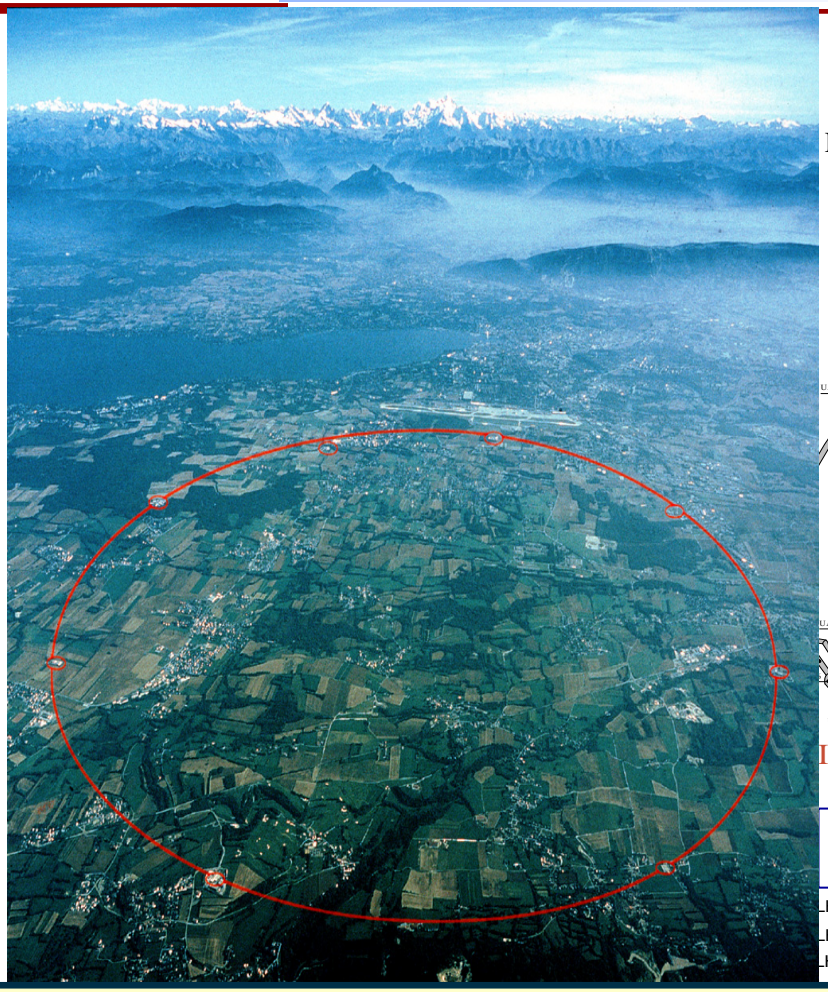
High Energy Physics: Networks and Grids for Global e-Science, and the Digital Divide

Harvey B. Newman

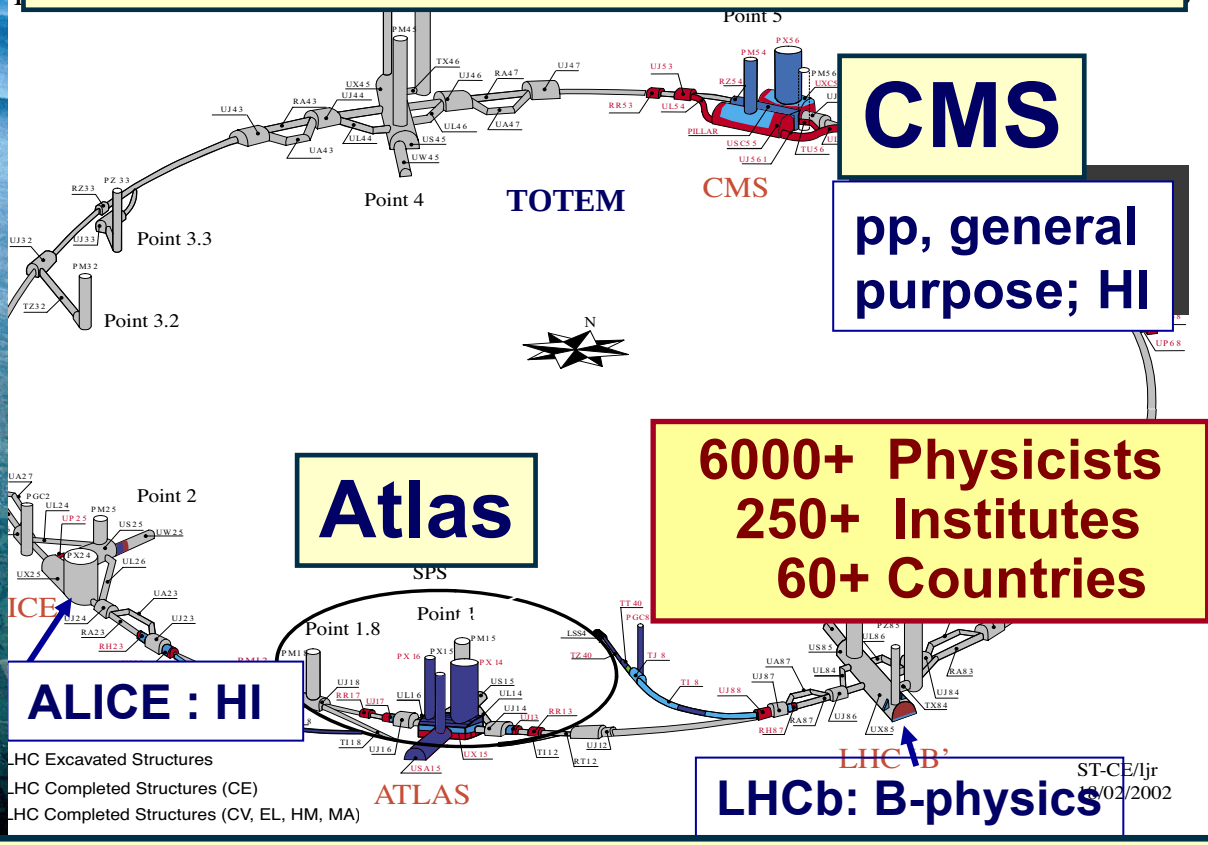
California Institute of Technology

Science & Development: Innovation Systems for Fighting Poverty Session
APS Dallas Meeting, April 22, 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

ST-CE/ljr
15/02/2002

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

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

CMS Experiment

Online System

0.1 - 1.5 GB/s

CERN/Outside Resource Ratio ~1:4

Tier0/(Σ Tier1)/(Σ Tier2) ~1:2:2

Tier 0

CERN T0

10-40 Gb/s

Tier 1

Taiwan T1 | Italy T1 | UK T1 | FNAL T1 | ...

2.5 - 30 Gbps

Tier 2

Physics caches across Tier 2

UltraLight

Wisconsin | Caltech | UCSD | Florida | ...

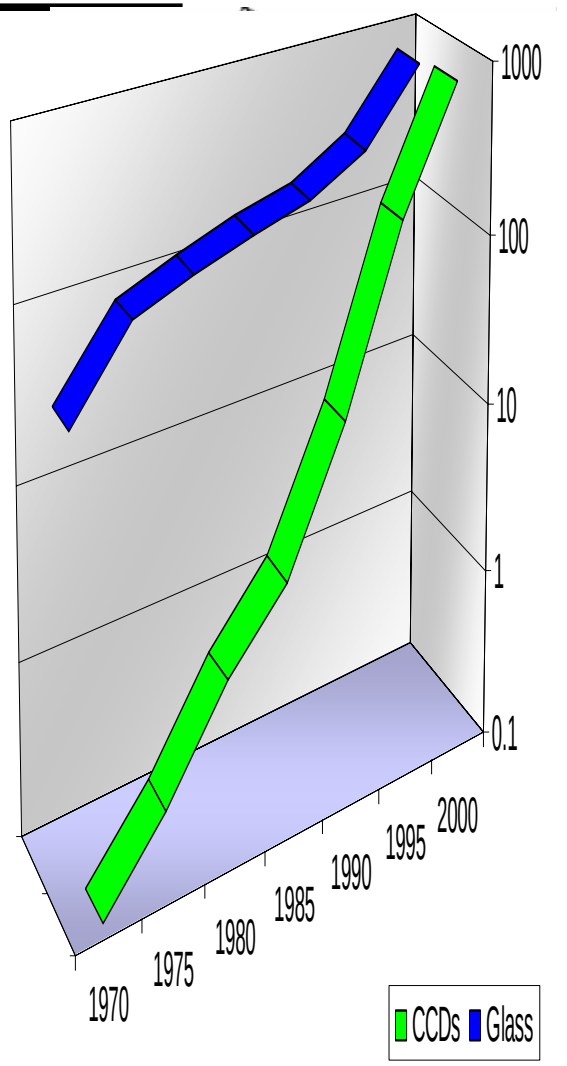
Tier 3

Univ. T3 | Univ. T3 | Univ. T3 | Univ. T3 | Univ. T3

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

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 & space correlations in 400-D space
  - **Redshift Survey of 1M Galaxies and 100k Quasars**
- **Few hundred TB now: moving to PBytes**
  - *1 pixel (byte) / sq arc second ~ 4TB*
  - *Multi-spectral, temporal, … ➡ PB's*
- **Data doubles every year;**
  Data is public after 1 year



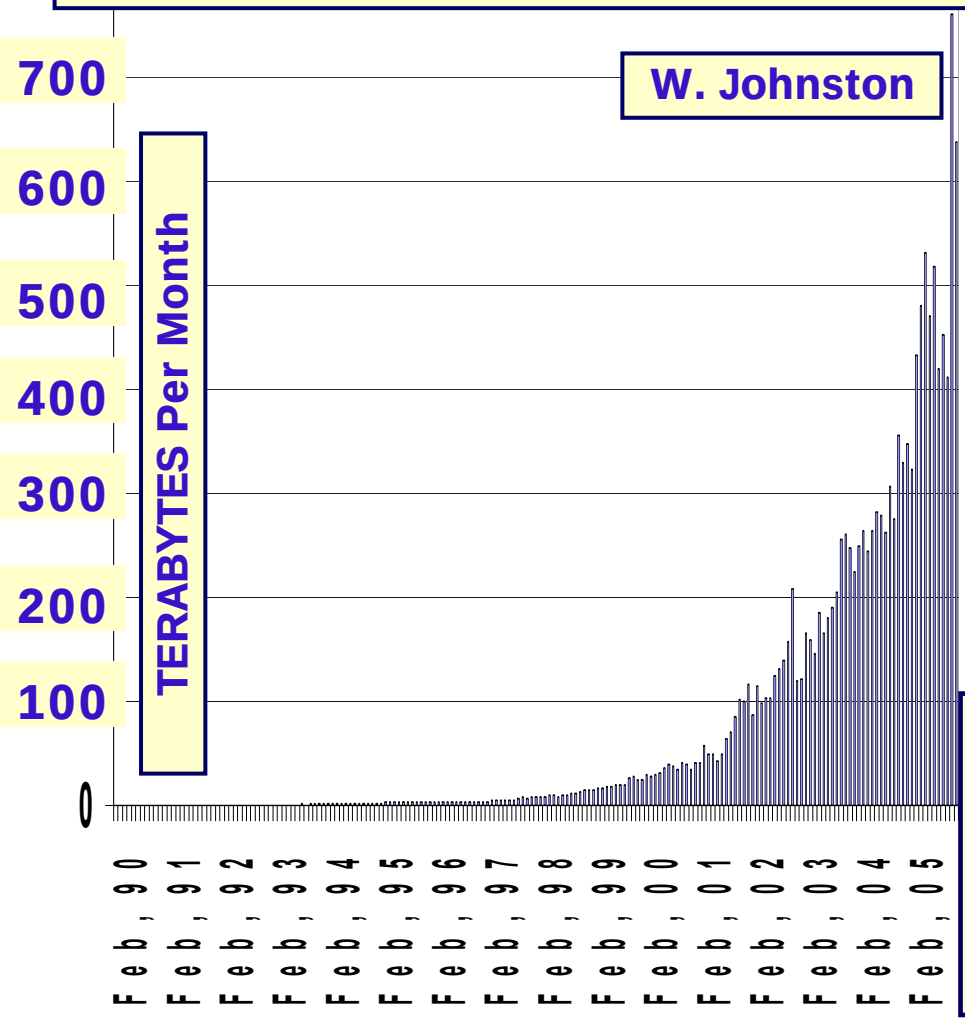
Challenges of Next Generation Science in the Information Age

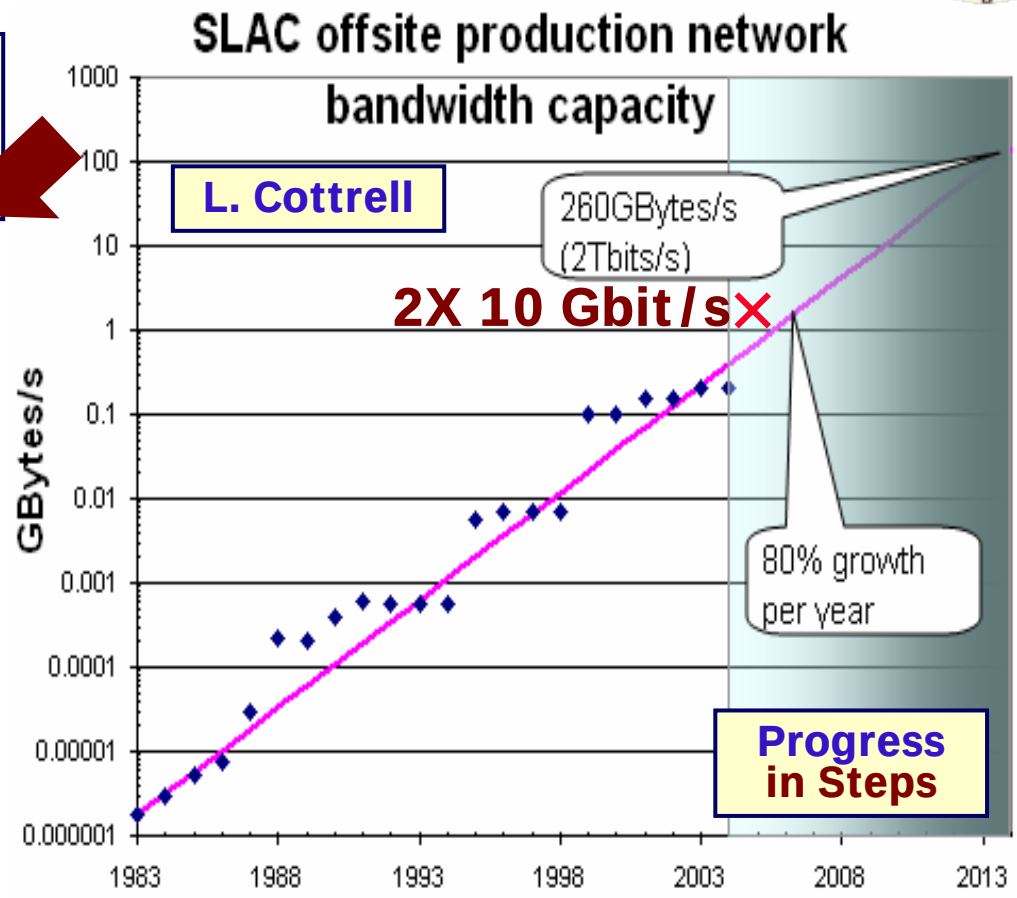
Petabytes of complex data explored and analyzed by 100s-1000s of globally dispersed scientists, in 10s-100s of teams

