Networks and Grids for High Energy Physics and Global e-Science, and the Digital Divide

Standing Committee on Inter-regional Connectivity

Harvey B. Newman

California Institute of Technology

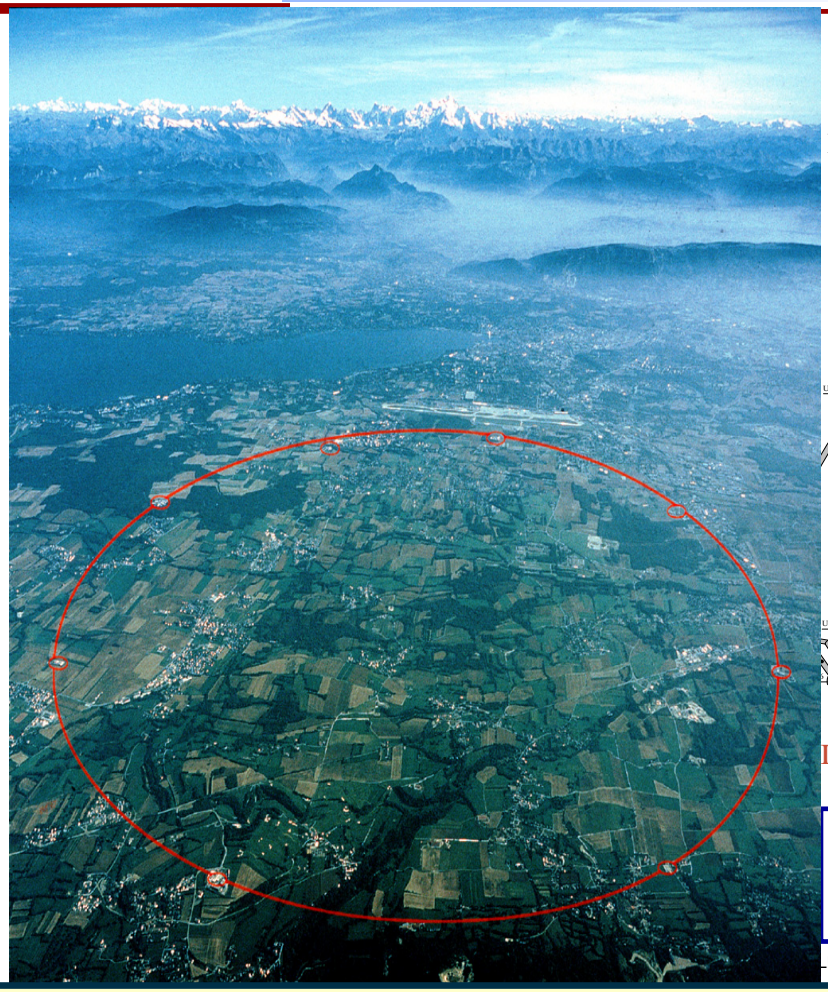
ICFA Digital Divide 2006 Workshop

Cracow and Sinaia, October 9-18, 2006

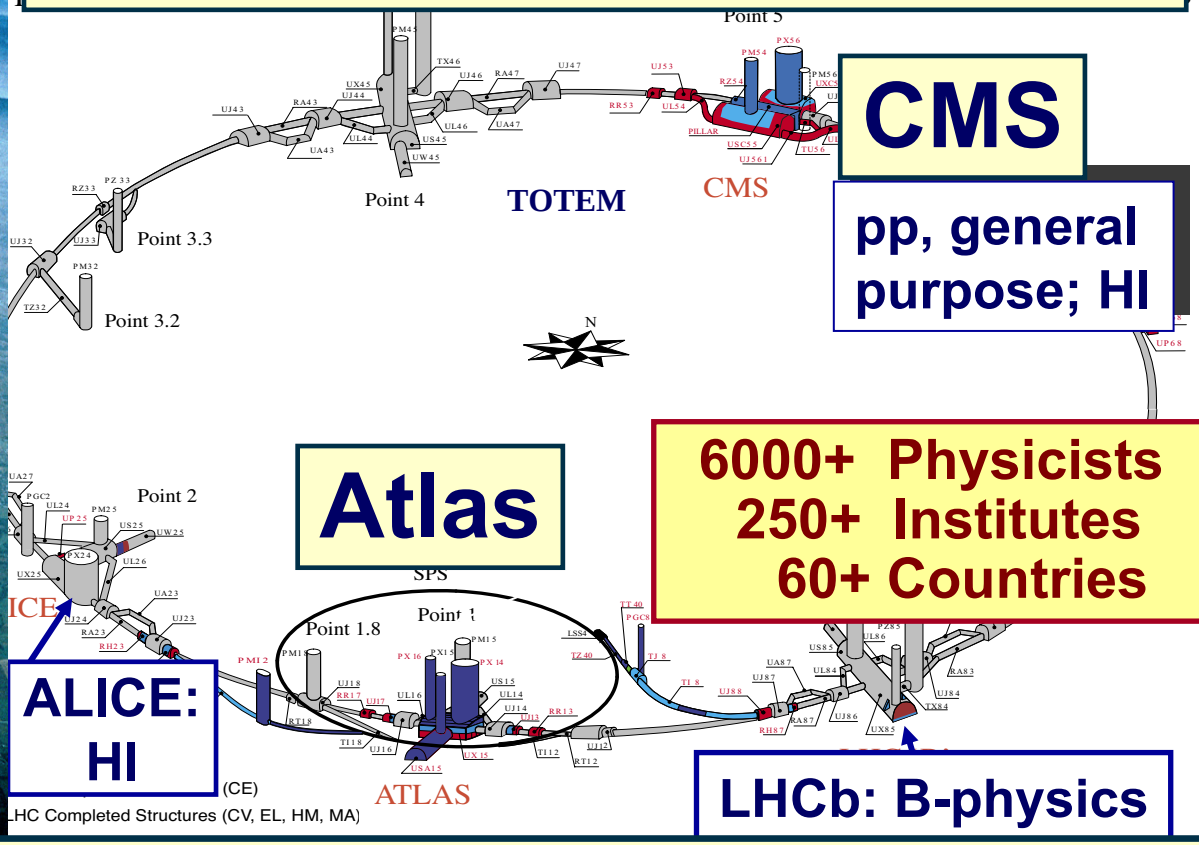
International ICFA Workshop on HEP Networking, Grid and Digital Divide Issues for Global E-Science

National Academy of Arts and Sciences
Cracow, October 9-11, 2006

Large Hadron Collider
CERN, Geneva: 2007 Start



- pp $\sqrt{s}$ =14 TeV L=10^{34} cm^{-2} s^{-1}
- 27 km Tunnel in Switzerland & France



CMS

pp, general purpose; HI

Atlas

6000+ Physicists
250+ Institutes
60+ Countries

ALICE: HI

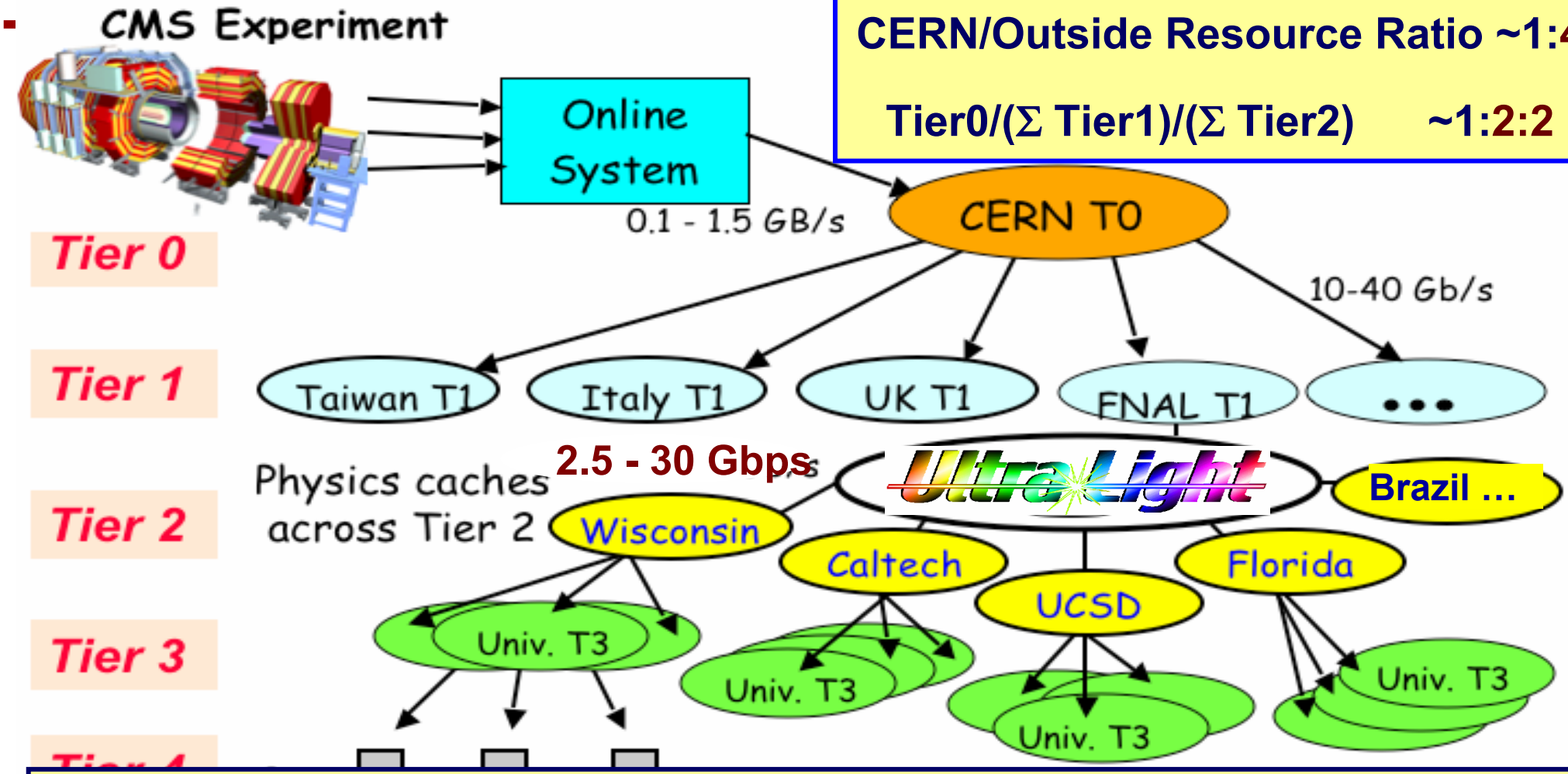
LHCb: B-physics

Challenges: Analyze petabytes of complex data cooperatively
Harness global computing, data & network resources

The LHC Data Grid Hierarchy Concept: Refined in DISUN, UltraLight

CERN/Outside Resource Ratio ~1:4

Tier0/(Σ Tier1)/(Σ Tier2) ~1:2:2



Outside/CERN Ratio Larger; Expanded Role of Tier1s & *Tier2s: Greater Reliance on Networks*

Tier-2s

The Proliferation of Tier2s
➡ LHC Computing will be
More Dynamic & Network-Oriented

~100 Identified – Number still growing

J. Knobloch

Global Networks for HENP

National and International Networks, with sufficient (and rapidly increasing) capacity and capability, are essential for

- ***Detector construction, software and computing system development & construction on a global scale***
- ***Data analysis, and the daily conduct of collaborative work in both experiment and theory, Involving physicists from all world regions***
- ***The conception, design and implementation of next generation facilities as "global networks"***

"Collaborations on this scale would never have been attempted, if they could not rely on excellent networks" (L. Price)

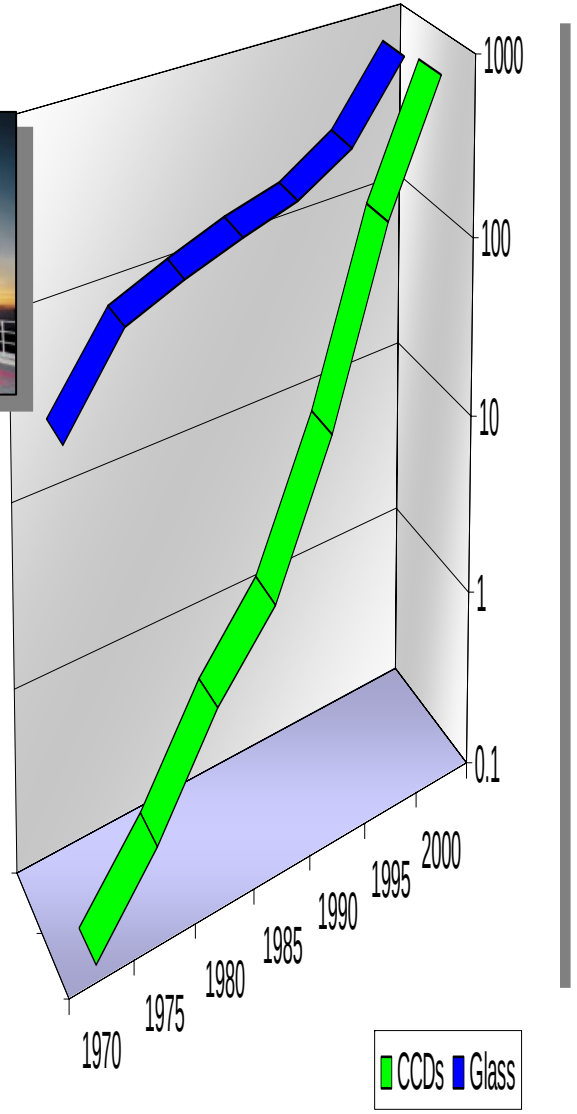
Challenges of Next Generation Science in the Information Age

Petabytes of complex data explored and analyzed by 100s-1000s of globally dispersed scientists, in 10s-100s of teams

- **Flagship Applications**
  - **High Energy & Nuclear Physics, AstroPhysics Sky Surveys: TByte to PByte "block" transfers at 1-10+ Gbps**
  - **eVLBI: Many real time data streams at 1-10 Gbps**
  - **BioInformatics, Clinical Imaging: GByte images on demand**
  - **Fusion Energy: Time Critical Burst-Data Distribution; Distributed Plasma Simulations, Visualization, Analysis**
- ***Analysis Challenge:*** **Harness global computing, storage and *NETWORK* resources, to *enable a global community to work collaboratively over great distances***

SLOAN Digital Sky Survey: Living in an Exponential World

- *300 M Celestial Objects; ¼ Sky in 5 Colors*
- **Mine the data for:**
  New (kinds of) objects or more of interesting ones (quasars); Density variations & correlations in very large parameter space
- *E.g. Redshift Survey of **1M Galaxies** **and 100k Quasars***
- **Several hundred TB now: moving to PByte**
  - *1 pixel (byte) / sq arc second ~ 4TB*
  - *Multi-spectral, temporal, … ➡ **Petabytes***
- **Data doubles every year;**
  Data is public after 1 year



ICFA Standing Committee on Interregional Connectivity (SCIC)

- Created in July 1998 in Vancouver ; Following ICFA-NTF

CHARGE:

- Make recommendations to ICFA concerning the connectivity between the Americas, Asia and Europe
- As part of the process of developing these recommendations, the committee should
  - Monitor traffic on the world's networks
  - Keep track of technology developments
  - Periodically review forecasts of future bandwidth needs, and
  - Provide early warning of potential problems
- Representatives: Major labs, ECFA, ACFA,North and Latin American Users, Russia, China

SCIC in 2005-2006
http://cern.ch/icfa-scic

Three 2006 Reports:
Rapid Progress, Deepening Digital Divide

- ***Main Report: "Networking for HENP"*** **[H. Newman, et al.]**
  - ➔ **Includes Updates on the Digital Divide, World Network Status; Brief updates on Monitoring and Advanced Technologies**
  - ➔ **29 Appendices: A World Network Overview**
    Status and Plans for the Next Few Years of Nat'l & Regional Networks, HEP Labs, & Optical Net Initiatives
- ***Monitoring Working Group Report*** **[L. Cottrell]**

Also See:

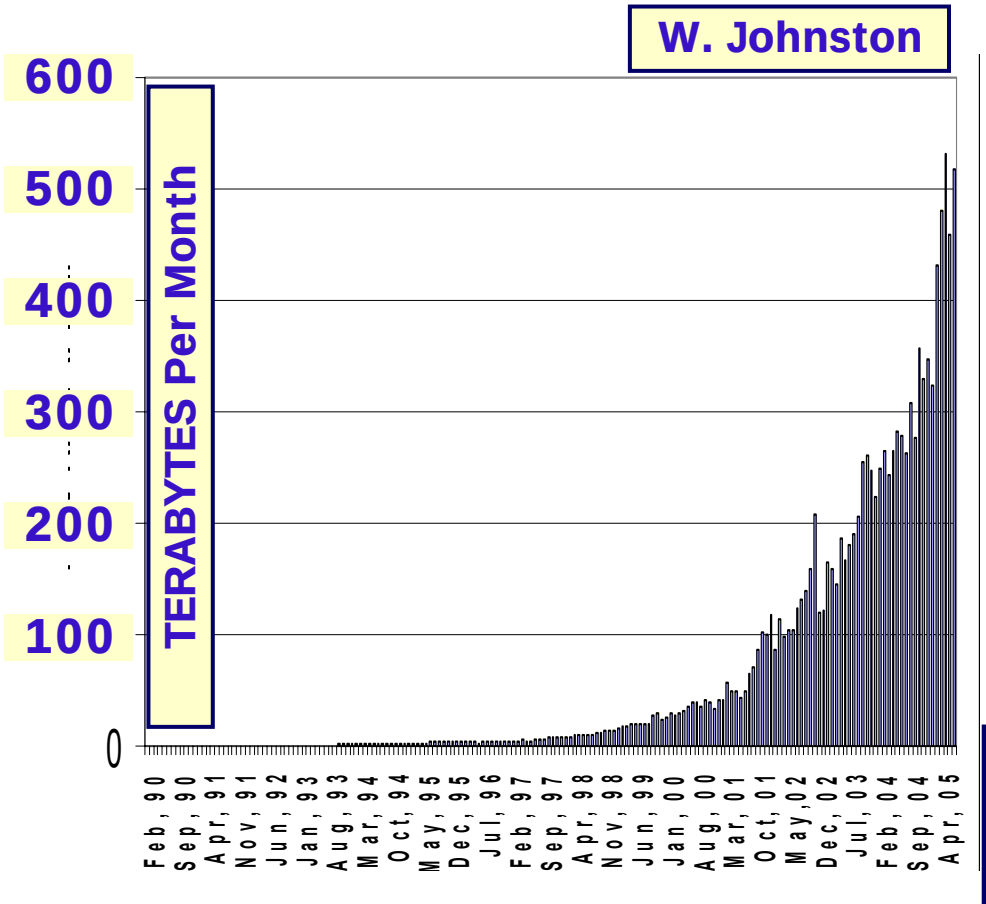
- **TERENA (www.terena.nl) *2005 Compendium:***
  In-depth Annual Survey on R&E Networks in Europe
- **http://internetworldstats.com: Worldwide Internet Use**
- ***SCIC 2003 Digital Divide Report*** **[A. Santoro et al.]**

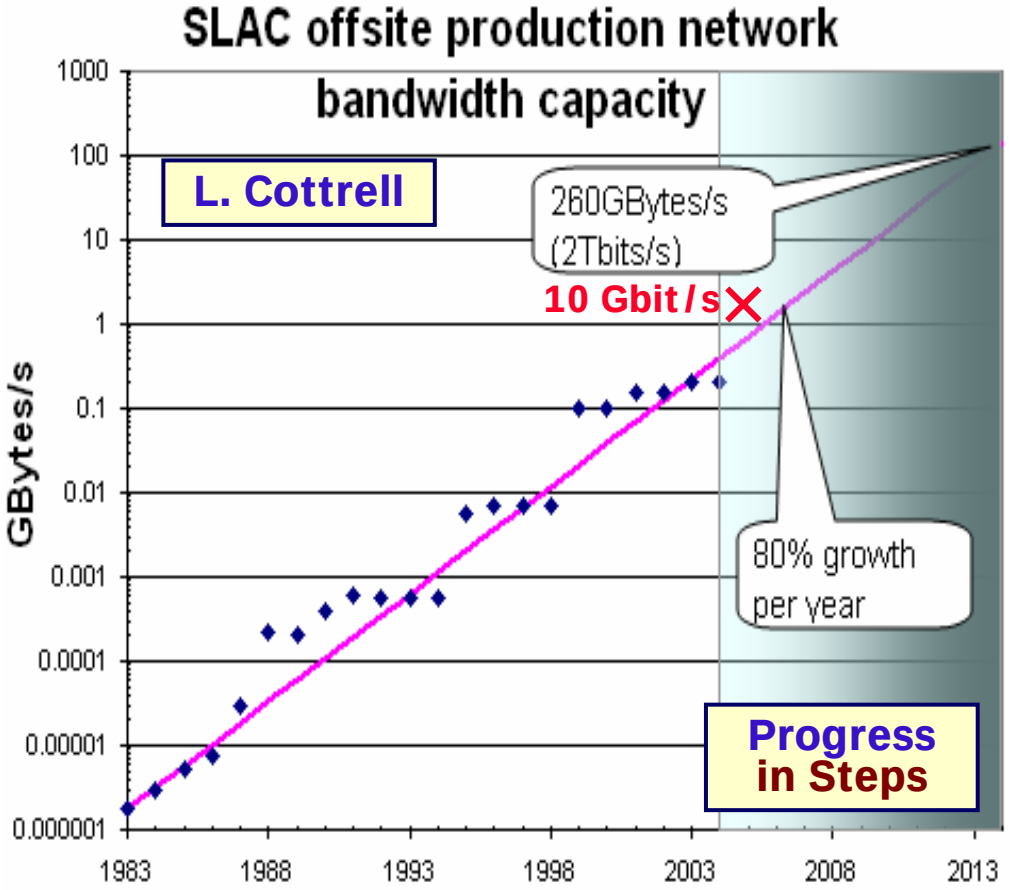
ICFA Report 2006 Update: Main Trends Deepen and Accelerate

- Current generation of 10 Gbps network backbones and major Int'l links arrived in 2001-5 in US, Europe, Japan, Korea; Now *China*
  - → Bandwidth Growth: from 4 to 1000 Times in 5 Years
  - → Much Faster than Moore's Law, and other areas of IT
- Rapid Spread of "Dark Fiber" and DWDM: the emergence of Continental, Nat'l, State & Metro "Hybrid" Networks in Many Nations
  - → Cost-effective 10G or N X 10G Backbones, complemented by Point-to-point "Light-paths" for "Data Intensive Science", notably HEP
- Proliferation of 10G links across the Atlantic & Pacific; Use of multiple 10G Links (e.g. US-CERN) along major paths began in Fall 2005
  - → On track for ~10 X 10G networking for LHC, in production by 2007-8
- Technology evolution continues to drive performance higher, equipment costs Lower
  - → Commoditization of Gigabit and now 10-Gigabit Ethernet on servers
  - → The release of new busses (PCI Express) in PC's and network interfaces is starting now
- ➡ 2006 Outlook: Continued growth in bandwidth deployment & use

Long Term Trends in Network Traffic Volumes: 300-1000X/10Yrs

ESnet Accepted Traffic 1990 – 2005
Exponential Growth:
+82%/Year for the Last 15 Years





- SLAC Traffic ~400 Mbps; Growth in Steps (ESNet Limit): ~ 10X/4 Years.
- Projected: ~2 Terabits/s by ~2014

HENP Bandwidth Roadmap for Major Links (in Gbps)

Year	Production	Experimental	Remarks
2001	0.155	0.622-2.5	SONET/SDH
2002	0.622	2.5	SONET/SDH DWDM; GigE Integ.
2003	2.5	10	DWDM; 1 + 10 GigE Integration
2005	10	2-4 X 10	λ Switch; λ Provisioning
2007	2-4 X 10	~10 X 10; 40 Gbps	1st Gen. λ Grids
2009	~10 X 10 or 1-2 X 40	~5 X 40 or ~20-50 X 10	40 Gbps λ Switching
2011	~5 X 40 or ~20 X 10	~25 X 40 or ~100 X 10	2nd Gen λ Grids Terabit Networks
2013	~Terabit	~MultiTbps	~Fill One Fiber

Continuing Trend: ~400-1000 Times Bandwidth Growth Per Decade
Paralleled by ESnet Roadmap for Data Intensive Sciences

Int'l Networks BW on Major Links for HENP: US-CERN Example

- ***Rate of Progress >> Moore's Law (US-CERN Example)***
  - ***9.6 kbps Analog*** ***1985)***
  - ***64-256 kbps Digital*** ***1989 - 1994)*** ***[X 7 – 27]***
  - ***1.5 Mbps Shared*** ***1990-3; IBM)*** ***[X 160]***
  - ***2 -4 Mbps*** ***1996-1998)*** ***[X 200-400]***
  - ***12-20 Mbps*** ***1999-2000)*** ***[X 1.2k-2k]***
  - ***155-310 Mbps*** ***2001-2)*** ***[X 16k – 32k]***
  - ***622 Mbps*** ***2002-3)*** ***[X 65k]***
  - ***2.5 Gbps (λ)*** ***2003-4*** ***[X 250k]***
  - ***10 Gbps*** ***2004-5*** ***[X 1M]***
  - ***2 x 10 Gbps*** ***2005-6*** ***[X 2M]***
  - ***3 to 4 x 10 Gbps*** ***2007-8*** ***[X 3-4M]***
  - ***6 to 8 x 10 Gbps*** ***2009-10*** ***[X 6-8M]***
- ***A factor of ~1M Bandwidth Growth over 1985-2005;***
  Slower growth: (10 X in 5 Years) until 100 Gbps λ's in ~2010-11
- ***HENP has become a leading applications driver,***
  and also a co-developer of global networks

Science Network Requirements Aggregation Summary

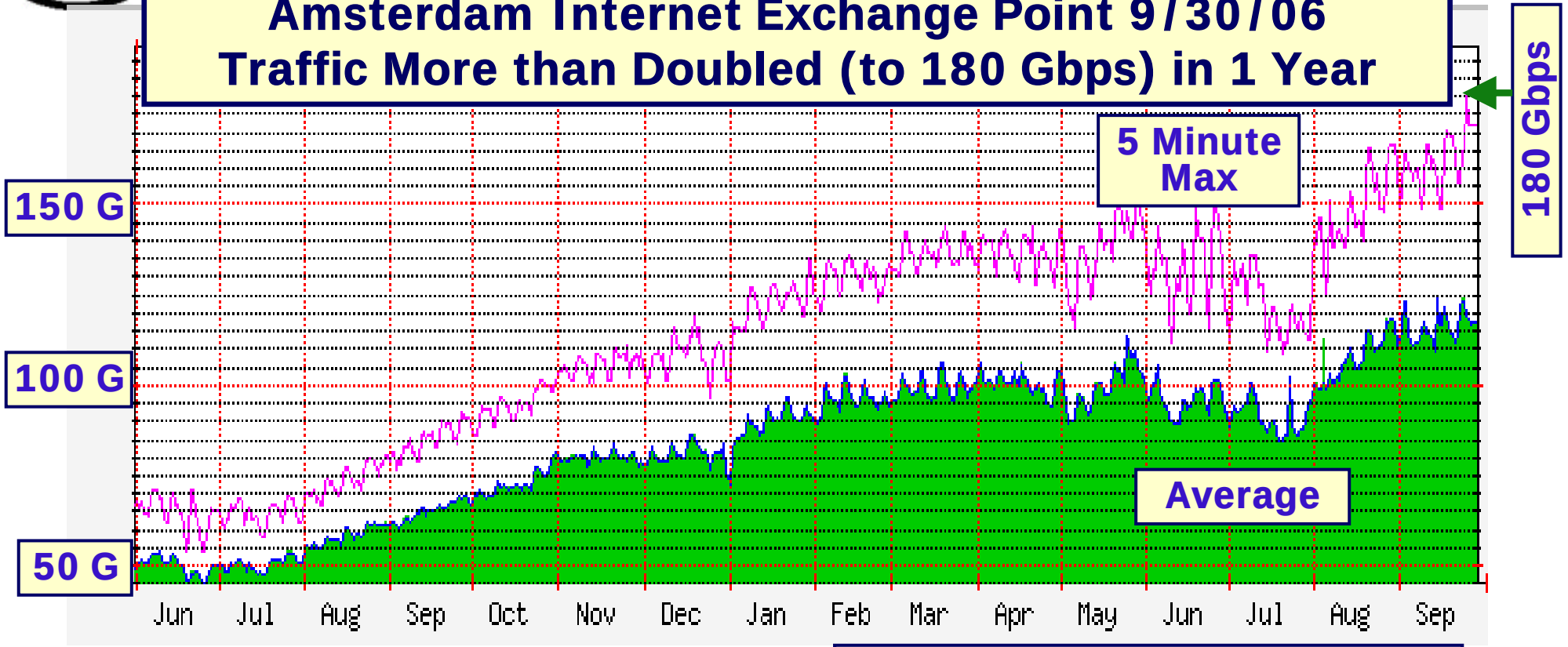
W. Johnston
ESnet

Science Drivers Science Areas / Facilities	End2End Reliability	Connectivity	Today End2End Band width	5 years End2End Band width	Traffic Characteristics	
Advanced Light Source	-	• DOE sites • US Universities • Industry	1 TB/day 300 Mbps	5 TB/day 1.5 Gbps	• Bulk data • Remote control	• Guaranteed bandwidth • PKI / Grid
Bio-informatics	-	• DOE sites • US Universities	625 Mbps 12.5 Gbps in two yrs	250 Gbps	• Bulk data • Remote control • Point-to-multipoint	• Guaranteed bandwidth • High-speed multicast
Chem./ Combustion	-	• DOE sites • US Universities • Industry	-	Tens of Gigabits/ second	• Bulk data	• Guaranteed bandwidth • PKI / Grid
Climate Science	-	• DOE sites • US Universities • Int'l	-	5 PB/year 5 Gbps	• Bulk data • Remote control	Guaranteed bandwidth • PKI / Grid
High Energy Physics (LHC)	99.95+% (< 4 hrs per year)	• US Tier1 (FNAL, BNL) • US Tier2 • International (Europe, Canada)	10 Gbps	60 to 80 Gbps (30-40 Gbps per US Tier1)	• Bulk data • Coupled computational processes	• Guaranteed bandwidth • Traffic isolation • PKI / Grid

Immediate Requirements

Internet Growth in the World At Large

Amsterdam Internet Exchange Point 9/30/06
Traffic More than Doubled (to 180 Gbps) in 1 Year



Some Annual Growth Spurts; Typically In Summer-Fall

"Acceleration" Last Summer

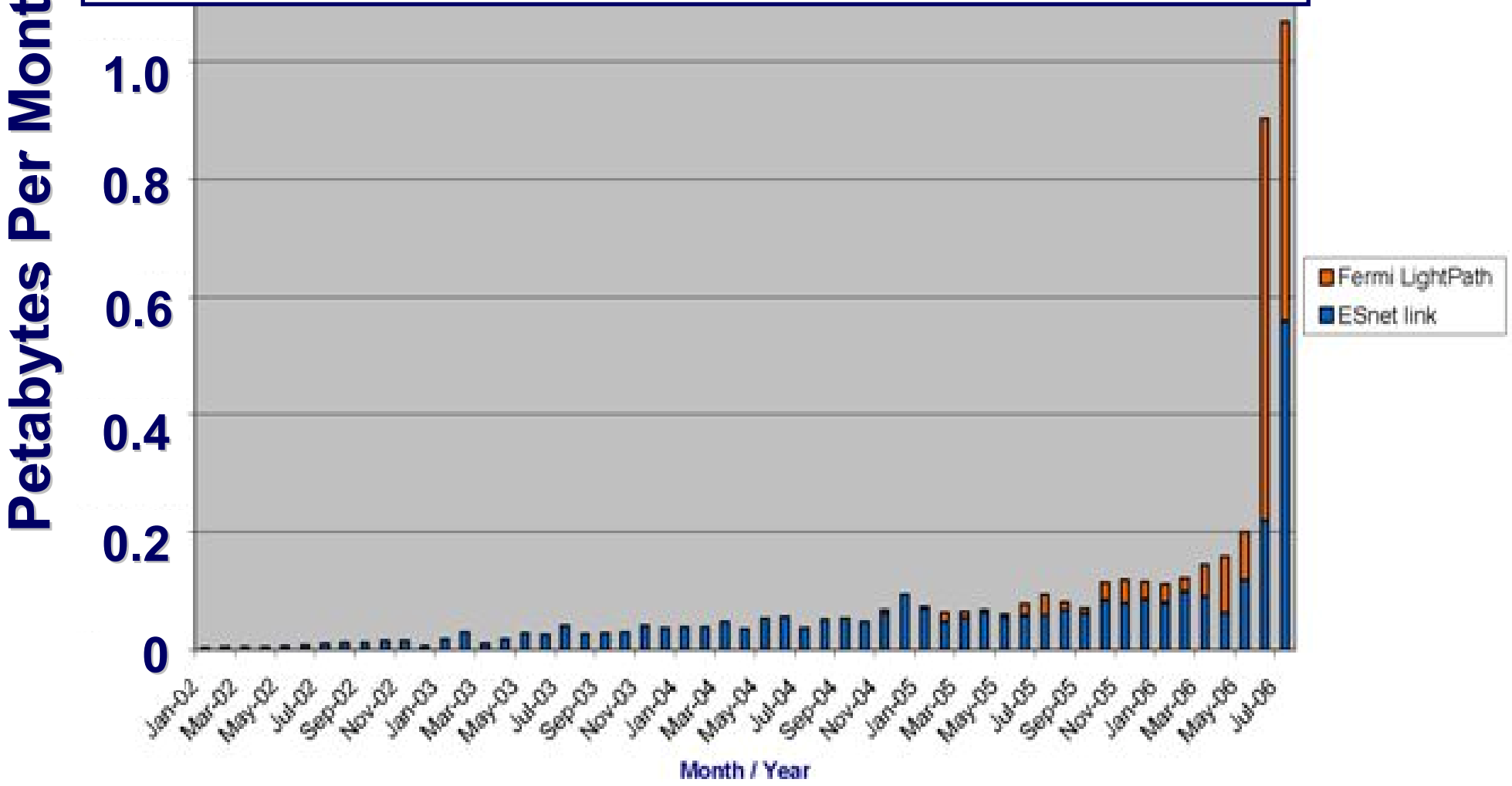
The Rate of HENP Network Usage Growth (80-100% Per Year) is Matched by the Growth of Traffic in the World at Large

Fermilab

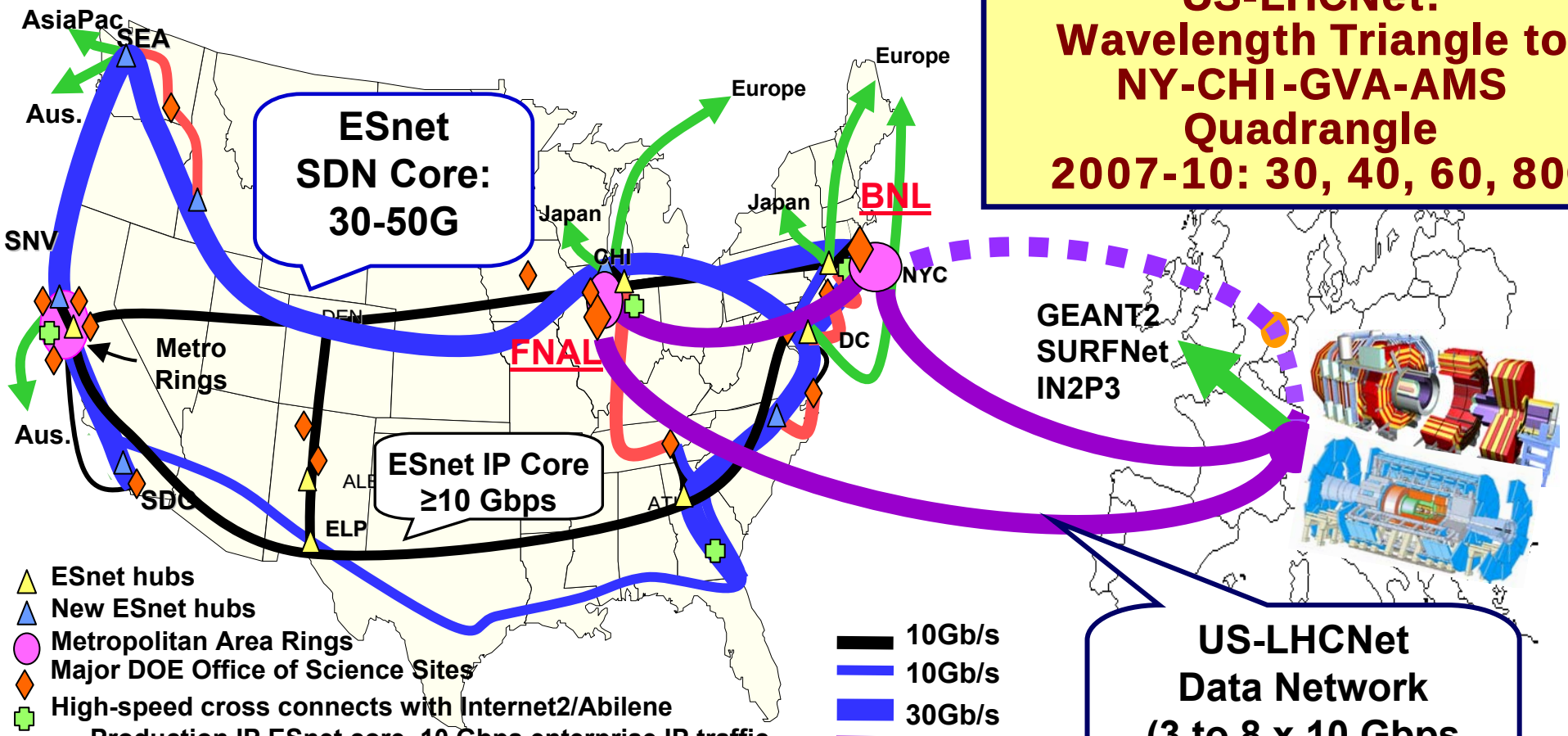
FNAL Outbound Traffic

Fermi LightPath

"Onslaught of the LHC"
0.2 to 1.1 Petabytes/Month in 2 Months



LHCNet, ESnet Plan 2006-2009: 20-80Gbps US-CERN, ESnet MANs, IRNC

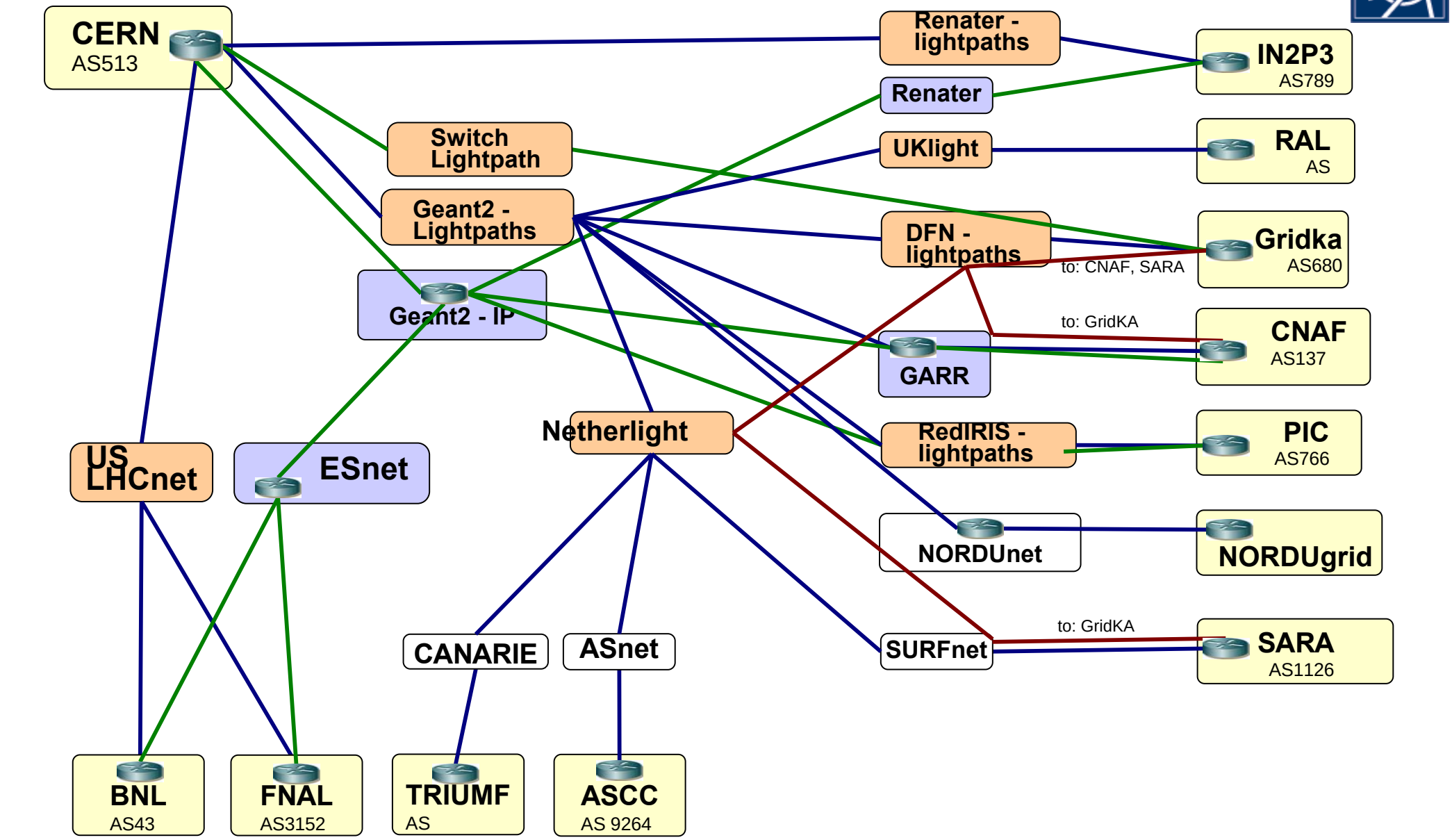


US-LHCNet: Wavelength Triangle to NY-CHI-GVA-AMS Quadrangle 2007-10: 30, 40, 60, 80G

