STAR TAP 2: Science, Technology And Research Transit Access Point
Award #ANI-9980480
Annual Report May 2000-April 2001

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1. Participants

1.A. Primary Personnel

Participant's Name(s)	Project Role(s)	>160 Hours/Yr
Thomas A. DeFanti	Principal Investigator	Yes
Maxine Brown	Co-Principal Investigator	Yes
John Jamison*	Co-Principal Investigator	Yes

* John Jamison worked at UIC on STAR TAP from Spring 1999-Spring 2000, but continues to act as consultant to the STAR TAP engineers, Alan Verlo and Linda Winkler.

1.B. Other Senior Personnel (Excluding PI and Co-PI)

Additional people who contributed greatly to the project, and received a salary, wage, stipend or other support from this grant:

Participant's Name(s)	Project Role(s)	>160 Hours/Yr
Alan Verlo	Professional staff	Yes
Linda Winkler+	Professional staff	Yes
Laura Wolf *	Professional staff	Yes
Michael McRobbie	Professional staff	Yes
Jim Williams**	Professional staff	Yes
Dana Plepys	Professional staff	Yes

+ It should be noted that Linda Winkler, while not compensated by the University of Illinois at Chicago, serves as part-time STAR TAP engineer with Alan Verlo of EVL/UIC.
* Laura is responsible for STAR TAP documentation, both print and web. She works with Dana Plepys, who has overall responsibility for EVL's web activities.
** Previously Doug Pearson was listed as Senior Personnel on the grant as he was in charge of the STAR TAP NOC at Indiana University. He has been replaced by Jim Williams at Indiana University

1.C. Other Organizations That Have Been Involved as Partners

1.C.1. Management Team

ELECTRONIC VISUALIZATION LABORATORY, UNIVERSITY OF ILLINOIS AT CHICAGO (EVL/UIC). [www.evl.uic.edu]
EVL, over the past several years, has worked with computer scientists and computational scientists at NCSA and Argonne National Laboratory to collect, maintain, develop, distribute, and evaluate tools and techniques for networked scientific computing. EVL is also the lead institution for the STAR TAP infrastructure.

MATHEMATICS AND COMPUTER SCIENCE DIVISION, ARGONNE NATIONAL LABORATORY (ANL). [www.mcs.anl.gov]
ANL has been, and continues to be, a strong supporter of STAR TAP activities. Linda Winkler has facilitated STAR TAP engineering since its inception, and is the lead engineer today; her salary comes from ANL. Rick Stevens, director of the ANL Math and Computer Science Division, is the chair of STAR TAP's International Advisory Committee.

AMERITECH ADVANCED DATA SERVICES (AADS). [www.aads.com]
The AADS Network Access Point (NAP) is an Internet Exchange Point where ISPs can meet to exchange traffic with other attached ISPs. The NAP is a layer 2 switched service that is not directly involved with routing IP datagrams; only forwarding Asynchronous Transfer Mode (ATM) cells between ISPs. The Chicago NAP is a large ATM switch providing both high speed and a high degree of scalability. Interface speeds currently supported

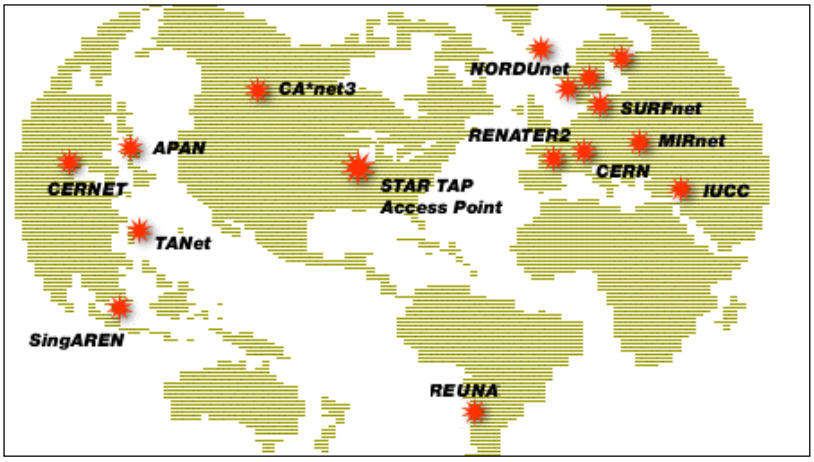
include: DS-3, OC-3c and OC-12c. Ameritech and STAR TAP thus far have been the model for the next generation of NGI eXchanges (NGIXs).

MREN. [http://www.mren.org]
The Midwest's Metropolitan Research and Education Network (MREN) is a 622Mb regional network connecting Midwest-area research institutions. It is a model for "GigaPoPs," or other regional networks. MREN is one of the world's most advanced high-performance broadband networks, developed to support a wide range of advanced research applications requiring high performance and high bandwidth. UIC is one of the founding members of MREN. Joe Mambretti, director of the iCAIR Center at Northwestern University, is the director of MREN and Linda Winkler of ANL is the technical director.

INDIANA UNIVERSITY. [http://www.indiana.edu/~ovpit/]
Indiana provides NOC services for Abilene, TransPAC, EuroLink, MIRnet and, most recently, STAR TAP. Indiana's telecommunications infrastructure consists of central office class voice switches, state-of-the-art ATM and Fast Ethernet networks, a video network, inter-campus WAN, connections to the vBNS, Abilene and TransPAC, and multiple access points to the commodity Internet. Indiana has one of the largest multi-protocol networks among higher education institutions in the US.

INTERNATIONAL CENTER FOR ADVANCED INTERNET RESEARCH (iCAIR), NORTHWESTERN UNIVERSITY. [www.icair.org]
The goal of iCAIR, under the leadership of Joe Mambretti, is to accelerate leading-edge innovation and enhanced global communications through advanced Internet technologies, in partnership with the international community. iCAIR was established to provide a focal point for leading-edge Internet research, innovation, and pre-production deployment. iCAIR is an international research and development center that creates large-scale, advanced digital communication systems based on Internet protocols, in part, by utilizing regional, national and international advanced research networks.

1.C.2. STAR TAP International Research Networks



APAN. [www.apan.net] Asia-Pacific Advanced Network, OC-3

CA*net3. [www.canet3.net] Canadian Network for the Advancement of Research, Industry and Education (CANARIE), OC-3

CERN. [http://cern.web.cern.ch] European Laboratory for Particle Physics, DS-3 and OC-3. (NOTE: As of January 31, 2001, CERN's new 155Mbps circuit to STAR TAP became operational. Initially, it will only be used to peer with Abilene. The old 45Mbps circuit will be retained a few more months to support ongoing experiments.)

CERnet. [www.cernet.edu.cn] China Education and Research Network, DS-3

IUCC. [www.internet-2.org.il] Israel Inter-University Computation Center, DS-3

MIRnet. [http://www.friends-partners.org/friends/mirnet/home.html] US-Russian High Performance International Internet Services, DS-3

NORDUnet. [www.nordu.net] Nordic Countries' National Networks for Research and Education (Denmark, Finland, Iceland, Norway, and Sweden), DS-3

RENATER2. [www.renater.fr] France Research and Education Network, DS-3

REUNA. [www.reuna.cl] Chile National University Network, DS-3

SingAREN. [www.singaren.net.sg] Singapore Advanced Research and Education Network, DS-3

SURFnet. [www.surfnet.nl] The Netherlands Research and Education Network, OC-3

TANet2. [www.tanet2.net.tw] Taiwan Academic Network, DS-3

1.C.3. STAR TAP "Affiliated" International Research Networks

These networks connect to the Ameritech NAP and currently peer with the STAR TAP Router (see Section 2.B). While these networks have not applied to NSF for official STAR TAP status, the STAR TAP Router is AUP-free and any participating STAR TAP member can receive their routes.

SINET. [www.sinet.ad.jp] Japan's Science Information Network. Note: SINET was connected to the STAR TAP Router until September 2000, and now peers with Abilene on the west coast of the USA.

