Dark Fiber for NRENs

International Perspective

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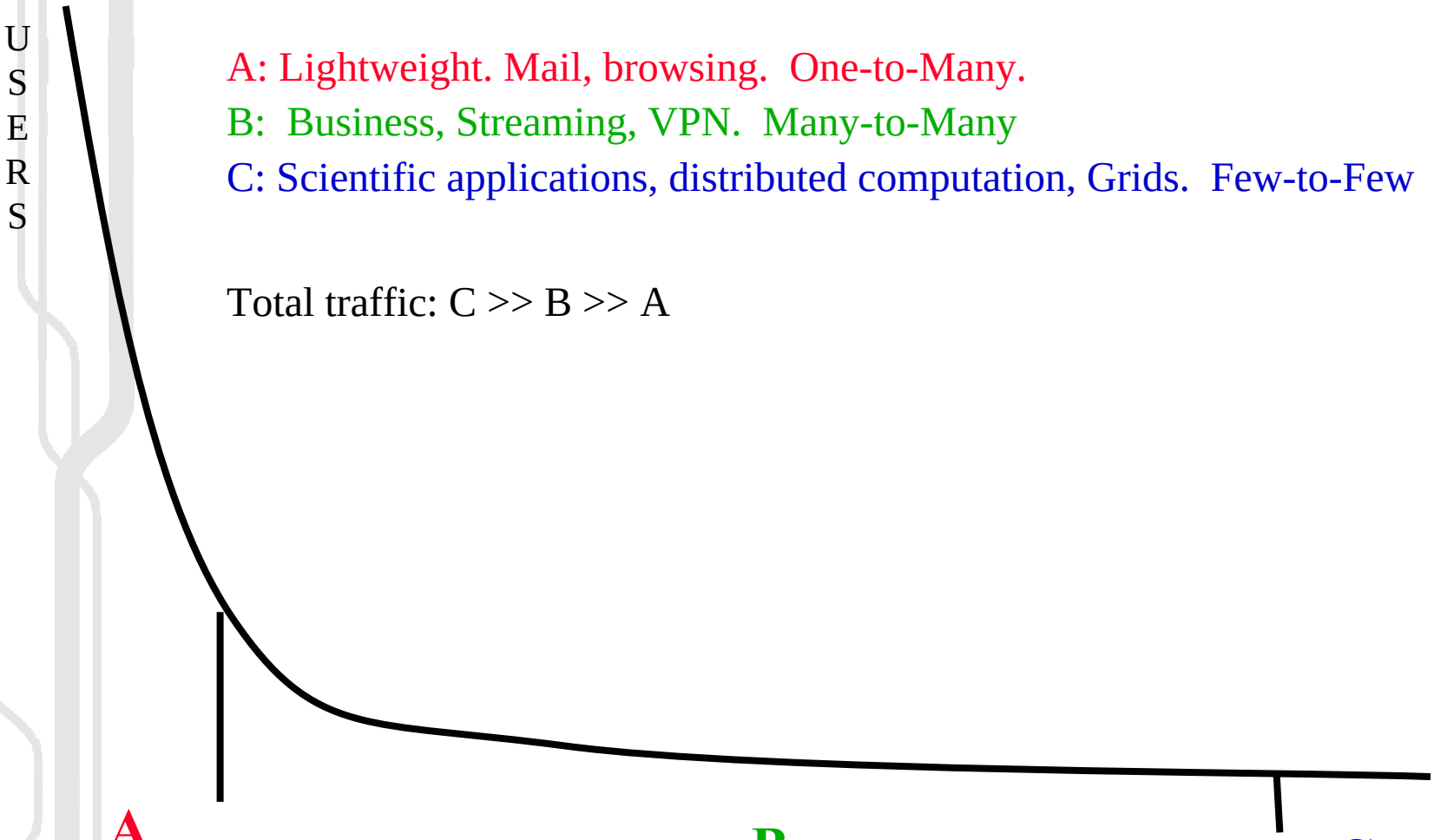
The short version

Everybody is doing it

NRENs on Fiber

- Most NRENs are moving from leased lines to Dark Fiber networks
  - Some run Ethernet directly on fiber, most run DWDM optical networks
- The drivers are
  - Bandwidth growth
  - Cost control
  - Hybrid networking / lambda networking

Network Users: A, B, C



A: Lightweight. Mail, browsing. One-to-Many.