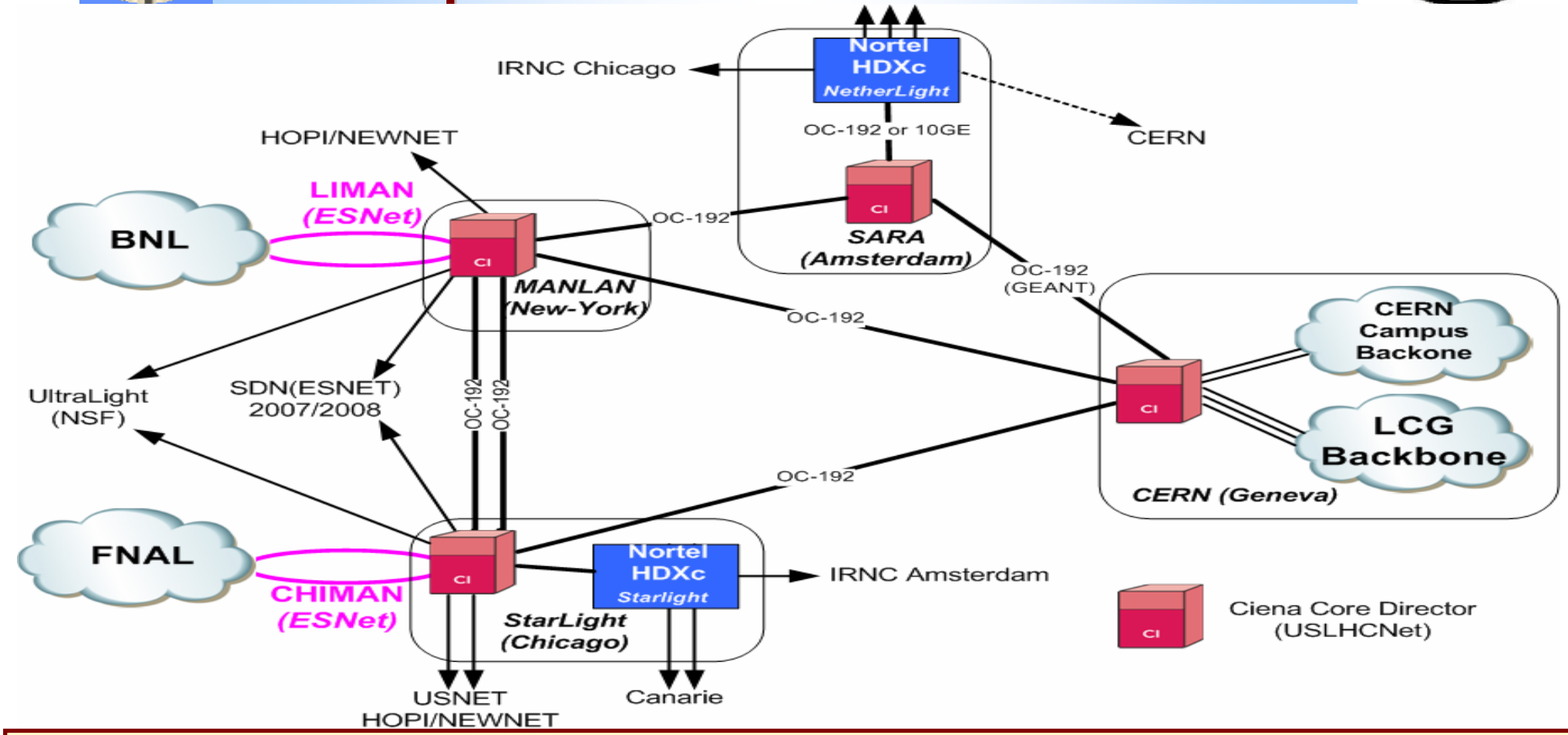
US-LHCNet Data Network (3 to 8 x 10 Gbps US-CERN)

ESNet MANs to FNAL & BNL; Dark fiber to FNAL

LHCOPN: Overlay T0-T1 Network (CERN-NA-EU)



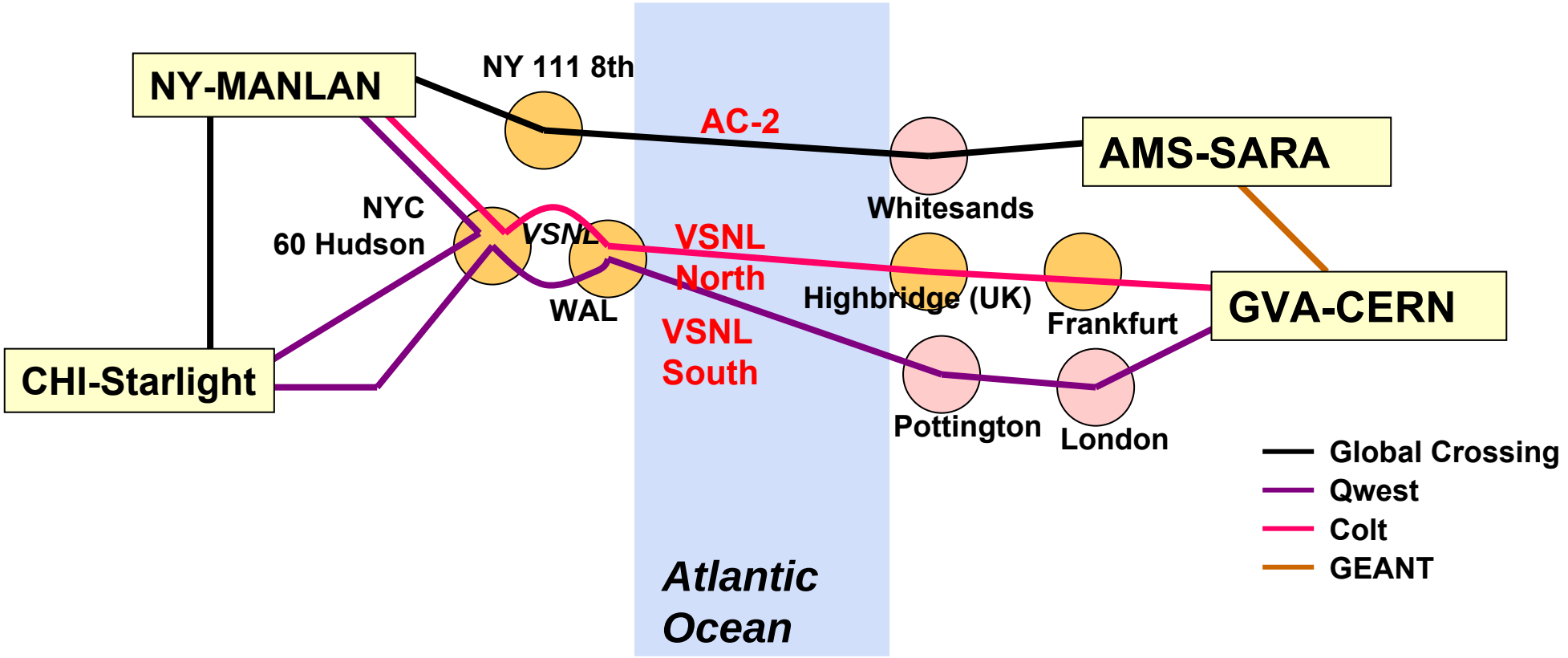
Next Generation LHCNet: Add Optical Circuit-Oriented Services



Based on CIENA "Core Director" Optical Multiplexers

- Robust fallback, at the optical layer
- Circuit-oriented services: Guaranteed Bandwidth Ethernet Private Line (EPL)
- New standards-based software: VCAT/LCAS: Virtual, Dynamic Channels

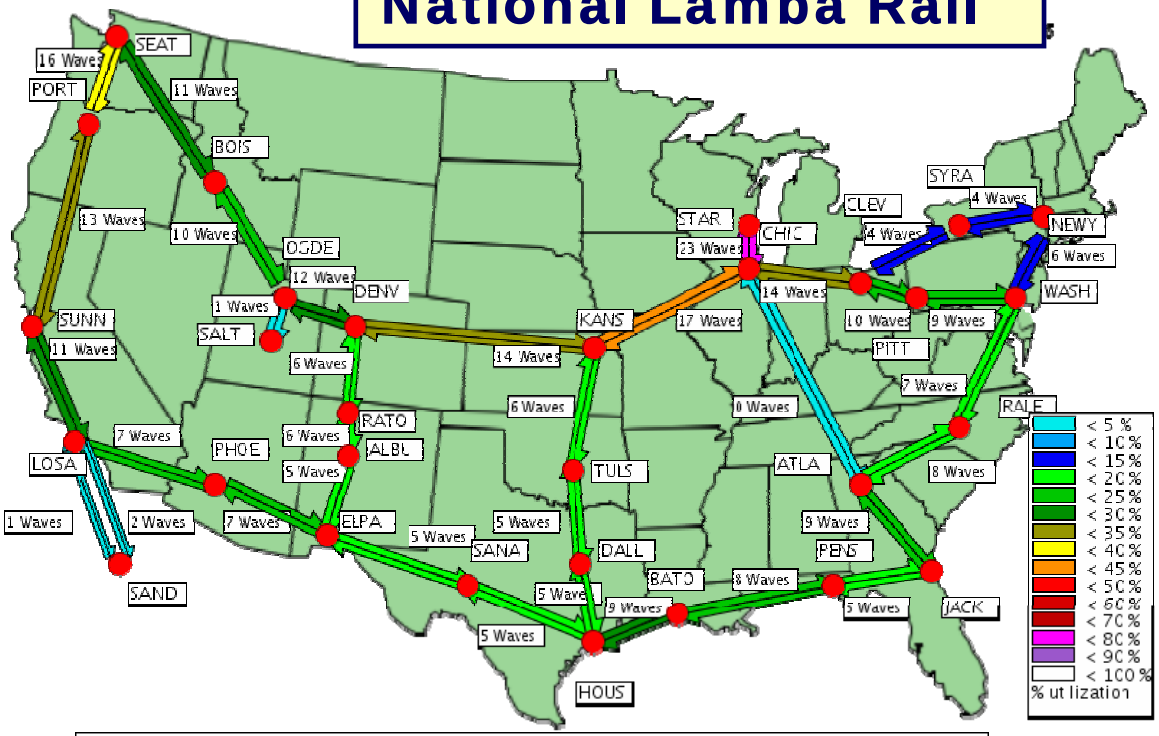
US LHCNet 2007 Multiple Fiber Paths: Reliability Through Diversity



- Four providers, three separate transatlantic cables
  - Colt, Qwest, Global Crossing
    GEANT (Contract via Surfnet, with CERN)

Transition to Community Owned or Operated Optical Infrastructures

National Lamba Rail



NEWY->WASH	5 Waves	WASH->RALE	7 Waves	NEWY->SYRA	4 Waves	RALE->ATLA	8 Waves
WASH->PITT	9 Waves	ATLA->JACK	9 Waves	PITT->CLEV	10 Waves	CLEV->CHIC	14 Waves
SYRA->CLEV	4 Waves	CHIC->KANS	17 Waves	KANS->TULS	6 Waves	TULS->DALL	5 Waves
DALL->HOUS	5 Waves	KANS->DENV	14 Waves	DENV->OGDE	12 Waves	OGDE->BOIS	10 Waves
BOIS->SEAT	11 Waves	SEAT->PORT	16 Waves	PORT->SUNN	13 Waves	SUNN->LOSA	11 Waves
LOSA->PHOE	7 Waves	PHOE->ELPA	7 Waves	ELPA->ALBU	5 Waves	ALBU->RATO	6 Waves
RATO->DENV	5 Waves	ELPA->SANA	5 Waves	SANA->HOUS	5 Waves	HOUS->BATO	9 Waves
BATO->PENS	3 Waves	PENS->JACK	5 Waves	CHIC->STAR	23 Waves	OGDE->SALT	1 Waves
LOSA->SAND	1 Waves	LOSA->SAND	2 Waves	CHIC->ATLA	0 Waves		

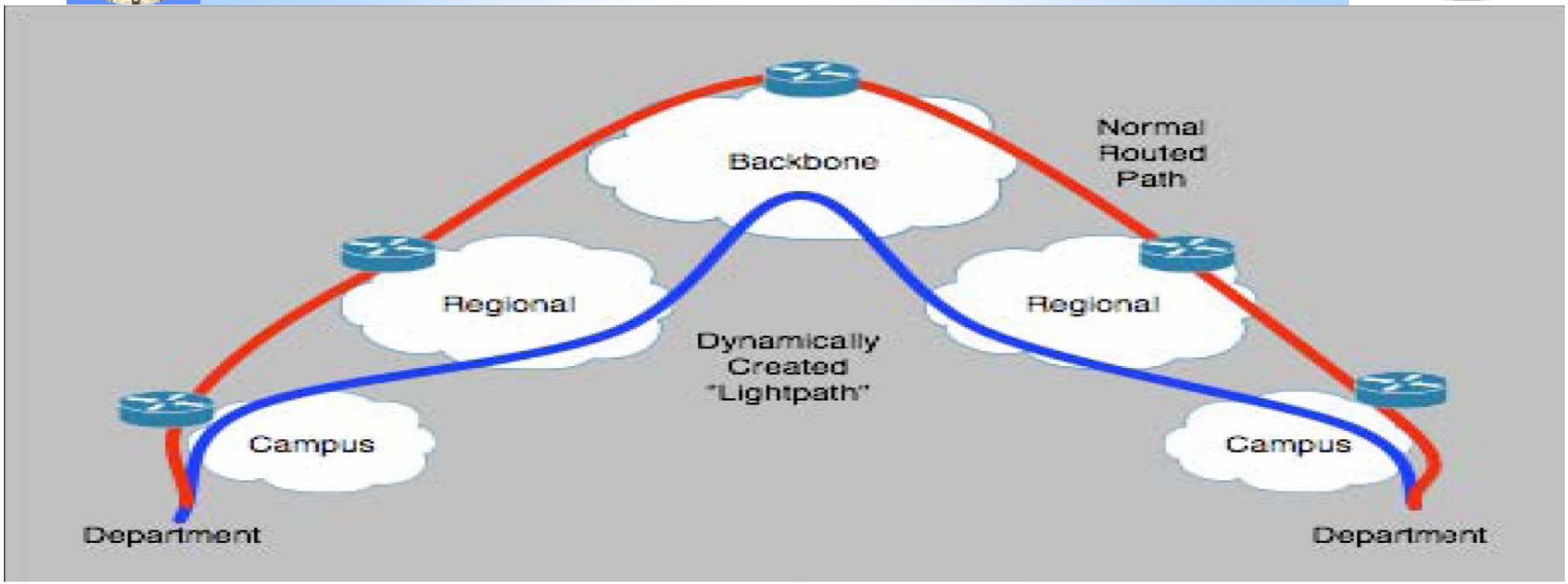
Example: NLR www.nlr.net

- *Each Link to 32 X 10G*
- *Cost Recovery Model*
- *Supports: Cisco Research Wave, UltraScience Net, Atlantic & Pacific Wave;* **Initiatives w/HEP**

A Network of Networks

- **WaveNet: point-to-point lambdas**
- **FrameNet: Ethernet based services**
- **PacketNet: IP Routed Nets**

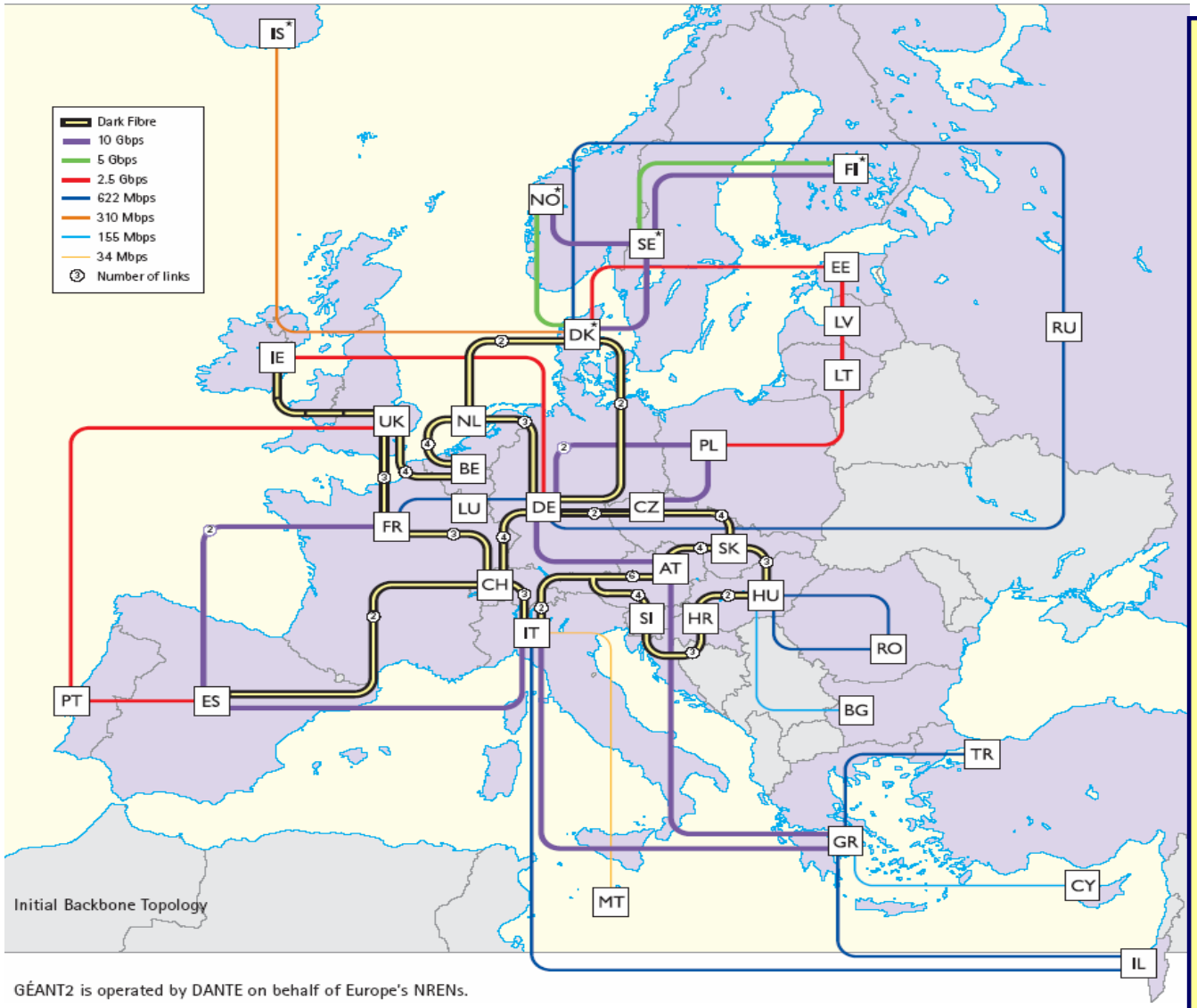
Internet2's "NewNet" Backbone



Initial deployment – 10 x 10 Gbps wavelengths over the footprint
Maximum capacity – 80 x 10 Gbps wavelengths
Scalability – potential migration to 40 Gbps or 100 Gbps capability
Reliability – carrier-class standard assurances for wavelengths
The community will transition to NewNet from now, over period of 15 months

+Paralleled by Initiatives in: nl, ca, jp, uk, kr; *pl, cz, sk, pt, ei, gr, hu, si, lu, no, is, dk* ... + >30 US states

The GÉANT2 Footprint: Now Being Implemented



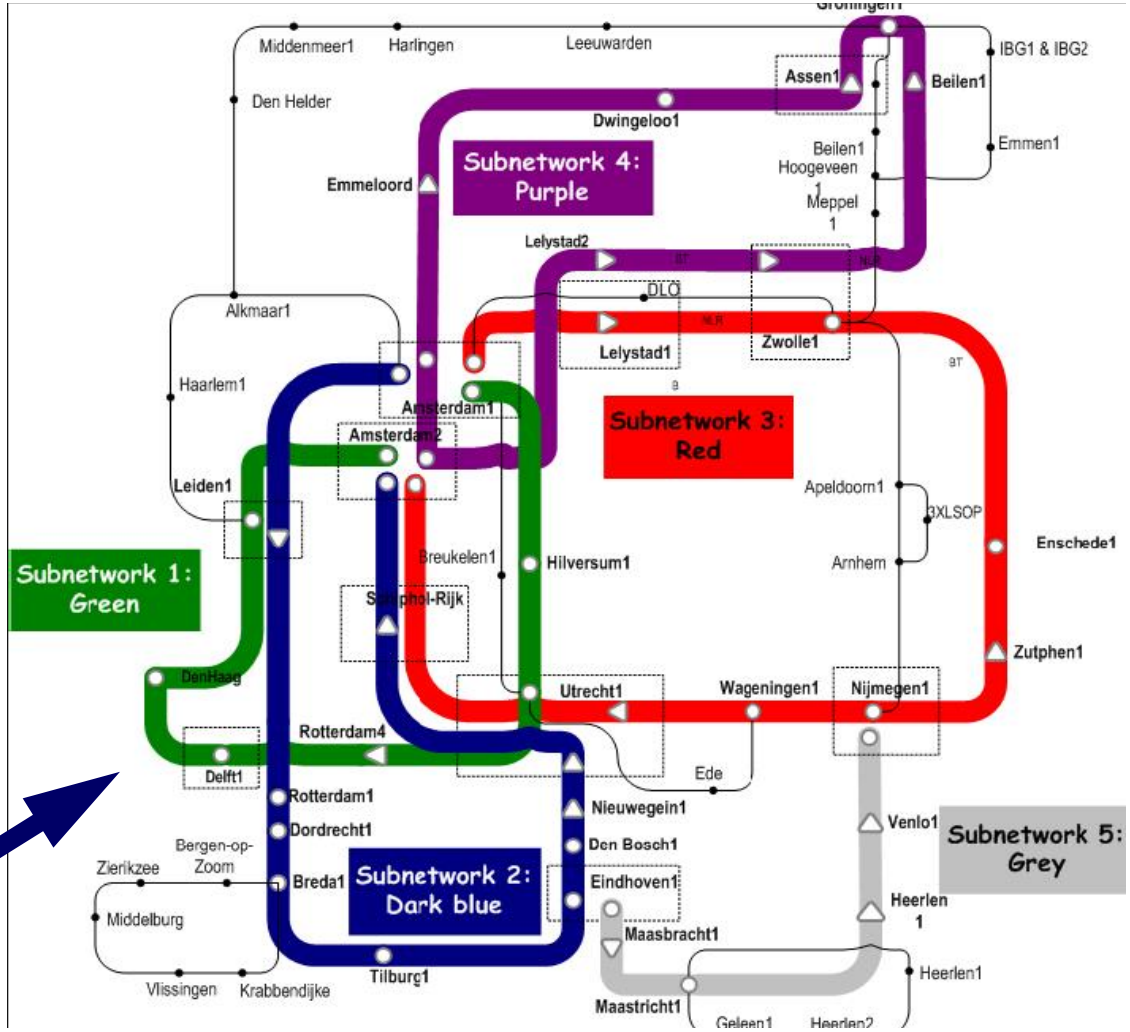
GÉANT2 is operated by DANTE on behalf of Europe's NRENs.

Multi-Wavelength Core + 0.6-10G Loops

Dark Fiber Connections Among 16 Countries:

- Austria
- Belgium
- Bosnia-Herzegovina
- Czech Republic
- Denmark
- France
- Germany
- Hungary
- Ireland
- Italy,
- Netherland
- Slovakia
- Slovenia
- Spain
- Switzerland
- United Kingdom

SURFNet6 in the Netherlands
5300 km of Owned Dark Fiber



Optical Layer: 5 Rings
Up to 72 Wavelengths
Support for HEP,
Radioastronomers
Medical Research

K. Neggers

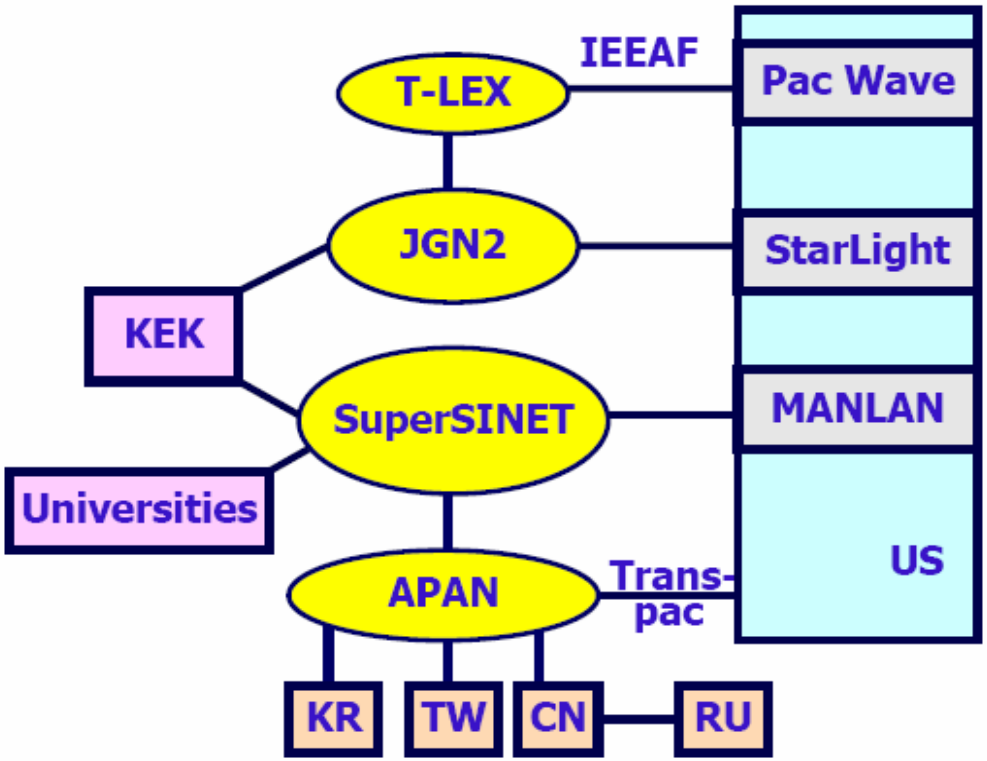
DFN (Germany): *X-WiN-Fiber* Network

- ***X-WiN* core in 2006**
  - ➔ 29 dark fiber links
  - ➔ 9 links with wavelength services
  - ➔ 9 with both
- Several fibre and wavelengths providers
- Fiber is relatively cheap – in most cases more economic than (one) wavelength
- X-Win creates many new options; cheaper than the previous G-WiN core

K. Schauerhammer
V. Guelzow

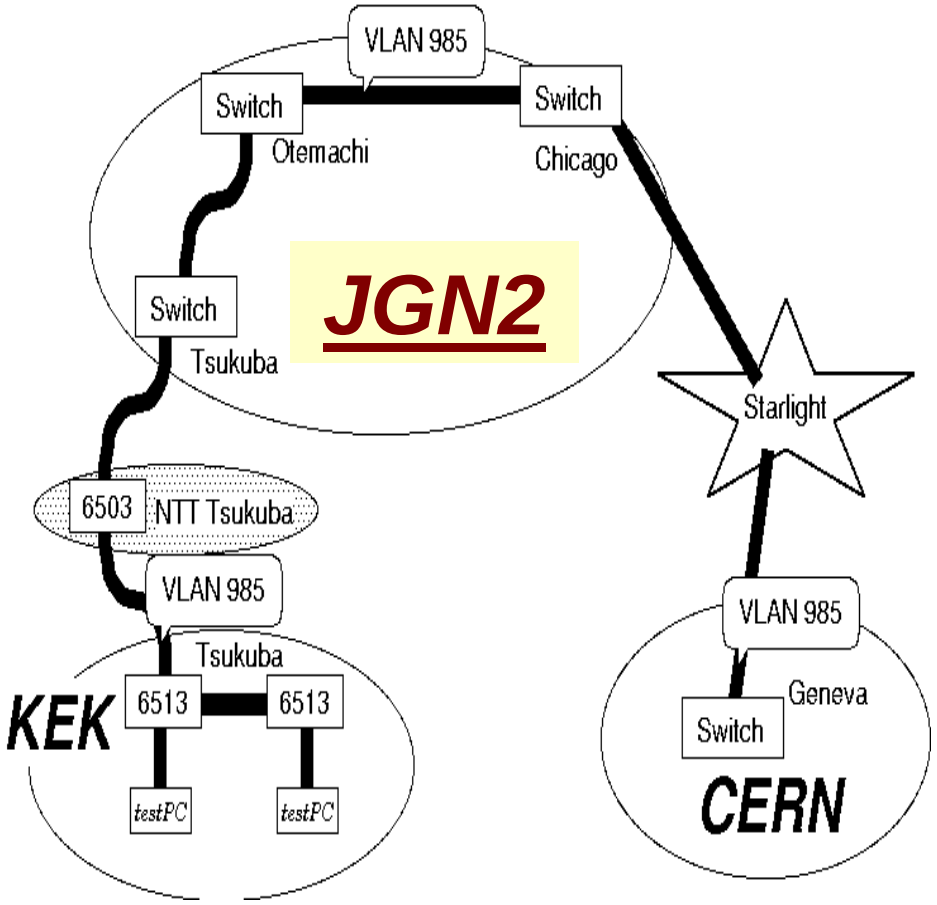
JAPAN: SuperSINET, JGN2, APAN

2005 Oct. 25



Research and Education Networks in Japan

Four 10G Links to US
High Speed Links to Asia Via APAN



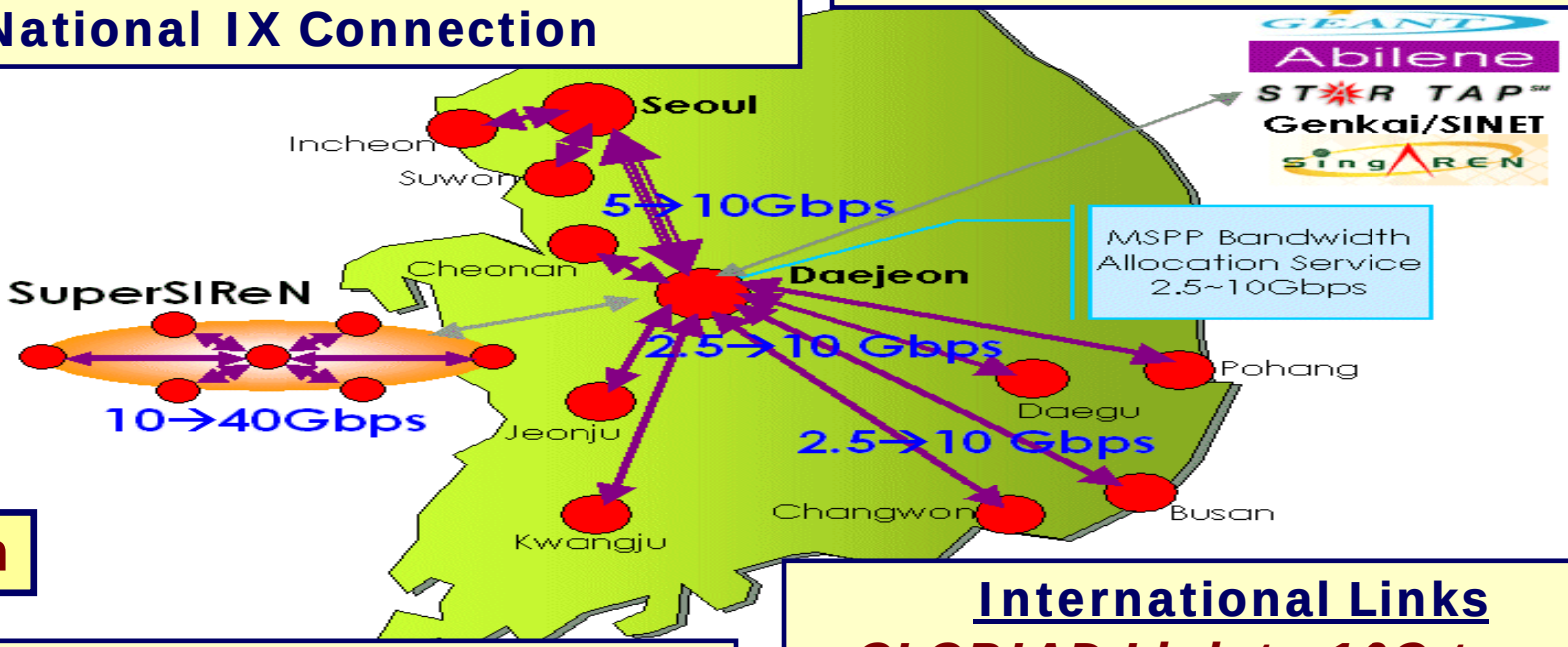
KEK – StarLight-CERN Layer 2 Link

Y. Karita

APAN-KR : KREONET/KREONet2 II

KREONET
- 11 Regions, 12 POP Centers
- Optical 2.5-10G Backbone; SONET/SDH, POS, ATM
- National IX Connection

KREONET2
- Support for Next Gen. Apps:
- IPv6, QoS, Multicast; Bandwidth Alloc. Services
- StarLight/Abilene Connection



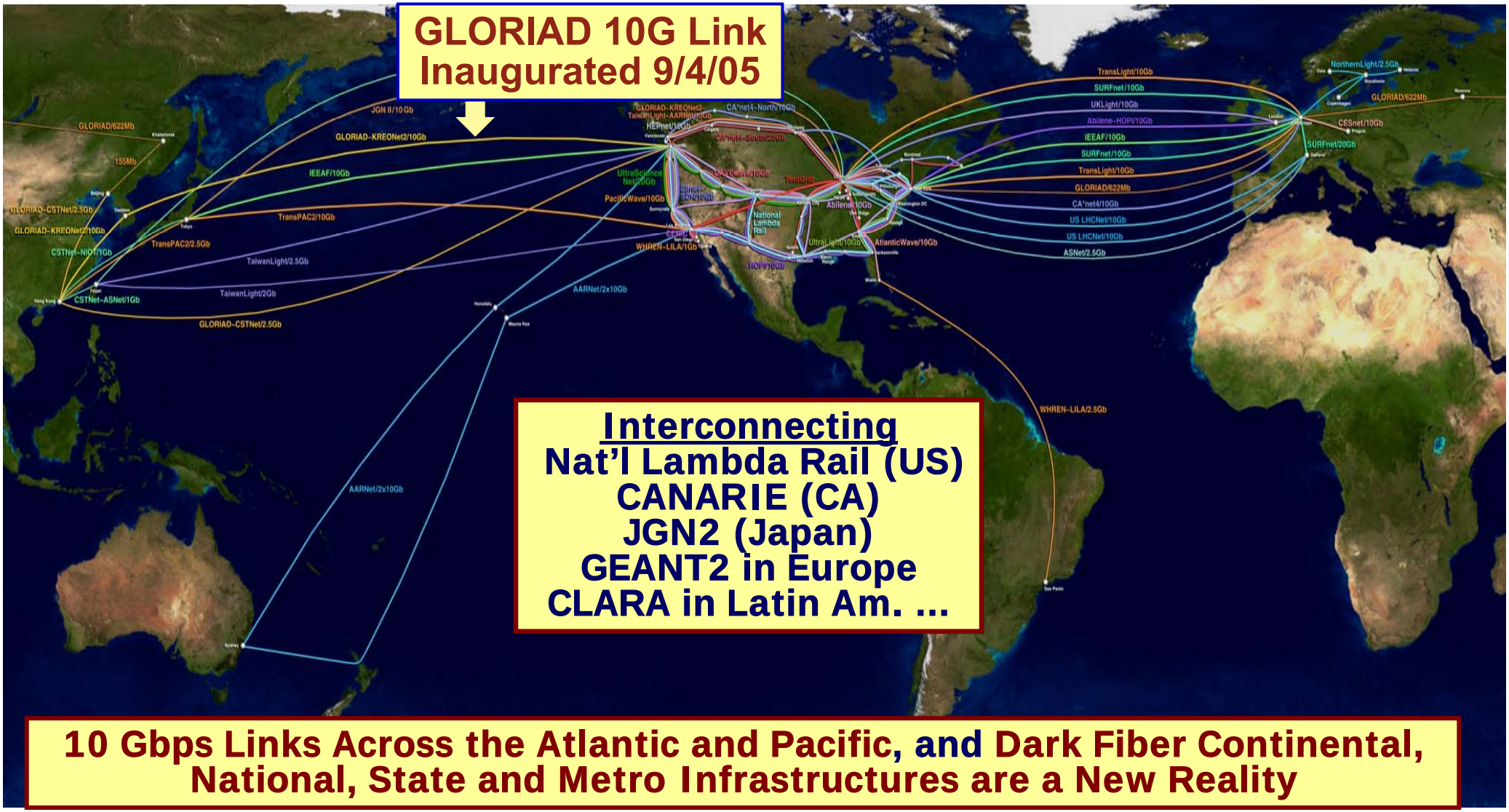
D. Son

SuperSIREN (7 Res. Institutes)
- Optical 10-40G Backbone
- Collaborative Environment Support
- High Speed Wireless: 1.25 G