- **Advanced integrated Grid applications rely on reliable, high performance operation of our LANs and WANs**
- **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 with rapid turnaround, *Work Collaboratively over great distances***

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

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





- SLAC Traffic ~400 Mbps; Growth in Steps (ESNet Limit): ~ 10X/4 Years.
- Fall '05: 2x10 Gbps links: one for production, one for R&D
- 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: ~1000 Times Bandwidth Growth Per Decade;
Paralleled by ESnet Roadmap for Data Intensive Sciences

Evolving Quantitative Science Requirements for Networks (DOE High Perf. Network Workshop)

See http://www.doecollaboratory.org/meetings/hpnpw/

Science Areas	Today *End2End* Throughput	5 years End2End Throughput	5-10 Years End2End Throughput	Remarks
High Energy Physics	0.5 Gb/s	100 Gb/s	1000 Gb/s	High bulk throughput
Climate (Data & Computation)	0.5 Gb/s	160-200 Gb/s	N x 1000 Gb/s	High bulk throughput
SNS NanoScience	Not yet started	1 Gb/s	1000 Gb/s + QoS for Control Channel	Remote control and time critical throughput
Fusion Energy	0.066 Gb/s (500 MB/s burst)	0.198 Gb/s (500MB/ 20 sec. burst)	N x 1000 Gb/s	Time critical throughput
Astrophysics	0.013 Gb/s (1 TB/week)	N*N multicast	1000 Gb/s	Computat'l steering and collaborations
Genomics Data & Computation	0.091 Gb/s (1 TB/day)	100s of users	1000 Gb/s + QoS for Control Channel	High throughput and steering

ICFA Standing Committee on Interregional Connectivity (SCIC)

Commissioned by ICFA in 1998

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 warning, help deal with 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:
Focus on the 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
  - ➔ 28 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:

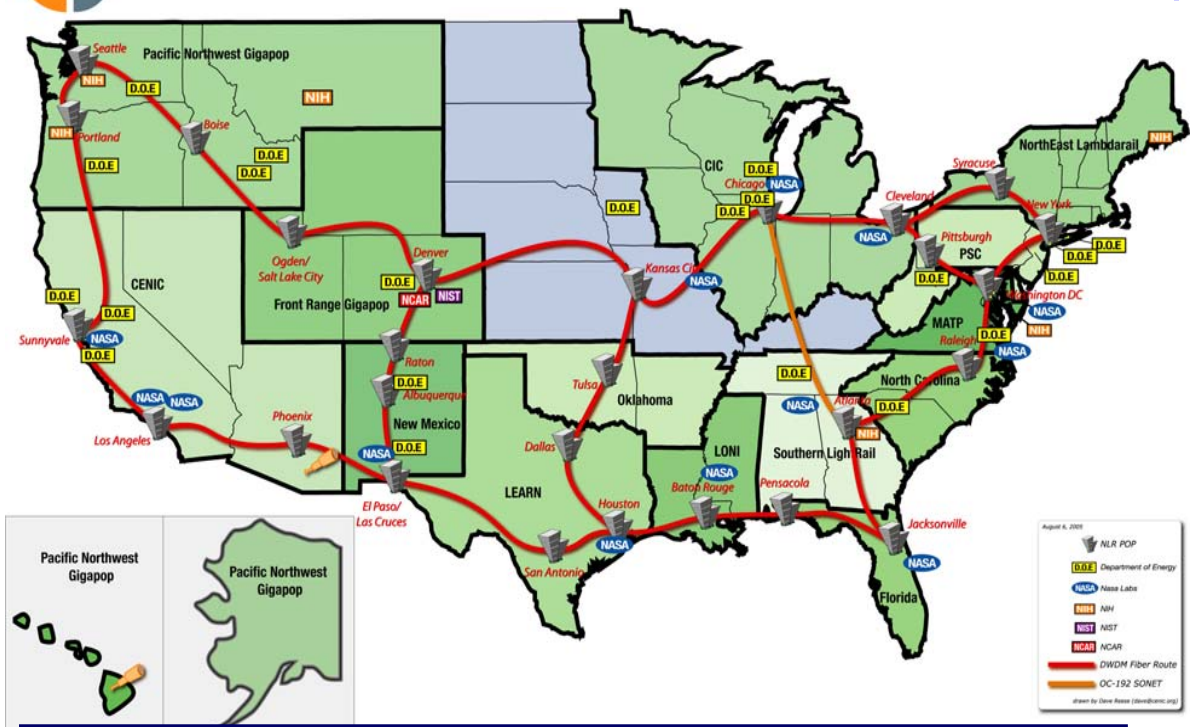
- TERENA (www.terena.nl) *2005 Compendium:* In-depth Annual Survey on R&E Networks in Europe
- http://internetworldstats.com: Worldwide Internet Use
- *SCIC 2003 Digital Divide Report* [A. Santoro et al.]

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*
  - → BW Growth: 4 to 2500X in 5 Yrs Much Faster than Moore's Law
- 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"
- Proliferation of 10G links across the Atlantic & Pacific; Use of multiple 10G Links (e.g. US-CERN) on major paths began in Fall 2005
  - →On track for ~10 X 10G networking for LHC, in production by 2007-8
- Technology evolution continues: performance higher, lower cost
  - →E.g. Commoditization of GbE and now 10 GbE
  - →Release of PCI Express network interfaces at end 2005
- ➡ 2006 Outlook: Continued growth in bandwidth deployment & use

Transition accelerating: to Community Owned or Leased "dark fiber" multi-wavelength networks for Research and Education

National Lambda Rail (NLR): www.nlr.net



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

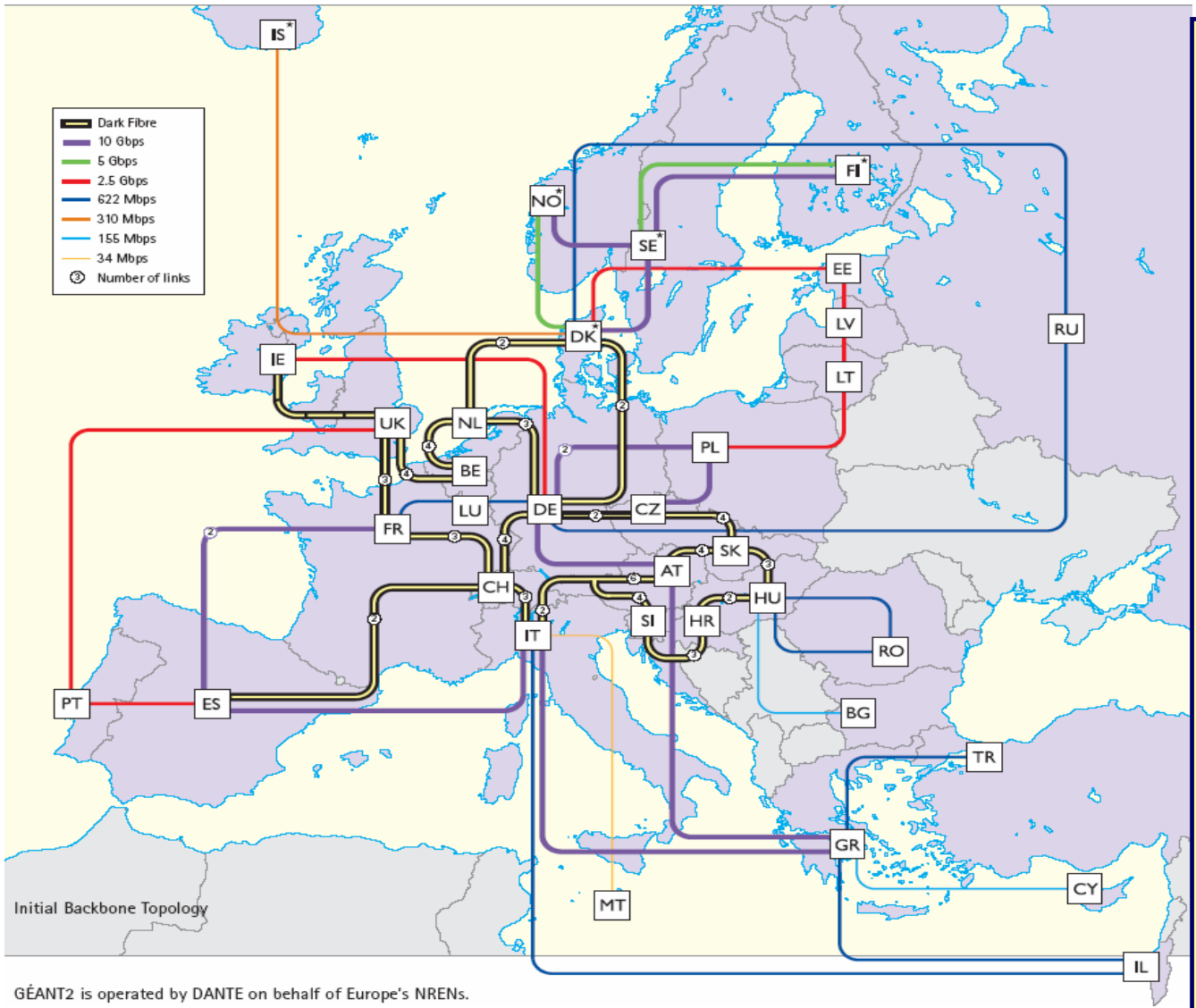
NLR

- Rollout Completed in 2005-6
- To 40 10G Waves
- *Supports: Ultralight, TeraGrid Internet2 HOPI, UltraScience Net* Initiatives w/ HEP

A Network of Networks

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

The GÉANT2 Footprint: Now Being Implemented



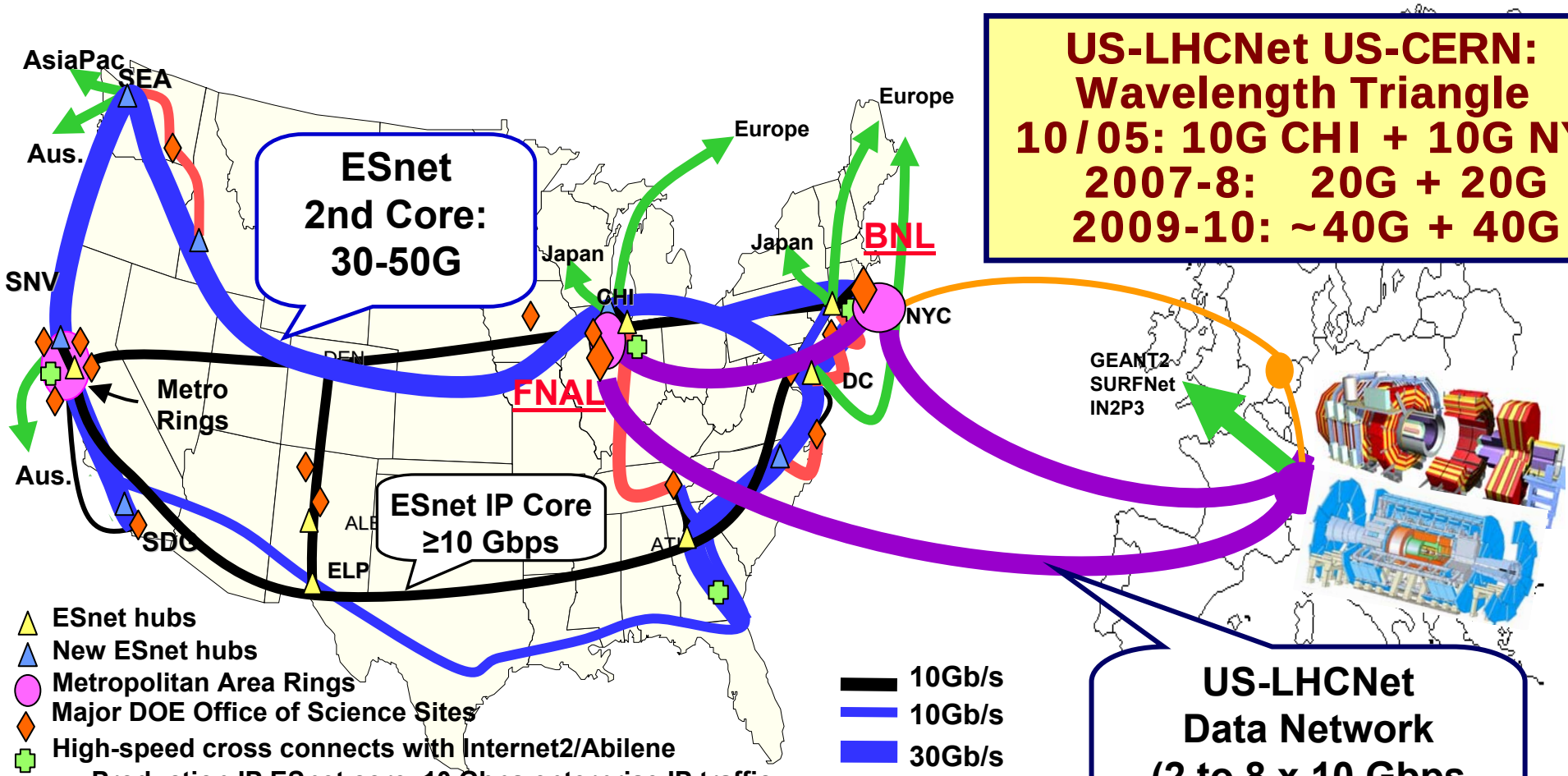
GÉANT2 is operated by DANTE on behalf of Europe's NRENs.

