The GLORIAD Federated Model of Community-focused Cyberinfrastructure: Thoughts on Next Steps for Development of Distributed, Decentralized Global Networking for Science and Education

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NSF Agreement Establishing GLORIAD/Taj
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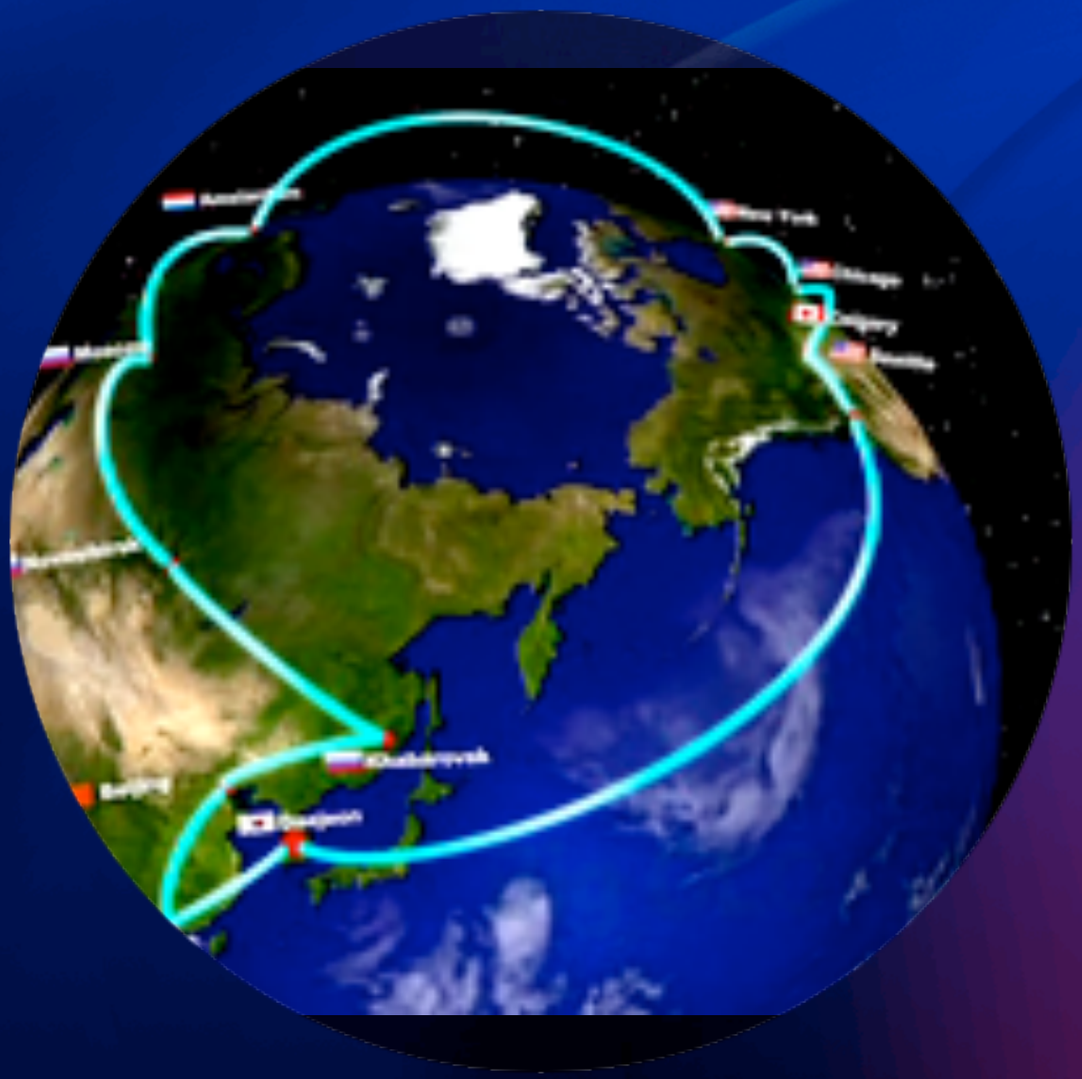
(parts of presentation prepared with Joe Mambretti)

GLORIAD



Animation by Korean partners at KISTI

- A cooperative R&E network ringing the northern hemisphere linking scientists, educators and students in Russia, USA, China, Korea, Netherlands, Canada, the Nordic countries – and soon India, Egypt, Singapore – and others with specialized network services; co-funded, co-managed by all international partners
- Collaborative International Program to Develop/Deploy advanced Cyberinfrastructure between partnering countries (and others) as effort to expand science, education and cultural cooperation and exchange
- Follow-on to NSF-/Russian MinSci-Funded MIRnet and NaukaNet programs (Total NSF $18.5M, 1998-2014; International: ~$200M). Part of larger NSF Program International Research Network Connections (IRNC).
- Started from a single email ..

Partners

- International: SURFnet, NORDUnet, CSTnet (China), e-ARENA (Russia), KISTI (Korea), CANARIE (Canada), SingaREN, ENSTInet (Egypt), National Knowledge Network (NKN)
- US: StarLight, NLR, Internet2, IU/ TransPAC/Ace, IRNC awardees, ESnet, FedNets, PacWave, Harvey Newman

GLORIAD Users*

- ~11.5 million unique IP addresses since 1999
- ~50,000 distinct IP addresses involved in significant flows per day
- ~80,000 active flows every second 24/7 (~8,000 large flows/second)
- many applications – web, ftp, idd, udp-based transfers, email, skype, video-conferences, etc.

*Through GLORIAD's exchange point in Chicago. Global numbers much higher.

Who?

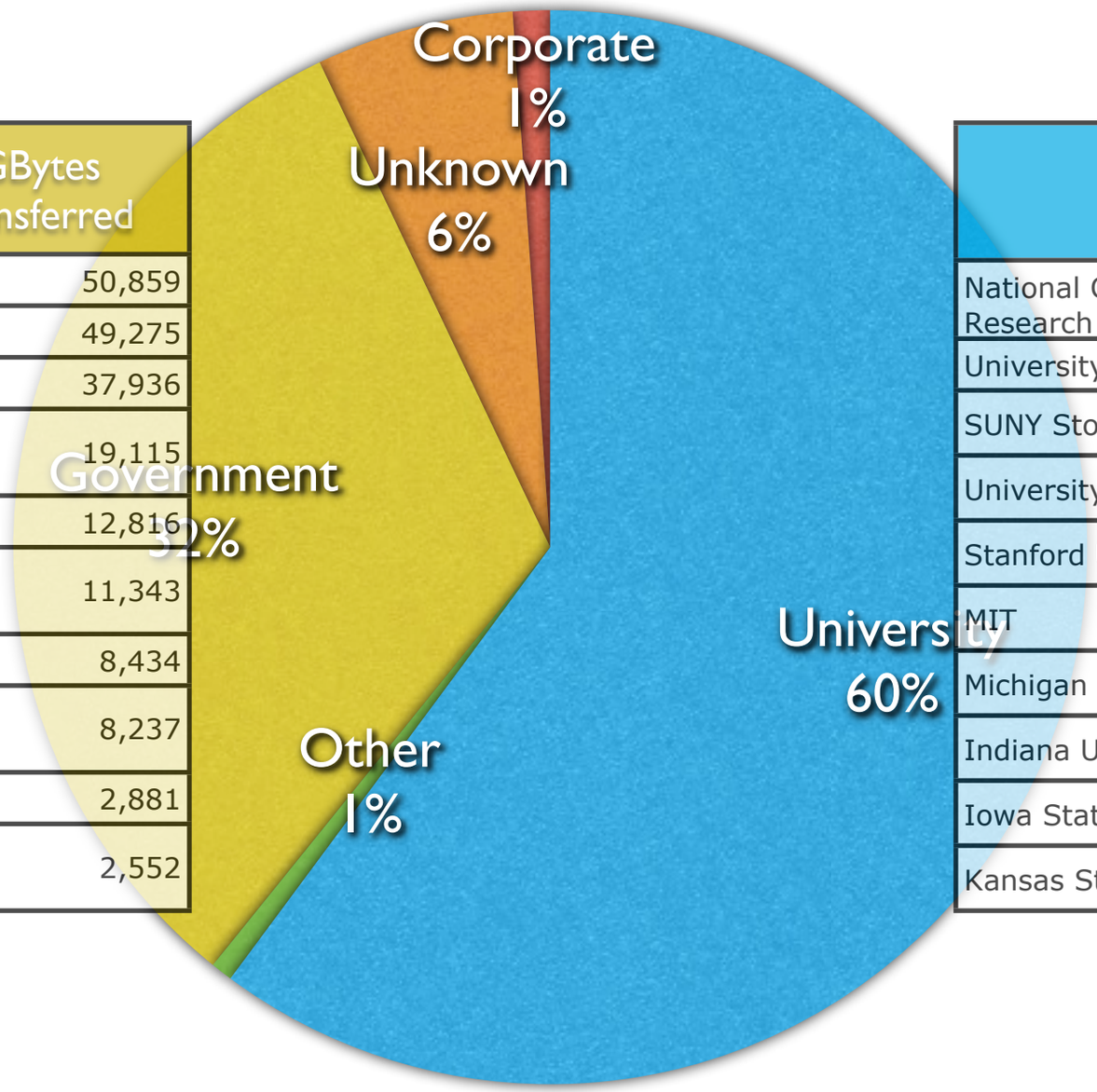
Top GLORIAD Users

Period: **since yesterday (1 day)** (since 2010-07-11 22:00:00 (Central Standard Time))

Source Country	Source/Organization	Network In	Destination Country	Destination/Organization	Network Out	Application	% Retransmits	Gigabytes	% Total
China	Institute of High Energy Physics, China Academy of Sciences (Beijing)	CSTnet	United States	Fermilab (Batavia, IL)		Other (TCP)	0.0329	368.76	12.7
United States	Fermilab (Batavia, IL)		China	Institute of High Energy Physics, China Academy of Sciences (Beijing)	CSTnet	Other (TCP)	0.9013	276.61	9.5
China	Institute of High Energy Physics, China Academy of Sciences (Beijing)		United States	Fermilab (Batavia, IL)		Other (TCP)	0.0317	219.11	7.6
United States	Fermilab (Batavia, IL)		China	Institute of High Energy Physics, China Academy of Sciences (Beijing)		Other (TCP)	0.0372	140.60	4.9
United States	Fermilab (Batavia, IL)	CSTnet	China	Institute of High Energy Physics, China Academy of Sciences (Beijing)		Other (TCP)	0.0027	103.49	3.6
United States	Fermilab (Batavia, IL)		China	CERNET (University in Beijing) (Beijing)	KREOnet2	Other (TCP)	0.0000	72.71	2.5
United States	National Aeronautics and Space Administration (Mountain View, CA)		China	Institute of Geographic Sciences and Natural Resources Research, China Academy of Sciences (Beijing)	CSTnet	Unknown (TCP)	0.1015	68.64	2.4
China	China Meteorological Administration (Beijing)	CSTnet	United States	National Center for Atmospheric Research (Boulder, CO)		Other (TCP)	7.6638	65.90	2.3
United States	Fermilab (Batavia, IL)		Russia	Institute for Nuclear Research (Troitsk)		Other (TCP)	0.0000	64.44	2.2
United States	Fermilab (Batavia, IL)		Russia	Institute for Theoretical and Experimental Physics (ITEP) (Moscow)		Other (TCP)	0.0000	61.76	2.1
United States	Fermilab (Batavia, IL)		Russia	Joint Institute for Nuclear Research (Dubna)		Other (TCP)	0.0000	60.60	2.1
United States	Fermilab (Batavia, IL)		Russia	LHC Computing Grid LAN (Moscow)		Other (TCP)	0.0000	39.17	1.4
United States	Fermilab (Batavia, IL)		Russia	Institute for High Energy Physics (Serpukhov)		Other (TCP)	0.0000	38.38	1.3
United States	Massachusetts Institute of Technology (Cambridge, MA)	NLR	China	Institute of High Energy Physics, China Academy of Sciences (Beijing)	CSTnet	Unknown (TCP)	1.8361	30.41	1.0
United States	National Library of Medicine (Bethesda, MD)		China	Beijing Genomics Institute, China Academy of Sciences (Beijing)	CSTnet	FTP	0.1100	27.23	0.9
United States	National Library of Medicine (Bethesda, MD)		China	China Science & Technology Network (Guangzhou)	CSTnet	FTP	0.0908	24.57	0.8
United States	University of Florida (Gainesville, FL)		China	Institute of High Energy Physics, China Academy of Sciences (Beijing)	CSTnet	Unknown (TCP)	0.8729	23.58	0.8
China	Institute of High Energy Physics, China Academy of Sciences (Beijing)	CSTnet	United States	Purdue University (West Lafayette, IN)	NLR	Unknown (TCP)	0.0474	19.96	0.7

