# GLORIAD: A Ring Around the Northern Hemisphere for Science and Education connecting North America, Russia, China, Korea and Netherlands with Advanced Network Services

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**Abstract**

This paper, written in February, 2005, provides an overview of current and expected future development of the Global Ring Network for Advanced Applications (GLORIAD) recently (December 2004) funded as a five-year program by the U.S. National Science Foundation under the International Research Network Connections (IRNC) solicitation. The paper looks at both the network itself and the applications it enables. The active participation of Science, Education and Government entities from countries around the world enables the GLORIAD project to effectively promote the advancement of high bandwidth applications and highlights the need for broader promotion of advanced network architecture and service delivery. The network itself rings the northern hemisphere – connecting scientists, educators and students via a global ring topology which transits North America, Europe, Russia, China, Korea and the oceans between.

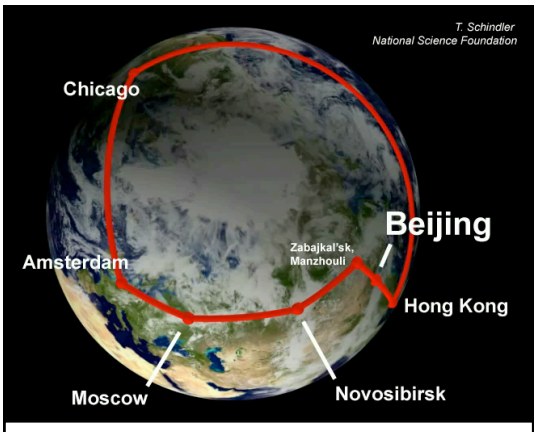


**Figure 1.** The "Little GLORIAD" network, launched in January 2004 by US, Russia and China, completes a ring around the northern hemisphere for advancing R&E collaboration. An animation of the ring's path is available at: http://www.gloriad.org/gloriad.nsf-animation.mov – produced by Tom Schindler of the US NSF.

## 1.1 GLORIAD

The Global Ring Network for Advanced Applications Development (GLORIAD) rings the northern hemisphere of the earth in an ambitious effort to link the R&E communities of the three organizing nations – US, Russia and China – and in close cooperation with core partners in Korea, Netherlands and Canada. Currently running at OC3 (155 Mbps) capacity around the northern hemisphere, GLORIAD received in late December, 2004 a five-year US funding commitment from the National Science Foundation (as part of an international package of funding with its partners in Russia, China and Korea and with additional contributions from CANARIE (Canada) and SURFnet (Netherlands)) to develop a hybrid (circuit-/packet-switched) network, aiming for multiple 10 Gbps wavelengths around the earth by 2008. The project is naturally interesting for the geo-political story of the three organizing countries undertaking the joint construction and shared management of such a network crossing their territories (and the oceans and continents between) and linking their scientists, educators and students – but it is also interesting for the changes in network service and telecommunications provisioning it requires.

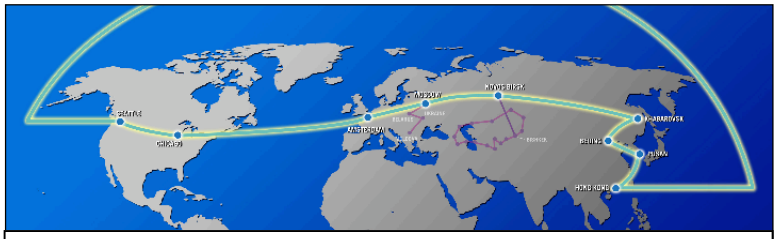

**Figure 2.** In its path around the northern hemisphere, GLORIAD transits network facilities in US, Russia, China, Korea, Canada and the Netherlands.