B: Business, Streaming, VPN. Many-to-Many

C: Scientific applications, distributed computation, Grids. Few-to-Few

Total traffic: C >> B >> A

Graph inspired by Cees de Laat

Lambda Networking

- Offload heavy users onto (simple) private circuit-switched networks
- Save capacity and cost on routed networks
- As a bonus, private networks provide predictable network parameters (i.e., true QoS)
- Problem: capability to create lambdas on the fly
- Problem: provisioning, routing
- Problem: multi-domain lambdas
- Solution: Dark Fiber + DWDM + ???

Global Lambda Integrated Facility

- GLIF is a collaboration, not an organization
- GLIF is not a network
- GLIF was founded on Iceland, during the 2003 NORDUnet conference (http://www.glif.is)
- Procedures
  - Multi-domain circuit creation and fault handling
- Tools development & Exchange
  - Network Description Language (now with Global Grid Forum)
  - Monitoring & Management Systems
- Control plane development

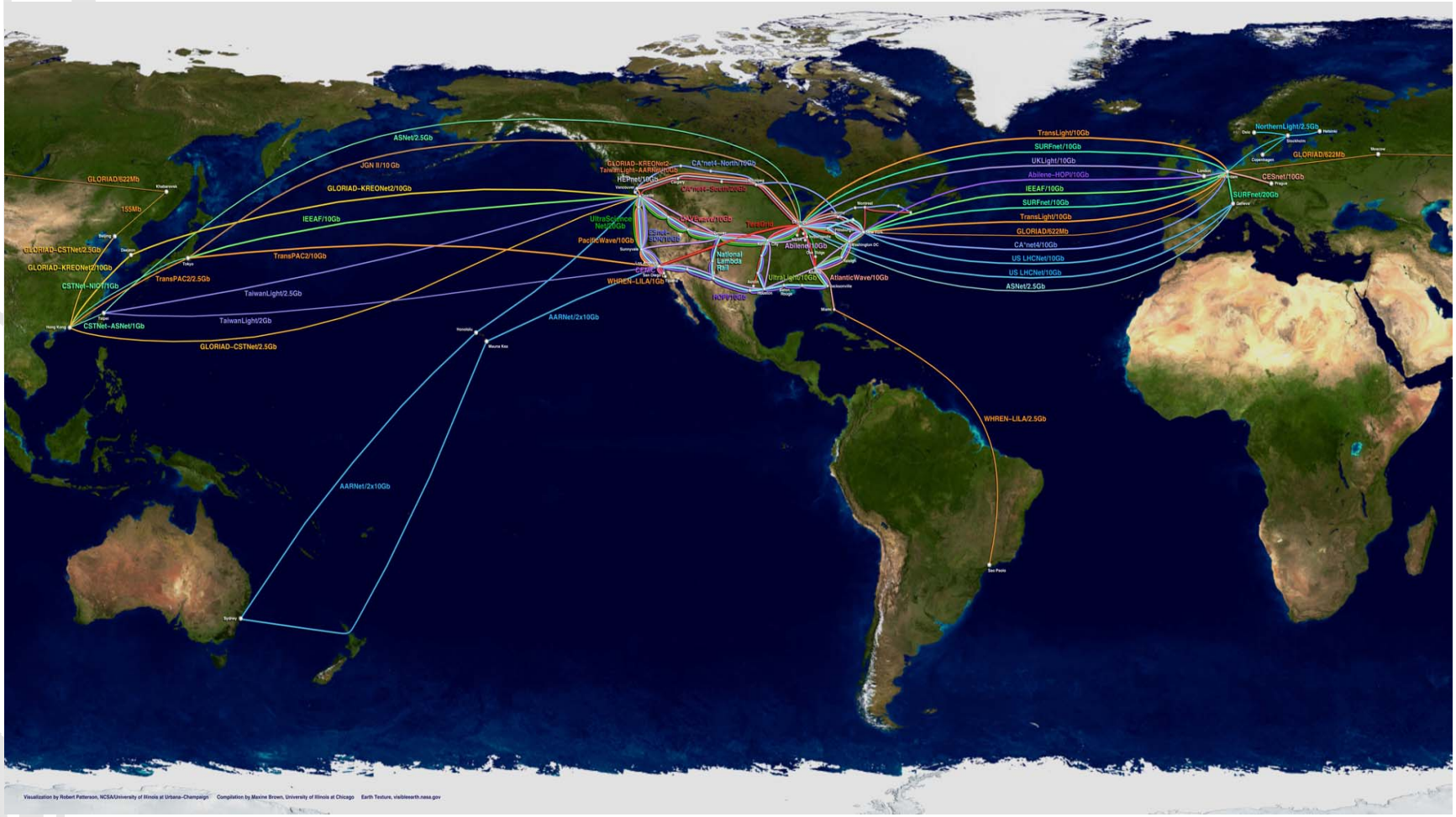
GLIF Open Lambda Exchanges

- The key infrastructure of the GLIF collaboration
- Open Exchange Points for circuit-switched network – in the tradition of IP Internet Exchanges
- Everyone can bring a circuit and exchange traffic with everyone
- A GOLE is typically a SDH/SONET switch matrix, possibly with Ethernet and photonic switching

GOLE-to-GOLE networking

- In GLIF, end-to-end connectivity is constructed by piecing together circuits from GOLE to GOLE, eventually connecting end-sites
- There are GOLEs all over the globe
- GOLEs are typically operated by NRENs
- GOLE operators have frequent coordination meeting
- Fiber is deployed to connect GOLEs

