied by country. The differences in approaches have resulted partly because of cultural differences and partly because the approaches were implemented at different times; that is, approaches often reflected available technological capabilities and understanding.

2.2.2 Network Development: United States & Worldwide Efforts

The development process that was begun at the country level (e.g., as in the United States or the United Kingdom), is now being repeated at the continent level (e.g., Europe) and the worldwide level. The following discussion includes an example of the similarities of the United States network development process with those of continent-wide or worldwide efforts.

In the United States, for example, networks have expanded and links to other networks have been established as the needs arose. Likewise, networks within a continent, for example Europe, and on different continents (e.g., the United States and Europe) have established interconnectivity as the needs arose. In both cases, what has resulted frequently is a multiplicity of low speed links, which are too expensive. Again, in both cases, the corrective action taken often has been to work towards consolidation.

These actions have led or are leading to nationwide, continent-wide and worldwide networks. Of particular interest for this study, is the similarity between the development of a nationwide backbone to link regional networks in a nation and the development, currently being discussed, of a worldwide backbone to connect nationwide networks. The intent in both cases is to improve services and reduce costs. In the later case, a nation's national research network, e.g., the NREN in the United States, would become a "regional" network in a worldwide network.

2.2.3 Examples Of Early Network Development

The network development in five countries (excluding the United States) which are leaders in research network development is discussed in this section. These countries are: the United Kingdom, France, Germany, Canada and Japan. Just as the ARPANET has been the forerunner of research networks in the United States, similar experimental research networks have been the forerunners of research networks in the first four countries listed above, and have led to the planning and development of national research networks. In the case of Japan, its current nationwide research network has the dual purposes of networking research and support for other research, but its earlier networks were designed only for other research.

2.2.3.1 The United Kingdom

The United Kingdom conducted some of the early work in experimental networks and now has a nationwide research network. One of the earliest packet switching networks was implemented at the National Physical Laboratory (NPL) in the United Kingdom in 1968, when the ARPANET was built. An international connection was established to CYCLADES in 1974 (See discussion below, on France, for description of CYCLADES).

Initial planning for the Science and Engineering Research Council Network (SERCnet), the country's first major network for supporting other research, actually began back in 1966. This network progressed through several developmental phases with several names during the late 1960's and early 1970's and was established as a research network, named SERCnet, in 1977. SERCnet, jast as NSFNET in the United States, was designed to connect regional computer centers.

A national research network, JANET (for Joint Academic Network), was formed in 1982, and SERCnet was integrated into JANET in 1984. Networks of other major national organizations (e.g., the Natural Environment Research Council) also merged with JANET. Because there was a single ultimate source of funding (i.e., the Department of Education and Science) for all of these early networks, the merging of all the networksdid not present much of a problem. This consolidation has led to increased connectivity, new services and reduced overall costs.

2.2.3.2 France

In France, the CYCLADES network, implemented in the early 1970s, was designed to serve as a research network as well as a platform for supporting other research. CYCLADES, similar in many ways to the earlier ARPANET in the United States, was coordinated by what is now called the National Research Institute for Computer Science and Automation. The network became operational in 1973, grew slowly through the 1970's because of budget constraints, underwent developmental changes, and established some international links. CYCLADES was phased out in 1981. This network, did, however, have a significant impact in France and internationally, on the development of network technology (e.g., the ISO-OSI model).

Two other French networks, developed relatively early, were RPC for Reseau Communication par Paquet and COSAC for Communications Sans Connections. RPC played a major role in the evolution of X.25, and research was conducted on COSAC during the mid 1980s.

As with the United Kingdom, these early networks efforts have led to the development of more advance research networks in France like REUNIR which is an acronym for Reseau des Universities et de la Recherche.

2.2.3.3 Germany (the Federal Republic of Germany)

Germany has contributed significantly to network development. One of its earlier networks, the Hahn-Meitner Institut (HMI) Network (HMI-NET) was established in Berlin during the mid to late 1970's. HMI-NET, is similar to CYCLADES and ARPANET in that it has been an experimental network and has contributed to the development of a community of network experts. HMI-NET also has contributed directly to the development of Germany's research networks, BERNET (a regional research network) and DFN (Deutsches Forchungsnetz), Germany's national research network. In fact, one of the early developers of HMI-NET has recently proposed a continent-wide fiber optic network with speeds of 100 Mbps and more.

2.2.3.4 Canada

One of Canada's earliest networks, the Defense Research Establishment Network (DREnet), also began as an ARPANET-like network. DREnet was begun in 1983 to link Defense Research Establishments in Ottawa, Ontario and Nova Scotia. Like the ARPANET, the DREnet is scheduled to be replaced by a more advanced network, the XDRENET.

As in the United States, other networks, like CDNnet and NetNorth, were designed to support a variety of research, education and development activities. Currently, the Canadian National

Research Council is developing a national research network, similar to the NSFNET (like NSFNET, it will have three levels: a backbone, mid-level regionals and campus networks), that will integrate all networks that support research activities. The network is called CA'net (for Canadian Network).

2.2.3.5 Japan

There was not much networking activity in Japan until the privatization of Nippon Telegraph and Telephone (NIT) and the corresponding deregulation of the public telephone system in 1985. Since then, networking activity in Japan has increased significantly. Today, there are a wide variety of networks in Japan, and many of the international networks (e.g., BITNET, CSNET, UUNET, HEPNET) reach Japan.

The oldest major network in Japan is N-1 which was started in 1981 as an interuniversity network. The National Center for Science Information Systems (NACSIS) Network, established in 1987, is the likely successor to N-1. Today NACSIS connects Inter-University Computing Centers throughout the main Japanese islands and gives researchers access to a wide range of computing facilities including supercomputers.

The major nationwide research network in Japan is JUNET which was begun in 1984. This network's purpose is to promote information exchange among Japanese researchers and with researchers outside Japan. It also provides a test environment for research in networking.

Also, the Japanese government is encouraging implementation of campus networks and is funding two new high-speed international links to the United States and Europe. These links are being developed in cooperation with the United States National Science Foundation, and are expected to be operational in the early 1990s.

2.3 MAJOR INTERNATIONAL ORGANIZATIONS

A number of internationl groups have been organized to recommed guidelines for planning, coordinating, and standardizing international networking activities. A brief discussion of a sample of such groups will help provide a perspective on some of the forces that will directly impact the international network research community.

2.3.1 Coordinating Committee For Intercontinental Research Networking

One of the most important organizations that provides guidance for international research network activity is the Coordinating Committee For Intercontinental Research Networking (CCIRN). The CCIRN, which was initially known as the Necessary Ad Hoc Coordinating Committee (NACC), was established in 1987 and held its first meeting in the Spring of 1988.

The purpose of the CCIRN is to facilitate the development of interoperable networking services between pariticipating entities to support open research and scholarly pursuit. It discusses policy, management and technical issues and aims to:

1. Stimulate cooperative intercontinental research by promoting enhanced interoperable networking services.
2. Optimize use of resources and coordinate international connections of the networks represented on the CCIRN.
3. Promote the evolution of an open international research network.
4. Coordinate development of international network management techniques.
5. Exchange results of networking research and development.

The CCIRN members represent organizations with an active interest in developing a worldwide network with the aims noted above. Initially, members were from the United States and Europe. Membership now includes Canada, and invitations have been given to other nations, like Australia and Japan. It is hoped that all nations interested in the aims noted above will eventually join. Examples of the types of organizations represented on the CCIRN are the following: United States---Federal Networking Council (FNC) which has replaced the Federal Research Internet Coordinating Committee (FRICC), Internet Activity Board and CSNET/BITNET; Europe---the Reseaux Associes pour la Recherche Europeenne (RARE), (see description below); Canada--- National Research Council. The CCIRN has two chairs: the chair of the FNC and the secretary General of RARE.

There are a number of groups that have been formed at the continent and nation level and that provide representation on the CCIRN. There is a North American CCIRN (NACCIRN) which includes the United States and Canada. Other nations are being asked to join NACCIRN. In the United States, the NACCIRN provides representation on the CCIRN. In Canada, a Canadian Coordinating Committee on Research Networking (CCCRN) has been established, includes represntatives of the national networks, and provides representation on the CCIRN and the NACCIRN. There also is a EUROCCIRN which corrdinates European networking needs and provides representation on the CCIRN.

2.3.2 Other Worldwide Organizations

Three other important worldwide bodies are the International Standards Organization (ISO), the International Electrotechnical Commission (IEC), and the International Consultative Committee for Telephony and Telegraphy (CCITT).

The ISO is the main international organization that handles networking issues and is composed of national standards bodies of 89 member countries. The IEC is composed of technical experts and pursues activities complimentary to those of the ISO. The IEC handles electrical and electronic standards and the ISO handles everything else.

The United Nations has several agencies that affect networking standards. The most notable is the CCITT. The CCITT is closely associated with the national telephone companies and develops specifications of networking protocols and related standards.

2.3.3 United States Organizations

There are several groups in the United States which are working on coordinating United States/International connections. These include the United States Internet Activities Board (IAB) and the FNC Engineering Planning Group (FEPG).

The IAB, recently reorganized, is responsible for Internet policy, standards, liaison, and facilities. The Internet Engineering Task Force (IETF) reports to the IAB and is responsible for host based services, Internet based services, network management, OSI interoperability, routing and user services. The Internet Research Task Force (IRTF) also reports to the IAB and is responsible for coordinating various network research activities. The IAB has liaison activities with, e.g., the FNC, the CCIRN, and RARE (discussed below).

The FNC Engineering Planning Group (FEPG) was set up to assist the FNC in translating its policy goals into implementable technical programs. It currently is developing a policy for United States international connections.

2.3.4 European Organizations

Three major European organizations concerned with international connectivity are the European Conference of Postal and Telecommunications Administrations, the CEPT, the International Collaboration Board (ICB), and the Reseaux Associes pour la Recherche Europeenne (RARE).

The CEPT is the European equivalent of the CCITT. Many of the individuals who belong to the CCIRN also belong to the ICB. The ICB is a European group that has been concerned primarily with the planning of a worldwide backbone.

RARE, is an association of European research network managers and users. Its purpose is to promote network services, with a special emphasis on international connectivity, for the research community in European countries. RARE is a membership organization funded by dues from its national members. There are a number of memberships types. For example, full national members are national academic and research network organizations (one per country).

Recently, talks were held between RARE and managers of the existing European continental networks EARN, EUnet, and HEPnet about the use of a common infrastructure. The networks and RARE agreed in principle, but there was some disagreement with the PTTs about charging. Also, these networks do not use the ISO-OSI protocols and make significant use of leased lines rather than the PTT Public Data Networks (PDNs). Consequently, it is uncertain whether these networks will be replaced by a new ISO-OSI network or be converted to become a part of it. Also, RARE considers interconnection with the United States a problem, because NSFNET uses TCP/IP protocol, and RARE considers TCP/IP to be a short-term solution to protocols for high-speed networks.

2.3.5 Other Nations - Japan As An Example

Most other nations involved in developing research networks also have coordinating and planning bodies. While these vary from country to country, a brief discussion of one country will help provide a perspective on other such national coordinating bodies.

In Japan, the Ministry of Posts and Telecommunications (MPT) oversees all telecommunications policy in Japan and performs many of the functions performed by the FRICC and the FCC in the United States. Also in Japan, the Interoperability Technology Association for Information Processing (INTAP) is a nonprofit research and development group established by the Ministry of International Trade and Industry to promote the development of interoperability technology for information processing. For example, the INTAP is interested in implementing ISO-OSI protocols and standards.

2.4 OVERVIEW OF RESEARCH NETWORKS

As noted, in the discussion of the history of international research networks outside of the United States, there are a wide variety of research networks throughout the world. Also, the various nations are at different stages in the development of such networks. A few already have nationwide research networks, while many are just beginning to develop their first research network. In this section, the status of research networks and a list of current research networks are presented. For this purpose, networks are categorized into seven categories depending upon the geographical extent of the network (See Exhibit 2-1).

The nations in each category are listed, if they have a research network that is more than a host on one of the worldwide or continent-wide networks. If a nation is not listed below, it is noted in the discussion of status of research networks in the area. The category, "North America" does not include the United States; the research networks in the United States were documented in a previous study (U.S. Research Networks, Current & Future. NASA Study Contract NAS3-25083, Task Order 2, December, 1989). This previous study will be referred to, throughout this report, and, when it is referred to, it will be called the U.S. Domestic Research Network Study.

The international research networks (i.e., the research networks not in the United States) are listed below. This list was used to identify the significant research networks that are described in Section 3.

2.4.1 Worldwide Networks

There are a number of networks whose funding and administration is decentralized, whose connections are worldwide, and whose purpose includes facilitating research. These networks are:

BITNET

CSNET

EXHIBIT 2-1. Network Categories

Network Category	Geographical Scope
Worldwide	Multi-Continent
North America	Canada. Mexico
Europe	Continent-wide; Multi-nation; France, Germany and United Kingdom; Austria, Denmark, Finland, Greece, Ireland, Italy, Netherlands, Norway, Soviet Union, Spain, Sweden; Switzerland; Yugoslavia.
Asia	Multi-nation; Japan; India, Indonesia, Israel, Hong Kong, Korea, Malaysia, Thailand.
Australia/Pacific	Multi-nation; Australia, New Zealand.
Central & South America	Multi-nation.
Africa	Multi-nation; Egypt, Tunisia.

USENET
UUCP Network.
UUNET
FIDONET

2.4.2 North America

2.4.2.1 Canada

As noted in the section on history of international research network development, Canada has a number of national and regional research networks. They are:

AHEN (Alberta Higher Education Network)
BCnet (British Columbia Network)
CDNnet (Canada Network)
CRIM (Computer Research Institute of Montreal) Network
DREnet (Defense Research Establishment Network)
NetNorth
CA'net (Canadian Research Network)
Onet (Ontario Network)

2.4.2.2 Mexico

Mexico has been developing two major networks and is planning to join the NACCIRN. These two networks are:

ITESM (Instituto de Estudioe Superiores de Monterrey) Network
UNAM Network (National University of Mexico Network)

2.4.3 Europe

There are several widely used networks or associations that have served the continent of Europe. Five examples are listed below under continent-wide networks. Another network, the European Informatics Network (EIN) was a mid-1970s attempt to provide a continental research network in Europe; it no longer exists. There also are examples of networks that serve several nations.

Many nations in Europe do not have their own research networks. Iceland, Luxemberg and Portugal only have hosts on EUnet, and Turkey only has a host on EARN. There have been very few network connections to the Soviet Union or the Eastern European countries. Also, these countries, except for the Soviet Union, don't tend to have their own networks. Bulgaria, Czechoslovakia, the Democratic Republic of Germany, Hungary and Poland all have connections to the multi-nation network, IASnet. There are no known systems in Albania or Romania. The following is a list of the research networks in Europe.

2.4.3.1 Continent-Wide Networks

Ean Europe

EARN (European Academic Research Network)

EUnet (European UNIX Network)

HEPNET Europe

RIPE (Reseau IP Europeen) Network

2.4.3.2 Multi-Nation Networks

NORDUnet (for Nordic countries)

IASnet (for Socialist countries)

2.4.3.3 France

ARISTOTE(Means: Association of Information Networks in a Completely Open and Very Elaborate System)

CYCLADES

FNET (French Nertwork)

PHYNET (Physicists Network)

REUNIR (Networks of Universities & Research)

RPC (Reseau Communication par Paquet) Network

SMARTIX

2.4.3.4 Germany

AGFNET (Association of National Research Centers Network)

BELWU (In Baden-Wurttemberg)

BERNET (Berlin Network)

DFN Network (Deutsches Forschungs Netz Network)

HMI-NET (Hahn-Meitner Institute Network)

2.4.3.5 United Kingdom

JANET (Joint Academic Network)

NPL Network (National Physical Laboratory Network)

SERCnet (Science and Engineering Research Council Network)

Starlink Network

UKnet (United Kingdom UNIX Network)

2.4.3.6 Austria

ACONET (Academic Computer Network)

2.4.3.7 Denmark

DENet (Danish Ethernet Network)

DKNet (Denmark Network)

2.4.3.8 Finland

FUNET (Finish University Network)

2.4.3.9 Greece

ADRIADNE

2.4.3.10 Ireland

HEANET (Higher Education Authority Network)

EuroKom

2.4.3.11 Italy

INFNET (Instituto Nazionale Fisica Nucleare Network)

2.4.3.12 Netherlands

SURFnet

2.4.3.13 Norway

UNINETT

2.4.3.14 Soviet Union

Academnet

Adonis

ANAS (Administrative Network of Academy of Sciences)

2.4.3.15 Spain

Enet

Ean

2.4.3.16 Sweden

SUNET (Swedish University Network)

2.4.3.17 Switzerland

SWITCH

2.4.3.18 Yugoslavia

SIS (Social Information System) Network

2.4.4 Asia

In addition to the three multi-nation networks and the networks in Japan and Korea, there are only modest networks in Hong Kong, India, Indonesia, Israel, Malaysia and Thailand. The other countries either have only connections to worldwide or multi-nation networks or no system at all.

The People's Republic of China has several connections to the rest of the world: a CSNET link to West Germany; a UUCP link to HARNET in Hong Kong; a 1200 bps link to Vienna, Austria. Singapore got the first BITNET node in Southeast Asia. Taiwan, the Republic of China, has connections to both BITNET and PACNET. There appears to be AUSEAnet connections in the Philippines and in Sri Lanka. Cyprus is an EARN member. Mongolia has a connection to IASnet. There are PDNs in Bahrain, Iraq, Qatar, Saudi Arabia and United Arab Emirates. There are CGNET (see Africa below) subscribers in Bandladesh, Nepal and Sri Lanka.

There are no known systems in Brunei, Cambodia, the Democratic People's Republic of Korea, Democratic Yemen, Iran, Jordan, Laos, Lebanon, Myanmar, Oman, Syria, Vietnam, or Yemen.

2.4.4.1 Multi-Nation Networks

AUSEnet (Association of South East Asian Nations Network)
GULFNET (Kuwait & Saudi Arabia)
PACNET (Pacific and Asian Academic Network)

2.4.4.2 Japan

JUNET
Kogaku-bu LAN
NACSIS (National Center for Science Information Systems) Network
N-1
Sigma

2.4.4.3 Hong Kong

HARNET (Hong Kong Academic and Research Network)

2.4.4.4 India

NICNET (National Informatics Centre Network)
ERNET (Education & Research Network)

2.4.4.5 Indonesia

UNInet

2.4.4.6 Israel

ILAN (Israeli Academic Network)

2.4.4.7 Korea

KREONet (Korea Research Environment Open Network)
SDN (System Development Network)

2.4.4.8 Malaysia

RangKom (Rangkaian Komputer Malaysia)

2.4.4.9 Thailand

TCSnet (Thai Computer Science Network)

2.4.5 Australia/Pacific

There are two multi-nation networks in this area, and both Australia and New Zealand have important research networks.

2.4.5.1 Multi-Nation Networks

PACCOM (Pacific regional network)
SPEARNET (South Pacific Educational & Research Network)

2.4.5.2 Australia

AARNET (Australian Academic & Research Network)
ABN (Australian Bibliographic Network)
ACSnet
QTInet (Queensland Tertiary Institution Network)
VICNET (Victorian colleges network)

2.4.5.3 New Zealand

DSIRnet (Dept. of Scientific & Industrial Research Network)

2.4.6. Central & South America

The situation in Central and South America is similar to that in Asia (especially Southeast Asia). There is a growing interest in networking, but there are few operating networks. In this area, there are two multi-nation networks, and links to other networks.

Puerto Rico has an active local branch of FidoNet called RED. The Center for Population and Family Health (at Columbia University) uses a Kermit connection to reach Haiti. There is a connection to IASnet in Cuba. There is a BITNET node in both Argentina and Chile. Brazil is planning to create an academic network to connect research centers in universities and industry and government laboratories. There are no known networks in Belize, Bolivia, Colombia, Ecuador, French Guiana, Guyana, Paraguay, Peru, Surinam, Uruguay, or Venezuela.

2.4.6.1 Multi-Nation Networks

CARINET (Development Network)

CATIENET(Tropical Agricultural Research & Training Center Network)

2.4.7 Africa

There are very few major networks in Africa. There is one multi-nation network, and Egypt and Tunisia each has one main network.

Ethiopia, the Ivory Coast, Mali, and Niger each have connections to CGNET. Algeria, the Ivory Coast, and Morocco each has an EARN connection. Senegal has a packet radio network. Kenya is setting up a PeaceNet type network. South Africa apparently has internal networks, but external connections are few, as requests to connect to major worldwide networks (e.g., EARN and BITNET) have been turned down. There are no known networks in Cameroon, Libya or Nigeria.

2.4.7.1 Multi-Nation Network

CGNET (Consultative Group Network)

2.4.7.2 Egypt

ENSTINET(Egyptian National Science and Technology Information Network)

2.4.7.3 Tunisia

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2.5 UNITED STATES GATEWAYS

The United States terrestrial and satellite international gateways are summarized briefly in this section. This information is presented here to provide a perspective for understanding subsequent discussions of United States-international network links and international connectivity requirements.

2.5.1 Cable - Terrestrial Gateways

The cable systems listed below are those that currently are active and that land on the U.S. mainland. If a system is fiber, fiber is written in parentheses after the sytem's name. New fiber systems are either being planned or are under construction in both the Pacific and the Atlantic oceans.

SYSTEM	U.S. LANDFALL
TAT5	Greenhill, RI
TAT6	Greenhill, RI
TAT7	Tuckerton, NJ
TAT8 (Fiber)	Tuckerton, NJ
TAT9 (Fiber)	Manahawkin, NJ (Oct.,1991)
St. Thomas 2	Jacksonville Beach, FL
St. Thomas 3	Vero Beach, FL
Florida-Bahamas	West Palm Beach, FL
TCS1	West Palm Beach, FL
HAW2	San Luis Obispo, CA
HAW3	San Luis Obispo, CA
HAW4	Pt. Arena, CA
PTAT (Fiber)	Mansaquan, NJ
TPacific 4	Pt. Arena, CA
TPC 3	Makaha, HA

2.5.2 Satellite Gateways

There are an estimated 118 United States international earth stations. About 50 percent of these are located on the East Coast, about 30 percent on the West Coast, and the remainder throughout the United States. The purposes of these earth stations include: general purpose international, international business service, international data records, and non-standard general purpose. The uplink and downlink frequencies of these earth stations are 6/4 GHz and 14/11 GHz.

2.6 SUMMARY

The history of the international research network community is similar, in many ways, to the history of research networks in the United States. At the country level, some nations have sponsored experimental networks like the ARPANET in the United States, most nations have had to work to sell the value of research networks, and all are facing similar policy and technological issues. At both the country and the international level, a variety of networks have been developed, inter-network links have been established as the need arose, and the need to consolidate and coordinate efforts has resulted.

A number of organizations have been formed to recommend and to implement guidelines for planning, coordinating, and standardizing international networking activities. The most important organizations are: CCIRN, ISO, CCITT, IAB, FRICC FEPG, ICB and RARE. The general purposes of all of these organizations are to improve services, increase connectivity, and reduce costs related to developing and maintaining research networks throughout the world.

In this description of the international research network community, networks were identified for the following areas: Worldwide, North America, Europe, Asia, Australia/Pacific, Central and South America and Africa. There are a wide variety of research networks throughout these areas. Also, the various nations are at different stages in the development of such networks. A few already have nationwide research networks, while many are just beginning to develop their first research network. Also, a good number of countries have little or no networking activity.

About 80 potentially significant research networks were identified throughout the world. About three-fourths of these are national networks, and about one-fourth are multi-nation, continent-wide or worldwide networks. The most advance networks, as expected, are in the more advance industrialized countries, e.g., Canada, France, Germany, Japan and the United Kingdom. Asia, Central and South America and Africa are far behind in network development, but interest is growing in these areas.

The United States terrestrial and satellite international gateways were summarized briefly to provide a perspective for understanding subsequent discussions of United States-international network links and international connectivity requirements. Some twelve cable systems and 118 earth stations were noted.

This information on the international research network community was used to select and describe research networks outside the United States and to determine United States requirements for connectivity with these networks. These descriptions and requirements are presented in the following sections.

SECTION 3

DESCRIPTION OF SELECTED INTERNATIONAL RESEARCH NETWORKS

3.1 OVERVIEW

3.1.1 Purpose

In this Section, many of the international research networks, identified in Section 2, are selected and described. The intent is to present a picture of the level of research network development around the world, so that the current and future levels of United States/International research network traffic flow can be estimated. The descriptions of the selected international research networks, along with information from managers of United States research networks and from other leaders in the field, will be used to identify current United States/international links. The identification of these links, along with current and future estimates of the topologies of the international networks, in turn, will be used to estimate current and future United States-international traffic flow. This section includes a brief summary of the approach used to select the international research networks and the descriptions of the individual networks.

3.1.2 Approach

To accomplish the aforementioned purpose, the completion of two major activities was required: selecting the networks and then describing the networks. The selection process is explained in the next sub-section. Once the international networks were selected, describing them involved collecting additional information, drafting summaries of network information, and reviewing and modifying the summary descriptions. Information on the selected international networks was collected through interviews and telephone calls with research network leaders and managers.

A-2

3.2 SELECTION OF INTERNATIONAL RESEARCH NETWORKS

3.2.1 Selection Criteria

Since the major intent was to present a picture of the level of research network development around the world, a comprehensive picture of a wide variety of network efforts had to be developed. Therefore, the criteria used to select the international research networks, had to result in the selection of networks that varied on such elements as size (i.e., extent of coverage), link speed, and connectivity. Consequently, a network was selected if information on the network was available and if it met one or more of the following criteria:

1. It is a major worldwide network.
2. It is a major multi-nation network.
3. It is the only multi-nation network serving a region of the world.
4. It is a major national network.
5. It is the only national network for a country.
6. Within a nation, it is an advanced regional (in contrast to nationwide) network.
7. Within a nation, or among nations, it is, or was, an important experimental network.
8. It has an international link with the United States.

3.2.2 List Of Networks Selected

The application of the criteria listed above resulted in the selection of most of the networks identified in Section 2. These networks are listed in Exhibit 3.1. The selected networks represent the following seven areas of the world: Worldwide, North America, Europe, Asia, Australia/Pacific, Central and South America, and Africa. A total of eighty-four international research networks are described on the following pages. The descriptions are presented by area of the world, starting with Worldwide networks. Information on these eighty-four networks is summarized at the end of Section 3.

EXHIBIT 3-1. International Research Networks

Location	Network
WORLDWIDE	BITNET CSNET USENET UUCP UUNET FIDONET
NORTH AMERICA (U.S. not included)	
CANADA	DREnet CDNnet NetNorth CA'net AHEN BCnet CRIM Onet
MEXICO	ITESM UNAM
EUROPE	
CONTINENT-WIDE	EUnet EARN HEPnet Ean RIPE
MULTI-NATION	IASnet NORDUnet
FRANCE	CYCLADES FNET ARISTOTE SMARTIX PHYNET REUNIR
GERMANY	HMI-NET DFN AGFNET BERNET BELWU
UNITED KINGDOM	NPL SERCnet JANET Starlink UKnet
OTHER EUROPE	
AUSTRIA	ACONET

EXHIBIT 3-1. International Research Networks
(Continued)

Location	Network
DENMARK	DENet
FINLAND	FUNET
ICELAND	EUNET
IRELAND	HEANET EuroKom
ITALY	INFNET
NETHERLANDS	SURFnet
NORWAY	UNINETT
SOVIET UNION	Academnet Adonis ANAS
SPAIN	Enet Ean
SWEDEN	SUNET
SWITZERLAND	SWITCH
YUGOSLAVIA	SIS
ASIA	
MULTI-NATION	AUSEAnet GULFnet PACNET
JAPAN	N-1 NACSIS JUNET Kogaku-bu LAN Sigma
Hong Kong	HARNET
INDIA	NICNET
INDONESIA	UNInet
ISRAEL	ILAN
KOREA	KREONet/SDN
MALAYSIA	RangKom

3.3.3 USENET

USENET, which means "User's Network," is one of the oldest and largest networks. It began in 1979 and one of its goals has been to give every UNIX-based system the opportunity to join and benefit from a computer network. Today it has over a half million users in 17 countries on five continents (i.e., North and South America, Europe, Asia, and Australia). Any one can join, and it is very decentralized. The two most common protocols used are UUCP and News Transfer Protocol (NTP). USENET has only one basic service, "news," and is sometimes called netnews. The news at each site is under the control of the site administrator, but there are no strict rules about user access to the USENET. There is no central funding source, and each host pays for its own transmission costs. Most of its backbone links run at about 11 Kbps.

3.3.4 UUCP NETWORK

UUCP (which is an acronym for UNIX to UNIX Copy Program) Network is one of the oldest dial-up networks in the world. It began in 1978. It extends throughout the world and mostly connects machines that run the UNIX operating system. There are probably more than a million users on the network making it one of the largest. The UUCP protocol is used, and mail is the only service provided throughout the world. UUCP is very decentralized and has no central authority that determines access. Its topology varies from almost random connections in North America to near tree structure on other continents. The speed of its links vary from 1200 bps to 11 Kbps, with 2400 bps most common.

3.3.5 UUNET

UUNET is a subscription network service for users on UUCP and USENET. UUNET offers access through X.25, dial-up and public data networks. It provides quick transfer of mail and news among the hosts on UUCP and USENET and provides a European connection (via EUnet) to the Internet. UUNET is administered from Falls Church

Virginia and is connected to NSFNET through SURAnet. There is an international link to Amsterdam. Subscribers are charged hourly connection charges and a flat monthly fee. Dial-up speeds range from 1200 bps to 11 Kbps. Plans for expanding this service are underway.

3.3.6 FIDONET

FIDONET, named for a computer, began in 1983 and was designed to connect IBM PCs or compatibles running MS-DOS. The network extends throughout the world and is arranged in a tree structure, divided into zones by continental areas. Most nodes are in the United States and Europe. It uses the Fido protocol which is a dial-up protocol, and its major services are mail and conferencing. FIDONET now has over 6000 nodes throughout the world. The speed of most long-distance links with high traffic volume is 9.6 Kbps; there are many lower volume links with speeds at 1200 and 2400 bps. The network is administered by the coordinators of the nodes at the various levels of its routing hierarchy. The International FidoNet Association also provides assistance.

3.4 NETWORKS IN NORTH AMERICA

Networks in North America, except in the United States, include major research networks in Canada and Mexico.

3.4.1 Networks In Canada

Canada has a number of national and regional research networks. As noted in Section 2, one of its earlier networks, DREnet, began as an ARPANET-like network. Others, like CDNnet and NetNorth, were designed to support a variety of research, education and development activities. Currently, the Canadian National Research Council is developing a national research network, similar to the NSFNET, that will integrate these networks that support research activities. The

EXHIBIT 3-1. International Research Networks
(Continued)

Location	Network
ASIA - Continued	
THAILAND	TCSnet
AUSTRALIA/PACIFIC	
MULTI-NATION	PACCOM SPEARNET
AUSTRALIA	ACSnet ABN QTInet VICNET AARNet
NEW ZEALAND	DSIRnet
CENTRAL & SOUTH AMERICA	
MULTI-NATION	CARINET CATIENET
AFRICA	
MULTI-NATION	CGNET
EGYPT	ENTSTINET
TUNISIA	Afrimail

In the following descriptions of these networks link speeds are noted. International link speeds often are indicated in terms different from those used in the United States. For examples, in Europe 11 Kbps is often used rather than 9.6 Kbps as in the United States, and 2 Mbps is typically used rather than 1.544 Mbps. When link speeds are indicated for each of the international network listed in this exhibit, the designation used in the particular country is used. However, in future sections of this report where forecasts of these international networks are developed and compared with forecasts of U.S. domestic networks, a common designation (i.e., the U.S. designation) of link speeds is used.

3.3 WORLDWIDE NETWORKS

There are a number of networks whose funding and administration is decentralized, whose connections are worldwide, and whose purpose includes facilitating research. Examples of these networks are: BITNET, CSNET, USENET, UUCP Network, UUNET and FIDONET.

3.3.1 BITNET

BITNET is a cooperative network which serves more than 2300 hosts at nearly 1000 sites in 32 countries. The main parts of the network are:

1. BITNET in the United States, Mexico and Chile.
2. NetNorth in Canada.
3. EARN in Europe with hosts in 24 countries.
4. Asianet with hosts in Japan, Singapore, Taiwan and Korea.

The major services include electronic mail and file transfer. Its link speed is typically 9.6 Kbps. BITNET, as indicated above, has connections throughout the world, including direct links to Canada, France, Germany, Japan, Malaysia, Saudi Arabia, Brazil, Chile, Mexico, and Puerto Rico. It has recently merged in the United States with CSNET.

3.3.2 CSNET

CSNET, whose purpose has been to facilitate research and development in computer science and engineering, began in 1981. It uses a variety of protocols, and electronic mail is the only service supported on all parts of CSNET. While the network is mostly in the United States and Canada, it has links to international members and affiliates in Australia, Finland, France, Germany, Israel, Japan, Korea, New Zealand, Sweden, Switzerland, the United Kingdom and the People's Republic of China. Its link speed is typically 9.6 Kbps. CSNET uses dial-up links and gateways to access other networks (e.g., NSFNET). As noted above, it has merged with BITNET.

network is called CA'net. Regional networks include: AHEN, BCnet, CRIM, and Onet.

