NSF International Research Network Connections Program

Final Report – January 8, 2008

International Meetings and IRNC Workshop materials and presentations

This report is a summary of the work conducted in support of NSF Award # OCI-0730691.

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I: IRNC Program Review Executive Summary

> *"…The conduct of science, intrinsically global, has become increasingly important to <u>addressing critical global issues</u>… ." [NSB 2000]*

The NSF International Research Network Connections (IRNC) program has provided international leadership in establishing networking connections to support science[i] since its inception. It is the foundation of the global cyberinfrastructure and the future of collaborative science and virtual teams[ii], and a cornerstone for NSF (US science) strategic investments in international research and educational activities. Since the IRNC program is nearing the end of its 2nd round of awards (2009), a series of international meetings and an invitation-only workshop have been conducted to get input and recommendations directly from scientists involved in international collaborative research. The question posed to the scientists at the workshop and the international meetings was this: what types of cyberinfrastructure is required to support international scientific collaboration in the year 2010 and beyond? This report is a summary of the findings and recommendations.

Three international meetings and an invitation-only workshop were conducted

- A Birds-of-Feather session at the TERENA annual meeting on the campus of the Danish Technical University, Copenhagen, Denmark, May 22, 2007
- NSF Beijing Office August 23, 2007 and the CANS Conference in Xian; August 25-27, 2007
- Panama City, Panama Meeting in conjunction with the CLARA meeting, November 19, 2007.
- Invitation-only workshop conducted in Arlington, Virginia October 23-25, 2007

Perhaps the most startling surprises from the scientific presentations and international collaborations given at the workshop and International meetings were how dependent International Science was on the network connections provided by the IRNC program and how most of the scientists and researchers had no knowledge of the NSF IRNC program. While this is a testament to the success of the program (enabling international collaboration and research) it is also troubling as the **value of the program does not seem to be adequately recognized within NSF**, and worse, this may lead to inadequate funding and continuation of the program. At the same time, it is abundantly clear that the IRNC program is a cross bearer for NSF internationally – it is highly valued and recognized by other nations and countries, and as a result of providing that leadership, has leveraged and obtained enormous support and resources far beyond the NSF contributions.

In brief, **the IRNC program is a critical element of U.S. international science policy and a core component of NSF's support of international cyberinfrastructure**. The IRNC program must not only be continued, but it needs to be significantly expanded (doubling of program budget) and enhanced to support the next generation of scientific collaborations. Without expansion, the U.S. will lose ground and credibility in scientific discovery and international partnerships.

II: General Themes

A recurring theme, especially at the International visits and meetings, was that the IRNC program has consistently been a catalyst for the development of new science and collaborative research in those countries which participate in the IRNC program. Many scientists and government science program officers stressed how participation in the IRNC infrastructure enabled them to leverage resources and expertise in their own countries and helped transform their level and quality of science. Some of the comments and sentiments sounded like testimonials.

Leading cyberinfrastructure projects from around the world are finding that they need to focus on elements of cyberinfrastructure farther up the stack than basic network connectivity and network infrastructure. Stated another way, network connectivity is necessary, but not sufficient for the next generation of international collaborations.

In general, the enormous growth of data and new scientific instruments[1] will quickly outstrip existing IRNC program connections. The next version of IRNC program will require more capacity (e.g., bandwidth, connections) and capability (e.g. features) to continue to transform science in the United States and to collaborate with others.

There was substantial conversation around the question of investment in experimental networks versus production research networks. Networking experts pointed out that modern optical networking technologies provided unprecedented opportunities to provide production research network services while deploying new technologies in a non-disruptive fashion. Indeed, development of new networking technologies benefits from close interaction with production customers; that interaction informs and guides network research and engineering. While it is unclear how much will be accomplished between now and 2010, issues around optical exchanges, dynamic circuit provisioning and IPV6 will be important to future international research networks

During specific discussions about the future of the IRNC program, all the scientists indicated that their projects, instruments and research would need more bandwidth and capacity moving forward and that they expected that appropriate cyberinfrastructure would be available. Networking experts in the workshop noted that the decreasing investment by the U.S. in research networking has already cost the nation its leadership position in a field that was invented and pioneered in the U.S. In general, Canada, Japan and Europe are now providing leadership in new optical research networking programs (having international collaborators come to their countries, hosting leading workshops, exploring leading edge cyberinfrastructure technologies), and the U.S. is playing "catch-up."

Future research networks will need to serve the needs of diverse applications. Some require immense bandwidth (LHC, eVLBI, high-definition imaging & visualization); some have difficult

[1] Astronomy projects such as Square Kilometer Array and eVLBI; sensor-rich oceanography; environmental video streaming

"last mile" requirements (astronomy, eVLBI, environmental sensor networks, ocean observatories); and still others have stringent latency requirements (interactive collaboration, real-time eVLBI). But all international projects require services and support to function and required an end-to-end capability across and through campus, regional, national and international network boundaries.

A continued lack of adequate investment in the IRNC program will begin to erode not only U.S. technical leadership, but even U.S. connectivity. For example, in the past, the U.S. could expect all nations to fund their own network connections in order to ensure connectivity with the U.S., which was the clear international leader in networking and its application to research. Leadership is increasingly being shown by other countries, particularly Japan and the EU, as they provide direct research connections to other parts of the world and between Asia and Europe. Other governments are now outspending the U.S. in advanced research networking technology and infrastructure

In asking the hard question of whether the commercial sector could provide all that it is needed, it was clear that the answer is still "no." The commercial participants were particularly helpful in elaborating on why a strong research networking program is important. Research networks challenge the economic viability of commercial providers and push the envelope of inter-domain services beyond what the competitive environment has fostered. Many requirements of the research community -- extremely high-bandwidth driving control plane work for dynamic circuit provisioning, low latency for real-time interaction, end-to-end performance management, multicast, IPV6 peering -- are not available across arbitrary commercial backbones. And yet these are required for international science.

NOTE: The October 23-24 Workshop benefited greatly from the presentation by Jon Strauss of the draft NSB Report on International Science and Engineering Partnerships. Workshop participants appreciated the extent to which the report focused on the role of international science as a tool of "soft diplomacy." But participants were dismayed at the apparent lack of recognition that the quality of U.S. science and engineering in many fields requires and depends on collaboration with scientists and scientific resources in other countries. This is not just a matter of outreach and diplomacy, but of ensuring that U.S. scientists participate at the leading edge. This is impossible to achieve on a purely domestic basis, and in many scientific areas relating to cyberinfrastructure, the U.S. is beginning to lose its international leadership and competitiveness position. In addition, collaboration with lesser developed nations may provide valuable access to expertise, knowledge, approaches, and shared resources that might otherwise be unavailable.

> *" It is imperative that the ACP [Advanced Cyberinfrastructure Program] <u>interoperate with cyberinfrastructure</u> being developed and deployed <u>in other countries</u>." [Atkins et.al. 2003]*

III. Recommendations

The IRNC Program is a strategic program for NSF and the US scientific community. It is part of the "soft" diplomacy needed to ensure continued US leadership in science. It is the cornerstone of future international science and education activities and the foundation for global cyberinfrastructure. The recommendations below are aimed at ensuring US leadership and collaboration in the international science community on issues of global importance, and thereby transforming US research and education in the future decades.

<u>Extend Strategic Position and Leverage:</u>

1. Additional funding must be provided to maintain and extend the current US leadership and strategic positioning in networking to all of the world as well as being able to leverage funding and contributions from other nations. This is particularly true in light of the increasing investments by other countries in links that bypass the U.S. In discussion of the current IRNC projects it was clear that the program has done a remarkable job of leveraging the government investments. Leverage factors have multiplied the value of every federal dollar beyond any reasonable expectation. In summary, the IRNC program has invested $24.3M over the last 5 years in international connectivity; foreign investments supporting the IRNC infrastructure is estimated to be $246M to $360M – a 10:1 or 15:1 ratio[iii]. Without that leverage, the U.S. would be even further behind in international research networking.

<u>Programmatic Strategies</u>

2. **Create Programmatic Flexibility:** The IRNC program should provide for "opportunistic" proposals that take advantage of unique moments in time. These include enabling investment in new commercial fiber optic cable projects at the time they are being developed when the costs are lowest and partnering with other international initiatives (e.g., TEIN3, or the new fiber builds taking place in Africa) as they are rolled out. The current 5-yr funding cycle does not maximize flexibility, and this will be even more important in the future to maximize leverage of U.S. investments.

3. **Encourage Partnerships with International Connection Programs:** The IRNC program should encourage the development and coupling of international connection funding programs from other countries such as the EU, Japan, China and so forth. This may also include more coordination with international projects such as GLIF and include funding of people and travel.

4. **Continue Dual Tract Strategy:** The IRNC program should continue to simultaneously support "production" research networking and research network R&D. The two components benefit from integration at the individual project and investigator level. It may be worth exploring the availability or feasibility of multiple lambdas or even dark fiber for some of the international connections. Other components to be addressed include best-effort IP networks, IPv6, international multicast and hybrid networks and

end-to-end connections programs. The need for peering across multiple international domains at line speed is important.

Programmatic Activities

5. **Broaden Programmatic Activities:** IRNC cannot just be about network connectivity; it needs to address higher levels in the network stack as well as the larger world of cyberinfrastructure; this includes attitude, people connections, exchanging knowledge and expertise, working together globally and virtually. This may include the need to create more "hubs" for international collaborations (like PRAGMA) where people and technology from various countries can come together.

6. **Orchestrate Interactions among International Collaborators:** The next instantiation of the IRNC program should have a component that focuses on creating a structure that will facilitate regular and frequent interaction between international collaborators, especially across domains. This will increase sharing and reduce duplicative and re-invention of software, tools and applications. The Workshop Organizers believe that greater national and international coordination would be useful in maximizing the value and utility of international cyberinfrastructure and networking investments. This needs to take place across disciplines (e.g., multiple NSF Directorates, agencies (including science agencies outside the U.S.), research methodologies (e.g., networking, data, computation, and visualization) and nations.

7. **Address Needs of End-to-End Support and Training:** As the importance of international collaboration continues to grow, the IRNC program should also address the need for end-to-end support and last mile services. Another aspect includes the need for more training and education, especially as scientists move up power and capability curves to conduct their science.

8. **Leverage Regional Programs:** Geographic realities suggest that international networking programs address domestic issues as well. The work of WHREN with Puerto Rico is one example, and that of TLPW with Hawaii is another. The IRNC program should leverage these opportunities and identify opportunities for domestic co-funding (e.g., EPSCoR) where appropriate.

9. **Interconnect Major Scientific Instruments:** It is clear that a more formal effort should be undertaken to interconnect all the major scientific instruments across the globe. However, this is outside the purview of the IRNC program itself. The IRNC program could play a role in encouraging appropriate domains and disciplines to partner or participate in specific IRNC awards. For example, through a more formal partnership with the Astronomy directorate, as well as with sister programs in the EU, Japan, China and so forth, the Astronomy community might be able to leverage some of the IRNC infrastructure to help connect all the telescopes to high speed networks so they can be

shared globally. This includes some early planning for projects like the Square Kilometer Array (SKA) which will have enormous data and transmission requirements.

10. **Address Network and Cyberinfrastructure Security:** Network and cyberinfrastructure security should be more explicitly addressed in the next version of the IRNC program – perhaps through specific out-of-band awards or as subprojects within the program. This includes encouraging policies and processes which support and enable international agreements and help develop an environment of trust to support collaboration science.

11. **Develop Tools and Standards for Collaboration:** Development of more easy-to-use tools for collaboration and support, especially support of international data standards, metadata generation, provenance and storage would be useful. This is especially important as the global network of instruments will increase by a factor of at least a 1,000 over the next 3 years. Data capacity and compute capability will increase by a factor of 500. Development of standards will require activity partnerships with other directorates at NSF and their communities.

12. **Extend Connections to All Countries:** Encourage deeper and wider international collaborations with scientists from every continent; some targeted efforts and funding for 3rd world countries and science similar to the EPSCoR program NSF supports domestically. This should probably include a partnership and joint program with multiple directorates working with OISE and OCI to address international cyberinfrastructure issues and develop new capabilities.

"*Peace and prosperity around the world depend on increasing the capacity of people to think and work on a global and intercultural basis. As technology opens borders, educational and professional exchange opens minds.*"[iv]

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[i] International science projects such as LHC, LIGO, BIRN, SDSS, eVLBI, GLEON, GLIF.

[ii] Cyberinfrastructure enables distributed knowledge communities that collaborate and communicate across disciplines, distances and cultures, …[to become] virtual organizations that transcend geographic and institutional boundaries (A. Bement, Cyberinfrastructure for 21st Century Discovery)

[iii] In summary, NSF has expended $24.3M over the last 5 years to support the International Research Network Connections Program. The return on this NSF investment (the leverage gained through non-U.S. matching coordinated investments) is conservatively estimated at a 10:1 ratio. That is, non-US foreign direct investments supporting the IRNC program are estimated to be over $246M over the 5-year IRNC program). The leveraging value of the IRNC program is considerably larger by including additional relevant factors. For example, by including connections and facilities enabled through domestic exchange points (i.e. PacificWave) supported through IRNC awards, the ratio increases to over 13:1. By including non-NSF U.S. funding, the total approaches $360M of accumulated leverage value over 2005-2010, or close to a 15:1 ratio.

