US National Science Foundation, Office of Cyberinfrastructure
International Research Network Connections (IRNC) Program

STARLIGHT
TR✦NS LIGHT

Maxine D. Brown and Thomas A. DeFanti
Electronic Visualization Laboratory
UNIVERSITY OF ILLINOIS AT CHICAGO
maxine@uic.edu, tom@uic.edu

Presented by Joe Mambretti (j-mambretti@northwestern.edu)
International Center for Advanced Internet Research (www.icair.org)
US LHC Network Working Group
Fermi National Accelerator Laboratory
October 23-24, 2006

evl
STARLIGHT
TR✦NS LIGHT glif NSF

US National Science Foundation (NSF) Funds 5 IRNC International Networking Projects

- Support science and engineering research and education applications

- Enable state-of-the-art international network services

- Share tools and best practices

- Work on major events and activities (SC, Grid, GLIF)

- IRNC is the international extension of National LambdaRail (NLR), Internet2 and ESnet

- **TransLight/StarLight works with US and European R&E networks:**

  - **to implement strategies to best serve production science**

  - **to identify and best serve pre-production data-intensive e-science applications**, for they are the drivers for new networking tools and services to advance the state-of-the-art of production science; e.g., persistent large data flows, real-time visualization and collaboration, and/or remote instrumentation scheduling
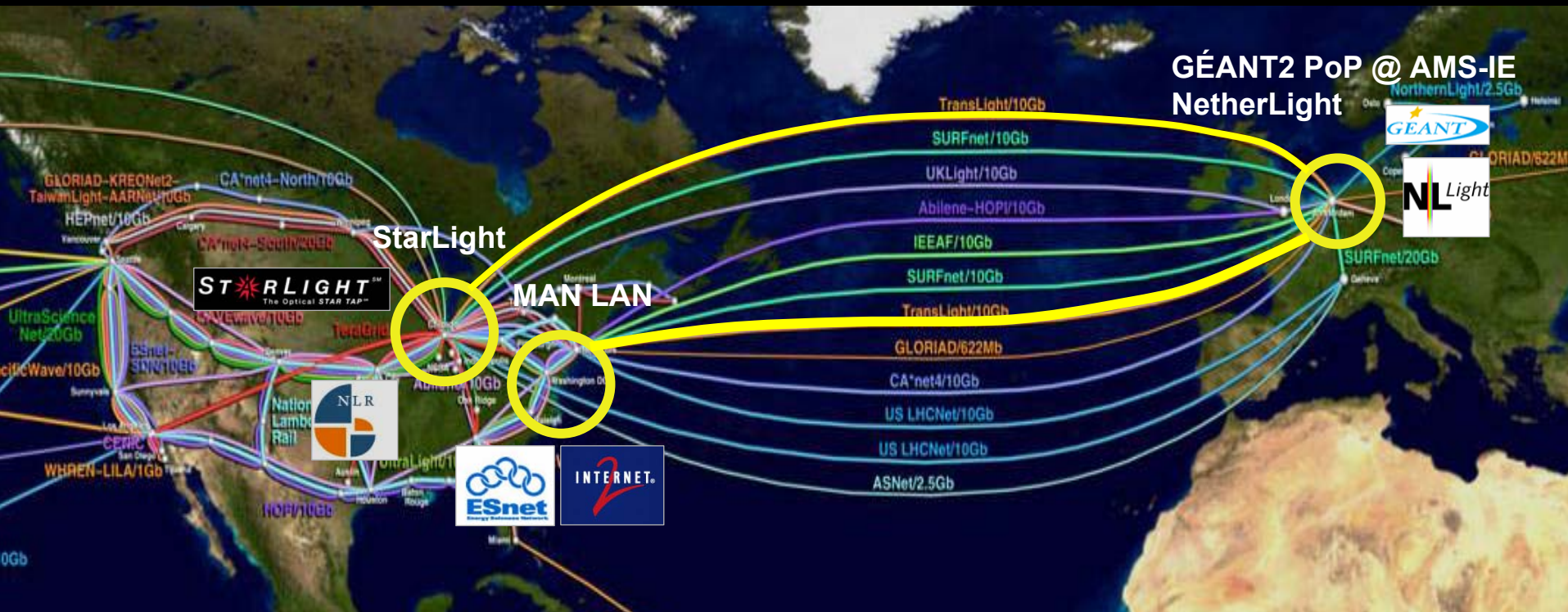
- **OC-192 routed connection between MAN LAN in New York City and the Amsterdam Internet Exchange that connects the USA Abilene and ESnet networks to the pan-European GÉANT2 network**

- **OC-192 switched connection between NLR and RONs at StarLight and optical connections at NetherLight; part of the GLIF LambdaGrid fabric**

10GE Wave Facilitates US West Coast Connectivity
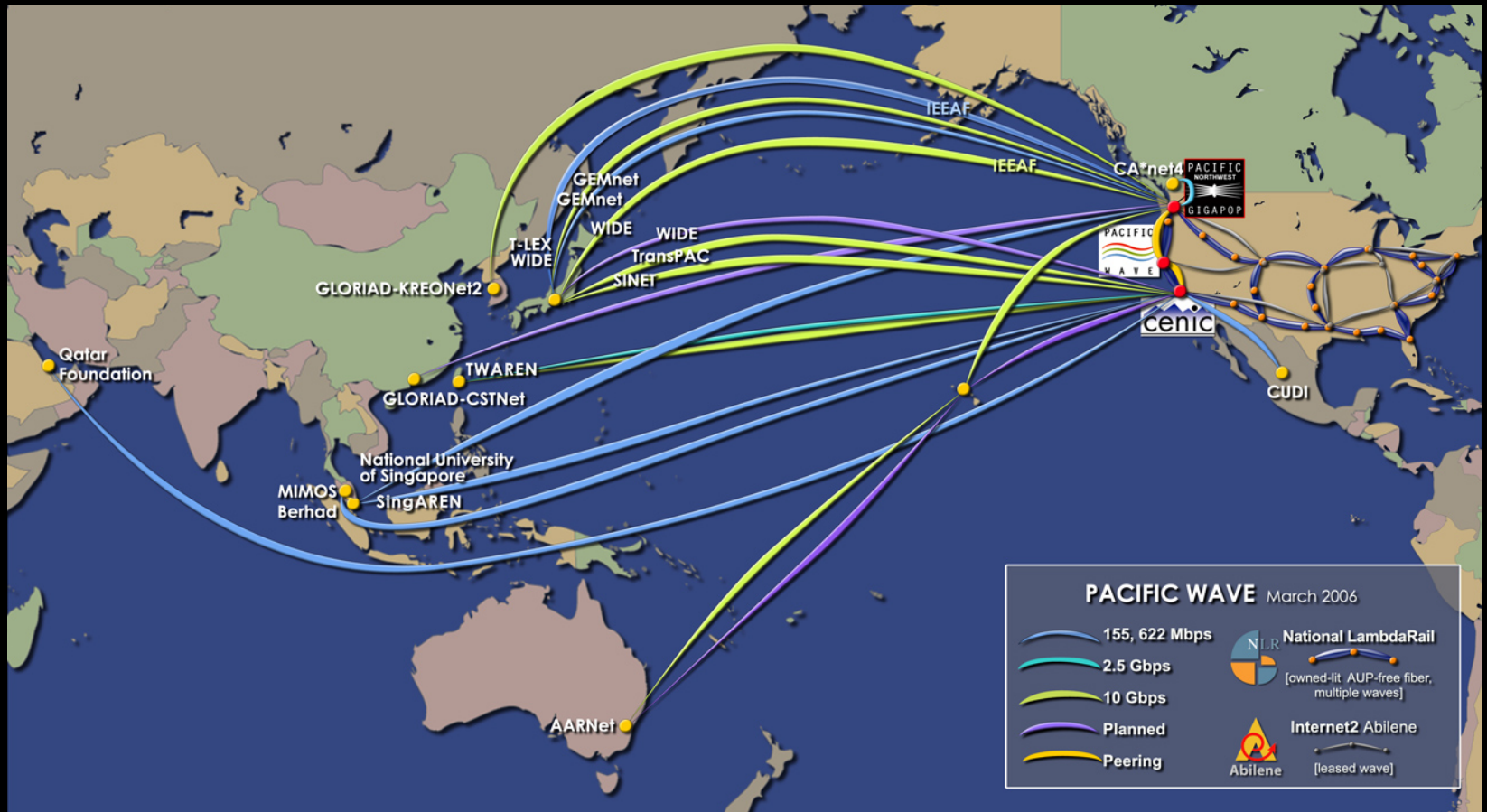
- **Developing a distributed exchange facility on the US West Coast (currently Seattle, Sunnyvale and Los Angeles) to interconnect international and US research and education networks**

