Overview of the InterPlanetary Internet

BroadSky Workshop

10th Ka and Broadband Communications Conference

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Roadmap of International Space Data Systems Standardization

1980 | 1990 | 2000 | 2010

Basic Space/Ground communications standards for all space missions

"Packet" Spacecraft Telemetry and Telecommand

Baselined by International Space Station and GN

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

CCSDS

Consultative Committee for Space Data Systems (CCSDS)

CCSDS Advanced Orbiting Systems

File Transfer: FTAM
Transport: TP4
Network: ISO 8473

The Dark Age Of GOSIP

File Transfer: FTP
Transport: TCP
Network: IP. Mobile IP

CCSDS Proximity-1

Space Internetworking in richly connected, short delay, stressed space environments

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

Next Generation Space Internet (NGSI) Project

Space Internetworking in sparsely connected, long delay, stressed space environments

CCSDS File Delivery Protocol

Delay Tolerant Networking

Standardized Space Mission Operations Services

CCSDS Space Link Extension and Service Management

CCSDS Spacecraft Monitor & Control

Technical Areas of International Space Standardization

Space Internetworking Services

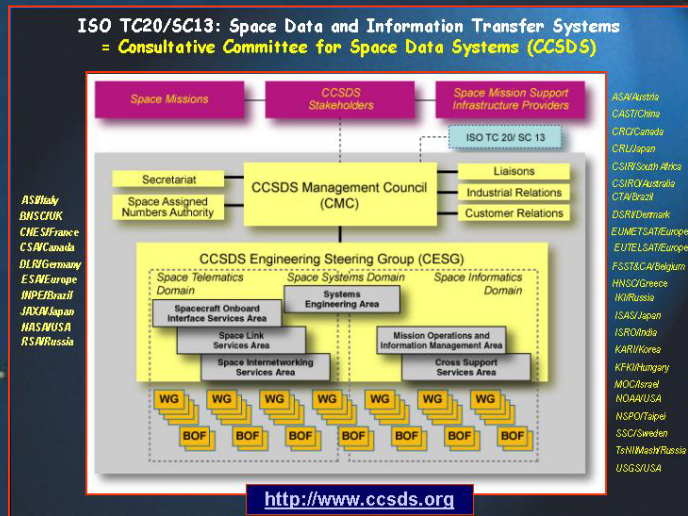
Spacecraft Onboard Interface Services

Mission Operations and Information Management Services

Space Link Services

Cross Support Services

Systems Engineering



Space Link