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

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



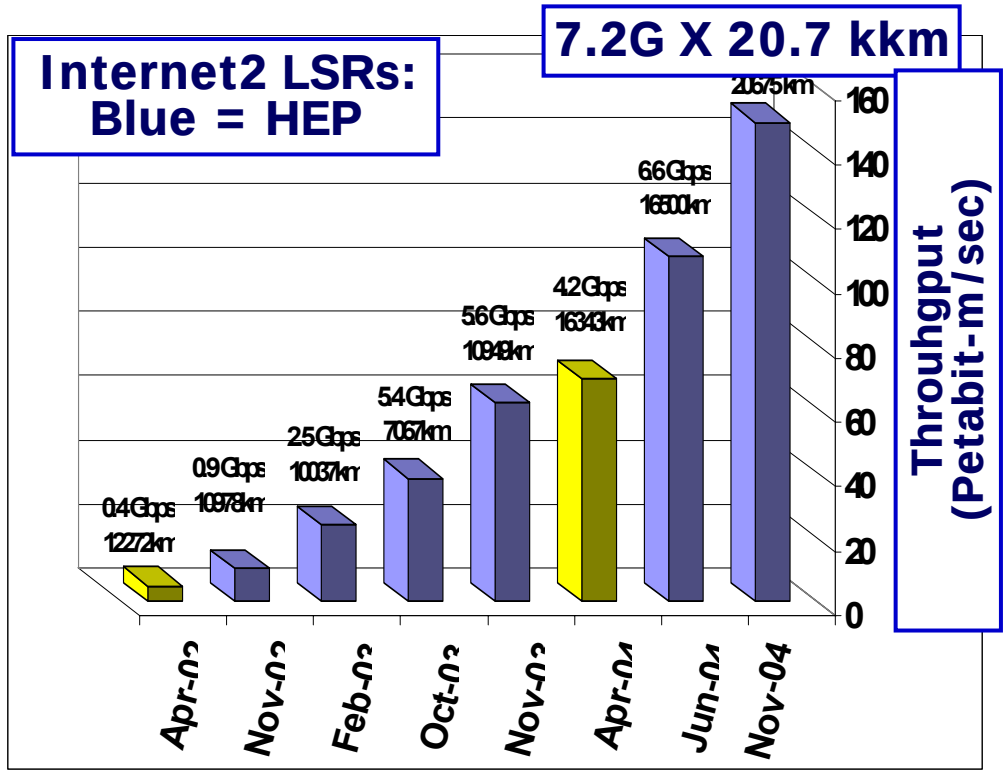
US-LHCNet US-CERN:
Wavelength Triangle
10/05: 10G CHI + 10G NY
2007-8: 20G + 20G
2009-10: ~40G + 40G

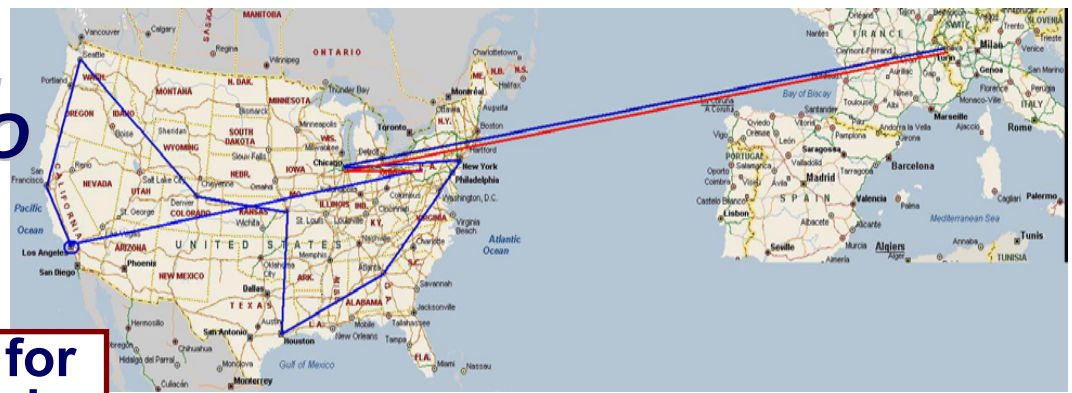
US-LHCNet Data Network (2 to 8 x 10 Gbps US-CERN)

ESNet MANs to FNAL & BNL; Dark fiber to FNAL

Internet2 Land Speed Records & SC2003-2005 Records

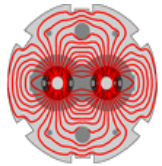
- IPv4 Multi-stream record with FAST TCP: 6.86 Gbps X 27kkm: Nov 2004
- PCI-X 2.0: 9.3 Gbps Caltech-StarLight: Dec 2005
- *Concentrate now on reliable Terabyte-scale file transfers*
  - *Disk-to-disk Marks: 536 Mbytes/sec (Windows); 500 Mbytes/sec (Linux)*
  - *System Issues: PCI-X Bus, Network Interfaces, Disk I/O Controllers, Linux Kernel,CPU*





NB: Computing Manuf.'s Roadmaps for 2006: One Server Pair ~ One 10G Link

SC|05 Global Lambdas for Particle Physics



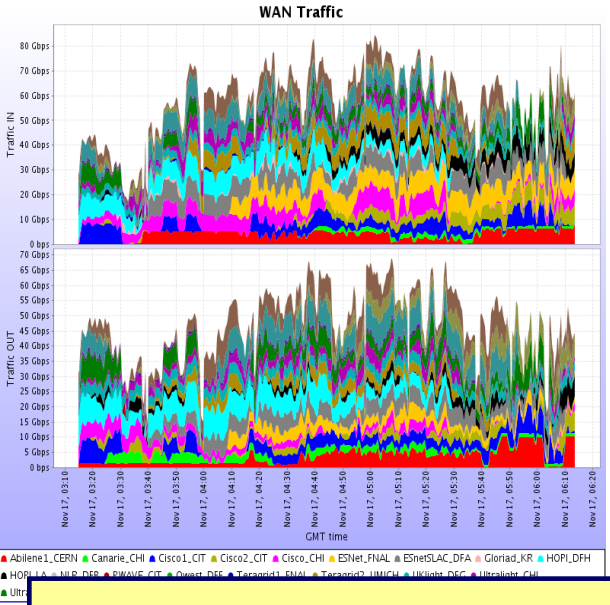
- **We previewed the global-scale data analysis of the LHC Era**

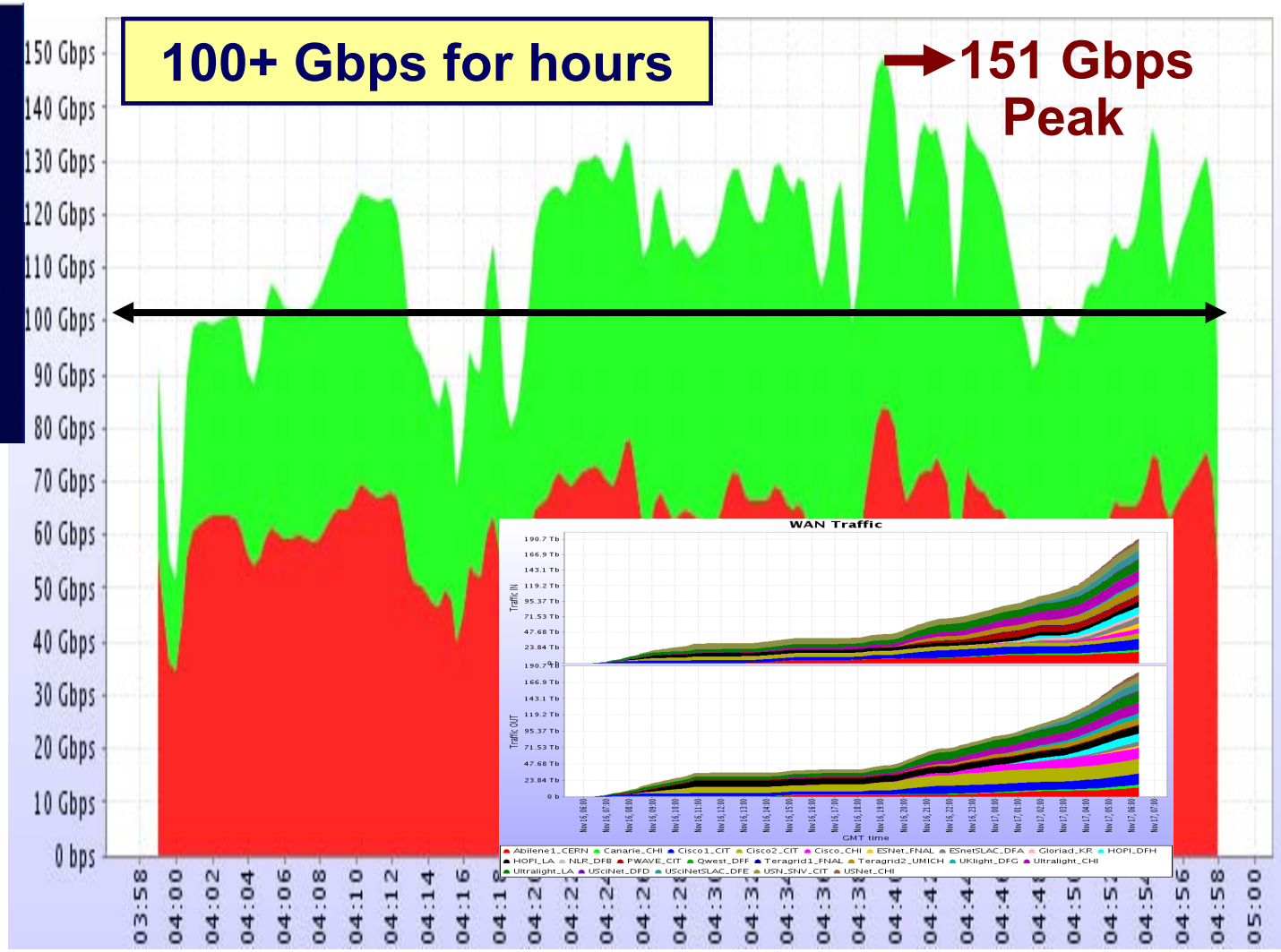
  Using a realistic mixture of streams:
  - **Organized transfer of multi-TB event datasets; plus**
  - **Numerous smaller flows of physics data that absorb the remaining capacity**

- ***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

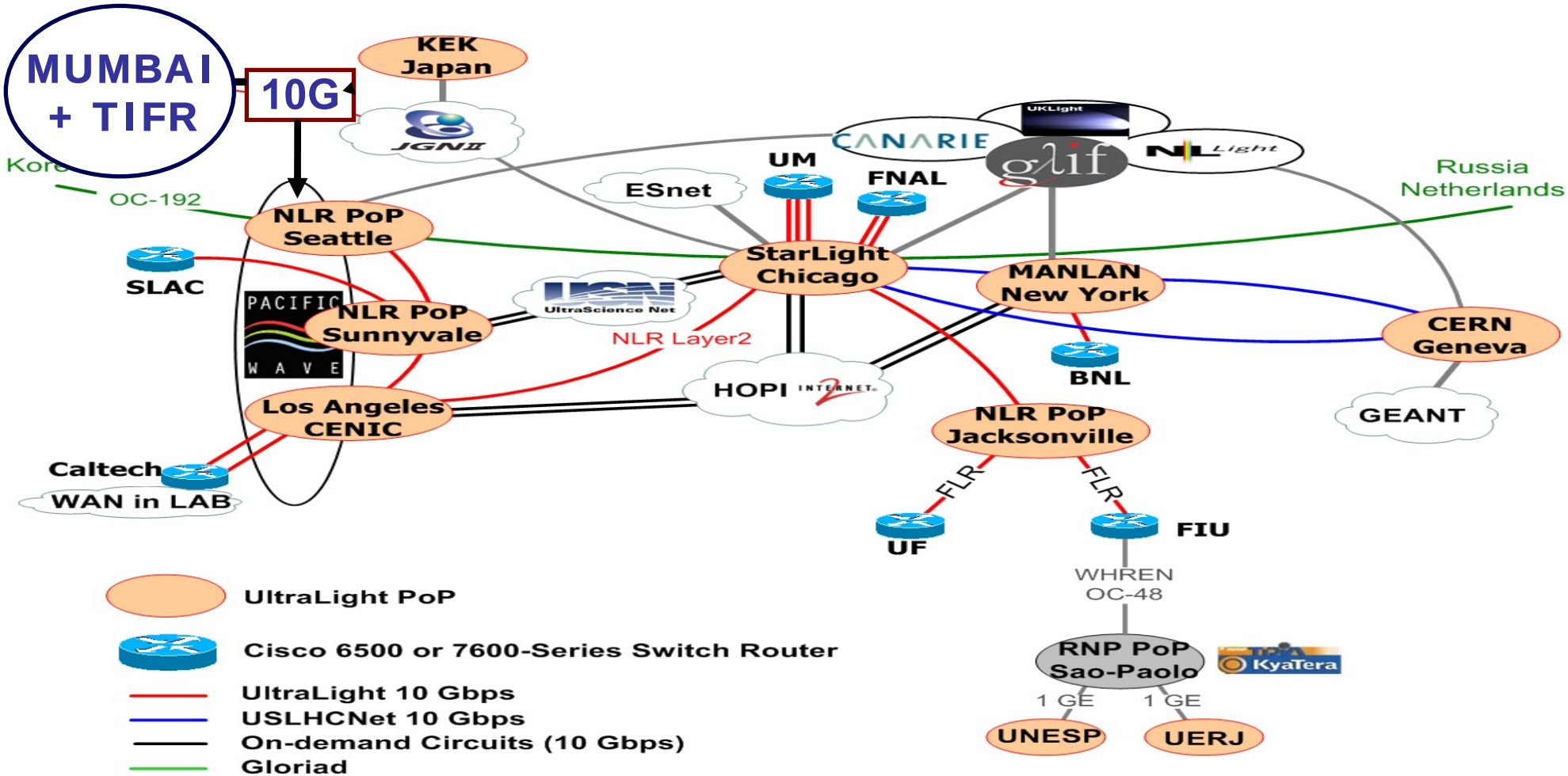




475 TB Total in < 24h; Sustained Rate of 1.1 Petabyte Per Day

UltraLight

4 Continent Testbed



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

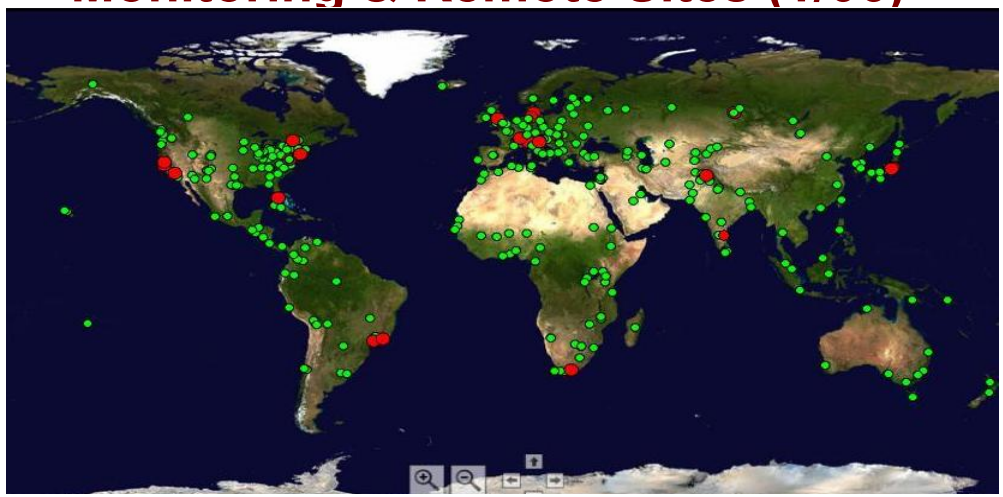
SCIC Main Conclusions for 2006

- ***As we progress we are in danger of leaving the communities in the less-favored regions of the world behind***
- ***<u>We must Work to Close the Digital Divide</u>***
  - ➔ ***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***
- ***We are learning to help do this effectively, in some cases***
  - ➔ ***Brazil and Central Europe***
- ***A great deal of work remains: India, Russia, China, Central and Eastern Europe are focal points for 2006***