www.pacificwave.net/participants/irnc/
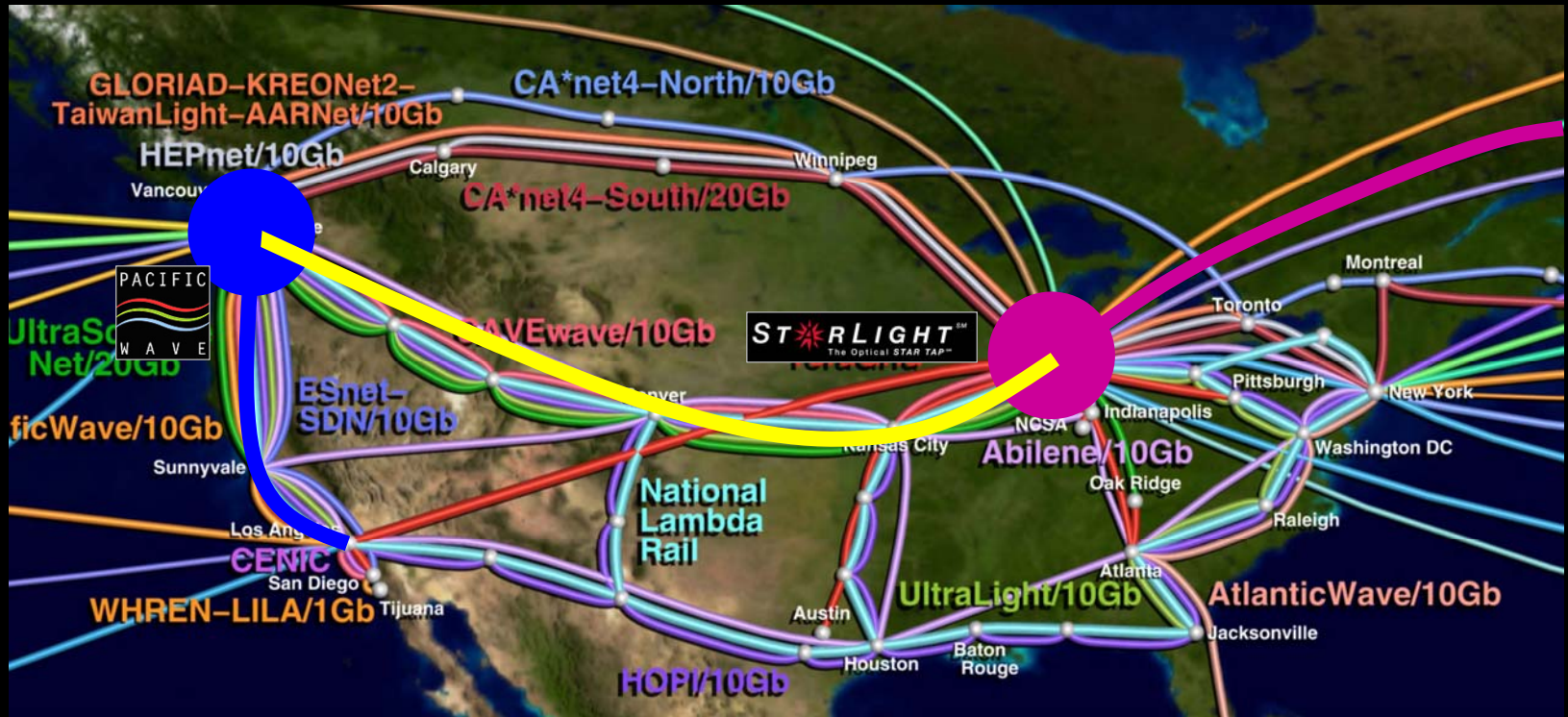
- **TransLight is a 10Gbps lightpath donated by Cisco and deployed by NLR that facilitates US, European and Pacific Rim network connections**

- **Enables participating networks to easily configure direct connections whenever needed**

- **Adds resiliency and stability to the North American segment of GLIF**

IRNC Is Part of the Global Lambda Integrated Facility
Available Advanced Network Resources − September 2005