3.4.1.1 DREnet

The Defense Research Establishment Network (DREnet) is a group of networks that link the sites and systems involved in research for the Canadian Department of National Defense. DREnet began in 1983 as an ARPANET like network linking Defense Research Establishments in Ottawa, Ontario and Nova Scotia. There are nine DREnet sites, 11 networks and about 45 hosts. The DREnet is scheduled to be retired and its sties will join the relatively new XDRENET. XDRENET uses TCP/IP over an X.25 PDN, and will have link speeds up to 64 Kbps.

3.4.1.2 CDNnet

CDNnet (CDN is an abbreviation for Canada) was designed to provide network services to the Canadian research, education, and advanced development community. Any organization, including universities, corporations, nonprofit organizations and government agencies, involved in research or education can join the network. It became operational in 1983 and is administered by CDNnet headquarters at the University of British Columbia. Small organizations usually have one link to the headquarters, while larger organizations have connections to the headquarters and other organizations. The network has an estimated 175 hosts at some 32 institutions.

The X.400 protocol is used for message handling service, and mail is the basic application service provided. Most long-haul links are 2400 bps, although the links vary from 1200 bps to 19.2 Kbps. A 19.2 Kbps link connects the network to the NSFNET backbone in the United States, at Seattle, WA. There are also interconnections with CSNET, BITNET and USENET. Funding has come from membership dues and government grants.

3.4.1.3 NetNorth

NetNorth, which became operational in 1983 and which is administered by the NetNorth Consortium, was designed using the same technology and some of the same basic assumptions used by BITNET in the United States. Link speeds range from 2400 bps to 9.6 Kbps. There is a direct 9.6 Kbps link to BITNET in the United States from the University of Guelph in Ontario to Cornell University at Ithaca, NY. A proposal to change this connection to a 56 Kbps link from Toronto to Cornell is being implemented. Such a link would serve both BITNET and NSFNET users.

3.4.1.4 CA'net

The National Research Council (NRC) in Canada is developing a new nationwide network, CA'net. This network will provide a transcontinental leased line backbone connecting regional networks and will provide more and faster services than the existing Canadian national networks, NetNorth and CDNnet. The network will have three levels like NSFNET: a backbone, mid-level regionals, and campus networks. Backbone link speed development is modeled after the NSFNET, starting with 56 Kbps and 1.544 Mbps links with plans for 45 Mbps links. The TCP/IP protocol is being used, and there are plans for migrating to ISO/OSI protocols.

A full range of services, including remote supercomputer access, are being provided. The user population is expected to reach about 30,000 users, at 80 institutions, by the early 1990s. Management is being directed by a consortium of users, providers and other participants. It is intended that, in five years, all funding for the network will come from its users. While CA'net will be primarily a service network, it will also support network development.

3.4.1.5 REGIONALS

The Alberta Higher Education Network, AHEN, connects a variety of organizations in Alberta, including school boards, hospitals, and oil exploration companies. This is a relatively small network that uses low-speed links. A proposal for a high-speed network (i.e., 1.544 Mbps) has been made.

The British Columbia network, or BCnet, is a regional network headquartered at the University of British Columbia. It supports TCP/IP, DECNET and X.25 protocols, and its link speeds range from 9.6 Kbps to 1.544 Mbps. It has a 19.2 Kbps connection to the NSFNET backbone at the University of Washington.

The Computer Research Institute of Montreal (CRIM) Network was developed in the mid 1980s and is a metropolitan 56 Kbps star network. CRIM uses DECNET and connects various local area networks at universities in the Montreal area. There are plans to expand CRIM and to connect it to the new CA'net.

The Ontario Network, Onet, connects the campus networks of six universities in Ontario. It is a TCP/IP network which provides access to a Cray supercomputer. The links are typically 19.2 Kbps leased lines. However, there is a 56 Kbps link from Toronto to the NSFNET backbone at Cornell. It is expected that Onet will be an NRCnet regional.

3.4.2 Networks In Mexico

Mexico has two major networks, the ITESM network, named for the Instituto de Estudioe Superiores de Monterrey, or the Monterrey Technological Institute of Higher Education, and the UNAM network, named for the Universidad Nacional Autonomidad de Mexico (the national university in Mexico City). The networks, which began in 1987, are linked together by a link from a UNAM site in Mexico City to an ITESM site in Monterrey. University sites are connected to each other via 9.6 Kbps leased lines, the public X.25 network, or 56 Kbps satellite links. There is a leased line to THEnet in the United States. Also, plans for two satellite links to NSFNET, via NCAR, are being implemented; a 64 Kbps link to Monterrey and a 64 Kbps link to Antizapan are planned.

3.5 NETWORKS IN EUROPE

There are several widely used networks that serve or have served the continent of Europe. Five examples are listed below under continent-wide networks. Another network, the European Informatics Network (EIN) was a mid-1970s attempt to provide a continental research network in Europe; it no longer exists. There also are examples of networks that serve several nations, that is, multi-nation networks.

Many nations in Europe do not have their own research networks. Belgium, Greece, Iceland, Luxembourg and Portugal only have hosts on EUnet, and Turkey only has a host on EARN. There have been very few network connections to the Soviet Union or the Eastern European countries. Also, these countries, except for the Soviet Union, don't tend to have their own networks. Bulgaria, Czechoslovakia, the Democratic Republic of Germany, Hungary and Poland all have connections to the multi-nation network, IASnet, discussed below. There are no known systems in Albania or Romania.

Recent changes in the Eastern European political and economic landscape will have, no doubt, a major impact on the manner in which scientific research is conducted in these countries. Greater cooperation with Western Europe and the United States will spurt the development of communications lines in Eastern Europe. The European research networks and the U.S. connectivity to these networks will undergo major expansion as the political and economical gains are consolidated and the attention is focused on scientific and cultural endeavors. Already, plans are underway for some Eastern European countries to join European communications associations. While interest in developing better communications in these countries is growing, it is not possible to predict how fast this interest will be translated into reality.

3.5.1 Continent Wide Networks In Europe

The best examples of continent wide networks are: EUnet, EARN, HEPNET, EIN and Ean, and RIPE.

3.5.1.1 EUnet

The European UNIX network, EUnet, is a European cooperative R&D network begun in 1982. While EUnet began as an application of the protocols and software used in USENET and UUCP and while most of its hosts run UNIX, the network is not restricted to UNIX. Today it uses UUCP and TCP/IP protocols. EUnet is designed to provide the European research and development community with a variety of services, primarily electronic mail and news, and with interconnections to other networks. EUnet has become an important means of technology transfer between industry and academia.

The network originally served the Netherlands, Denmark, Sweden, and the United Kingdom, but has spread throughout Western Europe. Today, there are over 1200 sites in 19 countries. The network is growing very rapidly in both sites and throughput. Total network throughput is estimated at about 3 Gigabytes per month.

The link speeds range from 2400 bps to 64 Kbps. There are connections from EUnet to EARN, JANET, DFN and other networks within Europe, plus intercontinental connections to Japan (JUNET), Korea (SDN), Australia (ACSnet), Malaysia (RanfKoM), New Zealand, Israel, and North America (CSNET, UUCP, UUNET via 64 Kbps leased line). There is a EUnet backbone host in each member country in Europe, and this host serves as a gateway for communications within its country. Funds are provided by the owners of the individual hosts and by the individual users. Currently, talks are being held among EUnet, EARN, HEPNET and RARE representatives about coordinating and integrating networking services throughout Europe.

3.5.1.2 EARN

The European Academic Research Network, EARN, which was formed in 1983 using the BITNET model, is a network for Europe, the Middle East, and Africa. It also is known as the European segment of the BITNET network. It has hosts in every Western European country, plus Austria, Yugoslavia, Cyprus, Turkey, Israel, Algeria, the Ivory Coast, Morocco, Tunisia, Egypt and India. Proposals for accepting connections from Bulgaria, Hungary and the Soviet Union are being considered.

As the first general purpose network serving this broad area of the world, it is widely used for scientific, research, educational and academic purposes. Today, EARN links more than 500 institutions and has more than 100,000 users in 24 countries. EARN is an association registered in France and its directors include one representative from each member country. Financing is the responsibility of the EARN nodes in each country.

EARN is based on the same technology used by BITNET and provides the same services. It uses IBM's Synchronous Network Architecture protocol, but is committed to migrating to ISO/OSI. Services provided include interactive messaging, mail and file transfer. The leased lines on the network range from 2400 bps to 64 Kbps, and the international links are at least 9.6 Kbps. EARN is directly connected to BITNET in the United States, forming along with NetNorth in Canada, a single logical network. EARN also has connections to CSNET and ESNET in the United States and to DFN, EUnet and JANET in Europe. Currently, as noted under the EUnet discussion, talks are being held among EARN, EUnet, HEPNET and RARE representatives about coordinating and integrating networking services throughout Europe.

3.5.1.3 HEPnet Europe

HEPnet in Europe includes the coordinated set of networking facilities used by High Energy Physicists in Europe. The network is administered by a coordinating committee with a chairperson from the Organisation Europeenne pour la Recherche Nucleaire (CERN). Networking for High Energy Physics is conducted over a variety of networks ranging from those dedicated to physicists in various countries to the several multidisciplinary networks in the different countries. That is, it includes components of other networks.

The various components of HEPnet Europe are interconnected through a set of international leased lines. As in the United States, DECNET is the primary protocol used. SNA, NJE and Coloured Book protocols are also used, and there are plans to migrate to ISO/OSI. Services include mail, file transfer and remote login and job entry. Most dedicated links operate at 64 Kbps. However, there are plans for the introduction of 2 Mbps links. The CERN connection (i.e., from Geneva) to the United States HEPNET terminates at the Massachusetts Institute of Technology in Cambridge, MA. It also has connections to EARN and EUnet in Europe and to the Internet and SPAN in the United States.

3.5.1.4 EIN & Ean Europe

The European Informatics Network (EIN) was a mid-1970s attempt to provide a continental research network in Europe. It no longer exists.

There are a number of networks in Europe and around the world that use the Ean (name given to the original X.400 protocol in Canada) implementation of X.400. In Europe, the association of these networks is called Ean Europe. Its objective is to establish communication links for the European community. Most of these links currently are 9.6 Kbps leased lines.The interconnectivity is growing throughout Europe.

3.5.1.5 RIPE

EUnet began setting up a continental TCP/IP network called

Reseau IP Europeen (RIPE) in 1989. It uses T1 links from Amsterdam to France (FNET) and to Stockholm (NORDUnet), and it will have connection to the NSFNET. It will be similar to NSFNET.

3.5.2 Multi-Nation Networks In Europe

There are two significant multi-nation networks in Europe: IASnet and NORDUnet.

3.5.2.1 IASnet

IASnet, the network for Socialist countries, is still being implemented. It is a star network with the central host at the Institute of Automated Systems (IAS) in Moscow and with X.25 connections to institutes of informatics in Bulgaria, Hungary, East Germany, Poland, Czechoslovakia, Cuba, Mongolia and Vietnam. Users at these institutes have access to Soviet and foreign databases. Access from the center host at IAS to other networks is via an X.75 line to the Austrian PDN and an X.25 line to the Finnish PDN. Languages used on the network include English, French and Russian.

3.5.2.2 NORDUnet

The Nordic countries have sponsored a number of early networking projects: Centernet (Denmark), FUNET (Finland), ICEP (Iceland), UNINETT (Norway) and SUNET (Sweden). Based on work at these projects, NORDUnet (a networking organization formed in 1985) established NORDUnet which became operational in 1988. Today, NORDUnet is an international network that connects the Nordic countries by connecting local area networks at Scandinavian universities with an international backbone.

The network configuration is a star network centered i Stockholm, Sweden, where it is connected to the Swedish national network SUNET. The network has nodes in Lyngby, Denmark (where it is connected to DENet), Trondheim, Norway (where it is connected to

UNINETT), and Espoo, Finland (where it is connected to FUNET). The purpose of NORDUnet is to provide coordinated network services to Nordic R & D users.

The protocols used are UUCP, TCP/IP, DECNET, NJE and X.25. Basic services like mail and file transfer are provided; access to supercomputers is also provided. The star links are 64 Kbps leased lines. There are connections to NSFNET, HEPNET, CSNET, EARN, and EUnet. Plans are underway for increasing some link speeds to 2 Mbps and to provide a connection to Iceland. Migration to ISO/OSI is expected.

3.5.3 Networks In France

As indicated in Section 2, France, like the United Kingdom and the Unites States, was involved in the early network development work. Three of its first networks were CYCLADES, RPC and COSAC. Networks currently used, to some degree, for research purposes include FNET, ARISTOTE, SMARTIX, PHYNET and REUNIR.

3.5.3.1 CYCLADES & OTHER EARLY NETWORKS

In France, the CYCLADES (Cyclades is an archipelago in the Aegean Sea, named for its circular configuration, hence the use of the name for this network) network, developed in the early 1970s, was designed for both network research and as a support for other research. CYCLADES, similar in many ways to the earlier ARPANET in the United States, was coordinated by what is now called the National Research Institute for Computer Science and Automation. The network became operational in 1973, grew slowly through the 1970's because of budget constraints, underwent developmental changes, and established some international links.

The network used a specially developed protocol, CIGALE, and provided a wide variety of services. Link speeds ranged from 4.8 Kbps to 19.2 Kbps, and there were a number of international connections (e.g., to London, Rome). CYCLADES was phased out in 1981. This network, did, however, have a significant impact in France and internationally, on the development of network technology (e.g., the ISO-OSI model).

Two other French networks, developed relatively early, were RPC for Reseau Communication par Paquet and COSAC for Communications Sans Connections. RPC played a major role in the evolution of X.25 packet networks, and network research was conducted on COSAC during the mid 1980s.

3.5.3.2 FNET

FNET, which is the French branch of EUnet, provides news and mail service and is similar in several ways to the French research network ARISTOTE (discussed below). For example, these two networks serve over 6500 users at public research laboratories, universities, private research organizations and a number of private companies. The most frequently used protocol on FNET is UUCP and the typical services are news and mail. However, new services (e.g., file transfer) are being planned, and there is a plan to migrate to ISO/OSI.

The typical link speed is 4800 bps. There currently is a satellite link to NSFNET, but this link will be changed to a fiber optic cable link. The Institut National de Recherche en Informatique et Automatique (INRIA) and the French UNIX Users's Group manages the network. INRIA pays for much of the cost of the backbone; member fees pay for the remaining costs. Because of its importance to its users throughout France, there are plans for improving this network. These improvements include: use of TCP/IP and ultimately ISO/OSI; increased speeds; more interconnections with other networks; the establishment of a permanent organization to manage it.

3.5.3.3 ARISTOTE

ARISTOTE is an acronym for Association de Reseaux Informatique en Systeme Totalement Ouvert et Tres Elabore (i.e., Association of Information Networks in a Completely Open and Very Elaborate System). The network is managed by a French nonprofit association whose primary purpose is to facilitate the development of networking technology. ARISTOTE members, mostly national agencies, are research institutions with industrial concerns. The typical protocol is TRANSPAC, and the services include mail and remote login, which have been available since 1988. Link speeds range from 4800 bps to 64 Kbps. There are interconnections with e.g., FNET, CSNET, and the Internet.

3.5.3.4 SMARTIX & PHYNET

SMARTIX was designed as an experiment to solve internal needs of the French National Telecommunications Research Center (CNET). This network is based on the work at COSAC and uses the COSAC version of X.400. Services include long-term archiving, access to other services like telex, and conferencing. SMARTIX's link speeds range up to 64 Kbps, and it has direct connections to ARISTOTE, and through ARISTOTE to EUNET, CSNET, and the Internet. It is funded by the French government.

PHYNET, which is the network for nuclear physicists in France is similar to HEPnet in Europe. It uses DECNET and its link speeds are 64 Kbps.

3.5.3.5 REUNIR

REUNIR is an acronym for Reseau des Universites et de la Recherche (i.e., Network of Universities and Research). The REUNIR Network connects many French universities and research institutions, and its basic purpose is operational support of other research. Its primary participants are the national universities, the National Center for Scientific Research and national agencies involved in research, e.g., agriculture, health and medicine. The network uses a variety of protocols (e.g., TRANSPAC, SNA, and TCP/IP), and provides several services, including mail, file transfer, and remote login. Link speeds range from 4800 bps to 2 Mbps. REUNIR has interconnections with EARN and FNET.

3.5.4 GERMANY

Germany (i.e., the Federal Republic of Germany) has contributed significantly to network development. As noted in Section 2, one of Germany's earlier networks, HMI-NET, is similar to CYCLADES and ARPANET in that it has been an experimental network and has contributed to the development of a community of network experts. Other important networks are Dnet, Germany's national branch of EUnet, and AGFNET, which connects many of Germany's research centers and universities.

3.5.4.1 HMI-NET

In Germany, the Hahn-Meitner Institut (HMI) Network (HMI-NET) was established in Berlin as an experimental networks and was operational during the mid to late 1970's. This network, like CYCLADES and ARPANET, helped to develop a community of network experts and to pave the way for the development of more advanced networks (e.g., Deutsches Forschungsnetz or DFN). In fact, one of the early developers of HMI-NET has recently proposed a continent-wide fiber optic network with speeds of 100 Mbps and faster.

3.5.4.2 DFN

The Deutsches Forschungs Netz (DFN), or German Science Network, is the national research network in Germany. In the early 1980s, a study by Stanford University recommended the development of a nationwide network that would provide ARPANET-like services for Germany, rather than expand BERNET as some had proposed. The Stanford recommendation was followed, and DFN was begun in the mid 1980s. DFN connects every university, college, and research laboratory in Germany. By the late 1980s it had over 65 hosts.

DFN uses X.400 and other ISO/OSI compatible protocols to provide a wide variety of services, including mail, file transfer and remote job entry. Most links are 9600 bps, some are 64 Kbps, but higher rates are planned. There are links to EUnet, EARN and CSNET. DFN-Verein in Berlin administers the network, while the Ministry of Research and Technology (MRT) provides funding. The network's managers have been involved in the development of ISO/OSI protocols, and DFN is Germany's representative in RARE.

3.5.4.3 AGFNET

Arbeitsgemeinschaft der Grossforschungseinrichtungen (AGF) is the Association of National Research Centers, and AGFNET has been its network. AGFNET, as a backbone network, connects all of AGF research centers and all of Germany's universities. There are twelve organizations on the backbone, and each has one host on the backbone and each has its own network. The total number of users is estimated at about 10,000.

The network supports multiple protocols (i.e., SNA, ISO/OSI, DECNET, TCP/IP), and provides a variety of services. Most links are 64 Kbps leased lines, and there are interconnections to other countries (e.g, Montpellier, France). Because IBM funding ended in the late 1980s for several of the networks connected to AGFNET, the networks affected (often sites of large laboratories) have planned to interconnect their networks to form a German EARN (i.e., DEARN). The network currently is administered and funded by AGF.

3.5.4.4 REGIONAL NETWORKS: BERNET & BELWU

The purpose of BERNET, started in 1976, is to link all academic and research institutions in West Berlin. The development of the network has been based on the work completed on HMI-NET. Today, BERNET is the Berlin regional part of DFN. It is one of the two major regional networks in Germany.

BELWU, in Baden-Wurttemberg, is the other major regional research network in Germany. It has been operational since early 1988. It uses 140 Mbps optical fiber long-distance trunks to connect campus Ethernets, HYPERchannel (data link protocol used with Cray 2s) installations, and FDDI (i.e., Fiber Distributed Data Interface, network layer protocol) installations. Higher level protocols tend to be TCP/IP, and the migration to ISO/OSI is planned.

3.5.5 Networks In The United Kingdom

As discussed in Section 2, The United Kingdom conducted some of the early work in experimental networks and now has a nationwide research network. Its early experimental network was the National Physical Laboratories (NPL) Network, and its first major network for supporting other research was the Science and Engineering Research Council Network (SERCnet). This early work has influenced the development of a national research network named JANET and Starlink, and UKnet.

3.5.5.1 NPL NETWORK

One of the earliest packet switching networks was implemented at the National Physical Laboratories (NPL) in the United Kingdom in 1968, when the ARPANET was built. An international connection was established to CYCLADES in 1974. This early work influenced the developed of SERCnet and ultimately, JANET.

3.5.5.2 SERCnet

Initial planning for the Science and Engineering Research Council Network (SERCnet) actually began back in 1966. SERCnet progressed through several developmental phases with several names during the late 1960's and early 1970's and was established as a research network, named SERCnet, in 1977.

The Computer Board for Universities and Research Councils (CBURC), funded by the Department of Education and Science (DES), began planning in the late 1960s for a network that would connect regional computer centers. The initial plan called for star networks using PTT leased lines. Some intersite connections were established by 1976, and by 1977 when the network was named SERCnet, many universities and polytechnic sites were connected. About this time the CBURC and the SERC were making plans for a national backbone network. In 1984, SERCnet was used as the core of this new network, named JANET.

3.5.5.3 JANET

The Joint Academic Network, JANET, as noted above, partly grew out of SERCnet in 1984. Also at this time, the networks of other major national organizations (e.g., the Natural Environment Research Council) merged with JANET. That is, JANET was established to interconnect the local networks in the United Kingdom research community, including those at the Councils, Universities and Polytechnics, and to provide access to networks around the world.

Today JANET is the major academic network in the United Kingdom. Because there was a single ultimate source of funding (i.e., the Department of Education and Science) for all the networks, the merging was simplified and facilitated. This consolidation has led to increased connectivity, new services and reduced overall costs.

JANET is a packet switching network. Local networks connected to JANET tend to be Ethernets, the long-haul network layer is X.25 over leased lines, and the higher layers use the Coloured Book protocol. The network can be used to provide access to a computer at another site, to send mail, to transfer files, or to submit a job from one computer system to run on another. Services include access to supercomputers (e.g., a Cray 1s and a CDC Cyber 205).

Currently, the main trunk network speed is 512 Kbps; some long-distance links are 64 Kbps digital or 48 Kbps analog, and subscriber lines are mostly 9.6 Kbps. There are interconnections to the Internet, Ean networks, EARN, BITNET, UUCP, EUnet, SPAN, and JUNET. The connection between JANET and NSFNET consists of a 56 Kbps digital data circuit between the University of London Computer Center (ULCC) and the John von Neumann National Supercomputer Center in Princeton. The number of registered hosts are estimated to be about 1500, including those on local area networks; about 20 hosts are connected directly on the JANET wide area network.

Administration is handled by a Network Executive at the SERC, Special Interest Groups, and a Network Advisory Committee. Usage is free of charge to members of institutions connected to JANET. JANET is funded by the Computer Board for Universities and Research Councils (CBURC). JANET is a member of RARE, and it plans to migrate to ISO/OSI.

3.5.5.4 Starlink

The Starlink Network, which became operational in 1980, is a network for astronomers. Its name is derived from its function and from its original star topology. Starlink, whose purpose is to provide astronomers with interactive computing facilities, is a national network with hosts throughout the United Kingdom connected by JANET links. Starlink uses the DECNET and Coloured Book protocols over Ethernets and JANET's X.25 leased lines. Services provided include: mail, file transfer, remote login, and a variety of astronomy applications. The typical link speed is 9.6 Kbps. There are direct interconnections with HEPNET and SPAN, and indirect links, via JANET, to other networks. There are about 50 hosts at 19 sites and about 1000 users. The network is administered and funded by SERC.

3.5.5.5 UKnet

UKnet, which began in 1984, is the United Kingdom (UK) UNIX

Network. It is the UK's part of EUnet, the European UNIX network. It is the major network in the UK connecting universities, research organizations, and commercial sites to the EUnet. Protocols used by the network are Coloured Book and UUCP. UKnet provides the same services as EUnet, which are mail, news and access to other networks. Link speeds range from 1200 bps to 19.2 Kbps. The network is run from the University of Kent at Canterbury in cooperation with a users group. While the network has received some government grants, most funding comes from charges to the user sites. The network plans to migrate to ISO/OSI.

3.5.6 Networks In Other European Countries

The other European countries which have major networks, used in some manner for research, are: Austria, Denmark, Finland, Iceland, Ireland, Italy, Netherlands, Norway, Soviet Union, Spain, Sweden, Switzerland and Yugoslavia. The research networks in these countries are described briefly.

3.5.6.1 Networks In Austria

Austria has an academic and research network (ACONET), a university network (UNA) and local branches of EARN and EUnet. The EUnet and EARN nodes became operational in the mid 1980s.

The Academic Computer Network (ACONET) was begun in 1986 by the Austrian Federal Ministry of Science and Research. ACONET, a member of RARE, is Austria's long-haul research network. It reaches most research and higher education institutions and has connections to EUnet and EARN. Administration is centered in Vienna. It uses special Austrian protocols but plans to migrate to ISO/OSI. Services provided include mail, file transfer, remote login, and remote job entry. Its link speeds range up to 19.2 Kbps, and it connects with UNA, with BITNET via EARN, and USENET via EUnet.The Austrian University Network (UNA) uses DECNET protocols to connect computers at Austrian universities.

3.5.6.2 Networks In Denmark

Denmark has two main networks, DENet, its academic and research network and DKnet, its branch of EUnet. The Danish Ethernet Network (DENet) connects many local Ethernets in university departments throughout Denmark. The network, which is the Danish part of NORDUnet and which replaced Centernet, provides nationwide access to computer facilities. Protocols used are TCP/IP and DECNET. Link speeds are 64 Kbps and 128 Kbps. DKnet is the Danish part of EUnet and provides mail and news services as does EUnet. The main backbone machine on the network has four 1200/2400 bps modems and two X.25 lines.

3.5.6.3 Networks In Finland

Finland has one major network, the Finnish University Network (FUNET), and connections to other major networks around the world. The purpose of FUNET, established in 1984, is to provide network services to the Finnish Universities and Research establishments. This network is star-shaped and is centered and administered at the Helsinki University of Technology. Universities, private companies and government agencies use the network.

FUNET uses a variety of protocols, with the most widely used being TCP/IP and DECNET. Services include mail, conferencing, file transfer, remote job entry, remote login and interactive graphics; access to supercomputers is provided. The network uses leased lines, ranging from 14 Kbps to 64 Kbps, with Ethernet bridges and routers to connect local Ethernets at Finnish universities. There are direct or indirect connections to EARN, EUnet, NORDUnet, BITNET, CSNET, NSFNET, SPAN and HEPNET. Future plans include increasing link speeds to 2 Mbps.

3.5.6.4 Networks In Iceland

The major network in Iceland is the local branch of EUnet.

There also are connections to EARN and Ean networks. The local branch of EUnet is administered by a users group, and mail and news are the main services. The network uses UUCP links over leased and dial-up lines and X.25 links at speeds ranging from 1200 bps to 9.6 Kbps. The network has connections to NORDUnet.

3.5.6.5 Networks In Ireland

The Republic of Ireland, which was connected to the early COSAC network, is one of the main centers of EARN and has a national backbone host on EUNET. Its major networks include HEANET and EuroKom.

The Higher Education Authority Network (HEANET) was begun in 1985 and is administered and funded by the Irish Higher Education Authority. The purpose of HEANET is to provide access to network facilities and to other networks. It currently connects seven colleges throughout Ireland. The primary protocol is the Coloured Book and services include mail, file transfer, and remote login. HEANET uses leased lines on the national PSN. Link speeds range up to 64 Kbps, and there are interconnections with EARN, Eunet and EARN.

EuroKom is a network for participants in the European Strategic Programme for Research in Information Technology (ESPRIT) of the European Community (EC). ESPRIT supports non-competitive research into software technology, computer integrated manufacturing, microelectronics, and related areas. EuroKom, which is based in Dublin, supports many of the ESPRIT projects and other key EC research initiatives. It provides electronic mail and computer conferencing services to both industry and universities, and its links speeds range up to 64 Kbps.

3.5.6.6 Networks In Italy

Italy's national research network is the Instituto Nazionale Fisica Nucleare Network (INFNET). INFNET's purpose is similar to the

French network PHYNET and to the European and worldwide network HEPNET. It uses DECNET protocols and has over 100 hosts. It plans to upgrade its lines from 9.6 Kbps to 48 Kbps. It has two international lines to CERN and one to SPAN.

3.5.6.7 Networks In The Netherlands

The Netherlands has two main networks, the national branch of EUnet and a national research network, SURFnet, which is also the national branch of EARN. SURFnet, the research and higher education network in the Netherlands, connects some 85 organizations. The network's protocols are DECNET and NJE. Its backbone has twenty-five 64 Kbps links; the speed of its other links is 9.6 Kbps. SURFnet is planning to move to X.400 electronic mail and is working on a dedicated, nationally managed, X.25 network.

3.5.6.8 Networks In Norway

The major network in Norway is UNINETT. There also are national components of several other networks. The original UNINETT became operational in 1978 and was used for both networking research and to support other research. A new UNINETT was established in 1987 by the Norwegian Ministry of Cultural and Scientific Affaris to provide advanced networking facilities for research and development.

The current UNINETT is an ISO/OSI-based research network and connects the universities in Norway via leased and dial-up lines and packet switched technoloby. Link speeds have been upgraded recently to 64 Kbps. Services include mail, file transfer, remote job entry, database access, remote login, and teleconferencing. UNINETT has connections to EUnet, EARN, HEPNET, and the Internet. Today, the network is working to integrate all research networks in Norway into one ISO/OSI research network.

3.5.6.9 Networks In The Soviet Union

The Soviet Union has several large networks. Academnet connects research and academic institutions in the republics of the Soviet Union to the Institute for Automated Systems (IAS) in Moscow. The purpose of this network is to provide access to Soviet and foreign databases, which is also the purpose of IASnet.

Adonis, still under development, is run by IAS and connects computer centers in the Soviet Union. ANAS is the administrative network of the Azerbaijan SSR Academy of Sciences and is used for information management. ANAS provides mail, remote login and several other services.

There is a connection between Moscow and San Francisco, known as the San Franscisco-Moscow Teleport. Links in the Soviet Union are estimated to range from 2400 bps up to 64 Kbps.

3.5.6.10 Networks In Spain

Spain has a RARE experimental R&D network, a national branch of EUnet, FAENET (the local branch of HEPNET), and RICA, a regional academic network. The national branch of EUnet is called Enet, which was started in 1986 and which is organized as a star with direct connections to all hosts in the country. The main protocol is UUCP and mail is the primary service. The speed of international links is 9.6 Kbps. Rapid growth is expected, and plans are being made to prepare for it. The RARE experimental R&D network is called Ean. Ean is a national research network that uses Ean software. The typical link speed is 9.6 Kbps, but there are plans to upgrade lines with heavy traffic to 64 Kbps. An international link to CERN is planned.

3.5.6.11 Networks In Sweden

The major network in Sweden is the Swedish University Network (SUNET), which began in 1980 and which includes several components of other networks. The purpose of SUNET, which interconnects local and regional networks at universities in Sweden, is to provide network facilities for researchers and teachers of all disciplines. The operation and management of this network is decentralized.

The SUNET backbone is a star network centered in Stockholm. There are six 64 Kbps lines interconnecting local Ethernets to one national Ethernet. An X.25 network provides the backbone; this X.25 network is also used for international traffic. Networks connected to the SUNET backbone include: a DECNET network coordinated with NORDUnet, SPAN, and HEPNET; a TCP/IP network with connections to the Internet; and an NJE EARN network. The network thus uses several protocols and provides a variety of services.

3.5.6.12 Networks In Switzerland

The national research network in Switzerland is SWITCH and the national EUnet backbone host is at CERN. SWITCH provides a wide variety of services to researchers throughout the nation, and its typical link speeds are 64 Kbps. CERN is one of the networking centers of the world, and it connects every European continental network, including HEPNET, EARN, EUnet, and the Ean networks. It is a testbed for local area networking technology, for interconnecting networks, and for protocol suites. CERN plays a leading role in European technology enhancement initiatives.

3.5.6.13 Networks In Yugoslavia

Yugoslavia has one network, the SIS network, which appears to serve as its research network, and a national backbone on EUnet. SIS (which probably refers to Social Information System) was developed in the late 1980s. Eventually, it will provide mail, remote job entry, file transfer and videotext. Link speeds range from 1200 bps to 19.2 Kbps. The network adheres to ISO standards, is a participant in RARE, but has no international connections.

3.6 NETWORKS IN ASIA

As noted in Section 2, major networks in Asia include three multi-nation networks, the networks in Japan and Korea, and only modest networks in Hong Kong, India, Indonesia, Israel, Malaysia and Thailand. The other countries either have only connections to worldwide or multi-nation networks or no system at all.

The People's Republic of China has several connections to the rest of the world: a CSNET link to West Germany; a UUCP link to HARNET in Hong Kong; a 1200 bps Kermit link to Vienna, Austria. Singapore got the first BITNET node in Southeast Asia. Taiwan, the Republic of China, has connections to both BITNET and PACNET. There appears to be AUSEAnet connections in the Philippines and in Sri Lanka. Cyprus is an EARN member. Mongolia has a connection to IASnet. There are PDNs in Bahrain, Iraq, Qatar, Saudi Arabia and United Arab Emirates. There are CGNET (see Africa below) subscribers in Bandladesh, Nepal and Sri Lanka.

