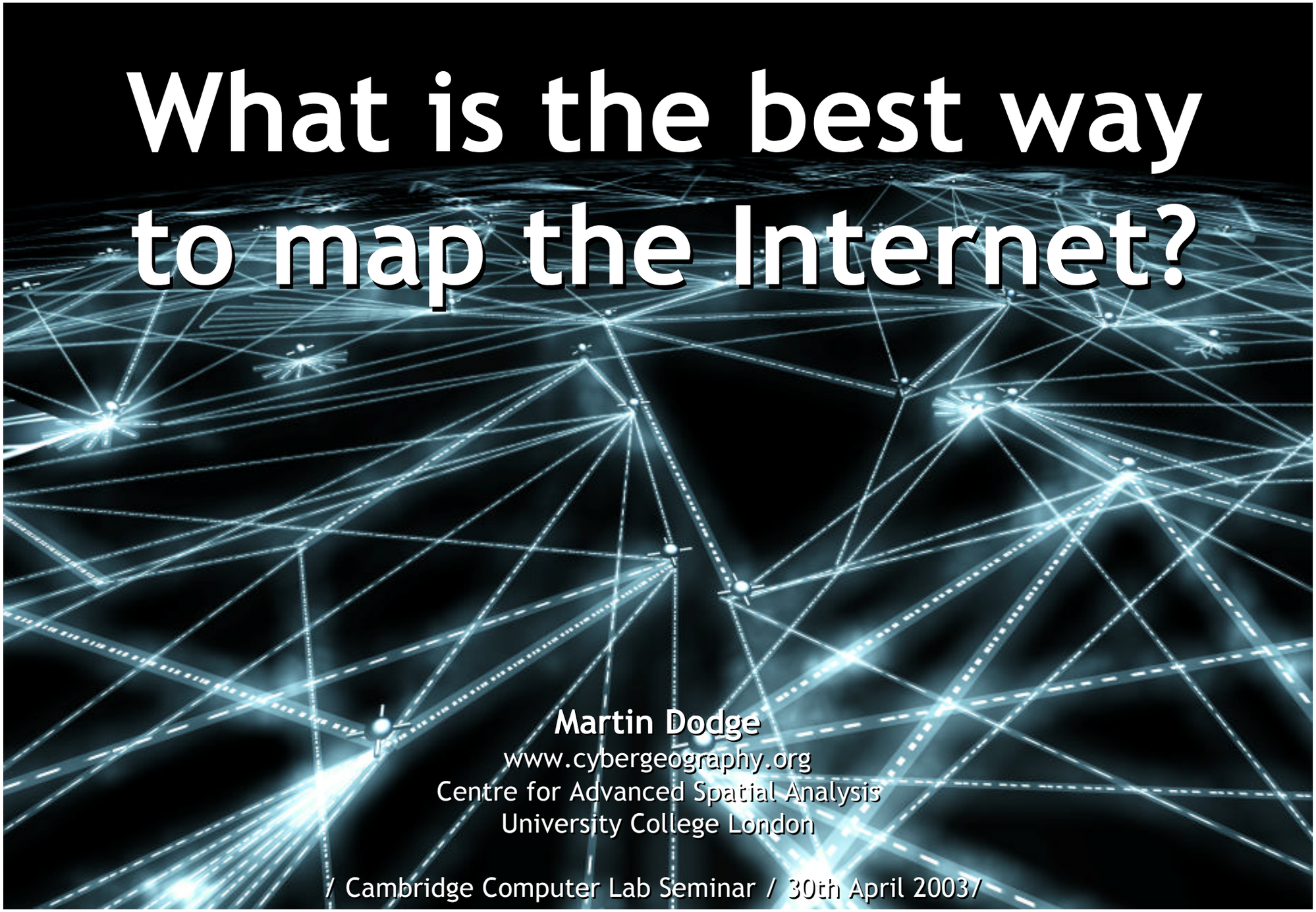
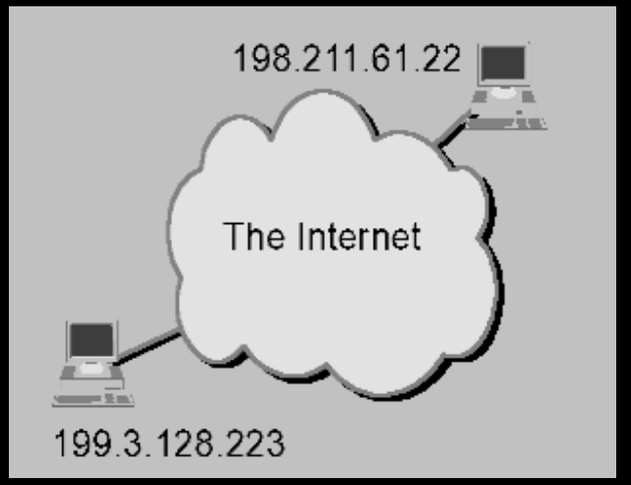
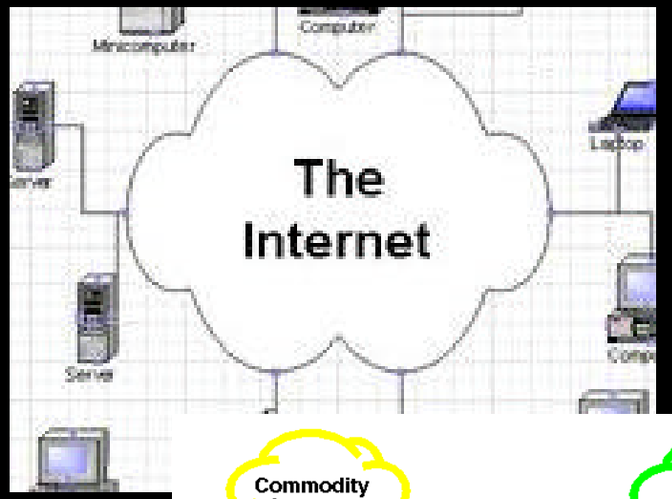
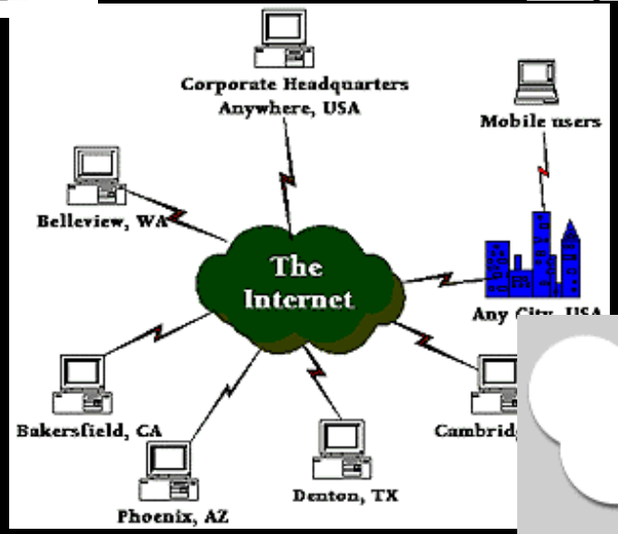

What is the best way to map the Internet?
Martin Dodge
www.cybergeography.org
Centre for Advanced Spatial Analysis
University College London
/ Cambridge Computer Lab Seminar / 30th April 2003/


198.211.61.22
The Internet
199.3.128.223

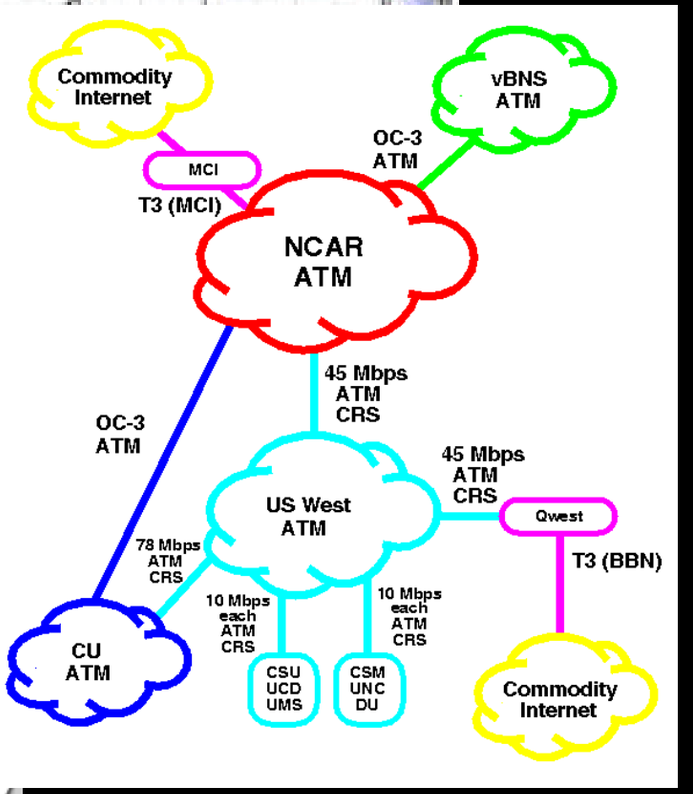

The Internet

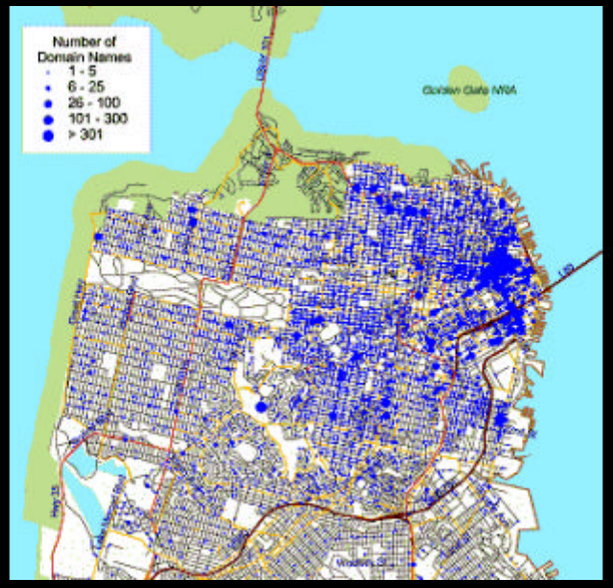

Internet


146.97.112.0


Corporate Headquarters
Anywhere, USA
Mobile users
Belleview, WA
The Internet
Any City, USA
Bakersfield, CA
Cambrid
Denton, TX
Phoenix, AZ


Internet


Commodity Internet
vBNS ATM
OC-3 ATM
MCI
T3 (MCI)
NCAR ATM
45 Mbps ATM CRS
OC-3 ATM
45 Mbps ATM CRS
US West ATM
Qwest
T3 (BBN)
78 Mbps ATM CRS
10 Mbps each ATM CRS
10 Mbps each ATM CRS
CU ATM
CSU UCD UMS
CSM UNC DU
Commodity Internet



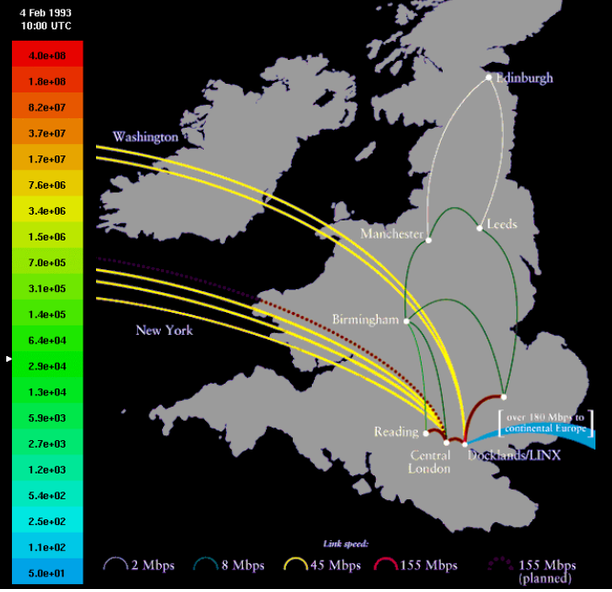
Maps let us look inside the cloud

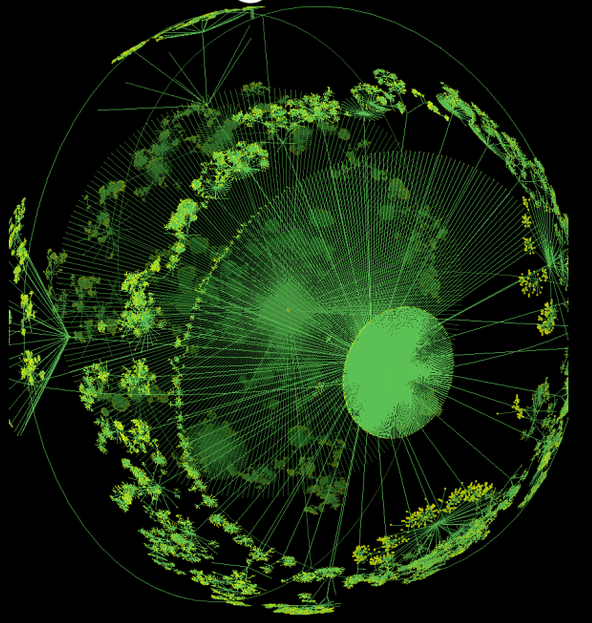
The talk in a nutshell

- there is no best way
- no one true map of the Internet
- there are good examples and (lots) of bad examples
- easy to map, much harder to map well
- but all the maps are interesting to some degree
- need maps that are fit for purpose. what do you want to show, what is the story you want to tell
- maps are less fixed. maps are increasingly just ‘thinking tools’ for interactive exploration of data
- only looking at published / public maps

mapping the ‘tin cans and string’

- many aspects of the Internet that you can map
- function, form, scale
- what they show? nodes, users, links, flows
- what form? geographic -> abstract ; static -> dynamic
- what scale? buildings, companies, cities -> global





- 30 years worth of maps, but most are from the last decade
- very diverse range of styles and forms
- Internet has no ‘natural’ representation, but some obvious visual metaphors keep popping up
- relevance of real-world geography?

My definition of ‘map’

- hey, half of your examples of not even maps!

- “maps are graphic representations that facilitate a spatial understanding of things, concepts, conditions, processes, or events in the human world”

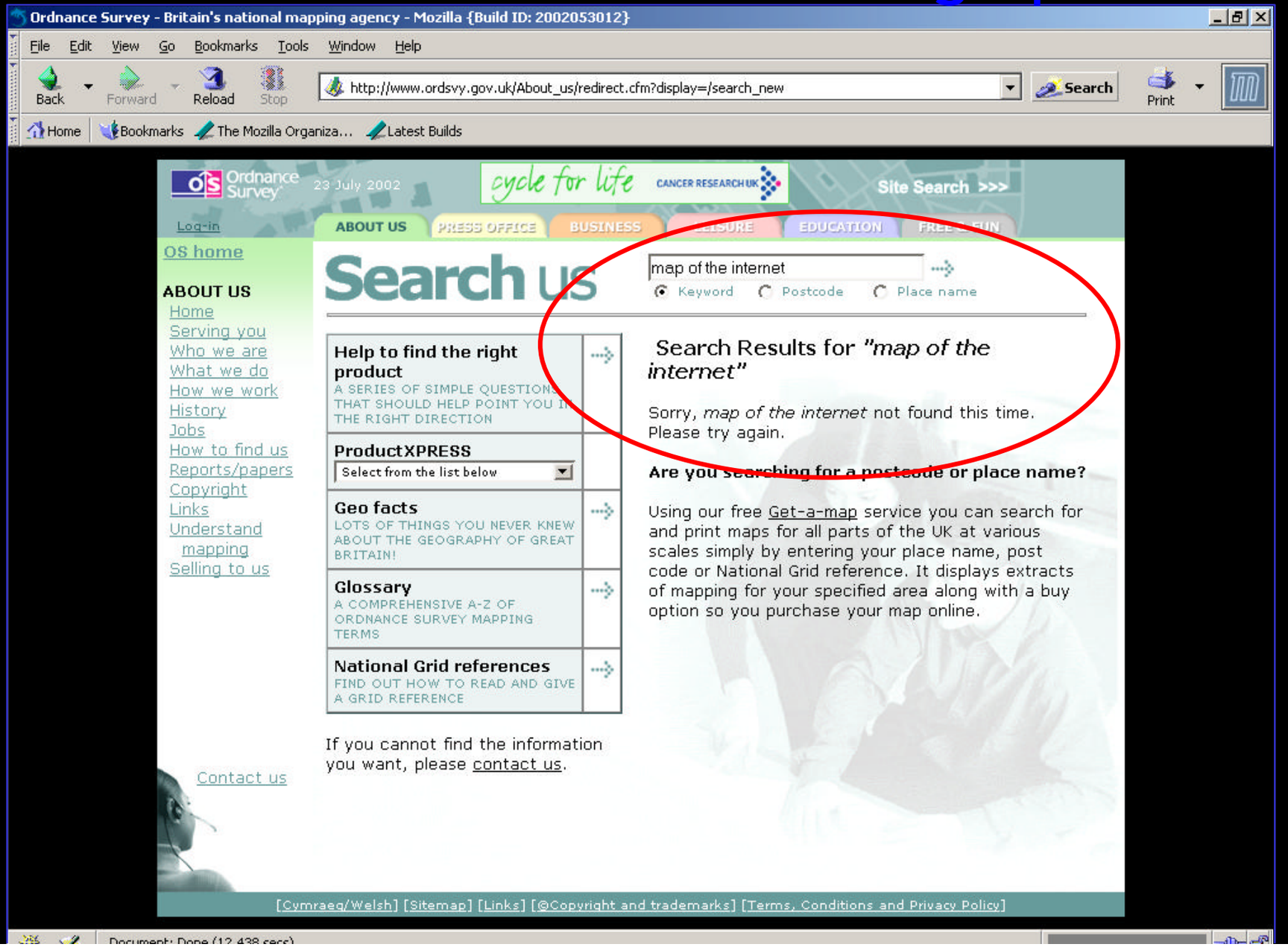
  (Harley and Woodward, *History of Cartography*, Volume 1, 1987)

- map versus graph versus diagram….

Purpose of Internet maps

- network planning
- network ops and maintenance
- network research (prove new theories)
- network marketing
- visualisation research
- market research & census taking
- security and policing
- grad student projects
- the urge to map it because its there
- (eye candy for posters, books & talks)

who makes them? not cartographers!



Why is it hard to map the Internet?

- its new, its fast changing
- complex and fast growing
- diversity of owners, heterogeneous, no one has overall responsibility
- banal, boring, background. Invisible internet
- secrecy - network security and commercial confidentiality
- has not been seen as a vital strategic asset. although this is changing with growing fears of cyber-terrorism

Okay, enough waffle. show me some maps.....

