Creating 21st Century Communications Services and Technology: Applications, Technology, and Global Facilities

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International Center for Advanced Internet Research (www.icair.org)
Northwestern University
Director, Metropolitan Research and Education Network (www.mren.org)
Co-Director, StarLight, PI-iGENI, PI-OMNINet (www.startap.net/starlight)

After Broadband
Imagining Hyperconnected Futures
Wharton, University of Pennsylvania
San Francisco, California

April 17, 2012

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Introduction to iCAIR:

Accelerating Leading Edge Innovation and Enhanced Global Communications through Advanced Internet Technologies, in Partnership with the Global Community

- **Creation and Early Implementation of Advanced Networking Technologies - The Next Generation Internet All Optical Networks, Terascale Networks, Networks for Petascale Science**
- **Advanced Applications, Middleware, Large-Scale Infrastructure, NG Optical Networks and Testbeds, Public Policy Studies and Forums Related to NG Networks**
- **Three Major Areas of Activity: a) Basic Research b) Design and Implementation of Prototypes c) Operations of Specialized Communication Facilities (e.g., StarLight)**

Advanced Communications Research Topics

- Many Current Topics Could Be Considered "Grand Challenges" In Communications
  - Scaling the Internet from A Service For 1-2 Billion Individuals (Current) to 4-6 Billion (Future) and Beyond
  - Improving the Current Internet (Creating a "Better Internet," Removing Limitations, Adding Capabilities, Increasing Security, Reliability, etc.)
  - Migrating Services from Layer 3 Only to Multi-Layer Services, Including L2.5, L2, L1, e.g., Lightpaths
  - Creating the "Internet of Things" (Currently 5 Billion Devices Are Connected – Soon 20 Billion)
  - Migration the Internet From Data and Image Services To Rich Multi-Media Services
  - Adding Massive Additional Capacity
  - Empowering *Edge* Processes, Applications, and Users
- ***Creating a Fundamentally New Architecture and Technology That Allows for Accomplishing All of These Goals***

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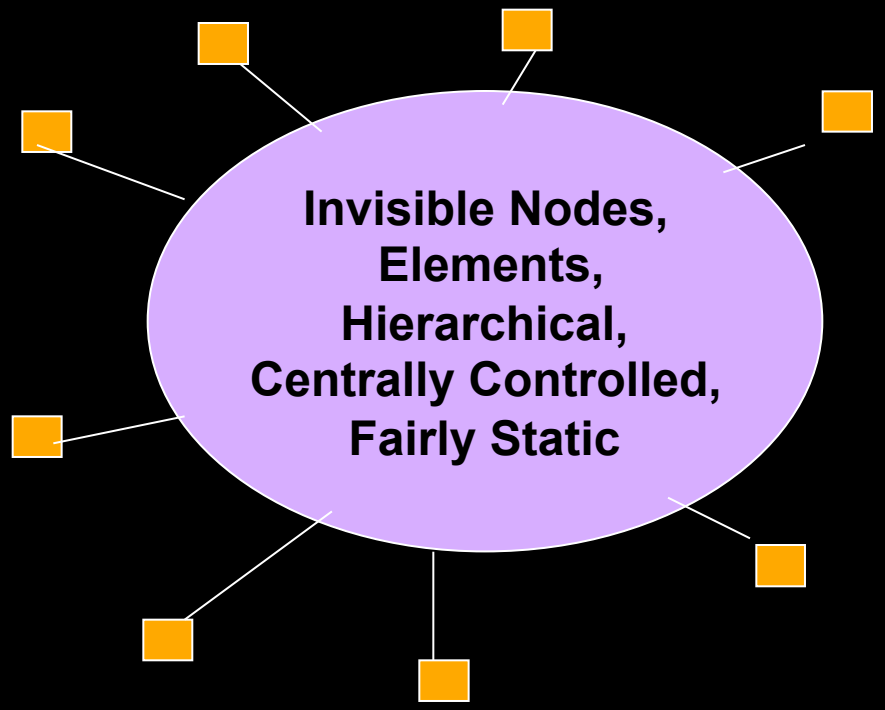
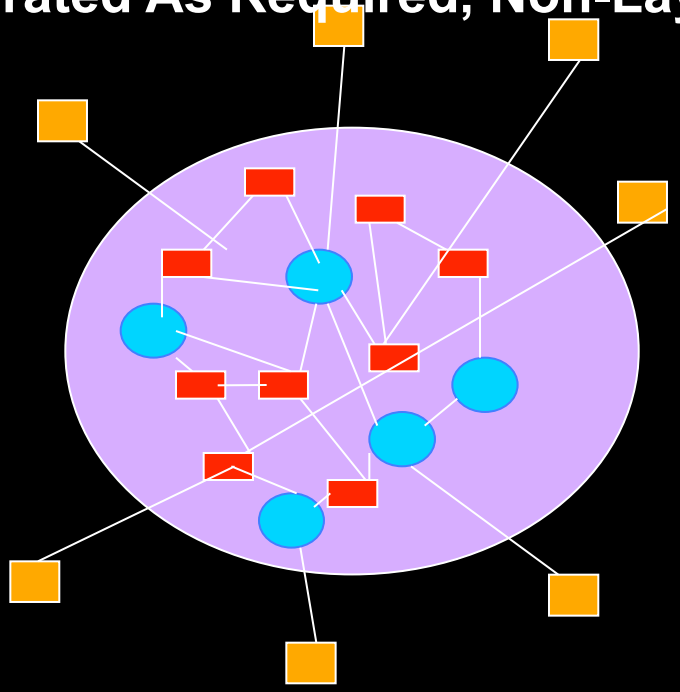
Paradigm Shift – Ubiquitous Services Based on Large Scale Distributed Facility vs Isolated Services Based on Separate Component Resources

Traditional Provider Services:
Invisible, Static Resources,
Centralized Management,
Highly Layered



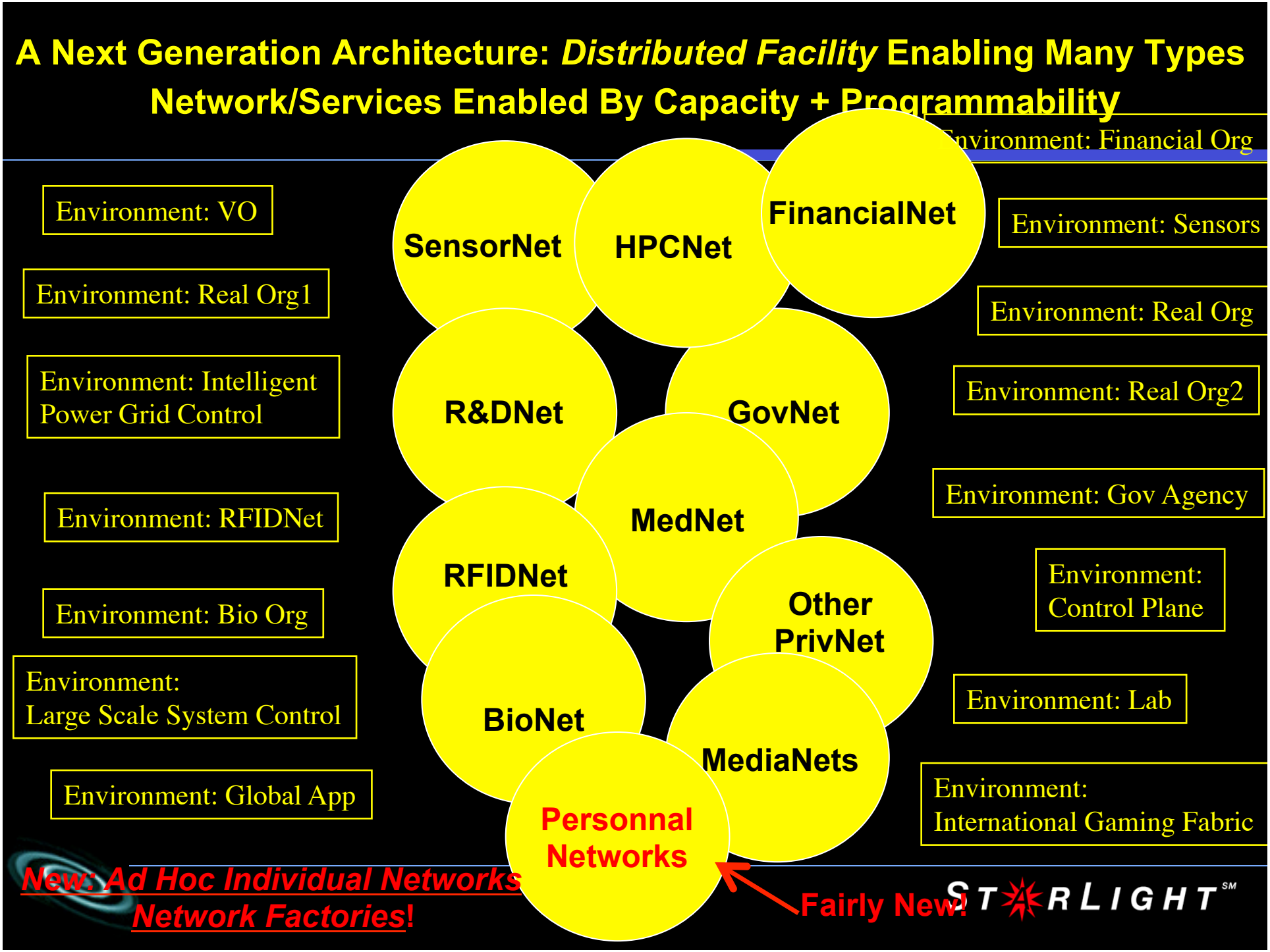
Limited Services, Functionality,
Flexibility, Expandability

Distributed Programmable Resources,
Dynamic Services,
Visible & Accessible Resources,
Integrated As Required, Non-Layered



Unlimited Services, Functionality,
Flexibility, Expandability

A Next Generation Architecture: *Distributed Facility* Enabling Many Types Network/Services Enabled By Capacity + Programmability



GriPhyN
Data Intensive Science

NEPTUNE
A Fiber-Optic Telescope to Inner Space

NEES

GENOMES to LIFE
BIOLOGICAL SOLUTIONS FOR ENERGY CHALLENGES
U.S. DEPARTMENT OF ENERGY

NG Digital Sky Survey

NEON
National Ecological Observatory Network

ATLAS

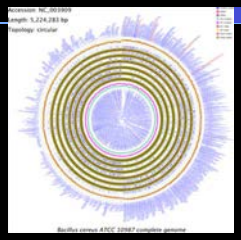
ALMA

ALMA: Atacama Large Millimeter Array

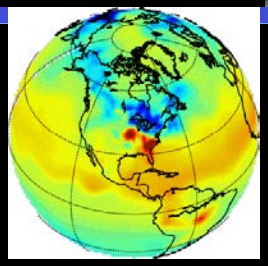
ANDRILL: Antarctic Geological Drilling
www.andrill.org

BIRN

BIRN: Biomedical Informatics Research Network
www.nbirn.net



CAMERA metagenomics
camera.calit2.net



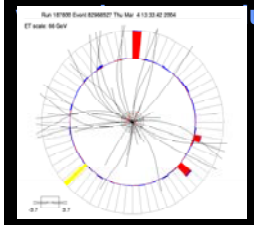
Carbon Tracker
www.esrl.noaa.gov/gmd/ccgg/carbontracker

CineGrid

CineGrid
www.cinegrid.org

LHC

LHCONE
www.lhcone.net



DØ (DZero)
www-d0.fnal.gov

GEON

GEON: Geosciences Network
www.geongrid.org

GLEON

GLEON: Global Lake Ecological Observatory Network

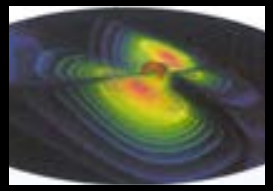
OOI OCEAN OBSERVATORIES INITIATIVE
CYBERINFRASTRUCTURE
Providing a link between ocean research and discovery