GLIF is a consortium of institutions, organizations, consortia and country National Research & Education Networks who voluntarily share optical networking resources and expertise to develop the *Global LambdaGrid* for the advancement of scientific collaboration and discovery
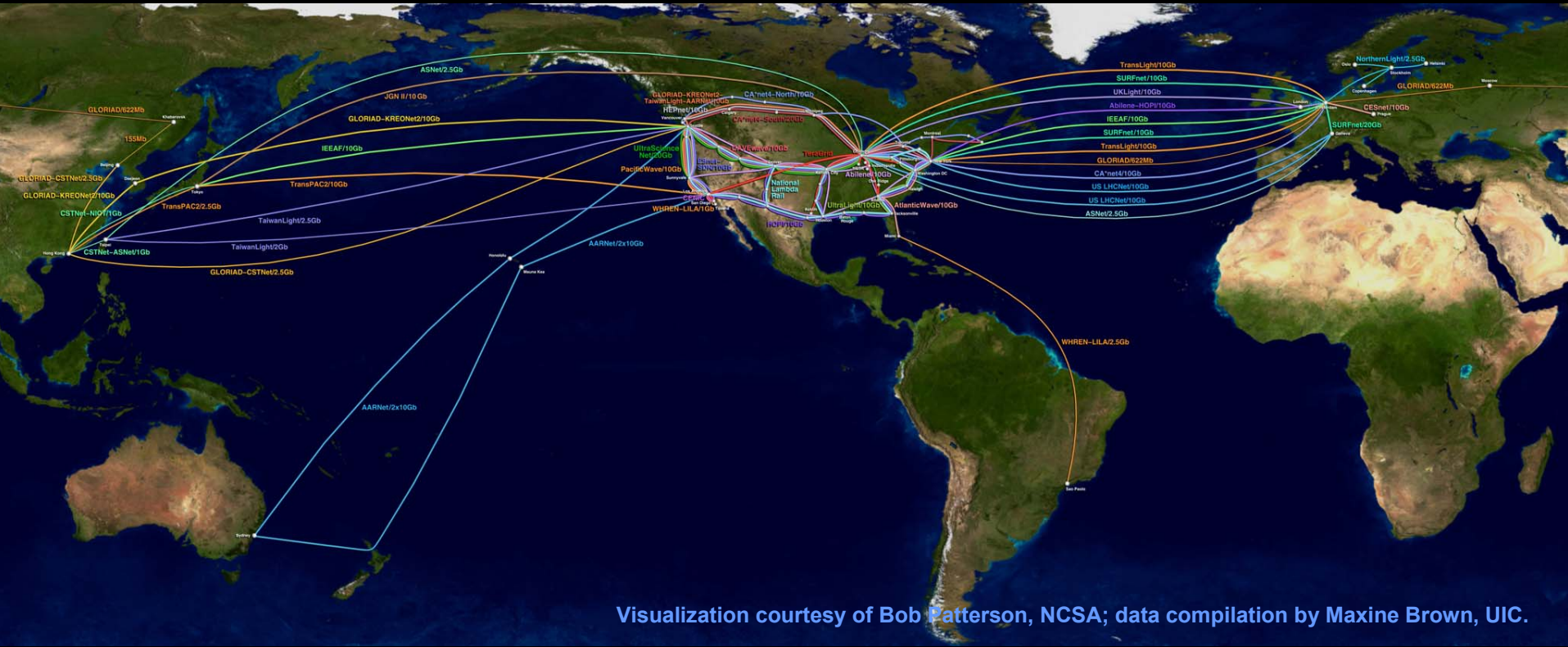

Visualization courtesy of Bob Patterson, NCSA; data compilation by Maxine Brown, UIC.

www.glif.is

IRNC Is About Architecture
Example: The OptIPuter

- **Hardware:** clusters of computers that act as giant storage, compute or visualization peripherals, in which each node of each cluster is attached at 1 or 10GigE to a *backplane* of ultra-high-speed networks

- **Software:** Advanced middleware and application toolkits are being developed for light path management, data management and mining, visualization, and collaboration

Commodity GigE Switch

Fibers or Lambdas
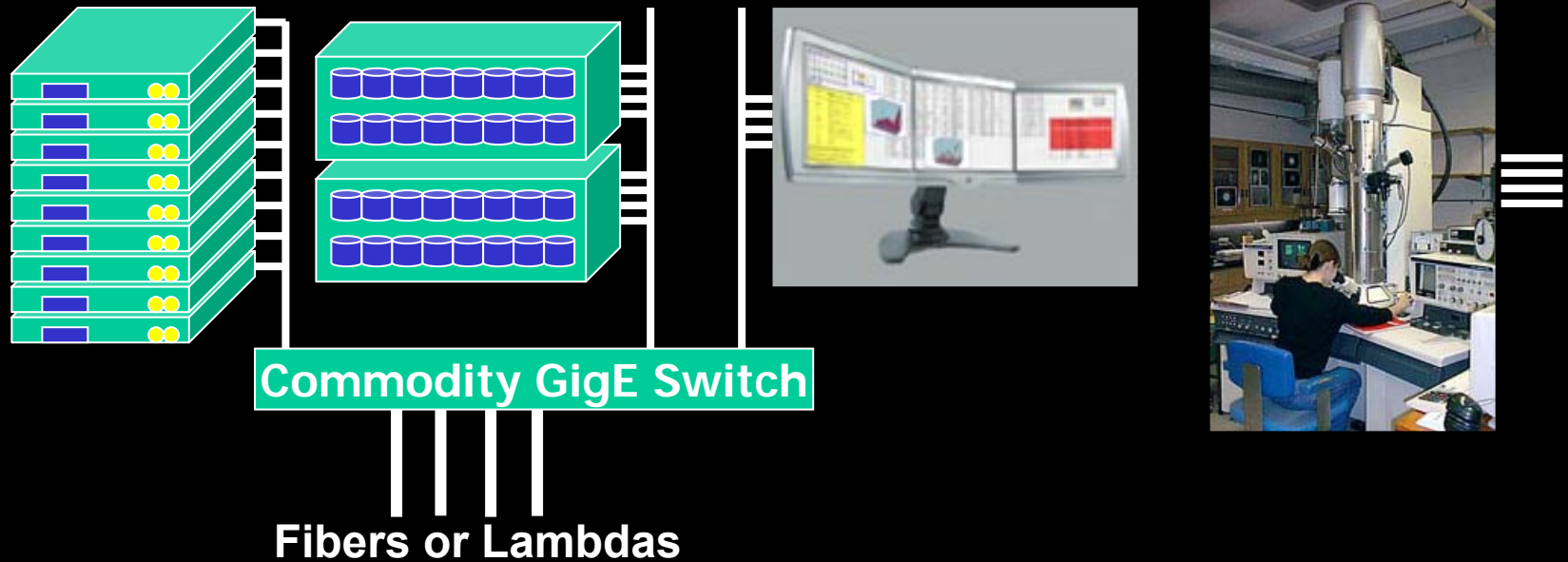
OptIPuter's Scalable Adaptive Graphics Environment (SAGE) Allows Integration of Multiple Data Sources
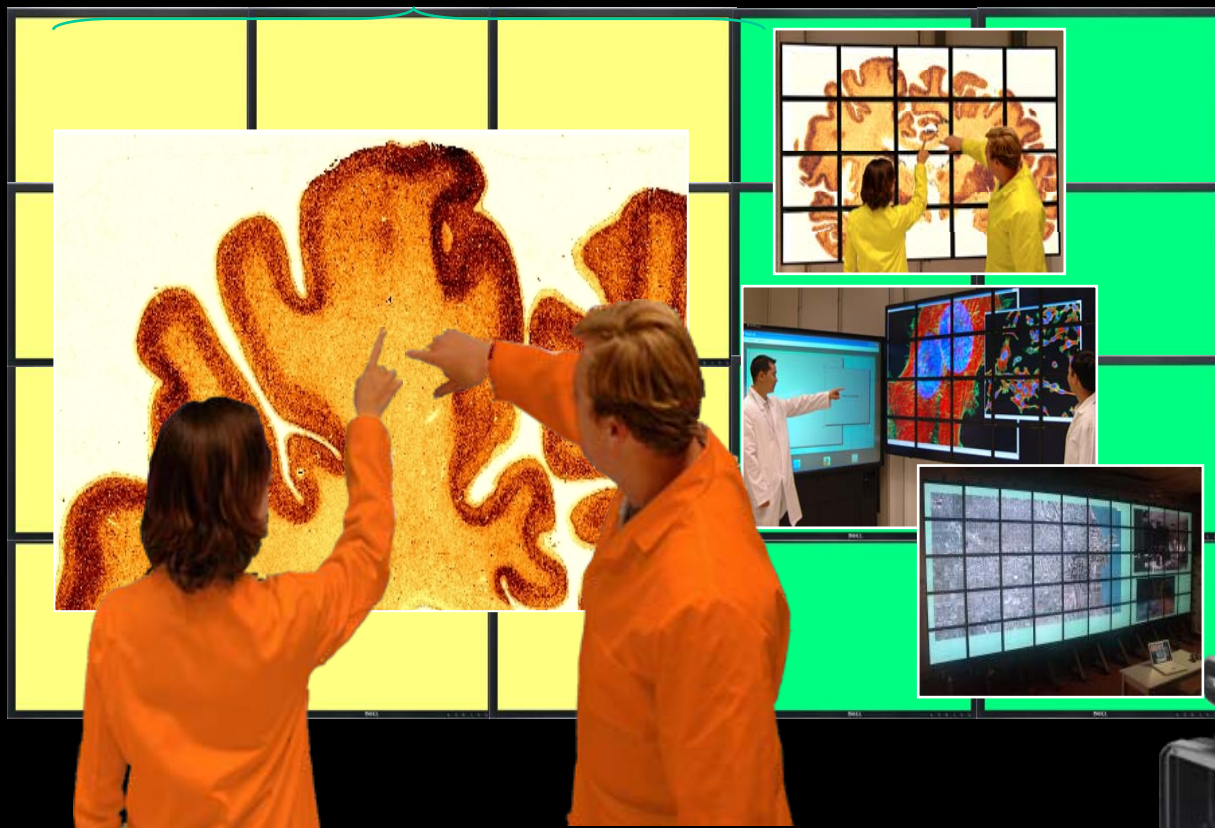
- **UCSD**
- **University of Illinois at Chicago**
- **University of California-Irvine**
- **San Diego State U**
- **University of Southern California**
- **NCSA**
- **Northwestern**
- **Texas A&M**
- **Univ of Michigan**
- **Purdue University**
- **USGS**
- **NASA**
- **CANARIE, Canada**
- **CRC, Canada**
- **SARA, Netherlands**
- **Univ of Amsterdam, The Netherlands**
- **KISTI, Korea**
- **AIST, Japan**