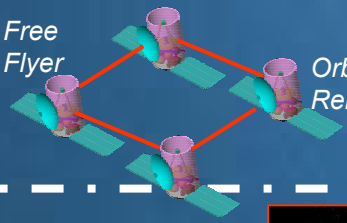
Access Services

Internet

Constellation

Free Flyer

Orbiting Relay



Terrestrial Internet

Long-Haul Space Backbone

Short-Haul Proximity Operations

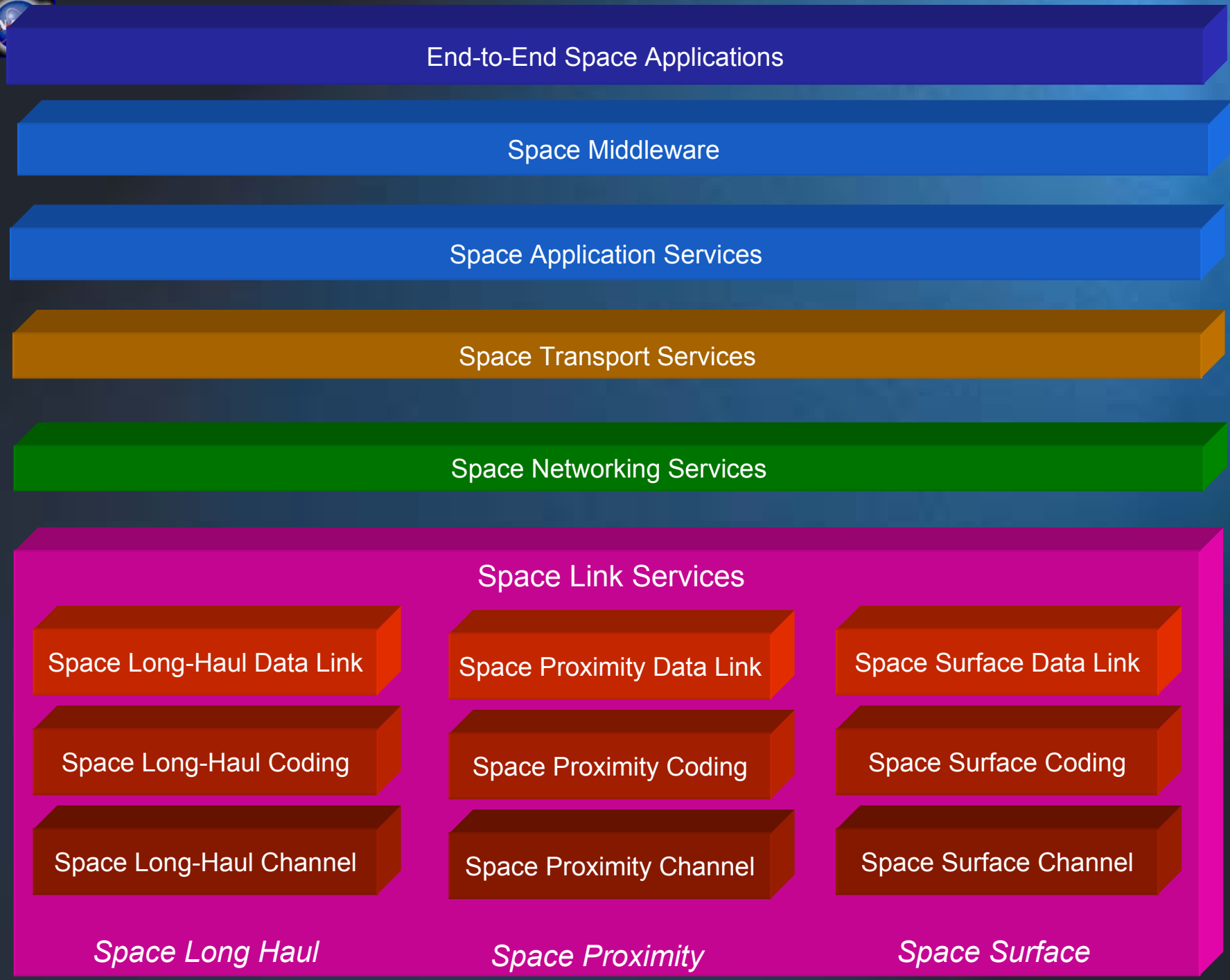
Surface Operations

End-to-end Space Internetworking

Internet-based ground mission operations systems	Long delay near-Earth and deep space links	Short delay proximity links	*in-situ* surface links

SPACE COMMUNICATIONS PROTOCOLS

SPACE COMMUNICATIONS PROTOCOL MODEL



1980s - now: standard "Packet Telemetry/Telecommand" space links

Free Flyer

Orbiter

Ground Operations

Long-Haul Space Backbone

Proximity Operations

Surface Operations

CCSDS Packet

CCSDS Long-haul Link

CCSDS Space Link Extension (SLE)

TCP, UDP

IPSEC

IP

Local Terrestrial Link

Local Terrestrial Wired

CCSDS Long-Haul Link and Coding

CCSDS S, X, Ka Band

CCSDS Proximity Link and Coding

CCSDS UHF

CCSDS UHF; local wired/ wireless


CCSDS:
The Fleet
Space Domain
Spacecraft Platforms
On-Board Systems
Space Qualified ASICs
CCSDS
Consultative Committee for Space Data Systems
300 Missions now using
CCSDS Space Link Protocols
http://www.ccsds.org/CCSDS/missions.jsp
Ground Domain
Commercial Ground Networks
Command & Telemetry Data Processing

Mid-1990s: a focus on space internetworking




Ground Operations

Long-Haul Space Backbone

Proximity Operations

Surface Operations

CCSDS Packet

CCSDS Long-haul Link

CCSDS Space Link Extension (SLE)

TCP, UDP

IPSEC

IP

Network - based

Upper Layer Services?