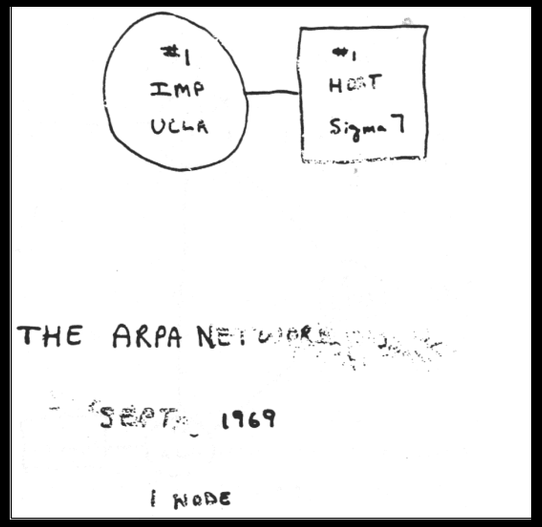
- where do the cables go? or logical routing?
- scales of mapping facilities
    - CAD schematics of rooms and buildings
    - street layout of fibre grids
    - city wide
    - regional
    - national
    - continental
    - global grids of glass, undersea cables
    - out into space - satellite constellations
- lets start at the most obvious map metaphor - links + node, with real-world geographic layout
- (try to spot any of the networks that are still in business)

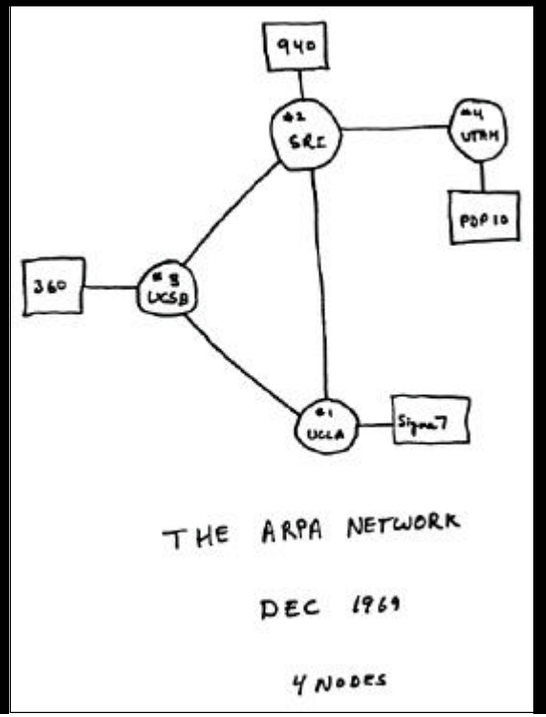
Just nodes and links

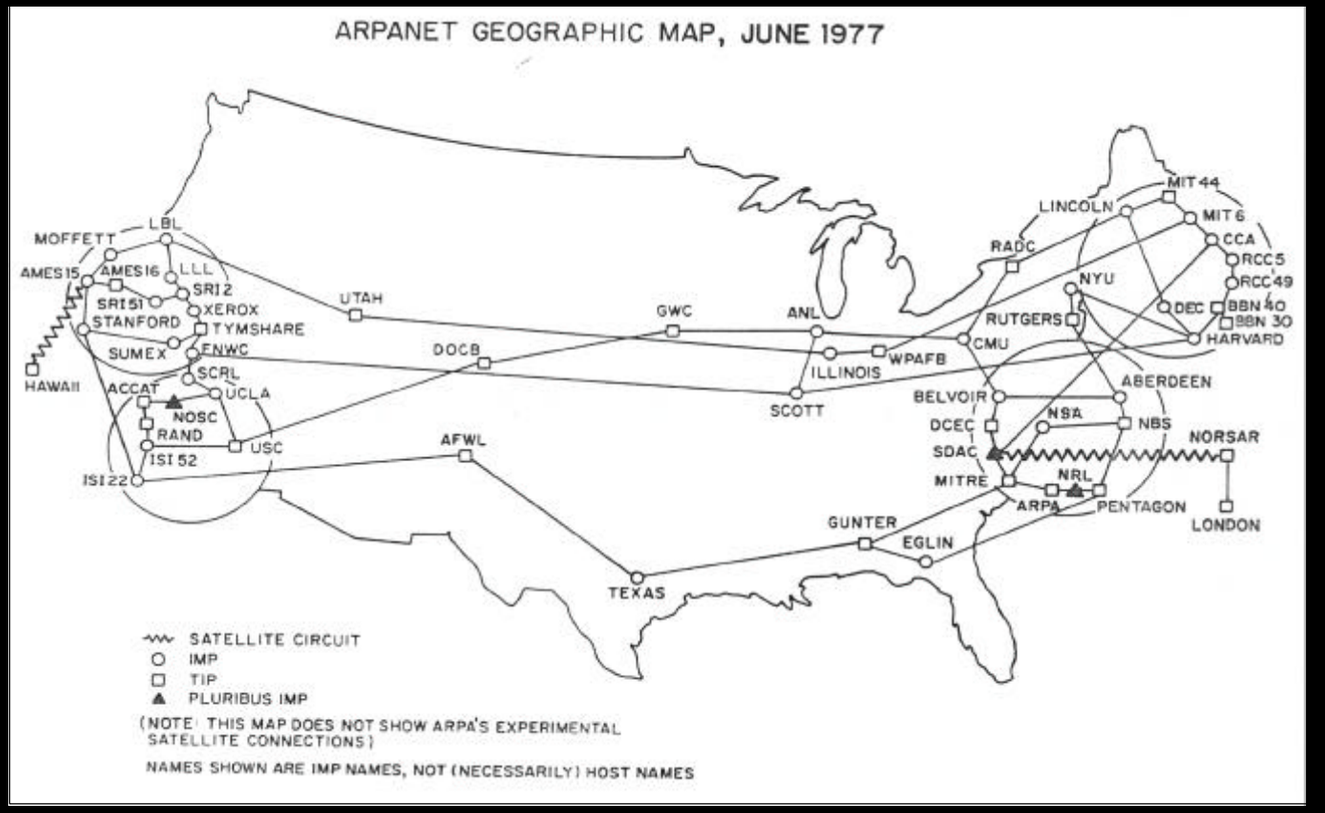
Internet, circa 1853

(Source: Library of Congress, http://hdl.loc.gov/loc.gmd/g3701p.ct000084)

mapping ARPANET's logical structure - topology v. geography

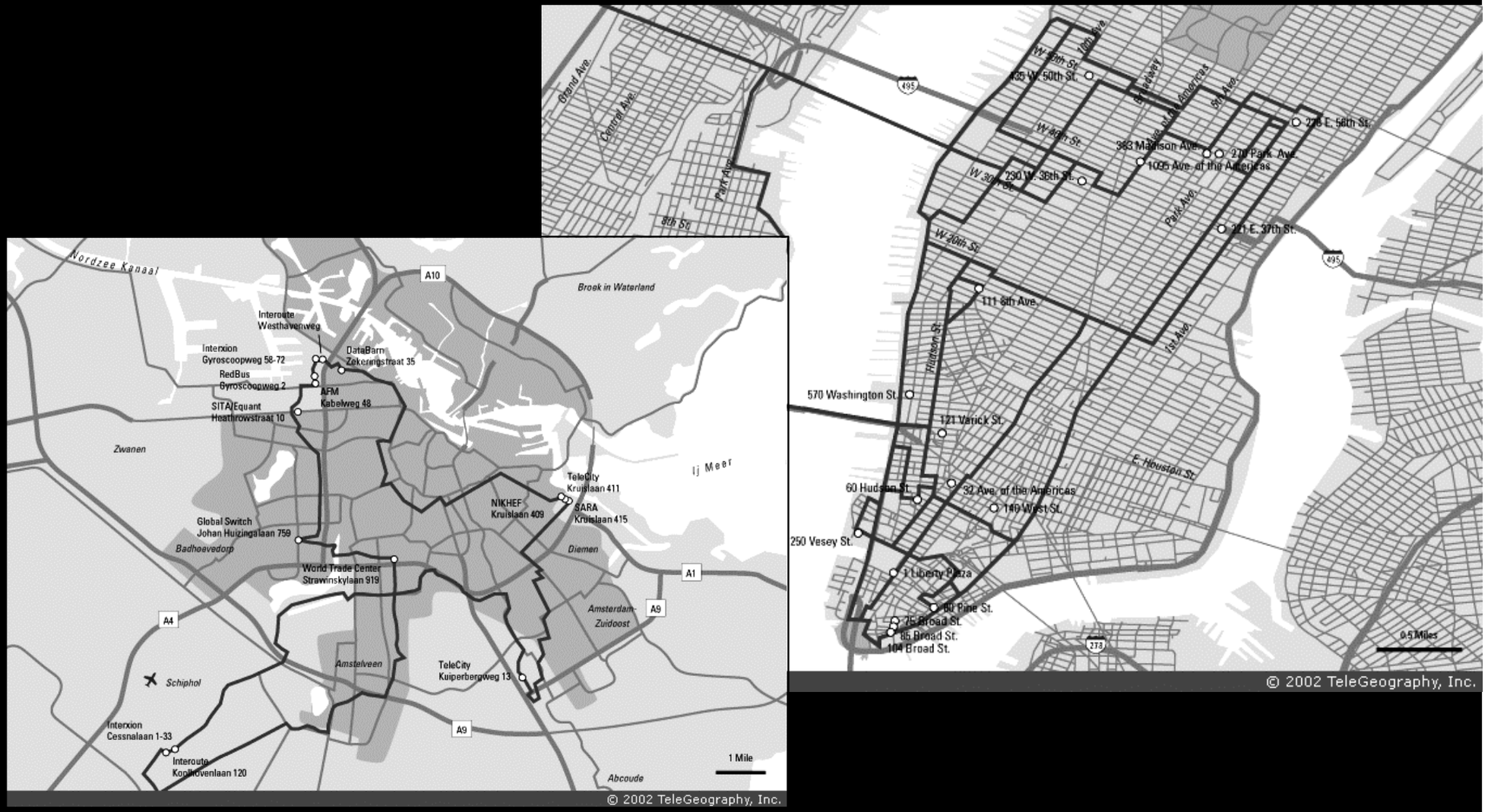




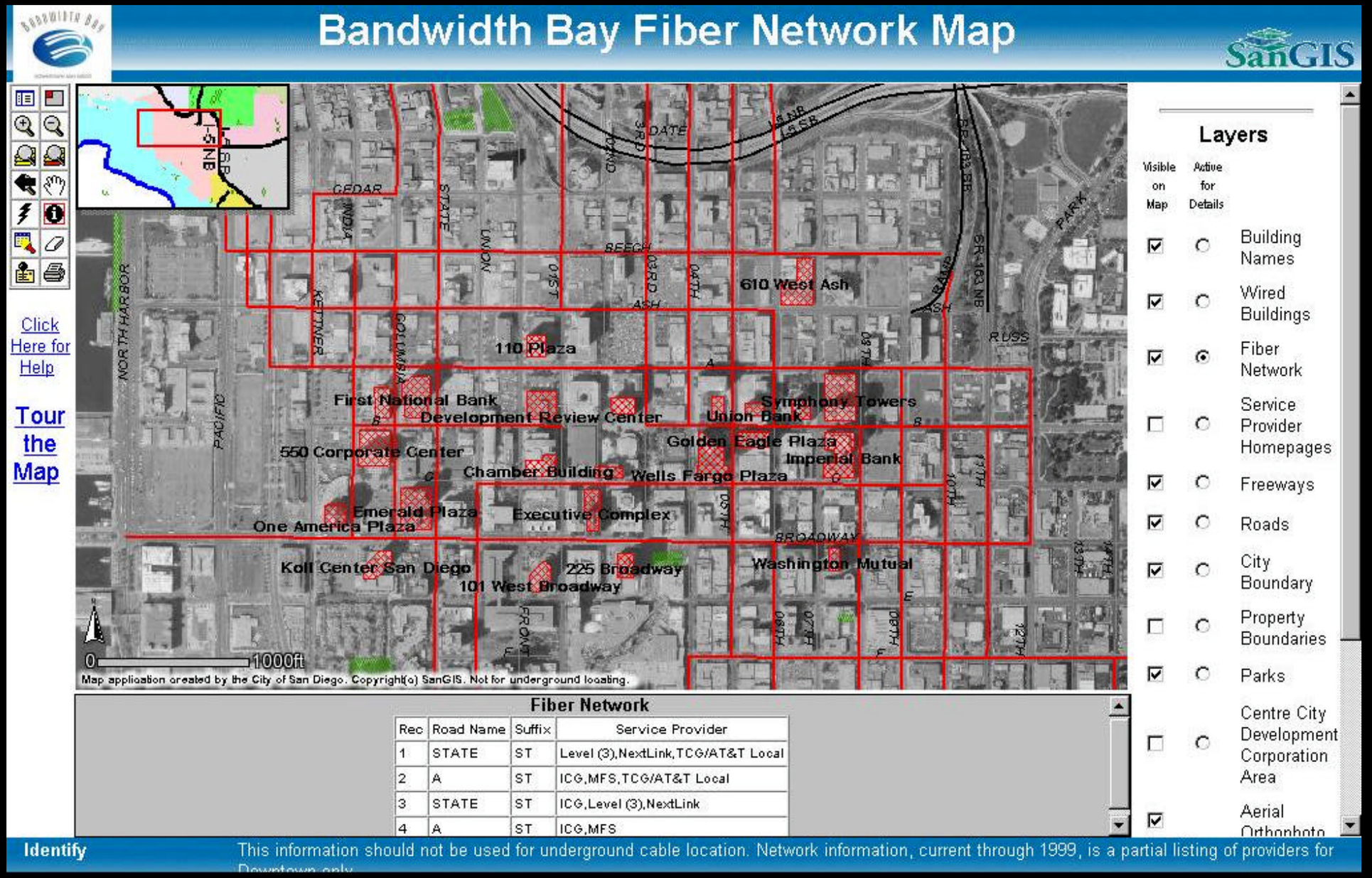


(source: Internet Archive, ARPANET documents)

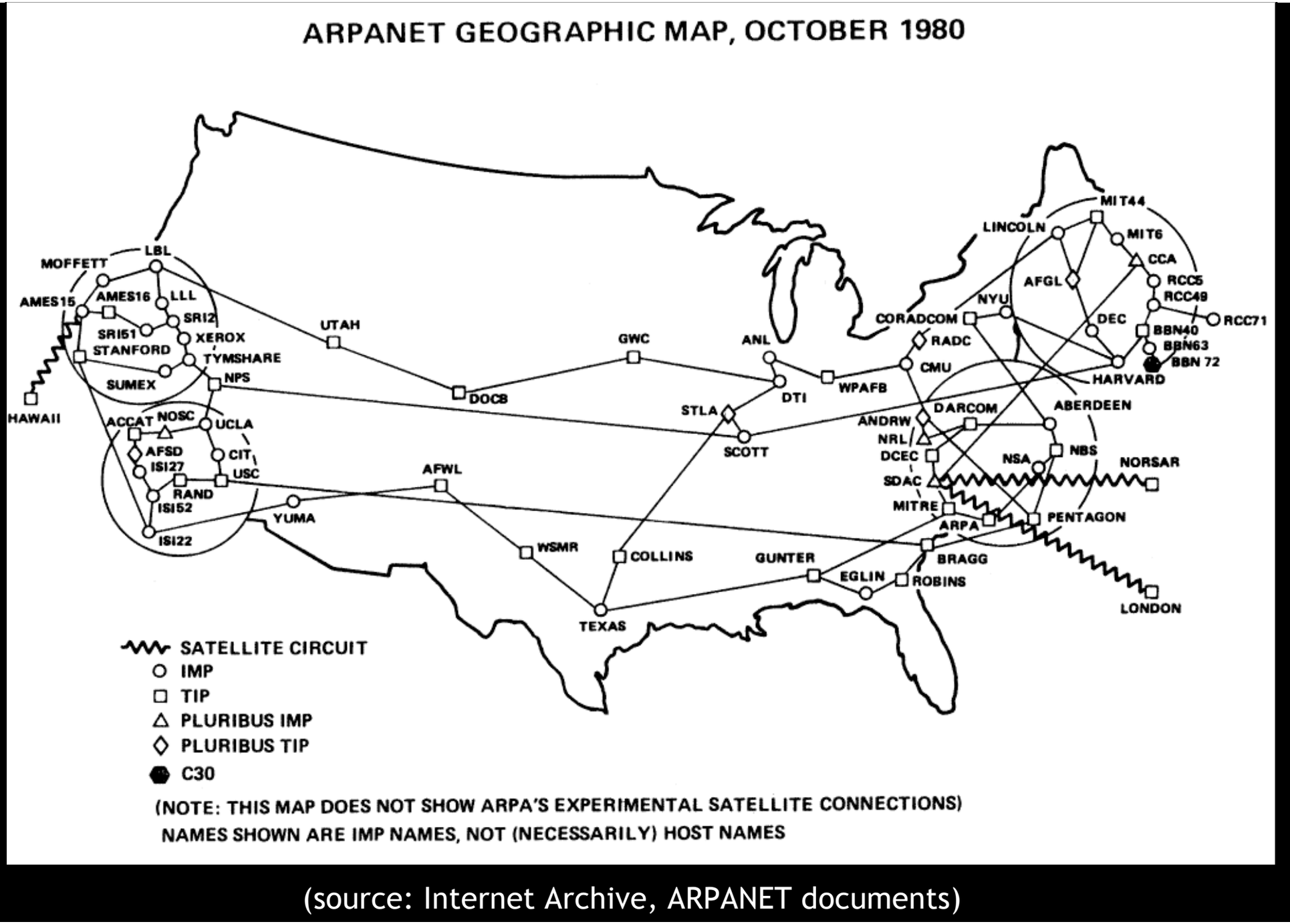
MAN maps from TeleGeography



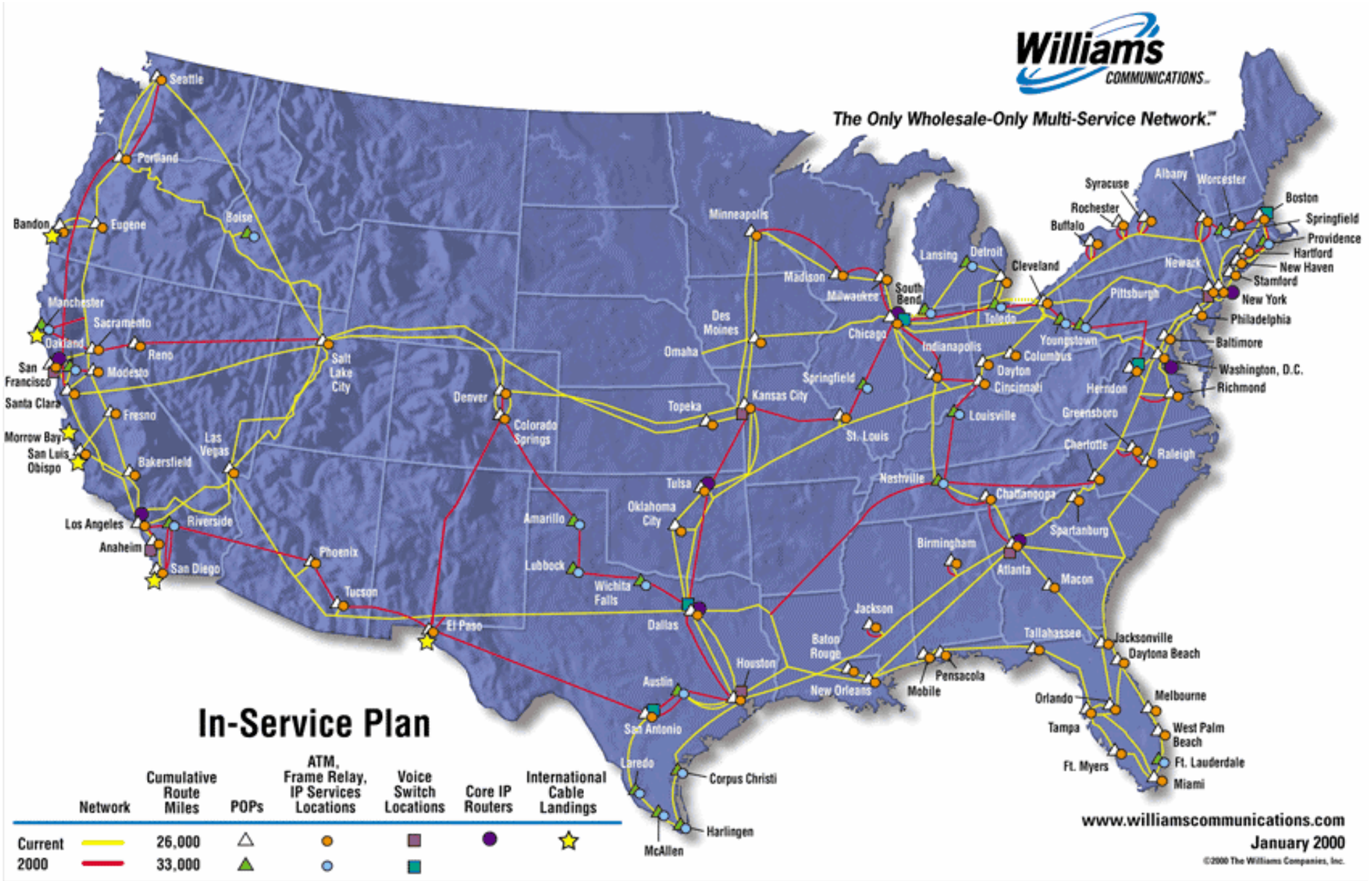
(source: www.telegeography.com)



(source: www.sangis.org/sangis/intmaps/fibermap.htm)

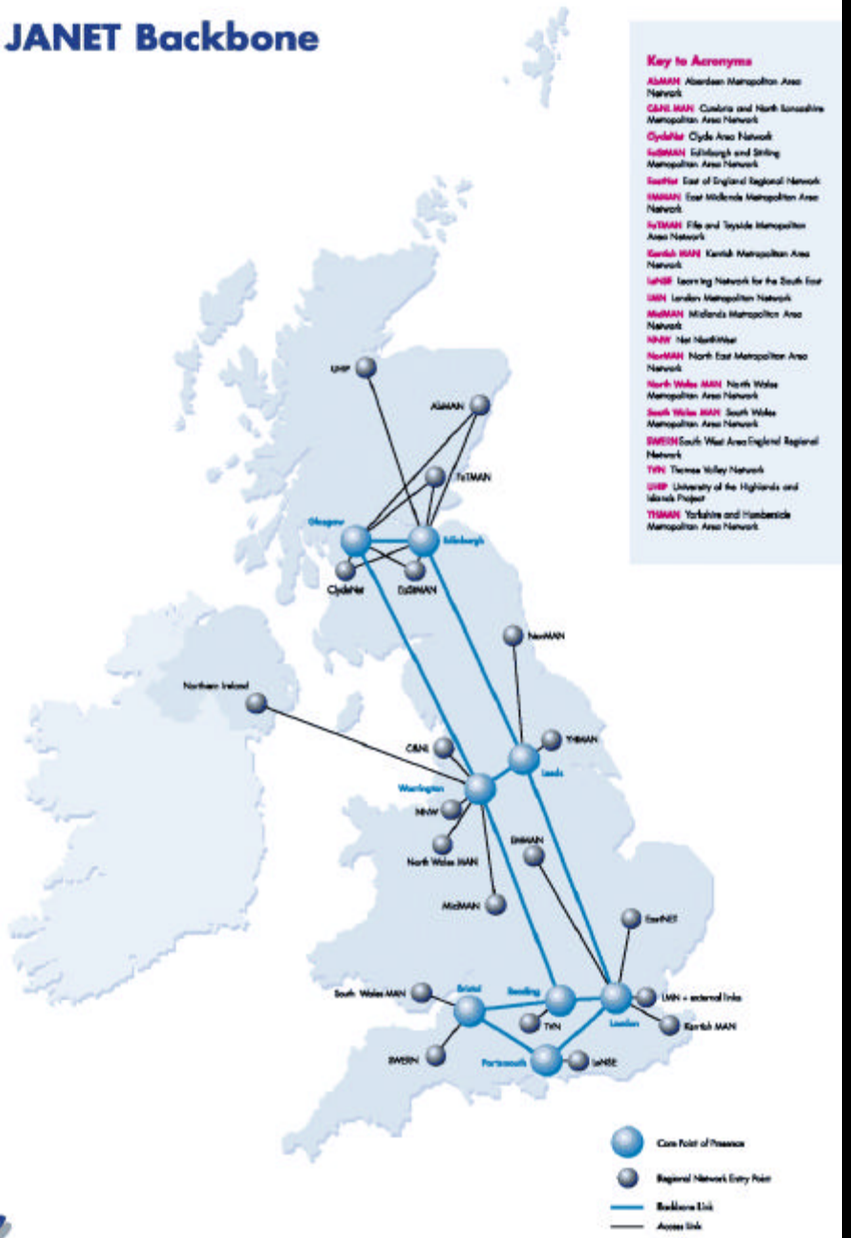


(source: Internet Archive, ARPANET documents)