GLORIAD traffic from US by organization category
Period: 1/1/2004 to 3/28/2010

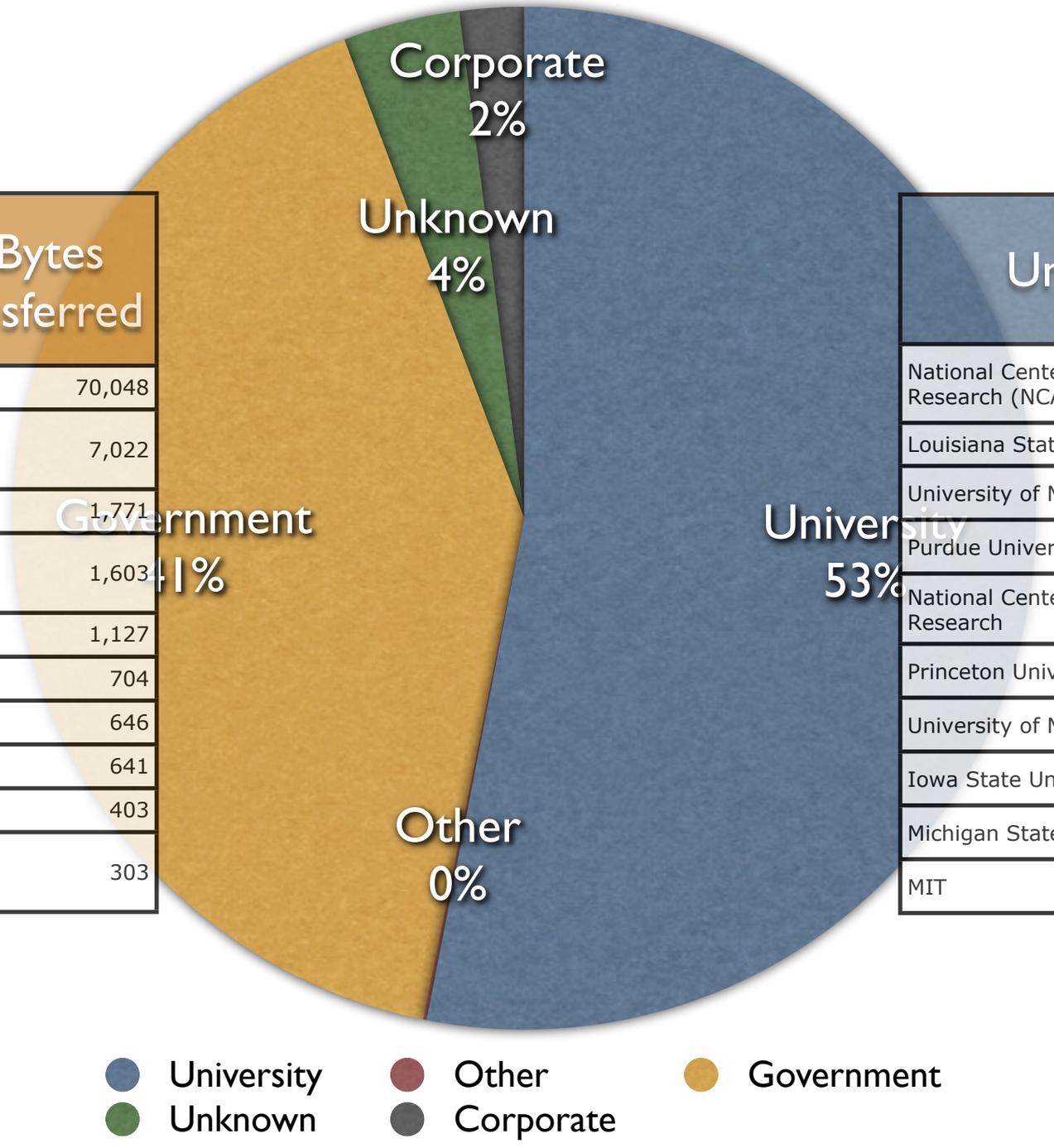
Gov. Institutes	GBytes transferred
Fermilab	50,859
NASA	49,275
USGS EROS Data Center	37,936
U.S. Geological Survey - EROS Data Center	19,115
National Library of Medicine	12,816
National Oceanic & Atmospheric Administration (NOAA)	11,343
National Institutes of Health	8,434
National Oceanic and Atmospheric Administration	8,237
Argonne National Laboratory	2,881
Lawrence Livermore National Laboratory	2,552



University	GBytes transferred
National Center for Atmospheric Research (NCAR)	181,379
University of Maryland	27,289
SUNY Stony Brook	12,035
University of Colorado	6,448
Stanford University	6,447
MIT	5,746
Michigan State University	5,391
Indiana University	5,248
Iowa State University	5,239
Kansas State University	4,311

GLORIAD traffic to US by organization category
Period: 1/1/2004 to 3/28/2010

Gov. Institutes	GBytes transferred
Fermilab	70,048
US Dept of Energy, Energy Sciences Network	7,022
NASA	1,771
U.S. Geological Survey - EROS Data Center	1,603
USGS EROS Data Center	1,127
National Library of Medicine	704
National Institutes of Health	646
Energy Sciences Network	641
Brookhaven National Laboratory	403
National Oceanic and Atmospheric Administration	303



University	GBytes transferred
National Center for Atmospheric Research (NCAR)	39,715
Louisiana State University	5,004
University of Maryland	931
Purdue University	829
National Center for Atmospheric Research	801
Princeton University	794
University of Minnesota	772
Iowa State University	664
Michigan State University	637
MIT	615

NSF Sponsorship

Organization Chart

National Science Foundation

- Office of the Director & Staff Offices
- NSF Director / Deputy Director
- National Science Board Chair / Vice Chair
- Office of Inspector General
- Directorate for Biological Sciences
- Directorate for Computer & Information Science & Engineering
- Directorate for Education and Human Resources
- Directorate for Engineering
- Directorate for Geosciences
- Directorate for Mathematical and Physical Sciences
- Directorate for Social, Behavioral and Economic Sciences
- Office of Cyberinfrastructure
- Office of International Science and Engineering
- Office of Polar Programs
- Office of Budget, Finance and Award Management
- Office of Information and Resource Management

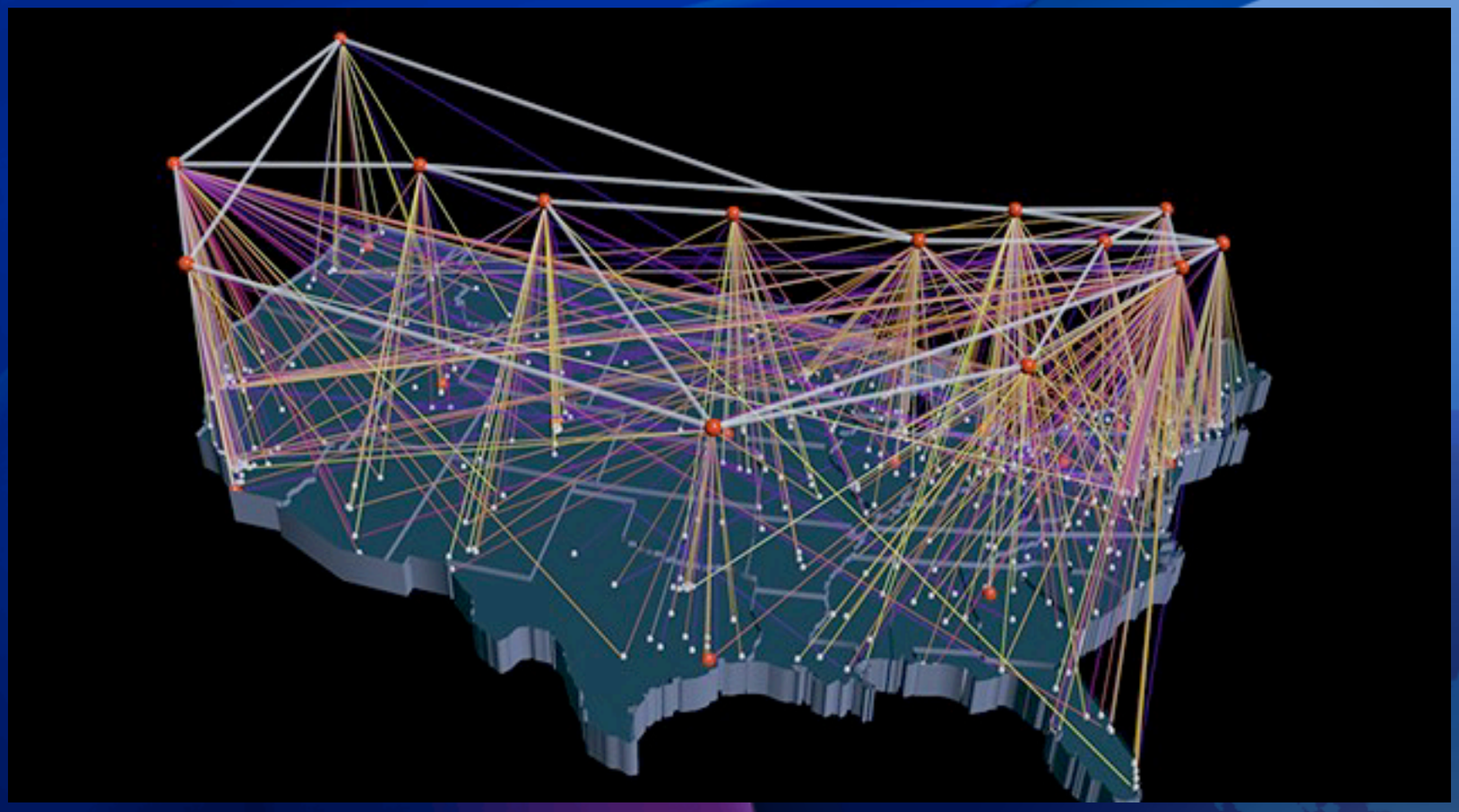
TATA

المصرية للاتصالات
Telecom Egypt

CRDF

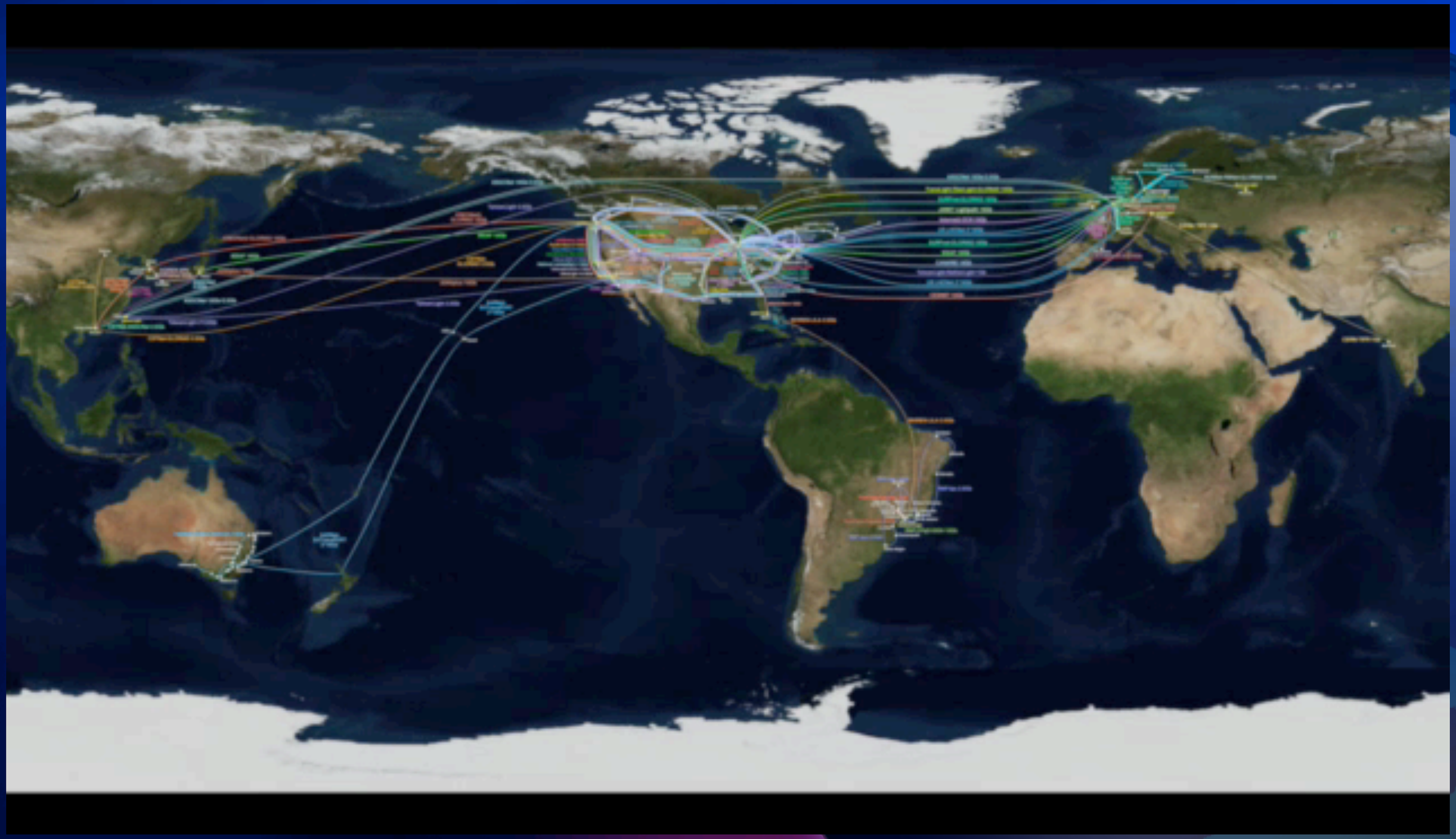
Follow-on to NSF-/Russian MinSci-Funded MIRnet and NaukaNet programs
(Total NSF $18.5M, 1998-2015; International: ~$200M)