GEMnet. [http://www-grd.rdh.ecl.ntt.co.jp/GEMnet/index.html] is an NTT Laboratory (Japan) research network provided to link Japanese universities to MREN and Abilene for specific networking research projects.

1.C.4. United States Advanced Networks

Abilene. [www.ucaid.edu/abilene] US University Corporation for Advanced Internet Development (UCAID), Internet2 Advanced Network, OC-12

DREN. [www.hpcmo.hpc.mil/Htdocs/DREN/index.html] US Dept. of Defense Research and Engineering Network, DS-3

ESnet. [www.es.net] US DOE Energy Sciences Network, OC-3

NISN. [www.nisn.nasa.gov] US NASA Integrated Services Network, OC-3

NREN. [www.nren.nasa.gov] US NASA Research and Education Network, OC-3

vBNS/vBNS+. [www.vbns.net] US NSF Very high-performance Backbone Network Service/MCI Research Network, OC-12

1.C.5. Consortia

Consortia of American universities and National Research Networks, which serve to facilitate connectivity to U.S. high-performance network service providers, such as the vBNS or Abilene. Euro-Link, MIRnet and TransPAC are funded in part by the NSF's High Performance International Internet Services (HPIIS) program.

AMPATH. [www.ampath.fiu.edu]
AmericasPATH, or AMPATH, is a Florida International University (FIU) and Global Crossing (GC) collaborative project to interconnect the Research and Education networks of South and Central America, the Caribbean, and Mexico, to networks in the US and other countries.

EURO-LINK. [www.euro-link.org]
Euro-Link is a HPIIS-funded consortium of UIC, the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden), the Netherlands, France, and Israel. Euro-Link, under the leadership of UIC, is a National Science Foundation-funded initiative that facilitates the connection of European and Israeli National Research Networks to the high-performance vBNS and Abilene networks via STAR TAP. EVL has an active research program with SARA (Academic Computing Services Amsterdam) in The Netherlands, and is developing application-level network performance/monitoring tools to help researchers better understand bandwidth and latency issues involved in transoceanic tele-immersion applications.

MIRNET. [http://www.friends-partners.org/friends/mirnet/home.html]
MIRnet is a HPIIS-funded consortium of the University of Tennessee and Russia

TRANSPAC. [www.transpac.org]
TransPAC is a HPIIS-funded consortium of Indiana University and the Asian-Pacific Advanced Network Consortium (APAN, which includes Australia, Japan, Korea, and Singapore)

1.D. Other Collaborators or Contacts

1.D.1. Collaborators

ALLIANCE and NATIONAL CENTER FOR SUPERCOMPUTING APPLICATIONS (NCSA), UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN. [http://alliance.ncsa.uiuc.edu]
The NSF Partnerships for Advanced Computational Infrastructure (PACI) Cooperative Agreement to the National Computational Science Alliance (the "Alliance"), whose lead institution is the National Center for Supercomputing Applications (NCSA), funds, in part, the UIC Electronic Visualization Laboratory (EVL) to deploy research results in virtual reality, networking, visual supercomputing, distributed computing, and networked collaboration. (PACI does not fund basic research; it assumes partners already *have* research results and are funded by peer review in their disciplines.) NCSA and Alliance director Dan Reed is very supportive of STAR TAP.

CALIFORNIA INSTITUTE FOR TELECOMMUNICATIONS AND INFORMATION TECHNOLOGY [Cal-(IT)2], UNIVERSITY OF CALIFORNIA SAN DIEGO. [www.calit2.net]
Cal-(IT)2, a new center founded by Larry Smarr, is a distributed center, conducting research at both the UCSD and UC-Irvine (UCI) campuses. UCSD and UCI will conduct research in core technologies needed to expand the reach and capacity of the global wireless Internet and its emerging all-optical core. Initially, it will use the new telecommunications infrastructure to advance applications important to California's economy, including education, environmental monitoring, health care delivery, transportation, and new media arts, but has ambitions to expand collaborations internationally. Cal-(IT)2 fully encourages the goals of STAR TAP.

CAVERNUS. [http://www.ncsa.uiuc.edu/VR/cavernus]
The CAVE Research Network User's Society (CAVERNUS) gives the worldwide community of VR device users a place to share ideas, solutions and discoveries as they interconnect over high-speed networks. The universities, research laboratories and commercial R&D facilities supporting this web site are also the primary users of EVL's CAVERNsoft. CAVERNUS hosts an advanced CAVE workshop series that introduces advanced programming and visualization techniques to optimize the use of projection-based virtual-reality display systems, and hosts Birds of a Feather (BoF) or Special Interest Group (SIG) meetings at major conferences. As EVL continues to enhance CAVERNsoft, we conduct network and visualization experiments with international collaborators via STAR TAP.

EMERGE. [http://www.evl.uic.edu/cavern/EMERGE/]
EMERGE is a DoE funded effort to achieve and demonstrate Differentiated Services (DiffServ) over the Midwest Metropolitan Research and Education Network (MREN), ESnet and Abilene. Several universities that connect to MREN, notably UIC, NU, UChicago/ANL, UIUC/NCSA and UWisconsin-Madison, have substantial DoE research grants for networked collaborative problem solving. One immediate goal of EMERGE has been to get these labs DiffServ-enabled with routers, Grid middleware and application test suites that verify the benefits of the DiffServ approach to Quality of Service (QoS). Another goal is to explore MREN interoperability with ESnet (an IP-over-ATM network) and Internet2/Abilene (an IP-over-SONET network) when DiffServ is enabled. A more ambitious

inter-agency and international goal is to extend these QoS experiments to Europe and Asia via STAR TAP. (CERN has already participated in EMERGE experiments, in part, by establishing a successful DiffServ testbed between its lab and Northwestern's iCAIR.)

GLOBUS/ GLOBAL GRID FORUM. [http://www.globus.org, www.globalgridforum.org]
Globus is a joint project of ANL and the University of Southern California's Information Sciences Institute, with significant contributions from NCSA, NASA Ames, the Aerospace Corporation, and other partners. The Globus project is developing basic software infrastructure for computations that integrate geographically distributed computational and information resources. CAVERNsoft uses Globus I/O software to tie geographically distributed virtual environments together for collaborative sessions. The Globus leadership recently founded the Global Grid Forum (Global GF), a community-initiated forum of individual researchers and practitioners working on distributed computing, or Grid, technologies; Global GF participants come from over 150 participating organizations, with financial and in-kind support coming from Global GF sponsoring companies and institutions.

GRID PHYSICS NETWORK (GriPhyN). [www.griphyn.org]
GriPhyN is a team of experimental physicists and information technology (IT) researchers who plan to implement the first Petabyte-scale computational environments for data-intensive science in the 21st century. Driving the project are unprecedented requirements for geographically dispersed extraction of complex scientific information from very large collections of measured data. To meet these requirements, GriPhyN will deploy computational environments called Petascale Virtual Data Grids (PVDGs) that meet the data-intensive computational needs of a diverse community of thousands of scientists worldwide. While GriPhyN is an NSF-funded program under the leadership of Paul Avery of the University of Florida and Ian Foster of ANL, the focus is on accessing data generated from CERN experiments. Hence, STAR TAP is of utmost importance to GriPhyN, and the European Union-funded counterpart, the European Data Grid project.

NETWORK FOR EARTHQUAKE ENGINEERING SIMULATION (NEES). [www.neesgrid.org, www.eng.nsf.gov/nees].
The NEESgrid integration project is being organized by NCSA and funded by the NEES program at NSF. The NEESgrid project is a six-month scoping study, with the goal of developing a systems design for the integration of experimental and computing and communications facilities for use by the earthquake engineering community.

1.D.2. Contacts

STAR TAP has consulted with the following International Research Networks about connecting to Chicago. An asterisk (*) precedes the names of those networks whose connections are imminent.

