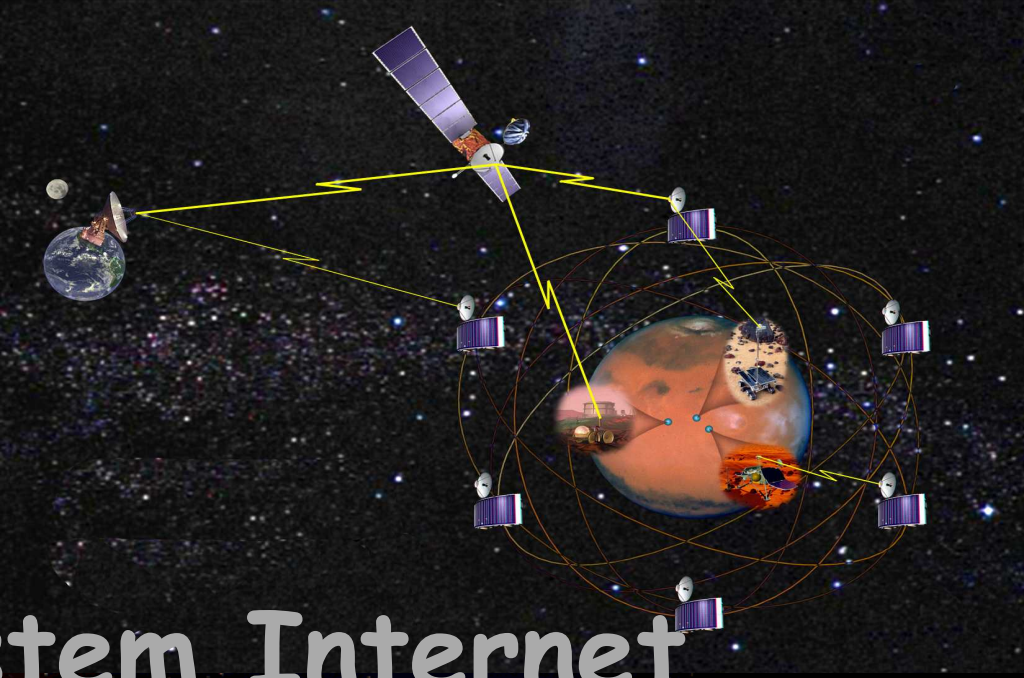
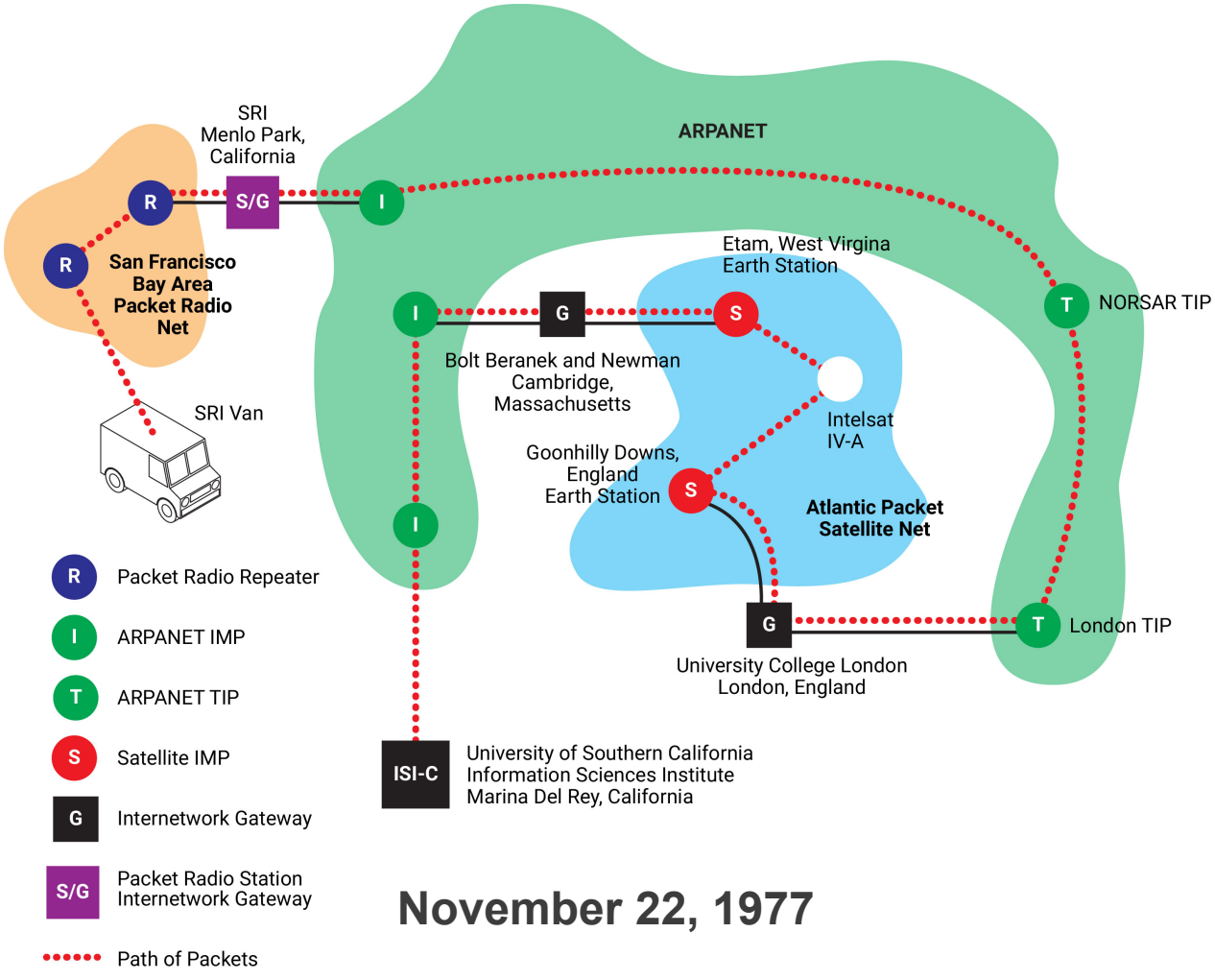