GLORIAD aims to better integrate, with its advanced network infrastructure, the research and education communities of the US, Russia and China – and with partners in Korea, the Netherlands, Canada, as well as broader Europe, Asia, and the Americas. Plans for GLORIAD include: (1) a jointly managed, hybrid circuit-/packet-switched network designed in a ring topology around the northern hemisphere; and (2) services to support increased R&E cooperation for both general and highly advanced user communities. In addition to supporting active scientific exchange with network services, the program provides a test bed for advancing the state-of-the-art in collaborative and network

technologies – including Grid-based applications development, end-to-end circuit provisioning, IPv4/IPv6 unicast/multicast services, advanced network monitoring, performance measurement, network security research and rich (and user-friendly) collaboration environments. Supporting the fast increasing state of global R&E cooperation, GLORIAD is actively cooperating with the world's most advanced R&E networks and programs to develop a rational, coherent strategy and architecture for the future of government-supported R&E networking. Tyco Global Networks is a partner at the very core of the GLORIAD team and effort, providing trans-Atlantic and trans-Pacific network services for connecting the US with Russia (and broader Europe and Central Asia) and the US with China (and broader Asia).

The broad range of scientific pursuits supported include the most advanced areas of collaborative research involving the partnering countries in high energy, nuclear and fusion energy physics, atmospheric science, astronomical observation, geological sciences, environmental monitoring, bioinformatics, nuclear materials protection and a host of others.

## 2. GLORIAD Overview


**Figure 3.** US, Russian, Chinese and Korean partners celebrate GLORIAD's grand opening at ceremony in Beijing, China on January 12, 2004.

The idea of the US, Russia and China encouraging broad R&E cooperation across a shared network ringing the entire northern hemisphere – and which they jointly build and operate across their territories (and the continents and oceans in between) – was *unthinkable* only a few years ago. But in fact, a smaller version of the network (with OC3 circuits) between the three countries operates today. This network, "Little GLORIAD," grew from the success of GLORIAD's predecessor, the US NSF- and Russian Ministry of Science-funded NaukaNet (operating since 1997), which on January 9, 2004 – with trans-atlantic and trans-pacific telecommunications services provided by Tyco Global Networks – extended its reach to China – and on June 14, 2004, crossed the Russia-China border to complete the ring around the northern hemisphere. This network already enables reasonably high capacity exchange between the three R&E communities. The same team now building the expanded GLORIAD network proposed, built and jointly operates "Little GLORIAD."

It is difficult to overstate the potential significance of the three originating countries pushing aside barriers that have restricted active engagement and cooperation for a century – and jointly building and operating a global infrastructure to actively encourage cooperation among their scientists, educators and students. GLORIAD's impact certainly includes the symbolic statement of the network itself. But GLORIAD extends participation in advanced scientific discovery to groups not participating today. Beyond it's own reach in the US, Russia and China – and with its many partners – GLORIAD is motivating infrastructure improvement discussions in such places as Central Asia– regions yet lacking sufficiently modern, fiber-based infrastructure deployed for science and education. As an advanced network, GLORIAD helps leverage facilities, instrumentation and science collaborations towards a more effective global partnership.

In addition to supporting the sciences, the GLORIAD program includes an ambitious program of education and outreach – through its "GLORIAD Classroom," the EduCultural Channel (a proposed 24/7 digital video channel), its development of an advanced collaboration infrastructure (including both multi-site, quality video-conferencing and a general IP telephony service for R&E) and its programs focused on young people – such as the global essay contest "Simple Words" and the partnership with Junior Achievement to encourage US, Russian and Chinese and other young people to learn about business development together. Given the tremendous impact of distrust, misinformation and harmful active engagement of the three organizing partner countries in a century only recently finished, GLORIAD represents a positive step in a quite different direction.

### 2.1 U.S. GLORIAD Team: Moves "Home" to East Tennessee

During the fall of 2004, the U.S. GLORIAD principal investigators moved the project (and the new NSF grant) from the National Center for Supercomputing Applications (NCSA) to the Joint Institute for Computational Sciences

managed by the Oak Ridge National Laboratory (ORNL) and the University of Tennessee. The NCSA had provided a good base for the predecessor NaukaNet program (which had itself moved to NCSA from the University of Tennessee in 2001). The UT-ORNL consortium offers an ideal home – from perspective of major international programs with Russia and China, advanced networking support and strong international science programs. Additionally, ORNL has been named (with Princeton Plasma Physics Lab) the US lead institution for the International Thermonuclear Experimental Reactor (ITER) – one of the science communities motivating GLORIAD's development. As the University of Tennessee (with Battelle) manages the ORNL, it is a good "meeting place" for joint NSF- and DOE- funded programs.