(source: www.williamscommunications.com)

The JANET Backbone



Key to Acronyms

ABMAN Aberdeen Metropolitan Area Network

C&NL MAN Cumbria and North Lancashire Metropolitan Area Network

ClydeNet Clyde Area Network

EdDMAN Edinburgh and Stirling Metropolitan Area Network

EastNet East of England Regional Network

EMMAN East Midlands Metropolitan Area Network

FaTMAN Fife and Tayside Metropolitan Area Network

Kentish MAN Kentish Metropolitan Area Network

LeNSE Learning Network for the South East

LMN London Metropolitan Network

MidMAN Midlands Metropolitan Area Network

NNW Net NorthWest

NorMAN North East Metropolitan Area Network

North Wales MAN North Wales Metropolitan Area Network

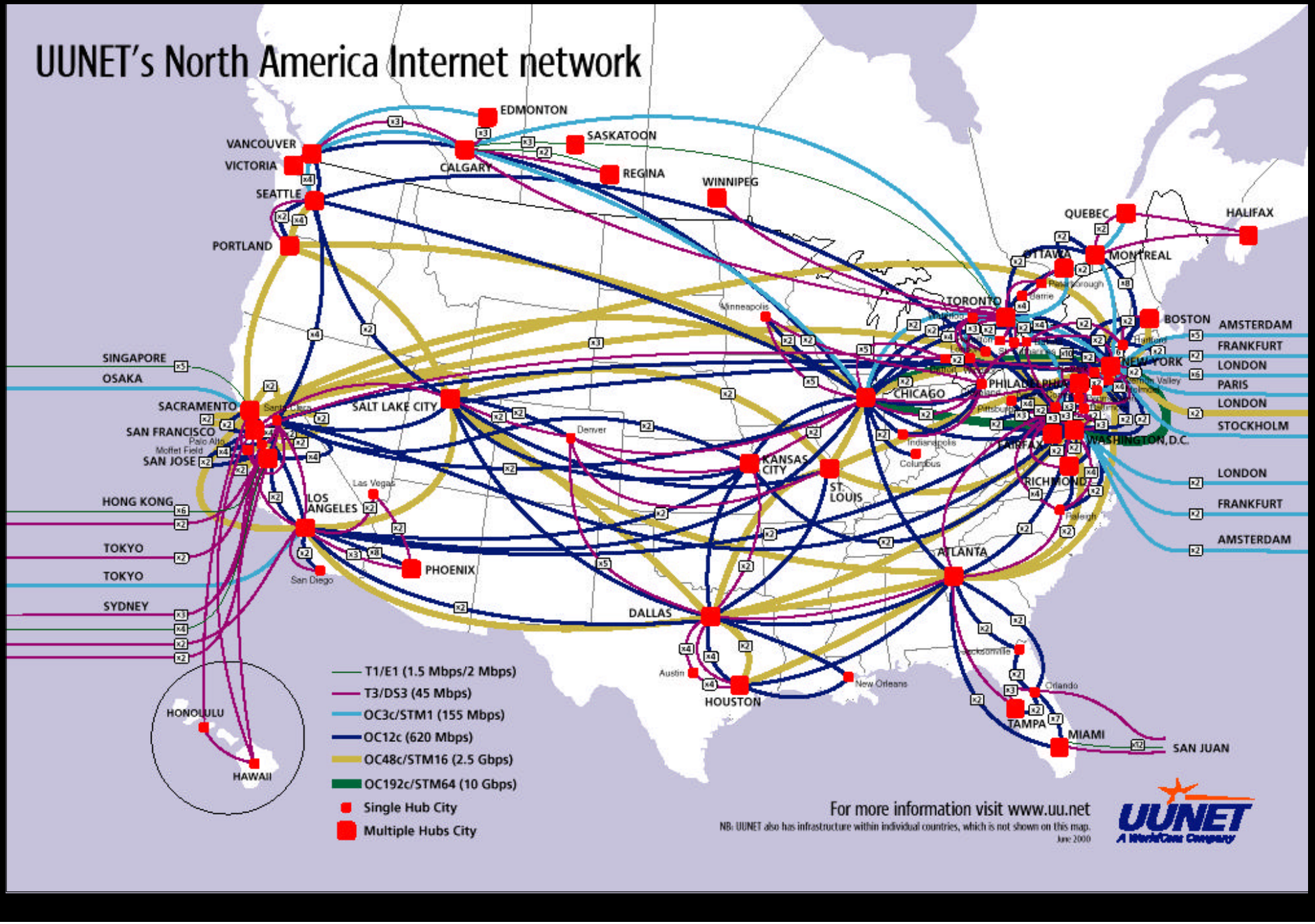
South Wales MAN South Wales Metropolitan Area Network

SWERN South West Area England Regional Network

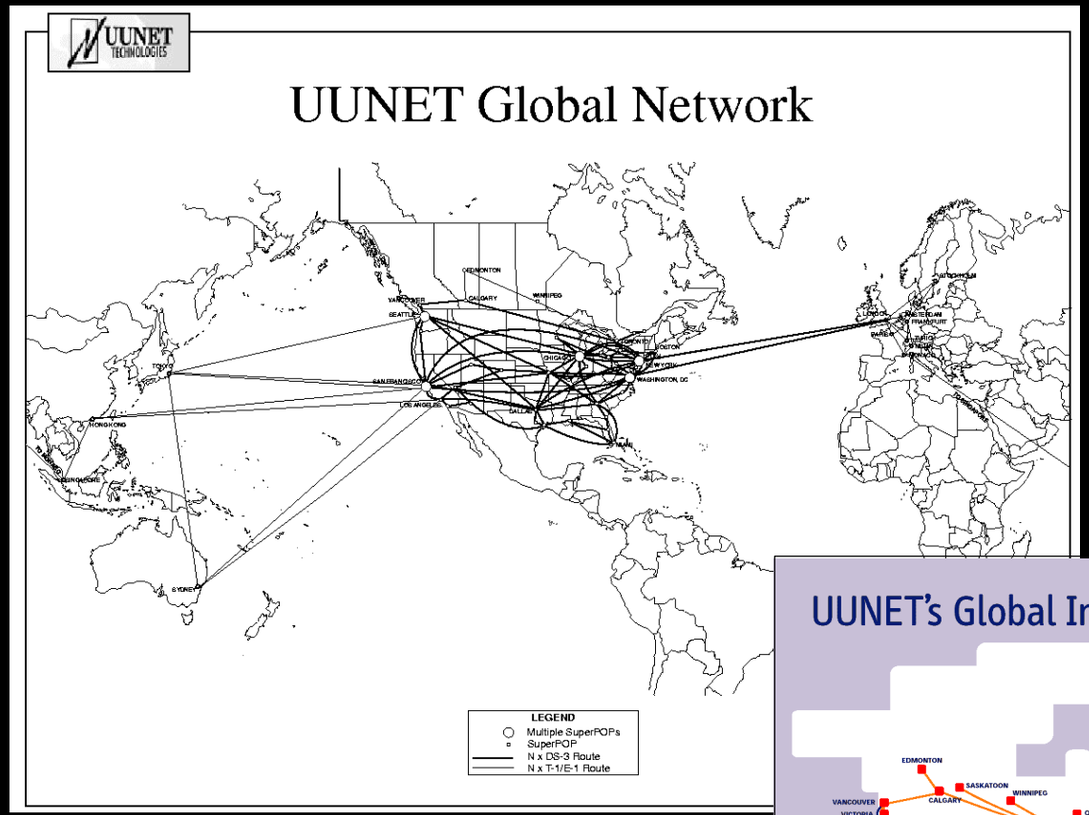
TVN Thames Valley Network

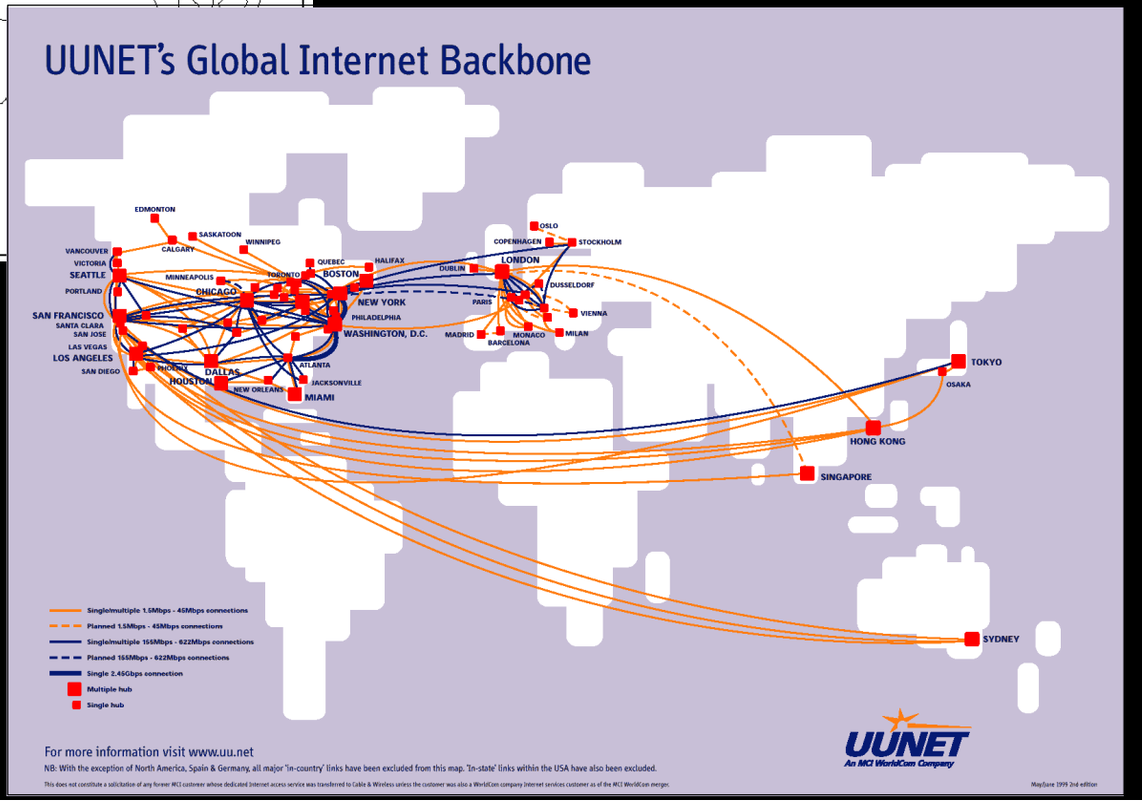
UHIP University of the Highlands and Islands Project

YHMAN Yorkshire and Humberside Metropolitan Area Network

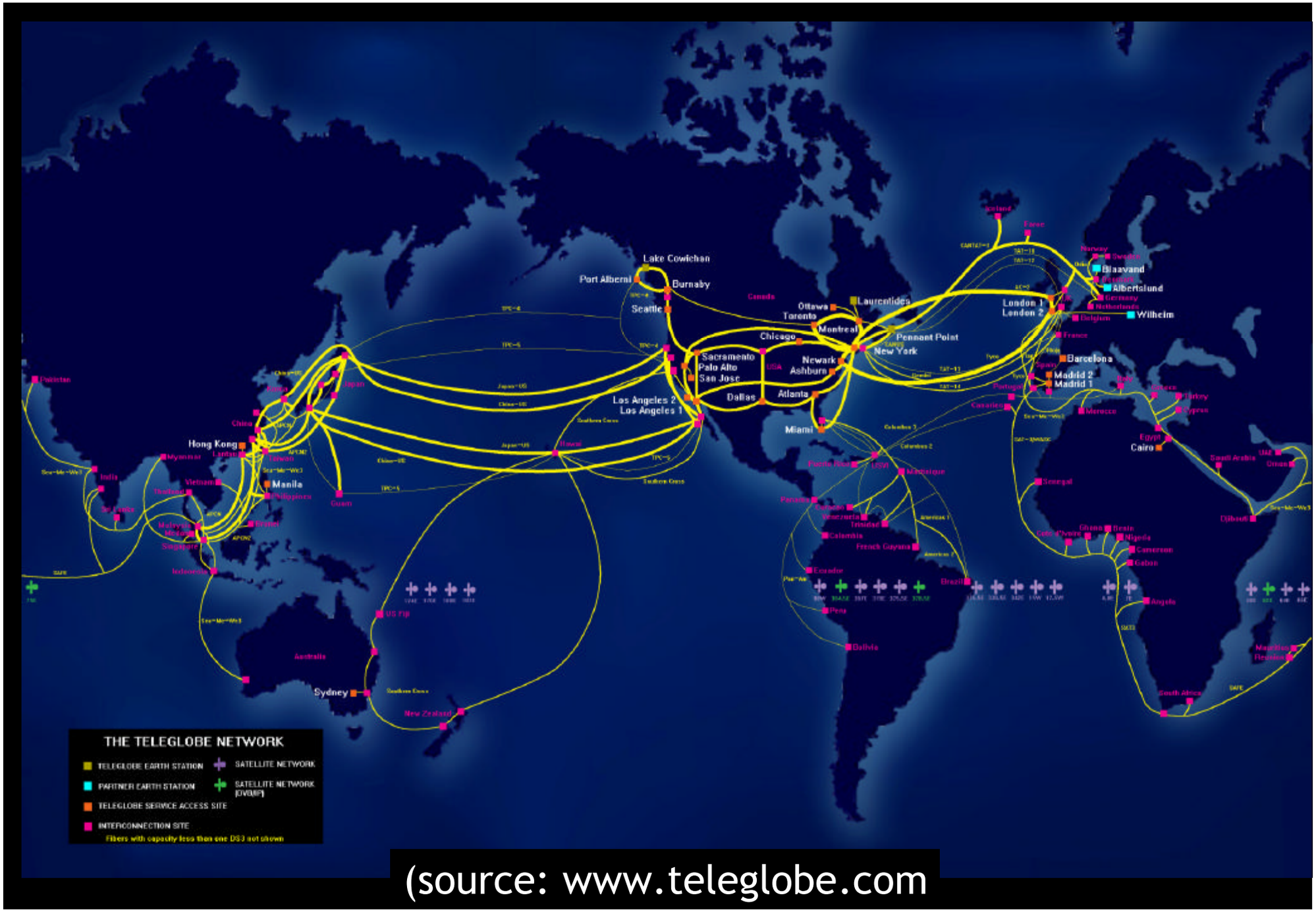

UUNET's North America Internet network
EDMONTON
SASKATOON
VANCOUVER
VICTORIA
CALGARY
REGINA
WINNIPEG
SEATTLE
PORTLAND
QUEBEC
HALIFAX
OTTAWA
MONTREAL
TORONTO
BOSTON
AMSTERDAM
FRANKFURT
LONDON
PARIS
LONDON
STOCKHOLM
NEW YORK
PHILADELPHIA
CHICAGO
WASHINGTON, D.C.
SINGAPORE
OSAKA
SACRAMENTO
SAN FRANCISCO
SAN JOSE
SALT LAKE CITY
KANSAS CITY
ST. LOUIS
LONDON
FRANKFURT
AMSTERDAM
HONG KONG
TOKYO
TOKYO
SYDNEY
LOS ANGELES
PHOENIX
ATLANTA
DALLAS
HOUSTON
TAMPA
MIAMI
SAN JUAN
HONOLULU
HAWAII
T1/E1 (1.5 Mbps/2 Mbps)
T3/DS3 (45 Mbps)
OC3c/STM1 (155 Mbps)
OC12c (620 Mbps)
OC48c/STM16 (2.5 Gbps)
OC192c/STM64 (10 Gbps)
Single Hub City
Multiple Hubs City
For more information visit www.uu.net
NB: UUNET also has infrastructure within individual countries, which is not shown on this map.
June 2000
UUNET
A WorldCom Company

backbone marketing maps

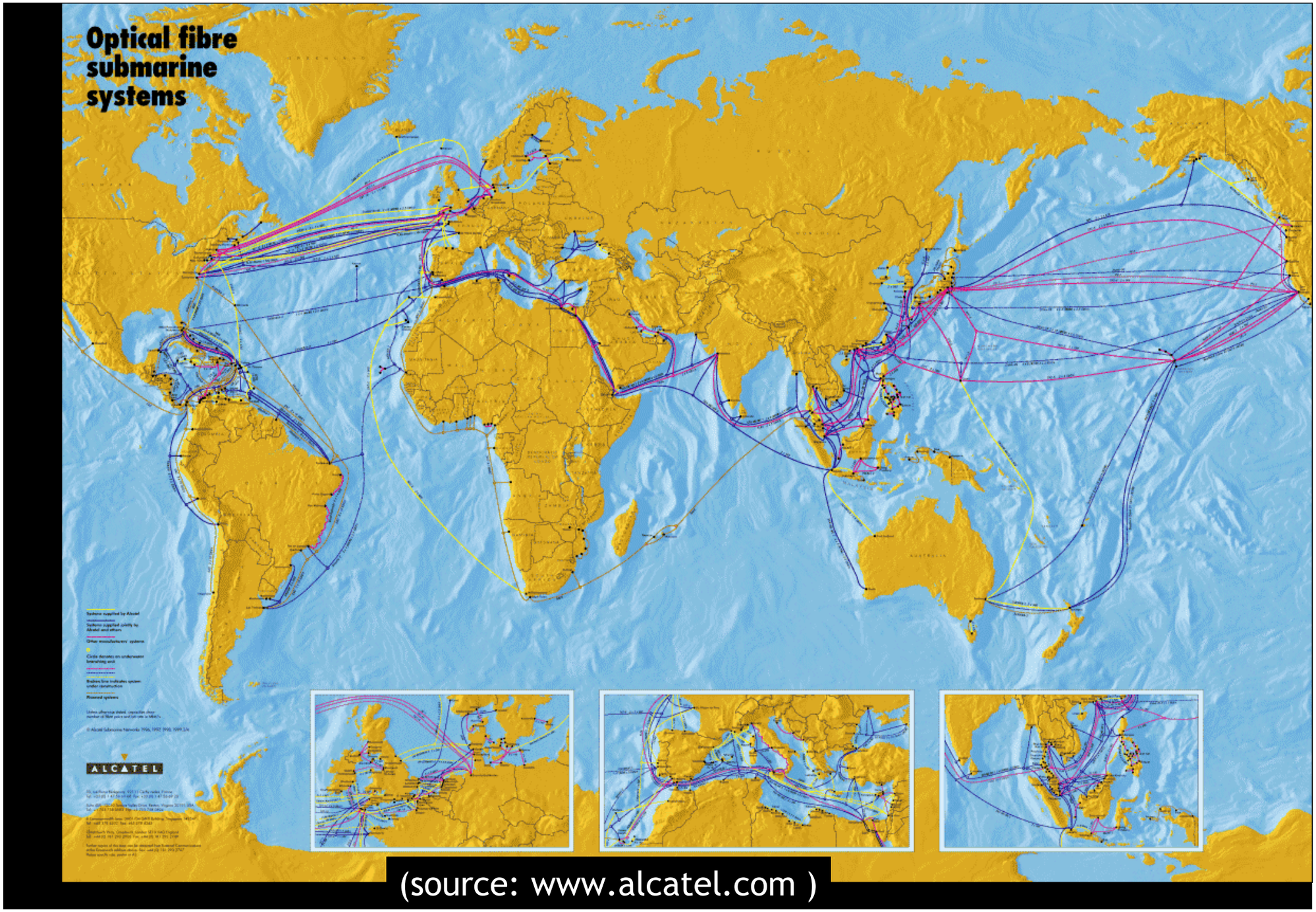




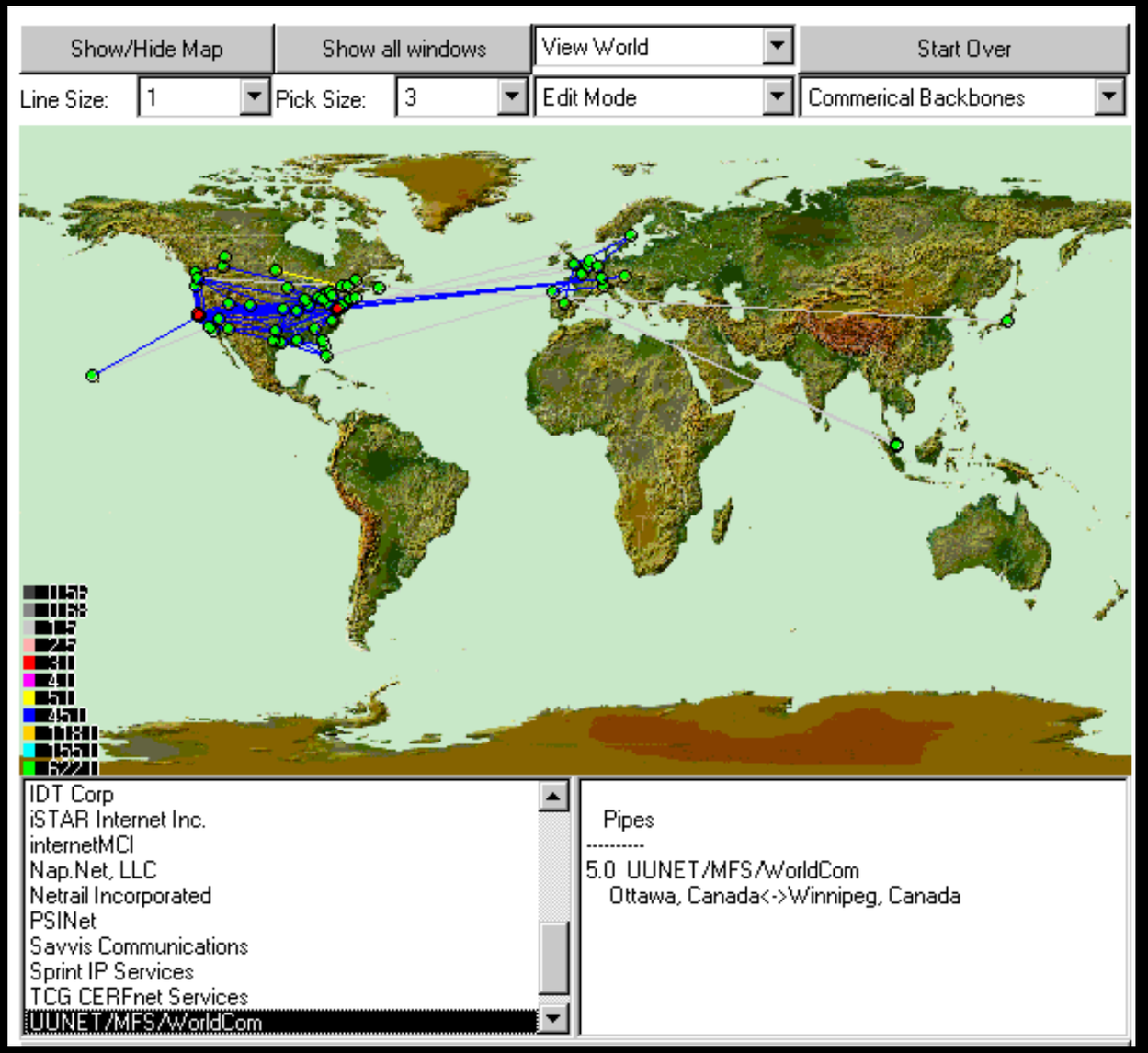
(Source: www.uu.net)