Africa (interest expressed by NIH and other US research institutions)
* Argentina (RETINA)
Australia (AAIREP, the Australian Advanced Internet Research and Education Program) (NOTE: Australia is currently connected to STAR TAP via APAN.)
Belgium (BELNET, the Belgian National Research Network) (Now connected through DANTE/Abilene in NYC)
* Brazil (ANSP, the Academic Network at Sao Paulo)
Brazil (RNP, the Brazilian National Research and Education Network)
Central and Eastern Europe (CEESat.net Satellite Network), in collaboration with the Central and Eastern Europe (CEENet) organization that represents the national academic network administrations of 27 CEE and some Asian countries, including a number of former USSR countries; also received an inquiry from Eastern European university network ZENWA. (Now connected through DANTE/Abilene in NYC)
Costa Rica (CRnet)
England (JANET) (Now connected through Abilene in NYC)
Europe (early inquiries from DANTE; interest from FLAG Telecom) (Now connected through DANTE/Abilene in NYC)
Germany (BelWue, the Baden-Wuerttemberg Extended LAN scientific regional network); in early days of STAR TAP, also had discussions with DFN. (DFN is now connected through Abilene in NYC)
Hong Kong (HARNET, Hongkong Academic and Research Network)
Ireland (HEAnet, the National Research and Educational network of Ireland)
* Korea (KOREN/KREONET networks, under the direction of KISTI)

Puerto Rico (Connecting via Abilene through AMPATH in Miami)
Philippines (PREGINET, the Philippines Research, Education, and Government Information Network)
Romania (Romanian Academic Network)
Saudi Arabia (King Fahd University of Petroleum and Minerals)
Switzerland (SWITCHng: Switzerland (SW) Information Technology (IT) Confederatio Helvetica (CH) next generation (ng)
Thailand (UniNet, the Thai Inter-University Network)
US JOI/CORE network (Joint Oceanographic Institutions, Inc., a consortium of 14 US oceanographic institutions. [www.joi-odp.org], and Consortium for Ocean Research and Education [http://core.ssc.erc.msstate.edu]

2. Activities and Findings

2.A. Research Activities

The Science, Technology and Research Transit Access Point (STAR TAP) initiative was created in 1997 by the National Science Foundation (NSF award ANI-9712283 to UIC) to provide a persistent infrastructure to facilitate the long-term interconnection and interoperability of advanced international networking in support of applications, performance measuring, and technology evaluations. Over the years, we have worked hard to successfully position STAR TAP as a testbed/model for next-generation global NGI eXchanges (NGIXs).

Beginning in 2000, STAR TAP funding was renewed (NSF award ANI-9980480 to UIC, and called *STAR TAP 2* only for the purposes of the proposal) for an additional three years, to implement advanced network engineering solutions to maintain and improve functionality. STAR TAP continues to be a global-scale laboratory in support of applications, performance measuring, and technology evaluations. STAR TAP's role in providing persistent services as a global exchange point for the Nation demands meeting these engineering challenges. Our users expect STAR TAP to grow in capacity and sophistication.

2.B. Research Findings

2.B.1. Peering: Bi-Lateral Agreements and STAR TAP Router

STAR TAP runs in an Acceptable Use Policy (AUP)-free mode; that is, connecting networks must agree pair-wise regarding acceptable use. STAR TAP relies on mature ATM switching as provided by Ameritech. Once connected to STAR TAP, the NRNs, in addition to connecting to the vBNS, can peer with other US Next Generation Internet networks, UCAID's Abilene, and advanced networks from other countries. They can peer by bilateral agreement, which is functionally implemented with a full-mesh ATM Private Virtual Circuit (PVC) layer-2 service at the switch. Or, they can do level-3 peering using the STAR TAP Router. They may also connect to one or more ISPs at the AADS facility, which is outside the scope of STAR TAP, but a useful capability nonetheless.

The STAR TAP Router was introduced in November 1999 to facilitate peering among the ~20 National Research Networks (NRNs) connected to STAR TAP. Due to individual policy restrictions, the vBNS, Abilene, and ESnet do not peer with the STAR TAP Router.

A current list of STAR TAP peers (both level 2 and level 3 peering) can be found on the STAR TAP site, at [http://www.startap.net/ENGINEERING/].

2.B.2. IPv6 Tunnel Service at the 6TAP

The 6TAP [www.6tap.net], an IPv6 service run by ESnet and CANARIE and hosted by STAR TAP, is up and running. 6TAP supports IPv6 over IPv4 tunnels and IPv6 performance measurement and statistics.

2.B.3. NLANR Web Cache

Duane Wessels of NLANR built and tested a Web Cache, running the Squid caching software, for STAR TAP. The cache PC was installed at Ameritech in December 1999. NAP.NET donated ISP service over a 1 MB connection. The cache is integrated into NLANR's Global Caching Hierarchy.

2.B.4. NLANR Performance Measurement

An NLANR AMP (Active Measurement Platform) box was installed at STAR TAP and information is accessible from the STAR TAP web pages [http://www.startap.net/ENGINEERING/PERFORM.html].

2.B.5. Differentiated Services (DiffServ) EMERGE Testbed

A STAR TAP Cisco 7507 DiffServ router, to be used for international EMERGE experiments, was installed at Ameritech in December 1999. To date, CERN and iCAIR have used it to run experiments [www.icair.org/inet2000]; Russia, Singapore and Amsterdam have expressed interest in running experiments as well. This router is an

extension of UIC's EMERGE project [www.evl.uic.edu/cavern/EMERGE] (see Section 1.D: Other Collaborators or Contacts).

EMERGE is a DoE funded effort to achieve and demonstrate DiffServ over MREN, ESnet and Abilene. One immediate goal of EMERGE has been to get these MREN-university labs DiffServ-enabled with routers, Grid middleware and application test suites that verify the benefits of the DiffServ approach to Quality of Service (QoS). Another goal is to explore MREN interoperability with ESnet (an IP-over-ATM network) and Internet2/Abilene (an IP-over-SONET network) when DiffServ is enabled. Local DiffServ experiments between EVL and ANL have been completed. One major finding is that while DiffServ is able to provide bandwidth guarantees to applications, it is unable to provide latency recovery. A draft report is available at [http://www.evl.uic.edu/cavern/papers/DiffServ12_12_2K.pdf]

Follow-on efforts with the EMERGE testbed and team will involve testing Multi-Protocol Label Switching (MPLS) to manage DiffServ and other flows, extending the Grid Services Package (authentication/security software developed at NCSA) and incorporating visualization into monitoring tools, adding haptic and rendering flows to the tele-immersion network performance tests, creating a test suite for multi-resolution compressed digital video, continuing interoperability testing and tuning with ESnet and Abilene, and increasing international efforts.

Given that ESnet-funded university labs will achieve connectivity for some time over a mixture of IP/ATM and IP/SONET links, interoperability of QoS is critical to high-performance scientific applications. EMERGE's goal is to build the teams and technology to help achieve guaranteed bandwidth across large distances.

2.B.6. Multicast

Many of the STAR TAP participants have Native Multicast enabled. These networks are documented at [http://www.startap.net/ENGINEERING/TECHINFO.html]. DREN recently contacted us to also be multicast enabled.

2.B.7. NOC Services

The Global NOC recently launched newly designed STAR TAP NOC web sie [http://noc.startap.net]. The Global NOC web site ties together all NOC-supported network services for Abilene, STAR TAP, TransPAC, Euro-Link, MIRnet and AMPATH [http://globalnoc.iu.edu/]. The Global NOC's email address is <globalnoc@iu.edu>.

2.B.8. Distributed STAR TAP

STAR TAP management has designated several international carriers as "Distributed STAR TAP" providers. These carriers can not only carry transoceanic or cross-continent National Research Network (NRN) traffic to the US, but can make sure the connections come in a timely and efficient manner to Chicago and the Ameritech NAP. This designation is for the convenience of our NRN partner networks, to assure them there won't be connectivity delays because a carrier is unfamiliar with Chicago's telecommunications infrastructure. Current "Distributed STAR TAP" providers are Teleglobe, Cable & Wireless and IMPSAT.

