The AMPATH Workshop

Identifying Areas of Scientific Collaboration Between the US and the AMPATH Service Area

Florida International University
August 15-17, 2001

CONFERENCE REPORT

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Executive Summary

Florida International University (FIU) has formed a strategic partnership with several major communications industry leaders to form the AMPATH project. With the recent completion of the Global Crossing fiber ring around South America, AMPATH is just beginning its actual operations. It has commitments to provide more than 500 Mbps valued at over $25M, between the US and its South and Central America, Mexico and Caribbean service area for high-performance research connections. These will include ten national research networks as well as other defined science research consortia in the area.

A wide range of strategically-important, US-based, or US-involved, research programs are already in place in the AMPATH service area. The involvement of South America in these programs in astronomy, biology, ecology, geoscience, materials science, and physics, with others on the drawing board, marks the emergence of 21st century scientific collaborations that are truly global in scope. The success of these efforts depends on enhanced connectivity. This includes greater network bandwidth to sustain both greater data throughput, and interactivity in collaborative work. Over the next decade the need for bandwidth will dramatically increase by several orders of magnitude, as planned new programs come to fruition and currently operational programs mature.

AMPATH is a connecting point for Abilene and the natural avenue between the US research-network infrastructure and the South. However, AMPATH's Abilene bandwidth is only 155 Mbps, while it has over 500 Mbps to the South. In addition, Abilene cannot transit International or US traffic between some of the US Federal-agency networks that are otherwise available through STAR TAP. Finally, although the AMPATH business model is based on reaching financial self-sufficiency over the next three years, until the program is more fully subscribed there is a cash flow crunch. All these factors threaten to impair the normal growth of the program.

FIU has done an excellent job of marshalling the resources of the communications industry to provide free or deeply discounted bandwidth for the benefit of the US and other Western-Hemisphere science communities. There is a significant opportunity to capitalize on AMPATH's efforts to connect North and South America together.

The National Science Foundation (NSF) has historically provided key assistance and coordination in facilitating international research-network connectivity between the US and other areas of the world, including Europe and the Asia-Pacific, through the STAR TAP and HPIIS programs.

Additional short-term financial support and other forms of assistance from the NSF to AMPATH can produce highly-leveraged results in opening research-network access to the southern half of the Western Hemisphere. The NSF and AMPATH are encouraged to explore ways in which they might mitigate these areas of concern with such proposals and programs as may be indicated. The scientific payoff will be significant for both US and global science.

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Introduction

The last ten years has seen a remarkable, worldwide explosion of high-bandwidth Internet infrastructure resulting from major capital investments by telecommunications providers. Broad areas of scientific enterprise have moved to high-speed, low-latency Internet connections, to facilitate a wide range of research activities, using a growing number of high-performance networking applications. Within the last 5 years, new paradigms of collaborative scientific research have emerged, based on the use worldwide-distributed facilities for terabyte-to-petabyte data access, processing and analysis, and collaborative work on a daily basis among groups of scientists residing on different continents. These new forms of research, and the developments in information technology that arose to meet these research needs, could not have taken place without the groundbreaking support for domestic and international research networks provided by the National Science Foundation (NSF)'s Advanced Networking Infrastructure and Research (ANIR) division in the Computer and Information Science and Engineering directorate (CISE).

The Role of ANIR

The goals of the CISE directorate include *contributing to universal, transparent and affordable participation in an information-based society*.[1] In support of this goal, ANIR helps *develop* and *maintain* cutting-edge national information infrastructure for research and education, and contributes to the education and training of the next generation of computer scientists and engineers.

The infrastructure programs are designed to address timely issues in the national infrastructure by supporting research, development, implementation, and testing of advanced, high-performance network technologies in support of the distributed information technology goals of the US research and education community.[2]

The ANIR strategy has been to engage the community with these enabling technologies by providing seed-money funding for limited periods of time for both backbone programs and institutional connections. The intention has been to allow institutions to prove the mission-related efficacy of those technologies during a start-up period, and then for them to develop long-term funding for continued services from their normal programmatic funding sources.

US High-Performance Research Internets

ANIR has been a leader in facilitating high-performance connections for hundreds of US universities and research centers throughout the country. It has approached this support by a number of

1 www.cise.nsf.gov
2 www.cise.nsf.gov/anir

paths. It has provided direct funding for network backbones and connection points, and infrastructure grants to research institutions to enable them to connect to backbone systems.

In the latter case, the NSF has established minimum technical standards that backbones must meet to qualify for NSF institutional access grants. This has opened the door for various consortia to develop alternate backbone infrastructures, thus promoting innovation while ensuring standards of quality. Usually, the backbones and connection points have employed partnerships between non-profit organizations and major commercial providers of both bandwidth and equipment. Frequently this has involved significant donations of bandwidth, equipment, and engineering support on the part of the commercial providers.

vBNS

The NSF initiated the backbone effort in 1995 by funding of a five-year cooperative agreement between itself and MCI Worldcom. This partnership produced vBNS, the very-high-performance Backbone Network Service. vBNS (now called vBNS+) is a specialized nationwide IP network that supports high-performance, high-bandwidth applications. Today, it is offered to the university and research community on a subscription basis by MCI Worldcom and UUNET.

Internet2

Internet2 itself is not a separate physical network. Rather, it is a not-for-profit consortium, led by over 180 US universities, developing and deploying advanced network applications and technology, accelerating the creation of tomorrow's Internet. With participation by over 60 leading companies, Internet2 recreates the partnership of academia, industry, and government that helped foster today's Internet in its infancy.

Abilene

Abilene is a backbone network used by the Internet2 community. It was developed in partnership with Qwest Communications, Nortel (Northern Telecom) and Cisco Systems. Abilene connects regional network aggregation points, called gigaPoPs, to support the work of Internet2 universities. Abilene complements other high-performance research networks. It is offered on a subscription basis to its university and research members by its managing entity the University Corporation for Advanced Internet Development (UCAID).

UCAID and MCI Worldcom have agreed to continue *interconnection* between currently vBNS-connected institutions and Abilene-connected institutions through MCI Worldcom's announced vBNS+ service. The agreement would also allow designated Abilene secondary participants to use the vBNS+ to connect to Abilene participants.[3]

The "Fednets"

In addition to the research network infrastructure directly or indirectly funded or seeded by ANIR, there are a number of specialized US Federal-agency networks doing significant research support. These include DREN, the Department of Defense research and engineering network; ESnet, the Department of Energy's research network; and NREN, NASA's research and education network and

3 www.ucaid.edu/abilene/faq-general.html#vbns+

NISN, NASA's Information Science Network. Generally speaking, these Federal networks are funded by their respective agencies.

Current Abilene policy forbids the transit of International or US traffic between non-Abilene-member US Federal-agency networks that are otherwise available through STAR TAP.[4]

International High-Performance Research Internets

ANIR has also played a key role in the development of interconnections between US research networks and their counterparts in many other parts of the world. The cornerstone of these international connections is an international network access point called STAR TAP.

STAR TAP

The Science, Technology, and Research Transit Access Point (STAR TAP) is a global network gateway for research and education, fostering the interconnection of facilities, instrumentation, and networks. STAR TAP provides connectivity to international networks that are not reachable through existing US backbones.

It is a persistent infrastructure funded by NSF/ANIR awards to the University of Chicago to facilitate the long-term interconnection and interoperability of advanced international networking. STAR TAP connects with the Ameritech Network Access Point (NAP) in Chicago, and enables network traffic to flow to international collaborators from over 150 US leading-edge research universities and institutions, including supercomputing centers.

In addition to its central connection point in Chicago, connectivity is available through International Transit Network (ITN), Internet2 Abilene, and Canadian CA*net3[5] to connect to foreign networks in Europe, the Middle East, and in Asia Pacific. These foreign networks connect to STAR TAP in a distributed fashion where they reach the US shore. All in all, high-performance national research networks (NRNs) of about 20 countries can interconnect with each other at STAR TAP to support multilateral high-performance research and education applications.