There are no known systems in Brunei, Cambodia, the Democratic People's Republic of Korea, Democratic Yemen, Iran, Jordan, Laos, Lebanon, Myanmar, Oman, Syria, Vietnam, or Yemen.

3.6.1 Multi-Nation Networks In Asia

There are three multi-nation networks in Asia: AUSEAnet, GULFnet, and PACNET.

3.6.1.1 AUSEAnet

AUSEAnet, which covers most of Southeast Asia plus several other countries, is a network for a joint microelectronics Very Large Scale Integration (VLSI) project among the Association of South East Asian Nations (ASEAN) countries (i.e., Brunei, Indonesia, Malaysia, the Philippines, Singapore and Thailand) and Australia. The purpose of this project, which started in 1986, is to permit electronic submission of VLSI designs to Australia and to exchange information about microelectronics techniques. Most funds come from the Australian government. AUSEnet uses UUCP and SUN-III over international X.25 networks, and most of its links are 1200 bps.

3.6.1.2 GULFnet

GULFnet is the Middle East segment of the BITNET Network, It was established in 1985, and connects 10 academic and research institutions in Kuwait and Saudi Arabia. It uses the same technology and provides the same services as EARN and BITNET, but is not interconnected to them. Link speeds range up to 9.6 Kbps.

3.6.1.3 PACNET

PACNET is the Pacific and Asian academic meta-network serving Australia, Hong Kong, Indonesia, Japan, South Korea, Malaysia, New Zealand, Singapore, and Taiwan. PACNET is made up of the networks of the countries it serves. It is a logical grouping of Pacific hosts and organizations with no centralized administration or funding. It is not yet fully operational. It ultimately will connect the Asian and Pacific sites with Canada via CDNnet, Europe via EUnet, and the United States with CSNET and NFSNET. Currently, most connections are 2400 bps dial-up links and mail and news are the only services generally supported.

3.6.2 Networks In Japan

As indicated in Section 2, there are a wide variety of networks in Japan including N-1, NACSIS, JUNET, Kogaku-bu LAN and Sigma. Also, many of the international networks (e.g., BITNET, CSNET, UUNET, HEPNET) reach Japan.

There was little communication by personal computer in Japan until the privatization of Nippon Telegraph and Telephone (NIT) and the corresponding deregulation of the public telephone system in 1985. Since then, networking activity in Japan has increased significantly.

One of the major problems being handled by Japanese researchers in networking involves the development of hardware and software that can handle the Japanese language. Today, the Japanese government is encouraging implementation of campus networks and is funding two new high-speed international links to the United States and Europe. These links are being developed in cooperation with the U.S. NSF.

3.6.2.1 N-1

The oldest major network in Japan is N-1 which became operational in 1981 and which is an inter-university network. It uses its own N-1 protocols, and its services include remote login and remote job entry, but not mail. Line speeds are typically 9.6 Kbps, but range from 4.8 Kbps to 48 Kbps.

3.6.2.2 NACSIS

The National Center for Science Information Systems (NACSIS) Network, established in 1987, is the likely successor to N-1. It is a tree-shaped network with direct links to the component institutions. The network connects Inter-University Computing Centers throughout the main Japanese islands and gives researchers access to a wide range of computing facilities including supercomputers.

NACSIS uses the N-1 protocols and provides the same services as N-1 does, i.e., remote login and remote job entry. Some links are converting to TCP/IP protocols. The link speeds of the links to the component institutions are 48 Kbps, and the speeds of links closer to origin range up to 768 Kbps.

3.6.2.3 JUNET

Today, the major nationwide researh network in Japan is JUNET which was begun in 1984. This network's purpose is to promote information exchange among Japanese researchers and with researchers outside Japan. It also provides a test environment for research in networking. JUNET connects major universities and research organizations through Japan; it is concentrated in Tokyo and Osaka.

The common protocol is UUCP, some links use TCP/IP, and there are no clear plans to migrate to ISO/OSI. Services include only mail and news. JUNET's 2000 nodes in about 200 organizations are connected via 2400 bps or 9.6 Kbps dial-up lines through UUCP; via 9.6 Kbps, 64 Kbps or T-1 leased lines with TCP/IP; and via X.25 for international connections. There are interconnections to EUnet, USENET, UUCPnet and CSNET. A connection to SURAnet on the NSFNET and one to Asianet (BITNET) are planned. Administration is handled by the major backbone hosts, and each host host's connection costs are paid by its institution.

3.6.2.4 Kogaku-bu LAN & Sigma

Other networks in Japan include Kogaku-bu LAN and Sigma. The University of Tokyo established Kogaku-bu LAN in 1987. This network uses TCP/IP over a 100 Mbps fiber-optic backbone that connects several local area networks running Ethernet. Currently, 400 Mbps fiber-optic technology is being developed. Sigma, started in 1987, is a research and development testbed network designed for use in the Sigma Project whose purpose is to produce a standard workstation environment for use in Japan. The basic protocols are TCP/IP.

3.6.3 Networks In Other Asian Countries

Korea has been developing a significant research network. Other Asian countries which have modest, but important, networks, used in some manner in research, are: Hong Kong, India, Indonesia, Israel, Malaysia, and Thailand.

3.6.3.1 Networks In Hong Kong

The national research network in Hong Kong is the Hong Kong Academic and Research Network (HARNET) which became operational in 1986. It serves research and academic institutions in Hong Kong by providing them with connections in Hong Kong and to the rest of the world. HARNET is a star-shaped network whose links are either UUCP over dial-up 1200 bps lines or PDN 2400 bps lines, or DECNET over 9.6 Kbps leased lines. Services include mail, news, file transfer and remote login. There are interconnections with Korea (via SDN), Australia (via ACSnet), Canada (via CDNnet), United States (via CSNET), and the United Kingdom (via JANET).

3.6.3.2 Networks In India

Currently, there is much planning activity in India, but few actual networks. The National Informatics Centre (NIC) is developing a network, NICNET, that will provide information services to various government agencies. Its links speeds will be either 1200 bps or 9.6 Kbps. The government is also developing an academic and research network, ERNET, to connect computing resources at academic and research institutions. ISO/OSI protocols are being used and initial services provided will include mail, file transfer, remote login, and database access. The last mile problem is significant in India, and the telephone system cannot support a wide-area network. Link speeds are expected to range up to 64 Kbps, and interconnections to other networks are planned.

3.6.3.3 Networks In Indonesia

Indonesia is developing a national research network called UNInet, a university research network. It is expected that some 45 government sponsored universities will be interconnected by this network.

3.6.3.4 Networks In Israel

Israel has a PDN, a commercial network, and a branch of EARN, called ILAN, or Israeli Academic Network begun in 1984. ILAN plans to migrate from NJE protocols to TCP/IP and eventually to ISO/OSI. Currently, services include mail, chat, and a PC library server.

3.6.3.5 Networks In Korea

The major national network in the Republic of Korea is the Korea Research Environment Open Network (KREONet). An earlier network, the System Development Network (SDN), was begun in 1982. Korea is also the center of PACNET and has connections to BITNET, UUNET and CSNET.

Starting in 1982, SDN served as a backbone network that interconnected local area networks, provided network facilities for communication and served as an R & D test environment. In 1988, the National Academy and Research Network Planning Group established KREONet as the nation's backbone network. It will link all the research and development institutes for improved research productivity and science and technology advancement in Korea. It is being developed in three stages between 1988 and 1996, and will require about $115 million. A T-1 backbone will be in place in 1991, and peripheral sites will be connected to the backbone via links ranging from 19.2 Kbps to 56 Kbps. Today, the network provides the following services: e-mail, database access, and file transfer. The primary network protocol is TCP/IP, with migration to OSI anticipated. Links to overseas research networks are planned.

3.6.3.6 Networks In Malaysia

The national research network in Malaysia is called Rangkaian Komputer Malaysia, or RangKom. The purpose of this network, which began in 1987, is to promote communication in research organizations and universities, coordinate public databases, and assist in network research projects. Most universities connect to the network through their own campus networks. UUCP is its primary protocol, and a migration to TCP/IP is expected. Services include mail, file transfer and news. Most traffic runs over the Malaysian Packet Switched Data Network or leased lines. Most Malaysian lines are run at 1200 bps, and most leased lines are 4.8 Kbps or 9.6 Kbps. Transmission speeds of 64 Kbps are planned. RangKom is the Malaysian part of AUSEAnet, and there are international connections to the United States, the Netherlands, Australia, Korea, and Indonesia.

3.6.3.7 Networks In Thailand

The national academic network in Thailand is the Thai Computer Science Network, or TCSnet. It has connected several universities since 1988, but has no dedicated funding since traffic is low. Connections are made by telephone dial-up at 1200 bps or 2400 bps. The Australian SUN-III protocols are used, and the services include mail, file transfer and remote job execution. There is a connection to UUNET.

3.7 NETWORKS IN AUSTRALIA/PACIFIC

There are two multi-nation networks in this area, and both Australia and New Zealand have important research networks.

3.7.1 Multi-Nation Networks In Australia/Pacific

The multi-nation networks in this area are PACCOM and SPEARNET.

3.7.1.1 PACCOM

PACCOM is an attempt to build a Pacific regional internet. This network is making use of the emerging fiber-optic cable plant in the Pacific. Hawaii is at the center of this network because most of the fibers pass through Hawaii. Hawaii is also the logical choice for the center becasue it is the home of the largest collection of optical telescopes in the world, has advanced research facilities and has a 56 Kbps link to JPL..

The major protocol being used is TCP/IP, but DECNET and others will be supported. The New Zealand link is a 19.2 Kbps link, the Australian link is at 64 Kbps, and the link to the U.S. West Coast is a 512 Kbps link. All links are or eventually will be fiber- optic links. Links are planned to Japan and to other regions in the Pacific. Funding is coming from NASA, NSF and the State of Hawaii.

3.7.1.2 SPEARNET

The South Pacific Educational and Research Network, SPEARNET, was started in 1986 by the universities in Australia and New Zealand. The purpose of SPEARNET is to improve computer based facilities available for teaching and research. SPEARNET is the main network in New Zealand where all of its universities have been connected. The network uses the Coloured Book protocols. Services include mail, remote login, file transfer, conferencing and remote job execution.

Most links run at 2400 bps or 9.6 Kbps. International connections between Australia and New Zealand and to other countries use the international X.25 network. It is expected that SPEARNET will migrate to ISO/OSI protocols, and there are plans for making the network into a national backbone research network, like NSFNET or BITNET in the United States or like RARE or EARN in Europe. A 2 Mbps backbone with costs shared by participants is anticipated.

3.7.2 Networks In Australia

There are a number of networks in Australia: ACSnet, ABN, QTInet, VICNET and AARNet.

3.7.2.1 ACSnet

ACSnet, which began in 1979, is the major network in Australia connecting universities and research organizations. It spans the continent and connects about 600 computers. It uses the Sydney UNIX Network (SUN) III protocols. ACSnet services include mail, file transfer, remote printing, and USENET news. Most connections are over leased lines, local area networks, or the Public Switched Telephone network. Most links run at 2400 bps. There is no central planning or government funding. Each host pays for its own links. There is a 64 Kbps leased line to the University of Hawaii that allows access to the Internet. There are also connections to CSNET.

3.7.2.2 ABN, QTInet, & VICNET

The Australian Bibliographic Network (ABN) is operated by the Australian National library. The Queensland Tertiary Institution Network (QTInet) connects institutions of higher education via leased lines at speeds of 2400 bps to 9.6 Kbps. VICNET is a network connecting the Victorian Colleges of Advanced Education and Institutes of Technology. The University of Queensland has both DECNET and TCP/IP networks.

3.7.2.3 AARNet

Plans for a conventional multi-protocol network around Australia are currently being implemented. This network, called AARNet for Australian Academic and Research Network, will links colleges and universities in Australia, will use 48 Kbps lines, and will have a connection to the Hawaii segment of the Internet.

3.7.3 Networks In New Zealand

Most of the networking activities in New Zealand are academic or research in nature, and they involve the universities, the Department of Scientific and Industrial Research (DSIR), and the Ministry of Agriculture and Fisheries. DSIRnet, named for DSIR, became operational in 1977 and uses a number of protocols (e.g., DECNET, Coloured Book). Most of the mail between the DSIR and the outside world passes through DSIRnet. There are two gateways from New Zealand to the rest of the world; one is a CSNET connection from Waikato and the other is a UUNET and ACSnet connection from Victoria University. Most links are relatively slow (i.e., 2400 bps), but, a unified national research network is being planned.

3.8 NETWORKS IN CENTRAL & SOUTH AMERICA

As indicated in Section 2, the situation in Central and South

America is similar to that in Asia (especially Southeast Asia). There is a growing interest in networking, but there are few operating networks. In Central and South America, there are two multi-nation networks and links to other networks.

Puerto Rico has an active local branch of FidoNet called RED. The Center for Population and Family Health (at Columbia University) uses a Kermit connection to reach Haiti. There is a connection to IASnet in Cuba. There is a BITNET node in both Argentina and Chile. Brazil is planning to create an academic network to connect research centers in universities and industry and government laboratories. There are no known networks in Belize, Bolivia, Colombia, Ecuador, French Guiana, Guyana, Paraguay, Peru, Surinam, Uruguay, or Venezuela.

3.8.1 Multi-Nation Networks In Central & South America

The two multi-nation networks in Central and South America are CARINET and CATIENET.

3.8.1.1 CARINET

CARINET, which began in 1982, is a general communications network used by business and development organizations in Central and South America, the Caribbean, Africa, the Middle East, Asia, Europe and North America. It has users in some 32 countries, concentrates on the less industrially developed regions, and has about 500 direct users. While the network serves much of the world, it focuses on Central and South America, and the languages used on the network are Spanish and English. CARINET is accessed via X.25 international PDNs, with a link speed of 1200 bps. It is used for accessing libraries, databases, news, mail, coordinating disaster assistance, and as a means for technology transfer. It was created by Partnerships for Productivity (PFP), a non-profit corporation specializing in Third World economic development. PFP sold CARINET in 1987 to a consortium that has made it an independent for-profit corporation. Today, its purpose is still to support development, and all funding is from fees charged to the users involved in the development.

3.8.1.2 CATIENET

CATIENET is named for the Centro Agronomico Tropical de Investigacion y Ensenanza, or Tropical Agricultural Research and Training Center, a regional organization headquartered in Costa Rica. It was created in 1973, countries have joined it throughout the years, and eventually all Spanish-speaking Central American countries will participate in the network. Today, the Dominican Republic, El Salvador, Guatemala, Honduras, Nicaragua, and Panama participate in CATINET. Its major purpose is to provide facilities for exchanging information about agriculture and forestry and to share computer resources. Services currently include mail and file transfer; planned services include batch remote job entry and interactive database access. Like CARINET, its links speeds are relatively slow (i.e., 1200 to 2400 bps).

3.9 NETWORKS IN AFRICA

There are very few major networks in Africa. There is one multi-nation network, and Egypt and Tunisia each have one main network.

Ethiopia, the Ivory Coast, Mali, and Niger each have connections to CGNET. Algeria, the Ivory Coast, and Morocco each has an EARN connection. Senegal has a packet radio network. Kenya is setting up a PeaceNet type network. South Africa apparently has internal networks, but external connections are few, as requests to connect to major worldwide networks (e.g., EARN and BITNET) have been turned down. There are no known networks in Cameroon, Libya or Nigeria.

3.9.1 Multi-Nation Networks In Africa

The one multi-nation network in Africa is called CGNET (Consultative Group Network). CGNET is a conferencing system founded in 1985 by the Consultative Group on International Agricultural Research (CGIAR). The purpose of the network is to help improve food production in developing nations. The networks main machine is located in Palo Alto, California, and it connects 130 remote outposts in more than 70 countries, all involved in agricultural research. It serves the same countries as CARINET, plus others including Bangladesh, Burkina Faso, Ethiopia, India, the Ivory Coast, Mali, Niger, Sri Lanka, and Zimbabwe. Most countries use PDNs, but some use international telephone direct dialing or Kermit links. Link speeds range up to 9.6 Kbps. The agricultural research is primarily sponsored by a consortium of international agricultural research centers, which in turn, are sponsored by the United Nations and the World Bank.

3.9.2 Networks In Egypt

Egypt has a PDN and a general purpose network (ENSTINET), and is a member of EARN. ENSTINET is the Egyptian National Science and Technology Information Network. Its link speeds range up to 9.6 Kbps, and it has connections to EARN and BITNET.

3.9.3 Networks In Tunisia

Tunisia has one main network, Afrimail, initiated by Tunisia and the Canadian government in the late 1980s. It has a connection to EARN and planned connections to African and Arab institutions. Its link speeds are relatively slow, i.e., 1200-2400 bps.

3.10 SUMMARY

Summaries of the eighty-four international research networks, which were selected and described in this section, are presented in Exhibits 3.2 and 3.3. The location, network name and link speeds for the eighty-four networks are listed in Exhibit 3.2. These networks are summarized by coverage extent, major geographical area and link speed in Exhibit 3.3.

Coverage extent is defined in terms of four groups: worldwide, continent-wide, multi-nation and single nation. About four-fifths of the selected networks serve a single nation. The other one-fifth serve either several nations, an entire continent, or most of the world. The world-wide networks have the lowest maximum link speed, while networks serving a single nation have the highest maximum link speed. Across all groups, link speeds range from 1.2 Kbps to 1.544 Mbps. The only exceptions are a limited distance 140 Mbps network linking high speed local area networks at several West Germany universities and two local area experimental networks in Japan.

As noted earlier in this section, seven major geographical areas of the world were used to group these networks. These areas are: Worldwide, North America, Europe, Asia, Australia/Pacific, Central and South America, and Africa. About half of the networks are in Europe, and the other half are distributed across the other major areas. The networks with the highest maximum link speeds are in Europe (Germany) and Asia (Japan). The networks with the lowest maximum link speeds are in Central and South America and Africa.

Networks were also grouped by maximum link speed. The three groups of link speeds are: 1.2 Kbps to 19.2 Kbps; 48 Kbps to 768 Kbps; and 1544 Kbps to 140,000 Kbps. About half of the networks fall into the category with the lowest link speeds. Only about ten percent have maximum link speeds of 1544 Kbps or higher.

These descriptions are used in Section 4 to help determine the current and future international links and traffic volumes.

EXHIBIT 3-2. International Research Networks

Location	Network	Link Speeds (Kbps)
WORLDWIDE	BITNET	9.6
	CSNET	9.6
	USENET	11
	UUCP	1.2 - 11
	UUNET	1.2 - 11
	FIDONET	1.2 - 9.6
NORTH AMERICA		
CANADA	DREnet	1.2 - 64
	CDNnet	1.2 - 19.2
	NetNorth	2.4 - 9.6
	CA'net	56 - 1544
	AHEN	2.4 - 9.6
	BCnet	9.6 - 1544
	CRIM	56
	Onet	19.2 - 56
MEXICO	ITESM	9.6 - 64
	UNAM	9.6 - 64
EUROPE		
CONTINENT-WIDE	EUnet	2.4 - 64
	EARN	2.4 - 64
	HEPnet	64
	Ean	9.6
	RIPE	1544
MULTI-NATION	IASnet	2.4 - 11
	NORDUnet	64 - 2000
FRANCE	CYCLADES	4.8 - 19.2
	FNET	4.8
	ARISTOTE	4.8 - 64
	SMARTIX	4.8 - 64
	PHYNET	64
	REUNIR	4.8 - 2000
GERMANY	HMI-NET	9.6
	DFN	9.6 - 64
	AGFNET	64
	BERNET	64
UNITED KINGDOM	NPL	2.4 - 9.6
	SERCnet	9.6
	JANET	9.6 - 64
	Starlink	9.6
	UKnet	1.2 - 19.2
OTHER EUROPE		
AUSTRIA	ACONET	2.4 - 19.2

EXHIBIT 3-2. International Research Networks
(Continued)

Location	Network	Link Speeds (Kbps)
DENMARK	DENet	64 - 128
FINLAND	FUNET	14 - 64
ICELAND	EUNET	1.2 - 9.6
IRELAND	HEANET	1.2 - 64
	EuroKom	1.2 - 64
ITALY	INFNET	9.6 - 48
NETHERLANDS	SURFnet	9.6 - 64
NORWAY	UNINETT	64
SOVIET UNION	Academnet	---
	Adonis	---
	ANAS	---
SPAIN	Enet	9.6
	Ean	9.6 - 64
SWEDEN	SUNET	64
SWITZERLAND	SWITCH	64
YUGOSLAVIA	SIS	1.2 - 19.2
ASIA		
MULTI-NATION	AUSEAnet	1.2
	GULFnet	1.2 - 9.6
	PACNET	2.4
JAPAN	N-1	4.8 - 48
	NACSIS	48 - 768
	JUNET	2.4 - 1544
Hong Kong	HARNET	1.2 - 9.6
INDIA	NICNET	1.2 - 9.6
INDONESIA	UNInet	---
ISRAEL	ILAN	9.6
KOREA	KREONet	56

EXHIBIT 3-2. International Research Networks
(Continued)

Location	Network	Link Speeds (Kbps)
ASIA - Continued		
MALAYSIA	RangKom	4.8 - 9.6
THAILAND	TCSnet	1.2 - 2.4
AUSTRALIA/PACIFIC		
MULTI-NATION	PACCOM	19.2 - 512
	SPEARNET	2.4 - 9.6
AUSTRALIA	ACSnet	2.4
	ABN	2.4 - 9.6
	QTInet	2.4 - 9.6
	VICNET	2.4 - 9.6
	AARNet	48
NEW ZEALAND	DSIRnet	2.4
CENTRAL & SOUTH AMERICA		
MULTI-NATION	CARINET	1.2
	CATIENET	1.2 - 2.4
AFRICA		
MULTI-NATION	CGNET	1.2 - 2.4
EGYPT	ENTSTINET	9.6
TUNISIA	Afrimail	1.2 - 2.4

EXHIBIT 3-3. International Research Networks
Summary By Coverage , Major Area & Link Speed

Summary Groups	# Of Networks	Link Speeds (Kbps)
BY COVERAGE		
Worldwide	6	1.2 - 11
Continent-Wide	5	2.4 - 1544
Multi-Nation	7	1.2 - 2000
Single Nation	66	1.2 - 1544
BY MAJOR GEOGRAPHICAL AREA		
Worldwide	6	1.2 - 11
North America	8	1.2 - 1544
Europe	40	1.2 - 1544
Asia	15	1.2 - 1544
Australia/Pacific	8	2.4 - 512
Central & South America	4	1.2 - 64
Africa	3	1.2 - 9.6
BY MAXIMUM LINK SPEED (Kbps)		
1.2 - 19.2	41	
48 - 768	30	
1544 or more	9	
N/A	4	

SECTION 4

UNITED STATES INTERNATIONAL RESEARCH NETWORK TRAFFIC FLOW

4.1 OVERVIEW

4.1.1 Purpose

The purpose of this section is to provide estimates of the United States' international research network connectivity requirements. The estimates are based on the current and future traffic flows, between the United States research networks described in a previous study (i.e., the U.S. Domestic Research Network Study) and the international research networks (i.e., those outside the United States) described in Section 3. The estimates of current and future traffic flows presented in this section will be used, along with information on recent changes in United States research networks and in National Research and Education Network (NREN) plans, to describe new current and future integrated research networks (IRNs). This section covers two major topics: the current international research network traffic flow, and the future international research network traffic flow.

4.1.2 Approach

Estimating the current and future traffic flows between United States and international research networks included the following activities: selecting the measure of traffic flow; identifying the current international links and specifying their speeds; determining the current link speeds of the selected international networks; estimating the future link speeds of these international networks; and projecting the future link speeds of the international links.

Based on a review of information on the selected international networks and on the international links, it was determined that installed capacity would be the best measure of traffic flow. As with the United States research networks, estimates of traffic loads or of peak hour traffic were not available for the international networks and for the international links.

To identify the current United States-international links three activities were conducted. First, managers of the United States networks were asked to identify all of their links with research networks outside the United States. Next, information on the selected international networks was reviewed to identify links with the United States research networks. Lastly, records of international links were obtained from members of the Coordinating Committee For International Research Networks (CCIRN) and members of the FNC Engineering Planning Group (FEPG). These records served as the basis for the specification of the international links. The findings from the first two activities were used as supportive data.

The current link speeds of the international links were obtained from the records on the international links. The current link speeds of the selected international networks were obtained from the international network descriptions presented in Section 3. The future links speeds of the international networks and of the international links were based on the future plans for these networks and links. The factors influencing the increase in link speeds are described below in the section on the future international traffic flow.

4.2 CURRENT INTERNATIONAL TRAFFIC FLOW

As noted above, the current traffic flow, between the United States research networks and the international networks was estimated by identifying and specifying the link speeds of the international links connecting these two groups of networks. That is, the installed capacity of these international links, along with the link capacity of the selected international networks, was used to develop a picture of the current international traffic flow.

4.2.1 Current United States-International Links

The current United States-International links are listed in Exhibits 4-1 and 4-2. In Exhibit 4-1, the links are organized by foreign country, while in Exhibit 4-2, the links are organized by United States city. In both exhibits, the following information is provided for each link: name of foreign city, name of United States city, name and purpose of United States network to which the link connects, and the speed of the link.

4.2.1.1. Current International Links By Foreign Country

As indicated in Exhibit 4-1, there currently are 77 United States-international links that connect United States cities to 48 cities in 18 countries. The numbers of links between the United States and each of the various countries, and cities within each country, are as follows: Canada-11/5 (i.e., 11 links, 5 cities), Mexico-4/3, France-11/6, Germany-13/6, United Kingdom-6/5, Other Europe-15/11, Japan-7/3, Other Asia-2/2, Australia/Pacific-2/2, Central and South America-6/5, and Africa-0. As noted in the footnote to Exhibit 4-1, these links do not include any MILNET links or any unique CSNET links.

4.2.1.2 Current International Links By United States City

Exhibit 4-2 shows that these 77 United States-international links connect 22 United States cities to 48 cities outside the United States. Over half of the 77 links originate from two United States cities: Greenbelt, Md-29 NASA network links; Princeton, NJ-15 BITNET and NSFNET links. Only three other cities have at least three links originating from it: Chicago, IL-6 DOE links; Ithaca, NY-3 NSFNET links; and Honolulu, HI-4 NASA network links. The other 17 cities have either one or two international links.

EXHIBIT 4-1. US-INTERNATIONAL LINKS *

(Organized By Foreign Country)

FOREIGN CITY	US CITY	US NET./PURPOSE	LINK SPEED (Kbps)
NORTH AMERICA			
CANADA			
Edmonton, BC	Princeton, NJ	BITNET, Acad Res	9.6
Montreal, QB	Princeton (JVNC), NJ	NSFNET, Research	56
Montreal, QB	Princeton, NJ	BITNET, Acad Res	9.6
Ottawa, QB	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Ottawa, QB	Rochester, NY	NSFNET, Research	56
Ottawa, QB	Princeton, NJ	BITNET, Acad Res	9.6
Toronto, ON	Chicago (FNAL), IL	ESNET/DOE HEP	56
Toronto, ON	Ithaca (CNSC), NY	NSFNET, Research	56
Toronto, ON	Princeton, NJ	BITNET, Acad Res	9.6
Vancover,BC	Seattle (UofW), WA	NSFNET, Research	19.2 (56)
Vancover,BC	Seattle (UofW), WA	BITNET, Acad Res	9.6
MEXICO			
Mexico City (UNAM)	Boulder (NCAR), CO	USAN Acad Research	64/128
Antizapan (ITESM)	Boulder (NCAR), CO	USAN Acad Research	64/128
Monterrey	San Antonio, TX	NSFNET, Acad Res	9.6
Monterrey	San Antonio, TX	BITNET, Acad Res	9.6
EUROPE			
FRANCE			
Sophia	Princeton, NJ	NSFNET, Research	64
Montepellier	Ithaca, NY	NSFNET, Supercomput.	56
Montepellier	New York (CUNY), NY	BITNET, Acad Res	56
Paris	Greenbelt (GSFC), MD	SPAN/NSN Research	9.6
Paris	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Toulouse	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Toulouse	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Moudon (Paris Obs)	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Moudon (Paris Obs)	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6 (1995)
Moudon (Paris Obs)	Greenbelt (GSFC), MD	SPAN/NASA Research	56 (1996)
Strasburg	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
GERMANY			
Bonn	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Bonn	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Bonn	Princeton, NJ	BITNET, Acad Res	9.6
Darmstadt	Greenbelt (GSFC), MD	SPAN/NASA Research	19.2
Darmstadt	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Garching	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Garching	Chicago (FNAL), IL	ESNET/DOE Research	64
Garching	Greenbelt (GSFC), MD	SPAN/NSN Research	9.6
Heidelberg	Greenbelt (GSFC), MD	SPAN/NSN Research	9.6
Max Plank	Greenbelt (GSFC), MD	SPAN/NSN Research	9.6
Max Plank	Greenbelt (GSFC), MD	SPAN/NSN Research	9.6
Oberfaf	Greenbelt (GSFC), MD	SPAN/NASA Research	56 (1995)
Oberfaf	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6

EXHIBIT 4-1. US-INTERNATIONAL LINKS *

(Organized By Foreign Country - Continued)

FOREIGN CITY	US CITY	US NET./PURPOSE	LINK SPEED (Kbps)
UNITED KINGDOM			
Abingdon	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Bristol	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
London	Princeton (JVNC), NJ	NSFNET, Acad Res	56
Malvern	Cambridge (BBN), MA	DRI/DARPA Research	64
Oxford	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Oxford	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
OTHER EUROPE			
ITALY			
Bologona	Chicago (FNAL), IL	ESNET/DOE HEP	9.6
Bologona	Chicago (FNAL), IL	ESNET/DOE HEP	64
Citta	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Frascati	Chicago (FNAL), IL	ESNET/DOE HEP	64
Frascati	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Frascati	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Pisa	Arlington (DARPA),VA	DRI/DARPA Research	64
NETHERLANDS			
Hague	Greenbelt (GSFC), MD	SPAN/NASA Research	19.2
Noordwijk	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Amsterdam	Falls Church, VA	EUNET, UNET	64
NORWAY			
Oslo	Seismo, Washington,DC	DRI/DARPA Research	64
SWEDEN			
Stockholm	Princeton (JVNC), NJ	NSFNET, Acad. Res.	64
SWITZERLAND			
Cern	Ithaca, NY	NSFNET, Supercomput	1544
Geneva	Cambridge (MIT), MA	ESNET/DOE HEP	256
Geneva	Chicago (FNAL), IL	ESNET/DOE HEP	64
ASIA			
JAPAN			
Jaeri	Lawrence (LLNL), CA	ESNET/DOE HEP	9.6
Nagoya	Lawrence (LLNL), CA	ESNET/DOE HEP	9.6
Tokyo	Berkeley (LBL), CA	ESNET/DOE HEP	56
Tokyo	Washington, DC (NSF)	NSFNET Acad Res	14.4
Tokyo	Honolulu, HA	NSN/NASA Research	64
Tokyo	Honolulu, HA	NSN/NASA Research	64
Tokyo	Princeton, NJ	BITNET, Acad Res	9.6
MALAYSIA			
Singapore	Princeton, NJ	BITNET, Acad Res	9.6
SAUDI ARABIA			
Riyadh	Princeton, NJ	BITNET, Acad Res	9.6

EXHIBIT 4-1. US-INTERNATIONAL LINKS *

(Organized By Foreign Country - Continued)

FOREIGN CITY	US CITY	US NET./PURPOSE	LINK SPEED (Kbps)
AUSTRALIA/PACIFIC			
AUSTRALIA			
Melbourne	Honolulu, HI	NSN/NASA Research	64
NEW ZEALAND			
Hamilton	Honolulu, HI	NSN/NASA Research	64
CENTRAL & SOUTH AMERICA			
BRAZIL			
Rio De Janeiro	Los Angeles, CA	BITNET, Acad Res	9.6
Rio De Janeiro	Princeton, NJ	BITNET, Acad Res	9.6
Sao Paulo	Princeton, NJ	BITNET, Acad Res	9.6
CHILE			
La Serena	Huntsville, AL	SPAN/NASA Research	56
Santiago	Princeton, NJ	BITNET, Acad Res	9.6
PUERTO RICO			
San Juan	Tampa, FL	BITNET, Acad Res	9.6

* 1. CSNET has connections to 17 cities in 12 foreign countries (Australia, Canada, Finland, France, Germany-GFR, Israel, Japan, Korea, New Zealand, Sweden, Switzerland, United Kingdom); CSNET uses either dial-up or links listed above, so no new links are listed.

2. MILNET has connections from 13 U.S. cities to five countries (Germany-GFR, Japan, Korea, Philippines, and United Kingdom). These are military links, so they are not listed.

