
Tracking the Internet into the 21st Century

Vint Cerf

October 2008





Internet Evangelist at Work

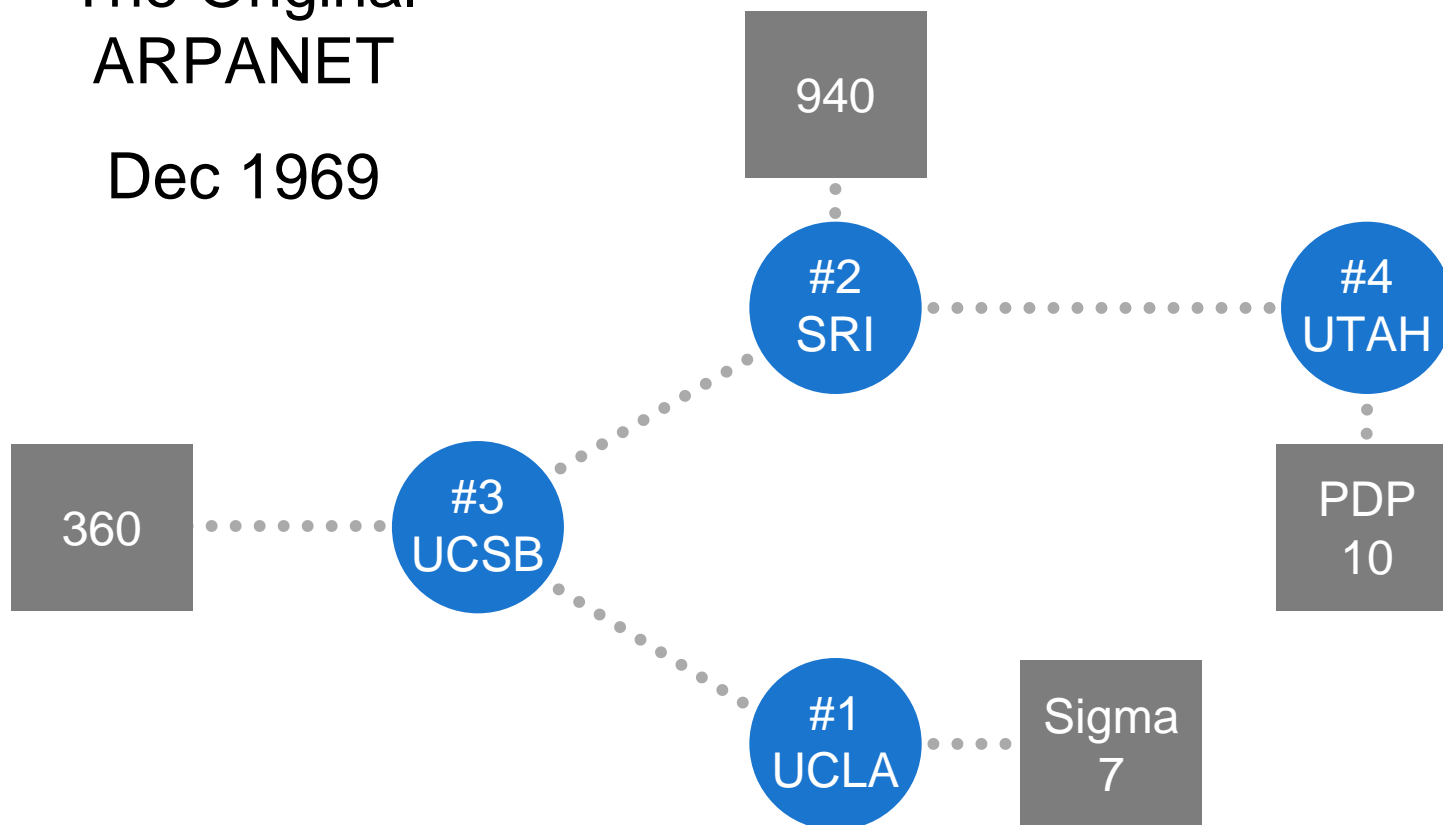
Huge thanks to NANOG and its participants



- Invisible to most users
 - 24 X 7 attention to reliability and availability
 - Continual battles (viruses, worms, Trojan Horses, DOS attacks, spam)
 - Cooperation among competitors for the benefit of the Net's users
- IPv6 Deployment
 - Dual mode operation a big challenge
 - Network management for IPv6 still immature
 - IPv6 global connectivity a key target
- MCI Operations Anecdote (Cary, NC)