(source: www.teleglobe.com


Optical fibre submarine systems
ALCATEL
(source: www.alcatel.com)

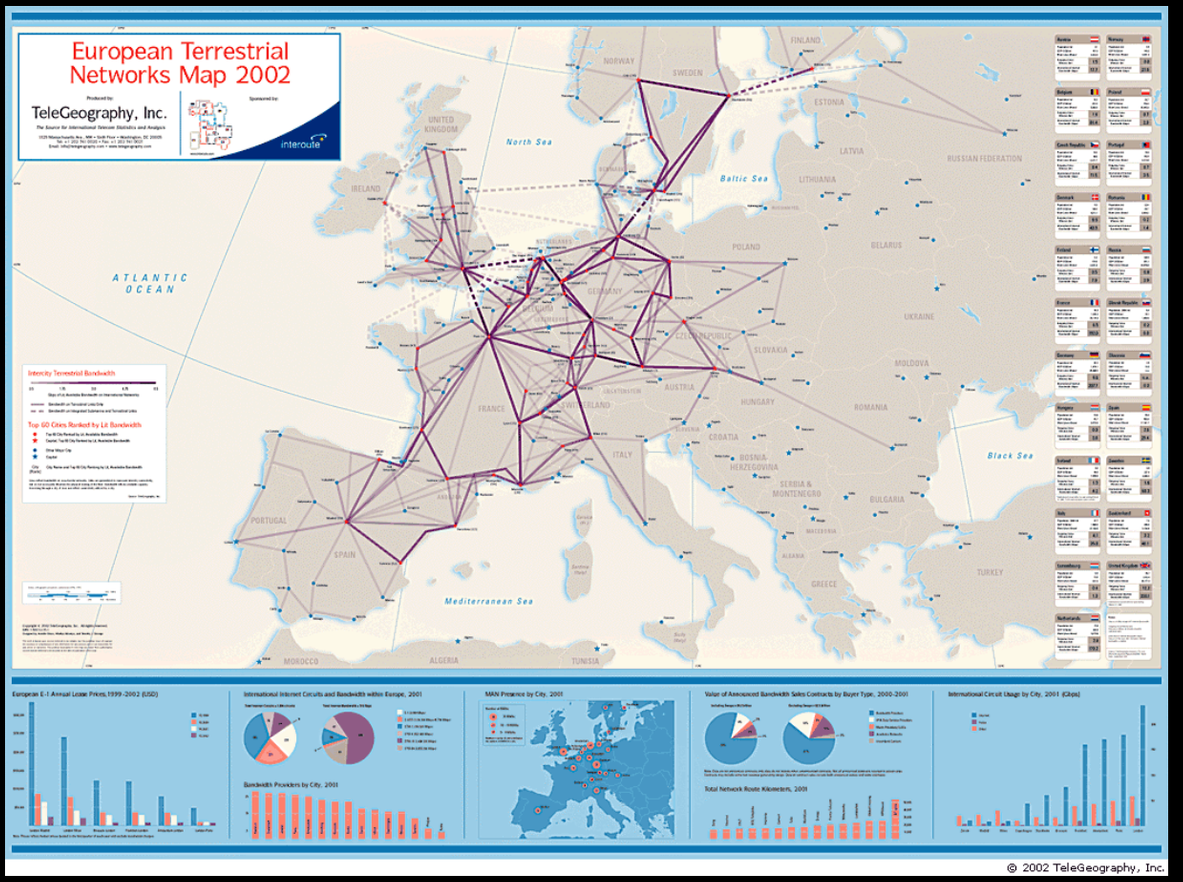
Comparing backbone networks



(source: Mapnet by CAIDA, www.caida.org/tools/visualization/mapnet/)

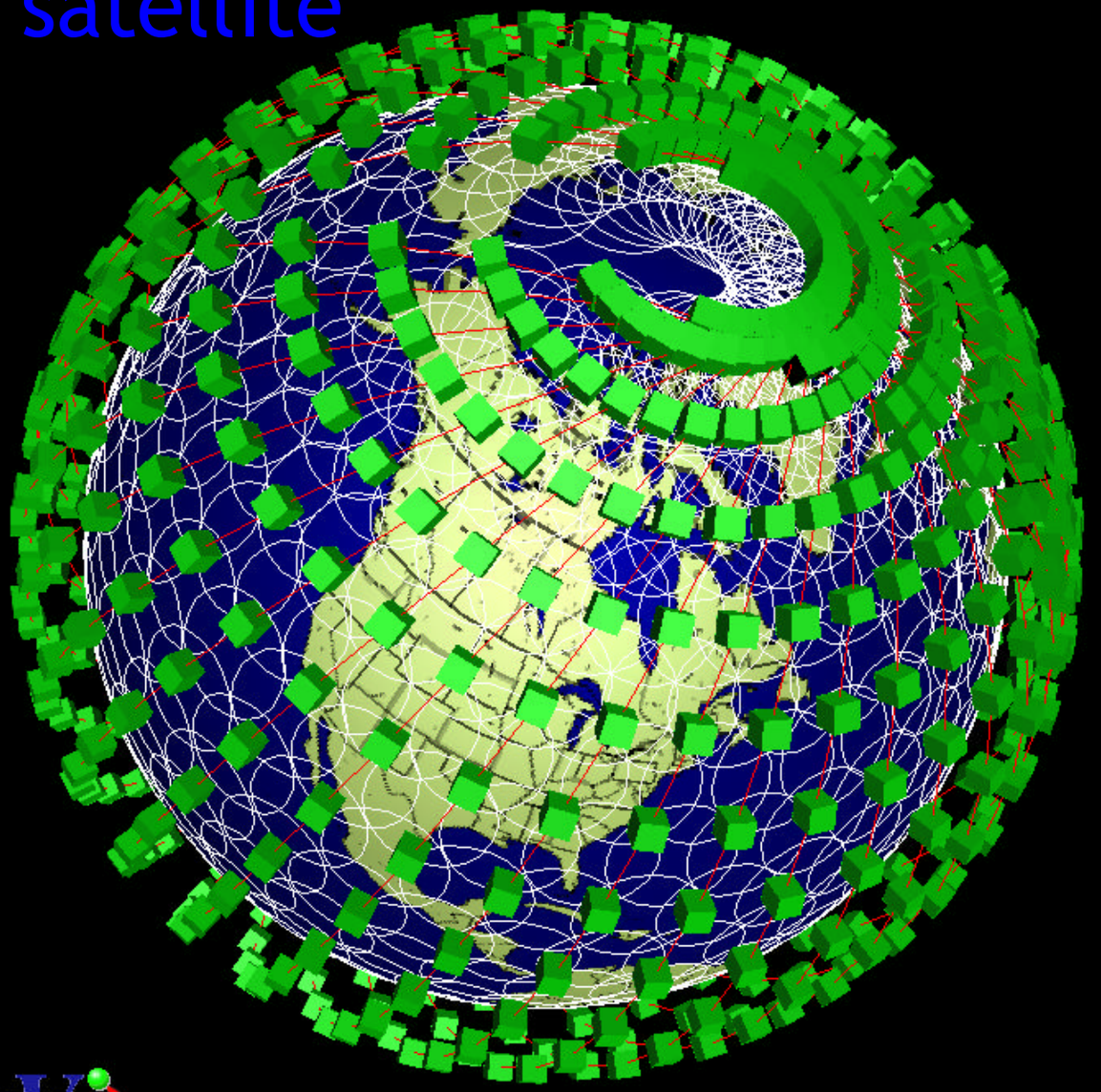
Poster maps of telco facilities ($$)

www.kmicorp.com



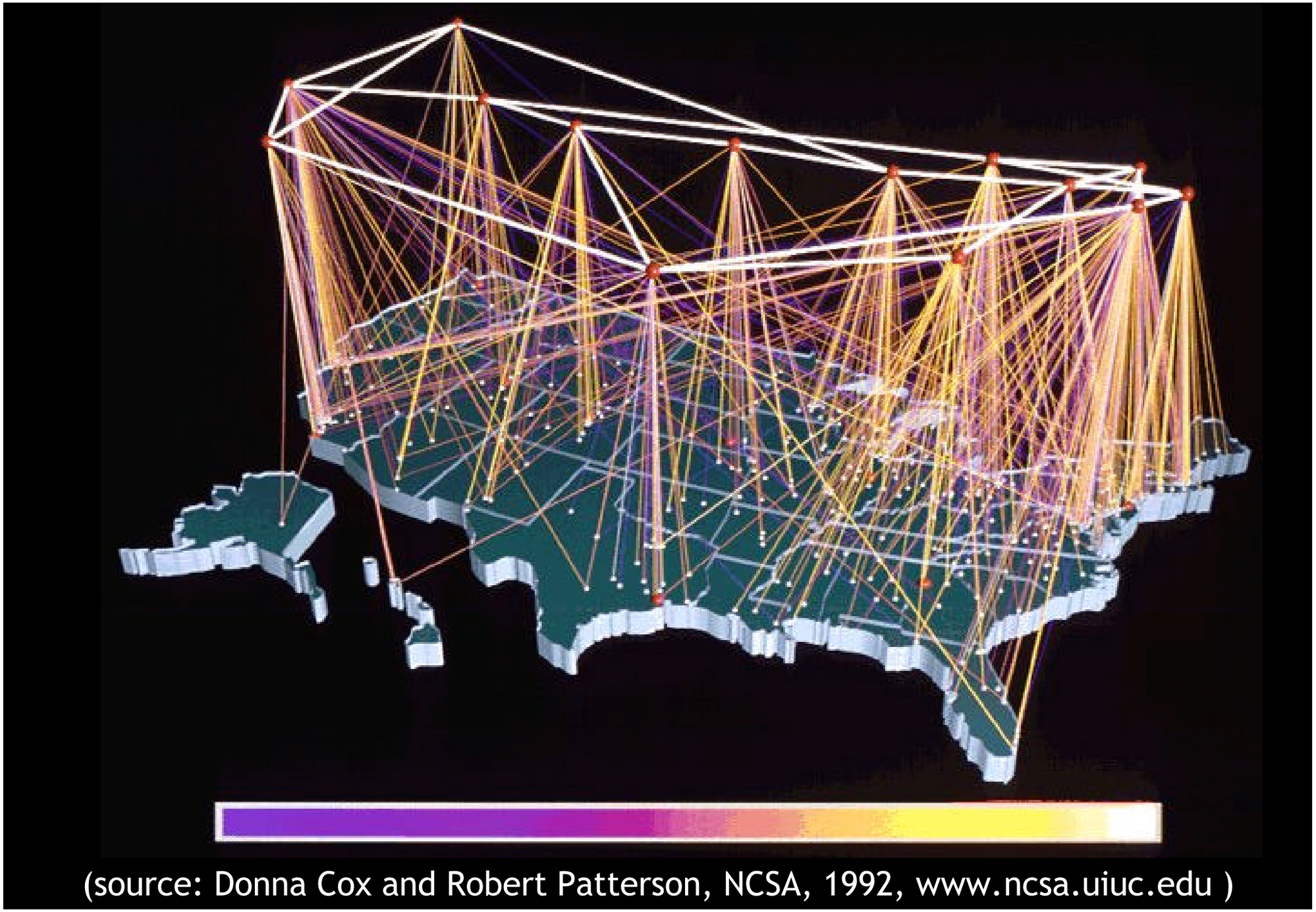
www.telegeography.com

Teledesic satellite Internet

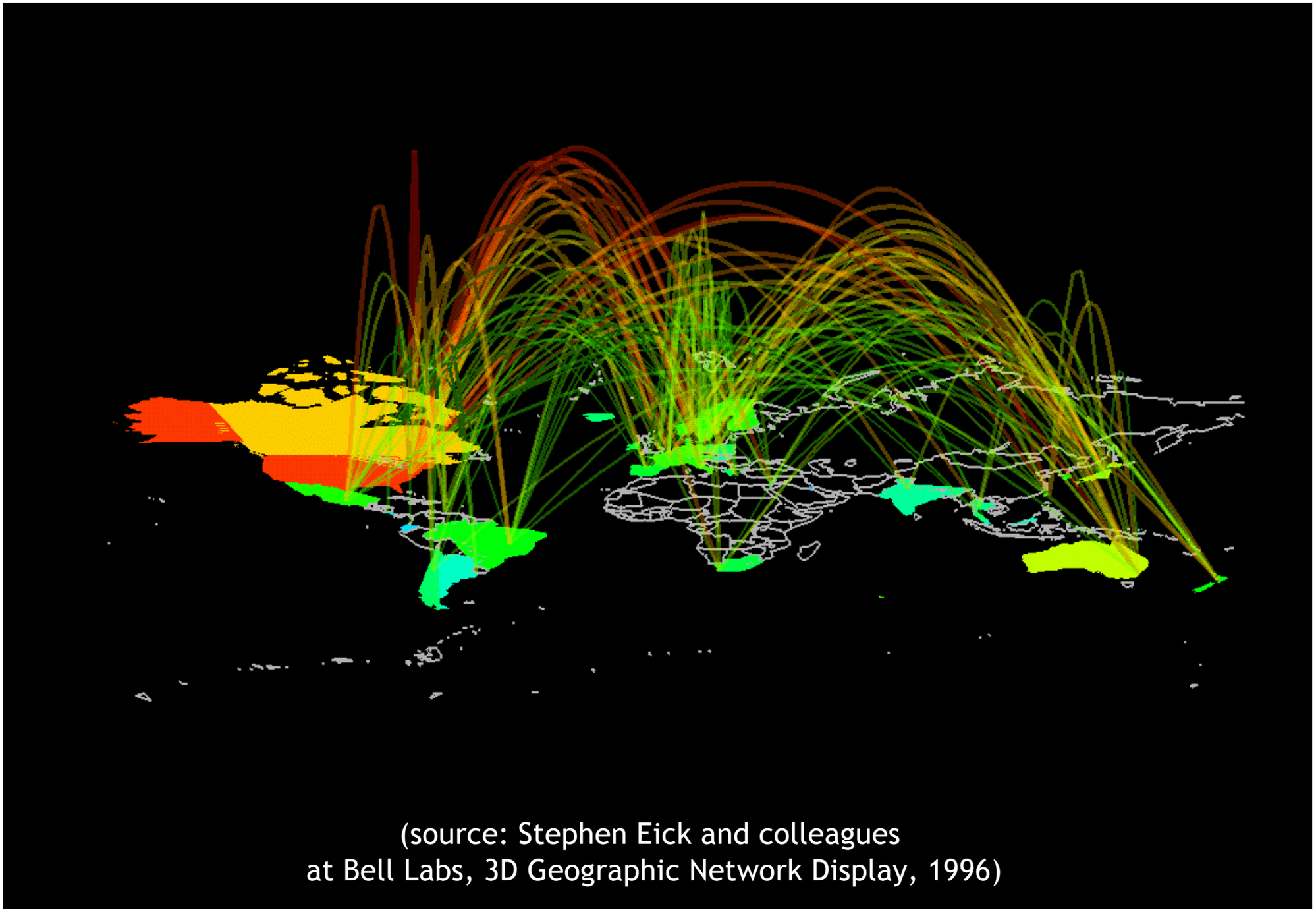


(source: Lloyd Wood, www.ee.surrey.ac.uk/Personal/L.Wood/software/SaVi/)

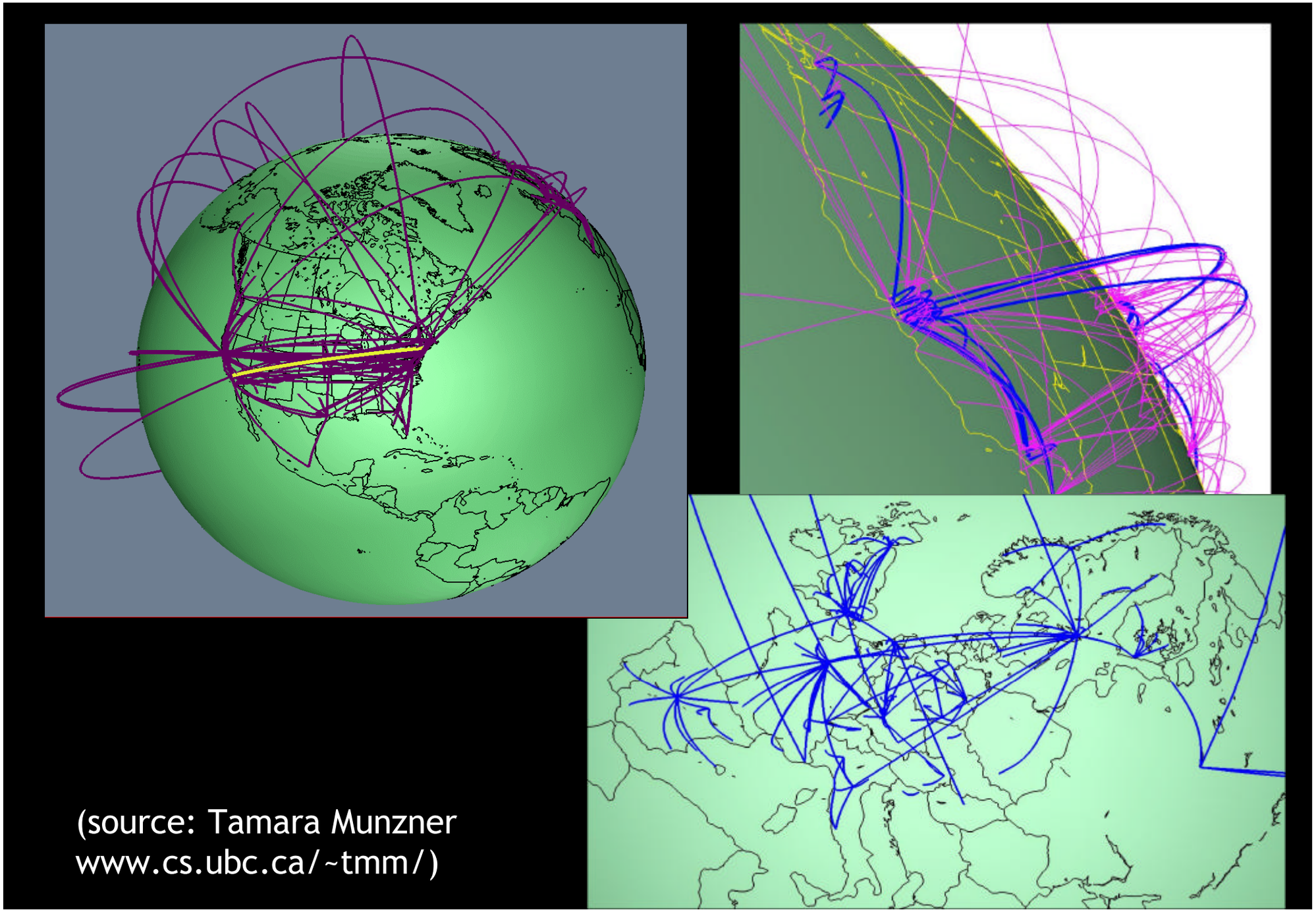
Beyond the the flat map



(source: Donna Cox and Robert Patterson, NCSA, 1992, www.ncsa.uiuc.edu)



(source: Stephen Eick and colleagues
at Bell Labs, 3D Geographic Network Display, 1996)