2.B.9. International Transit Network (ITN)

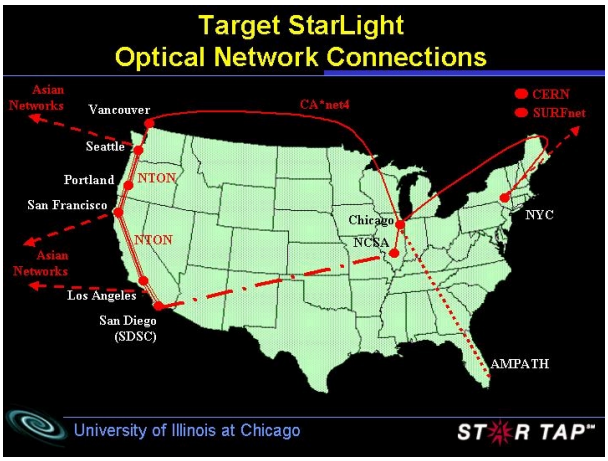
In October 2000, the CA*net3 ITN and Abilene ITN services were offered by CANARIE and Internet2 to facilitate connectivity among NRNs that now connect to one of the coasts of North America. We will soon update the STAR TAP web page with information and pointers to the CANARIE and Internet2 web pages that contain more information.

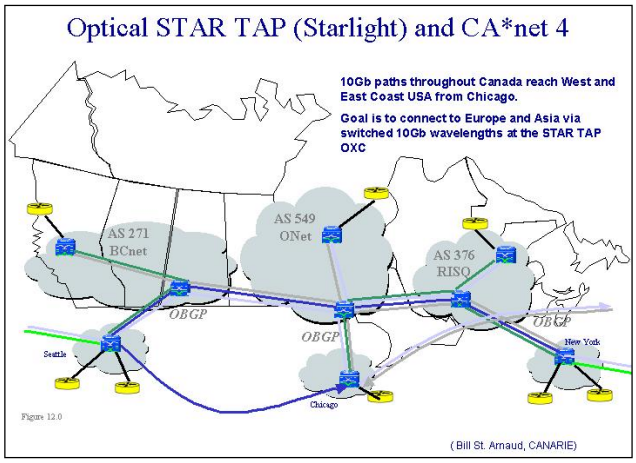
2.B.10. StarLight

StarLight Connectivity

StarLight, the next-generation Optical STAR TAP, is planned to be operational in 2001, with expansion plans running until 2006. The StarLight facility is being first located at Northwestern University's downtown campus, at 710 N. Lake Shore Drive, and managed and operated by iCAIR. StarLight will provide a mechanism for (university) customer-controlled 10 Gigabit network flows to be switched and routed to research networks and commercial

networks. Its architecture is designed to be distributable among opportune points of presence, university campuses, carrier meet points, and so on. StarLight will enable ways, via grid middleware, for bandwidth to be scheduled, allocated, and delivered for use by high-performance computational, data and visualization grids. StarLight moves the network intelligence to the edges, that is, the campuses, inverting the current high-cost telco model of central backbone control. StarLight is leveraging the intellectual lead of CA*net4, the Canadian optically switched network planned to stretch coast-to-coast, connecting to the US in Chicago, Seattle and New York City.





StarLight expects to handle wavelengths from Canada and Holland this year, CERN and Japan next year, as well as, of course, I-WIRE/Indiana. Asian and European connectivity would be greatly facilitated by donated wavelengths to the coasts, which we are investigating. South American connectivity depends on Miami's AMPATH.

- Canadian projects include research in large-scale distributed storage, customer-empowered networks, and OBGP.
- Dutch projects include distributed supercomputing, QoS, and collaborative virtual reality.
- CERN needs bandwidth to enable scientists worldwide to access high-energy physics data generated by colliders in Geneva.
- Japanese projects involve super-high-definition digital cinema, optical routing, QoS, access to large physics, biology, and astronomy instruments via the Japan Gigabit Network, WIDE network and others.
- South American projects involve major observatories in Chile, Argentina, and, via Miami, Puerto Rico.

StarLight Services

STAR TAP has demonstrated the importance of providing advanced digital communication services to a worldwide scientific research community. However, current initiatives, such as the iGrid, clearly indicate that the next-generation of global scientific research will require a set of advanced networking services that is significantly more sophisticated, with much higher capacity potential and substantially higher performance.

StarLight will provide these advanced network services by implementing an advanced optical infrastructure optimized for large-scale global scientific research. This infrastructure will provide mechanisms to allow for application signaling via specialized APIs designed to interact with high-performance optical networks. The StarLight architecture will be based primarily, although not exclusively, on IETF techniques for IP management of optical components as well as new methods for provisioning IP-over-wavelength.

A general control mechanism will be derived from existing architecture and toolkits now used for distributed high-performance computing applications, such as Globus, which provides Grid resource access and allocation services, including network resources. In addition, StarLight will provide a range of new tools, based, in part, on L3 IP control, including GMPLS and OBGP signaling, for designing, configuring and managing optical networks and their components; e.g., optical links, lightpath meshes, etc. These mechanisms will include the implementation of a new generation of tools for appropriate monitoring and measurements at multiple levels–device, lightpath, physical link, etc.–regionally, nationally, and internationally.

Optical networks allow for a far greater degree of network configuration flexibility than existing networks. StarLight will provide the required tools and techniques, allowing this flexibility to dynamically adjust network resources to optimize global applications. StarLight will also provide multiple autonomous peering lightpaths for its community, using a common set of protocols, and will provide interconnections to distributed OCX services. Because not all researchers will have access to these advanced services, StarLight will also provide mechanisms that enable gateways to be established for a variety of additional services, such as ATM SONET, POS, high-performance IP, GbE and 10GbE.

2.C. Research Training

There is clearly a fine team of professors, staff and engineers from UIC, ANL, NCSA, MREN, iCAIR and Indiana University involved with STAR TAP, as indicated in this report, facilitating greater advances in global networking than a single-investigator effort would afford. Moreover, if we count all the people involved in STAR TAP, not just the management team in the Chicago area, the involvement extends nationally (NLANR, NGI networks, Internet2) and internationally. All the people working on STAR TAP and STAR TAP-related projects are involved in furthering its goals, either within their respective disciplines, or by helping us better understand the limitations and future directions of long, fat networks.

2.D. Education/Outreach

Because we also manage the NSF HPIIS-funded Euro-Link project, many of the European-related activities listed below overlap with those listed in our Euro-Link reports.

2.D.1. Overview

Our primary education and outreach activities include web documentation, journal articles, and conference presentations and demonstrations. We also provide videotapes, PowerPoint presentations, and other teaching materials to collaborators to give presentations at conferences, government briefings, etc.

Since 1986, EVL has partnered with NCSA, ANL, and more recently iCAIR, in ongoing efforts to develop national/international collaborations at major professional conferences, notably ACM SIGGRAPH, ACM/IEEE Supercomputing (SC), IEEE High Performance Distributed Computing (HPDC) and INET, as well as Internet2 meetings. We have also participated in NRN conferences, including the annual CANARIE Workshop, the NORDUnet annual conference, and Israel's Internet-2 and Telecomm conferences. Our success has been in the development of teams, tools, hardware, system software, and human interface models on an accelerated schedule to enable multi-site collaborations for complex problem solving. We have received a great deal of media attention for our work; news articles are posted at [www.startap.net/PUBLICATIONS].

Past events we have organized include iGrid '98 at SC'98 and iGrid 2000 at INET 2000. (The iGrid 2000 event at INET in Yokohama last July, organized by EVL, featured 24 collaborative projects from 14 nations [www.startap.net/igrid2000]. iGrid '98 featured 22 demonstrations from 10 countries [www.startap.net/igrid98].) We are already involved in the SC'2001 conference [www.sc2001.org] in Denver, November 10-16, 2001; we are both assisting ANL host the SC Global event, which will use Access Grid technology [www.accessgrid.org] to link the SC "core" at the Denver Convention Center with dozens of Access Grid nodes or "constellation sites" throughout the world, and we are planning an optical networking demo (if possible, from Chicago to Denver) to promote the goals of StarLight. We will also encourage our international collaborators to develop conference events (such as iGrid) to showcase meritorious applications among their own researchers.