The Original ARPANET

Dec 1969



The ARPANET IMP



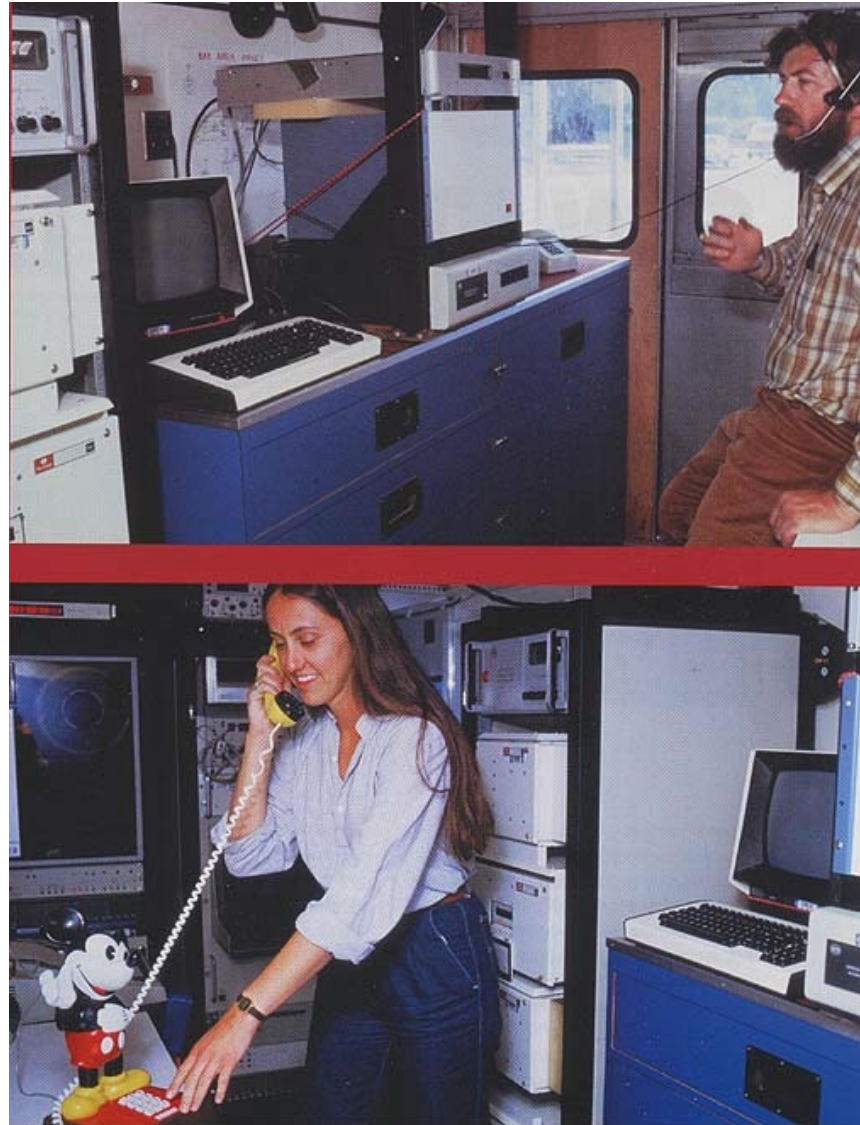
Packet Radio Van



Inside the PR Van



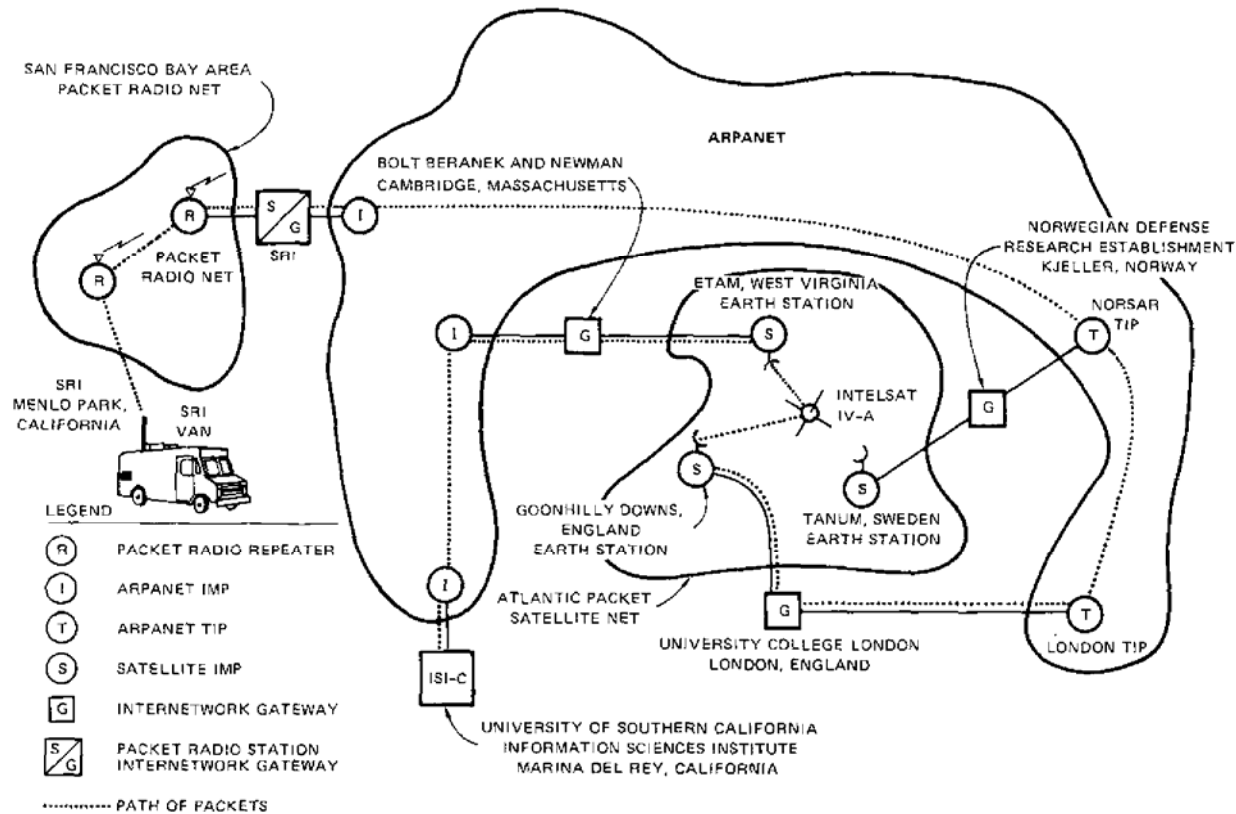
Inside the PR Van (2)



Intelsat IVA - Packet Satellite Network

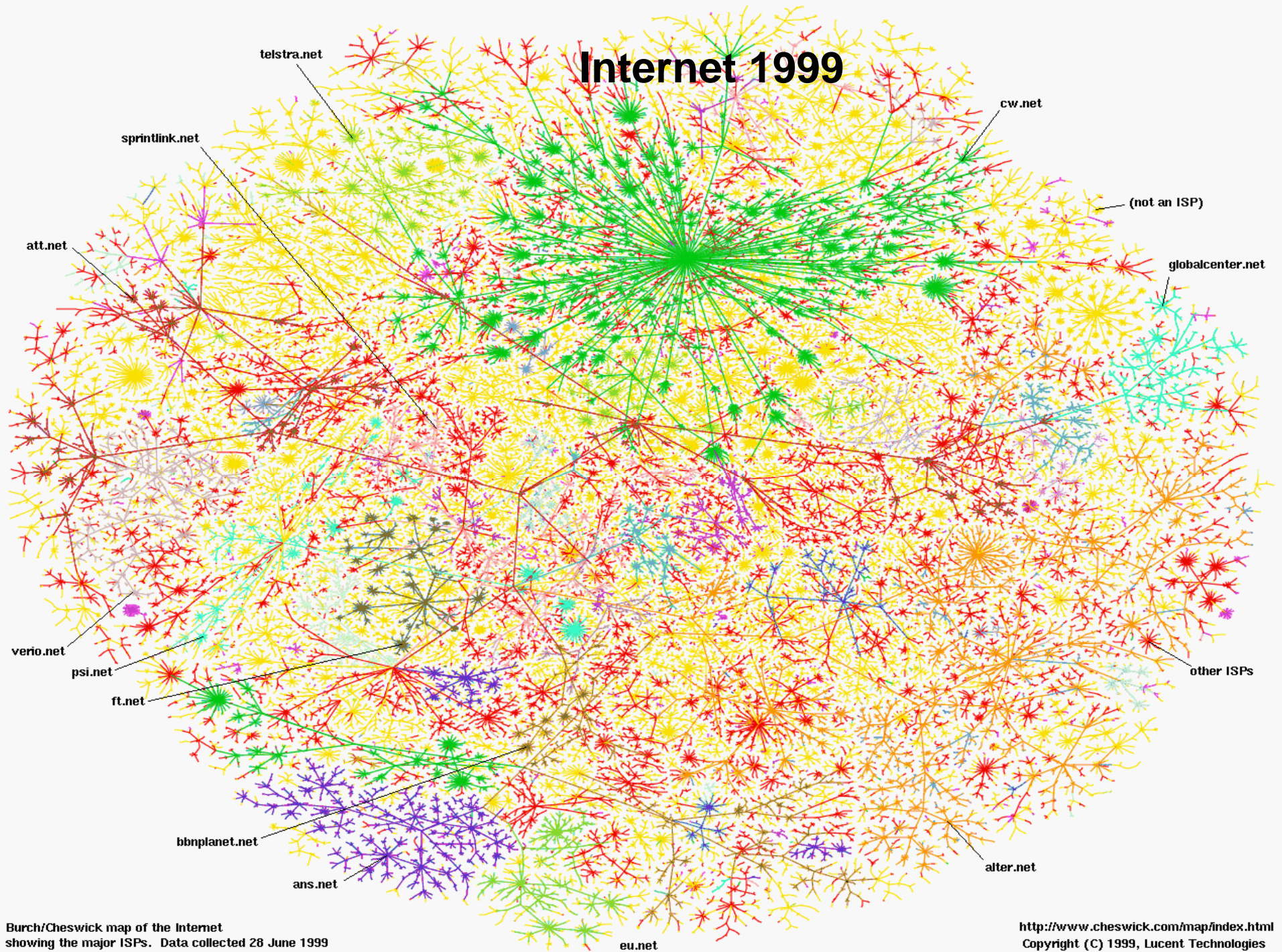


First Three-Network Test of Internet



November 22, 1977

Internet 1999



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

542 Million Hosts

(ISC Jan 2008)