OOI-CI
ci.oceanobservatories.org

ISS: International Space Station
www.nasa.gov/station

CLASS

Comprehensive Large-Array Stewardship System
www.class.noaa.gov



LIGO
www.ligo.org

PRAGMA

Pacific Rim Applications and Grid Middleware Assembly
www.pragma-grid.net

WLCG
Worldwide LHC Computing Grid

WLCG
lcg.web.cern.ch/LCG/public/

TeraGrid

TeraGrid
www.teragrid.org

IVOA

IVOA: International Virtual Observatory
www.ivoa.net

Open Science Grid

OSG
www.opensciencegrid.org

the globus alliance

Globus Alliance
www.globus.org

SKA
SQUARE KILOMETRE ARRAY

SKA
www.skatelescope.org

Sloan Digital Sky Survey
www.sdss.org

XSEDE

XSEDE
www.xsede.org

Compilation By Maxine Brown

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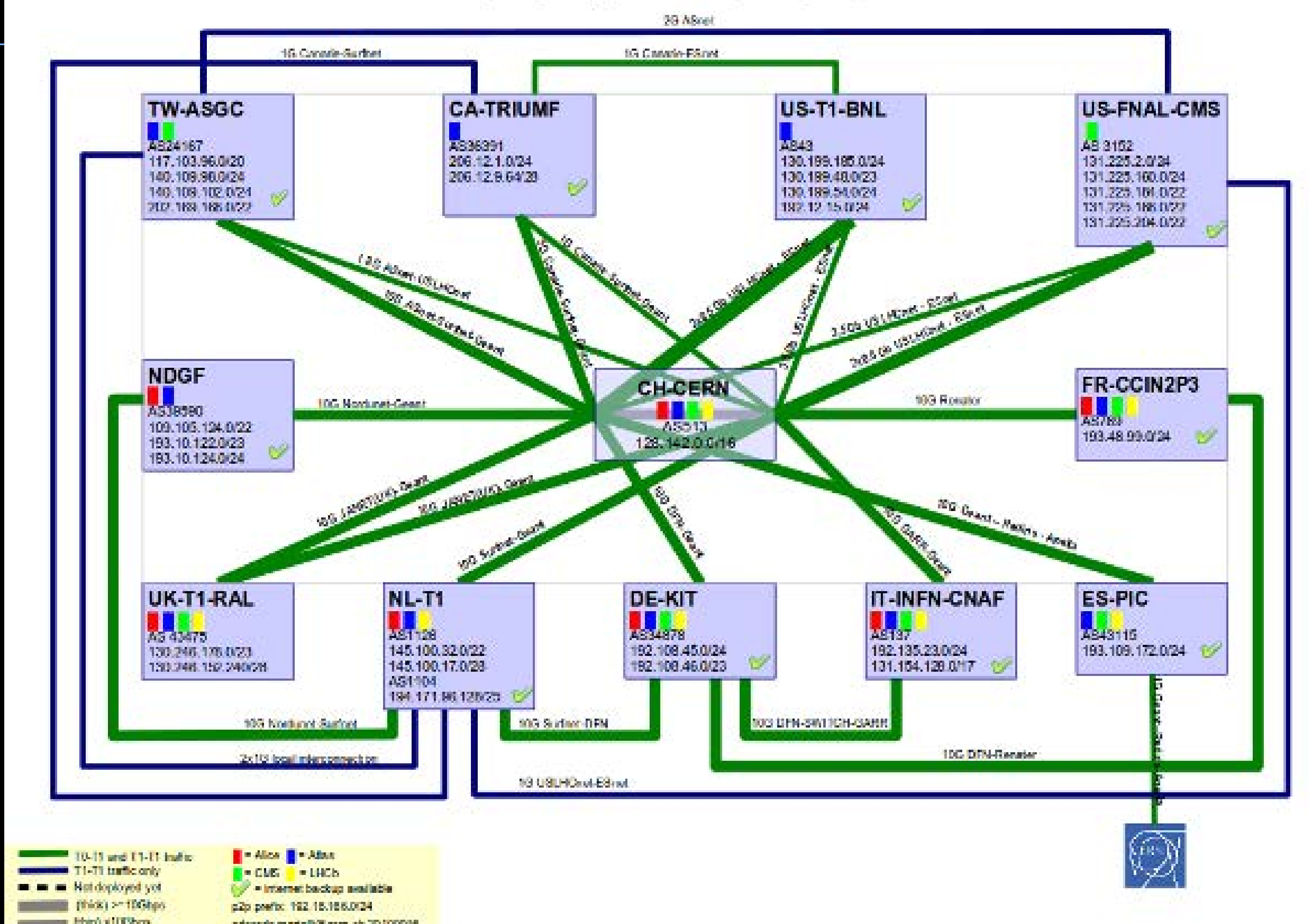
LHCOPN



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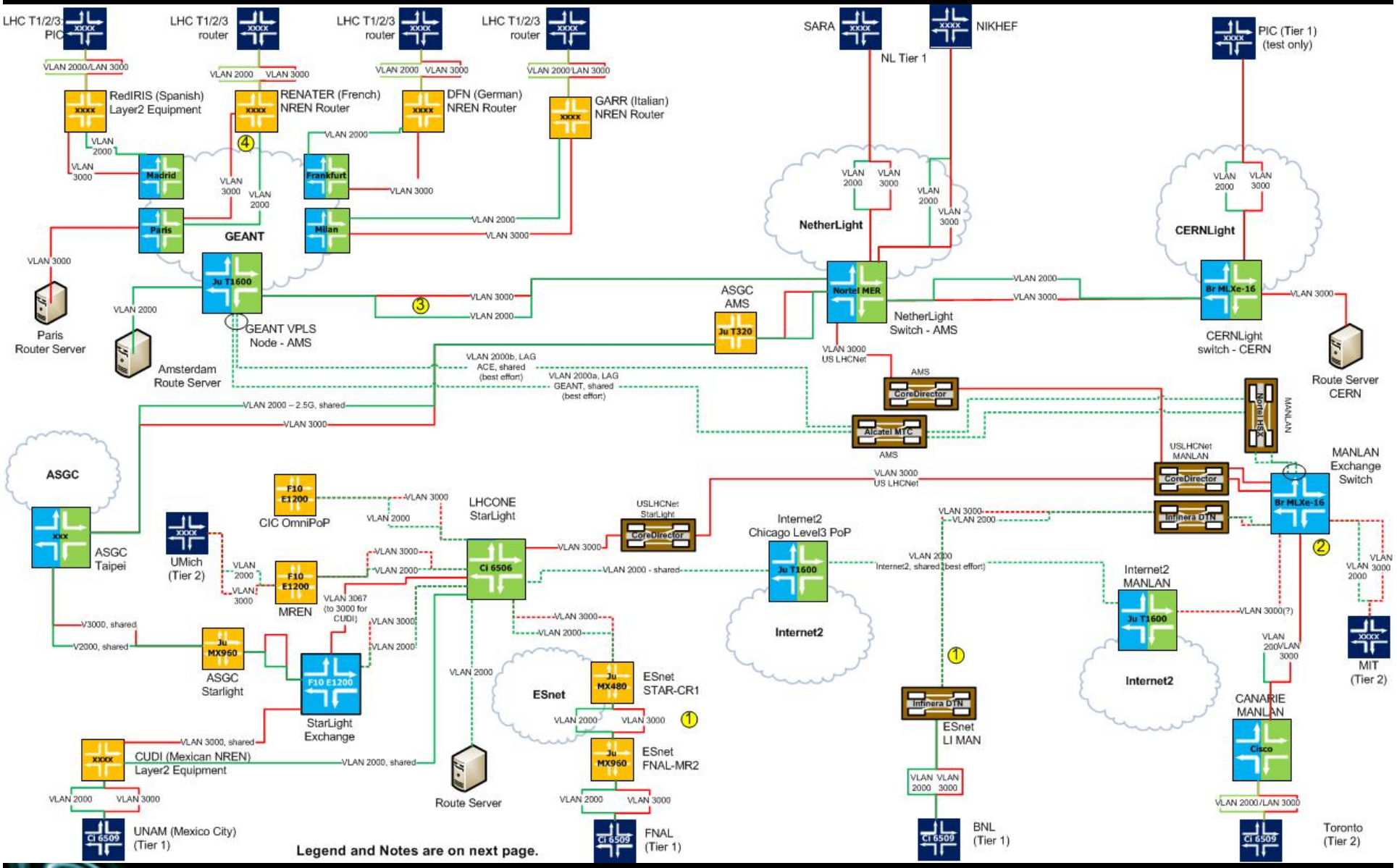
LHC Open Network Environment