Over the next few years, the STARLIGHT project will provide an optical access point with very high bandwidth using wavelength services and links to the Distributed TeraGrid facility. This will be a driver of applications using from 1 to 10 Gbps, and eventually higher bandwidths.

*CA*net3 (CANARIE)*

Canada's Research and Education Internet backbone, CA*net3, connects individual universities, federal and provincial government labs and research institutes through provincially based Regional Advanced Networks. The Canadian network connects with the US and the other foreign networks available at STAR TAP. There are plans for a CA*net4 using wavelength multiplexing and Optical BGP.

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4 www.ucaid.edu/abilene/html/abilenepolicyonfedpeering.html

[5] Transit services interconnecting National Research Networks, via the Internet2 Abilene and Canadian CA*net3 networks, see www.startap.net/CONNECT/ and www.ucaid.edu/abilene/html/itnservice.html.

The HPIIS Network Connections

These networks[6], Euro-Link, TransPAC and MIRnet respectively, are supported through grants from the National Science Foundation under the auspices of ANIR through its High Performance International Internet Services (HPIIS) program. These network consortiums were developed to encourage foreign national research networks to connect to the vBNS or other recognized high-performance Internet service providers, such as Abilene, via STAR TAP.

All of these networks now connect with the US high-performance networks including vBNS, Abilene, NASA's NREN and NISN, and DoE's ESnet as well as with each other, and with the networks of other countries that connect at their own expense at the STAR TAP in Chicago. Future plans for the next generation networks include using wavelengths between continents, starting with Euro-Link and TransPAC in partnership with research networks in Europe and Asia. These plans build on the facilities, expertise and methodologies that have been developed starting with the NSF's seed programs.

Euro-link

The Euro-Link program maintains multiple, high-performance connections between The Netherlands, France, the Nordic countries, Israel and CERN[7] (NORDUnet, SURFnet, Renater and Israel's Internet2), and the STAR TAP. Euro-Link connectivity to STAR TAP is heavily used and brings major benefits to the research communities both in the US and in the various countries and organizations supported by Euro-Link.

TransPAC

The TransPAC program supplies an OC-3 connection between Tokyo and the STAR TAP in Chicago connecting Japan, Korea, Singapore and Australia via the APAN network. The TransPAC program has been very successful in developing a number of sustainable collaborative applications as well as much greater number of database and file transfer applications. Although, at this time only a very small number of research institutions in Asia currently have access to TransPAC.

MIRnet

MIRnet provides connection between selected sites in Russia and STAR TAP. Overall, MIRnet is off to an excellent start. At present, it is primarily used for transferring files. This is expected to continue to be a major use. However, as remote computing and instrument control become more widely used, it is expected that MIRnet will be called on for those functions.

Other International Networks

As noted above, together with the NSF-supported HPIIS networks, there are more than 20 other foreign research networks that are accessible to US scientists through STAR TAP.

International Network Coverage

To summarize the international connectivity, at the present time the US and Canadian high-performance networks are connected via STAR TAP to NRNs in Europe, including a few Russian

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[6] The *Report of Review Committee of the NSF's High Performance International Internet Services (HPIIS) Project*, October 25, 2000.

[7] CERN is a full member of Internet2 because of its close partnership with US high-energy physics research.

sites (Euro-Link and MIRnet). They are also connected to a relatively small, though important, number of Asian sites on the Pacific Rim (TransPAC/APAN). In addition there are several other international networks in place with services in Europe and the Mediterranean, and Asia, some with bandwidths as low as 10 Mbps.

TABLE I

Geographical Distribution of International NRN Connections

REGION	WORLD POPULATION (%)	CONNECTED (%)
North America	5	5
Europe	12	12
Asia/Oceania	61	<1
Africa	13	0
South/Central America	9	0[8]

While it is an imprecise metric, it is significant to note that North America accounts for about 5% of the world's population, and Europe has another 12%. Although Asia as a whole has 61% of the population, the countries connected by TransPAC constitute only about 1%. Meanwhile, South and Central America with its 9% of the world's population were essentially *not connectable* until just a few weeks ago, with the onset of availability of AMPATH. Africa, and its 13%, remain essentially unconnected.

As a consequence, US scientists have access to counterparts in the Northern Hemisphere accounting for about 12% of the population, and *almost zero percent of the Southern Hemisphere*. From a scientific perspective, there are at least two negative impacts from this situation.

The first is that there are many branches of physical and biological sciences where, for reasons tied to geography, network access to research sites in the Southern Hemisphere *is essential*, and yet presently severely hampered.

For example, South America is a significant natural laboratory for studies concerning Global Warming, including effects such as El Niño and deforestation. At the same time, astronomy at all wavelengths *must* rely on the Southern Hemisphere to observe scientifically critical objects that cannot be seen from northern sites. These include some of the closest stars to the Earth besides the Sun, and the closest galaxies outside our own Milky Way.

The second issue is a practical one. At present North America is only connected to countries representing about 13% of the world's population. At the highest level, connecting *either one* of

[8] Not including the AMPATH connection being discussed here.

South/Central America, or Africa, would nominally *double* the size of the potentially accessible population and significantly open the opportunities for fruitful science collaborations.

If one were to decide *which* of these two regions to connect first, a number of factors favor South America. Compared to Africa, the South American countries are relatively modern industrialized nations with reasonably stable political infrastructures, especially in those countries representing the majority of the population. Moreover, they are near neighbors to the US and already connected to it by many diplomatic and trade agreements[9]. They have vigorous science communities that are already engaged in a large number of science collaborations with US counterparts. Finally, unlike Africa, the international network infrastructure in South America actually exists in abundance, as of this year, and there are well-developed national infrastructures in many countries.

The AMPATH Project

The state of South/Central American connectivity is on the crest of a major sea change. Over the last two years, Florida International University (FIU) has developed an international, high-performance research connection point in Miami Florida, called AMPATH (AMericas PATH). AMPATH enables wide-bandwidth digital communications between the Abilene network and ten National Research Networks (NRNs) in South and Central America, the Caribbean and Mexico as well as a variety of US research programs in the region.

Florida International University – Strategically Positioned, Right Mission

FIU itself is a Research I university and a part of Florida's State University System with a student population of about 30,000. It is unique in that it has the highest proportion of international students and faculty of any major university in the country. FIU is a Minority Institution with the largest contingent of Hispanic students of any doctoral-granting university in the country and awards more Bachelors degrees to Hispanics than any other school in the Nation. Its mission includes being the principal educational and research interface between the State universities and South and Central America and the Caribbean. In this context, AMPATH represents a very natural extension of this mission.

Connecting South Florida Universities – Sharing Resources

With important funding from ANIR, FIU first established itself as an Abilene connecting point for South Florida in 1999. In addition to itself, the University now provides Internet2 connectivity to Florida Atlantic University and the University of Miami through the South Florida GigaPoP, with all three Research I universities as charter members.

AMPATH – Going South of the Border

From this base, FIU realized that South Florida – because of the number of undersea fiber cables landing on its east coast and because it possesses a rich terrestrial fiber infrastructure - is strategically positioned to become a major exchange point for high-volume networks in South America, Central America, Mexico and the Caribbean.

[9] North-South scientific collaborations have great potential. For US-Europe-Japan collaborations separated by 6 to 17 time zones, the small-to-nonexistent overlap in work hours is a significant impediment. North-South collaborations will not have this limitation. Computer-assisted collaborative sessions will be as easy as those within the continental US, thus supporting the formation of Western Hemisphere "regional groups" analogous to those in Europe.

FIU developed the AMPATH project in collaboration with industrial partners Global Crossing, Lucent Technologies, Cisco Systems, Juniper Networks, and Terremark Worldwide, Inc. Its purpose is to interconnect the research and education networks in South America, Central America, the Caribbean, and Mexico to Internet2, and thus to the US and non-US research and education networks again through the AMPATH PoP at Terremark's NAP of the Americas in Miami. AMPATH uses Global Crossing's undersea optical-fiber network to build a high-performance ATM and IP network to connect the research networks in its Service Area[10] to Internet2 connected networks.