Early* NSF vision of R&E networking



*1992, by Donna Cox and Bob Patterson of NCSA

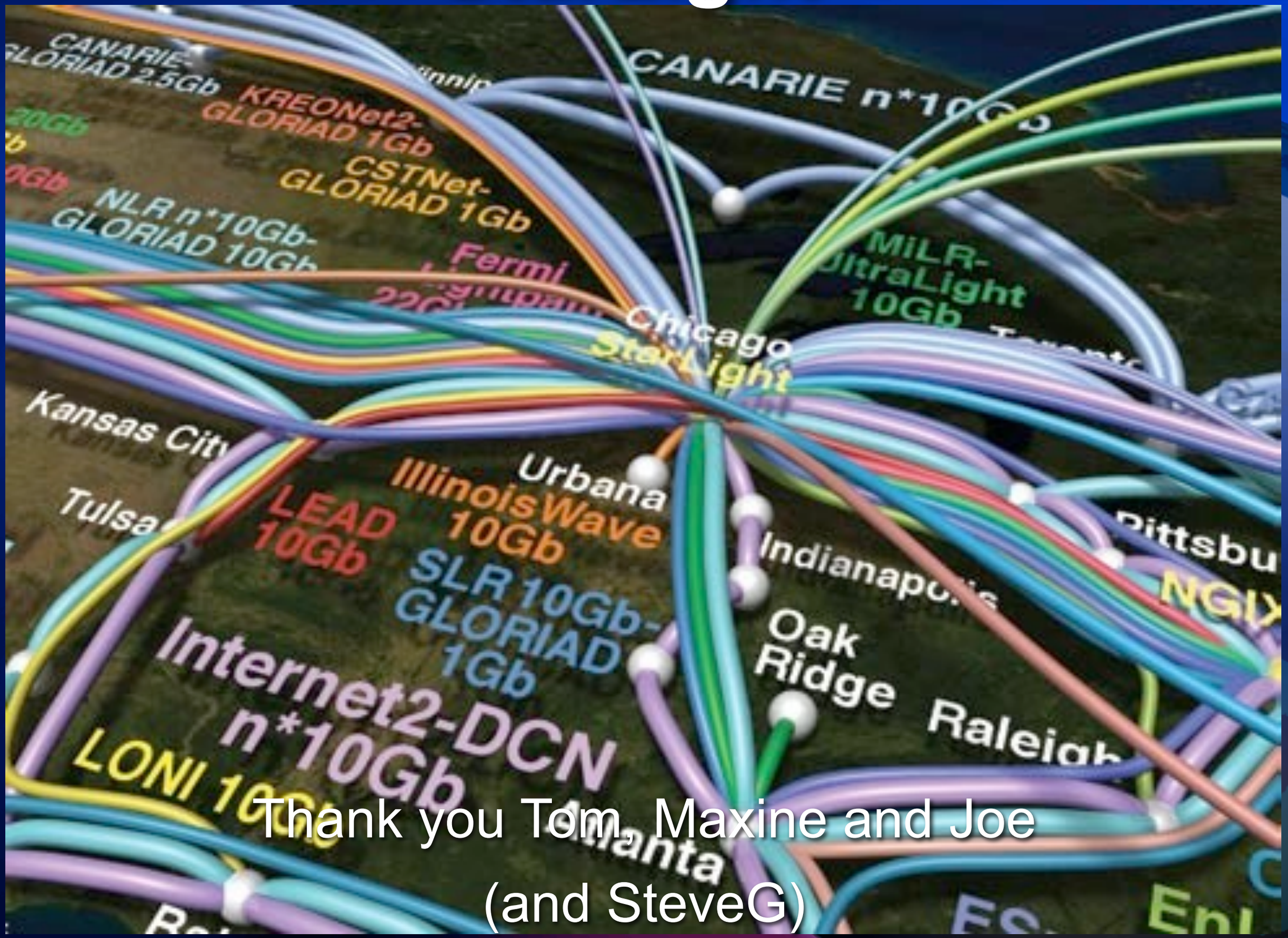
Advanced R&E networking today



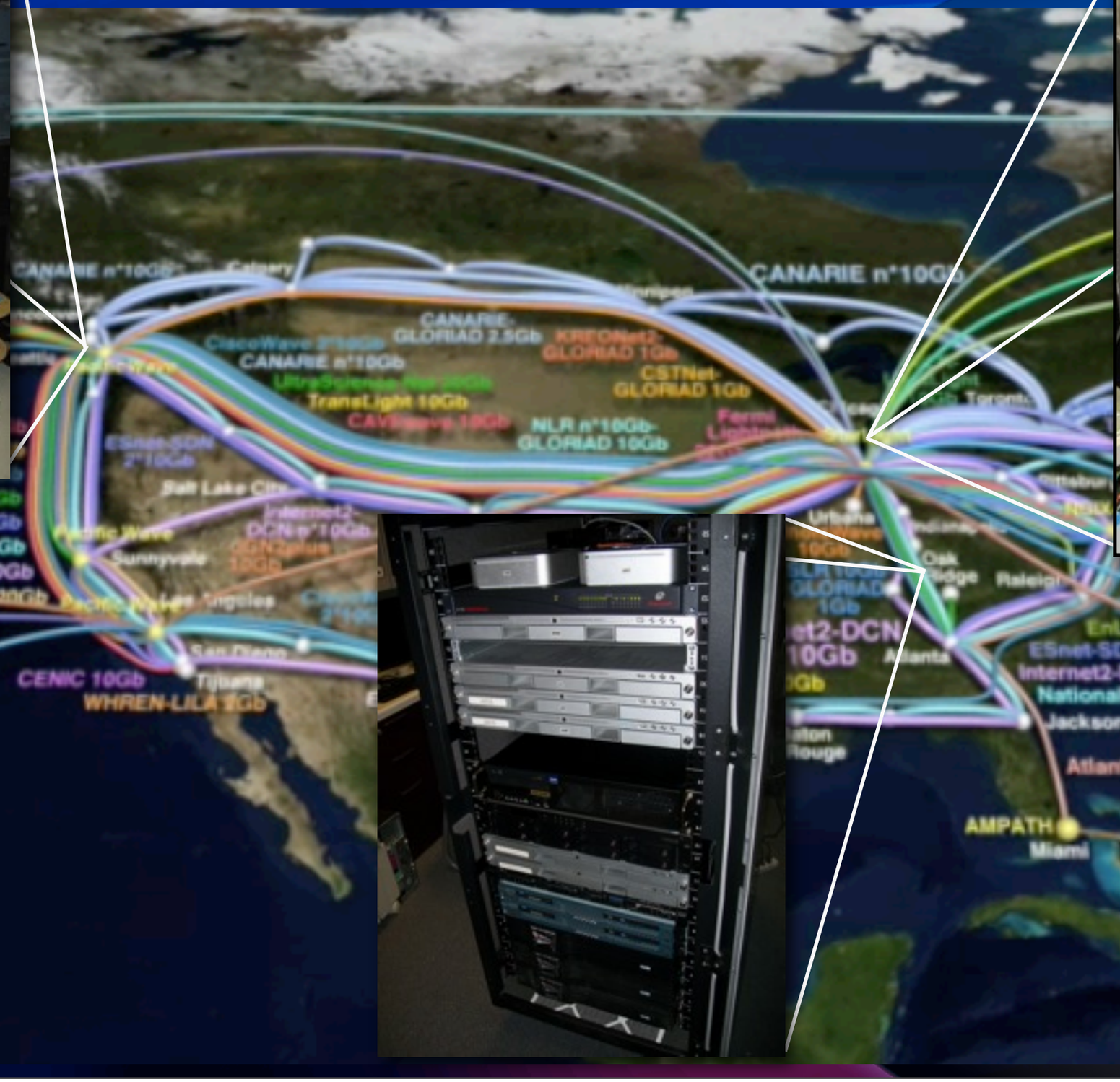
*2008, by Maxine Brown, Bob Patterson, TransLight/StarLight, NCSA, GLIF

FROM: HTTP://WWW.GLIF.IS/PUBLICATIONS/MAPS/GLIF_8-08_640X368.MOV

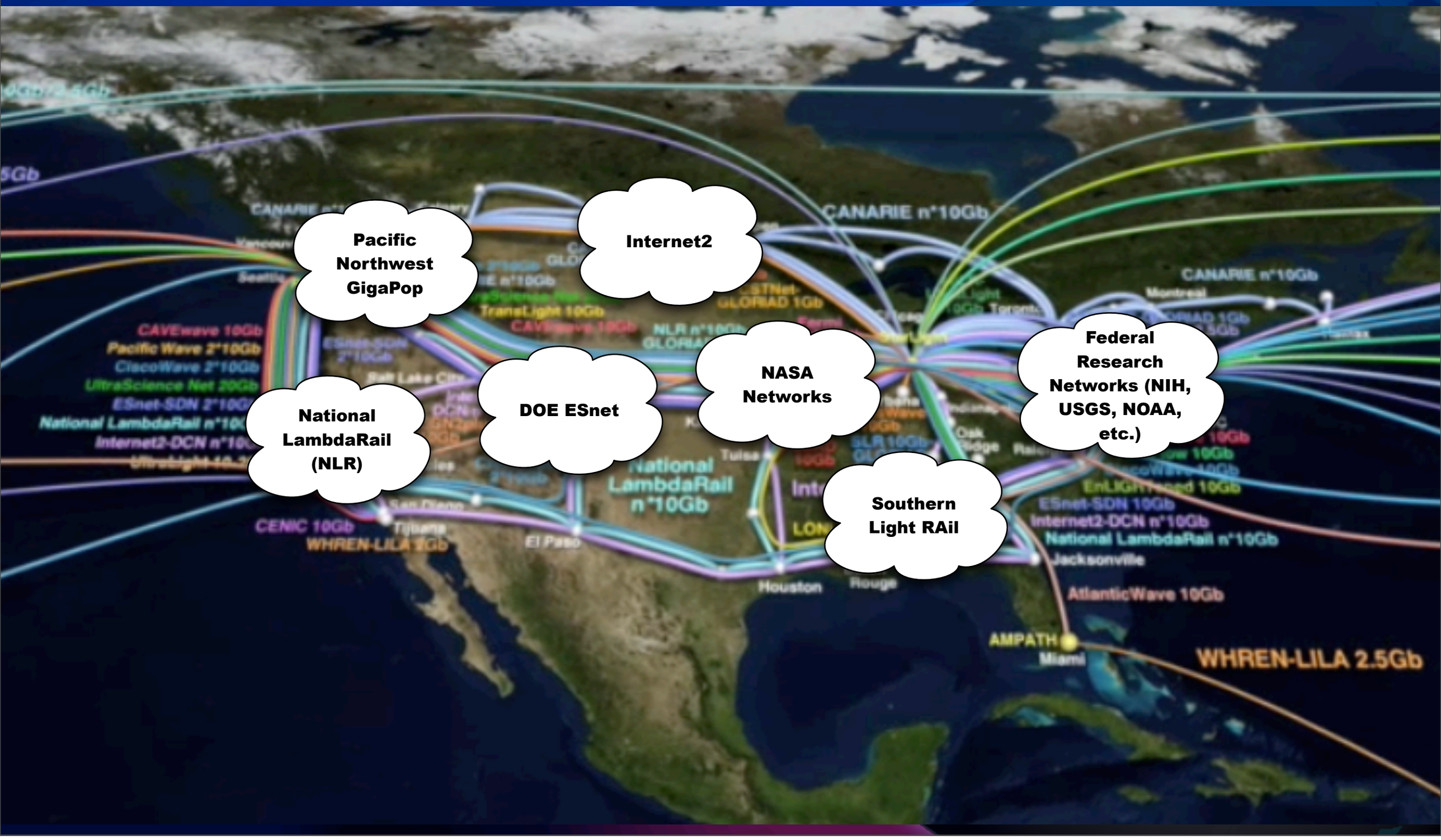
StarLight


CANARIE-
GLORIAD 2.5Gb
KREONet2-
GLORIAD 1Gb
CSTNet-
GLORIAD 1Gb
NLR n*10Gb-
GLORIAD 10Gb
CANARIE n*10Gb
MiLR-
UltraLight
10Gb
Fermi
Chicago
StarLight
Kansas City
Tulsa
LEAD
10Gb
IllinoisWave
10Gb
Urbana
SLR 10Gb-
GLORIAD
1Gb
Internet2-DCN
n*10Gb
LONI 10Gb
Atlanta
Indianapolis
Oak
Ridge
Raleigh
Pittsbu
NGIX
Thank you Tom, Maxine and Joe
(and SteveG)

