GSAW 2003

Session 3:

"Interplanetary Internet"

Adrian Hooke
Jet Propulsion Laboratory

"Advanced Internet Technologies for Spacecraft TT&C"

Keith Scott
The MITRE Corporation

"CCSDS File Delivery Protocol in Delay-Tolerant Networking"

Scott Burleigh
NASA Jet Propulsion Laboratory

04 March 2003

GSAW 2003

Session 3:

InterPlaNetary Internet

Scott Burleigh, JPL
Vint Cerf, WorldCom Inc.
Robert Durst, MITRE Corporation
Kevin Fall, Intel Research
Adrian Hooke, JPL
Keith Scott, MITRE Corporation
Leigh Torgerson, JPL
Howie Weiss, Sparta Inc.

04 March 2003

1970 1980 1990 2000

NASA Telemetry Standardization

"Packet" Spacecraft Telemetry and Telecommand

02 January, 1996
STRV-1b
IP address:
192.48.114.156

NASA/ESA Working Group

Basic Space/Ground Communications Standards for Space Missions

Baselined by Space Station and Ground Network

Consultative Committee for Space Data Systems (CCSDS)

CCSDS Recommendation for Advanced Orbiting Systems

Extension of Standards for More Complex Space Missions

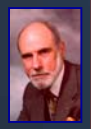
International Space Station

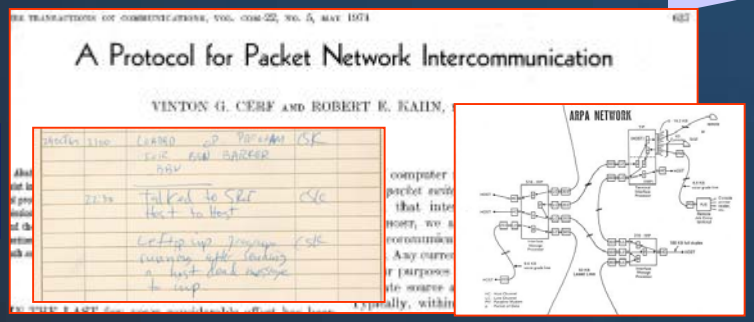
File Transfer: FTAM
Transport: TP4
Network: ISO 8473

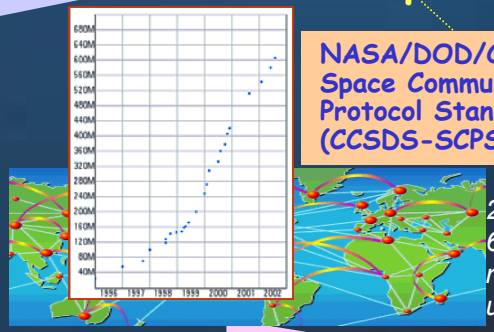
The Dark Age Of GOSIP

Extension of the Terrestrial Internet into Space

Evolution of space standards







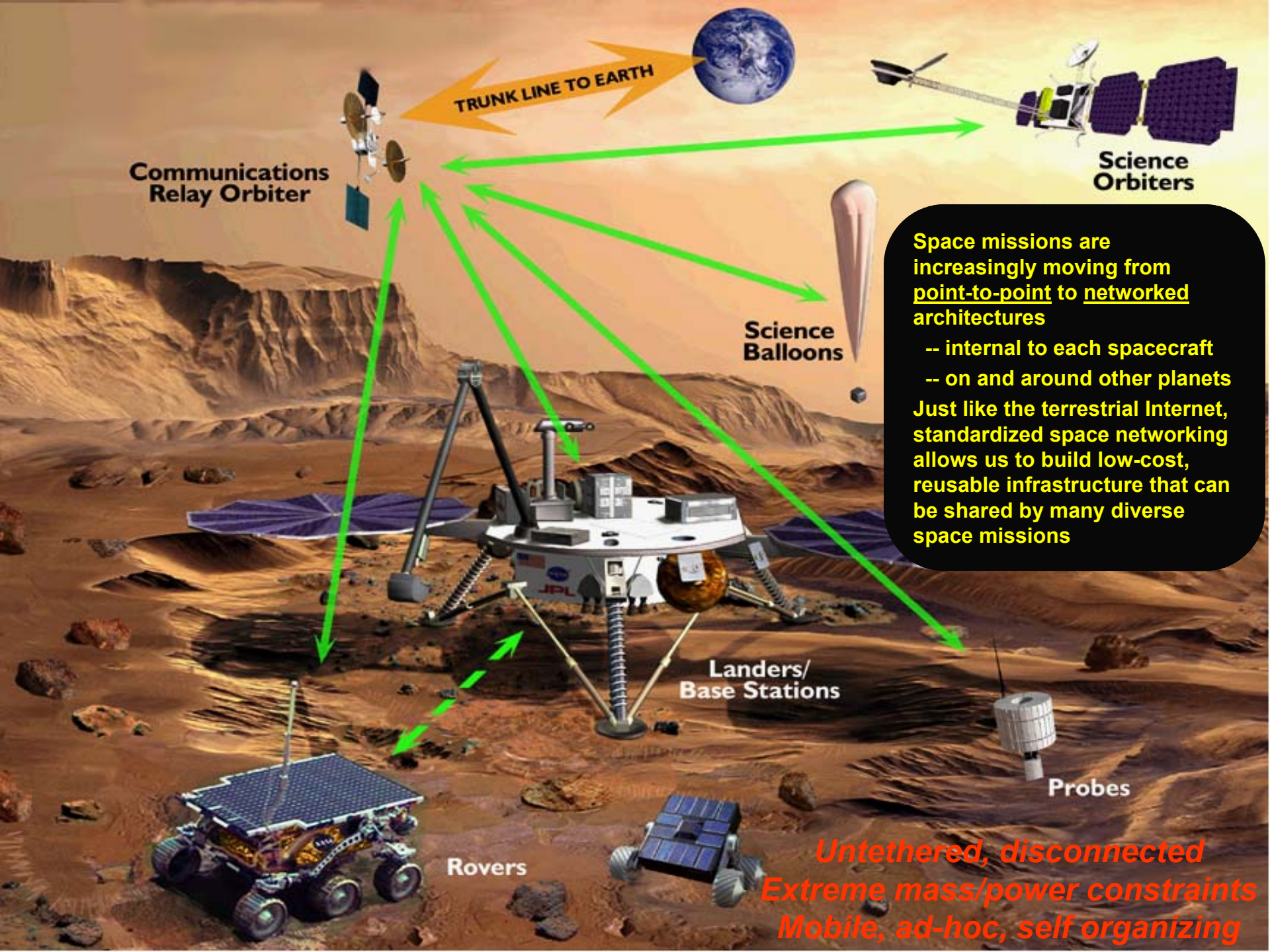
NASA/DOD/CCSDS Space Communications Protocol Standards (CCSDS-SCPS) Project