[iv] *[i] [Annual Report IIE 2005, and http://www.iie.org/ "About"]*

Appendix One

TERENA B0F Report: DTU, Copenhagen, May 22, 2007

The BoF was held at the TERENA annual meeting on the campus of the Danish Technical University, Copenhagen, Denmark. The B0F started at 5:45 and ran until 7:15 pm; 23 people attended the BOF which was led by Kevin Thompson and Alan Blatecky.

The BoF was entitled: "What Type of infrastructure will be required for international collaboration and research in 2010 and beyond?" The description for the BoF follows:

> *International collaboration between scientists is becoming more important each year. Although most of the infrastructure needs for international collaboration are being met by international networks and circuits, it is anticipated that by the year 2010, international collaboration will require a complex mix of infrastructure and network integration beyond physical networks and the provision of high bandwidth connections between regions of the world.*
>
> *This BoF will explore and discuss the next generation of infrastructure required for science in 2010 and beyond. The ideas and findings from the BoF will be presented and be made part of workshop sponsored by the US National Science Foundation (NSF) in October, 2007. That workshop will help NSF model and design the next iteration of the International Research Network Connections (IRNC) program.*

Kevin Thompson started the BoF with a brief overview of the IRNC program and awardees, and also provided context for the discussion. Alan Blatecky then outlined the intent of the workshop and the draft agenda. Following are the notes from the wide ranging discussion.

International collaboration really focuses on people and brains, and in that sense network connections are really about connecting to the right people. While physical networks are an important component, the need to support scientists and researchers is an order of magnitude more important than the physical infrastructure. An example of this is that research on AIDS in Africa can not be done by researchers in other parts of the world but must be done in Africa.

A concern was raised that many different research networks may be built to meet the needs of specific domains, research, or even specific projects, which will severely impact the ability of the infrastructure to support Virtual Organizations across all of science. That multiple interfaces will be deployed with the result that the research community will end up with a mess similar to the mobile industry today in Europe which is not able to leverage common infrastructure and applications suffer. The scientific community doesn't want or need multiple research networks.

One participant put it simply: “We need a single Internet”. Separate from commodity Internet, the sentiment was about the community needing its own global research and education fabric.

There is a tremendous need for network transparency and a concurrent need to

- focus on services and standardize interfaces
- define vocabularies and agreed vocabularies
- insure efficiency of networking
- “push” EU and US Federal science agencies to stress user requirements

Virtualization capabilities are essential for research collaboration and infrastructure must support virtualization. Virtualization is also important for researchers.

Stronger international coordination on science exists today but not all user requirements are necessarily clearly defined and matched such as that of LHC.

DEISA and TeraGrid (and the follow-on Petascale initiatives in the US and Europe) should be consistent and should interoperate with each other.

One of the most important capabilities of infrastructure is to go beyond providing bandwidth and physical networks. It should

- focus on creating a seamless experience for the user
- be designed so users don’t have to become experts to use the infrastructure
- provide true end-to-end services
-

There is a need for dynamic circuit services as well as static circuits; a need to connect to the IP world and the emerging optical networks.

Efficient networking monitoring is essential, especially for distributed collaborations. It

- help users get better applications
- increase value of network usage itself
- perhaps perfSONAR may be one of the effective monitoring tools (note the TERENA conference here had further evidence of European investment and cooperative activities in perfSONAR as an interdomain monitoring framework)

A major theme from the participants was the need to focus on services rather than just on physical infrastructure help users get better applications.

- a need to support and make services successful and useful for users
- need services which are “dumb” that can be reconfigured by end user
- networks should be more autonomic with some capability for self-repair
- a focus on network usability, where the user can”mash-up” what they need to do their research or develop their application.

-

Another consensus point made was the importance of support for end-to-end networking. In fact many of the comments made in the BoF and reported in this summary reflect this in some form. Technology changes are making infrastructure more difficult to support and sustain; wise choices need to be made up front in the design and implementation.

Encourage and support users to really "use" the network and fill the pipes. There are few users who can push the edge of the networks and infrastructure – it is important that the few users become many users

.

Perception is that the real bottleneck in networking may be the campus; it limits what can be done and by whom.

Need a tight migration and integration of services and grid middleware.

Need for public addressing, and a naming structure (not monolithic, but federated) so that the scale of collaboration can increase and that multiple domains will engage.

There is a fear that the community is creating infrastructure pillars because of a lack of common definitions.

Rapid growth in data will impact infrastructure requirements, especially network-wide. Real-time data may be one of the most important drivers of infrastructure. The sharing of data at large scale is essential.

A major concern noted was the need for persistency of services, especially in the ability to establish optical links for collaboration.

Collaboration is not just about networks and links anymore; it is about design, data, services and support

The next generation of networking needs to incorporate mobility capabilities.

The need to address the next generation of ip, whatever it is, was also noted.

Appendix Two

Beijing Visit; NSF Beijing Office**,** August 23, 2007

To help NSF and the science community address what will be required to support international collaborative science in 2010 and beyond, OCI's International Research Network Connections (IRNC) program management is participating in a series of international meetings and conferences, including several conducted in China over August 22-28. In particular, a day-long meeting was convened at the NSF Beijing Office involving a range of scientists, network researchers, and managers of international network infrastructures. Attendees represented leaders of major R&E networks in China, Japan, Taiwan, and Korea.

It is important to note that NSF's investment for connectivity in Asia has had a tremendous impact on international science. The IRNC program supports U.S.-Asia connectivity in three of its five awards: GLORIAD (connecting to China-CSTnet, Russia, and Korea); Transpac2 (connecting to Japan , China-Cernet, and Asia countries connected through the EU-supported TEIN2 network); and TransLight/PacficWave (connects to Australia). At roughly $1M per year for each award, NSF investments for Asia connectivity are about $15M over 5 years. Asia and Europe together have invested another $50M over the same time frame to increase capabilities and capacity as well. In the end, NSF investments are about our scientists, and the IRNC program has positioned them to have the opportunity to participate in a wide range of international projects. International collaboration will be even more important in the next decade. Attendees to the Beijing discussion made the following main points.

Recommendations for the next IRNC Program

- Reach and scope of the IRNC program should be broadened in order to meet the emerging needs of the international science community.
- Other components of cyberinfrastructure, beyond networking and pure connectivity, should be integrated with these connections and services toward an end-to-end delivery and management of international CI environments.
- Significant barriers to access and collaboration exist in some parts of world, where bandwidth connectivity is poor or non-existent; this includes areas such as Africa. IRNC should make this a future priority.
- Support is needed for a persistent infrastructure to support scientists and focus on specific applications leading to prototypes and routine use, rather than demonstrations.
- IRNC has the opportunity to solidify and grow a leadership role by working with governments and agencies to continue to support international collaboration and require/encourage significant partnering.

AGENDA
MEETING AND DISCUSSION OF NSF IRNC ACTIVITIES
NSF BEIJING OFFICE
U.S. EMBASSY BEIJING
1816 SILVER TOWER
CHAO YANG DISTRICT, BEIJING
TEL: 86-10-6410-6931

9:30 – 12:00 (NOON)

WELCOME	BILL CHANG
NSF IRNC PROGRAM	KEVIN THOMPSON/ALAN BLATECKY
CERNET	WU JIANPING
CSTNET/GLORIAD	LI JUN/GREG COLE/MINSUN LEE
LUNCH (noon – 2:00 p.m.)	HOTPOT
TRANSPAC/APAN	JIM WILLIAMS/KONISH KARUNORI
INTERNET 2	HEATHER BOYLES
PACIFIC WAVE/U. W.	AMY PHILIPSON
TANET 2	EUGENE YEH/CHUSING YANG
U. MARYLAND	DON RILEY
GEORGETOWN U.	SHUIGEN XIAO
TEIN2	LI XING
SURFNET	KEES NEGGERS
DINNER	BEIJING DUCK

HOPE TO FINISH BY 7:30 PM, SO ALL VISITORS CAN GO TO TIANANMEN

Appendix Three

Workshop on Cyberinfrastructure Applications in Latin America

Panama City
Graduate Studies Center
Universidad Tecnológica de Panamá
November 19, 2007

Workshop on Cyberinfrastructure Applications in Latin America

November 19, 2007
Final Program

Slides of each presentation slides can be found at:
http://www.redclara.net/05.htm

08:30-9:00	Introduction Dr. Salvador Rodríguez, Rector, Universidad Tecnológica de Panamá Joaquín Guerrero, President of CLARA Kevin Thompson, Program Director of Cyberinfrastructure, NSF, USA
09:00-09:30	RedCLARA Florencio Utreras, Executive Director CLARA
09:30-10:00	Astronomy. Eduardo Unda-Sanzana Universidad Católica del Norte Chile
10:00-10:30	Oceanography Francisco Gavidia Universidad Centroamericana José Simeón Cañas El Salvador
10:30-11:00	Earth Sciences. Luis León Universidad de Guadalajara México
11:00-11:30	Coffee Break
11:30-12:00	High Energy Physics Anibal Gattone Universidad de Buenos Aires Argentina
12:00-12:30	Climate Change José Luis Santos ESPOL Ecuador
12:30-14:00	Lunch
14:00-14:30	Pollution Arturo Zapata Universidad Nacional de Ingeniería Perú

Workshop on Cyberinfrastructure Applications in Latin America con't

14:30-15:00	Biodiversity Dora Canhos Centro de Referência em Informação Ambiental – CRIA Brazil
15:00-15:30	Grids Luis Núñez Universidad de Los Andes Venezuela
15:30-16:00	Coffee Break
16:00-16:30	WHREN/LILA Infrastructure Julio Ibarra Florida International University
16:30-17:00	RedCLARA Projections and Proposals Florencio Utreras, Executive Director of CLARA Eriko Porto, Chief Engineer, CLARA
17:00-18:00	Open discussion on combined IRNC/RedCLARA possibilities

Appendix Four

NSF IRNC Workshop
Westin Hotel, Arlington, Virginia

Slides of the presentations can be found at:
http://www.renci.org/publications/irncworkshop.php

Day 1: October 24, 2007

8:00 Breakfast
8:30 Welcome, introductions — Alan Blatecky, Kevin Thompson
8:45 Workshop Charge, agenda review

International Collaborative Science and Projects 2010 and beyond: representative presentations about the science and the required collaboration. Emphasis is on collaborative science rather than on technology solutions or physical networks

Questions to be addressed by panels 1-4:

What is the science being done now?
What tools, facilities, instruments and infrastructure are being shared now?
What science will be done in 2010 and beyond?
What shared tools, facilities, instruments and infrastructure will be required in 2010?
What facilities and infrastructure will be new or coming on line?
Who will be involved, and where will the collaborations take place?
What are the perceived gaps in infrastructure in 2010 and beyond?
Consider total infrastructure requirements, not just network bandwidth or circuits
What assumptions are being made about what types of infrastructure will be available?

9:00 Scientific Facilities: Panel 1 — Moderator: Miron Livny

Panelists:

Pepi Fabbiano -- Sloan Digital Sky Survey, NVO
Ian Fisk (Fermi Lab) – Large Hadron Collider

10:00 Scientific Instruments: Panel 2 — Moderator: Alan Blatecky

Panelists:

Yervant Terzian (Cornell) – SKA; Square Kilometer Array
Alan Whitney (MIT) – eVLBI; electronic Very Long Base Interferometry)
Shinji Shimojo (Osaka University) – Electronic Microscope

11:00 Break

11:30 Cyber- environments
Distributed Instruments: Panel 3 — Moderator: David Lassner

Panelists:

Chaitan Baru (UCSD) – GEON; Geosciences Network (David Lassner filled in as Chaitan couldn't attend the meeting

Fang-Pang Lin (NCHC-Taiwan) – LTER; Long Term Ecological Research

Dennis Gannon (Indiana) – LEAD; Linked Environments for Atmospheric Discovery

12:30 Lunch (pick-up lunch quickly and return to seats for Luncheon speaker)

12:45 Lunch – Invited Speaker Jon Strauss (member of NSB Board)

1:30 Small Teams including Single Investigator Collaborative Science: Panel 4 David Lassner

Panelists

Peter Hunter (Aukland University) – Physiome project –

Paul Hanson (UWisc) – GLEON; Global Lake Ecological Observatory Network

2:30 Infrastructure Research: Panel 5 Moderator: Alan Blatecky

What types of infrastructure research is being done today?

What types of infrastructure research will likely be done in 2010 and beyond?

What infrastructure challenges and problems still need to be addressed?

Panelists:

Cees de Laat (Netherlands) – SURFNET

Jun Murai (Japan) – WIDE

Rene Buch (Norway) – NORDUNET

3:30 Break

4:00 Major Grid Projects and Plans: Panel 6 Moderator: Miron Livny

What types of Grid infrastructure exist today?