Solar System Internet

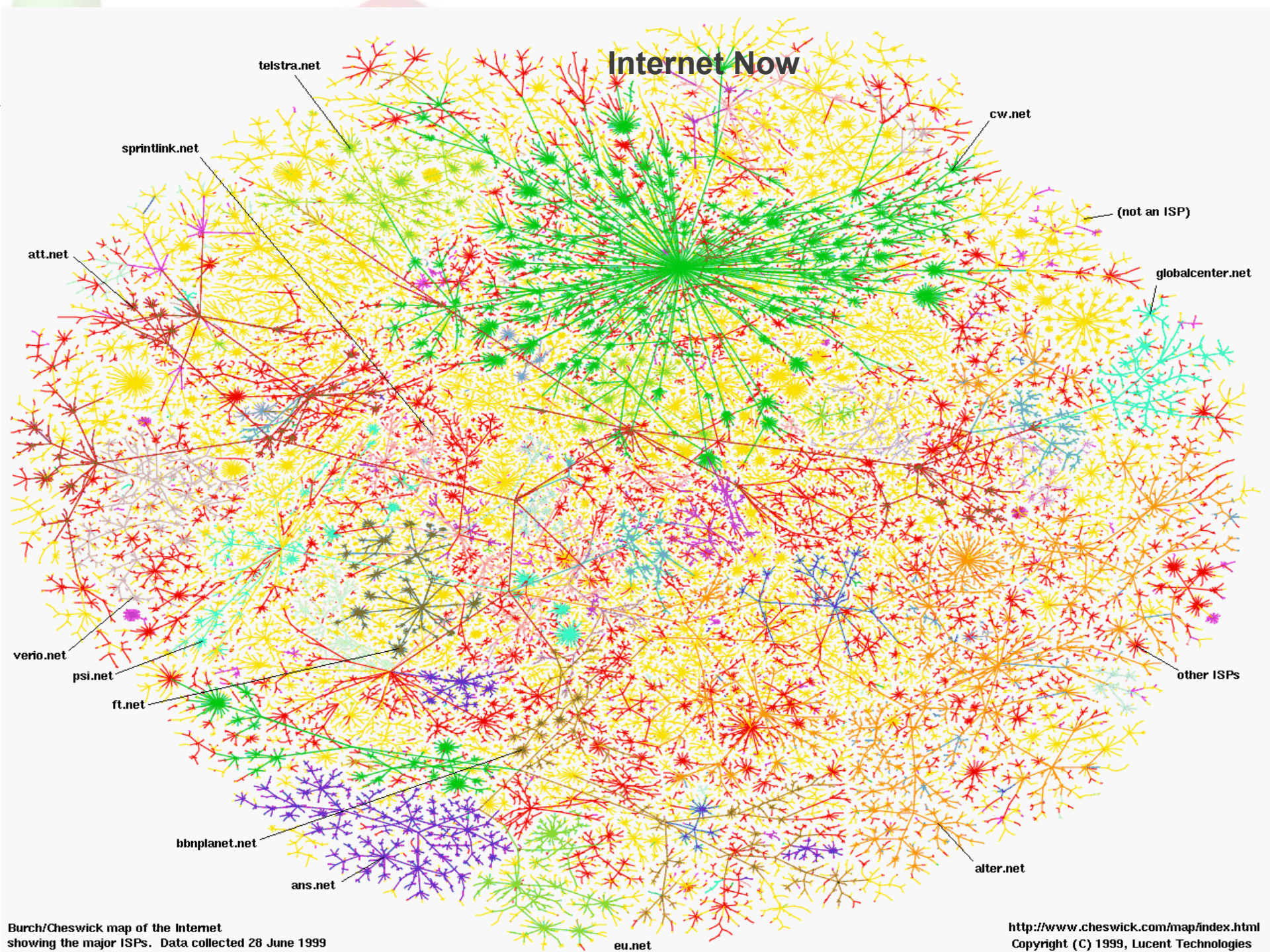
April 2021

First Three-Network Test of Internet Protocols

Heterogeneous networks and computers



November 22, 1977


Internet Now
telstra.net
sprintlink.net
att.net
verio.net
psi.net
ft.net
bbnplanet.net
ans.net
eu.net
alter.net
other ISPs
globalcenter.net
(not an ISP)
cw.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


Google Earth
N
Image NASA / USGS
ESA / DLR / FU Berlin (G.Neukum)
©2009 Google
38°57'34.00" N 95°15'55.87" W elev 422 m
Eye alt 11001.42 km