Real-Time Global e-Very Long Baseline Interferometry: Exploring TransLight/StarLight Persistent Connectivity

Onsala 20m

MIT Haystack Observatory

Haystack Correlator

Westford Telescope

Kashima 34m

GGAO mv-3

Westerbork Array

Optical connections dynamically managed using the DRAGON control plane and Internet2 HOPI network

- **Real-time e-VLBI data correlation from telescopes in USA, Sweden, Netherlands, UK and Japan**
- **Achieved 512Mb transfers from USA and Sweden for iGrid 2005**

- **Mid Atlantic Crossroads (MAX) GigaPoP, USA**
- **Information Sciences Institute, USA**
- **Westford Observatory, MIT Haystack, USA**
- **Goddard Geophysical and Atmospheric Observatory, NASA, USA**
- **Kashima, NiCT, Japan**
- **Onsala, Sweden**
- **Jodrell Bank, UK**
- **JIVE, The Netherlands**
- **Westerbork, Observatory/ ASTRON, The Netherlands**

STARLIGHT TRANSLIGHT

Global Lambdas for Particle Physics Analysis Large Hadron Collider

- **Analysis tools for use on advanced networks are being developed that will enable physicists to control worldwide grid resources when analyzing major high-energy physics events**

- **Components of this "Grid Analysis Environment" are being developed by such projects as UltraLight, FAST, PPDG, GriPhyN and iVDGL**

First prize for the SC|05 Bandwidth Challenge went to the team from CalTech, Fermi and SLAC for their entry "Distributed TeraByte Particle Physics Data Sample Analysis," which was measured at a peak of 131.57 Gbps of IP traffic. This entry demonstrated high-speed transfers of particle physics data between host labs and collaborating institutes in the USA and worldwide. Using state-of-the-art WAN infrastructure and Grid Web Services based on the LHC Tiered Architecture, they showed real-time particle event analysis requiring transfers of Terabyte-scale datasets.
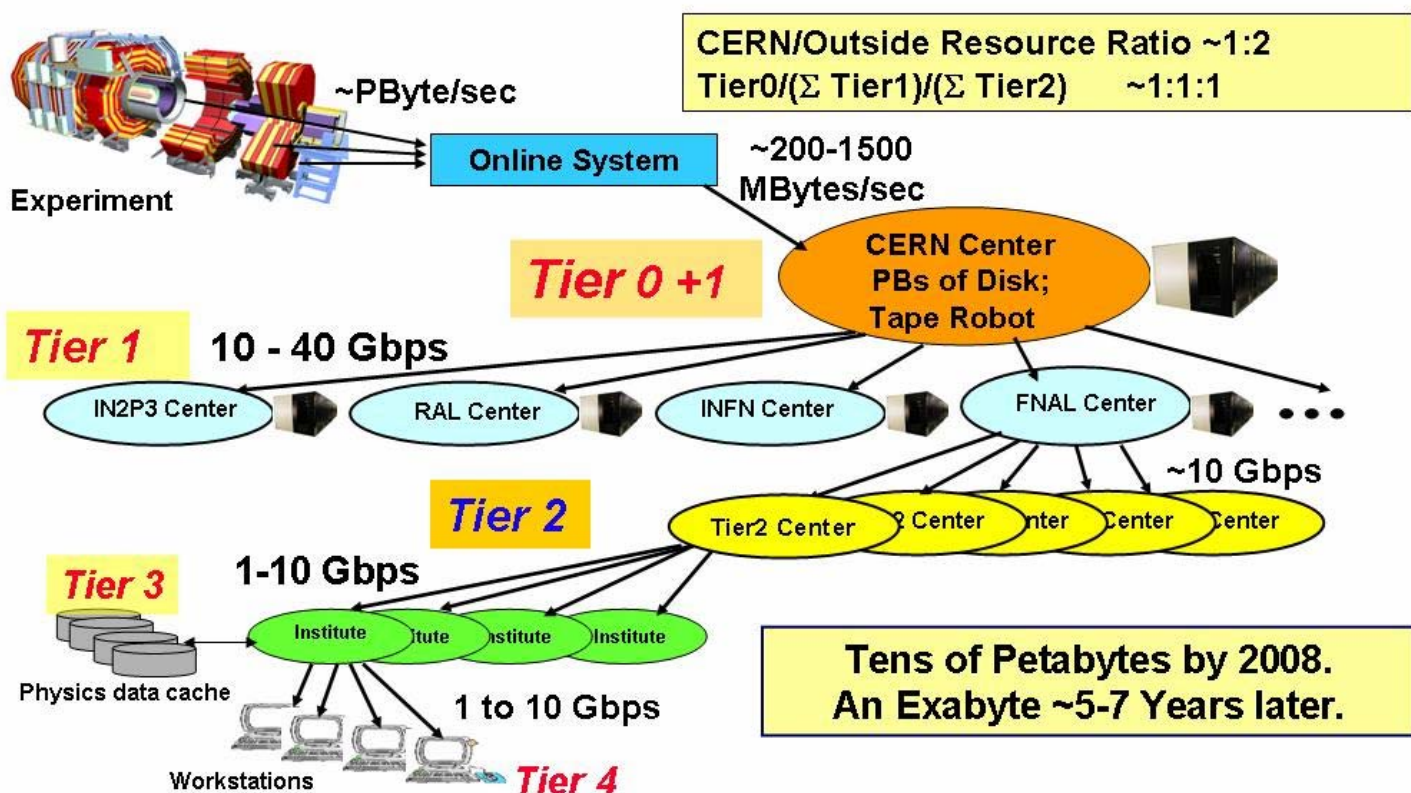
http://ultralight.caltech.edu/web-site/igrid