What will it be in 2010, or what will it look like?

What dependencies are assumed? For example, will network connectivity be provided by the project, the domain or by others?

What infrastructure gaps threaten the future viability and vitality of research in 2010?

Panelists:

Dennis Gannon (Indiana) TeraGrid

Ruth Pordes (Fermi) – OSG; Open Science Grid

5:00 Discussion and Dialogue

6:00 Break – Dinner everyone on their own (except for workshop report team)

6:30 – 8:30 Workshop committee dinner and planning meeting

Day 2: October 25, 2007

8:00 Breakfast

8:30 IRNC Status: Panel 7 Moderator: Alan Blatecky
IRNC updates and plans from each PI

Panelists:
Maxine Brown (UCSD) – Translight/Starlight
John Silvester (USC) – Translight/Pacific Wave
James Williams (IU) – Transpac2
Greg Cole (UT Knoxville) – GLORIAD
Julio Ibarra (FIU) – WHREN

10:00 Network Infrastructure in the year 2010 and beyond: Panel 8 Moderator: David Lassner
Panelists:
Wes Kaplow (Qwest)
Javad Boroumand (Cisco)
Heather Boyles (Internet2)

11:00 Break

11:30 Scientific requirements for International Collaboration
(Panel Summary Reports and Discussion)

1:00 Lunch

IRNC Workshop Attendance list 10-24		
Attendees/Presenters	email address	
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Appendix Five
Foreign Investment in IRNC Program

The five IRNC awards were asked by NSF to provide leveraging data and to clearly identify any assumptions and interpretations made. Some responses were more expansive than others and the reports are included in the appendix.

In summary, taking into account the IRNC program overall as currently a $5M/year ($23.4M total investment), the leverage gained through non-U.S. matching coordinated investments is conservatively estimated at a 10:1 ratio (over $246M in direct foreign investments estimated over the 5-year IRNC program). The total leveraging of the IRNC program increases significantly by including additional relevant factors. For example, by including connections and facilities enabled through domestic exchange points (i.e. PacificWave) supported through IRNC awards, the ratio increases to over 13:1. By including the leveraging of non-NSF U.S. funding, the total approaches $360M of accumulated leverage value over 2005-2010, close to a 15:1 ratio.

Lastly, it should be noted that some of the individual reports refer to U.S. funded scientific projects and facilities overseas, but these projects were not counted in the leveraging ratios assembled. Such investments rely directly on IRNC supported high speed network links and services, now and in the future. Were such investments to be included in an estimate of IRNC leveraging, the ratio values would skyrocket, but would not be meaningful. What is meaningful, for example, is that without the IRNC program supporting connectivity to Latin America, astronomical instruments in Chile (whose U.S. investments in ALMA, Gemini, and LSST are estimated at $894M) would not be accessible by researchers either in Latin America or the U.S., to say nothing of Europe and other nations across the Pacific.

Reports:

1.	GLORIAD	2 pages
2.	TransPac2	1 page
3.	WHREN	5 pages
4.	Translight/Starlight	13 pages
5.	Translight/Pacific Wave	4 pages

International Leverage of US NSF Funding for GLORIAD

The issue of funds leveraged against NSF investment in international circuits for GLORIAD is complex. There are three circuits for which figures are provided here. But because GLORIAD rings the northern hemisphere of the earth and the US R&E community gains benefit from connections not terminating in the US, the leverage figures here should be considered a low minimum.

The $120,000 annual NSF investment in the US-China-Korea 10G circuit (provided by VSNL and FLAG) is matched by $2,300,000 annual investment by KISTI (with funds provided by the Korean Ministry of Science and Technology) providing a basic match ratio of nearly 20:1. But the US gains additional benefit from the $1 million non-circuit funds invested per year in GLORIAD activities by KISTI including network and programming support, applications support, sizeable equipment investment, travel and other operations expenses.

The US benefits from the Korean participation in GLORIAD not only for US-Korea collaborative activity – but the 10G circuits from Hong Kong to Daejeon and Daejeon to Seattle support US-China activity also. By routing CERNet traffic between Hong Kong and Seattle, the US gains uncongested network capacity with universities across China (in addition to the research facilities routed by GLORIAD partners at CNIC).

The total 5-year cost to the NSF of cost sharing on the US-China-Korea links is $400,000 (40 months x $10K). The corresponding 5-year commitment of KISTI for circuit costs (only) is $10.2M. The resulting ratio for circuit costs (Korea:US) is 25:1 for the 5-year project.

The identical $120,000 annual NSF investment in the US-China 2.5G circuit (provided by VSNL) has been matched by $780,000 annual investment by the Chinese Academy of Sciences, providing a basic match ratio of nearly 7:1. But, as with the Korean example, the US gains additional benefit from at least $500,000 of annual investment by the China Academy of Sciences in personnel, travel, equipment and operations costs.

The total 5-year cost to the NSF of cost sharing on the US-China links is $480,000 (48 months x $10K – we did not cost share during the first program year). The corresponding 5-year commitment of the CAS for circuit costs is approximately $3.9M, yielding a basic China:US funding ratio of 8:1.

VSNL provides a donation to GLORIAD-US of a 622 Mbps circuit which connects the US R&E community with Russia (via interconnect in Amsterdam) – this can be valuated at roughly $2.5K monthly for a total annual donation of $30,000. There are no costs assessed to the NSF – neither now nor since the GLORIAD program began in January 2005. (Note: the capacity provided by the TransLight project for US-Russia high performance (3 GbE circuits) connections can be accounted for by that IRNC program). Figures for Russian connectivity from Moscow and St. Petersburg to the GLORIAD European interconnect in Amsterdam are difficult to account for here since the capacity from Russia to Amsterdam is used also for Russia-European connectivity. A conservative estimate however of Russian annual financial commitment for connectivity facilitating connectivity with the US is $500,000. A more accurate estimate will be developed with Russian GLORIAD leadership in 2008. There is no match ratio calculable here since there is no direct US GLORIAD (NSF) investment in telecommunications costs for US-Russia.

Of course, there are myriad other donations to the international GLORIAD effort provided by partners in Canada (including high-capacity circuits and access to L1 and L2 equipment), in Netherlands (2 10GbE circuits available for high performance applications as needed – but for broad US use (i.e., not exclusively for GLORIAD use) – and access to L1 and L2 equipment), via NorduNet (including a connection from Amsterdam to near the Russian border), via Russia (the trans-Russian connection – although this has rarely been made available to the US community) and via China (connections across China – from the Russia-China border to Hong Kong). For this current leverage study, the value of these connections is not included – but they clearly provide additional value beyond the direct expenditures enumerated here.

Considering only telecommunication costs, the 5-year investment of NSF in GLORIAD is $880,000. This is matched via firm numbers from Korea and China of $14.1 million and another $2.5 estimated from Russia for a total of $16.6 million of international investment, leveraging NSF funds almost 19:1.

But the total 5 year investment of NSF in GLORIAD-US including all programming support, investment in security, monitoring, equipment, personnel, operations is $4.1 million. This is matched by (reasonable estimates) from Korea and China of all support (telecommunications and other) of $24.1 million, providing an overall project leverage of NSF funds of almost 6:1.

Thus, whether total funds are included in the estimate (in which case the ratio is 6:1) or whether only the telecommunications portion is included (yielding a ratio of 19:1), US NSF dollars invested in GLORIAD are highly leveraged by our international partners. As mentioned earlier, these figures however must be considered minimal because, in fact, Canadian, Dutch and Scandinavian investment in and contribution to GLORIAD is also sizeable.

Foreign investment leveraging Transpac2
IRNC Program

(Costs are estimated, as organizations are very hesitant to provide detailed information about the costs of their infrastructure)

1. Tokyo – Hong Kong OC-48 (delivered as 2 x 1Gb) connecting China (CERNET and CSTNET) to TP2. Funded by NICT. Estimated costs about $50,000/mo or $600,000/year plus equipment and POP space in HK.

2. Tokyo – Singapore 622Mbps link connecting South Asia to TP2. Funded by NII. This is the TP2 South Asia link. It is also the connection that TEIN2 uses to send traffic to the US. It provides the basis for the current TP2-TEIN2 partnership. Estimated costs about $50,000/month or $600,000/year. This link is also critical in the US-Pakistan connection and a potential US-India connection.

3. EU TEIN2 leveraged investment:

    a. Use of TEIN2 POP and router in Singapore. Value is quite high. The investment required to put in place a complete POP is at least $50,000 with $2,500/month or $30,000/year ongoing fees.

    b. Partnership with TEIN2 allows for delivery of SA packets via a direct Singapore-Tokyo-LA route rather than a route through the Middle East-London-NYC. The TEIN2 program budget is about 3M euros per year which translates into about $4,500,000/year.

4. TP2 – (NICT-JGN2) joint secondary backup. TP2 provides backup for JGN2 and vice versa in LA. So, in theory, only an oceanic cable cut or a very unlikely (but possible as the past month indicated) catastrophic outage would require switching to our third level backup. Estimated costs of JGN2 link $40,000/month or $480,000/year (same as TP2 link). This backup capability is used quite regularly.

5. TP2 – NII joint 3rd level backup. If the JGN2 link and the TP2 link both fail, then TP2 traffic switches to the NII links. There is an NII link into LA and one into NYC. Traffic is split across these links based on destination. In the first three years of the TP2 Project this third level backup has only been used two times, once with a cable cut (extended outage) and once with an outage at a critical location in Japan (short outage). I don't have any realistic costs estimates here.

6. APAN-TP2 landing site and connections in Tokyo. APAN provides a facility similar to the TP2 LA facility tin Tokyo. Based on our costs for the TP2 facility in LA, I estimate that the APAN-TP2 facility has a fixed investment of at least $400,000 and ongoing costs of $2,500/month or $30,000/year.

Foreign investment leveraging WHREN
IRNC Program

Background

The WHREN/LILA project was funded January 1, 2005 as part of the International Research Network Connections program. This award, called WHREN (Western Hemisphere Research and Education Networks) addresses the existing and future needs for improved North American (especially the U.S.)–South American network connectivity. Activities focus on the need for improved connectivity through new network links: LILA (Links Interconnecting Latin America). WHREN formed a consortium of organizations from across the Western Hemisphere to participate in developing and operating a next-generation model for international networking that is now fostering collaborative research and advance education throughout the Western Hemisphere and other world regions. WHREN also serves to increase the rate of discovery both in the U.S. and across the Western Hemisphere. U.S. researchers are part of communities of scientists undertaking experiments that require increased and improved network resources throughout the Americas. WHREN-LILA is developing, implementing, assessing, and updating a cogent plan to support evolving researchers' needs and to foster new inter-disciplinary communities of researchers and learners.

Value to U.S. science

A number of U.S. science initiatives depend critically upon facilities or environments located in Latin America. One example is observational astronomy. Astronomical observatories located, or to be located, in the Caribbean and South America include Arecibo Observatory, Pierre Auger, the Gemini South, CTIO and NOAO optical telescopes and the Atacama Large Millimeter Array (the latter two in Chile). Another example is the Inter-American Institute for Global Change Research (IAI). This intergovernmental organization coordinates research into environmental and socio-economic change in the Americas, and it counts 17 member countries in the Latin America area as well as the U.S. and Canada. Also, NASA's International Space Station (ISS) project seeks to provide access to the ISS for scientific investigators worldwide, including those in the Latin America. All of these U.S.-led initiatives now depend or will depend crucially upon high-speed connectivity between the U.S. and Latin America. Several federal agencies currently operate networks in Latin America using point-to-point low-bandwidth circuits. The WHREN/LILA project provides a coordinated and effective approach to these connectivity needs.