International Links
- *GLORIAD Link to 10G to Seattle since Sept. 2005*
- US: 2 X 622 Mbps via CA*Net; GbE via TransPAC
- Japan: 2 Gbps

The Global Lambda Integrated Facility for Research and Education (GLIF)

Architecting an International LambdaGrid Infrastructure



Data Samples and Transport Scenarios

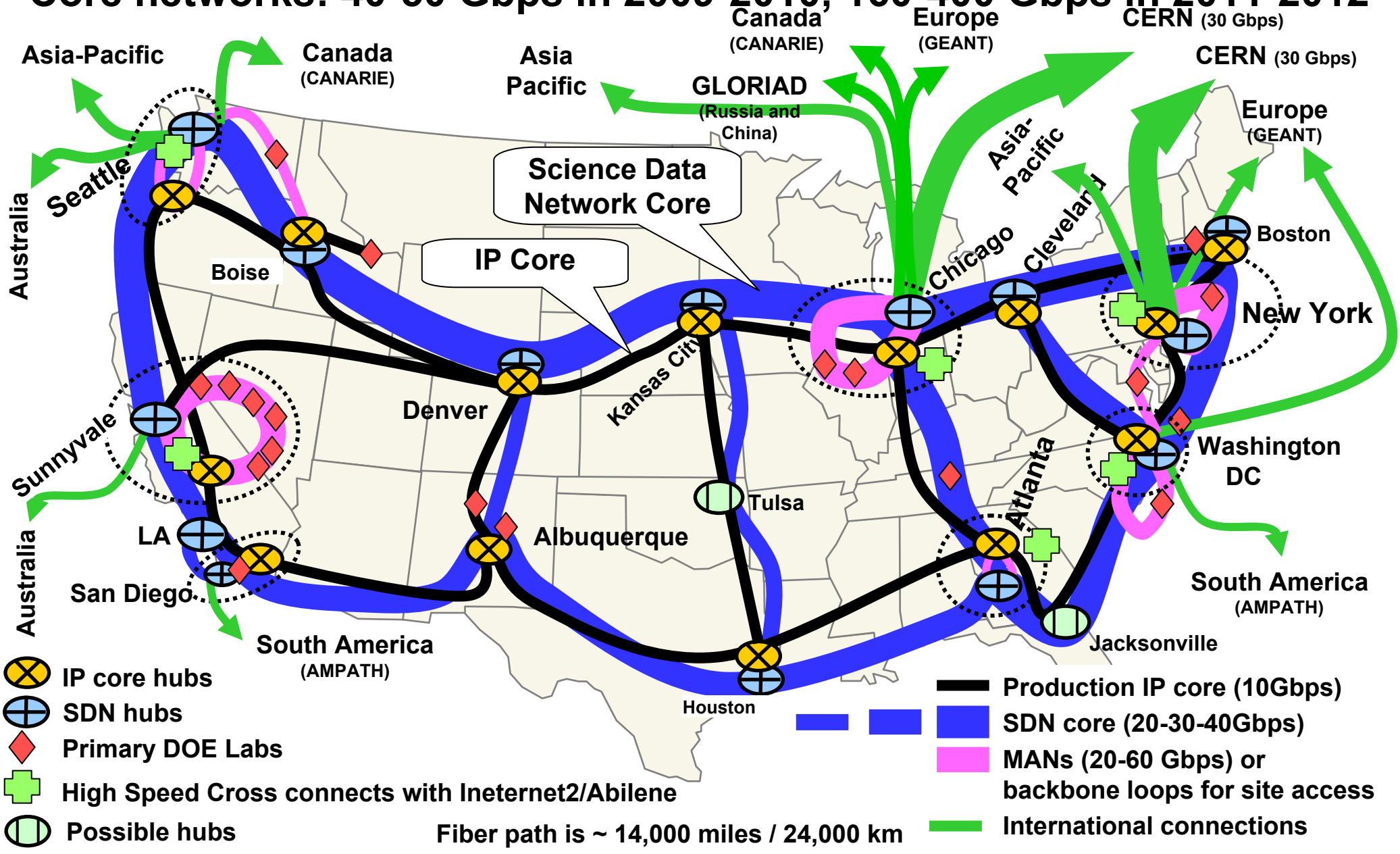
10^7 Event Samples	Data Volume (TBytes)	Transfer Time (hrs) @ 0.9 Gbps	Transfer Time (hrs) @ 3 Gbps	Transfer Time (hrs) @ 8 Gbps
AOD	0.5-1	1.2 – 2.5	0.37-0.74	0.14 – 0.28
RECO	2.5 - 5	6 - 12	1.8 – 3.7	0.69 – 1.4
RAW+RECO	17.5 - 21	43 - 86	13 - 26	4.8 – 9.6
MC	20	98	30	11

- 10^7 Events is a typical data sample for analysis or reconstruction development [Ref.: MONARC]; equivalent to just ~1 day's running
- ➡ One can only transmit ~2 RAW + REC or MC samples per day on a fully utilized 10G path
- ➡ *Transport of significant data samples will require one, or multiple 10G links*
- ➡ *Movement of 10^8 event samples takes ~1 week (RAW, MC), fully utilizing a 10G link*

ESnet4 Prototype Architecture and Configuration

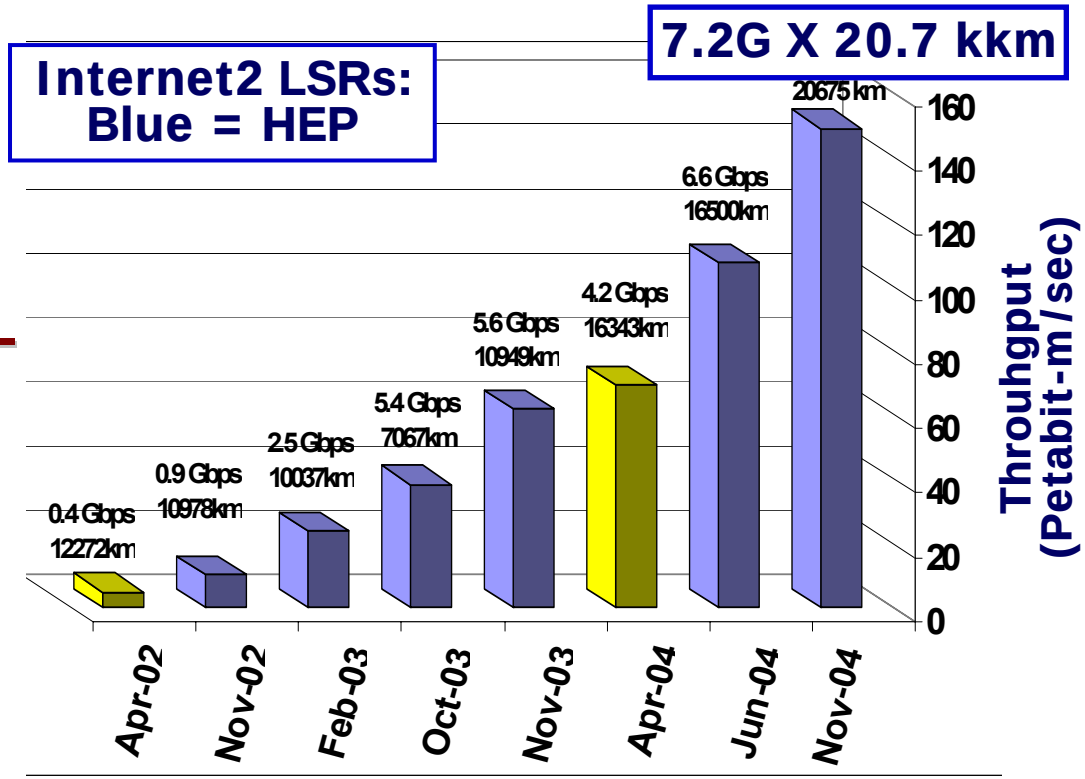
W. Johnston ESnet

Core networks: 40-50 Gbps in 2009-2010, 160-400 Gbps in 2011-2012

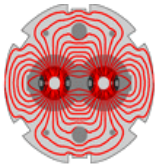


Internet2 Land Speed Records & SC2003-2005 Records

- IPv4 Multi-stream record
  6.86 Gbps X 27kkm: Nov 2004
- ✸ PCI-X 2.0: 9.3 Gbps Caltech-StarLight: Dec 2005
- ✸ PCI Express: 9.8 Gbps Caltech – Sunnyvale, July 2006
- *Concentrate now on reliable Terabyte-scale file transfers*
  - *Disk-to-disk Marks:*
    536 Mbytes/sec (Windows);
    500 Mbytes/sec (Linux)
  - *System Issues: PCI Bus, Network Interfaces, Disk I/O Controllers, Linux kernel,CPU*
- ◆ *SC2003-5: 23, 101, 151 Gbps*
- ◆ *Fast Data Transport (FDT) Streaming Application*



SC|05 Global Lambdas for Particle Physics



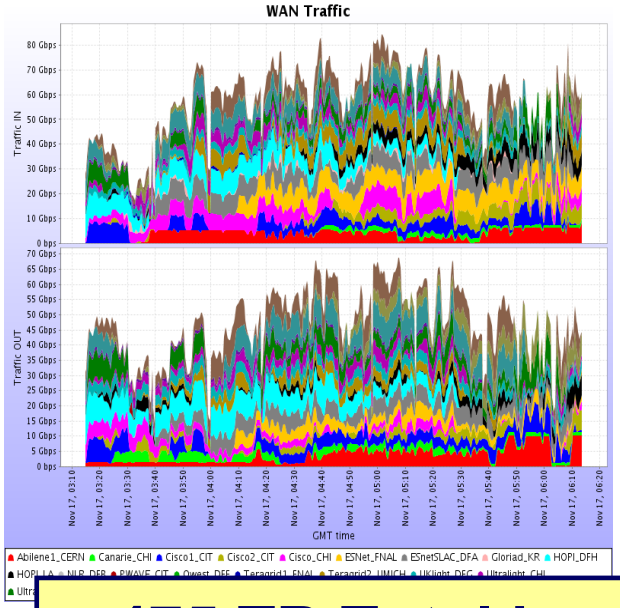
- **We previewed the global-scale data analysis of the LHC Era**

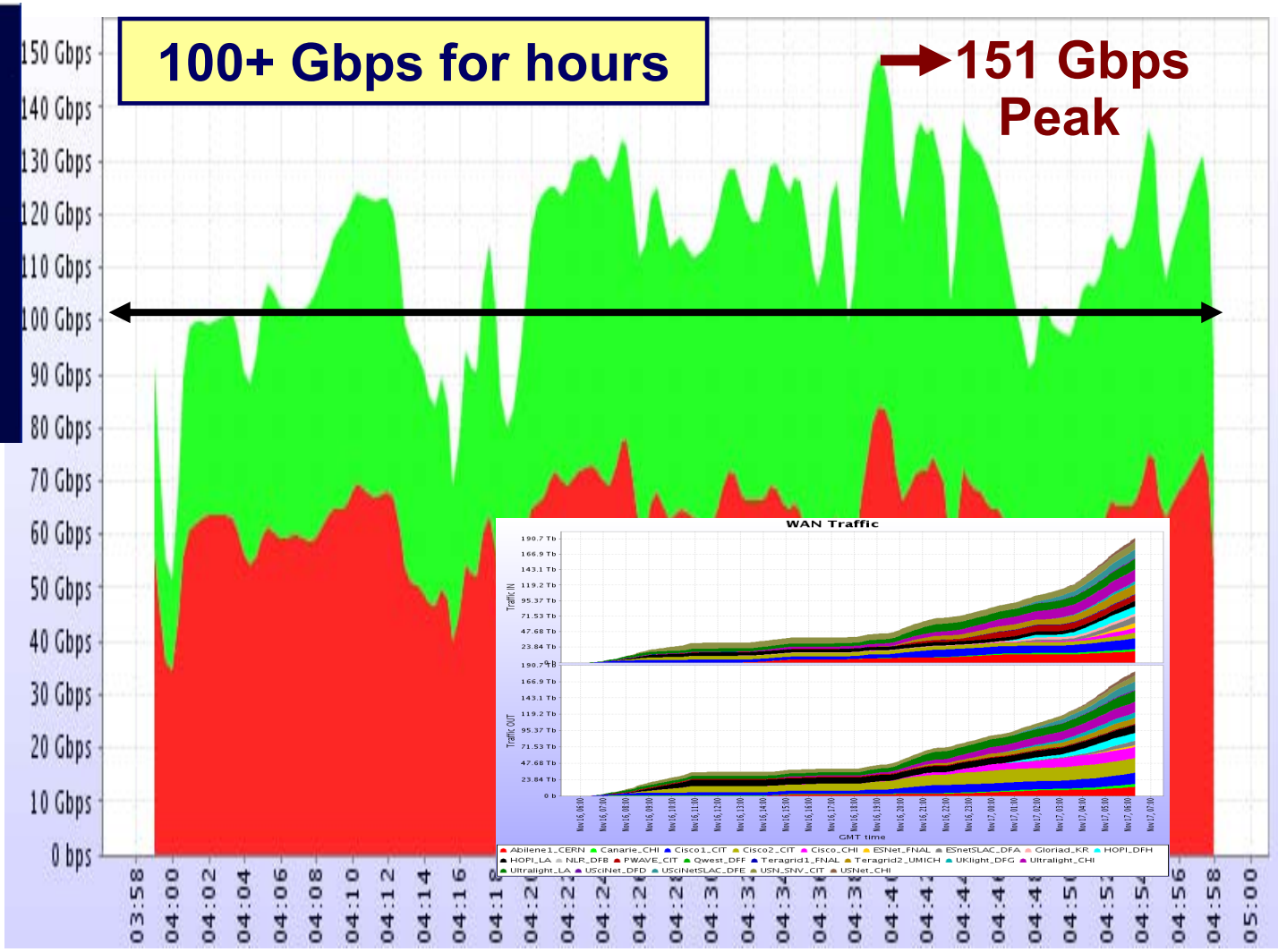
  Using a realistic mixture of streams:
  - **Organized transfer of multi-TB event datasets; plus**
  - **Numerous smaller flows of physics data that absorb the remaining capacity**

- ***We used Twenty Two [*] 10 Gbps waves to carry bidirectional traffic between Fermilab, Caltech, SLAC, BNL, CERN and partner Grid sites including: Michigan, Florida, Manchester, Rio de Janeiro (UERJ) and Sao Paulo (UNESP) in Brazil, Korea (Kyungpook), and Japan (KEK)***

[*] 15 10 Gbps wavelengths at the Caltech/CACR Booth and 7 10 GBps wavelengths at the FNAL/SLAC Booth

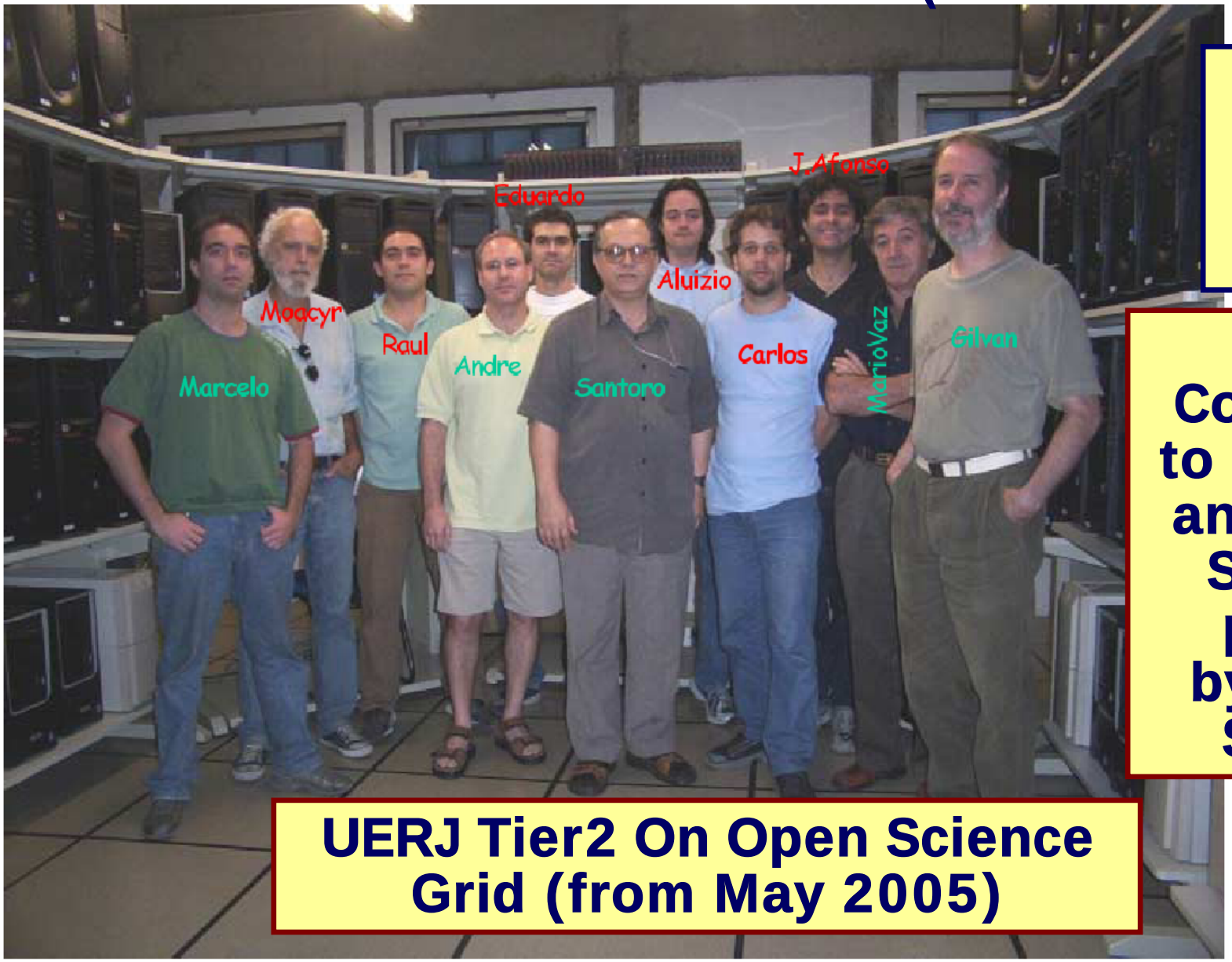
Bandwidth Challenge at SC2005





475 TB Total in < 24h; Sustained Rate of 1.1 Petabyte Per Day

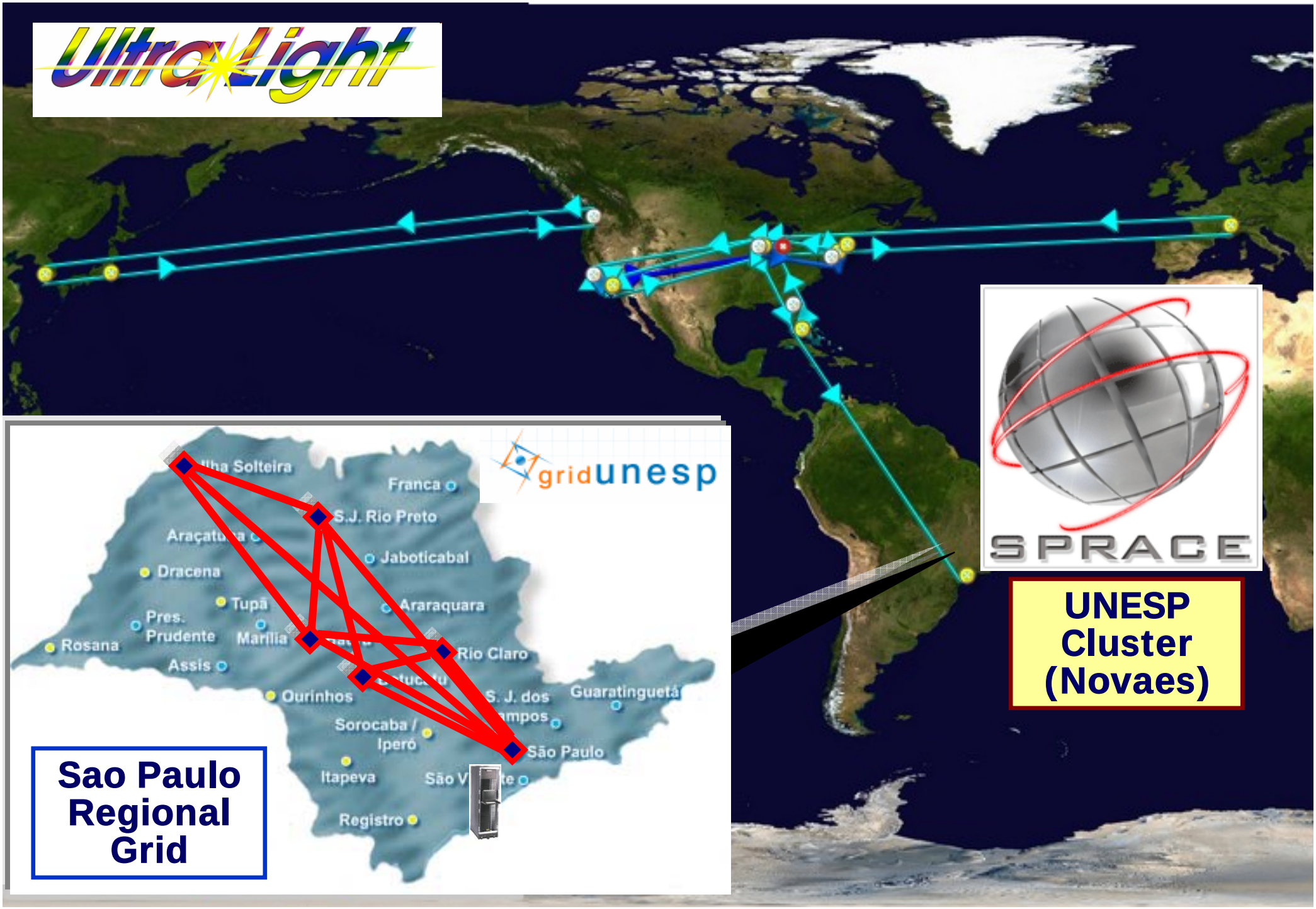
UERJ T2 HEPGRID Inauguration: Dec. 2004: The Team (Santoro et al.)



Work Locally; Think Globally

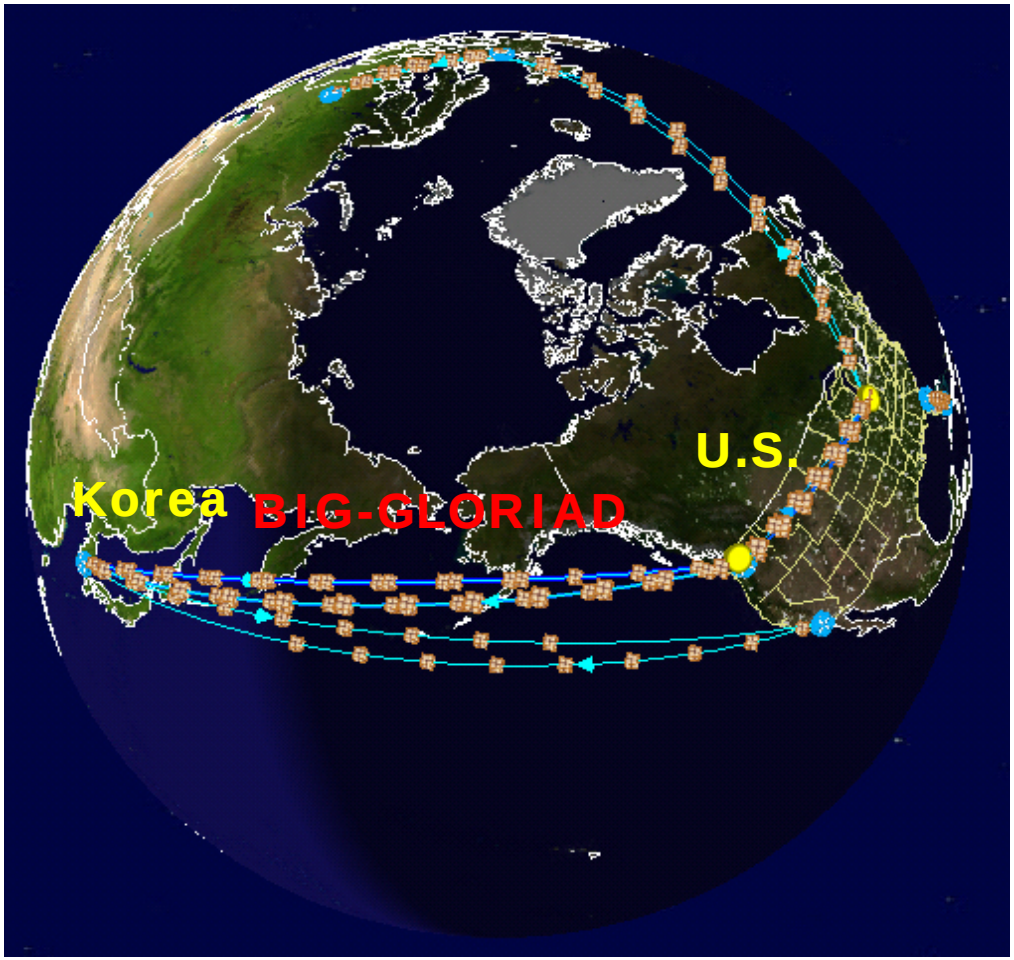
1 Gbps Connections to UERJ Tier2 and Tier3 in Sao Paulo provided by RNP (M. Stanton)

UERJ Tier2 On Open Science Grid (from May 2005)

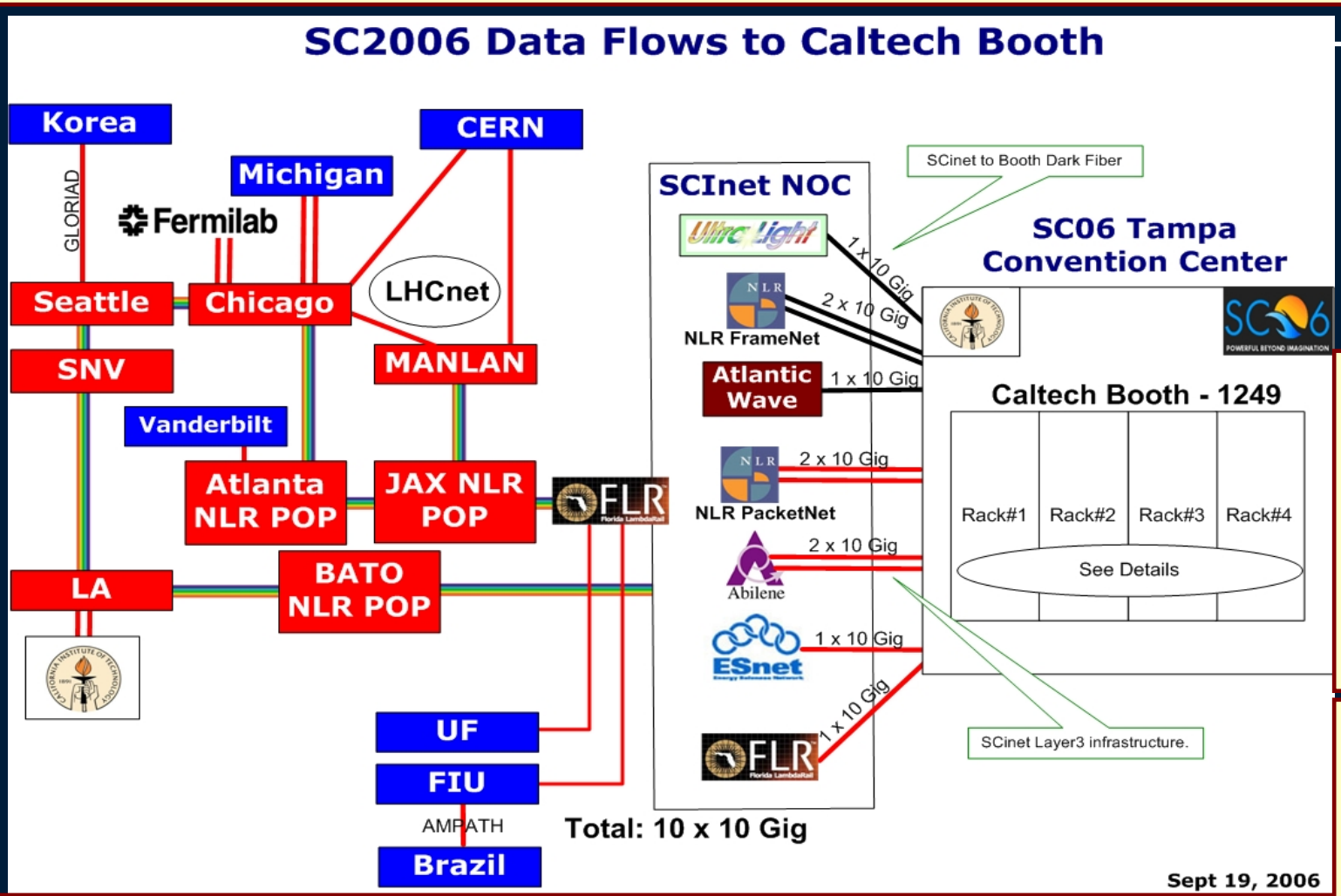

UltraLight
gridunesp
Franca
S.J. Rio Preto
Jaboticabal
Araraquara
Dracena
Tupã
Pres. Prudente
Marília
Rosana
Assis
Rio Claro
Ourinhos
S. J. dos
Guaratinguetá
Sorocaba /
Iperó
São Paulo
Itapeva
Registro
SPRACE
UNESP Cluster (Novaes)
Sao Paulo Regional Grid

Kyungpook National University (Korea) at SC05

- Uses 10Gbps GLORIAD link from Korea to US, which is called BIG-GLORIAD, also part of UltraLight
- Try to saturate this BIG-GLORIAD link with servers and cluster storages connected with 10Gbps
- Korea is planning to be a Tier-1 site for LHC experiments



Caltech and CERN at SC2006: Petascale Transfers for Physics at ~100 Gbps



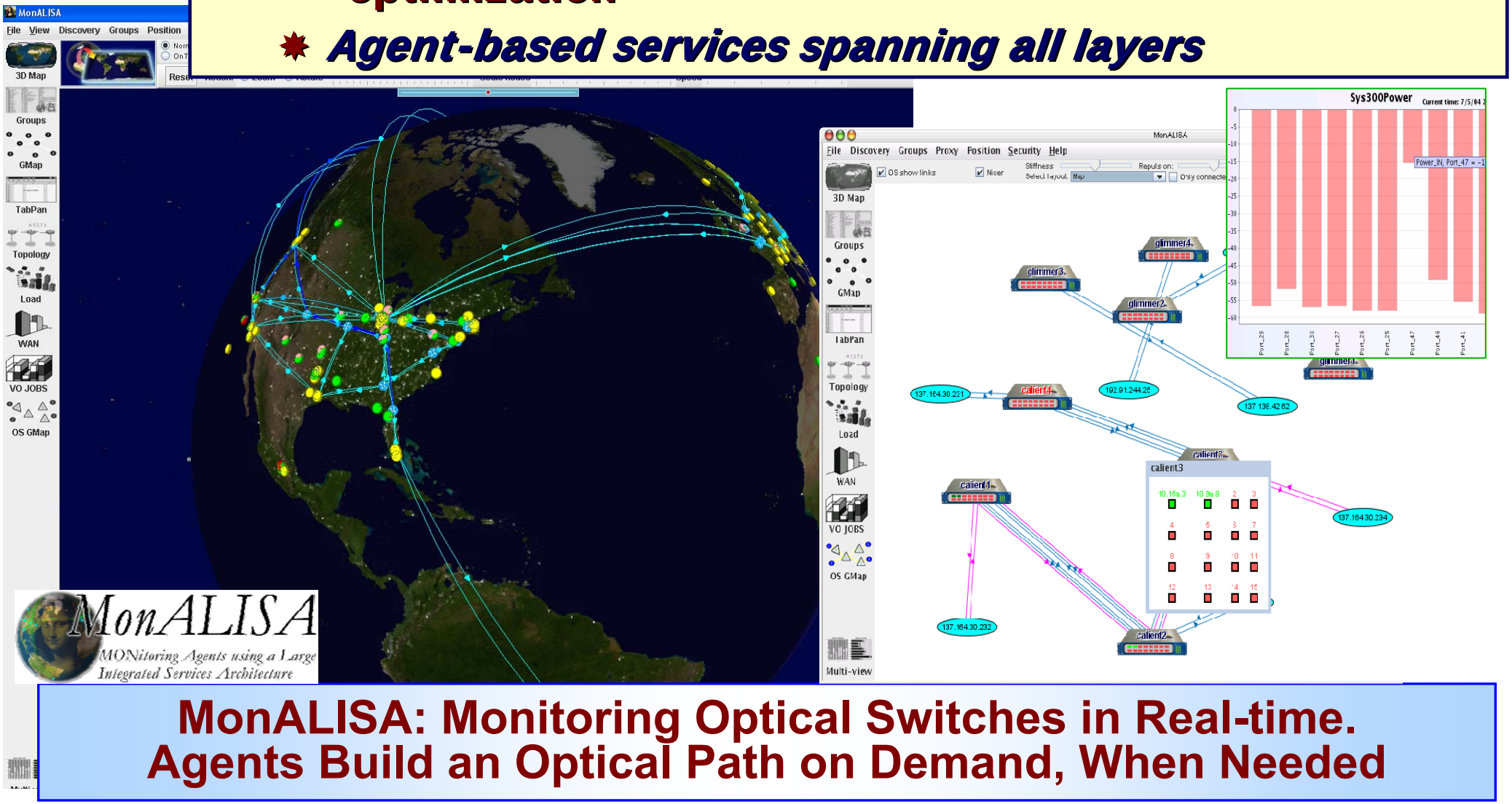
~250 CPU
~40 10G Ports
50 10G NICs
80 TB Disk

Partners:
CERN, US LHC T1/T2, ESnet
UERJ, UNESP, KNU, KISTI

Disk-to-disk: New Applications for science (FDT, LStore)

A New Network & Grid Services Paradigm

- Real-time end-to-end monitoring and tracking
- Dynamic bandwidth provisioning for workflow optimization
  - *Agent-based services spanning all layers*



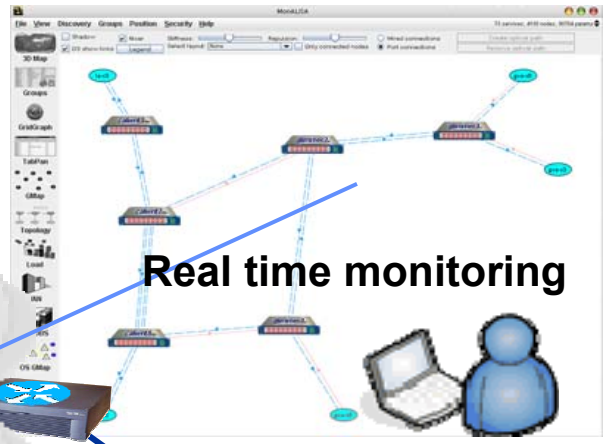
MonALISA: Monitoring Optical Switches in Real-time. Agents Build an Optical Path on Demand, When Needed

Dynamic Network Path Allocation Automated Dataset Transfer

Detects errors and automatically recreates the path in less than the TCP timeout (<1second)

```
>bbcopy  A/fileX  B/path/

OS path available
Configuring interfaces
Starting Data Transfer
```



Internet

MonALISA Distributed Service System

APPLICATION

DATA

Regular IP path

A

B

Control

Monitor

MonALISA Service

OS Agent

LISA Agent

TL1

Active light path

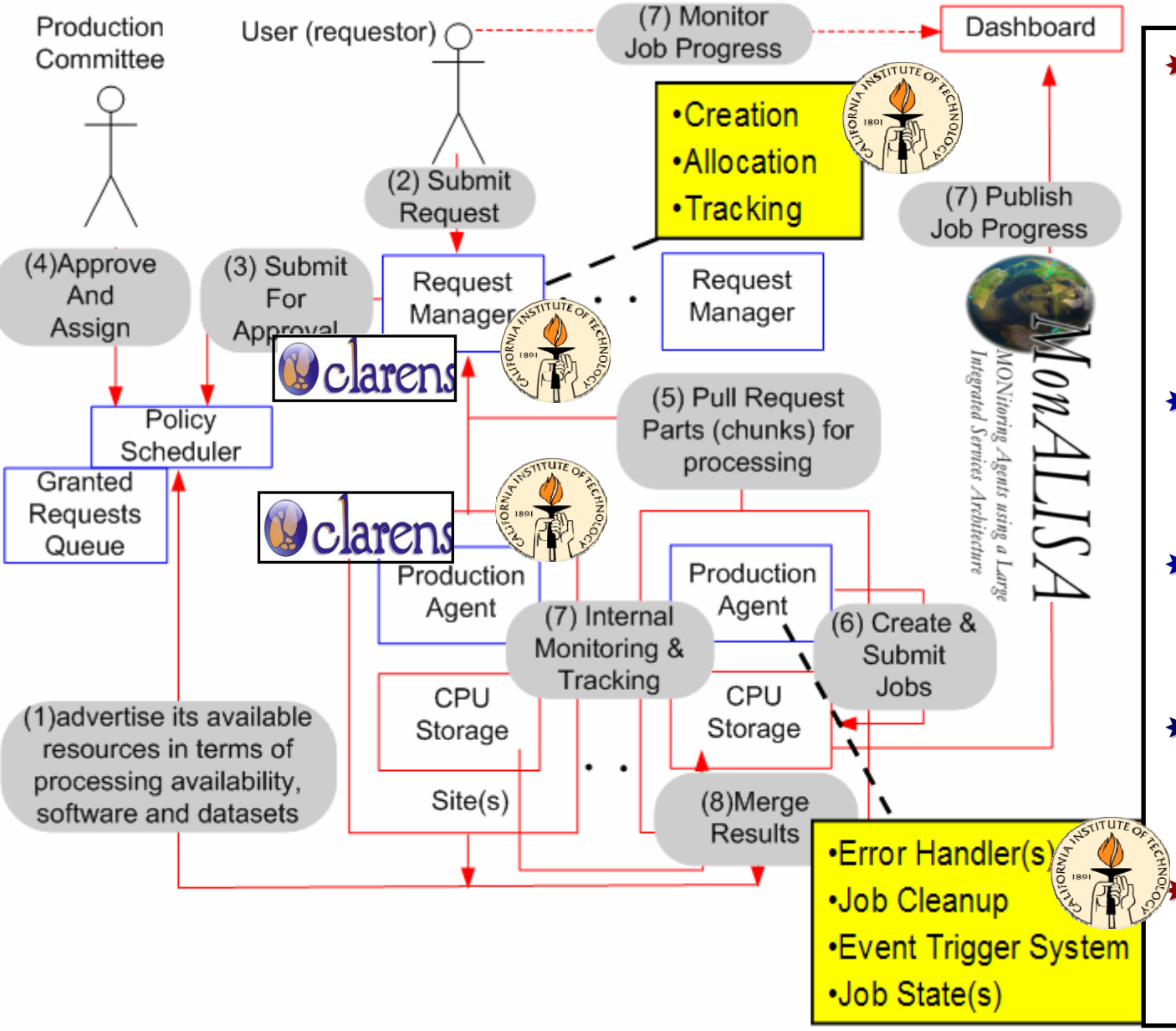
Optical Switch

LISA AGENT

LISA sets up
- Network Interfaces
- TCP stack
- Kernel parameters
- Routes

LISA → APPLICATION
"use eth1.2, …"