### 2.2 International Partners

GLORIAD's partners in both Russia and China provide senior and determined support for the program – and necessary government, financial and science community support prompting important domestic infrastructure improvements, as well. For example, GLORIAD has helped motivate current efforts in Russia to provision a 10 Gbps wavelength for R&E across its entire territory – proposing an increase in capacity of more than 2 orders of magnitude to important science communities in the Russian Far East. Indeed, as stated by the Russian leader, Academician Evgeny P. Velikhov[1], "[GLORIAD] has become the very backbone of Russia's domestic R&E network plan.[2]"

One of Russia's most senior scientists, Academician Velikhov is President of the prestigious national laboratory "Kurchatov Institute,"[3] and Academician-Secretary (functionally, Vice President) of the Russian Academy of Sciences[4] (RAS) (responsible for IT and cyberinfrastructure programs). He leads the GLORIAD consortium in Russia – comprising the most senior science and government organizations in the country. These range from the Russian Academy of Science to the Ministry of Education and Science, agencies of Communications and Atomic Energy, and his own Kurchatov Institute, among others. Dr. Velikhov is widely recognized as a most consistent and effective promoter of improved US-Soviet/-Russian R&E ties for 40+ years. He has been the international organizer and leader of the effort to build the International Thermonuclear Experimental Reactor (ITER)[5], a $10 billion international collaboration that points toward future supply of clean energy from fusion-based reactors. ITER is the US DOE's number one science priority for its 20-year science facility plan[6].

China provides equally senior support. Dr. Mianheng Jiang[7] leads the GLORIAD effort for the China Academy of Sciences (CAS) where he serves as Vice President responsible for computing, networking and IT issues. He is occasionally referenced as "China's Prince of IT"[8] for his work developing China's telecommunications and IT industries and national infrastructures. Dr. Baoping Yan[9] directs the 360 staff of the China-wide Computer Network Information Center[10] (CNIC) and is responsible for the development of the CAS network, CSTnet, and E-Science program across China, as well as the operation, support and use of GLORIAD within China. Her recent success in establishing the HKLight (Hong Kong Open Exchange point) is creating an improved pan-Asian networking environment.

The importance of the senior level of support in both Russia and China cannot be overemphasized. Without it, no amount of desire, intelligent engineering or financial support can bridge the barriers of trust, understanding and approval necessary to create and fund this shared infrastructure. With it, a remarkable opportunity is opened for the US R&E community to build not just a shared infrastructure but unprecedented opportunities for active partnership in a wide range of disciplines.

Very importantly, GLORIAD's team includes the Korea Institute of Science & Technology Information[11] (KISTI) and its advanced KREOnet national network, which will connect on the GLORIAD ring, the SURFnet/Netherlight[12] team which is providing the European connection point in Amsterdam and the Canadian CANARIE network which is generously providing transit across North America – from New York to Chicago to Seattle. These three national networks/partners represent three of the most advanced domestic S&E networks in the world; their joining the GLORIAD effort and their contribution to the GLORIAD team, network and program are considered one of the most important developments for GLORIAD during the 2004 year.

## 2.3 Network Partners

While focused on needs and interests of its partnering countries, GLORIAD aims to be a good global citizen – fostering direct partnership with other R&E networking efforts and national science communities. It features close partnerships with the StarLight[13] (SL) and TransLight[14] (TL) projects in Chicago as well as the TransLight/PacificWave[15] (PW) project at CENIC and the University of Washington.

