Everything is Connected

Vint Cerf

Internet 1999

telstra.net

sprintlink.net

att.net

verio.net

psi.net

ft.net

bbnplanet.net

ans.net

cw.net

(not an ISP)

globalcenter.net

other ISPs

alter.net

eu.net
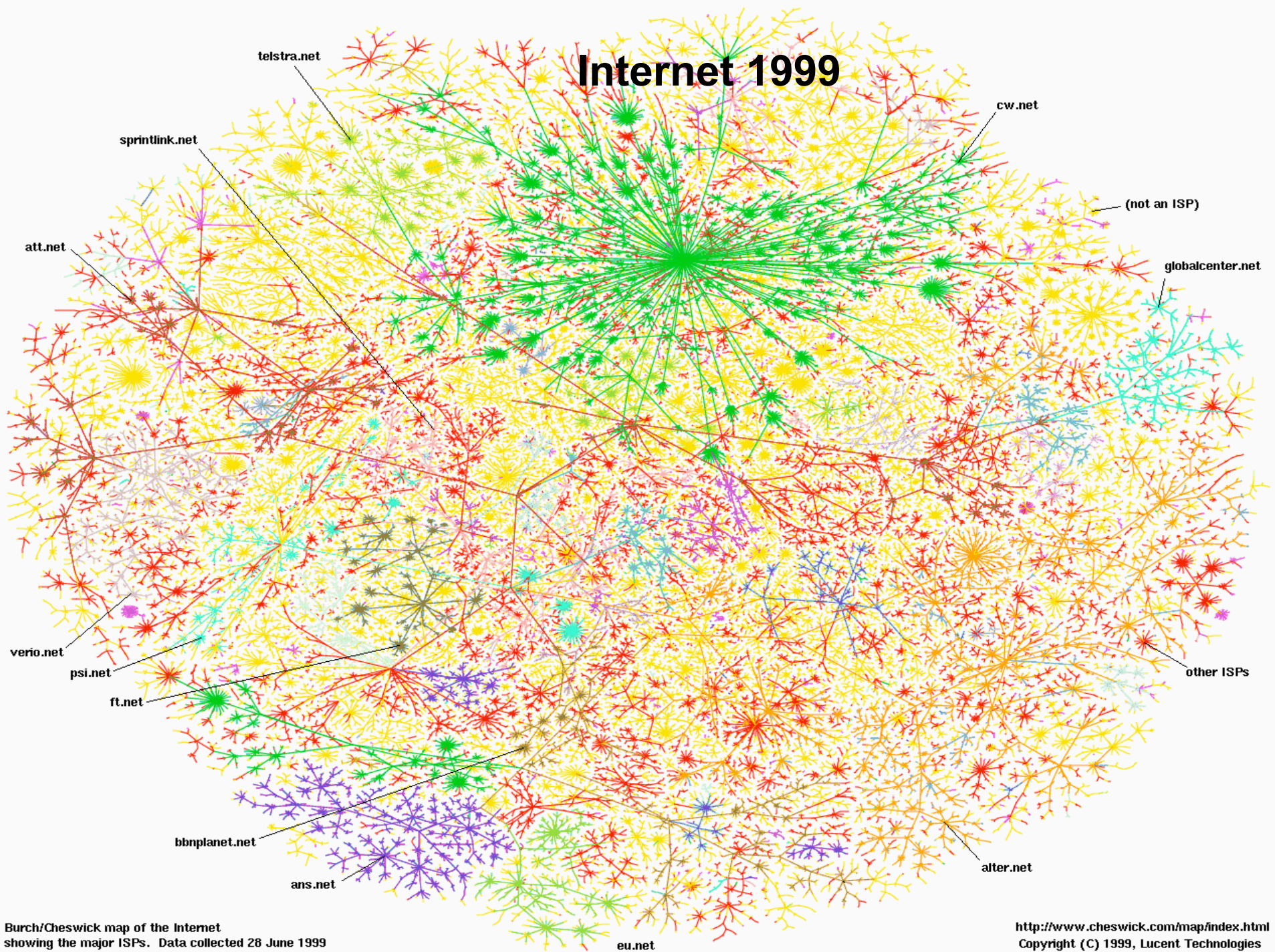
Burch/Cheswick map of the Internet
showing the major ISPs. Data collected 28 June 1999