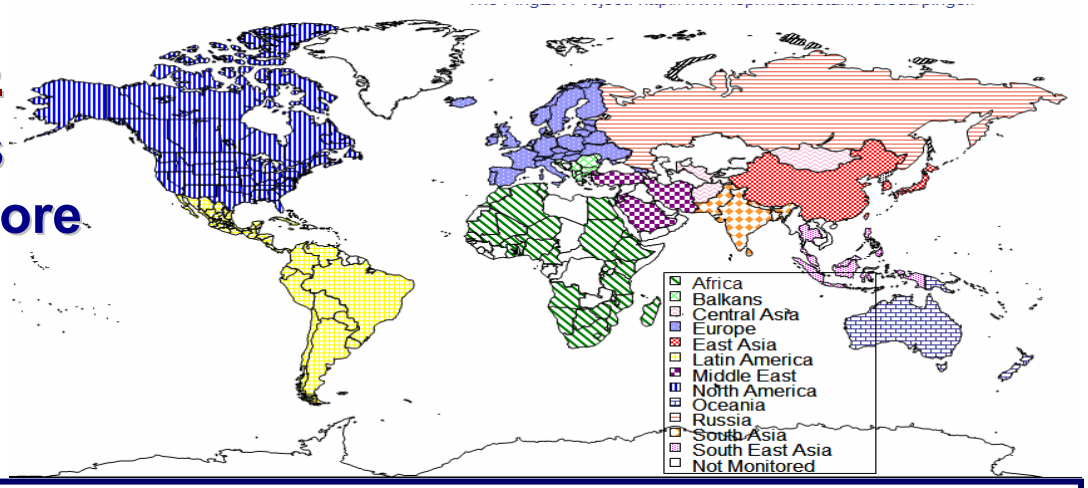
SCIC Monitoring WG
PingER (Also IEPM-BW)

R. Cottrell

Monitoring & Remote Sites (1/06)



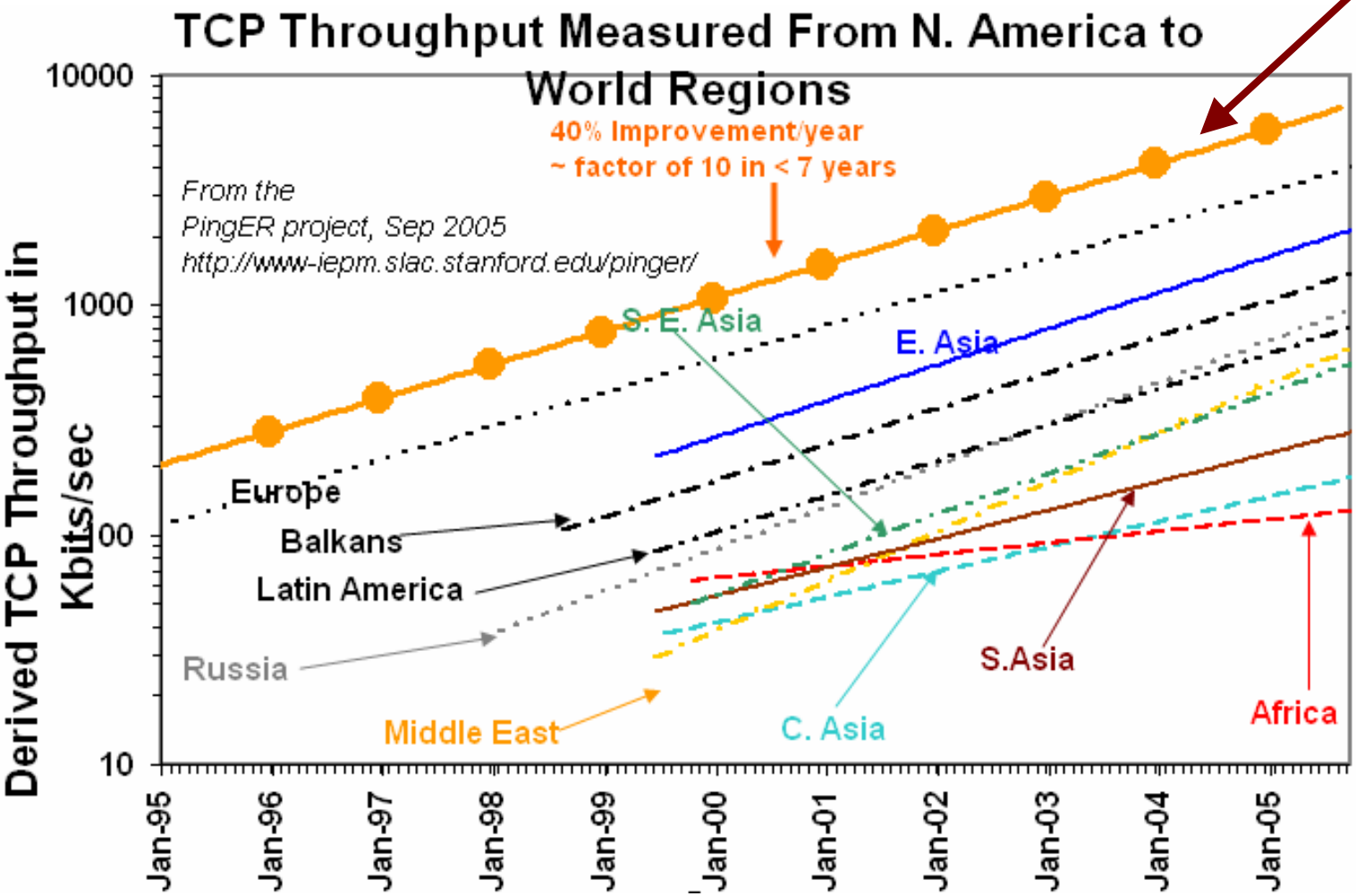
- **Measurements from 1995 On**
  - *Reports link reliability & quality*
- **Countries monitored**
  - → Contain 90% of world population
  - → 99% of Internet users
- **3700 monitor-remote site pairs**
  - → 35 monitors in 14 countries Capetown,Rawalpindi, Bangalore
  - → 1000+ remote sites in 120 Countries



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

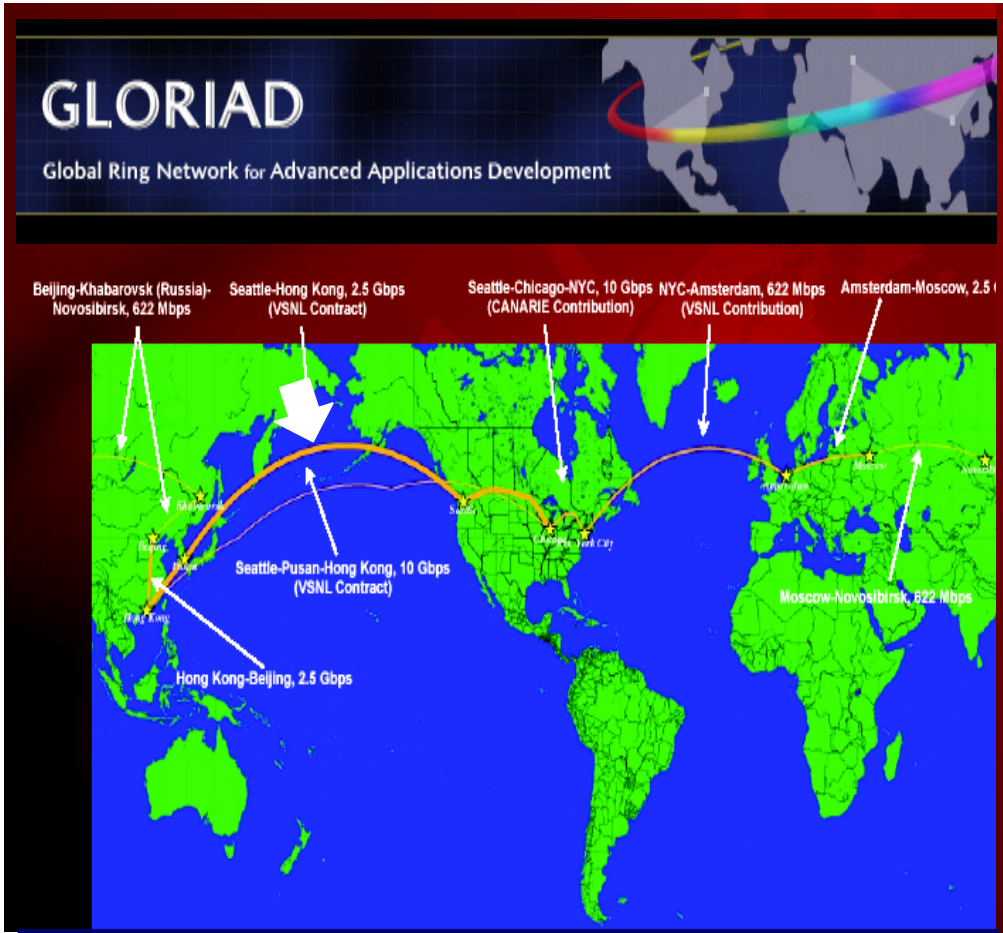
*Bandwidth of TCP < MSS/(RTT*Sqrt(Loss))*

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

Work on the Digital Divide from Several Perspectives

- **Work Within the Community: Locally and Globally**
- **Technical Help with Modernizing the Infrastructure:**
  - **Provide Tools for Effective Use: Data Transport, Monitoring, Collaboration**
  - **Design, Commissioning, Development**
- **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***

GLORIAD: 10 Gbps Optical Ring Around the Globe by Spring 2007



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

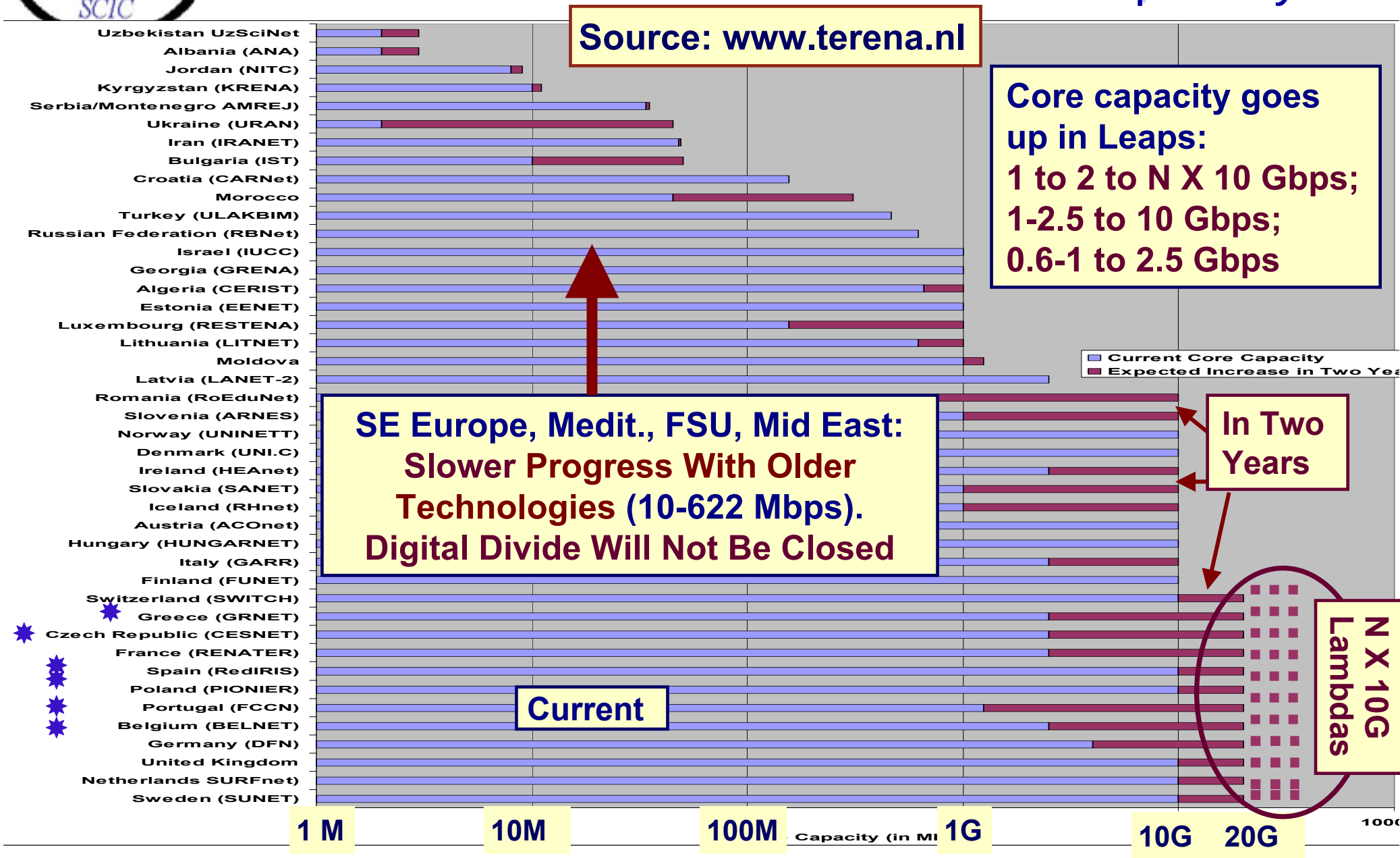
US: NSF IRNC Program

GLORIAD Circuits Today

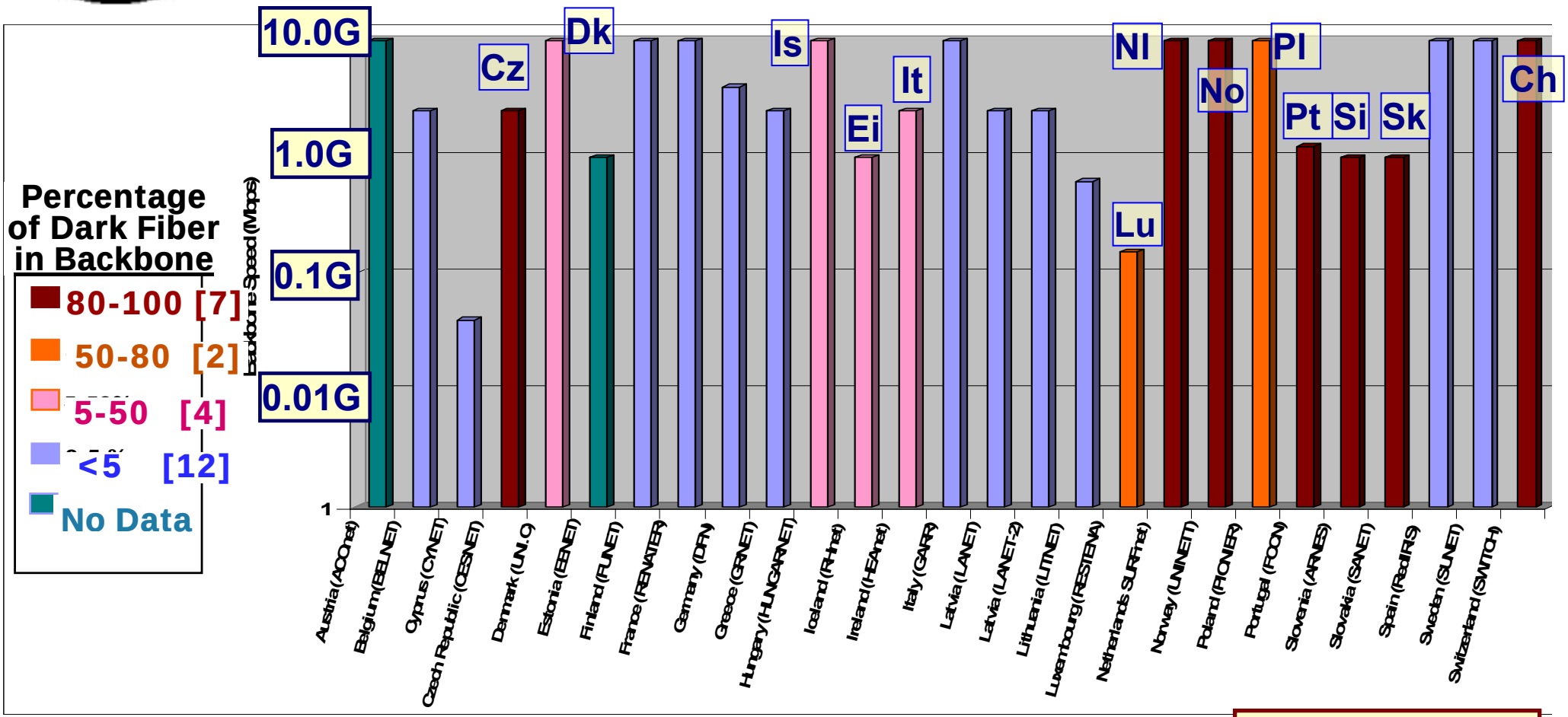
- 10 Gbps Busan-Hong Kong-Daejon-Seattle
- 10 Gbps Seattle-Chicago-NYC (CANARIE contribution to GLORIAD)
- 2.5 Gbps Moscow-AMS
- 2.5 Gbps Beijing-Hong Kong
- 622 Mbps Moscow-AMS-NYC
- 155 Mbps Beijing-Khabarovsk-Moscow
- 1 GbE NYC-Chicago (CANARIE)