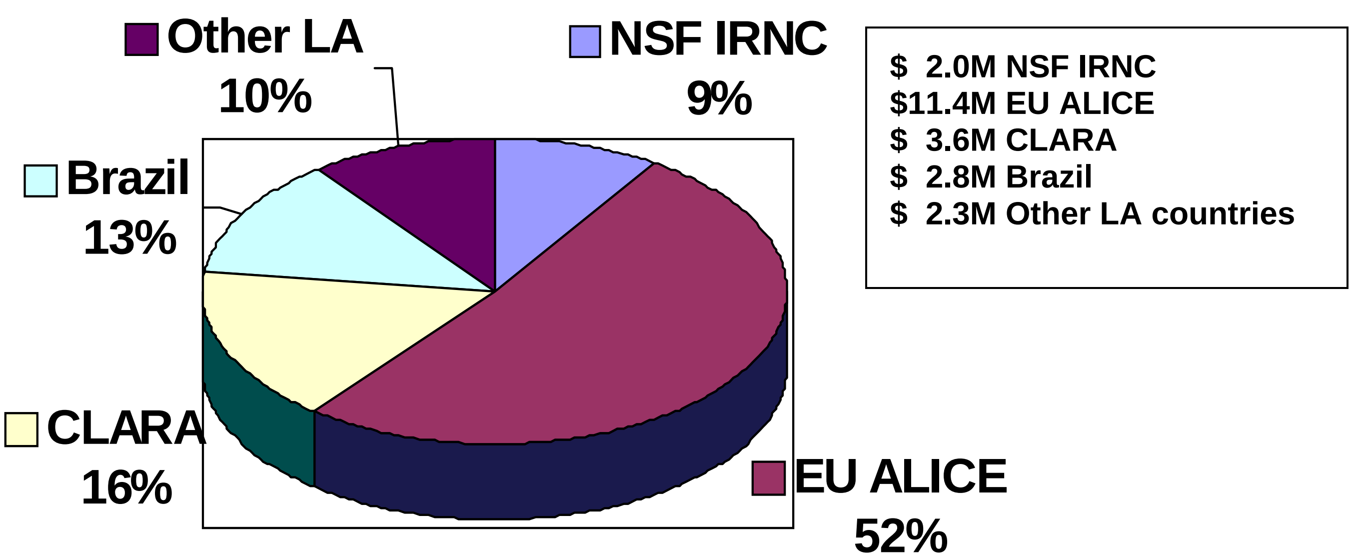
Assessing Leverage of the WHREN-LILA project

The WHREN-LILA project has a qualitative problem documenting its criticalness to U.S. research. WHREN can point to a list of researchers who state that their research depends on access to collaborators or tools in South America. However it is up to domain specific peer review to establish the quality of their research. Education effectiveness is also eventually a qualitative assessment. Without WHREN a different picture of connectivity would exist. For example the European Union stipulated that the ALICE intercontinental link from South America to Europe could traverse North America, but could not route data there. U.S. investigators connecting to

U.S. owned telescopes in South America would without WHREN need to route from the U.S. to Europe, then back to the U.S. This is exactly what happened before WHREN.

Quantitatively WHREN can document the ration of NSF investment in inter-American networking (for purposes of this year's report, all inter-American[1] networking data only reflects U.S.-Latin America. Canada is omitted.) This will be rectified in year four.

Leveraging of Network Centric Investment
Quantitatively, since the start of the IRNC program in 2004, $2 Million dollars has been expended. During that same time period the European union expended $11.4 Million dollars on establishing a regional network in Latin America through CLARA, who additionally contributed $3.6 Million dollars. WHREN-LILA interconnects with RedCLARA network now in Sao Paulo, Miami, and Mexico City. Brazil has spent $2.8 Million dollars and is committed to matching all NSF expenditures dollar for dollar. Venezuela, El Salvador, Panama, and Mexico have collectively spent $2.3 million dollars since 2004 for connectivity to the U.S. ***Since the beginning of the project, IRNC funds have been leveraged 10 to 1 for Inter-American network connectivity.***



This assessment does not include the full contributions from other non-NSF sources in the U.S. (both R&E and industrial) that include equipment, people, and capital. For example, the Atlan-

[1] Inter-American connectivity means connectivity from the U.S. to foreign countries in the western hemisphere, from 2004 to date, not including connectivity from the U.S. to Canada

ticWave[2] project. NSF, but non-IRNC contributions during this time period (from CHEPREO) have totaled $426,000 with an unfulfilled commitment for $426,000 additional in 2007.

In the future, there is likely to be an upswing in contributions from CLARA, and Brazil, with a reduction in EU funding. Although the HEP community is the largest user of the north-south international bandwidth provided by the WHREN-LILA project, there are other important U.S.-Latin America science research communities being served. There is a growing list of NSF instruments and research foci that depend on reliable, available, high-bandwidth connectivity throughout Latin America.

Communities benefiting from the WHREN-LILA shared link

Astronomy: The U.S. astronomy program has a major presence in La Serena, Chile – the site of the US National Optical Astronomy Observatory (NOAO) and the international Gemini Observatory. NOAO and Gemini supported the WHREN-LILA proposal and the concept of leveraging the use of a high-speed network service from Miami to São Paulo that is provided under the auspices of the NSF-funded WHREN-LILA project. Availability to additional bandwidth as demand increases is a priority for the astronomy community. Potential increases are in the horizon with the addition of a dark energy camera, connections to ALMA, and the connections of other telescopes. Radio astronomy antennas in Fortaleza, Brazil and in Chile, will be using the WHREN-LILA link. Pierre Auger in Malargue, Argentina, is another important U.S.-Latin American collaboration.

Major Research Equipment and Facilities Construction (MREFC) account projects in Latin America. The MREFC is funding the following astronomical instruments that are located in the northern plains of Chile. ***Total U.S. investments of these new instruments in Chile are estimated at $894M.*** Details for each of these new instruments are described below.

Atacama Large Millimeter Array (ALMA) will be a single research instrument composed of up to 80 high-precision antennas, located on the Chajnantor plain of the Chilean Andes (http://www.alma.nrao.edu/). ALMA will enable transformational research into the physics of the cold Universe, regions that are optically dark but shine brightly in the millimeter portion of the electromagnetic spectrum. Providing astronomers a new window on celestial origins, ALMA will probe the first stars and galaxies, and directly image the formation of planets. **The U.S. investment in ALMA is approximately $500M.**

The ***Gemini Observatory*** consists of twin 8-meter optical/infrared telescopes located on two of the best sites on our planet for observing the universe (http://www.gemini.edu). Together these telescopes can access the entire sky. **The U.S. investment for the construction of Gemini was $184M ($92M each to build the two telescopes and their first suites of instruments). Total expenditures from inception through 2007 for all classifications of capital and expenses is something more around $450M.**

[2] Funding for the AtlanticWave project is provided by the Southeast University Research Association (SURA), FIU/AMPATH, University of Maryland/MAX, Southern LightRail (SLR/SoX); Internet2/MANLAN, Florida LambdaRail in the amount of $1.6M.

Large Synoptic Survey Telescope (LSST) is a proposed ground-based 8.4-meter, 10 square-degree-field telescope that will provide digital imaging of faint astronomical objects across the entire sky, night after night (http://www.lsst.org/lsst_home.shtml). **The U.S. investment in LSST is approximately $300M.**

Other U.S.-Latin America CI-enabled international science research and education opportunities:

The Dark Energy Camera is an NSF, DOE and university consortium partnership. **The U.S. investment is approximately $40M.**

Genomics: Genomics research is a growing area of collaborative research and education between the U.S. and Peru. FIU and Michigan State University are collaborating with Peru and CLARA to develop a plan to enhance U.S.-Peru science research and education collaborations through the use of the WHREN-LILA and RedCLARA shared cyberinfrastructure.

Biodiversity and Ecological Research: Biodiversity, Bioinformatics and ecological research is an active area of collaboration between the U.S. and Brazil; for example, involving the University of Kansas with groups in Campinas and Manaus. In the WHREN-LILA project, FIU, ANSP and RNP are exploring ways to better connect these communities.

Contributions to Science

The adoption of cyberinfrastructure tools is changing the practices of science towards network dependent collaborations to support data intensive science. This phenomenon has started to accelerate as a result of the NSF-funded IRNC links providing a high-availability science and engineering research and education production environment to support science in the western hemisphere.

This section describes activities that are contributing to the knowledge production of science as a result of the availability of the WHREN-LILA links. Significant contributions are being made in the areas of particle physics, biodiversity and ecological research, and environmental sensor networks involving collaborations between the U.S. and Latin America. Work is underway to increase knowledge production in U.S.-Latin America genomics science research and education collaborations mediated by network-enabled cyberinfrastructure.

Environmental Sensor Networks:

In the U.S., the WATERS and the GLEON lakes research projects are creating and sharing knowledge with similar projects in Argentina (see The Pan-American Sensors for Environmental Observatories (PASEO) Workshop report at https://eng.ucmerced.edu/paseo/). In Costa Rica, an environmental sensor network will be installed at the La Selva rain forest. This sensor network will draw many U.S. scientists to work at La Selva, as well as across the RedCLARA network infrastructure that connects Costa Rica to the U.S. The nascent collaborations that are in formation between the U.S. and Argentina, and also the U.S. with Central America, should produce notable scientific papers that will be the result of science enabled by the WHREN-LILA network infrastructure.

Particle Physics:

The U.S. particle physics community is one of the most active in U.S.-Latin America collaborations involving the Large Hadron Collider (LHC) and the CMS experiments at CERN. Through the NSF CHEPREO and UltraLight projects, and projects that require access to FermiLab, such as DZero, the WHREN-LILA links are being used to support many experiments. “The use of the WHREN-LILA link is vital for preparatory studies prior to LHC running, using simulated data, including large scale operations such as "CSA07" (Computing, Storage and Analysis 2007). Once data taking commences, there will be hundreds of publications, including many where the partners in CHEPREO will have central roles”, (Harvey Newman personal communication). CMS Notes describe experiments and results using simulated data. While they are not publications in physics journals, CMS Notes are refereed. They are available at http://cmsdoc.cern.ch/docnotes.shtml

The Tier2 facility in Sao Paulo, SPRACE, participated in two DZero data reprocessing (P17 and P20) experiments that utilized the WHREN-LILA link between Sao Paulo and Miami to reach FermiLab. This activity produced 75 DZero papers that are cited at http://tinyurl.com/37wqhs.

Astronomy:

Gemini and the National Optical Astronomy Observatory (NOAO) manage the optical telescopes in Chile that produce data products for U.S. optical astronomy science. The data management processes are data intensive and require access to a high-performance network to transfer data products to archives that geographically distributed to serve the international optical astronomy community. These data products are also being incorporated into the Virtual Observatory (http://www.ivoa.net/). A significant number of refereed publications have been produced based on data taken with the telescopes in Chile that are supported by the WHREN-LILA project. A significant number of citations are available at http://www.gemini.edu/science/publications/users.html for Gemini; and at http://www.noao.edu/noao/library/pubs/fy2006tel.ctio for NOAO.

Foreign investment leveraging Translight/Starlight IRNC Program

1. Value to US Science

Since the beginning of the project, IRNC TransLight/StarLight funds have been leveraged approximately 20:1 internationally and an additional 8:1 non-Federal nationally.

1.A. Assessing Leverage of the Project

1.A.1. Leveraging to Date of IRNC Award Investment

Introduction and Assumptions

TransLight/StarLight (TL/SL) receives $1,000,000/year, over 5 years (2005-2010) to procure, engineer, maintain, develop, and document two OC-192 (10Gbps) circuits from the US to Europe. One is managed as a Layer-3 (L3) routed connection between the Internet2 Network at MAN LAN (NYC) and the GÉANT2 Network at their PoP in (Amsterdam); this link costs $240,000/yr. The second is a Layer-2 (L2) switched connection between StarLight (SL) in Chicago and NetherLight (NL) in Amsterdam; this second link costs $300,000/yr. SL and NL are the primary connection points for many national, international, and regional networks at L2. There is also approximately $40,000/yr in the TL/SL IRNC budget for switch/router maintenance costs at SL for equipment purchased with prior NSF HPIIS and related SL awards.

This document attempts to describe leveraging of NSF's total TL/SL investment of $5,000,000, which includes past, current, and future estimates. The expenditures used to show leveraging are contemporaneous with the IRNC award, to our knowledge. Some of the leveraged costs are confidential, so our estimates may be disputable, and in many cases, costs of equipment have dropped over the years, but we will use what the costs were when spent. We will also attempt to separate domestic and international leveraging, and mention, but not include in our totals, leveraging of US Federal Agency network expenses.

A circuit has several costs:

- the link itself as contracted from a carrier, per year
- the cost (or partial cost) of the Layer-1 (L1) terminating equipment at each end, plus yearly maintenance contracts and rack space rental (assumed in calculations below to be 10% of equipment cost)
- the cost (or partial cost) of the Layer-2/3 (L2/3) switching/routing equipment, plus yearly maintenance contracts and rack space rental
- the non-circuit costs (of engineering, documenting, promoting, outreach, travel, supplies, and indirect costs on these)—in TL/SL's case, this is about $420,000/yr or 42% of the $5,000,000 award. Other circuit owners and operators surely have similar costs beyond the circuit cost and equipment maintenance as well, but this is impossible to accurately estimate.

In each case below, we give our best estimate of the L1 equipment cost, and if it is a shared or single-circuit device. Some circuit owners also maintain single-user L2/3 devices for control at both ends, adding significantly to the costs (and TL/SL leveraging). For instance, UKLight has its own L1 equipment at SL, which then delivers 4 Gigabit Ethernet circuits to the SL Force10 L2/3 switch, which then connects to Fermilab and TeraGrid. As a second example, US LHCnet has both its own L1 and L2/3 equipment, but also connects to the SL Force10. At MAN LAN, GÉANT2 and Internet2 maintain L1 and L2/3 equipment for IRNC, GÉANT2, and other circuits.

Since Internet2 charges US connections $480,000/yr per 10GE, then for simplicity, we will use that figure as the leveraging value for connections to the Internet2 Network below, as if Internet2 were charging to connect to a US GigaPoP or single entity at 10GE, since we consider this a fair value for services rendered.