http://www.cheswick.com/map/index.html
Copyright (C) 1999, Lucent Technologies

Internet Domain Survey Host Count
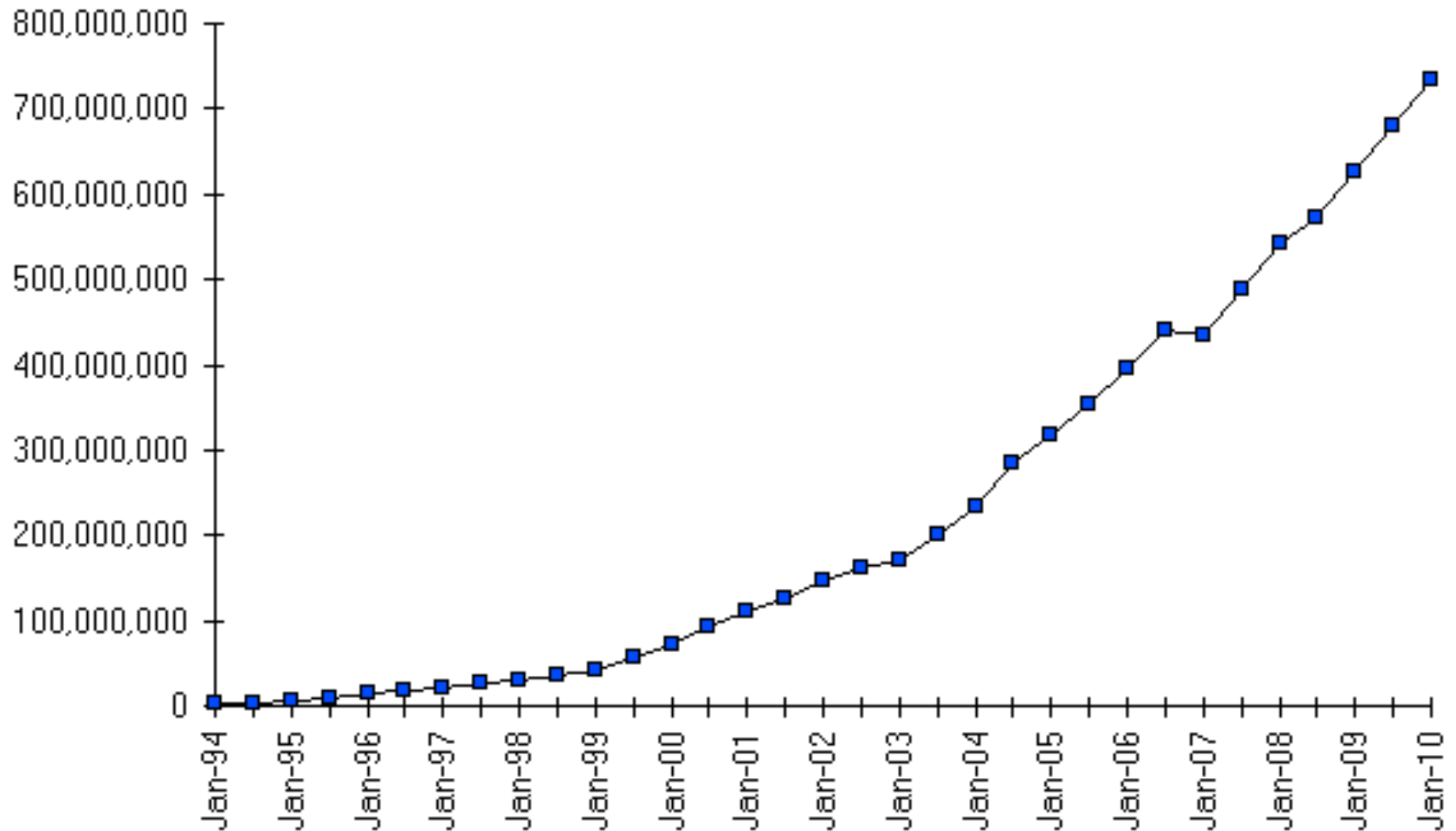
Source: Internet Systems Consortium (www.isc.org)

3

Internet - Global Statistics 2010

732,740,444

(ftp.isc.org/www/survey/reports/current/

Jan 2010)

1,802 Million Users

(InternetWorldStats.com, Dec 31, 2009)
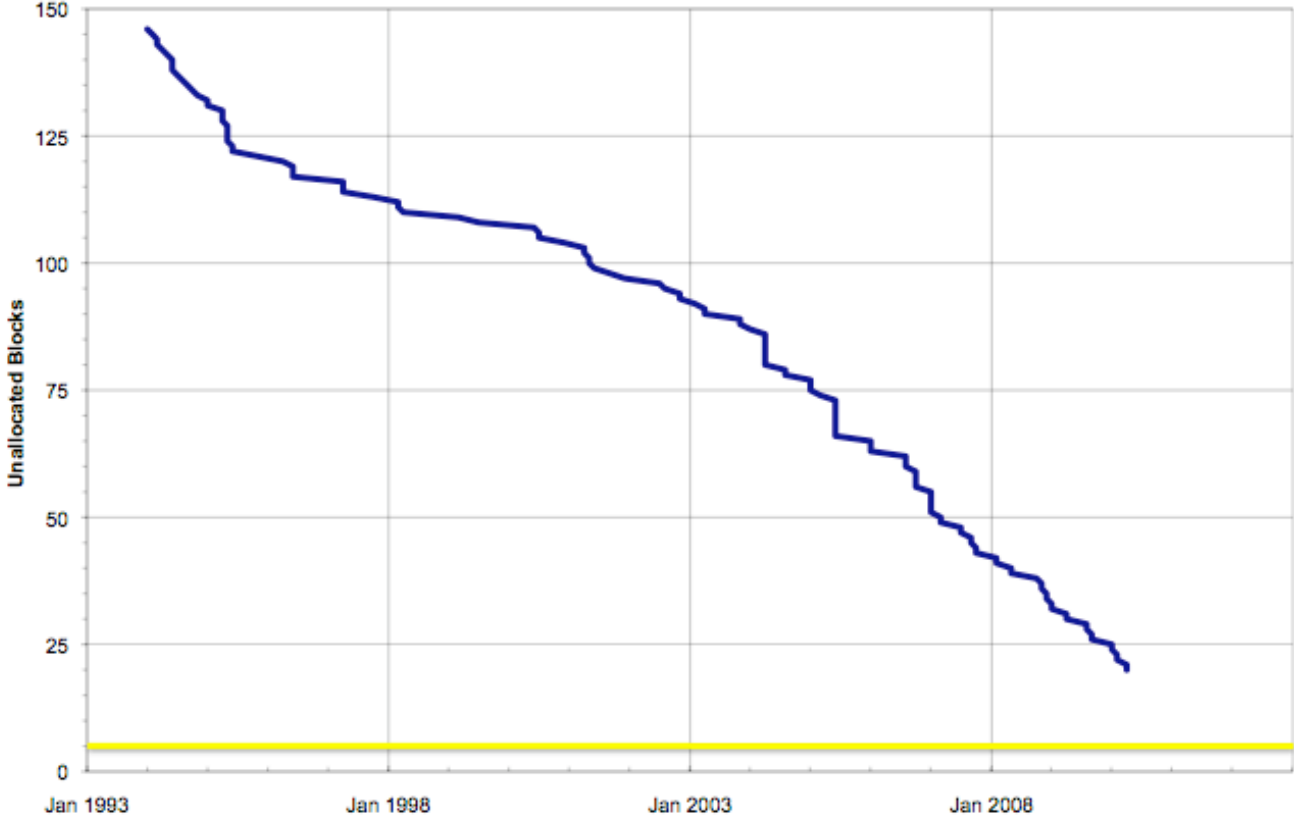
(approx. 4.2 B mobiles and 1.3 Billion PCs)