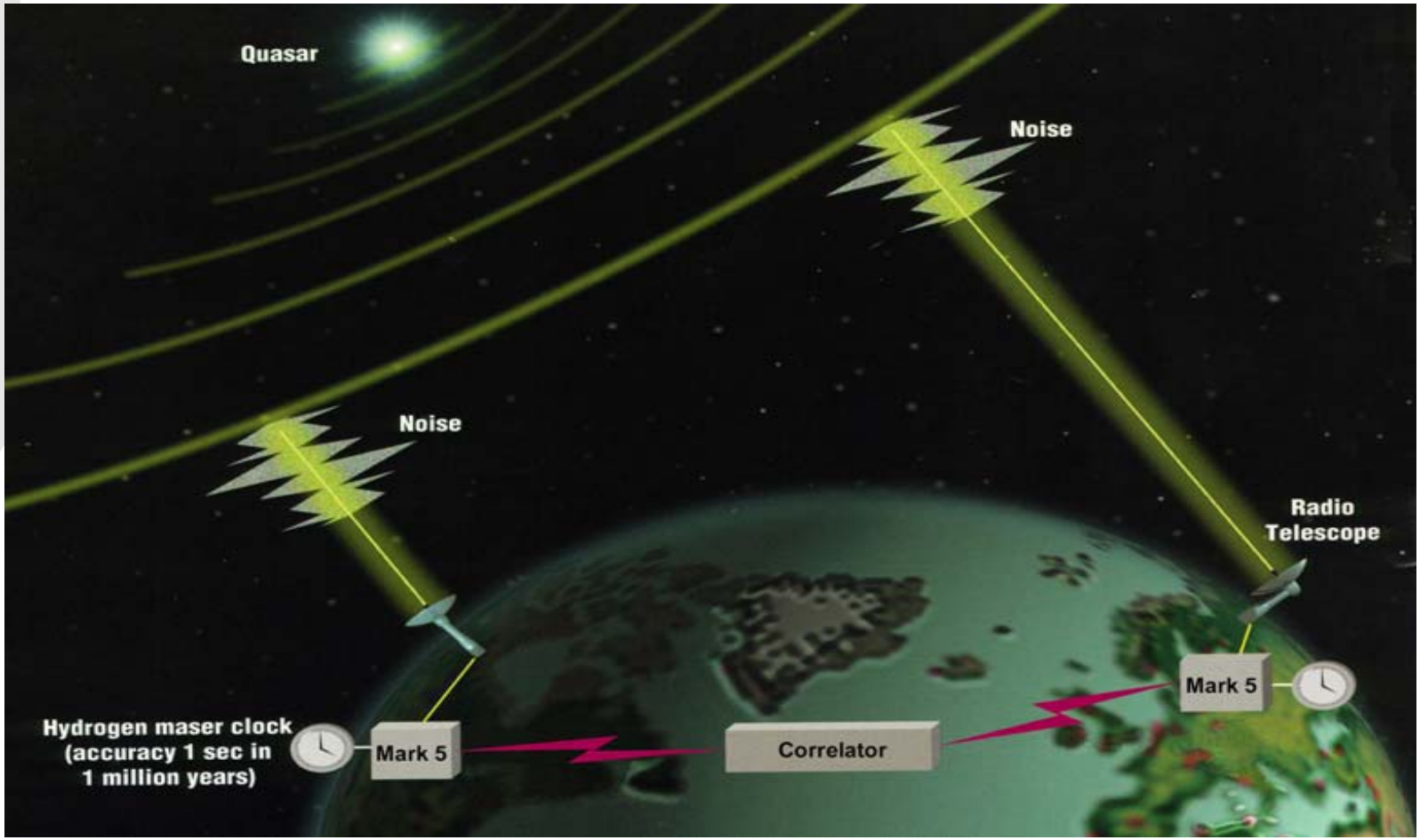
GLIF map


ASNet/2.5Gb
JGN II/10Gb
GLORIAD/622Mb
GLORIAD-KREONet2/10Gb
155Mb
IEEAF/10Gb
GLORIAD-CSTNet/2.5Gb
GLORIAD-KREONet2/10Gb
TransPAC2/10Gb
CSTNet-NIDT/1Gb
TransPAC2/2.5Gb
TaiwanLight/2.5Gb
CSTNet-ASNet/1Gb
TaiwanLight/2Gb
GLORIAD-CSTNet/2.5Gb
GLORIAD-KREONet2-TaiwanLight-AARNet/10Gb
CA*net4-North/10Gb
HEPnet/10Gb
CA*net4-South/10Gb
UltraScienceNet/10Gb
PacificWave/10Gb
ESnet-SDN/10Gb
TeraGrid
National Lambda Rail
WHREN-LILA/1Gb
HOPI/10Gb
Abilene/10Gb
UltraLight/10Gb
AtlanticWave/10Gb
AARNet/2x10Gb
TransLight/10Gb
SURFnet/10Gb
UKLight/10Gb
Abilene-HOPI/10Gb
IEEAF/10Gb
SURFnet/10Gb
TransLight/10Gb
GLORIAD/622Mb
CA*net4/10Gb
US LHCNet/10Gb
US LHCNet/10Gb
ASNet/2.5Gb
NorthernLight/2.5Gb
GLORIAD/622Mb
CESnet/10Gb
SURFnet/20Gb
WHREN-LILA/2.5Gb
AARNet/2x10Gb

GLIF projects w/Nordic partners

- e-VLBI: Connecting a number of radio telescopes to a correlator in New Hampshire. Requires fairly large bandwidth and predictable delay and jitter. 1 GE network built.
- SCORE: PhD student training over large distances with combinations of media. Requires pridictable delay and jitter. 1GE network built