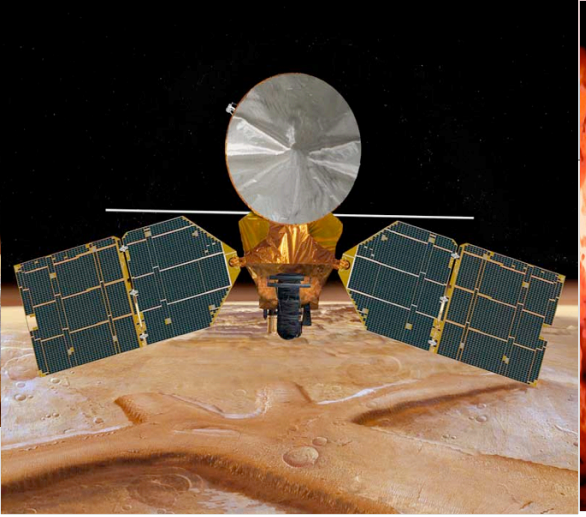

Spirit
& Opportunity
2004
Sojourner
1997
Curiosity
2012

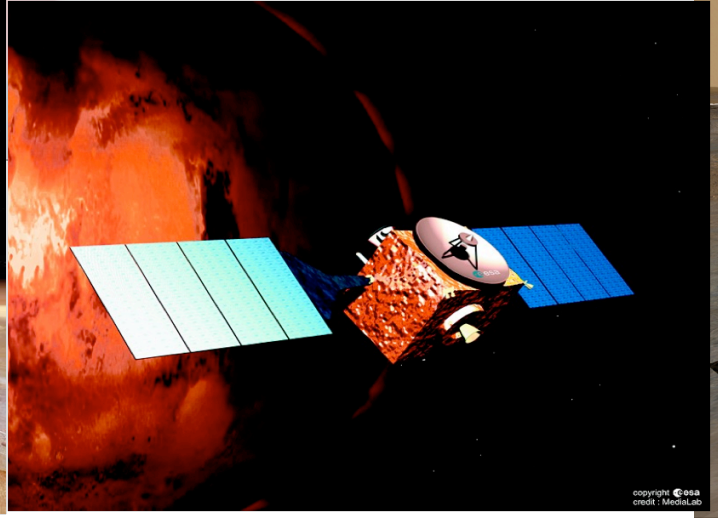
Initial Considerations

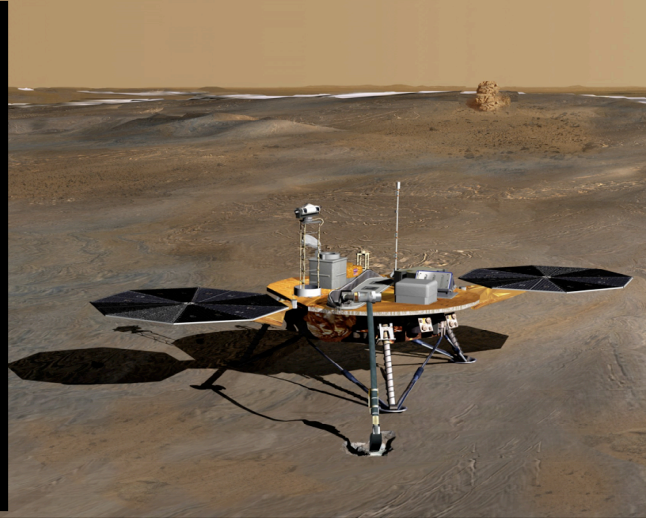
- 1998: Use TCP/IP?
- Round-trip times to Mars: 7 – 40 minutes
- TCP Flow control?
- DNS Lookup?
- Delay and Disruption Tolerant Networking (DTN)
- Bundle Protocol (layered architecture)
  - Delayed Name Resolution (two steps)
  - Store (in the network) and forward when links are available