- **Caltech, Stanford Linear Accelerator Center, Fermi National Accelerator Laboratory, University of Florida, University of Michigan, Cisco, USA**
- **CERN**
- **Korea Advanced Institute of Science and Technology, Kyungpook National University, Korea**
- **Universidade do Estado do Rio de Janeiro, Brazil**
- **University of Manchester, UK**

LHC Data Grid Hierarchy

LHC Data Grid Hierarchy:

Experiment

~PByte/sec

Online System

~200-1500 MBytes/sec

CERN/Outside Resource Ratio ~1:2
Tier0/(Σ Tier1)/(Σ Tier2)   ~1:1:1

Tier 0 +1

CERN Center
PBs of Disk;
Tape Robot

Tier 1   10 - 40 Gbps

IN2P3 Center   RAL Center   INFN Center   FNAL Center   . . .

~10 Gbps

Tier 2   Tier2 Center   2 Center   nter   Center   Center

1-10 Gbps

Tier 3

Physics data cache

Institute   Itute   Institute   Institute

1 to 10 Gbps

Workstations   **Tier 4**

Tens of Petabytes by 2008.
An Exabyte ~5-7 Years later.

Emerging Vision: A Richly Structured, Global Dynamic System

Data Reservoir Project

- **Goal to create a global grid infrastructure to enable distributed data sharing and high-speed computing for data analysis and numerical simulations**

- **Online 2-PFLOPS system (part of the GRAPE-DR project), to be operational in 2008**

Won April 26, 2006 Internet2 Land Speed Records (I2-LSR) in theIPv4 and IPv6 single and multi-stream categories. For IPv4, created a network path over 30,000 kilometers crossing eight international networks and exchange points, and transferred data at a rate of 8.80Gbps, or 264,147 terabit-meters per second(Tb-mps). For IPv6: created a path over 30,000 kilometers, crossing five international networks, and transferred data at a rate of 6.96 Gbps, or 208,800 Tb-mps.

- **University of Tokyo, WIDE Project, JGN2 network, APAN, Fujitsu Computer Technologies, NTT Communications, Japan**
- **Chelsio Communications**
- **StarLight, PNWGP, IEEAF, USA**
- CANARIE, Canada
- SURFnet, SARA and University of Amsterdam, The Netherlands

http://data-reservoir.adm.s.u-tokyo.ac.jp
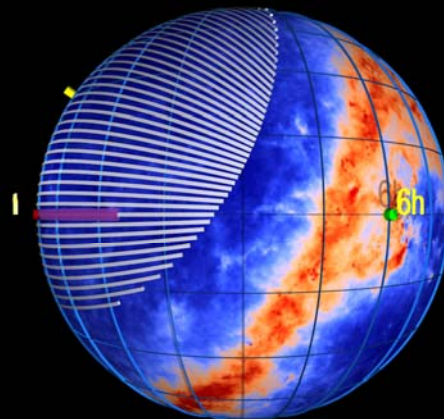
Sloan Digital Sky Survey

Moving Large Data Files with Advanced Network Protocols

- **SDSS-I**
  - **Imaged 1/4 of the Sky in Five Band passes**
    - 8000 sq-degrees at 0.4 arc sec accuracy.
  - **Detecting Nearly 200 Million Celestial Objects**
  - **Measured Spectra Of:**
    - > 675,000 galaxies
    - 90,000 quasars
   - 185,000 stars
- **SDSS-II**
  - **Underway until 2008**

- **Johns Hopkins University, USA**
- **National Center for Data Mining (NCDM), University of Illinois at Chicago, USA**
- **University of California, San Diego**
- **NASA Goddard Space Flight Center; US**
- **Korea Astronomy and Space Science Institute, KISTI, Korea**
- **Institute for Cosmic Ray Research, University of Tokyo, Japan**
- **National Astronomical Observatory, Chinese Academy of Sciences, China**
- **University of Melbourne, Australia**
- **Max-Planck-Institut fur Plasmaphysik, Germany**
- **SARA, The Netherlands**
- **University of Amsterdam, Netherlands**

SDSS 2TB UDT Data Distribution

www.sdss.org

STARLIGHT TRANSLIGHT glif NSF

Interactive Remote Visualization

- **Interactive visualization coupled with computing resources and data storage archives over optical networks enhance the study of complex problems, such as the modeling of black holes and other sources of gravitational waves.**