EXHIBIT 4-2. US-INTERNATIONAL LINKS

(Organized By United States (US) City)

US CITY	FOREIGN CITY	US NET./PURPOSE	LINK SPEED (Kbps)
Arlington (DARPA),VA	OTHER EUROPE		
	ITALY		
	Pisa	DRI/DARPA Research	64
Berkeley (LBL), CA	ASIA		
	JAPAN		
	Tokyo	ESNET/DOE HEP	56
Boulder (NCAR), CO	NORTH AMERICA		
	MEXICO		
	MexicoCity(UNAM)	USAN Acad Research	128/64
	Antizapan(ITESM)	USAN Acad Research	128/64
Cambridge (BBN), MA	EUROPE		
	UNITED KINGDOM		
	Malvern	DRI/DARPA Research	64
Cambridge (MIT), MA	OTHER EUROPE		
	SWITZERLAND		
	Geneva	ESNET/DOE HEP	256
Chicago (FNAL), IL	NORTH AMERICA		
	CANADA		
	Toronto, ON	ESNET/DOE HEP	56
	EUROPE		
	GERMANY		
	Garching	ESNET/DOE Research	64
	OTHER EUROPE		
	ITALY		
	Bologona	ESNET/DOE HEP	9.6
	Bologona	ESNET/DOE HEP	64
	Frascati	ESNET/DOE HEP	64
	SWITZERLAND		
	Geneva	ESNET/DOE HEP	64
Falls Church, VA	OTHER EUROPE		
	NETHERLANDS		
	Amsterdam	EUNET, UNET	64
Greenbelt (GSFC), MD	NORTH AMERICA		
	CANADA		
	Ottawa, QB	SPAN/NASA Research	56
	EUROPE		
	FRANCE		
	Paris	SPAN/NSN Research	9.6
	Paris	SPAN/NASA Research	9.6
	Toulouse	SPAN/NASA Research	9.6
	Toulouse	SPAN/NASA Research	9.6
	Moudon (ParisObs)	SPAN/NASA Research	9.6
	Moudon (ParisObs)	SPAN/NASA Research	9.6 (1995)
	Moudon (ParisObs)	SPAN/NASA Research	56 (1996)
	Strasburg	SPAN/NASA Research	9.6
	GERMANY		
	Bonn	SPAN/NASA Research	9.6
	Bonn	SPAN/NASA Research	56

EXHIBIT 4-2. US-INTERNATIONAL LINKS
(Organized By United States (US) City - Continued)

US CITY	FOREIGN CITY	US NET./PURPOSE	LINK SPEED (Kbps)
Greenbelt (GSFC), MD (Continued)	**EUROPE**		
	GERMANY		
	Darmstadt	SPAN/NASA Research	19.2
	Darmstadt	SPAN/NASA Research	9.6
	Garching	SPAN/NASA Research	56
	Garching	SPAN/NSN Research	9.6
	Heidelberg	SPAN/NSN Research	9.6
	Max Plank	SPAN/NSN Research	9.6
	Max Plank	SPAN/NSN Research	9.6
	Oberfaf	SPAN/NASA Research	56 (1995)
	Oberfaf	SPAN/NASA Research	9.6
	UNITED KINGDOM		
	Abingdon	SPAN/NASA Research	56
	Bristol	SPAN/NASA Research	9.6
	Oxford	SPAN/NASA Research	56
	Oxford	SPAN/NASA Research	9.6
	OTHER EUROPE		
	ITALY		
	Citta	SPAN/NASA Research	9.6
	Frascati	SPAN/NASA Research	56
	Frascati	SPAN/NASA Research	9.6
	NETHERLANDS		
	Hague	SPAN/NASA Research	19.2
	Noordwijk	SPAN/NASA Research	9.6
Honolulu, HI	**ASIA**		
	JAPAN		
	Tokyo	NSN/NASA Research	64
	Tokyo	NSN/NASA Research	64
	AUSTRALIA/PACIFIC		
	AUSTRALIA		
	Melbourne	NSN/NASA Research	64
	NEW ZEALAND		
	Hamilton	NSN/NASA Research	64
Huntsville, AL	**CENTRAL & SOUTH AMERICA**		
	CHILE		
	La Serena	SPAN/NASA Research	56
Ithaca, NY	**NORTH AMERICA**		
	CANADA		
	Toronto, ON	NSFNET, Research	56
	EUROPE		
	FRANCE		
	Montpellier	NSFNET, Supercomput.	56
	OTHER EUROPE		
	SWITZERLAND		
	Cern	NSFNET, Supercomput	1544
Lawrence (LLNL), CA	**ASIA**		
	JAPAN		
	Jaeri	ESNET/DOE HEP	9.6
	Nagoya	ESNET/DOE HEP	9.6

EXHIBIT 4-2. US-INTERNATIONAL LINKS
(Organized By United States (US) City - Continued)

US CITY	FOREIGN CITY	US NET./PURPOSE	LINK SPEED (Kbps)
Los Angeles, CA	CENTRAL & SOUTH AMERICA		
	BRAZIL		
	Rio De Janeiro	BITNET, Acad Res	9.6
New York (CUNY), NY	EUROPE		
	FRANCE		
	Montepellier	BITNET, Acad Res	56
Princeton, NJ	NORTH AMERICA		
	CANADA		
	Edmonton, BC	BITNET, Acad Res	9.6
	Toronto, ON	BITNET, Acad Res	9.6
	Montreal, QB	BITNET, Acad Res	9.6
	Ottawa, QB	BITNET, Acad Res	9.6
	EUROPE		
	FRANCE		
	Sophia	NSFNET, Research	64
	GERMANY		
	Bonn	BITNET, Acad Res	9.6
	ASIA		
	JAPAN		
	Tokyo	BITNET, Acad Res	9.6
	MALAYSIA		
	Singapore	BITNET, Acad Res	9.6
	SAUDI ARABIA		
	Riyadh	BITNET, Acad Res	9.6
	CENTRAL & SOUTH AMERICA		
	BRAZIL		
	Rio De Janeiro	BITNET, Acad Res	9.6
	Sao Paulo	BITNET, Acad Res	9.6
	CHILE		
	Santiago	BITNET, Acad Res	9.6
Princeton (JVNC), NJ	NORTH AMERICA		
	CANADA		
	Montreal, QB	NSFNET, Research	56
	EUROPE		
	UNITED KINGDOM		
	London	NSFNET, Acad Res	56
	OTHER EUROPE		
	SWEDEN		
	Stockholm	NSFNET, Acad. Res.	64
Rochester, NY	NORTH AMERICA		
	CANADA		
	Ottawa, QB	NSFNET, Research	56
San Antonio, TX	NORTH AMERICA		
	MEXICO		
	Monterrey	NSFNET, Acad Res	9.6
	Monterrey	BITNET, Acad Res	9.6
Seattle (UofW), WA	NORTH AMERICA		
	CANADA		
	Vancover,BC	NSFNET, Research	19.2 (56)
	Vancover,BC	BITNET, Acad Res	9.6

EXHIBIT 4-2. US-INTERNATIONAL LINKS

(Organized By United States (US) City - Continued)

US CITY	FOREIGN CITY	US NET./PURPOSE	LINK SPEED (Kbps)
Seismo, Washington,DC	OTHER EUROPE		
	NORWAY		
	Oslo	DRI/DARPA Research	64
Tampa, FL	CENTRAL & SOUTH AMERICA		
	PUERTO RICO		
	San Juan	BITNET, Acad Res	9.6
Washington, DC (NSF)	ASIA		
	JAPAN		
	Tokyo	NSFNET Acad Res	14.4

4.2.1.3 Current U.S.-International Links By U.S. Networks

The numbers of links from each of the United States networks are as follows: SPAN/NSN-34, BITNET-16, NSFNET-13, ESNET-10, DRI-3, and EUNET-1. That is, about 45% of the links are NASA network links.

4.2.1.4 Current U.S.-International Links By Link Speed

The speeds of these international links range from 9.6 Kbps to 1.544 Mbps. The information in parentheses following the link speed for several international links refers to either the installation data (i.e., the link has not yet been installed) or a planned link speed (i.e., a higher link speed about to be installed). The numbers of links by speed are as follows:

Link Speed (Kbps)	Number of Links
9.6	38
14.4/19.2	4
56/64	31
128	2
256	1
1544	1

Thus, over half of the links are 19.2 Kbps or slower, and there currently is only one T-1 international link.

4.2.2 Current International Network Link Speeds

As noted earlier, in addition to information on the current United States-international links, information on the current link speeds of the selected international networks was needed to develop a picture of the international traffic flow. The current link speeds of the selected international networks were presented in Section 3 (See Exhibit 3-2 and 3-3). The information on current international links and networks is used in the following section to develop projections of the future international traffic flow. It also will be used, with information on changes in United States networks, to describe, in Section 6, a new Current IRN.

4.3 FUTURE INTERNATIONAL TRAFFIC FLOW

The future international traffic is anticipated to grow because of growth in the international networks. The growth will be in the number of networks as well as in the capacities of networks. Therefore, to estimate the future international traffic flow, projections were made of the future link speeds of the international networks the international links. These projections were based on four sources of information: CCIRN drafted policy, FEPG proposed policy, CCIRN perspective on worldwide research network requirements, and major factors affecting international network requirements. These four groups of information and the guidelines for developing projections are described below. Then the projections of the speeds of the international networks and of the United States-international links are presented.

4.3.1 Basis For Projecting International Traffic Flow

As noted above, the projection of international traffic flow was based on CCIRN drafted policy, FEPG proposed policy, CCIRN perspective on worldwide reserch network requirements, and major factors affecting international network requirements. These topics are described below.

4.3.1.1 CCIRN Policy

Of special significance to the current study is a recently drafted CCIRN policy on intercontinental leased lines. The following are the key points of this policy:

1. The CCIRN considers that improved coordination of the ordering and operation of intercontinental leased lines will have significant benefits in terms of cost savings and improved service levels for the research community.

2. It expects its members to inform and consult the CCIRN on the

future plans of the organizations, which they represent, in respect to the statement in "1." The CCIRN expects proposals for new leased lines to take account of the following guidelines:

a. Leased lines should be shared to the extent that this is permitted by applicable and international regulations and the policies of the funding organizations.

b. To the extent that intercontinental links are considered "infrastructural" there should be an equitable sharing of costs; to the extent that links are established for specific projects, they should be funded by those projects.

c. Links that are used for infrastructural purposes should be connected at the highest appropriate level in the network hierarchy.

d. The proposal should include a technical review of the effect the link is expected to have on the interconnected networks.

e. Operation of the links should be on the basis of an agreed written document. Day-to-day management should be the responsibility of a single organization if possible and appropriate.

4.3.1.2 FEPG Proposed Policy

A similar policy was recently proposed by the FEPG, which was set up to assist the FNC in translating its policy goals into technical programs that can be implemented. The FEPG policy was developed in parallel with that developed by the CCIRN and was developed because of the need for better management and support. Such support has been difficult because of the large distances involved, the need to work with a number of carriers, time zone differences, language barriers, and lack of a shared culture.

The following are the proposed FEPG guidelines for U.S./international connections:

1. The U.S. side should connect to an agency backbone network to avoid multi-administration problems.

2. There should be one primary link between any two countries.

3. Administration should include 24-hour 7-day coverage on both sides, a power supply that cannot be interrupted, and agreement to a single management of components on each end.

4.3.1.3 CCIRN Worldwide Perspective

The CCIRN envisions a worldwide research network that ultimately will provide high speed, high quality service to researchers throughout the world. While there is worldwide connectivity today, the quality of this service varies tremendously from region to region and country to country within regions.

The future topology of the worldwide research network is expected to be similar to the United States' NSFNET which has a backbone, regional networks and local area networks. For the worldwide network topology, the backbone would connect countries, the regionals would be the country networks, and the local networks would be networks connected to a backbone within a country.

An example of efforts leading to such a worldwide topology is a RARE proposed IXI Project which would provide improved services throughout Europe. A proposed backbone for this IXI Project would connect the Netherlands with Switzerland, using two 2 Mbps backbone links. Switzerland, in turn, would have 64 Kbps links to networks within Switzerland and to networks in countries such as Austria, Greece, Italy, Spain, and France. Similarly, the Netherlands would have 64 Kbps links to networks in the Netherlands and 64 Kbps or 2 Mbps links to networks in the Scandinavian countries, Germany, Brussels, Luxembourg, Ireland and the United Kingdom. This is only one of several possible topologies for an improved European network. The United States likely would have T-1 connections to the United Kingdom, Germany and Switzerland.

4.3.1.4 Factors Affecting Link Speeds & Connectivity

In addition to these events, noted above and taking place at the international level, several major factors will influence the requirements for increased link speeds and services for each of the international networks described in Section 3 and for the international links described above in Section 4.2. These factors include those related to an increase in cooperative worldwide efforts and to an increase in sophistication in environmental, energy, medical and space studies. The following are some examples:

1. The ever increasing globalization of the impacts of each nation's activities will encourage more worldwide cooperation and will lead to increased network requirements.

2. The recent breakdown of barriers with Eastern Block countries will stimulate a need for more and better research networks among all nations.

3. The general increase in multi-nation research efforts for a wide variety of reasons including both business and government goals.

4. The increase in network requirements for long-term environmental research (LTER) efforts having worldwide implications and requiring worldwide cooperation.

5. The increase in network requirements for space research, including that involving deep space projects and the Earth Observing System Platforms projects, many of which will involve researchers worldwide.

6. The increase in network requirements for medical research, e.g., for the human genome experiments involving the mapping of genes.

7. The increase in network requirements for energy research, especially that involving new energy sources and their impacts on the environment.

8. The current, ongoing network technology research and development in the United States and other highly industrialized countries will encourage network development in other countries.

4.3.1.5 Summary Of Basis For Link Speed Projections

The future link speeds for the selected international networks and for the international links are based on the following expectations which reflect the events and trends discussed above:

1. International organizations like the CCIRN will encourage worldwide network development and coordination.

2. World events are leading to an increase in multi-nation and even global cooperative research efforts which will require increased connectivity.

3. Specific research in the areas of the environment, energy, medicine and space are demanding more advanced network functions and new network applications.

4. Network technology research and development will encourage and facilitate network development worldwide.

4.3.2 Guidelines For Projecting Future Link Speeds

Projections for the future link speeds for the international networks and the international links are presented below. First, the guidelines used to develop these projections are outlined. These guidelines were based on the events and trends summarized above.

4.3.2.1 Guidelines For Projecting International Network Link Speed

The following guidelines were used when projecting the future link speeds of the international networks:

1. All nations, currently represented by the list of selected international networks, will eventually move toward a nationwide research network.

2. The link speeds of the backbones of these nationwide networks will progress from the networks current speeds, ranging from 9.6 Kbps to 64 Kbps, to higher speeds, ranging from 45 Mbps to 5 Gbps; for most networks this progression would involve intermediate steps at various slower link speeds including: 64 Kbps, 1.544 Mbps, 45/90 Mbps, 274/564 Mbps, and 1 Gbps.

3. Only the backbone of these nationwide networks will be projected in this section.

4. While many nations, currently not represented by the list of selected international networks, are expected to develop networks sometime in the future, they will not be considered in this section. When describing the new Future IRN in Section 6, such future development will be considered.

4.3.2.2 Guidelines For Projecting Speeds Of International Links

The following guidelines were used when projecting the future speeds of the United States-international links:

1. The United States-international links will be consolidated.

2. The speeds of these consolidated links will progress from their initial speeds in 1991 of 9.6 Kbps-1.544 Mbps to 2010 speeds of 45 Mbps-5 Gbps; for most consolidated links, this progression will involve intermediate steps at various slower link speeds including: 64 Kbps, 1.544 Mbps, 45/90 Mbps, 274/564 Mbps, and 1 Gbps.

3. Only the consolidated links will be projected in this section.

4. While new links will be established to provide connectivity with

nations, currently not represented by the list of selected international networks but which are expected to develop networks sometime in the future, these possible future links will not be considered in this section. However, they will be considered when describing the new Future IRN in Section 6.

4.3.3 Projections Of International Network Link Speeds

Projections have been developed for 1991, 1996, 2000 and 2010. These benchmark years were selected so that these international projections could be used with the information developed in the previous U.S. Domestic Research Network Study.

4.3.3.1 1991 Projections Of International Network Link Speeds

The 1991 projected link speeds for the international research networks are presented in Exhibit 4-3 and summarized in Exhibit 4-4. As explained in the guidelines outlined above, only one link speed is projected for each location (i.e., nation, multi-nation, continent, or world), and this link speed is for the backbone for the location. A total of 36 projections were made for 1991 and for each of the later benchmark years which are discussed below.

It appears that most of the international networks are several years behind the United States in terms of network link speed. As indicated in Exhibit 4-3, in 1991, backbone link speeds range from 9.6 Kbps to 1.544 Mbps. Exhibit 4.4 shows that, in 1991, about half of the international networks are expected to have only a 9.6 Kbps backbone, about one-third are expected to have a 64 Kbps backbone, and only about one-seventh are projected to have a 1.544 Mbps backbone.

The impetus for the four 1.544 Mbps backbones are cooperative efforts between the United States and Japan and similar efforts among European nations. The United States/Japan efforts will stimulate the development of Japan's 1.544 backbone and the Australia/Pacific

EXHIBIT 4-3. 1991 Projected Link Speeds International Research Networks

Location	Link Speeds
WORLDWIDE Networks	9.6 Kbps
NORTH AMERICA	
Canada	64 Kbps
Mexico	64 Kbps
EUROPE	
Continent-Wide Nets.	1.544 Mbps
Multi-Nation Nets.	1.544 Mbps
France	64 Kbps
Germany	64 Kbps
United Kingdom	64 Kbps
OTHER EUROPE	
Austria	9.6 Kbps
Denmark	64 Kbps
Finland	64 Kbps
Iceland	9.6 Kbps
Ireland	64 Kbps
Italy	64 Kbps
Netherlands	64 Kbps
Norway	64 Kbps
Soviet Union	9.6 Kbps
Spain	9.6 Kbps
Sweden	64 Kbps
Switzerland	64 Kbps
Yugoslavia	9.6 Kbps
ASIA	
Multi-Nation Nets.	9.6 Kbps

EXHIBIT 4-3. 1991 Projected Link Speeds

International Research Networks
(Continued)

Location	Link Speeds
ASIA (Continued)	
Japan	1.544 Mbps
Hong Kong	9.6 Kbps
India	9.6 Kbps
Indonesia	9.6 Kbps
Israel	9.6 Kbps
Korea	1.544 Mbps
Malaysia	9.6 Kbps
Thailand	9.6 Kbps
AUSTRALIA/PACIFIC	
Multi-Nation Nets.	1.544 Mbps
Australia	9.6 Kbps
New Zealand	9.6 Kbps
CENTRAL & SOUTH AMERICA	
Multi-Nation Nets.	9.6 Kbps
AFRICA	
Multi-Nation Nets.	9.6 Kbps
Egypt	9.6 Kbps
Tunisia	9.6 Kbps

EXHIBIT 4-4. Summary-1991 Link Speeds
International Research Networks

Summary Groups	# Of Networks	Link Speeds
BY COVERAGE		
Worldwide	1	9.6 Kbps
Continent-Wide	1	1.544 Mbps
Multi-Nation	5	9.6 Kbps - 1.544 Mbps
Single Nation	29	9.6 Kbps - 1.544 Mbps
BY MAJOR GEOGRAPHICAL AREA		
Worldwide	1	9.6 Kbps
North America	2	64 Kbps
Europe	18	9.6 Kbps - 1.544 Mbps
Asia	8	9.6 Kbps - 1.544 Mbps
Australia/Pacific	3	9.6 Kbps - 1.544 Mbps
Central & South America	1	9.6 Kbps
Africa	3	9.6 Kbps
BY LINK SPEED		
9.6 Kbps	18	
64 Kbps	13	
1.544 Mbps	5	

multi-nation PACCOM 1.544 backbone. Two cooperative efforts in Europe, the IXI Project and NorduNet, will stimulate both continent-wide and multi-nation 1.544 backbones in Europe.

4.3.3.2 1996 Projections Of International Network Link Speeds

The 1996 projected link speeds for the international research networks are presented in Exhibit 4-5 and summarized in Exhibit 4.6. The same 36 locations (i.e., nation, multi-nation, continent, or world) used to project 1991 link speeds are used for 1996.

As indicated in Exhibit 4-5, in 1996, backbone link speeds range from 64 Kbps to 45 Mbps. Exhibit 4-6 shows that, in 1996, about thirty percent the international networks are expected to have a 64 Kbps backbone, about thirty percent are expected to have a 1.544 Mbps backbone, and about forty percent are projected to have a 45 Mbps backbone.

It appears that some of the international networks are catching up somewhat with the United States in terms of network link speed. That is, in 1991 most international network backbones were either 9.6 Kbps or 64 Kbps, compared with the United States' 45 Mbps backbone; in 1996, over a third of the international networks are projected to have a 45 Mbps backbone compared with the United States projected 1 Gbps backbone.

4.3.3.3 2000 Projections Of International Network Link Speeds

The 2000 projected link speeds for the international research networks are presented in Exhibit 4-7 and summarized in Exhibit 4-8. The same 36 locations (i.e., nation, multi-nation, continent, or world) used to project 1991 and 1996 link speeds are used for 2000.

As indicated in Exhibit 4-7, in 2000, backbone link speeds range from 1.544 Mbps to 1 Gbps. Exhibit 4-8 shows that, in 2000, about

EXHIBIT 4-5. 1996 Projected Link Speeds

International Research Networks

Location	Link Speeds
WORLDWIDE Networks	1.544 Mbps
NORTH AMERICA	
Canada	45 Mbps
Mexico	1.544 Mbps
EUROPE	
Continent-Wide Nets.	45 Mbps
Multi-Nation Nets.	45 Mbps
France	45 Mbps
Germany	45 Mbps
United Kingdom	45 Mbps
OTHER EUROPE	
Austria	1.544 Mbps
Denmark	45 Mbps
Finland	1.544 Mbps
Iceland	1.544 Mbps
Ireland	1.544 Mbps
Italy	45 Mbps
Netherlands	45 Mbps
Norway	45 Mbps
Soviet Union	1.544 Mbps
Spain	1.544 Mbps
Sweden	45 Mbps
Switzerland	45 Mbps
Yugoslavia	64 Kbps
ASIA	
Multi-Nation Nets.	64 Kbps

EXHIBIT 4-5. 1996 Projected Link Speeds

International Research Networks
(Continued)

Location	Link Speeds
ASIA (Continued)	
Japan	45 Mbps
Hong Kong	64 Kbps
India	64 Kbps
Indonesia	64 Kbps
Israel	64 Kbps
Korea	1.544 Mbps
Malaysia	64 Kbps
Thailand	64 Kbps
AUSTRALIA/PACIFIC	
Multi-Nation Nets.	45 Mbps
Australia	1.544 Mbps
New Zealand	1.544 Mbps
CENTRAL & SOUTH AMERICA	
Multi-Nation Nets.	64 Kbps
AFRICA	
Multi-Nation Nets.	64 Kbps
Egypt	64 Kbps
Tunisia	64 Kbps

EXHIBIT 4-6. Summary-1996 Link Speeds

International Research Networks

Summary Groups	# Of Networks	Link Speeds
BY COVERAGE		
Worldwide	1	1.544 Mbps
Continent-Wide	1	45 Mbps
Multi-Nation	5	64 Kbps - 45 Mbps
Single Nation	29	64 Kbps - 45 Mbps
BY MAJOR GEOGRAPHICAL AREA		
Worldwide	1	1.544 Mbps
North America	2	1.544 Mbps - 45 Mbps
Europe	18	64 Kbps - 45 Mbps
Asia	8	64 Kbps - 45 Mbps
Australia/Pacific	3	1.544 Mbps - 45 Mbps
Central & South America	1	64 Kbps
Africa	3	64 Kbps
BY LINK SPEED		
64 Kbps	11	
1.544 Mbps	11	
45 Mbps	14	

EXHIBIT 4-7. 2000 Projected Link Speeds

International Research Networks

Location	Link Speeds
WORLDWIDE Networks	45 Mbps
NORTH AMERICA	
Canada	1 Gbps
Mexico	45 Mbps
EUROPE	
Continent-Wide Nets.	1 Gbps
Multi-Nation Nets.	1 Gbps
France	1 Gbps
Germany	1 Gbps
United Kingdom	1 Gbps
OTHER EUROPE	
Austria	45 Mbps
Denmark	1 Gbps
Finland	45 Mbps
Iceland	45 Mbps
Ireland	45 Mbps
Italy	1 Gbps
Netherlands	1 Gbps
Norway	1 Gbps
Soviet Union	45 Mbps
Spain	45 Mbps
Sweden	1 Gbps
Switzerland	1 Gbps
Yugoslavia	1.544 Mbps
ASIA	
Multi-Nation Nets.	1.544 Mbps

EXHIBIT 4-7. 2000 Projected Link Speeds

International Research Networks
(Continued)

Location	Link Speeds
ASIA (Continued)	
Japan	1 Gbps
Hong Kong	1.544 Mbps
India	1.544 Mbps
Indonesia	1.544 Mbps
Israel	1.544 Mbps
Korea	45 Mbps
Malaysia	1.544 Mbps
Thailand	1.544 Mbps
AUSTRALIA/PACIFIC	
Multi-Nation Nets.	1 Gbps
Australia	45 Mbps
New Zealand	45 Mbps
CENTRAL & SOUTH AMERICA	
Multi-Nation Nets.	1.544 Mbps
AFRICA	
Multi-Nation Nets.	1.544 Mbps
Egypt	1.544 Mbps
Tunisia	1.544 Mbps

EXHIBIT 4-8. Summary-2000 Link Speeds
International Research Networks

Summary Groups	# Of Networks	Link Speeds
BY COVERAGE		
Worldwide	1	45 Mbps
Continent-Wide	1	1 Gbps
Multi-Nation	5	1.544 Mbps - 1 Gbps
Single Nation	29	1.544 Mbps - 1 Gbps
BY MAJOR GEOGRAPHICAL AREA		
Worldwide	1	45 Mbps
North America	2	45 Mbps - 1 Gbps
Europe	18	1.544 Mbps - 1 Gbps
Asia	8	1.544 Mbps - 1 Gbps
Australia/Pacific	3	45 Mbps - 1 Gbps
Central & South America	1	1.544 Mbps
Africa	3	1.544 Kbps
BY LINK SPEED		
1.544 Mbps	11	
45 Mbps	11	
1 Gbps	14	

thirty percent of the international networks are expected to have a 1.544 Mbps backbone, about thirty percent are expected to have a 45 Mbps backbone, and about forty percent are projected to have a 1 Gbps backbone.

Many of the international networks continue to catch up somewhat with the United States in terms of network link speed. In 1996, the most advance international networks had 45 Mbps backbones, compared with the United States' projected 1 Gbps backbone; in 2000, over a third of the international networks are projected to have a 1 Gbps backbone compared with the United States projected 5 Gbps backbone.

4.3.3.4 2010 Projections Of International Network Link Speeds

The 2010 projected link speeds for the international research networks are presented in Exhibit 4-9 and summarized in Exhibit 4-10. The same 36 locations (i.e., nation, multi-nation, continent, or world) used to project 1991, 1996 and 2000 link speeds are used for 2010.

As indicated in Exhibit 4-9, in 2010, backbone link speeds range from 45 Mbps to 5 Gbps. Exhibit 4-10 shows that, in 2010, about thirty percent of the international networks are expected to have a 45 Mbps backbone, about thirty percent are expected to have a 1 Gbps backbone, and about forty percent are projected to have a 5 Gbps backbone.

In 2010, the most advance international networks are projected to have a 5 Gbps backbone compared with the United States projected 25 Gbps backbone.

4.3.4 Projections Of Speeds Of U.S.-International Links

As with the projection of international network link speeds, projections of the speeds of the United States-international links have been developed for 1991, 1996, 2000 and 2010.

EXHIBIT 4-9. 2010 Projected Link Speeds
International Research Networks

Location	Link Speeds
WORLDWIDE Networks	1 Gbps
NORTH AMERICA	
Canada	5 Gbps
Mexico	1 Gbps
EUROPE	
Continent-Wide Nets.	5 Gbps
Multi-Nation Nets.	5 Gbps
France	5 Gbps
Germany	5 Gbps
United Kingdom	5 Gbps
OTHER EUROPE	
Austria	1 Gbps
Denmark	5 Gbps
Finland	1 Gbps
Iceland	1 Gbps
Ireland	1 Gbps
Italy	5 Gbps
Netherlands	5 Gbps
Norway	5 Gbps
Soviet Union	1 Gbps
Spain	1 Gbps
Sweden	5 Gbps
Switzerland	5 Gbps
Yugoslavia	45 Mbps
ASIA	
Multi-Nation Nets.	45 Mbps

EXHIBIT 4-9. 2010 Projected Link Speeds

International Research Networks

(Continued)

Location	Link Speeds
ASIA (Continued)	
Japan	5 Gbps
Hong Kong	45 Mbps
India	45 Mbps
Indonesia	45 Mbps
Israel	45 Mbps
Korea	1 Gbps
Malaysia	45 Mbps
Thailand	45 Mbps
AUSTRALIA/PACIFIC	
Multi-Nation Nets.	5 Gbps
Australia	1 Gbps
New Zealand	1 Gbps
CENTRAL & SOUTH AMERICA	
Multi-Nation Nets.	45 Mbps
AFRICA	
Multi-Nation Nets.	45 Mbps
Egypt	45 Mbps
Tunisia	45 Mbps

EXHIBIT 4-10. Summary-2010 Link Speeds
International Research Networks

Summary Groups	# Of Networks	Link Speeds
BY COVERAGE		
Worldwide	1	1 Gbps
Continent-Wide	1	5 Gbps
Multi-Nation	5	45 Mbps - 5 Gbps
Single Nation	29	45 Mbps - 5 Gbps
BY MAJOR GEOGRAPHICAL AREA		
Worldwide	1	1 Gbps
North America	2	1 Gbps - 5 Gbps
Europe	18	45 Mbps - 5 Gbps
Asia	8	45 Mbps - 5 Gbps
Australia/Pacific	3	1 Gbps - 5 Gbps
Central & South America	1	45 Mbps
Africa	3	45 mbps
BY LINK SPEED		
45 Mbps	11	
1 Gbps	11	
5 Gbps	14	

4.3.4.1 1991 Projections Of Speeds Of U.S.-International Links

As indicated earlier in Exhibits 4-1 and 4-2, currently there are 77 United States-international links connecting 22 United States cities to 48 foreign cities in 18 countries. When projecting the 1991 speeds of the United States-international links, it was assumed that these links would be consolidated. It also was assumed that network development in each foreign country would be sufficiently advanced to permit effective indirect access to foreign cities no longer (i.e., after link consolidation) directly linked to the United States cities. The results of this consolidation and the 1991 link speed projections are presented in Exhibit 4-11.

As indicated in Exhibit 4-11, the number of international links, the number of United States cities, and the number of foreign cities have been reduced significantly. The only constant is the number of foreign countries. The number of international links has been reduced from 77 to 20. As proposed by the CCIRN and the FEPG, there is only one major link to each foreign country, except in the cases of Canada and Mexico, for which there are two links because they are neighbors of the United States. The number of United States cities has been reduced from 22 to seven. The number of foreign cities has been reduced from 48 to 20.

The projections of the 1991 links speeds were based on the following: the current number and speeds of links to each foreign country; the 1991 projected link speed of the backbone of the network in each foreign country; and the policies proposed by various organizations concerned with international traffic. As indicated in Exhibit 4-11, the projected 1991 link speeds of the new 20 international links range from 9.6 Kbps to 1.544 Mbps. About 40 percent of these links are expected to operate at 1.544 Mbps, about 40 percent at 64/128 Kbps, and about 20 percent at 9.6 Kbps. As noted earlier, the range of the link speeds of the current 77 international links is the same but the percentages of these 77 links at each speed, are much different (i.e., 2% at 256 Kbps-1.544 Mbps, 43% at 56-64 Kbps, and 55% at 9.6-19.2 Kbps).

EXHIBIT 4-11. 1991 Projected Link Speeds

U.S.-International Links

U.S. City	Foreign City/Country	Link Speed
Chicago, IL	Toronto, Canada	1.544 Mbps
Ithaca, NY	Montpellier, France	1.544 Mbps
	Cern, Switzerland	1.544 Mbps
Princeton, NJ	Bonn, Germany	1.544 Mbps
	Stockholm, Sweden	64 Kbps
	Rio De Janeiro, Brazil	64 Kbps
	La Serena, Chile	64 Kbps
	Singapore, Malaysia	9.6 Kbps
	Riyadh, Saudi Arabia	9.6 Kbps
Greenbelt, MD	Ottawa, Canada	1.544 Mbps
	Oxford, United Kingdom	1.544 Mbps
	Franscati, Italy	1.544 Mbps
	Amsterdam, Netherlands	64 Kbps
	Oslo, Norway	64 Kbps
Boulder, CO	Mexico City, Mexico	128 Kbps
Austin, TX	Monterrey, Mexico	9.6 Kbps
	San Juan, Puerto Rico	9.6 Kbps
Honolulu	Tokyo, Japan	1.544 Mbps
	Melbourne, Australia	64 Kbps
	Hamilton, New Zealand	64 Kbps

Thus, the consolidation of United States-international links will make it possible to provide, in 1991, better service between the United States and many of the foreign countries. Improved service to some countries will not be possible yet, because of the limited number of links to those countries (e.g., Malaysia). As neighbors of those countries develop their networks and acquire a need to connect to United States networks, consolidation and the resulting improved service will be more feasible. This development of new networks in foreign countries will be considered in Section 6.