  - Redefinition of network management in a DTN environment (no PING)
  - Built in strong authentication and encryption

Prototyping

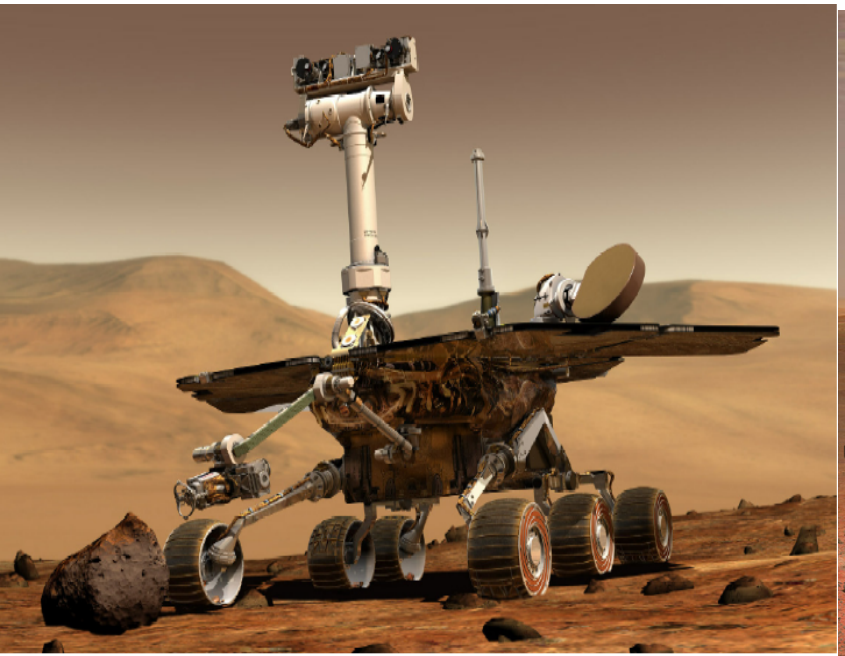
- 2004: Spirit and Opportunity land on Mars
- 28.5 Kb/s Direct to Earth radio link
- Radio overheats – reduce duty cycle
- Version of CCSDS File Delivery Protocol (CFDP) exported to Rovers and Orbiters (2007 CCSDS 727.0-B-4)
- Use “manual” CFDP since 2004 for data delivery to/from Mars
- Contract Graph Routing (orbital dynamics)