Production System: Integrating our Distributed Services-Architecture



- **Pluggable structures:**
  - **LCG & OSG submission**
  - **Job alloc. & request completeness policies**
- **Clarens Services for distributed component interaction**
- **MonALISA for dash-board,T2 and network monitor**
- **Multiple managers, agents: no single point of failure**
- **Emphasis on avoiding or mitigating failure modes**

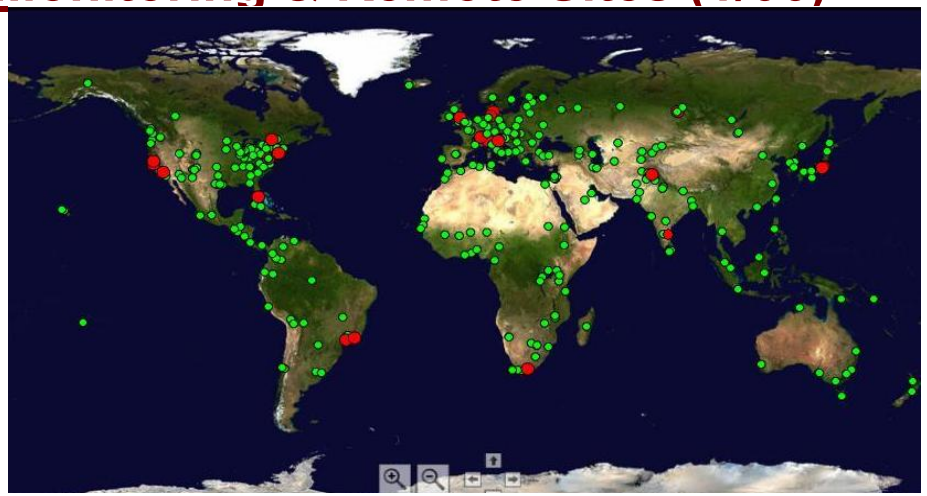
SCIC Main Conclusion for 2006

- ***As we progress we are in danger of leaving the communities in the less-favored regions of the world behind***
- ***We must Work to Close the Digital Divide***
  - ➔ ***To make physicists from all world regions full partners in the scientific discoveries***
  - ➔ ***This is essential for the health of our global collaborations, and our field***

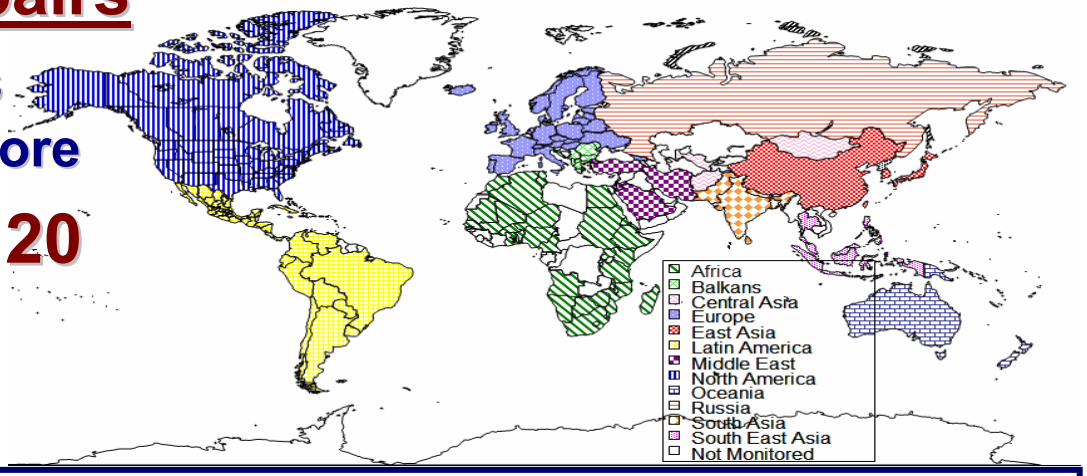
SCIC Monitoring WG
PingER (Also IEPM-BW)

R. Cottrell

Monitoring & Remote Sites (1/06)



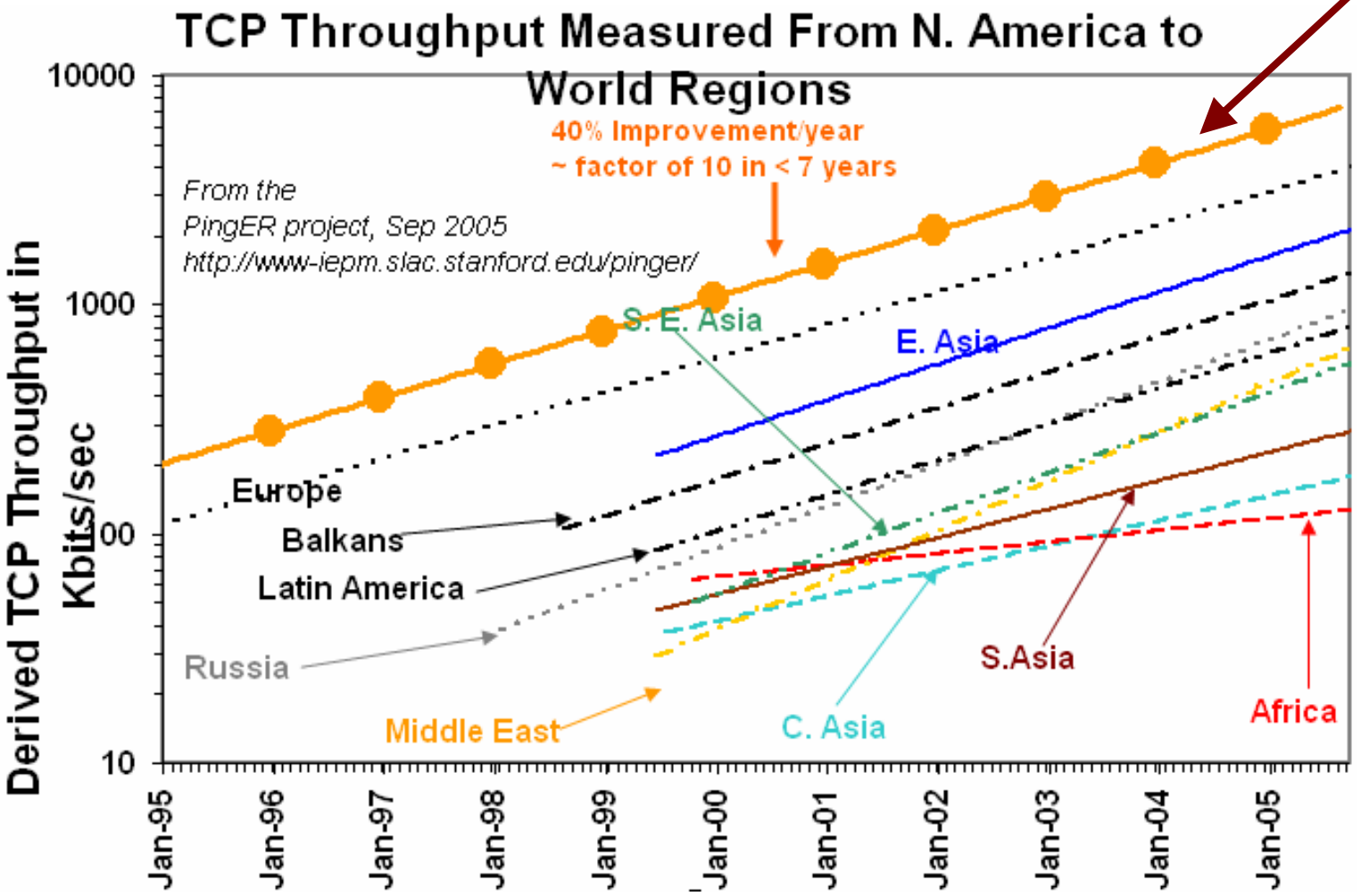
- **Measurements from 1995 On**
  - *Reports link reliability & quality*
- **Countries monitored**
  - ➔ Contain 90% of world population
  - ➔ 99% of Internet users
- **3700 monitor-remote site pairs**
  - ➔ 35 monitors in 14 countries
    Capetown,Rawalpindi, Bangalore
  - ➔ 1000+ remote sites in 120 Countries



Countries: N. America (2), Latin America (18), Europe (25), Balkans (9), Africa (31), Mid East (5), Central Asia (4), South Asia (5), East Asia (4), SE Asia (6), Russia includes Belarus & Ukraine (3), China (1) and Oceania (5)

SCIC Monitoring WG - Throughput Improvements 1995-2006

Progress: but Digital Divide is Mostly Maintained



40% annual improvement Factor ~10/7 yrs

Behind Europe

- **6 Yrs: Russia, Latin America**
- **7 Yrs: Mid-East, SE Asia**
- **10 Yrs: South Asia**
- **11 Yrs: Cent. Asia**
- **12 Yrs: Africa**

India, Central Asia, and Africa are in Danger of Falling Even Farther Behind

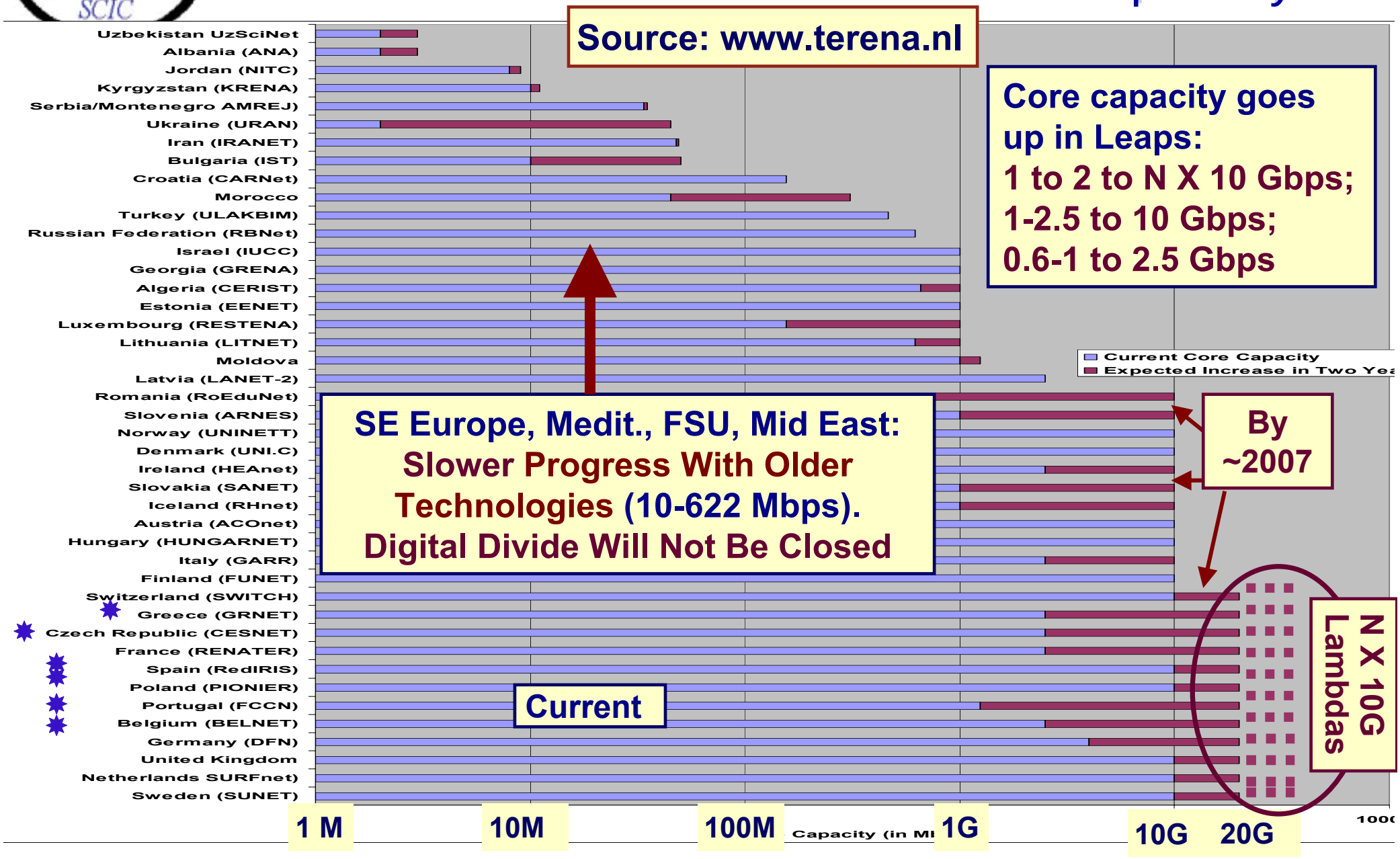
*Bandwidth of TCP < MSS/(RTT*Sqrt(Loss))*

Matthis et al., Computer Communication Review 27(3), July 1997

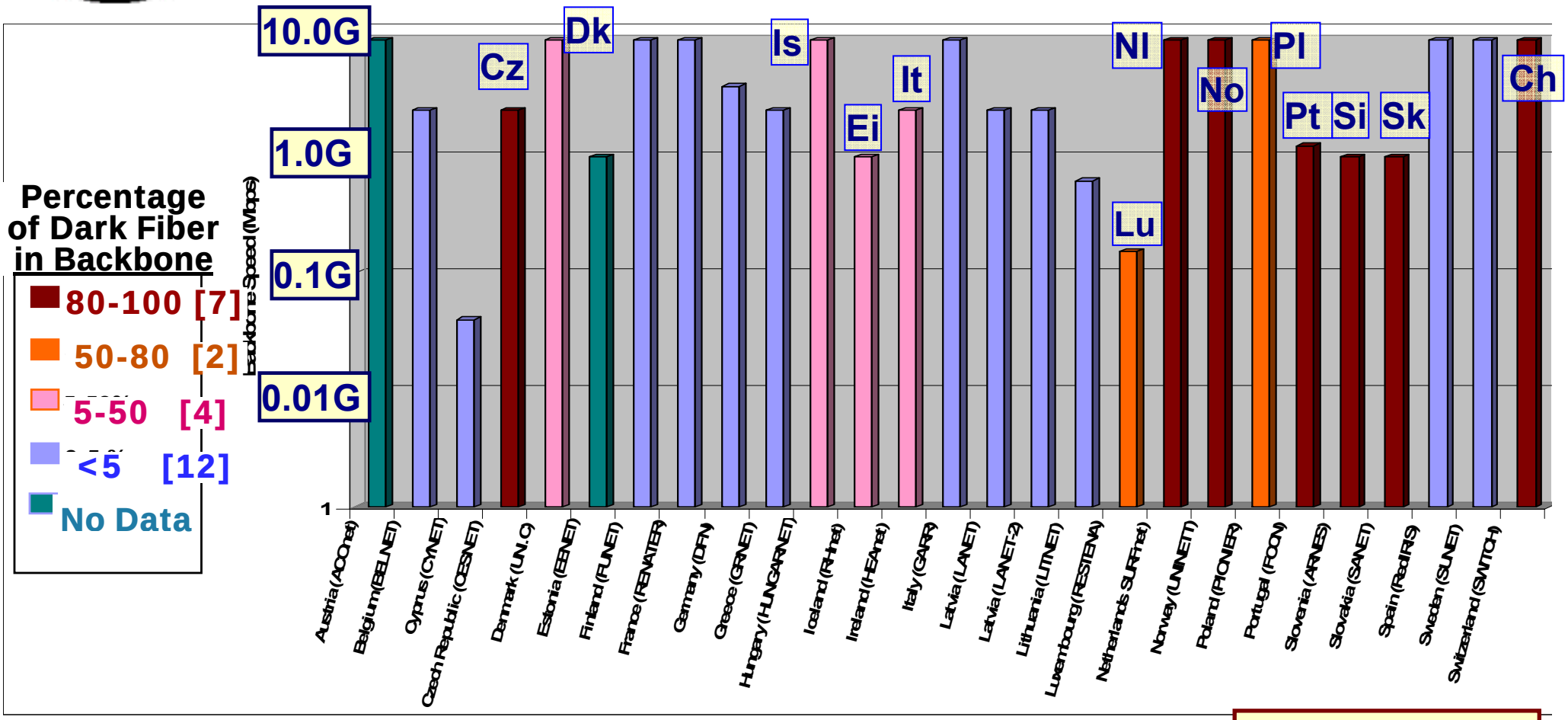
Work on the Digital Divide from Several Perspectives

- Share Information: *Monitoring, BW Progress*; Dark Fiber Projects & Pricing
  - Model Cases: Poland, Slovakia, Brazil, Czech Rep., China …
  - Encourage Access to Dark Fiber
- Encourage, and Work on Inter-Regional Projects
  - GLORIAD, Russia-China-Korea-US-Europe Optical Ring
  - Latin America: CHEPREO/WHREN (US-Brazil); RedCLARA
  - Mediterranean: EUMEDConnect; Asia-Pacific: TEIN2
  - India Link to US, Japan and Europe
- Technical Help with Modernizing the Infrastructure:
  - Provide Tools for Effective Use: Data Transport, Monitoring, Collaboration
  - Design, Commissioning, Development
- Raise Awareness: Locally, Regionally & Globally
  - Digital Divide Workshops
  - Diplomatic Events: WSIS, RSIS, Bilateral: e.g. US-India

Digital Divide Illustrated by Network Infrastructures: TERENA Core Capacity



Highest Bandwidth Link in European NREN's Infrastructure; The Trend to Dark Fiber



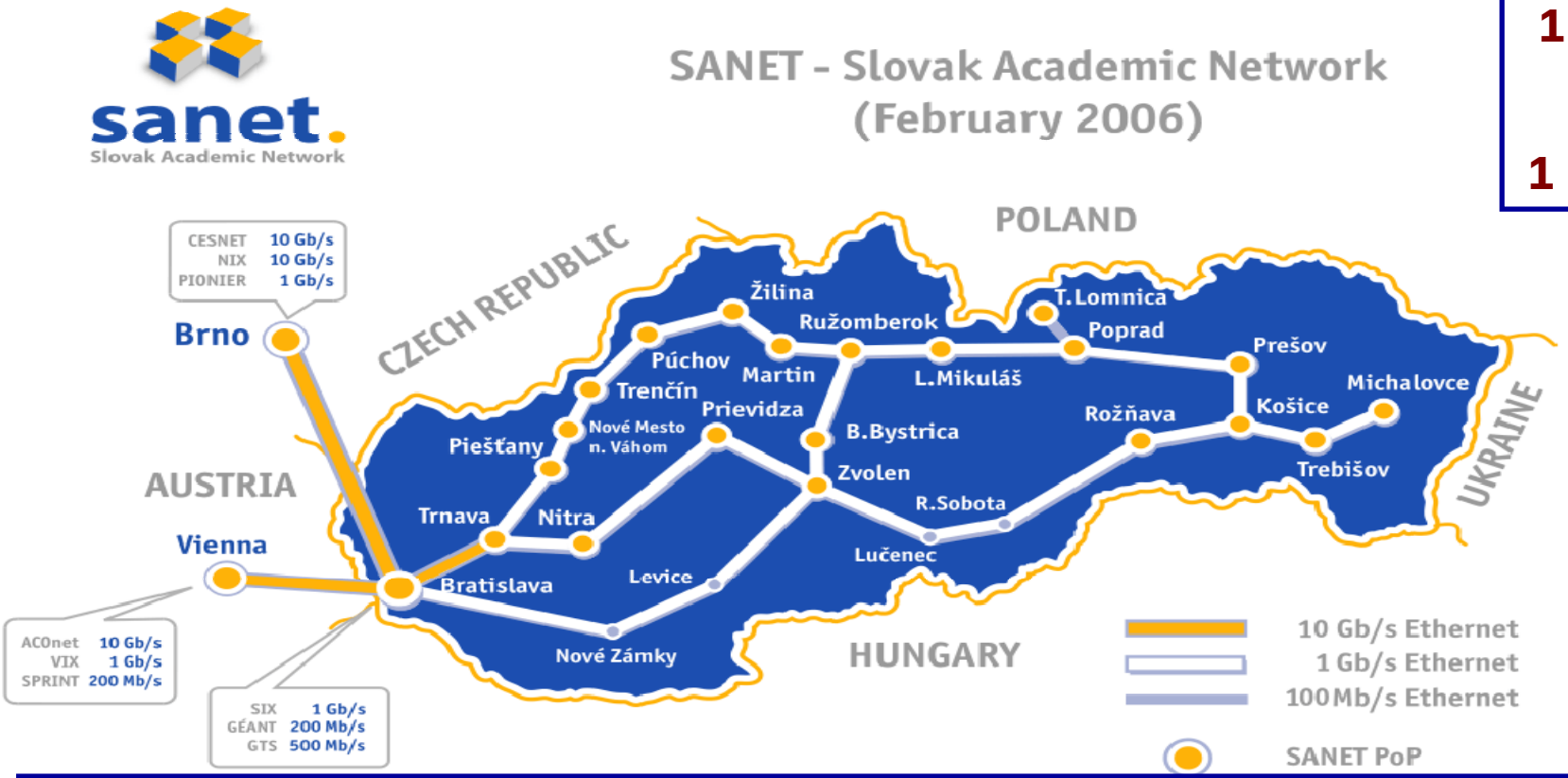
NRENs with dark fiber can deploy light paths, to support separate communities &/or large pplications. Up to 100X gain in some cases, at moderate cost

Source: TERENA

www.terena.nl

SLOVAK Academic Network
February 2006: All Switched Ethernet

120km CBDF
Cost 4 k€
Per Month
1 GE 2/16/05

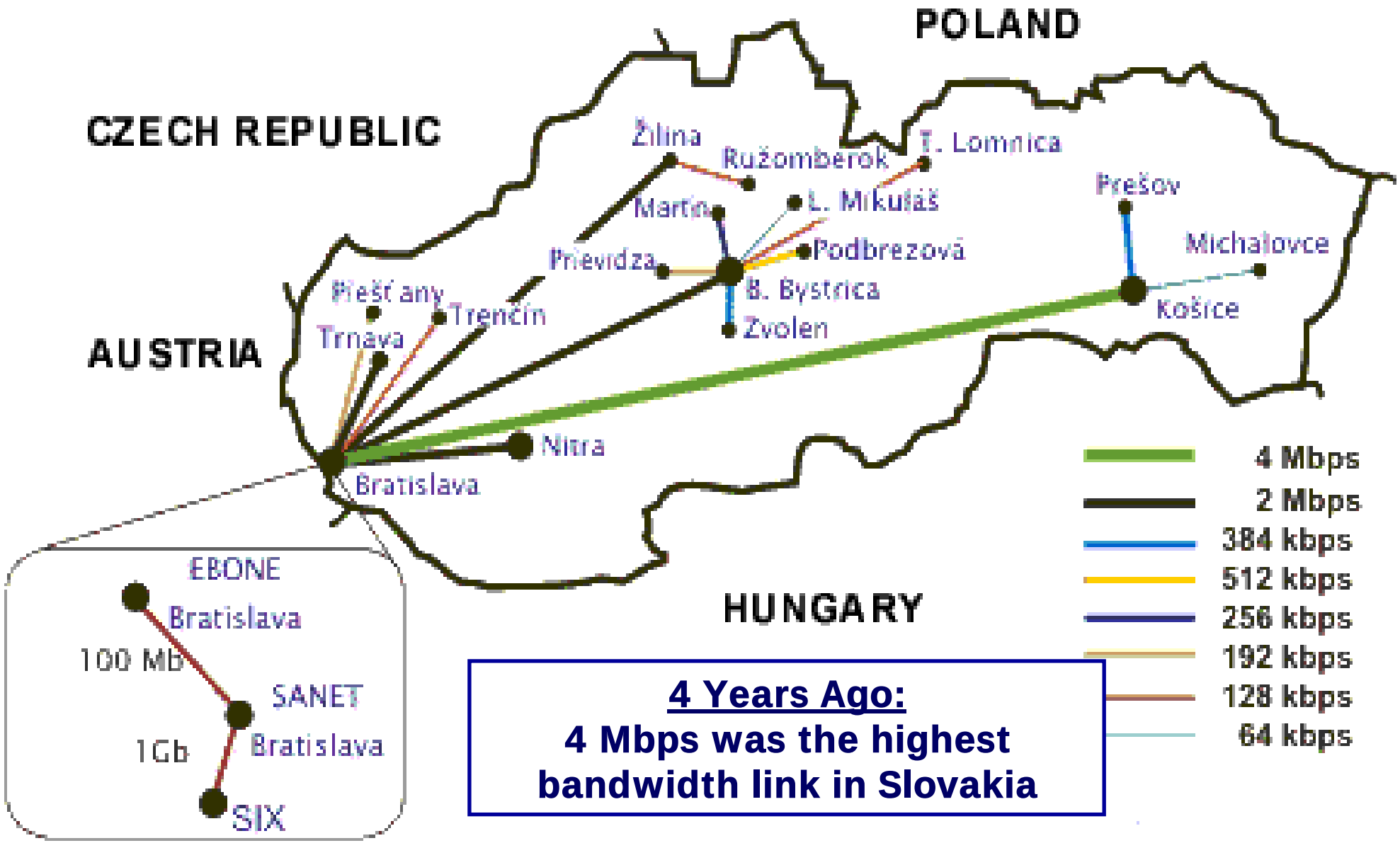


T. Weis

- 1660 km of Dark Fiber CWDM Links, 1 to 4 Gbps (GbE)
- August 2002: Dark Fiber Link, to Austria
- April 2003: Dark Fiber Link to Czech Republic
- 2004: Dark Fiber Link to Poland
- Planning 10 GbE Backbone; Dark Fiber to Austria and Czech Republic, and Regional and Metro Nets

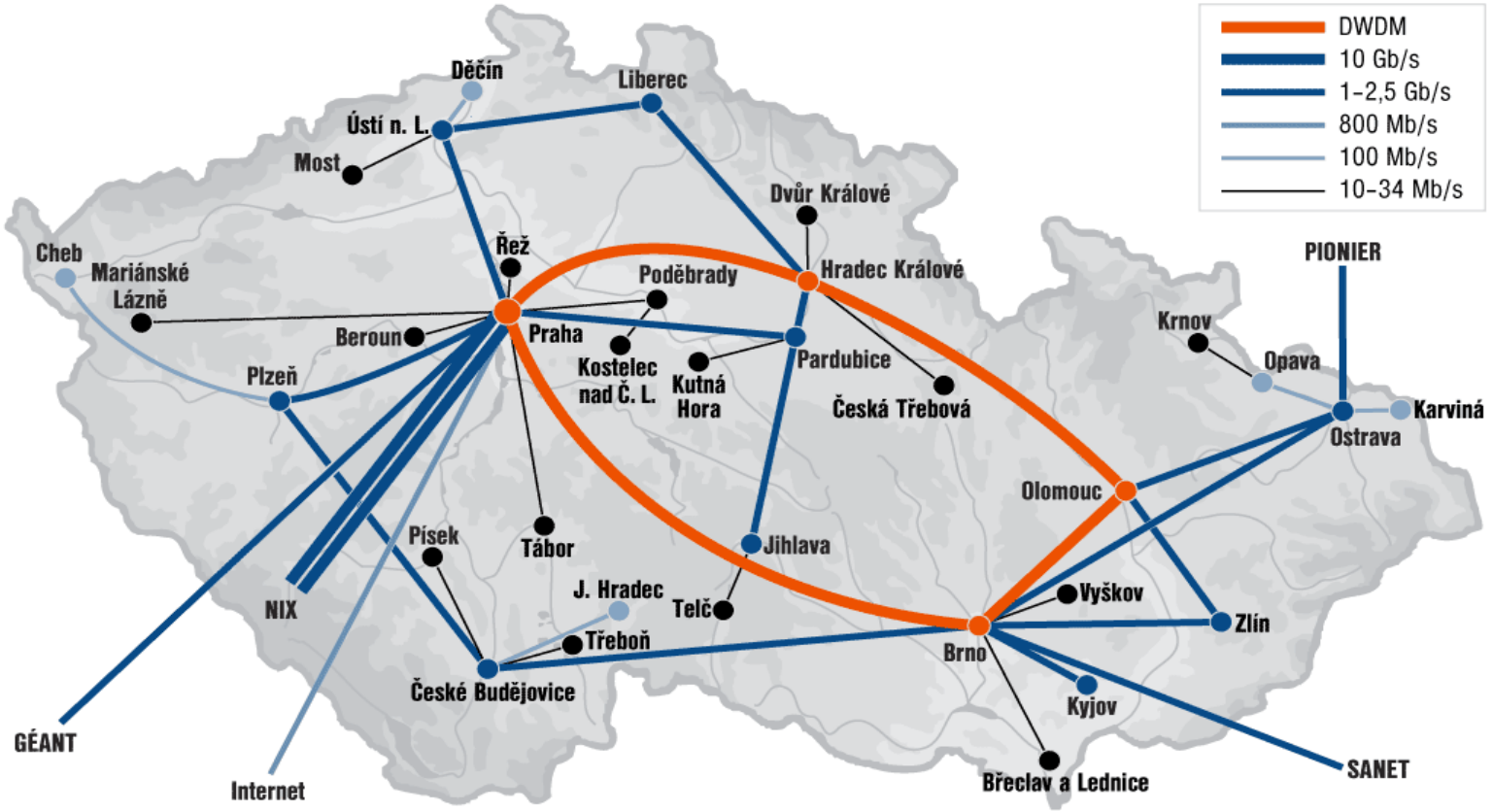
2500x: 2002-2006

SANET - Slovak Akademic Data Network
(January 2002)



4 Years Ago:
4 Mbps was the highest bandwidth link in Slovakia

Czech Republic: CESNET2



2500 km Leased Dark Fibers (since 1999)

1 GbE Light-Paths in CzechLight;

1 GbE to Slovakia;

1 GbE to Poland

2005-6: 32 Wavelength Software-Configurable DWDM Ring + More 10GE Connections Installed

Poland: *PIONIER* 20G + 10G Cross Border Dark Fiber Network (Q4 2006)

6000 km of Owned Fiber;
Multi-Lambda Core

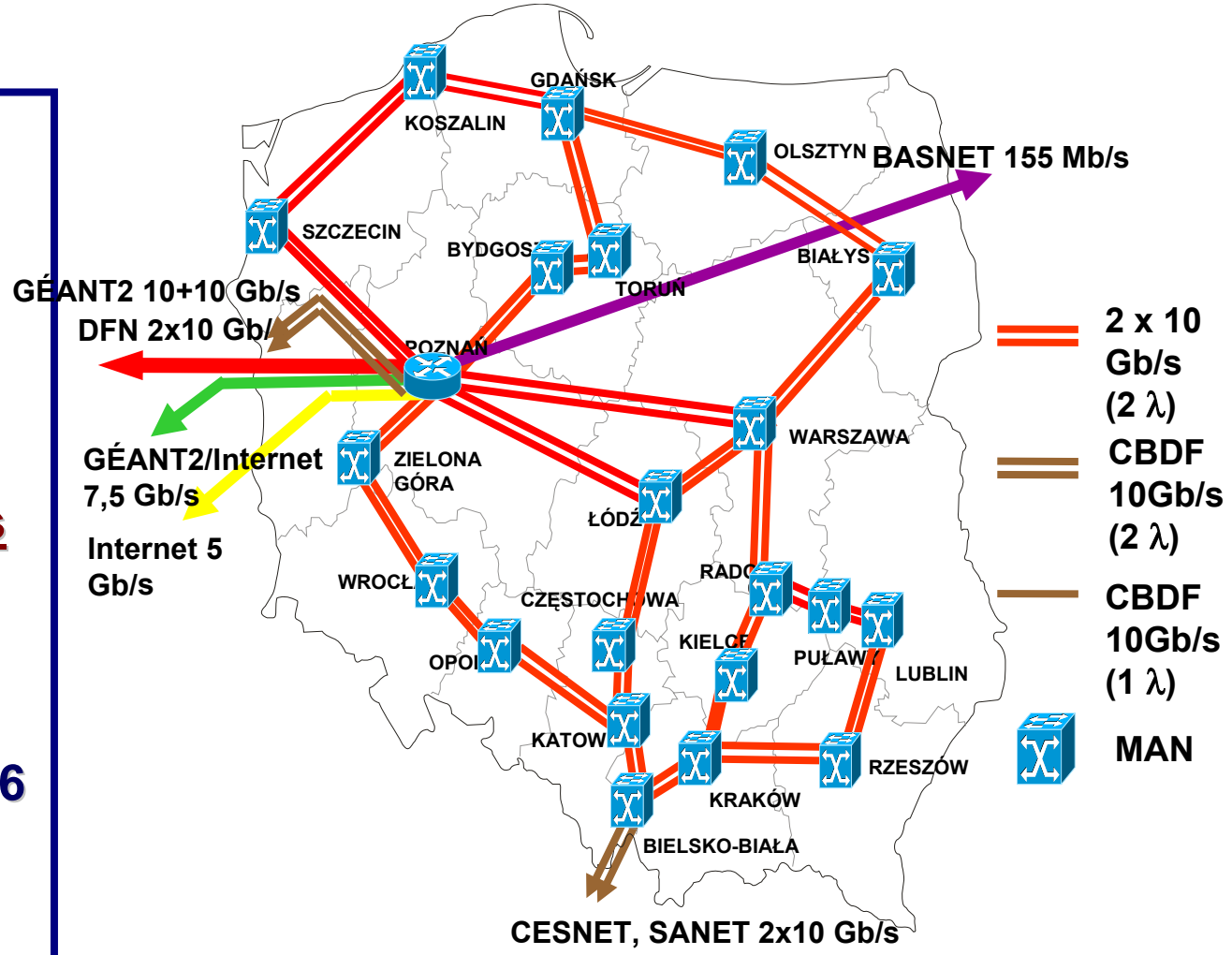
21 Academic MANs
5 HPCCs

➡ **Moving to 20G on all major links**

Cross Border Dark Fibers

- **20G to Germany**
- **10G Each to Cz, Sk**
- **Move to Connect All Neighbors at 10G in 2006**

20G to GEANT;
10G to Internet2



- **Supports Grids, Digital Libraries, Interactive TV**
- **e-Regional Initiatives**

PIONIER (Poland) Cross Border Dark Fiber Plan Locations

64X Backbone Improvement 2002-5

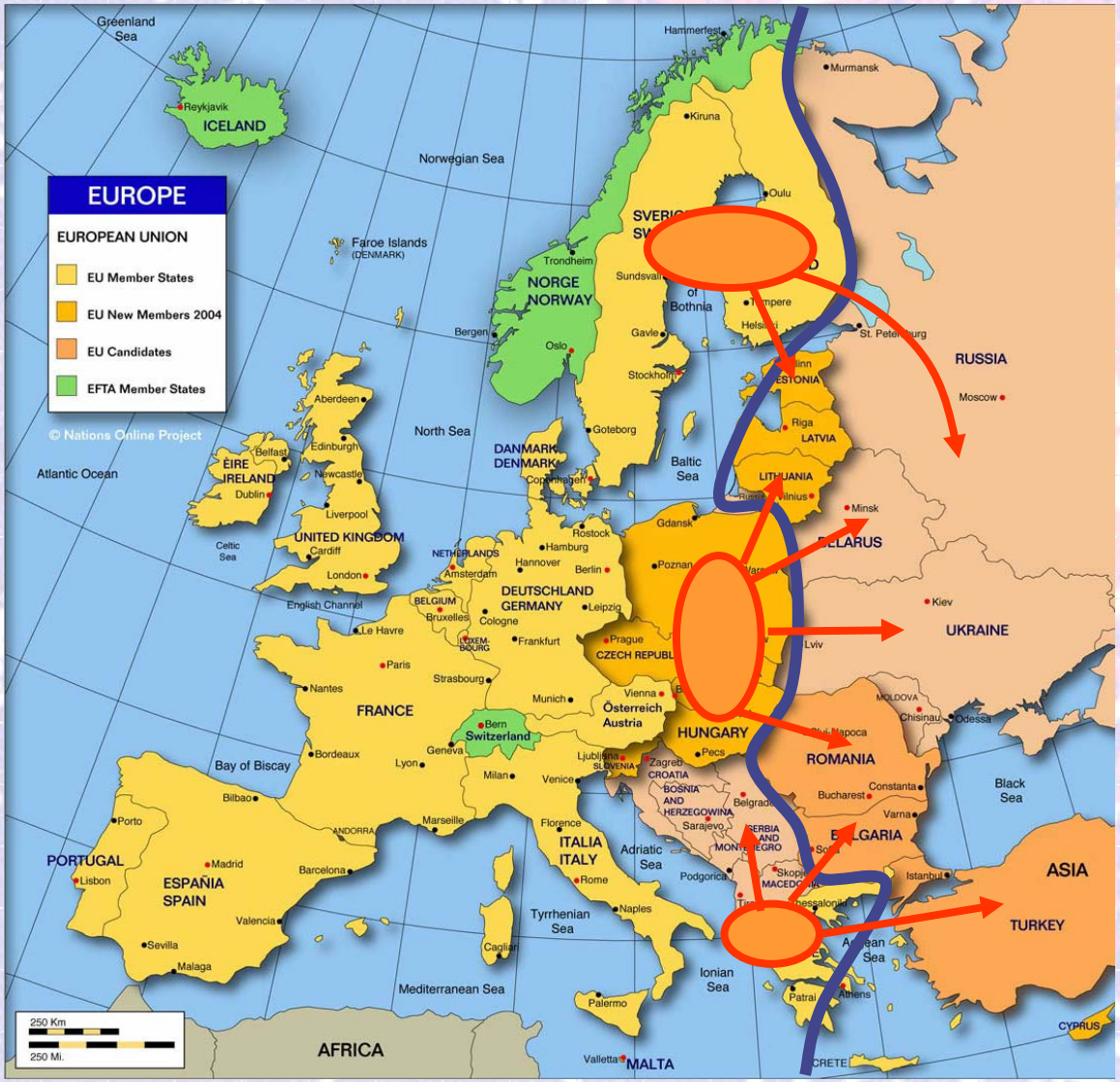
Single GEANT PoP in Poznan

Key Enabler of Networking in Czech Rep., Slovakia, & the Ukraine

Digital Divide Workshop DDW06

M. Turala

„Porta Optica – a coordinated task to Heal the Digital Divide to the East ...