Ten Southern National Research Networks for Free

Global Crossing has given AMPATH the use of ten DS3 (45 Mbps) circuits, valued at over $25 million. AMPATH is providing one of these circuits, at no cost, to a national research network in each of ten service-area countries for three years to connect to Internet2. While the DS3s are free, the participating NRNs financially contribute to AMPATH to share the other associated costs.

The Global Crossing South-American fiber ring was only activated in the second quarter of 2001, and the donated AMPATH bandwidth only became available in July 2001. As of mid August 2001, AMPATH already has connected two NRNs: Chile's REUNA, and Brazil's RNP2. These research networks are connected and peering with the Internet2's Abilene network.

Several other national networks are targeted for connection in the next few quarters. Argentina's RETINA will connect to AMPATH about October 2001. The new Panamanian network, SENACYT, has signed a Memorandum of Understanding (MoU) with Internet2 and is expected to join AMPATH in Q4 2001. In Venezuela, high-level government discussions indicate that REACCIUN will join the project by Q1 2002. Discussions between universities and organizations in Peru, Internet2, and AMPATH have resulted in efforts to either reinvigorate the original RCP network or form a new entity, with connectivity projected in Q1 2002.

In Colombia the government-backed network CINTEL has issued a RFP for connectivity to Internet2 and AMPATH has offered a DS3 for the standard cost-sharing contribution. The award of the RFP is expected in Q4 2001.

A second regional university network in Brazil, FAPESP, is interested in joining AMPATH. FAPESP received permission to connect to STAR TAP; however there have been technical delays. While no date has been set, FAPESP is expected to join AMPATH in the near future. The University of the Virgin Islands (UVI) is slated for a donation to join AMPATH, but has been struggling with local connection challenges; discussions continue.

Connecting Additional Research Programs in the South

In addition to the circuits contributed for the national networks, the South Florida GigaPOP/AMPATH is supporting connections from other research programs in its service area. The University of Puerto Rico is already connected and its partner, the Arecibo Observatory, will be connected in the near future.

[10] The countries in the Service Area currently are: Argentina, Brazil, Chile, Colombia, Mexico, Panama, Peru, US Virgin Islands and Venezuela. With some intermediate interconnections, Puerto Rico and other Caribbean islands are also accessible.

Led by the NSF-funded Gemini Observatory, a consortium of four US astronomy observatories located in Chile (Gemini South, Cerro Tololo Inter-American Observatory, SOAR, and the Carnegie southern observatory), will make their Abilene connections through AMPATH using a leased circuit beginning in November 2001.

While Global Crossing does not land in Costa Rica, the Costa Rican Science Minister has indicated that the Costa Rican national network will connect to AMPATH by a leased circuit in Q2 2002. The ARCOS[11] submarine cable system of New World Networks, a Miami-based company, offers a viable solution to connect Costa Rica, as well as other countries in Central America and several Caribbean islands to AMPATH.

The AMPATH Business Model

AMPATH operates through significant industry support, with participants sharing the cost of operational expenses incurred by FIU in association with the project. The major cost-shared components are administration, network engineering personnel and support, hardware maintenance, and cost-shared bandwidth for Abilene and/or STAR TAP.

The rather sudden, nothing-to-huge, availability of high-performance international bandwidth between the southern countries and the US has posed a financial planning challenge for virtually all of the expected AMPATH participants. Governments and research institutions generally work with multi-year budget projections. They have had little reasonable basis for projecting international circuit costs in the years prior to the arrival of the two fiber rings.

Several countries in the AMPATH service area have well-developed in-place national research network infrastructures. However, absent the previous impetus of available high-performance international circuits, others have found the local telecommunications infrastructure build-out (the *local loop* or *last mile*) an economic challenge. Some of the potential AMPATH participants are struggling to build the financial commitment to sign on with FIU, obtain the equipment and collocation space in-country, as well as build out the local infrastructure to the universities.

It could be critical for the cost-sharing component to be significantly lowered or eliminated to allow the AMPATH network to mature. By providing the international connectivity at little or no cost for the first three years, those participants would have the incentive and financial freedom to develop the in-country connections to universities and research centers needed for stable NRNs. Moreover, all participants would have a reasonable opportunity to budget reasonable future costs for the international component of their circuits. Grant assistance or additional donations could be sought to offset these costs for a suitable period of time.

The costs per unit bandwidth are predicted to decrease over the same timeframe, making it reasonable for NRNs to assume the international circuit costs at the end of the Global Crossing bandwidth donation. It is even possible that the international-circuit donation will be extended beyond the initial three-year period either by Global Crossing or another carrier.

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[11] The ARCOS fiber-optic submarine cable system consists of a fully redundant, self-healing, bi-directional ring architecture with an initial capacity of 15 Gbps, upgradeable to 960 Gbps, www.arcos1.com

The Miami Workshop

The AMPATH program has just recently begun its operations phase with the connection of the first South American NRN, REUNA (Chile). Several other users are expected to connect in the next few months. At this juncture it seemed appropriate to explore ways in which AMPATH could shape its future development to meet its users needs even better by engaging the current and potential user community in a wide ranging dialog about their needs and wants.

Through the course of the AMPATH workshop presentations, we heard US scientific researchers and in many cases, their AMPATH service area colleagues, confirm the benefits that an advanced networking infrastructure such as AMPATH would provide. The AMPATH project has made tremendous strides over the past year with the support of its industry sponsors, most notably Global Crossing that has provided the networking infrastructure over a staggered three-year period. Nevertheless, there are significant challenges faced by AMPATH.

Purpose of the Workshop – US Interest, Collaborations, Infrastructure

With cooperation and support from the NSF and its ANIR division in CISE directorate, AMPATH convened a user workshop in Miami from August 15 to 17, 2001 to:

Identify areas of Scientific Collaboration between the US and the AMPATH Service Area,

Identify scientific activities in the AMPATH Service Area of strategic US interest, and to

Demonstrate that AMPATH is an enabling infrastructure for Research and Education and for the support of science applications from the US, Canada, Asia-Pacific, and Europe.

Conference Report – Summing It Up

The ultimate deliverable for the workshop itself is this report, directed to ANIR as both an evaluation of AMPATH and a source of recommendations. A small, yet representative, committee of current and potential science research users prepared a draft report following the workshop,. This was distributed to the conference presenters for their comments. The comments were received, and then the Final Report was prepared. It is hoped that this report will provide a basis for one or more proposals to appropriate division(s) of NSF and/or other funding agencies in support of the AMPATH project.

The Report Committee – Research Users

The US researchers invited to act as the reporting team were:

Roy Armstrong, University of Puerto Rico, Marine and Atmospheric Science

Bob Bradford, NASA, Space Science

Dick Crutcher, Univ. of Illinois at Urbana Champaign, NCSA

Jim Kennedy, Gemini Observatory, Astronomy, (Committee Chair)

Michael McClain, Florida International University, Environmental Science

Harvey Newman, Caltech, High Energy Physics

Surendra Saxena, Florida International University, Materials Science

It should be noted that all of the Committee members were also presenters at the conference. Each is affiliated with one or more organizations that have important scientific stakes in the success of AMPATH and AMPATH-like programs.

The Charge – Needs, Opportunities, and Challenges

Based on the conference presentations, ensuing discussions, and on their own individual experience and expertise, the Conference Committee was charged to:

> Summarize and evaluate the degree to which AMPATH establishes a foundation for the growth of research and education networking between the AMPATH Service Area countries, the US, and the rest of the world, to benefit US science;
>
> Comment on how current and anticipated scientific research collaborations would be enabled by high-performance connections between the AMPATH Service Area, and the US and non-US research and education networks; and
>
> Make such short-term and long-term recommendations as they might with regard to the growth and utilization of the AMPATH project.

The Workshop Structure – Broad User Interest

The main body of the conference was held all day on August 16th. It consisted of a series of presentations by scientists and network professionals. The presentations were broadcast to a number of remote sites in North and South American and in Europe by videoconference. Two of the science presentations by US researchers were made by videoconference from sites in Europe and the US. On the previous day Cisco Systems provided a well-received half-day tutorial on latest and emerging network technologies. On the day following the main conference, there were several topical breakout sessions.