Local Terrestrial Link

CCSDS Long-Haul Link and Coding

CCSDS Proximity Link and Coding

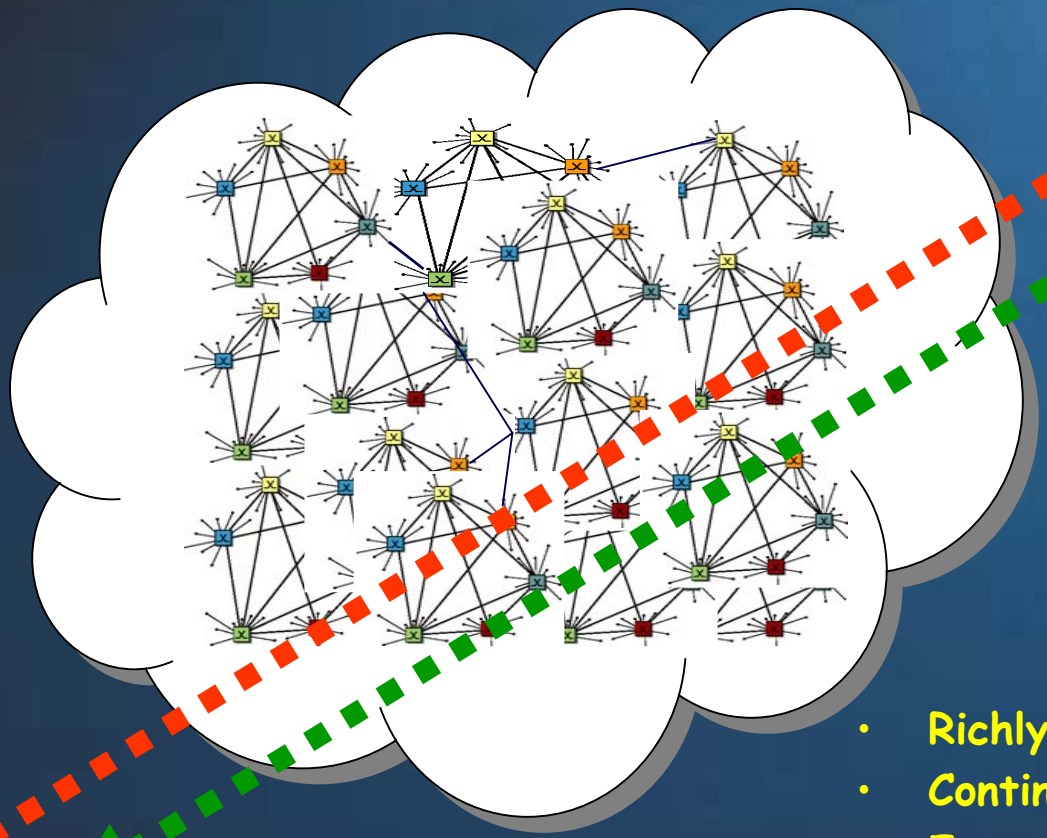
Local Terrestrial Wired

CCSDS S, X, Ka Band

CCSDS UHF