File Transfer: FTP
Transport: TCP
Network: IP

2002: 605 million users

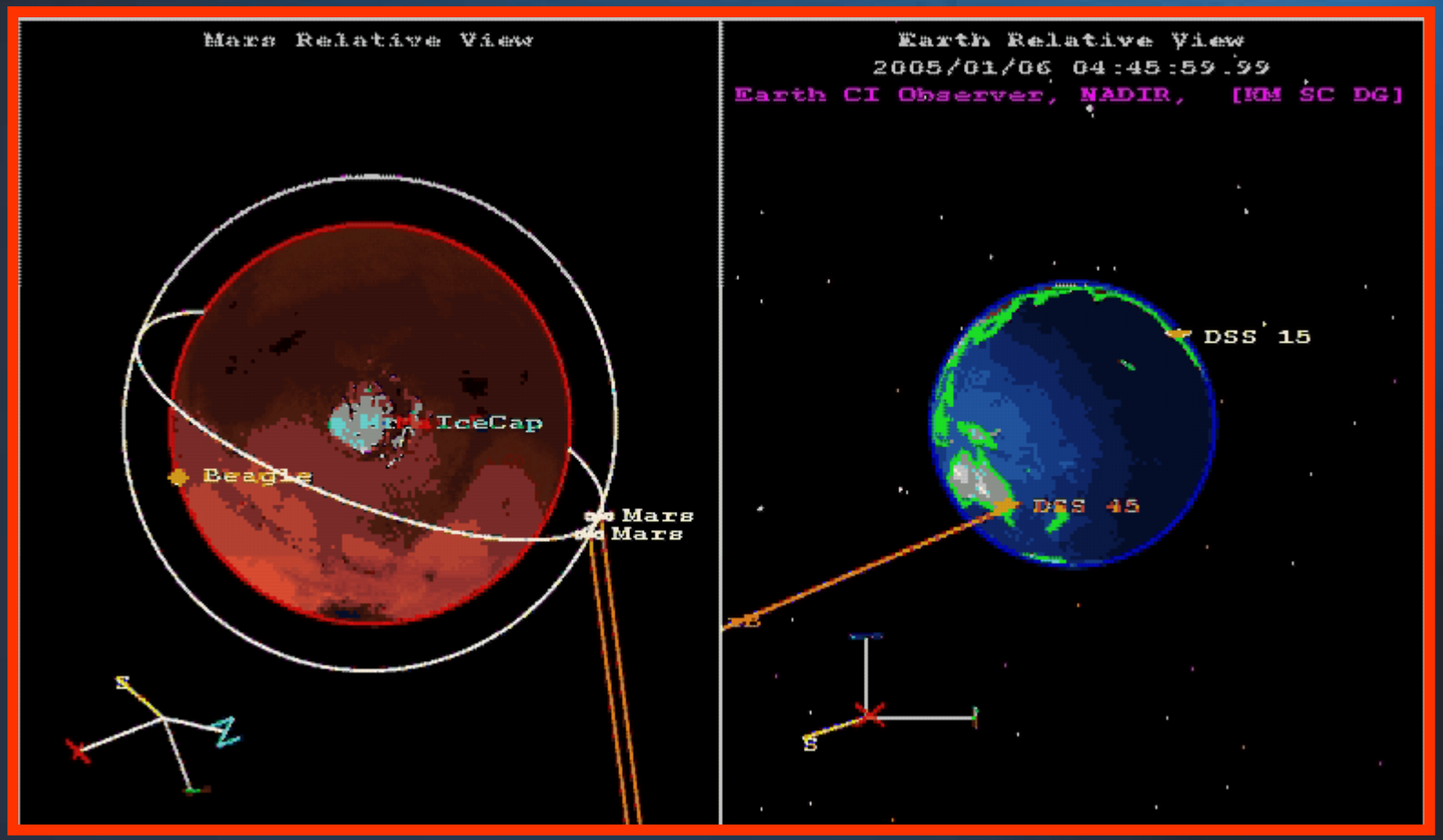
InterPlaNetary Internet (IPN)

Evolution of the terrestrial Internet


TRUNK LINE TO EARTH
Communications Relay Orbiter
Science Orbiters
Science Balloons
Landers/ Base Stations
Probes
Rovers
Space missions are increasingly moving from point-to-point to networked architectures
-- internal to each spacecraft
-- on and around other planets
Just like the terrestrial Internet, standardized space networking allows us to build low-cost, reusable infrastructure that can be shared by many diverse space missions
Untethered, disconnected
Extreme mass/power constraints
Mobile, ad-hoc, self organizing

The Internet is a connected, chatty 'network of networks' based on a wired backbone with negligible delay and errors (with untethered "edges" emerging)

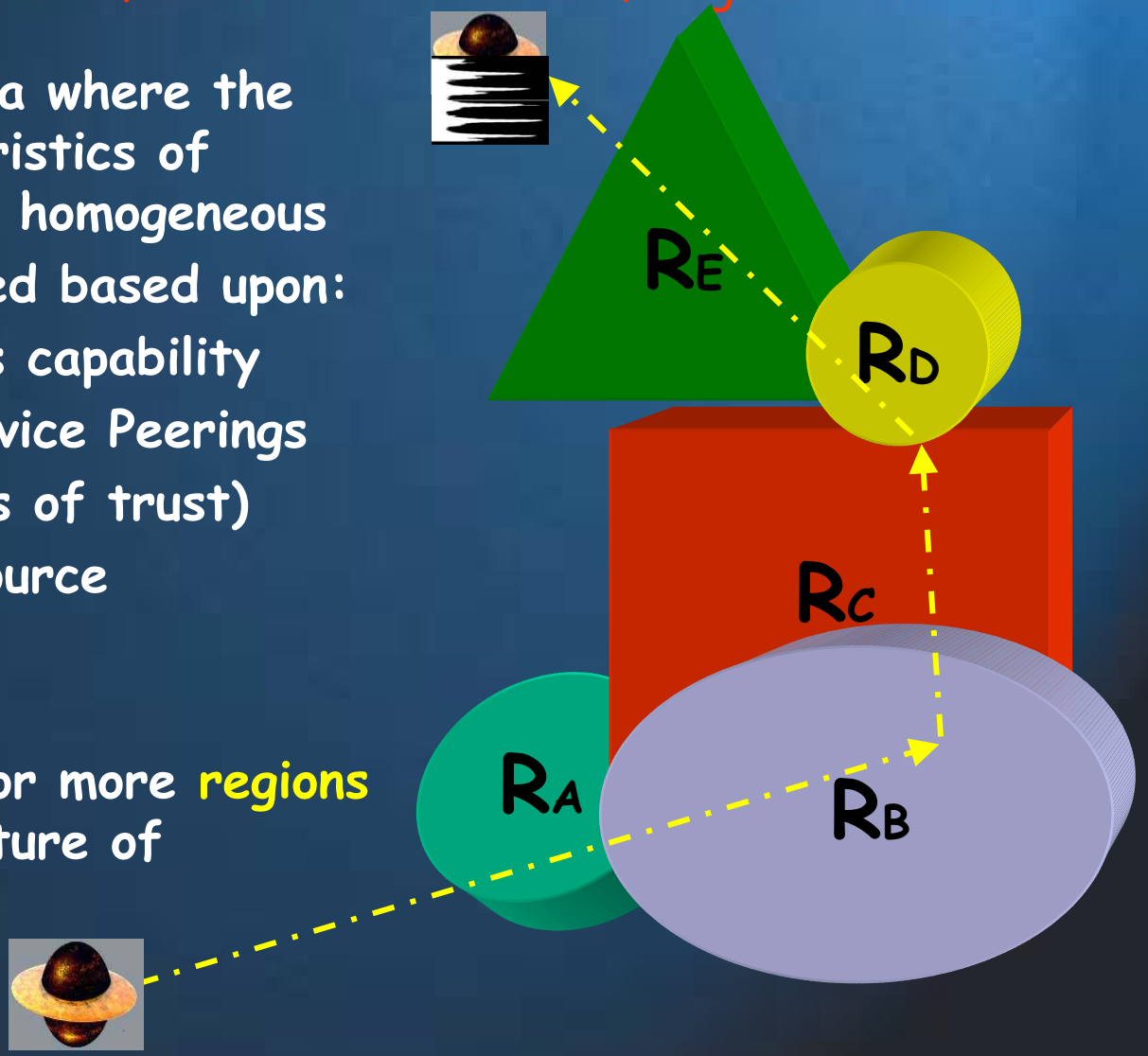
The InterPlaNetary Internet is a often disconnected, store-and forward 'network of Internets' based on a wireless backbone with huge delays and error prone links