TABLE 2

Disciplines Represented by Presenters

FIELD	NUMBER
Biology	1
Chemistry	1
Environmental Science	3
Physics, High Energy	1
Public Health	1
Marine Science	1
Materials Science	2
Computer Application Science	3
Astronomy, Optical/IR	2
Astronomy, Radio	2
Space Science	1
Networking	8

The Presenters, Their Fields, and Their Countries – Some Demographics

In all, there were 26 separate presentations that varied in length from 10 to 30 minutes. The end-user speakers represented a wide range of physical, biological, health, and computer science disciplines, 12 in all. Of the 26 presentations, 18 were from end-user science researchers from programs that had actual operations, or collaborations, in the AMPATH service area, and 8 were from network research, user support, or provider fields.

There were 18 speakers from the US, and two each from Argentina, Brazil, and Chile, and one each from Columbia and Cost Rica. There were 23 different institutions represented, 16 represented end-user research and 8 represented network research, user support, or provider agencies.

TABLE 3

Institutions and Countries Represented by Presenters

	INSTITUTION	COUNTRY
Science	ALMA/NCSA	USA
	California Institute of Technology	USA
	Florida International University	USA
	Gemini Observatory	USA
	Georgia Institute of Technology	USA
	NASA/Ames	USA
	NASA/Marshall	USA
	University of Kentucky	USA
	University of Puerto Rico	USA
	University of Utah	USA
	Instituto Balseiro	Argentina
	Universidad de Buenos Aires	Argentina
	Inter-American Institute for Global Change Research	Brazil
	U. Federal do Rio Grande	Brazil
	CONICYT	Chile
	Univ. Nacional de Colombia	Colombia
Networking	AMPATH	USA
	California Institute of Technology	USA
	Indiana University	USA
	Internet2	USA
	NSF/ANIR	USA
	STAR TAP	USA
	Ministry of Science	Costa Rica
	REUNA	Chile

Summary of the Presentations

It is not practical to summarize each and every one of the 26 presentations individually. However, there were many recurrent themes that emerged that map onto several important networking dimensions. Consequently, the summary will examine the presentations in view of these axes.

At the highest level, some US science would be intrinsically driven outside the US by geography and/or the availability of leading-edge experimental facilities, even if no collaborations were involved at all. A broad sector of US researchers also participate with international collaborators because of the value of the collaboration itself.

Strategic US Science Interests in the South – Driven by Geography

In many science fields one can do the research within the geographical boundaries of the US. However, there are many other fields where the nature of the science and the geography of the planet demand that important aspects of the work be done in foreign countries. What follows is a sampling from the presentations of research programs that *must* rely on operations in the south due to the nature of the science studied. However, in all of these programs there are indeed very powerful international collaborations as well, that exist for their own value to the science involved.

Global Warming and Ecology

The climate of the US, and the whole planet, is influenced by significant events occurring or observable rather exclusively in the South. Several speakers spoke on the need for network access to support environmental studies that must be carried out in South America. The ozone hole cannot be observed from the Northern Hemisphere. El Niño, which affects global weather on short time scales, impinges on the northwest coast of South America. The most dynamic areas of deforestation and associated alterations to the carbon cycle are found mainly in the Amazon basin of northern South America and affects four extensive regions in the continent: Ecuador, northern Amazonia, southeastern Brazil, and eastern Argentina. The disappearance of tropical glaciers in the Andes is an early indicator of global climate warming and a significant threat to water supplies in many arid urban settings along the Pacific coast of South America. All of these effects impact the degree of biodiversity in the affected regions, and feedback into the complex ecological system of the planet.

Whether conducted directly as US-sponsored research projects or as international collaborations based on our common dependence on the Earth's environment, the venue for gathering much of the data is South America. This fact is recognized by the current US administration, and on June 10, 2001, President Bush underlined the US commitment to collaboration in these fields. He made mention to collaborations throughout the Western Hemisphere and specifically stated that "We will work with the Inter-American Institute for Global Change Research and other institutions to better understand regional impacts of climate change."

The Inter-American Institute for Global Change Research (IAI) stimulates and funds global change research in 18 countries of the Americas. US participation in IAI began in 1992 and is realized through the specific activities of more than 30 investigators in as many US research institutions. AMPATH is in discussions with IAI Headquarters now to become the US Node for the IAI Distributed Information System, pending a successful response to a future announcement of opportunity from NSF.

Astrobiology

Linking the Earth and space, those who study the possibilities of life on other planets, either originating in place or inserted as alien species (for example, by visits from terrestrial spacecraft), find the ecological dependencies on the Earth form a point of departure. Studies of the Earth provide a "ground truth", from which researchers can extrapolate what might happen elsewhere. The NASA Ames Research Center has established an Ecosystem Computer Facility for the analysis of remote sensing data. With plans to develop a virtual laboratory for the analysis of remotely sensed data, Ames has focused on biological studies of South America as an analog for a cooling drying biosphere. In the process it has formed collaborations with many institutions in Puerto Rico and South America.

The Battle for the Southern Sky

The US has long been a world leader in the field of astronomy. However, in recent years this predominance has been severely challenged by international European collaborations. The battleground for this challenge is South America, and Chile in particular.

There is a significant portion of the southern sky that cannot be seen by telescopes in the Northern Hemisphere. Nevertheless, there are a large number of scientifically interesting objects in that part of the sky that are critical to furthering our understanding of the origin, current status, and destiny of the universe. These are objects that cannot be observed by telescopes in the US. Without this access, US astronomy would be hamstrung in the international astronomy world.

The geography and climate in northern Chile provide the best available sites for astronomical work on the southern sky. The US has several observatories, including a number of different telescopes, in Chile. The largest of these is the new Gemini South 8-meter IR/optical telescope. However, the European Southern Observatory has no fewer than *four* 8-meter telescopes in operation in the same area.

The same sky, geography, and climate considerations also make Chile an ideal place to conduct very-short-wavelength radio astronomy observations. The NSF and its partners, representing 13 countries, are on the verge of building the $700M Atacama Large Millimeter Array at 16,000 feet in the northern Chilean Andes. In addition, there are other US astronomy programs in the general region, such as the Pierre Auger Cosmic Ray Observatory in Argentina.

While not exactly "outside" the US, the NAIC's radio telescope near Arecibo Puerto Rico, the largest in the world, is also in the AMPATH service area, and like the other facilities above, seriously starved for economical bandwidth. Its location is also determined by observing strategies, in this case to provide the best compromise on accessible sky for a single telescope.

Atmospheric Lightning Research

Both as an atmospheric phenomenon and as a hazard to human activity, the study of lightning, why it happens – when it happens – where it happens, has many scientific and practical applications. Aside from the hazards it can have for human life, it is an enormous problem for both the electrical power and petroleum industries. It has been a subject of intensive study at sites in Northern Florida, Southern Arizona, and Colombia for decades. The 20-year-long project of the National University of Colombia is particularly interesting in that it samples the true tropical environment. The program has 11 sensors in a nation-wide network and employs sophisticated signal processing techniques to extract meaningful information from the sensor array. It has major collaborations with MIT and Colorado State, as well as with workers in South America and Europe.

Counter Drug Research

Another example of the site of critical US interests being determined by external factors was provided by the presentation on the United Counter Drug project. In the public health realm, it is a well-known fact that a significant threat comes from the illegal use of drugs, and a significant fraction of these drugs originate in South and Central America. The UCD program is a seventeen-country collaboration establishing searchable databases to provide essential rapid-turnaround data in support of drug enforcement activities. The principal thrust of this aspect of the program is to allow multinational agencies, regardless of their language, to exchange information by searching multilingual databases.

Strategic US Science Interests in the South – Driven by Collaborations

Scientific excellence and experience know no borders. There are many areas where US strategic interests are effected primarily by the availability of talented foreign researchers pursuing similar lines of investigation, and where geography itself is of secondary importance, if at all.