STARLIGHT SM

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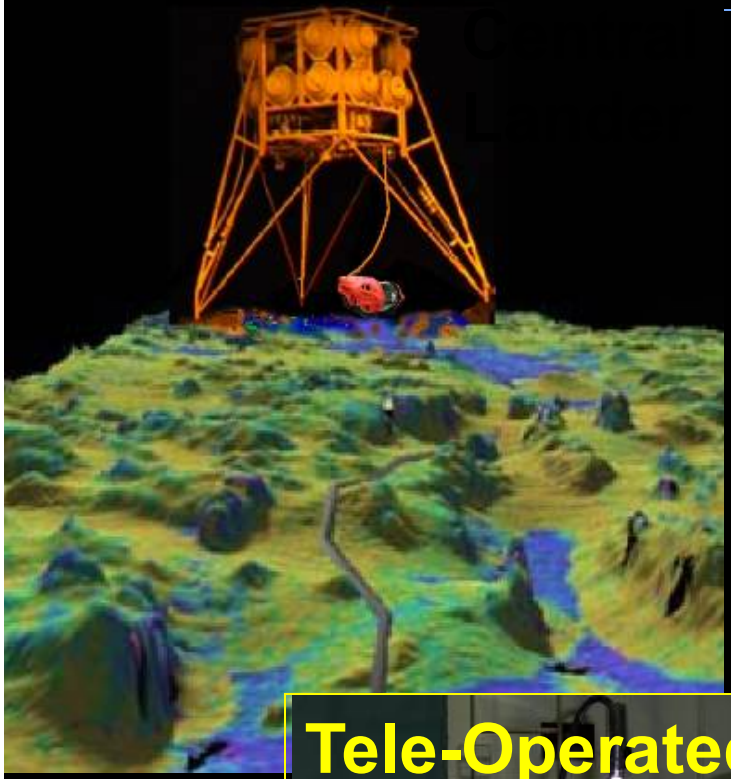
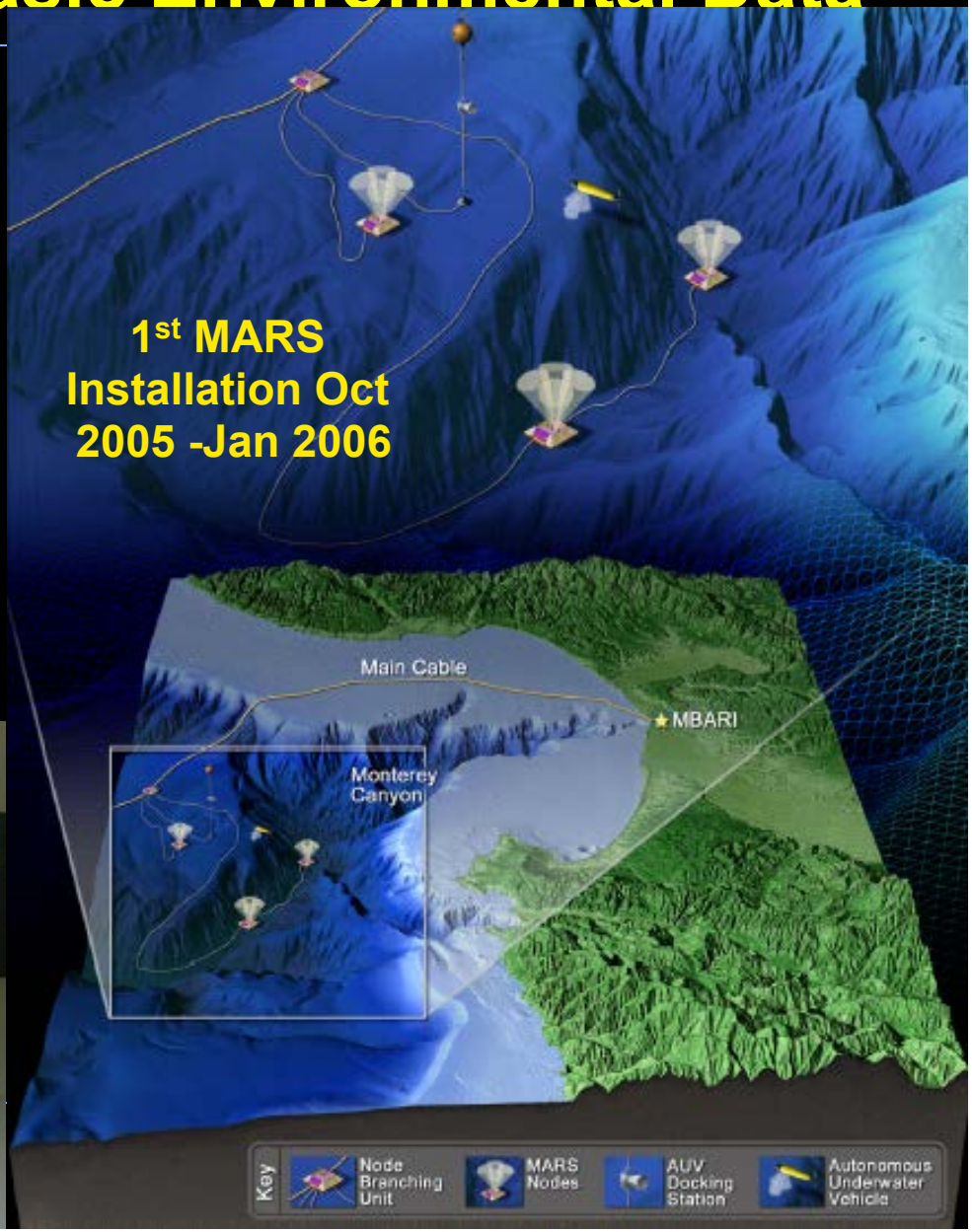
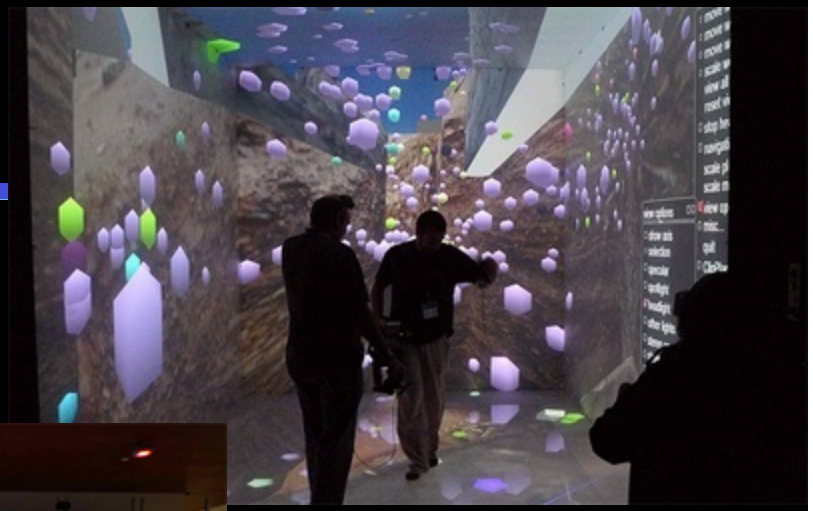
MARS New Gen Cable Observatory Testbed - Capturing Real-Time Basic Environmental Data



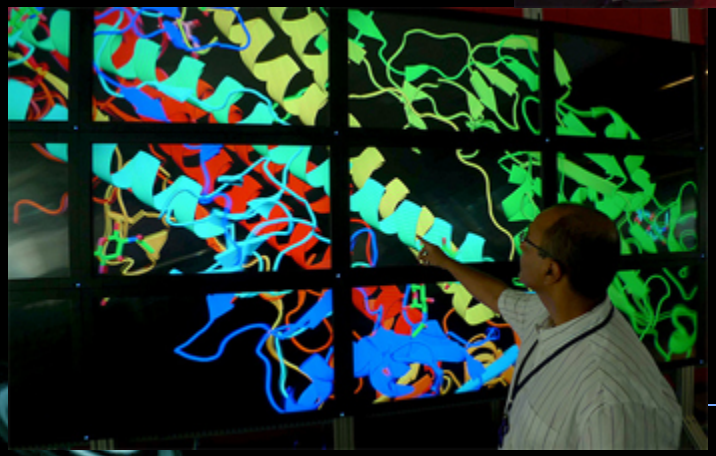


Tele-Operated Crawlers

Source: Jim Bellingham , MBARI



KAUST
CORNEA



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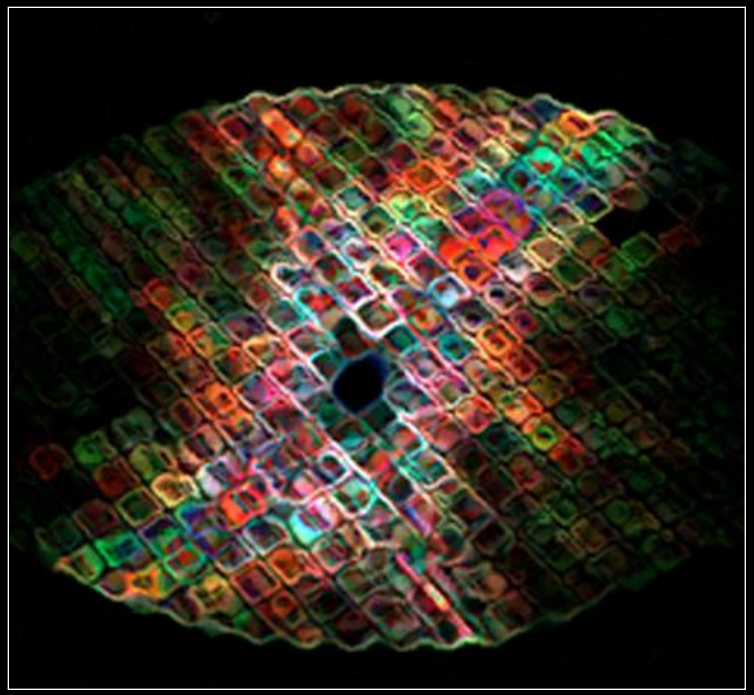
Digital Media (iGrid 2000, Yokohama Japan

USA, Canada, Japan, Singapore, Netherlands, Sweden, CERN, Spain, Mexico, Korea)

GiDVN: Global Internet Digital Video Network

- Digital Video Working Group, Coordinating Committee for International Research Networks
- CERN, Switzerland
- APAN, Japan; KDD, Japan
- APAN-KR, Korea; Seoul National University, Korea
- SURFnet, The Netherlands
- DFSCA-UNAM, Mexico
- SingAREN, Singapore
- Universitat Politecnica de Catalunya, Spain
- Royal Institute of Technology, Sweden
- Int'l Center for Advanced Internet Research (iCAIR), Northwestern, USA



GiDVN projects have enhanced media capabilities for the next-generation Internet, enabling new applications to interoperate throughout the world.

www.icair.org/inet2000

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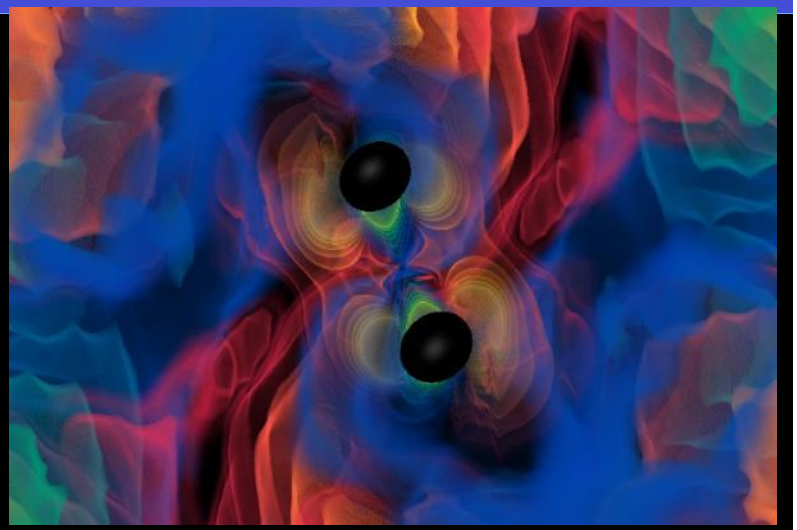
High-Performance Digital Media

For Interactive Remote Visualization (2006)

- 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
- Northwestern University
- MCNC, USA
- NCSA, USA
- Lawrence Berkeley National Laboratory, USA
- Masaryk University/CESNET, Czech Republic
- Zuse Institute Berlin, Germany
- Vrije Universiteit, NL

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

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4K Media

4K Digital Media
Ultra High Definition
Digital
Communications

Digital communications using SHD transmits extra-high-quality, digital, full-color, full motion images.