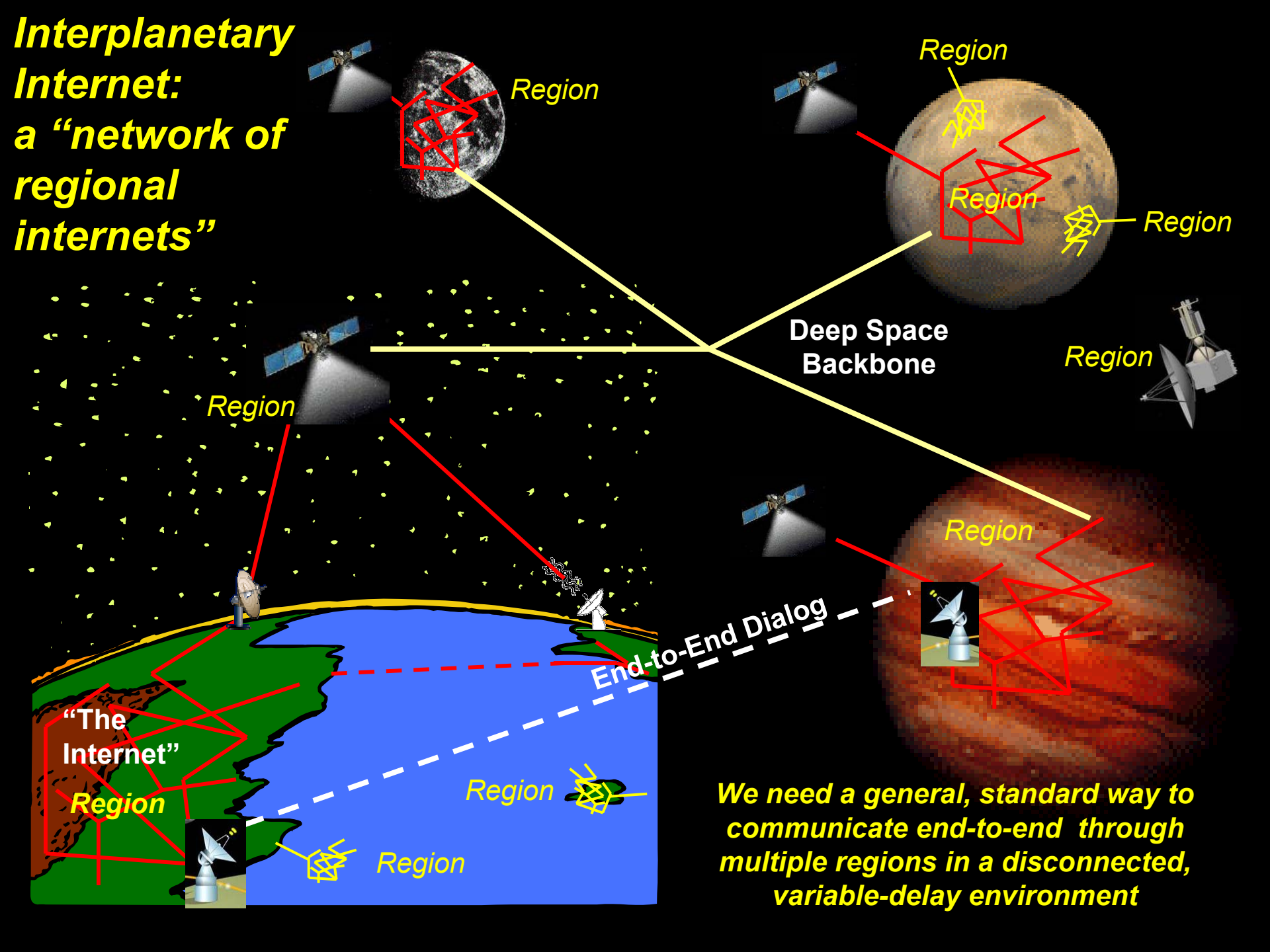


The Interplanetary Internet:

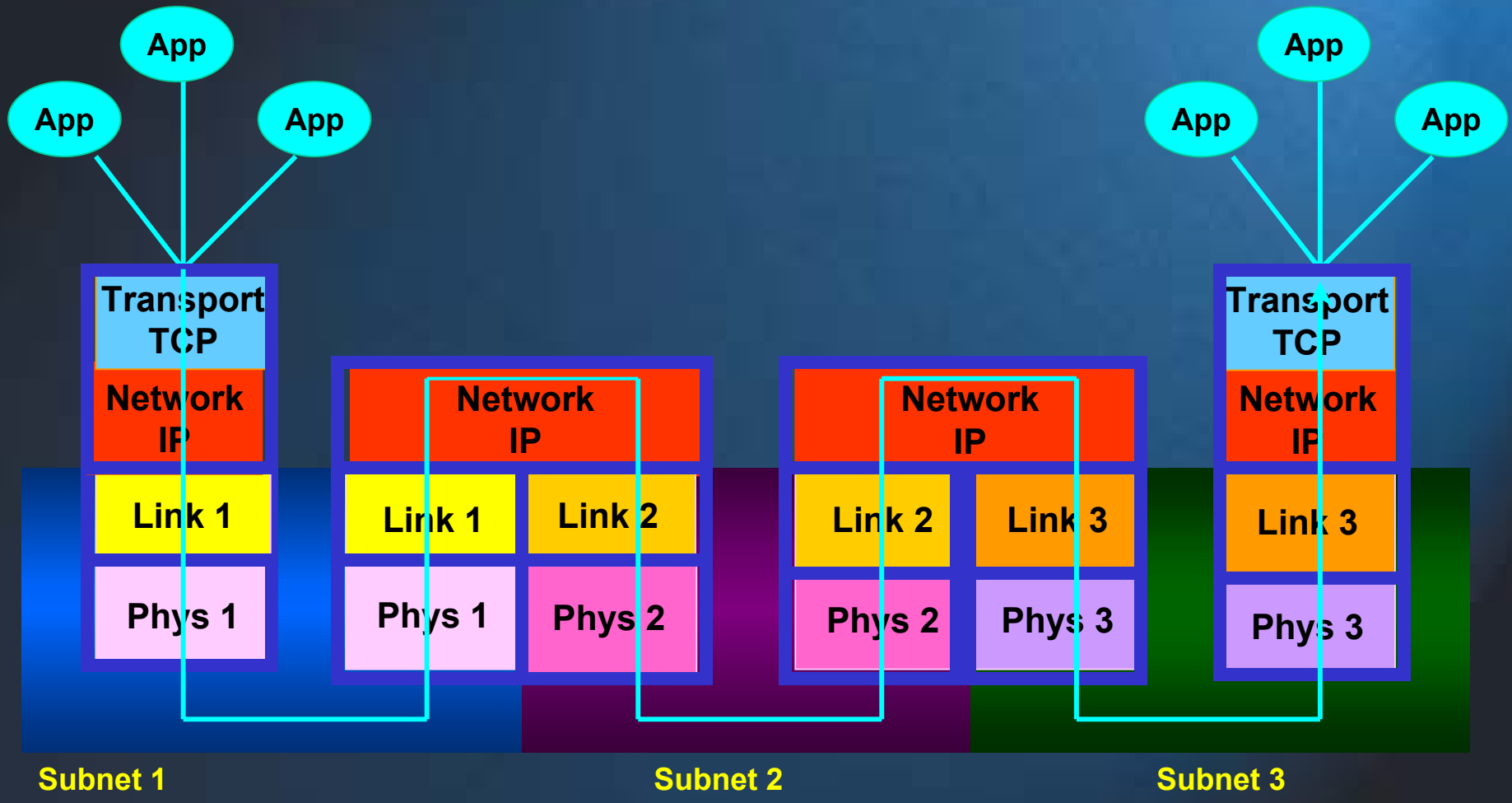
An overlay network for interconnection of regional internets

- A *region* is an area where the relevant characteristics of communication are homogeneous
- Regions are defined based upon:
  - Communications capability
  - Quality of Service Peerings
  - Security (levels of trust)
  - Degree of resource management
  - Etc.
- Traversal of two or more regions will affect the nature of communications



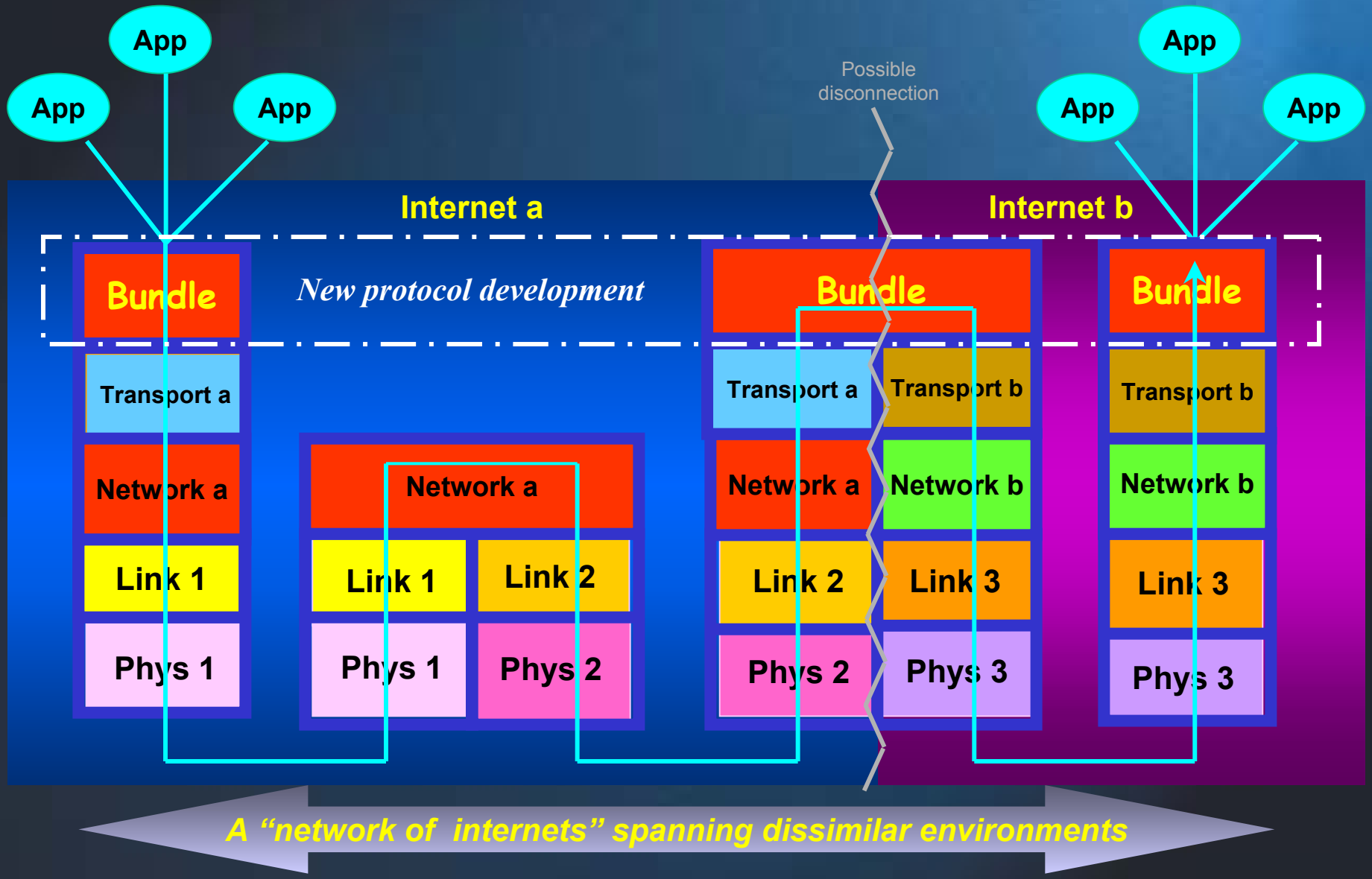

Interplanetary Internet: a "network of regional internets"
Region
Region
Region
Region
Region
Deep Space Backbone
Region
Region
Region
End-to-End Dialog
"The Internet"
Region
Region
Region
We need a general, standard way to communicate end-to-end through multiple regions in a disconnected, variable-delay environment