EVL also collaborates with the NSF-funded GriPhyN and NEES initiatives, as well as the CAVE Research Network Users' Society (CAVERNUS) (see Section 1.D: Other Collaborators or Contacts).

Harvey Newman, Caltech researcher and CERN collaborator, when recently asked to forecast GriPhyN and CERN data grid bandwidth requirements, said:

"The CMS (Compact Muon Solenoid) detector is being designed to measure the signatures of new physics, to be generated by CERN's LHC (Large Hadron Collider), expected to come online in 2005. In the first full year of operation, the CMS will require 11 PB of tape and 4 PB of disk storage, and 80 Teraops computing power. These numbers will increase over subsequent years.

The [bandwidth] baseline will be OC-48 to OC-192 for a national center's terrestrial links, and OC-192 for the major transoceanic links. Since we forsee about 1 Tbyte/sec internal data flow at CERN, you might guess we could build a tightly coupled system with up to 0.1-1 Tbps on the cross-ocean links. Of course I am talking about data transfer using light protocols that have little to do with TCP.

These estimates are for the CMS alone. For the whole LHC program, one would need more bandwidth links and 2-4 times more computing power and data storage."

2.D.2. Conference and Workshop Participation

April 4-6, 2001. An "Internet2" Scientific Workshop in Valparaiso, Chile. EVL is shipping an ImmersaDesk and sending Greg Dawe, Javier Girado and Brenda Lopez to do tele-immersive demonstrations. Collaborator Paul Morin of the University of Minnesota (working with EVL on earthquake simulation visualization as part of the NEESgrid initiative) was invited to give a talk.

March 7, 2001. Tom DeFanti and Maxine Brown attend the Internet2 Spring Member Meeting in Washington DC. Brown gives a StarLight update at the International Task Force meeting. DeFanti and Brown also meet with John Jamison of Juniper about future router grants/donations.

March 6, 2001. Tom DeFanti, Maxine Brown and Andy Schmidt (recently hired as STAR TAP Engineer) meet with Aubrey Bush, Tom Greene and Steve Goldstein about international networking.

March 5, 2001. Bill St. Arnaud and René Hatem (CANARIE) and Kees Neegers (SURFnet) visit Chicago to talk with Tom DeFanti (EVL et. al.), Joe Mambretti of Northwestern and Linda Winkler of ANL about StarLight.

March 1, 2001. Tom DeFanti gave a presentation entitled "Joint Tokyo-Chicago Research Opportunities on the Global Grid" to University of Tokyo in honor of their new School of Information Technology using live video streaming (DVoverIP).

February 28, 2001. StarLight meeting at EVL with Tom DeFanti (EVL et. al.), Joe Mambretti of Northwestern and Charlie Catlett and Linda Winkler of ANL.

February 19-21, 2001. Tom DeFanti attended the Internet WorkShop (IWS) 2001 in Tokyo and gave a presentation entitled "StarLight: Applications-Oriented Optical Wavelength Switching for the Global Grid at STAR TAP" [http://iws2000.jp.apan.net, http://www.jp.apan.net/IWS2000/apan-session.html].

February 14, 2001. Andre Choo, previously of Teleglobe and currently with Velocita, visited Chicago to talk with Tom DeFanti and Maxine Brown of EVL, Joe Mambretti of Northwestern University and Charlie Catlett of ANL about I-WIRE and StarLight and how his new company might work with us.

February 13, 2001. Olivier Martin of CERN visited Chicago to talk with Tom DeFanti and Maxine Brown of EVL and Joe Mambretti of Northwestern University about StarLight.

January 28-31, 2001. The APAN/TransPAC/NLANR/Internet2 Joint Techs Workshop was held in Hawaii. Linda Winkler, representing STAR TAP, attended. Steve Peck and the Global NOC held a BOF session on NOC services and interaction between engineering groups. Participants included the Global NOC, APAN, and CA*net3. Special emphasis was placed on sessions relating to Asian networks.

January 21-23, 2001. Joint Workshop on Virtual Intelligent Environments and Technology, Universidad Veracruzana in Veracruz, Mexico. Tom DeFanti and Maxine Brown attended this NCSA/Alliance Education, Outreach and Training (EOT) workshop. DeFanti gave a presentation titled, "Virtual Reality over Gigabit Networks."

January 10-12, 2001. Tom DeFanti and Maxine Brown visited the AMPATH organizers at Florida International University, where DeFanti gave two presentations to the School of Computer Science, "StarLight: Optical Switching for the Global Grid" and "Virtual Reality over Gigabit Networks," and Brown gave one presentation, "STAR TAP Overview and Applications."

January 8-9, 2001. Tom DeFanti participated in the Extreme Networking Workshop on research and technology needs in High Performance Networks, sponsored by San Diego Supercomputing Center, San Diego, CA.

December 19, 2000. John Jamison of Juniper Systems, who donated a $50,000 M5 router to STAR TAP, visited EVL to videotape Tom DeFanti and the CAVE for a promotional video for his company.

December 13, 2000. Indiana University hosted a STAR TAP/Euro-Link/TransPAC engineering meeting. The budding ITN was discussed, as were other projects involving STAR TAP, CA*net3, and the Global NOC. Extracts from Steve Peck's report follows:

- STAR TAP Juniper Router Deployment – Linda Winkler expects to receive and become familiar with the router by the end of December. IU engineers will do the same in January. STAR TAP router tools need to be modified.
- AADS Issues – Recent outages and lack of response continues to be documented.
- Network Tools – Due to the NSF's urging to report TransPAC traffic flow, Linda Winkler has turned on the CFLOWD data. IU engineers are currently choosing an appropriate visualization tool, possibly MADAS from UTK, to analyze this data.

December 14, 2000. Networking personnel from STAR TAP, AADS, ANL, MREN and UIC met at EVL to resume discussion of I-WIRE, fiber co-location and optical STAR TAP configurations. Equipment has been ordered, a co-location site has been determined (Northwestern University's Chicago campus), and fiber build negotiations are progressing. Tom DeFanti and Joe Mambretti agreed that an optical STAR TAP would focus on international and big science project wavelength connectivity, rather than broader concepts like connecting US GigaPoPs.

December 12-13, 2000. John Jamison and Steve Peck held a Juniper Networks-sponsored JUNOS class at IUPUI. The main focus was to learn the IOS in preparation for the deployment of a Juniper router for STAR TAP in 2001. Networking personnel from STAR TAP, IU, CA*net3, and ANL attended.

December 4-5, 2000. Tom DeFanti attended an NSF-sponsored Workshop on the Future Revolution in Optical Communications and Networking, held at the DoubleTree Hotel in Crystal City, Virginia. The meeting was sponsored by the NSF Division on Electronics, Photonics and Device Technologies, and chaired by Alan Willner of University of Southern California.

December 1, 2000. Tom DeFanti attended an NSF ANIR-sponsored Working Group on Middleware meeting in Berkeley, California. The meeting chair was David G. Messerschmitt of UC-Berkeley.

November 27-29, 2000. Tom DeFanti and Maxine Brown attended "The Networked Nation" CANARIE's 6th Advanced Networks Workshop. In attendance were NSF's Steve Goldstein, ANL's Linda Winkler, NU's Joe Mambretti, SURFnet's Kees Neggers, NORDUnet's Peter Villemoes and host Bill St. Arnaud.

- Optical STAR TAP was discussed.
- DeFanti presented, "StarLight: Applications-Oriented Optical Wavelength Switching for the Global Grid at STAR TAP."
- The day before the conference started, DeFanti gave a lecture at McGill University titled, "3D Telephony: Virtual Reality and the Ten Gigabit Telephone Call." He addressed the 3rd meeting of the Canadian Working Group on Virtualized Reality.
- DeFanti, Brown, Mambretti and Goldstein met Teleglobe's Yves Poppe to discuss future STAR TAP plans.