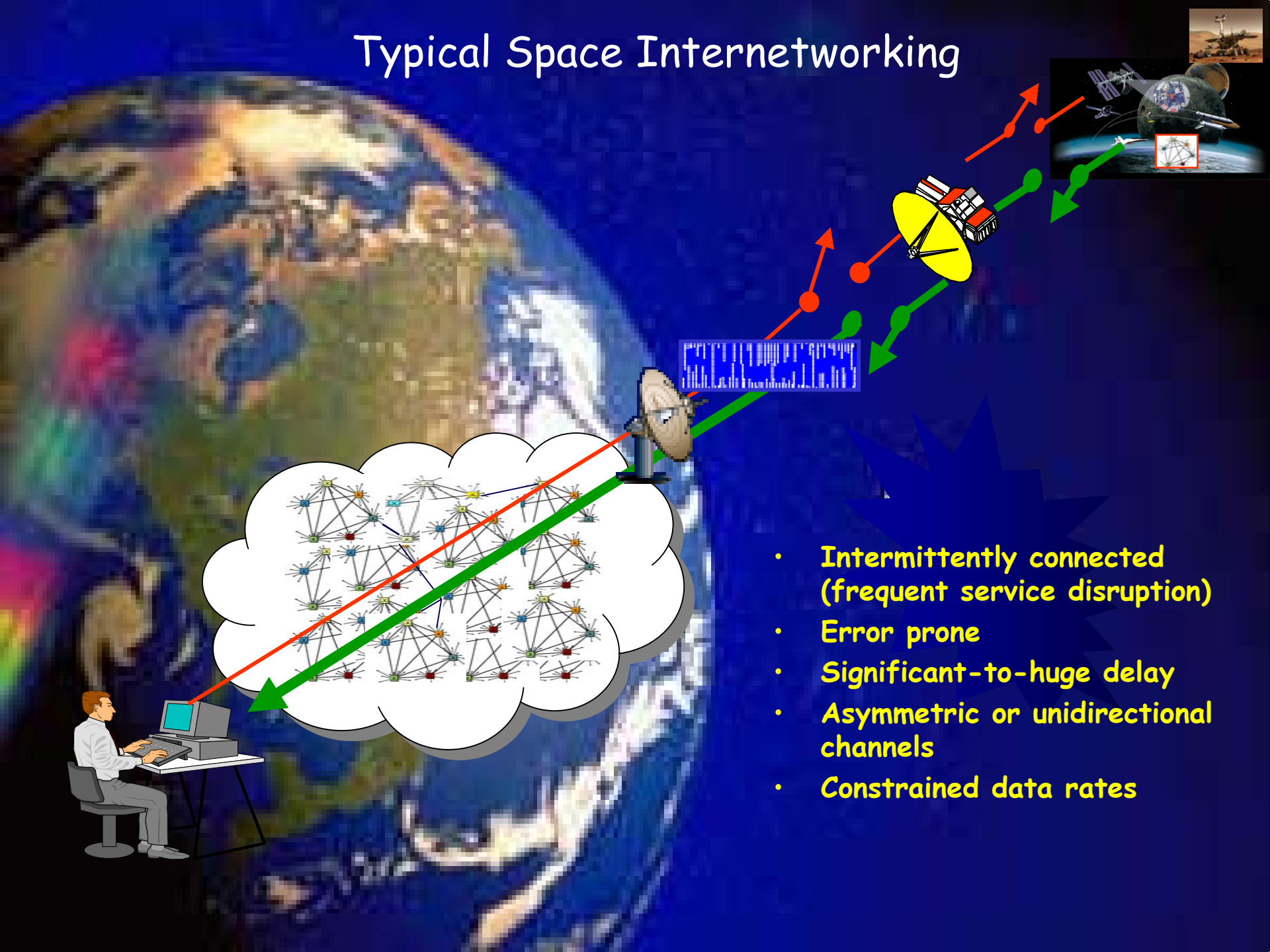
CCSDS UHF; local wired/ wireless

Conventional Internetworking



- Richly connected
- Continuous availability
- Error free
- Negligible delay
- Symmetric channels
- High data rates