As GLORIAD develops, it expects to build on partnerships with other advanced networks in North America (the US DOE's ESnet[16], the National LambdaRail[17] (NLR)), South and Central America (WHREN/FIU[18]), and broader Asia (via the GLORIAD presence in Hong Kong). GLORIAD partners in Russia and China also maintain peering agreements with Internet2's Abilene[19] network. GLORIAD features an especially close communications service and research partnership with Tyco Global Networks, Inc.[20] as well as Cisco Networks, Inc.[21] which has provided substantial equipment and technical services towards GLORIAD's development and its work on establishing an IP telephony infrastructure for R&E.

GLORIAD's partners lead development of the Global Lambda Integrated Facility (GLIF). The partnership with these and other advanced networking efforts will provide interoperability for essential layer 3 services and for a developing global circuit-switched infrastructure, which will enable layer 2 (and eventually layer 1) circuit provisioning for end-users. Close cooperation with its partner networks will enable GLORIAD to serve not only its primary communities, but also to make its circuits and services available to the global R&E community for advanced applications, network experimentation and for network backup and protection.

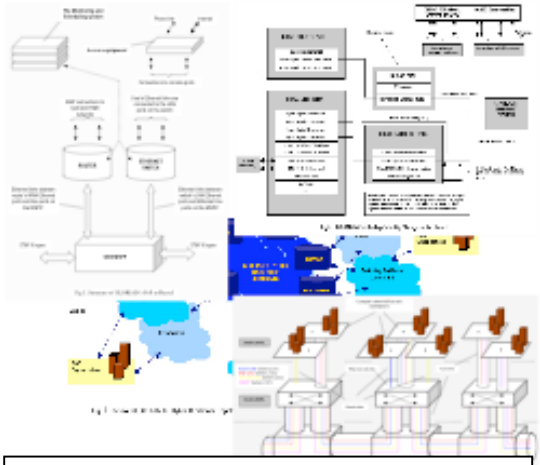

**Figure 4.** Technical System Design of GLORIAD available at: http://www.gloriad.org/gloriad/eng/system.design.html

## 2.4 Network Design

The recent NSF decision to fund GLORIAD's development will enable the team (with even more substantial support from its international partners) to build a vastly improved network (over "Little GLORIAD") transiting the main GLORIAD network centers – open exchange points based on the StarLight/Netherlight model. From a US vantage point, the ring begins in Chicago at the StarLight facility where the US team (based at the Oak Ridge National Laboratory and the University of Tennessee) maintains the US GLORIAD equipment. It reaches NYC via CANARIE and then, via Tyco Global Network reaches the Netherlight facility in Amsterdam, to Moscow, and through the European part of Russia to the science city of Novosibirsk/Akademgorok. The ring continues across Siberia to a major developing network exchange point in the Russian Far East in Khabarovsk, and continues across the Russia-China border to Beijing and then to Hong Kong (HKLight). As mentioned briefly above, in late 2004, the Chinese Academy of Sciences organized a grand opening ceremony for HKLight – an entirely new R&E network exchange point for Asia based on the successful Starlight (North America) and Netherlight (Europe) models – with connections already made to Japan and other connections soon from Taiwan, local Hong Kong S&E community and others. From Hong Kong, the ring crosses the Pacific Ocean (again, via Tyco Global Network) to Seattle and then, via the CANARIE network, back to Chicago/SL.

While the current "Little GLORIAD" network is currently operational as a series of OC3 circuits, the larger GLORIAD network will provide segments in year 1 (i.e., 2005) provisioned as OC12 from Moscow to Amsterdam and – via a GbE Tyco donation to GLORIAD – connecting facilities in Amsterdam and New York City (and, then via CANARIE's GbE contribution, to Chicago) (note: these circuits are to be operational in early February 2005), a Chinese 2.5 Gbps (STM-16) circuit from Hong Kong to Chicago (to be operational in March, 2005), a Korean 10 Gbps (STM-64) circuit from Hong Kong to Pusan to Seattle/Chicago (to be operational in June, 2005), and, for the Moscow-Beijing portion, STM-1 (155 Mbps – and already operational). These segments will be upgraded to 10G capacity during years 2 and 3 – with anticipated support for multiple 10G wavelengths by year 5. Shared protection service arrangements will be made with partnering R&E networks.