Category 1: Direct Contributions

UIC (the TL/SL awardee) pays the fees for two 10Gbps TL/SL circuits to SURFnet, who then handles the tenders and contracts for the services along with SURFnet's own circuits to MAN LAN and SL; we estimate the value of contract handling services to be ~10% of the circuit costs. SURFnet, MREN (at SL), GÉANT2 and Internet2 supply significant engineering and NOC services, which we estimate to be each valued at 10% of our circuit costs. Internet2 contributes a 10GE connection into the Internet2 Network at MAN LAN, which is valued at $480,000/yr <www.internet2.edu/network/fees.html>. We assume the value of the SL link into NLR and the midwest Regional Optical Networks (RONs) to be equivalent. TL/SL's share of SL engineering services are paid for by IRNC, so are not included in the leveraged costs.

Category 1 total: $810,000 international plus $5,340,000 non-Federal US (together $6,150,000) over 5 years.

TL / SL Category 1: Direct Contributions

Assumptions

5	Number of years (I2, GÉANT2, SURFnet, NLR, etc)
540,000	IRNC TL/SL link costs/yr
10%	Percent of circuit used to calculate Tender and Contract services/yr
10%	Percent of link costs for engineering and NOC services
480,000	Cost of Internet2 usage fee/10Gb connection/yr

	Annual Contribution	Total Contribution	
International Direct Contributions			
SURFnet Contract Services	54,000	270,000	
SURFnet NL engineering and NOC services	54,000	270,000	
GÉANT2 AMS engineering and NOC services	54,000	270,000	
SUBTOTAL			**810,000**
Non-Federal Direct Contributions			
MAN LAN Internet2 engineering and NOC services	54,000	270,000	
SL engineering and NOC services contributed by MREN	54,000	270,000	
MAN LAN Internet2 10GE IRNC/I2 connection	480,000	2,400,000	
SL NLR/RON IRNC connections (assume equivalent value)	480,000	2,400,000	
SUBTOTAL			**5,340,000**
TOTAL			**6,150,000**

Category 2: Contributions of Equipment, Port Fees and Engineering Services

TL/SL receives contributions (in terms of estimated dollars/yr) of equipment, equipment maintenance, and port fees/engineering services at the terminal points of its circuits, for which IRNC is ***not*** charged. In the following calculations, it is assumed that L1 devices cost $500,000 each, and that one circuit consumes a domestic and an international port at $50,000 each ($100,000 total). L2/3 devices cost about $100,000, and two 10GE ports (typically) at each site per circuit is estimated to be $10,000 each ($20,000 total). We estimate maintenance to be 10% of the cost of the equipment ports ($10,000/yr for the L1 device and $2,000/yr for the L2/3 device)[1]. Some circuit owners have their own L2/3 switches at SL or MAN LAN for control reasons, and some owners plug directly into the SL Force10, into ports that pre-existed IRNC.

- ***International:*** SURFnet owns and operates the L1 HDXc switching gear at NL into which both TL/SL circuits terminate. SURFnet hands off one circuit to a SURFnet L2 switch and the other circuit to a GÉANT2 router. GÉANT2 also maintains a router at MAN LAN. CANARIE provides the HDXc at SL into which the TL/SL Chicago circuit terminates; from there it goes into SL's Force10.
- ***Non-federal US sources:*** Internet2 provides the L1 HDXc and L2/3 switch at MAN LAN into which the TL/SL NYC link terminates. SL provides the L2/3 switch, which was bought with NSF funds prior to 2005.

Category 2 total: $720,000 over 5 years.

TL / SL Category 2: Contributions of Equipment, Port Fees and Engineering Services

Assumptions	
5	Number of years (I2, GÉANT2, SURFnet, NLR, etc)
500,000	L1 Terminating Equipment cost/device (up-front charge)
100,000	L1 Ports ($50,000 each x 2) (one-time charge)
10%	Percent of L1 Ports for estimated maintenance and rack space charges/yr
100,000	L2/L3 Terminating Equipment cost/device (up-front charge)
20,000	L2/L3 Ports ($10,000 each x 2) (one-time charge)
10%	Percent of L2/L3 Ports for estimated maintenance and rack space charges/yr

	Total Port Fee Contributions	Total Maint / Rack Space Contributions (all yrs)	
International Equipment / Port Fee Contributions			
NL SURFnet L1 HDXc Port (IRNC CHI circuit)	100,000	50,000	
NL SURFnet L1 HDXc Port (IRNC NYC circuit)	100,000	50,000	
NL SURFnet L2 Switch Port	20,000	10,000	
NL GÉANT2 L3 Router Port	20,000	10,000	
MAN LAN GÉANT2 L3 Router Port	20,000	10,000	
SL CANARIE HDXc Port	100,000	50,000	
SUBTOTAL	**360,000**	**180,000**	**540,000**
Non-Federal Direct Contributions			
MAN LAN Internet2 HDXc Port	100,000	50,000	
MAN LAN Internet2 Switch Port	20,000	10,000	
SL switch purchased with NSF funds	0	0	
SUBTOTAL	**120,000**	**60,000**	**180,000**
TOTAL			**720,000**

[1] The majority L1/L2/L3 devices that TL/SL leverages are shared by many people (e.g., the HDXc's at SL, MAN LAN and NL) and/or were purchased prior to IRNC, so rather than use a percentage of the actual costs of the devices, we use the port counts to calculate maintenance. We could use a percentage of the actual device costs if preferred.

Category 3: International Circuits

Below are international circuits expenditures that TL/SL IRNC funds directly leverage. For the five-year IRNC period, we have estimated the total costs of the links, the up-front equipment costs, FTE engineer salaries, and equipment maintenance (10% of the equipment cost/yr). While the internationals do not charge connection fees, we assume that there is a value associated with connecting, which we estimate to be equivalent to the Internet2 Network connection fee ($480,000/yr).

- ***International transatlantic circuits relevant to TL/SL:***
  1. GÉANT2 maintains 2 OC-192 and 1 10GE links to the US, which we consider leverage to the TL/SL MAN LAN circuit and Internet2's circuit to London.
  2. SURFnet maintains 1 OC-192 link to SL and one to MAN LAN, which we consider leverage to the TL/SL MAN LAN and SL circuits, respectively.
  3. CESNET maintains an OC-192 link to SL. (CESNET just started this year, so we only calculate costs over a 3-year period). This circuit is considered leverage to the TL/SL Chicago circuit.
  4. UKLight maintains an OC-192 link to SL, which is used to connect to Fermilab and other DOE sites for high-energy physics as well as to the TeraGrid. We will count 25% for TL/SL leverage and 75% for ESnet leverage.
- ***International transpacific circuits relevant to TL/SL:***
  1. JGN2 maintains a 10GE link to SL from Tokyo via Los Angeles. JGN2 has its own L1/L2/L3 equipment in Tokyo, LA and SL. JGN2 is a four-year project, so we only calculate costs over a 4-year period. Since JGN2 does not peer with Pacific Wave in Los Angeles, we claim 100% leverage.
  2. SINET maintains a 10GE link to MAN LAN from Tokyo. Most of the use of this link is for Internet2 connectivity and connection to European circuits, the IRNC being one. Therefore, we claim 100% leverage.
  3. HARNET maintains a 1Gb connection from Hong Kong to SL (Chicago). We claim 100% leverage. Internet2 connection fees for 1Gb is valued at $250,000, so we will use this value <www.internet2.edu/network/fees.html>.
  4. CERNET maintains a 155Mb connection from China to SL (Chicago). We claim 100% leverage. Internet2 connection fees for 1Gb is valued at $250,000, so we will use this value <www.internet2.edu/network/fees.html>.
  5. TaiwanLight maintains a 2.5Gb link from Taipei to SL, and then has a 1Gb connection via CANARIE to MAN LAN. TaiwanLight has its own L1/L2/L3 equipment in Taipei. Internet2 connection fees for 2.5Gb is valued at $340,000, so we will use this value <www.internet2.edu/network/fees.html>. *TaiwanLight has a second 2.5Gb link from Taipei to Los Angeles, which TransLight/Pacific Wave should use as leverage.* Therefore, TL/SL will use 100% of the TaiwanLight circuit to SL as leverage.
  6. *Note: ASGCNet, the Taiwan Academica Sinica network in support of the LHC (Taiwan is a Tier-1 site) has a 2.5Gb link from Taipei to Chicago to Amsterdam (and then Geneva). At SL, ASGCNet connects with the FermiLab Lightpath and DOE metro ring, which is operated by ANL, FermiLab, ESnet and LHCnet. Given that this link is devoted to DOE/LHC, TL/SL claims 0% leverage.*

Category 3 total (TL/SL part): $99,069,000 over 5 years.

TL/SL Category 3: International Circuits

Assumptions

5	Number of years (I2, GÉANT2 , SURFnet, IEEAF, UKLight, SINET, TaiwanLight, CERNET, HARNET)
3	Number of years (CESNET)
4	Number of years (JGN2)
10%	Equipment maintenance/yr is a percentage of up-front equipment cost
$200,000	FTE costs/yr
$480,000	Cost of Internet2 usage fee/10Gb connection/yr
$340,000	Cost of Internet2 usage fee/2.5Gb connection/yr
$250,000	Cost of Internet2 usage fee/1Gb connection/yr
100%	Percent value claimed equivalent to the Internet2 Network connection fee
$240,000	MAN LAN GÉANT2 OC-192 Estimated circuit cost/yr
$240,000	MAN LAN GÉANT2 OC-192 Estimated circuit cost/yr
$240,000	DC GÉANT2 10GE Estimated circuit cost/yr
$240,000	MAN LAN SURFnet OC-192 Estimated circuit cost/yr
$300,000	StarLight SURFnet OC-192 Estimated circuit cost/yr
$500,000	SL CESNET OC-192 Estimated circuit cost/yr
$340,000	SL UKLight OC-192 Estimated circuit cost/yr

	Total Circuit Cost	Est. Cost Equip Up-front	Total Equip Maint (1)	Total FTE (all yrs)	Connec-tion fee (2)	Subtotal	IRNC % share	Total IRNC Leverage	
International Transatlantic Circuits that land first at SL or MAN LAN or Washington DC									
MAN LAN GÉANT2 OC-192	1,200,000	360,000	180,000	1,000,000	2,400,000	**5,140,000**	100%	5,140,000	
MAN LAN GÉANT2 OC-192	1,200,000	360,000	180,000	1,000,000	2,400,000	**5,140,000**	100%	5,140,000	
DC GÉANT2 10GE	1,200,000	360,000	180,000	1,000,000	2,400,000	**5,140,000**	100%	5,140,000	
MAN LAN SURFnet OC-192	1,200,000	160,000	80,000	1,000,000	2,400,000	**4,840,000**	100%	4,840,000	
SL SURFnet OC-192	1,500,000	160,000	80,000	1,000,000	2,400,000	**5,140,000**	100%	5,140,000	
SL CESNET	1,500,000	820,000	246,000	600,000	1,440,000	**4,606,000**	100%	4,606,000	
SL UKLight (3)	1,700,000	1,200,000	600,000	1,000,000	2,400,000	**6,900,000**	25%	1,725,000	
SUBTOTAL									**31,731,000**
International Transpacific Circuits that land first at SL or MAN LAN									
SL JGN2	14,500,000	800,000	320,000	800,000	1,920,000	**18,340,000**	100%	18,340,000	
MAN LAN SINET	20,000,000	1,000,000	500,000	1,000,000	2,400,000	**24,900,000**	100%	24,900,000	
SL HARNET	3,000,000	800,000	400,000	48,000	1,000,000	**5,248,000**	100%	5,248,000	
SL CERNET	3,000,000	800,000	400,000	200,000	1,000,000	**5,400,000**	100%	5,400,000	
SL TaiwanLight	10,000,000	500,000	250,000	1,000,000	1,700,000	**13,450,000**	100%	13,450,000	
SUBTOTAL									**67,338,000**
TOTAL									**99,069,000**

(1) Equipment maintenance is a percentage of up-front equipment cost (10%/year) * IRNC award (5 years)

(2) While internationals do not charge IRNC any connection fees, nor does Internet2 or NLR charge internationals connection fees, assume there exists an equivalent value based on Internet2 fees to connect to US GigaPoPs at 10GE

(3) UKLight link – assume 75% DOE ESnet leverage and 25% IRNC TL/SL leverage

Category 4: US Non-Federal Networks

Below are US non-Federal circuit expenditures that TL/SL IRNC funds directly leverage. For the five-year IRNC period, we have estimated the total costs of the links, the up-front equipment costs, FTE engineer salaries, and equipment maintenance (10% of the equipment cost/yr).