G. Cole

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

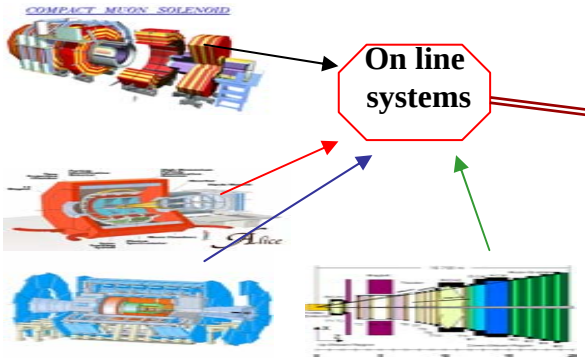
Source: TERENA www.terena.nl

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 and Internet2 Workshops on R&E Networking in Africa***
- ***In 2006***
  - ***CHEP06 Mumbai: Digital Divide Panel [SCIC, TIFR, CDAC, Internet2]***
  - ***Workshop on "Moving India into the Global Community Through Advanced Networking"***
  - ***Side Event to ICHEP06 (Moscow), on Networking in Russia***
  - ***DDW06 Workshop: Cracow and Romania, October 11-14, 2006***

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 and bilateral projects with Caltech Group**



Brazilian HEPGRID

T0 +T1

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

CERN

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

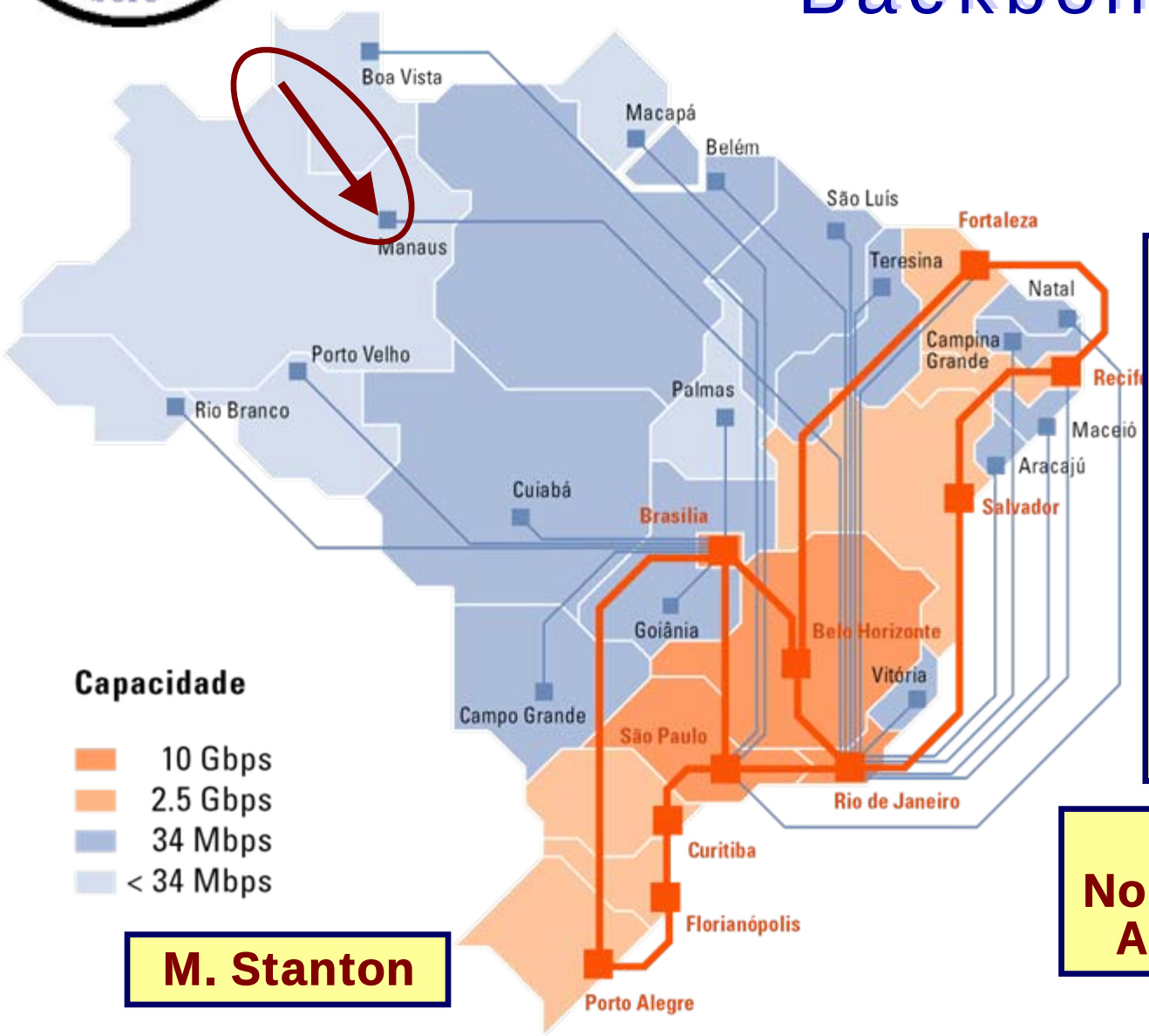
UFRJ

T4

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

Extend to Colombia by 2006

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**
- **Expect 200 Institutions Connected at 1 GbE in 2006**
- **2.5G WHREN (NSF) Link to US; 622M Link to GEANT**

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

Mumbai-Japan-US Links

INDIA

Chennai POP VSNL
LANDING STATIONS

SINGAPORE LANDING STATION

JAPAN

JAPAN LAND
STANDING

VSNL MUX

TIC MUX

TIC

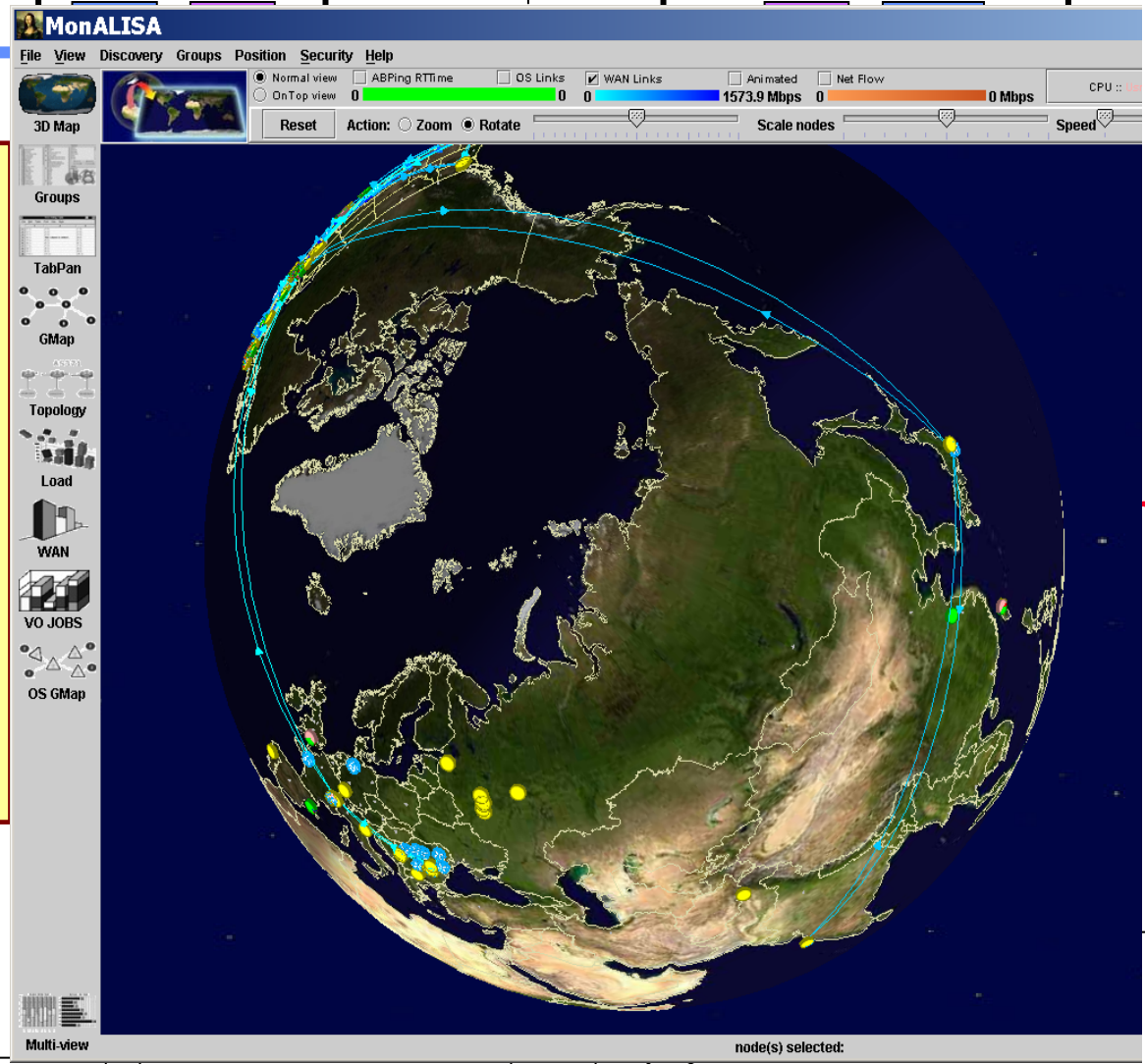
Cable

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:
Pricing a Challenge



STM-16 Ring

Juniper M10 with STM-4 interface

TTML MUX

INTERFACE TYPES

STM 4

INTERFACE TYPES

OC-12

TIFR Mumbai, INDIA

NTT Otemachi Bldg, JAPAN

+ Onward to US, Europe ➡

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

Coincident with Data Transfers of > 500 Mbps

PIONIER (Poland) Cross Border Dark Fiber Plan Locations

Plan: Single GEANT PoP in Poznan

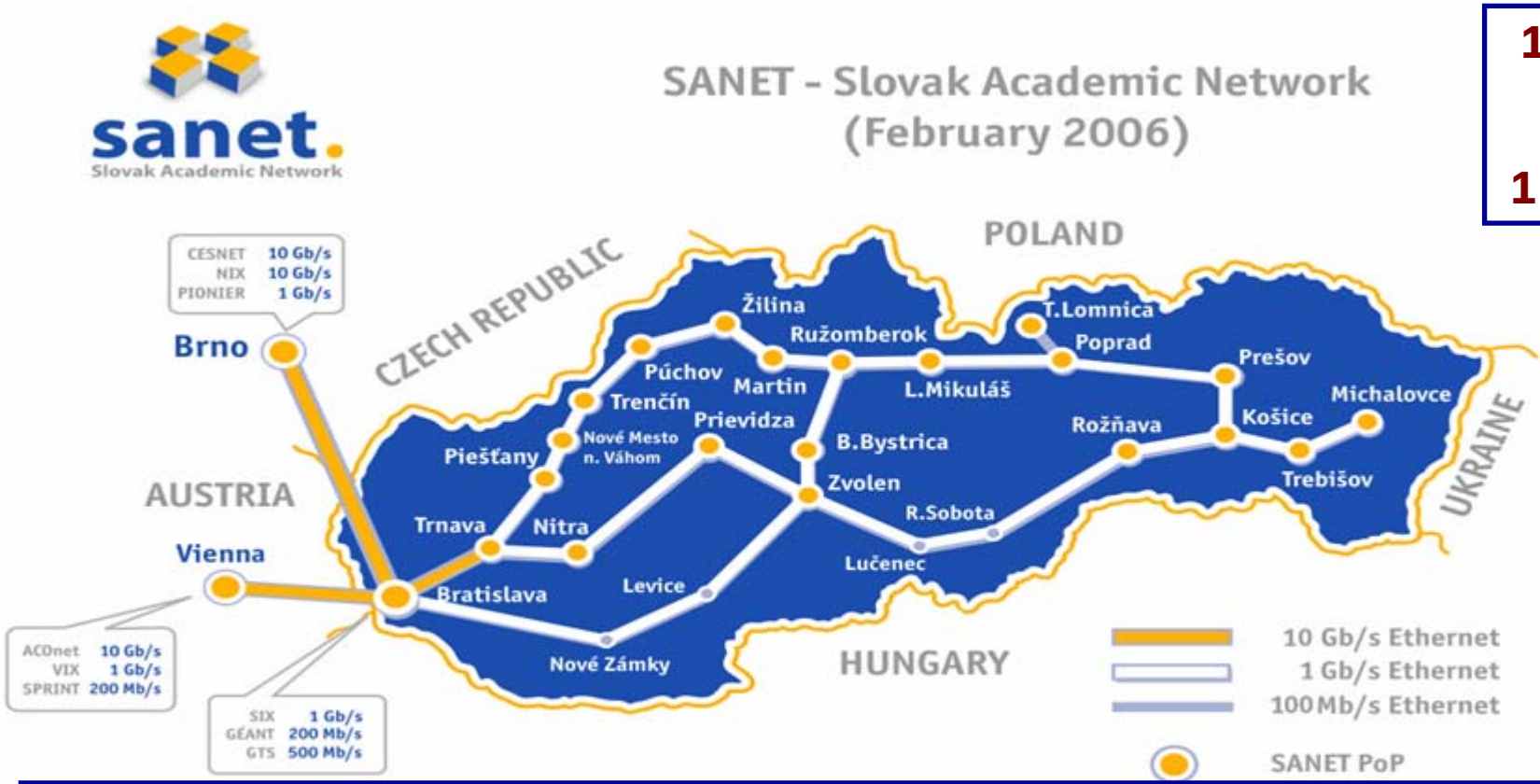
Key Enabler of Networking in Czech Rep., Slovakia, & the Ukraine