1,464 Million Users

(InternetWorldStats.com,
June 30, 2008)

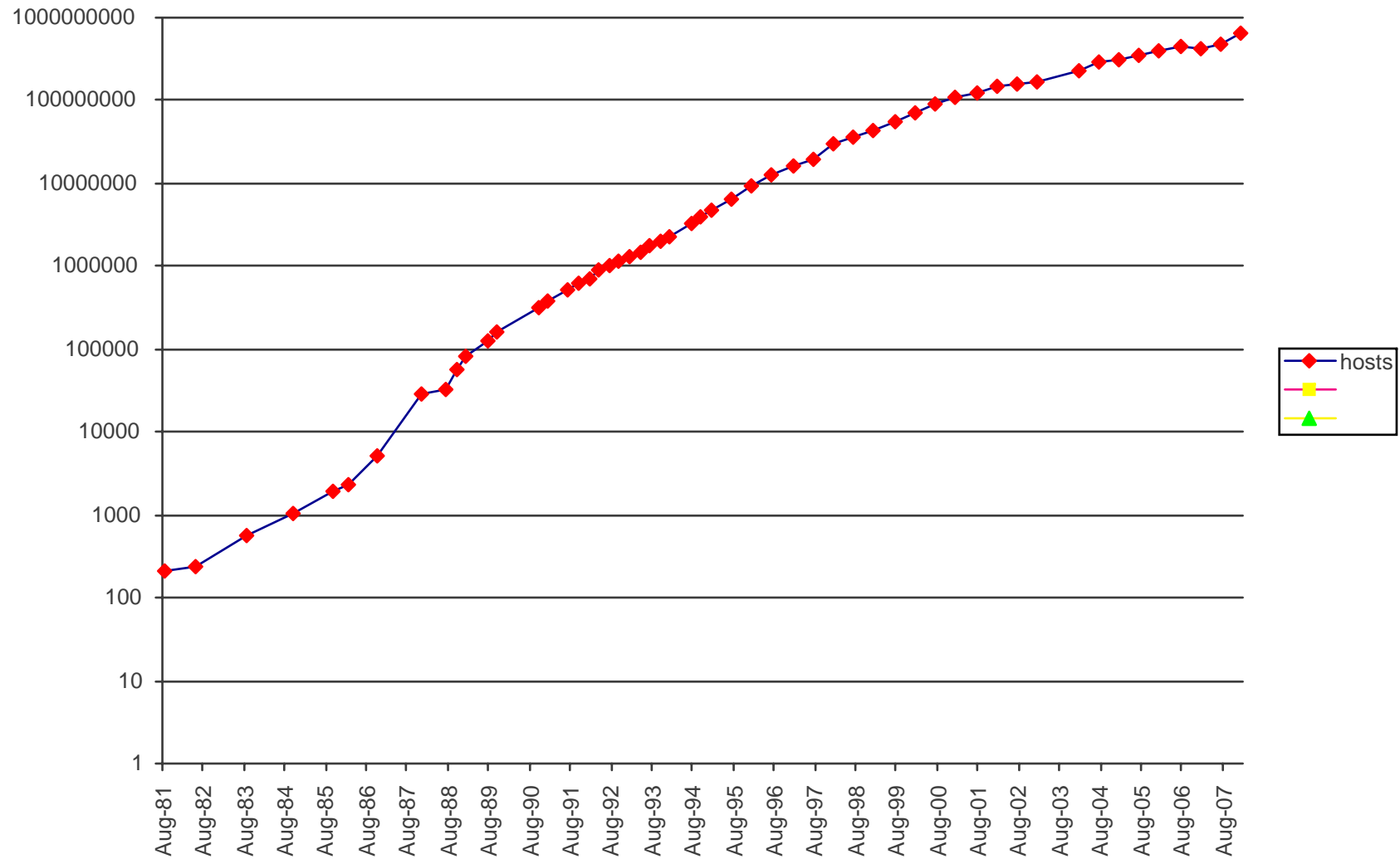
(approx. 3 B mobiles and 1 Billion PCs)

Regional Internet Statistics 6/30/08



| Region | Internet Population | % penetration |
|-----------|---------------------|---------------|
| Asia | 578.5 Mil. | 15.3 % |
| Europe | 384.6 Mil. | 48.1 % |
| North Am. | 248.2 Mil. | 73.6 % |
| LATAM/C | 139.0 Mil. | 24.1 % |
| Mid-East | 41.9 Mil. | 21.3 % |
| Oceania | 20.2 Mil. | 59.5 % |
| Africa | 51.0 Mil. | 5.3 % |
| TOTAL | 1,463.6 Mil. | 21.9 % |