GLORIAD-US Operations



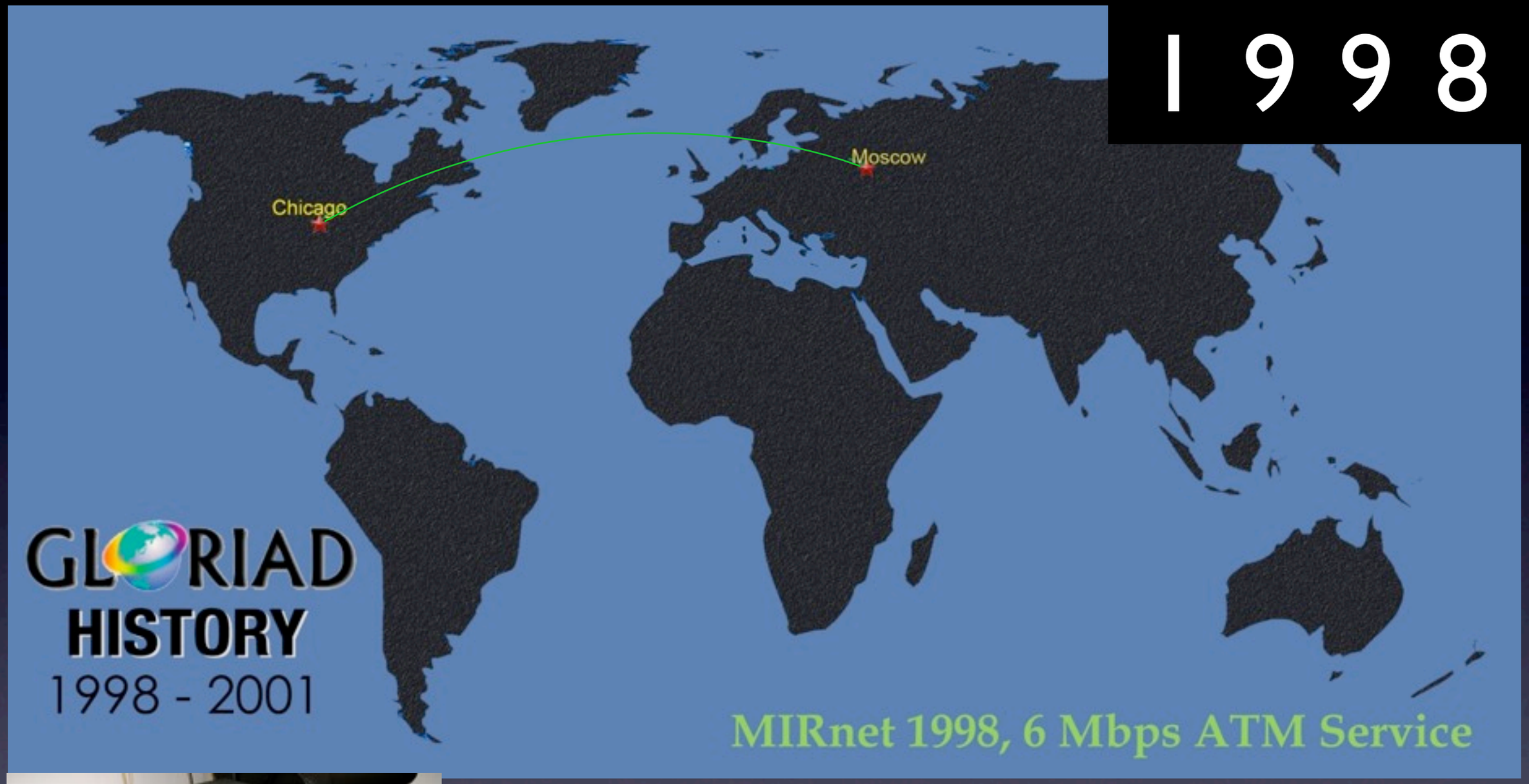
GLORIAD Operations



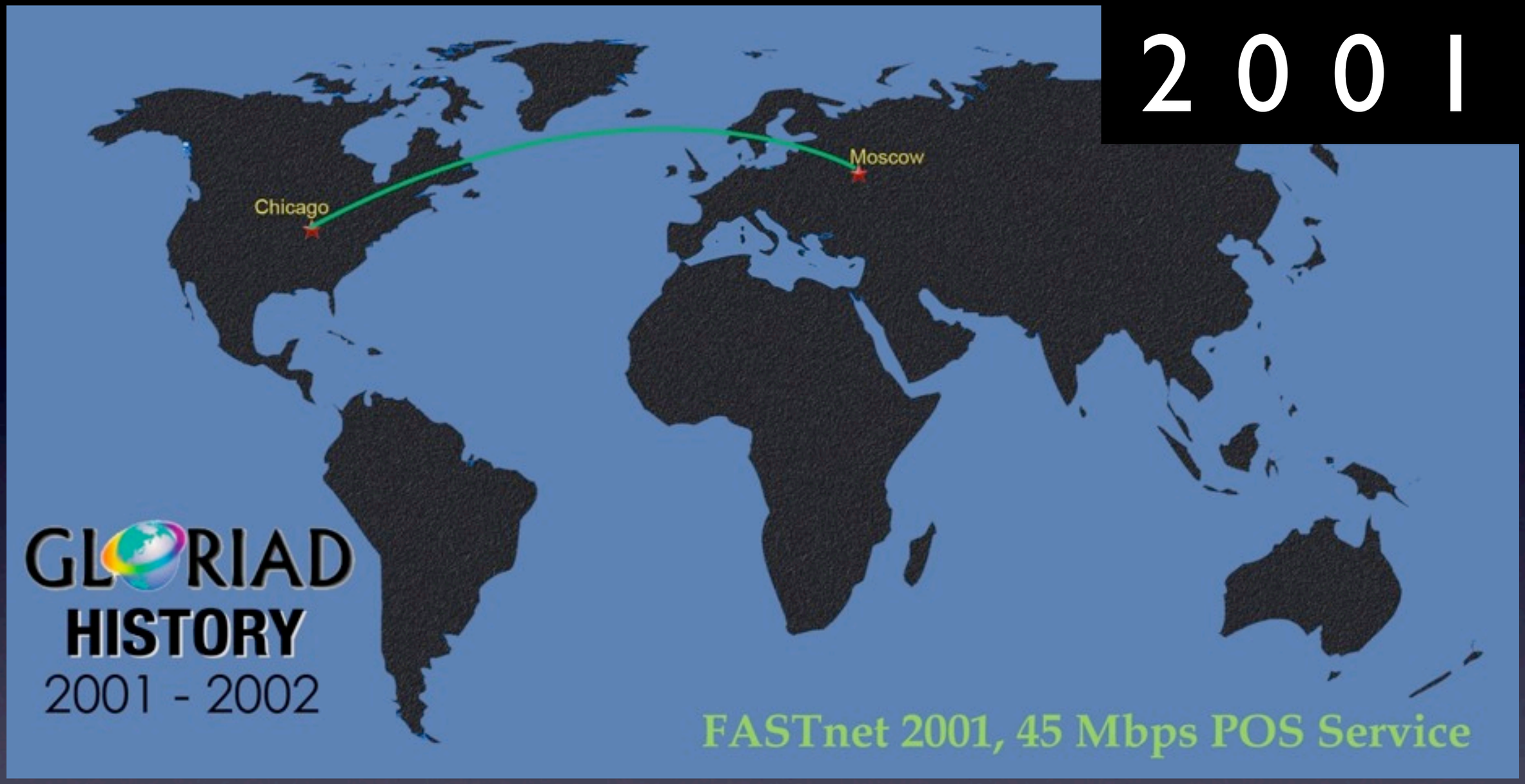
A quick history ..

A quick history ..

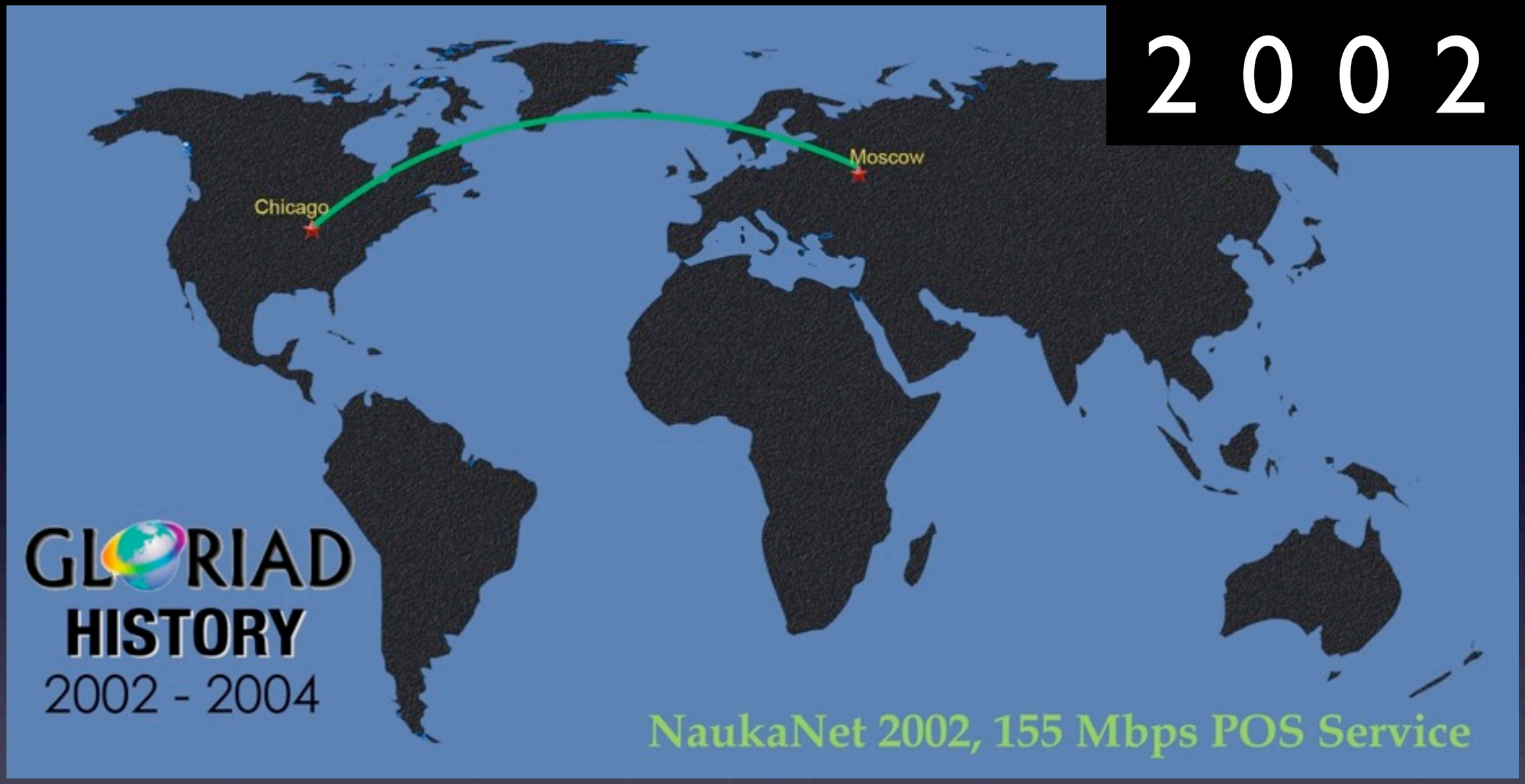
1998



A quick history ..