64X Backbone Improvement 2002-5

M. Turala

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 Ausria and Czech Republic, and Regional and Metro Nets**

2500x: 2002-2006

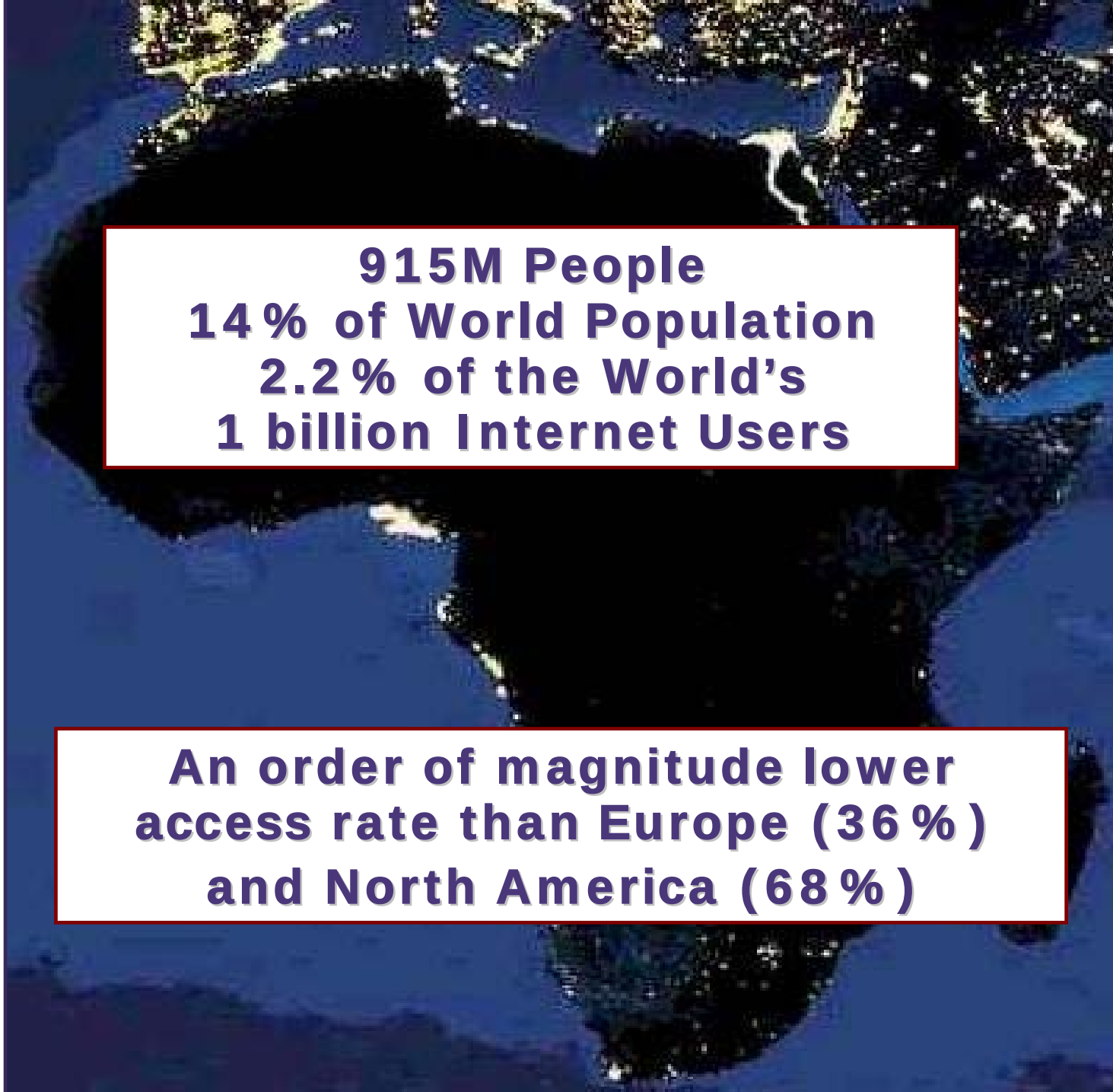
New Focus on AFRICA

Only world region genuinely in decline:

Lack of energy, infrastructure. Lack of expertise

Problems of
- **Disease**
- **Political unrest**
- **Protectionist trade policies**
- **Corruption**

M. Jensen



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

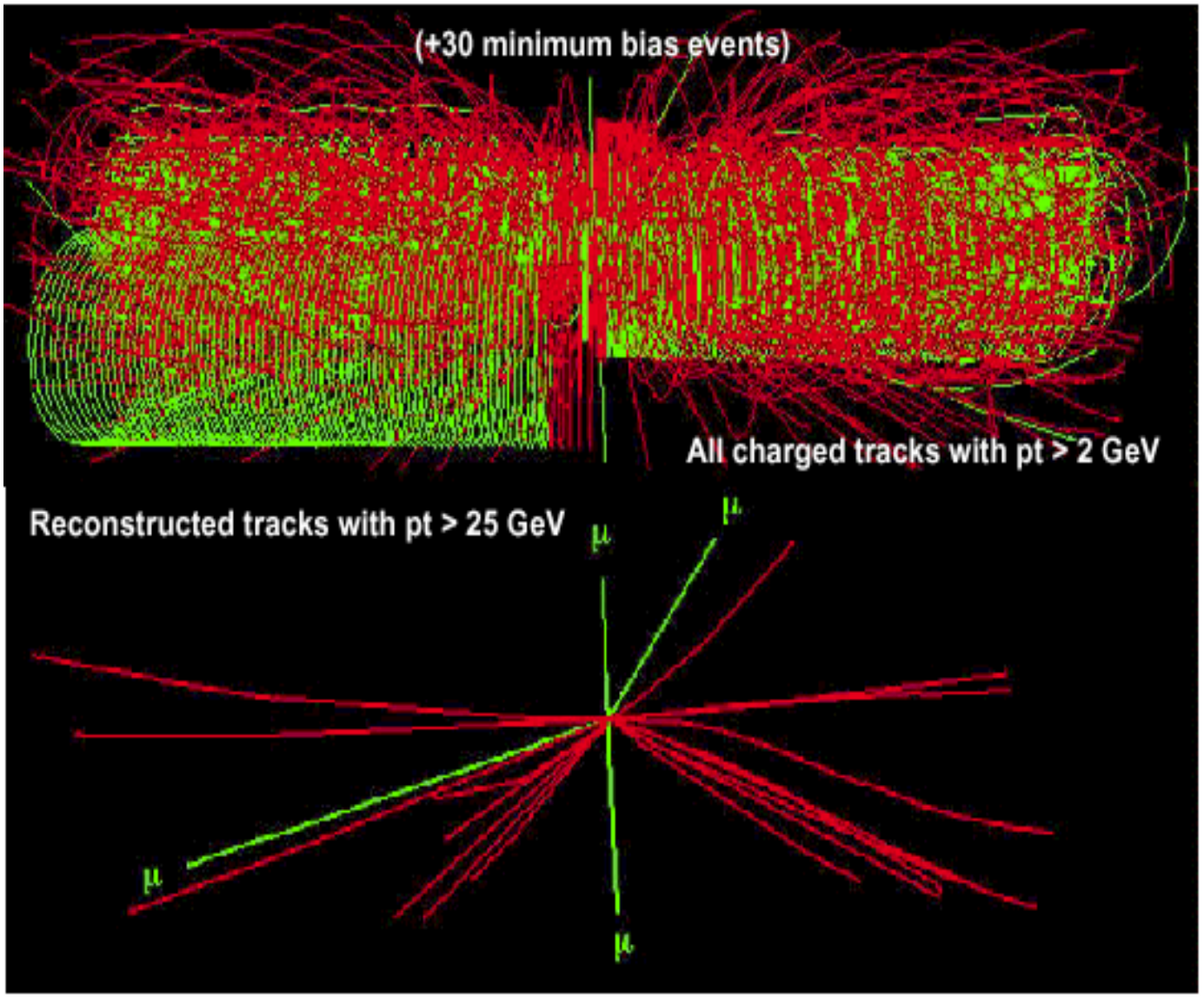
- The national, continental and transoceanic networks used by HEP and other fields of DIS are moving to the N X 10G range
  - Much faster than Moore's Law
- Hybrid "Dark Fiber", R&E community owned/operated hybrid networks are emerging, and fostering rapid progress, in a growing list of nations:
  - 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***
  - ***Helping with the design, implementation and showing effective utilization of modern infrastructures***
  - ***Sharing tools & best practices: in networks, grids and software***
  - ***Providing education and training in a broad range of state of the art technologies & methods***
- ***For the scientific mission, and more broadly:***
  - ***To initiate a sustainable process of innovation, and economic development***
- ***A Long Road Ahead:***
  India, China, SE Europe, Central Asia, Africa

Extra Slides Follow

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

Tier-2s

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

~100 Identified – Number still growing

J. Knobloch

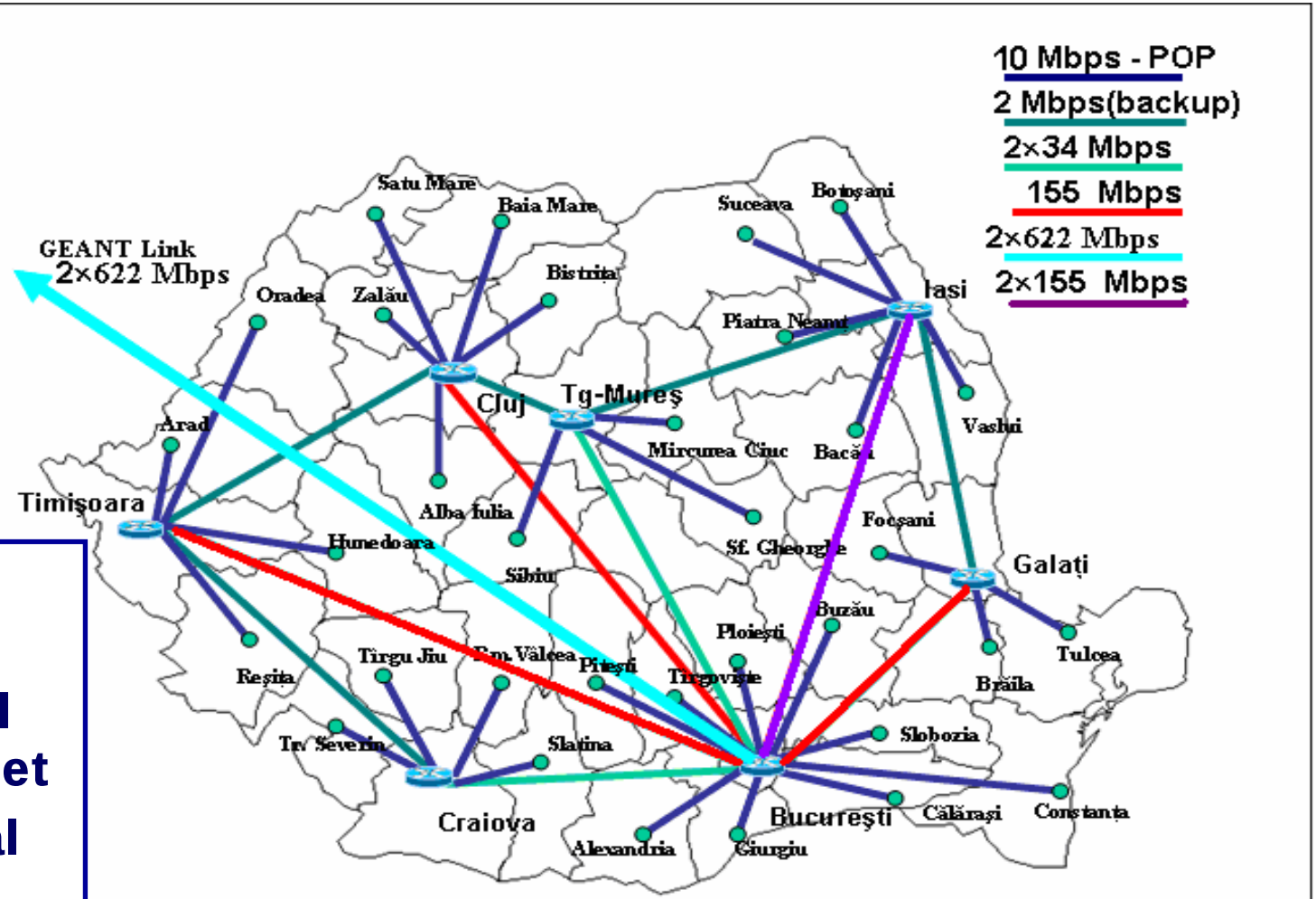
Romania: RoEduNet Topology

Connects 610 Institutions to GEANT:

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

RoGrid Plans for 2006

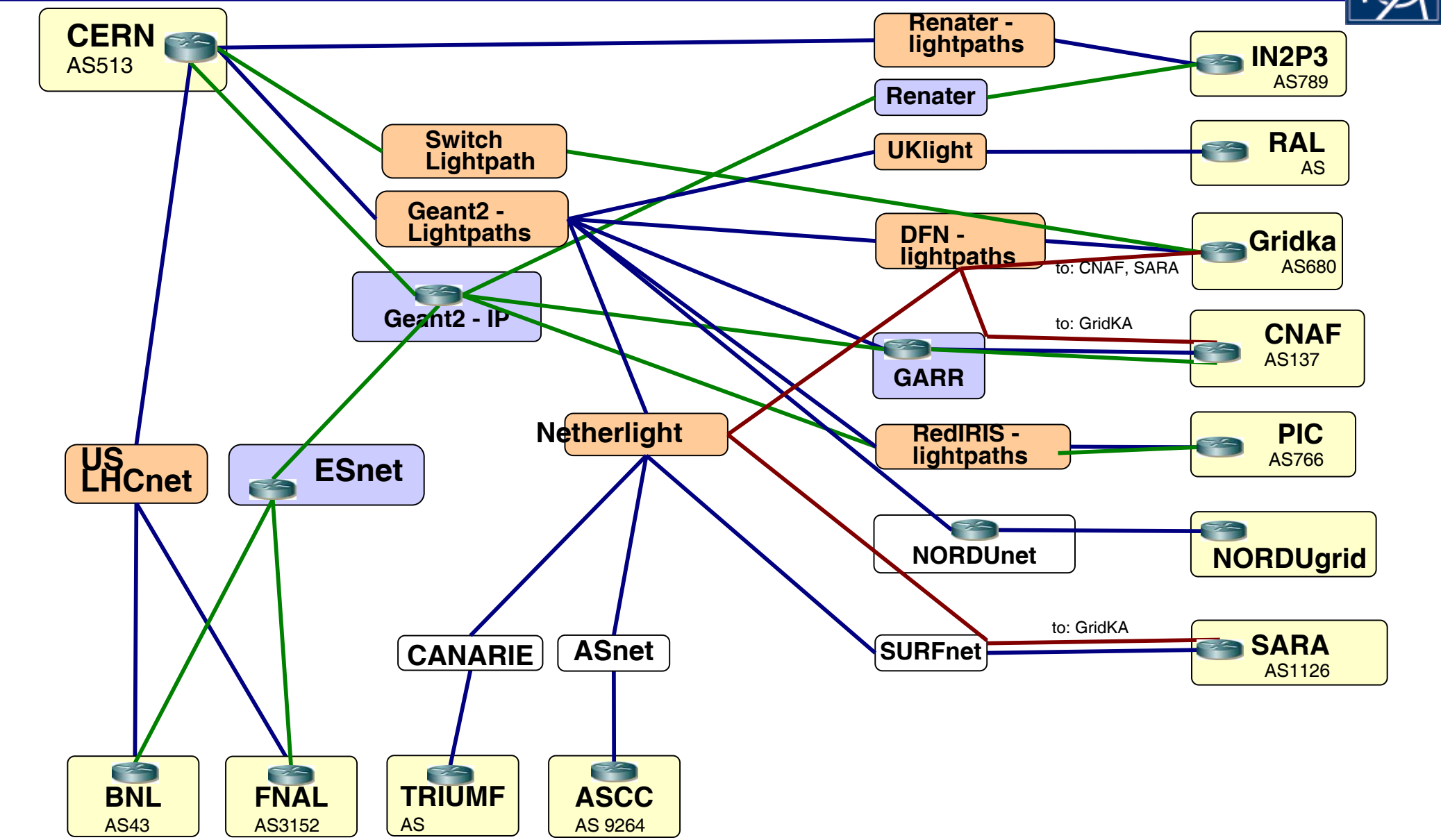
- 10G Experimental Link UPB-RoEdunet
- Upgrade 3-4 Local Centers to 2.5G