Example: e-VLBI



Very-Long Baseline Interferometry

Visualization

- iGrid2005 demonstration of visualization
- Simulation done in Amsterdam, display in San Diego
- Bandwidth: 19 Gbps

A ”LambdaVision” display, using 55 LCDs
Resolution: 17.600 x 6.000 pixels

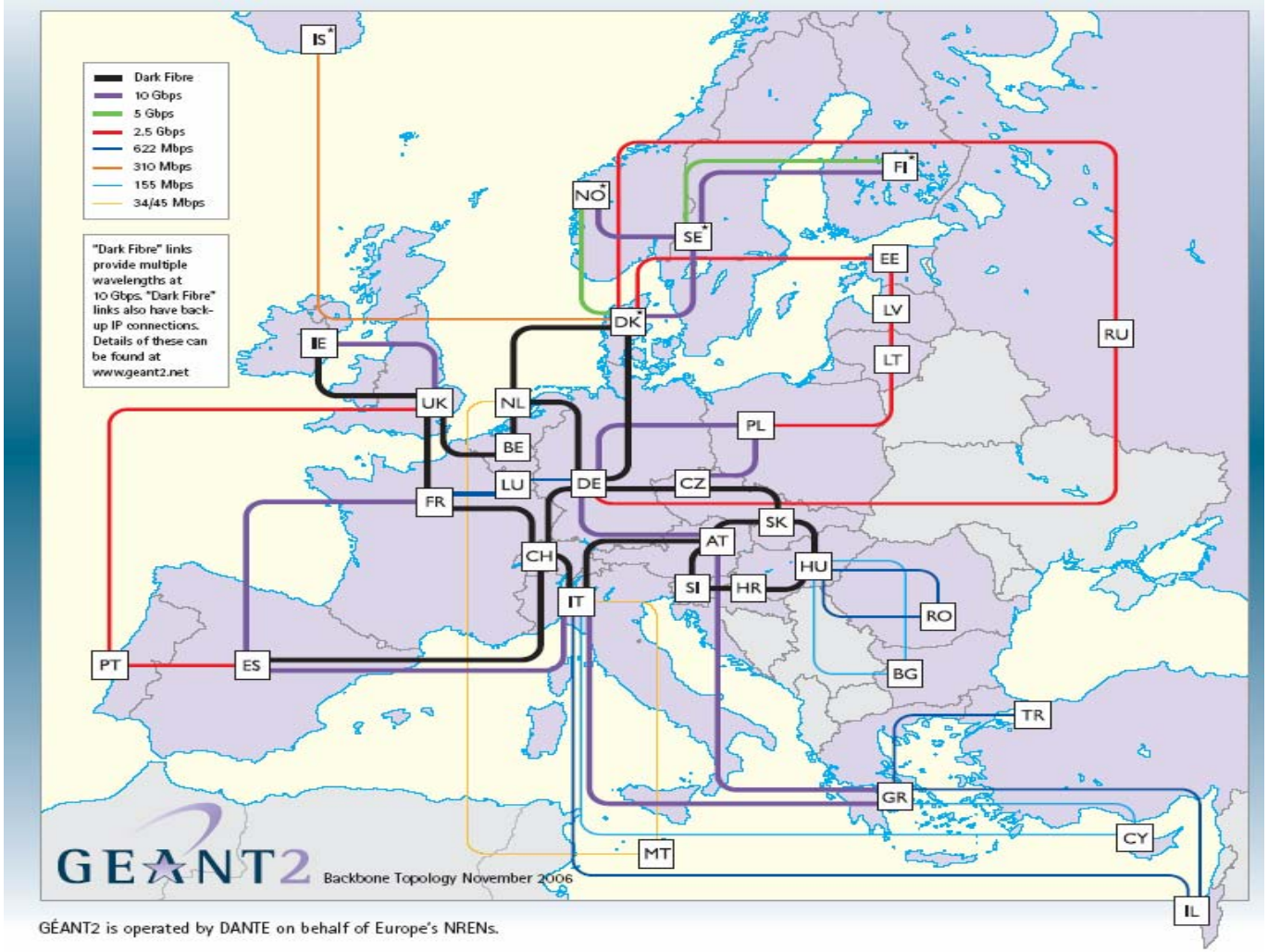
NorthernLight

- 1 GE service, OC48 capacity
- Projects:
  - e-VLBI
  - SCORE
  - MUPBED
- Established NORDUnet as a GLIF partner
- Connects to NetherLight GOLE