4k pixels horizontal, 2k vertical

4 * HDTV – 24 * DVD

4K Video is approximately 4X standard HD

HD = 720x1280 or 1080x1920 pixels

4K = 3840x2160 pixels

www.onlab.ntt.co.jp/en/mn/shd

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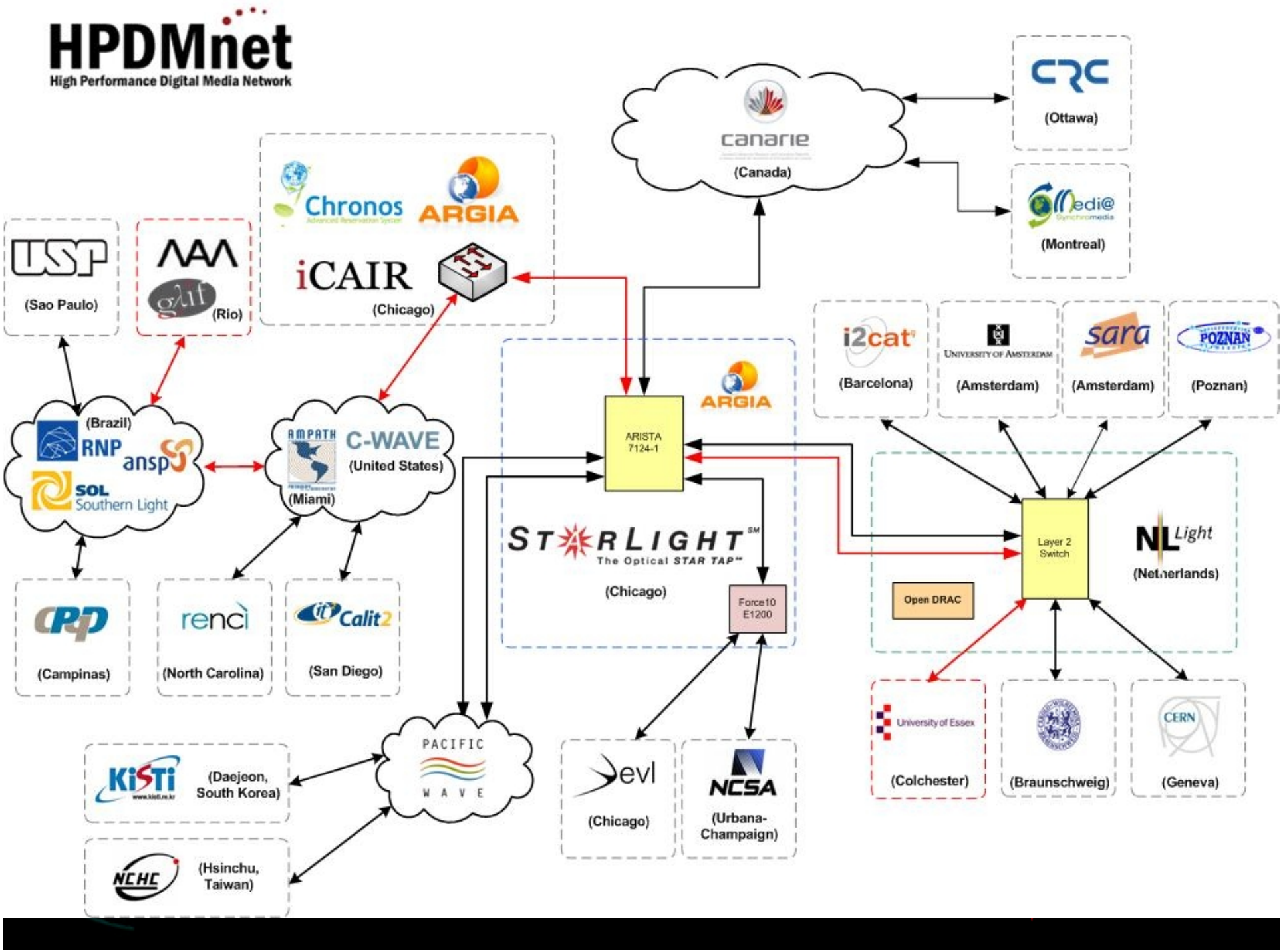
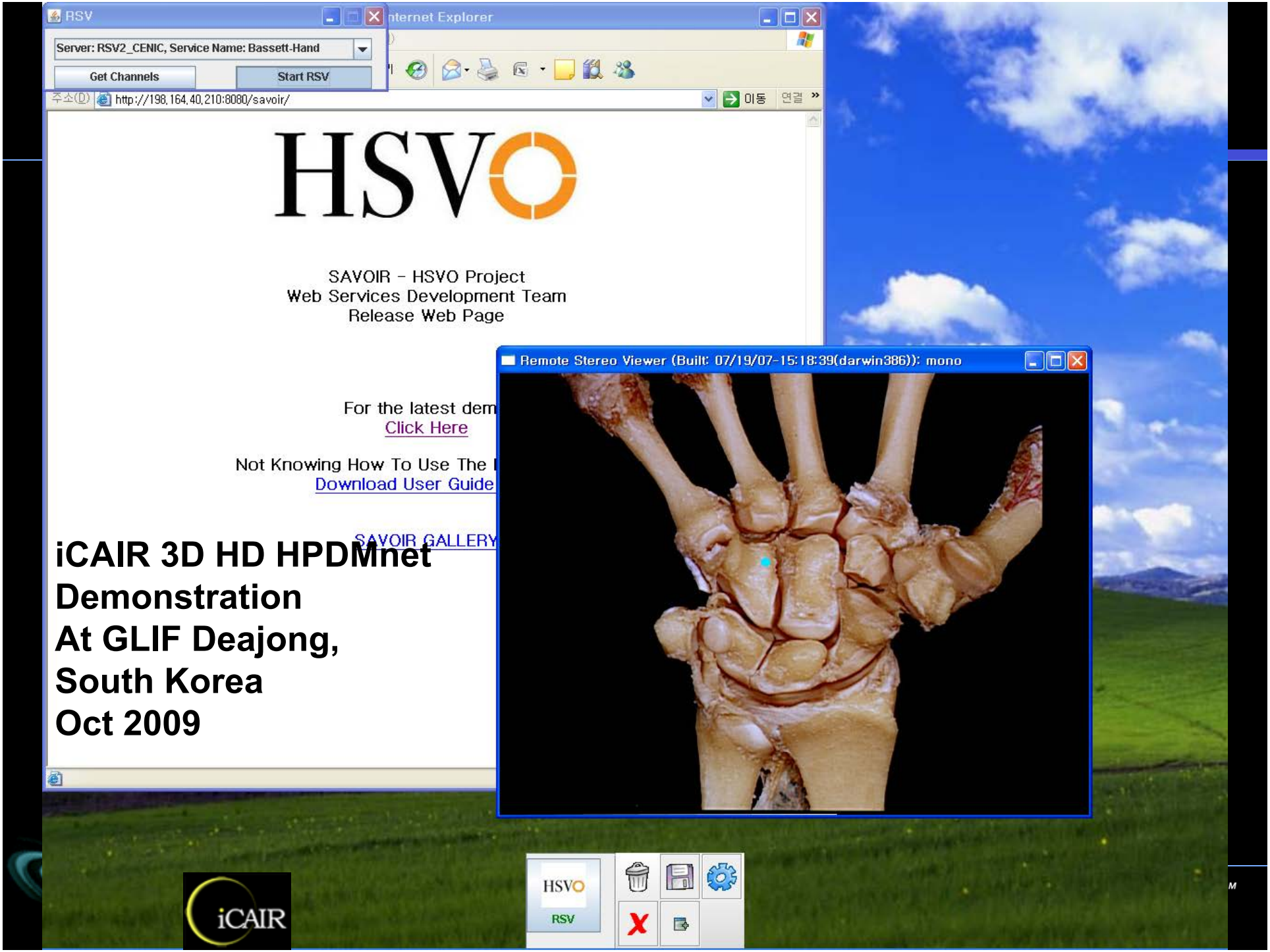
8k Media Experiments At the Univ of Essex


HPDMnet
High Performance Digital Media Network
canarie
(Canada)
(Ottawa)
(Montreal)
Chronos
ARGIA
iCAIR
(Chicago)
(Sao Paulo)
(Rio)
i2cat
(Barcelona)
(Amsterdam)
(Amsterdam)
(Poznan)
(Brazil)
RNP
ansp
SOL
Southern Light
AMPATH
C-WAVE
(United States)
(Miami)
ARISTA
7124-1
STARLIGHT
The Optical STAR TAP
(Chicago)
Force10
E1200
Layer 2
Switch
Open DRAC
NL Light
(Netherlands)
(Campinas)
renci
(North Carolina)
Calit2
(San Diego)
University of Essex
(Colchester)
(Braunschweig)
CERN
(Geneva)
PACIFIC
WAVE
KiSTi
(Daejeon,
South Korea)
NCHC
(Hsinchu,
Taiwan)
evl
(Chicago)
NCSA
(Urbana-
Champaign)


RSV
Server: RSV2_CENIC, Service Name: Bassett-Hand
Get Channels
Start RSV
nternet Explorer
http://198.164.40.210:8080/savoir/
이동
연결
HSVO
SAVOIR - HSVO Project
Web Services Development Team
Release Web Page
For the latest dem
Click Here
Not Knowing How To Use The
Download User Guide
SAVOIR GALLERY
Remote Stereo Viewer (Built: 07/19/07-15:18:39(darwin386)): mono
iCAIR 3D HD HPDMnet
Demonstration
At GLIF Deajong,
South Korea
Oct 2009
iCAIR
HSVO
RSV

Testbed Demonstrations With National Science Foundation at the Annual Conference of The American Association for the Advancement of Science February 2009

Using An Optical Fiber Extension from StarLight/GLIF

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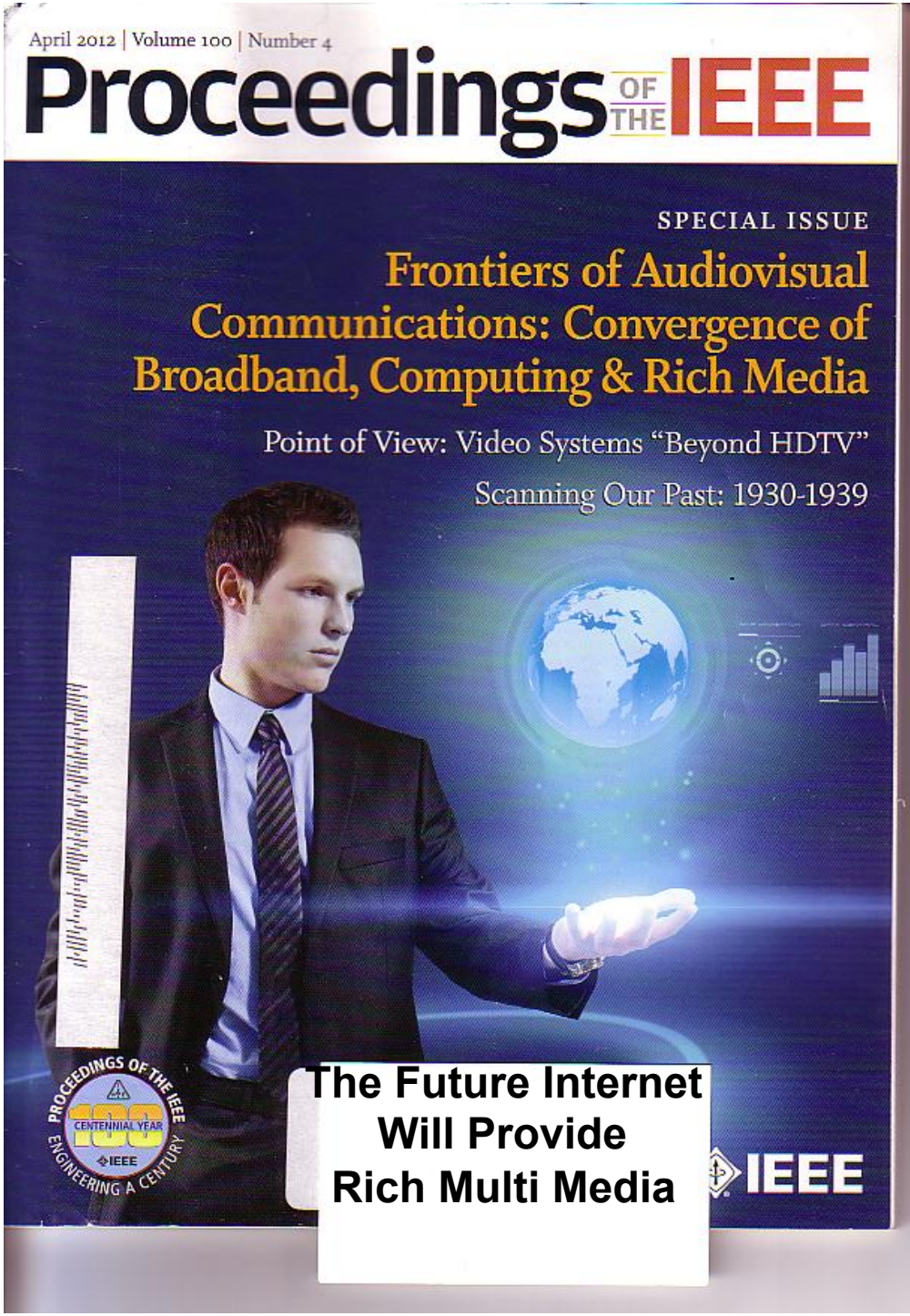

The Future Internet Will Provide Rich Multi Media

Invitational Paper
Evolution of Optical Networking Toward Rich Digital Media Services

Admela Jukan and Joe Mambretti
April 2012
Vol 100, Number 4

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StarLight – "By Researchers For Researchers"

StarLight is an experimental optical infrastructure and **proving ground for network services** optimized for high-performance applications

GE+2.5+10GE Exchange

Soon:

Multiple 10GEs Over Optics – World's "Largest" 10GE Exchange

First of a Kind Enabling Interoperability At L1, L2, L3

View from StarLight

Abbott Hall, Northwestern University's Chicago Campus

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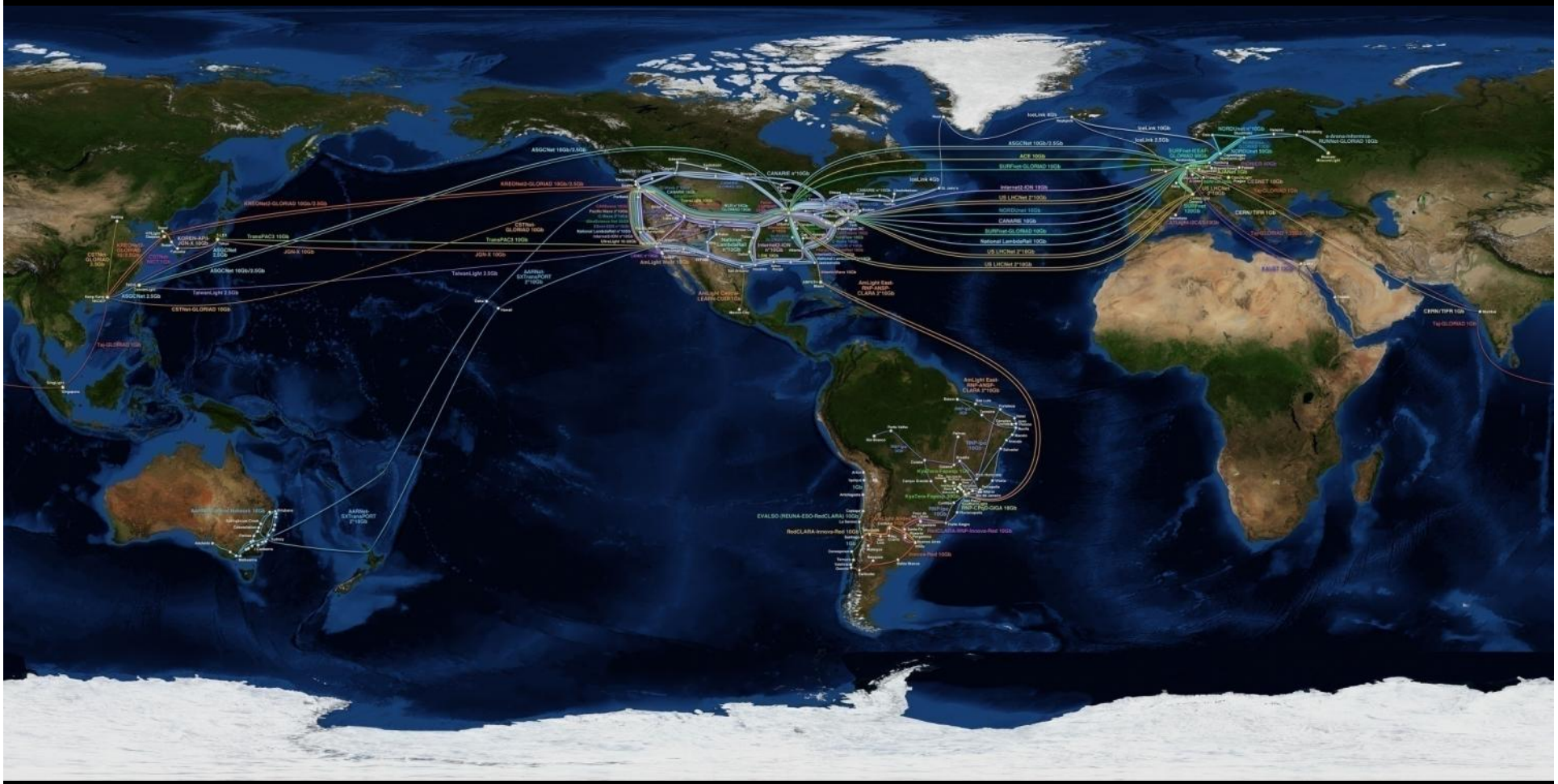
iCAIR: Founding Partner of the Global Lambda Integrated Facility
Available Advanced Network Resources



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

www.glif.is

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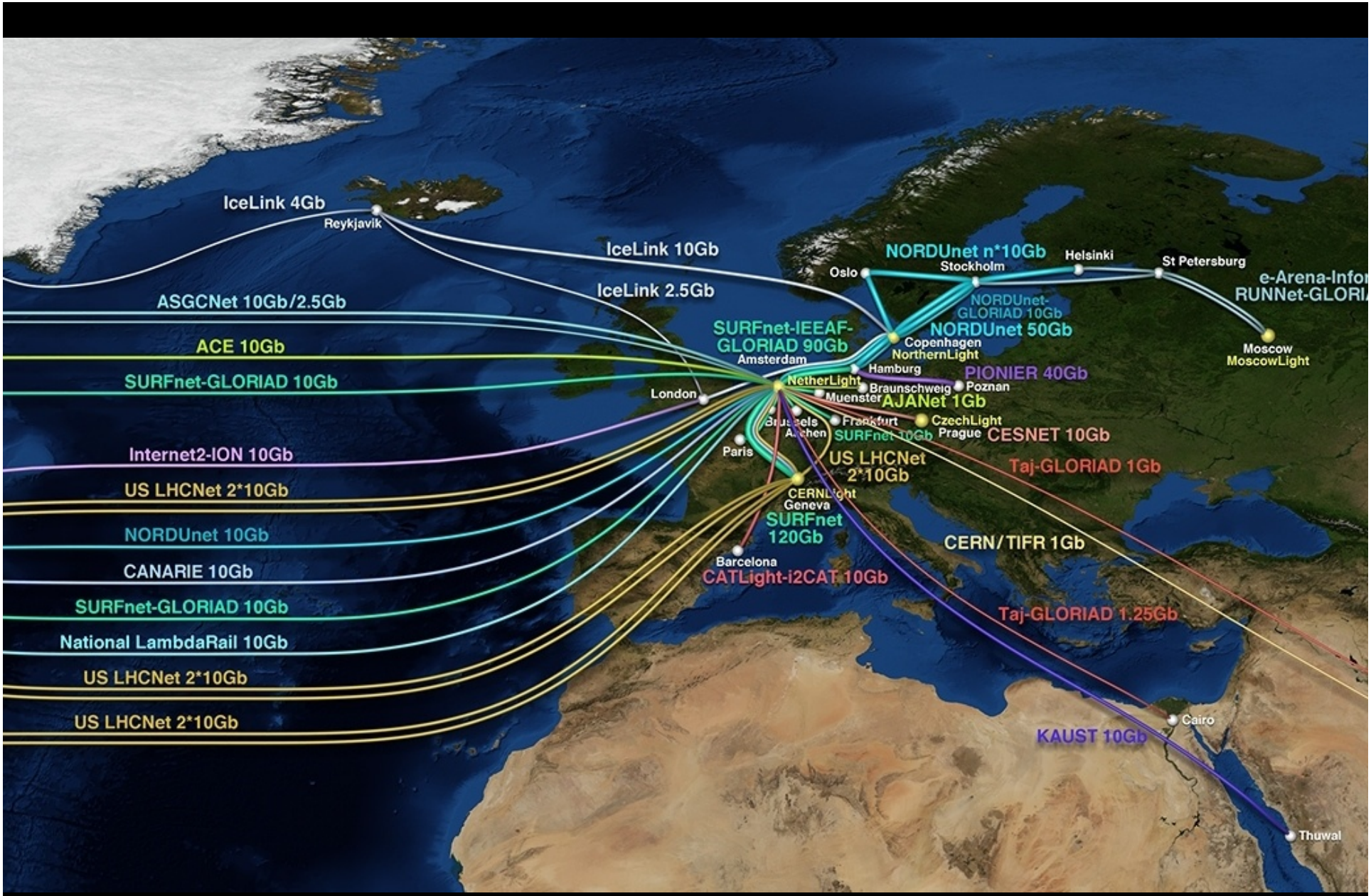

GLIF 2011

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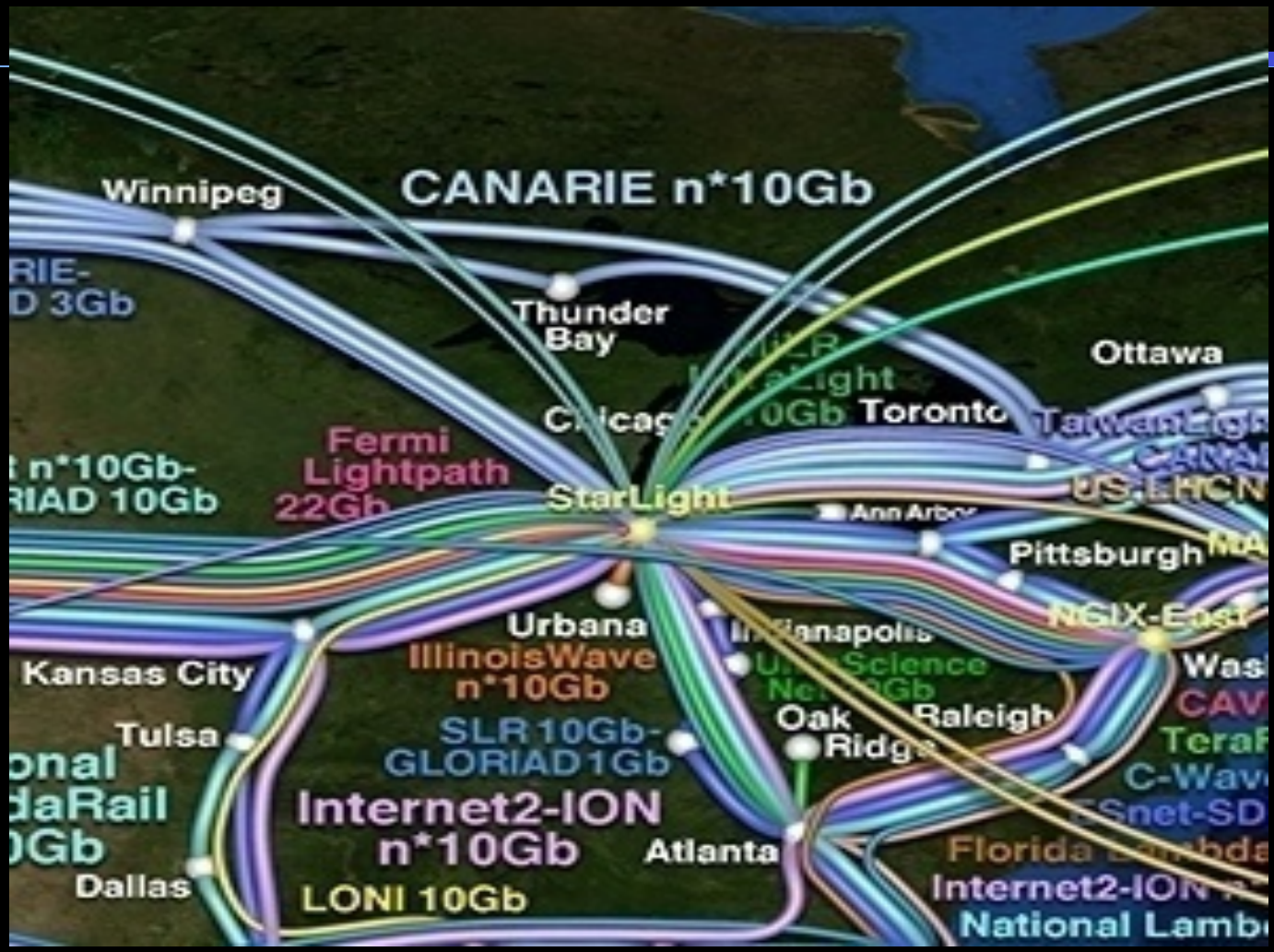
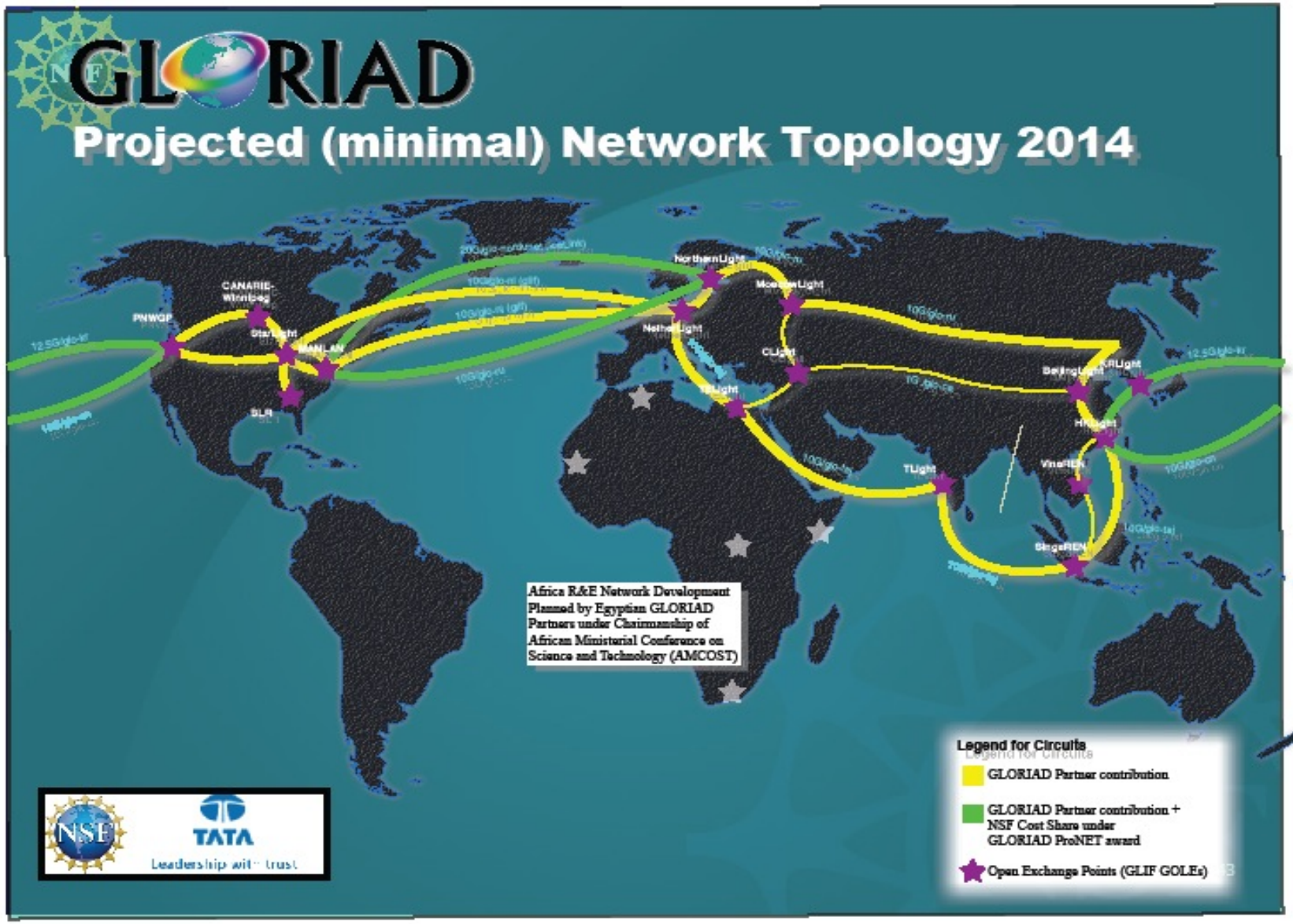