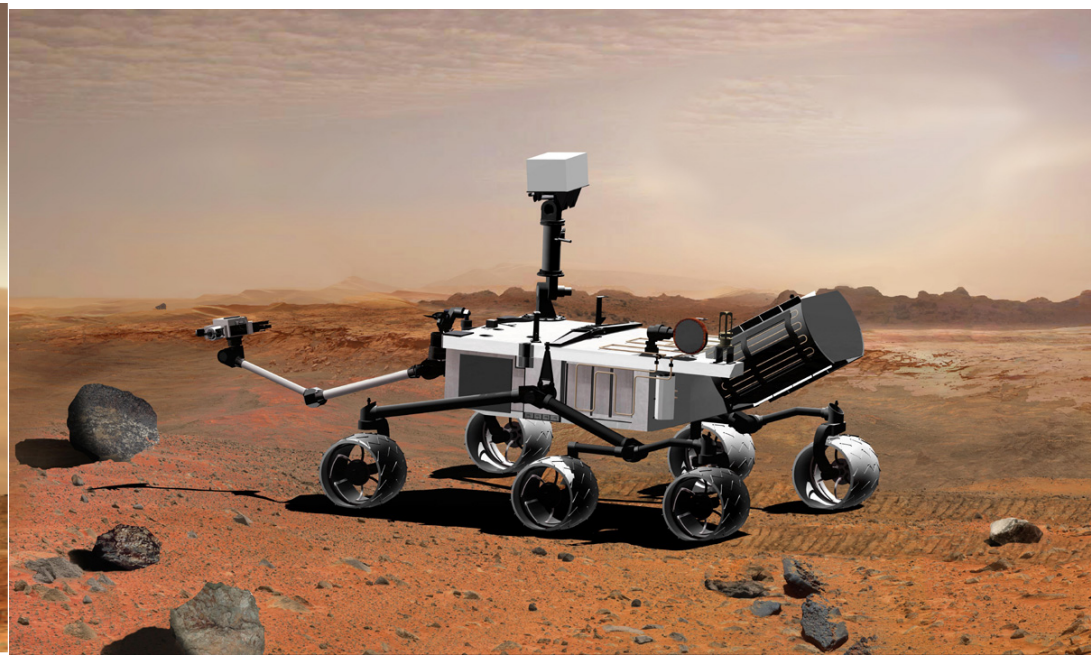






MARS RECONAISSANCE ORBITER, MARS EXPRESS, PHOENIX, MARS ROVERS, MARS SCIENCE LABORATORY





Refining and testing DTN

- 2008, 2009, 2011 – Testing DTN at 81 light seconds on the Deep Impact space craft used in the EPOXI mission (to visit two comets).
- 2009-2018 – Testing of DTN on the International Space Station (messaging applications)
- 2012-2016 – Multi-purpose End-to-End Robotic Operations Network (METERON) DTN tests conducted on ISS by ESA. Remote real-time control of a robotic vehicle at ESA Operations Center in Germany.
- October 2013 – April 2014 – Lunar Laser Communications Demonstration (Earth to Moon Orbit and back) at 622 Mb/s using the Lunar Atmosphere and Dust Environment Explorer (LADEE) spacecraft.