GEANT – European Fiber Network

- GEANT2 – European Dark Fiber infrastructure
  - For ”core” countries only
  - Based on price and availability
  - Eastern and Southern Europe remains largely on leased lines
- Status
  - Network largely deployed and operational
  - Layer 3 IP / MPLS service operational
  - Layer2 SDH & Ethernet point-to-point services

GEANT2 Network Map



GEANT2 Hybrid Network Development

- JRA1 – Performance Measurement and Management – also for hybrid networks
- JRA3 – Bandwidth-on-Demand services. Aims to develop a multi-domain provisioning system for lambdas
- JRA4 – Testbed, technology testing
- JRA4 – European Cross Border Fiber coordination

GEANT Poster-child Projects

- LHC OPN: a global OPN for the Worldwide LHC Computing Grid. European components run mostly on GEANT 10GE lambdas (including one for NDGF)
- DEISA: 10 GE network connecting European supercomputing sites (deployment ongoing, CSC to be connected).
- JIVE Express: 1 GE network linking radio telescopes to JIVE. Plans for 10GE. Deployment ongoing, telescopes in Sweden and Finland).

European Dark Fiber NRENs

- Most European NRENs are planning, deploying or operating dark fiber networks
  - SURFnet
  - DFN
  - CESNET
  - PIONIER
  - UKERNA
  - .... with most networks following
- A lot of activity in Eastern Europe.

Cross Border Fiber in Europe

- In parallel to the development of CBF, a number of fiber-enabled European NREN are connecting directly on fiber
- Some network-to-network, some network-to-remote-resource
- Some with EU sponsorship, some without
- A critical mass of NREN-owned dark fiber is being aquired

CBF in Western Europe

- Relatively few examples
- Network-to-resource
  - France to CERN
  - Netherlands to Philips centers in Germany
- Network-to-network
  - SURFnet-to-NORDUnet (in progress)
  - SURFnet-to-DFN
  - DFN-to-RENATER
  - DFN-to-SWITCH
  - SWITCH-to-GARR

CBF in Eastern Europe

- A lot of activity, often grassroots-like
- Groups of connected countries, with major internal fiber infrastructure
  - Poland
  - Czech republic
  - Hungary
  - + connections to neighboring countries
- Often done on Ethernet, with no DWDM

CBF Projects

- There are a number of larger initiatives in developing the CBF approach to European networking
  - Porta Optica: Acquisition of fiber infratructure for former east block, to bring easter Europe to the same level as the ”core” GEANT countries
  - Phosperus: Investigation of control plane challenges for ”quilt” type networks and international networking built from CBF.

