Networking for High Energy and Nuclear Physics

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Abstract

This report gives an overview of the status and outlook for the world's research networks and major international links used by the high energy physics and other scientific communities, network technology advances on which our community depends and in which we have an increasingly important role, and the problem of the Digital Divide, which is a primary focus of ICFA's Standing Committee on Inter-regional Connectivity (SCIC).

Wide area networks of sufficient, and rapidly increasing end-to-end capability are vital for every phase of high energy physicists' work. Our bandwidth usage, and the typical capacity of the major national backbones and intercontinental links used by our field have progressed by a factor of more than 1000 over the past decade, and the outlook is for a similar increase over the next decade. This striking exponential growth trend, outstripping the growth rates in other areas of information technology, has continued in the past year, with many of the major national, continental and transoceanic networks supporting research and education progressing from a 10 Gigabits/sec (Gbps) backbone to multiple 10 Gbps links in their core. This is complemented by the use of point-to-point "light paths" to support the most demanding applications, including high energy physics, in a growing list of cases.

As we approach the era of LHC physics, the growing need to access and transport Terabyte-scale and later 10 to 100 Terabyte datasets among more than 100 "Tier1" and "Tier2" centers at universities and laboratories spread throughout the world has brought the key role of networks, and the ongoing need for their development, sharply into focus. Bandwidth itself on an increasing scale is not enough. Realizing the scientific wealth of the LHC and our other major scientific programs depends crucially on our ability to use the bandwidth *efficiently and reliably*, with reliable high rates of data throughput, and *effectively*, where many parallel large-scale data transfers serving the community complete with high probability, often while coexisting with many other streams of network traffic. Responding to these needs, and to the scientific mission, physicists working with network engineers and computer scientists have made substantial progress in the development of protocols and systems that promise to meet these needs, placing our community among the world leaders in the development as well as use of large-scale networks. A great deal of work remains, and is continuing.

As we advance in these areas, often (as in the past year) with great rapidity, there is a growing danger that we will leave behind our collaborators in regions with less-developed networks, or with regulatory frameworks or business models that put the required networks financially out of reach. This threatens to further open *the Digital Divide that already exists* among the regions of the world. In 2002, the SCIC recognized the threat that this Divide represents to our global scientific collaborations, and since that time has worked assiduously to reduce or eliminate it; both within our community, and more broadly in the world research community of which HEP is a part.

Key words: High-energy Physics, Network Research

1. Introduction: HEP Networking Challenges

Wide area networking is a fundamental and mission-critical requirement for High Energy

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Physics. National and international networks of sufficient (and rapidly increasing) bandwidth and end-to-end performance are now essential for each part and every phase of our physics programs, including:

– The daily conduct of collaborative work in small and large groups, in both experiment and theory
– The formation and successful operation of worldwide collaborations
– Data analysis involving physicists from all world regions
– Detector development and construction on a global scale
– The increasingly ubiquitous use of tools and systems for remote collaboration
– The conception, design and implementation of next generation facilities as "global networks"

Moreover, HEP's dependence on high performance networks is increasing rapidly, as our field's bandwidth usage has progressed by a factor of more than 1000 during the past decade. The next decade is going to be a challenge, as the outlook is for a similar factor increase during this time in the major network backbones and international links required to support HEP and other traffic, from the current level of 1 to 10 Gigabits/sec (Gbps) on major links which is increasingly typical today, to the Terabit/sec range.

In an era of global collaborations, and data intensive Grids, advanced networks are required to interconnect the physics groups seamlessly, enabling them to collaborate throughout the lifecycle of their work. For the major experiments, networks that operate seamlessly, with quantifiable high performance and known characteristics are required to create data Grids capable of processing and sharing massive physics datasets, rising from the Petabyte (10^{15} byte) to the Exabyte (10^{18} byte) scale within the next decade. Within the past two years there has been a growing realization that large scale, rapidly advancing network requirements extend beyond the "Tier1" grid facilities at major HEP laboratories and national computing centers, to the smaller but still substantial "Tier2" centers at universities and the smaller research laboratories in many countries. In the past year the number of Tier2 centers in operation or planned throughout the world for the LHC and current physics programs has passed 100. In the US, a growing number of Tier2s have 10 Gbps links, and a few have multiple 10 Gbps links that connect them to Fermilab, Brookhaven and CERN, and to other Tier2 sites.