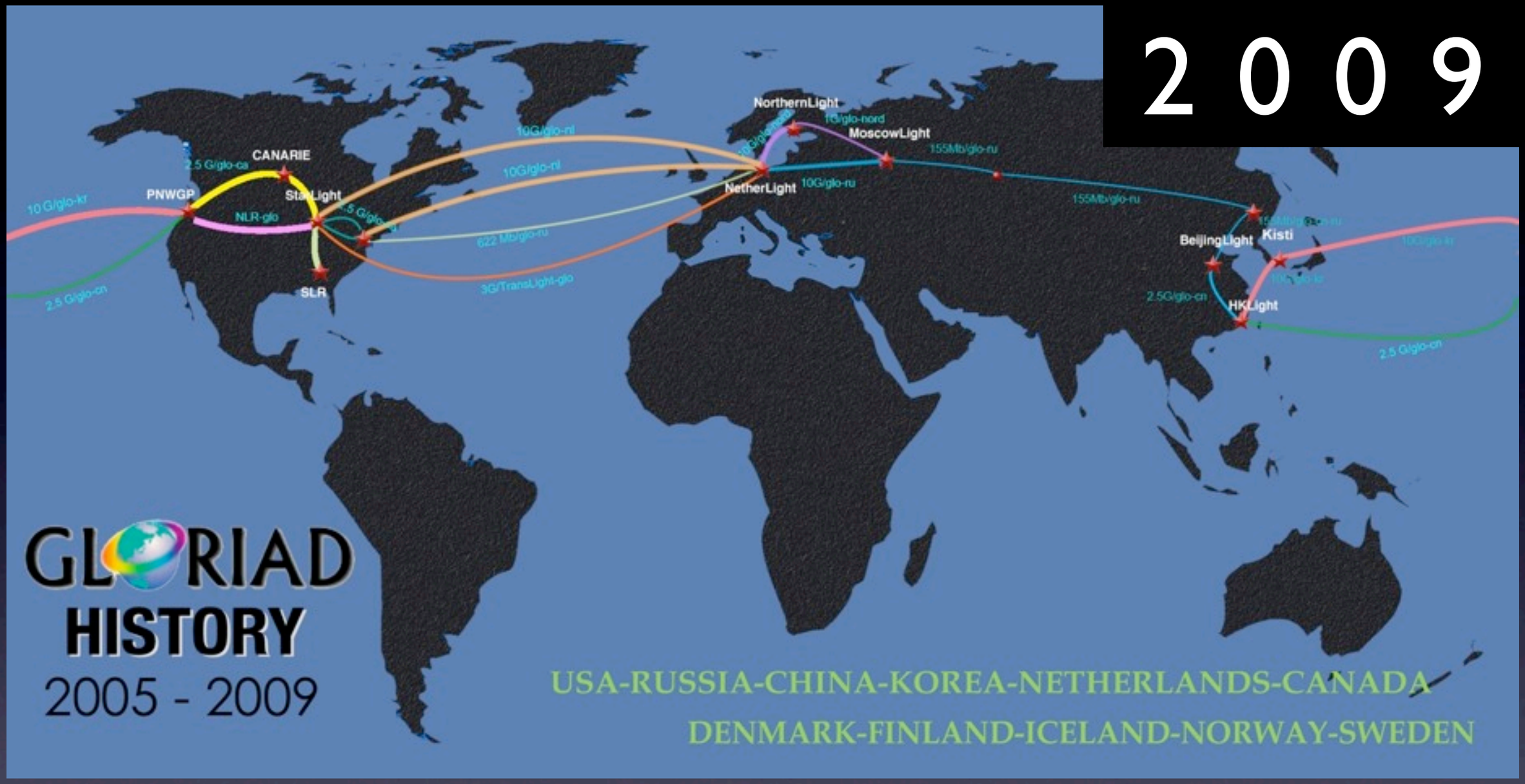


A quick history ..



A quick history ..

A quick history ..



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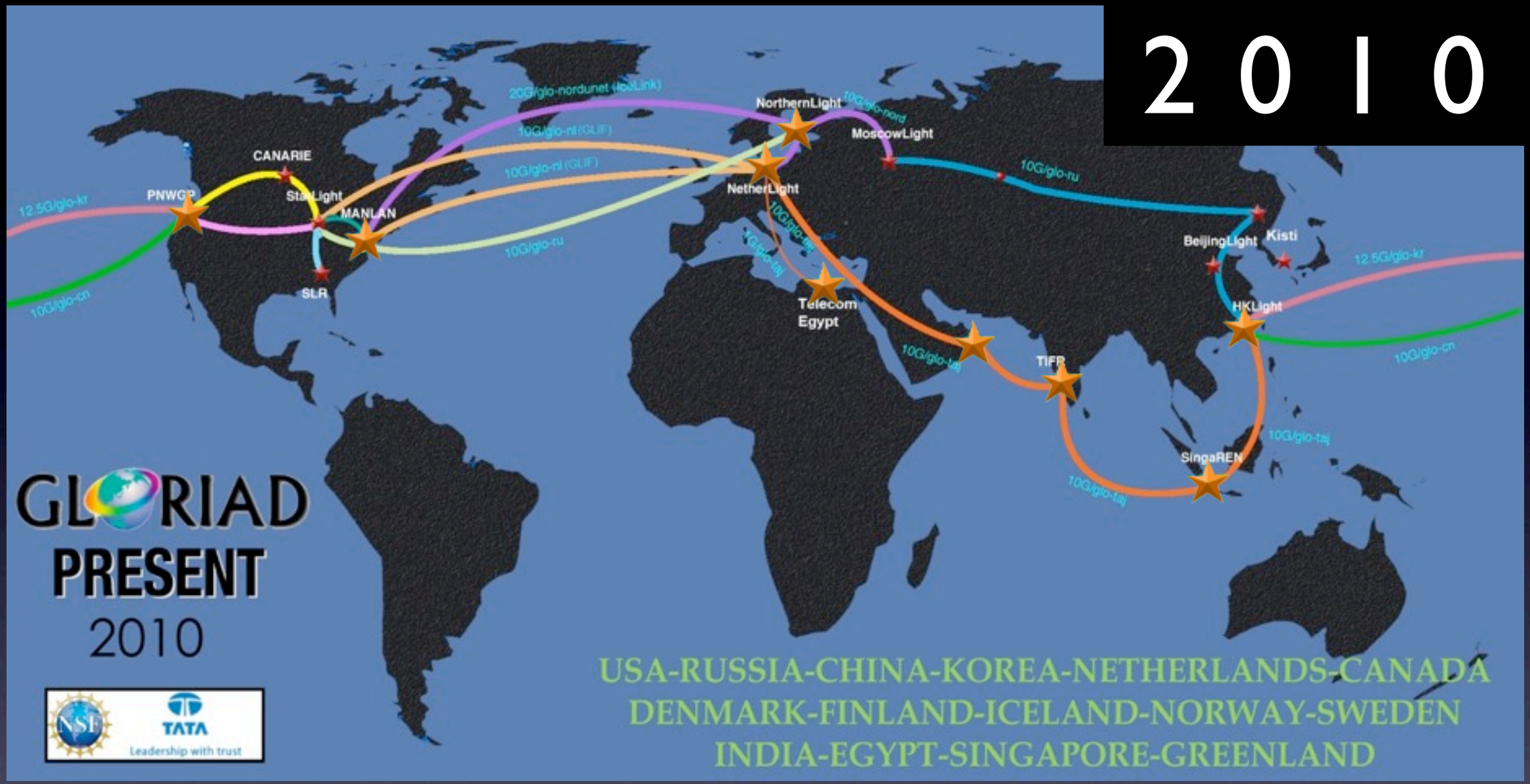
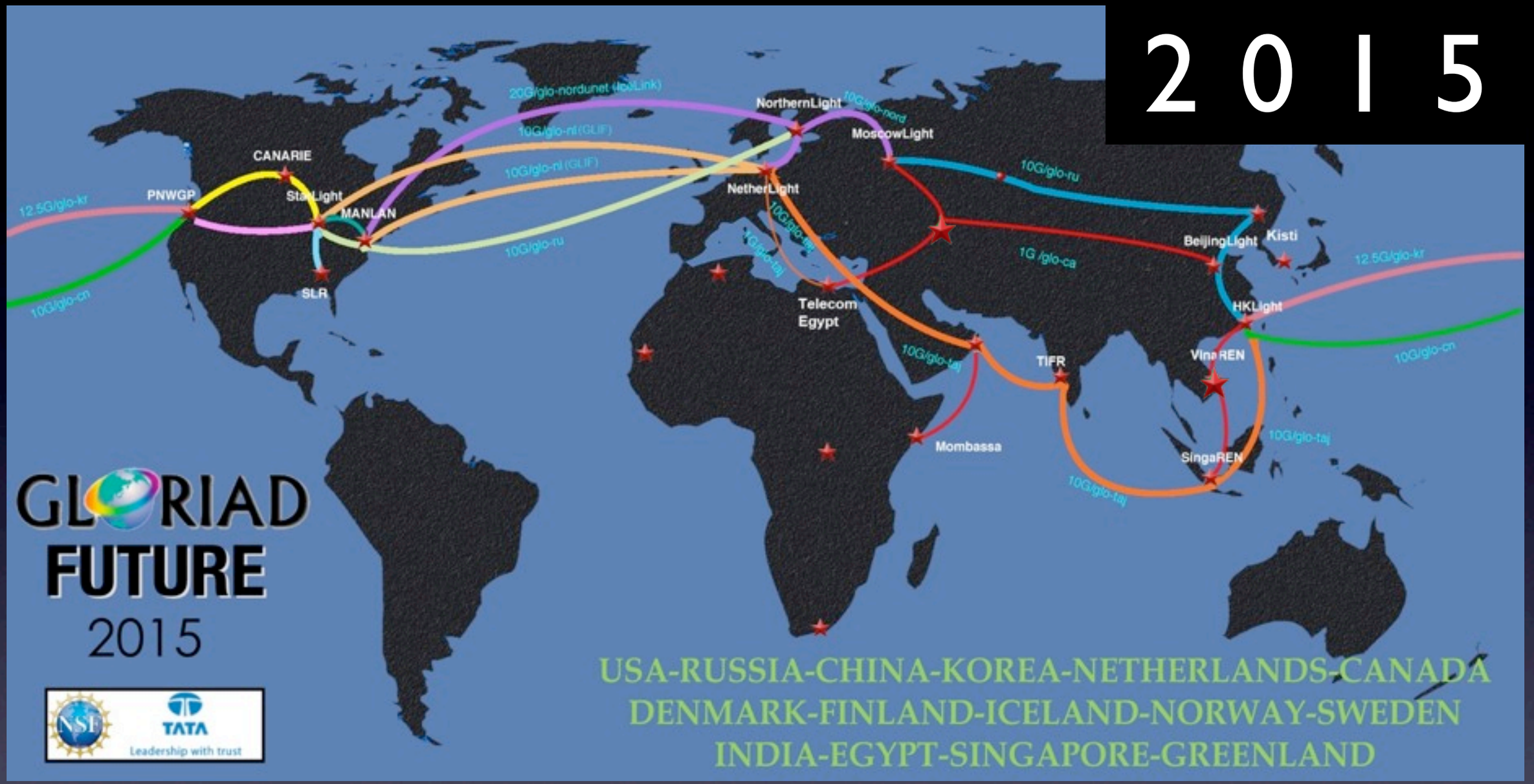


A quick history ..