- DeFanti, Winkler, Mambretti and Neggers met representatives of Level3 about transatlantic wavelengths.
- DeFanti, Brown, Winkler, Mambretti and Goldstein met Joerg Micheel, WAND and NLANR MOAT, The University of Waikato, New Zealand, about developing Passive Monitoring Analysis (PMA) boxes for wavelengths; Hans-Werner Braun subsequently expressed strong interest.
- DeFanti, Brown, Winkler, Mambretti and Goldstein met Brian Pratt of edgeflow Inc. in Canada, about products based on OBGP and STAR TAP's (specifically Star Light's) potential interest.

November 21, 2000. Networking personnel from STAR TAP, AADS, ANL, MREN and UIC met at EVL to discuss I-WIRE, fiber co-location and StarLight configuration specifications. Ameritech fiber loans in Chicago are progressing up the chain of command at SBC. Joe Mambretti is in charge of negotiations. Charlie Catlett continues to work on I-WIRE fiber. Co-location issues persist; we are considering alternative co-lo spaces. Discussion of procuring/adding to Cisco 6509s properly configured for NU, UIC Goldberg and EVL, the StarLight co-lo facility and ANL.

November 20-22, 2000. Professor Hiroyuki Ohno from Tokyo Institute of Technology visited EVL to further discuss his network monitoring software "Stetho" that produces audio information for use with STAR TAP.

November 17, 2000. John Jamison of Juniper Networks gave a presentation at UIC/EVL to representatives from UIC, NCSA, ANL and Northwestern on MPLS.

November 16-17, 2000. Tom DeFanti, UIC, was keynote speaker at a symposium celebrating the 25th anniversary of the Fraunhofer-Institut fuer Graphische Datenverarbeitung in Darmstadt, Germany. Presented "3D Telephony: Virtual Reality and the Ten Gigabit Telephone Call."

November 6-9, 2000. SC'2000, attended by Maxine Brown, Alan Verlo, Chris Scharver and Eric He (UIC), and Linda Winkler (ANL). Tele-immersive demonstrations were run between Israel and Chicago; also a real-time demonstration by UIC's Bob Grossman with Europe and Australia. Brown and Winkler attended an organizational meeting for SC Global, to be held at SC'2001 in Denver, November 10-16, 2001, to link Denver with dozens of SC constellation sites distributed throughout the world, all of which support the Access Grid real-time, Internet-based videoconferencing system.

November 6-9, 2000. A US State Department-issued warning advising against travel to Israel caused Jason Leigh, Greg Dawe and Michael Lewis (UIC) to cancel plans to attend Telecom 2000 in Tel Aviv, Israel's largest annual telecommunications conference. EVL's ImmersaDesk, however, was shipped to the site in Tel Aviv, and remotely deployed by Technion University engineers. Using a Polycom system to conduct real-time remote training, the EVL and Technion teams conducted a tele-collaborative session on November 5. EVL researchers used CAVERNsoft-based applications to remotely debug ImmersaDesk hardware. A real-time collaboration among Israelis, EVL in Chicago, SARA in Amsterdam and EVL personnel in the Alliance booth at SC00 in Dallas, Texas, took place November 8-9. On December 7, Joe van Zwaren, Israeli Ministry of Science, reported the following about the Telecom 2000 conference: "The ImmersaDesk made a tremendous impact. Many people got the full impact of the technology. I am now exploring the possibility of getting a museum to buy an ImmersaDesk to give a real-time 3D view produced by an electron microscope (the company that might sponsor this is in the electron microscope business). This would provide a permanent exhibition of the technology in Israel."

November 8, 2000. Tom DeFanti gave a presentation on Optical STAR TAP at the Japanese Gigabit Network (JGN) Symposium in Kita-Kyushu, Japan.

November 2, 2000. Networking personnel from STAR TAP, AADS, ANL, MREN and UIC met at EVL to discuss I-WIRE, fiber co-location space possibilities and configuration specifications for Optical STAR TAP (StarLight). ANL's Charlie Catlett is working on securing I-WIRE fiber bids and UIC's Will Marcyniuk (UIC) is exploring a possible Cisco donation. SBC/Ameritech, who is donating fiber, wants to be designated as "official" administrative operators of endpoints.

October 29-30, 2000. Tom DeFanti and Maxine Brown attended the International Task Force and Application Strategy Council meetings at Internet2. Maxine gave presentations on iGrid 2000. During the week of the Fall

meeting, Joel Mambretti gave a talk on iGrid 2000 in one of the conference sessions focused on applications. In all cases, the presentation was well received.

October 25, 2000. HPIIS Performance Review meeting was held in San Diego, CA to review the merits of the High Performance International Internet Services (HPIIS) program, notably the US/international scientific applications enabled, in order to recommend the program's continued support. PI's from TransPAC, Euro-Link and MIRnet presented data and fielded questions before a multi-disciplinary review panel chaired by UCSD's Larry Smarr.

October 24, 2000. Tom DeFanti gave a presentation describing the StarLight switching state concept and international science-oriented wavelengths, to NSF officers and networking experts assembled for the October 24 HPIIS Performance Review Meeting in San Diego, CA. In attendance were Steve Goldstein, Aubrey Bush, Tom Greene and Karen Sollins form NSF. Harvey Newman (Caltech), Larry Smarr (UCSD), Ian Foster (ANL) and Kim Mish (NTON) were also in attendance.

October 5, 2000. Networking people from STAR TAP, Ameritech, ANL, MREN and UIC met at EVL to discuss I-WIRE, fiber co-location possibilities and configuration specifications for Optical STAR TAP.

September 27-30, 2000. Tom DeFanti and Maxine Brown of EVL attended NORDUnet 2000 in Helsinki, Finland [http://www.csc.fi/nordunet2000/program.phtml]. DeFanti gave a presentation "The Global Grid;" Brown presented "Global Tele-Immersion Applications." Also represented at NORDUnet 2000 were Bill St. Arnaud (CANARIE), Kees Neggers (SURFnet), Peter Villemoes (NORDUnet) and David Williams (CERN). DeFanti, Brown, St. Arnaud, Neggers and Williams had meetings on our future "StarLight" project, as both SURFnet and CERN are interested in installing wavelengths across the Atlantic Ocean.

September 14, 2000. Tom DeFanti, Joe Mambretti, Andy Schmidt, Linda Winkler, Alan Verlo, Oliver Yu, Akihiro Tsutsui, Cliff Nelson and Ameritech's Anthony Haeuser met to discuss (1) the status of dark fiber available between UIC/Goldberg, NU campuses and Bell Nexxia, (2) co-location space available at Ameritech, and (3) I-WIRE and MREN (StarLight) plans for GigE, 10GigE, DWDM/CWDM.

September 7, 2000. Bill St. Arnaud, Rene Hatem (CANARIE), Charlie Catlett, Linda Winkler, Bill Nickless (ANL), Cliff Nelson (UIC), Tom DeFanti, Alan Verlo, Akihiro Tsutsui, Oliver Yu, Jason Leigh (EVL) met at EVL to discuss Optical STAR TAP. Discussion included goals, and hardware, middleware and fiber needs.

August 23, 2000. StarLight meeting, EVL. Tom DeFanti and Joe Mambretti of Northwestern attended.

August 2, 2000. Networking people from STAR TAP, TransPAC, Internet2 and CANARIE met to discuss the issues and procedures for an International Transit Network (ITN).

July 18-21, 2000. iGrid 2000 at INET 2000 in Yokohama, Japan. The International Grid (iGrid) special event showcased 24 demonstrations, featuring the latest in technological innovations and application advancements supporting global community networking [www.startap.net/igrid2000]. iGrid 2000 was jointly sponsored by EVL/UIC, the Office of the Vice President for Information Technology at Indiana University, University of Tokyo and Keio University. Via STAR TAP, it provided global connectivity to 14 countries: Canada, CERN (Switzerland), Germany, Greece, Japan, Korea, Mexico, Netherlands, Singapore, Spain, Sweden, Taiwan, United Kingdom and the USA. Technical innovations demonstrated included tele-immersion, large datasets, distributed computing, remote instrumentation, collaboration, streaming media, human/computer interfaces, digital video and high-definition television, and grid architecture development. Applications represented the fields of science, engineering, cultural heritage, distance education, media communications, and art and architecture.