The need for global network-based systems that support our science has made the HEP community a leading early-adopter, and more recently a key co-developer of leading edge wide area networks. Since 1999, several groups of physicists and engineers in our field, in North America, Europe and Asia, have worked with computer scientists to make significant advances in the development and optimization of network protocols, and methods of data transfer. During 2004–5 these developments, together with the availability of 10 Gigabit/sec (Gbps) wide area links and advances in data servers and their network interfaces (notably 10 Gigabit Ethernet) have made it possible for the first time to utilize networks with relatively high efficiency in the 1 to 10 Gigabit/sec (Gbps) range over continental and transoceanic distances. Sustained aggregate data flows of more than 100 Gbps over these distances have been demonstrated in the Fall of 2005 for the first time. By the start of the LHC era next year, when many 10 Gbps links interconnecting the CERN Tier0, national Tier1, and regional Tier2 centers are expected to be in production service, it is expected that 1–10 Gbps data flows supporting Terabyte-scale data transfers as part of physicists' data analysis work will be an increasingly common, everyday occurrence.

The success of the LHC and other global scientific collaborations depends on sustaining this mode of operation, and hence on the ability to make use of long range networks composed of 10 Gbps links *effectively and reliably*, on an increasing scale, from now on.

But reaching these important goals, that now look technically achievable if still difficult, requires a substantial ongoing commitment. Strong financial support, and in many cases growing support from the funding agencies is required to cover the costs of (1) connections to the major networks and of dedicated links where appropriate, (2) network routing and switching equipment, and (3) the development and deployment of the software needed to operate and manage a new generation of networked systems. Provision of this strong support is essential for the realization of the discovery potential of the LHC and other major programs, especially when it comes to the contributions of physicists and students remote from the experiment, working at their universities and laboratories in their home countries.

The rapid technical developments of tools and systems capable of high throughput have been paralleled by the continued rapid advance of continental core network infrastructures in North America, Western Europe as well as Japan and Korea, as well as the key links across the Atlantic and Pacific used for high energy physics, or more generally for research and education, to typical bandwidths of 10 Gbps. A prime example during 2005 was the rapid advance of the research and education networks in Brazil, to a 10 Gbps core. The transition to the use of "dense wavelength division multiplexing" (DWDM) to support multiple links on a single optical fiber-pair has made these links increasingly affordable, and this has resulted in a substantially increased number of these links coming into service during 2004–5. A new development in 2005 is the deployment of point-to-point "light paths" across DWDM infrastructures in several countries, notably in 12 countries in Europe, as well as Canada and the U.S.

We expect this trend to continue throughout 2006. U.S. LHCNet between the U.S. and CERN has been upgraded from one to two 10 Gbps links in the Fall of 2005, and the plan is to move to four links by 2007. The GEANT Pan-European backbone is now being replaced by GEANT2 with an optical fiber core supporting several 10 Gbps wavelengths, and Internet2 and the Energy Sciences Network (ESnet) in the U.S. are planned to be upgraded to a similar level. This trend also is spreading to other world regions, notably including 10 Gbps links across the Atlantic and Pacific linking Australia and North America, and Russia, China, Japan, Korea and the US through the "GLORIAD" optical ring project, links between New York and Amsterdam as well as Seattle and the Asia Pacific region provided by the Internet Education Equal Access Foundation (IEEAF), and the Translight links funded by the U.S. National Science Foundation under its IRNC program.