Using optical termination devices (such as Cisco ONS 15454s) and Ethernet switches, the network will provide VLAN services over 1G and 100M Ethernet links with the ability to offer non-Ethernet circuits if needed. The switched services will enable both scheduled and dynamic allocation of various capacity VLANs across the core networks and, for those advanced users appropriately equipped, end-to-end. VLANs over GbE circuits will be utilized initially to provide the essential L3 routed service (supporting IPv4, IPv6, and multicast) between Chicago-Moscow, Chicago-Beijing, Moscow-Amsterdam, Beijing-Amsterdam (and by year 3, Moscow-Beijing) – with the remaining capacities available to high-end user applications requiring, for example, GbE or FastE throughput and for backup and protection services. GLORIAD's ring topology (particularly by year 3 when the 10G wavelength ring is fully operational) will enable backup and alternate routes for L2 transit (eventually, L1 transit as well) - not only for the GLORIAD organizers but also for other compatibly designed networks. For example, a US-European network service interruption for any reason could be remedied by temporarily re-routing the affected traffic across the Pacific, Asian and Siberian segments of GLORIAD and to Europe via GLORIAD's presence in Amsterdam.

GLORIAD addresses three general areas of need - 1) general R&E applications – needs of which can be met by a "best effort" routed network (managed for minimal packet loss); 2) communities and scientists needing dedicated high-capacity (ex. 100/1000 Mbps Ethernet or greater), high-quality, and reliable network service (which, if networks such as GLORIAD and its partners do not provide, they must build themselves); 3) a network research test bed for experimentation with new protocols and applications that cannot be run on a general routed infrastructure and for applications such as the Canadian wavelength disk drive[22] (WDD) with which GLORIAD hopes to engage in experimentation and development[23].

## 3. Science Beneficiaries of the GLORIAD Network

The many science communities and applications requiring such committed services (and more completely documented at the GLORIAD web site[24]) include the network-intensive fields of high energy and fusion energy physics, the international THORPEX program developing more accurate models for improved weather forecasting, atmospheric scientists tracking global climate changes, the International Virtual Observatory (IVO), large radio interferometry programs, the International Square Kilometer Array (SKA) construction, and projects in the geological sciences related to seismic monitoring and earthquake prediction.

GLORIAD will also enhance the ability of materials scientists in the partner countries to better collaborate - both by the proposed network access given to the Spallation Neutron Source (SNS) being constructed in Oak Ridge, Tennessee (involving many international scientists) and through various nanomaterials efforts/centers. There is interest among the medical communities in the 3 countries to cooperate in various telemedical applications and practices. GLORIAD will also support cooperative programs in Arctic and Antarctic research, human genomics and broader bioinformatics and bioengineering efforts, and various environmental programs. Finally, GLORIAD already supports programs related to US-Russia national and international security - including network support for the past 6 years for US-Russian programs in nuclear weapons disposal, nuclear materials protection, accounting and control and active discussions between US and Russian leaders (via videoconferences over the network) on combating terrorist threats. Efforts have recently begun to explore GLORIAD use between new US-China nuclear non-proliferation programs.

These are a small sample of the thousands of active collaborations that will be served by both the general and advanced network services provided. Many of these are well understood because of the 6+ years the US team has worked in the area of advanced network applications with the Russian team - and now with 2 years of discussion (and one year of joint network operation) with the Chinese Academy of Sciences. Further description of these application areas is provided below.