July 17, 2000. Annual meeting, STAR TAP International Advisory Committee, INET 2000, Yokohama, Japan. Minutes posted to http://www.startap.net/ABOUT/MEETINGS.html

July 16, 2000. Tom DeFanti, Maxine Brown and Laura Wolf met with SURFnet's Kees Neggers to discuss SURFnet's DWDM network, now under construction, and future plans to connect it to STAR TAP and Canada.

July 11, 2000. Florida International Universiy's Mark Rosenberg (Provost), Art Gloster (CIO) and Julio Ibarra visited EVL to talk with Tom about STAR TAP and how they should position AMPATH.

June 28, 2000. Euro-Link representatives Tom DeFanti and Maxine Brown participated in a conference call with MIRnet, TransPAC and NSF people to discuss plans for the upcoming HPIIS Review meeting.

June 27, 2000. Professor Hiroyuki Ohno from Tokyo Institute of Technology visited EVL to discuss his network monitoring software "Stetho" that produces audio information. He is interested in our using this software to monitor STAR TAP traffic.

June 14-16, 2000. Tom DeFanti was keynote speaker at the Industrial Virtual Reality Show & Conference in Tokyo, Japan.

June 1-2, 2000. EVL Senior Research Scientist Jason Leigh and student Chris Scharver attended the Eurographics Workshop in Amsterdam and demonstrated a semi-public VR walkthrough of Amsterdam architect Rem Koolhaas' new Illinois Institute of Technology (IIT) building, as well as "TIDE: The Tele-Immersive Data Explorer." TIDE [www.evl.uic.edu/cavern], developed by EVL in collaboration with UIC National Center for Data Mining (Bob Grossman, director) and DOE ASCI researchers, is a CAVERNsoft-based collaborative, immersive environment for querying and visualizing data from massive and distributed datastores. The fully immersive demo, shown in SARA's CAVE, was a huge success. Leigh reported both demos went off without a single problem, and noted, "We got a lot of positive reaction from the audience, especially of TIDE. Many were as impressed by our work as with the quality of the networking supporting the collaboration." He referred those interested in the networking aspect to Tom DeFanti and Maxine Brown, and to the STAR TAP web site. Leigh met with Laurent Grizon of Institut Francais du Petrole to discuss a possible future collaboration.

While at the conference, they met with a student of Ralf Schaefer, the Head of the Image Processing Department at Heinrich-Hertz-Institut in Berlin, Germany, to discuss their participation in N*VECTOR, EVL's collaborative effort with researchers at University of Tokyo and NTT.

Also, while at SARA in Amsterdam, Jason and Chris met with Ed Breedveld, a SARA researcher with whom they have been collaborating on "Saranav"–a Performer-based CAVE application to load and view 3D polygonal datasets in the CAVE–as well as QoS experiments.

May 31-June 2, 2000. Maxine Brown, Tom DeFanti and Linda Winkler met with Hiroshi Esaki of University of Tokyo and researcher Gorochan Kunito to discuss iGrid 2000 and international networking. There is great concern about transiting Germany's applications to Yokohama, since DANTE (which brings German DFN traffic to the USA) wants to only let limited IP addresses through to STAR TAP, due to bandwidth constraints on their Atlantic links.

May 22-23, 2000. Tom DeFanti and Maxine Brown attended the DoE's Mathematical, Information, and Computational Sciences (MICS) division review of its network research program at the Dulles Hyatt in Herndon, Virginia.

May 20, 2000. Tom DeFanti met with George Strawn at O'Hare airport to give an update on STAR TAP in preparation for a trip to Portugal by President Clinton and NSF CISE Associate Director Ruzena Bajcsy.

May 16, 2000. Linda Winkler presented "STAR TAP ITN International Transit Network" to Internet2/NLANR Joint Techs meeting in Minneapolis, MN. Met with Jim Williams, Steve Peck and Kazunori Konishi (APAN) to discuss Euro-Link/STAR TAP/TransPAC network issues. Discussion focused on the coming iGrid 2000 demonstrations at INET 2000.

May 11, 2000. Maxine Brown, staff Laura Wolf and student Brenda Lopez held a meeting with Linda Winkler on the Access Grid to discuss visualizing STAR TAP international traffic for iGrid 2000 in July. STAR TAP Router traffic is posted on the STAR TAP web site [www.startap.net/ENGINEERING].

2.D.3. STAR TAP International Advisory Committee

As of March 2001, the STAR TAP International Advisory Committee (IAC) consists of the following members; the email alias is <advisory@startap.net>. [Note: This group consists of representatives of the international and HPIIS networks connected to STAR TAP. The group serves as an external advisory body to the STAR TAP Principal Investigator, Tom DeFanti, to assure that the international groups connected to STAR TAP make decisions that affect the policies and operations of STAR TAP. For the first three years of STAR TAP, the IAC chair was Larry Smarr. Rick Stevens became chair in July 2000.]

- Rick Stevens, ANL/USA (Chair)
- Tomonori Aoyama, JGN/Japan
- Natasha Bulashova, Russia/MirNET
- Greg Cole, UTennessee/MirNET
- Manuel Delfino, CERN
- Shigeki Goto, APAN
- Michael McRobbie, IndianaU/TransPAC
- Kees Neggers, SURFnet/Netherlands
- Bill St. Arnaud, CANARIE
- Dany Vandromme, RENATER/France
- Peter Villemoes, NORDUnet
- Jer-Nan Juang, NCHC/TANet2
- Ralphi Rom, IUCC/Israel
- Ngoh Lek Heng, SingAREN, Singapore

STAR TAP Engineering staff is on the Advisory Committee; the following people ex-officio members.

- Alan Verlo, STAR TAP Engineering (Ex Officio)
- Linda Winkler, STAR TAP Engineering (Ex Officio)
- Akihiro Tsutsui, STAR TAP Engineering (Ex Officio)*
- John Jamison, STAR TAP consultant (Ex Officio)**
- Andy Schmidt, STAR TAP Engineering (Ex Officio)

* Akihiro Tsutsui works for NTT Optical Network Laboratory and was on loan to EVL for 9 months to assist on optical networking. Although he recently returned to Japan, he has asked to remain a consultant to the StarLight project.

** John Jamison was STAR TAP Engineer from 1999-2000 and now works for Juniper Networks, but remains a consultant to STAR TAP.

*** Andy Schmidt, formerly of Ameritech, will assume STAR TAP Engineering duties at EVL/UIC on April 2001.

STAR TAP Administrative staff is on the Advisory Committee; the following people ex-officio members.

- Tom DeFanti, UIC/STAR TAP/EuroLink (Ex Officio) <tom@uic.edu>
- Maxine Brown, UIC/STAR TAP/EuroLink (Ex Officio) <maxine@uic.edu>
- Laura Wolf, UIC/STAR TAP/EuroLink (Ex Officio) <laura@evl.uic.edu>
- Steve Goldstein, NSF (Ex Officio) <sgoldste@nsf.gov>

STAR TAP International Advisory Committee meetings are held annually at the INET conference. Minutes are posted [http://www.startap.net/ABOUT/MEETINGS.html].

- INET 2000 (July 17), Yokohama, Japan

3. Publications and Products

3.A. Journals/Papers

In addition to overseeing the growth and development of STAR TAP, the faculty, staff and students of EVL/UIC are users of STAR TAP. Specifically, EVL/UIC develops tele-immersion tools and applications with collaborators worldwide. In addition, EVL/UIC studies the effects of long, fat networks on application performance. To this end, EVL is building tools into its CAVERNsoft communications library to facilitate optimal use, and is developing applications-level network performance analysis tools to help next-generation networks meet the high-bandwidth, quality-of-service (QoS) and connectivity needs of academic researchers running high-performance scientific applications. The publications listed below are relevant to all these activities.