In 2003–5 we also saw the emergence of growing trend towards privately owned or leased wide area fiber infrastructures, managed by non-profit consortia of universities and regional network providers, to be used on behalf of research and education. "National Lambda Rail (NLR)" covering much of the US has been deployed, accompanied by initiatives in more than 30 states (notably Illinois, California, and Florida). In Europe, nine National Research and Education networks (NRENs) have "dark fiber" making up 50% or more of their backbone, and similar initiatives are underway in many European countries as well as in Southeast Europe, the middle East, the republics of the former Soviet Union. A related trend led by Poland's Pionier network is the use of "cross border dark fiber", allowing the neighboring countries to make use of Pionier's connection to the GEANT backbone.

In some cases high energy physics laboratories or computer centers also have acquired leased dark fiber to their site, where they are able to connect to the principal wide area networks they use with one or more wavelengths. Fermilab is a notable example.

These trends have also led to a forward-looking vision of much higher capacity "hybrid" networks based on many wavelengths in the future, where statically provisioned shared network links are complemented by dynamically provisioned optical paths (also called "lambdas") to form "Lambda Grids" for the most demanding applications. The Global Lambda Integrated Facility (GLIF) for example, is "an international virtual organization that promotes the paradigm of lambda networking". The visions of advanced networks and Grid systems are beginning to converge, where future Grids will include end-to-end monitoring and tracking of networks as well as computing and storage resources, forming an integrated information system supporting data analysis, and more broadly research in many fields, on a global scale.

Starting in the Fall of 2004 we began to see progress towards the realization of this vision, in U.S. projects such as the NSF-funded "UltraLight" project, as well as in work on network-service provisioning in the EGEE project. Specific progress achieved during 2005 includes the development of (1) new fair-sharing, stable, high performance TCP-based network protocols (such as FAST, MaxNet), (2) tuned Linux kernels and network interface settings capable of sustained data transport in the range approaching 10 Gigabits/second (Gbps) for individual streams (3) global-scale agent-based systems, exemplified by Caltech's MonALISA system, that autonomously monitor and help manage major research networks, hundreds of grid clusters and other distributed systems around the clock.

Some of these advances are documented further in the following sections of this report, as well as a series of Appendices to this report covering the status and outlook for some of the major national and international networks, as well as some of the leading network R&D projects.

The rapid progress and the advancing vision of the future in the "most economically favored regions" of the world during 2004–5 also has brought the problem of the Digital Divide into sharp focus. As advances take hold and accelerate in the U.S., Canada, parts of Europe, Japan, Korea, and Brazil, there is an increasing danger that the groups in the less-favored regions, including Southeast Europe, Latin America, much of Asia, and Africa will be left behind. This problem needs concerted action on our part, if our increasingly global physics collaborations are to succeed in enabling scientists from all regions of the world to take their rightful place as full partners in the process of scientific discovery. The SCIC has therefore been working over the last four years to understand this problem, and working with partners in academia, government and industry, to find ways to mitigate or eliminate this Divide as it affects our field: country by country, and region by region.

2. ICFA SCIC in 2005

The intensive activities of the SCIC continued in 2005 (as foreseen), and we expect this level of activity to continue in 2005. The committee met four times in the last 12 months, complemented by a wide variety of activities of SCIC members in the field, and continued its carry out its charge to:

- Track network progress and plans, and connections to the major HEP institutes and universities in countries around the world;
- Monitor network traffic, and end-to-end performance in different world regions
- Keep track of network technology developments and trends, and use these to "enlighten" network planning for our field
- Focus on major problems related to networking in the HEP community; determine ways to mitigate or overcome these problems; bring these problems to the attention of ICFA, particularly in areas where ICFA can help.

The SCIC working groups (formed in the Spring of 2002) continued their work.