Regional Internet Statistics 9/30/2009

Region	Internet Population	% penetration
Asia	764.4 Mil.	20.1 %
Europe	425.8 Mil.	53.0 %
North Am.	259.6 Mil.	76.2 %
LATAM/C	186.9 Mil.	31.9 %
Mid-East	58.3 Mil.	28.8 %
Oceania	21.1 Mil.	60.8 %
Africa	86.2 Mil.	8.7 %
TOTAL	1,802.0 Mil.	26.6 %

Remaining IPv4 /8 Allocations

Major Near-Term Changes to Internet

- IPv6 - in parallel with IPv4 (128 bit vs 32 bit addresses)
  - 3.4×10^{38} vs 4.3×10^{9}

- Internationalized Domain Names

- Domain Name System Security (DNSSEC)

- Digitally-Signed Address Registration (RPKI)

- Sensor Networks

- Smart Grid

- Mobile Devices

- Cloud Computing

- Social Networking

IMPLICATIONS

Google™

Mobility

- Persistent state, disrupted connectivity (transactions)

- Variable but increasing bandwidth
  - Multiple radios/Software Defined Radios
  - Multiple networks (WiFi, WiMax, 3G, 4G, LTE…)

- New sensory ensembles
  - Video/imagery
  - Sound/speech
  - Multi-touch
  - Environmental (chemical, bio, other)

Beyond Text Search

- Image search - Google Goggles, similar images

- Speech recognition

- Gestures (Patti Maes - TED)

- Deep-linking/Semantic Web
  - Dark information in the Web (like dark matter/energy)
  - Web "publication" (significance for organized data)
  - Semantic "printing" (analog of print publication)

Identifiers

- **Internationalized Domain Names**

  – Analogs for URLs, URIs, URNs

- **Persistent Object Identifiers**

  – What's an object?

  – How is it found?

  – Uniqueness vs any-instance

  – Object interpretation

  – How do I interact with it?

  – Integrity?

  – Provenance?

Authenticity

Google

- Digital Signatures
  - What do they really mean?
  - Can we trust certificates and certificate authorities?

- Authentication (of everything)

- Escalating identify scenario (Joe and his public key)

Security Problems

- Spam

- Viruses/Worms/Trojan Horses
    - Infected websites
    - Infected thumb drives
    - Infected CD-ROMs, DVDs, etc.

- DOS and DDOS attacks

- Social Engineering

- Poor passwords (re-usable especially)

- Phishing, Pharming (DNS compromise)

- IP address poaching

- Spectacular human error (configuration esp.)

Origins of Security Weaknesses

- Weak operating systems

- Naïve Browsers (running with too much privilege)

- Poor access control practices

- Improper configuration of hosts and clients

- Compromised lap/desktops + servers

  Leading to BOTNETS

- Hackers, Organized Crime, State-sponsored cyberwarfare

- [Advertisement] StopBadWare

  – www.stopbadware.org

Privacy Problems

- Lax user behaviors (social networking, unsafe configuration)

- Weak protection of personal data by business, government
    - Lost laptops, thumb drives
    - Weak security configuration of servers
    - Poor access controls
    - Bad business practices (sharing personal information)

- Invasive devices
    - Mobiles with cameras and sound recording capacity
    - GPS tracking
    - RFID tracking
    - Closed Circuit TV surveillance (traffic, stores, public places)

New Technology and Applications

- Flow Routers (Nick McKeown - Stanford)

- Massive Data Correlation
  - MAP/Reduce - Cloud computing data centers
  - Jeff Jonas: every datum is a query
  - Tweetstream, sigint/humint/sensors, web, media (YouTube, Flickr)
  - Computers in the Real World
    - http://www.ted.com/talks/pattie_maes_demos_the_sixth_sense.html
    - TIA - DARPA (Poindexter)

Cloud Collaboration

- Multiple Data Centers (replication, responsiveness)

- Dynamic capacity sharing

- Data sharing ("latest copy is always in the cloud")

- Video and audio conferencing with data sharing

- Inter-Cloud interactions (new research area!)

    – How to refer to other clouds?

    – How to refer to data in other clouds?

    – How to make data references persistent (unlike URLs)?

    – How to protect Clouds from various forms of attack (inside, outside)?

    – How to establish an access control regime (inside, between clouds)?

    – What semantics can we rely on with inter-cloud data exchange?

    – What notion of "object" would be useful for inter-cloud exchange?

Bandwidth/Storage

- "Short Circuit" - INNNNNNNPUT!!

- Monotonic trends toward more BW/Memory

- High density storage but slow access

- Solid state - fast and expensive

- Mixing memory, processing, parallel architecture
  - Think "cloud"

http://woodhurst.webhop.org:8080/mgmt/

G ▾ Google

Moma   GMail   logout

ARCH ROCK
PhyNet Server

Woodhurst sensor net
2008-09-21 4:16:38 pm EDT

Home

Setup
Server
Routers
Nodes
Software Update

System and Network
Connectivity
Energy
Traffic
Reliability

Sensing and Control
Sensor/Actuator Devices
Sensor Data Analysis
Actuator Control
Data Export

Support
User Guide
Network Admin Guide
Developer Guide

I wish this page would...