Winnipeg
CANARIE n*10Gb
Thunder Bay
Ottawa
Toronto
Fermi Lightpath 22Gb
StarLight
Pittsburgh
Urbana
IllinoisWave n*10Gb
Kansas City
Tulsa
SLR 10Gb-GLORIAD 1Gb
Oak Ridge
Raleigh
Internet2-ION n*10Gb
Atlanta
Dallas
LONI 10Gb
National Lamb

GLIF South America

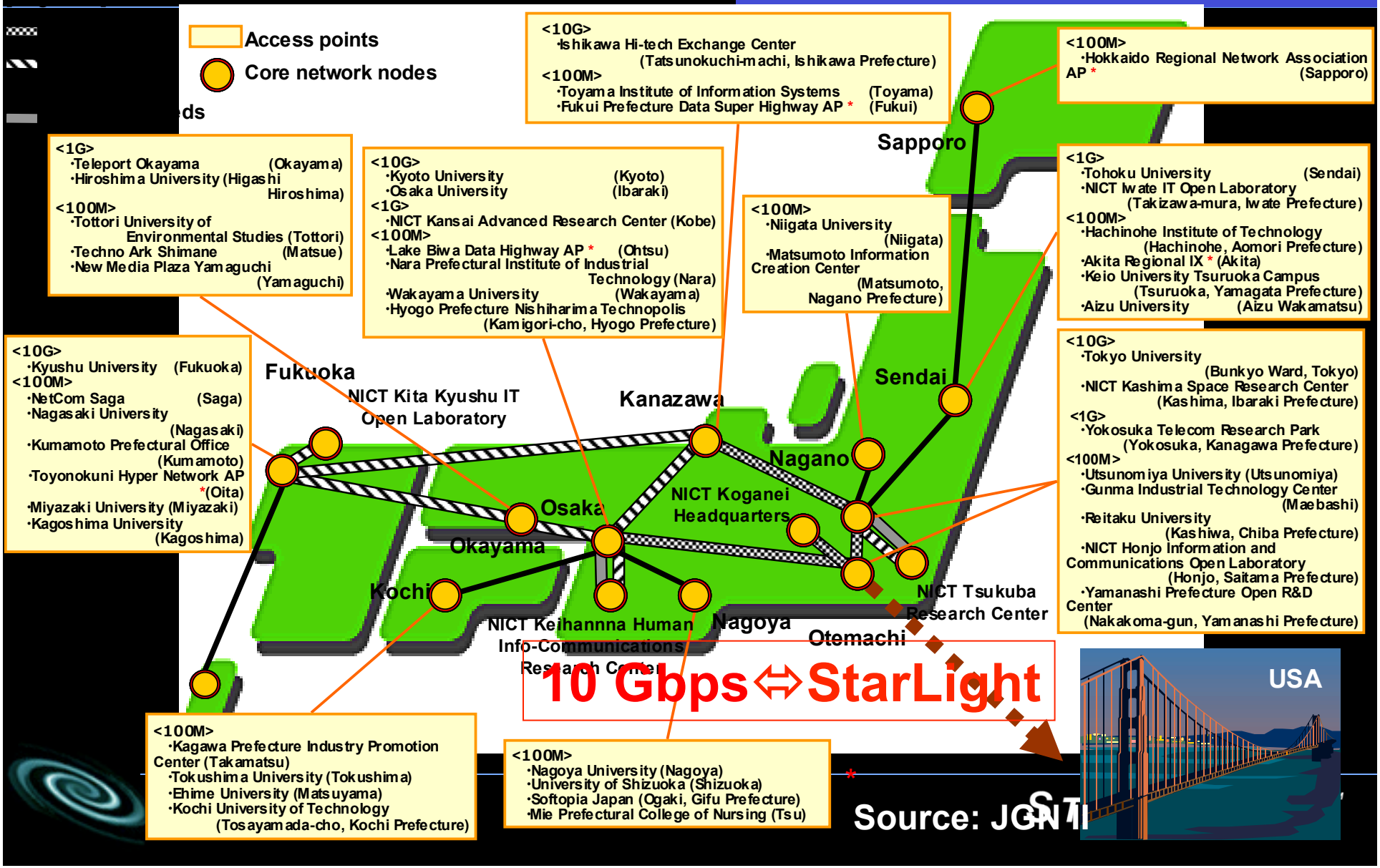
iCAIR

IGHT SM


GLORIAD
Projected (minimal) Network Topology 2014
CANARIE-Winnipeg
PNWGP
StarLight
MANLAN
SLR
NetherLight
CLight
TLight
TLight
VnaREN
SingAREN
Africa R&E Network Development Planned by Egyptian GLORIAD Partners under Chairmanship of African Ministerial Conference on Science and Technology (AMCOST)
Legend for Circuits
GLORIAD Partner contribution
GLORIAD Partner contribution + NSF Cost Share under GLORIAD ProNET award
Open Exchange Points (GLIF GOLEs)
NSF
TATA
Leadership with trust

SM

JGNIIplus Network Topology Map
National Institute for Information Communication Technology (NICT)