The Internet: a Network of Connected Sub-Networks

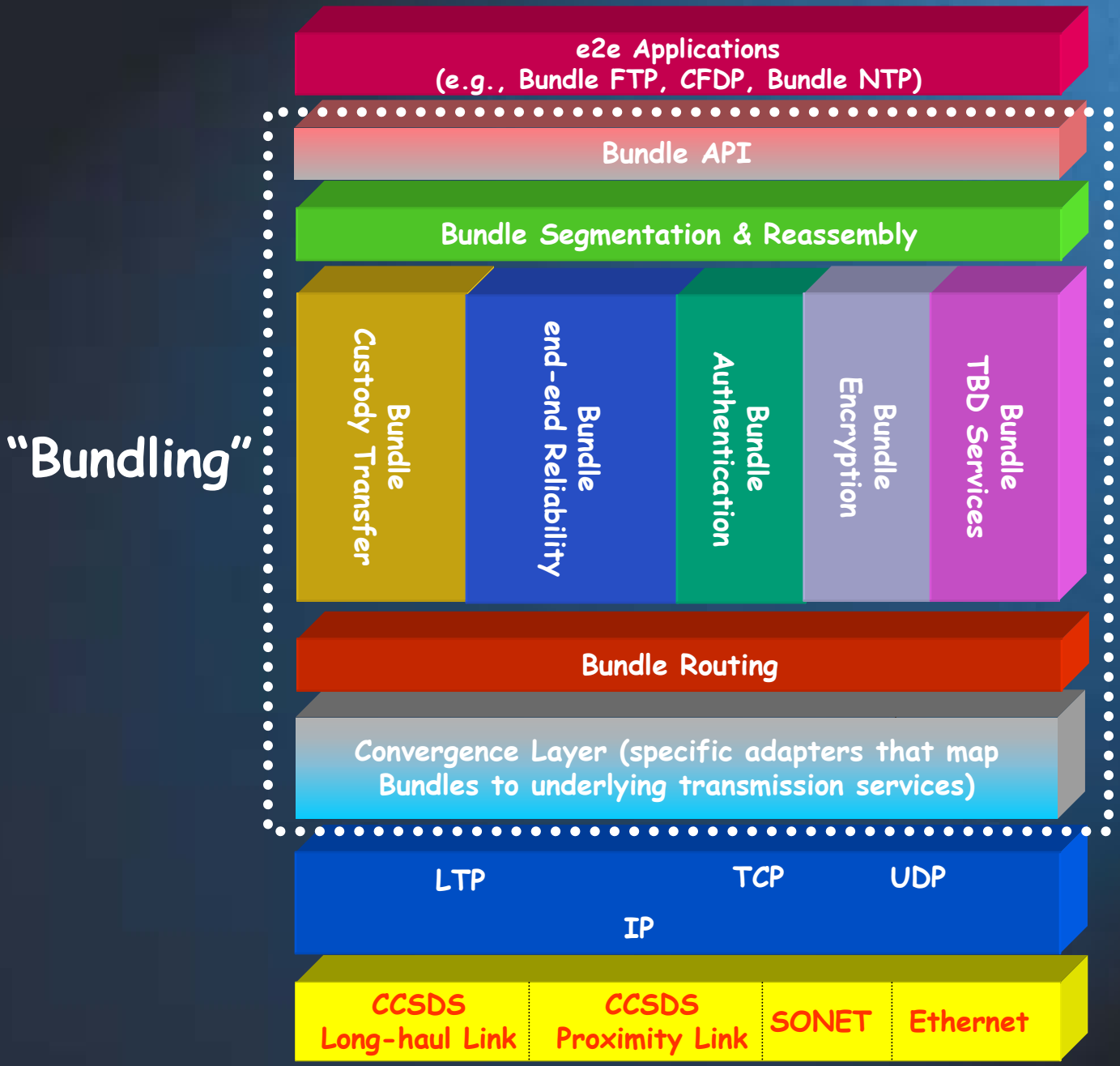


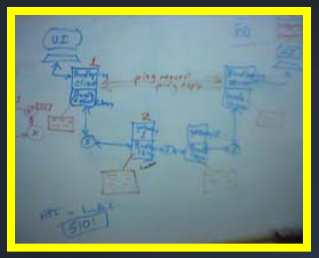
Bundles: A Store and Forward Application Overlay

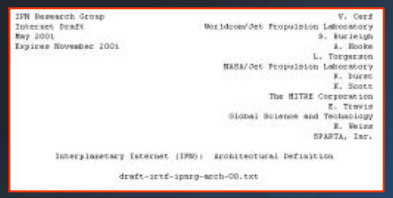
The "Thin Waist" of the Interplanetary Internet



Bundle Service Layering





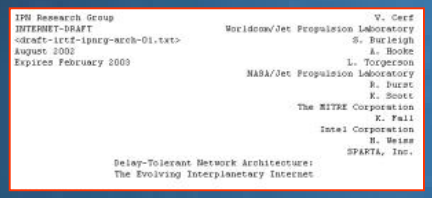

IPN Research Group
Internet Draft
May 2001
Expires November 2001

V. Cerf
Worldcom/Jet Propulsion Laboratory
S. Burleigh
A. Hooke
L. Torgerson
NASA/Jet Propulsion Laboratory
R. Durst
K. Scott
The MITRE Corporation
K. Fall
Intel Corporation
H. Weiss
SPARTA, Inc.

Interplanetary Internet (IPN): Architectural Definition

draft-irtf-ipnrg-arch-00.txt

IPN
Architecture
(Internet Draft 1)
May 2001


IPN Research Group
INTERNET-DRAFT
<draft-irtf-ipnrg-arch-01.txt>
August 2002
Expires February 2003

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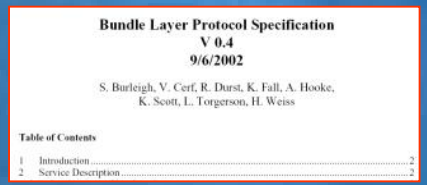
SPARTA, Inc.