[Send Feedback]

Home

● Server   ● Router   ● Node   ● Missing Router or Node

Deployment started on 2008-07-11 12:35:48 pm EDT, running for 72d 3h 40m 51s.

Deployment Map
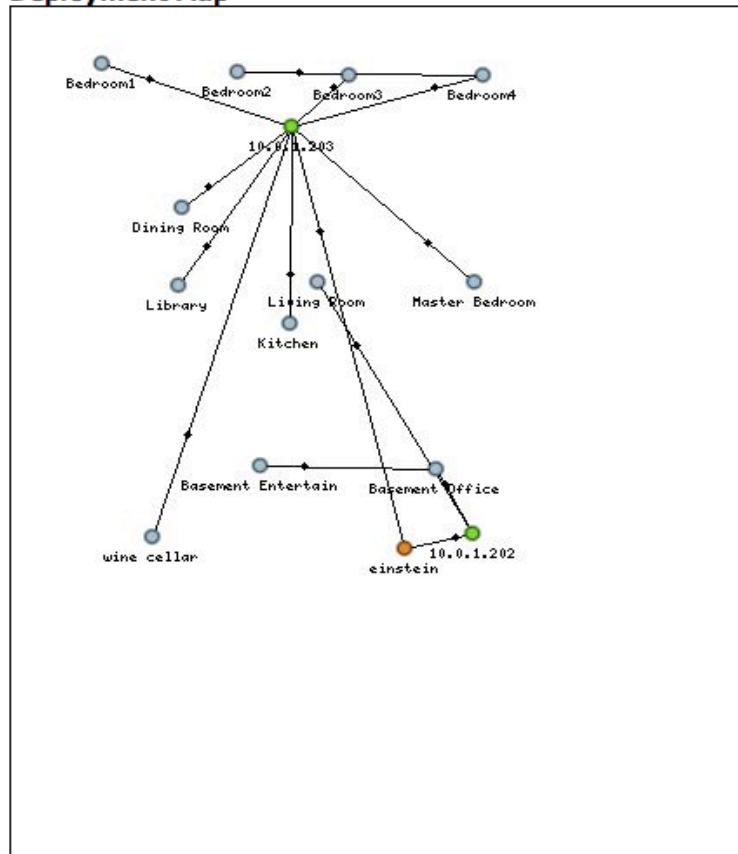
Network Devices
15 Devices

● **einstein**

● **10.0.1.202**
4:15:01 pm

● **10.0.1.203**
4:15:00 pm

1st Floor

● **Dining Room**
4:15:05 pm
71 °F   55.3 %   10 lux   1 lux

● **Kitchen**
4:12:03 pm
72.9 °F   51 %   21 lux   1 lux

● **Library**
4:12:35 pm
73.3 °F   50.1 %   10 lux   0 lux

● **Living Room**
4:14:57 pm
70.4 °F   51.5 %   7 lux   0 lux

● **Master Bedroom**
4:15:13 pm
70.1 °F   56 %   14 lux   2 lux

2nd Floor

● **Bedroom1**
4:12:14 pm
74 °F   48 %   14 lux   1 lux

● **Bedroom2**
4:15:10 pm
74.4 °F   49 %   80 lux   17 lux

● **Bedroom3**
4:15:12 pm
73.5 °F   47.9 %   14 lux   1 lux

● **Bedroom4**
4:15:06 pm
70.7 °F   56.7 %   3 lux   0 lux

Done

The Data Will Come to Us!

- Sensor networks everywhere!

    – Seismic, oceanographic, atmospheric, satellite

    – Smart buildings, instrumented highways

    – Video sensors (traffic, security…)

- The Smart Grid

    – (Google) PowerMeter application

    – Hybrid and Plug-In vehicles

    – Injecting power into the Grid

    – Tracking usage for better lifestyle decisions

    – Office and building efficiencies

Security at all levels

Internet "Erlang" formulas

QOS debates (smart routers?)

Internationalized Domain Names (ccTLDs & GTLDs)

Distributed Algorithms

Presence (multi-level)

Mobility, persistence (processes, connections, references)

Multihoming

Multipath routing

Broadcast utilization

Mesh and Sensor networks

Virtualization (net, storage, processing)

Internet Research Problems - 2

Authentication, Identity, Authorization

Multi-core Processor Algorithms

Delay and Disruption Tolerance

Integration of Applications (e.g. drag/drop gadgets in calendar)

Intellectual Property Protection (tracking rights, enforcement)

Role of Layering

Governance

- Law Enforcement

- Policy Development

- Homologation

- Facilitation of electronic commerce

- Privacy and confidentiality

Internet Research Problems - 3

Mobile operation

Dynamic joining (new IP address?, Authentication?)

Dynamic Routing (Dynamic Topology)

Persistent connection (ID at TCP/UDP/RTP layer?)

Self-organization (security risks?)

Performance

Latency, Throughput (cf: Greg Chesson's work)

Resilience (AS partitioning)

Rate management vs CWND flow control

Route convergence

Addressing (Identification)

What objects should be addressable?

New bindings of IP to Identifiers (new DNS?)