Source: John Silvester

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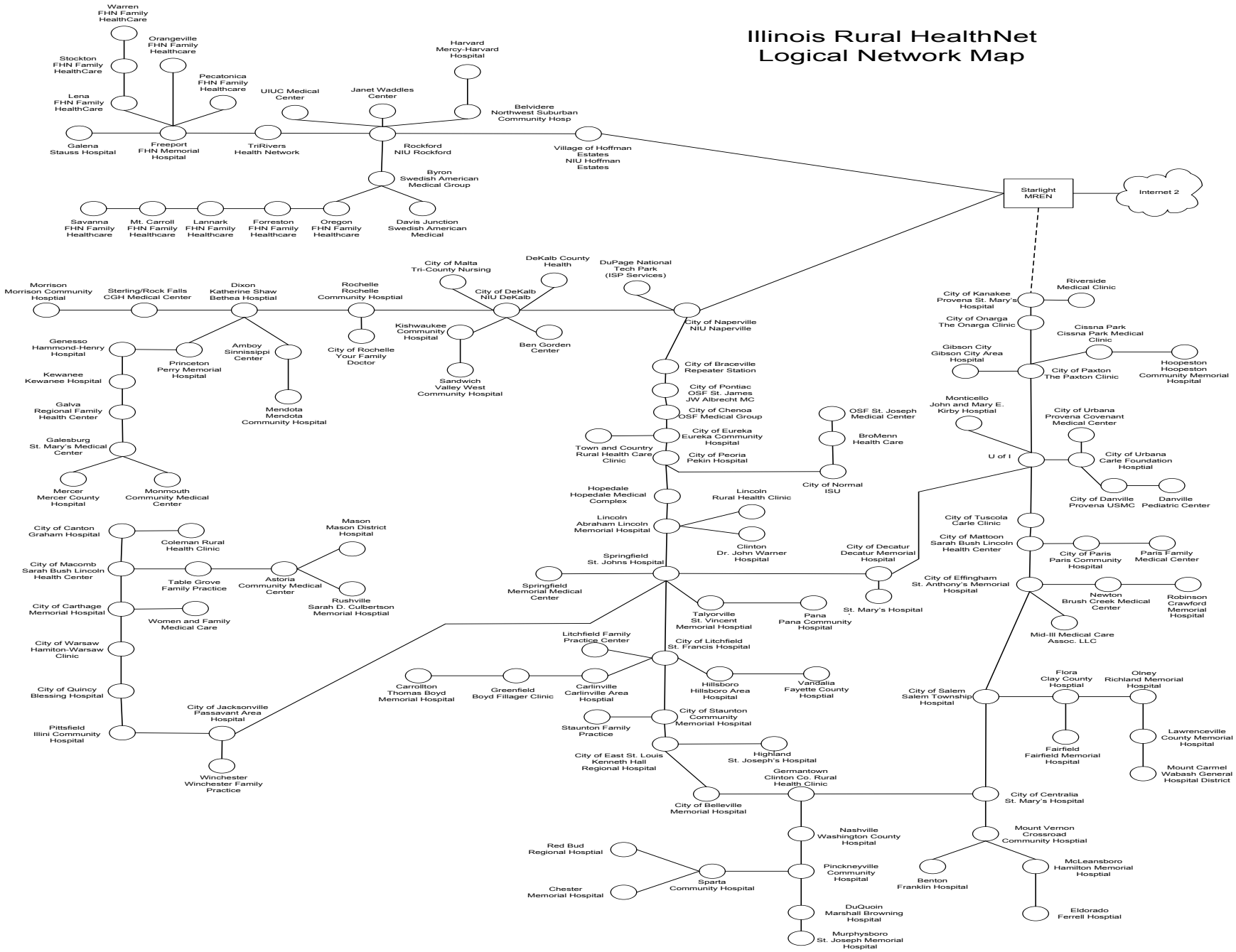
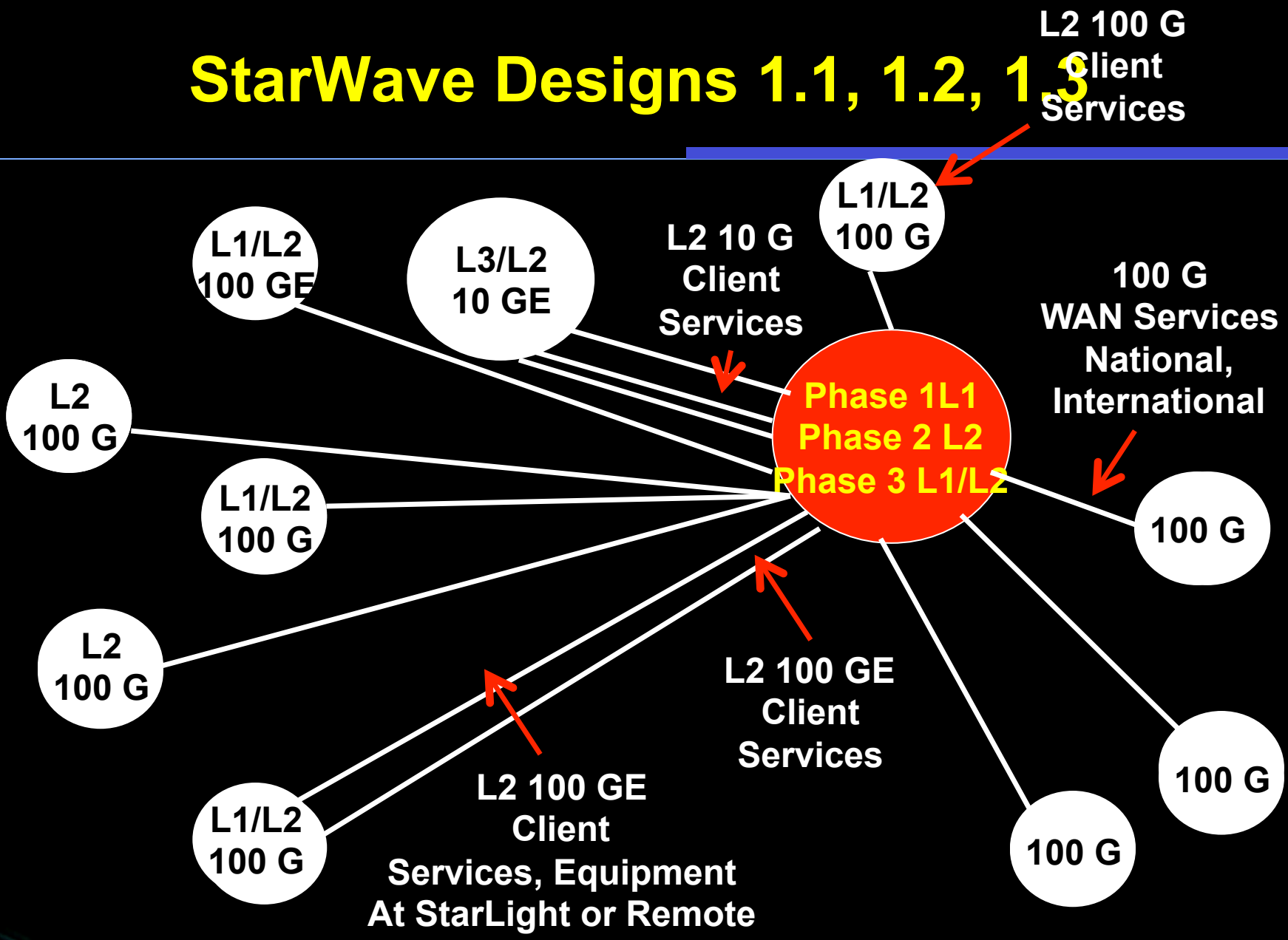

Illinois Rural HealthNet
Logical Network Map
Warren FHN Family HealthCare
Orangeville FHN Family Healthcare
Stockton FHN Family HealthCare
Pecatonica FHN Family Healthcare
Lena FHN Family HealthCare
Galena Stauss Hospital
Freeport FHN Memorial Hospital
TriRivers Health Network
UIUC Medical Center
Janet Waddles Center
Harvard Mercy-Harvard Hospital
Belvidere Northwest Suburban Community Hosp
Rockford NIU Rockford
Byron Swedish American Medical Group
Savanna FHN Family Healthcare
Mt. Carroll FHN Family Healthcare
Lannark FHN Family Healthcare
Forreston FHN Family Healthcare
Oregon FHN Family Healthcare
Davis Junction Swedish American Medical
Village of Hoffman Estates NIU Hoffman Estates
Starlight MREN
Internet 2
Morrison Morrison Community Hosptial
Sterling/Rock Falls CGH Medical Center
Dixon Katherine Shaw Bethea Hospital
Rochelle Rochelle Community Hospital
City of Rochelle Your Family Doctor
City of Malta Tri-County Nursing
DeKalb County Health
City of DeKalb NIU DeKalb
DuPage National Tech Park (ISP Services)
Kishwaukee Community Hospital
Sandwich Valley West Community Hospital
Ben Gorden Center
City of Naperville NIU Naperville
Genesso Hammond-Henry Hospital
Princeton Perry Memorial Hospital
Amboy Sinnissippi Center
Mendota Mendota Community Hospital
Kewanee Kewanee Hospital
Galva Regional Family Health Center
Galesburg St. Mary's Medical Center
Mercer Mercer County Hospital
Monmouth Community Medical Center
City of Braceville Repeater Station
City of Pontiac OSF St. James JW Albrecht MC
City of Chenoa OSF Medical Group
City of Eureka Eureka Community Hospital
Town and Country Rural Health Care Clinic
City of Peoria Pekin Hospital
OSF St. Joseph Medical Center
BroMenn Health Care
City of Normal ISU
Hopedale Hopedale Medical Complex
Lincoln Abraham Lincoln Memorial Hospital
Lincoln Rural Health Clinic
Clinton Dr. John Warner Hospital
Springfield St. Johns Hospital
Springfield Memorial Medical Center
City of Decatur Decatur Memorial Hospital
St. Mary's Hospital
Talyorville St. Vincent Memorial Hospital
Pana Pana Community Hospital
City of Canton Graham Hospital
Coleman Rural Health Clinic
City of Macomb Sarah Bush Lincoln Health Center
Table Grove Family Practice
Mason Mason District Hospital
Astoria Community Medical Center
Rushville Sarah D. Culbertson Memorial Hosptial
City of Carthage Memorial Hospital
Women and Family Medical Care
City of Warsaw Hamiton-Warsaw Clinic
City of Quincy Blessing Hospital
Pittsfield Illini Community Hospital
City of Jacksonville Passavant Area Hospital
Winchester Winchester Family Practice
Litchfield Family Practice Center
City of Litchfield St. Francis Hospital
Carrollton Thomas Boyd Memorial Hospital
Greenfield Boyd Fillager Clinic
Carlinville Carlinville Area Hospital
Hillsboro Hillsboro Area Hospital
Vandalia Fayette County Hospital
City of Staunton Community Memorial Hospital
Staunton Family Practice
City of East St. Louis Kenneth Hall Regional Hospital
Highland St. Joseph's Hospital
Germantown Clinton Co. Rural Health Clinic
City of Belleville Memorial Hospital
Red Bud Regional Hosptial
Chester Memorial Hospital
Sparta Community Hospital
Nashville Washington County Hospital
Pinckneyville Community Hospital
DuQuoin Marshall Browning Hospital
Murphysboro St. Joseph Memorial Hospital
City of Kanakee Provena St. Mary's Hospital
Riverside Medical Clinic
City of Onarga The Onarga Clinic
Cissna Park Cissna Park Medical Clinic
Gibson City Gibson City Area Hospital
City of Paxton The Paxton Clinic
Hoopeston Hoopeston Community Memorial Hospital
Monticello John and Mary E. Kirby Hosptial
City of Urbana Provena Covenant Medical Center
U of I
City of Urbana Carle Foundation Hosptial
City of Danville Provena USMC
Danville Pediatric Center
City of Tuscola Carle Clinic
City of Mattoon Sarah Bush Lincoln Health Center
City of Paris Paris Community Hospital
Paris Family Medical Center
City of Effingham St. Anthony's Memorial Hospital
Newton Brush Creek Medical Center
Robinson Crawford Memorial Hospital
Mid-Ill Medical Care Assoc. LLC
City of Salem Salem Township Hospital
Flora Clay County Hosptial
Olney Richland Memorial Hospital
Fairfield Fairfield Memorial Hospital
Lawrenceville County Memorial Hospital
Mount Carmel Wabash General Hospital District
City of Centralia St. Mary's Hospital
Mount Vernon Crossroad Community Hosptial
Benton Franklin Hospital
McLeansboro Hamilton Memorial Hospital
Eldorado Ferrell Hosptial