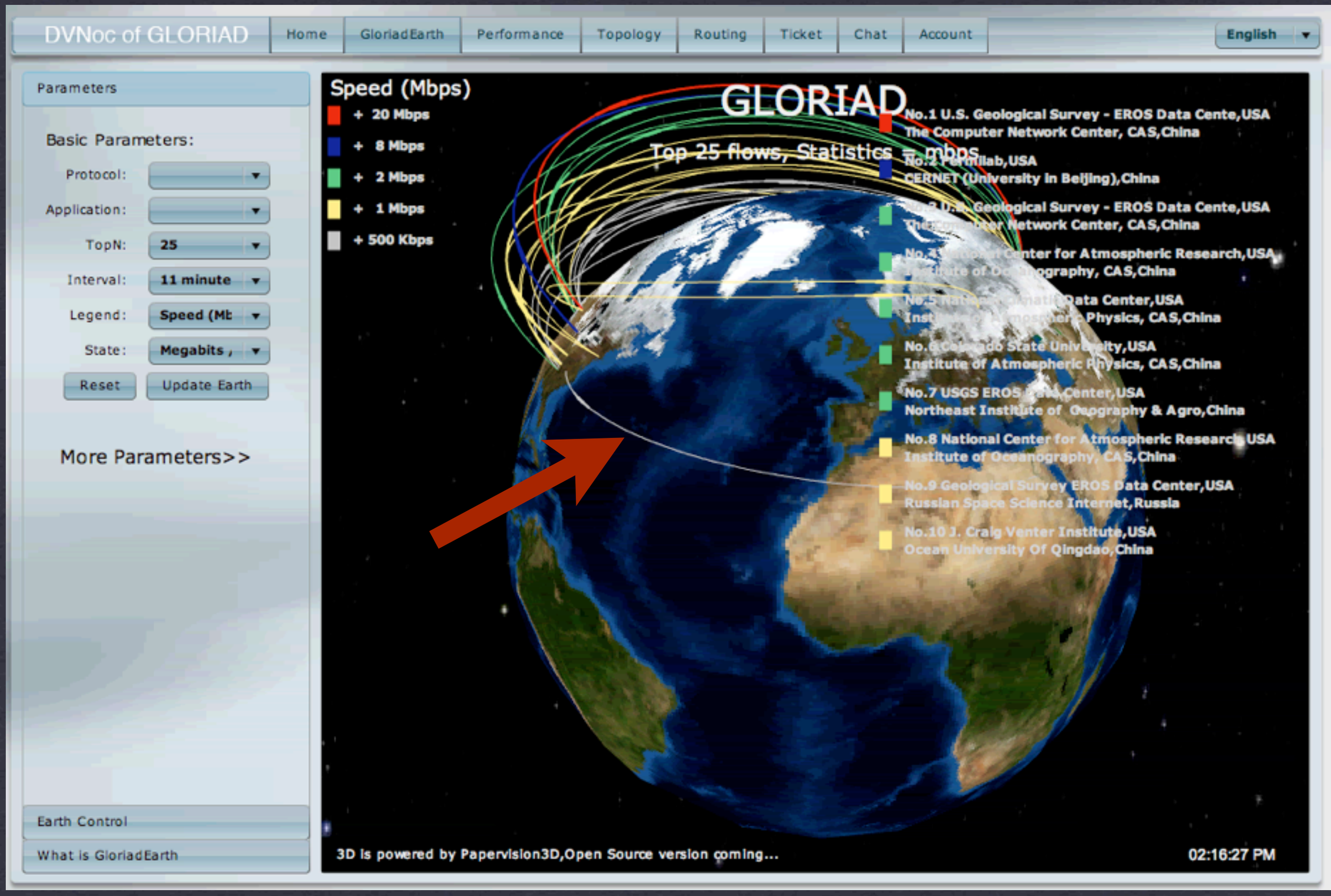
A quick history ..

Taj: NSF Grant Deliverables

- Gratis 1-year contribution by Tata Communications (est. $6M) of a new 1 Gbps service with exchange points in Hong Kong, Singapore, Egypt, India and Europe, extending access to India, SE Asia and Egypt, including a likely connection to Vietnam, and possibly North & East Africa.
- ~$3M commitment by the Chinese Academy of Sciences (w/$240K match from Taj proposal) to expand US-China connectivity by a factor of 4 (to 10 Gbps), offering greater capacity for US collaborations with China - but also India, Egypt and across SE Asia, and providing new equipment to enable better deployment of hybrid services for more advanced science applications.
- ~$600K annual commitment (+ equip. needed to hand capacity to R&E community) from NORDUnet (w/ $300K NSF match) to deploy a new high-capacity circuit connecting the US with Greenland & the 5 Nordic countries, serving polar, climate change, cyberinfrastructure and other research.
- This will also expand US-Russia capacity through Nordic infrastructure to St. Petersburg. Contingent on the network capacity, the Nordic Research Council is planning green- powered supercomputing facilities in Iceland, supporting a variety of key global research initiatives.
- Implementing across Taj a new model of distributed, decentralized network measurement, security and management tools for newly-connected India, SE Asia & Egypt, and communities in US, Asia, Europe. This enables sharing of global network management tasks and focuses on user-level performance.
- Deploying a new program of targeted information dissemination, education, outreach and training to help cyberinfrastructure providers and users better understand available infrastructure and improve global collaborations.

Comments for March 10, 2010

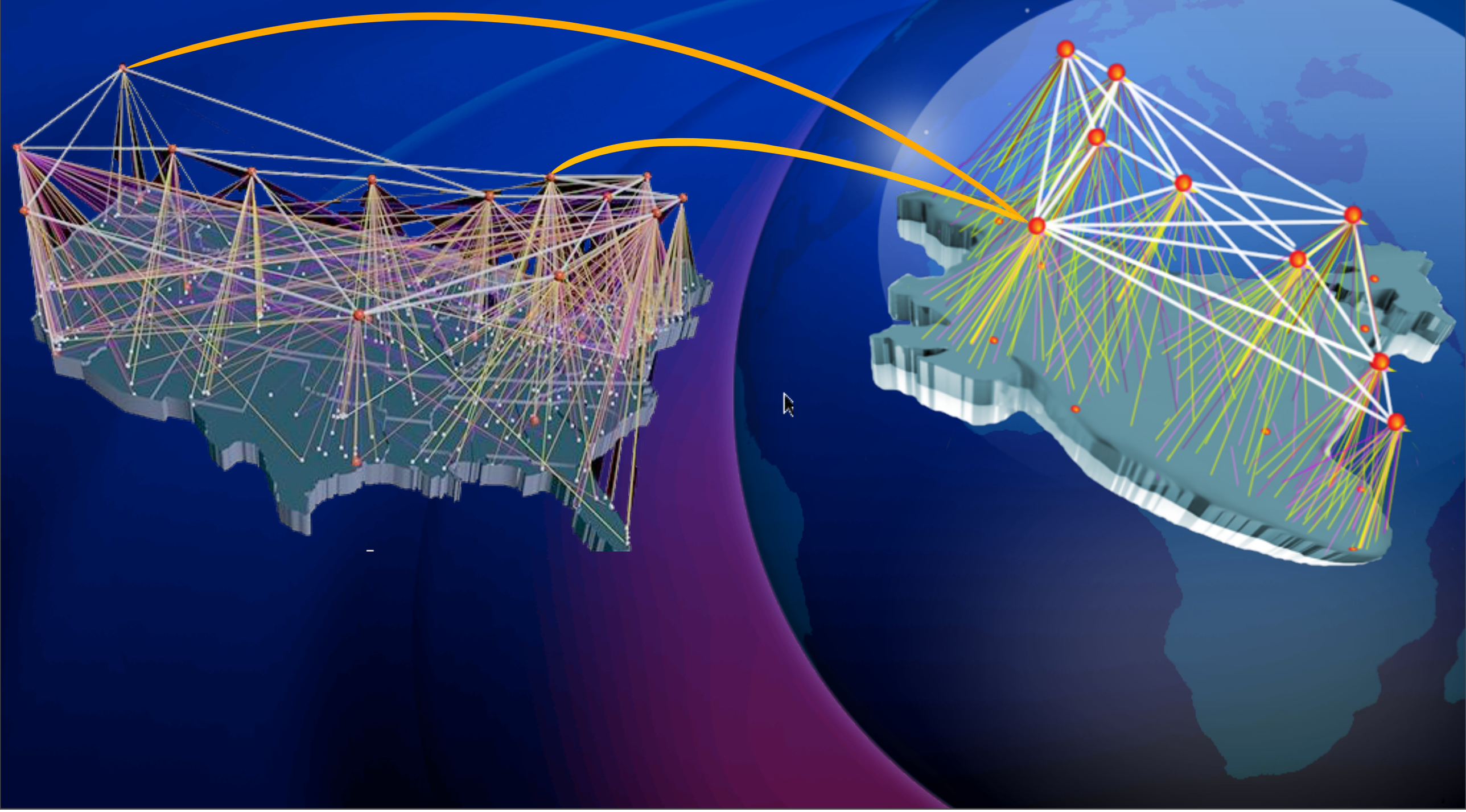
"It was 9 months ago that the US President spoke at Cairo University and in an address aimed at fostering an improved environment for active collaboration and exchange, promised to "invest in online learning for teachers and children around the world; and create a new online network, so a young person in Kansas can communicate instantly with a young person in Cairo." With our Egyptian friends, we share this vision of a world connected for science and education – and today marks a milestone achievement towards that vision and towards realizing President Obama's promise." – Arden Bement, Director, U.S. National Science Foundation



LIVE DVNOC DISPLAY

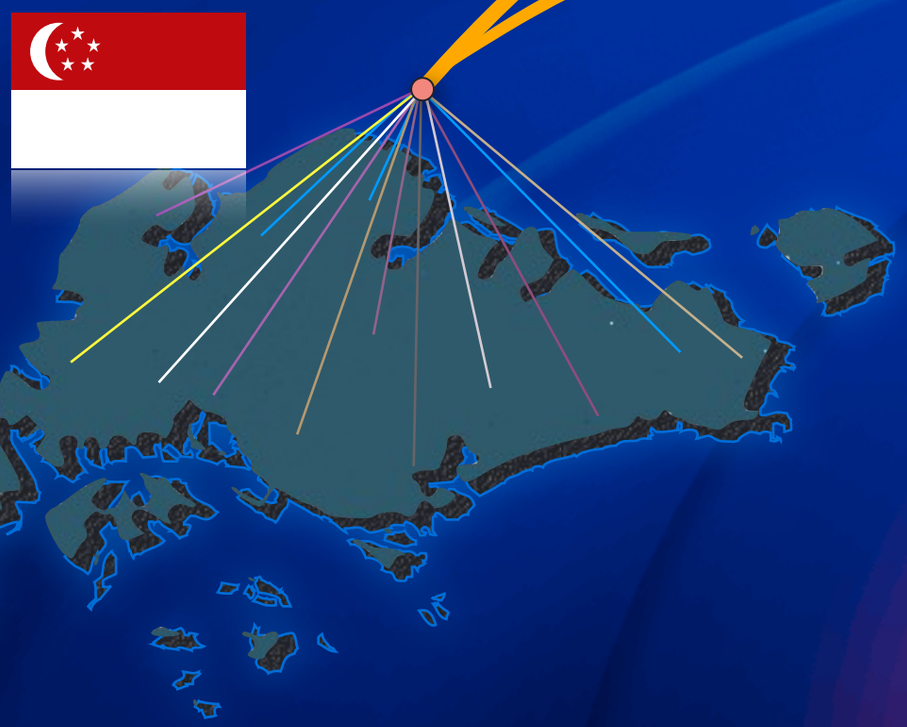
MARCH 24, 2010, 2:16 PM (STARBUCKS ON L STREET)