Challenges of the Digital Age

- Intellectual property treatment
  - Digital material is easy to copy and distribute

- Semantic Web (Data and its interpretation)

- Complex objects that can only be rendered via computer or clouds!!! Eeek!
  - 3D interactive objects
  - Complex spreadsheets
  - Interactive environments

- BIT ROT!
  - Preserving interpretive programs (Windows 3000 and PPT 1997)
  - And the operating systems that run them
  - And the hardware/cloud that runs the operating systems
  - For thousands of years!!
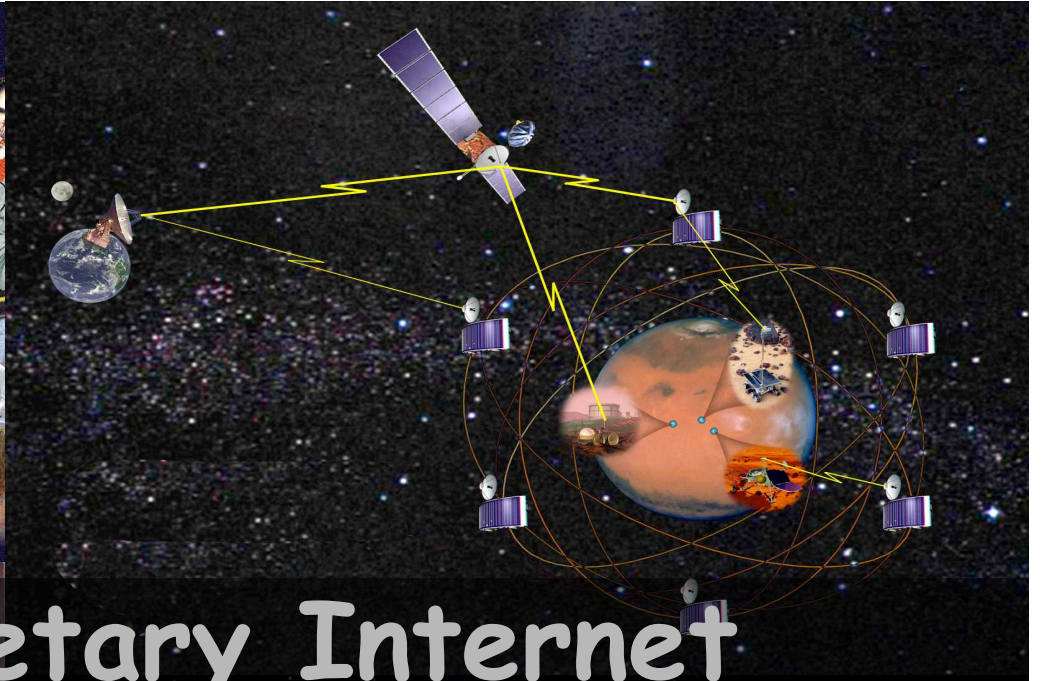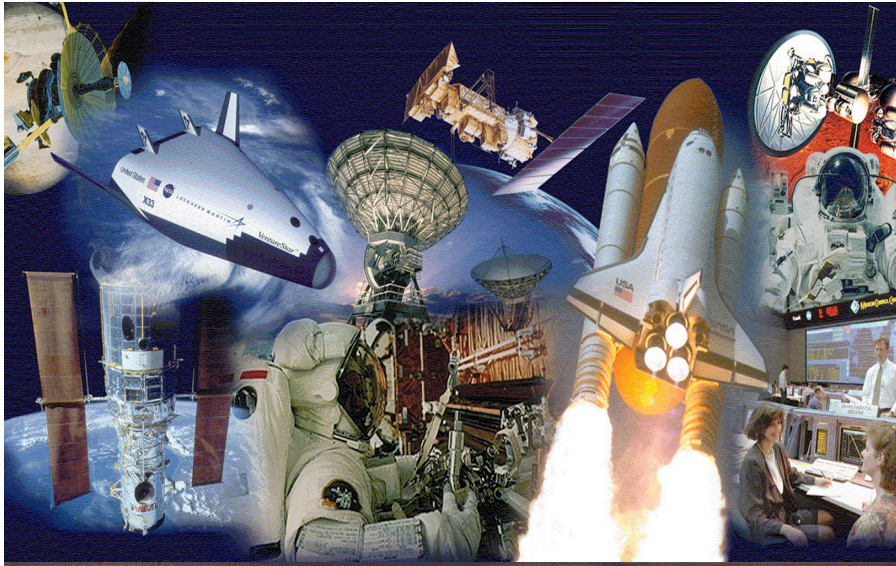
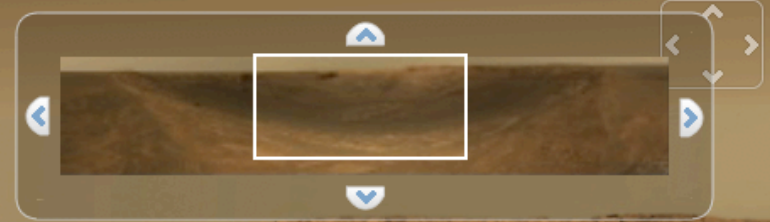InterPlaNetary Internet
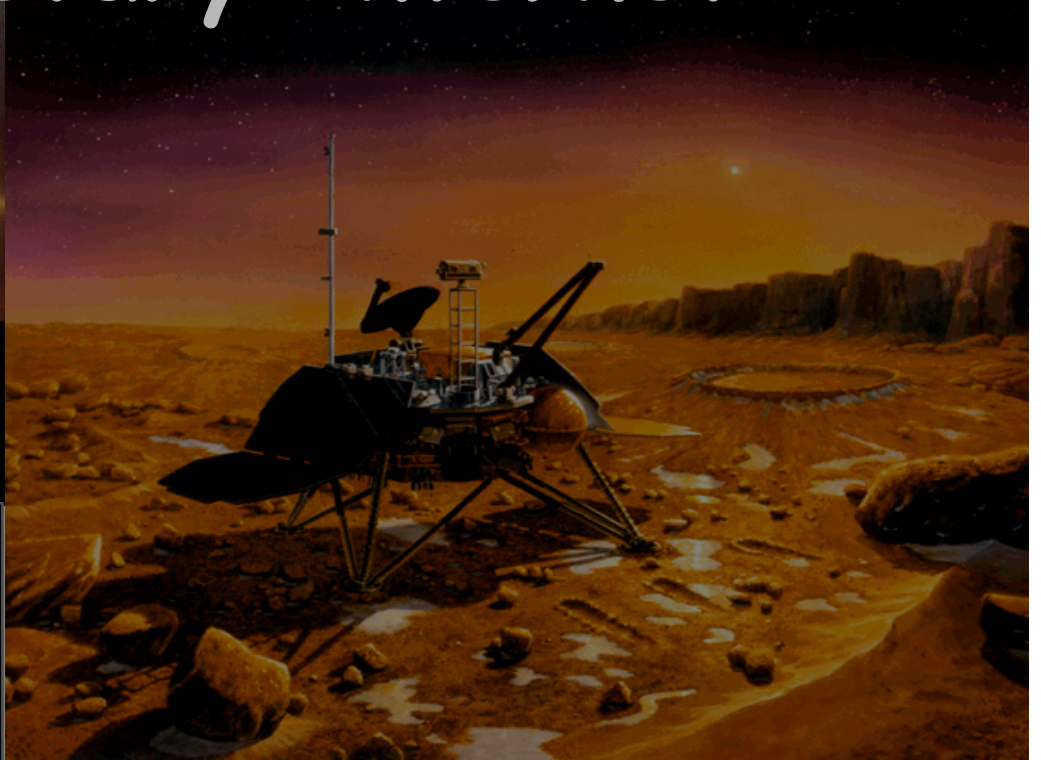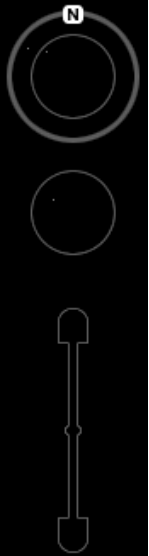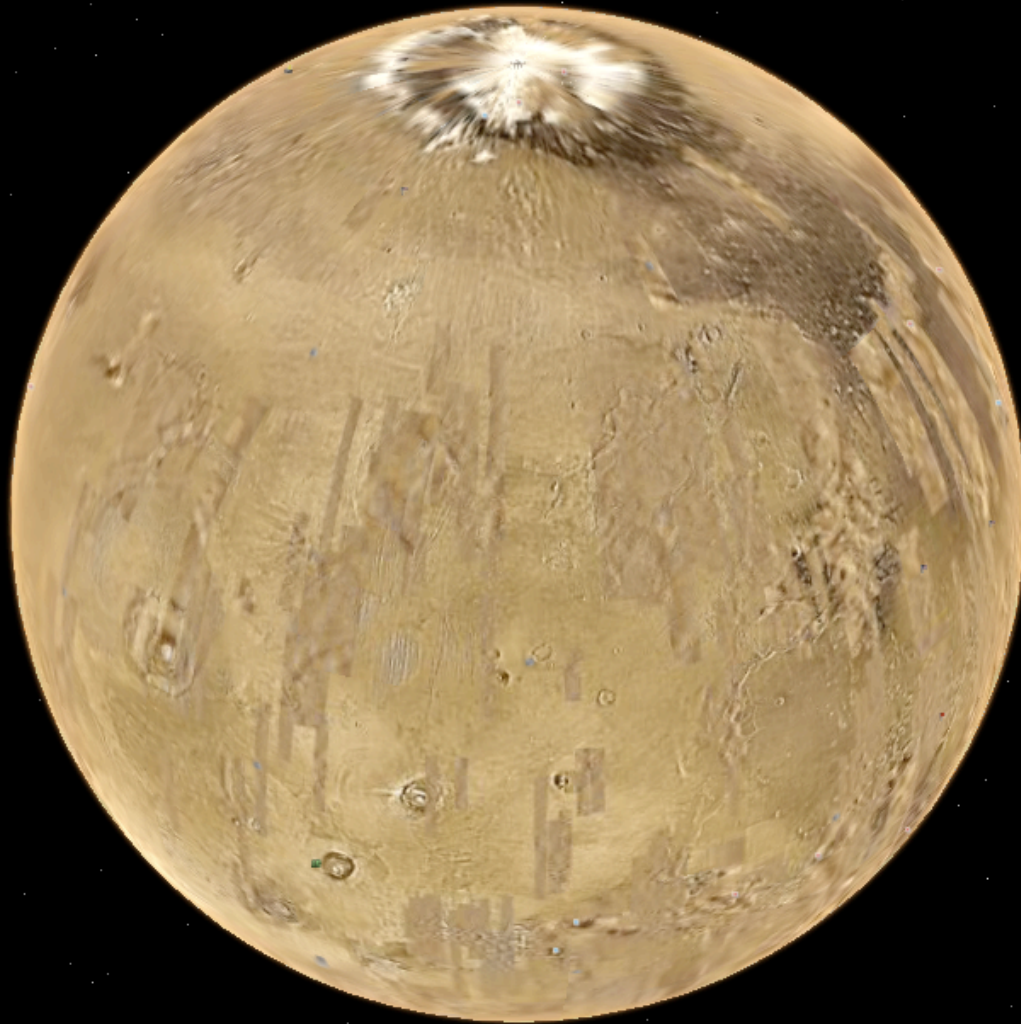
Image NASA / USGS
ESA / DLR / FU Berlin (G.Neukum)