4.3.4.2 1996 Projections Of Speeds Of U.S. International Links

When projecting the 1991 speeds of the United States-international links, it was assumed that the consolidation that had taken place in 1991 would remain the same. That is, the number of links, the number of United States cities, and the number of foreign cities/countries were projected to remain the same in 1996 as they were in 1991.

It is quite possible that by 1996, two important events might have occurred. Firstly, new international networks might have been developed in various foreign countries, requiring new connectivity with the United States. Secondly, continent-wide networks might have been expanded (e.g., in Europe) permitting indirect access to foreign countries which now are linked directly with the United States (e.g., Norway). Both of these possible events will be considered in Section 6, when the new IRNs are described.

The projections of the 1996 links speeds were based on factors similar to those used for projecting 1991 link speeds: the 1991 speeds of links to each foreign country; the 1996 projected link speed of the backbone of the network in each foreign country; and the policies proposed by various organizations concerned with international traffic. As indicated in Exhibit 4-12, the projected 1996 link speeds of the new 20 international links range from 64 Kbps to 45 Mbps. About 55 percent of these links are expected to operate at 45 Mbps, 30 percent at 1.544 Mbps, and 15 at 64 Kbps.

EXHIBIT 4-12. 1996 Projected Link Speeds

U.S.-International Links

U.S. City	Foreign City/Country	Link Speed
Chicago, IL	Toronto, Canada	45 Mbps
Ithaca, NY	Montpellier, France	45 Mbps
	Cern, Switzerland	45 Mbps
Princeton, NJ	Bonn, Germany	45 Mbps
	Stockholm, Sweden	45 Mbps
	Rio De Janeiro, Brazil	1.544 Mbps
	La Serena, Chile	1.544 Mbps
	Singapore, Malaysia	64 Kbps
	Riyadh, Saudi Arabia	64 Kbps
Greenbelt, MD	Ottawa, Canada	45 Mbps
	Oxford, United Kingdom	45 Mbps
	Franscati, Italy	45 Mbps
	Amsterdam, Netherlands	45 Mbps
	Oslo, Norway	45 Mbps
Boulder, CO	Mexico City, Mexico	1.544 Mbps
Austin, TX	Monterrey, Mexico	1.544 Mbps
	San Juan, Puerto Rico	64 Kbps
Honolulu	Tokyo, Japan	45 Mbps
	Melbourne, Australia	1.544 Mbps
	Hamilton, New Zealand	1.544 Mbps

4.3.4.3 2000 Projections Of Speeds Of U.S. International Links

When projecting the 2000 speeds of the United States-international links, it was assumed that the consolidation that had taken place in 1991 and 1996 would remain the same. That is, the number of links, the number of United States cities, and the number of foreign cities/countries were projected to remain the same in 2000 as they were in 1991 and 1996.

As discussed for 1996, it is quite possible that by 2000, two important events might have occurred. Firstly, new international networks might have been developed in various foreign countries, requiring new connectivity with the United States. Secondly, continent-wide networks might have been expanded (e.g., in Europe) permitting indirect access to foreign countries which now are linked directly with the United States (e.g., Norway). Again, both of these possible events will be considered in Section 6, when the new IRNs are described.

The projections of the 2000 links speeds were based on factors similar to those used for projecting 1991 and 1996 link speeds: the 1996 speeds of links to each foreign country; the 2000 projected link speed of the backbone of the network in each foreign country; and the policies proposed by organizations concerned with international traffic. As indicated in Exhibit 4-13, the projected 2000 link speeds of the new 20 international links range from 1.544 Mbps to 1 Gbps. About 55 percent of these links are expected to operate at 1 Gbps, 30 percent at 45 Mbps, and 15 percent at 1.544 Mbps.

4.3.4.4 2010 Projections Of Speeds Of U.S. International Links

When projecting the 2010 speeds of the United States-international links, it again was assumed that the consolidation that had taken place in 1991, 1996 and 2000 would remain the same. That is, the number of links, the number of United States cities, and the number of foreign cities/countries were projected to remain the same

EXHIBIT 4-13. 2000 Projected Link Speeds

U.S.-International Links

U.S. City	Foreign City/Country	Link Speed
Chicago, IL	Toronto, Canada	1 Gbps
Ithaca, NY	Montpellier, France	1 Gbps
	Cern, Switzerland	1 Gbps
Princeton, NJ	Bonn, Germany	1 Gbps
	Stockholm, Sweden	1 Gbps
	Rio De Janeiro, Brazil	45 Mbps
	La Serena, Chile	45 Mbps
	Singapore, Malaysia	1.544 Mbps
	Riyadh, Saudi Arabia	1.544 Mbps
Greenbelt, MD	Ottawa, Canada	1 Gbps
	Oxford, United Kingdom	1 Gbps
	Franscati, Italy	1 Gbps
	Amsterdam, Netherlands	1 Gbps
	Oslo, Norway	1 Gbps
Boulder, CO	Mexico City, Mexico	45 Mbps
Austin, TX	Monterrey, Mexico	45 Mbps
	San Juan, Puerto Rico	1.544 Mbps
Honolulu	Tokyo, Japan	1 Gbps
	Melbourne, Australia	45 Mbps
	Hamilton, New Zealand	45 Mbps

in 2000 as they were in 1991, 1996 and 2000.

As indicated for 1996 and 2000, it is quite possible that by 2010, two important events might have occurred. Firstly, new international networks might have been developed in various foreign countries, requiring new connectivity with the United States. Secondly, continent-wide networks might have been expanded (e.g., in Europe) permitting indirect access to foreign countries which now are linked directly with the United States (e.g., Norway). As before, both of these possible events will be considered in Section 6, when the new IRNs are described.

The projections of the 2010 links speeds were based on factors similar to those used for projecting 1991, 1996 and 2000 link speeds: the 2000 speeds of links to each foreign country; the 2010 projected link speed of the backbone of the network in each foreign country; and the policies proposed by various organizations concerned with international traffic. As indicated in Exhibit 4-14, the projected 2000 link speeds of the new 20 international links range from 1 Gbps to 5 Gbps. About 55 percent of these links are expected to operate at 5 Gbps, 30 percent at 1 Gbps, and 15 percent at 45 Mbps.

4.4 SUMMARY

The current and future United States international research network traffic flows were estimated and presented in this section.

4.4.1 Current Traffic Flow

The current traffic flow was estimated by determining the installed capacity of the international links between the United States networks described in the previous U.S. Domestic Research Network Study and the international networks described in Section 3. That is, the installed capacity of the international links, along

EXHIBIT 4-14. 2010 Projected Link Speeds

U.S.-International Links

U.S. City	Foreign City/Country	Link Speed
Chicago, IL	Toronto, Canada	5 Gbps
Ithaca, NY	Montpellier, France	5 Gbps
	Cern, Switzerland	5 Gbps
Princeton, NJ	Bonn, Germany	5 Gbps
	Stockholm, Sweden	5 Gbps
	Rio De Janeiro, Brazil	1 Gbps
	La Serena, Chile	1 Gbps
	Singapore, Malaysia	45 Mbps
	Riyadh, Saudi Arabia	45 Mbps
Greenbelt, MD	Ottawa, Canada	5 Gbps
	Oxford, United Kingdom	5 Gbps
	Franscati, Italy	5 Gbps
	Amsterdam, Netherlands	5 Gbps
	Oslo, Norway	5 Gbps
Boulder, CO	Mexico City, Mexico	1 Gbps
Austin, TX	Monterrey, Mexico	1 Gbps
	San Juan, Puerto Rico	45 Mbps
Honolulu	Tokyo, Japan	5 Gbps
	Melbourne, Australia	1 Gbps
	Hamilton, New Zealand	1 Gbps

with the link capacity of the selected international networks, was used to develop a picture of the current international traffic flow.

There currently are 77 United States-international links that connect 22 United States cities to 48 foreign cities in 18 countries. Over half of these links are to Europe, over half originate from two United States cities (i.e., Greenbelt, MD and Princeton, NJ), and about half are NASA network links. The speeds of these international links range from 9.6 Kbps to 1.544 Mbps. Over half of the links are 19.2 Kbps or slower, and there currently is only one 1.544 Mbps link.

As discussed in Section 3, the link speeds of the foreign networks, to which these 77 United States-international links connect, range from 1.2 Kbps to 1.544 Mbps. About half of these foreign networks have link speeds of 19.2 Kbps or less, and only about ten percent have links speeds of 1.544 Mbps or higher.

4.4.2 Future Traffic Flow

To estimate the future international traffic flow, the future link speeds of the international networks described in Section 3 and the future link speeds of the United States-international links were projected. These projections were based on: CCIRN drafted policy, FEPG proposed policy, CCIRN perspective on worldwide research network requirements, and major factors affecting international network requirements. These policies, perspectives and factors were summarized in terms of the following expectations:

1. International organizations like the CCIRN will encourage worldwide network development and coordination.
2. World events are leading to an increase in multi-nation and even global cooperative research efforts which will require increased connectivity.
3. Specific research in the areas of the environment, energy, medicine and space are demanding more advanced network functions and new network applications.

4. Network technology research and development will encourage and facilitate network development worldwide.

On the basis of these expectations, guidelines were developed for projecting future link speeds for the international networks and for the international links. The guidelines for projecting international network link speeds were: all foreign countries would move toward developing a nationwide research network; the link speeds of the backbones of these networks would increase to speeds as high as 5 Gbps; only the backbone of these nationwide networks would be projected; and networks that might be developed in the future would be considered in Section 6, but not when making these projections. The guidelines for projecting the speeds of the United States-international links were: these links would be consolidated in 1991; the speeds of these links would increase to speeds as high as 5 Gbps; only the consolidated links would be projected; new links that might be required in the future would be considered in Section 6, but not when making these projections. In both instances, projections would be developed for 1991, 1996, 2000, and 2010.

The following is a summary of the projections of international network link speeds:

1. 1991: slightly over half of the international networks are expected to have only a 9.6 Kbps backbone, about one-third are expected to have a 64 Kbps backbone, and only one-tenth are projected to have a 1.544 Mbps backbone.
2. 1996: about one-third of the international networks are expected to have a 64 Kbps backbone, slightly less than one-third are expected to have a 1.544 Mbps backbone, and slightly more than one-third are projected to have a 45 Mbps backbone.
3. 2000: about one-third of the international networks are expected to have a 1.544 Mbps backbone, slightly less than one-third are expected to have a 45 Mbps backbone, and slightly more than one-third are projected to have a 1 Gbps backbone.
4. 2010: about one-third of the international networks are expected to have a 45 Mbps backbone, slightly less than one-third are

expected to have a 1 Gbps backbone, and slightly more than one-third are projected to have a 5 Gbps backbone.

To develop the projections of the United States-international links, the current 77 links were consolidated. This process reduced the number of international links, the number of United States cities, and the number of foreign cities. The only constant was the number of foreign countries. The number of international links was reduced from 77 to 20. The number of United States cities was reduced from 22 to seven. The number of foreign cities was reduced from 48 to 20.

In addition to the guidelines noted above, the projections of the speeds of the international links were based, each year, on the following: the number and speeds of links to each foreign country during the previous benchmark year; the projected link speed of the backbone of the network in each foreign country during the same benchmark year; and the policies proposed by various organizations concerned with international traffic.

The following is a summary of the projections of the speeds of the United States-international links:

1. 1991: link speeds of the new 20 international links range from 9.6 Kbps to 1.544 Mbps; about 40 percent of these links are expected to operate at 1.544 Mbps, about 40 percent at 64/128 Kbps, and about 20 percent at 9.6 Kbps.
2. 1996: link speeds of the new 20 international links range from 64 Kbps to 45 Mbps; about 55 percent of these links are expected to operate at 45 Mbps, 30 percent at 1.544 Mbps, and 15 at 64 Kbps.
3. 2000: link speeds of the new 20 international links range from 1.544 Mbps to 1 Gbps; about 55 percent of these links are expected to operate at 1 Gbps, 30 percent at 45 Mbps, and 15 percent at 1.544 Mbps.
4. 2010: link speeds of the new 20 international links range from 1 Gbps to 5 Gbps; about 55 percent of these links are expected to operate at 5 Gbps, 30 percent at 1 Gbps, and 15 percent at 45 Mbps.

These estimates of current and future traffic flows will be used, along with information on recent changes in United States networks and in NREN plans, to describe new current and future IRNs in Section 6. Also to be considered in Section 6 are the impacts, on the current and future IRNs, of the development of new international foreign country and continent-wide networks. Such impacts likely will include additional consolidation of United States-international links to produce a more efficient and effective research network.

SECTION 5

UPDATE OF UNITED STATES RESEARCH NETWORKS

5.1 OVERVIEW

5.1.1 Purpose

In this section, information collected in the earlier study (i.e., the U.S. Domestic Research Network Study) on the United States research networks and on the National Research and Education Network (NREN) is updated. That is, the purpose of this section is to describe unanticipated changes in United States networks that have taken place, since the completion of the earlier study, and that might have significant impacts on the current and future Integrated Research Network (IRN) defined in the earlier study. For this purpose, the focus is on changes related to the topologies of the United States networks and to the plans for the NREN. This update of the United States networks and of the NREN will be used, along with the estimates of current and future traffic flows presented in Section 4, to describe new current and future IRNs. This section discusses two major topics: changes in United States research networks, and plans for the NREN.

5.1.2 Approach

Updating the information on the United States research networks and the NREN entailed the following activities: collecting information from the managers of each network; collecting information on the NREN from industry leaders; and organizing this information so its impact on the current and future IRNs could be determined.

To collect information on the United States networks, the managers of all the networks described in the earlier study (see Exhibit 5.1) were contacted by mail and by telephone. Each manager was sent a copy of the narrative description and the topology map prepared for his network. He was asked to review this information and to identify any major changes that should be made in either the narrative description or the topology map. This mailing was followed up by telephone calls until the necessary information was obtained. The information then was organized so that the impact of the significant changes could be assessed in Section 6.

Current information on the NREN plans was obtained by interviewing industry leaders identified in the earlier study and by reviewing documents describing current NREN plans. Interviews were conducted in person (e.g., during the EDUCOM National Net'90) and over the telephone. Documents were obtained from the various groups and committees which are involved in the planning of the NREN. Based on this information, the current status and future plans for the NREN were summarized and used in Section 6 to describe the new current and future IRNs.

5.2 CHANGES IN UNITED STATES RESEARCH NETWORKS

As noted above, the changes in the United States research networks that are the most important for the purposes of this study are those pertaining to the topologies of these networks. These changes are summarized below for each network. The network summaries are presented in the same order as the networks appear in Exhibit 5.1. When no significant changes were identified for a network, only a statement indicating that finding is presented for the network.

5.2.1 DoD Networks

5.2.1.1 ARPANET

As expected, the ARPANET has been discontinued.

EXHIBIT 5-1. United States Networks

Described In Earlier Network Study

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:
       - BARRNet, JvNCnet, MERIT, MIDnet, NCSAnet, NorthWestNet, NYSERNet, PSCNET, SDSCnet, SESQUINet, SURAnet, USAN, WestNet, .
     - Eight New Regional Network:
       - CERFnet, CICNet, Los Nettos, MRNet, NEARnet, OARnet, PREPnet, THEnet.

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

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

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

5.2.1.2 DRI

The DRI is progressing as planned with a variety of testbeds underway. The testbed program and its relationship to the development of the NREN are discussed below in Section 5.3 - Current Plans for the NREN.

5.2.2 NSF Networks

5.2.2.1 NSF Backbone

By the second half of 1989, the NSF backbone had 19 links connecting its 13 major nodes or hubs, giving most nodes three T1 connections. During National Net'90, a T3 link was demonstrated. As predicted in the earlier study , most of the NSF backbone is expected to have T3 speeds by the end of 1991. Therefore, there were no unexpected changes in the NSF backbone that must be considered when describing the new current and future IRNs.

5.2.2.2 BARRNet

While there were new members (i.e., LANs) on BARRNet, there were no unexpected changes in the BARRNet topology that must be considered when describing the new current and future IRNs.

5.2.2.3 JvNCnet

As with BARRNet, there were new members on JvNCnet, but there were no unexpected changes in the JvNCnet topology that must be considered when describing the new current and future IRNs.

5.2.2.4 MERIT

There were some new members on MERIT, but there were no unexpected changes in the MERIT topology that must be considered when describing the new current and future IRNs.

5.2.2.5 MIDnet

Again, there were new members on MIDnet, but there were no unexpected changes in the MIDnet topology that must be considered when describing the new current and future IRNs.

5.2.2.6 NCSAnet

One of the 56 Kbps links (from Argonne Nat'l Lab to University of Illinois at Chicago) was increased to a T1. There were no other unexpected changes in the NCSAnet topology that must be considered when describing the new current and future IRNs.

5.2.2.7 NorthWestNet

Several new members (i.e., LANs) joined NorthWestNet, but there were no unexpected changes in the NorthWestNet topology that must be considered when describing the new current and future IRNs.

5.2.2.8 NYSERNet

Like the other regionals discussed above, NYSERNet added new members, but there were no unexpected changes in the its topology that must be considered when describing the new current and future IRNs.

However, an important development involving NYSERNet has taken place. A new company, Performance Systems International, Inc. (PSI), was created to sell access to NYSERNet. This development may mark the beginning of the commercialization of the NREN. PSI has named its new network PSInet which now includes NYSERNet (which serves the New York region) and CAPNet (which serves the Washington, D.C. area). Plans for expanding PSInet nationwide are being considered.

5.2.2.9 PSCNET

PSCNET also added new members, but there were no unexpected changes in the PSCNET topology that must be considered when describing the new current and future IRNs.

5.2.2.10 SDSCnet

There were no unexpected changes in the SDSCnet topology that must be considered when describing the new current and future IRNs.

5.2.2.11 SESQUINet

There were no unexpected changes in the SESQUINet topology that must be considered when describing the new current and future IRNs.

5.2.2.12 SURAnet

Many new members (i.e., LANs) have been added to SURAnet, but as with many of the other regionals, there were no unexpected changes in the SDSCnet topology that must be considered when describing the new current and future IRNs.

5.2.2.13 USAN

The site in Wisconsin has been dropped. The two sites in Mexico are now UNAM (Mexico City) and ITESM (Atizapan de Zaragoza). All other aspects of this network have remained the same or as projected.

5.2.2.14 WESTNet

The University of Arizona is connected to the University of Utah, not to the University of New Mexico as indicated in the earlier study. Also, the network's major links have been upgraded from 56 Kbps to T1. Except for the addition of new members, all other aspects of this network have remained the same or as projected.

5.2.2.15 CERFnet

This network has been rapidly adding new members, but there were no unexpected changes in the CERFnet topology that must be considered when describing the new current and future IRNs.

5.2.2.16 CICNet

There were no unexpected changes in the CICNet topology that must be considered when describing the new current and future IRNs.

5.2.2.17 Los Nettos

There were no unexpected changes in the Los Nettos topology that must be considered when describing the new current and future IRNs.

5.2.2.18 MRNet

While MRNet has been adding new members, there were no unexpected changes in the CERFnet topology that must be considered when describing the new current and future IRNs.

5.2.2.19 NEARnet

NEARnet also has added members, but there were no unexpected changes in the NEARnet topology that must be considered when describing the new current and future IRNs.

5.2.2.20 OARnet

As with most of the other regional networks, OARnet has added members, but there were no unexpected changes in the OARnet topology that must be considered when describing the new current and future IRNs.

5.2.2.21 PREPnet

There were no unexpected changes in the PREPnet topology that must be considered when describing the new current and future IRNs.

5.2.2.22 THEnet

There were no unexpected changes in the THEnet topology that must be considered when describing the new current and future IRNs.

5.2.2.23 NSFNET Summary

There were only a few unexpected changes in the NSFNET topologies that must be considered when describing the new current and future IRNs. These few changes involved the dropping or adding of a site (e.g., with USAN), the changing of a city-pair (e.g., with WestNet), or the changing of the typical link speed of the network (e.g., WestNet). The most consistent change across all regional networks was the addition of new members (i.e., LANs); but this change was anticipated and discussed in the Task Order 2 report.

5.2.3 NASA Research Networks

5.2.3.1 NSN

While new members were added to the NASA Science Network, there were no unexpected changes in the NSN topology that must be considered when describing the new current and future IRNs.

5.2.3.2 NASCOM

While new members were added to, and some old members were dropped from, the NASA Communications (NASCOM) Network, there were no unexpected changes in the NASCOM topology that must be considered when describing the new current and future IRNs.

5.2.3.3 NASNET

There were no unexpected changes in the Numerical Aerodynamics Simulation Network (NASCOM) topology that must be considered when describing the new current and future IRNs.

5.2.3.4 SPAN

There were no unexpected changes in the Space Physics Analysis Network (SPAN) topology that must be considered when describing the new current and future IRNs.

5.2.4 DOE Research Networks

5.2.4.1 ESNET

There were no unexpected changes in the Energy Science Network (ESNET) topology that must be considered when describing the new current and future IRNs.

5.2.4.2 HEPNET

There were no unexpected changes in the High Energy Physics Network (HEPNET) topology that must be considered when describing the new current and future IRNs.

5.2.4.3 LEP3NET

There were no unexpected changes in the LEP3NET (a Cern Accelerator Experiment Network) topology that must be considered when describing the new current and future IRNs.

5.2.4.4 OPMODEL

There were no unexpected changes in the OPMODEL topology that must be considered when describing the new current and future IRNs.

5.2.5 BITNET & CSNET

Effective September, 1989, BITNET and CSNET were merged under a new organization, the Corporation for Research and Educational Networking (CREN). CREN is a continuation of the old BITNET, Inc., under the new name and with revised bylaws, and it accepted responsibility from UCAR for the CSNET network. CREN now provides BITNET and CSNET networking services to members throughout the world.

This merger was anticipated, when developing the Task Order 2 report, and it has not caused any unexpected changes in topologies that must be considered when describing the new current and future IRNs.

5.2.6 Summary Of United States Research Network Changes

There have been very few unexpected changes in the United States Research Networks, since the preparation of the Task Order 2 report, that must be considered when describing the new current and future IRNs. The most important changes, those involving growth of the various networks, were anticipated. Examples of changes included: one of the cities of a city pair was changed; a site was dropped; and a network with slower link speeds increased its backbone link speed from 56 Kbps to 1.544 Mbps several months earlier than anticipated. None of these changes will have any significant effects on the planning of the new current and future IRN.

5.3 CURRENT NREN PLANS

The current NREN plans are summarized below by presenting a description of the NREN, an outline of the implementation of the NREN, and a listing of recent events concerning the NREN. This summary of current NREN plans will be used in Section 6 to help describe the new current and future IRNs.

5.3.1 Current NREN Description

The current NREN is described below in terms of its goal, objectives, benefits, access, services, network structure, management and financing.

5.3.1.1 Goal

The goal of the NREN, as typically presented, is to enhance national competitiveness and productivity through a high speed, high quality network infrastructure which supports a broad set of applications and network services for the research and education community.

5.3.1.2 Objectives

To accomplish this NREN goal the following objectives have been proposed:

1. Support development of advanced United States network technology and services.
2. Increase technology transfer among government, industry and education.
3. Provide access to and encourage development of information resources, instruments, and computation centers whose characteristics make them national assets worth sharing.
4. Create a network architecture that will evolve to meet capacity, connectivity, security, management and service requirements.

5.3.1.3 Benefits

Accomplishing the NREN goal and objectives are expected to result in a wide range of public and private benefits, including:

1. Increased research productivity, education and technology transfer.
2. Maintenance of United States leadership in research and education.

3. Improvement of United States competitiveness in world markets.
4. Acceleration of the development of commercial networks and electronic information services.

5.3.1.4 Access

It has been proposed that the NREN be accessible by the entire United States higher education, research and development community for uses that are consistent with the NREN goal. Some have proposed that anyone doing research, at any level, should have access.

5.3.1.5 Services

It is expected that the development of the NREN will result in the modernization and enhancement of services available on current networks to meet the needs of research users and to provide connection to specialized databases and computational facilities not currently accessible.

5.3.1.6 Network Structure

The most frequently discussed model for the NREN is a three-level structure comprised of:

1. An interstate backbone supporting high volume network traffic with at least one access node in every state.
2. A mid-level tier of state and regional networks providing broad intrastate connectivity.
3. A third level composed of individual campuses and government and industrial laboratories.

5.3.1.7 Management

A number of management structures have been proposed, ranging from a public corporation to an industry operated venture. The public corporation would involve a partnership among government, industry and education. The industry operated venture would be similar to current industry efforts.

5.3.1.8 Funding

Typical funding proposals suggest a shared responsibility of federal research sponsors, educational agencies and private sector organizations. The major funding questions, which still exist, concern when, how and how much the various entities should contribute.

5.3.2 Implementation Plans

The current NREN implementation plans are described below in terms of connectivity, R&D stages, and its testbed program.

5.3.2.1 NREN Connectivity

It is expected that the NREN will interconnect the following:

1. Educational institutions.
2. National laboratories, non-profit research institutions, and government facilities.
3. Commercial organizations engaged in government-supported research or collaborating in such research.
4. Unique national scientific and scholarly resources such as supercomputer centers, major experimental facilities, databases, and libraries.

5.3.2.2 NREN R&D Stages

As presented in the earlier study, the NREN is expected to progress through the following three R&D stages (It is currently in Stage 2):

Stage 1 - Upgrade existing U.S. agency trunks to 1.544 Mbps.

Stage 2 - Combine multi-agency trunks into a shared 45 Mbps trunk system.

Stage 3 - Perform research and development to lead to a shared national network with multi-gigabit-per second trunks (here, technologies are yet to be developed).

These stages are diagramed in Exhibit 5-2. As indicated in Exhibit 5-2, the following is anticipated:

1. A 45 Mbps NREN backbone should be operational by the end of 1991.
2. A multi Gbps NREN backbone should be operational during the last half of the 1990s.
3. The transition to commercial services should begin as the Gbps backbone is initiated during the mid-1990s.

5.3.2.3 NREN Testbed Program

The NREN testbed program is summarized below in terms of management, objectives, and planned testbeds.

Management & Objectives

The NREN testbed program is managed jointly by DARPA and NSF. Existing funding for the program is about $15 million, and significant increases are being requested. The specific testbed projects are managed by the Corporation for National Research Initiatives in Reston, Virginia.

Planned NREN Testbeds

The following NREN testbeds have been planned:

1. Technology Testbed #1: The purpose of this technology testbed is to develop very high speed switching and routing technology, with applications in engineering and operations research. Involved organizations: CMU, Pittsburgh Supercomputer Center, MCI.

2. Technology Testbed #2: The purpose of this technology testbed is

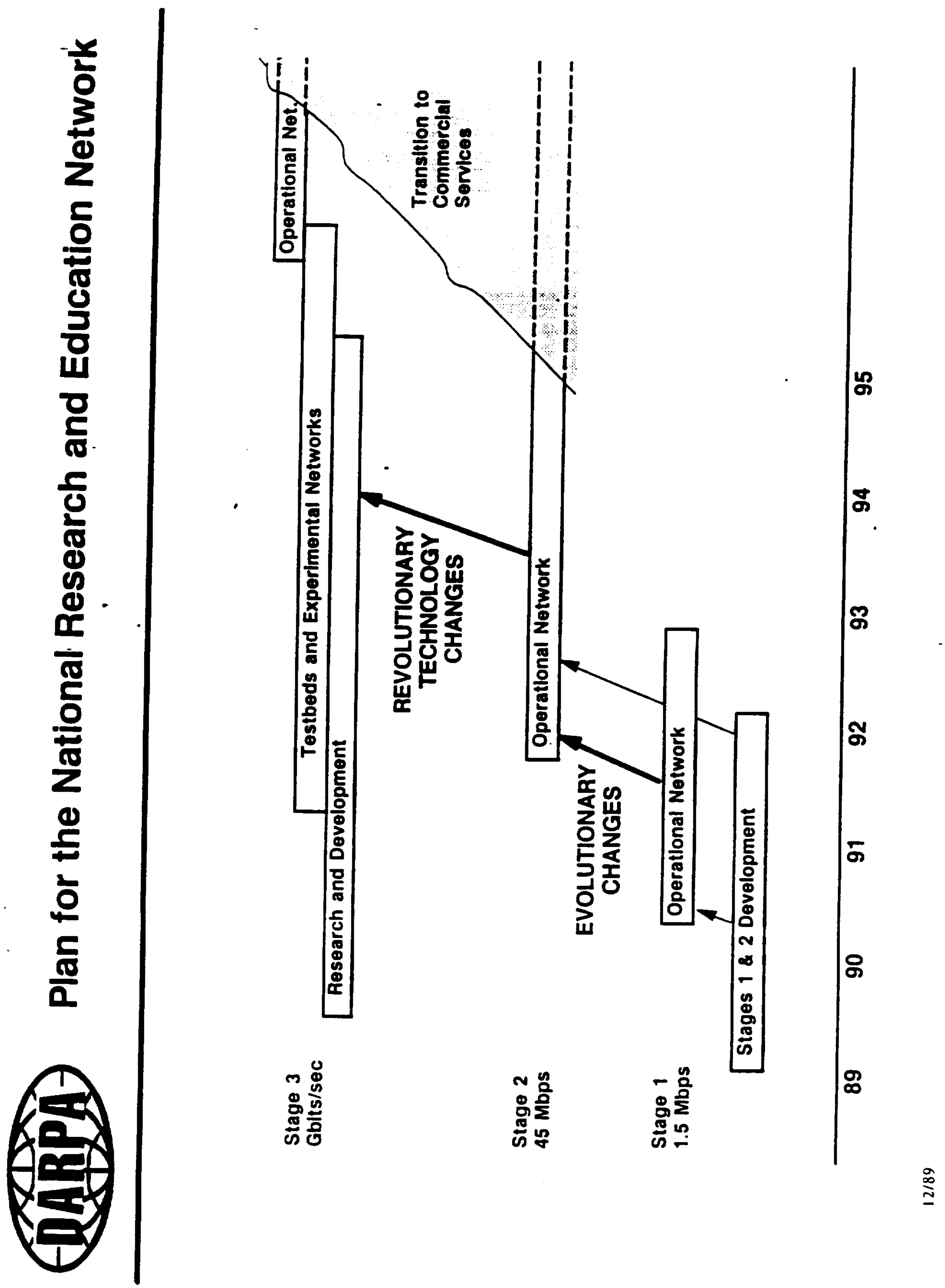

EXHIBIT 5-2. Three-Stage NREN Plan

to explore high speed switching and virtual memory networking. Applications for multi-media telecommunications. Organizations involved: UPenn, BellCor, IBM, MIT, MCI.

3. Distributed Computing Testbed: Using synchronized access to distributed Cray and Connection supercomputers. Application for composite 3-D imagery from simultaneous real-time sources, e.g., combined seismic and remote sensed data. Organizations involved: LANL, CalTech, JPL, San Diego Supercomputer Center, MCI.

4. Medical Testbed: Using Cray supercomputers and high performance workstations for radiation therapy planning. Organizations involved: GTE, Bell Northern Research, and the University of North Carolina.

5. Atmospheric Model Testbed: Purpose is to develop high speed switches using virtual circuits. Applications for severe storm models. Organizations involved: AT&T, Bell Labs, NCSA, U.Illinois, Cray Computers, U.Wisconsin, UCB, LBL.

6. Ocean Model Testbed: Purpose is to explore multiple supercomputer applications for ocean modelling and interactive simulation. Organizations involved: NRL, CMU, NASA.

These planned NREN Gigabit testbeds are diagramed in Exhibit 5-3. One of these testbeds will involve transcontinental Gbps transmission, while the other five will involve Gbps transmission within one or across several states.

5.3.3 Recent Events Impacting The NREN

In this section, some of the recent events directly impacting the NREN are outlined. These events are grouped under the following headings: federal agency activity, federal legislation, network activity, and NREN issues.