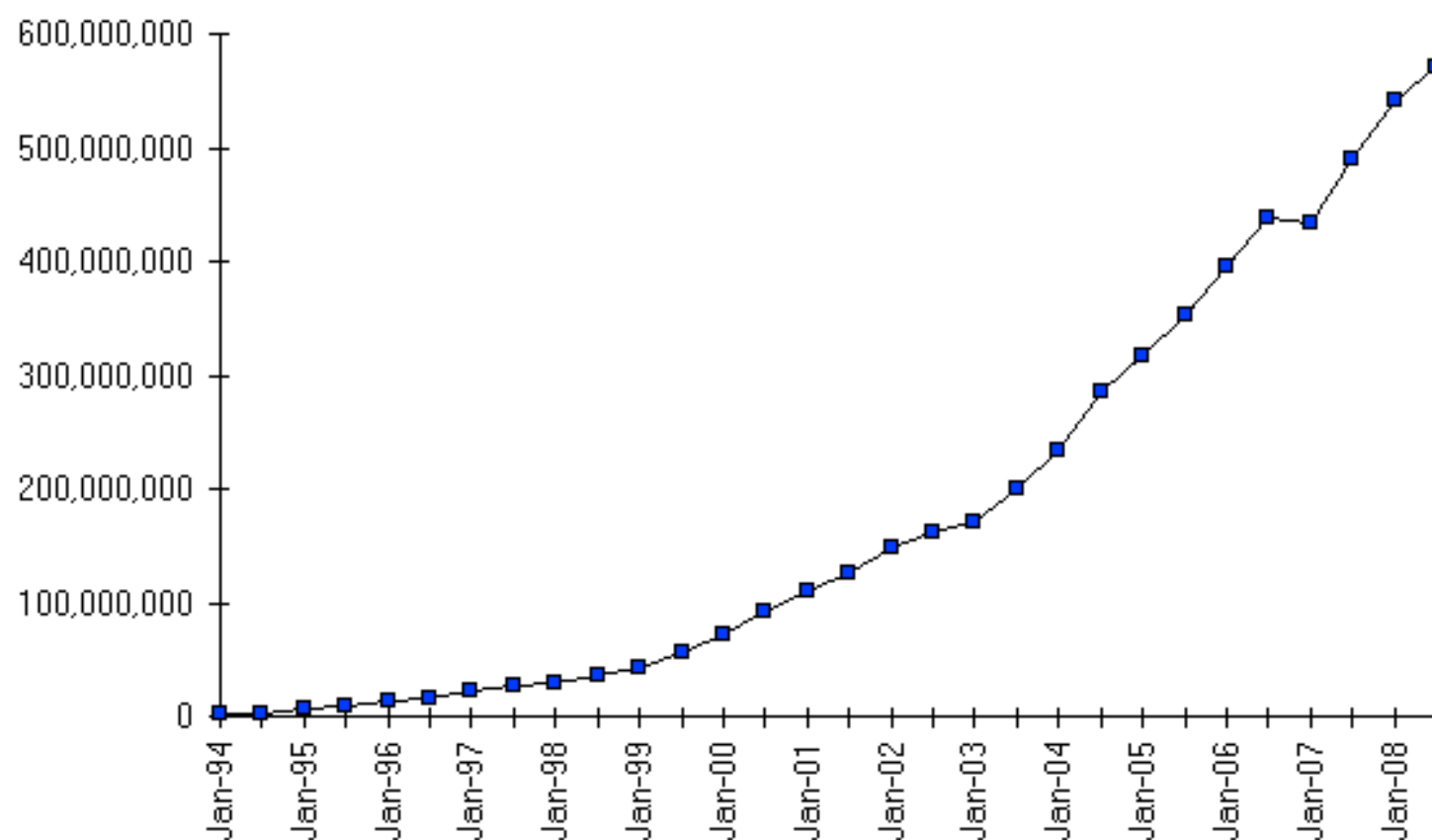
Internet Host Growth 1981-2008



Past Results

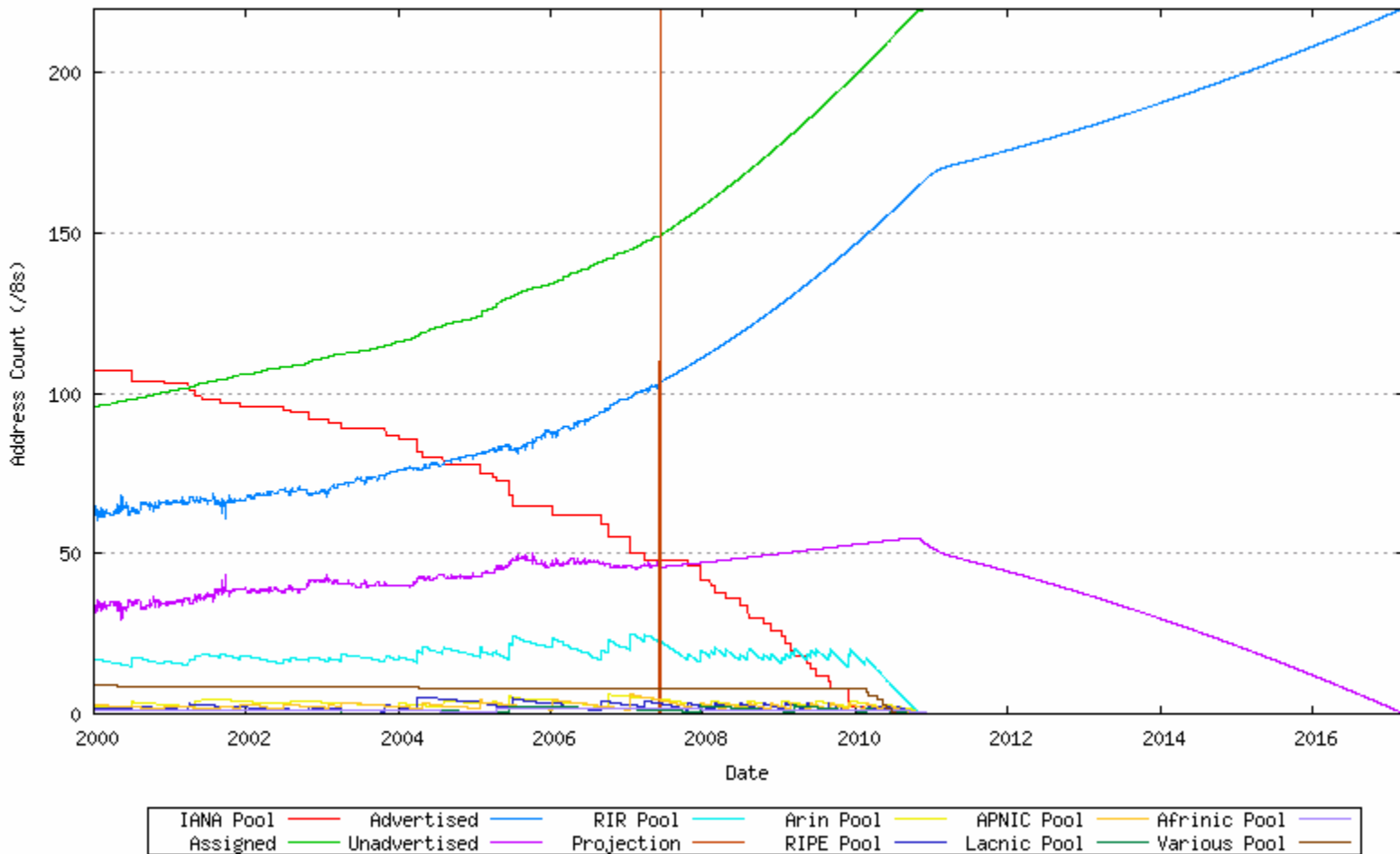
Jan 08
 Jul 07
 Jan 07
 July 06
 Jan 06
 Jul 05
 Jan 05
 Jul 04
 Jan 04
 Jan 03
 Jul 02
 Jan 02
 Jul 01
 Jan 01
 Jul 00
 Jan 00
 Jul 99
 Jan 99
 Jul 98
 Jan 98

Internet Domain Survey Host Count



Source: Internet Systems Consortium (www.isc.org)

IPv4 runout diagram (Geoff Huston)



<http://www.potaroo.net/tools/ipv4/index.html>

- 3 Billion Mobiles and counting (15% Internet enabled)
- Text/Web Access
- Payment systems
- Innovative interfaces - Note I/O discovery
- Navigation systems
 - GPS, Galileo?, Mobile Tower triangulation, Bldg Announcements?
- Geo-location based services

Internet-enabled Devices



An Internet of Things



Programmable – Java, Python, etc.