- CE countries – CBDF links to East Europe neighbours:
  - Poland: DF connectivity to every eastern neighbour
  - Scandinavia: the northern route
  - GRNET: activity in the Balkan region (SEEREN/ SEEFIRE) + the south route
- GEANT/TERENA: political & organisational support
- all: influencing the EE countries wrt. DF acqusition, importance of DF infrastructure & business models

M. Turala

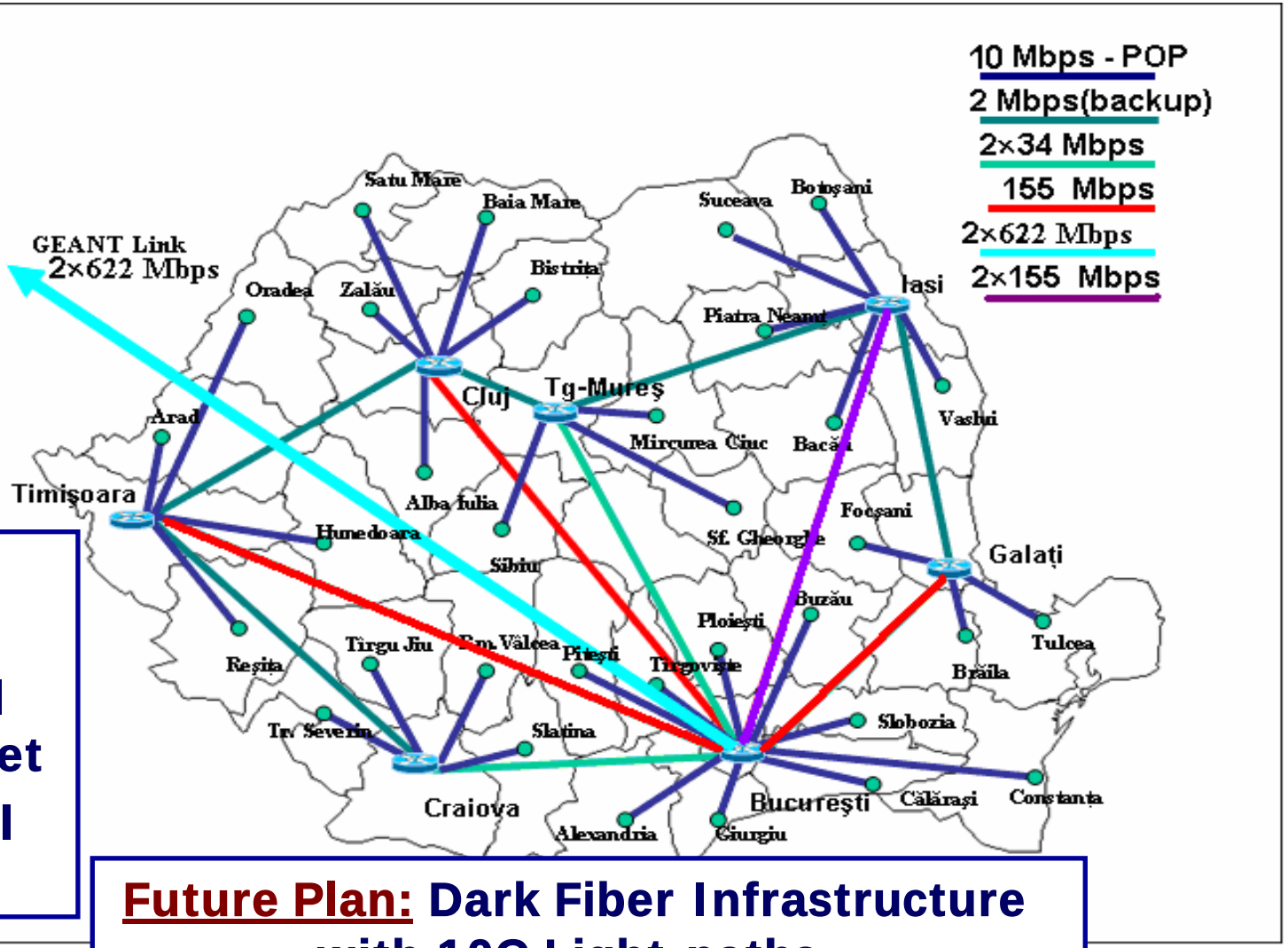
Romania: RoEduNet Topology

Connects 610 Institutions to GEANT:

- 38 Universities
- 32 Research Institutes
- 500 Colleges & High Schools
- 40 Others

RoGrid Plans for 2006

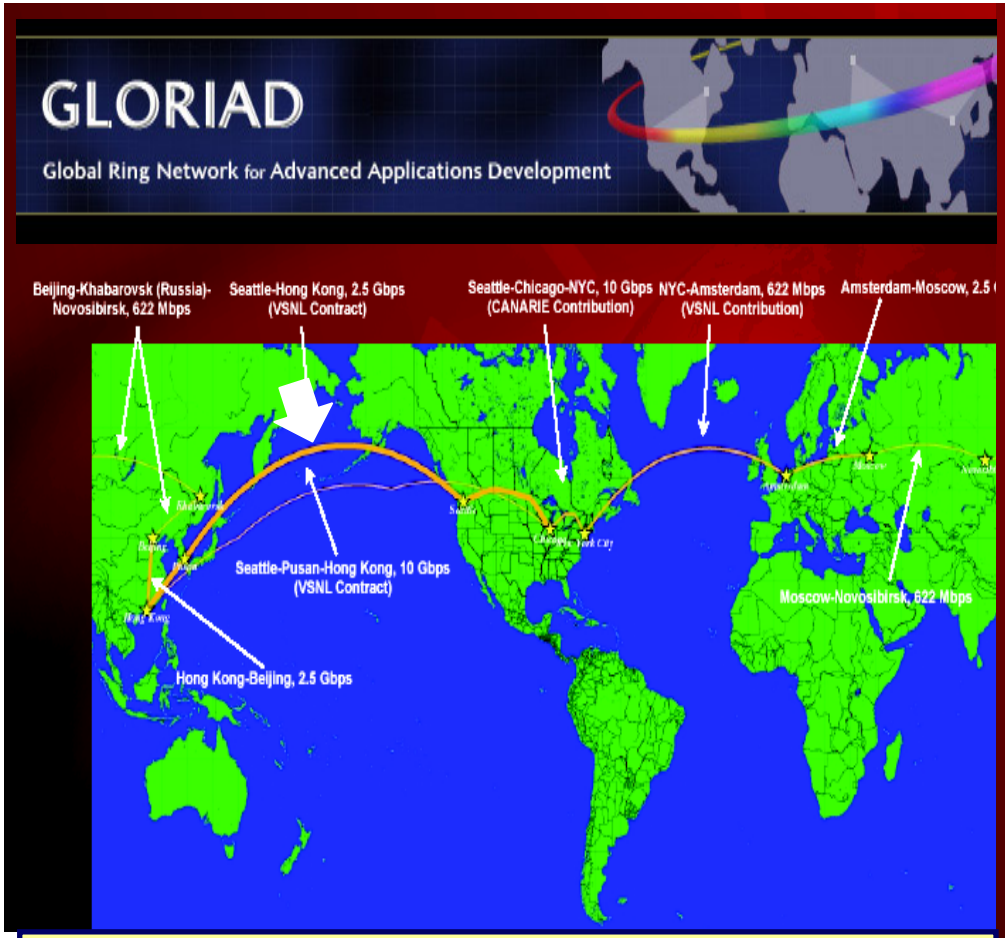
- 10G Experimental Link UPB-RoEdunet
- Upgrade 3-4 Local Centers to 2.5G



Future Plan: Dark Fiber Infrastructure with 10G Light-paths (help from Caltech and CERN)

N. Tapus

GLORIAD: 10 Gbps Optical Ring Around the Globe by 2007



China, Russia, Korea, Japan, US, Netherlands Partnership

US: NSF IRNC Program

GLORIAD Circuits

- 10 Gbps Korea (Busan)-Hong Kong-Daejon-Seattle
- 10 Gbps Seattle-Chicago-NYC (CANARIE contribution to GLORIAD)
- 2.5 Gbps Moscow-AMS
- 2.5 Gbps Beijing-Hong Kong
- 622 Mbps Moscow-AMS-NYC
- 155 Mbps Beijing-Khabarovsk-Moscow
- 1 GbE NYC-Chicago (CANARIE)

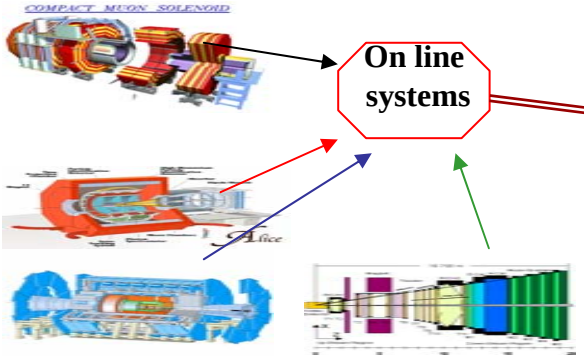
G. Cole

SCIC Digital Divide Workshops and Panels

- ***2002-2005:***
  An effective way to raise awareness of the problems, and discuss approaches and opportunities for solutions with national and regional communities, and gov't officials
  - ***ICFA Digital Divide Workshops: Rio 2/2004; Daegu 5/2005***
  - ***CERN & Internet2 Workshops on R&E Networks in Africa***
- ***February 2006***
  - ***CHEP06 Mumbai: Digital Divide Panel & Workshop [SCIC, TIFR, CDAC, Internet2, Caltech] "Moving India into the Global Community Through Advanced Networking"***
- ***October 9-15 2006:***
  - ***ICFA Digital Divide Workshops in Cracow & Sinaia***
- ***April 14-17 2007: APS Meeting in Jacksonville, FL***
  APS Forum for International Physics Digital Divide Session

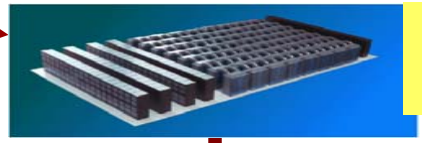
Science-Driven: HEPGRID (CMS) in Brazil

HEPGRID-CMS/BRAZIL is a project to build a Grid that
- **At Regional Level will include CBPF,UFRJ,UFRGS,UFBA, UERJ & UNESP**
- **At Int'l Level will be integrated with CMS Grid based at CERN, FNAL; focal points include OSG, LCG and bilateral projects with Caltech Group**



On line systems

Brazilian HEPGRID



T0 +T1

CERN

ICFA DD Workshop 2/04; T2 Inauguration + GIGA/RNP Agree 12/04

2.5 to 10Gbps:No Longer a Dream

T1

France | Germany | Italy | BRAZIL | USA

622 Mbps

UNESP/USP SPRACE-Working

UERJ Regional Tier2 Ctr

T2 ➔T1

T3 ➔T2

UFRGS

Gigabit

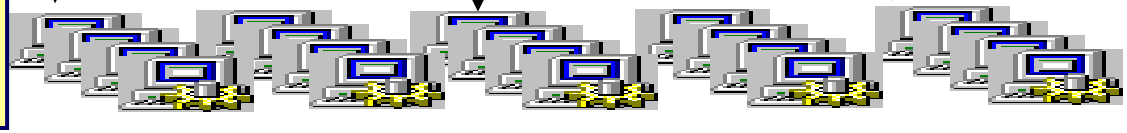
UERJ

CBPF

UFBA

UFRJ

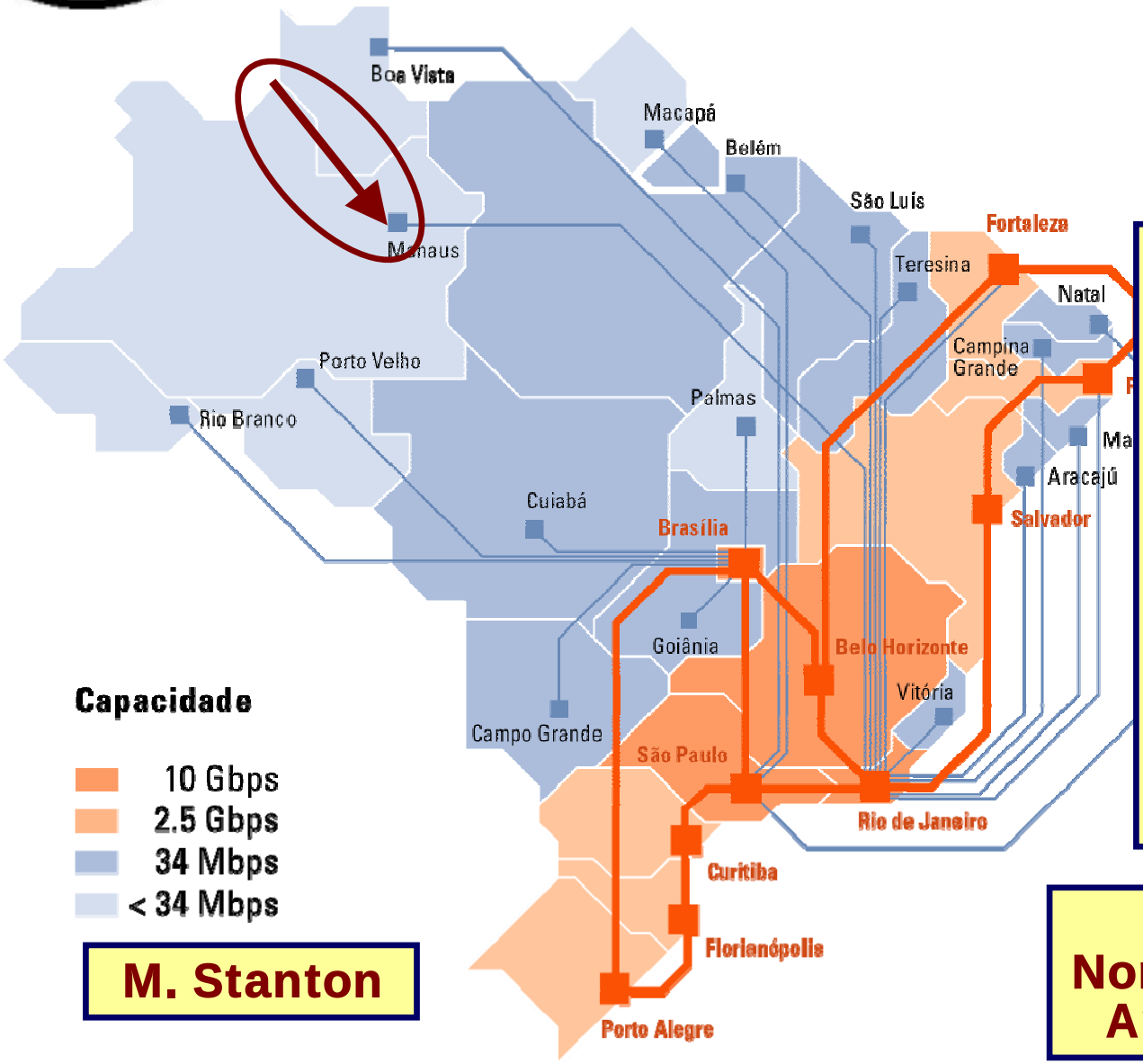
T4



UERJ: T2➔T1, 100➔500 Nodes; Plus T2s to 100 Nodes

Extend to Colombia

Brazil: RNP2 Next-Generation Backbone



M. Stanton

New vs. Old
A factor of 70 to 300 in Bandwidth

2006:

- **Buildout of dark fiber nets in 27 cities with RNP PoPs underway**
- **200 Institutions Connected at 1 GbE in 2006-7**
- **2.5G (to 10G) WHREN (NSF/RNP) Link to US; 622M Link to GEANT**

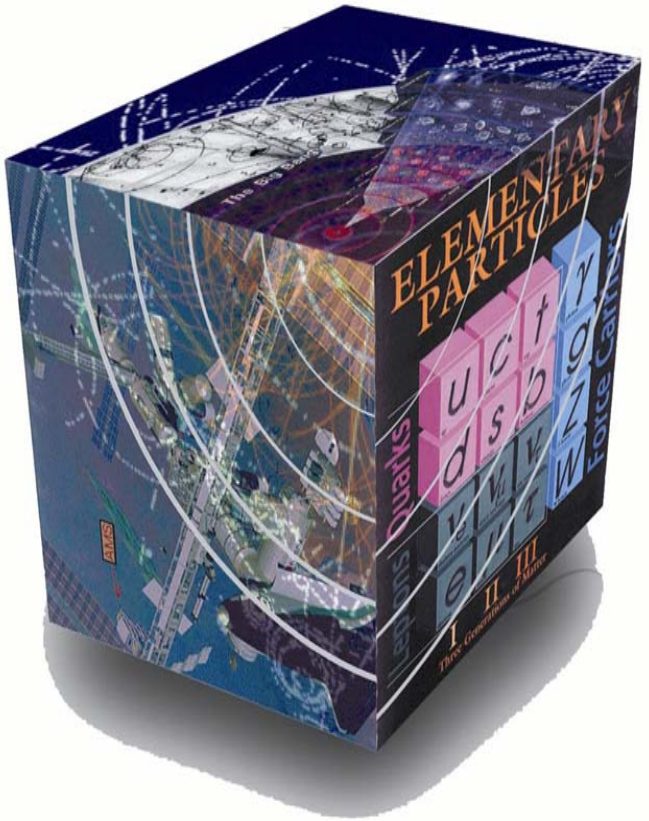
Plan: Extend to the Northwest; Dark fiber across Amazon jungle to Manaus

International ICFA Workshop on HEP Networking, Grids, and Digital Divide Issues for Global e-Science

http://chep.knu.ac.kr/HEPDG2005

Workshop Missions

- Review the status and outlook, and focus on issues in data-intensive Grid computing, inter-regional connectivity and Grid enabled analysis for high energy physics
- Relate these to the key problem of
  the Digital Divide
- Promote awareness of these issues in various regions, focusing on the Asia Pacific, Latin America, Russia, and Africa
- Develop approaches to eliminate the Divide and
- Help ensure that the basic requirements for global collaboration are met, related to all of these aspects



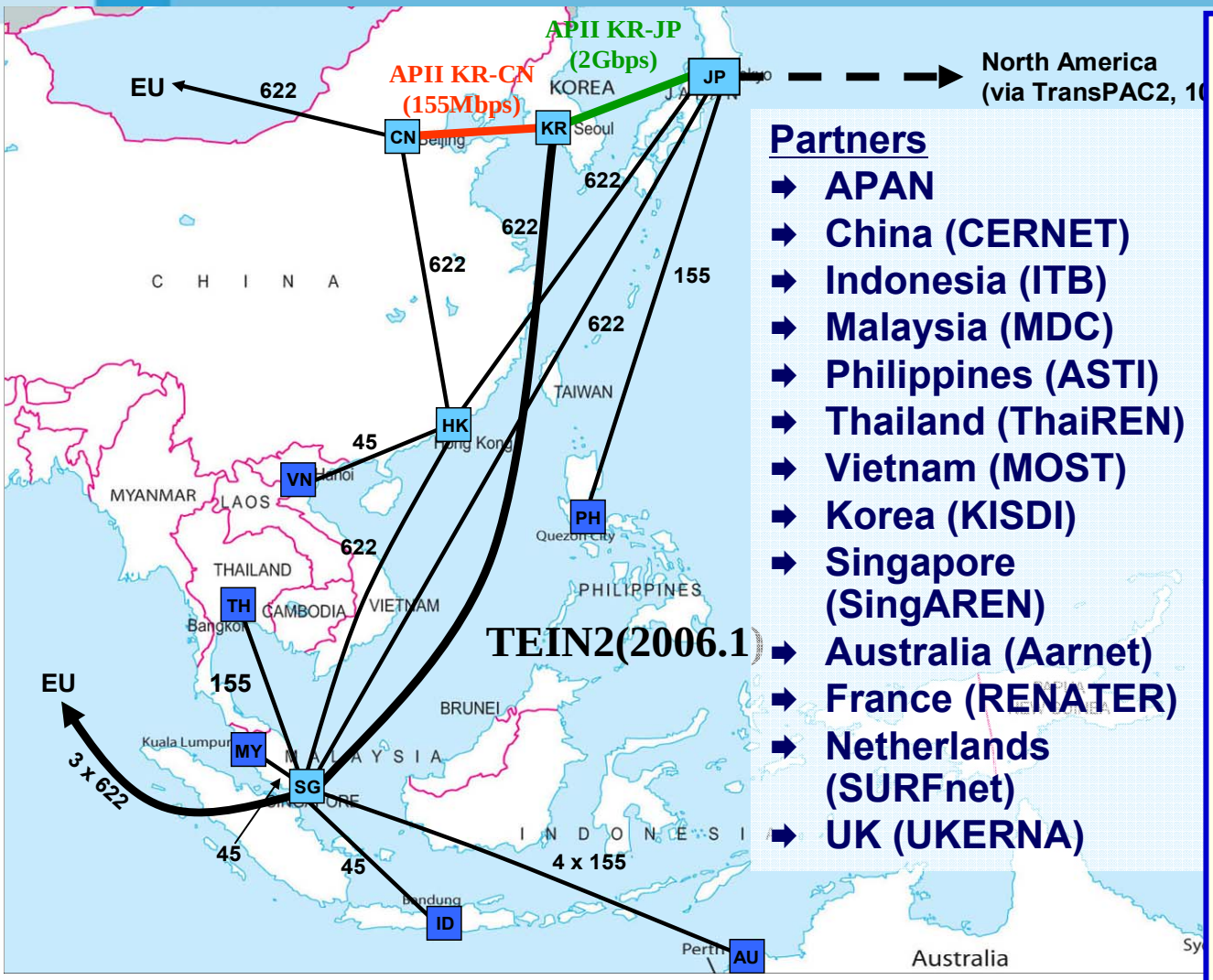
CHINA: CERNET Map January 2006

- Backbone raised to multiples of 10 Gbps
- Regional bandwidth to multiples of 2.5 Gbps
- 2.5 Gbps GLORIAD Link
- Setting up 622 Mbps or 2.5G link to GEANT2 in the CNGI (China Next Generation Internet) Project

From 6 to 78M Internet Users in China from January – July 2004; 111M Users in January 2006

http://www.cnnic.net.cn/en/index/0O/02/index.htm

TEIN2 (EU and Partner NRENs and Agencies): Improving Connectivity in the Asia-Pacific Region [*]



Partners

- APAN
- China (CERNET)
- Indonesia (ITB)
- Malaysia (MDC)
- Philippines (ASTI)
- Thailand (ThaiREN)
- Vietnam (MOST)
- Korea (KISDI)
- Singapore (SingAREN)
- Australia (Aarnet)
- France (RENATER)
- Netherlands (SURFnet)
- UK (UKERNA)

622 Mbps Core
Tokyo, Hong Kong, Singapore
+2G Korea-China Spurs

622M: China, Korea
4 X 155M: Australia
155M: Thailand
Philippines
Taiwan
45M: Vietnam
Malaysia
Indonesia

10G to US (TransPAC)

4 X 622 Mbps to GEANT

[*] Before TEIN2 many North-South links were 0.5 -2 Mbps

New Focus on AFRICA

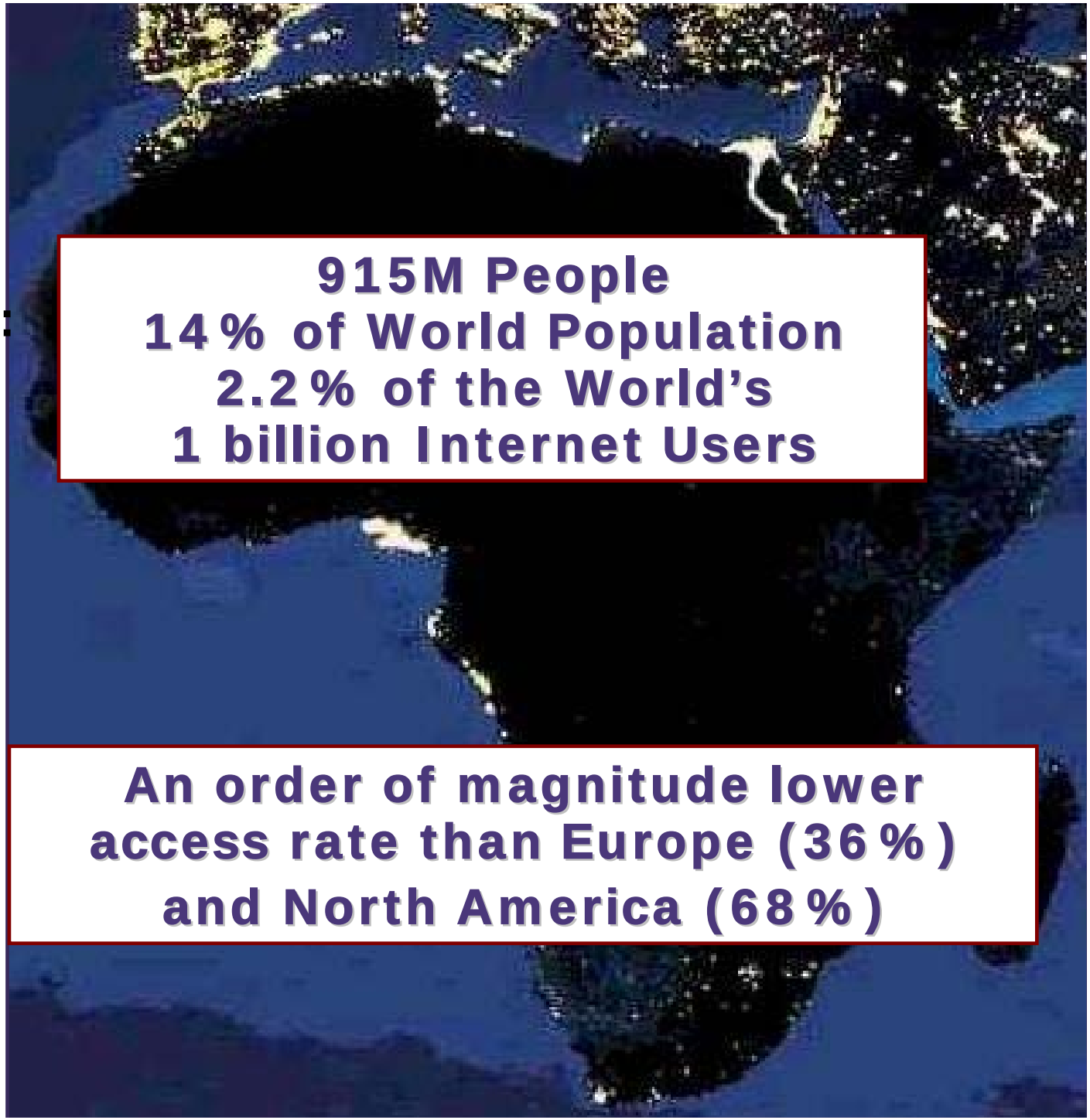
Only world region genuinely in decline:

Lack of energy, infrastructure.
Lack of expertise

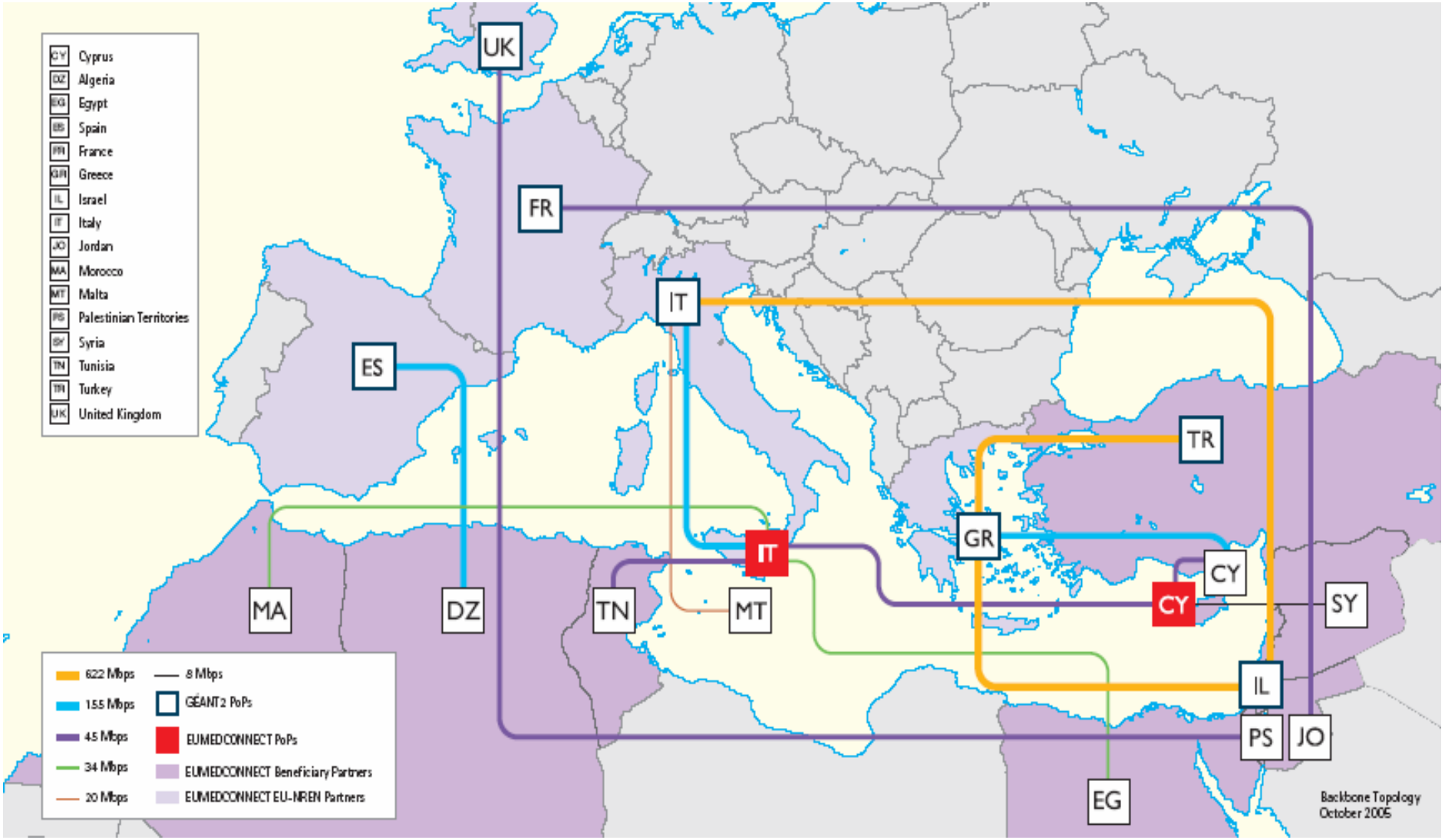
Problems of

- ➡ Disease
- ➡ Political unrest
- ➡ Protectionist trade policies
- ➡ Corruption

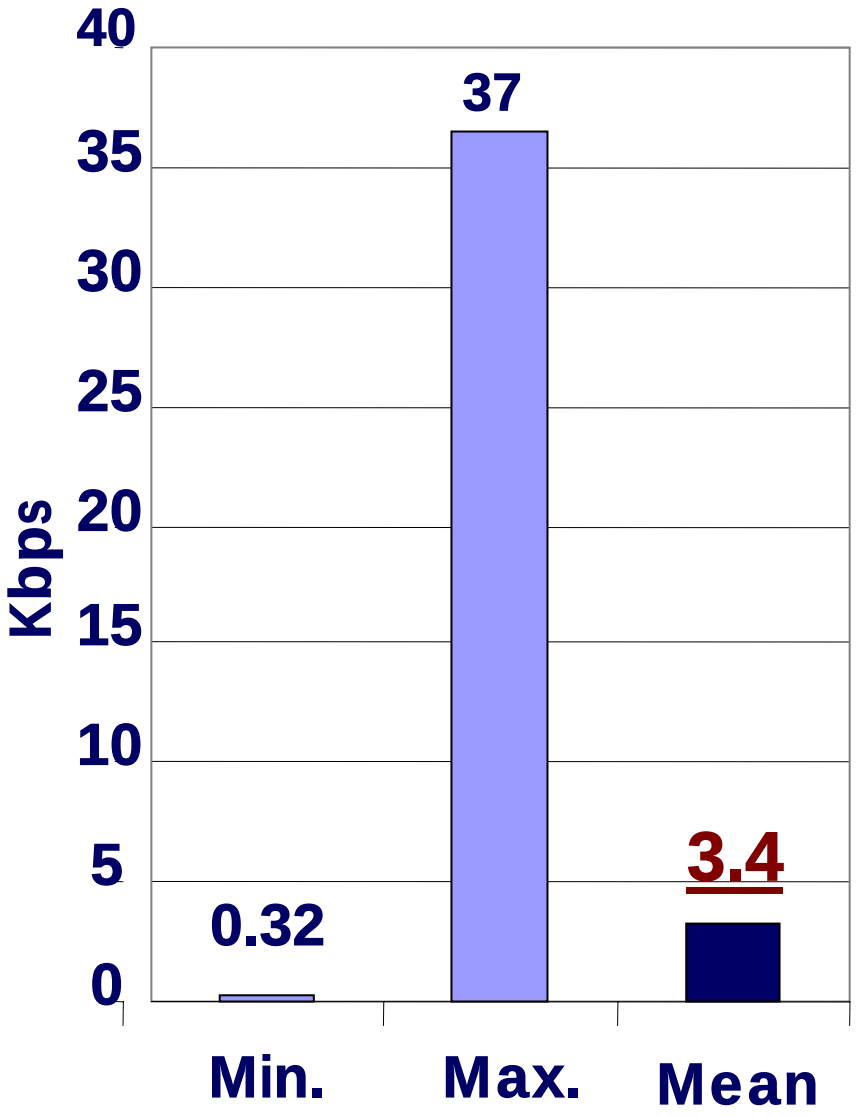
M. Jensen



EUMEDConnect: *First Mediterranean Regional IP Network, Connected to GEANT*

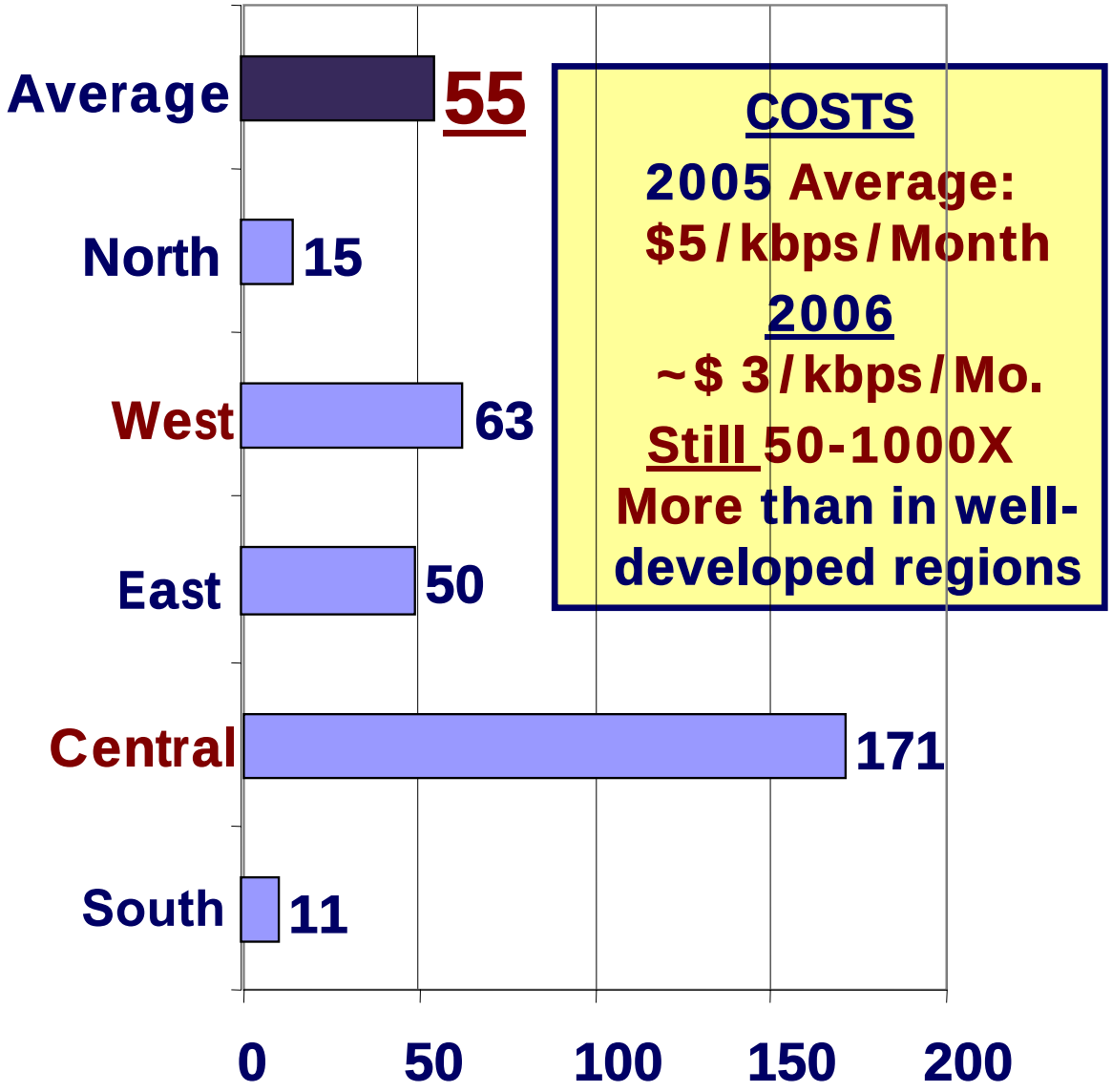


AFRICA: Bandwidth per networked computer (Kbps)



M. Jensen

Users Per Networked Computer by African Region



COSTS

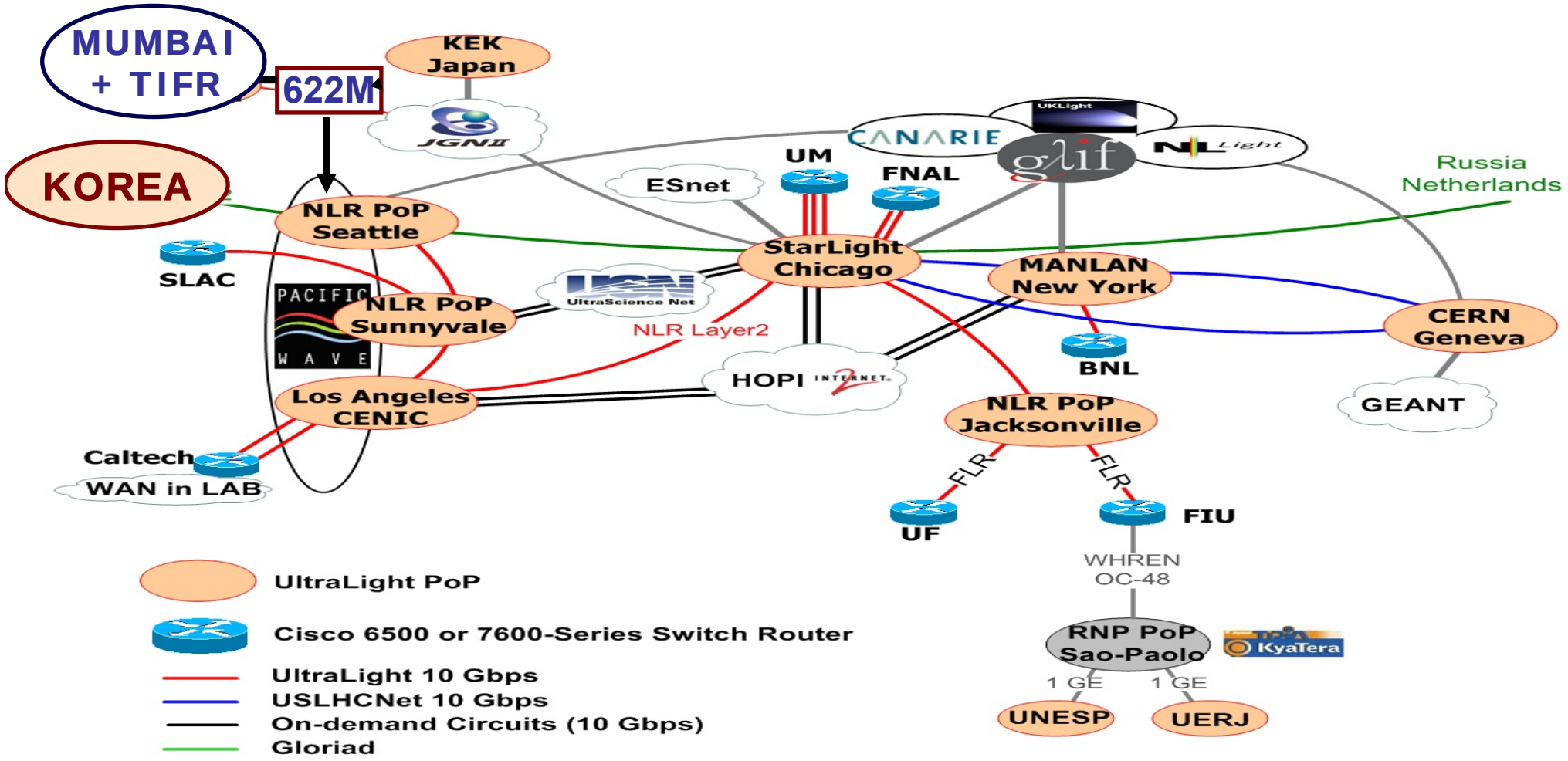
2005 Average:
$5/kbps/Month

2006
~$ 3/kbps/Mo.