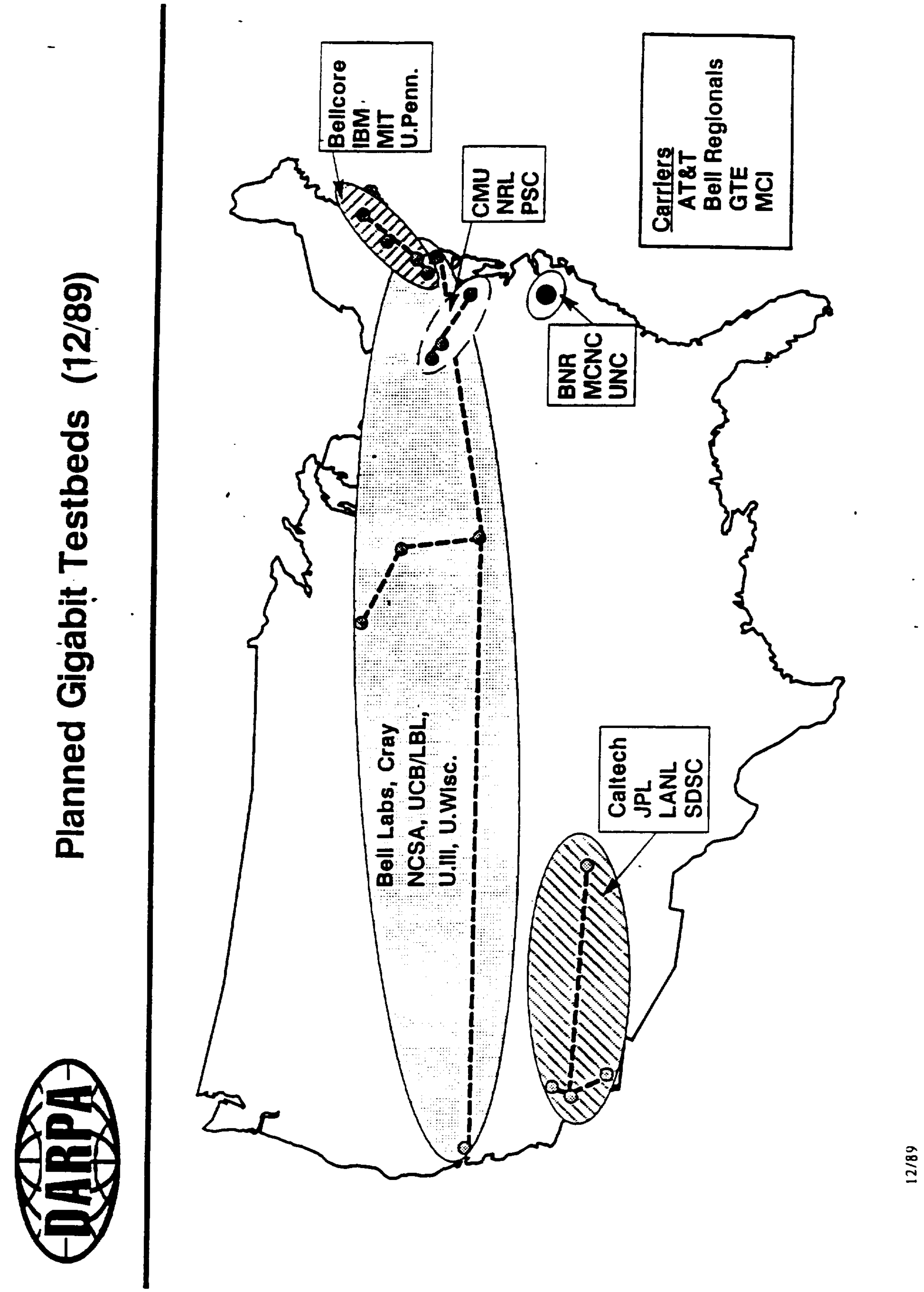

EXHIBIT 5-3. Planned Gigabit Testbeds

5.3.3.1 Federal Agency Activity

The following are examples of recent federal agency activity having a direct impact on the NREN:

1. The FRICC issued a Program Plan for the NREN.
2. The White House OSTP published a report on the Federal High Performance Computing Program, which incorporated the FRICC Program Plan.
3. The White House Science Advisor voiced strong support for the NREN.
4. The proposed federal budget for FY91 included $469 million in budget authority for High Performance Computing (this represents a five percent increase).
5. The FRICC was replaced by the Federal Networking Council (FNC).

5.3.3.2 Federal Legislation

Three bills are currently pending in Congress to authorize the NREN:

1. Senate Bill 1067: Introduced by Senator Gore in May, 1989; creates the NREN and authorizes $390 million in funding for the network over fiscal years 1991 through 1995.
2. House Bill 3131: Companion bill to Senate bill 1067; introduced by Congressman Walgren.
3. Senate Bill 1976: Introduced in November 1989 on behalf of the DOE by Senator Johnston. Provisions relating to the NREN are parallel to those of the Gore Bill.

5.3.3.3 Network Activity

The following network activities are especially relevant to the NREN:

1. The increase in the link speed of the NSFNET backbone from 1.544 Mbps to 45 Mbps was begun.

2. Over 1000 networks are now connected to the NSFNET; an increase of about 400 since mid-1989.
3. Research in advanced networking techniques (i.e., Gbps testbeds) continued on schedule.

5.3.3.4 Current NREN Issues

The following are the four most frequently discussed issues related to the NREN:

1. Ubiquity: How many people have access? Who should have access?
2. Performance: What peak and aggregate rates are necessary?
3. Funding: Who should fund what portions of the NREN? When?
4. Management: What type of management should the NREN have? Public? Private? Combination?

5.3.4 Summary Of Current NREN Plans

Since the completion of the earlier U.S. Domestic Research Network Study, NREN plans have become more clearly delineated. The NREN, in terms of its goal, objectives, benefits, access, services, network structure, management and funding, has been articulated. The NREN implementation plans are on schedule. Connectivity expectations have been well specified, the NREN is in the second of three R&D stages, and the NREN testbed program is equally well planned. Finally, a number of recent federal agency, legislative and network development activities are directly impacting the NREN and are helping to clarify major NREN issues related to ubiquity, performance, funding and management.

5.4 SUMMARY OF UPDATE OF U.S. RESEARCH NETWORKS

There have been very few unexpected changes in the United States Research Networks, since the completion of the earlier study, that must be considered when describing the new current and future IRNs.

In fact, it is expected that none of these unexpected changes will have any significant effects on the planning of the new current and future IRN. The current NREN plans are progressing smoothly, but not without a lot of effort from those involved in its development. While no groups have indicated opposition to the development of an NREN, a number of major issues remain unresolved, and funding for the network is only increasing very slowly because of the tremendous competition for funds. In summary, the status of the NREN has improved significantly during the last year, but much work remains to be done.

SECTION 6

CURRENT AND FUTURE

INTEGRATED RESEARCH NETWORKS

6.1 OVERVIEW

6.1.1 Purpose

In this Section, new current and future Integrated Research Networks (IRNs) are described. That is, the results of the current study, presented in Sections 2 - 5, are used to modify the original IRNs developed in previous U.S. Domestic Research Network Study. The findings presented in Sections 2 and 3, which include descriptions of the international research network community and major research networks outside of the United States, provide a worldwide perspective for developing the new IRNs. Estimates of the current and future international traffic flows presented in Section 4 and the update of the United States Research networks and the NREN plans discussed in Section 5 are used, along with the current and future IRNs described in the previous domestic study, to develop new current and future IRNs. These new IRNs, while still focused on the United States, now include international as well as domestic research network requirements. This section includes three major topics: impact of unexpected changes in United States networks, the current IRN, and the future IRNs.

6.1.2 Approach

To update the IRNs, the completion of three activities were required:

1. The assessment of the impact of unanticipated changes in the United States research networks and in the NREN plans;
2. The incorporation of the current international research

network traffic flow in the current IRN; and

3. The incorporation of the future international research network traffic flows in the future IRNs.

To determine the impact of the unanticipated changes in United States research networks on the current and future IRNs, each change was reviewed to determine whether or not it would have an impact on the original topology maps developed for the current and future IRNs. That is, if the change required a modification of the major access points, the connectivity, or the link speeds of any of the IRN topology maps, these modifications were made.

In a similar manner, the current NREN plans were reviewed to determine if any unanticipated changes in these plans required modifications in the original projections of future research network requirements. Since this study does not focus on the political and social implications of the NREN, but on its technical network requirements, changes in the planned NREN technical network requirements were given the most attention.

To incorporate the current estimate of international research network traffic in the current IRN, the United States-International links and the international network link speeds were added to the information on the original current IRN topology map. The international links were not consolidated, because currently they are not consolidated. The composite diagram now depicts the new current IRN, i.e., it is the new IRN topology map.

In a similar manner, the estimates of the future international research network traffic flow were incorporated in the future IRNs. That is, the information depicted on the original future IRN topology maps was supplemented with the future link speeds of the international research networks and the descriptions of the future United States-international links. The information was presented in a single composite diagram for each future benchmark year. As noted in Section 4, the same future benchmark years (i.e., 1991, 1996, 2000 and 2010) used in the earlier study were used again for this study.

Also, as noted in Section 4, the United States-international links initially were consolidated to give each United States city only one link to any foreign country. When developing the new future IRNs, an additional consolidation of links was made based on an understanding of network requirements between the United States and each foreign country. When making this additional consolidation, it was assumed that continent-wide networks would be developing in selected parts of the world (e.g., Europe), and that the United States would have several links to these continent-wide networks and would not need direct access to every major country. This resulted in a maximum of one United States-international link to each foreign country and only indirect links to some countries.

While it is possible that some researchers in the United States may desire to have dedicated links to some foreign countries for special projects, such dedicated links are not reflected in the new future IRN topologies. It is believed that these requirements are related to security and redundancy and will have minimal impact on traffic projections. Four new future topology maps were developed to depict the results of these analyses of the future IRNs.

6.2 IMPACT OF UNEXPECTED CHANGES IN UNITED STATES NETWORKS

The impact of unexpected changes in the United States networks on the current and future IRNs are discussed under two topics: changes pertaining to the specific research networks and changes pertaining to NREN plans.

6.2.1 Unexpected Changes In Research Networks

As noted earlier in Section 5, there have been very few unexpected changes in the United States Research Networks, since the completion of the earlier domestic study, that must be considered when describing the new current and future IRNs. The most important changes, those involving growth of the various networks, had been anticipated when completing the earlier study. The reasons for this lack of unexpected change include the following:

1. The earlier study was completed only about six months ago.
2. Input was obtained from experts at all levels of the industry, so the composite of their insights is still valid.
3. The earlier study required, just as the current study does, the anticipation of future events and trends and the reflection of their impact on the IRNs; consequently all of the more important changes were expected and incorporated in the original results.

However, each unexpected change in the specific research networks was reviewed and analyzed. Unexpected changes in specific research networks included: one of the cities of a city pair was changed; a site was dropped; and a network with slower link speeds increased its backbone link speed from 56 Kbps to 1.544 Mbps several months earlier than anticipated. Based on this review and analysis, it was concluded that none of these changes will have any significant effects on the planning of the new current and future IRNs. That is, these specific network changes were not sufficiently significant to require changes in the original current and future IRN topology and capacity maps which reflected domestic research network requirements.

6.2.2 Unexpected Changes In NREN Plans

In Section 5, the current NREN plans were summarized by presenting a current description of the NREN, an outline of the implementation of the NREN, and a listing of recent events concerning the NREN. The current NREN was described in terms of its goal, objectives, benefits, access, services, network structure, management and financing. Implementation plans were described in terms of connectivity, R&D stages, and its testbed program. Recent events were grouped under the following headings: federal agency activity, federal legislation, network activity, and NREN issues. These NREN plans and related events then were analyzed to determine whether significant unexpected changes had been made in NREN plans.

Since the completion of the earlier study, NREN plans have become more clearly delineated, but this clarification has not resulted in any unanticipated changes in the NREN. The description of the NREN, in terms of its goal, objectives, benefits, access, services, network structure, management and funding, now has been articulated. While this additional detail concerning NREN plans is useful in providing a perspective for developing the new current and future IRNs, this detail has not affected the original current and future IRN topology maps.

The NREN implementation is on schedule, as projected in the earlier study. All major interest groups are having an impact on the planning for the NREN. The NREN implementation is, as expected at the end of the earlier study, in the second of three R&D stages. The NREN testbed program is being implemented, perhaps slightly faster than anticipated.

Finally, a number of recent federal agency, legislative and network development activities are directly affecting the NREN and are helping to clarify major NREN issues related to ubiquity, performance, funding and management. Again, these activities were anticipated. Activities by the FRICC (replaced by the FNC), the White House OSTP, and the United States Congress suggest that the NREN perspective presented in the earlier study was not too optimistic. Similarly, network activity, in terms of improving ubiquity and performance, indicates that the IRN topology maps presented in the earlier study appropriately reflect expected progress.

6.2.3 Summary Of Impacts Of Unexpected Changes

The evolution of the United States research networks and of the NREN plans have not affected the original topology and capacity maps, developed in the earlier study for the current and future IRNs. The original topology maps can be used, as they were presented in the earlier study, along with information on the networks outside of the United States and on the United States-international links, to develop the new current and future IRNs. Hence, changes will be made in these original topology maps only if the information on the international networks and the United States-international links indicates changes are necessary.

6.3 THE NEW CURRENT IRN

The new current IRN reflects international, as well as domestic, research network requirements. It was developed, as previously noted, using the original current IRN topology map (see Exhibit 6-1), the current link speeds of the international research networks (see Exhibit 6-2), and the United States-international links (see Exhibit 6-3). Exhibit 6-1 was presented initially in the earlier study, and Exhibits 6-2 and 6-3 were presented previously in Section 4.

The new current IRN topology map is presented in Exhibit 6-4. The information in the box in the center of this exhibit shows the major access points and the T1 connectivity of the current IRN developed in the earlier study. As noted above in Section 6.2, the original current IRN (see Exhibit 6-1) adequately reflects the updated domestic network requirements.

The boxes surrounding the center box in Exhibit 6-4 include information, taken from Exhibit 6-2, on each of the six major areas of the world discussed in Sections 2 and 3: Canada/Mexico, Europe, Central/South America, Australia/Pacific and Asia. For each of these major areas, the range of the typical link speeds of the backbones of the research networks in the countries in the area is indicated. For example, in Europe the typical backbone links speeds of the research networks in the European countries is 9.6 Kbps through 64 Kbps.

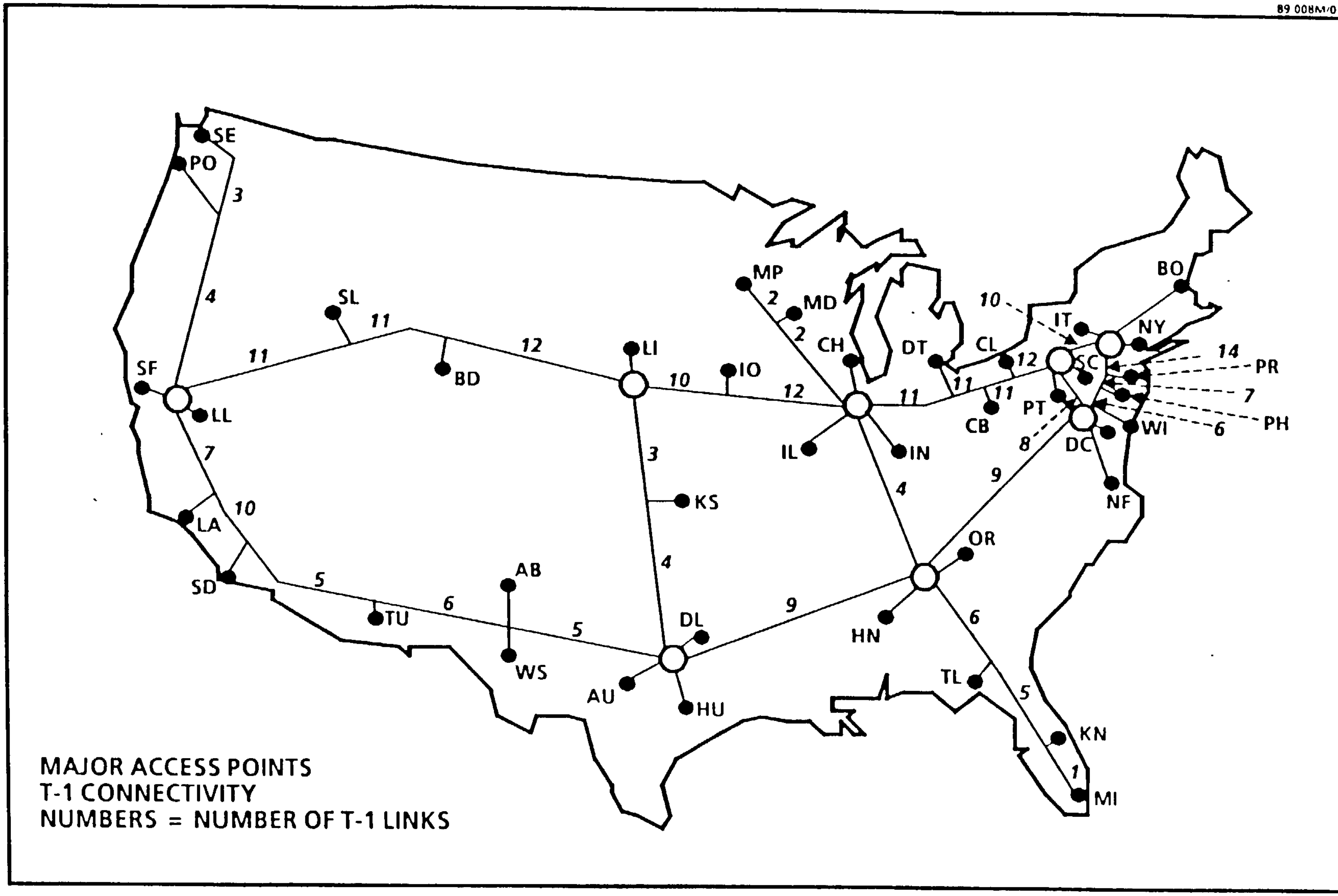

EXHIBIT 6-1. The Current (1990) U.S. Domestic Integrated Research Network

EXHIBIT 6-2. Current International Research Networks

Location	Network	Link Speeds (Kbps)
WORLDWIDE	BITNET	9.6
	CSNET	9.6
	USENET	11
	UUCP	1.2 - 11
	UUNET	1.2 - 11
	FIDONET	1.2 - 9.6
NORTH AMERICA		
CANADA	DREnet	1.2 - 64
	CDNnet	1.2 - 19.2
	NetNorth	2.4 - 9.6
	CA'net	56 - 1544
	AHEN	2.4 - 9.6
	BCnet	9.6 - 1544
	CRIM	56
	Onet	19.2 - 56
MEXICO	ITESM	9.6 - 64
	UNAM	9.6 - 64
EUROPE		
CONTINENT-WIDE	EUnet	2.4 - 64
	EARN	2.4 - 64
	HEPnet	64
	Ean	9.6
	RIPE	1544
MULTI-NATION	IASnet	2.4 - 11
	NORDUnet	64 - 2000
FRANCE	CYCLADES	4.8 - 19.2
	FNET	4.8
	ARISTOTE	4.8 - 64
	SMARTIX	4.8 - 64
	PHYNET	64
	REUNIR	4.8 - 2000
GERMANY	HMI-NET	9.6
	DFN	9.6 - 64
	AGFNET	64
	BERNET	64
UNITED KINGDOM	NPL	2.4 - 9.6
	SERCnet	9.6
	JANET	9.6 - 64
	Starlink	9.6
	UKnet	1.2 - 19.2
OTHER EUROPE		
AUSTRIA	ACONET	2.4 - 19.2

EXHIBIT 6-2. Current International Research Networks
(Continued)

Location	Network	Link Speeds (Kbps)
DENMARK	DENet	64 - 128
FINLAND	FUNET	14 - 64
ICELAND	EUNET	1.2 - 9.6
IRELAND	HEANET EuroKom	1.2 - 64 1.2 - 64
ITALY	INFNET	9.6 - 48
NETHERLANDS	SURFnet	9.6 - 64
NORWAY	UNINETT	64
SOVIET UNION	Academnet Adonis ANAS	--- --- ---
SPAIN	Enet Ean	9.6 9.6 - 64
SWEDEN	SUNET	64
SWITZERLAND	SWITCH	64
YUGOSLAVIA	SIS	1.2 - 19.2
ASIA		
MULTI-NATION	AUSEAnet GULFnet PACNET	1.2 1.2 - 9.6 2.4
JAPAN	N-1 NACSIS JUNET	4.8 - 48 48 - 768 2.4 - 1544
Hong Kong	HARNET	1.2 - 9.6
INDIA	NICNET	1.2 - 9.6
INDONESIA	UNInet	---
ISRAEL	ILAN	9.6
KOREA	KREONet	56

EXHIBIT 6-2. Current International Research Networks
(Continued)

Location	Network	Link Speeds (Kbps)
ASIA - Continued		
MALAYSIA	RangKom	4.8 - 9.6
THAILAND	TCSnet	1.2 - 2.4
AUSTRALIA/PACIFIC		
MULTI-NATION	PACCOM	19.2 - 512
	SPEARNET	2.4 - 9.6
AUSTRALIA	ACSnet	2.4
	ABN	2.4 - 9.6
	QTInet	2.4 - 9.6
	VICNET	2.4 - 9.6
	AARNet	48
NEW ZEALAND	DSIRnet	2.4
CENTRAL & SOUTH AMERICA		
MULTI-NATION	CARINET	1.2
	CATIENET	1.2 - 2.4
AFRICA		
MULTI-NATION	CGNET	1.2 - 2.4
EGYPT	ENTSTINET	9.6
TUNISIA	Afrimail	1.2 - 2.4

EXHIBIT 6-3. Current US-International Links

(Organized By Foreign Country)

FOREIGN CITY	US CITY	US NET./PURPOSE	LINK SPEED (Kbps)
NORTH AMERICA			
CANADA			
Edmonton, BC	Princeton, NJ	BITNET, Acad Res	9.6
Montreal, QB	Princeton (JVNC), NJ	NSFNET, Research	56
Montreal, QB	Princeton, NJ	BITNET, Acad Res	9.6
Ottawa, QB	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Ottawa, QB	Rochester, NY	NSFNET, Research	56
Ottawa, QB	Princeton, NJ	BITNET, Acad Res	9.6
Toronto, ON	Chicago (FNAL), IL	ESNET/DOE HEP	56
Toronto, ON	Ithaca (CNSC), NY	NSFNET, Research	56
Toronto, ON	Princeton, NJ	BITNET, Acad Res	9.6
Vancover,BC	Seattle (UofW), WA	NSFNET, Research	19.2 (56)
Vancover,BC	Seattle (UofW), WA	BITNET, Acad Res	9.6
MEXICO			
Mexico City (UNAM)	Boulder (NCAR), CO	USAN Acad Research	64/128
Antizapan (ITESM)	Boulder (NCAR), CO	USAN Acad Research	64/128
Monterrey	San Antonio, TX	NSFNET, Acad Res	9.6
Monterrey	San Antonio, TX	BITNET, Acad Res	9.6
EUROPE			
FRANCE			
Sophia	Princeton, NJ	NSFNET, Research	64
Montepellier	Ithaca, NY	NSFNET, Supercomput.	56
Montepellier	New York (CUNY), NY	BITNET, Acad Res	56
Paris	Greenbelt (GSFC), MD	SPAN/NSN Research	9.6
Paris	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Toulouse	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Toulouse	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Moudon (Paris Obs)	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Moudon (Paris Obs)	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6 (1995)
Moudon (Paris Obs)	Greenbelt (GSFC), MD	SPAN/NASA Research	56 (1996)
Strasburg	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
GERMANY			
Bonn	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Bonn	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Bonn	Princeton, NJ	BITNET, Acad Res	9.6
Darmstadt	Greenbelt (GSFC), MD	SPAN/NASA Research	19.2
Darmstadt	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Garching	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Garching	Chicago (FNAL), IL	ESNET/DOE Research	64
Garching	Greenbelt (GSFC), MD	SPAN/NSN Research	9.6
Heidelberg	Greenbelt (GSFC), MD	SPAN/NSN Research	9.6
Max Plank	Greenbelt (GSFC), MD	SPAN/NSN Research	9.6
Max Plank	Greenbelt (GSFC), MD	SPAN/NSN Research	9.6
Oberfaf	Greenbelt (GSFC), MD	SPAN/NASA Research	56 (1995)
Oberfaf	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6

EXHIBIT 6-3. Current US-International Links
(Organized By Foreign Country - Continued)

FOREIGN CITY	US CITY	US NET./PURPOSE	LINK SPEED (Kbps)
UNITED KINGDOM			
Abingdon	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Bristol	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
London	Princeton (JVNC), NJ	NSFNET, Acad Res	56
Malvern	Cambridge (BBN), MA	DRI/DARPA Research	64
Oxford	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Oxford	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
OTHER EUROPE			
ITALY			
Bologona	Chicago (FNAL), IL	ESNET/DOE HEP	9.6
Bologona	Chicago (FNAL), IL	ESNET/DOE HEP	64
Citta	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Frascati	Chicago (FNAL), IL	ESNET/DOE HEP	64
Frascati	Greenbelt (GSFC), MD	SPAN/NASA Research	56
Frascati	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Pisa	Arlington (DARPA),VA	DRI/DARPA Research	64
NETHERLANDS			
Hague	Greenbelt (GSFC), MD	SPAN/NASA Research	19.2
Noordwijk	Greenbelt (GSFC), MD	SPAN/NASA Research	9.6
Amsterdam	Falls Church, VA	EUNET, UNET	64
NORWAY			
Oslo	Seismo, Washington,DC	DRI/DARPA Research	64
SWEDEN			
Stockholm	Princeton (JVNC), NJ	NSFNET, Acad. Res.	64
SWITZERLAND			
Cern	Ithaca, NY	NSFNET, Supercomput	1544
Geneva	Cambridge (MIT), MA	ESNET/DOE HEP	256
Geneva	Chicago (FNAL), IL	ESNET/DOE HEP	64
ASIA			
JAPAN			
Jaeri	Lawrence (LLNL), CA	ESNET/DOE HEP	9.6
Nagoya	Lawrence (LLNL), CA	ESNET/DOE HEP	9.6
Tokyo	Berkeley (LBL), CA	ESNET/DOE HEP	56
Tokyo	Washington, DC (NSF)	NSFNET Acad Res	14.4
Tokyo	Honolulu, HA	NSN/NASA Research	64
Tokyo	Honolulu, HA	NSN/NASA Research	64
Tokyo	Princeton, NJ	BITNET, Acad Res	9.6
MALAYSIA			
Singapore	Princeton, NJ	BITNET, Acad Res	9.6
SAUDI ARABIA			
Riyadh	Princeton, NJ	BITNET, Acad Res	9.6

EXHIBIT 6-3. Current US-International Links
(Organized By Foreign Country - Continued)

FOREIGN CITY	US CITY	US NET./PURPOSE	LINK SPEED (Kbps)
AUSTRALIA/PACIFIC			
AUSTRALIA			
Melbourne	Honolulu, HI	NSN/NASA Research	64
NEW ZEALAND			
Hamilton	Honolulu, HI	NSN/NASA Research	64
CENTRAL & SOUTH AMERICA			
BRAZIL			
Rio De Janeiro	Los Angeles, CA	BITNET, Acad Res	9.6
Rio De Janeiro	Princeton, NJ	BITNET, Acad Res	9.6
Sao Paulo	Princeton, NJ	BITNET, Acad Res	9.6
CHILE			
La Serena	Huntsville, AL	SPAN/NASA Research	56
Santiago	Princeton, NJ	BITNET, Acad Res	9.6
PUERTO RICO			
San Juan	Tampa, FL	BITNET, Acad Res	9.6

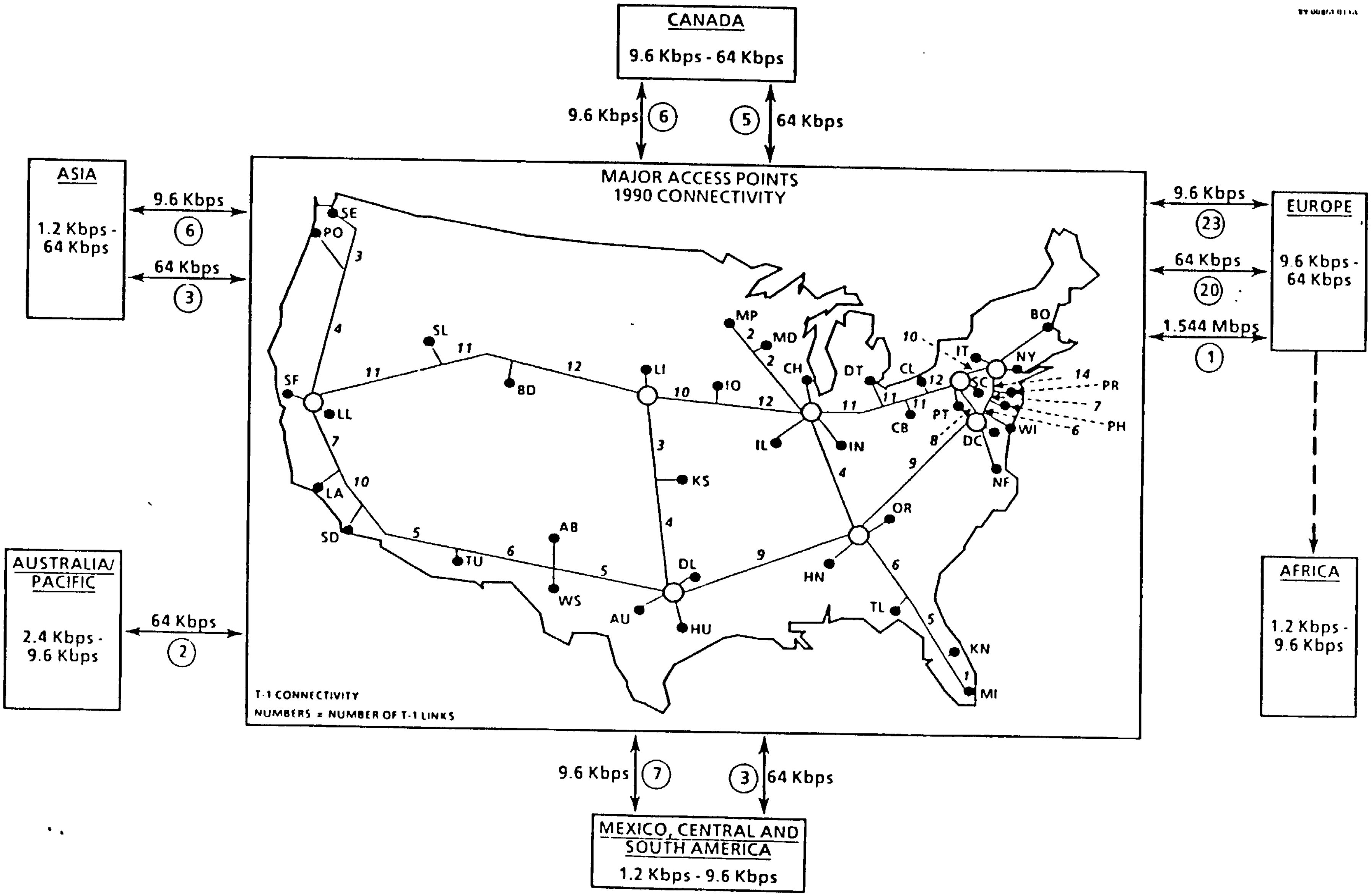

EXHIBIT 6-4. The Current (1990) U.S. Integrated Research Network With International Links.

The lines connecting the center box with the surrounding boxes show actual United States-international links. That is, these lines depict actual links between United States cities and cities in other parts of the world. As previously noted, these are not consolidated links. The numbers in the circles by each line indicate the number of links that the line represents. For example, the lines connecting the United States to Europe shows that there are twenty-three 9.6 Kbps link, twenty 64 Kbps links and one 1.544 Mbps link connecting the United States to Europe. This information was taken from Exhibit 6.3.

As indicated in Exhibit 6-4, there are some 76 links connecting the United States research networks to research networks in countries around the world. These links range in speeds from 9.6 Kbps to 1.544 Mbps, and they connect a T1 backbone in the United States to research networks around the world, and that have link speeds ranging from 1.2 Kbps to 64 Kbps. Currently, there are no direct United States links to Africa.

A perusal of Exhibits 6-2 to 6-4 shows that the current United States research network backbone link speed is higher than the backbone link speed of the various networks in other parts of the world. Also, note that the backbone link speed is higher than the typical link speed of links connecting the United States to other parts of the world. It is, therefore, apparent that the original current IRN topology and capacity map does not have to be altered to incorporate current international network requirements. In view of the number of duplicate United States-International links, it is also apparent that consolidating the international links would save money just as integrating the networks in the United States would save money.

6.4 THE NEW FUTURE IRNS

As noted earlier, the new future IRNs reflect anticipated growth in international as well as domestic research network requirements. A new future IRN was developed for each of the benchmark years (i.e., 1991, 1996, 2000, and 2010) used in the earlier study. Future IRNs were developed using a procedure similar to that used to develop the new current IRN. Each new future IRN is discussed below.

6.4.1 The New 1991 IRN

The new 1991 IRN was developed using the original 1991 IRN topology map (see Exhibit 6-5), the 1991 link speeds of the international research networks (see Exhibit 6-6), and the 1991 United States-international links (see Exhibit 6-7). Exhibit 6-5 is taken from the earlier domestic study, and Exhibits 6-6 and 6-7 were presented previously in Section 4.

The new 1991 IRN topology and capacity map is presented in Exhibit 6-8. The information in the box in the center of this exhibit shows the major access points and the T3/T1 connectivity of the 1991 IRN developed in the earlier study. As noted above in Section 6.2, the original 1991 IRN (see Exhibit 6-5) adequately reflects the updated domestic network requirements.

As with the new current IRN, the boxes surrounding the center box in Exhibit 6-8 includes information (taken from Exhibit 6-6) on each of the six major areas of the world discussed in Sections 2 and 3: Canada/Mexico, Europe, Africa, Central/South America, Australia/ Pacific and Asia. Again, for each of these major areas, the range of the typical link speeds of the backbones of the research networks in the countries in the area is indicated. For example, in Europe the typical backbone links speeds of the research networks in the European countries is projected to be in, 1991, 9.6 Kbps through 1.544 Mbps.