- ***Monitoring*** (Chaired by Les Cottrell of SLAC)
- ***Advanced Technologies*** (Chaired by Richard Hughes-Jones of Manchester, together with Sylvain Ravot of Caltech)
- ***The Digital Divide*** (Chaired by Alberto Santoro of UERJ, Brazil)

  The working group membership was strengthened through the participation of several technical experts and members of the community with relevant experience in networks, network monitoring, and other relevant technologies throughout 2005.

The SCIC web site, hosted by CERN (http://cern.ch/icfa-scic) that was set up in the summer of 2002 provides information on the membership, meetings, minutes, presentations and reports. An extensive set of reports and presentations, used in the preparation of this annual SCIC report, is available at the Web site.

SCIC members took an active and often central role in a large number of conferences, workshops and major events related to networking and the Digital Divide during the past two years. These events, some of which are listed below, tended to focus attention on the needs of the HEP community, as well as its key role as an application driver, and also a developer of future networks:

- World Summit on the Information Society Meeting, Geneva, December 2003;
  accompanied by "The Role of Science in the Information Society" hosted by CERN
- LISHEP 2004: Digital Divide and HEPGrid Workshop, Rio De Janiero, Feb 16–20, 2004
- Internet 2 meeting: Extending the Reach of Advanced Networking: Special International Workshop, Arlington, VA., April 22, 2004
- Grid Performance Workshop UCL, May 12–13, 2004
- Networks for Non-Networkers (NFNN) workshop, University College London, July 2004
- CAIDA ISMA workshop, at SDSC June 2004
- 18th APAN International Conference Network Research Workshop, Cairns, Australia, July, 2004
- Internet 2 Joint Techs E2Epi BOF Columbus Ohio, July 2004
- NASA/LSN Workshop on Optical Network Technologies at NASA Ames August 9–12
- 3^{rd} HEP Data Grid Workshop, Daegu, Korea, August 2004
- GLIF: "4th Annual Global LambdaGrid Workshop" Nottingham, United Kingdom September 2–3, 2004
- Network Research Meeting, FNAL September 15–17, 2004
- CHEP 2004 Conference for Computing in High Energy and Nuclear Physics; Interlaken, Switzerland, September 30 – October 5, 2004
- SC2004 Supercomputing Conference, "Bridging Communities", November 6–10, 2004
- Chinese American Network Symposium, Miami, USA, November 30 – December 2, 2004
- Brazilian T2 HEPGrid Inauguration, Rio de Janeiro, Brazil, December 20 – 21, 2004
- International ICFA Workshop on HEP Networking, Grids and Digital Divide Issues for Global e-Science, Daegu, Korea, May 2005
- Internet2 Joint Techs Workshop, Vancouver, July

2005
- Bridging the Gap Workshop, Internet2, Ann Arbor, Michigan, August 2005
- Big GLORIAD Inauguration, Seoul Korea, September 2005
- iGrid2005 and the GLIF LambdaGrid Workshop, University of California, San Diego, September 2005
- Chinese American Networking Symposium (CANS), Shenzhen China, October 2005
- Supercomputing 2005 (SC|05), Seattle, November 2005
- PAK-US Symposium, High Capacity Optical Networks and Enabling Technologies (HONET), December 2005

The conclusion from the SCIC meetings, and the other meetings listed above throughout 2004–5, setting the tone for 2006, is that the scale and capability of networks, their pervasiveness and range of applications in everyday life, and dependence of our field on networks for its research in North America, Europe, Asia and now Latin America are all increasing rapidly. One recent development accelerating this trend is the worldwide development and deployment of data-intensive Grids, especially as physicists begin to develop ways to do data analysis, and to collaborate in a "Grid-enabled environment".

However, as the pace of network advances continues to accelerate, the gap between the technologically "favored" regions and the rest of the world is, if anything, in danger of widening. Since networks of sufficient capacity and capability in all regions are essential for the health of our major scientific programs, as well as our global collaborations, we must encourage the development and effective use of advanced networks in ***all*** world regions. We have therefore agreed to make closing the ***Digital Divide*** a prime focus of the work of our committee (from 2002 onwards), and to enlist ICFA's help on a continuing basis in achieving this important goal.