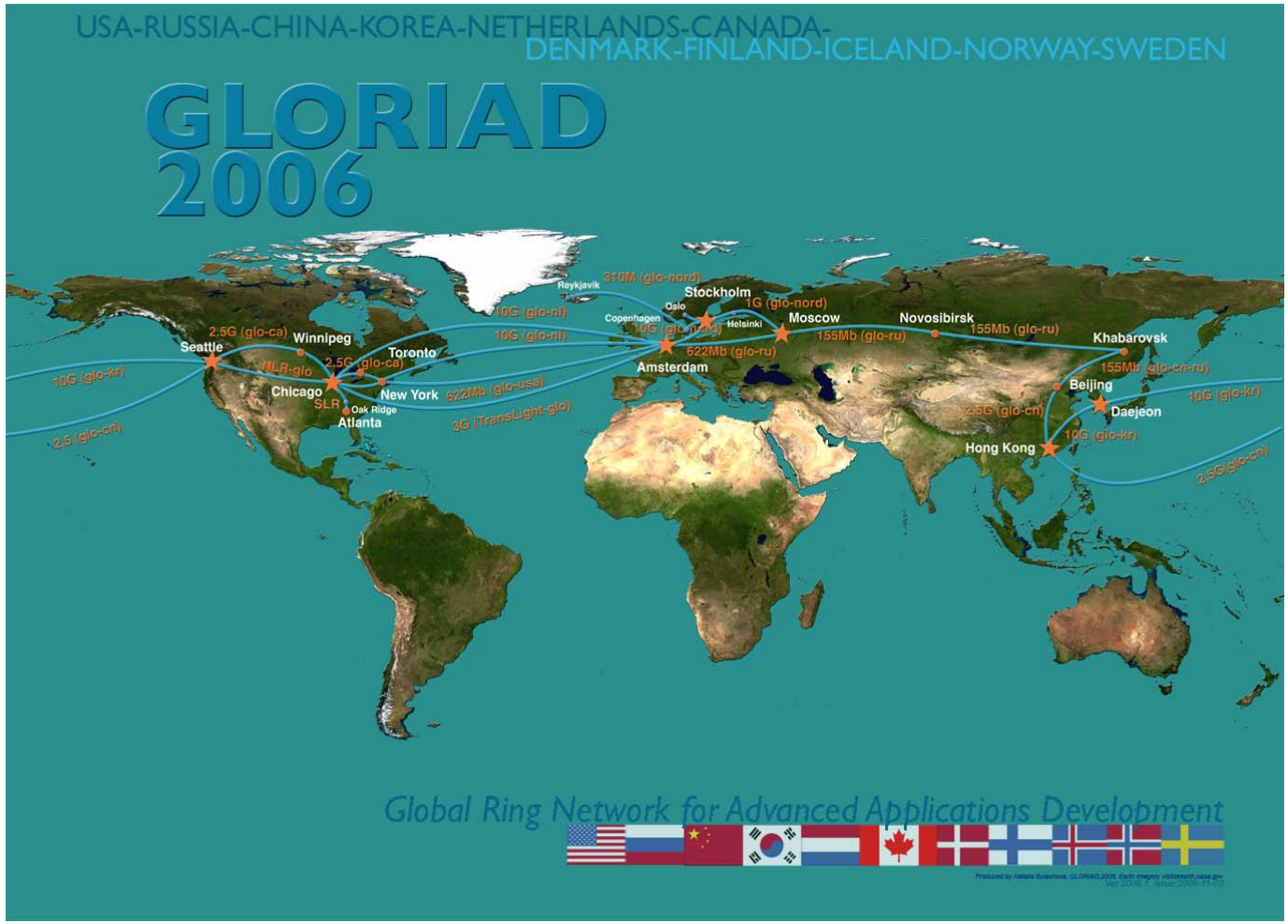
North America

- CANARIE has operated hybrid network for years
- Two competing networks in the US
  - Internet2: IP NREN, has existed for 10 years, next generation hybrid network currently being installed
  - National Lambda Rail: Initially dark fiber / DWDM initiative, evolving upwards in the stack
- Many, many regional dark fiber networks,
- Several key GOLEs: Pacific Wave, MANLAN, STARLIGHT

Asia & Russia

- Korea, Japan, China deploying dark fiber and DWDM infrastructure
- Key GOLE's established: Tokyo, Hong Kong, Seul, (Moscow)
- International connectivity typically OC48 or OC192
- Connectivity across Russia (Siberia) problematic, but initiatives are forthcoming.

The GLORIAD Collaboration



Crossing the Oceans

- A number of networks have circuits across the Atlantic and the Pacific
- Many of these are used as GLIF ressources and connect GOLE's
- Dark Fiber cannot be acquired or used
- Typical circuits are OC192, connected to SDH-layers of GOLE switching equipment

Questions?

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