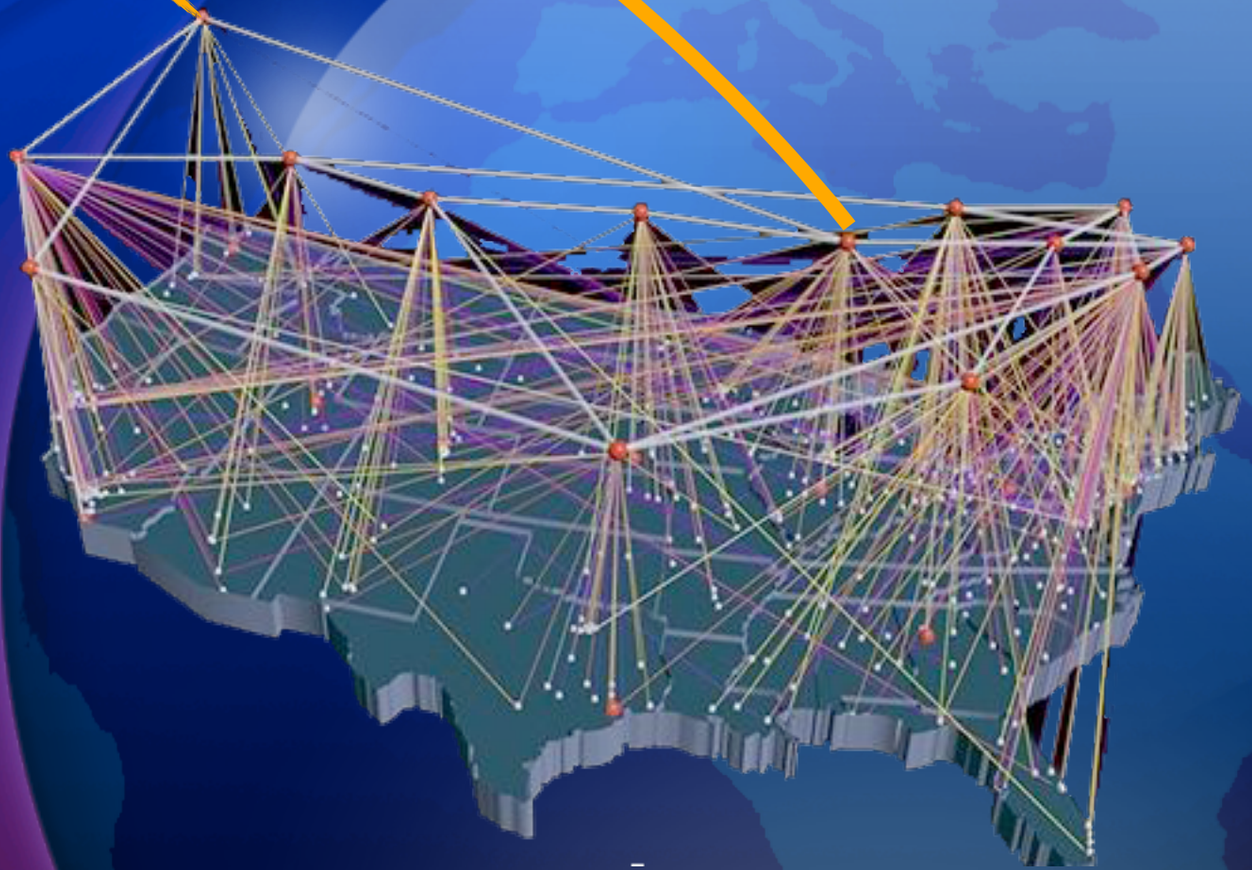
Taj: working to connect US-India Science and Education



US-India Applications

Taj: Working to Connect US-Singapore Science and Education





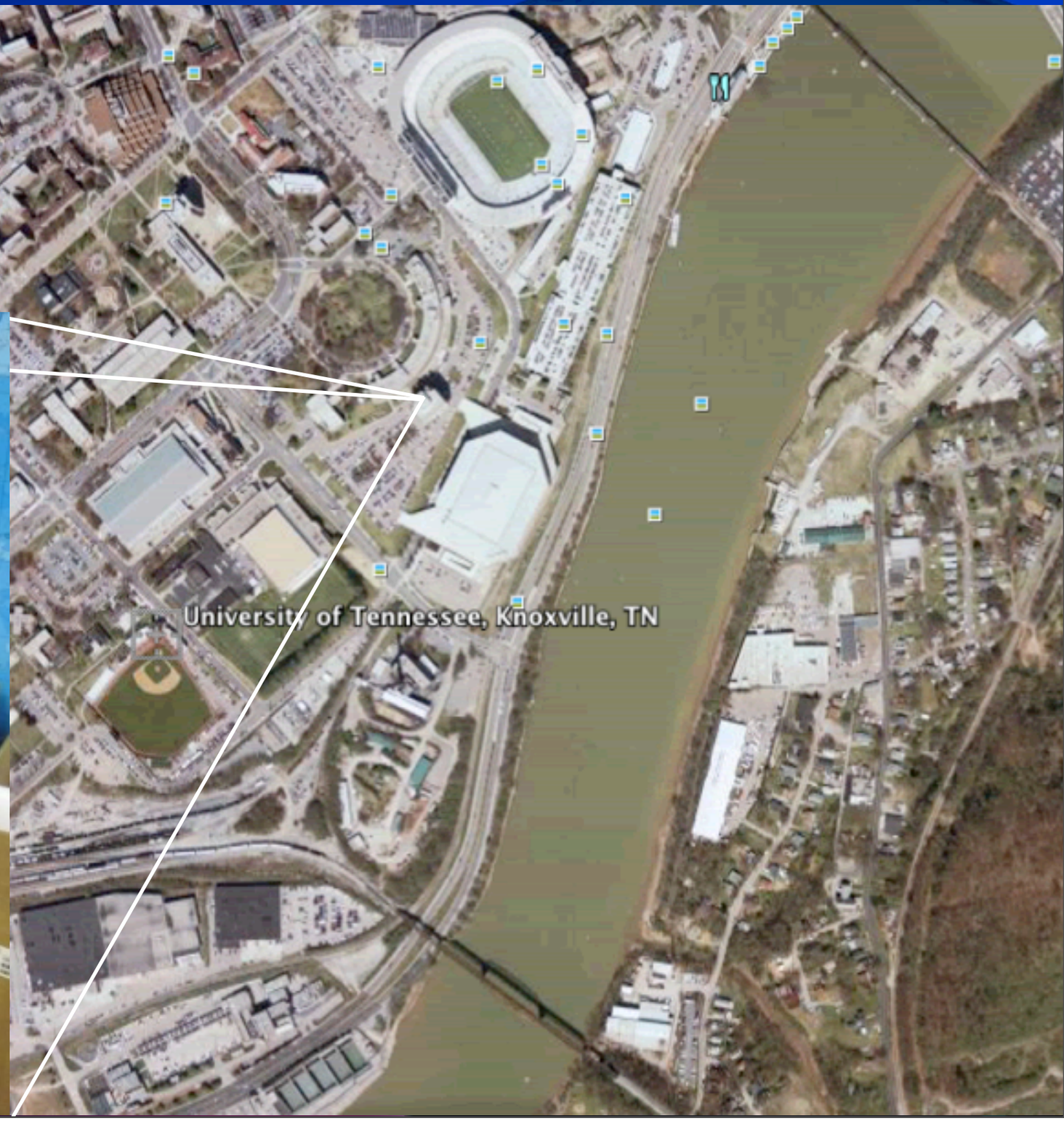
glif

SingAREN Singapore Advanced Research & Education Network

STARLIGHT℠ The Optical STAR TAP℠

GLORIAD

Next steps



SingLight: Motivation

- Enable New Applications and Services
- Accelerate Transition from Limited Peering Facilities To Unlimited Service Communication Exchanges
- Enable Customization At All Service Layers
- Enable Enhanced Capabilities For Many Types of Peerings, Regionally and Globally
- Enable Migration Paths To New Architecture and Technology

SingLight Will Enable Peers at All Layers

SingLight

International NREN-1

International NREN-2

R&E Science TestBed

Aggregation Association

NREN-1

Campus Net-1

GLORIAD-2

Specialized Extensions

Science Net-1

Regional Science Net

R&D Network Testbed

International NREN

GLORIAD-1

Campus Science Net

G-N = Core Resources *Dedicated* To GENI

Community Building

- Zeeba
- dvNOC

Zeeba.net

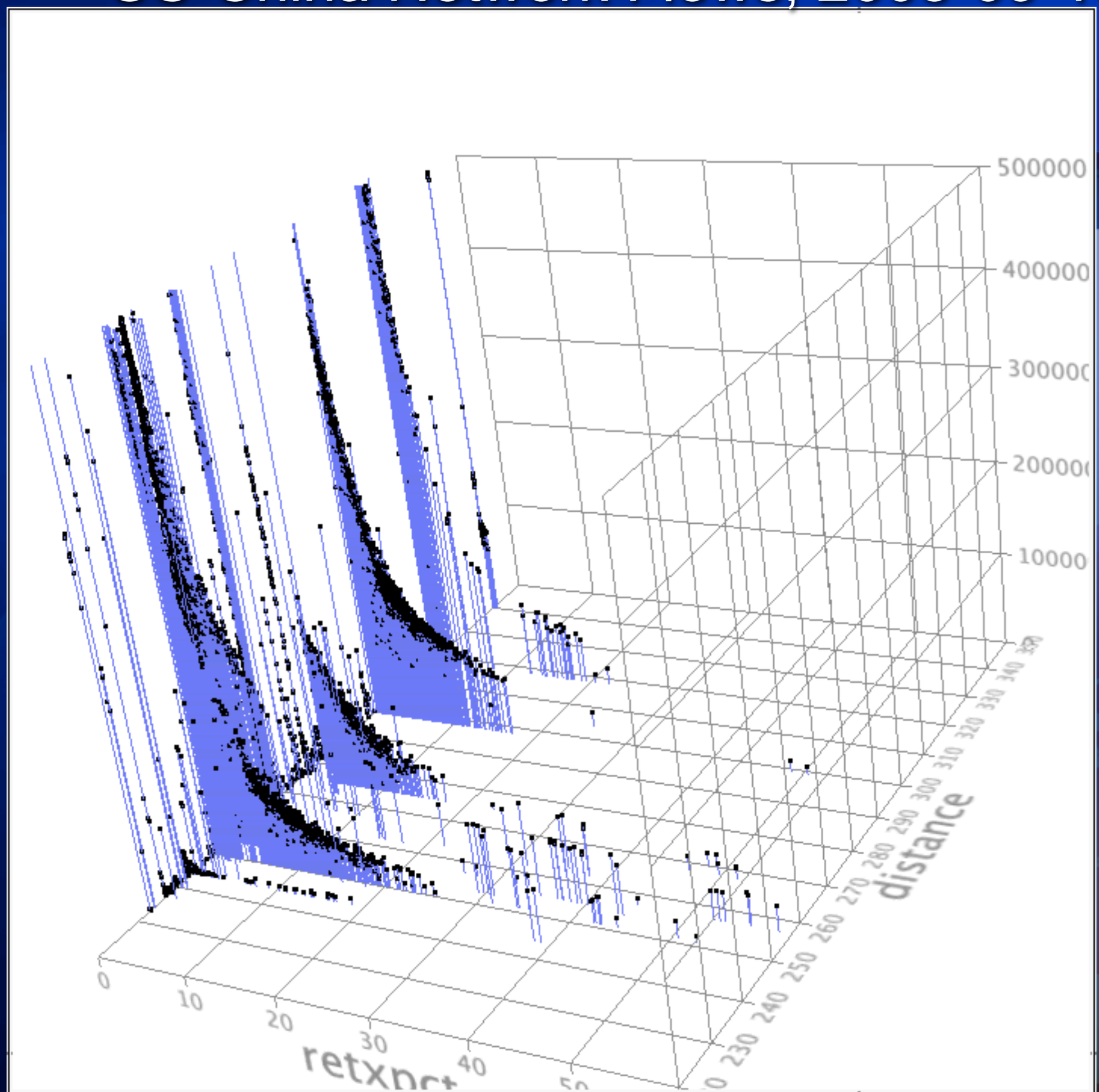
- Addresses lack of awareness of global cyberinfrastructure, of opportunities for global collaboration and resources and of “how to use” cyberinfrastructure effectively
- a “social networking” platform designed to enable the science + cyber community to educate/inform/ support itself (i.e., broader community)
- via partnership with CRDF, will integrate full access to scientific literature (including full-text articles) for countries in Africa, Middle East and Southeast Asia and build social dialog around quality information services

dvNOC

- Addresses need for all levels of cyberinfrastructure operators (and users) to collaborate on decentralized, distributed and reliable operations of links and services
- Consensus-driven approach to common standards, tools and software
- Enormous development effort on part of US, Chinese, Korean and Nordic (and we hope, soon, other international partenr) GLORIAD teams

Distributed Virtual Network Operations Center (dvNOC)