- **HD video teleconferencing is used to stream the generated images in real time from Baton Rouge to Brno and other locations**
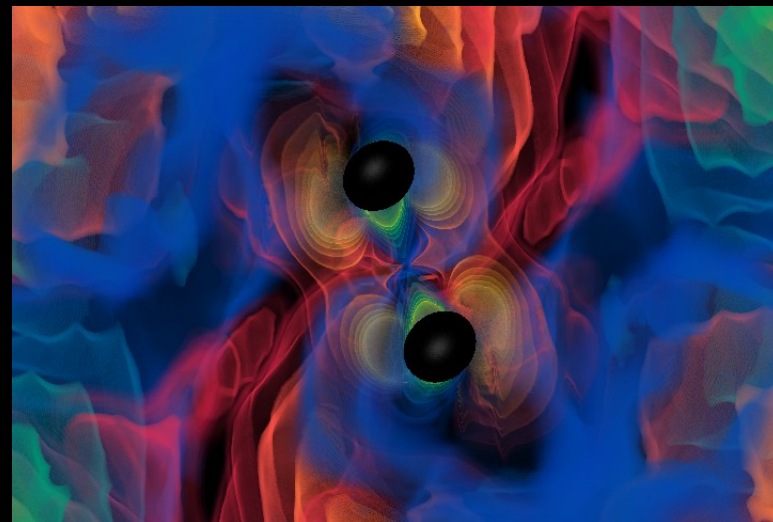
- **Center for Computation and Technology, Louisiana State University (LSU), USA**
- **MCNC, USA**
- **NCSA, USA**
- **Lawrence Berkeley National Laboratory, USA**
- **Masaryk University/CESNET, Czech Republic**
- **Zuse Institute Berlin, Germany**
- **Vrije Universiteit, NL**

www.cct.lsu.edu/Visualization/iGrid2005
http://sitola.fi.muni.cz/sitola/igrid/

evl

STARLIGHT
TRANSLIGHT

glif

NSF

Yangbajing (YBJ) International Cosmic Ray Observatory Chinese/Italian Collaboration

- **The ARGO-YBJ Project is a Sino-Italian cooperation in the Tibetan highland, to be fully operational in 2007**

- **To research the origin of high-energy cosmic rays**

- **Will generate more than 200 terabytes of raw data per year, which will then be transferred from Tibet to the Beijing Institute of High Energy Physics, processed and made available to physicists worldwide**

- **Chinese Academy of Sciences (CAS), China**
- **Istituto Nazionale di Fisica Nucleare, Italy**

http://argo.ihep.ac.cn

iGrid 2005
September 26-30, 2005, San Diego, California

- **4th community-driven biennial International Grid event attracting 450 participants**
  - **An international testbed for participants to collaborate on a global scale**
  - **To accelerate the use of multi-10Gb international and national networks**
  - **To advance scientific research**
  - **To educate decision makers, academicians and industry about hybrid networks**
- **49 demonstrations** showcasing global experiments in e-Science and next-generation shared open-source LambdaGrid services
- **20 countries:** Australia, Brazil, Canada, CERN, China, Czech Republic, Germany, Hungary, Italy, Japan, Korea, Mexico, Netherlands, Poland, Russia, Spain, Sweden, Taiwan, UK, USA
- **25 lectures,** panels and master classes as part of a symposium
- **100Gb into the Calit2 building on the UCSD campus**
- **All IRNC links used!**

www.igrid2005.org

Applications Capable of Insatiable Appetites
Starting on the "S" Curve of Acceptance and Dependence

Most extreme usage is currently done at conferences, to advance understanding and prove concepts, which ultimately get put into practice
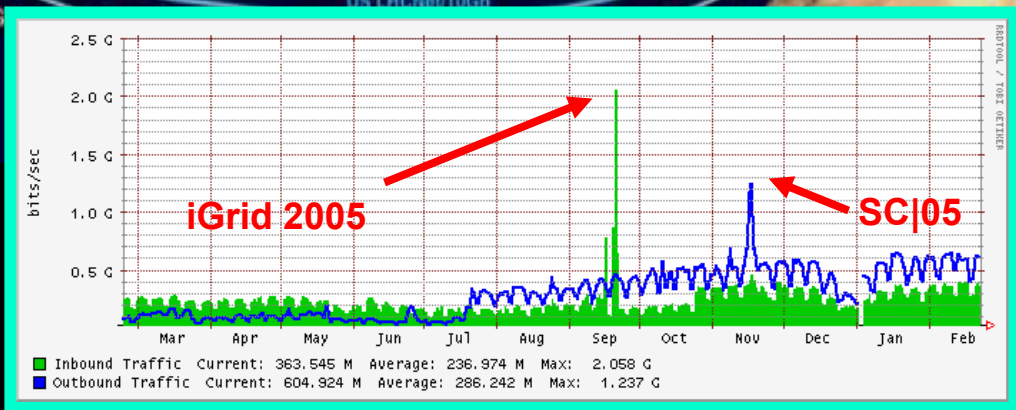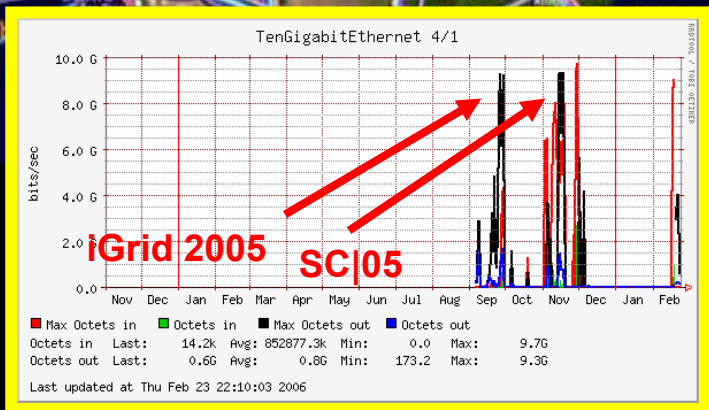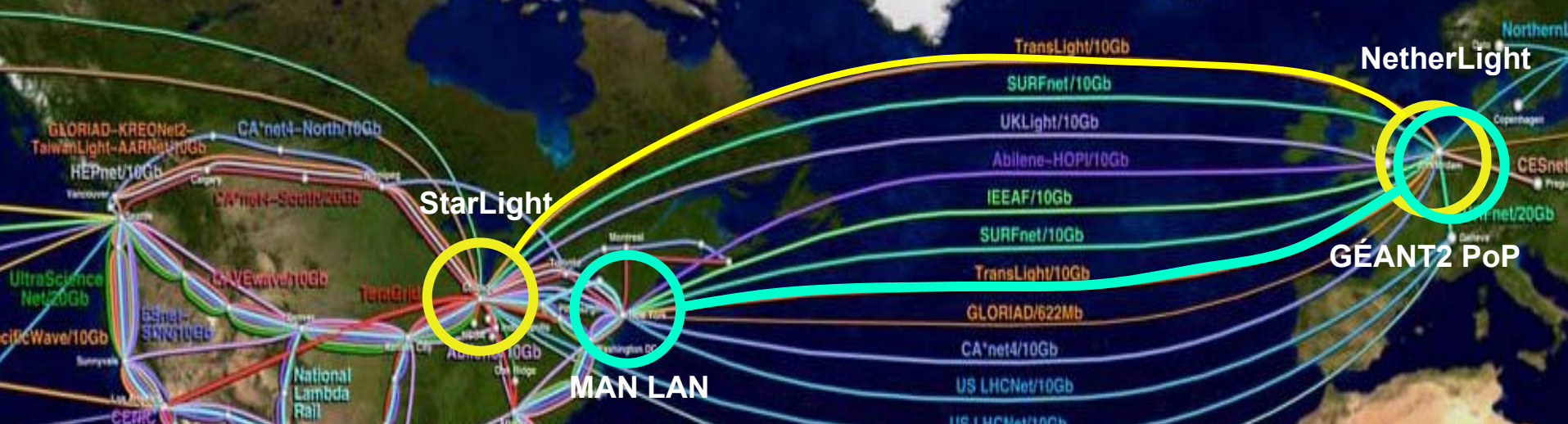
iGrid 2005 Receives CENIC Award