Examples:

- WebTV, Personal Digital Assistants, Mobiles, Video games, Picture Frames, Washing Machines, Surf Board!
- Refrigerator (and the bathroom scales)
- Automobiles
- Internet-enabled wine corks (also note new quantum theory of wine: Schrödinger's wine bottle)
- Internet-enabled socks (clothing)
- Universal Remote Controls
- Sensor Networks



Woodhurst sensor net

2008-09-21 4:16:38 pm EDT

[Help on this Page](#)
[How to Build this Page](#)

[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](#)
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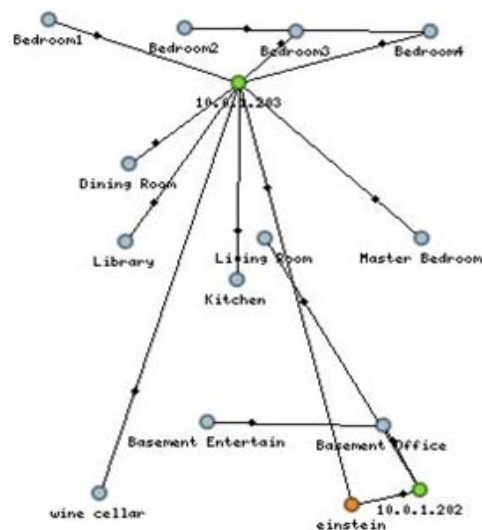
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Home

● 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



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2008-09-21 4:18:36 pm EDT

[Help on this Page](#)
[How to Build this Page](#)

[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](#)

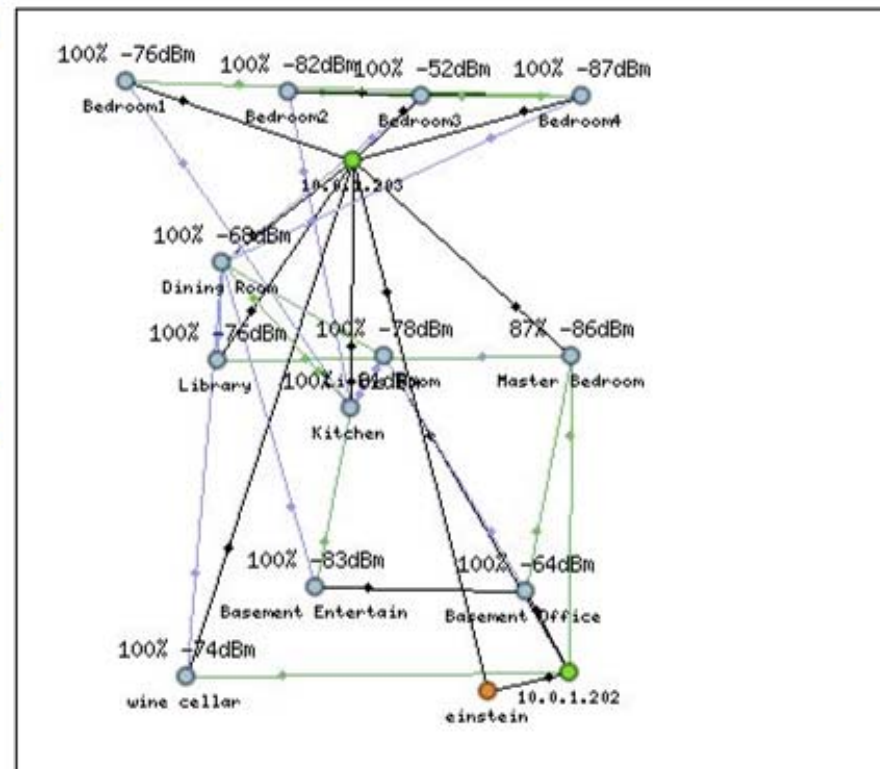
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Connectivity

[Discover Nodes](#)
[Rebuild Routing Tree](#)
[Ping All Nodes](#)
[Request Heartbeat Report from All Nodes](#)
[Survey All Nodes](#)

[Tree View](#) [List View](#) [Map View](#) [Chart View](#) [Prior Surveys](#)





Woodhurst sensor net

2008-09-21 4:19:41 pm EDT

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[How to Build this Page](#)

[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](#)

Sensor Data Analysis

[Enable Sensor Devices](#)

[Request Sample from All Enabled Sensors on All Nodes](#)

List View

[Map View](#)

[Chart View](#)

Select a Sensor: [Refresh Data](#) ☐ Auto-refresh every 60 seconds.

| Name | Last Data | External | Temperature | Humidity | Light (PAR) | Light (TSR) |
|--------------------------------------|------------|----------|-------------|----------|-------------|-------------|
| ● Basement Entertain | 4:17:18 pm | | 68.8 °F | 57.7 % | 10 lux | 1 lux |
| ● Basement Office | 4:15:15 pm | | 67.9 °F | 59 % | 14 lux | 0 lux |
| ● Bedroom1 | 4:17:14 pm | | 74.1 °F | 48.1 % | 7 lux | 0 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 |
| ● Dining Room | 4:15:05 pm | | 71 °F | 55.3 % | 10 lux | 1 lux |
| ● Kitchen | 4:17:04 pm | | 73 °F | 51 % | 10 lux | 0 lux |
| ● Library | 4:17:35 pm | | 73.3 °F | 50.1 % | 18 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 |
| ● wine cellar | 4:17:09 pm | | 58 °F | 80.3 % | 7 lux | 0 lux |

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Home Server Routers Nodes Software Update

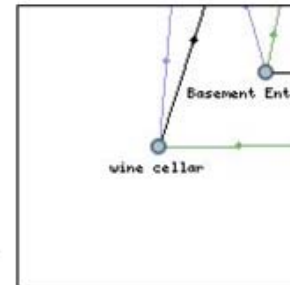
wine cellar

Group: basement

Description:

[Edit Node Information](#)

Last Heard: 4:17:16 pm



[Edit Node Location](#)

Servers

[einstein](#)

Parent Nodes

[10.0.1.203](#)

[10.0.1.202](#)

[Dining Room](#)

Signal

Child Nodes

None

Signal

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Sensing and Control

[Serial Interface](#)