- ***Non-Federal national circuits relevant to TL/SL:***
  1. 10% of the Internet2 Network (estimated operation cost, $20,000,000/yr), credit TL/SL with **$10,000,000** leveraging over 5 years.
  2. 10% of NLR ($60,000,000 up-front plus $500,000/yr maintenance) (including multiple waves provided by Pacific Wave, Cisco (3x10GE for CiscoWave), EVL/Calit2 (1 10GE for CAVEwave), and NLR (1 10GE for TL/SL↔TL/PW transit), credit TL/SL with **$6,250,000** leveraging over 5 years.
  3. Plus 5% of regional networks (e.g., Atlantic Wave, MREN, LONI, CENIC, PNWGP, I-WIRE, other state networks connected to StarLight and MAN LAN) costing $120,000,000 (est.) plus $12,000,000 maintenance/yr) which use the IRNC connections to Europe on a regular basis, **$9,000,000 over 5 years.**
- ***Non-Federal transatlantic circuits relevant to TL/SL:***
  1. Internet2 Network has a NYC/London transatlantic circuit that we will value at the same cost as the SURFnet NYC/AMS circuit (see Category 3, $4,840,000).
  2. IEEAF has a NYC/AMS transatlantic circuit that we will value at the same cost as the SURFnet NYC/AMS circuit (see Category 3, $4,840,000).

Category 4 total: $34,180,000 over 5 years.

TL/SL Category 4: US Non-Federal Networks

Assumptions	
5	Number of years
18,000,000	Internet2 estimated operations cost/yr
10%	Percentage of Internet2 operations cost considered IRNC TL/SL match
13,000,000	NLR estimated up-front investment (one-time cost)
10%	Percentage of NLR costs considered IRNC TL/SL leverage
120,000,000	Regional Optical Networks (RONs) estimated up-front investment (one-time cost)
12,000,000	RON estimated operations/yr
5%	Percentage of RON costs considered IRNC TL/SL leverage

	TL/SL Leverage from US Non-Fed Netwks	
Non-Federal National Circuits		
Internet2 (Operations/yr * % leverage * all years)	9,000,000	
NLR (Operations/yr * % leverage * all years)	6,500,000	
RONs at MAN LAN and SL (Up-front investment * % leverage)	6,000,000	
RONs at MAN LAN and SL (Operations/yr * % leverage * all years)	3,000,000	
Non-Federal Transatlantic Circuits		
Internet2 Network NYC/London	4,840,000	
IEEAF NYC/AMS	4,840,000	
SUBTOTAL		**34,180,000**
TOTAL		**34,180,000**

Category 5: US Federal Networks

US Federal networks that TL/SL IRNC directly leverages, because of European IRNC traffic, including testbeds:

- ***Federal national circuits relevant to TL/SL:***
  1. TeraGrid (NSF)
  2. NASA
  3. NOAA
  4. DOE ESnet (IP and SDN)
  5. DOE Ultra Science Network
  6. DOE Fermi Lightpath
  7. NASA NISN
  8. NIH
  9. DOI USGS

- ***Federal national circuits relevant to TL/SL:***
  1. US LHC maintains 4 OC-192 links from StarLight and MAN LAN to Europe (Chicago/Geneva, New York/Geneva, New York/Amsterdam and, starting February 2998, New York/London). We estimate the value of each of the three circuits originating in New York at the same cost as the SURFnet NYC/AMS circuit (see Category 3, $4,840,000), though we realize that the links to Geneva are probably more money. We estimage the value of the Chicago/Geneva to equal the SURFnet CHI/AMS circuit (see Category 3, $5,140,000), for a total cost of $19,660,000. These circuits are used primarily for high-energy physics as a connection to Fermilab and other DOE sites and ESnet universities. We will count it as leveraging ESnet, not IRNC funds.

Category 5 total: $0 (Federal leveraging doesn't count for IRNC)

Category 6: Non-US Networks

Category 6: Non-US networks that TL/SL IRNC indirectly leverages, because NSF's funding of IRNC and connection to Internet2 and NLR inspires other nations' funding of their networks:

1. CANARIE (~20 10Gb links to SL, Seattle, MAN LAN, and 10Gb to Europe)
2. GÉANT2 and its national partners (3 direct 10Gbs link to MAN LAN)
3. SURFnet (2 direct 10Gb links to SL and MAN LAN, and several 10Gb links from NL to CERN)
4. CESNET (direct 10Gb link to SL)
5. NORDUnet (direct 10Gb link to NL)
6. i2CAT (Barcelona) (direct 10Gb link to NL)

Category 6 total: $0 (this huge international contribution to R&E networking isn't counted below here for IRNC TL/SL leveraging)

Conclusions

Total Categories 1-4: $93,085,000 over 5 years ($62,315,000 international, $30,770,000 national)

Since the beginning of the project, IRNC TransLight/StarLight funds have been leveraged approximately 20:1 internationally and an additional 8:1 non-Federal nationally.

1.A.2. Future Leveraging Opportunities

In the future, as transatlantic connections get more economical and as scientific demands increase, there is likely to be an upswing in additional connectivity between North America and Europe from Internet2, DANTE/GÉANT2 and other European, Asian and South American countries. NSF's costs, as shown above, are well leveraged, and continued IRNC investment assures that US researchers can benefit from ongoing and increasing global scientific efforts. There is a growing list of NSF instruments and research foci that depend on reliable, available, high-bandwidth connectivity between the US and Europe.

1.A.2.1. Communities Benefiting from the Network Services

A number of US science initiatives depend critically upon equipment, facilities and/or expertise located in Europe. All of these US-led initiatives now depend or will depend on high-speed connectivity between the US and Europe, and, in most cases, sites in Canada, Asia and South America as well.

Major large-scale facilities mentioned in this report are the Atacama Large Millimeter Array (ALMA), the International Space Station (ISS), the Large Hadron Collider (LHC) and the TeraGrid. Other NSF OCI initiatives mentioned include Sloan Digital Sky Survey (SDSS) terabyte data-transfer efforts, DRAGON, EnLIGHTened, OptIPuter and PRAGMA. Previous reports have described other major NSF investments, such as ANDRILL (ANtarctic geological DRILLing). These applications are documented in detail in NSF IRNC reports and on the TransLight/StarLight website.

1.A.2.2. Assessing Use

Current usage can be obtained from MRTG and Cricket graphs available via the TransLight/StarLight website. These links are clearly utilized, though they are not saturated.

The cost of transatlantic (and domestic) OC-192s is within reach of single domain large-scale projects, so we expect high-bandwidth users to "graduate" from the IRNC-provided links and get their own. Layer1 transatlantic links from SURFnet, UKLight, CESNET, GÉANT2, US LHC (DOE/CERN), Internet2, and others compete with IRNC links, and this has and will negatively impact usage statistics. However, IRNC also leverages greatly from the links and equipment provided by these other organizations, and through the Global Lambda Integrated Facility (GLIF), network engineers are collaborating to support and assist one another to create a worldwide LambdaGrid fabric.

However, how does one assess usage? This is a high-level issue. TransLight/StarLight principal investigators are working hard to attract, manage and retain high-bandwidth users. When do we claim success: (1) when an application runs? (2) when a link is saturated? or, (3) when the successful users procure their own links? We continue to actively recruit high-bandwidth users and provide VLANs.

1.B. Contributions to Science

NSF funds basic research and related activities to sustain the Nation's leadership in science and engineering, funds the acquisition, construction, commissioning, and upgrading of major research equipment and facility resources to enable transformational research, and funds cyberinfrastructure – the information technologies and collaboratories (networking, computing, visualization, data, middleware) – to provide ubiquitous access and enhanced usability.

The adoption of cyberinfrastructure is forever changing the nature of science. Science has no geographical boundaries, so science is increasingly global. And, science relies on high-performance computing and communications, so science is increasingly *e-science*. With NSF IRNC-funded persistent links in place, researchers are becoming more dependent on networked collaborations to support data-intensive science. IRNC provides a science and engineering research and education production network environment to support global e-science. This section describes some of the activities that contribute to scientific knowledge as a result of the availability of TransLight/StarLight links. Significant contributions are being made in the areas of astronomy, biodiversity and ecological research, computer science, geoscience, medical, physics and space exploration, involving collaborations between the US and Europe and, in many cases, to other continents as well.

Astronomy

ALMA, the Atacama Large Millimeter Array, is an international astronomy facility that receives major support from North America (US National Science Foundation and the National Research Council of Canada), Europe (European Southern Observatory and the European Regional Support Center) and Japan, in cooperation with the

Republic of Chile. Taiwan also contributes to ALMA as a partner of Japan. Currently under construction on an Andean plateau in Chile, ALMA will be the forefront instrument for studying the cool universe – the relic radiation of the Big Bang, and the molecular gas and dust that constitute the building blocks of stars, planetary systems, galaxies, and life itself. Several IRNC initiatives, including WHREN-LILA and TransLight/StarLight, will enable data transfers from South America to the US and to European partners.

The YBJ International Cosmic Ray Observatory, located in the Yangbajing (YBJ) valley of the Tibetan highland, is a Chinese-Italian partnership, with international connectivity supported by the Chinese Academy of Sciences, a founding GLORIAD partner; the ARGO-YBJ (Astrophysical Radiation with Ground-based Observatory) experiment studies cosmic rays, mainly cosmic gamma-radiation. TransLight/StarLight and GLORIAD are partnered to enable data transfers from China to the US and to European partners.

The International Virtual Observatory Alliance (IVOA) mission is to "facilitate the international coordination and collaboration necessary for the development and deployment of the tools, systems and organizational structures necessary to enable the international utilization of astronomical archives as an integrated and interoperating virtual observatory." The IVOA comprises 16 virtual observatory projects from Armenia, Australia, Canada, China, Europe (European Virtual Observatory), France, Germany, Hungary, India, Italy, Japan, Korea, Russia, Spain, the UK and the US (National Virtual Observatory). The Gemini Observatory – the Gemini South telescope is located in the Chilean Andes and the Gemini North Telescope is located on Hawaii's Mauna Kea – and the National Optical Astronomy Observatory (NOAO) produce data products for US optical astronomy science, which are also being incorporated into the IVOA. All the IRNC initiatives will surely facilitate collaboration among IVOA partners.

The eVLBI (Electronic Very Long Baseline Interferometry) community, since 2005, has been developing the necessary infrastructure for real-time correlation of radio-astronomy telescope data. At iGrid 2005, radio astronomers in the USA (MIT Haystack), Japan (Kashima) and Europe (Onsala in Sweden, Jodrell in the UK, Westerbork in The Netherlands) achieved real-time correlations with 512Mbps transfers. On August 28, 2007, collaborators did the first successful real-time correlation of eVLBI data from Chinese and Australian telescopes, Chinese and European telescopes, and Australian and European telescopes. Additional tests with telescopes in Puerto Rico and Chile are planned for the near future. The eVLBI community's goal is to do 16 simultaneous 1Gbps network connections between the central processor at JIVE in The Netherlands and partner telescopes across Europe, Asia, Australia, South Africa, South America and the US by 2009. Again, all IRNC initiatives will surely facilitate collaboration among eVLBI partners.

Biodiversity and Ecology

CAMERA, the Community Cyberinfrastructure for Advanced Marine Microbial Ecology Research and Analysis, is a Gordon and Betty Moore Foundation-funded project under the leadership of the UCSD division of the California Institute for Telecommunications and Information Technology (Calit2). The field of *environmental metagenomics* is a component of biocomplexity, which is an NSF priority. The term *biocomplexity* refers to the interrelationships that arise when living things at all levels – from their molecular structures to genes to organisms to ecosystems to urban centers – interact with their environment. CAMERA is accelerating the field of environmental metagenomics by creating a globally accessible community resource of microbial metagenomic data. CAMERA has 1300 registered users from 48 countries, with major users in the UK, Germany, Canada, France, as well as South America and Asia. Again, all IRNC initiatives will surely facilitate collaboration among CAMERA partners.

GLEON (Global Lake Ecological Observatory Network) is a grass roots association of limnologists, information technology experts and engineers from the US, Asia, Europe, and Canada who are building a scalable, persistent network of lake ecology observatories. Data from these observatories will help researchers better understand key processes, such as the effects of climate and land use change on lake function, the role episodic events such as typhoons in resetting lake dynamics, and carbon cycling within lakes. Many IRNC initiatives will surely facilitate collaboration among GLEON partners.

Computer Science

CineGrid: Digital streaming…CineGrid is an organization whose mission is to enable the production, use and exchange of very-high-quality digital media over photonic networks. In the past year, CineGrid members conducted the first successful transatlantic demonstration of streaming 4K digital motion pictures and 5.1 surround sound; the first prototype workflow for remote color grading of digital rushes from a 4K digital camera shoot in Prague to a specialized rendering processor in San Diego and a 4K color correction system in Prague operated by a colorist in

Toronto; and, the first 4K uncompressed transmission and the first 4K live streaming over both the Atlantic and Pacific oceans. These technologies are apropos to scientific visualization collaboration and streaming, and CineGrid has the support and participation of many computer scientists, computational scientists, network engineers, and the entire Global Lambda Integrated Facility (GLIF) community. TransLight/StarLight facilitates collaboration among CineGrid partners.