Still 50-1000X
More than in well-developed regions

UltraLight

4 Continent Testbed



Building a global, network-aware end-to-end managed real-time Grid

President of India Collaborating with US, CERN, Slovakia via VRVS/EVO

Coincident with Data Transfers of ~500 Mbps

15 TBytes to/from India in 2 Days

Mumbai-Japan-US Links

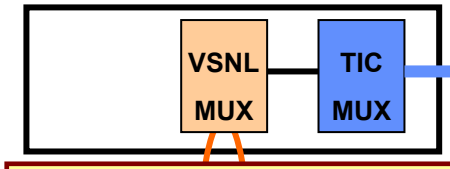
INDIA

Chennai POP VSNL
LANDING STATIONS

JAPAN

JAPAN LAND
STANDING

SINGAPORE LANDING STATION



TIC

Cable

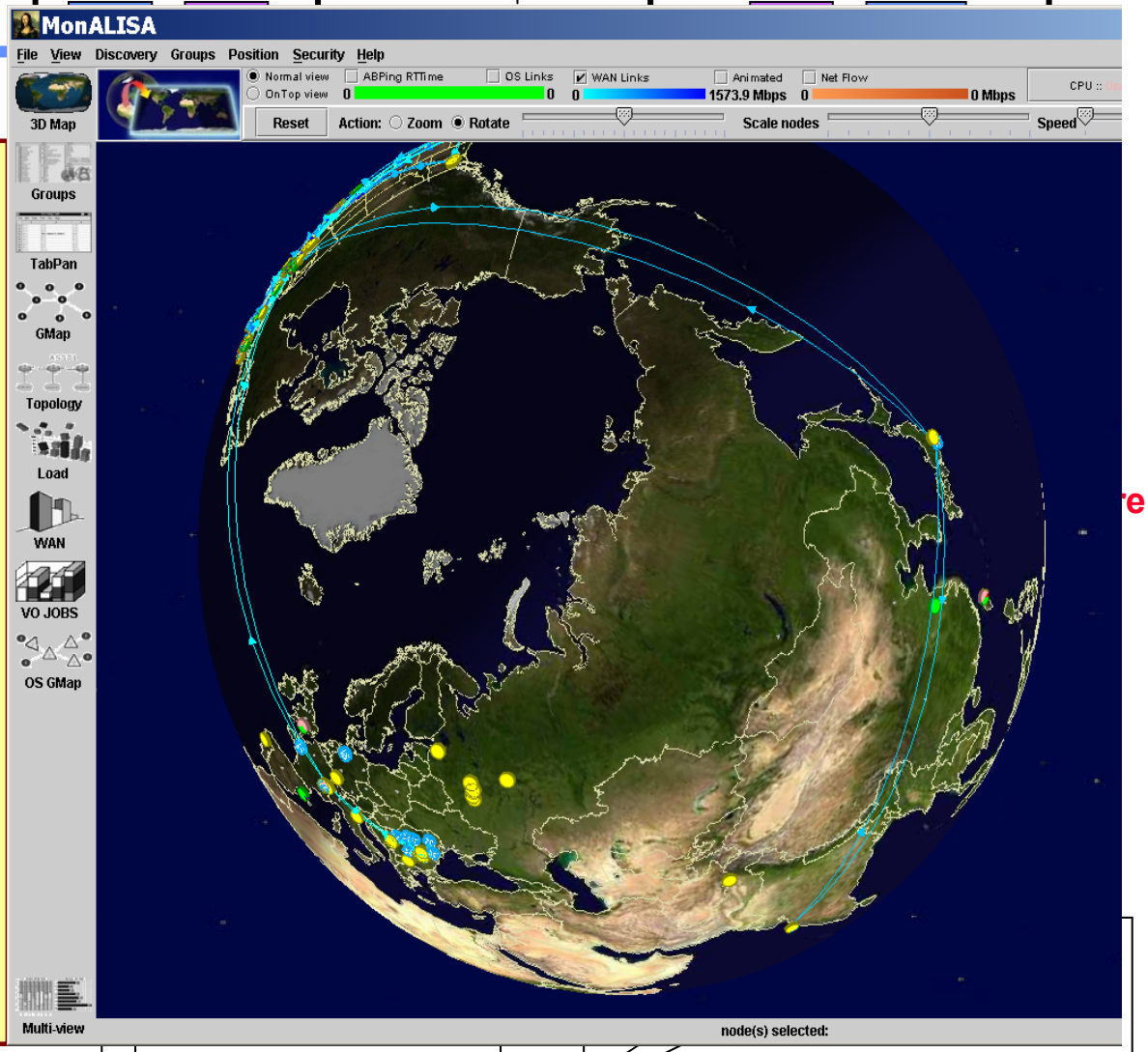
TIFR Link to Japan
+ Onward to US & Europe

Loaned Link from VSNL at CHEP06

End to End Bandwidth 4 X 155 Mbps on SeMeWe3 Cable

Goal is to Move to 10 Gbps on SeMeWe4

Sparked Planning for a Next Generation R&E Network in India



INTERFACE TYPES

STM 4

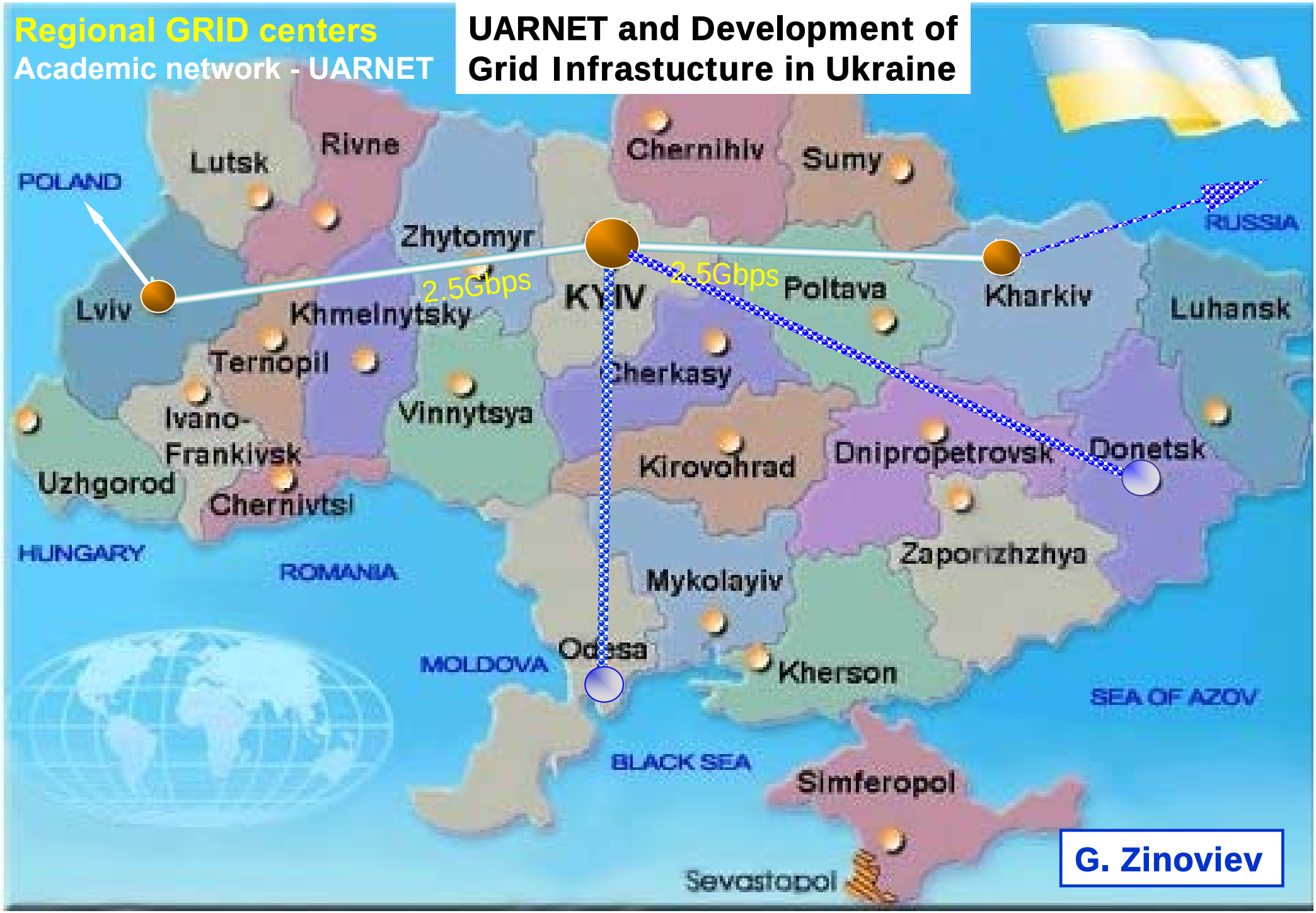
INTERFACE TYPES

OC-12

TIFR Mumbai, INDIA

NTT Otemachi Bldg, JAPAN

+ Onward to US, Europe ➡


Regional GRID centers
Academic network - UARNET
UARNET and Development of Grid Infrastucture in Ukraine
POLAND
Lutsk
Rivne
Chernihiv
Sumy
RUSSIA
Zhytomyr
2.5Gbps
2.5Gbps
Lviv
Khmelnytsky
KYIV
Poltava
Kharkiv
Luhansk
Ternopil
Cherkasy
Vinnytsya
Ivano-
Frankivsk
Kirovohrad
Dnipropetrovsk
Donetsk
Uzhgorod
Chernivtsi
HUNGARY
ROMANIA
Zaporizhzhya
Mykolayiv
MOLDOVA
Odesa
Kherson
SEA OF AZOV
BLACK SEA
Simferopol
Sevastopol
G. Zinoviev

UARNET and Development of Grid Infrastucture in Ukraine

Fortunately our efforts were rewarded, we have found not only an understanding and also … reasonable financial support

- Concept of developing grid infrastructure in NAS was officially accepted.
- Special academic board representing various sciences and institutes was established.
- In 2005 we obtained 1 million hrivnas (~$200K)
- These year (2006) we have 3M hrs
- Next year we expect 6M hrs to develop the branched grid infrastructure in NAS
- UARNET had about 25M hrs for main & local optical fiber lines during last 2 yrs.

At Present

- Ukraine is a member of WLCG (MoU of 25 April 2006).
- BITP has optical fiber cable (*academic network UARNET*) – 100Mbps (to go to a few Gbps), modern internal network (100Mbps) with 250 links for PCs; computing cluster contains 20 dual CPU nodes (Xeon 3GHz) SE~10TB
- BITP grid-cluster passed all tests of AliEn-grid and already is included in AliEn-grid infrastructure as a full operatinal grid-site.
- Grid-clusters in a few Academic Institutes in Kiev, Kharkov and Lvov are under construction.

G. Zinoviev

The HEP Community: Progress, Impact, and Working to Close the Digital Divide

- **The national, continental and transoceanic networks used by HEP and other fields of DIS are moving to the N X 10G range**
  - ➡ **Growth rate much faster than Moore's Law**
- **"Dark Fiber"-based, hybrid networks, owned and/or operated by the R&E community are emerging, and fostering rapid progress, in a growing list of nations:**
  - ❒ **ca, nl, us, jp, kr; *pl, cz, br, no, cn, pt, ie, gr, sk, si, …***
- **HEP & CS are learning to use long range networks effectively**
  - ❒ **7-10 Gbps TCP flows over 10-30 kkm; 151 Gbps Record**

Working to Close the Digital Divide, for Science, Education and Economic Development

- ***HEP groups in US, EU, Japan, Korea, Brazil, Russia are working with int'l R&E networks and advanced net projects, and Grid Organizations. Leading the way by***
  - ***Co-developing and deploying next generation Optical nets, monitoring and management systems***
  - ***Developing high throughput tools and systems***
  - ***Adapting the tools & best practices for broad use in the science and Grid communities***
  - ***Providing education and training in state of the art technologies & methods***
- ***A Long Road Ahead Remains:***
  Eastern Europe, Central & SE Asia, India, Pakistan, Africa

Extra Slides Follow

Sinaia, Romania
October 13-18, 2006

International ICFA Workshop

GRID Activities within Large Scale International Collaborations

Sinaia, Romania, 13 – 18 Oct. 2006

(http://niham.nipne.ro/events2006)

Topics:

- Grid Applications for HEP
- Grid Applications for other domains
- Status of Grid developments at LHC
- LCG project
- Networking and Digital Divide Issues

Speakers:

Cristina Aiftimiei
Eduard Andrei
Nick Brook
Rene Brun
Federico Carminati
Catalin Carstoiu
Philippe Charpentier
Joel Closier
Greg Cole
Serban Constantinescu
Les Cottrell
Mihnea Dulea
Ulrik Egede
Christoph Eck
Ricardo Graciani Diaz
V.V. Ivanov
Mihai Jalobeanu
Iosif Legrand
Frank Van Lingen
Fairouz Malek
Pere Mato
Catalin Nae
Gabriel Neagu
Harvey Newman
Andreas Peters
Ruth Pordes
Gilbert Poulard
Titus Preda
Ognjen Prnat
Octavian Rusu
Pablo Saiz
Alberto Santoro
Claudiu Schiaua
Kilian Schwarz

International Advisory Committee:

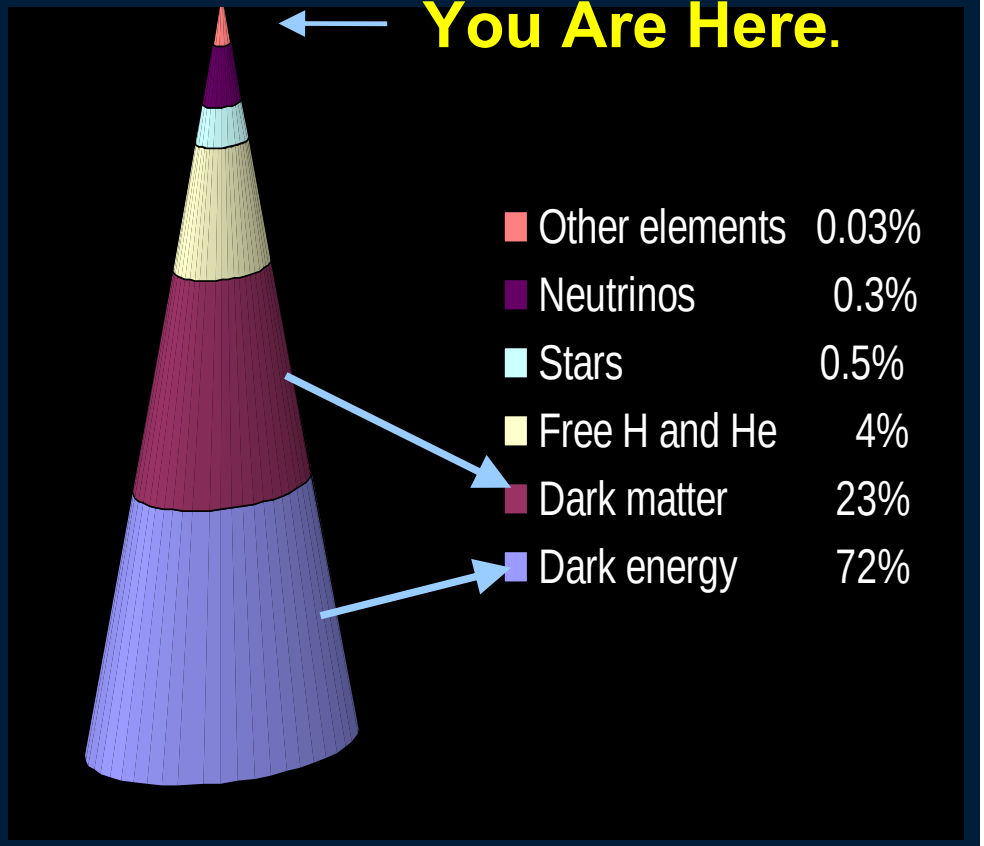
Paul Avery (U.Florida)
Nick Brook (CERN)
Rene Brun (CERN)
Federico Carminati (CERN)
Greg Cole (JICS, ORNL)
Les Cottrell (SLAC, Stanford)
Ulrik Egede (Imp.College, London)
David Foster (CERN)
Viatcheslav Ilyin (SINP,Moscow)
V.V. Ivanov (JINR, Dubna)
Peter Jenni (CERN)
Massimo Lamanna (CERN)
Iosif Legrand (CALTECH)
Tatsuya Nakada (CERN)
Harvey Newman (CALTECH)
Sergio Novaes (UNESP, Sao Paulo)
Gilbert Poulard (CERN)
Jurgen Schukraft (CERN)

Organized by:

National Institute of Physics and Nuclear Engineering,
Bucharest, ROMANIA

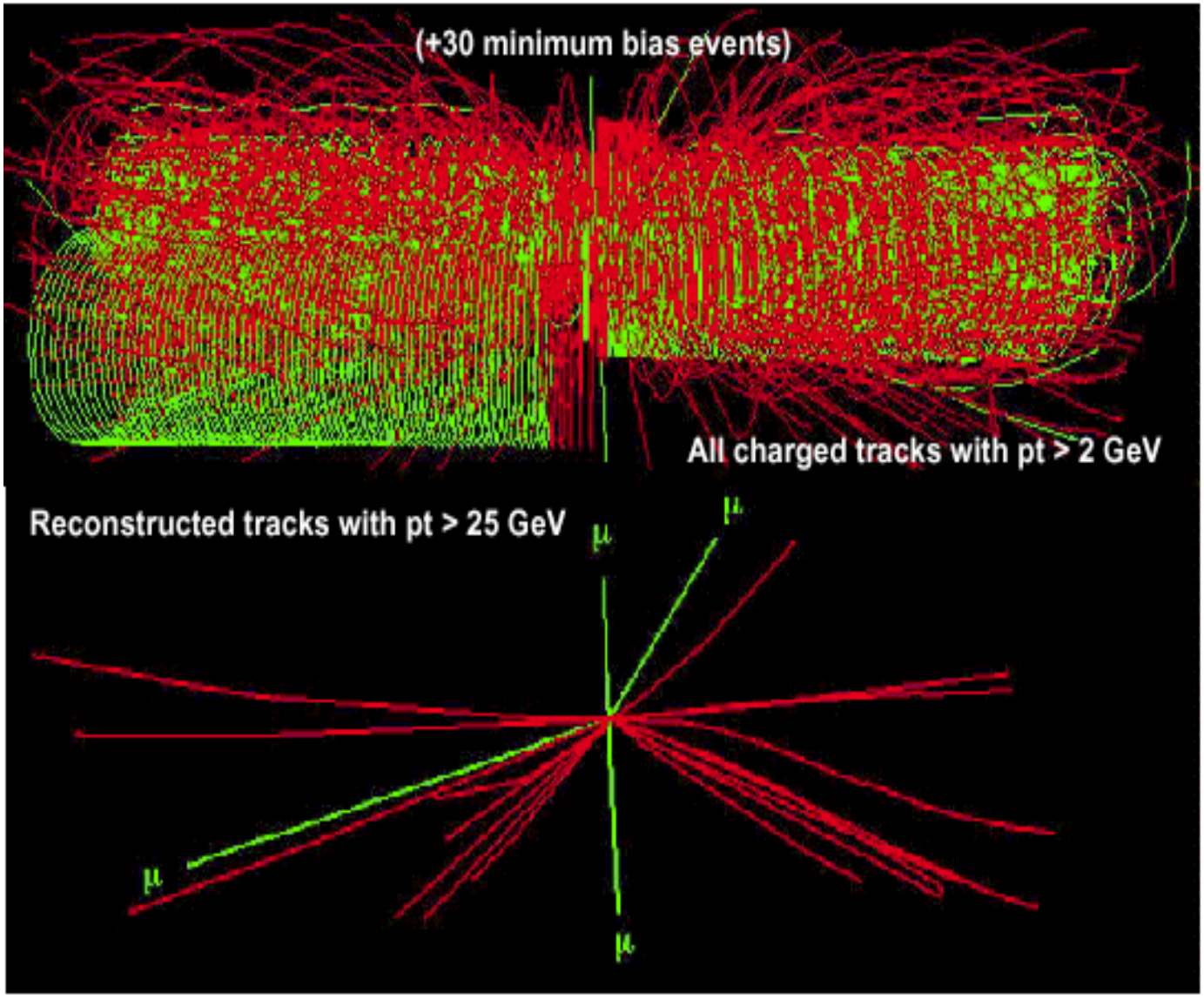
Beyond the SM: Great Questions of *Particle Physics and Cosmology*

1. Where does the pattern of particle families and masses come from ?
2. Where are the Higgs particles; what is the mysterious Higgs field ?
3. Why do neutrinos and quarks oscillate ?
4. Is Nature Supersymmetric ?
5. Why is any matter left in the universe ?
6. Why is gravity so weak?
7. Are there extra space-time dimensions?



We do not know what makes up 95% of the universe.

LHC: Many Petabytes/Yr of Complex Data Unprecedented Instruments, IT Challenges



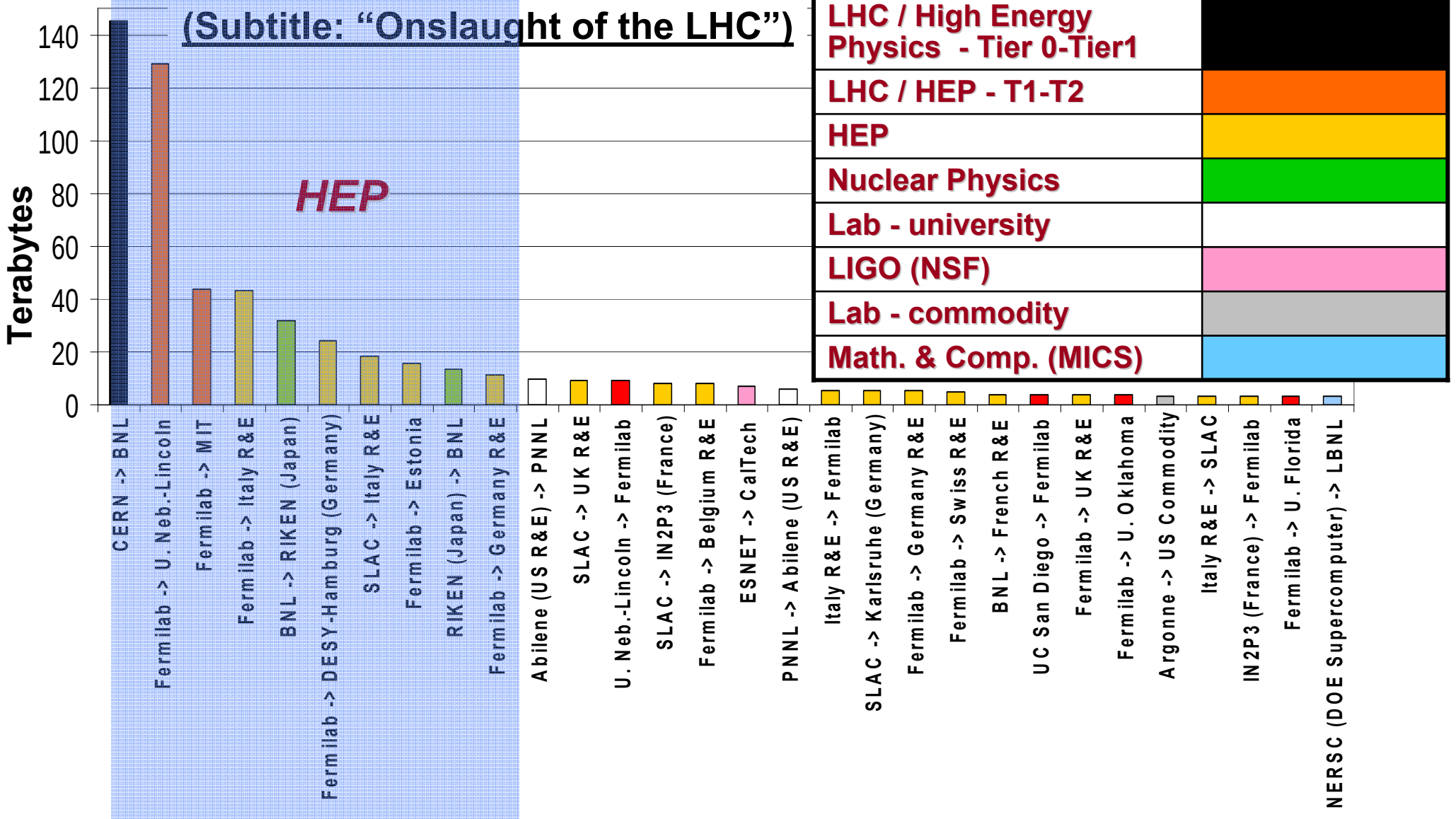
At 10^{34} Luminosity
A Bunch Crossing Every 25 nsec (40 MHz)

~20 Events from Known Physics Superimposed Per Crossing:
10^9 Interactions/s

<u>Instruments</u>
E.g. CMS Tracker: 223 Sq-meters of Silicon Sensors

Traffic Volume of the Top 30 AS-AS Flows on ESNET June 2006 (W. Johnston, ESNet Program Manager)

(Subtitle: "Onslaught of the LHC")



SCIC Work in 2005 – 2006: Partnerships

Continue Digital Divide Focus

- *Work on Specific Improvements, Case by Case:*
  - → *India with TIFR, Internet2 the World Bank, CDAC & VSNL: CHEP06 Side Event*
  - → *Russia and China: With MSU, IHEP Beijing and GLORIAD*
  - → *Pakistan with PERN and NUST*
  - → *Brazil and Latin America, with RNP, ANSP, WHREN, RedCLARA*
  - → *Asia-Pacific with Kyungpook, KEK, Aarnet, and APAN*
  - → *Africa, with IEEAF, CERN, UNU, ICTP Trieste, …*
- *New Initiatives started in 2005; Continuing in 2006: Armenia, Ukraine*
- **Help with Modernizing the Infrastructure:**
  - ❒ **Provide Tools for Effective Use: Data Transport, Monitoring, Collaboration**
  - ❒ **Design, Commissioning, Development**
- *Encourage Creation of New "Culture of Collaboration", for example in the LHC Computing (& Analysis) Models*

Internet Users: Africa and the Rest of the World

- **Internet Penetration in Africa is 2.5% (1.4% in 2004): Still more than an order of magnitude less than Europe (36%), and North America (68%)**

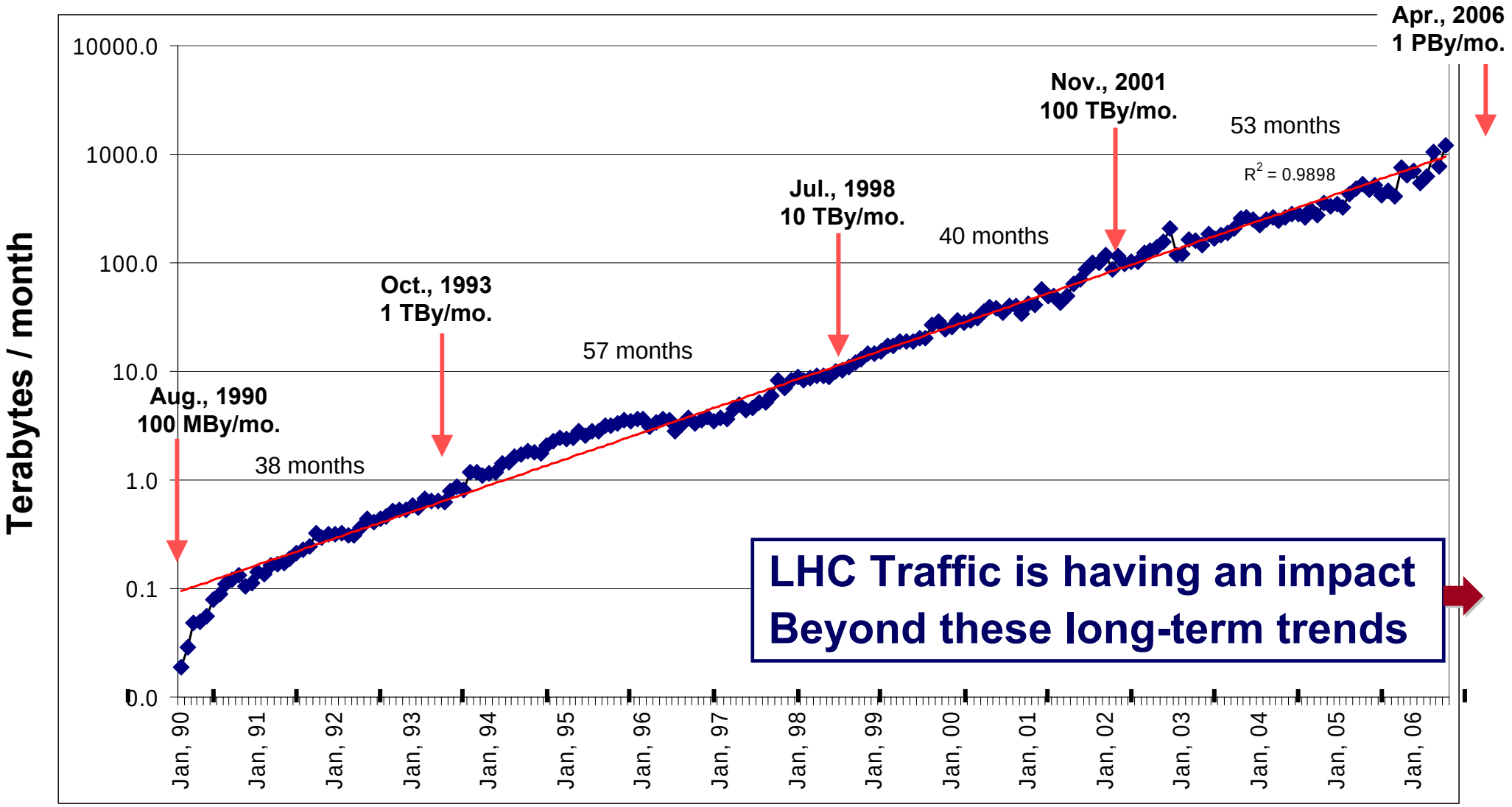
WORLD INTERNET USAGE AND POPULATION STATISTICS Updated December 31, 2005 http://www.internetworldstats.com						
World Regions	Population (2006 Est.)	Population % of World	Internet Usage, Latest Data	% Population Penetration	Usage % of World	Usage Growth 2000-2005
Africa	915,210,928	14.1 %	22,737,500	2.5 %	2.2 %	403.7 %
Asia	3,667,774,066	56.4 %	364,270,713	9.9 %	35.7 %	218.7 %
Europe	807,289,020	12.4 %	290,121,957	35.9 %	28.5 %	176.1 %
Middle East	190,084,161	2.9 %	18,203,500	9.6 %	1.8 %	454.2 %
North America	331,473,276	5.1 %	225,801,428	68.1 %	22.2 %	108.9 %
Latin America/Caribbean	553,908,632	8.5 %	79,033,597	14.3 %	7.8 %	337.4 %
Oceania / Australia	33,956,977	0.5 %	17,690,762	52.9 %	1.8 %	132.2 %
WORLD TOTAL	6,499,697,060	100.0 %	1,018,057,389	15.7 %	100.0 %	182.0 %

INTERNET USAGE AND POPULATION IN ASIA http://internetworldstats.com						
ASIA	Population (2006 Est.)	Internet Users, (Year 2000)	Internet Users, Latest Data	Penetration (% Population)	(%) Users in Asia	Use Growth 2000-2005
China	1,306,724,067	22,500,000	111,000,000	8.5 %	30.5 %	393 %
Hong Kong *	7,054,867	2,283,000	4,878,713	69.2 %	1.3 %	113 %
India	1,112,225,812	5,000,000	50,600,000	4.5 % [*]	13.9 %	912 %
Indonesia	221,900,701	2,000,000	18,000,000	8.1 %	4.9 %	800 %
Japan	128,389,000	47,080,000	86,050,000	67.2 %	23.7 %	83 %
Korea, South	50,633,265	19,040,000	33,900,000	67.0 %	9.3 %	78 %
Malaysia	27,392,442	3,700,000	10,040,000	36.7 %	2.8 %	171 %
Pakistan	163,985,373	133,900	7,500,000	4.6 %	2.1 %	5,501 %
Philippines	85,712,221	2,000,000	7,820,000	9.1 %	2.1 %	291 %
Singapore	3,601,745	1,200,000	2,421,000	67.2 %	0.7 %	102 %
Taiwan	22,896,488	6,260,000	13,800,000	60.3 %	3.8 %	120 %
Vietnam	83,944,402	200,000	5,870,000	7.0 %	1.6 %	2,835 %
TOTAL ASIA	3,667,774,066	114,303,000	364,270,713	9.9 %	100.0 %	219 %

[* Less Than 1M Broadband Users in India]

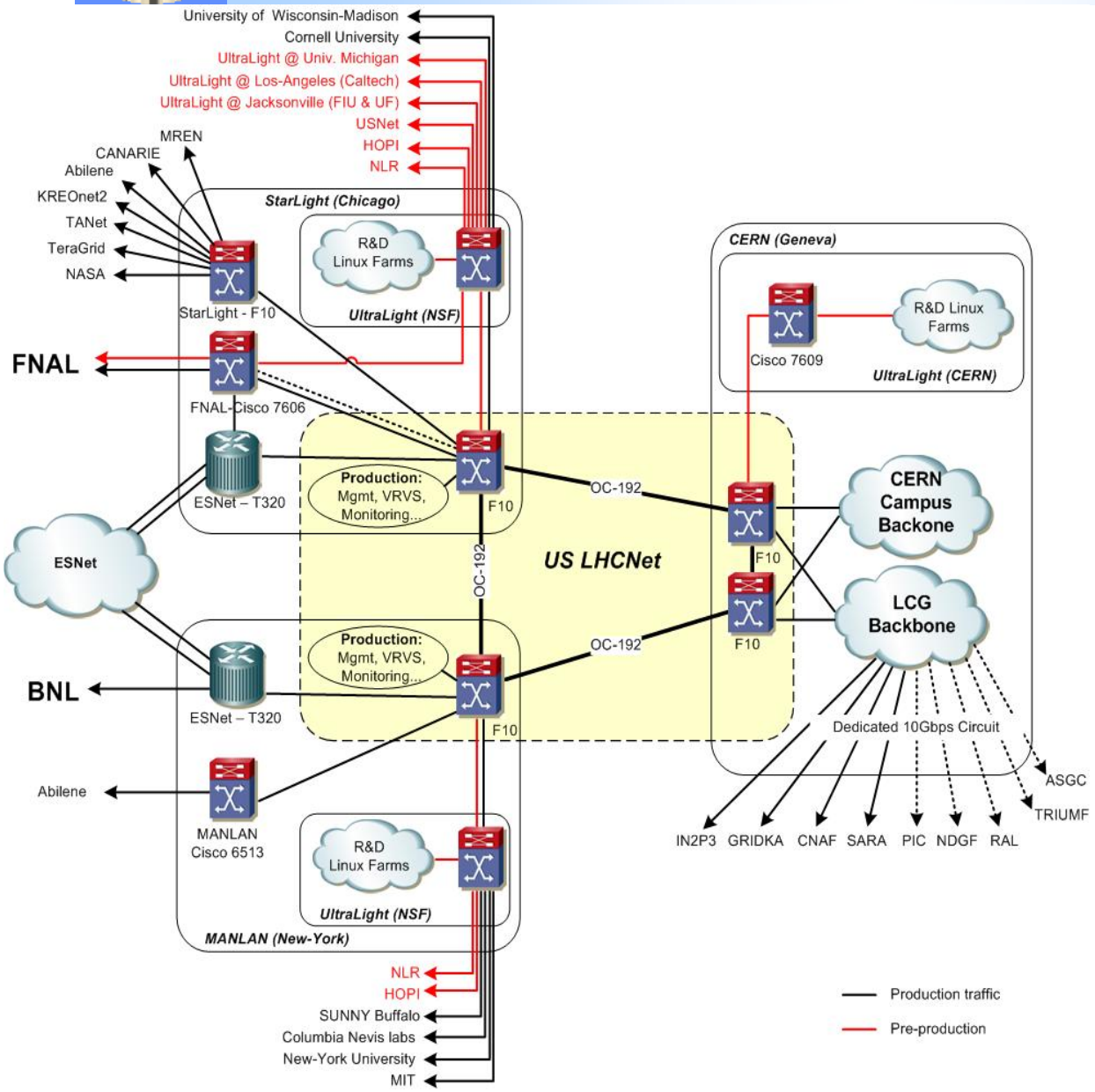
ESnet Traffic has Increased by 10X Every 47 Months, on Average, Since 1990