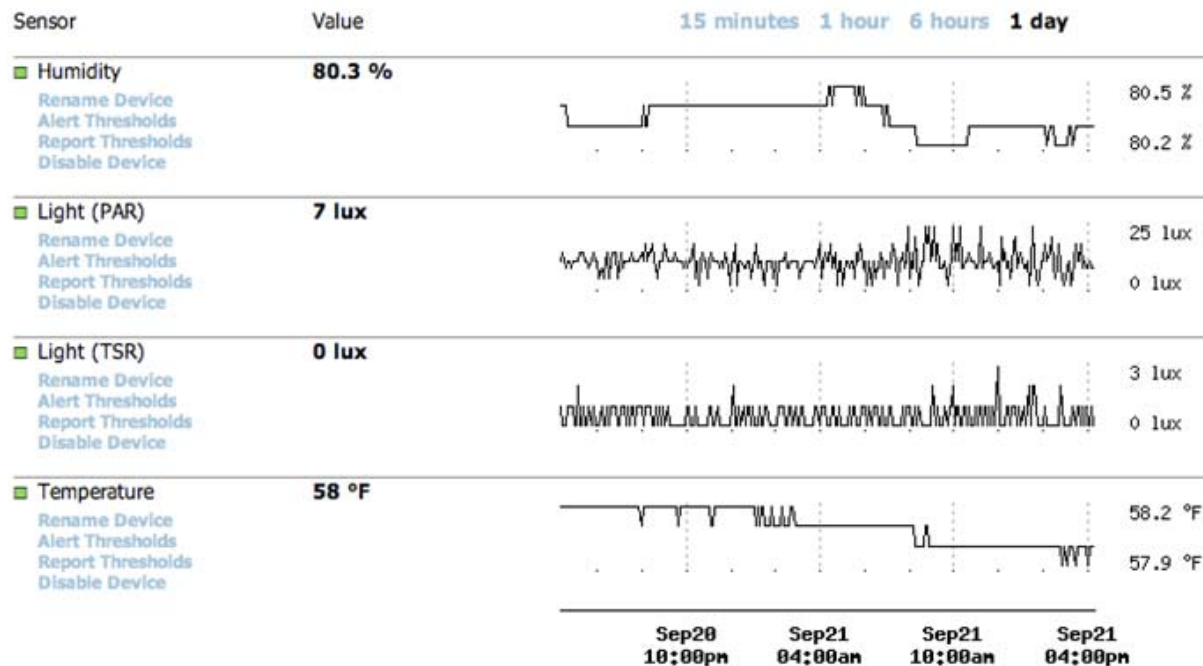
[Node Management](#)

Sample Period (in seconds): 300 [\[edit\]](#)

[Enable All Internal Sensors](#)

[Disable All Internal Sensors](#)

Last Sample: 4:17:09 pm [Request New Sample Now](#)



- non-Latin Character Domain Names
 - Original Domain Name Design: A-Z, a-z, 0-9, “-”
 - New UNICODE character sets
 - Cyrillic, Chinese, Japanese, Korean, Devanagiri (Hindi...), Thai, Greek, ...
- Introduction of IPv6 in parallel with IPv4
- Digitally-signed Domain Names (for integrity)
- Influx of Mobile Applications (Note Android)
- New Browser from Google: Chrome
- Significant growth of Social Networking applications

- Streaming and Downloading
 - iPOD and vPOD behaviors?
- Mixing of all media as IP packets
- Ancillary information access
 - Downloaded texts, programs, videos, audio, captions
 - Advertising material
- Screen Control (icons, widgets)
- Multiple streams to multiple displays (beauty of packet switching)
- Online interaction while viewing
 - Group commentary
 - Advertising and product information

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)

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 ecommerce
- Privacy and confidentiality

Mobile operation

- Dynamic joining (new IP address?, Authentication?)

- Dynamic Routing (Dynamic Topology)

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

Interplanetary Long-Haul Architecture (RFC 4838)

- Licklider Transport Protocol (LTP)

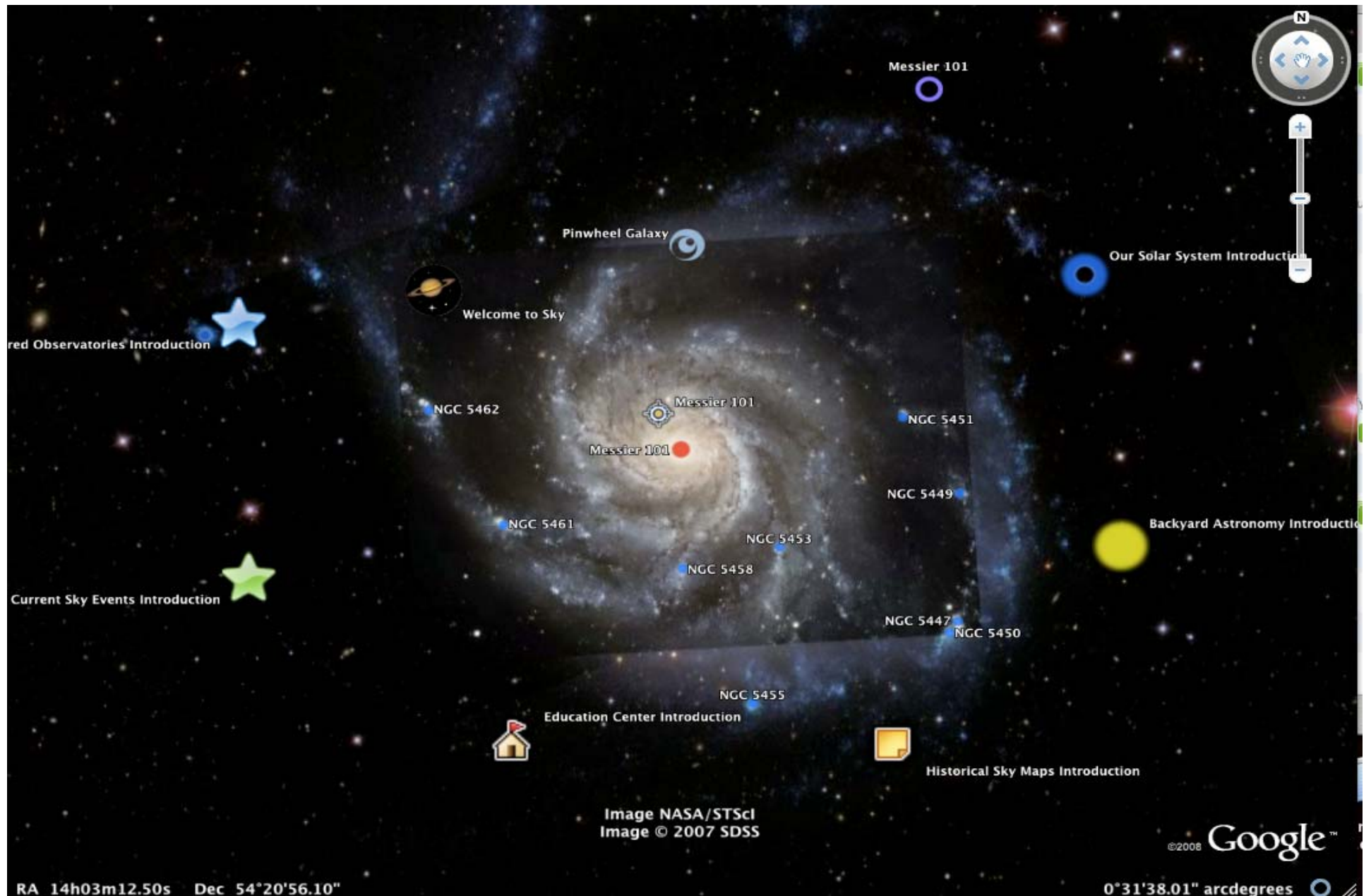
- Bundle Protocol (RFC 5050)