Data Reservoir is a Japanese research project to create a global grid infrastructure for distributed data sharing and high-speed computing for the 2-PFLOPS system being developed as part of the GRAPE-DR project, to be operational in 2008. At the Internet2 Spring 2007 meeting, April 2007, the Data Reservoir project won two consecutive Land Speed Records (LSRs) in the IPv6 single and multi-stream categories for trials to see how fast and far data could be transferred. The network path went over 30,000 kilometers in distance, from Tokyo to Amsterdam and back. Since the project wanted dedicated links for these trials, the SURFnet link from Chicago to Amsterdam was used instead of the TransLight/StarLight link. While this is an example of IRNC leveraging its capabilities with those of its European partners, actual data transfers once the GRAPE-DR is online may indeed use IRNC links.

DICE (DANTE-Internet2-CANARIE-ESnet) partners hold regular technical meetings to discuss issues of common interest. University of Amsterdam is working with DICE to integrate its Token Based AAA mechanism inside OSCARS (ESnet domain controller development) and the DRAGON (NSF-funded GMPLS based control plane/ routing/resource brokering functions). This work will also be embedded into the EU-funded Phosphorus project. This project primarily performs trials on the Internet2 Dynamic Circuit between New York and London; however, it is an example of IRNC TransLight/StarLight leveraging its capabilities with partner institutions.

EnLIGHTened, an NSF-funded project being developed by MCNC, focuses on the development of dynamic, adaptive, coordinated and optimized use of networks connecting geographically distributed high-end computing resources and scientific instrumentation. EnLIGHTened collaborates with the AIST G-Lambda project in Japan and the Phosphorus project in Europe. MCNC has a Cisco Research Wave (EnLIGHTened) deployed on National LambdaRail from Raleigh to StarLight in Chicago, where it uses IRNC TransLight/StarLight to connect to collaborators in Europe, and JGN2 to connect to collaborators in Japan.

High-Performance Digital Media Network (HPDMnet), under the leadership of Northwestern University, has collaborators in the US, Canada, Japan, Barcelona, Czech Republic, and The Netherlands who are developing new communication services based on optical transport (i.e., optical multicast) of high-resolution digital media streams. HPDMnet relies on the SURFnet, CESNET and IRNC TransLight/StarLight links at StarLight to reach European partners, and the JGN2 link to reach Japanese partners.

Indiana University (IU) Data Capacitor, a system designed to store and manipulate massive datasets, was developed by IU and collaborators in Germany, and was awarded first place in an SC07 Bandwidth Challenge competition. This project could take advantage of either the IRNC TransLight/StarLight or Internet2 transatlantic networks.

The Inter-Domain Controller protocol is being developed by Internet2 partners and collaborators to interoperate the Internet2 Dynamic Circuit Network with ESnet, GÉANT2 in Europe, as well as regional and other international networks and testbeds (e.g., GRNET in Greece, HEAnet in Ireland, PIONIER in Poland, and the Phosphorus testbed at the University of Amsterdam via SURFnet's NetherLight. This project primarily performs trials on the Internet2 Dynamic Circuit between New York and London; however, it is an example of IRNC TransLight/StarLight leveraging its capabilities with partner institutions.

OptIPuter, an NSF-funded ITR to UCSD, has as one of its major outcomes the Scalable Adaptive Graphics Environment (SAGE), specialized middleware developed by OptIPuter partner UIC that simultaneously enables human-to-human communication and data-sharing communication on variable-sized tiled displays connected via optical networks. SAGE serves as a window manager; allowing users to move, resize, and overlap windows as easily as on standard desktop computers. SAGE Visualcasting supports global collaboration by enabling two or more users to share application content, sending multi-gigabit streams as required. International trials with partners of the OptIPuter project and participants in the Global Lambda Visualization Facility (GLVF) are taking place, particularly among sites in US, The Netherlands, Czech Republic and now Russia. TransLight/StarLight/GLORIAD facilitates collaboration among OptIPuter and GLVF partners.

OptIPuter's LambdaRAM, developed by OptIPuter partner UIC, is middleware that prefetches data to eliminate I/O bottlenecks from data storage devices. OptIPuter partner NASA Goddard is now working with UIC to incorporate LambdaRAM into its simulation system process. LambdaRAM is being used to mitigate I/O bottlenecks inherent in current applications and to enable data coupling among multiple supercomputers and data storage devices, with the goal of creating more timely weather predictions and employing more powerful forecasting models. Initial results using LambdaRAM with an I/O intensive application demonstrated a 20-fold performance improvement over traditional storage systems. LambdaRAM was originally developed to prefetch data from remote (and international) data storage devices, requiring the IRNC TransLight/StarLight link. While NASA's application is national in scope, the technology has implications for international "federated grid" architectures in the future.

Phoebus is an Internet2/University of Delaware project to enable applications to seamlessly set up dynamic lightpaths regardless of the user's edge network access method. This has been tested on regional, national and international networks. This project primarily performs trials on the Internet2 Dynamic Circuit between New York and London; however, it is an example of IRNC TransLight/StarLight leveraging its capabilities with partner institutions.

Phosphorus is an EU-funded alliance with European and North American partners (MCNC and Louisiana State University) who are developing advanced application-level middleware and underlying management and control plane technologies. This project relies on SURFnet, CESNET and IRNC TransLight/StarLight links at StarLight to enable US/European collaboration.

The PRAGMA (Pacific Rim Applications and Grid Middleware Assembly) Grid Testbed is composed of cluster systems and technical expertise from PRAGMA member institutions. It provides the infrastructure and a collaborative environment for grid middleware and grid applications to interoperate and improve. In addition to members from the US, the Asia-Pacific and South America, University of Zurich in Switzerland is also a member. All IRNC initiatives surely facilitate collaboration among PRAGMA partners.

TeraGrid is working with the UK National Grid Service and the EU DEISA (Distributed European Infrastructure for Supercomputing Applications) to create a federated grid of computing resources. TeraGrid is also working with PRAGMA sites, the European Commission-funded Enabling Grids for E-Science (EGEE) project, and NorduGrid in the Nordic countries, as well as sites in Canada and South America, on the Grid Interoperation Now (GIN) testbed, a grass-root, multi-application international testbed to enable real science applications to run on a routine basis. All IRNC initiatives surely facilitate collaboration between TeraGrid and its partners.

The Teraflow Testbed is an international collaboration, under the leadership of the UIC National Center for Data Mining, with funding from National Science Foundation, the US Army, and the Department of Energy. This Testbed is used to explore, integrate, analyze, and detect changes in massive and distributed data over optical networks, with sites in the US, Asia, and Europe (Russia, Germany, The Netherlands and CERN). It consists of computer clusters distributed over three continents that can transmit, process, and mine very-high-volume data flows, or teraflows. Notably, teraflow data services are used to process and distribute Sloan Digital Sky Survey (SDSS) data. TransLight/StarLight facilitates connectivity between the US and European partners.

Geoscience

ANDRILL (ANtarctic geological DRILLing) is a multinational collaboration comprised of more than 200 scientists, students, and educators from five nations (Germany, Italy, New Zealand, the UK and the US) to recover stratigraphic records from the Antarctic margin. The chief objective is to drill back in time to recover a history of paleo-environmental changes that will guide our understanding of how fast, how large, and how frequent were glacial and interglacial changes in the Antarctica region. Several IRNC initiatives surely facilitate collaboration among ANDRILL partners.

National Oceanic & Atmospheric Administration (NOAA) has several collaborations with European and Russian sites: CarbonTracker, a scientific tool that, together with long-term monitoring of atmospheric CO2, will help improve our understanding of how carbon uptake and release from land ecosystems and oceans are responding to a changing climate and other environmental changes, including human management of land and oceans; CLASS (Comprehensive Large-Array Stewardship System), NOAA's premier on-line facility to distribute NOAA and US Department of Defense (DoD) Polar-orbiting Operational Environmental Satellite (POES) data, NOAA Geostationary Operational Environmental Satellite (GOES) data, and derived data; ESSE (Environmental Scenario Search Engine), an easy-to-use "natural language" search engine for mining environmental data archives; NCEP/NCAR (National Centers for Environmental Prediction/National Center for Atmospheric Research) Reanalysis Project, a new atmospheric analyses that uses both historical and current atmospheric data; and, SPIDR (Space Physics Interactive Data Resource), a de facto data source for solar terrestrial physics. TransLight/StarLight and GLORIAD facilitate connections between US and European collaborators.

Medical

Amyotrophic Lateral Sclerosis (ALS) genome-wide analysis research is being facilitated between the University Medical Center Utrecht and the David Geffen School of Medicine and Neuroscience and Genetics Research Center at UCLA. SURFnet, The Netherlands Research & Education network, working with National LambdaRail and Cisco, is establishing a lightpath between Utrecht and Los Angeles. This lightpath is the result of the “Enlighten Your Research” lightpath competition organized by SURFnet and NWO. Dutch scientists received a lightpath to their research lab and the sum of 20,000 Euros for integrating the use of a lightpath in their research. This project relies on the SURFnet link between Amsterdam and Chicago; however, it is an example of IRNC TransLight/StarLight leveraging its capabilities with partner institutions.

The AtlanTICC Alliance (Atlantic Technology Innovation and Commercialization Center) is a joint venture between Imperial College London, Georgia Institute of Technology and Oak Ridge National Laboratory. One project on which they collaborate is remote operation of state-of-the-art equipment. Currently Imperial scientists can manipulate an aberration corrected electron microscope (ACEM) at Oak Ridge in real time, while the Oak Ridge and Georgia teams can use the nuclear magnetic resonance (NMR) facility at Imperial. This project relies on the UKLight link between London and Chicago; however, it is an example of IRNC TransLight/StarLight leveraging its capabilities with partner institutions.

The **Microscopy Distributed Laboratory Demonstrator** is being developed by the UCSD National Center for Microscopy Imaging Research (NCMIR) in cooperation with Oxford University’s Materials Research Center at Begbroke and Oxford e-Research Centre in the UK. NCMIR, an OptIPuter partner, has extended SAGE software to run on Microsoft-enabled visualization systems in order to remotely collaborate and control two of the world’s most advanced electron microscopes at NCMIR and Oxford University. At SC07, they demonstrated shared views of the complexities of the nervous system and of complex nanomaterials. This project relies on the UKLight link between London and Chicago; however, it is an example of IRNC TransLight/StarLight leveraging its capabilities with partner institutions.

Surgery via Video 2007 was a demonstration at the 24th APAN Meeting, August 27-31, 2007, in Xi’an, China, by collaborators at hospitals in Korea, Australia, China, Japan, Singapore, Philippines, India and France who are developing live, multi-way digital video connections, enabling medical specialists around the world to learn and teach each other advanced surgical procedures. Several IRNC initiatives surely assisted collaboration among these medical institutions.

Physics

The DØ Experiment is a worldwide collaboration headquartered at Fermilab's Tevatron Collider. It is focused on precise studies of interactions of protons and antiprotons at the highest available energies in a search for subatomic clues that reveal the character of the building blocks of the universe. Collaborators are located in Argentina, Brazil, Canada, China, Colombia, Czech Republic, Ecuador, France, Germany, India, Ireland, Korea, Mexico, Netherlands, Russia, Sweden, Switzerland, UK, US and Vietnam. Several IRNC initiatives surely assist collaboration among these DØ collaborators.

The Large Hadron Collider (LHC), an international collaboration headquartered at CERN, is highly anticipated among teams of physicists, computer scientists and networking engineers who have been collaborating for several years now on the development of the Worldwide LHC Computing Grid (WLCG). The WLCG consists of over 200 sites, including LHC Tier-1 and Tier-2 sites, where LHC data from the detectors will be processed and delivered to physicists at their home research institutions. DOE funds several LHCnet transatlantic links, though TransLight/StarLight has had discussions with Harvey Newman (Caltech), Don Petravick (Fermi) and Bill Johnston (ESnet) about using a portion of the TransLight/StarLight links for LHC data grid production.

UltraLight, an NSF-funded project headquartered at Caltech, is focused on providing network advances required to enable petabyte-scale analysis of globally distributed LHC data. UltraLight has numerous collaborators, including CERN and other sites in the US, Korea, Brazil, UK, Pakistan and Romania, to name a few. This year UltraLight was the recipient of the 2007 Internet2 Driving Exemplary Applications (IDEA) Awards program, and also set new records at SC07 for sustained storage-to-storage data transfer over wide-area networks from a single rack of servers on the exhibition floor. While UltraLight uses DOE-funded LHCnet transatlantic links, a portion of TransLight/StarLight will be made available for LHC data grid production.

Space Exploration

The International Space Station (ISS) is a joint effort of the US (NASA), the Russian Federal Space Agency, the Japan Aerospace Exploration Agency, the Canadian Space Agency and the European Space Agency. Researchers on Earth are using several experiments aboard the international space station to study various issues, so data from these experiments must be accessible to scientific investigators worldwide. All IRNC initiatives surely facilitate collaboration among the ISS research community.