Tom DeFanti   Maxine Brown   Larry Smarr

iGrid 2005 received the CENIC 2006 Innovations in Networking Award for Experimental/ Developmental Applications

CENIC is the Corporation for Education Network Initiatives in California
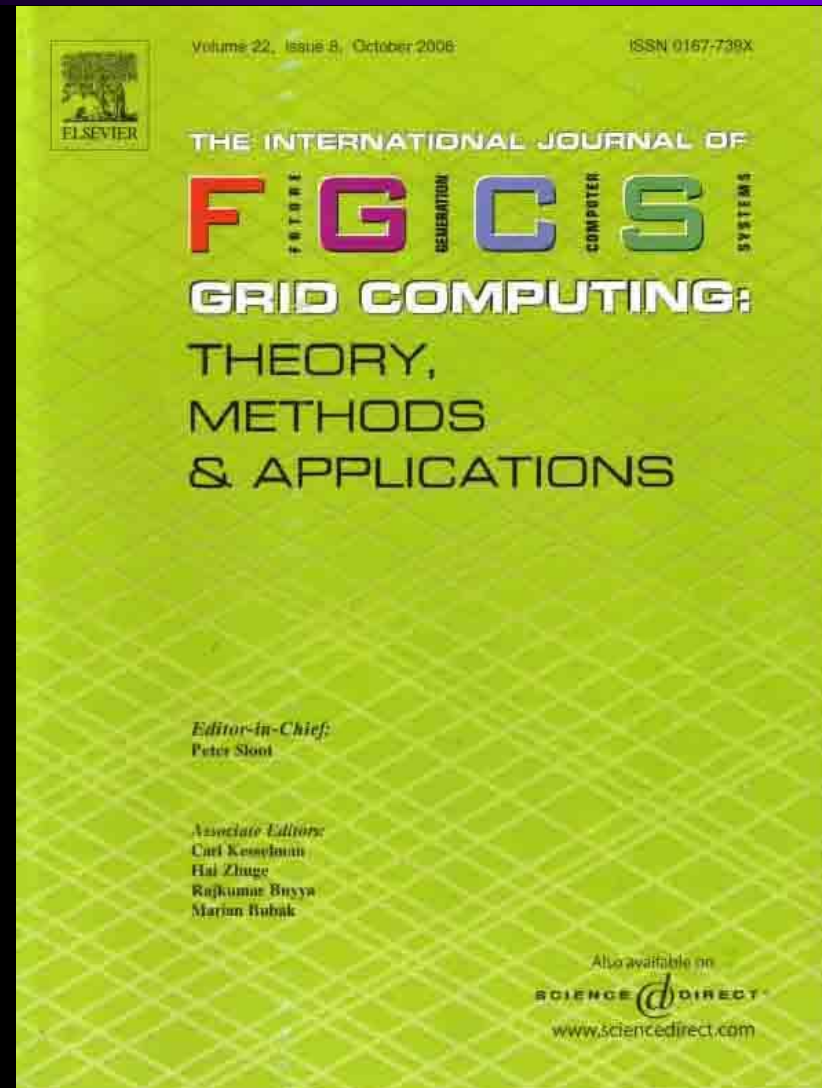
www.igrid2005.org
www.cenic.org

iGrid 2005 Proceedings Available!

Special issue on iGrid 2005: The Global Lambda Integrated Facility
27 referred papers!

Smarr, Larry, Maxine Brown, Tom DeFanti and Cees de Laat (guest editors)

Future Generation Computer Systems, Volume 22, Issue 8, Elsevier, October 2006, pp. 849-1054
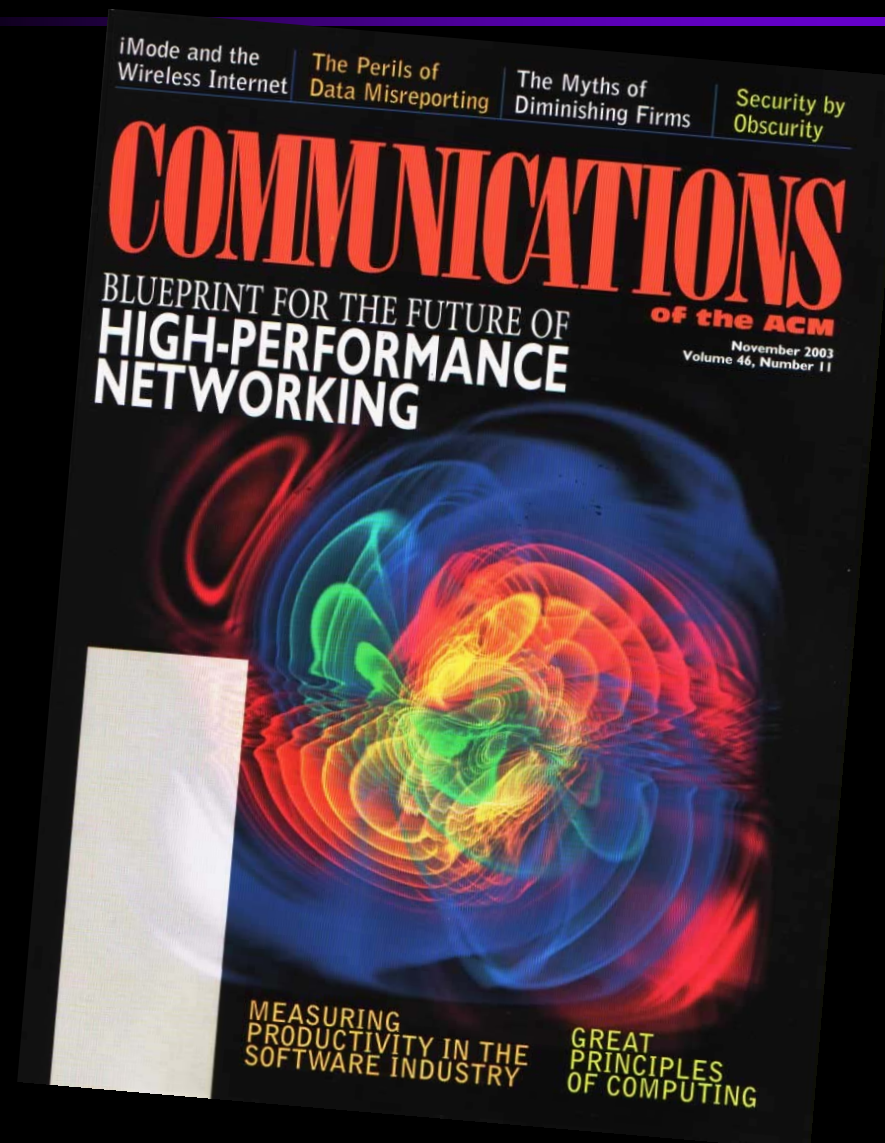