High Energy Physics

The multi-TeV energy scales needed to advance the study of the nature of matter and its most basic interactions, and to search for new particles and forces, has led to unprecedented challenges in petabyte data access and analysis. This has led in turn to worldwide scientific collaborations where each nation contributes its share to the construction of the experiment, and to the resources needed to analyze the data, while participating in the global process of search and discovery. The Large Hadron Collider (LHC) program at CERN in Geneva, encompasses four major experiments searching for the Higgs particles thought to be responsible for mass, as well as the states of matter and violation of symmetries that existed in the early moments of the universe. The US is a major player in the two largest of these experiments, ATLAS and CMS, with approximately 400 US physicists and engineers (20% of the total) involved in each one.

The CERN/LHC program is a large, but not atypical, example of a collaboration-driven project[12]. The US has expended significant resources in this research area. The principal experimental devices are located in Europe, with major US contributions, and the Computational Data Grids that are being developed will be worldwide. Nevertheless, the program asks questions on such a grand scale that more than 5,000 individual researchers (in four large collaborations) are involved in working with various aspects of the problem. The Parallel and Distributed Processing Group of the Federal University of Rio Grande du Sul, in collaboration with its physics research staff, is an important player in the development of the Grid processing and data handling techniques necessary for the success of the LHC.

[12] Although it faces a number of technical and human challenges because of the scale and scope of the scientific problems it is tackling, as well as the size of the collaborations themselves.

Physical and Organic Chemistry

The University of Utah and the University of Buenos Aires are engaged in a collaboration, funded jointly by the NSF and several Argentine agencies, to model chemical shifts in complex organic crystals. The collaboration itself is rooted in special expertise available in Utah and Buenos Aires. One of the objectives of the study is to develop robust techniques to include intermolecular effects in the calculations. Subsequently these techniques will be applied to solve structural problems in biologically active compounds from marine invertebrates from the South Atlantic in collaboration with researchers in the organic chemistry group and Buenos Aires.

Remote Biological, Marine, and Atmospheric Sensing

Although somewhat influenced by geography, the University of Puerto Rico's remote sensing program represents a collaboration of a different kind – one across many disciplines. This program acquires large, generally geographically-based, data sets from remote ocean sensing devices, earth-sensing satellites, and a variety of other sources. These data are then applied to problems in oceanography, marine biology, and a variety of related fields.

Biodiversity

Another broad collaboration, based at the University of Buenos Aires and sponsored by IAI, is examining the role of biodiversity and climate in functioning ecosystems. The group is studying the interrelationships between the atmospheric composition, climate, land use, biodiversity, and the ecosystem as a whole and how that impacts on the provision of human services. This is a global program in terms of the systems studied and it relies on a collaboration between several senior scientists in six South and North American countries. Two of the participating researchers are in the United States, one in Mexico, and several more are in South America.

Materials Science

The Instituto Balseiro in Argentina is pursuing a program aimed at understanding the thermodynamic, phase stability, and transformation of complex material systems. This effort involves a broad collaboration involving research centers in Florida, France, and Sweden. It includes an important distance learning component directed at the upper-division and graduate level.

Shared Resources - Teamwork

The presentations revealed that sharing resources to optimize their effect was commonplace at least at two different levels.

Unique Facilities and Science Collaborations

Whether sponsored by the NSF, DOE, NASA, or other public or private agencies, today's major US science projects take on economic scales that innately require international participation through partnerships and other forms of collaboration. Thus, for many of these programs the interests of US science and policy are inexorably linked to the international communications infrastructure because the science is being done with internationally shared resources.

Many of the presentations spoke on actual, planned, or desired collaborations to share unique, one-of-a-kind or few-of-a-kind, research tools. There were many examples of in-place programs. The CMS experiment at CERN is a 144-institution partnership across 31 countries, and the ATLAS experiment is a collaboration of similar size and scope. The Gemini observatory is a seven-nation program, managed by the US (NSF), with three South American partners including Chile's CONICYT. The International Space Station is a 15-nation partnership. The UCD program consists of 17 partner nations in the Americas.

A number of other examples of currently active, planned, or desired programs had the same flavor. ALMA is a major international cooperative project involving the US, Canada, Japan, Chile, and the European Southern Observatory which, itself, has nine member countries. FIU has a center for electron microscopy that can be operated remotely from any part of the world and would like to establish a partnership to fund and operate a remotely accessible high-temperature and high-pressure physics laboratory. NASA/Ames would like to establish a similar facility for the analysis of a wide variety of remote ecological, marine, and atmospheric sensor data, as would the University of Puerto Rico with oceanography data.

In many of these cases, the unique facility includes large expensive pieces of equipment, such as telescopes or particle accelerators. In every case, there were one or more remotely-accessed shared databases or data archives.

Network Access Collaborations – The Rule, Not Exception

Focussing on science end users, there were many instances of the sharing of network facilities and the associated cost burdens, whether or not the users were also collaborating on the science itself.

For example, Arecibo and the University of Puerto Rico have formed a partnership for AMPATH access. The Gemini observatory has formed and led three different access partnerships. One of these is in Hawaii (twelve observatories and two university campuses) and the other two are in Chile (four, multi-telescope, US-funded observatories).

Florida International University partnered with two other South Florida universities to start up the AMPATH program. In Chile, nine universities and research institutes partnered to form the REUNA national network program. The Costa Rican Ministry of Science sponsored a partnership of 29 academic institutions and 18 government agencies to form CRNet and will be participating in MAYA 1 and ARCOS 1. The Argentine national research network, RETINA, currently has 22 institutional members and is cooperating with the Uruguayan academic network, RAU, to connect to AMPATH through the Buenos Aires PoP.

High-Performance Applications

In the main, the applications in use or needed seemed to fall into six different categories. Most programs had a need for applications in more than one of these categories, and several needed many of them.

Video/Audio Communications

Collaboration was an intimate part of all the science presentations. Videoconferencing, both for direct science collaboration and for operations purposes including data gathering, is becoming ubiquitous. Video over IP and Access Grid applications are becoming increasing common. The LHC experiments use the VRVS system for video/IP, including many meetings per day, throughout the year, as an integral part of the collaborations' daily work.

These technologies are especially useful adjuncts to programs involving remote operations or remote users, such as ALMA, Gemini, the University of Utah crystal modeling project with the University of Buenos Aires, and the International Space Station to mention a few. Some programs with multiple sites also mentioned integrating voice over IP into their telephone plants, as a convenience and cost-saving measure.

While some the systems use are already well-advanced[13], these will be developed into integrated environments for multi-site collaborative work; either on their own or in the context of Data Grids.

Remote Operations

Another common theme was the desire, or critical need, to permit users at remote locations to manipulate and control observational or experimental equipment. Some described this as remote operation, and others as virtual operation[14]. In any case, there is a lot of cross coupling between remote data taking, virtual laboratories, and archival data analysis.

The Arecibo and Gemini observatories both make use of observing by scientists at remote sites as an alternative to astronomers having to travel to the telescope. It is intrinsic to Gemini operations, and they plan to expand the capability significantly, to include additional remote observing centers in Arizona, Florida, and Chile. Located at 16,000 feet, the ALMA observatory will have to be operated in this mode.

The FIU Center for the Study of Matter Under Extreme Conditions expressed the hope it could develop a "virtual" laboratory for high-pressure physics and materials science in Miami. There is a similar concept at FIU to create, maintain and share thermodynamic and physical property databases for use in earth and environmental sciences and materials science. In both cases, the intention is to develop a consortium to build a set of unique experimental tools and databases and share them remotely.

The NASA/Ames Ecosystem Computer Facility not only is engaged in the analysis of remote sensing data, put has a suite of analysis instrumentation that it plans to enable to allow remote analysis of remotely sensed data.

The Utah/Buenos Aires crystal project, the FIU study of the Andean rivers, and the International Space Station effort all require the remote manipulation of sensor equipment. NASA/Marshall has already developed a remote payload control packed for International Space Station PIs.

Virtual Laboratories/Observatories

This might be defined as doing remote science from centralized or distributed archives, libraries, and databases, using standardized suites of access and processing tools made for the purpose. One example of such tools is the FIU/NASA Regional Applications Center's Terrafly package that allows the overlay and moving-map visualization of multiple geographically-parsed data sets.