38°57'34.00" N   95°15'55.87" W   elev 422 m

Eye alt 11001.42 km
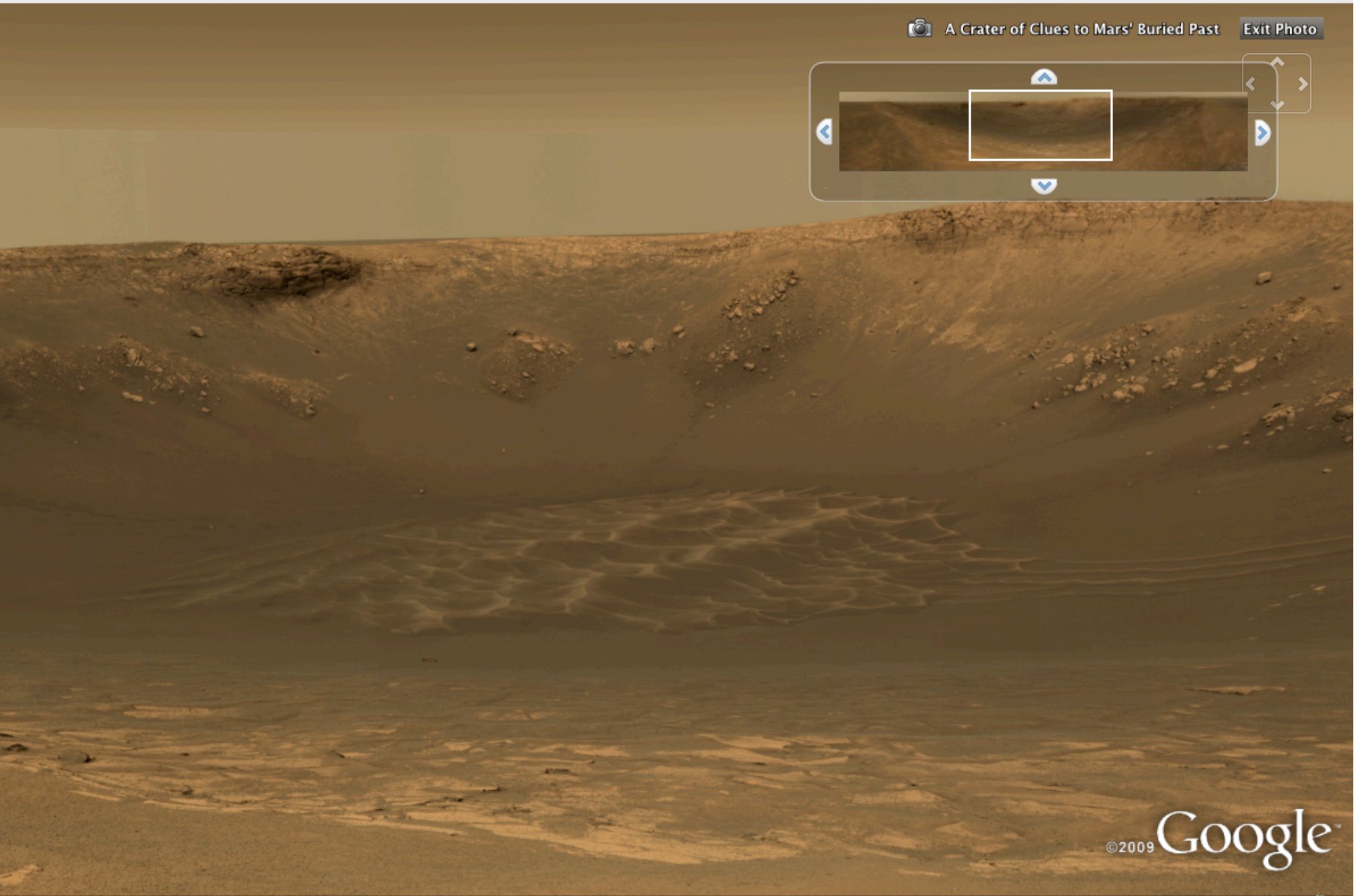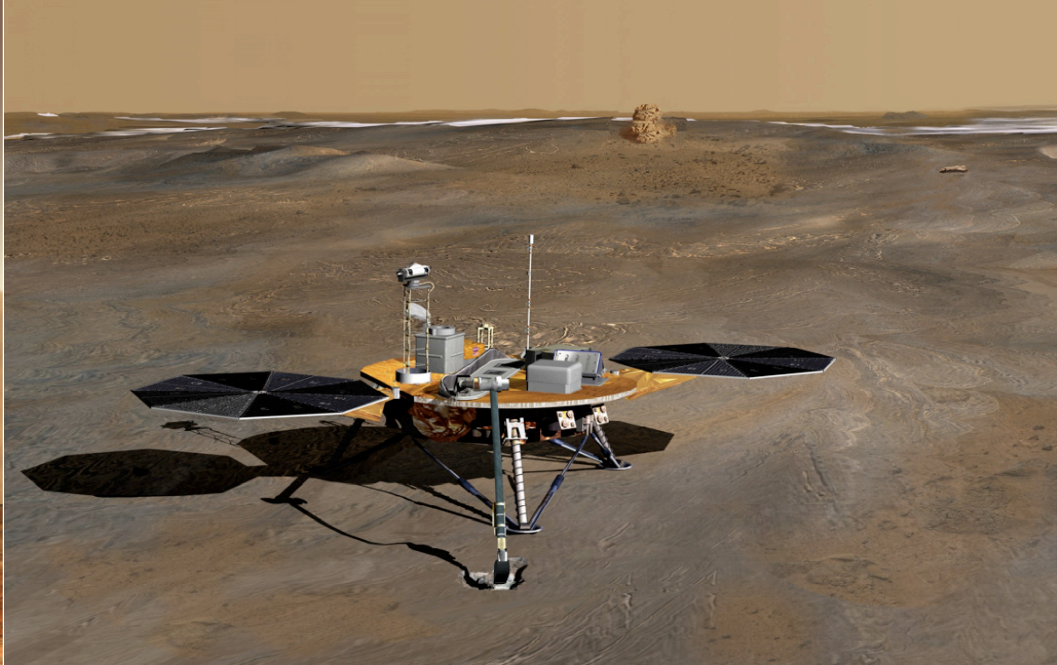
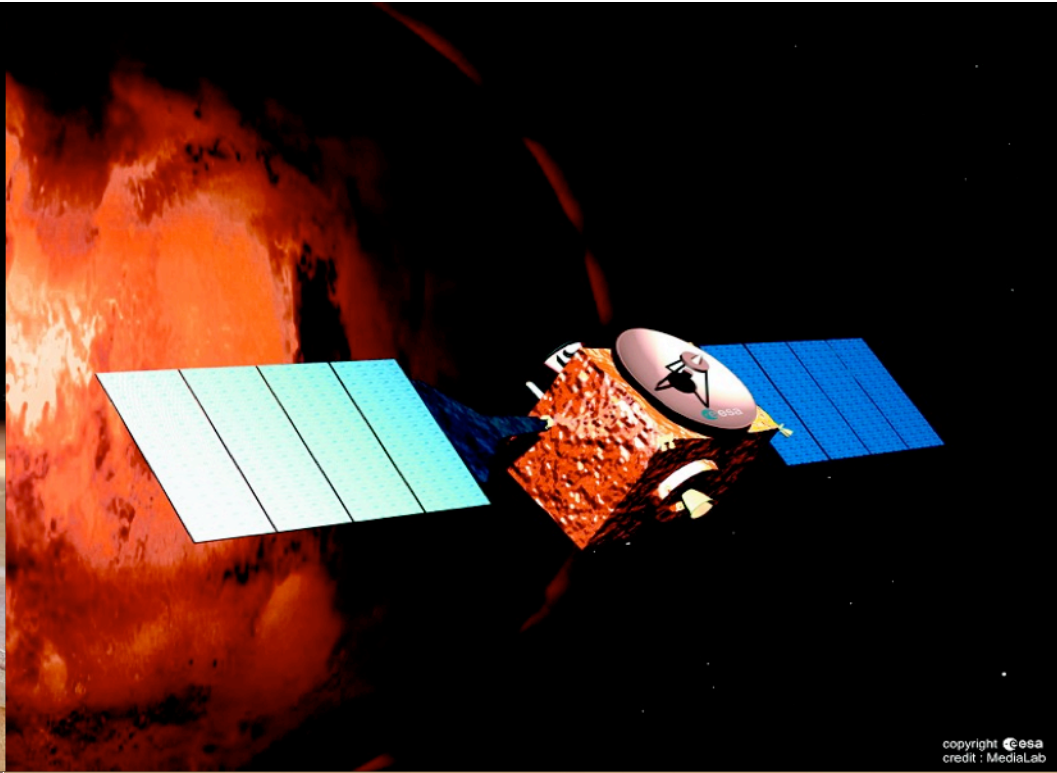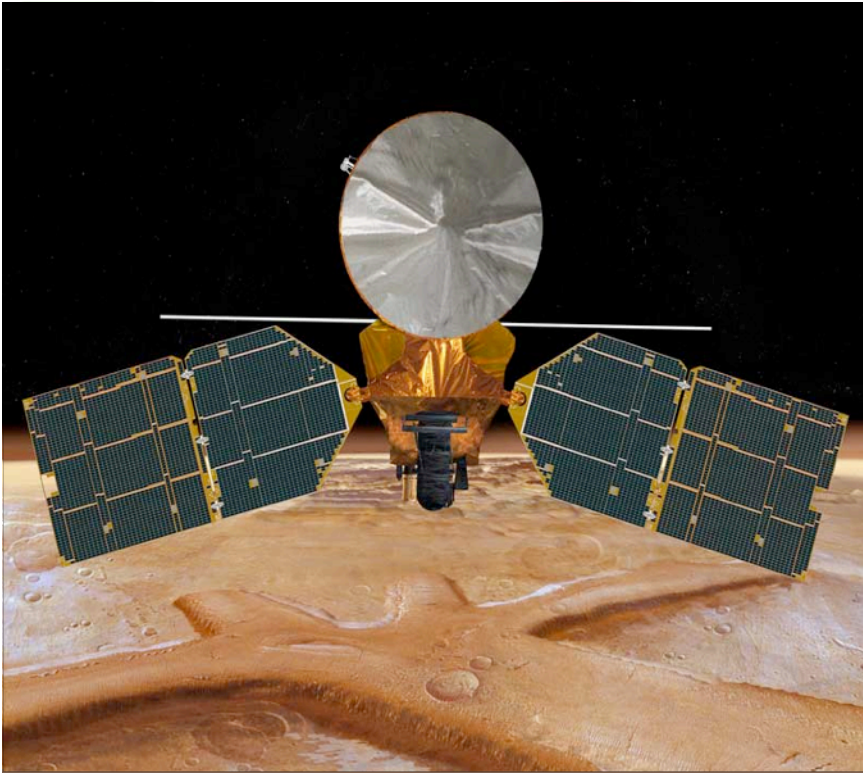# Interplanetary Internet: "InterPlaNet" (IPN)

- Planetary internets

- Interplanetary Gateways

- Interplanetary Long-Haul Architecture   (RFC 4838)
  - Licklider Transport Protocol (LTP)
  - Bundle Protocol (RFC 5050)
    - Delayed Binding of Identifiers
    - Email-like behavior

- TDRSS and NASA in-space routing

- Delay and Disruption Tolerant Protocols
  - Tactical Mobile applications (DARPA)
  - Civilian Mobile applications (SameNet!)
  - Deep Impact Testing October 2008
  - Space Station Testing July 2009
  - EPOXI Testing October 2009

Interplanetary Internet

- End-to-end information flow across the solar system
- Layered architecture for evolvability and interoperability
- IP-like protocol suite tailored to operate over long round trip light times
- Integrated communications and navigation services