Volume 22, Issue 8, October 2006 — ISSN 0167-739X

ELSEVIER

THE INTERNATIONAL JOURNAL OF

FGCS
FUTURE GENERATION COMPUTER SYSTEMS

GRID COMPUTING:
THEORY, METHODS & APPLICATIONS

Editor-in-Chief:
Peter Sloot

Associate Editors:
Carl Kesselman
Hai Zhuge
Rajkumar Buyya
Marian Bubak

Also available on
SCIENCE DIRECT
www.sciencedirect.com

IRNC Is About More Than Networks…
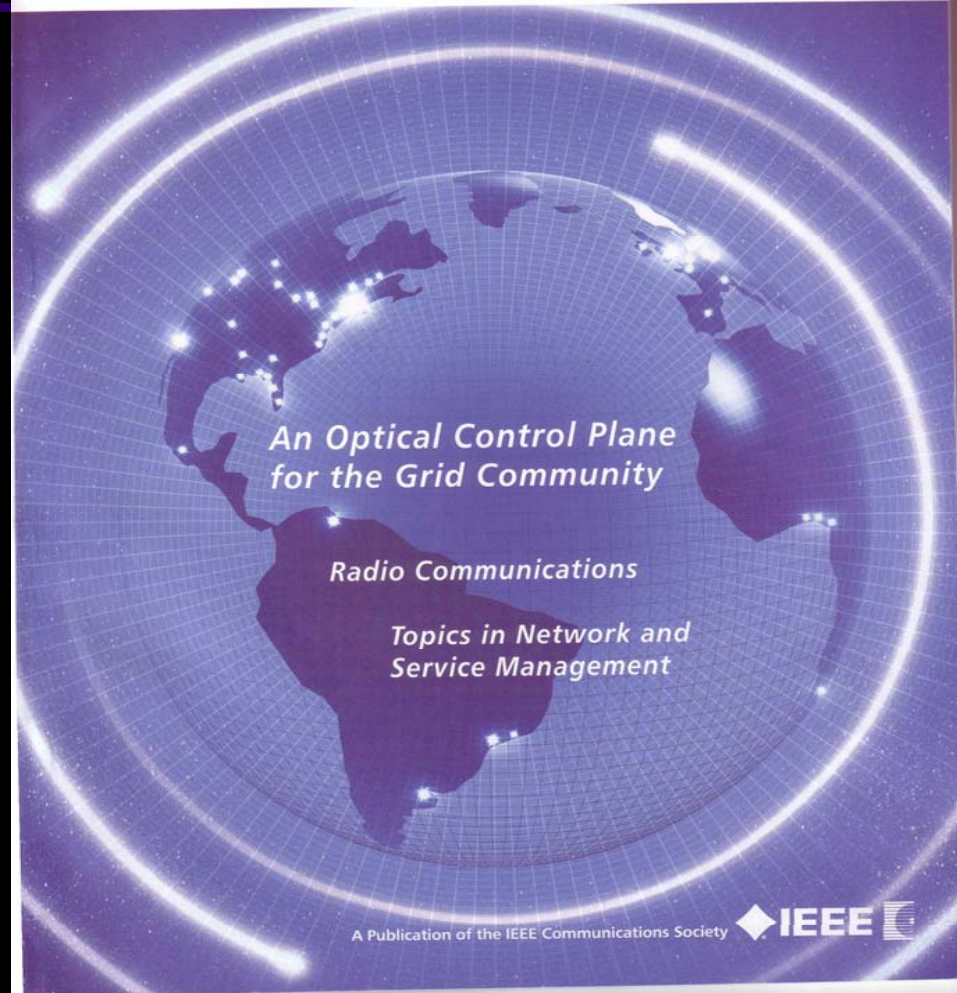## System Integration: Applications, Middleware, Networks

Communications of the ACM (CACM)
Volume 46, Number 11
November 2003

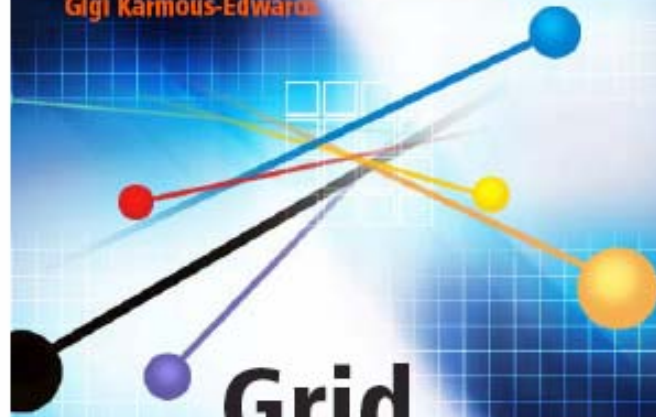**Special issue: Blueprint for the Future of High-Performance Networking**

- *Introduction,* **Maxine Brown (guest editor)**
- *TransLight: a global-scale LambdaGrid for e-science,* **Tom DeFanti, Cees de Laat, Joe Mambretti, Kees Neggers, Bill St. Arnaud**
- *Transport protocols for high performance,* **Aaron Falk, Ted Faber, Joseph Bannister, Andrew Chien, Robert Grossman, Jason Leigh**
- *Data integration in a bandwidth-rich world,* **Ian Foster, Robert Grossman**
- *The OptIPuter,* **Larry Smarr, Andrew Chien, Tom DeFanti, Jason Leigh, Philip Papadopoulos**
- *Data-intensive e-science frontier research,* **Harvey Newman, Mark Ellisman, John Orcutt**

iMode and the Wireless Internet — The Perils of Data Misreporting — The Myths of Diminishing Firms — Security by Obscurity

COMMUNICATIONS of the ACM

BLUEPRINT FOR THE FUTURE OF HIGH-PERFORMANCE NETWORKING

November 2003
Volume 46, Number 11

MEASURING PRODUCTIVITY IN THE SOFTWARE INDUSTRY — GREAT PRINCIPLES OF COMPUTING

www.acm.org/cacm

IEEE Communications March 2006

TransLight/StarLight Sponsors and Collaborators

- **StarLight/TransLight is made possible by NSF cooperative agreement OCI-0441094 to University of Illinois at Chicago**

- **StarLight support from NSF/OCI, DoE/Argonne National Laboratory and Northwestern University**

- **Kees Neggers of SURFnet for his networking leadership**

- **Collaborators National LambdaRail, Internet2 and DANTE/GÉANT2**