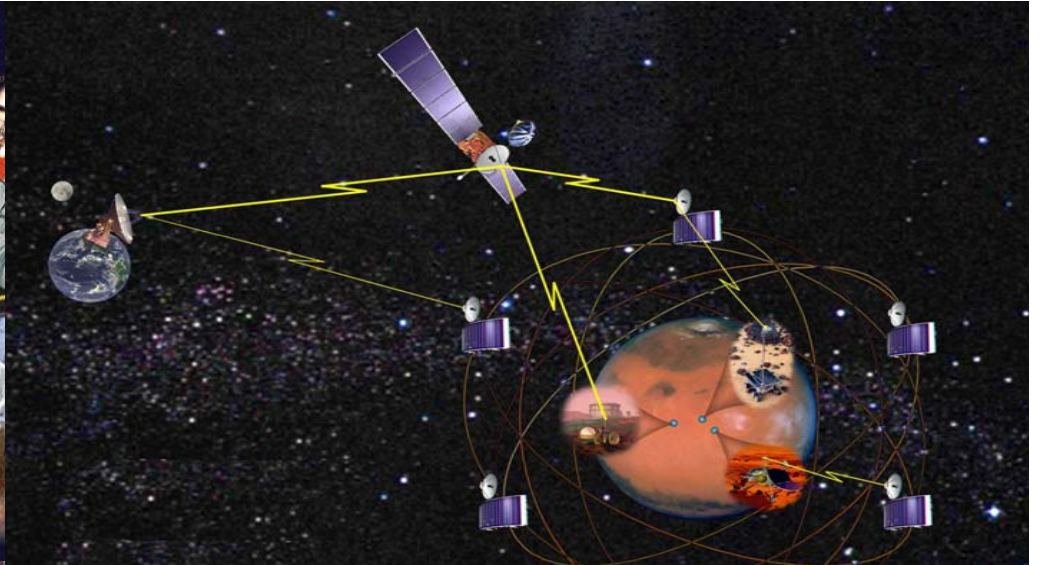
 - Delayed Binding of Identifiers

 - Email-like behavior

- Intellectual property treatment
 - Digital material is easy to copy and distribute
- Semantic Web
- Complex objects that can only be rendered via computer
 - 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 that run the operating systems
 - For thousands of years!!