Delay-Tolerant Network Architecture:
The Evolving Interplanetary Internet

DTN
Architecture
(Internet Draft 2)
August 2002


Bundle Layer Protocol Specification
V 0.4
9/6/2002

S. Burleigh, V. Cerf, R. Durst, K. Fall, A. Hooke,
K. Scott, L. Torgerson, H. Weiss

Table of Contents

1 Introduction 2
2 Service Description 3

Bundle Protocol
Specification, Draft1
September 2002

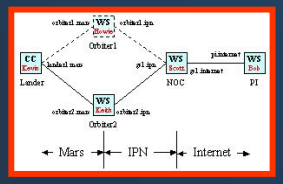
Bundle Specification

Specifications

Code base

Bundle Prototyping

1st. Rough Code August 2000



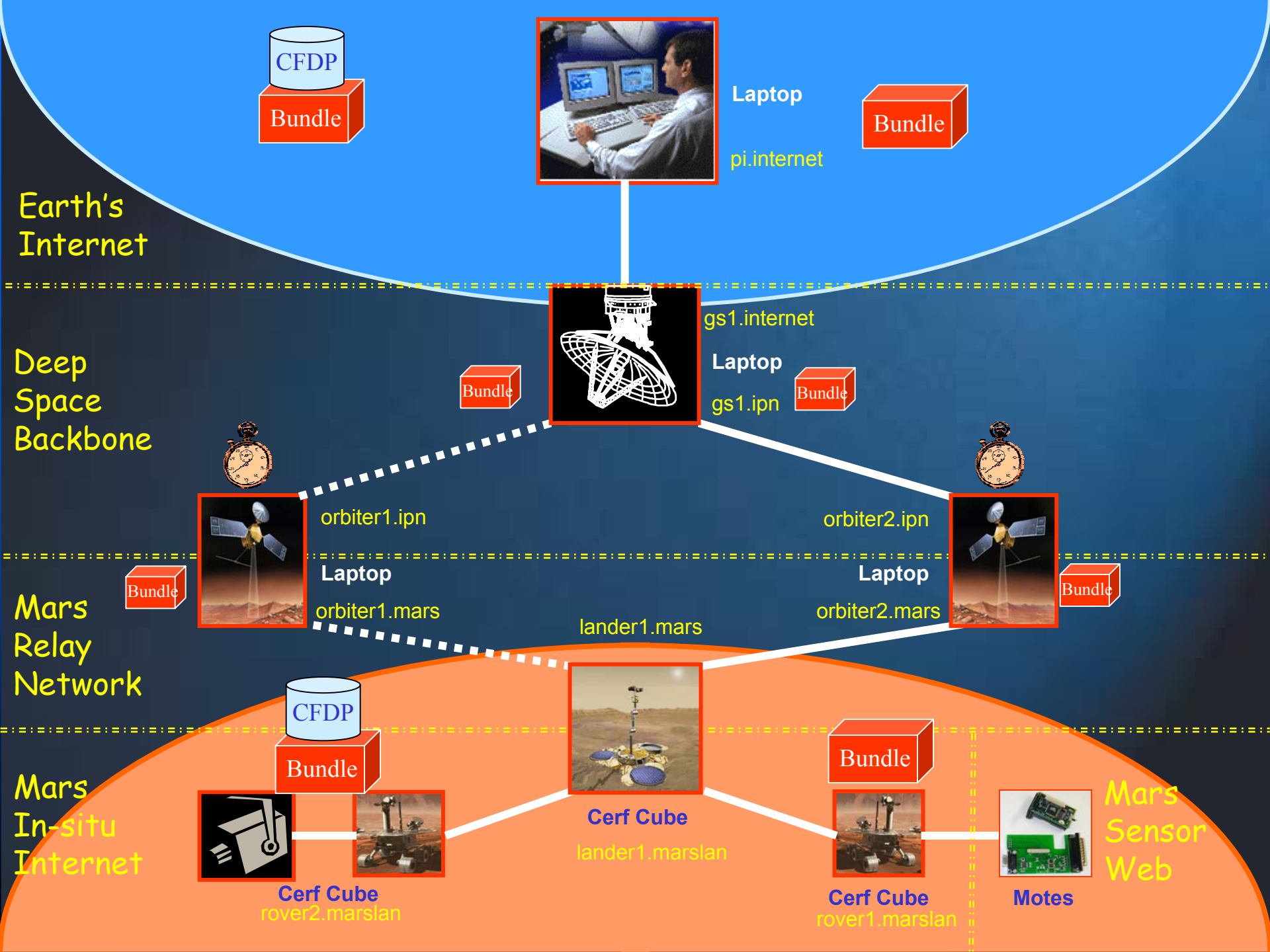
2nd. Proto. Code May 2002

3rd. Proto. Code July 2002

4th Proto. Code Sept. 2002

5th Proto. Code Nov. 2002

Files/Images/UGS-over-Bundles Experiment


CFDP
Bundle
Laptop
pi.internet
Bundle
Earth's Internet
Deep Space Backbone
gs1.internet
Laptop
gs1.ipn
Bundle
Bundle
orbiter1.ipn
Laptop
orbiter1.mars
orbiter2.ipn
Laptop
orbiter2.mars
Bundle
Bundle
Mars Relay Network
lander1.mars
CFDP
Bundle
Cerf Cube
lander1.marslan
Bundle
Mars In-situ Internet
Cerf Cube
rover2.marslan
Cerf Cube
rover1.marslan
Motes
Mars Sensor Web

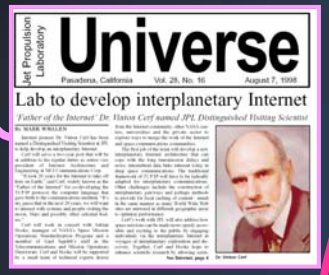
The Interplanetary Internet

1998 | 1999 | 2000 | 2001 | 2002 | 2003

DARPA-ATO

DARPA-NGI Initiative

NASA

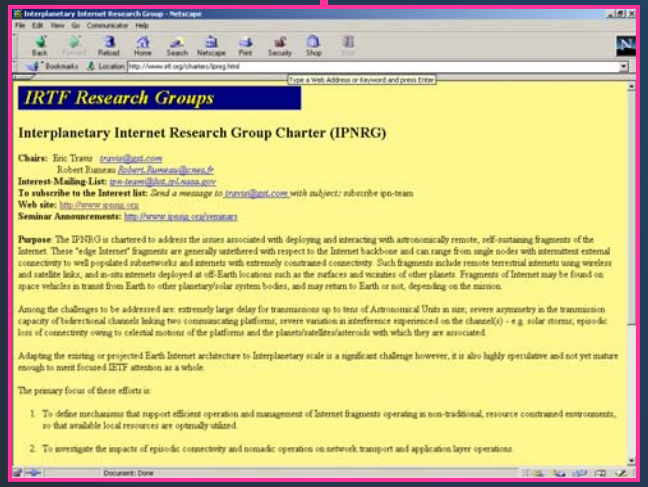

Jet Propulsion Laboratory

Universe

Pasadena, California Vol. 28, No. 16 August 7, 1998

Lab to develop interplanetary Internet

'Father of the Internet' Dr. Vinton Cerf named JPL Distinguished Visiting Scientist