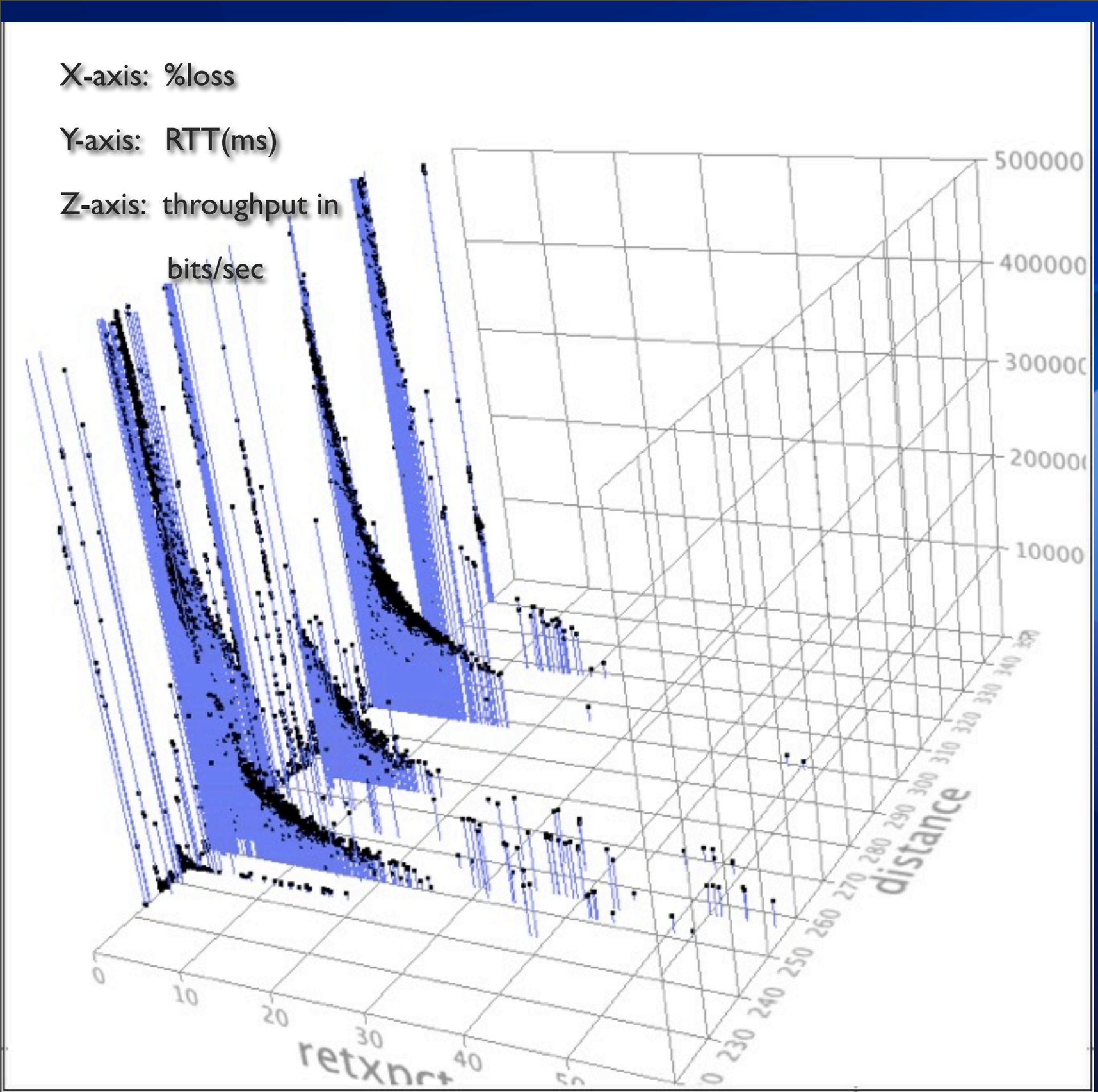
US-China Network Flows, 2008-09-15



X-axis: %loss

Y-axis: RTT(ms)

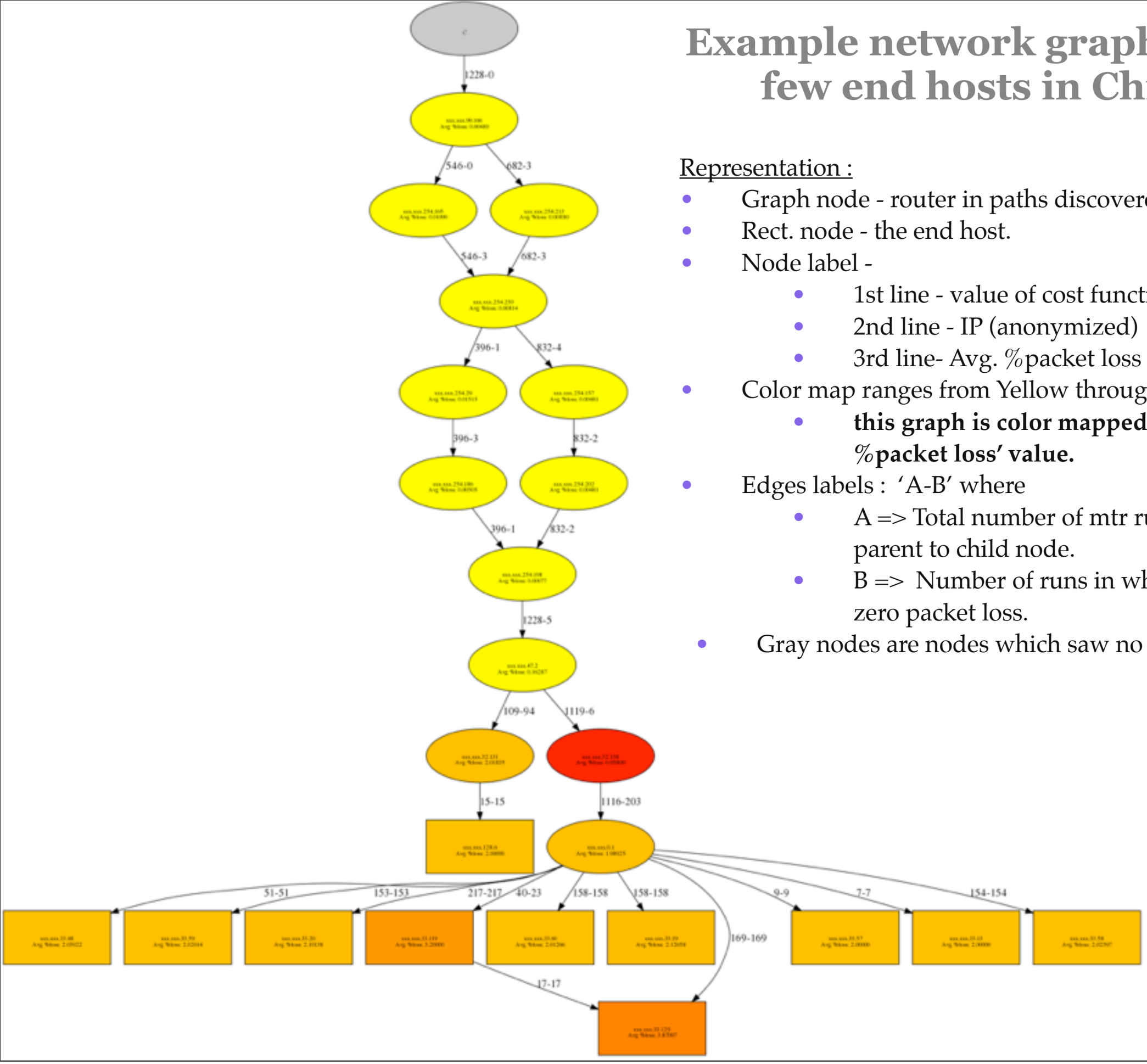
Z-axis: throughput in bits/sec



“Needle" chart i.e., a blue needle (topped by a black marker) illustrates one flow

3-D plot of throughput , loss & RTT using flow data from US to CSTNET over a 24hr period on GLORIAD network

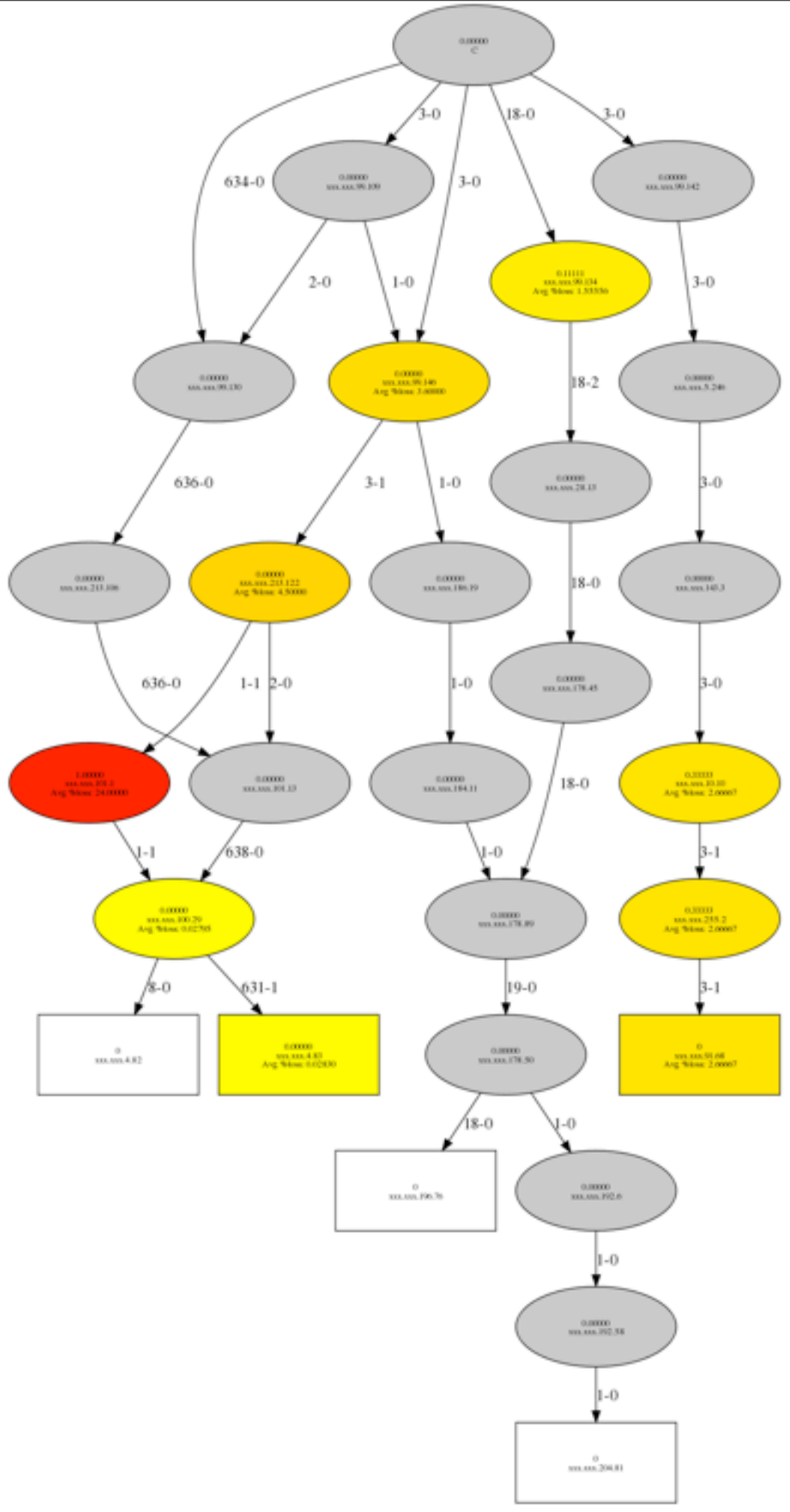
Example network graphs for a few end hosts in China



Representation :

- Graph node - router in paths discovered by MTR.
- Rect. node - the end host.
- Node label -
  - 1st line - value of cost function
  - 2nd line - IP (anonymized)
  - 3rd line- Avg. %packet loss at the node.
- Color map ranges from Yellow through orange to red.
  - **this graph is color mapped based on the 'Avg. %packet loss' value.**
- Edges labels : 'A-B' where
  - A => Total number of mtr runs through the parent to child node.
  - B => Number of runs in which there was non-zero packet loss.
- Gray nodes are nodes which saw no packet loss.

Example network graphs for a few end hosts in U.S.



5 Years Out

- Innumerable science and education success stories
- Thriving network of science/cyber collaborators
- Distributed operations of global cyberinfrastructure
- Fiber-pair around the earth for science/education/ public purposes
- Community-owned fiber for science/education/ public purposes
- “Green-powered” IT
- GLORIAD fades away ..

Final Thoughts

- Establish partnership with private sector
- Connect broadly (students first)
- Overprovision networks ...
- Enable the community to educate/support the community on possibilities and tools
- “Dark fiber” - local, regional, national

Thank you from the GLORIAD/Taj-U.S. Team

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Harika Tandra
Software Engineer

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Principal Investigator

Graduate Research Assistants

Ashwini Chegu

Anuradha Bulusu

Krishna Chaitanya

Kartheek Bodanki

“Friends and Partners”

..the internet as a tool for global citizen-to-citizen networking..

http://www.friends-partners.org/friends/

http://www.friends-partners.ru/friends/