Note that in Exhibit 6-8, the lines connecting the center box with the surrounding boxes show consolidated, not actual (as they did in the previously presented exhibit depicting the new current IRN),

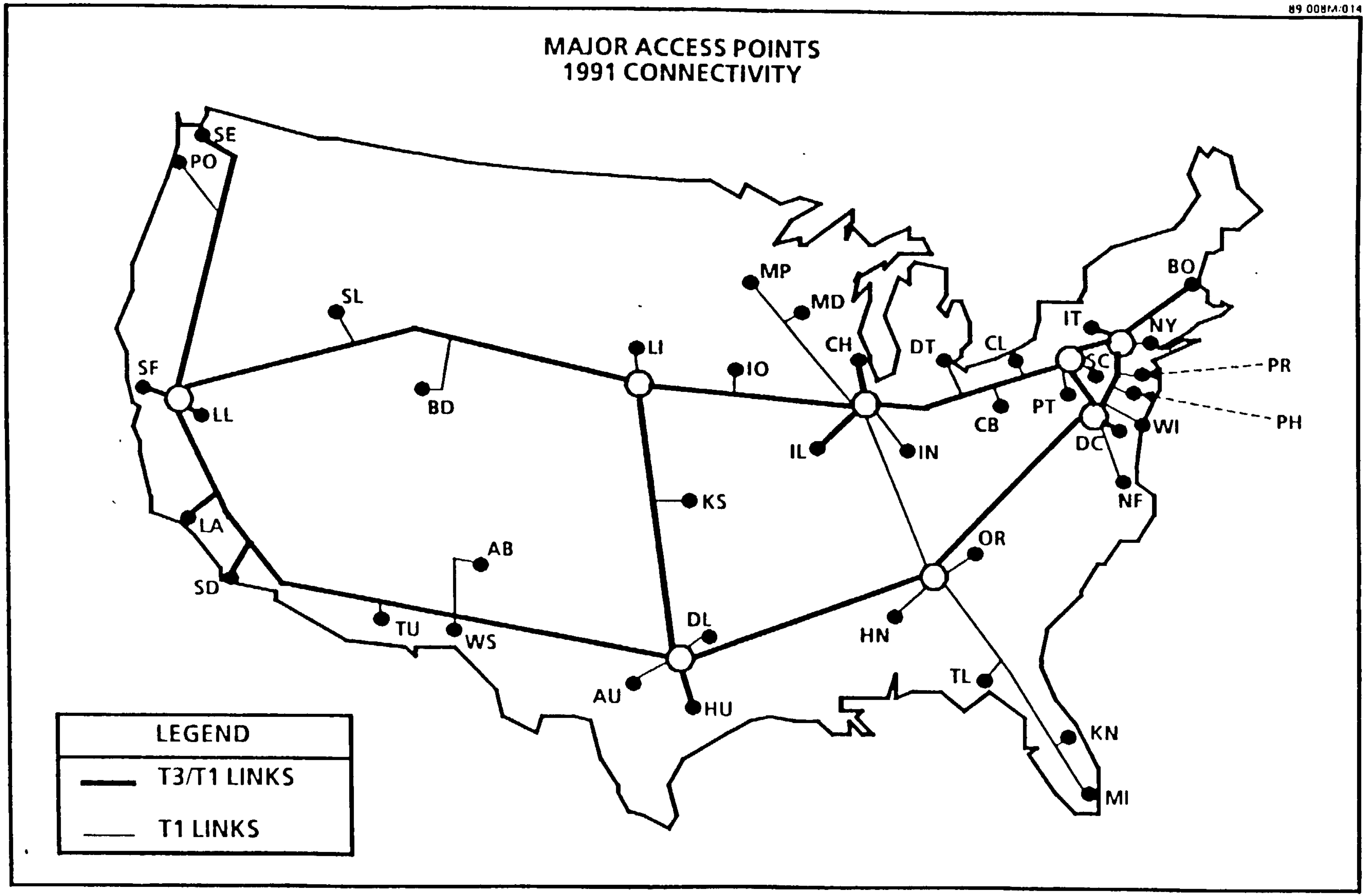

EXHIBIT 6-5. The 1991 U.S. Domestic Integrated Research Network

EXHIBIT 6-6. 1991 Projected Link Speeds International Research Networks

Location	Link Speeds
WORLDWIDE Networks	9.6 Kbps
NORTH AMERICA	
Canada	64 Kbps
Mexico	64 Kbps
EUROPE	
Continent-Wide Nets.	1.544 Mbps
Multi-Nation Nets.	1.544 Mbps
France	64 Kbps
Germany	64 Kbps
United Kingdom	64 Kbps
OTHER EUROPE	
Austria	9.6 Kbps
Denmark	64 Kbps
Finland	64 Kbps
Iceland	9.6 Kbps
Ireland	64 Kbps
Italy	64 Kbps
Netherlands	64 Kbps
Norway	64 Kbps
Soviet Union	9.6 Kbps
Spain	9.6 Kbps
Sweden	64 Kbps
Switzerland	64 Kbps
Yugoslavia	9.6 Kbps
ASIA	
Multi-Nation Nets.	9.6 Kbps

EXHIBIT 6-6. 1991 Projected Link Speeds

International Research Networks
(Continued)

Location	Link Speeds
ASIA (Continued)	
Japan	1.544 Mbps
Hong Kong	9.6 Kbps
India	9.6 Kbps
Indonesia	9.6 Kbps
Israel	9.6 Kbps
Korea	1.544 Mbps
Malaysia	9.6 Kbps
Thailand	9.6 Kbps
AUSTRALIA/PACIFIC	
Multi-Nation Nets.	1.544 Mbps
Australia	9.6 Kbps
New Zealand	9.6 Kbps
CENTRAL & SOUTH AMERICA	
Multi-Nation Nets.	9.6 Kbps
AFRICA	
Multi-Nation Nets.	9.6 Kbps
Egypt	9.6 Kbps
Tunisia	9.6 Kbps

EXHIBIT 6-7. 1991 Projected Link Speeds

U.S.-International Links

U.S. City	Foreign City/Country	Link Speed
Chicago, IL	Toronto, Canada	1.544 Mbps
Ithaca, NY	Montpellier, France	1.544 Mbps
	Cern, Switzerland	1.544 Mbps
Princeton, NJ	Bonn, Germany	1.544 Mbps
	Stockholm, Sweden	64 Kbps
	Rio De Janeiro, Brazil	64 Kbps
	La Serena, Chile	64 Kbps
	Singapore, Malaysia	9.6 Kbps
	Riyadh, Saudi Arabia	9.6 Kbps
Greenbelt, MD	Ottawa, Canada	1.544 Mbps
	Oxford, United Kingdom	1.544 Mbps
	Franscati, Italy	1.544 Mbps
	Amsterdam, Netherlands	64 Kbps
	Oslo, Norway	64 Kbps
Boulder, CO	Mexico City, Mexico	128 Kbps
Austin, TX	Monterrey, Mexico	9.6 Kbps
	San Juan, Puerto Rico	9.6 Kbps
Honolulu	Tokyo, Japan	1.544 Mbps
	Melbourne, Australia	64 Kbps
	Hamilton, New Zealand	64 Kbps

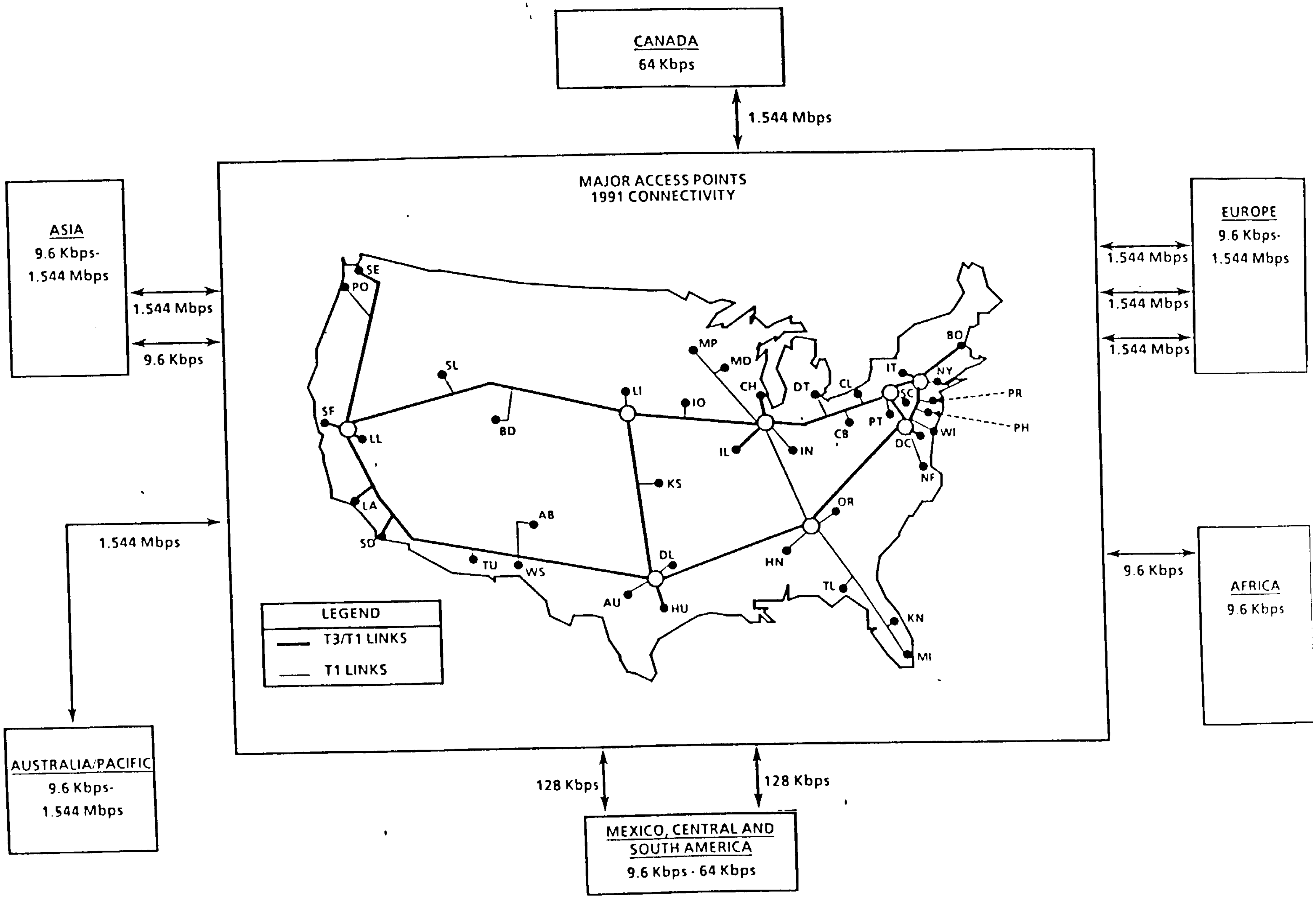

EXHIBIT 6-8. The 1991 U.S. Integrated Research Network With International Links

United States-international links. As noted in Section 4 and in the overview for this section, the United States-international links initially were consolidated to give each United States city only one link to any foreign country (see Exhibit 6-7).

When developing the new 1991 IRN, an additional consolidation of links was made based on an understanding of 1991 network requirements between the United States and the major areas of the world (e.g., Europe). When making this additional consolidation, it also was assumed that continent-wide networks would be developing in selected parts of the world (e.g., Europe), and that the United States would have several links to these continent-wide networks and, therefore, would not need direct access to every major country. This resulted in a maximum of one United States-international link to each foreign country, and only indirect links to some countries.

While it is possible that the United States' researchers may require more than one link to some foreign countries, or may require separate links for special projects, these requirements were not reflected in the new 1991 or other new future IRN topologies. It is believed that these requirements would be based more on needs related to security and redundancy than on capacity needs. Thus, the link lines in Exhibit 6-8 depict what are expected to be consolidated United States' international link requirements in 1991. For example, Exhibit 6.8 shows three 1.544 Mbps links between the United States and Europe, indicating that three such links will meet expected United States link connectivity requirements with Europe in 1991.

As indicated in Exhibit 6-8, there are only 10 links connecting the United States research networks to research networks in countries around the world. These links are all 1.544 Mbps links except for the two links to Mexico and Central/South America which are 128 Kbps links and one of the two links to Asia which is a 9.6 Kbps link. The ten links connect a T3/T1 backbone in the United States to research networks that are located around the world and that have link speeds ranging from 9.6 Kbps to 1.544 Mbps.

Note that the 1991 United States research network backbone link speed is still higher than the backbone link speed of the various networks in other parts of the world. Also, note that it is higher than the typical projected link speed of links connecting the United States to other parts of the world. It is apparent, therefore, that the original 1991 topology and capacity map does not have to be altered to incorporate international research network requirements. However, continual improvements are needed in the United States-international links.

6.4.2 The New 1996 IRN

The new 1996 IRN was developed using the original 1996 IRN topology map (see Exhibit 6-9), the projected 1996 link speeds of the international research networks (see Exhibit 6-10), and the 1996 United States-international links (see Exhibit 6-11). Exhibit 6-9 was presented initially in the earlier domestic study, and Exhibits 6-10 and 6-11 were presented previously in Section 4.

The new 1996 IRN topology map is presented in Exhibit 6-12. The information in the box in the center of this exhibit shows the major access points and the connectivity, with link speeds ranging from 45 Mbps to 1 Gbps, of the 1996 IRN developed in the earlier study (see Exhibit 6-9). As noted above in Section 6.2, the original 1996 IRN (see Exhibit 6-9) adequately reflects the updated domestic network requirements.

As with the new 1991 IRN, the boxes surrounding the center box in Exhibit 6-12, showing the new 1996 IRN, include information (from Exhibit 6-10) on each of the six areas of the world discussed in Sections 2-3: Canada/Mexico, Europe, Africa, Central/South America, Australia /Pacific and Asia. Again, for each of these areas, the range of the typical link speeds of the backbones of the research networks in the countries in the area is noted. For example, in Europe the typical backbone links speeds of the research networks in European countries is projected to be in, 1996, 64 Kbps to 45 Mbps.

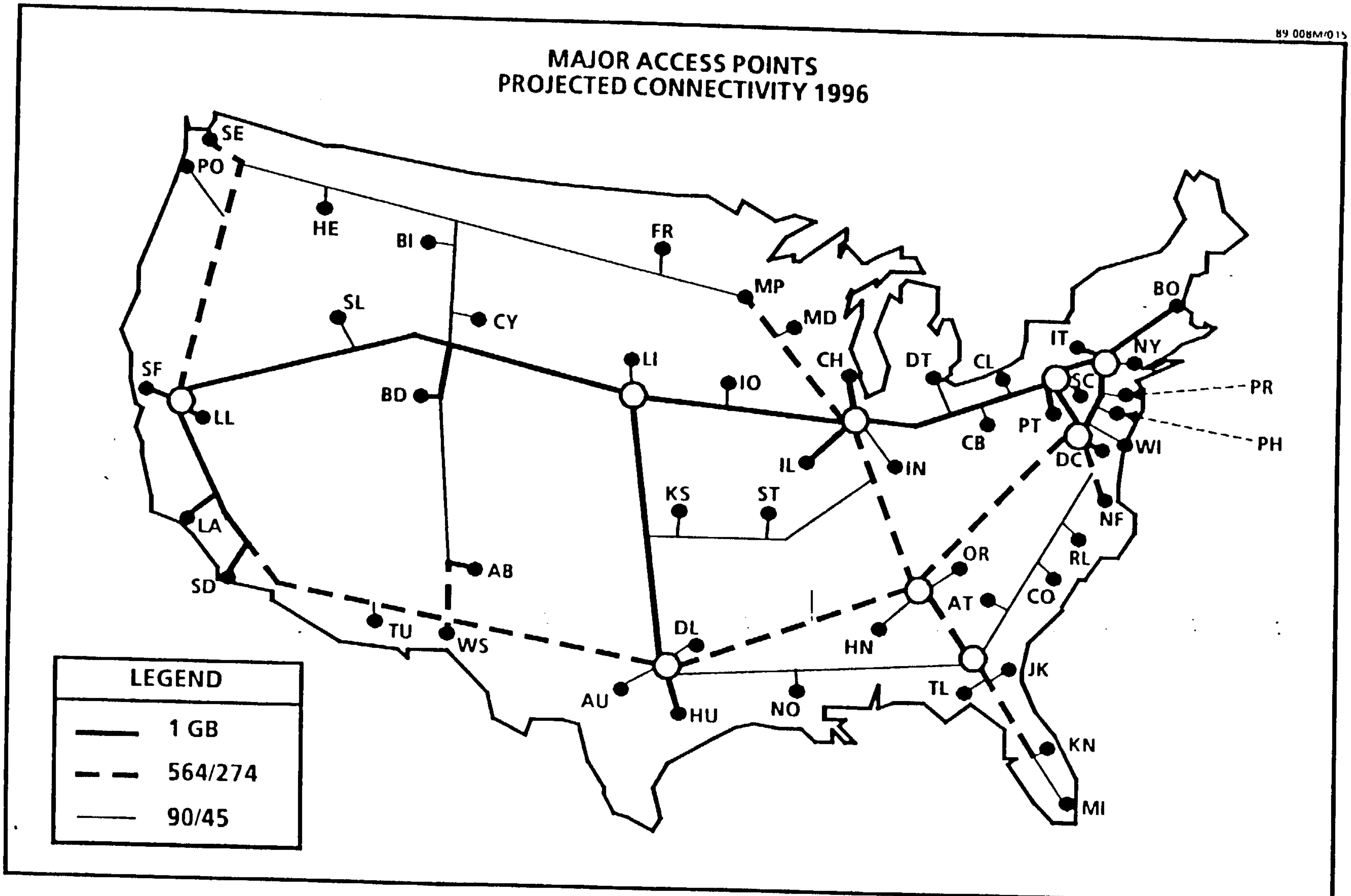

EXHIBIT 6-9. The 1996 U.S. Domestic Integrated Research Network.

EXHIBIT 6-10. 1996 Projected Link Speeds

International Research Networks

Location	Link Speeds
WORLDWIDE Networks	1.544 Mbps
NORTH AMERICA	
Canada	45 Mbps
Mexico	1.544 Mbps
EUROPE	
Continent-Wide Nets.	45 Mbps
Multi-Nation Nets.	45 Mbps
France	45 Mbps
Germany	45 Mbps
United Kingdom	45 Mbps
OTHER EUROPE	
Austria	1.544 Mbps
Denmark	45 Mbps
Finland	1.544 Mbps
Iceland	1.544 Mbps
Ireland	1.544 Mbps
Italy	45 Mbps
Netherlands	45 Mbps
Norway	45 Mbps
Soviet Union	1.544 Mbps
Spain	1.544 Mbps
Sweden	45 Mbps
Switzerland	45 Mbps
Yugoslavia	64 Kbps
ASIA	
Multi-Nation Nets.	64 Kbps

EXHIBIT 6-10. 1996 Projected Link Speeds

International Research Networks

(Continued)

Location	Link Speeds
ASIA (Continued)	
Japan	45 Mbps
Hong Kong	64 Kbps
India	64 Kbps
Indonesia	64 Kbps
Israel	64 Kbps
Korea	1.544 Mbps
Malaysia	64 Kbps
Thailand	64 Kbps
AUSTRALIA/PACIFIC	
Multi-Nation Nets.	45 Mbps
Australia	1.544 Mbps
New Zealand	1.544 Mbps
CENTRAL & SOUTH AMERICA	
Multi-Nation Nets.	64 Kbps
AFRICA	
Multi-Nation Nets.	64 Kbps
Egypt	64 Kbps
Tunisia	64 Kbps

EXHIBIT 6-11. 1996 Projected Link Speeds

U.S.-International Links

U.S. City	Foreign City/Country	Link Speed
Chicago, IL	Toronto, Canada	45 Mbps
Ithaca, NY	Montpellier, France	45 Mbps
	Cern, Switzerland	45 Mbps
Princeton, NJ	Bonn, Germany	45 Mbps
	Stockholm, Sweden	45 Mbps
	Rio De Janeiro, Brazil	1.544 Mbps
	La Serena, Chile	1.544 Mbps
	Singapore, Malaysia	64 Kbps
	Riyadh, Saudi Arabia	64 Kbps
Greenbelt, MD	Ottawa, Canada	45 Mbps
	Oxford, United Kingdom	45 Mbps
	Franscati, Italy	45 Mbps
	Amsterdam, Netherlands	45 Mbps
	Oslo, Norway	45 Mbps
Boulder, CO	Mexico City, Mexico	1.544 Mbps
Austin, TX	Monterrey, Mexico	1.544 Mbps
	San Juan, Puerto Rico	64 Kbps
Honolulu	Tokyo, Japan	45 Mbps
	Melbourne, Australia	1.544 Mbps
	Hamilton, New Zealand	1.544 Mbps

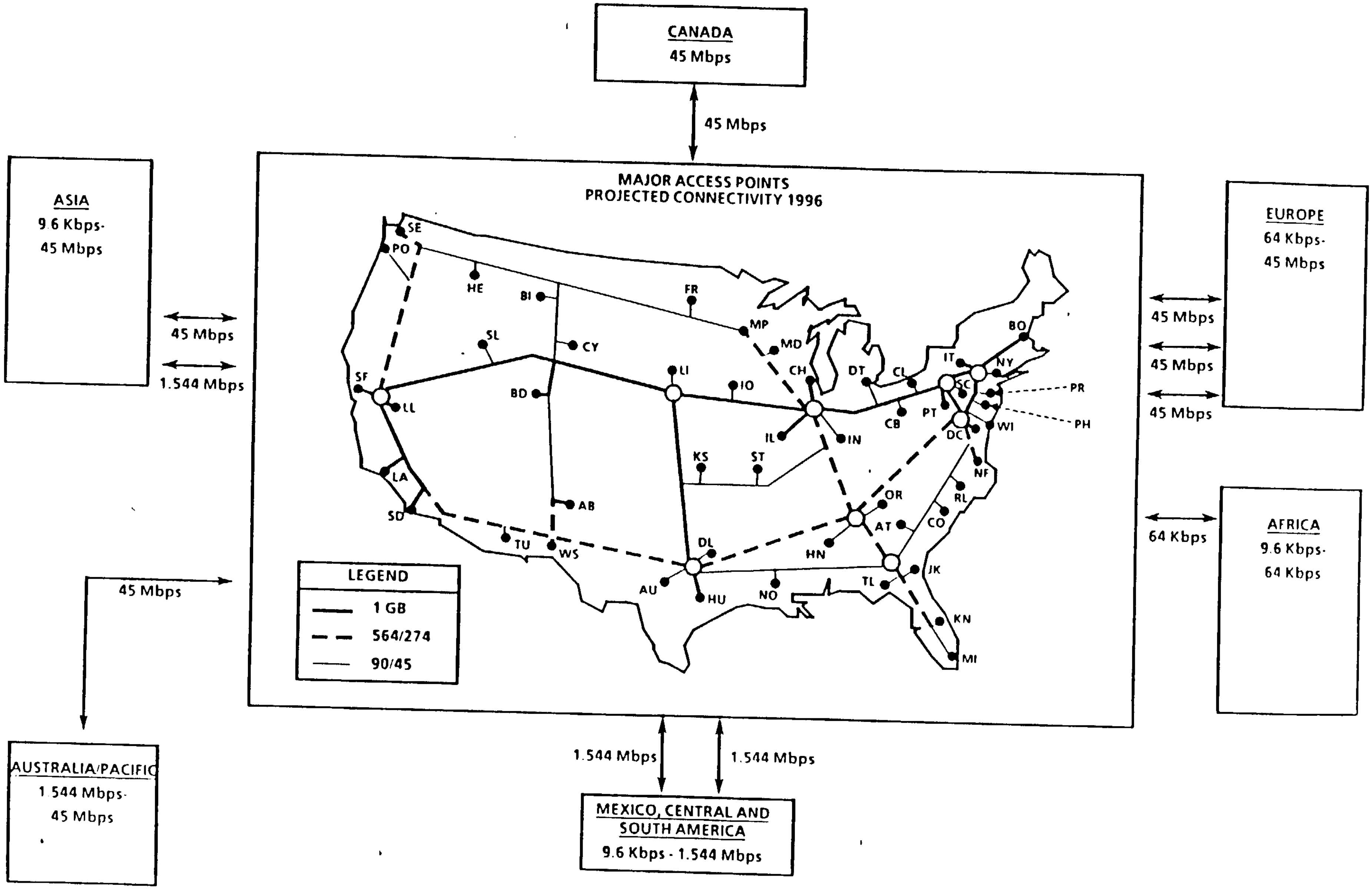

EXHIBIT 6-12. The 1996 U.S. Integrated Research Network With International Links

In Exhibit 6.12, as in Exhibit 6-8 showing the new 1991 IRN topology, the lines connecting the center box with the surrounding boxes represent consolidated, not actual United States-international links (see Exhibits 6-11). As with 1991, an additional consolidation of links was made based on an understanding of 1996 network connectivity requirements between the United States and each of the major areas of the world (e.g., Europe). This understanding is built upon the 1991 projected link speeds of the United States-international links (see Exhibit 6-8).

As indicated in Exhibit 6-12, there are (as there were for 1991) only 10 links connecting the United States research networks to research networks in countries around the world. These links in 1996 are all 45 Mbps links except for two links to Mexico and Central and South America and one to Asia which are 1.544 Mbps links. The ten links connect a backbone, ranging in link speeds from 45 Mbps to 1 Gbps, in the United States to research networks that are around the world that have link speeds ranging from 9.6 Kbps to 45 Mbps.

Again, note that the 1996 United States research network backbone link speed is still higher than the backbone link speed of the various networks in other parts of the world. It is also higher than the typical link speed of links connecting the United States to other parts of the world. Therefore, just as for 1991, it is apparent that the original 1996 topology and capacity map does not have to be altered to incorporate international research network requirements. However, continual improvements are needed in the United States-international links.

6.4.3 The New 2000 IRN

The new 2000 IRN was developed using the original 2000 IRN topology map (see Exhibit 6-13), the projected year 2000 link speeds of the international research networks (see Exhibit 6-14), and the year 2000 United States-international links (see Exhibit 6-15).

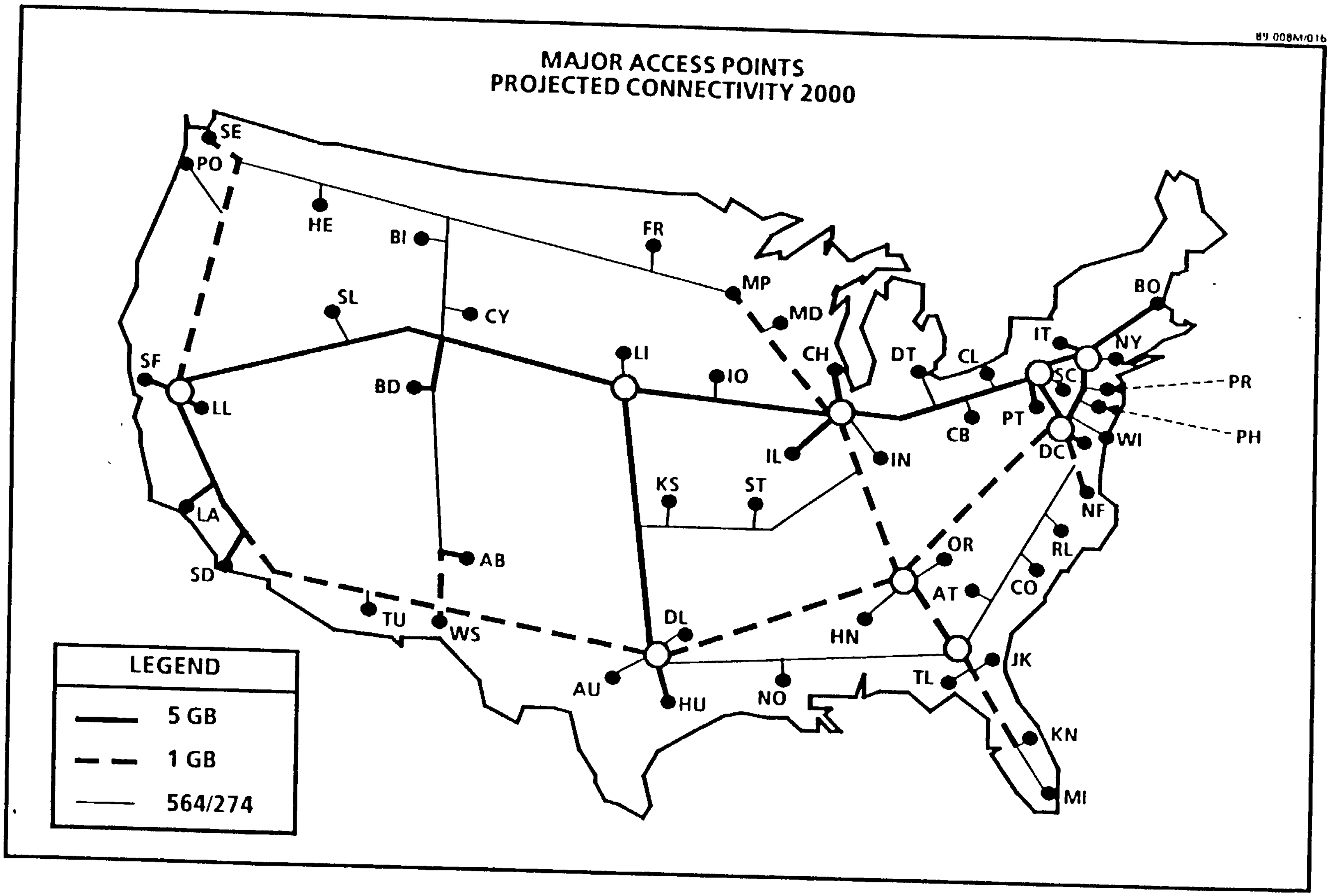

EXHIBIT 6-13. The Year 2000 U.S. Domestic Integrated Research Network

EXHIBIT 6-14. 2000 Projected Link Speeds International Research Networks

Location	Link Speeds
WORLDWIDE Networks	45 Mbps
NORTH AMERICA	
Canada	1 Gbps
Mexico	45 Mbps
EUROPE	
Continent-Wide Nets.	1 Gbps
Multi-Nation Nets.	1 Gbps
France	1 Gbps
Germany	1 Gbps
United Kingdom	1 Gbps
OTHER EUROPE	
Austria	45 Mbps
Denmark	1 Gbps
Finland	45 Mbps
Iceland	45 Mbps
Ireland	45 Mbps
Italy	1 Gbps
Netherlands	1 Gbps
Norway	1 Gbps
Soviet Union	45 Mbps
Spain	45 Mbps
Sweden	1 Gbps
Switzerland	1 Gbps
Yugoslavia	1.544 Mbps
ASIA	
Multi-Nation Nets.	1.544 Mbps

EXHIBIT 6-14. 2000 Projected Link Speeds

International Research Networks
(Continued)

Location	Link Speeds
ASIA (Continued)	
Japan	1 Gbps
Hong Kong	1.544 Mbps
India	1.544 Mbps
Indonesia	1.544 Mbps
Israel	1.544 Mbps
Korea	45 Mbps
Malaysia	1.544 Mbps
Thailand	1.544 Mbps
AUSTRALIA/PACIFIC	
Multi-Nation Nets.	1 Gbps
Australia	45 Mbps
New Zealand	45 Mbps
CENTRAL & SOUTH AMERICA	
Multi-Nation Nets.	1.544 Mbps
AFRICA	
Multi-Nation Nets.	1.544 Mbps
Egypt	1.544 Mbps
Tunisia	1.544 Mbps

EXHIBIT 6-15. 2000 Projected Link Speeds

U.S.-International Links

U.S. City	Foreign City/Country	Link Speed
Chicago, IL	Toronto, Canada	1 Gbps
Ithaca, NY	Montpellier, France	1 Gbps
	Cern, Switzerland	1 Gbps
Princeton, NJ	Bonn, Germany	1 Gbps
	Stockholm, Sweden	1 Gbps
	Rio De Janeiro, Brazil	45 Mbps
	La Serena, Chile	45 Mbps
	Singapore, Malaysia	1.544 Mbps
	Riyadh, Saudi Arabia	1.544 Mbps
Greenbelt, MD	Ottawa, Canada	1 Gbps
	Oxford, United Kingdom	1 Gbps
	Franscati, Italy	1 Gbps
	Amsterdam, Netherlands	1 Gbps
	Oslo, Norway	1 Gbps
Boulder, CO	Mexico City, Mexico	45 Mbps
Austin, TX	Monterrey, Mexico	45 Mbps
	San Juan, Puerto Rico	1.544 Mbps
Honolulu	Tokyo, Japan	1 Gbps
	Melbourne, Australia	45 Mbps
	Hamilton, New Zealand	45 Mbps

Exhibit 6-13 was presented initially in the earlier study, and Exhibits 6-14 and 6-15 were presented previously in Section 4.

The new 2000 IRN topology map is presented in Exhibit 6-16. The information in the box in the center of this exhibit shows the major access points and the connectivity, link speeds ranging from 274 Mbps to 5 Gbps, of the 2000 IRN developed in the earlier domestic study. As noted above in Section 6.2, the original 2000 IRN (see Exhibit 6-13) adequately reflects the updated domestic network requirements.