The SCIC also continued and expanded upon its work on monitoring network traffic and performance in many countries around the world through the ***Monitoring Working Group***. An updated report from this Working Group accompanies this report. We continued to track key network developments through the ***Advanced Technologies Working Group***.

3. General Conclusions of the SCIC

A key issue for our field is to close the Digital Divide in HEP, so that scientists from all regions of the world have access to high performance networks and associated technologies that will allow them to collaborate as full partners: in experiment, theory and accelerator development.

While the throughput obtainable on networks, monitored by SLACs Internet2 End-to-end Performance Monitoring (IEPM) project is improving year by year in all world regions, Central Asia, Russia, Southeast Europe, Latin America, the Middle East and China remain 4–5 years behind the US, Canada, Japan and most of Europe. India and Africa are 7–8 years behind, and are in danger of falling farther behind.

The rate of progress in the major networks in the U.S., Europe and Asia has maintained the rapid pace set in 2004. The current generation of network backbones, representing an upgrade in bandwidth by factors ranging from 4 to several hundred in some countries, arrived in the last two to three years in the US, Europe and Japan. This rate of improvement is faster, and in some cases many times the rate of Moore's Law. The rapid rate of progress, confined mostly to the US, Europe, Japan and Korea, as well as the major transoceanic routes, threatens to open the Digital Divide further, unless we continue to take action to reduce the inequalities among regions, in both technical capability and pricing.

Reliable high End-to-end Performance of networked applications such as large file transfers and Data Grids is required. Achieving this requires:
- ***End-to-end monitoring extending to all regions serving our community.***
- ***Upgrading campus infrastructures. While National and International backbones have reached 10 Gbps speeds in many countries, many campus network infrastructures and/or regional networks are still not designed to support gigabit/sec and higher speed data transfers to and from many HEP centers.***
- ***Removing local, last mile, and national and international bottlenecks end-to-end, whether the bottlenecks are technical or political in origin.***
- ***Removing Firewall bottlenecks.***
- ***Developing and deploying high performance network toolkits and systems developed by***

our community and its partners, in a form that is suitable for widespread use by users.

4. Recommendations (Ongoing)

ICFA should work vigorously locally, nationally and internationally, to ensure that networks with sufficient raw capacity and end-to-end capability are available throughout the world. This is now a vital requirement for the success of our field, and the health of our global collaborations.

The SCIC, and other members of ICFA, should work in concert with the HEP laboratories, the research and education networks and network providers serving the scientific community, universities engaged in network research and development, as well as other the funding agencies and corporate sponsors on problems of national and global networking for HEP as well as other fields of research and education. The organizations include in particular Internet2, GEANT, NLR, TERENA, AMPATH, IEEAF, GLIF, CANARIE, SURFNet, GLORIAD, as well as other national and regional research and education networks such as KREONet in Korea, RNP and ANSP in Brazil, CERNet and CSTNet in China, major Grid projects such as the WLCG, EGEE, the Open Science Grid, and the Global Grid Forum.

4.1. *Recommendations to Close the Digital Divide, Where ICFA and HEP Laboratory Directors Can Help*

The world community will only reap the benefits of global collaborations in research and education, and of the development of advanced network and Grid systems, if we are able to close the Digital Divide that separates the economically and technologically most-favored from the less-favored regions of the world. It is imperative that ICFA members work with and advise the SCIC on the most effective means to close this Divide, specifically:

- **Identify and work on specific problems, country by country and region by region, to enable groups in all regions to be full partners in their experiments**

  Networks with adequate bandwidth tend to be too costly or otherwise hard to obtain in the economically poorest regions. Particular attention to Russia, India, Pakistan, Southeast Asia, Southeast Europe, Latin America, China and Africa is required.