Further Refining of the DTN protocols

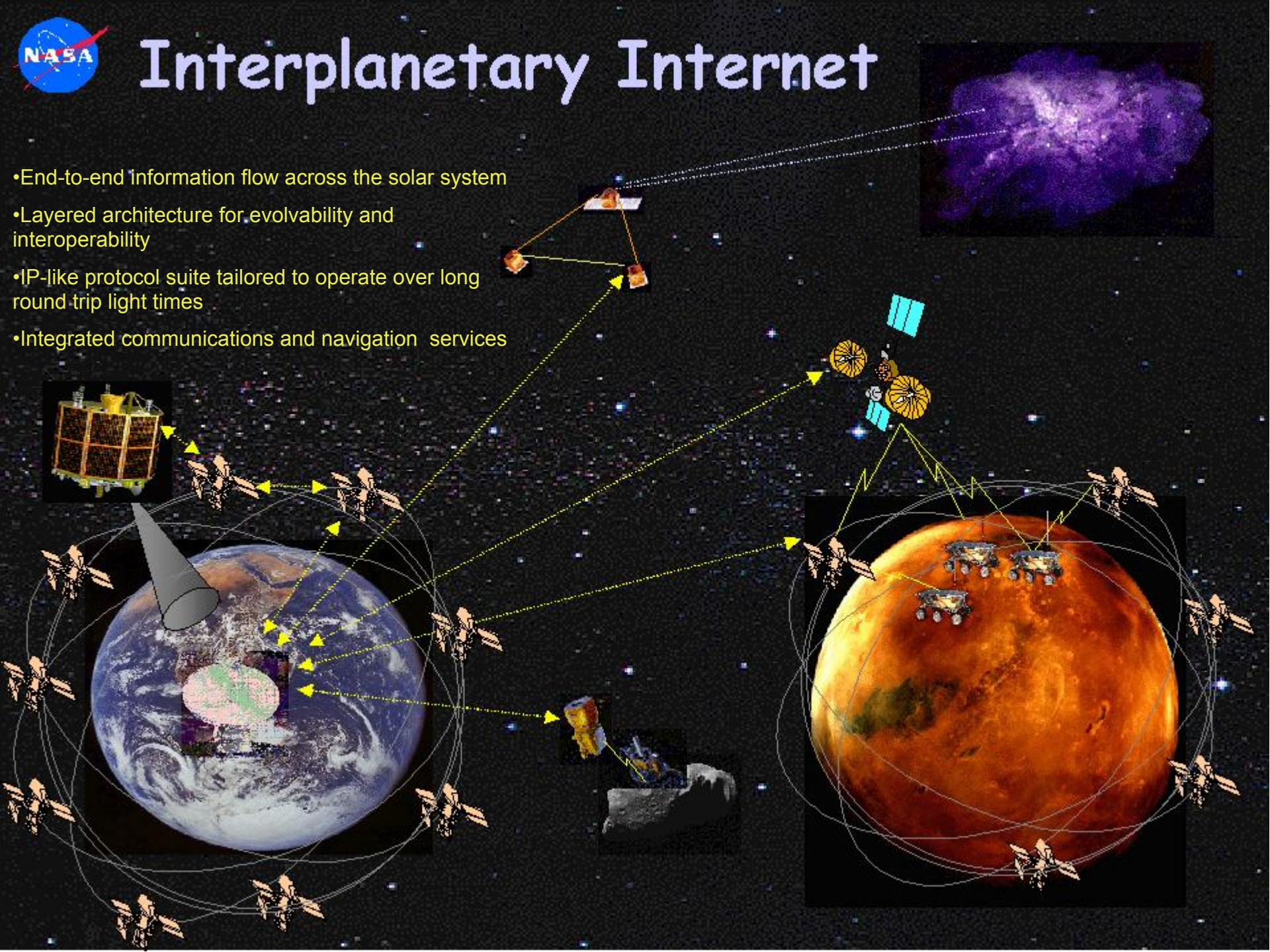
- 2013: Interoperability testing of Interplanetary Overlay Network (ION) implementation of DTN between NASA and JAXA
- 2014 - Present: IETF Working Group: DTNWG
  - Bundle Protocol V6 and V7
- 2008 – Present: Continued Consultative Committee on Space Data Systems (CCSDS) standardization of the Bundle Protocol, Licklider Transmission Protocol, etc.
- 2008 - Present N4C project at Luleå University in Sweden to use DTN to provide communications for the Sami reindeer herders in the Arctic.

Further Refining of the DTN Protocols

- Present: Technische Universität Braunschweig, IBR-DTN implementation for RouterBoard 532A or Ubiquiti RouterStation Pro and for Android (see IBR-DTN GooglePlay)
- Present: NASA, ESA, JAXA, KARI deployment activities
- Software available at Github.com
  - IBR-DTN (TU Braunschweig)
  - ION (from NASA)
- Future plans or expectations:
  - Implementation of DTN for 2020's missions to Moon
  - IPNSIG.ORG long-term proposals and public engagement

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



Next Stop: Alpha Centauri?