W. Johnston
ESnet



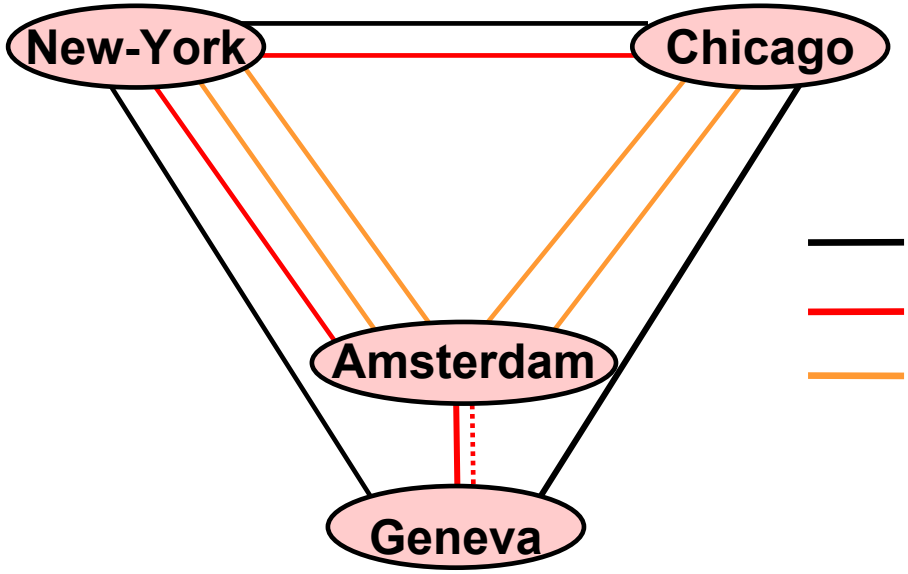
Log Plot of ESnet Monthly Accepted Traffic, January, 1990 – June, 2006

LHCNet configuration (July 2006)



- Co-operated by Caltech and CERN engineering teams
- Force10 platforms, 10GE WANPHY
- New PoP in NY since Sept. 2005
- 10 Gbps path to BNL since April 2006
- Connection to US Universities via UltraLight (NSF & university funded) backbone

Future backbone topology

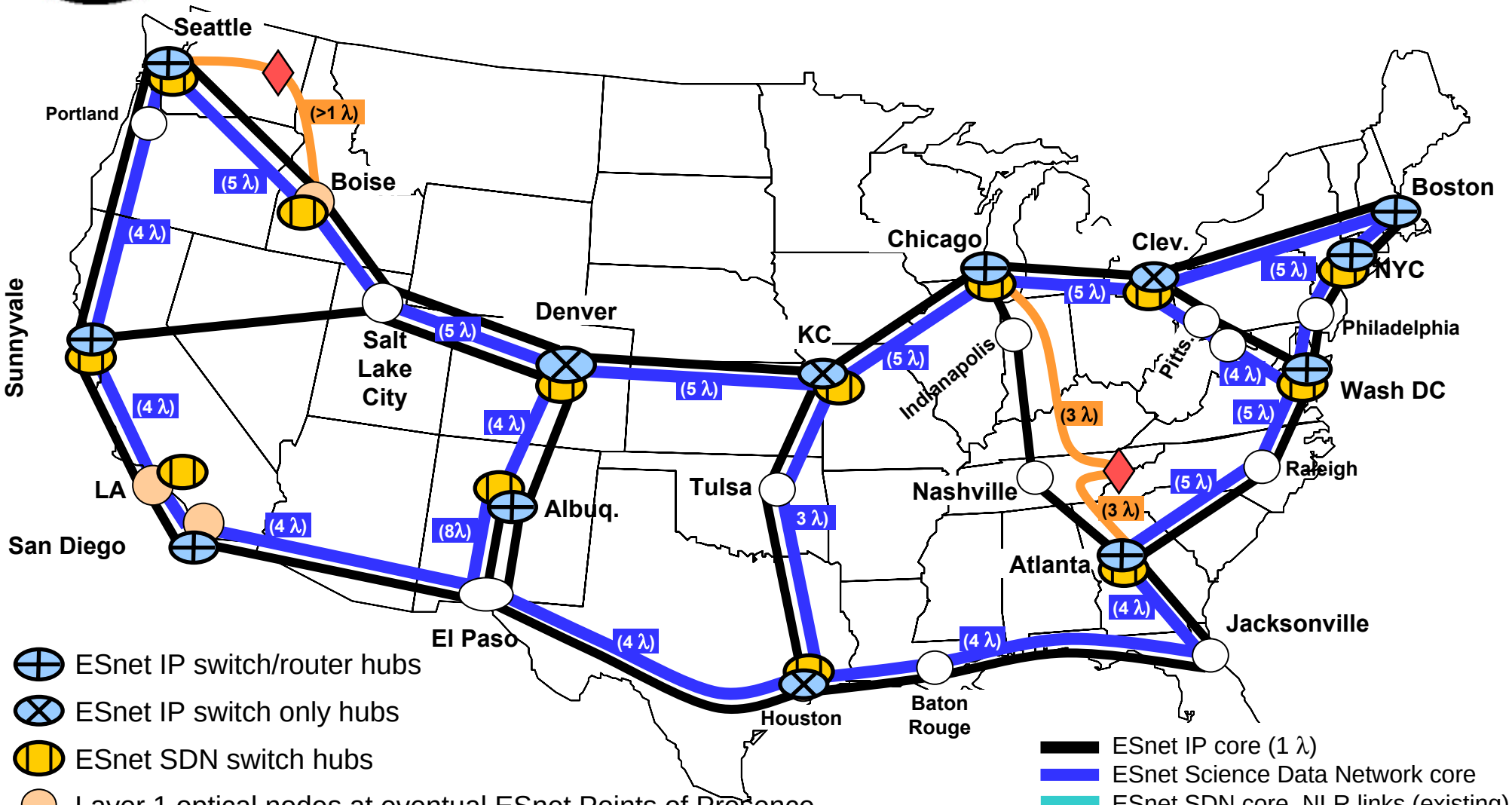


GVA-CHI-NY triangle

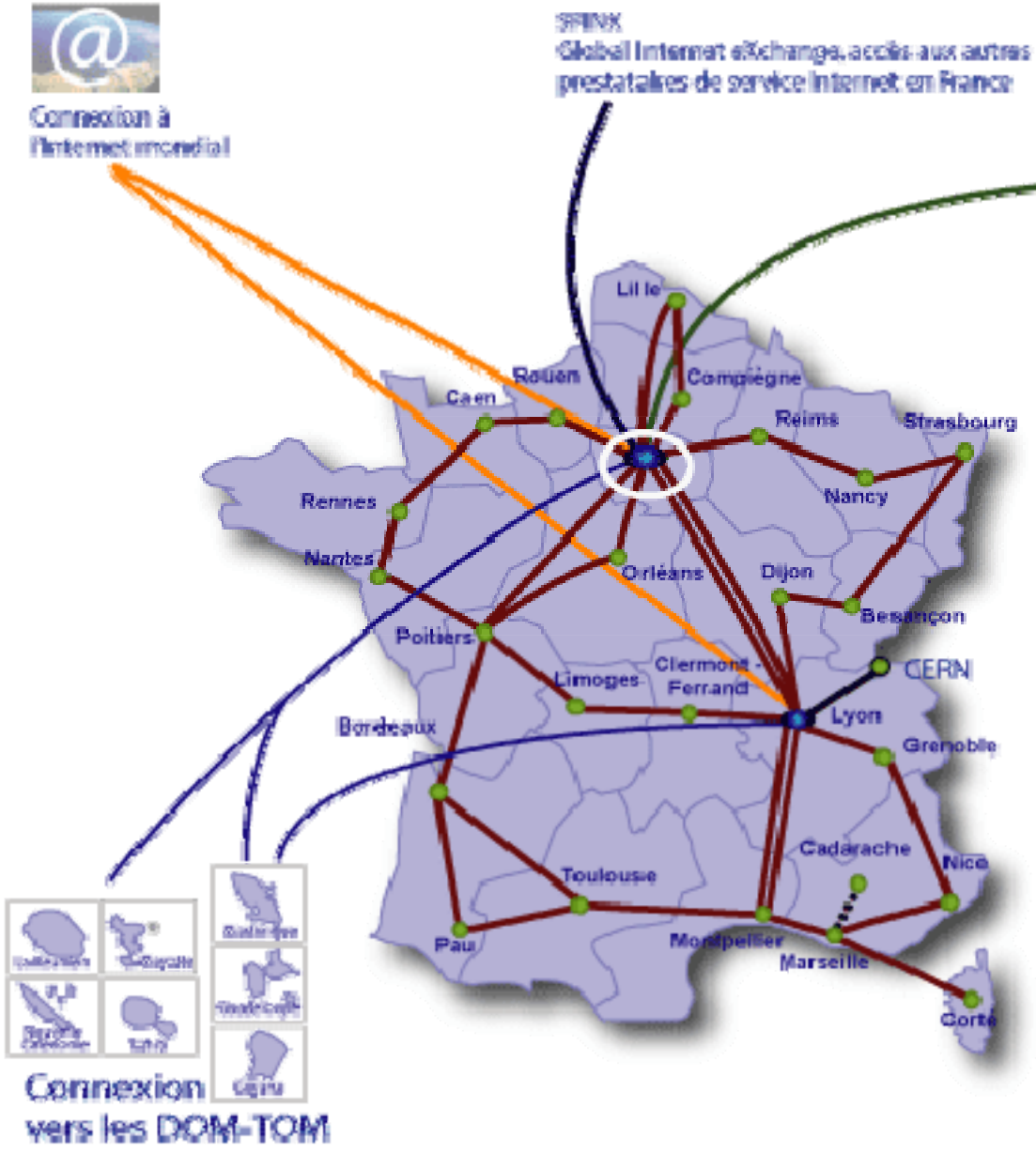
New PoP in Amsterdam

- GEANT2 circuit between GVA and AMS
- Access to other transatlantic circuits ➡ backup paths and additional capacity
- Connection to Netherlight, GLIF (T1-T1 traffic and R&D)

ESnet4 IP + SDN, 2011 Configuration



France: RENATER 4 2.5G WDM Backbone (Dark Fiber Footprint)



CCIN2P3

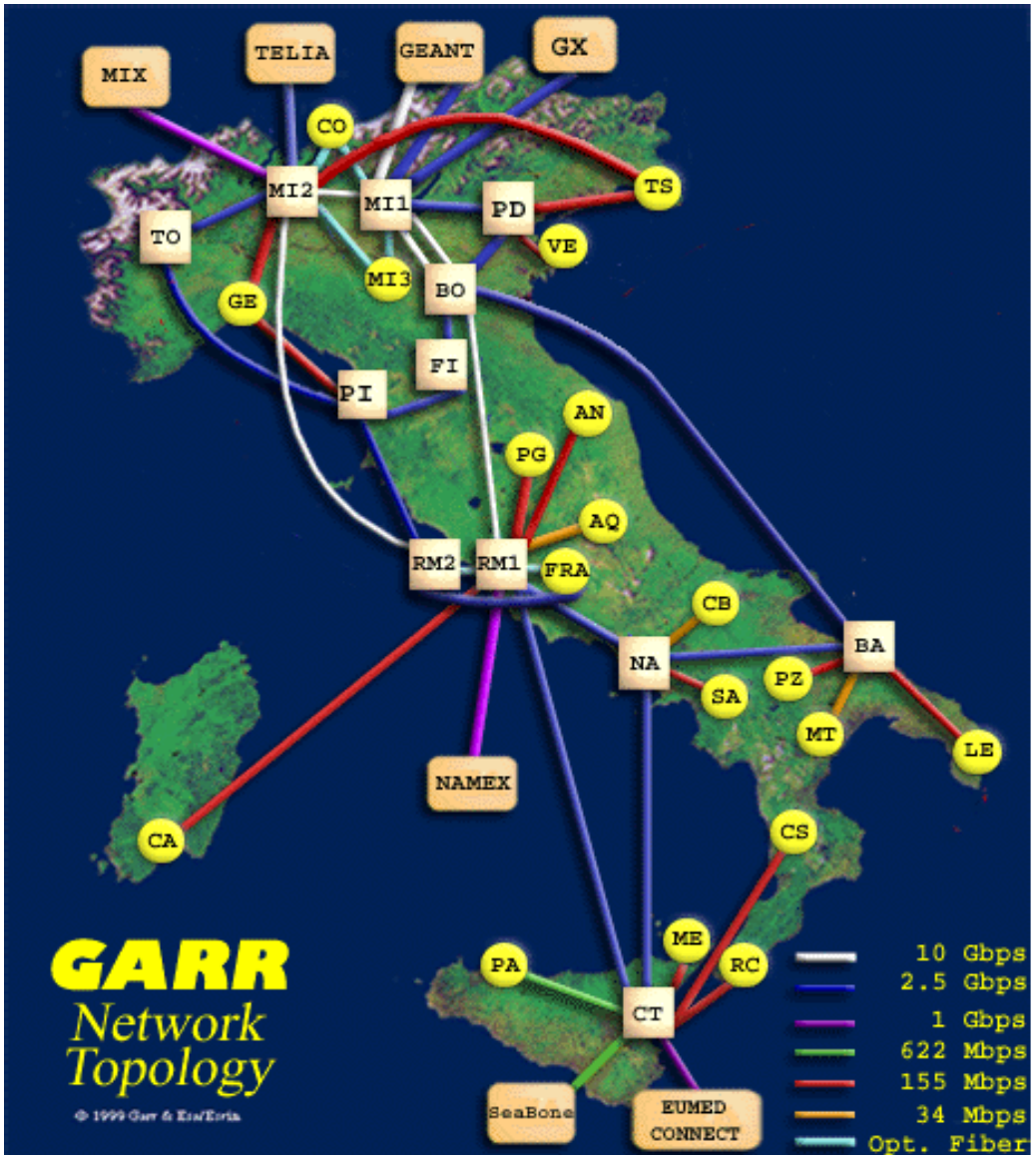
- 2005: 10G CERN Link
- 2006: Two 10G Light-paths for Global Connectivity, via GEANT2 or CBF

ITER

Planning dedicated fiber: Marseilles - Cadarache

D. Vendromme

Italy: Garr-B: New 10G Core Rome-Bologna-Milan



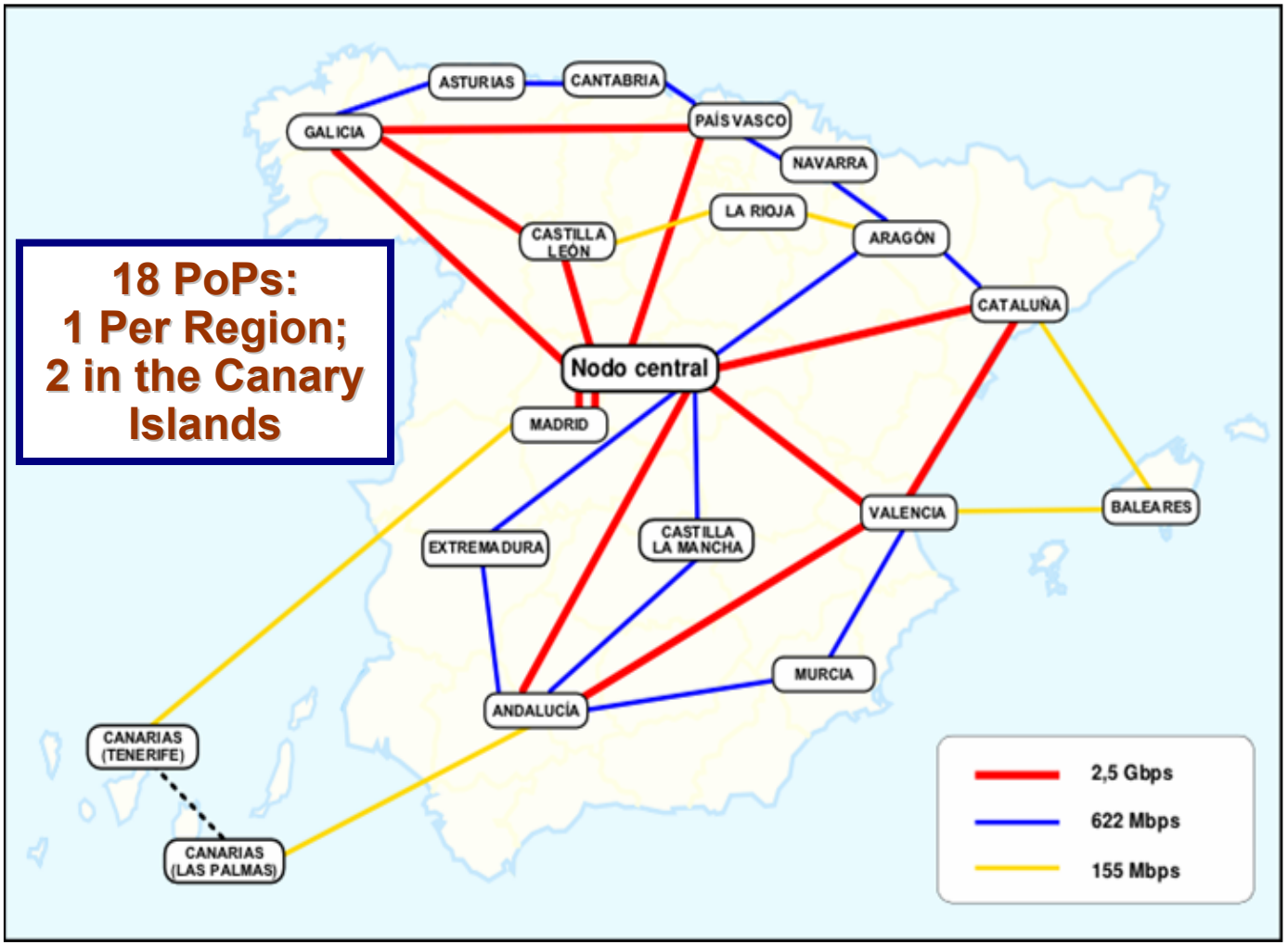
Garr-G
Lightpaths of at least 2.5G

E. Valente

Spain: RedIRIS 2.5G Mesh Network

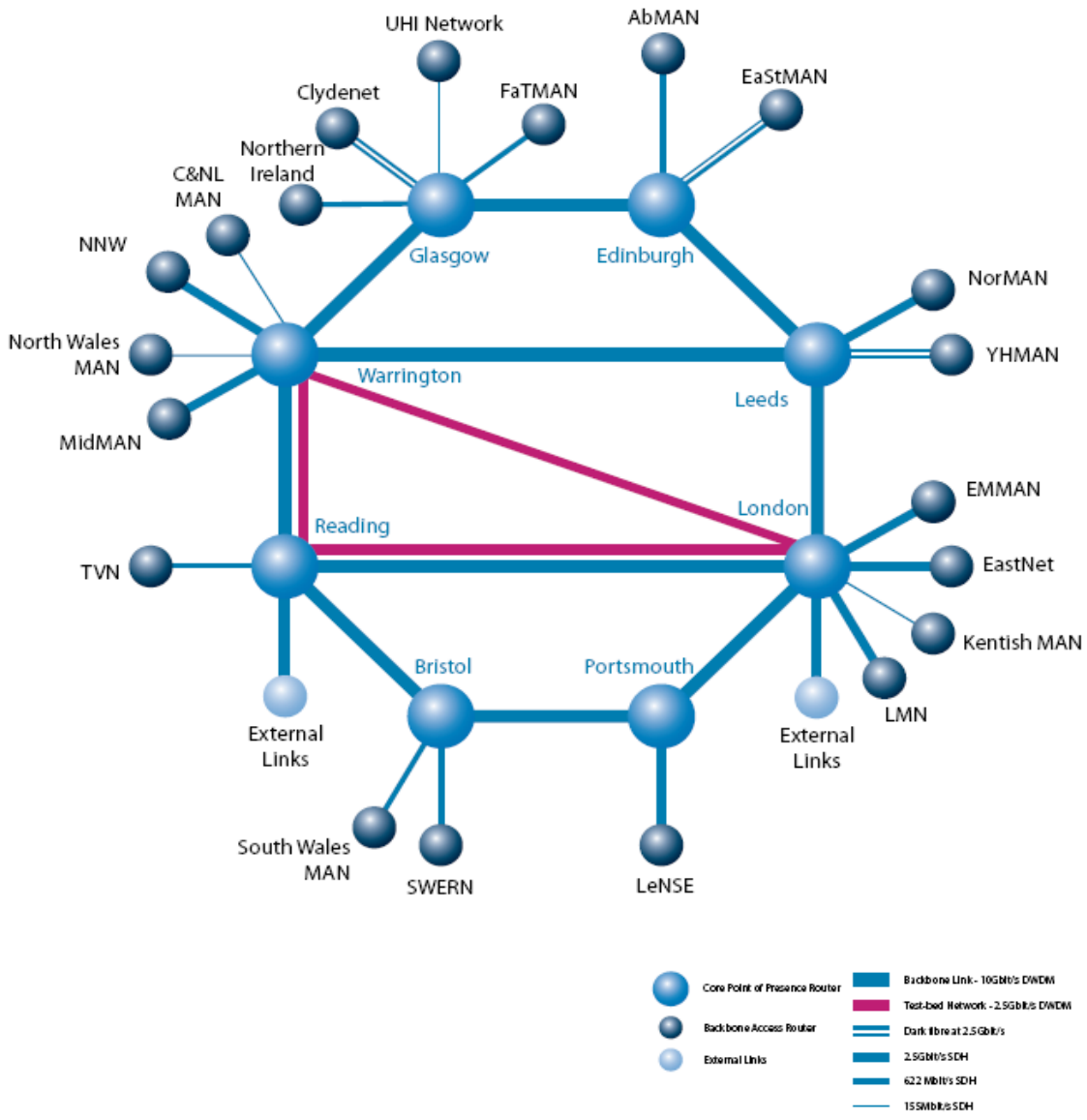
2006 Plans

- Move to 10G Core + Several 10G Links to PoPs
- Madrid-Geneva dark fiber link
- Add Madrid-Paris dark fiber link to existing 10G Madrid- Paris-Milan path



M. Delfino

UK: SuperJanet4 and SuperJanet5



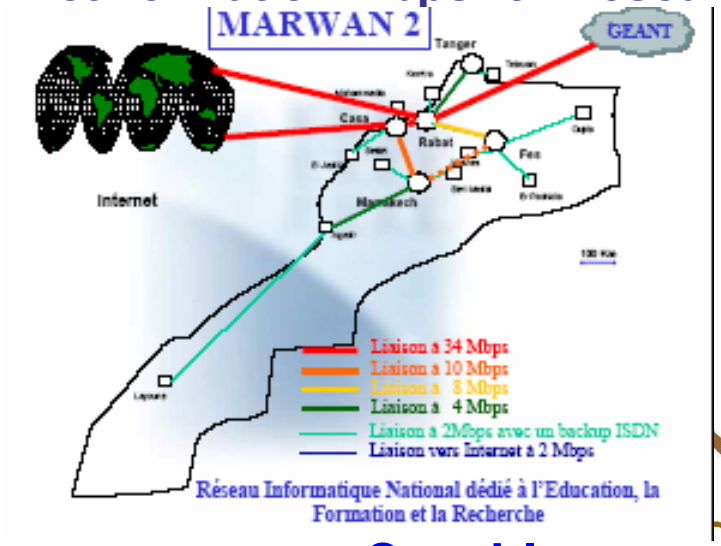
- 10 Gbps DWDM Backbone
- 2.5 Gbps Connections to Regional Networks
- 2.5 Gbps Connection to GEANT
- 10 Gbps Connections to Amsterdam and StarLight: *UKLight*
- SuperJanet5 is in the procurement phase
  - Dark Fiber Leasing & Lighting is Considered an Option
  - SJ5 Rollout Starts at the End of 2005

P. Clarke

Maroc Wide Area Network

MARWAN 2

Network at 34 Mbps for Research and high education



Réseau GEANT

Connexion vers les ré-seaux de la Recherche, Europe, Amérique...

45 Mbps

Algeria & tunisia connected to Geant - 45 Mbs

Rabat

Casablanca

Université

Université

Université

Institut

Université

Université

34 Mbps

2 Mbps

Institut

Université

Institut

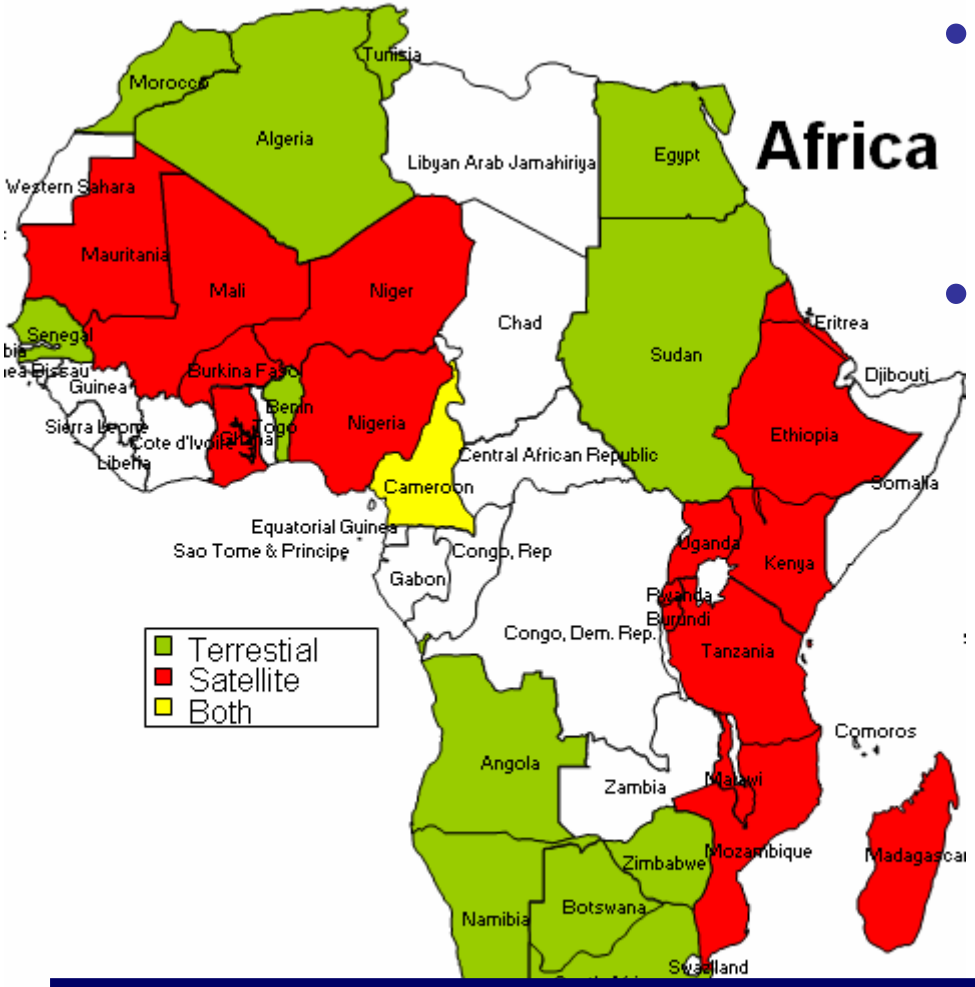
45 Mbit/s

34 Mbit/s

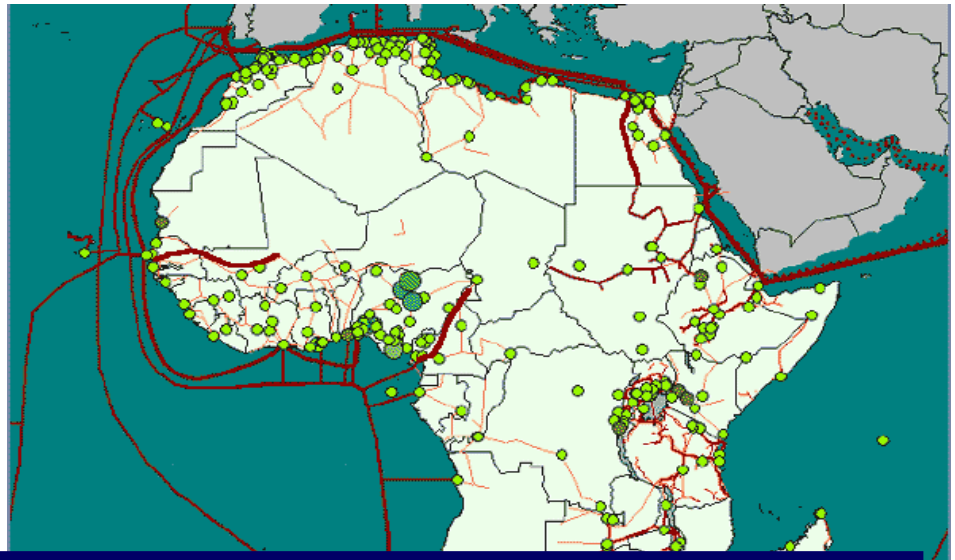
2 Mbit/s

Abdeslam Hoummada

Satellites vs Terrestrial



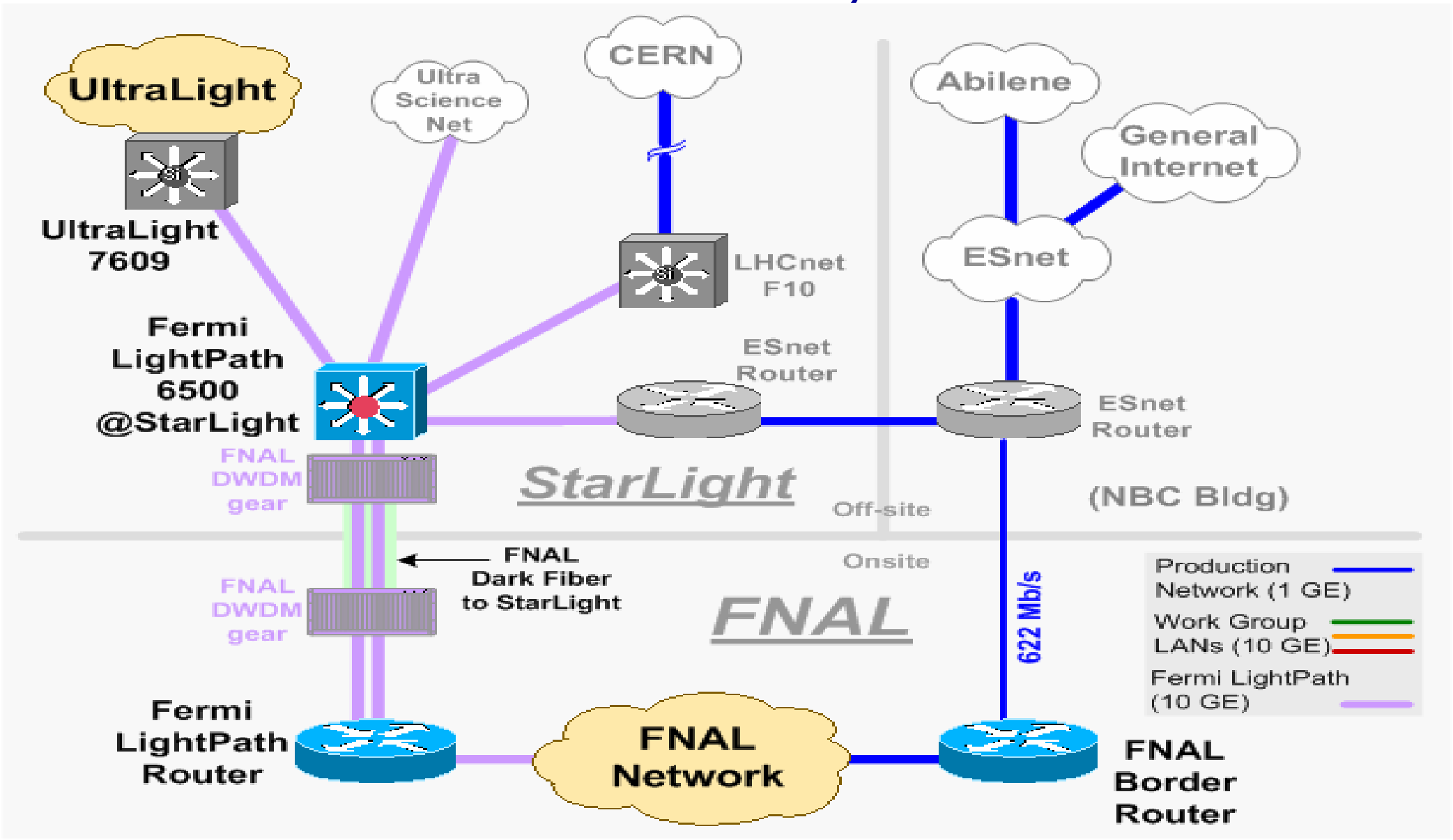
- Terrestrial links via SAT3 & SEAMEWE (Mediterranean & Red Sea)
- Terrestrial not available to all within countries



Note: More satellite links could be a Boon to the Region, but typical unit bandwidth costs are 300-1000X more than Fiber.

There is a Continued Need for Fiber Infrastructure

Fermi LightPath to StarLight, US LHCNet UltraLight, USNet; Production Net to ESnet, USLHCNet & Abilene



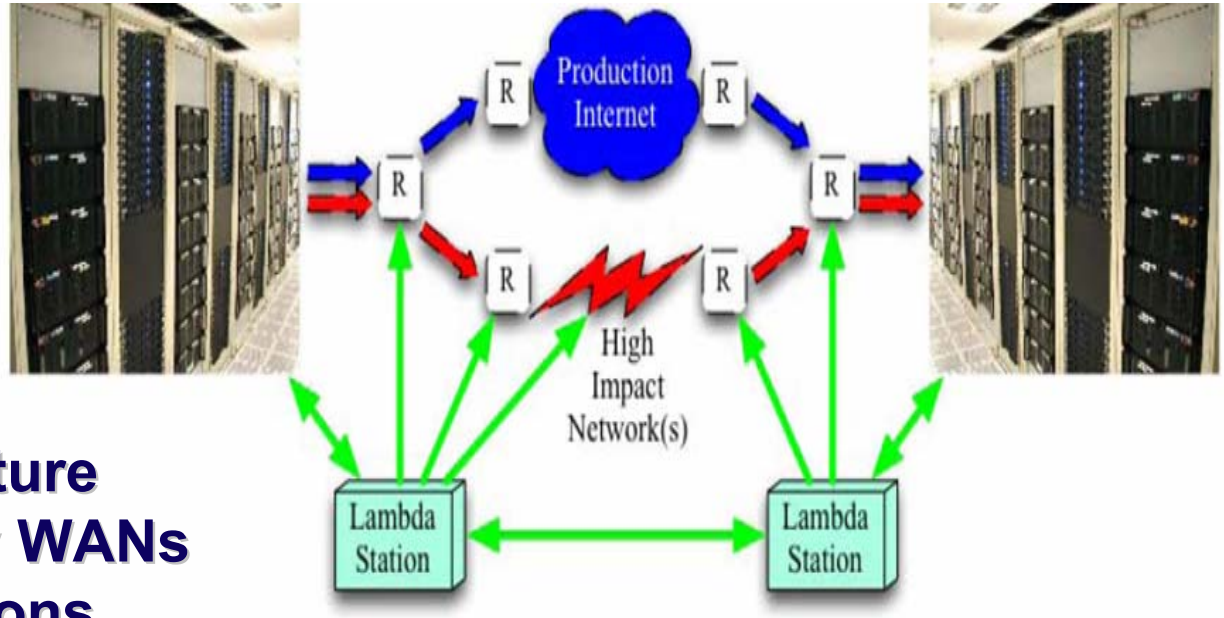
Lambda Station

A network path forwarding service to interface production facilities with advanced research networks:

- Goal is selective forwarding on a *per flow* basis
  - Alternate network paths for high impact data movement
- Dynamic path modification, with graceful cutover & fallback
- Current implementation is based on policy-based routing & DSCP marking

Lambda Station interacts with:

- Host applications & systems
- LAN infrastructure
- Site border infrastructure
- Advanced technology WANs
- Remote Lambda Stations

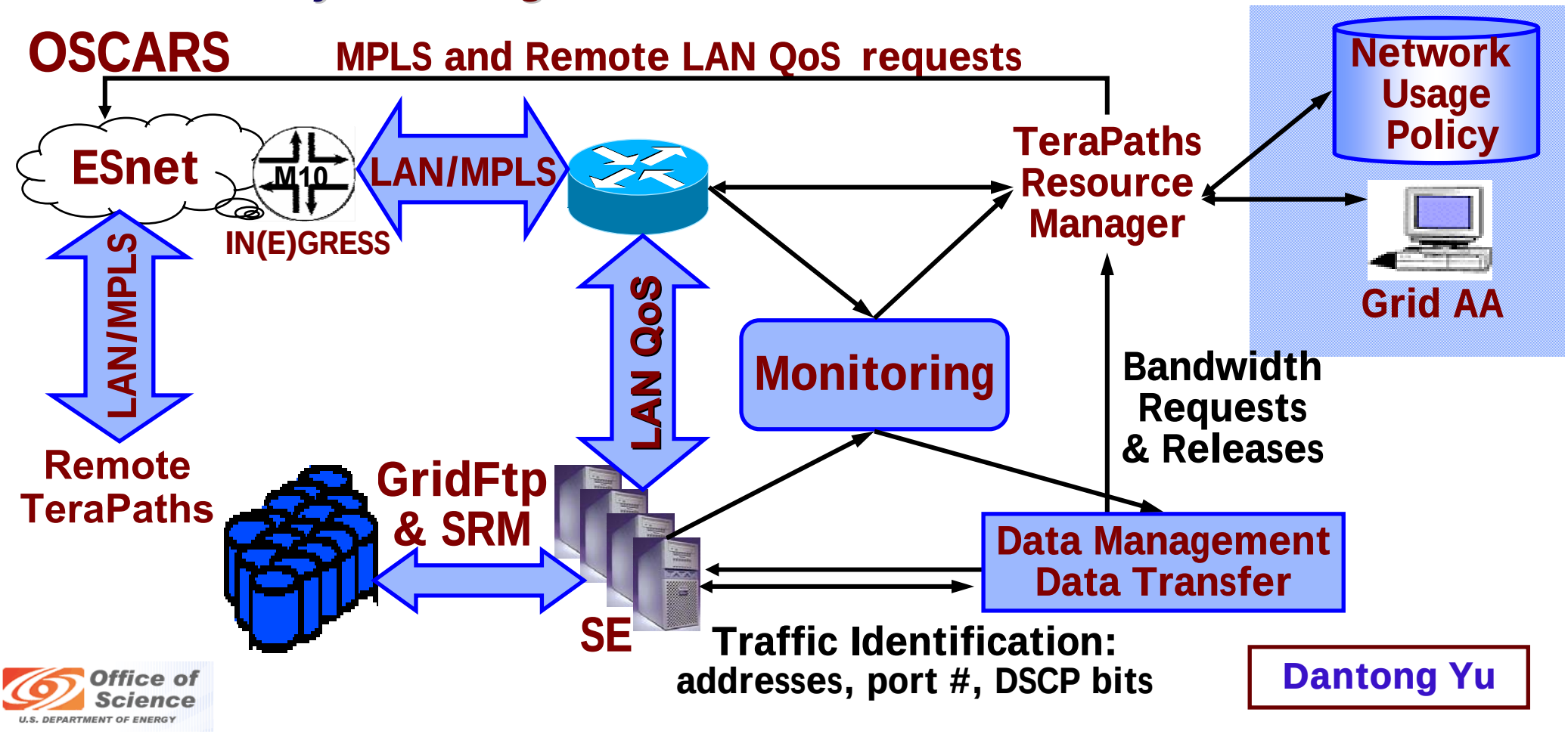


Office of Science U.S. DEPARTMENT OF ENERGY

D. Petravick, P. DeMar

TeraPaths: BNL and Michigan; Partnering with OSCARS (ESnet), LStation (FNAL) and DWMI (SLAC)