  Performance on existing national, metropolitan and local network infrastructures also may be limited, due to lack of competition and monopolistic pricing, the use of outmoded equipment, unfavorable economic and regulatory policies, or a lack of coordination (or peering arrangements) among different network organizations.
- **Create and encourage inter-regional programs to solve specific regional problems.**

  Leading examples include (1) the GLORIAD project linking Russia, China, Japan, the Netherlands, Korea and the US, (2) the support for links in Asia by the KEK High Energy Accelerator Research Organization in Japan (http://www.kek.jp) together with the Asia Pacific Academic Network (APAN), (3) the transatlantic and transpacific links provided by the IEEAF and NSF's IRNC program, (4) the support of network connections for research and education in Latin America by the AMPATH "Pathway to the Americas" (http://www.ampath.fiu.edu) based at Florida International University together with RNP and ANSP in Brazil, as well as the CHEPREO (http://www.chepreo.org) and WHREN (http://whren.ampath.net) projects led by FIU, (5) the TIEN2 Project (http://www.tein2.net) that provides improved the links within the Asia-Pacific region, as well as between the Asia-Pacific and Europe. A pioneering example is the Virtual Silk Highway project (http://www.silkproject.org/) led by DESY throughout its early stages.
- **Make direct contacts, and help educate government officials on the needs and benefits to society of the development and deployment of advanced infrastructure and applications:** for research, education, industry, commerce, and society as a whole. This can be done individually, or through focused workshops that include the participation of officials. An important upcoming example is a Digital Divide Panel during the Computing for HEP conference (CHEP06) in Mumbai, organized by TIFR and the SCIC, where the President of India will speak, followed by a workshop focused on bringing advanced networking to India.
- **Use (lightweight; non-disruptive) network monitoring to identify and track prob-**

lems, and keep the research community (and the world community) informed on the evolving state of the Digital Divide. One leading example in the HEP community is the Internet End-to-end Performance Monitoring (IEPM) initiative (http://www-iepm.slac.stanford.edu) at SLAC.

It is vital that support for the IEPM activity in particular, which covers more than 100 countries with 90% of the world population (and 99% of the population connected to the Internet) be continued and strengthened, so that we can monitor and track progress in network performance in more countries and more sites within countries, around the globe. This is as important for the general mission of the SCIC in our community as it is for our work on the Digital Divide.

The inadequate funding for the IEPM over the last two years has been an issue brought to ICFA's attention. This issue is still pending.

- **Share and systematize information on the Digital Divide.** The SCIC is gathering information on these problems, and since 2003 has expressed the need to develop a Web site on the Digital Divide problems of research groups, universities and laboratories throughout its worldwide community. This would be coupled to general information on link bandwidths, quality, utilization and pricing. Monitoring results from the IEPM, complemented by monitoring results from MonALISA, would continue to be used to track and highlight ongoing and emerging problems. This Web site would promote our community's awareness and understanding of the nature of the problems: from lack of backbone bandwidth, to last mile connectivity problems, to policy and pricing issues.

  NOTE: Progress on construction and maintenance of this Web site and database was hampered in 2003-5 by lack of funding and manpower. The SCIC is continuing to seek funding, or increased manpower support from the HEP Labs, to achieve these important goals.

Specific aspects of information sharing that would help develop a general approach to solving the problem globally include:

- **Sharing examples of how the Divide can be bridged, or has been bridged successfully in a city, country or region.** One class of solutions is the installation of short-distance optical fibers leased or owned by a university or laboratory, to reach the "point of presence" of a network provider. Another is the activation of existing national or metropolitan fiber-optic infrastructures (typically owned by electric or gas utilities, or railroads) that have remained unused. A third class is the resolution of technical problems involving antiquated network equipment, or equipment-configuration, or network software settings, etc.
- **Making comparative pricing information available.** Since international network prices are falling rapidly along the major Transatlantic and Transpacific routes, sharing this information should help us set lower pricing targets in the economically poorer regions, by pressuring multinational network vendors to lower their prices in the region, to bring them in line with their prices in larger markets.
- **Identifying common themes in the nature of the problem, whether technical, political and financial, and the corresponding methods of solution.**
- **Create and maintain a "new culture of collaboration" in the major experiments and at the HEP laboratories,** as described in the following section of this report.
- **Work with the Internet Educational Equal Access Foundation (IEEAF) (http://www.ieeaf.org), and other organizations that aim to arrange for favorable network prices or outright bandwidth donations**, where possible.
- **Take part in major political events that relate to information technology infrastructure. The World Summit on the Information Society** (WSIS; http://www.itu.int/wsis/) was a major example. The first phase of the WSIS took place in Geneva in December 2003. The SCIC was active in this major event, and remains active in the WSIS process which aims to develop a society where

  "...highly-developed... networks, equitable and ubiquitous access to information, appropriate content in accessible formats and effective communication can help people achieve their potential...".

  The second WSIS phase took place will take place in Tunis, in November 2005. The SCIC was represented by Hans Hoffmann of CERN, who made available the 2005 SCIC Report, and a brief summary on the SCIC and its activities, to the leaders attending the conference.

The aims of the WIS are clearly synergistic with the aims of our field, and its need to provide worldwide access to information and effective communications in particular. HEP has been recognized as having relevant experience in effective methods of initiating and promoting international collaboration, and harnessing or developing new technologies and applications to achieve these aims. HEP has been involved in WSIS preparatory and regional meetings in Bucharest in November 2002 and in Tokyo in January 2003. It has been invited to run a session on The Role of New Technologies in the Development of an Information Society , and was invited to take part in the planning process for the Summit itself.

On behalf of the world's scientific community, in December 2003, CERN organized the Role of Science in the Information Society (RSIS) conference, a Summit event of WSIS. RSIS reviewed the prospects that present developments in science and technology offer for the future of the Information Society, especially in education, environment, health, and economic development. Further details about the participation of the HEP community in the WSIS and RSIS are given in Appendix 26 of the SCIC's 2004 Report.

The WSIS Stocktaking Report (July 2005) following the first phase in Geneva, recognized the SCIC. The report showed that among more than 2,000 projects and organizations taking part in the WSIS, the SCIC was among the very few emphasizing the specific goal of equal access to networks of advanced capability among the world regions. The need for equality is based on the principle of equal partnership in our global scientific collaborations.

- **Formulate or encourage bi-lateral proposals, through appropriate funding agency programs.** Examples of programs are the US National Science Foundation's IRNC program, the European Union's Sixth Framework and LIS programs, and NATO's Science for Peace program, and bilateral programs (such as the PAK-US program in which SCIC members take part) sponsored by the U.S. State Department.
- **Help start and support workshops on networks, Grids, and the associated advanced applications.** These workshops could be associated with helping to solve Digital Divide problems in a particular country or region, where the workshop will be hosted. One outcome of such a workshop is to leave behind a better network, and/or better conditions for the acquisition, development and deployment of networks. The workshops as well as major events such as SC2004 and SC2005 have been effective in this respect, helping to leave behind advanced network connections to UERJ in Rio de Janeiro and UNESP in Sao Paulo. It is hoped that the upcoming workshop in India (February 2006) will have a similar, lasting effect.
- **Help form regional support and training groups for network and Grid system development, operations, monitoring and troubleshooting.** The benefits of this activity, to broaden the base of network expertise and in the longer term to accelerate progress through this expertise, apply to all regions. Training and joint developments in grid systems is increasingly widespread, but ongoing training and joint developments in advanced networks is still relatively rare. Notable examples currently underway include the CHEPREO and UltraLight projects.

Over the last two years it has been increasingly recognized that HEP and its worldwide collaborations could be a model for other scientific disciplines, and for new modes of information sharing and communication in society at large. The provision of adequate networks in our field, and the success of our Collaborations in the Information Age, thus has broader implications for our field and for the world scientific community as a whole.