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[13] As an example, the Virtual Room Videoconferencing System (VRVS) has 6100 registered computers in more than 50 countries. See http://www.vrvs.org.

[14] The word "virtual" is used somewhat ambiguously. As used here, the term means to collect the data in the first place through remote real-time intervention with the experimental equipment. However, it was also used by other presenters to refer to doing research using previously archived data at a remote site.

The Caltech/CERN/University of Buenos Aires Large Hadron Collider (LHC) collaboration expects to make extensive use of this approach. ALMA, Gemini, and Arecibo expect to participate in a collaboration called the National Virtual Observatory to permit the mining and analysis of various astronomy data sets with standardized tools.

Distributed Archives and Libraries

A substantial fraction of the presentations pointed to the need to move very large data sets from the point of collection to remote and usually distributed or mirrored archival systems. The CERN group will need to transport tens of petabytes by 2006. The Space Station, ALMA, Gemini, and the Utah/Buenos Aires crystal programs all have multiple international archive sites.

The University of Puerto Rico's Tropical Center for Earth and Space Studies' satellite down-link facility maintains a large digital database of the tropical Western Atlantic Region that is accessed online by NASA and other federal agencies, universities, and the private sector. Ecological programs such as the FIU rivers project and other global change research projects like the Buenos Aires biodiversity and climate study all intimately rely on access to large data sets maintained in many different places.

The IAI global change data and information service project currently has two access nodes (Brazil and Uruguay) and expects to expand to 18 in the near future using AMPATH. This system uses a distributed network of libraries and databases accessed with a Yahoo-like search tool that yields relevant metadata and can provide ftp access if required.

Distributed Processing

One message that came through rather clearly was that as the size of data sets continue to grow. Network-based strategies for processing those data are becoming increasingly important in a wide range of fields.

The Federal University of the Rio Grande in Brazil has several programs that will require distributed processing, including research in that subject itself, biological cell modeling efforts, 3D thermodynamic modeling, and high energy physics problems (with Caltech/CERN).

The Buenos Aires/LHC collaboration will take part in the GriPhyN network-based data-grid program, and will be part of the International Virtual Data Grid Laboratory (iVDGL) being supported by NSF. The FIU rivers project expects to use grid techniques in doing soil and fluids models. The Utah/Buenos Aires project expects to use grid processing in its crystals program. Gemini and ALMA expect that grid approaches will become necessary in the future to handle complex image processing with large data sets.

Education

The bulk of the presentations were focussed on research programs rather than the specific direct delivery of educational products separate from their research functions. A stronger representation from the strictly educational sector, no doubt, would have resulted in a clearer picture from that perspective. Nevertheless, a substantial fraction of the organizations presented were teaching institutions with undergraduate and graduate educational programs, where research is an intimate part of the educational process. Moreover, a number of the research programs described have self-contained education or public outreach components that are operational and make use of Internet resources.

The FIU rivers project is involved in distance learning programs about the environment being delivered to remote sites in northwestern South America. Instituto Balseiro engages in distance learning programs. Gemini offers web-based material, virtual tours, and other graphics-intensive material. In partnership with the Cerro Tololo Inter-American Observatory, it uses video over IP for outreach programs connecting elementary and high school students in Hawaii and Chile. The Federal University of Rio Grande du Sul is developing Internet teaching and learning tools in its computer science area.

Mission Criticality and Urgency – How Necessary, How Soon

The many programs presented to the workshop had varying degrees of essential dependence on high-performance Internet connections. There were at least two flavors of dependence: *criticality* – the intrinsic need for basic program functionality, and *urgency* – the nearness of the need in time.

Both criticality and urgency need to be examined to establish a clear picture of the needs. For example, a program with an intrinsic need for high-performance connections to operate, but which will not be operational for several years might not be as “urgent” today as would a program with the intrinsic need, but which is already struggling to function.

Video/Audio Communications

Few programs placed significant emphasis on these video and voice Internet applications, from the perspective of urgency. For members of large collaborations, participation in working groups that meet regularly via videoconferencing is a way of life. No doubt programs that engage in remote operations applications will continue to find it useful, if not essential. However, for these same programs, the real driver for connectivity will be the remote operations aspect, for which video connections to the remote site(s) is just one aspect of overall operability. The point is that there is a real need and it is urgent, but if the needs asserted for the other applications below are met, then the bandwidth for video and voice will be there too.

Remote Operations

The Gemini Observatory is in operation at its Hawaiian site, and deeply into its commissioning phase in Chile spending considerable “time on the sky”. Thus, the Chilean facility is also called upon to perform the operations of a functioning observatory. The telescopes are normally operated from the base facilities, rather than the summits using already in-place circuits. Gemini is also in the process of establishing “remote observing rooms” in Florida, Arizona, and Chile, with more expected in the future. During these “live” operations there is a critical need to provide near-real-time images back to the remote observers for “quick look” evaluation as the observations unfold. Gemini also archives these large-format images at the Canadian Astronomy Data Center in Victoria BC. This is an example of a program with a critical *and* urgent operational need for connectivity, and connecting to AMPATH shortly.

The ALMA observatory, also destined for Northern Chile, must operate remotely because of the 16,000-foot altitude. It will process and move even larger data sets than Gemini to North American, Japanese, and European sites, substantially for the same reasons. However, construction on this program has not yet begun on the Chilean site. However, it will reach both the critical and urgent stage by 2006 or 2007.

The International Space Station, while not fully complete, is allowing remote manipulation of PI instruments using a web-based tool developed by the NASA/Marshall center. NASA has other means of operating these payload experiments, but the optimal solution is to permit the experimenters themselves, who are most familiar with both the equipment and the underlying science to do this remotely and economically, particularly when those researchers are located in South or Central America. This mode is not strictly essential to the science, but it is a part of the long-term plan, and it can be implemented now.

Several other programs discussed plans for remotely operated laboratory facilities in the materials science, physical chemistry, and ecological science areas. Generally speaking these were plans in various stages of development that require additional research and other forms of funding to be ready to implement. Undoubtedly, the availability of high-performance connections will greatly facilitate the completion of the remaining steps necessary to having operation applications.

Virtual Laboratories/Observatories

There were a number of projects presented that, in one way or another, participate in supplying data to archives organized to permit doing research in a variety of fields using measurements or observations already taken at points in the (distant to very-recent) past. Except that there may be some specialized software tools required to access and to manipulate specific kinds of data (e.g. Terrafly), the needs of this category are basically the same as the distributed archives group below.

Distributed Archives and Libraries

Virtually all of programs presented require the ability to deliver and access large, or very-large (terabyte to petabyte) data sets to and from remote archival sites. A substantial number of these find this need both critical and urgent. In all of these cases the data have to move in one direction or the other between the US and southern sites. The currently operational programs include the IAI data and information service, all the many IAI supported ecology research programs, the UPR and NASA/Ames remote sensing programs, the Utah/Buenos Aires crystals project, CERN/LHC in its current development phase, the Space Station, the Gemini observatory, the National Virtual Observatory, and the Brazilian and FIU applications centers.

Significant future programs that are critical, but not *yet* urgent include the full operation of CERN/LHC and ALMA. A number of other projects that are presently in the early stages of thinking including the FIU remote high pressure physics and material thermodynamics laboratories.

Distributed Processing

Several projects appear to be posed to undertake Internet-based distributed processing programs. GriPhyN work is beginning, CERN/LHC is prototyping its systems, the Brazilian Rio Grande du Sul applications group is well into applications work. These and others appear critical and near, if not, urgent.

A number of projects indicated an expectation that their data sets and processing requirements would move in this direction over the next few years and that it was essential that the field mature in the meantime. These included the FIU rivers program, Utah/Buenos Aires crystals program, and both the Gemini and ALMA observatories.

Education

There can be no doubt that educational efforts are a key part of virtually all of the programs presented. Nor can there be any doubt about the importance of education in and of itself. Owing to the research focus of the workshop, none of the presentations really stressed a mission-critical educational component, while many pointed to having integral educational elements. Not withstanding, enhancing and empowering connectivity based on the research programs presented will have a powerful and positive impact on the delivery of educational programs in the Americas.