## 4. Network Access Extensions

Just as the predecessor MIRnet/NaukaNet program assisted in making high quality network access possible to scientists and institutions in Russia and the US, GLORIAD proposes to do so on a wider scale by extending 10 Gbps network capacity across the vast expanse of Russia (thus, changing the way networking is delivered in this scientifically important and remote part of the world), but also in the even more remote (to US) region of Kyrgyzstan and Central Asia. As noted by GLORIAD team member, geologist Eric Frost, this region is a

"geologist's Disneyland" but not yet accessible in any sense (but travel) to the US community. Senior government officials in Kyrgyzstan have committed to building the necessary infrastructure to connect to and utilize GLORIAD – not only for development of a Kyrgyz service, but also of a Central Asia "ring" network connecting other republics in this region. Much of the fiber infrastructure exists today; GLORIAD provides the motivation to provision the capacities for R&E. Whether for the large science communities in Siberia, Far East Russia and previously inaccessible locations in China – or in other countries of the former Soviet Union – GLORIAD promises to open new opportunities for US scientists and educators. The scientific and geopolitical possibilities/benefits are substantial.

## 5. Network Contributions

With its own experience of the past 6 years – and now working with its Starlight, TransLight, Netherlight, CANARIE, KREOnet, WHREN, and GLIF consortium partners, GLORIAD is experienced in developing and delivering a set of advanced network services. The ring topology of GLORIAD will provide enhanced reliability and an interesting space for experimentation for technology advancements such as the CANARIE Wavelength Disk Drive.


**Figure 5.** GLORIAD's web site displays current top users of the network around the world and is updated every 10 minutes. See: http://www.gloriad.org/ .

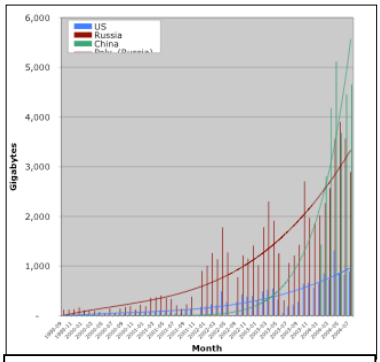


**Figure 6.** GLORIAD's monitoring system enables analysis of IP flows host-host, institution-institution, country-count and includes traffic volume, average throughput and application class. See http://www.gloriad.org/madasd/ for more information.

The GLORIAD team's experience cooperatively managing and monitoring international networks has yielded a utilization monitoring hardware/software system, MADAS[25] giving the GLORIAD team detailed knowledge about its customer base, the general applications used, as well as basic performance measures. This is being supplemented in the larger GLORIAD program with an increased emphasis on end-to-end performance monitoring (with NLANR MNA[26], San Diego) and new experimentation with more detailed network monitoring systems to gauge real applications performance[27].

GLORIAD will provide a useful and innovative set of Network Operations Center (NOC) tools to integrate its several monitoring tools with its own developed trouble ticketing system. GLORIAD also proposes the development of a collaboration infrastructure[28] - addressing the still difficult problem of holding online "meetings" with current video conferencing tools. This program is being developed with the High Energy Physics VRVS[29] effort, and via an infrastructure being developed in partnership with Cisco, which has donated $100K equipment for deploying a useful IP telephony service.

## 6. Education and Outreach

The "GLORIAD Classroom"[30] is being built to provide a useful Internet-based service – a curated repository of useful information describing science resources, applications, success stories, technology solutions, etc. – as well as a means of targeting new information to subscribers based on their own specific interests (called the Current Awareness service). Such information-based "community building" tools have been used successfully by the US project leaders in their work with US-Russia[31] and US-China[32] for more than 10 years. Other programs include the EduCultural Channel[33] (a 24x7 broadcast and on-demand video service - making "science" accessible), the large "Virtual Science Museum of China[34]" the Russia-developed "Simple Words"[35] global essay contest and a special partnership with the International Junior Achievement Organization[36] – enabling young people in the US, Russia,

and China to engage in joint civics education, as well as practice skills for developing domestic and international businesses. While each of these programs merits its own funding source (and the GLORIAD team is committed to pursuing such), they will all be developed and piloted within the GLORIAD framework using advanced networking technologies. In the US, the Chicago Public Schools has agreed to partner with GLORIAD and model activities system-wide.