Google Sky



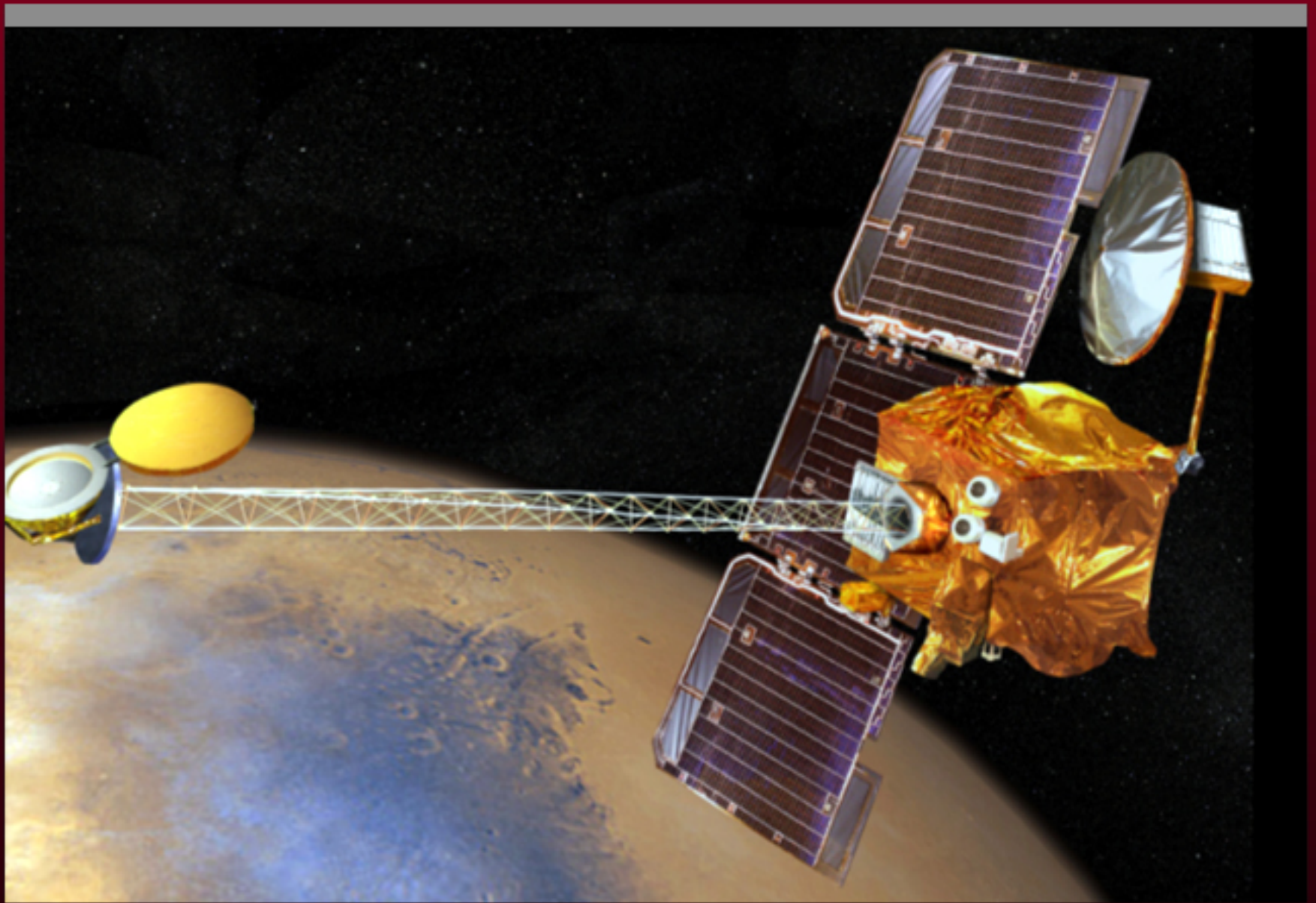


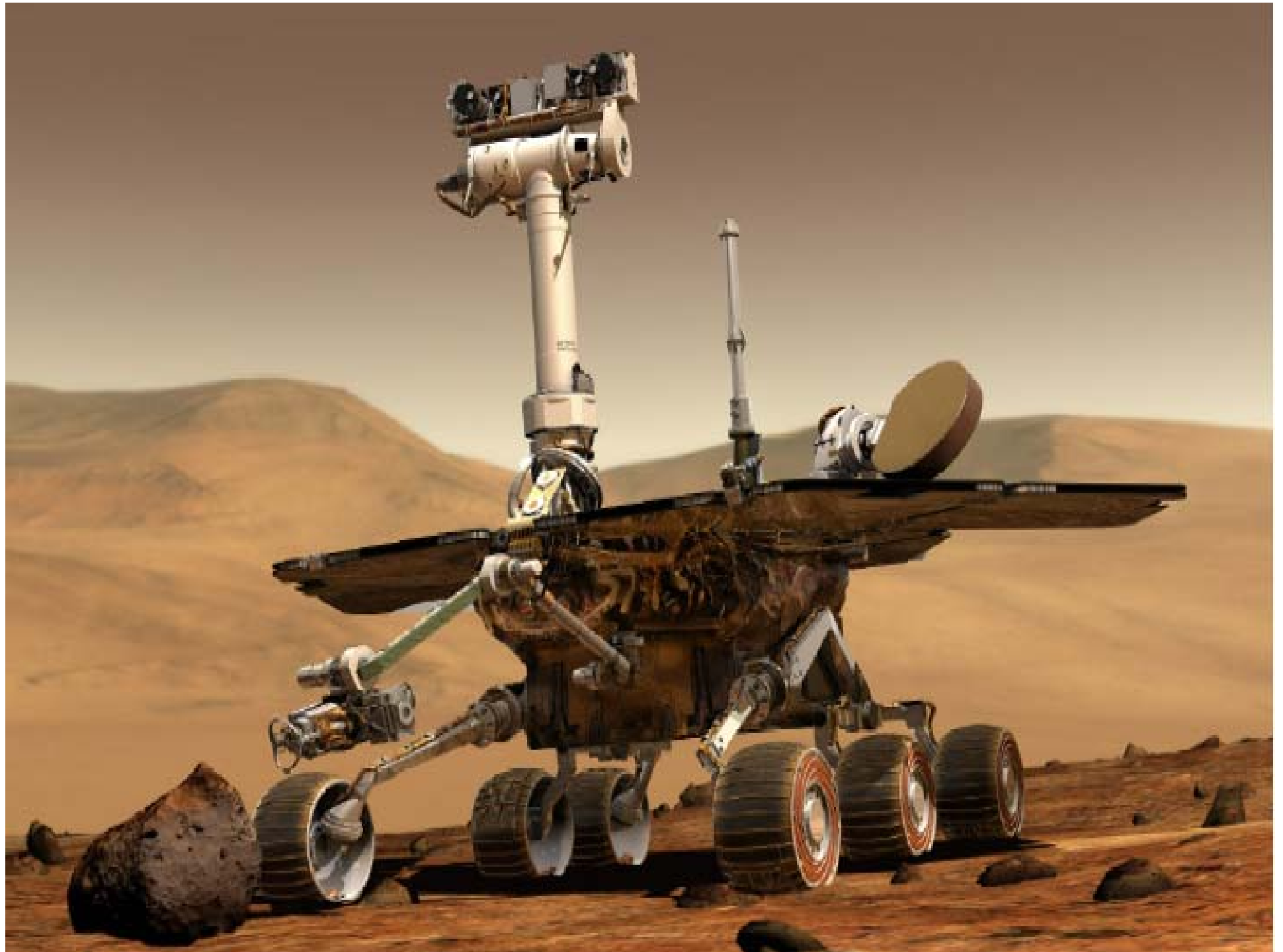
InterPlaNetary Internet

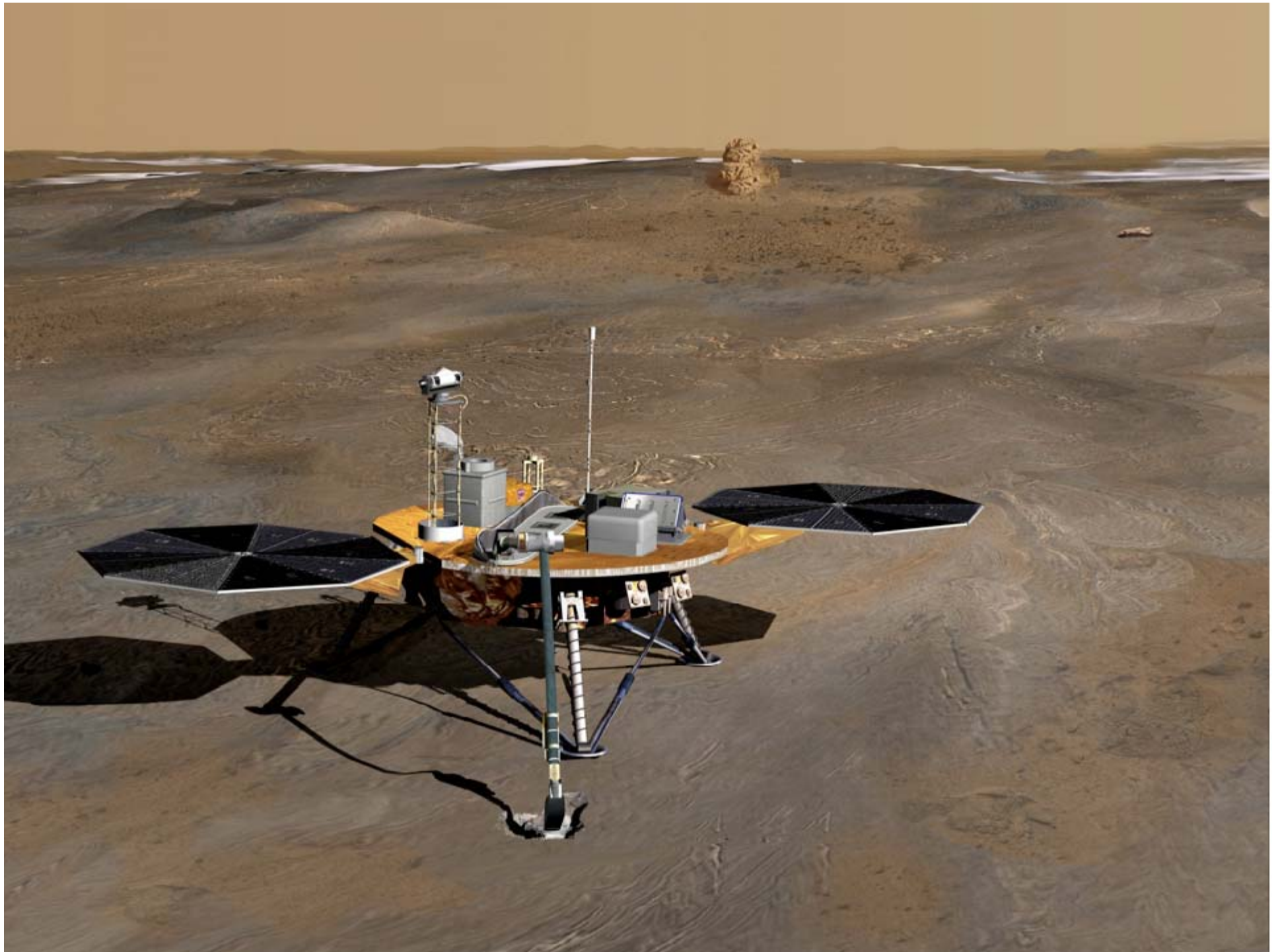














Interplanetary Internet: “InterPlaNet” (IPN)



- 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 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*