Summary and Conclusions

In his keynote address to the Workshop, Michael McRobbie[15] pointed to the fact that scientific research is becoming progressively more global with network-enabled worldwide collaborative communities rapidly forming in a broad range of areas. In many cases these research efforts are based on a few expensive, sometimes unique, instruments or distributed complexes of sensors that produce vast amounts of data required for the studies, and that the global communities then carry out their research on those data. Frequently, these data must be analyzed by supercomputers or large computer clusters and employ advanced display technologies.

In the view of the Committee, this was a very accurate description of the picture that subsequently emerged during the Workshop. McRobbie had quite concisely summarized the overall effect of the presentations. It is very clear that the South and Central American and Caribbean area that AMPATH is opening up is a prime candidate for this enabling technology and matches extremely well the profile that has pervaded the opening of the other network pathways into Europe and the Asia-Pacific.

NSF Support in the Past

The US network infrastructure has become a central focus of the efforts in connecting the world's research Internets. Although many agencies have made major contributions, in recent years the NSF has taken the US lead in supporting the initial development of internal US high-speed research Internet infrastructure, and the world lead in developing international connection points. There are already three, mature, successful US-supported programs that have effectively coupled North America to Europe and parts of Russia and the Middle East, the Asian Pacific Rim, and Australia.

US Research Interests in the South

More and more, the economic scale of major US science programs is large enough that the US must engage in international partnerships and other forms of collaborations to meet US goals. Thus, there is a broad and continually growing need for high-performance, high-bandwidth, low-latency, packet-loss free research Internet connectivity across a wide range of science and technology disciplines.

[15] Michael A. McRobbie is Vice President of Information Technology and CIO of Indiana University.

Even when not driven by economic factors, there are large numbers of research programs managed by US entities with experimental or observational sites in South and Central America because they study phenomena with some special connection with those geographical regions, such a global warming or southern-sky astronomy. The presentations revealed that there are many of these programs already in place and that they were dealing with subjects of significant import to US science.

South and Central American Research Interests

The globalization of science that Prof. McRobbie spoke of is a reality that makes it very difficult to separate "US interests" from "South and Central American interests". In so many regards, the interests are the same. Fundamental research in nuclear physics, materials science, biology, ecology, astronomy, chemistry, and so forth has been cutting across national borders for decades, but never before in the way it does now, especially as a result on network technologies and access. The presentations showed many examples of current ongoing collaborations.

The South-American-based Inter-American Institute for Global Change Research programs are of worldwide importance, not just South American importance, and the multinational character of their collaborations strongly reflect this. The astronomy community has engaged in international programs as a matter of course for a very long time. The CERN/LHC collaboration, in and of itself, is truly global.

The Western Hemisphere Science Community – A Partnership of People and Ideas

Taken overall, the presentations showed that there is a well-established, vigorous, collaborative multinational, hemispheric science community in the Americas, despite currently poor network access. With modern levels of high-performance connectivity it is inevitable that this community will be further enabled to grow and flourish to unprecedented levels.

Physical Infrastructure – In Place

Though geographically closer to the US than most other world regions, the southern half of the Western Hemisphere, Central and South America, heretofore has remained outside the research Internet family. Until recently, the foremost barrier has been the lack of international network infrastructure. This barrier has now been removed.

Another important factor has been the status of the local network infrastructure in the south. Here the situation is rather like that in the HPIIS world. In a number of the more modern and populous countries, a significant fraction of the most important universities and research centers are well connected one to another.

Again like the HPIIS countries, a number of others are at various levels of infrastructure maturity. Here it is reasonable to expect that empowerment by the actual possibility of high-performance connections to the rest of world science will become a driving force to escalate and shape that development. The HPIIS experience already has established that there is relatively low administrative and technical risk in establishing similar programs for the South.

International Connections – Up and Running

In the last few months two separate commercial providers have produced submarine/terrestrial fiber rings around the region, each with capacities in the 40 Gbps[16] range. Global Crossing has provided FIU with the gift of 10 x 45 Mbps to be given to ten South and Central American national research networks. In addition, a number of other southern and Caribbean programs have committed to join AMPATH with funded connections. As a result, AMPATH has 450 Mbps of gifted capacity to South and Central America, 45 to 90 Mbps more of expected paid connections for other users, and 155 Mbps of committed capacity to its various Florida university clients.

Southern Research Networks – Many in Good Shape

The NRNs of Argentina, Brazil, Chile, and Costa Rica have fairly well developed, in-country, high-performance research and education networks supporting universities with established scientific collaborations in the US and globally. The Puerto Rican commercial infrastructure is more than adequate. Brazil's regional Sao Paulo network, FAPESP[17], is also well developed and interested in joining AMPATH.

In some other countries the infrastructure is less developed. Panama has successfully formed a NRN under these conditions and is expected to connect to the AMPATH network as soon as the local PoP is completed. Colombia has a university-based collaborative scientific research community of interest to US scientists. It still relies, in large part, on frame relay and ISDN links.

Both Venezuela and Peru had previously formed NRNs for Internet connectivity about a decade ago. Efforts have been made to reengage the original leadership with some success to date. The current Venezuelan effort is being fostered by its government. Peru has several Internet Service Providers with access to a high-performance network and exchange point, but the universities are lagging in the development of a high-performance network infrastructure. There can be no doubt that the availability of low-cost international connectivity will stimulate the current rebirth of these efforts.

Global Cooperation at STAR TAP – The Meeting Place

Repeatedly, the presenters spoke of broad, in-place international collaborations. It was very clear that many of the programs not only had significant ties between their US and southern counterparts, but that there were also important scientific and operational requirements for connections to many countries in Europe and the Asia-Pacific area. Virtually all of these countries are already served by STAR TAP through the HPIIS and other networks.

Typical examples of US-funded programs included the International Space Station with its many partners, the Gemini Observatory with partners in Europe, Australia, and North and South America,

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[16] Global Crossing's South American Crossing (SAC) is a four-fiber-pair system linking major cities in South America. The SAC uses advanced wavelength division multiplexing technology to provide 40 Gbps initial capacity. www.globalcrossing.com/network/net_sac.htm?bc=Network%20>%20South%20American%20Crossing.

Telefonica's SAm-1 is a 25,000 km long, self-healing ring comprised of four fiber pairs. The initial capacity of SAm-1 will be 40 Gbps. Dense wavelength division multiplexing (DWDM) upgrades to 1.92 Tbps are possible. www.fcc.gov/Bureaus/International/Orders/2000/da001826.txt

[17] Fundação de Amparo à Pesquisa do Estado de São Paulo

and ALMA with partners in the US, Canada, Europe, Japan, and Chile. Funded in part by the US, the CERN/LHC collaboration has partners worldwide.

Many programs based in South America, with partners and collaborators in the US, also have important partners and collaborators outside the Americas. These include the Argentine Instituto Balseiro's materials science efforts (Europe and US), the National University of Columbia's lightning research program (Europe and US), and virtually all of the many IAI-coordinated global ecology programs which depend on access to databases in Europe and Asia, with many having active collaborations.

Clearly, STAR TAP will play a pivotal role in enabling the full realization of the enormous science opportunities afforded by the connections provided by AMPATH.

Enthusiastic Corporate Partners

The AMPATH project has engaged a powerful team of industrial partners in order to connect the research and education networks in its service area to Internet2 connected networks.

Global Crossing, a major provider of state-of-the-art international fiber bandwidth, has entered into an MoU with FIU to provide AMPATH with ten DS3 circuits in Global's South American fiber ring for three years. The agreement is arranged in a very flexible fashion so that the three-year term of each individual DS3 begins when the circuit is first put into use, thus allowing AMPATH and its NRN users to realize the full benefit of the gift irrespective of the starting date of each connection. The value of these circuits is about $25M.

On the equipment side, Lucent Technologies, Cisco Systems, and Juniper Networks have each donated major pieces of network terminal equipment for the Miami end of the circuits. These items, two routers and an ATM switch, have a combined value of nearly $1.2M. Terremark Worldwide, Inc., the owner of the brand new NAP of the Americas in Miami where the Global Crossing fibers terminate, has donated collocation space in the new NAP to AMPATH to facilitate the actual AMPATH connections to the ring, valued at $360K.