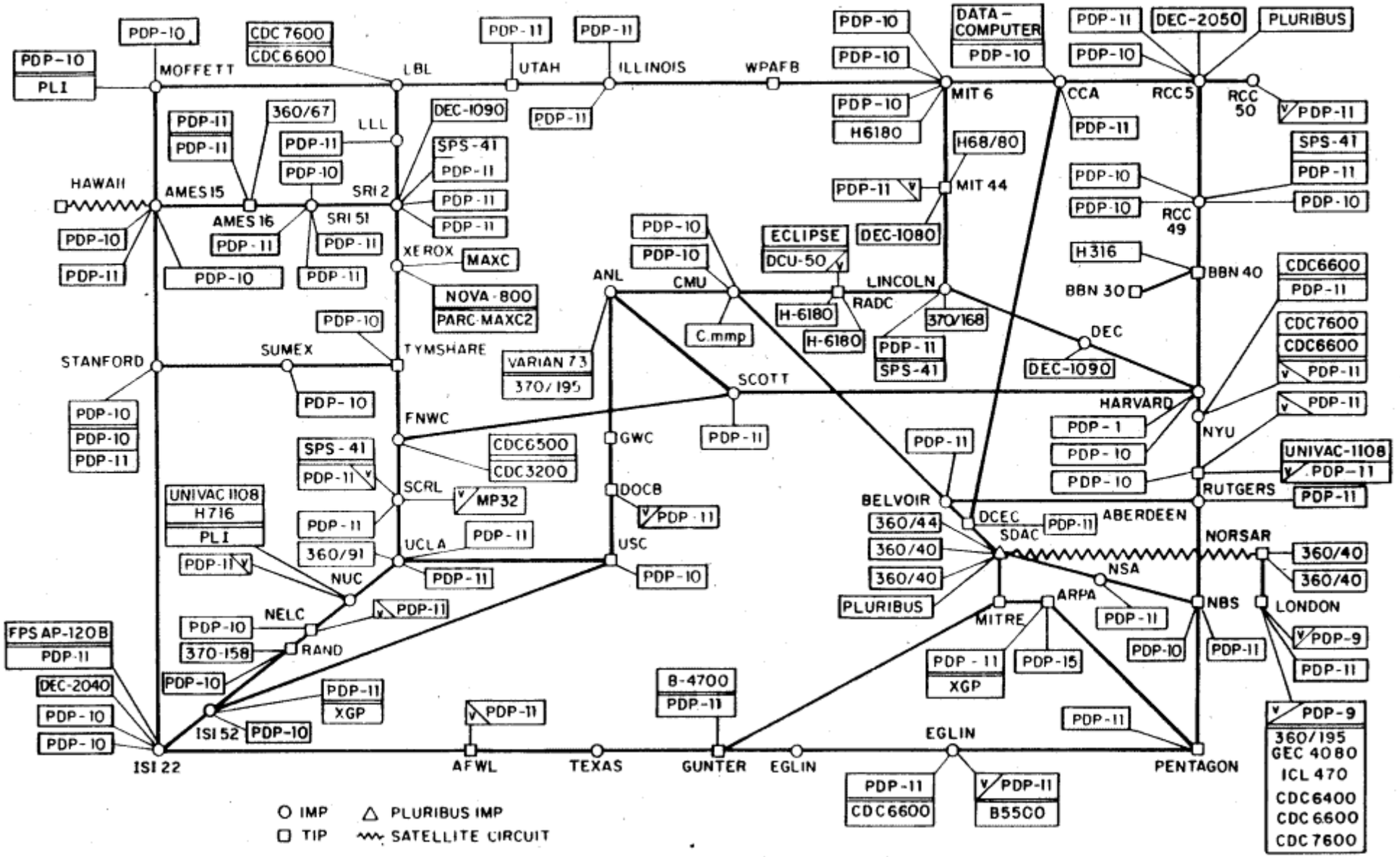


(source: Tamara Munzner
www.cs.ubc.ca/~tmm/)

Bye, bye to the geographic world

- focus is on topology, not geography
- Internet engineers often don't care about where things are, but how they are connected
- wiring diagrams rather than maps

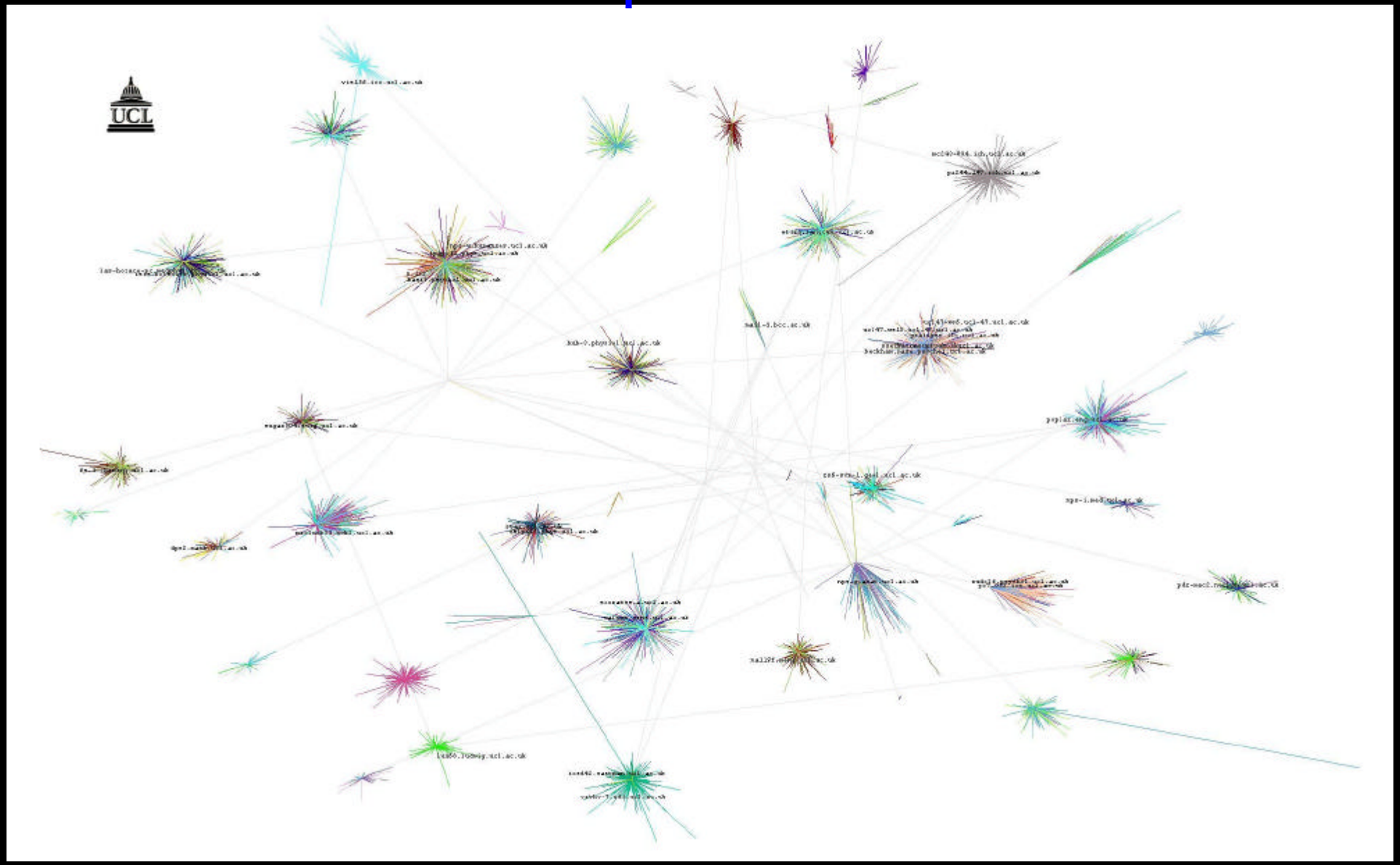
ARPANET LOGICAL MAP, MARCH 1977



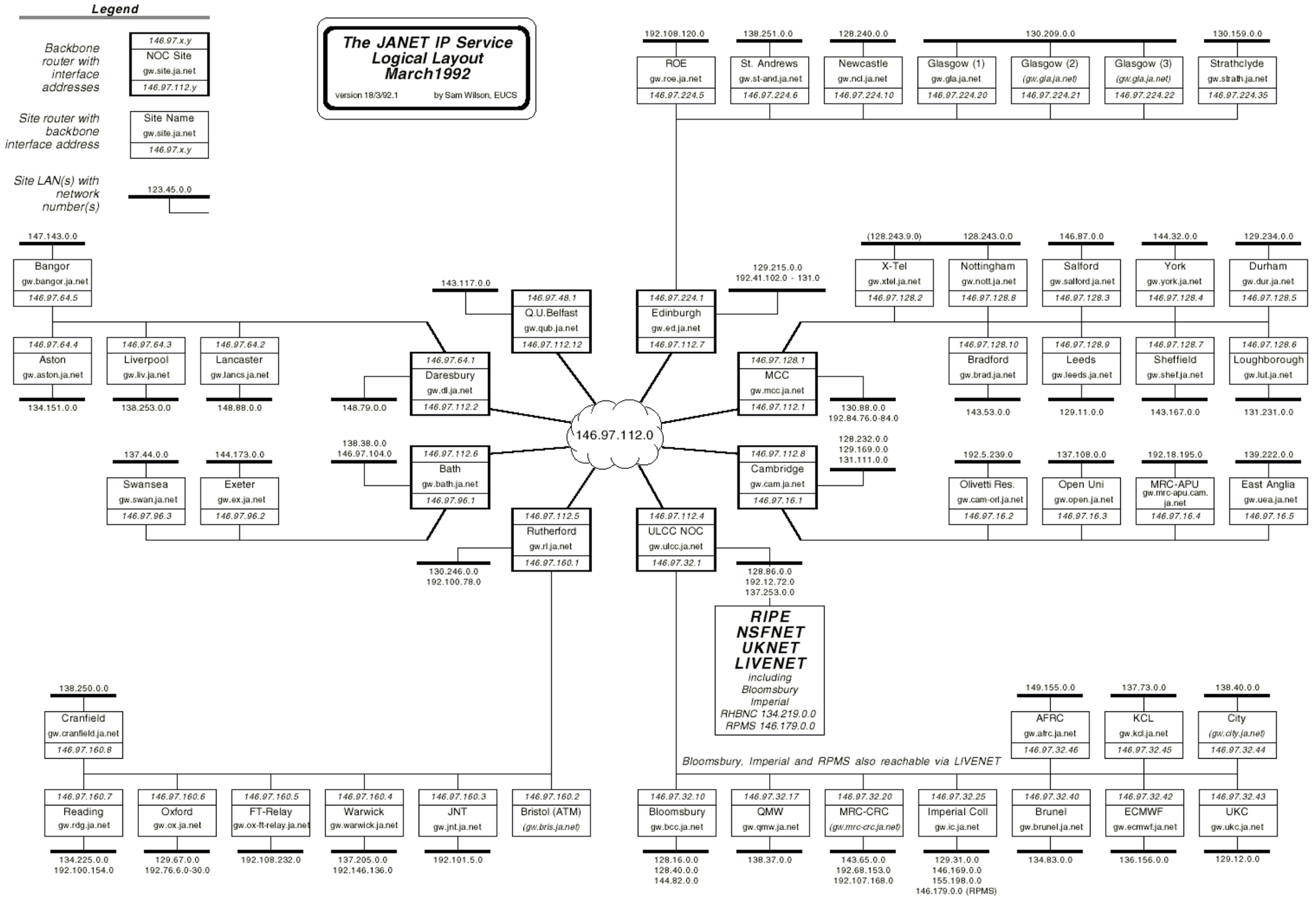
(PLEASE NOTE THAT WHILE THIS MAP SHOWS THE HOST POPULATION OF THE NETWORK ACCORDING TO THE BEST INFORMATION OBTAINABLE, NO CLAIM CAN BE MADE FOR ITS ACCURACY)

NAMES SHOWN ARE IMP NAMES, NOT (NECESSARILY) HOST NAMES

UCL's dept. networks



(source: Steve Coast, www.fractalus.com/steve/stuff/ipmap/index.html)


Legend
Backbone router with interface addresses
146.97.x.y
NOC Site
gw.site.ja.net
146.97.112.y
Site router with backbone interface address
Site Name
gw.site.ja.net
146.97.x.y
Site LAN(s) with network number(s)
123.45.0.0
The JANET IP Service Logical Layout March1992
version 18/3/92.1
by Sam Wilson, EUCS
146.97.112.0
ROE
gw.roe.ja.net
146.97.224.5
192.108.120.0
St. Andrews
gw.st-and.ja.net
146.97.224.6
138.251.0.0
Newcastle
gw.ncl.ja.net
146.97.224.10
128.240.0.0
Glasgow (1)
gw.gla.ja.net
146.97.224.20
Glasgow (2)
(gw.gla.ja.net)
146.97.224.21
Glasgow (3)
(gw.gla.ja.net)
146.97.224.22
130.209.0.0
Strathclyde
gw.strath.ja.net
146.97.224.35
130.159.0.0
Bangor
gw.bangor.ja.net
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147.143.0.0
Aston
gw.aston.ja.net
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134.151.0.0
Liverpool
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146.97.64.3
138.253.0.0
Lancaster
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148.88.0.0
Daresbury
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148.79.0.0
143.117.0.0
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Edinburgh
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MCC
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146.97.128.1
130.88.0.0
192.84.76.0-84.0
X-Tel
gw.xtel.ja.net
146.97.128.2
(128.243.9.0)
Nottingham
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128.243.0.0
Bradford
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York
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Sheffield
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Durham
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129.234.0.0
Loughborough
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131.231.0.0
Swansea
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146.97.96.3
137.44.0.0
Exeter
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146.97.96.2
144.173.0.0
Bath
gw.bath.ja.net
146.97.96.1
146.97.112.6
138.38.0.0
146.97.104.0
Cambridge
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146.97.16.1
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128.232.0.0
129.169.0.0
131.111.0.0
Olivetti Res.
gw.cam-orl.ja.net
146.97.16.2
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Open Uni
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146.97.16.3
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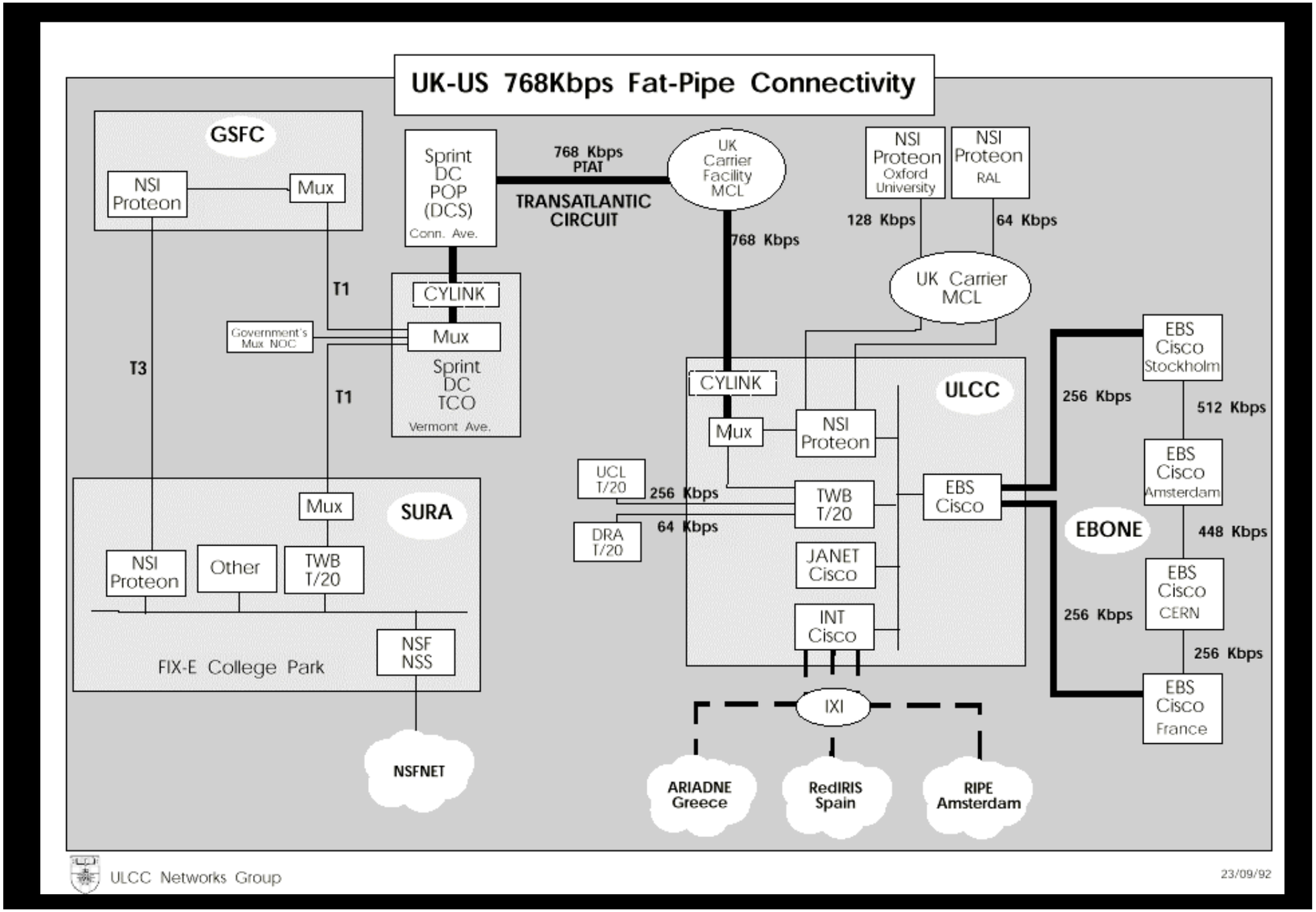
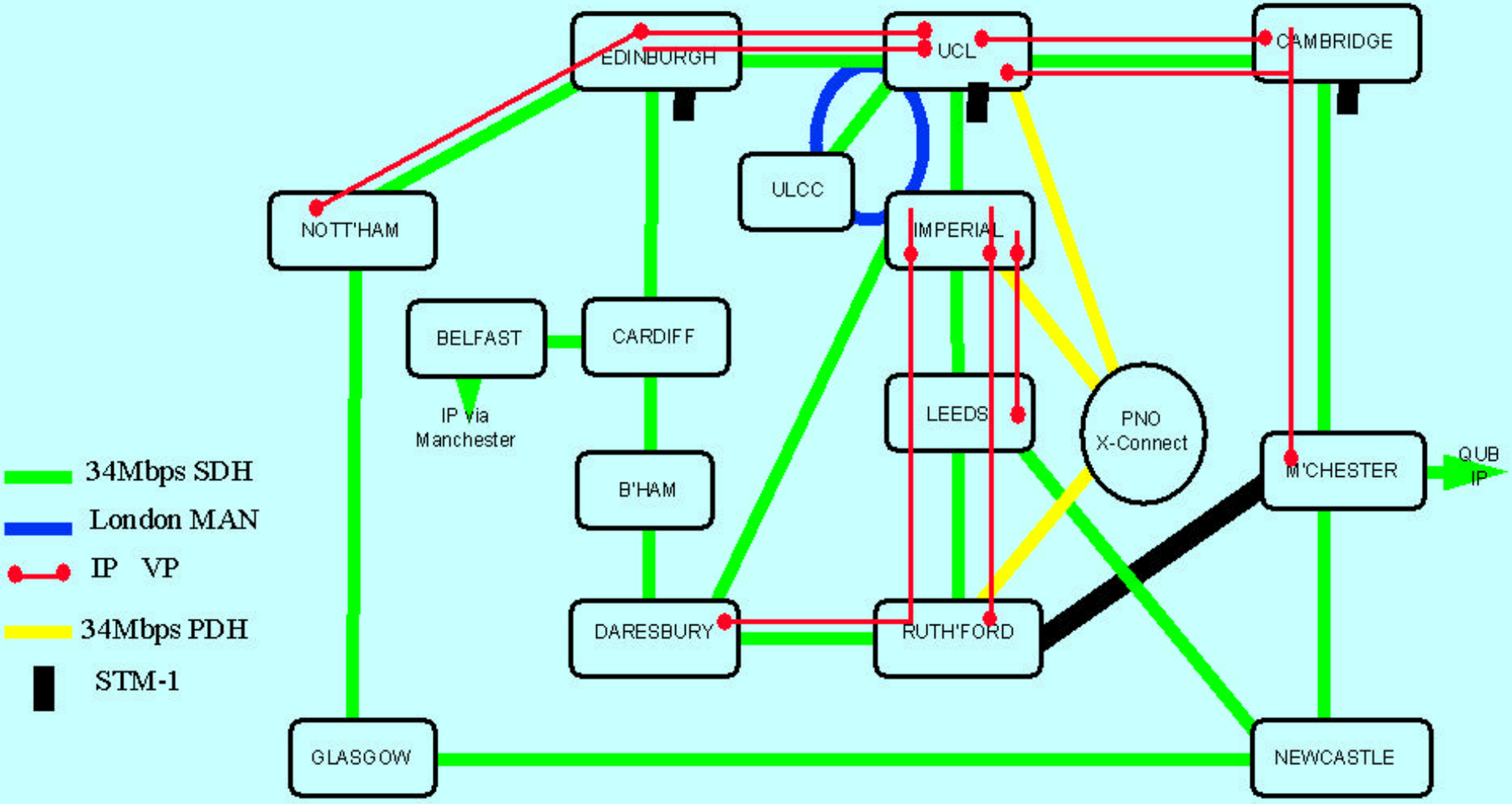
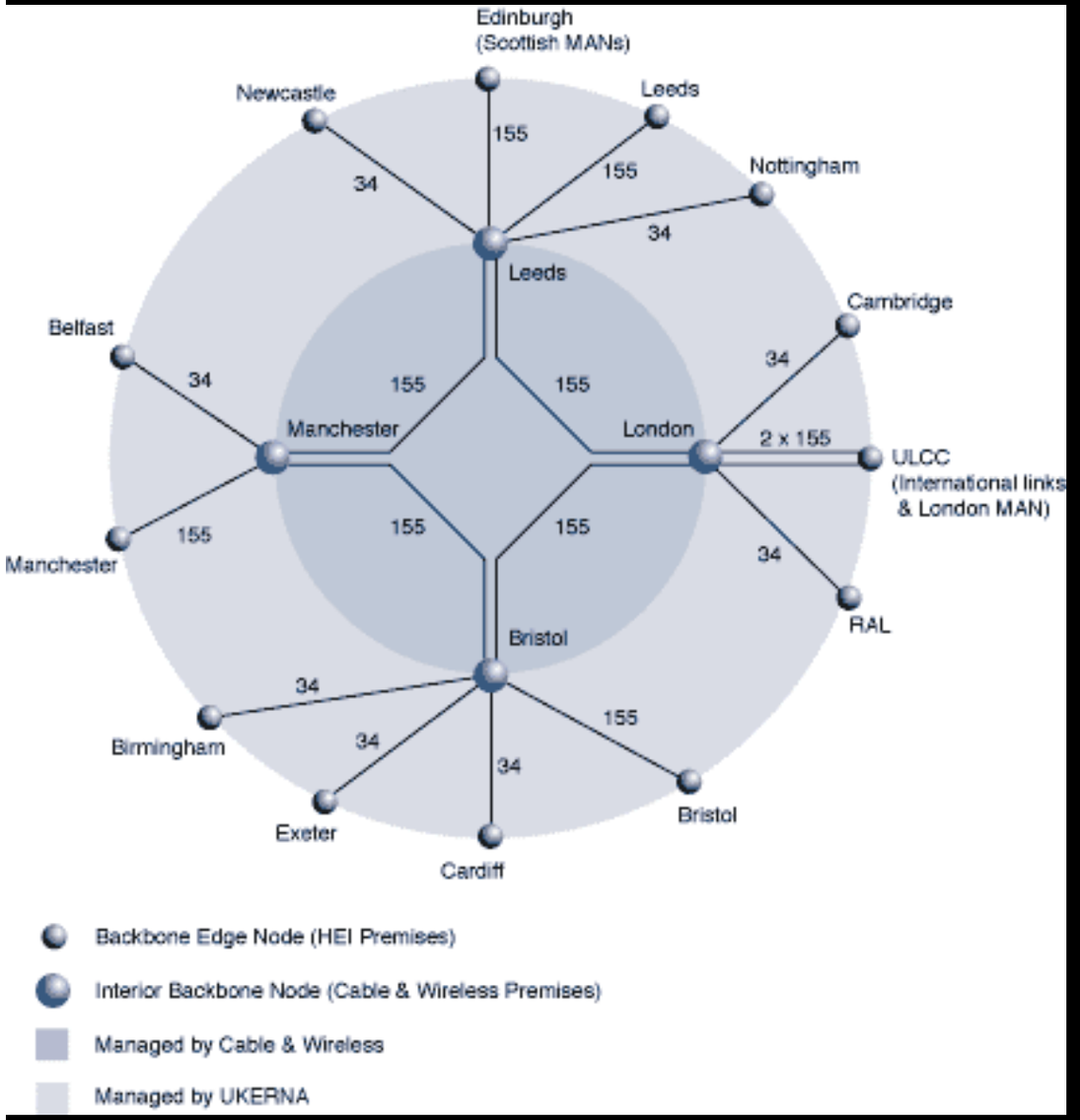
MRC-APU
gw.mrc-apu.cam.ja.net
146.97.16.4
192.18.195.0
East Anglia
gw.uea.ja.net
146.97.16.5
139.222.0.0
Rutherford
gw.rl.ja.net
146.97.160.1
146.97.112.5
130.246.0.0
192.100.78.0
ULCC NOC
gw.ulcc.ja.net
146.97.32.1
146.97.112.4
128.86.0.0
192.12.72.0
137.253.0.0
RIPE
NSFNET
UKNET
LIVENET
including
Bloomsbury
Imperial
RHBNC 134.219.0.0
RPMS 146.179.0.0
Bloomsbury, Imperial and RPMS also reachable via LIVENET
Cranfield
gw.cranfield.ja.net
146.97.160.8
138.250.0.0
Reading
gw.rdg.ja.net
146.97.160.7
134.225.0.0
192.100.154.0
Oxford
gw.ox.ja.net
146.97.160.6
129.67.0.0
192.76.6.0-30.0
FT-Relay
gw.ox-ft-relay.ja.net
146.97.160.5
192.108.232.0
Warwick
gw.warwick.ja.net
146.97.160.4
137.205.0.0
192.146.136.0
JNT
gw.jnt.ja.net
146.97.160.3
192.101.5.0
Bristol (ATM)
(gw.bris.ja.net)
146.97.160.2
Bloomsbury
gw.bcc.ja.net
146.97.32.10
128.16.0.0
128.40.0.0
144.82.0.0
QMW
gw.qmw.ja.net
146.97.32.17
138.37.0.0
MRC-CRC
(gw.mrc-crc.ja.net)
146.97.32.20
143.65.0.0
192.68.153.0
192.107.168.0
Imperial Coll
gw.ic.ja.net
146.97.32.25
129.31.0.0
146.169.0.0
155.198.0.0
146.179.0.0 (RPMS)
AFRC
gw.afrc.ja.net
146.97.32.46
149.155.0.0
Brunel
gw.brunel.ja.net
146.97.32.40
134.83.0.0
KCL
gw.kcl.ja.net
146.97.32.45
137.73.0.0
ECMWF
gw.ecmwf.ja.net
146.97.32.42
136.156.0.0
City
(gw.city.ja.net)
146.97.32.44
138.40.0.0
UKC
gw.ukc.ja.net
146.97.32.43
129.12.0.0