IRTF Research Groups

Interplanetary Internet Research Group Charter (IPNRG)

Chairs: Eric Travis travis@jpl.com
Robert Rumeau Robert.Rumeau@cnes.fr
Interest-Mailing-List: ipn-team@shat.jpl.nasa.gov
To subscribe to the Interest list: *Send a message to travis@jpl.com with subject: subscribe ipn-team*
Web site: http://www.ipnsig.org
Seminar Announcements: http://www.ipnsig.org/seminars

Purpose: The IPNRG is chartered to address the issues associated with deploying and interacting with astronomically remote, self-sustaining fragments of the Internet. These "edge Internet" fragments are generally untethered with respect to the Internet backbone and can range from single nodes with intermittent external connectivity to well populated subnetworks and internets with extremely constrained connectivity. Such fragments include remote terrestrial internets using wireless and satellite links, and in-situ internets deployed at off-Earth locations such as the surfaces and vicinities of other planets. Fragments of Internet may be found on space vehicles in transit from Earth to other planetary/solar system bodies, and may return to Earth or not, depending on the mission.

Among the challenges to be addressed are: extremely large delay for transmissions up to tens of Astronomical Units in size, severe asymmetry in the transmission capacity of bidirectional channels linking two communicating platforms, severe variation in interference experienced on the channel(s) - e.g. solar storms, episodic loss of connectivity owing to celestial motions of the platforms and the planets/satellites/asteroids with which they are associated.

Adapting the existing or projected Earth Internet architecture to Interplanetary scale is a significant challenge however, it is also highly speculative and not yet mature enough to merit focused IETF attention as a whole.

The primary focus of these efforts is:

1. To define mechanisms that support efficient operation and management of Internet fragments operating in non-traditional, resource constrained environments, so that available local resources are optimally utilized.
2. To investigate the impacts of episodic connectivity and nomadic operation on network transport and application layer operations.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Conferences and Events