TransLight / PacificWave IRNC Award: Leverage

TransLight/PacificWave (TL/PW) receives $1,000,000/year to pursue three main objectives and a related outreach one: i) partner with the Australian Research Network (AARNet) to land and operate 2 10Gbps circuits from Sydney through the Hawaiian Isles to the West Coast of the US (Seattle and Los Angeles); ii) provide operating support for the distributed West Coast R&E exchange points in Seattle, Sunnyvale, and Los Angeles that comprise PacificWave and to the Foreign networks that peer with US domestic networks (and each other) there; iii) enhance the connectivity to Hawaii, both Oahu and the Island of Hawaii and to improve connectivity to the observatories on the Mauna Kea summit; and iv) various outreach activities to encourage use of the facility and provide assistance to science and engineering projects utilizing networks that transit PacificWave.

This document attempts to describe leveraging of NSF's $5,000,000 for TL/PW in the period 2005-2010, which includes past, current, and future estimates. Effort has been made to make the expenditures and value assessments contemporaneous with the period of the IRNC award. Most of the costs are confidential, often resulting from special arrangements between NRENS, national governments and preferred carriers and vendors. We have tried to make reasonable estimates of the costs that would be incurred to provide the service to a R&E entity in the open market. In addition, equipment prices have dropped significantly over the years and particular pricing depends on the relationship of the purchaser and vendor in many cases, as well as the timing and size of the purchase.

A circuit has several costs: the link itself as contracted from a carrier, per year; the cost (or partial cost) of the Layer 1 (L1) terminating equipment at each end, plus yearly maintenance contracts, rack space and power costs; cost of the Layer2/3 (L2/3) switching/routing equipment, plus its yearly maintenance contracts, rack space and power costs; and, finally, the cost of engineering, documenting, promoting, outreach (all of which encourages use by the community), indirect costs, and so on. We have broken out our estimates of these various costs components in a spreadsheet so that the model can be refined or experimented with.

We have used simple estimates rather than trying to identify precisely what equipment is used, how much space is rented, or exact operations costs. While some costs may be over-estimated some are likely under-estimated and any more than a rough estimate is not that valuable given changing prices and technologies.

We have broken down the leveraging estimation into three sections.

1. Estimation of the direct leverage of the project. As we see from the Spreadsheet, the total spent (or value made available) by all parties on activities directly supported by the project is $28.5M for an NSF/IRNC investment of $5M – a leveraging factor of over 5.
2. However, by virtue of operating the exchange point PacificWave we are facilitating foreign networks peering with US networks (and themselves) on US soil. This allows the US networks to take advantage of all of the foreign networks that utilize the PacificWave facility at no charge. We estimate the value of those foreign-supported links that connect US networks to foreign networks at $72,300,000 over the duration of the award (we do not count those international links that are supported through other IRNC awards except for KREONET which is mostly paid for by Korea.) We could go further and estimate the value of the foreign networks that US networks are able to access through the PacificWave facility but have not done so.
3. We also list the US networks that make use of the PacificWave facility (to peer with foreign networks and sometimes between themselves). Estimating the leveraging value of access to these networks is somewhat arbitrary but we chose to give them a value corresponding to a connection port onto those networks (based on Internet2 access charges). The resulting value of these connections is estimated to be $5.5M

Overall, then, we find that the leveraging ratio for the PacificWave IRNC project when we include the International links is approximately 20:1 and 25:1 when we include the value of domestic networks.

		Project Paid		*Years of operation*	*IRNC Project Total (over 5 years)*	*Contributed Amount*		*Contributor*	*Life (years)*	*Years in Service*	*Total Contributed (over 5 years)*	*Total (project + contributions)*	*Notes*
		OTC	ARC			OTC	ARC						
US-AUS Connectivity													
N	10G Sydney-OAHU-Hillsboro						$ 1,500,000	AARNet		5	$ 7,500,000	$ 7,500,000	
	10G Hillsboro-Portland-Seattle						$ 20,000	PNWG		5	$ 100,000	$ 100,000	
	Sydney Router					$ 300,000	$ 75,000	AARNet	5	5	$ 675,000	$ 675,000	
	Seattle Router					$ 300,000	$ 75,000	Various	5	5	$ 375,000	$ 375,000	
S	10G Sydney-Hawaii-Los Osos						$ 1,500,000	AARNet		5	$ 7,500,000	$ 7,500,000	
	10G Los Osos-SLO (fiber)	$ 20,000	$ 2,000	4	$ 28,000							$ 28,000	
	10G SLO-LA (Wave)						$ 20,000	CENIC				$ -	
	Cards to create circuit Los Osos-SLO-LA	$ 30,000	$ 3,000	3	$ 39,000							$ 39,000	
	Sydney Grooming/MPX Eqiupment (MSPP)					$ 150,000	$ 15,000	AARNet	5	3	$ 135,000	$ 135,000	
	LA Router					$ 60,000	$ 15,000	AARnet	5	3	$ 81,000	$ 81,000	
	Engineering, Operations, Admin				$ 900,000							$ 900,000	1
												$ -	
Pacific Wave Exchange												$ -	
	Wave (SEA-SNY-LA) (10G) Layer 3 interconnect						$ 174,000	CENIC, NLR-LLC		5	$ 870,000	$ 870,000	2
	Wave (SEA-SNY-LA) (10G) 2nd wave L3 interconnect						$ 174,000	CENIC, NLR-LLC		3	$ 522,000	$ 522,000	
	Wave (SEA-SNY-LA) (10G) for L2 interconnect						$ 174,000	CENIC, NLR-LLC		3	$ 522,000	$ 522,000	
	Grooming/MPX Eqiupment (MSPP)	$ 70,000	$ 15,000	3	$ 115,000							$ 115,000	
	Grooming/MPX Equipment (SEA)					$ 250,000	$ 25,000	Canarie/PNWG	5	3	$ 75,000	$ 75,000	3
	Switches (SEA, SNY, LA)					$ 150,000	$ 15,000	CENIC/PNWG/CISCO	5	5	$ 75,000	$ 75,000	
	Translight Wave SEA-CHI						$ 360,000	Cisco (Research Wave)		4	$ 1,440,000	$ 1,440,000	4
	Engineering, Operations, Admin				$ 900,000			PW fees, CENIC, PNWG			$ 2,100,000	$ 3,000,000	5
												$ -	
Hawaii Connectivity												$ -	
	Hawaii Circuit Equipment											$ -	
	Hawaii Grooming/MPX Eqiupment (MSPP)	$ 70,000	$ 15,000	5	$ 145,000				5	5		$ 145,000	6
	Hawaii Router					$ 50,000	$ 5,000	UH	5	5	$ 75,000	$ 75,000	
	Mauna Kea Upgrade				$ 400,000							$ 400,000	7
	Backhaul										$ 30,000	$ 30,000	
	Hawaii Router	$ 60,000	$ 15,000	3	$ 105,000				5	3		$ 105,000	
	Oahu Router		$ 75,000	3	$ 187,500	$ 300,000		IRNC/UH	5	3		$ 187,500	
	Engineering, Operations, Admin		$ 65,000	3	$ 195,000					3		$ 195,000	
												$ -	
CUDI/CLARA Backhaul		$ 25,000		4	$ 25,000		$ 5,000	IRNC/CENIC	5	4	$ 20,000	$ 45,000	8
												$ -	
Outreach and Workshops		$ 100,000			$ 100,000	$ 200,000		AARNET/REANNZ/GRIDASIA			$ 200,000	$ 300,000	
												$ -	
Other Activities					$ 660,000							$ 660,000	
												$ -	
Administration, Travel, Overhead					$ 1,200,000						$ 1,200,000	$ 2,400,000	9
													RATIO
TOTAL					$ 4,999,500						$ 23,495,000	$ 28,494,500	5.7
LEVERAGE DUE TO OTHER INTERNATIONAL CIRCUITS SUPPORTED BY PW													
International R&E Circuits Supported (see sheet)											$ 72,300,000	$ 100,794,500	20.2
Domestic R&E Circuits Supported (see sheet)											$ 22,910,000	$ 123,704,500	24.7

NOTES

1 Half of project contribution to CENIC and PNWG

2 Value of wave based on 3xNLR cost (hard to evaluate NLR cost due to high membership component)

3 HDxC

4 Value of wave based on 3xNLR cost (hard to evaluate NLR cost due to high membership component)

5 Half of project to CENIC and PNWG is for PW ops (900K over 5 yrs); need total PW number for CENIC and PNWG (est. 2 FTE at 200K per yr (loaded) each plus 200K per year in costs, total is $3M over 5 yrs

Owner	*From*	*To*	*Speed*	*Transport*	*Type*	*Circuit Cost*	*Equipment*		*Operations, Space, Admin, etc.*	*Years of operation*	*Value*	*Notes*
						ARC	*OTC*	*ARC*	*ARC*			
AARNet	SYD	SEA	10G	OC192	IP							See main sheet
AARNet	SYD	LA	10G	OC192	8xGE, L1/2							See main sheet
CA*net4	VAN	SEA	10G		IP		$ 300,000	$ 60,000	$ 500,000	5	$ 3,100,000	One end for equip
CUDI	TJ	LA	1G		IP							See main sheet
CLARA	TJ	LA	1G		IP							See main sheet
GEMNET	TOKYO	SEA	1G		IP	$ 200,000	$ 100,000	$ 20,000	$ 500,000	5	$ 1,200,000	
GEMNET	TOKYO	SEA	10G		IP	$ 1,000,000	$ 600,000	$ 120,000		3	$ 5,460,000	
KAREN	AUCKLAND	SEA	1G		IP	$ 1,000,000	$ 100,000	$ 20,000	$ 500,000	3	$ 4,660,000	
KREONET2/KOREN		SEA	10G		L1/2	$ 1,500,000	$ 600,000	$ 120,000	$ 500,000	3	$ 6,960,000	
MIMOS/Berhad		LA	1G		IP	$ 1,000,000	$ 100,000	$ 20,000	$ 500,000	5	$ 7,700,000	
NII/SINET	TOKYO	LA	3x1G		IP	$ 600,000	$ 100,000	$ 20,000	$ 500,000	5	$ 5,700,000	
NUS	SINGAPORE	LA	1G		IP	$ 1,000,000	$ 100,000	$ 20,000	$ 500,000	5	$ 7,700,000	
Qatar		LA	1G		IP	$ 1,000,000	$ 100,000	$ 20,000	$ 500,000	5	$ 7,700,000	
Singaren		LA	1G		IP	$ 1,000,000	$ 100,000	$ 20,000	$ 500,000	3	$ 3,900,000	Disconnect date?
TLEX (WIDE)	TOKYO	SEA	10G		L1/2	$ 1,000,000	$ 300,000	$ 60,000	$ 500,000	5	$ 8,100,000	One end for equip
TRANSPAC2	TOKYO	LA	10G		IP							Not included
TWAREN	Taiwan	LA	10G		L1/2	$ 1,000,000	$ 600,000	$ 120,000	$ 500,000	3	$ 5,460,000	
UniNet/Thairen		LA	1G		IP	$ 1,000,000	$ 100,000	$ 20,000	$ 500,000	3	$ 4,660,000	
TOTAL											$ 72,300,000	

Maintenance cost 20%

TLPW Leverage (Domestic Nets)

Owner	*Location*	*Speed*	*Type*	*Value (annual)*	*Number of Years*	*Total Value*	*Notes*
Internet2	SEA	10G	IP	$ 480,000	5	$ 2,400,000	
Internet2	LA	10G	IP	$ 480,000	5	$ 2,400,000	
CENIC	LA	1G	IP	$ 250,000	3.5	$ 875,000	
CENIC	LA	10G	IP	$ 480,000	1.5	$ 720,000	Moving to 10G in 2008
CENIC	SNY	1G	IP	$ 250,000	2.5	$ 625,000	
CENIC	SNY	10G	IP	$ 480,000	1.5	$ 720,000	Moving to 10G in 2008
DREN	SEA	1G	IP	$ 250,000	5	$ 1,250,000	
ESNET	SEA	10G	IP	$ 480,000	5	$ 2,400,000	
ESNET	SNY	10G	IP	$ 480,000	3	$ 1,440,000	
Los Nettos	LA	10G	IP	$ 480,000	3	$ 1,440,000	
NLR	SEA	10G	IP	$ 480,000	3	$ 1,440,000	
NLR	LA	10G	IP	$ 480,000	3	$ 1,440,000	
NREN	SNY	10G	IP	$ 480,000	3	$ 1,440,000	
PNWGP	SEA	10G	IP	$ 480,000	5	$ 2,400,000	
Ultralight	LA	10G	IP	$ 480,000	4	$ 1,920,000	
TOTAL						$ 22,910,000	

Netorks listed have connect to PacifcWave at the speed indicated. They gain benefit from accessing PW peers. Loikewise, Pacific Wave (and it peers) have a port into these netowrks. We estimate the valu ofthat connection by using Internet2 standard fees (since the other networks conneciton fees are not not really a fair estimate of value due to substantial membership fees or subsidised by a closed community.

From Internet2 annual usage fees chart

10G Port	$	480,000
2.5G Port	$	340,000
1G Port	$	250,000

We only list networks (not projects) that use PW facilities.

We have not included layer 1 and 2 connections that utilize the PW exchange since this is an emerging area of activity.