StarWave Designs 1.1, 1.2, 1.3



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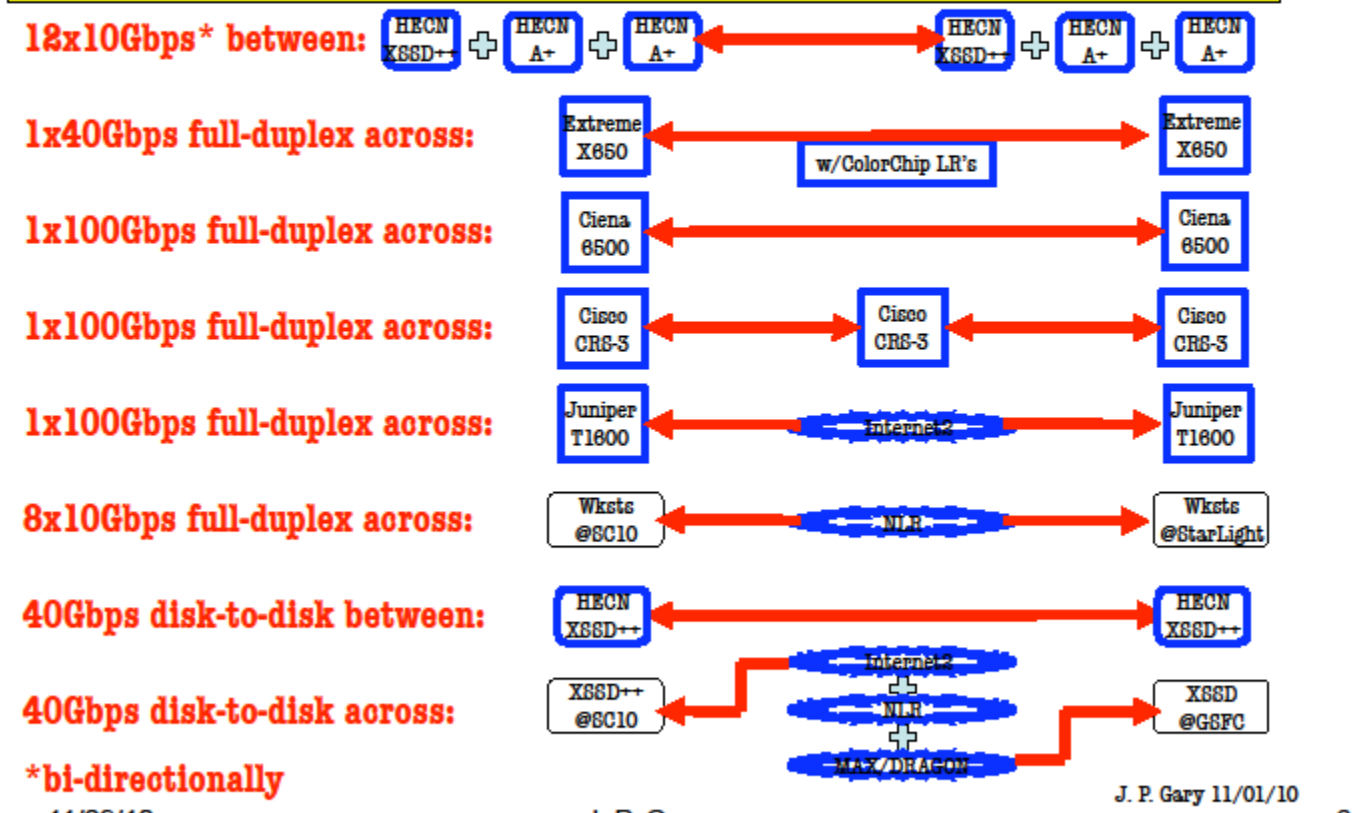
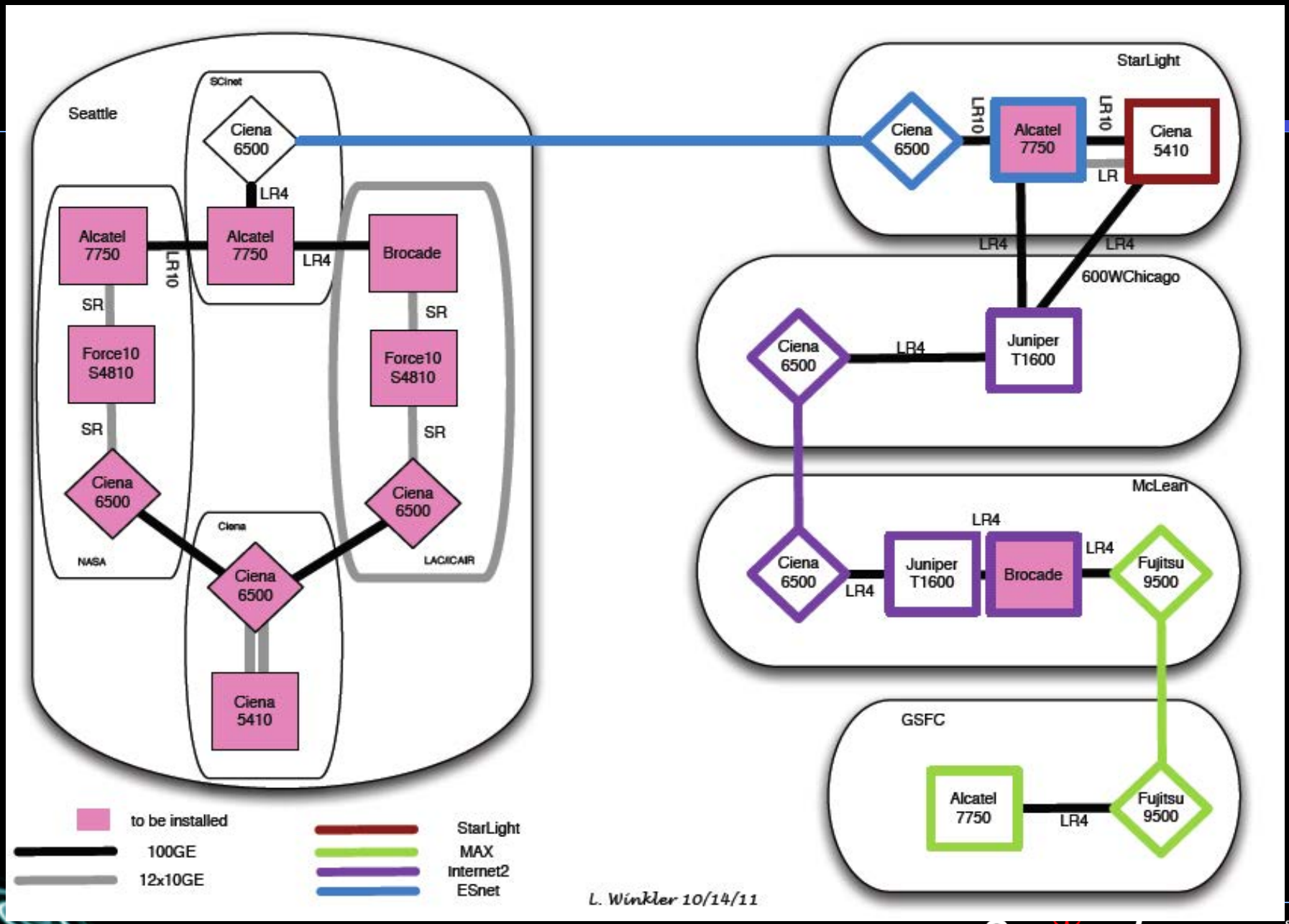
Using 100G Network Technology in Support of Petascale Science

A Collaborative Initiative Among NASA, NLR, NOAA, Northwestern/iCAIR, SCinet & UIC/LAC
Also Using Internet2's Multi-Vendor 100GigE Infrastructure Between StarLight and SC10

Demo Summary



STARLIGHT℠


Seattle
SCinet
Ciena 6500
LR4
Alcatel 7750
LR10
Alcatel 7750
LR4
Brocade
SR
Force10 S4810
SR
Ciena 6500
NASA
Ciena
Ciena 6500
Ciena 5410
SR
Force10 S4810
SR
Ciena 6500
LACIICAIR
StarLight
Ciena 6500
LR10
Alcatel 7750
LR10
LR
Ciena 5410
LR4
LR4
600WChicago
Ciena 6500
LR4
Juniper T1600
McLean
LR4
Ciena 6500
LR4
Juniper T1600
Brocade
LR4
Fujitsu 9500
GSFC
Alcatel 7750
LR4
Fujitsu 9500
to be installed
100GE
12x10GE
StarLight
MAX
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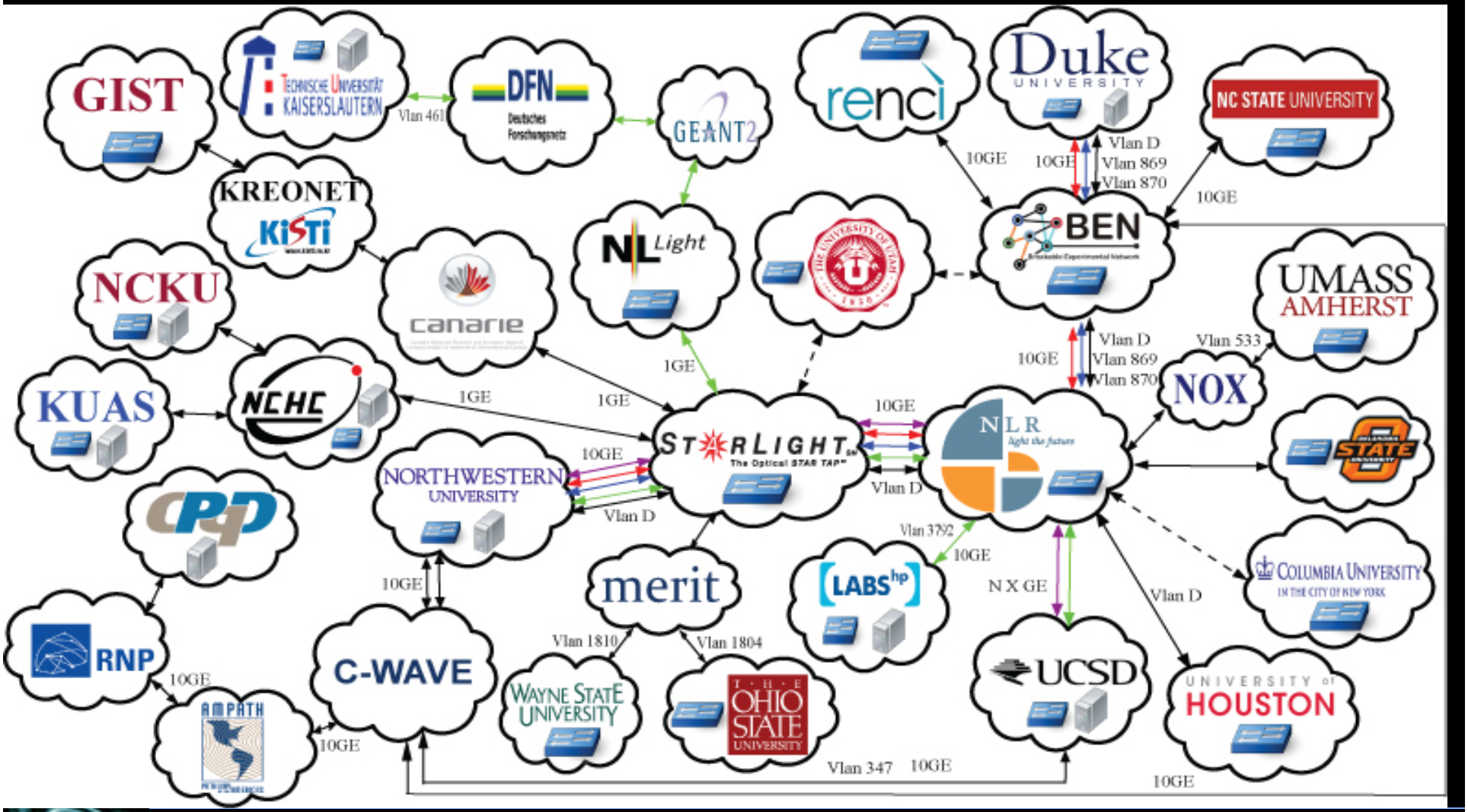
L. Winkler 10/14/11

International Global Environment for Network Innovation (iGENI)



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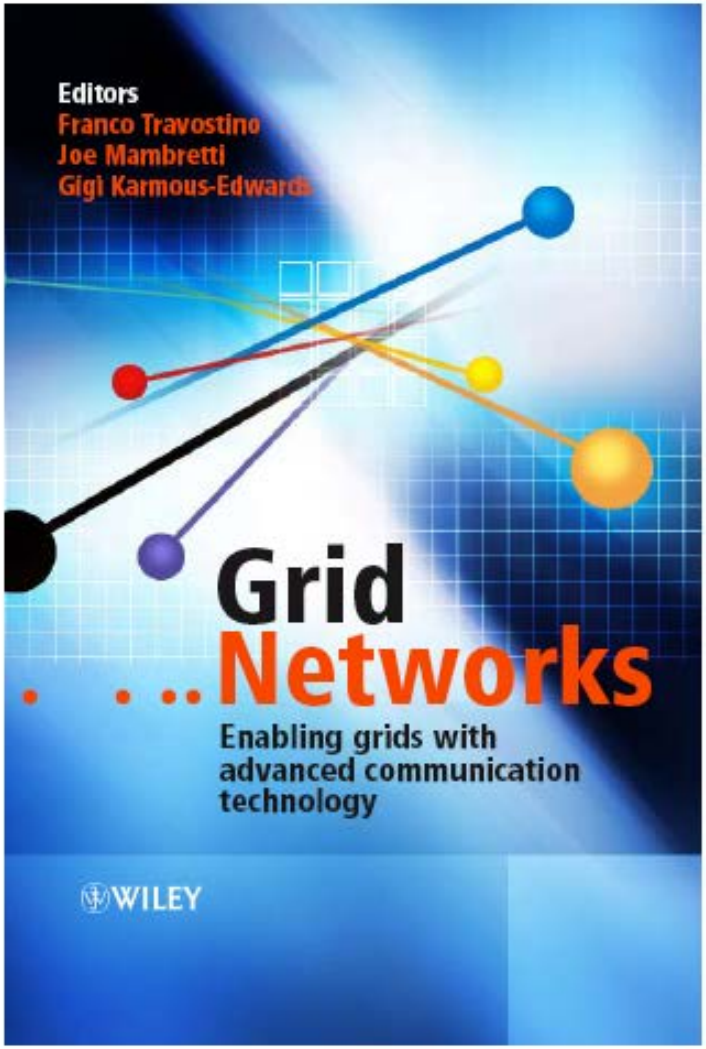
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