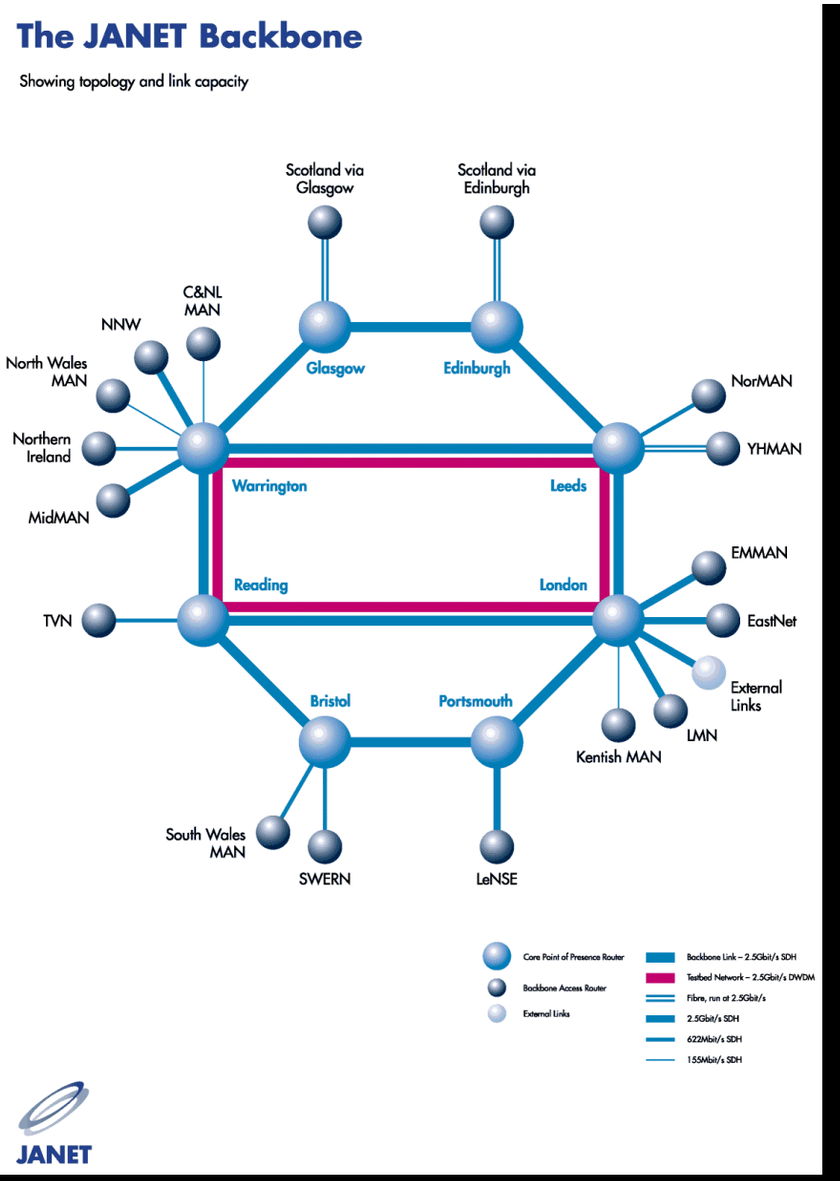

UK-US 768Kbps Fat-Pipe Connectivity
GSFC
NSI Proteon
Mux
Sprint DC POP (DCS)
Conn. Ave.
768 Kbps PTAT
TRANSATLANTIC CIRCUIT
UK Carrier Facility MCL
NSI Proteon Oxford University
NSI Proteon RAL
128 Kbps
64 Kbps
768 Kbps
UK Carrier MCL
T1
CYLINK
Government's Mux NOC
Mux
Sprint DC TCO
Vermont Ave.
T3
T1
CYLINK
ULCC
Mux
NSI Proteon
UCL T/20
256 Kbps
TWB T/20
EBS Cisco
DRA T/20
64 Kbps
JANET Cisco
INT Cisco
EBS Cisco Stockholm
256 Kbps
512 Kbps
EBS Cisco Amsterdam
EBONE
448 Kbps
EBS Cisco CERN
256 Kbps
256 Kbps
EBS Cisco France
Mux
SURA
NSI Proteon
Other
TWB T/20
NSF NSS
FIX-E College Park
IXI
NSFNET
ARIADNE Greece
RedIRIS Spain
RIPE Amsterdam
ULCC Networks Group
23/09/92

SuperJANET ATM Topology



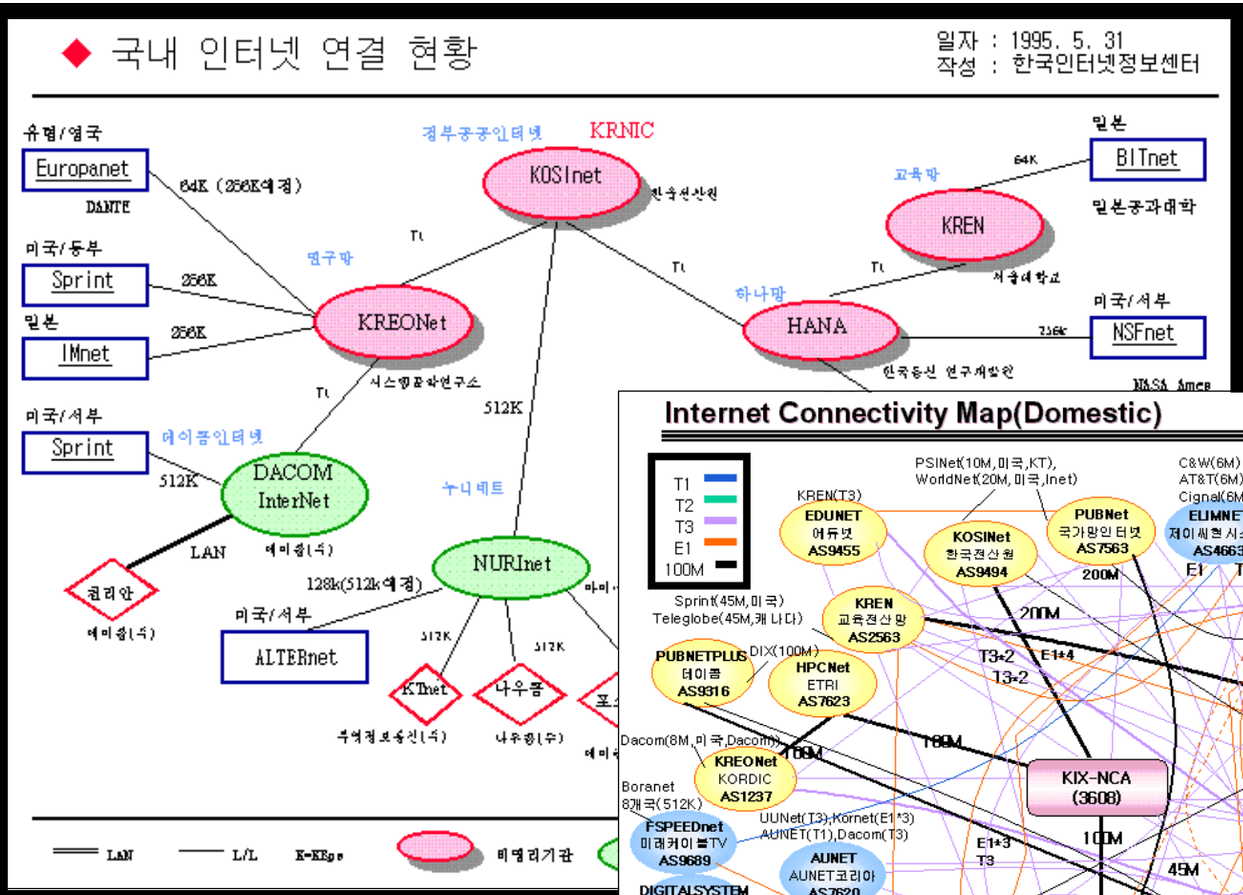
Updated by Baoyu Wang on 27 September, 1996

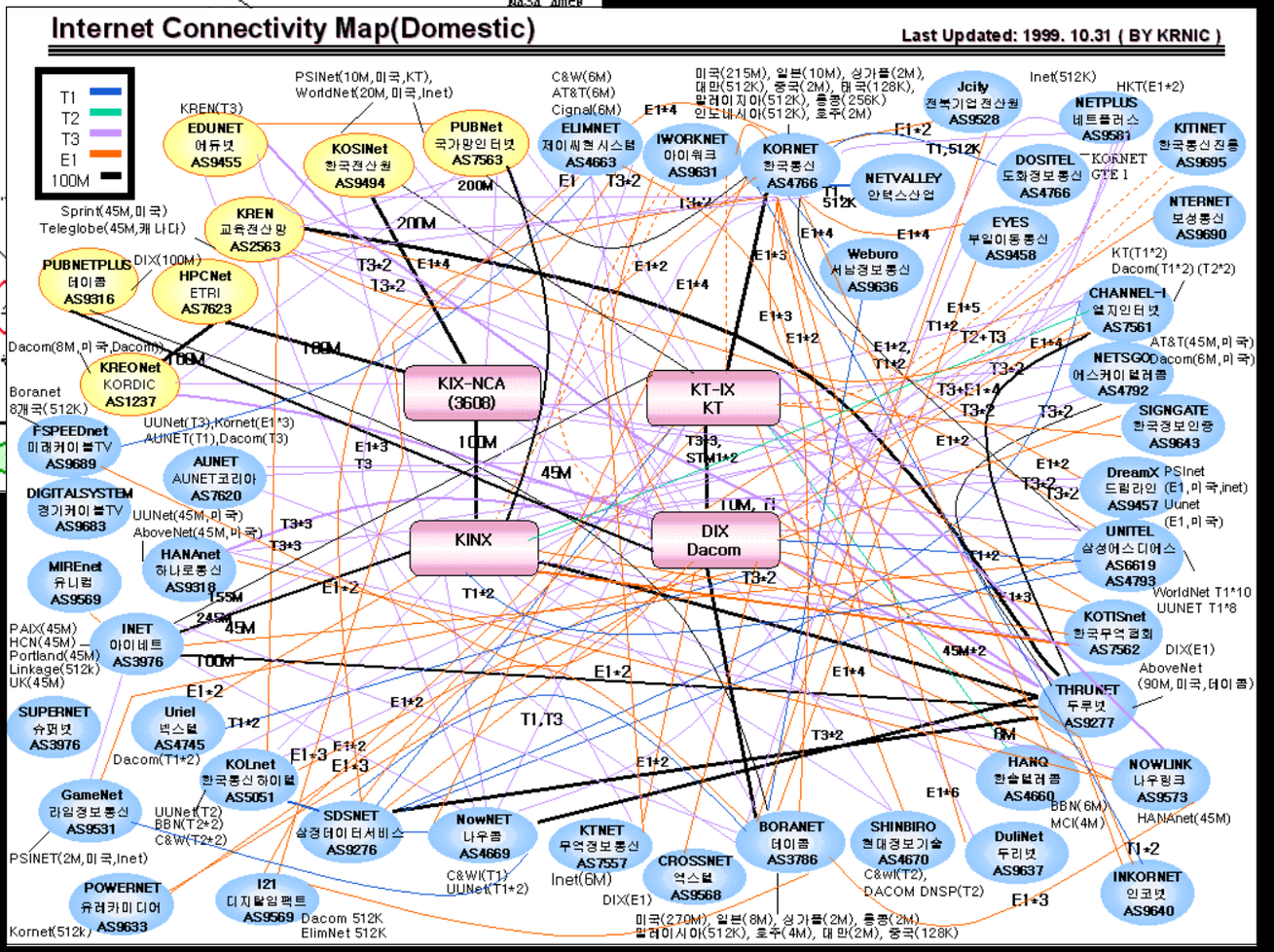




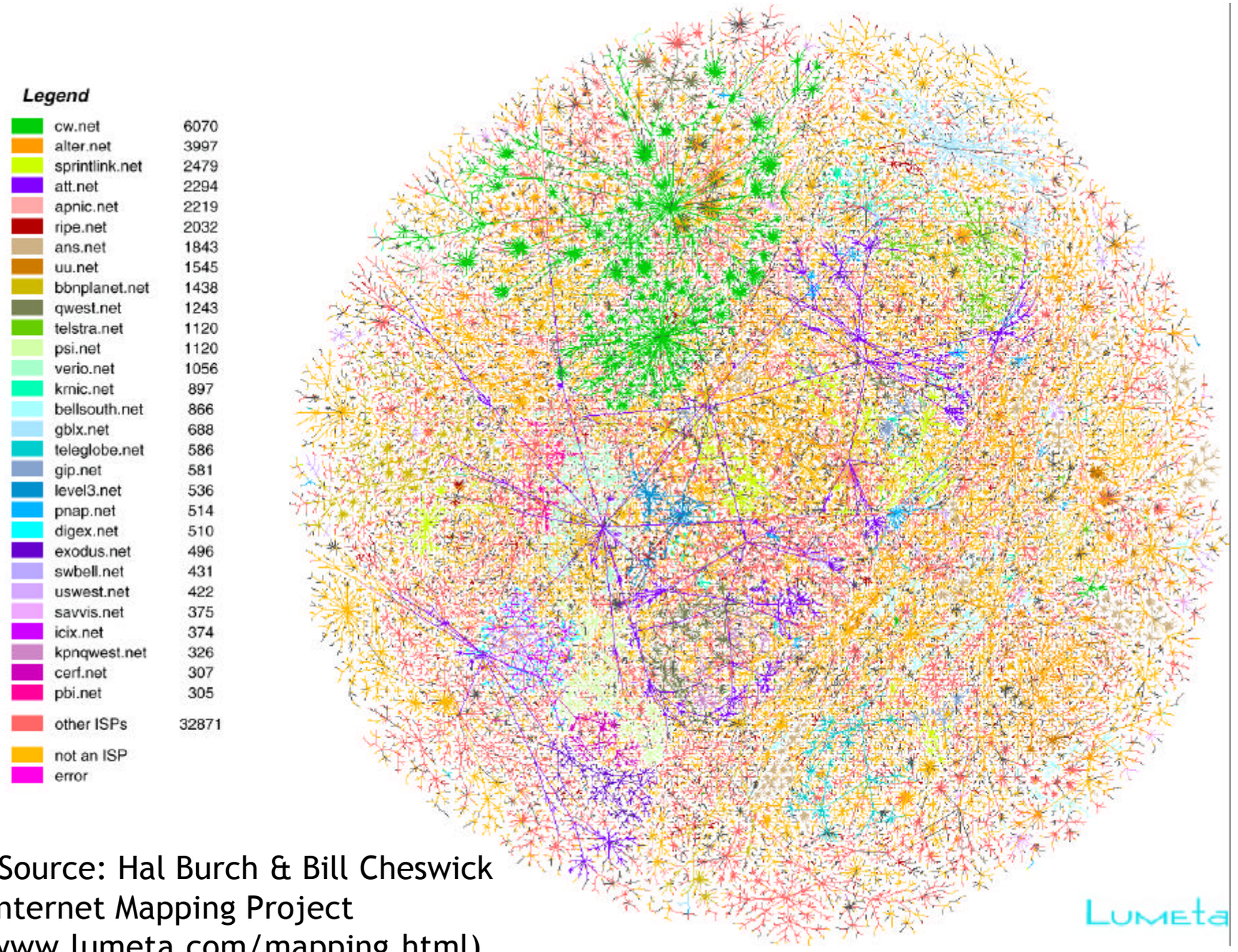
(source: http://www.ja.net)

korean internet topology

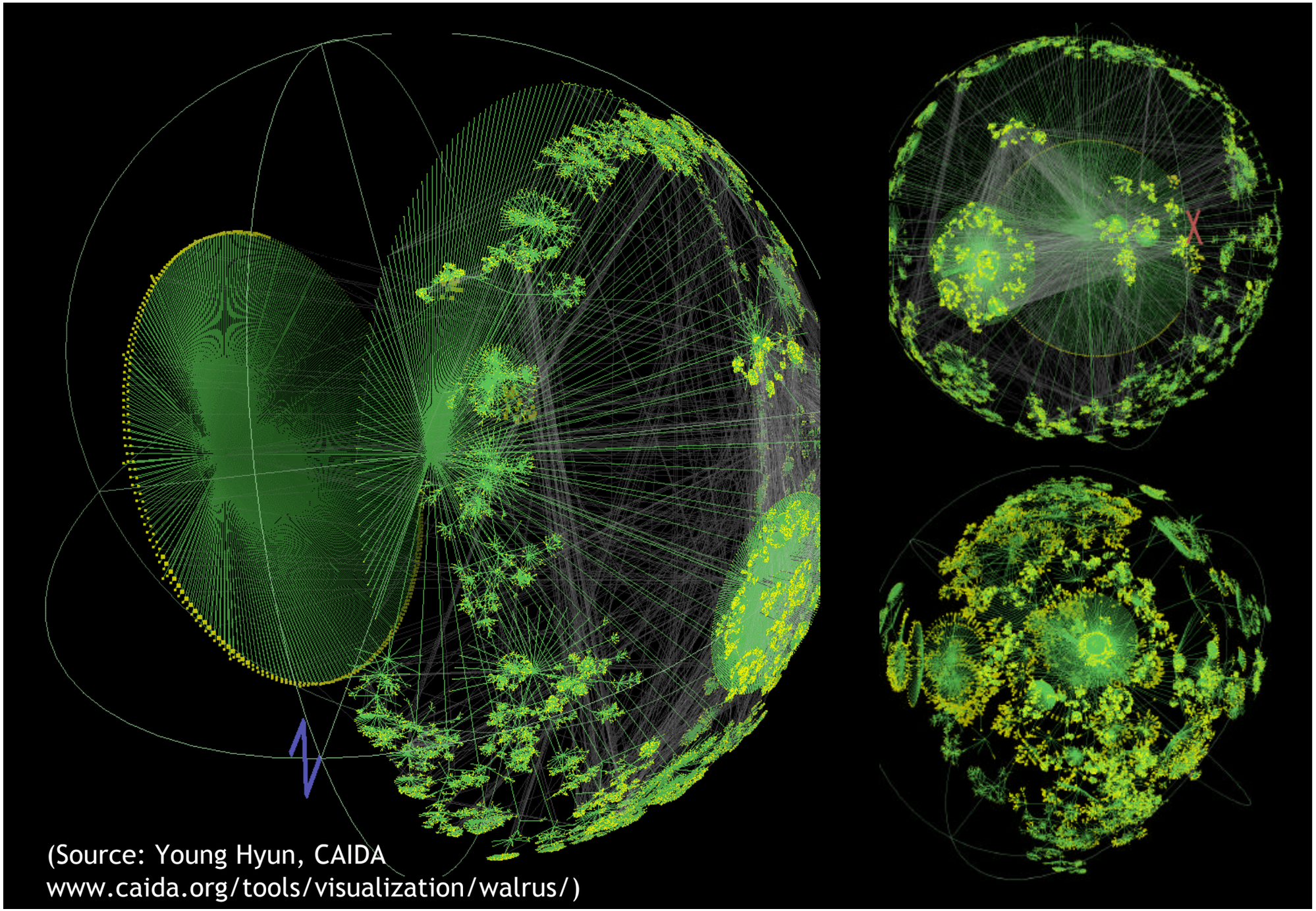




(Source: KR-NIC
http://stat.nic.or.kr)