Y. Zhou, T. Murata, T. DeFanti, and H. Zhang, "Fuzzy-Timing Petri Net Modeling and Simulation of a Networked Virtual Environment – NICE," Institute of Electronics, Information and Communication Engineers (IEICE) Transactions, Fundamentals, Special Section on Concurrent Systems Technology, Vol. E83-A, No. 11, November 2000. [http://www.euro-link.org/PUBLICATIONS/FuzzyTiming_IEICE_Murata_June00.pdf]

K. Park, Y. Cho, N. Krishnaprasad, C. Scharver, M. Lewis, J. Leigh, A. Johnson, "CAVERNsoft G2: A Toolkit for High Performance Tele-Immersive Collaboration," Proceedings of the ACM Symposium on Virtual Reality Software and Technology 2000, October 22-25, 2000, Seoul, Korea, pp. 8-15.

Y. Zhou, T. Murata, T. DeFanti, "Modeling and Performance Analysis Using Extended Fuzz-Timing Petri Nets for Networked Virtual Environments," IEEE Transactions on Systems, Man and Cybernetics, Part B, Vol. 30, No. 5, pp. 737-756, October 2000. [http://www.euro-link.org/PUBLICATIONS/Yi_CollabVirtualEnv_IEEE.pdf]

Jason Leigh, Maggie Rawlings, Javier Girado, Greg Dawe, Ray Fang, Muhammad-Ali Khan, Alan Cruz, Dana Plepys, Daniel J. Sandin, Thomas A. DeFanti, "AccessBot: An Enabling Technology for Telepresence," INET 2000 Proceedings, The 10th Annual Internet Society Conference, 18-21 July 2000, Yokohama, Japan, CD ROM. http://www.evl.uic.edu/cavern/papers/Inet2000AccessBot.pdf

Tomoko Imai, Zhongwei Qiu, Sowmitri Behara, Susumu Tachi, Tomonori Aoyama, Andrew Johnson, Jason Leigh, "Overcoming Time-Zone Differences and Time Management Problem with Tele-Immersion," INET 2000 Proceedings, The 10th Annual Internet Society Conference, 18-21 July 2000, Yokohama, Japan, CD ROM. [http://www.startap.net/images/timezone.pdf]

D. He, F. Liu, D. Pape, G. Dawe, D. Sandin, "Video-Based Measurement of System Latency," Proceedings of the 4th International Immersive Projection Technology Workshop, Ames IA, June 19-20, 2000.

N. Sawant, C. Scharver, J. Leigh, A. Johnson, G. Reinhart, E. Creel, S. Batchu, S. Bailey, R. Grossman, "The Tele-Immersive Data Explorer: A Distributed Architecture for Collaborative Interactive Visualization of Large Datasets," Proceedings of the Fourth International Immersive Projection Technology Workshop 2000, June 19-20, Ames, Iowa.

A. Johnson, "Creating Tele-Immersion Environments," Tutorial presentation at the 11th Annual Workshop on Interconnections Within High Speed Digital Systems, Santa Fe NM, May 21-24, 2000.

3.B. Books/Publications

A. Johnson, J. Leigh, "Tele-Immersive Collaboration in the CAVE Research Network" (chapter), Collaborative Virtual Environments: Digital Places and Spaces for Interaction, edited by Churchill, Snowdon and Munro, January 2001, pp.225-243.

3.C. Internet Dissemination

www.startap.net

3.D. Other Specific Products

Other than the information reported here, we have not developed any other specific product of significance.

4. Contributions

4.A. Contributions within Discipline

STAR TAP, by its very nature, is interdisciplinary. There is clearly a fine team of computer scientists, computational scientists and networking engineers involved with STAR TAP, facilitating greater advances in global networking than unconnected single-investigator efforts could produce. STAR TAP developed its management team in the Chicago area (EVL/UIC, ANL, MREN, iCAIR, Indiana), and leveraged the efforts of national networking groups (NLANR, NGI networks, Internet2) and international NRN technical and administrative contacts.

4.B. Contributions to Other Disciplines

Within the Computational Science and Engineering and the Computer Science communities, STAR TAP is a necessary and integral part of application advances and technological innovations. STAR TAP also impacts the network community by providing an infrastructure to study long-distant, high-bandwidth networks. NLANR is working with STAR TAP on network measurement and web caching. ESnet and CANARIE are working with STAR TAP on 6TAP. Networking companies, such as Cisco and Juniper, have given STAR TAP router donations.

EVL not only manages the STAR TAP facility, but the Lab is also one of STAR TAP's major users. EVL's networking interest is a natural outgrowth of its focus on visualization; i.e., EVL is not only interested in producing graphic images and display technologies, but is focusing on moving visualizations over networks. In the early '90s EVL focused on distributed computing (connecting visualization/virtual-reality technologies to vector and parallel remote supercomputers), and by the mid-90s EVL focused on tele-immersion (collaborative virtual reality over networks, an extension of the "human/computer interaction" paradigm to "human/computer/human collaboration"). Now, at the beginning of a new decade, EVL is focusing on latency issues in tele-immersion. While today's tele-immersion sessions typically have little going on besides collaborative 3D interactive graphics, transoceanic tele-immersion software and middleware must provide for latency-tolerant and time-shifted usage as well as archival storage and content-based retrieval of multi-flow, multi-participant virtual-reality sessions. EVL is examining the problems of managing these flows in real time and creating adaptive latency-tolerant solutions for international distances.

4.C. Contributions to Human Resource Development

We promote the power of STAR TAP through web documentation, journal articles, demonstrations and presentations at major networking conferences (e.g., Supercomputing, INET and Internet2), videotapes, PowerPoint presentations and other instructional material. We teach the infrastructure, the grid advancements, the technological innovations and the application advancements that global connectivity enables.

STAR TAP has helped change the way international science is done, by providing a persistent infrastructure for global collaboration. STAR TAP has enabled a worldwide community of application scientists, computer scientists, networking engineers and artists. STAR TAP has a mailing list of ~600 <stars@startap.net> individuals, from academia, government and industry, interested in information about international networking developments. The success of iGrid '98 and iGrid 2000 has sparked interest from the Europeans about sponsoring an iGrid 200x sometime in the future.

While we have no quantitative metrics to evaluate STAR TAP's role in education/human resources development, there were 300 people actively involved in iGrid 2000 – from academia, government research laboratories and companies – to develop 24 applications from 14 countries. We have documented more than 150 applications on the STAR TAP web site, meaning that thousands are involved in STAR TAP-related international high-performance networking and applications development.

4.D. Contributions to Resources for Research and Education

In Section 4.B (Contributions to Other Disciplines), we note that STAR TAP is a necessary and integral part of application advances and technological innovations for the Computational Science and Engineering and the Computer Science communities, as well as of major interest to research Network Engineers. STAR TAP is a major

– and unique – resource for Science and Technology. STAR TAP is more than a switch for traffic exchange; it is an infrastructure and proving ground in which to implement new network engineering solutions to advance the state of the art.

4.E. Contributions Beyond Science and Engineering

Because of STAR TAP's interest in QoS, IPv6 and lambda switching, we have recently gotten inquiries from network equipment manufacturers and optical networking providers about partnering with us to create and showcase a marketplace for wavelength-based network services and products. We look forward to working with these companies and introducing them to the Nation's foremost university and Federal laboratory networking engineers, computer programmers and applications scientists, who are developing and using today's evolving grid technologies.

STAR TAP is evolving into a national/international optical-networking proving ground, to demonstrate an entirely new information architecture whereby bandwidth becomes the *enabling,* rather than gating, technology. Our research colleagues will showcase new optical networking capabilities to their collaborators as well as Federal and corporate sponsors, thereby building new opportunities. Our users expect STAR TAP to grow in capacity and sophistication, and we look forward to the engineering challenges ahead.

5. Special Requirements

5.A. Objectives and Scope

A brief summary of the work to be performed during the next year of support if changed from the original proposal.
Our scope of work has not changed.

5.B. Special Reporting Requirements

Do special terms and conditions of your award require you to report any specific information that you have not yet reported?
No.

5.C. Unobligated Funds

Do you anticipate that more than twenty percent of the funds under your NSF award will remain unobligated at the end of the period for which NSF currently is providing support?
No.

5.D. Animals, Biohazards, Human Subjects

Has there been any significant change in animal care and use, biohazards, or use of human subjects from what was originally approved (or approved later)?
No.