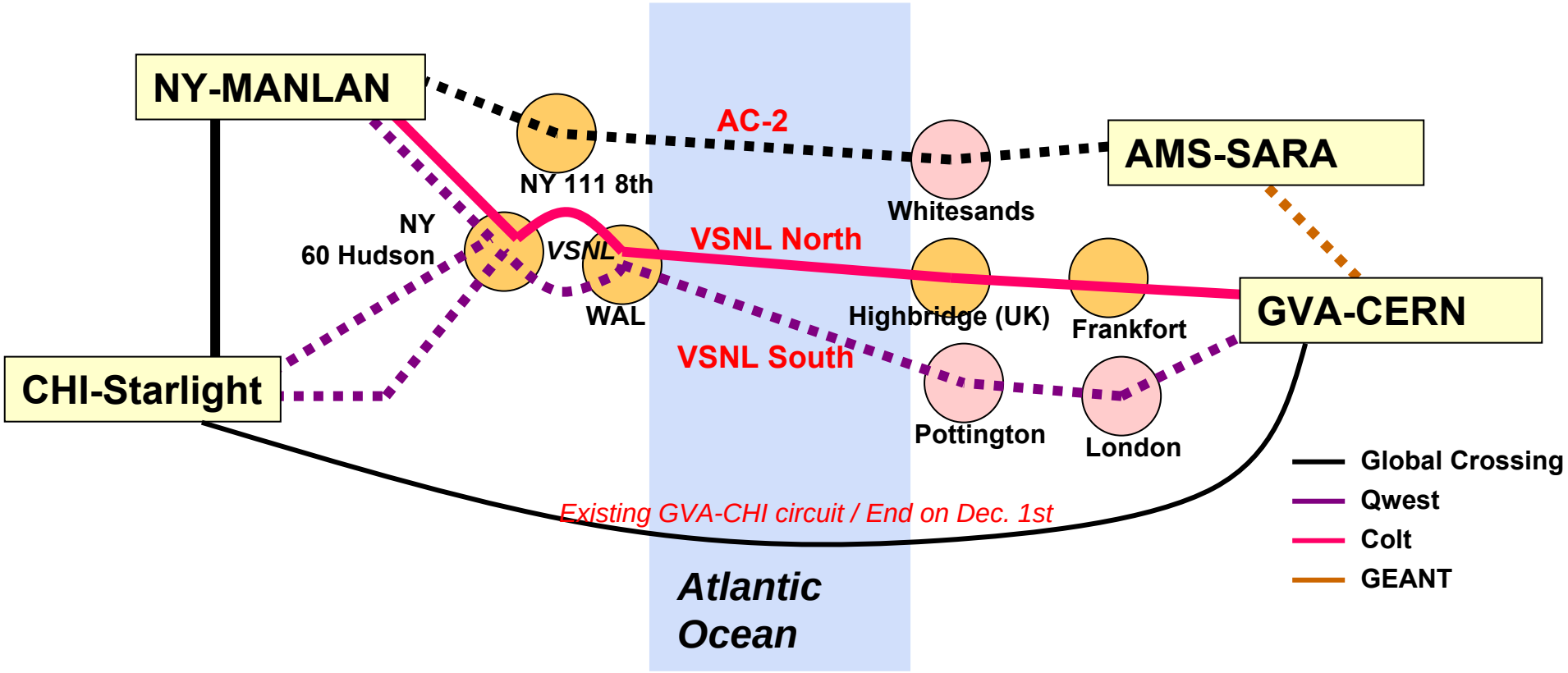
- **Investigate:** Integration & Use of LAN QoS and MPLS-Based Differentiated Network Services in the ATLAS Distributed Computing Environment
  - *As a Way to Manage the Network As a Critical Resource*



Office of Science U.S. DEPARTMENT OF ENERGY

Dantong Yu

New Topology deployment



In Production

In Production

November 1st

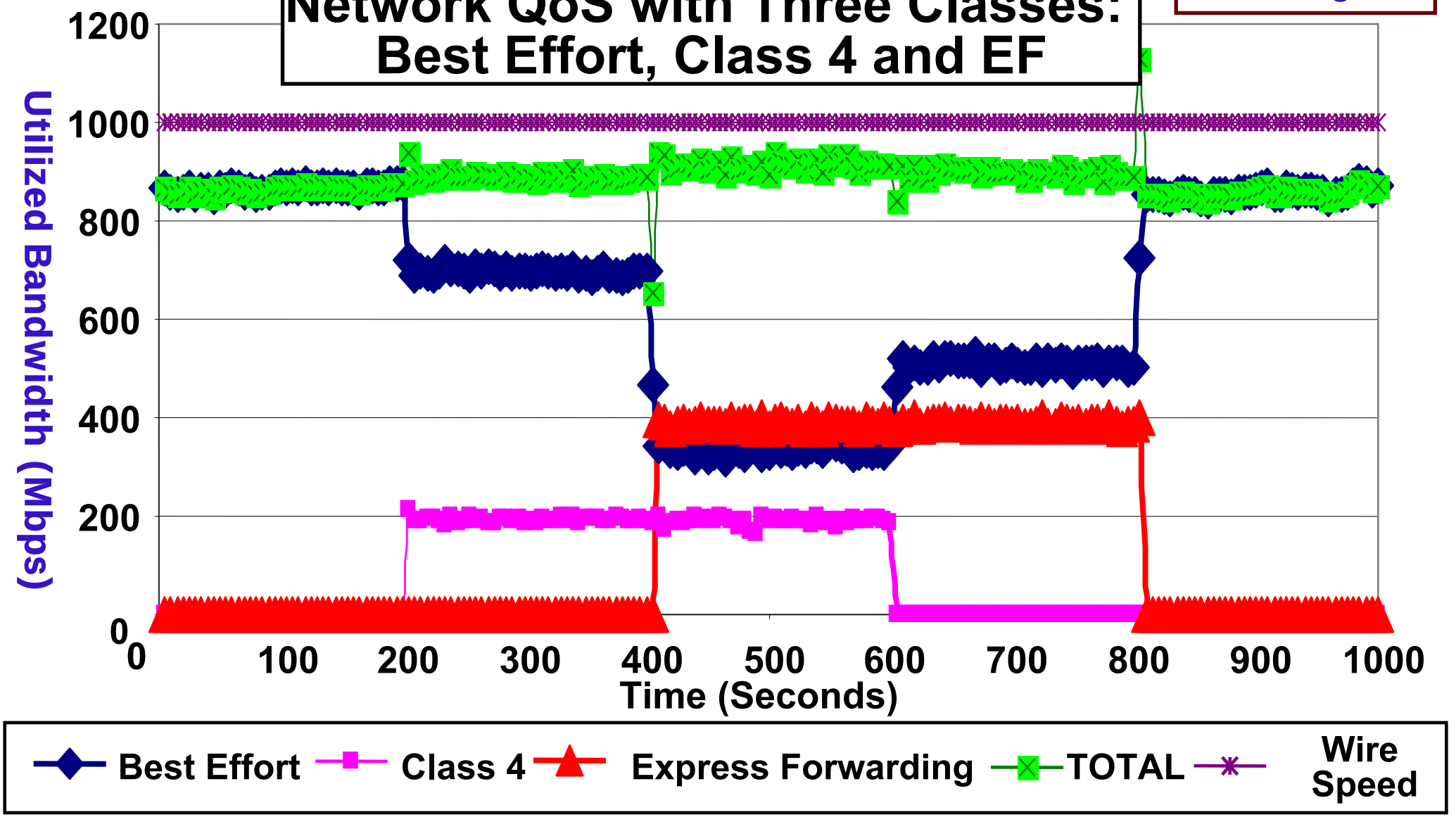
January 2007

January 2007

New PoP in AMS: January 2007

TeraPaths: Prioritized Traffic Coexists with Best Effort Traffic

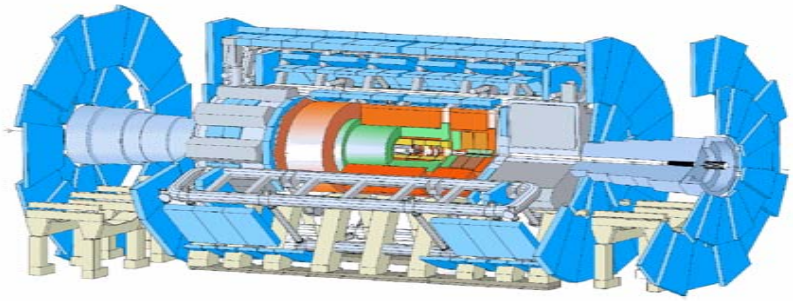
Dantong Yu

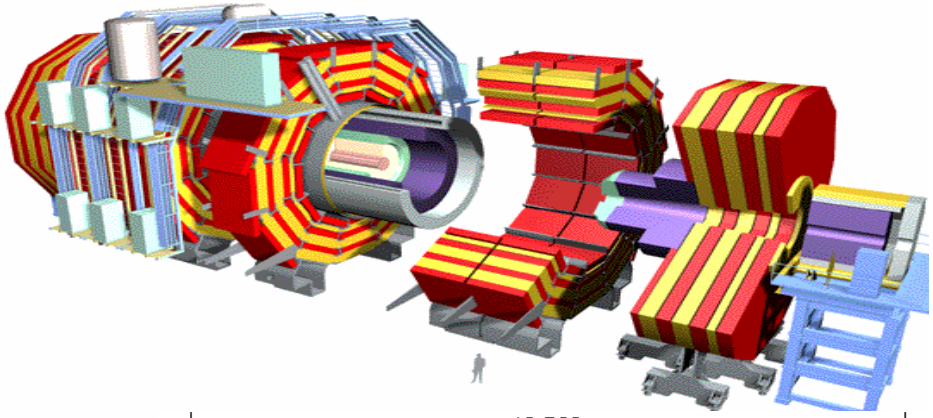


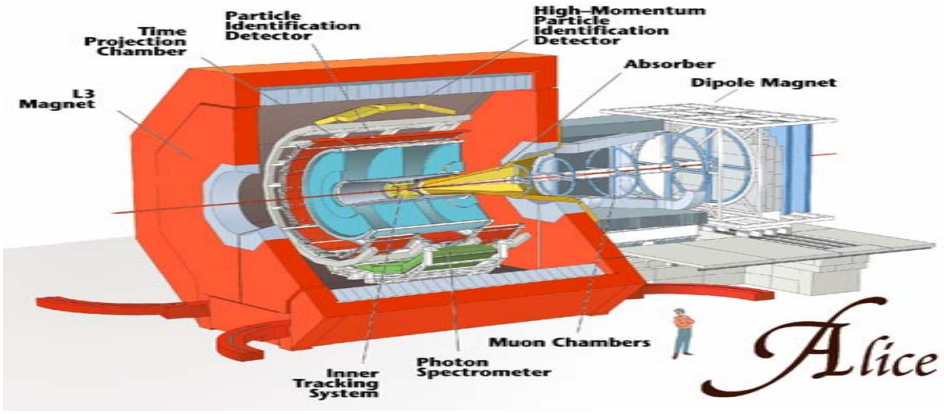
Four LHC Experiments: The Petabyte to Exabyte Challenge

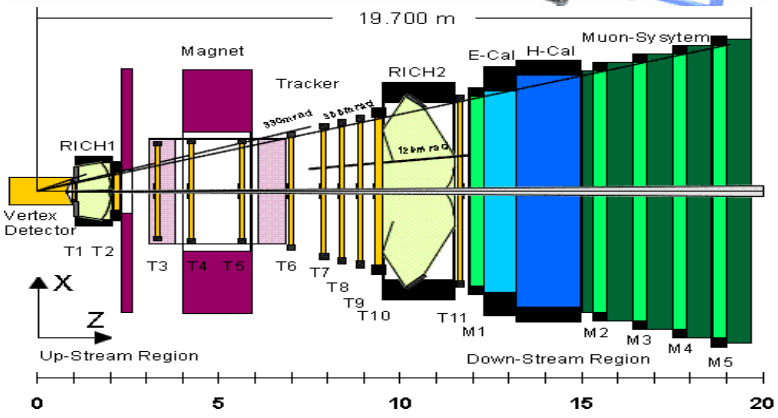
ATLAS, CMS, ALICE, LHCB

Higgs + New particles; Quark-Gluon Plasma; CP Violation





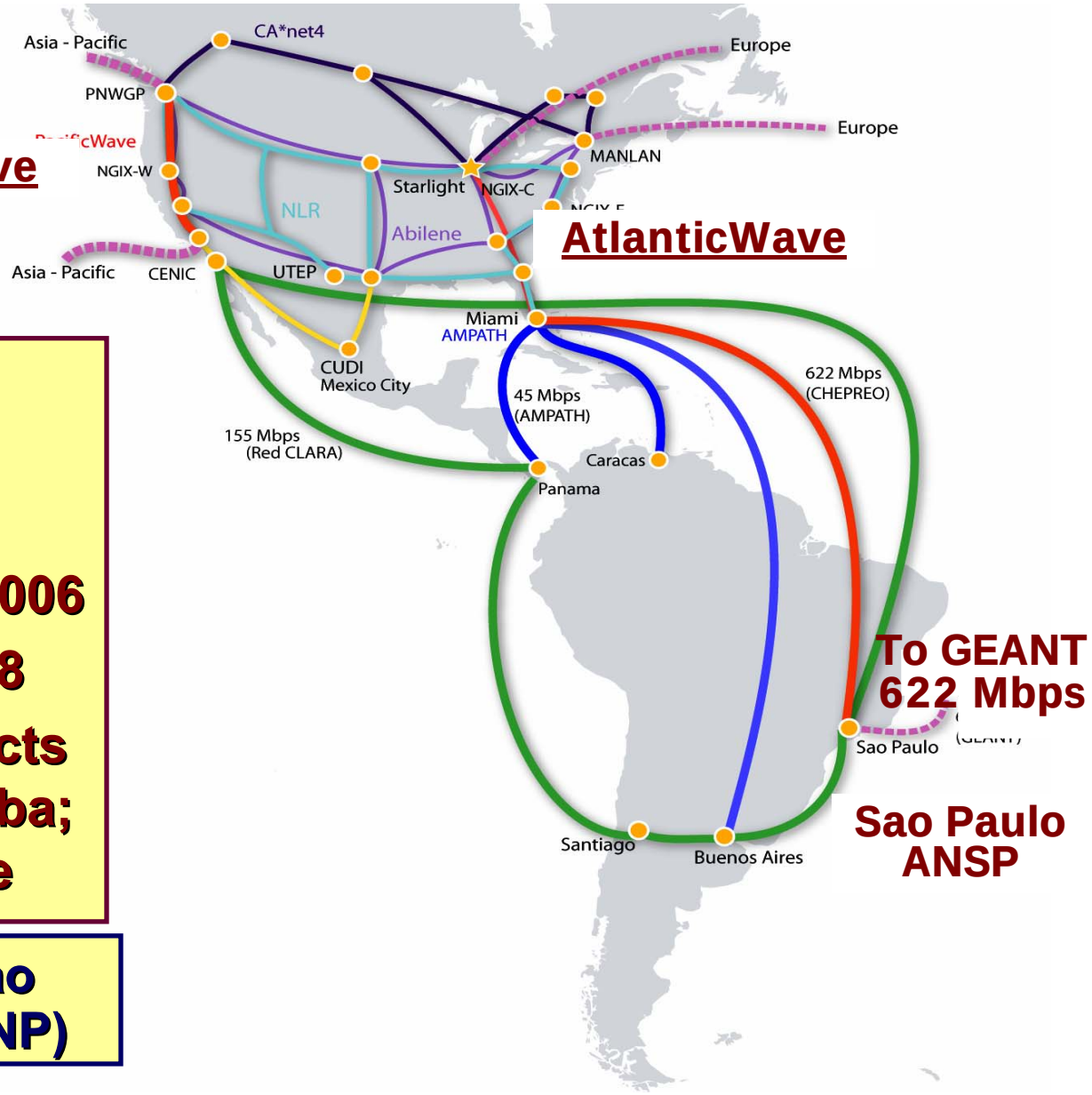




0.1 to 1 Exabyte (1 EB = 10^{18} Bytes)

(2008) (~2012 ?) for the LHC Experiments

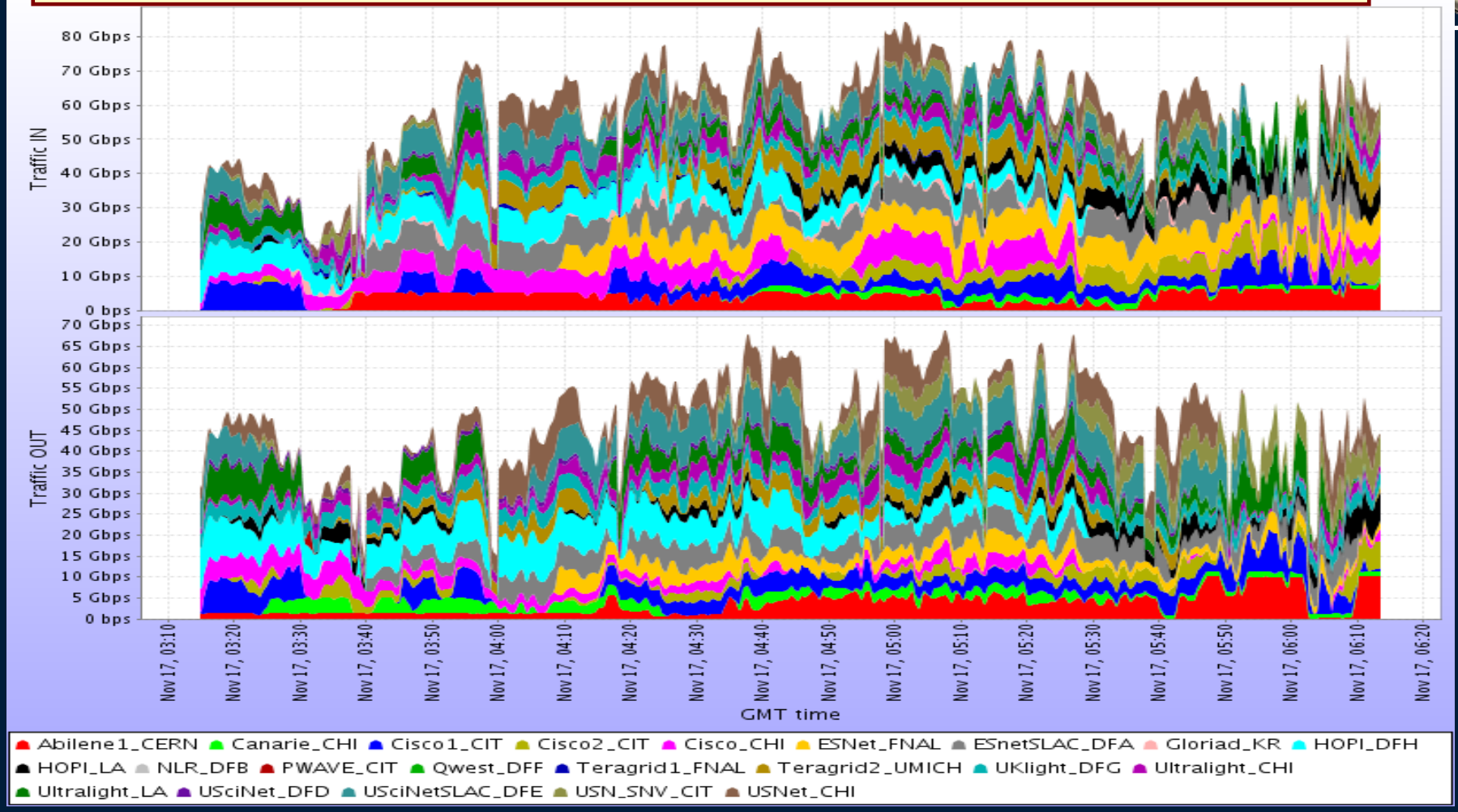
Closing the Digital Divide: R&E Networks in / to Latin America



- RNP2 (Rio de Janeiro) and ANSP (Sao Paulo)
- WHREN/LILA (US NSF)
  - ➔1.2 to 2.5 G by Nov. 2006
  - ➔10G Planned by ~2008
- RedCLARA (EU): Connects 18 Latin Am. NRENs, Cuba; 622 Mbps Link to Europe

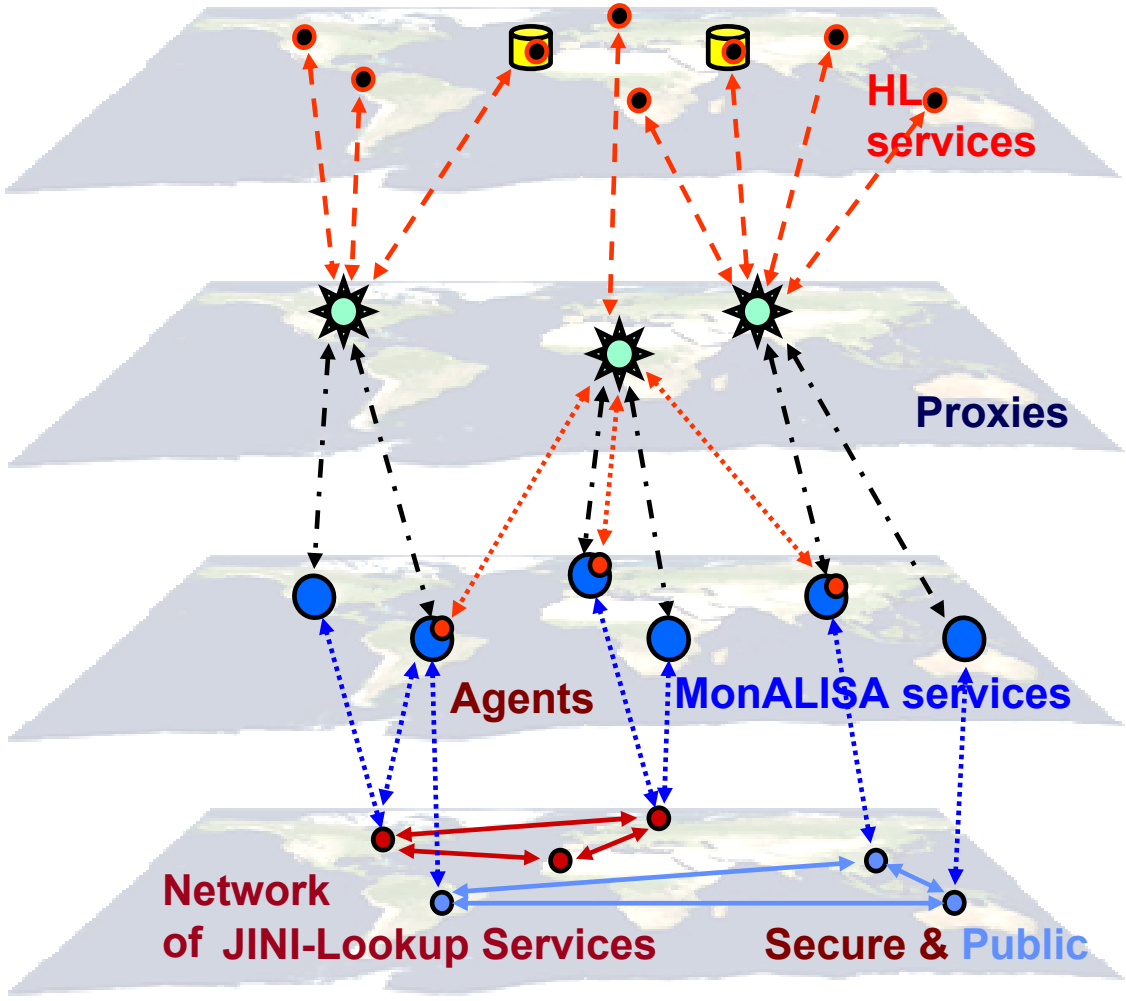
iGrid05, SC05, SC06: 2.5G Sao Paulo to San Diego (with RNP)

It was the first time: a struggle for the equipment and the team



We are working to stabilize, package and deploy these methods and tools widely in 2006-7

The Four-Layer MonALISA Architecture



Regional or Global High Level Services, Repositories & Clients

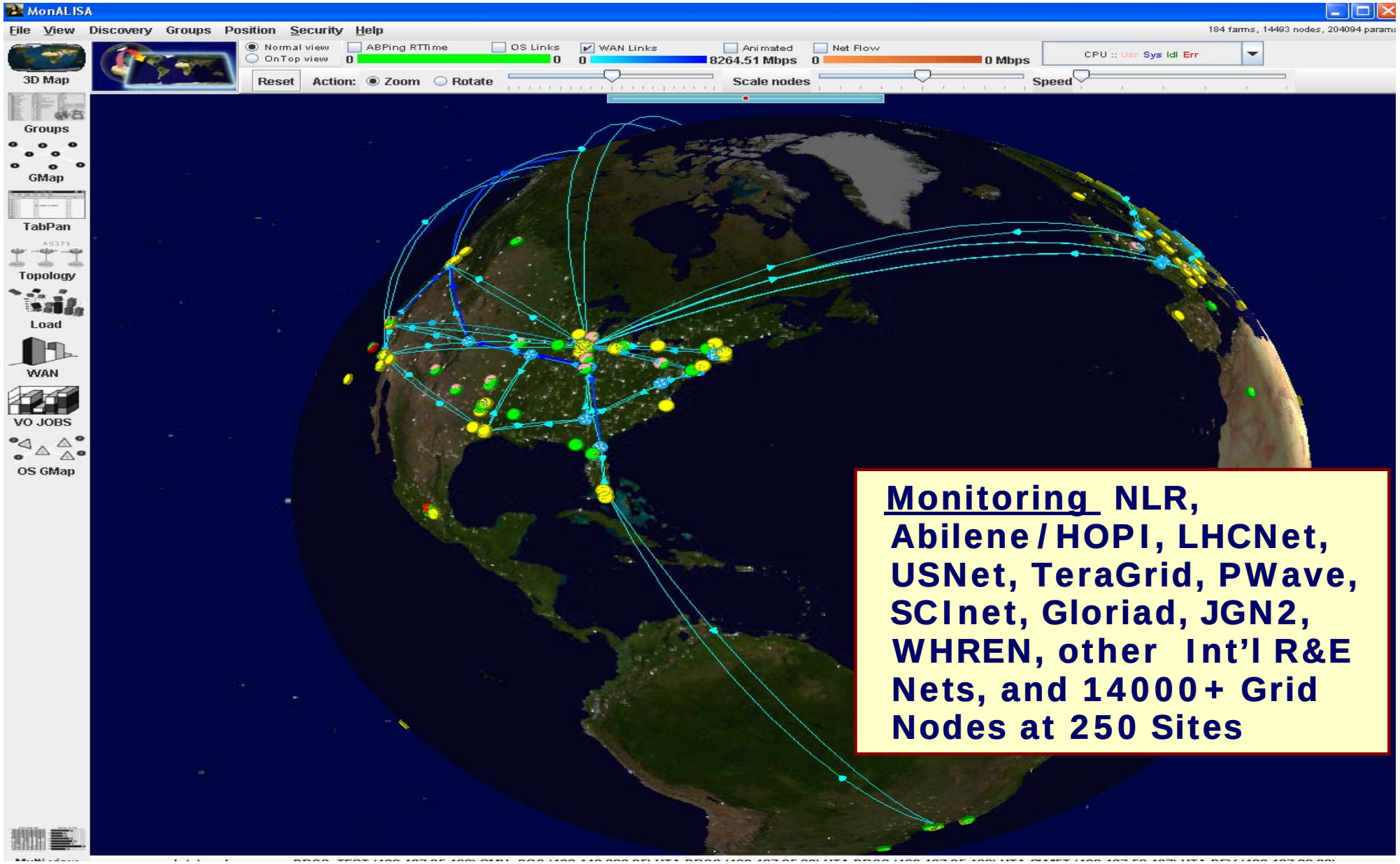
Secure and reliable communication, Dynamic load balancing, Scalability & Replication,AAA for Clients

Distributed System for gathering and analyzing information based on mobile agents: Customized aggregation, Triggers, Actions

Distributed Dynamic Registration and Discovery. Based on a lease mechanism, and robust event-propagation

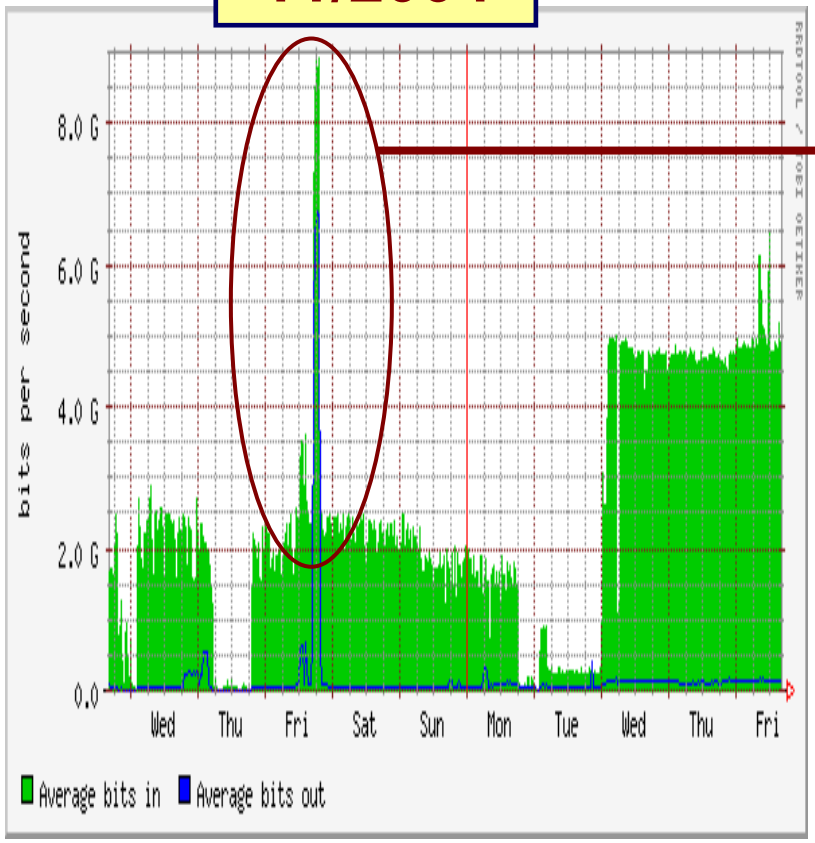
A Distributed System with No Single Point of Failure

MonALISA Monitoring during Bandwidth Challenge



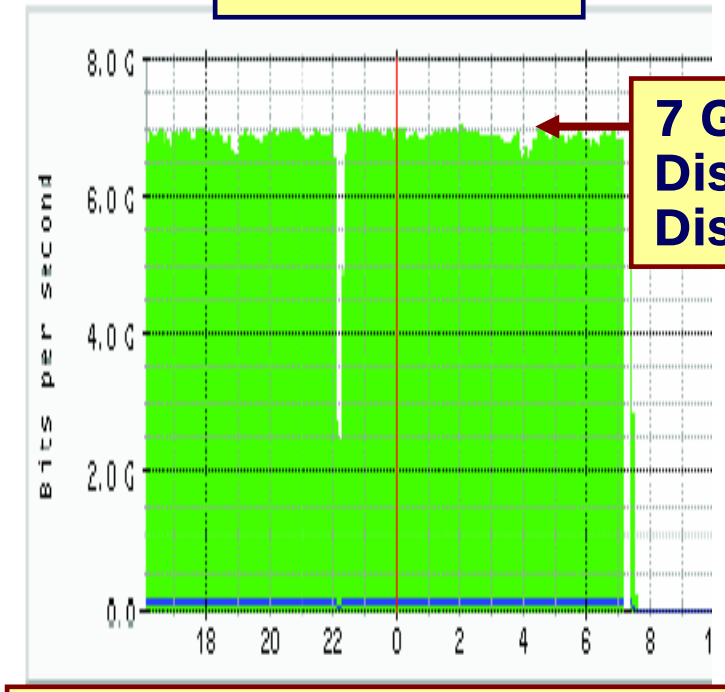
FNAL-CERN Service Challenges
Traffic Over LHCNet (Starlight-CERN)

SC1: 11/2004



FAST TCP Flows don't affect production traffic; Not the case with std. TCP, to 9 Gbps

SC2 4/5/2005



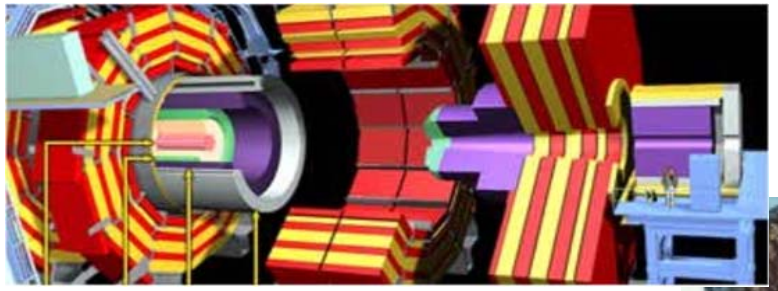
7 Gbps Disk to Disk

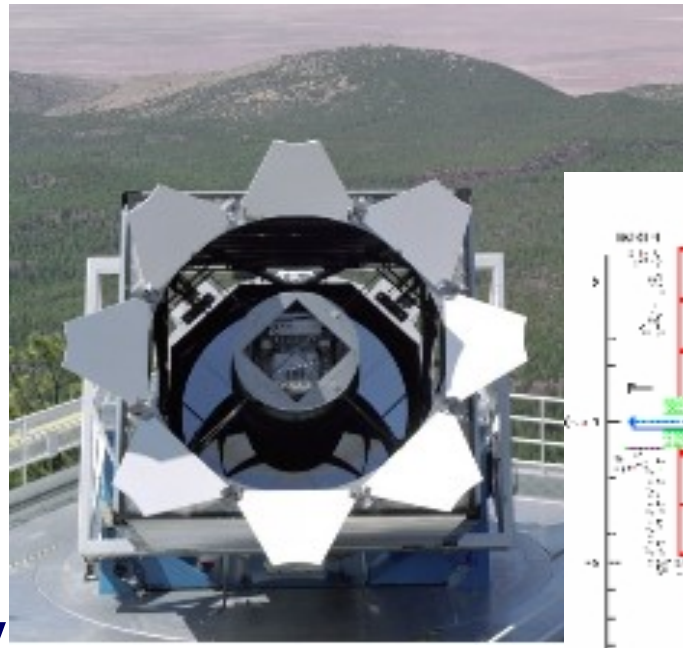
Cluster Capability ~60 Gbps Limited by the Network

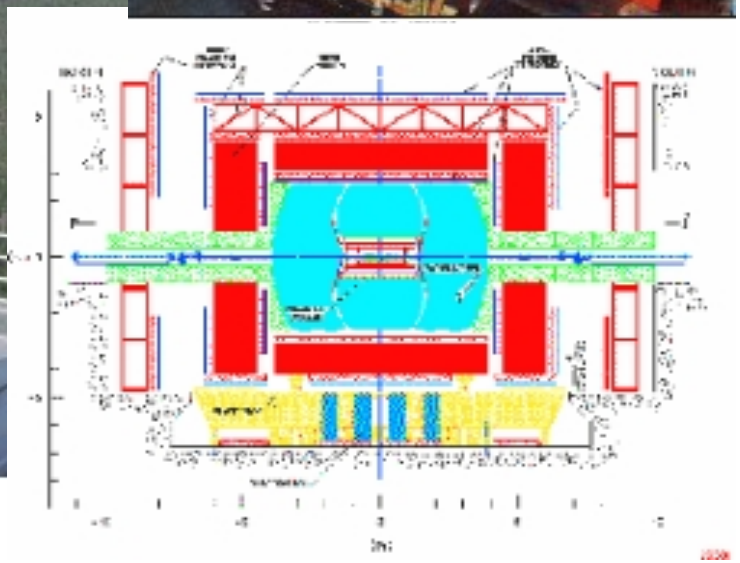
Data Analysis in the LHC Era Will Be a New Experience

Fermilab

- BWC data sources were the *Production Storage Systems and File Servers* used by:
  - CDF
  - DØ
  - US CMS Tier 1
  - Sloan Digital Sky Survey
- ~600 gridftp servers (of 1000s) were directly involved
- Each of these produces, stores and moves Multi-TB to PB-scale data: Tens of TB per day





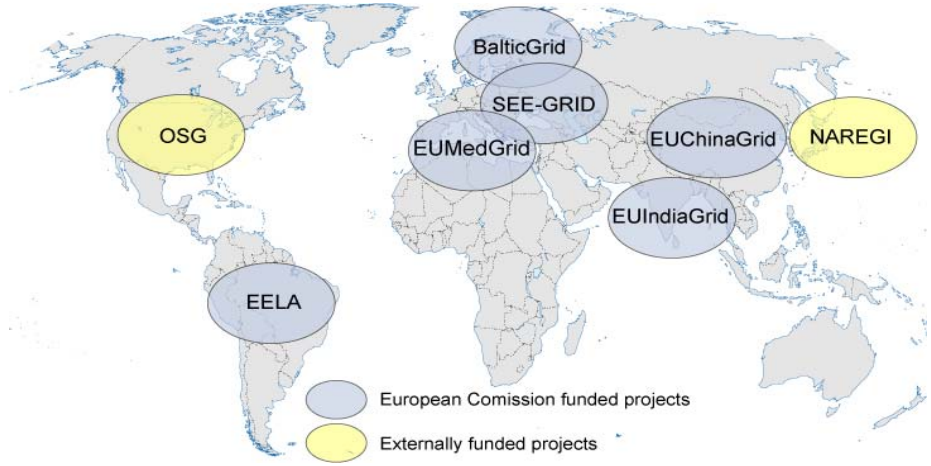


EGEE-II Scope & Outreach

- 32 countries
- 13 federations

→ Major and national Grid projects in Europe, USA, Asia

+ 27 countries through related projects:
  - BalticGrid
  - EELA
  - EUChinaGrid
  - EUIndiaGrid
  - EUMedGrid
  - SEE-GRID



At the end of this year

We build the first segment of the academic grid network to join:

- Bogolyubov institute for theoretical physics
- Kharkov institute of physics and technology
- Institute of microbiology and genetics
- Main astronomic observatory
- Kiev National University
- Lvov institute of condensed matter physics
- Institute of cell biology and genetic engineering

Expected resources of the segment:

Approx. 200 CPU; total SE capacity 30 – 50 TB.

Next year

We plan to expand the segment of UAGI, to involve other Ukrainian organizations:

Institute of cybernetics (NASU),
Institute of scintillating materials (NASU),
Kharkov National University,
Institute of physics of metals (NASU),
Institute of physics (NASU) …