## 7. Benefits to the US R&E community

GLORIAD is building a specialized infrastructure for US science disciplines that, without the network, face technical limits in their engagement with Chinese and Russian colleagues. The US science community will have access to previously inaccessible facilities - both via the network infrastructure and by the political support of this project in Russia and China in opening up science cooperation. Assuming success of efforts extending access to Central Asia, GLORIAD will provide a level of advanced network access to this region of the world superior to that existing today - opening access to major research facilities such as the Bishkek Geologic Proving Ground that hold real promise for US scientists. GLORIAD lends additional support to the development of the GLIF and consortium member networks, all of which are being developed to meet advanced application requirements of the global science community. Through its partnership with the National LambdaRail and with CANARIE, GLORIAD supports the development of necessary infrastructures in North America.

The unique global ring topology of GLORIAD holds promise of providing additional reliability for US networking across Asia and Europe due to the Eurasian segment of GLORIAD crossing Russia and China. Due to hard-won political and networking support for this program in Russia and China, GLORIAD provides the US with a seat at the table in both countries for keeping networking and broader cyberinfrastructure developments aligned - and with commitment to common standards and engineering approaches.

## 8. Conclusion

The current GLORIAD ring network will expand from 155 Mbps circuit to 10 Gbps by year three of the project, and will enable scientists around the globe to manage their own network service requirements quickly and efficiently.

Already, the GLORIAD project has fostered stronger ties and working relationships between three large countries that did not embrace the benefits of cooperation with one another in the past century. Beyond the direct science benefits, these relationships help to dispel myths and misinformation and build trust and understanding from the highest levels of government and science down to the next generation of leaders still in the classroom. Additionally, the GLORIAD ring activity championed by the partnering countries has already encouraged other regions “near” the ring, particularly in central and east Asia, to address network infrastructure requirements to attach to this ring, someday establishing additional benefits for scientists, educators and students in their respective countries, as well as for citizens more broadly across the globe.

End Notes

[1] See brief bio at: http://www.gloriad.org/gloriad/team/russia/evelikhov.html
[2] In letter of support from Acad. Velikhov for US GLORIAD proposal to NSF.
[3] See http://www.kiae.ru/
[4] See http://www.ras.ru/
[5] See http://www.iter.org/
[6] See http://energy.gov/engine/content.do?PUBLIC_ID=14440&BT_CODE=PR_PRESSRELEASES&TT_CODE=PRESSRELEASE
[7] See brief bio at: http://www.gloriad.org/gloriad/team/china/mjiang.html
[8] See http://news.bbc.co.uk/2/hi/asia-pacific/1832448.stm
[9] See brief bio at: http://www.gloriad.org/gloriad/team/china/byan.html
[10] See http://www.cnic.ac.cn/english/index.html
[11] See http://www.kisti.re.kr/
[12] See http://www.surfnet.nl/en/
[13] See http://www.startap.net/starlight/
[14] See http://www.startap.net/translight/
[15] See http://www.pacificwave.net/
[16] See http://www.es.net/
[17] See http://www.nlr.net/
[18] See http://www.ampath.fiu.edu/
[19] See http://www.internet2.edu/
[20] See http://www.tycotelecom.com/
[21] See http://www.cisco.com/
[22] See http://www.canarie.ca/canet4/library/general/wavelengthdiskdrives.html
[23] See http://www.gloriad.org/gloriad/disciplines/network/index.html
[24] See http://www.gloriad.org/
[25] See http://www.gloriad.org/madasd/
[26] See http://moat.nlanr.net/
[27] See http://packeteer.com/prod-sol/products/packetshaper.cfm
[28] See http://www.gloriad.org/gloriad/eot/collaboration/index.html
[29] See http://www.vrvs.org/
[30] See http://www.gloriad.org/gloriad/classroom/index.html
[31] See http://www.friends-partners.org/friends/ourstory/newserver.html
[32] See http://www.friends-partners.org/fpchina/welcome/index.html
[33] See http://www.gloriad.org/gloriad/eot/educultural/index.html
[34] See http://www.gloriad.org/gloriad/eot/virtualmuseum/index.html
[35] See http://www.gloriad.org/gloriad/eot/simplewords/index.html
[36] See http://www.gloriad.org/gloriad/eot/ja/index.html