As with the new 1996 IRN, the boxes surrounding the center box in Exhibit 6-16, showing the new 2000 IRN, include information (taken from Exhibit 6-14) on each of the six major areas of the world discussed in Sections 2 and 3: Canada/Mexico, Europe, Africa, Central/South America, Australia/Pacific and Asia. Again, for each of these major areas, the range of the typical link speeds of the backbones of the research networks in the countries in the area is indicated. For example, in Europe the typical backbone links speeds of the research networks in the European countries is projected to be 45 Mbps through 1 Gbps by the year 2000.

In Exhibit 6-16, as in Exhibit 6-12 showing the new 1996 IRN topology, the lines connecting the center box with the surrounding boxes show consolidated, not actual United States-international links (see Exhibits 6-15). An additional consolidation of links was made based on an understanding of 2000 network connectivity requirements between the United States and each of the major areas of the world (e.g., Europe). This understanding is built upon the 1996 projected link speeds of the US-international links (see Exhibit 6-12).

As indicated in Exhibit 6-16, there are (as there were for 1996) only 10 links connecting the United States research networks to research networks in countries around the world. These links in 2000 are all 1 Gbps links except for two links to Mexico and Central and South America and one to Asia which are 45 Mbps links. The ten links connect a backbone, ranging in link speeds from 274 Mbps to 5 Gbps,

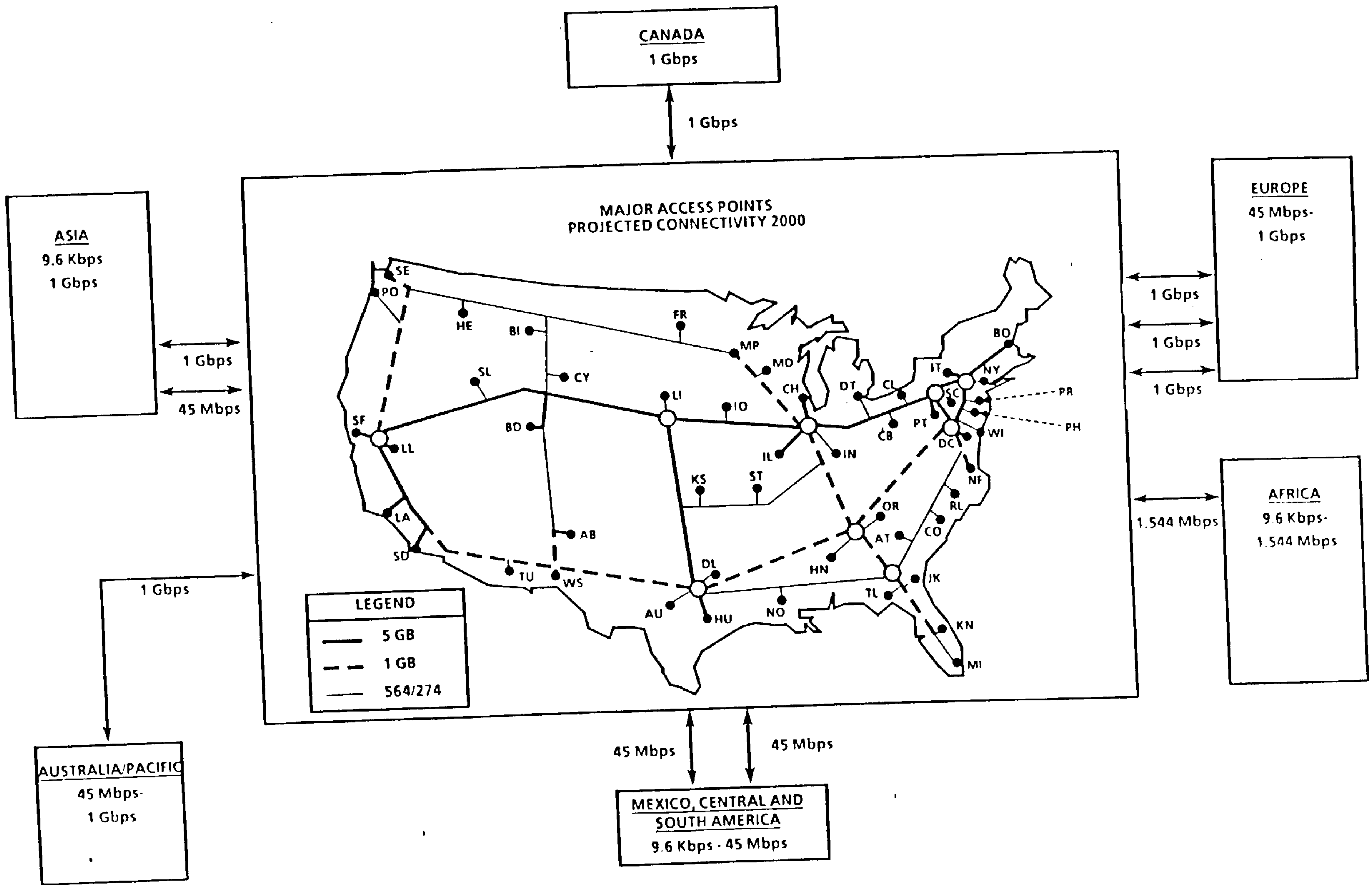

EXHIBIT 6-16. The Year 2000 U.S. Integrated Research Network With International Links.

in the United States to research networks around the world that have link speeds ranging from 9.6 Kbps to 1 Gbps.

Again, note that the year 2000 United States research network backbone link speed is still higher than the backbone link speed of the various networks in other parts of the world. Also, it is higher than the typical link speed of links connecting the United States to other parts of the world. Therefore, as before for 1996, it is apparent that the original 2000 topology and capacity map does not have to be altered to incorporate international research network requirements. However, continual improvements in terms of link speeds are needed in the United States-international links.

6.4.3 The New 2010 IRN

The new 2010 IRN was developed using the original 2010 IRN topology map (see Exhibit 6-17), the projected 2010 link speeds of the international research networks (see Exhibit 6-18), and the 2010 United States-international links (see Exhibit 6-19). Exhibit 6-17 was presented initially in the earlier domestic study, and Exhibits 6-18 and 6-19 were presented previously in Section 4.

The new 2010 IRN topology map is presented in Exhibit 6-20. The information in the box in the center of this exhibit shows the major access points and the connectivity, with link speeds ranging from 1 Gbps to 25 Gbps, of the 2010 IRN developed in the earlier domestic study (see Exhibit 6-17). As noted above in Section 6.2, the original 2010 IRN (see Exhibit 6-17) adequately reflects the updated domestic network requirements.

As with the new 2000 IRN, the boxes surrounding the center box in Exhibit 6-20, showing the new 2010 IRN, include information (taken from Exhibit 6-18) on each of the six major areas of the world discussed in Sections 2/3: Canada/Mexico, Europe, Africa, Central/ South America, Australia/Pacific and Asia. Again, for each of these

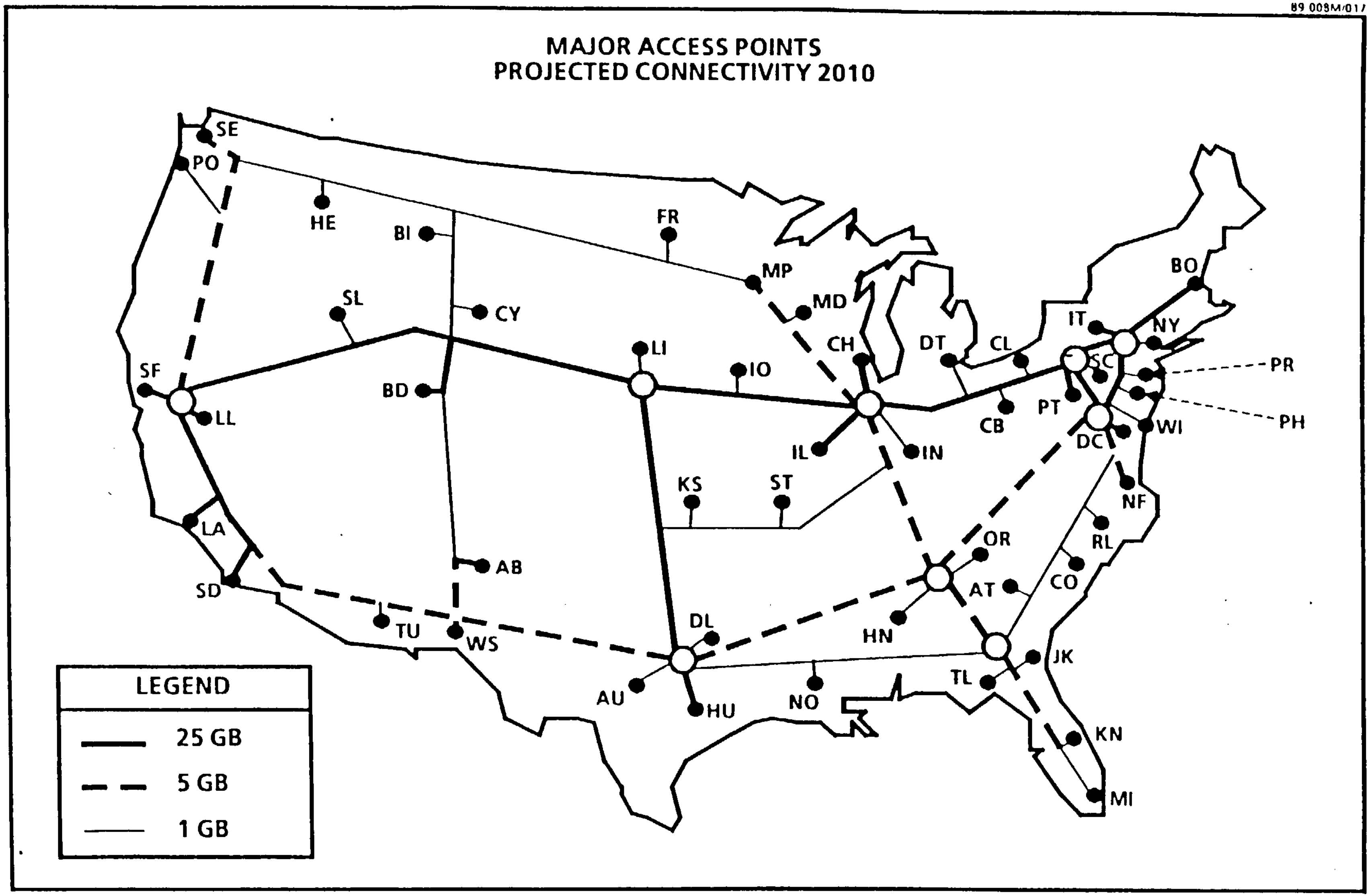

EXHIBIT 6-17. The 2010 U.S. Domestic Integrated Research Network.

EXHIBIT 6-18. 2010 Projected Link Speeds
International Research Networks

Location	Link Speeds
WORLDWIDE Networks	1 Gbps
NORTH AMERICA	
Canada	5 Gbps
Mexico	1 Gbps
EUROPE	
Continent-Wide Nets.	5 Gbps
Multi-Nation Nets.	5 Gbps
France	5 Gbps
Germany	5 Gbps
United Kingdom	5 Gbps
OTHER EUROPE	
Austria	1 Gbps
Denmark	5 Gbps
Finland	1 Gbps
Iceland	1 Gbps
Ireland	1 Gbps
Italy	5 Gbps
Netherlands	5 Gbps
Norway	5 Gbps
Soviet Union	1 Gbps
Spain	1 Gbps
Sweden	5 Gbps
Switzerland	5 Gbps
Yugoslavia	45 Mbps
ASIA	
Multi-Nation Nets.	45 Mbps

EXHIBIT 6-18. 2010 Projected Link Speeds

International Research Networks

(Continued)

Location	Link Speeds
ASIA (Continued)	
Japan	5 Gbps
Hong Kong	45 Mbps
India	45 Mbps
Indonesia	45 Mbps
Israel	45 Mbps
Korea	1 Gbps
Malaysia	45 Mbps
Thailand	45 Mbps
AUSTRALIA/PACIFIC	
Multi-Nation Nets.	5 Gbps
Australia	1 Gbps
New Zealand	1 Gbps
CENTRAL & SOUTH AMERICA	
Multi-Nation Nets.	45 Mbps
AFRICA	
Multi-Nation Nets.	45 Mbps
Egypt	45 Mbps
Tunisia	45 Mbps

EXHIBIT 6-19. 2010 Projected Link Speeds

U.S.-International Links

U.S. City	Foreign City/Country	Link Speed
Chicago, IL	Toronto, Canada	5 Gbps
Ithaca, NY	Montpellier, France	5 Gbps
	Cern, Switzerland	5 Gbps
Princeton, NJ	Bonn, Germany	5 Gbps
	Stockholm, Sweden	5 Gbps
	Rio De Janeiro, Brazil	1 Gbps
	La Serena, Chile	1 Gbps
	Singapore, Malaysia	45 Mbps
	Riyadh, Saudi Arabia	45 Mbps
Greenbelt, MD	Ottawa, Canada	5 Gbps
	Oxford, United Kingdom	5 Gbps
	Franscati, Italy	5 Gbps
	Amsterdam, Netherlands	5 Gbps
	Oslo, Norway	5 Gbps
Boulder, CO	Mexico City, Mexico	1 Gbps
Austin, TX	Monterrey, Mexico	1 Gbps
	San Juan, Puerto Rico	45 Mbps
Honolulu	Tokyo, Japan	5 Gbps
	Melbourne, Australia	1 Gbps
	Hamilton, New Zealand	1 Gbps

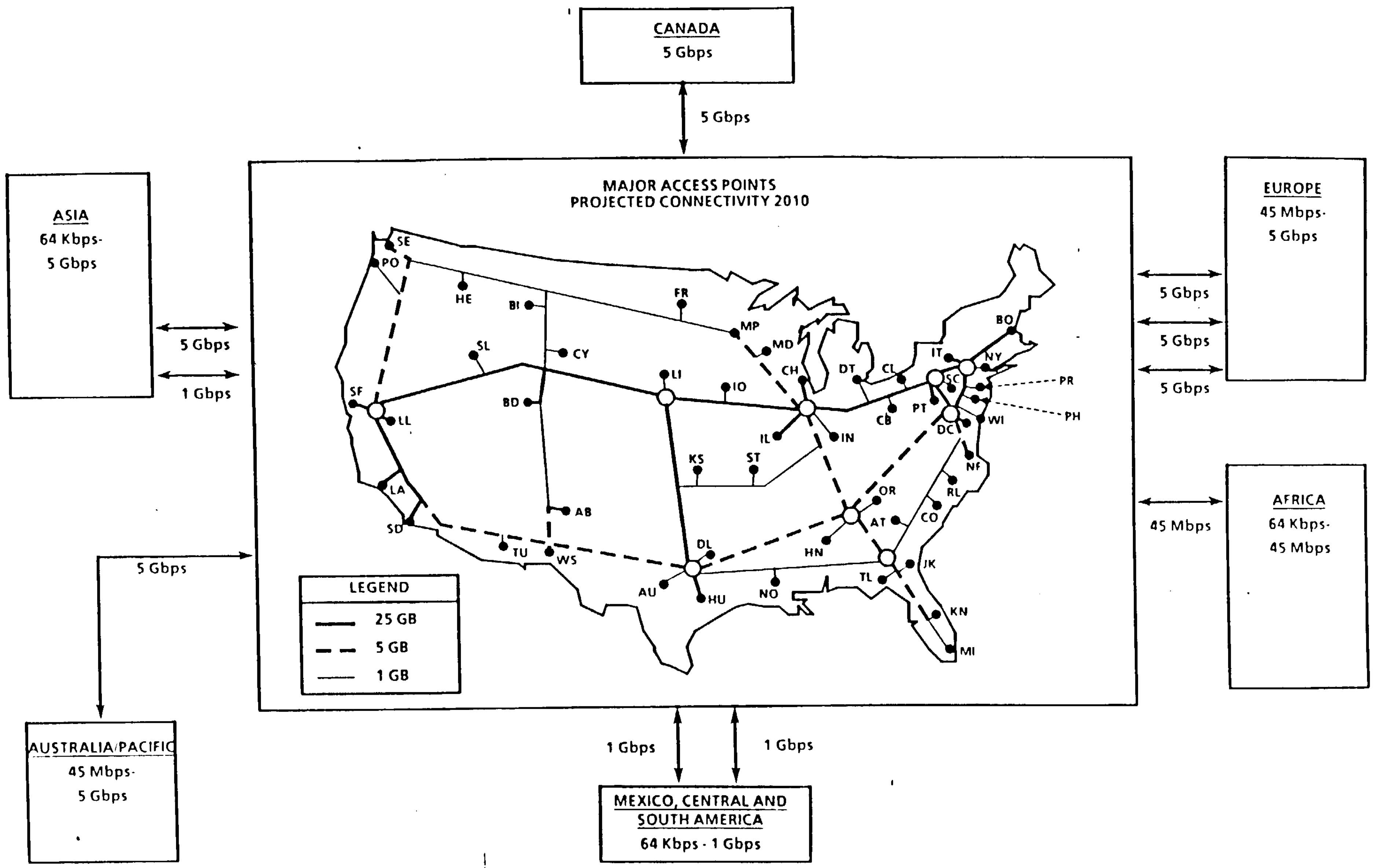

EXHIBIT 6-20. The 2010 U.S. Integrated Research Network With International Links.

major areas, the range of the typical link speeds of the backbones of the research networks in the countries in the area is indicated. For example, in Europe the typical backbone links speeds of the research networks in the European countries is projected to be in, 2010, 45 Mbps through 5 Gbps.

In Exhibit 6-20, as in Exhibit 6-16 showing the new 2000 IRN topology, the lines connecting the center box with the surrounding boxes show consolidated, not actual United States-international links (see Exhibits 6-19). As for 2000, an additional consolidation of links was made based on an understanding of 2010 network connectivity requirements between the United States and each of the major areas of the world (e.g., Europe). This understanding included the year 2000 projected link speeds of the United States-international links (see Exhibit 6-16).

As indicated in Exhibit 6-20, there are (as there were for 2000) only 10 links connecting the United States research networks to research networks in countries around the world. These links in 2010 are all 5 Gbps links except for the two links to Mexico and Central and South America and one to Asia which are 1 Gbps links. The ten links connect a backbone, ranging in link speeds from 1 Gbps to 25 Gbps, in the United States to research networks around the world that have link speeds ranging from 64 Kbps to 5 Gbps.

Again, the 2010 United States research network has a backbone link speed that is still higher than the backbone link speed of the various networks in other parts of the world. Also, it is higher than the typical link speed of links connecting the United States to other parts of the world. Therefore, as was the case with year 2000, it is apparent that the original 2010 topology map does not have to be altered to incorporate international research network requirements. However, as was the case for each of the previous benchmark years, continual improvements and consolidation are needed in the United States-international links to make certain that benefits from economies of scale accrue.

6.5 SUMMARY OF NEW CURRENT & FUTURE IRNS

The new current and future IRNs were described in this section. The results of the current study, presented in Sections 2-5, were used to modify the original IRNs developed in the previous U.S. Domestic Research Network Study. First, the impact, on the current and future IRNs, of unexpected changes in the United States research networks and in the NREN plans was assessed and summarized. Then, the current international research network traffic flow was incorporated in the projection of the new current IRN. Lastly, and in a similar manner, the future international research network traffic flow was incorporated in the descriptions of the new future IRNs. The results of these efforts are briefly summarized below.

6.5.1 Summary of Update

A review of the update of the United States research networks and the NREN plans suggested that the original topology maps, developed in the earlier study for the current and future IRNs, still reflect expected domestic research network requirements. Therefore, it was concluded that these original topology maps could be used, along with information on the networks outside of the United States and on the United States-international links, to develop the new current and future IRNs.

6.5.2 The New Current IRN

The incorporation of the current international research network traffic flow in the development of the new current IRN, resulted in no change to the original current IRN domestic topology map, but suggested a need to consolidate and improve the performance of United States-international links. Currently, there are some 77 links connecting the United States research networks to research networks in countries around the world. These links range in speed from 9.6 Kbps to 1.544 Mbps, and they connect a T1 backbone in the United States to research networks around the world that have link speeds ranging from 1.2 Kbps to 64 Kbps. Currently, there are no direct United States links to Africa.

Thus, the current domestic United States integrated research network has a backbone link speed that is higher than the backbone link speed of the various networks in other parts of the world. Also, it is higher than the typical link speed of links connecting the United States to other parts of the world. Therefore, it was concluded that the original current IRN topology map did not have to be altered to incorporate current international network requirements. Because there are a large number of international links, it was suggested that consolidating the international links would save money just as integrating the networks in the United States would save money.

In summary, the new current IRN topology map includes the following: the original current domestic topology map developed in the earlier study; the 77 international links to six major areas of the world; and the range of the typical link speeds of the backbones of the research networks in the countries in the six major areas. Please see Exhibit 6-4, page 6-14.

6.5.3 The New Future IRNs

The incorporation of the future international research network traffic flows in the new future IRNs resulted in no changes to the original future IRN domestic topology maps. But, as was the case with the new current IRN, this incorporation suggested a need to consolidate and improve the performance of United States-international links for each benchmark year. The four new future IRNs are briefly described below.

6.5.3.1 The New 1991 IRN

A Consolidation of the United States-international links in 1991 resulted in only 10 links connecting the United States research networks to research networks in countries around the world. In 1991, these links are all projected to be 1.544 Mbps links except for the two links to Mexico and Central/South America which are expected to be 128 Kbps links and one of the two links to Asia which is expected to be a 9.6 Kbps link. The ten links connect a T3/T1 backbone in the United States to research networks around the world that have link speeds ranging from 9.6 Kbps to 1.544 Mbps.

Thus, the 1991 United States research network has a backbone link speed that is still higher than the backbone link speed of the various networks in other parts of the world. Also, it is higher than the typical link speed of projected links for connecting the United States to other parts of the world. It was therefore concluded that the original 1991 topology map does not have to be altered to incorporate international research network requirements. However, it was also noted that continual improvements are needed in the United States-international links to make certain the United States research networks have adequate connectivity with research networks around the world. These improvements were indicated by the increase, noted above, in the speeds of the United States-international links.

In summary, the new 1991 IRN topology map includes the following: the original 1991 domestic topology map developed in the earlier study; the 10 1991 consolidated international links to six major areas of the world; and the range of the typical 1991 link speeds of the backbones of the research networks in the countries in the six major areas. Please see Exhibit 6-8, page 6-21.

6.5.3.2 The New 1996 IRN

In 1996, only 10 links are projected (the same as projected for 1991) for connecting the United States research networks to research networks in countries around the world. These links in 1996 are all projected to be 45 Mbps links except for two links to Mexico and Central/South America and one to Asia which are each expected to be

1.544 Mbps links. The ten links connect a backbone, ranging in link speeds from 45 Mbps to 1 Gbps, in the United States to research networks around the world that have link speeds ranging from 9.6 Kbps to 45 Mbps.

Thus, the 1996 United States research network has a backbone link speed that is still higher than the backbone link speed of the various networks in other parts of the world. Also, it is higher than the typical link speed of links connecting the United States to other parts of the world. Therefore, as was the case for 1991, it was concluded that the original 1996 topology map does not have to be altered to incorporate international research network requirements. Improvements in United States-international links were indicated by the increase, noted above, in the speeds of the United States-international links.

In summary, the new 1996 IRN topology map includes the following: the original 1996 domestic topology map; the 10 1996 consolidated international links to six major areas of the world; and the range of the typical 1996 link speeds of the backbones of the research networks in the countries in the six major areas. Please see Exhibit 6-12, page 6-28.

6.5.3.3 The New 2000 IRN

In the year 2000, the same 10 links are projected for connecting the United States research networks to research networks in countries around the world. However, these links in the year 2000 are all projected to be 1 Gbps links except for two links to Mexico and Central/South America and one to Asia which are each expected to be 45 Mbps links. The ten links connect a backbone, ranging in link speeds from 274 Mbps to 5 Gbps, in the United States to research networks around the world that have link speeds ranging from 9.6 Kbps to 1 Gbps.

Thus, the 2000 United States research network has a backbone link speed that is still higher than the backbone link speed of the various networks in other parts of the world. Also, it is higher than the typical link speed of links connecting the United States to other parts of the world. Therefore, as was the case for 1996, it was concluded that the original 2000 topology map does not have to be altered to incorporate international research network requirements. Continual improvements are needed in the United States-international links to make certain the United States research networks have adequate connectivity with research networks around the world. These improvements were indicated by the increase, noted above, in the speeds of the United States-international links.

In summary, the new year 2000 IRN topology map includes the following: the original year 2000 domestic topology map developed in the earlier domestic study; the 10 consolidated international links to six major areas of the world; and the range of the typical year 2000 link speeds of the backbones of the research networks in the countries in the six major areas. Please see Exhibit 6-16, page 6-35.

6.5.3.4 The New 2010 IRN

In year 2010, the same 10 links are projected for connecting the United States research networks to research networks in countries around the world. As before, these links are expected to be operating at higher speeds. In the year 2010, they are all projected to be 5 Gbps links except for two links to Mexico and Central/South America and one to Asia which are each expected to be 1 Gbps links. The ten links connect, in the year 2010, a backbone, ranging in link speeds from 1 Gbps to 25 Gbps, in the United States to research networks around the world that have link speeds ranging from 64 Kbps to 5 Gbps.

Hence, the year 2010 United States research network has a backbone link speed that is still higher than the backbone link speed of the various networks in other parts of the world. Also, it is higher than the typical link speed of links connecting the United States to other parts of the world. Therefore, as was the case for year 2000, it was concluded that the original year 2010 topology map does not have to be altered to incorporate international research network requirements. Again, it was also suggested that continual improvements are needed in the United States-international links to make certain the United States research networks have adequate connectivity with research networks around the world. And again, these improvements were indicated by the increase, noted above, in the speeds of the United States- international links.

In summary, the new year 2010 IRN topology map includes the following: the original year 2010 domestic topology map developed in the earlier domestic study; the 10 consolidated international links to six major areas of the world; and the range of the typical year 2010 link speeds of the backbones of the research networks in the countries in the six major areas. Please see Exhibit 6-20, page 6-41.

APPENDIX A

LIST OF ABBREVIATIONS

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
AARNET	Australian Academic & Research Network
ABN	Australian Bibliographic Network
Academnet	Soviet Union Network
ACONET	Australian Academic Computer Network
ACSnet	Australian Computer Science Network
ADRIADNE	Greek Network
Afrimail	Tunisia network
AGFNET	Arbeitsgemeinschaft der Grossforschungseinrichtungen (Association of National Research Networks) Network
AHEN	Alberta Higher Education Network
ANAS	Administrative Network of Academy of Sciences
ARISTOTE	Association of Information Networks In A Completely Open & Very Elaborate System Network
ARPANET	Advanced Research Projects Agency Network
AUSEnet	Association of South East Asian Nations Network
BARRNET	Bay Area (No. California) Regional Research Network
BCnet	British Columbia Network
BELWU	Baden-Wurttemberg Network
BERNET	Berlin Network
BITNET	Before Its Time Network
CA'net	Canadian Research Network
CARINET	Latin American Development Network
CATIENET	Tropical Agricultural Research & Training Center Network
CCCRN	Canadian Coordinating Committee On Research Networking
CCIRN	Coordinating Committee for Intercontinental Research Networking

LIST OF ABBREVIATIONS

(Continued)

ABBREVIATION	MEANING
CCITT	Consultative Committee for International Telephony & Telegraphy
CDNnet	Canadian Network
CEPT	Conference of European Postal & Telecommunications
CICNET	Committee on Institutional Cooperation Network
CGNET	Consultative Group Network
CRIM Network	Computer Institute of Montreal Network
CRN	Computer Research Network
CSNET	Computer + Science Network
CYCLADES	Network named after Cyclades, an archipelago in the Aegean Sea
DARPA	Defense Advanced Research Projects Agency
DENet	Danish Ethernet Network
DFN Network	Deutsches Forschungs Netz Network
DKNet	Denmark Network
DOD	Department of Defense
DOE	Department of Energy
DREnet	Defense Research Establishment Network
DRI	Defense Research Internet
DSIREnet	Dept. of Scientific & Industrial Research Network
EARN	European Academic Research Network
EDUCOM	Non-profit consortium of institutions of higher education.
EIN	European Informatics Network
Enet	Spain branch of EUnet
ENSTINET	Egyptian National Science & Technology Information Network
ERNET	Education & Research Network
ESNET	Energy Science Network
ESPRIT	European Strategic Programme for Research in Information Technology

LIST OF ABBREVIATIONS

(Continued)

ABBREVIATION	MEANING
EUnet	European UNIX Network
EUROCCIRN	European CCIRN
EuroKom	Network of participants in European Strategic Programme for Research in Information Technology
FAENET	Spain Branch of HEPNET
FCCSET	Federal Coordinating Council for Science, Engineering & Technology
FEPG	FRICC Engineering Planning Group
FIDONET	Network named after a computer
FNC	Federal Networking Council
FNET	French Network (Branch of EUnet)
FRICC	Federal Research Internet Coordinating Committee
FUNET	Finish University Network
GSFC	Goddard Space Flight Center
GULFNET	Kuwait & Saudi Arabia
HARNET	Hong Kong Academic & Research Network
HEANET	Higher Education Authority Network
HEPNET	High Energy Physics Network
HMI-MET	Hahn-Meitner Institute Network
IAB	Internet Activity Board
IASnet	Institute of Automated Systems Network (Socialist Countries-Soviet Union)
IEC	International Electrotechnical Commission
IETF	Internet Engineering Task Force
ILAN	Israel Academic Network
INFNET	Instituto Nazionale Fisica Nucleare Network
INTAP	Interoperability Technology Association for Information Processing
IRN	Integrated Research Network
IRTF	Internet Research Task Force
ISO	International Standards Organization
ITESM	Instituto de Estudioe Superiores de Monterrey

LIST OF ABBREVIATIONS
(Continued)

ABBREVIATION	MEANING
JANET	Joint Academic Network
JUNET	Japanese University Network
JVNC	John von Neumann Center
JVNCNET	John von Neumann National Supercomputer Center Network
LEP3NET	LEP = an accelerator at Cern, 3 = experiment number
MERIT	Membership consortium of Michigan universities
MIDNET	Membership consoritum of midwestern universities
MPT	Ministry of Posts & Telecommunications (Japan)
MRNET	Minnesota Regional Network
N-1	Japanese Network
NACC	Necessary Ad Hoc Coordinating Committee
NACCIRN	North American CCIRN
NACSIS Network	National Center for Science Information Systems Network
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
NetNorth	Canadian network
NICNET	National Informatics Centre Network (India)
NIT	Nippon Telegraph & Telephone
NORDUnet	Network of Nordic countries
NORTHWESTNET	Membership consortium in Northwest
NPL	National Physical Laboratory
NREN	National Research & Education Network
NRI	National Research Initiatives
NSF	National Science Foundation
NSFNET	National Science Foundation Network
NSN	NASA Science Network
NYSERNET	New York State Education and Research Network (Cornell)

LIST OF ABBREVIATIONS
(CONTINUED)

ABBREVIATION	MEANING
OARNET	Ohio Academic Resources Network
Onet	Ontario Network
OPMODEL	DOE Operational Model Network
OSI	Open Systems Interconnect
OSTP	Office of Science & Technology Policy (White House)
PACCOM	Pacific regional network
PACNET	Pacific & Asian Academic Network
PHYNET	Physicists Network
PSCAA	Pittsburgh Supercomputer Center Academic Affiliates
PSCN	Program Support Communications Network (MSFC)
PSCNET	Pittsburgh Supercomputing Center Network
QTInet	Queensland Tertiary Institution network
RangKom	Rangkaian Komputer Malaysia Network
RARE	Reseaux Associes pour la Recherche Europeenne
REUNIR	French network of universities & research
RIB	Research Interagency Backbone
RICA	Spain regional academic network
RIG	Research Interagency Gateways
RIPE	Reseau IP European Network
RPC	Reseau Communication par Paquet Network
SDCS	San Diego Supercomputer Center
SDN	Systems Development Network (Korea)
SDSCNET	San Diego Supercomputer Center Network
SERCnet	Science & Engineering Research Council Network
SESQUINET	Texas Sesquicentennial Network
Sigma	Japan Network
SIS	Social Information Systems Network
SMARTIX	French network
SPAN	Space Physics Analysis Network
SPEARNET	South Pacific Education & Research Network
SUNET	Swedish University Network

LIST OF ABBREVIATIONS
(CONTINUED)

ABBREVIATION	MEANING
SURANET	Southeastern Universities Research Association Network
SURFnet	Netherlands network (branch of EARN)
SWITCH	Switzerland Network
TCSnet	Thai Computer Science Network
THENET	Texas Higher Education Network
UKnet	United Kingdom Network
UNAM	National University of Mexico Network
UNInet	Indonesia network
UNINETT	Norway Network
USAN	University Satellite Network
USENET	Users Network
UUCP	UNIX to UNIX copy program
UUNET	UUCP & USENET Network
VICNET	Victorian colleges network
WESTNET	Network of five western states: AZ, CO, NM, UT, and WY
XDRENET	Advanced DREnet