Future Plan: Dark Fiber Infrastructure with 10G Light-paths

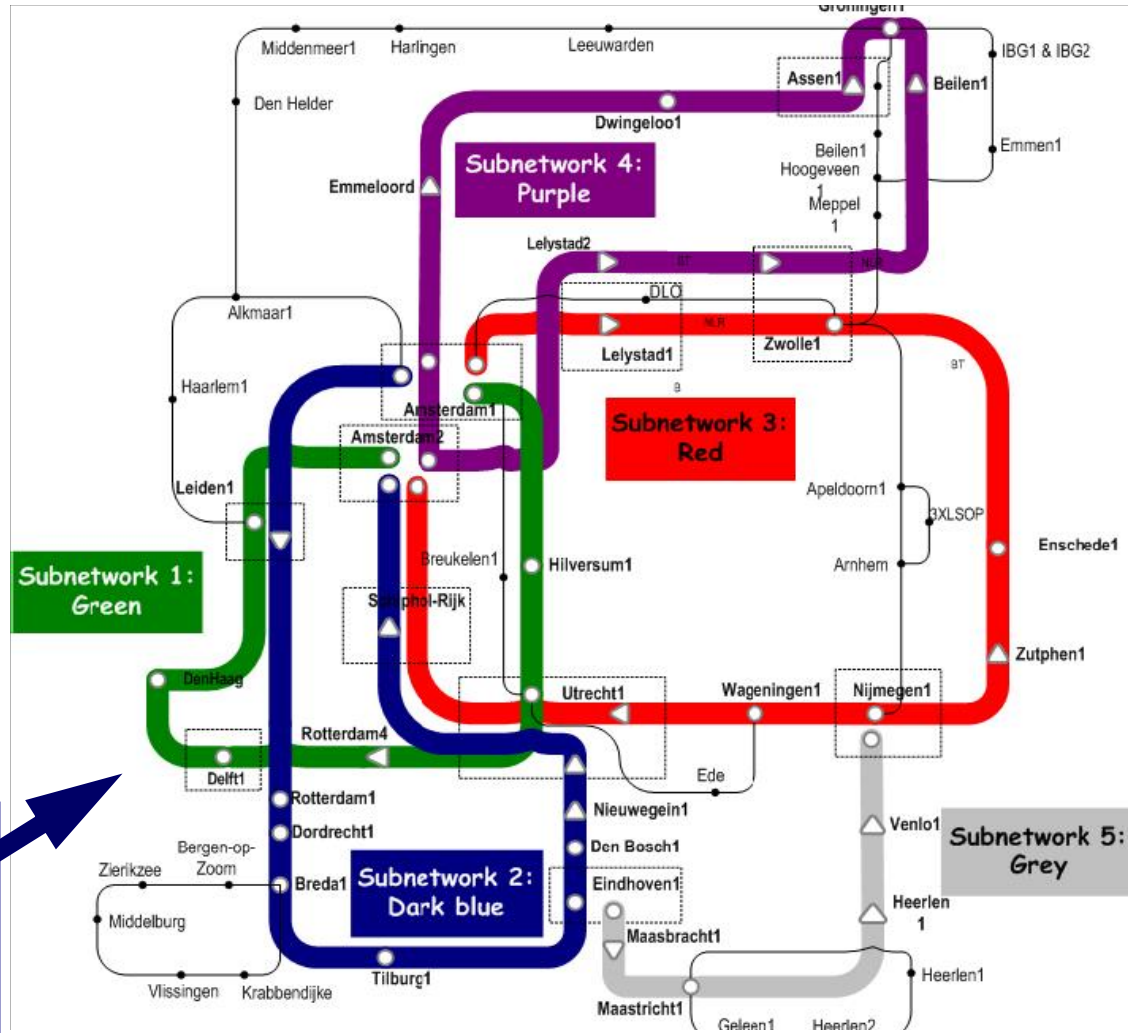
N. Tapus

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



E. Martelli

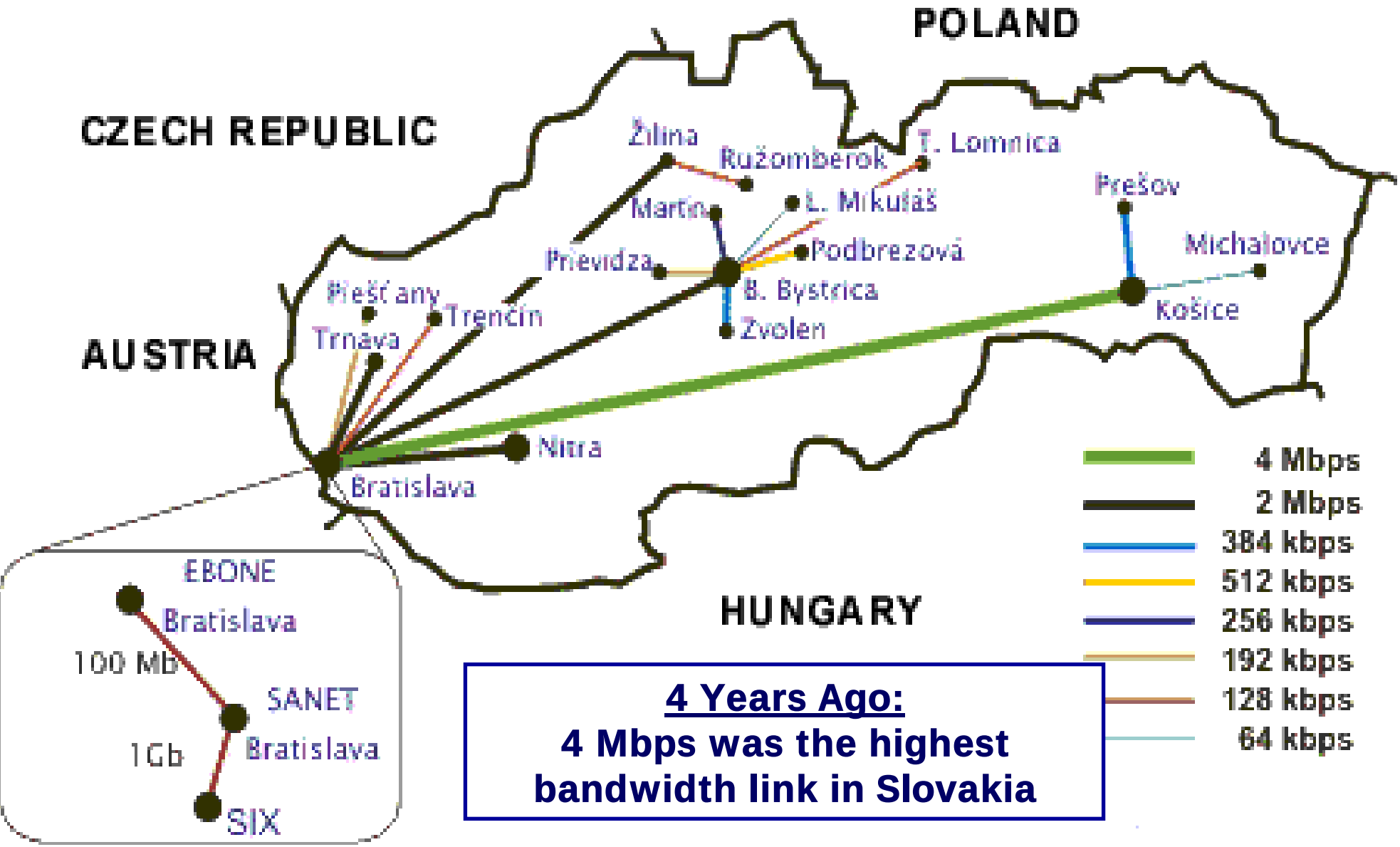
SURFNet6 in the Netherlands
5300 km of Owned Dark Fiber



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

K. Neggers

SANET - Slovak Akademic Data Network
(January 2002)

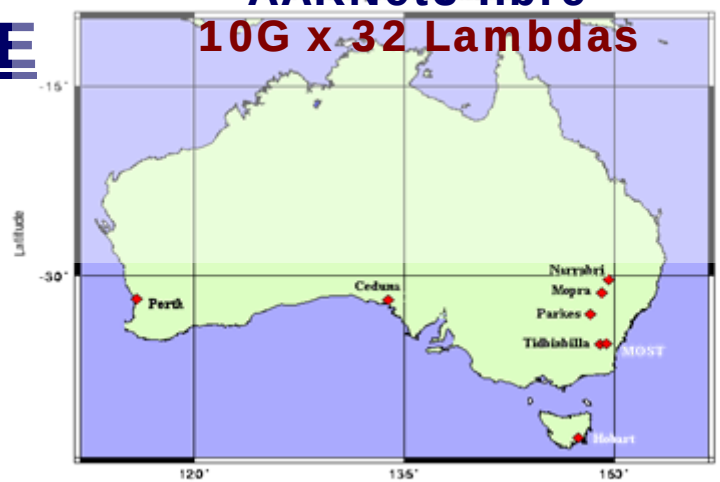


4 Years Ago:
4 Mbps was the highest bandwidth link in Slovakia

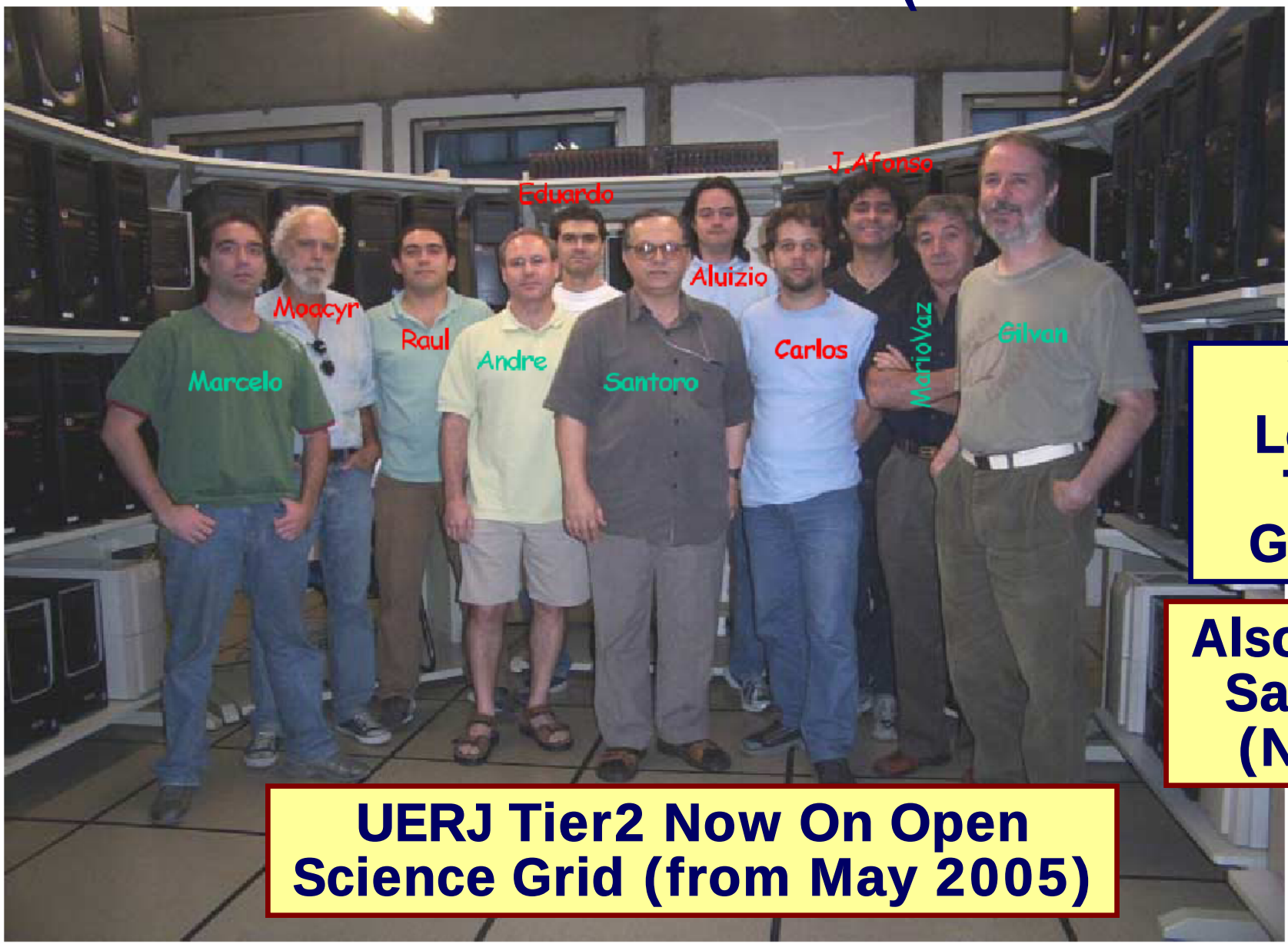
e-EVN ➡ EXPReS

- 6 Telescopes "on-line"
  - NL - WSRT 14x25m
  - Torun, PL: 32m
  - Onsala, SE: 26m & 25m
  - Jodrell Bank, UK: 76m & 25m
  - Cambridge, UK
  - Arecibo, USA at 155 Mbps
- Robust real-time fringes at 128 Mbps demonstrated
- EXPReS (EU Funded):
  <u>Connect 16 Telescopes to JIVE</u>
  - To 16 X 1 Gbps; then *16 X 10 Gbps*
  - *Greater Discovery Reach*
  - *Target of Opportunity Capability*