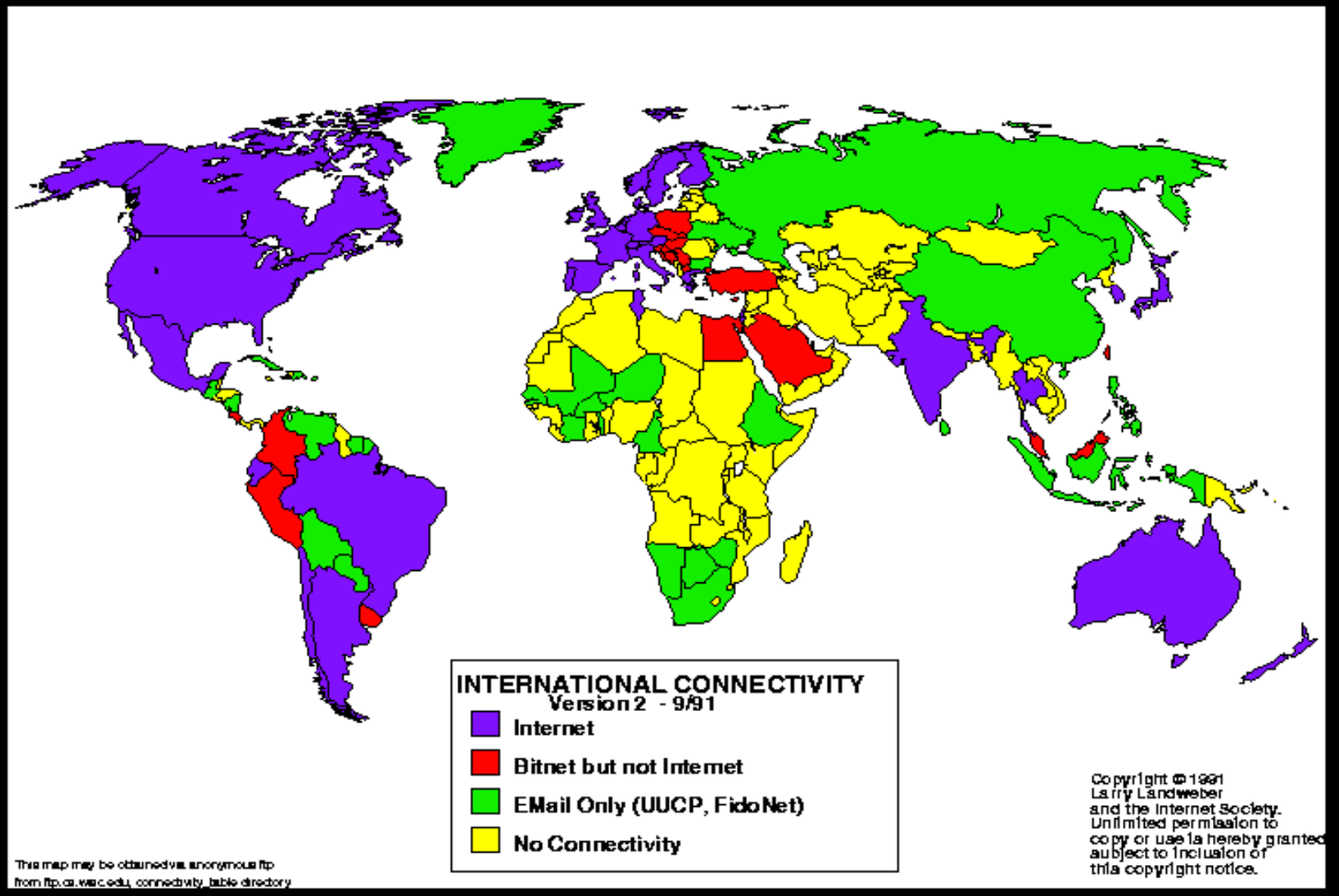
(Source: Hal Burch & Bill Cheswick
Internet Mapping Project
www.lumeta.com/mapping.html)



(Source: Young Hyun, CAIDA
www.caida.org/tools/visualization/walrus/)

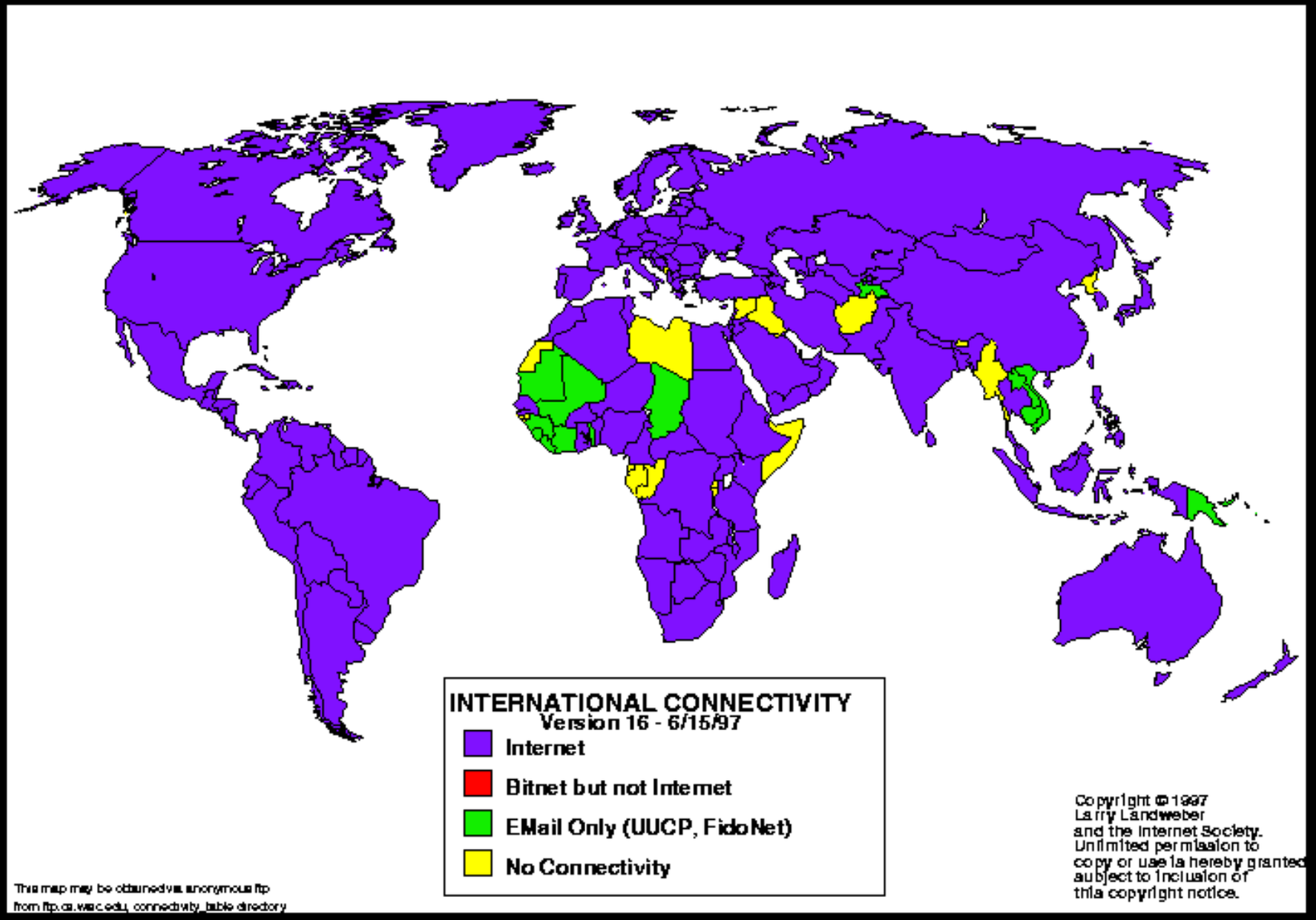
Census maps of Internet geography

Larry Landweber & ISOC national level network connectivity maps from 1990s



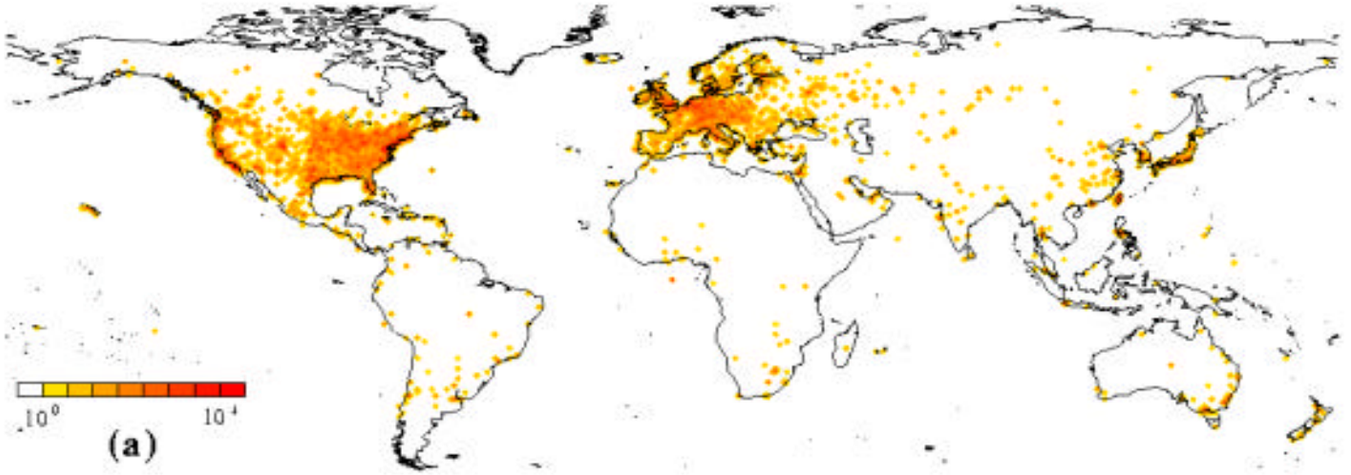
(source: ftp.cs.wisc.edu/connectivity_table/)

the whole world now pretty much wired??

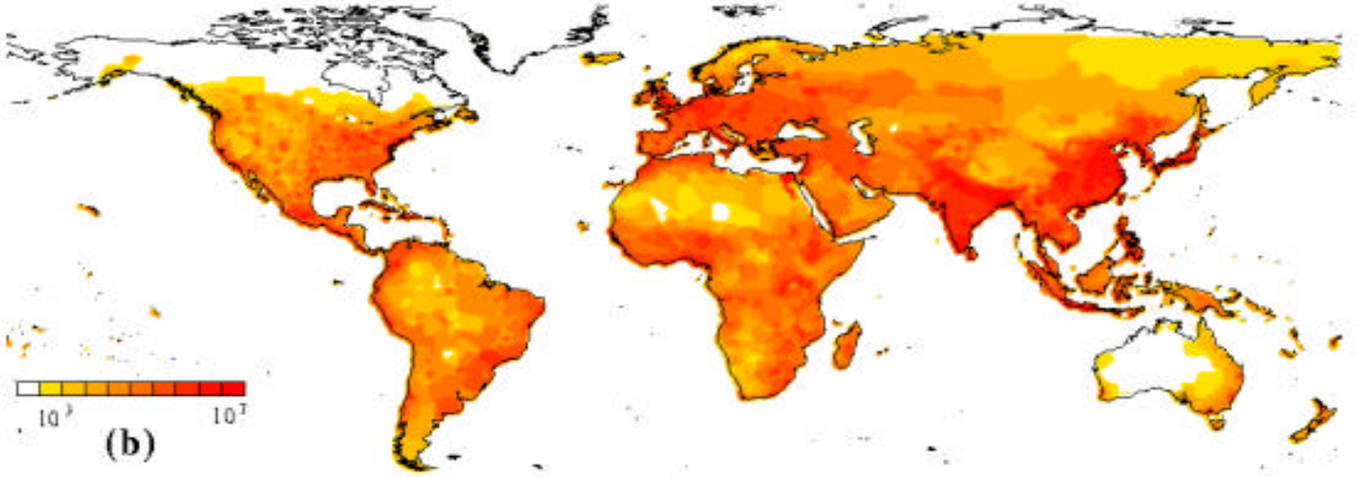


Geographic density of Internet routers

Router density

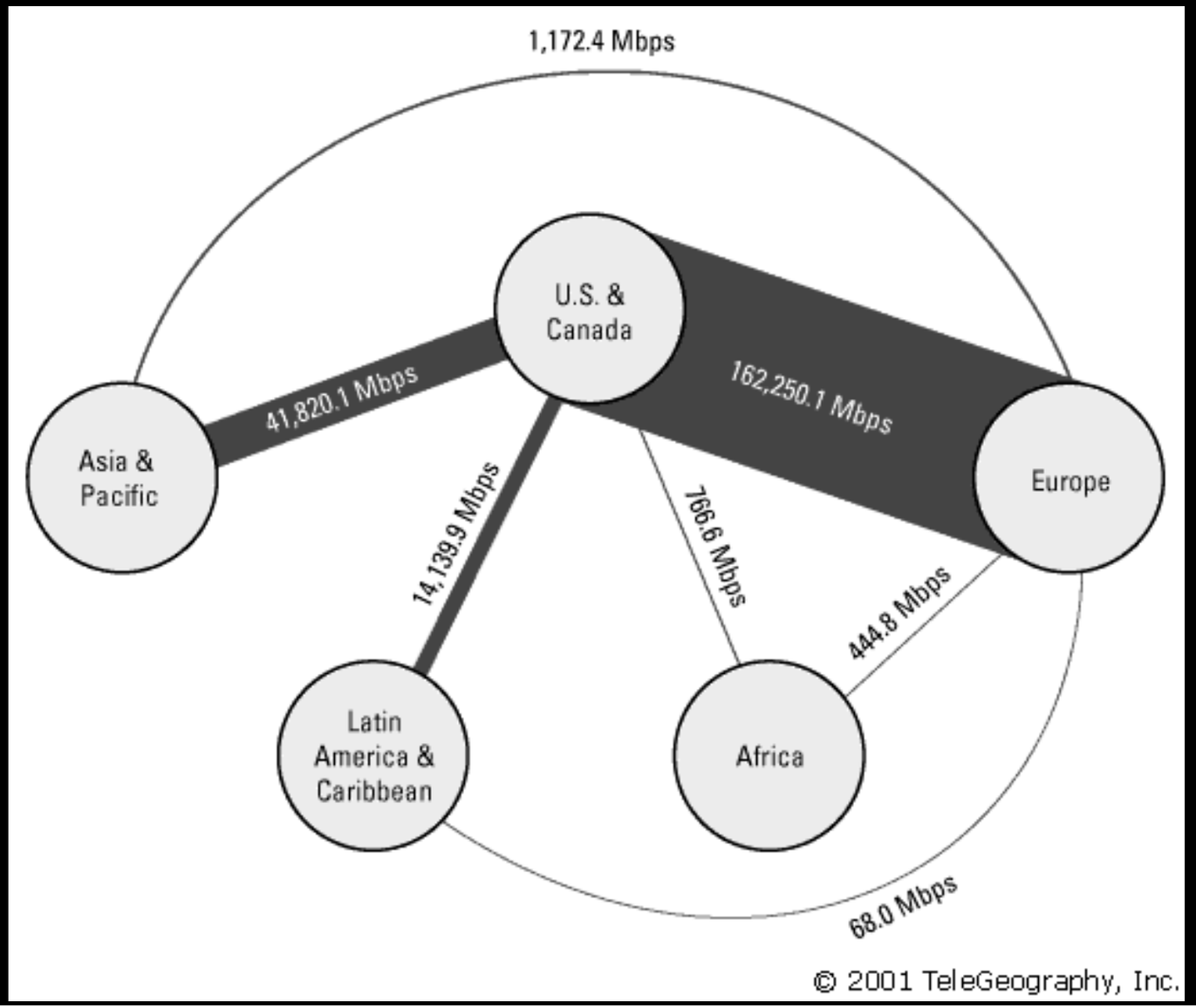


Population density

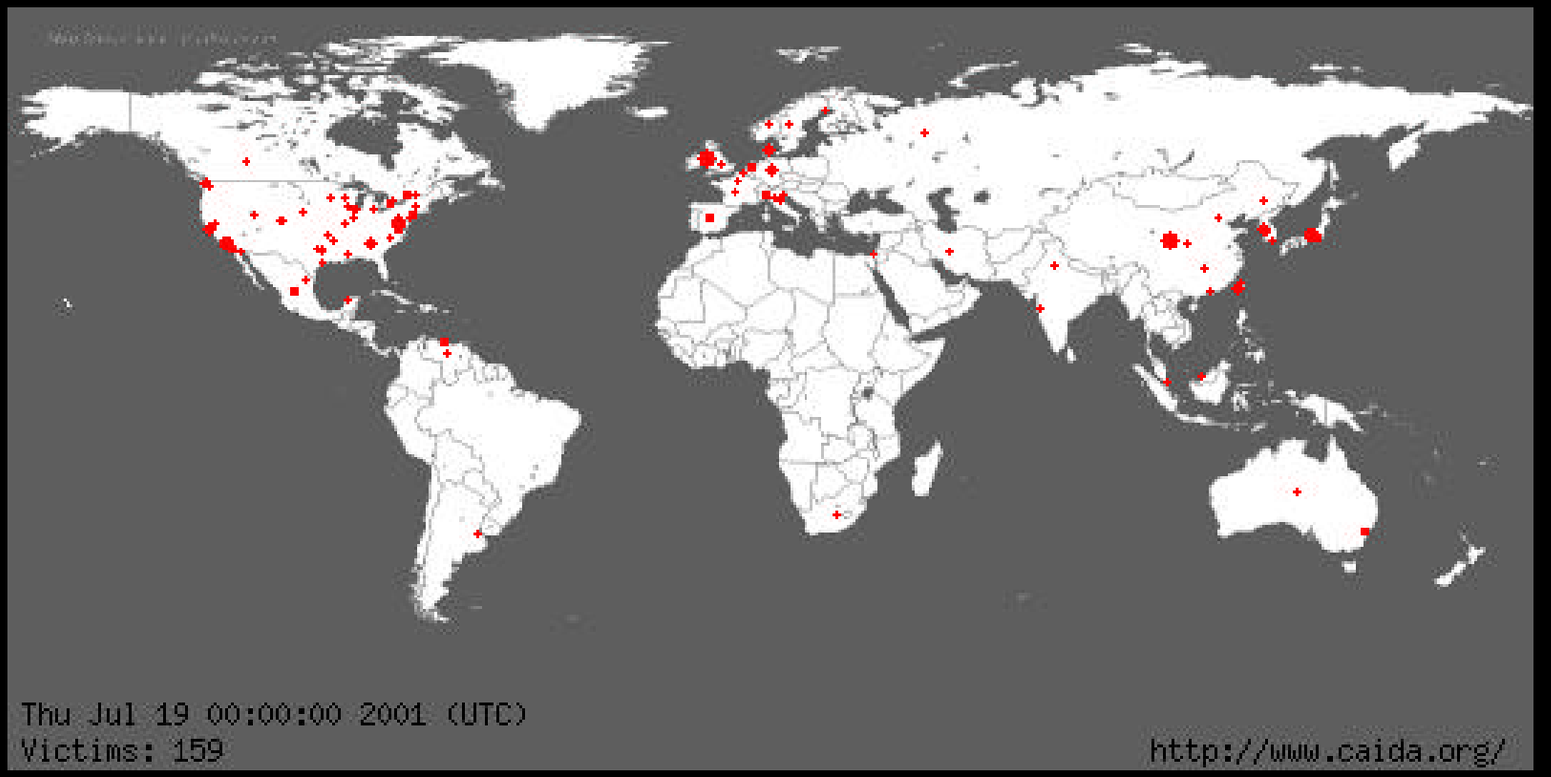


(source: Modeling the internet 's large-scale topology, http://xxx.lanl.gov/abs/cond-mat/0107417)