Headlines

Features

IPN

InterPlaNet

InterPlanNet iSIG

Discusses issues related to the application of the Internet in outer space.


```
IPN Research Group                                    V. Cerf
Internet Draft                    Worldcom/Jet Propulsion Laboratory
May 2001                                            S. Burleigh
Expires November 2001                                 A. Hooke
                                                    L. Torgerson
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                                        Global Science and Technology
                                                       H. Weiss
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Universe

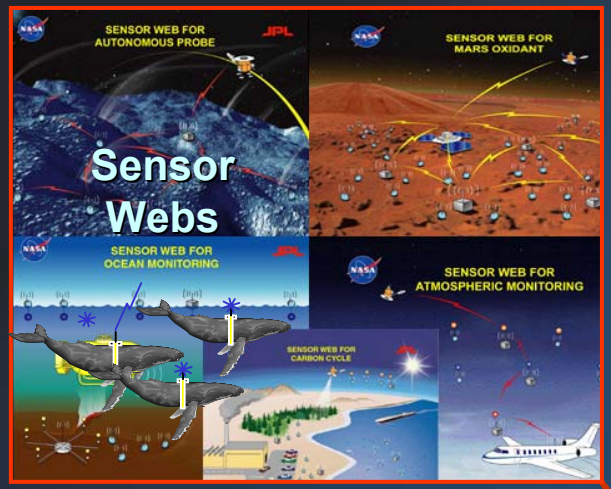
Special Issue

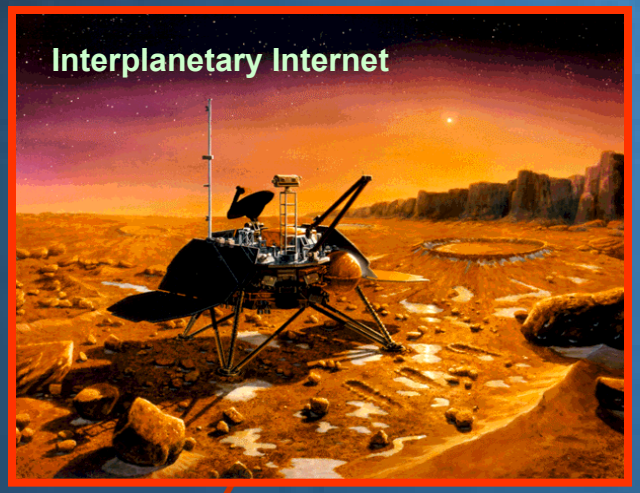
Director Elachi's 2020 vision

Interplanetary Internet and Information Systems

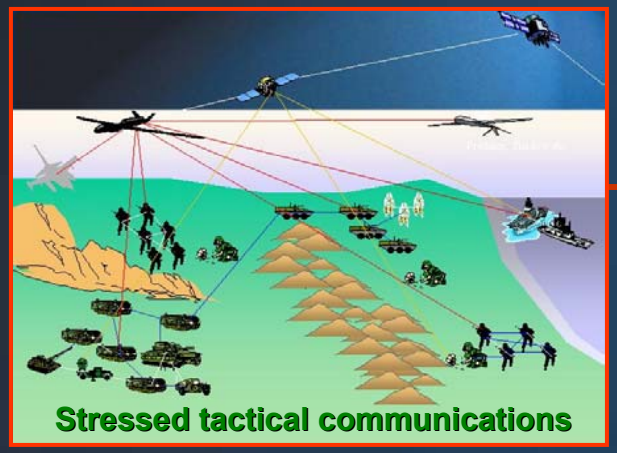
Besides listening to all of you, I also spoke to people outside of JPL who shared their advice with me. I often asked: "What is the most unique thing about JPL? What capabilities, what assets do we have that can be found nowhere else?"

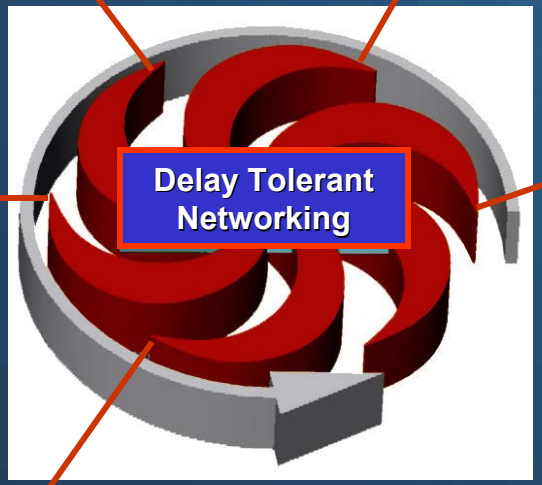
I heard many answers. But one that kept coming up was the Deep Space Network. We now need to create the next generation of the Deep Space Network. And that requires creating the interplanetary Internet of the next 20 years. This is a very exciting challenge. The DSN will be the backbone for this network, and the spacecraft we will have across the solar system and around Earth are information nodes that will interconnect to our network across the Lab and to the World Wide Web.

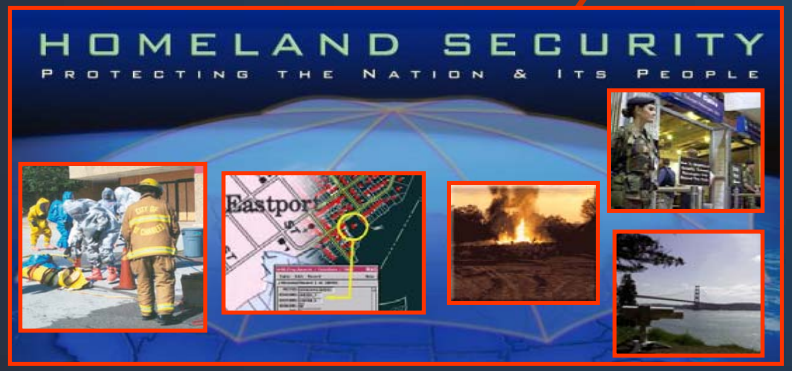




- "Non-chatty" message-oriented communications
- Store-and-forward between nodes
- Routing algorithms cognizant of scheduled connectivity
- Use transport and network technologies appropriate to the environment
- Integral infrastructure protection



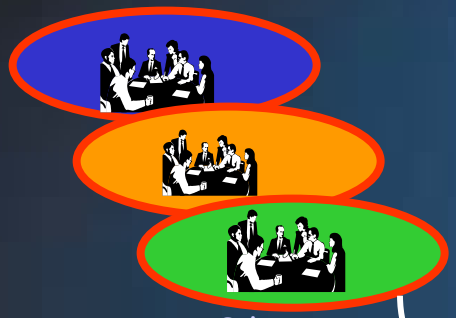




Realization:
Broader applicability
Nearer term utility
Larger research community

Delay Tolerant Networking:

a broad community effort



Other
DTN communities

Open Architecture
Open Specifications
Open Implementations

Fielded DTN Deployments

Public

IPNSIG

http://www.ipnsig.org

Internet Society

IRTF
Internet Research Task Force

DTN Research Group

http://www.dtnrg.org

I E T F

ISO

CCSDS

http://www.ccsds.org

Interplanetary
Internet

DARPA Advanced Technology Office

Fielded deployments of DTN technology

2002 2003 2004 2005

DTN Research Group:

Focal point for DTN

DTN Core Engineering

- DTN Architecture
- DTN Design Documents

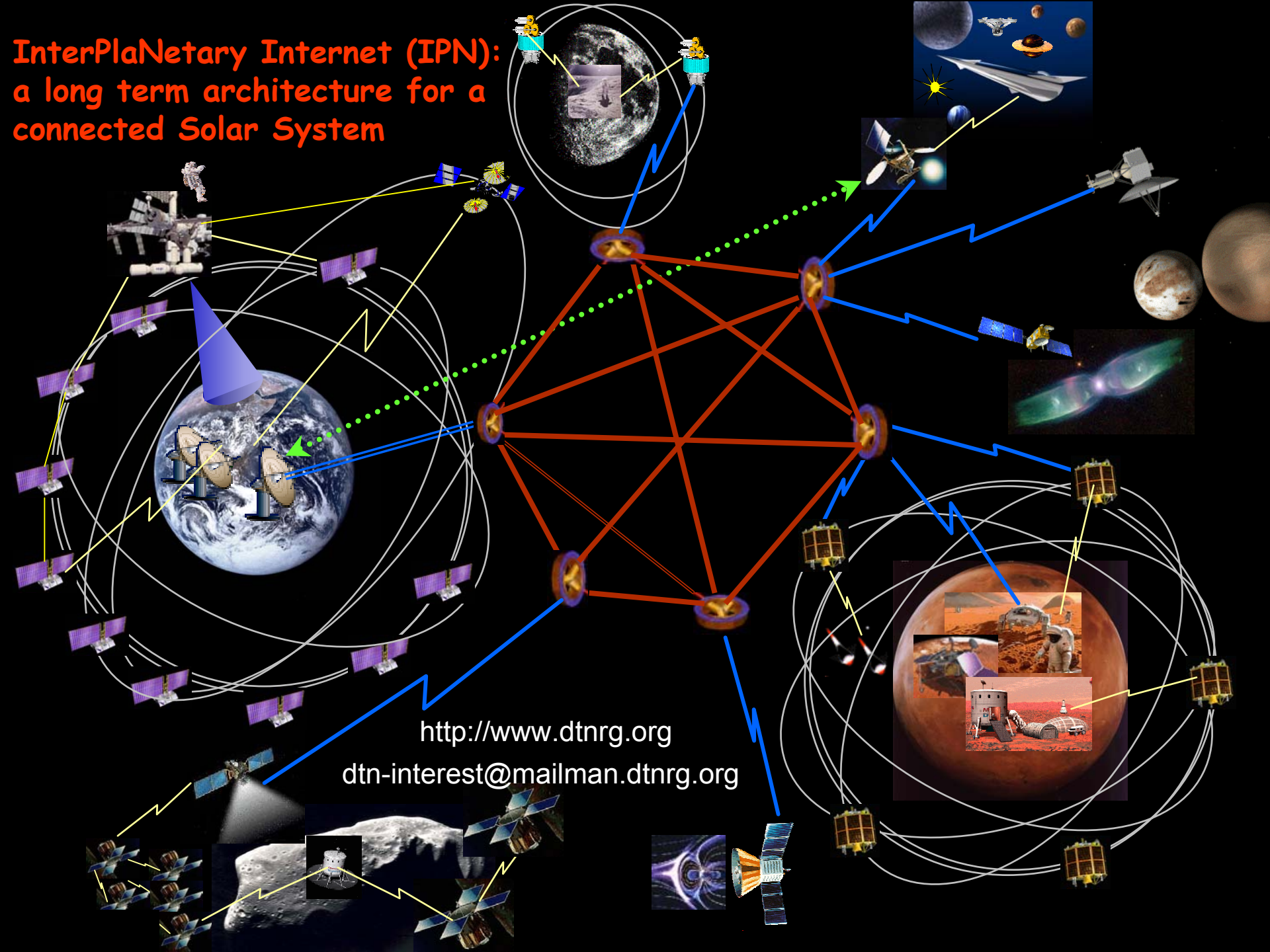
DTN Open Source

- Reference Software
- Configuration Control

DTN Standardization

- International Standards

InterPlaNetary Internet (IPN): a long term architecture for a connected Solar System



http://www.dtnrg.org

dtn-interest@mailman.dtnrg.org