Direct participant interactions with the industrial partners certainly conveyed the sense that they were all very engaged with the AMPATH program at the personal, as well as, the corporate level.

Dedicated Individuals

The Committee was very impressed with the level of effort and, even more so, the striking success of the AMPATH team. They have put together a remarkable partnership of corporate, national and regional research-network, academic, and research organizations to create the substance and scalable framework of the AMPATH project.

What is even more remarkable is that, while strongly encouraged by the FIU administration, these achievements have been brought about almost entirely through the effort, energy, and determination of FIU's Julio Ibarra, Heidi Alvarez, Eric Johnson, and their small support staff. They are to be commended for their extraordinary entrepreneurial success.

The Committee is very comfortable that the direction of AMPATH is in good and capable hands for the present and the future.

Areas of Concern

Despite the excellent base program so far assembled by the AMPATH staff and their partners, there were a few areas of concern about the near-term evolution of the program that were flagged by the project itself and also some of the research presenters.

Startup Cash Flow

The AMPATH project has significant hardware and circuit assets at their command as a result of their hard work and the generosity of their corporate partners. AMPATH also currently holds signed MoUs from the NRNs in Chile, Brazil, and Argentina. In addition, it has connected the University of Puerto Rico, and through them, the Arecibo Observatory in the near future. It has a strong commitment to connect the Gemini consortium of US observatories in Chile, again in the near future.

AMPATH has a base of current and committed initial users, and a reasonable group of prospective users. Nevertheless, the project has identified some cash-flow challenges in the prompt implementation of its full capabilities. These involve AMPATH's direct costs for administration and technical support. There are two basic factors that effect the project's cash flow: the time required to bring the break-even number of new users on line, and the time required for new users to make actual cost-sharing payments. These payments amount to $155,000 annually per NRN, paid in quarterly installments.

In the first case, some of the prospective NRNs with less-well-developed network infrastructure necessarily are finding the ancillary costs of connection to the free DS3s something of a problem. While they are working hard to meet their connection target dates, it is not certain that they all will be able to do so. In any case, many such programs are making difficult short-term decisions between funding the external connection and further developing their internal build out.

The other issue is the margin between the delivery of services and the receipt of payment. In the short term, FIU's Department of Sponsored Research (DSRT) has recognized the existing NRN MoUs as grant awards. Consequently DSRT has funded AMPATH's cash accounts in anticipation of the respective NRNs making their quarterly payments. In essence, AMPATH is operating by the grace of FIU and AMPATH's industrial affiliates until the participants process the cash to meet their commitments.

The Bandwidth Disconnect

The ten DS3s donated by Global Crossing that are committed to the foreign national research networks, the leased bandwidth already earmarked for other southern programs (generally US research projects), and the bandwidth provided to the three South Florida universities already approaches 600 Mbps. Longer-lead US projects in the south will easily take this above 1 Gbps in a few years time.

On the other hand, AMPATH currently only has a 155 Mbps connection to Abilene, and no direct connection to STAR TAP at all. Moreover, it is also important to note that the current 155 Mbps is actually committed to AMPATH's three South Florida universities, who have allowed the unused portion to be used to support the South and Central American users. There is no independent bandwidth for the international users.

Thus, there is a significant discrepancy between the bandwidth that AMPATH has been able to secure to service its southern and local university users, and that which AMPATH has available to connect those same programs to the US high-performance research Internet backbone.

AMPATH users and bandwidth use are still ramping up. Consequently, this north-south constriction is not an immediate problem. However, Brazil is already hitting peak rates in the 30 Mbps range. When combined with traffic from AMPATH's Florida universities, peaks in excess of 100 Mbps are seen on the 155 Mbps circuit. Moreover, if the desired prompt development of the southern connections is realized, it could very well be a problem in the near future.

Access to Fednets

Abilene peers with STAR TAP, allowing connectivity to the international networks that connect there. However, under present use policy, Abilene will not transit traffic to the Fednets that are not members of Abilene. Essentially, this will exclude connections between AMPATH's international users in the south and those Federal research networks. This is an unfortunate asymmetry in the connections that will hamper science and the growth of the AMPATH program.

Recommendations

The Committee believes that AMPATH presents an unprecedented opportunity to advance both US science and world science. The NSF has played a key role in enabling research connectivity within the US, and then between the US and science programs in Europe and the Asia-Pacific. The NSF can continue the US's central role in research networking by helping to foster and nurture the AMPATH effort.

Managing Rapid Change – Seeding Start-up Efforts Works

The rapid development of network capabilities, such as the beginning of the international fiber-ring services to South America, has made it nearly impossible for many research institutions in the US and elsewhere to have properly-planned internal funding in their long-range budget plans, even those created fairly recently.

Although AMPATH has schedule targets for bringing the remaining southern NRNs on board, such connections were not anticipated by these agencies as little as 20 months ago. It is reasonable to assume that some of the less-well-funded networks will find it difficult to meet these target dates. Delays in connections or payments will be a problem for AMPATH in the interim.

Although such circuits must become self-supporting in the longer term, start-up or seed-money funding has already been demonstrated to be both essential and very successful in enabling the initial opening of new international opportunities, such as with the STAR TAP and HPIIS programs. In these other venues, NSF support has been crucial, and very successful, in bridging this start-up gap in the near past. The AMPATH project has reached a very similar position in its development.

The Committee recommends that the NSF consider providing additional funding to AMPATH for operations during the three-year period of the Global Crossing gift.

The Committee feels that the AMPATH project is in a much better position to articulate a detailed strategy for the optimum use of such funding. However, one approach might be for AMPATH to use this suggested funding to offer their services free, or at deeply discounted rates, to some or all of the NRN recipients of the free-DS3s.

This would ensure that the less-well-developed NRNs could connect quickly, and immediately enhance bilateral access to the science collaborations in those countries in the timely interests of both US and international science.

At the same time, such access would undoubtedly result in the stimulation of their own internal development and allow orderly insertion of realistic sustaining funding into their out-year budgets. Circuits will be cheaper then, and Global Crossing has not closed the door on the possibility of extending free access to the DS3s beyond the first three years.

Matching the North and South Bandwidths

The utilization of southern bandwidth in AMPATH shows peaks in the 100 Mbps range and is growing. Brazil, alone, accounts for 30 Mbps of that traffic. With more southern clients poised to come on in the immediate future, it is clear that something needs to be done to address the discrepancy between the 500-600 Mbps of available bandwidth to the South and the 155 Mbps available north to the US high-performance backbone.

The Committee recommends that the NSF assist in balancing the bandwidth from AMPATH to the US high-performance backbone with that which AMPATH has to the south.

Here again, as a group of research-network users and not network technical experts, the Committee is reluctant to assert specific solutions. The NSF and AMPATH have the technical expertise to develop the necessary steps. Notwithstanding, it seems clear that there needs to be a plan and financial support to increase the US-side connectivity significantly in the near future to include a bandwidth allocation for the users to the south.

The Committee recommends that steps taken to balance the US-side connectivity also take into account the need to establish sufficient and appropriate bandwidth to STAR TAP.

Although perhaps related to the next section, this recommendation stands in view of the fact that there are significant US and foreign programs in the south that need the STAR TAP connection.

Connections to the Fednets

It was disturbing to learn that, in relying on Abilene to reach STAR TAP, a number of important US Federal-agency research networks may not be able to connect to the international AMPATH users. The Committee recognizes that this is a complex policy problem that involves the Federal agencies and Abilene. Nevertheless, this situation cannot be good for the science.

The Committee recommends that the NSF and AMPATH work with the entities involved to try to resolve the Fednet connection problem.

As before, the Committee cannot comfortably recommend a specific solution. From its position, the Committee would assume that the range of possible solutions would include establishing a direct connection from AMPATH to STAR TAP, or securing some, perhaps exceptional, modification to Abilene policy, prevailing on the Fednets involved to join Abilene, or establishing an NGIX in Miami.

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APPENDICES