Australia LBA
AARNet3 fibre
10G x 32 Lambdas



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

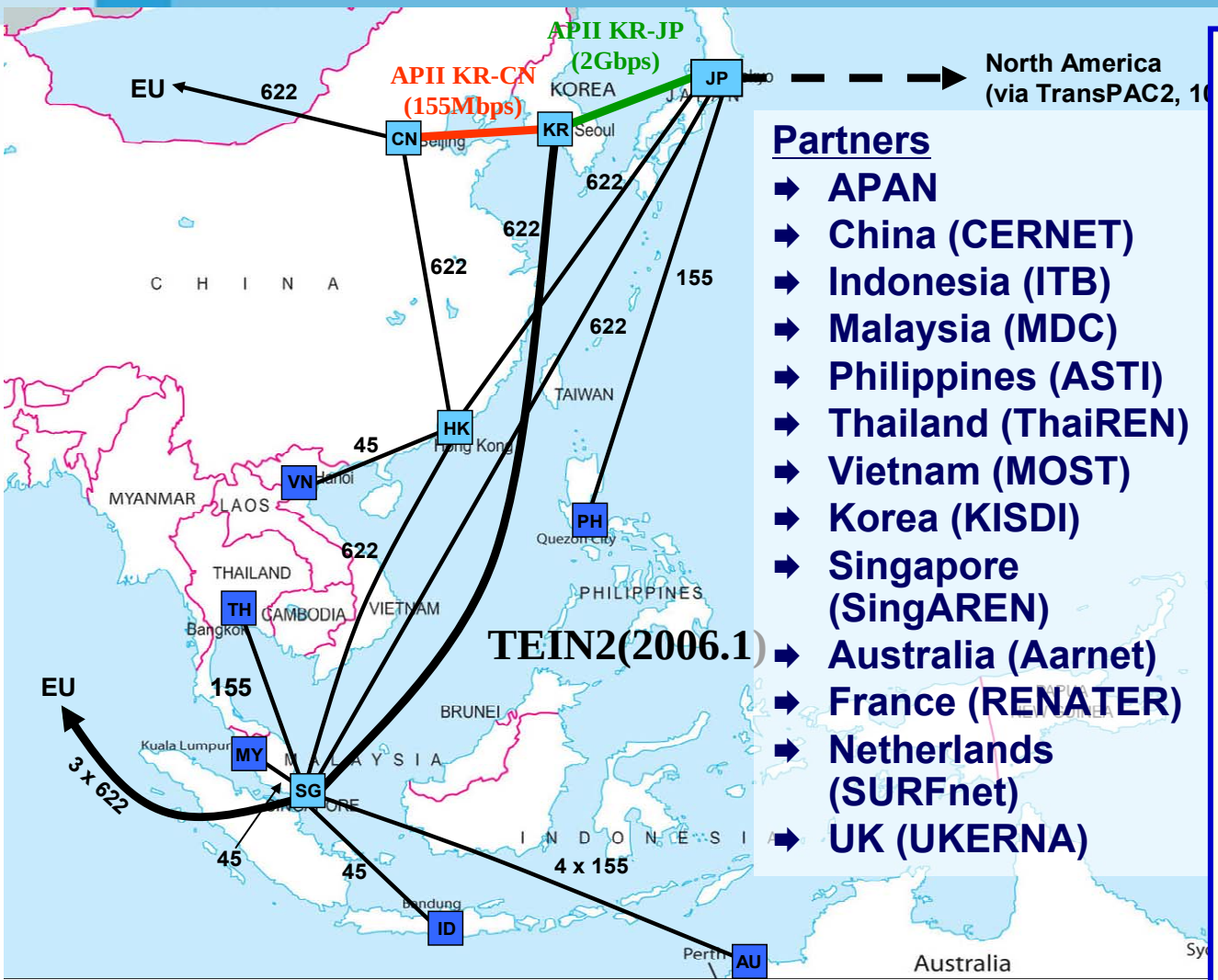


Work Locally; Think Globally

Also Tier3 in Sao Paulo (Novaes)

UERJ Tier2 Now On Open Science Grid (from May 2005)

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, Singapore

Spurs

622M: China, Korea
+2G Korea-China

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

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

Internet Users: Africa and the Rest of the World

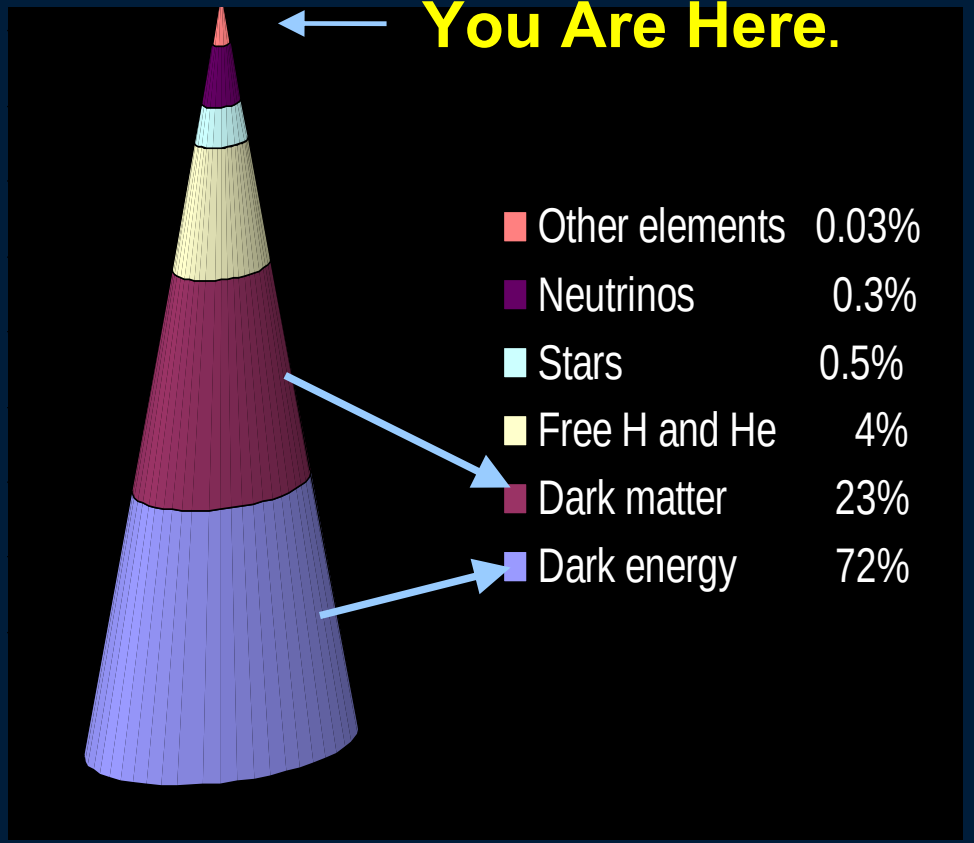
- **Internet Penetration in Africa is 2.5% (1.4% in 2004): Still more than an order of magnitude less than Europe (36%), and North America (68%)**

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 %

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

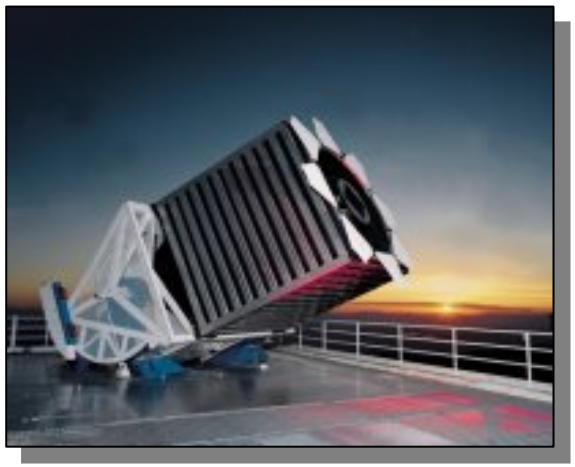
1. Where does the pattern of particle families and masses come from ?
2. Where are the Higgs particles; what is the mysterious Higgs field ?
3. Why do neutrinos and quarks oscillate ?
4. Is Nature Supersymmetric ?
5. Why is any matter left in the universe ?
6. Why is gravity so weak?
7. Are there extra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

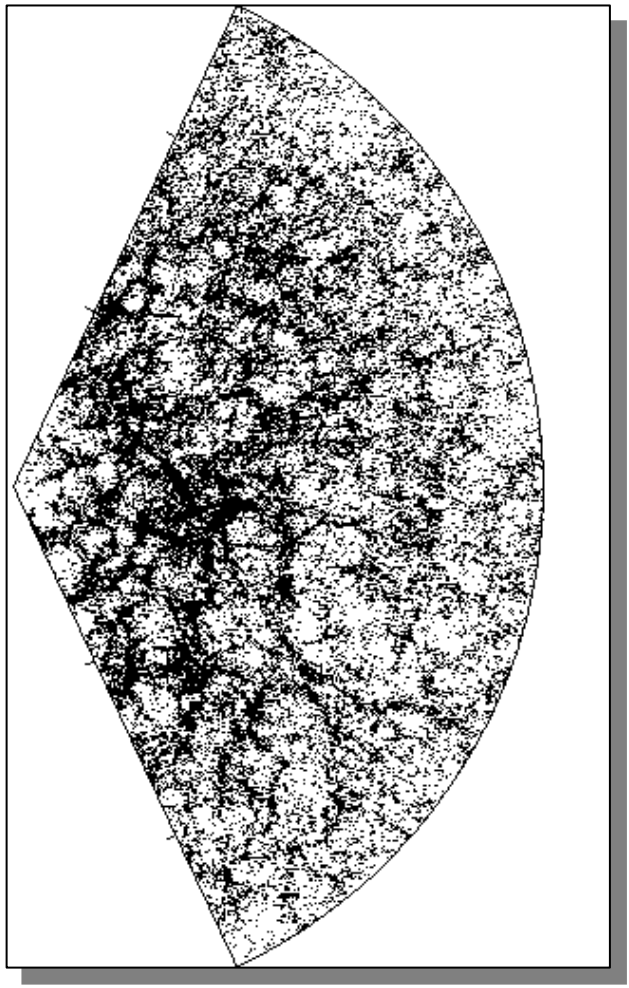


We do not know what makes up 95% of the universe.

Sloan Digital Sky Survey
Spectroscopic Survey Example

- **The Sloan Digital Sky Survey (SDSS)**
  The "Cosmic Genome Project"
  - *5 color images of ¼ of the sky*
  - *Pictures of 300 million celestial objects*
  - *Distances to the closest 1 million galaxies*
- **SDSS Redshift Survey**
  - *1 million galaxies*
  - *100,000 quasars*
  - *100,000 stars*






gridunesp
Solteira
Franca
S.J. Rio Preto
Araçatuba
Jaboticabal
Dracena
Tupã
Araraquara
Pres. Prudente
Marília
Rosana
Rio Claro
Assis
Ourinhos
S. J. dos Campos
Guaratinguetá
Sorocaba / Iperó
São Paulo
Itapeva
Registro
SPRACE
UltraLight

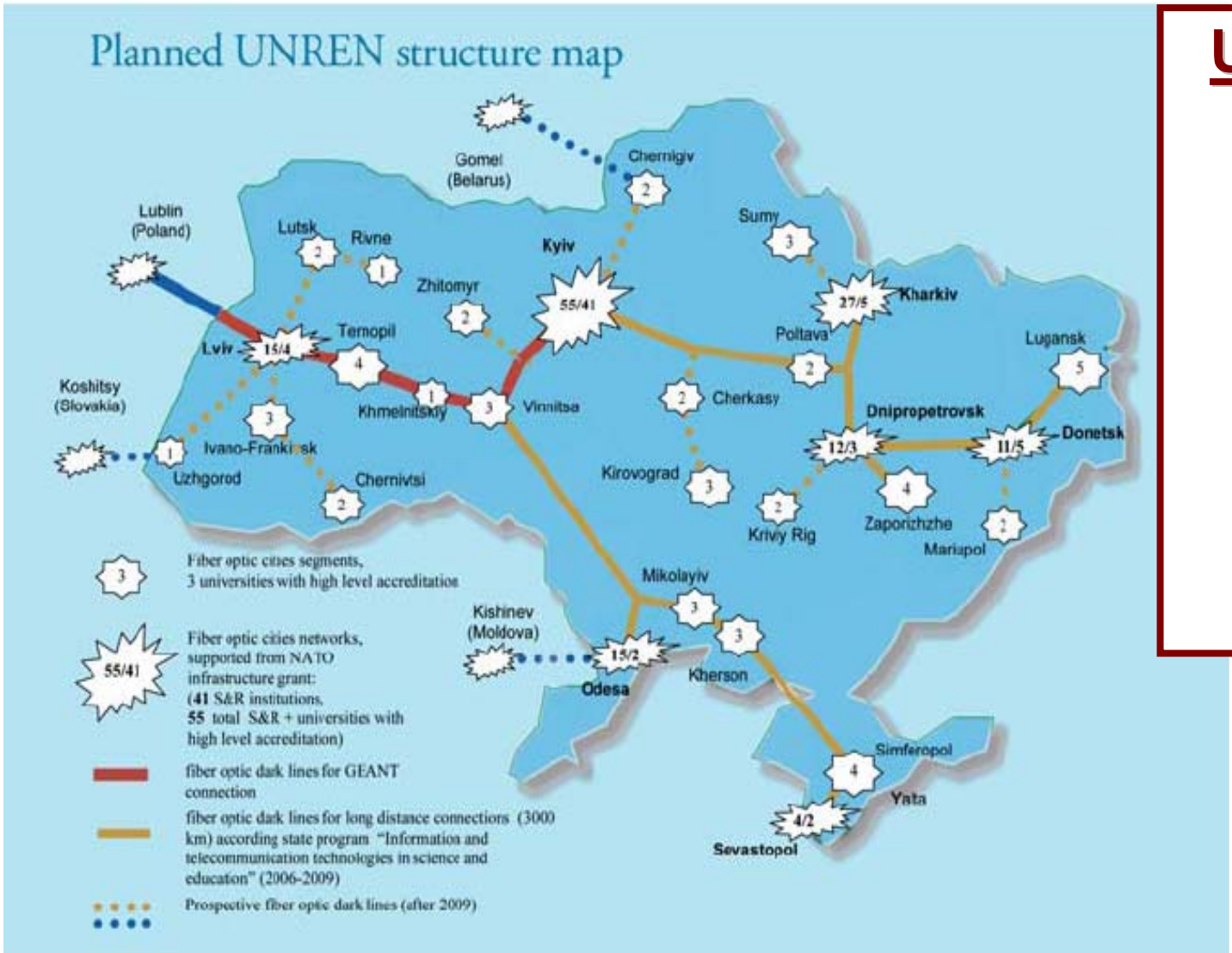
INTERNET USAGE AND POPULATION IN ASIA

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]

Ukraine: UNREN Research and Education Network Plan



UNREN (2006-9)

3000 km Dark Fiber Infrastructure

Kyiv-Lublin (Poland) Dark Fiber Link to Connect to GEANT2