Uneven bandwidth geography - stylised TeleGeography ‘map’

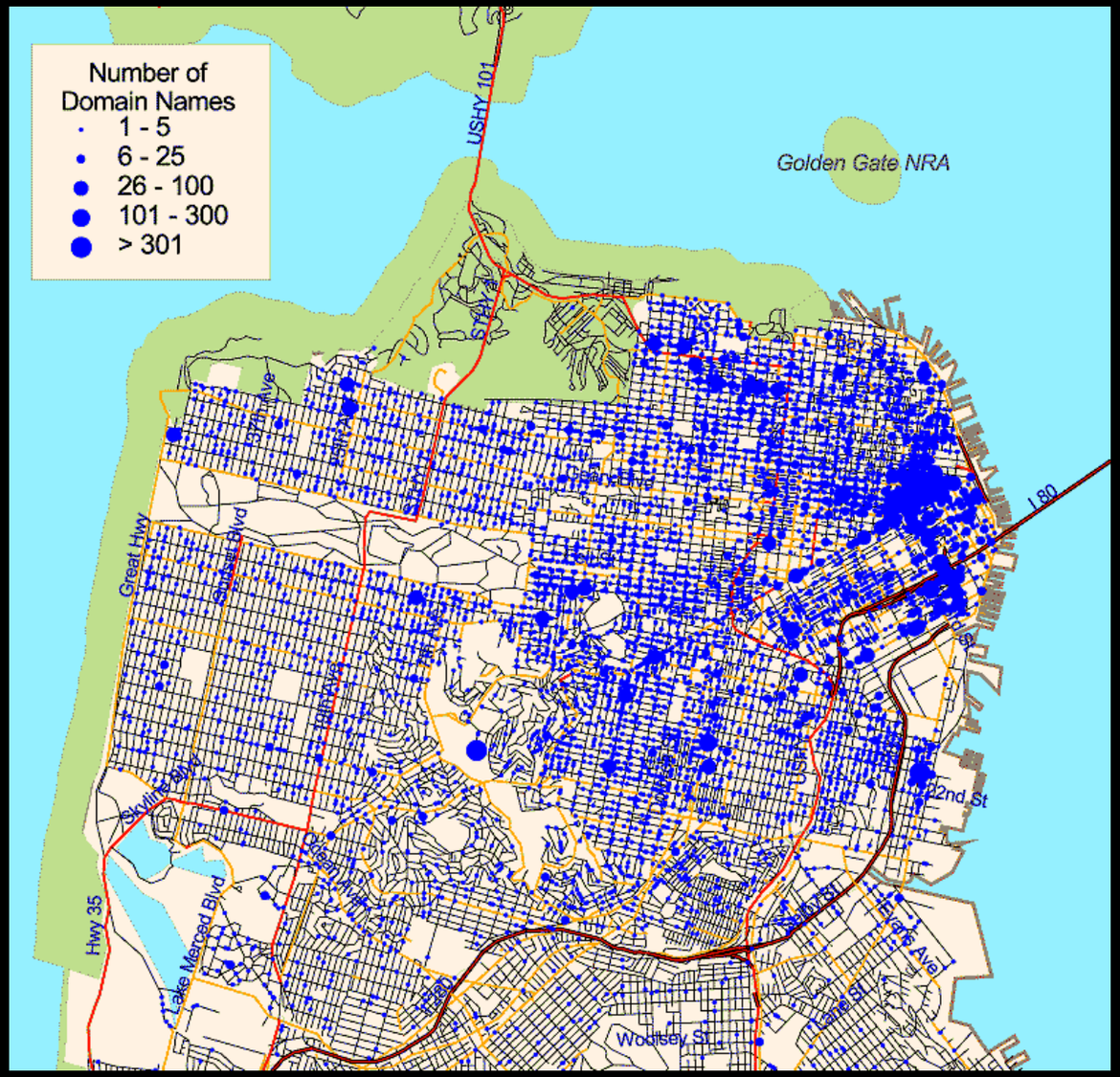


Mapping virus diffusion - Code-Red



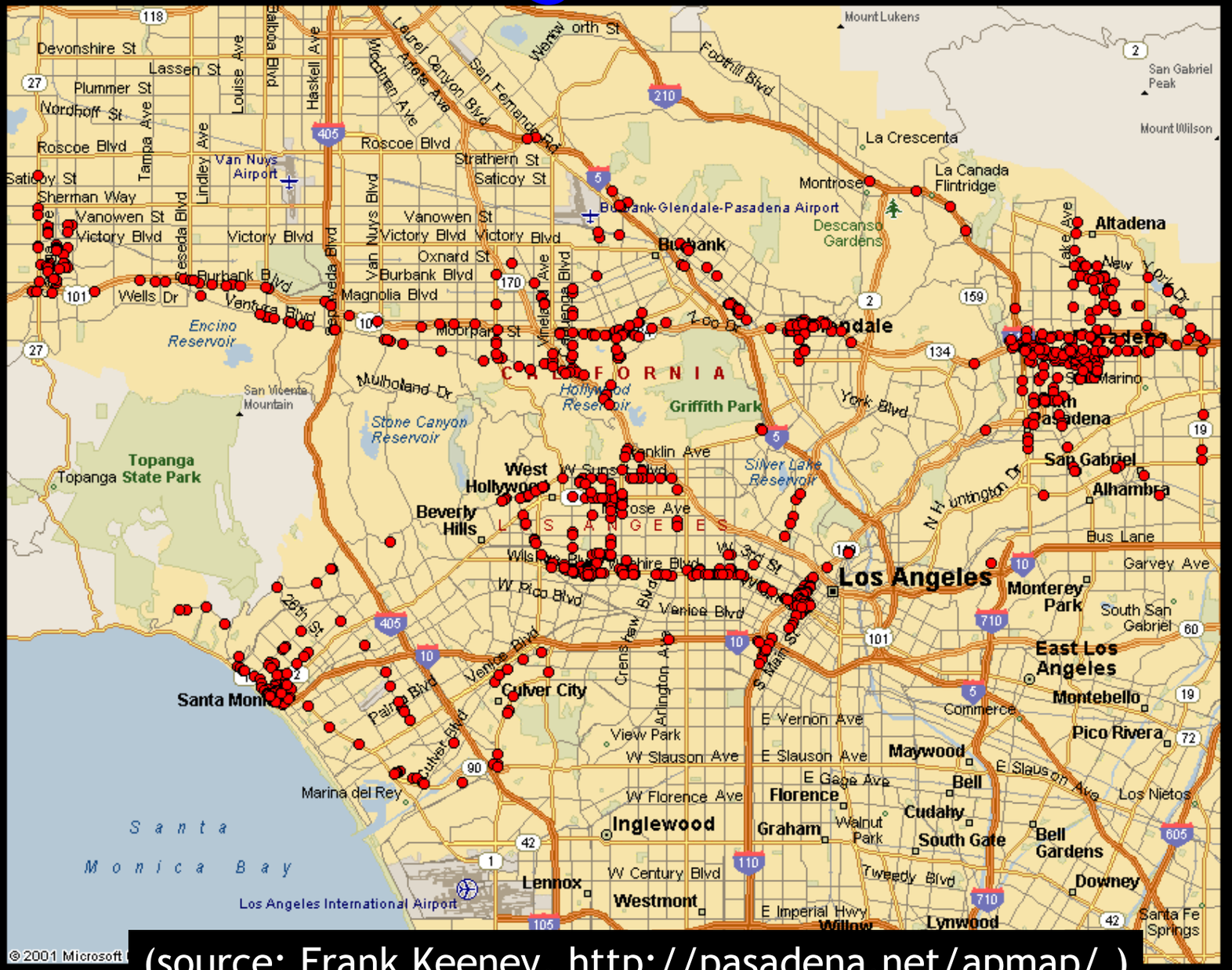
(source: Caida, www.caida.org/analysis/security/code-red/)

Dotcom domain names in SF

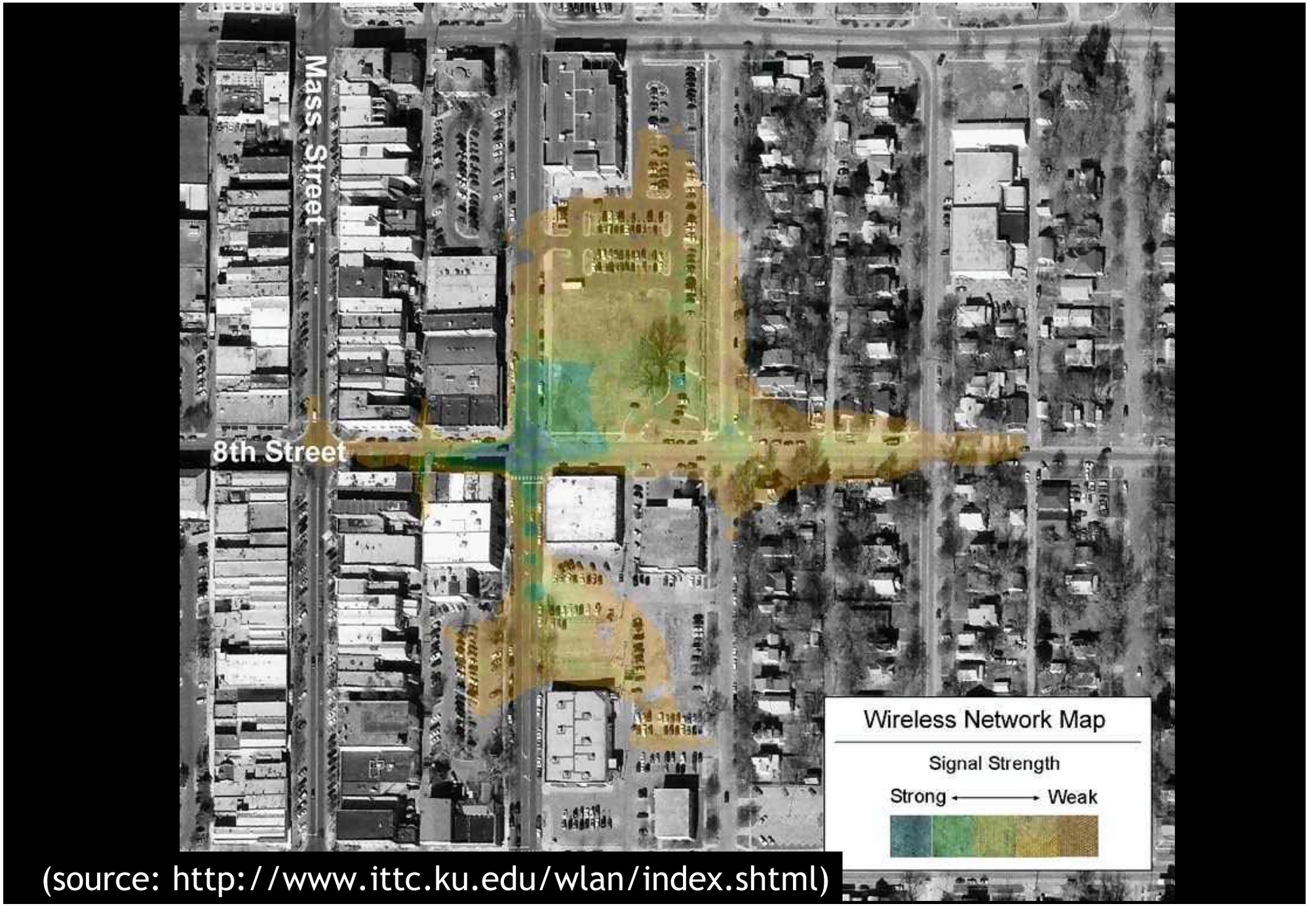


(source: Matthew Zook, www.zooknic.com)

War driving wifi nodes



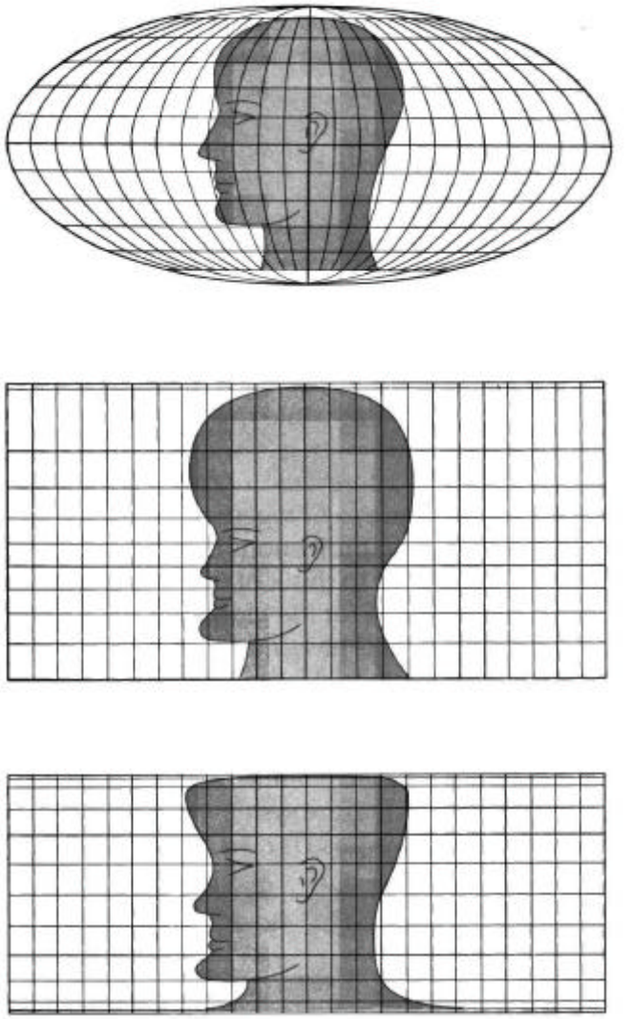
(source: Frank Keeney, http://pasadena.net/apmap/)



(source: http://www.ittc.ku.edu/wlan/index.shtml)

Distortion and deception "how to lie with maps"

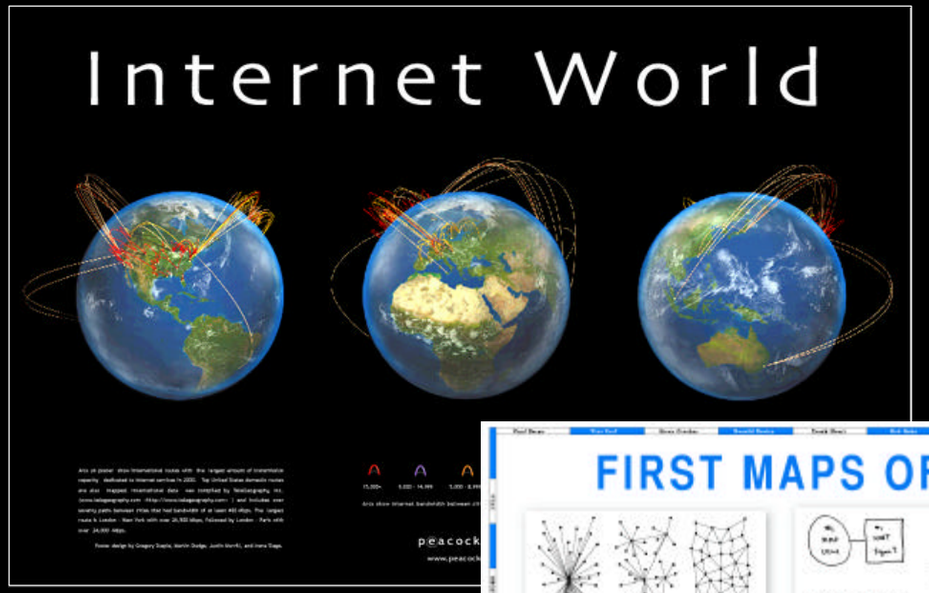
- all maps are subjective
- all maps are selective
- most obvious being through
  - data selection/omission
  - projections
- how are maps of Internet deceiving?
- clearly there are many ways to project the Internet onto a map

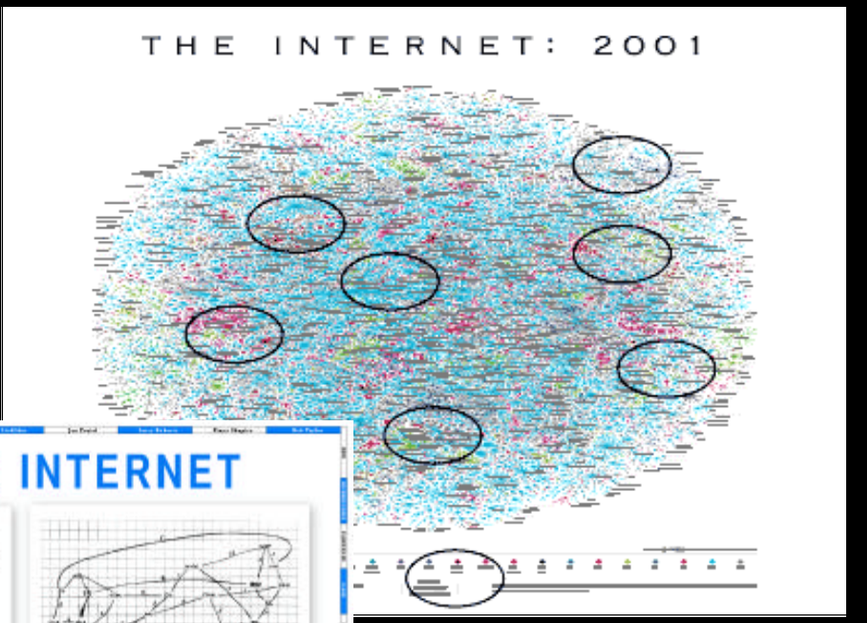


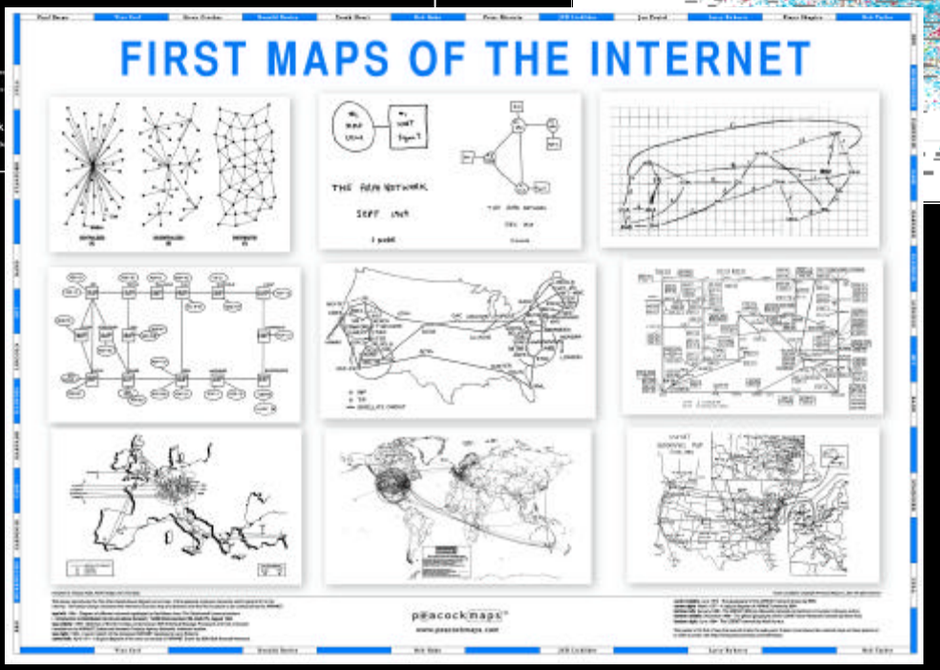
A head drawn on the Mollweide projection (top) has been transferred to Mercator's projection (center) and to the cylindrical equal-area projection with standard parallels at 30° (bottom). Just because the profile looks most natural on Mollweide's projection, that projection is not necessarily "better." The natural profile could have been drawn on any projection and then plotted on the others.

Maps of the Internet on your wall

Peacock Maps Posters, www.peacockmaps.com

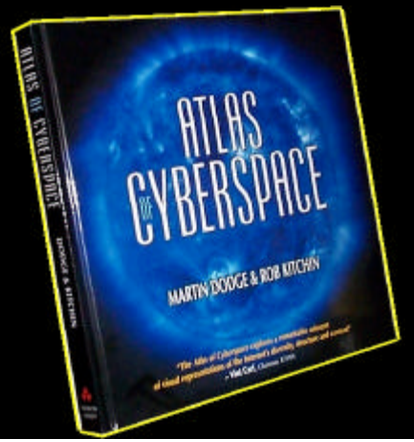






Also available at www.thinkgeek.com

- many other aspects of the cyberspace to map, especially the information spaces
- many different ways to map and visualise
- I'm still waiting for the best map of the Internet
- these slides are at www.casa.ucl.ac.uk/martin/cambridge_seminar.pdf
- comments ?? welcome to send feedback to m.dodge@ucl.ac.uk



more info, many more maps - www.cybergeography.org