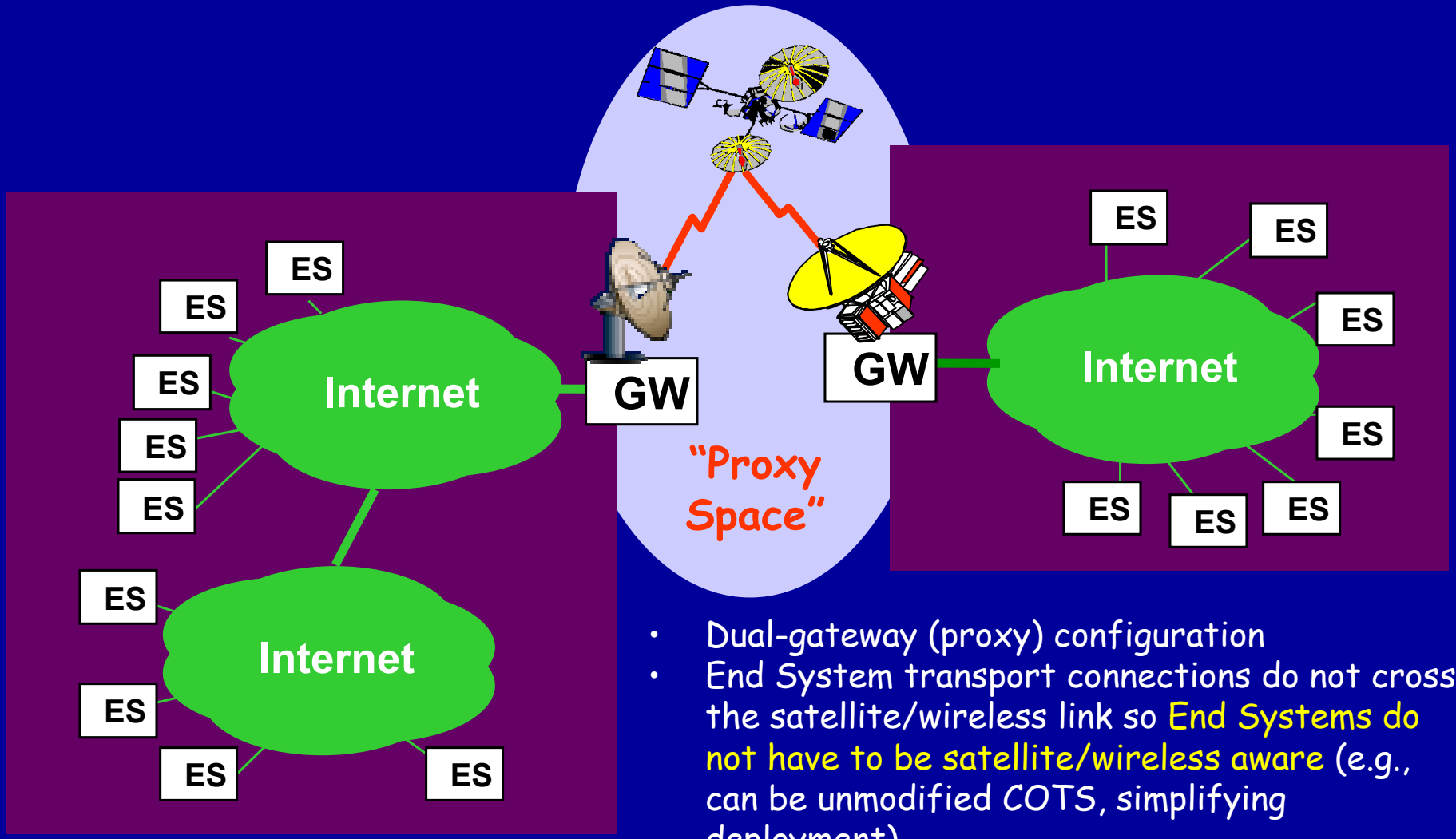
Typical Space Internetworking



- Intermittently connected (frequent service disruption)
- Error prone
- Significant-to-huge delay
- Asymmetric or unidirectional channels
- Constrained data rates

CCSDS approach to extending the terrestrial Internet into space

Proxy-Based Operation



ES = End System
GW = Transport Layer Gateway (Proxy)

- Dual-gateway (proxy) configuration
- End System transport connections do not cross the satellite/wireless link so End Systems do not have to be satellite/wireless aware (e.g., can be unmodified COTS, simplifying deployment)
- Security above transport or via trusted gateways

Current CCSDS Space Internet Protocol Options

Space extensions to FTP

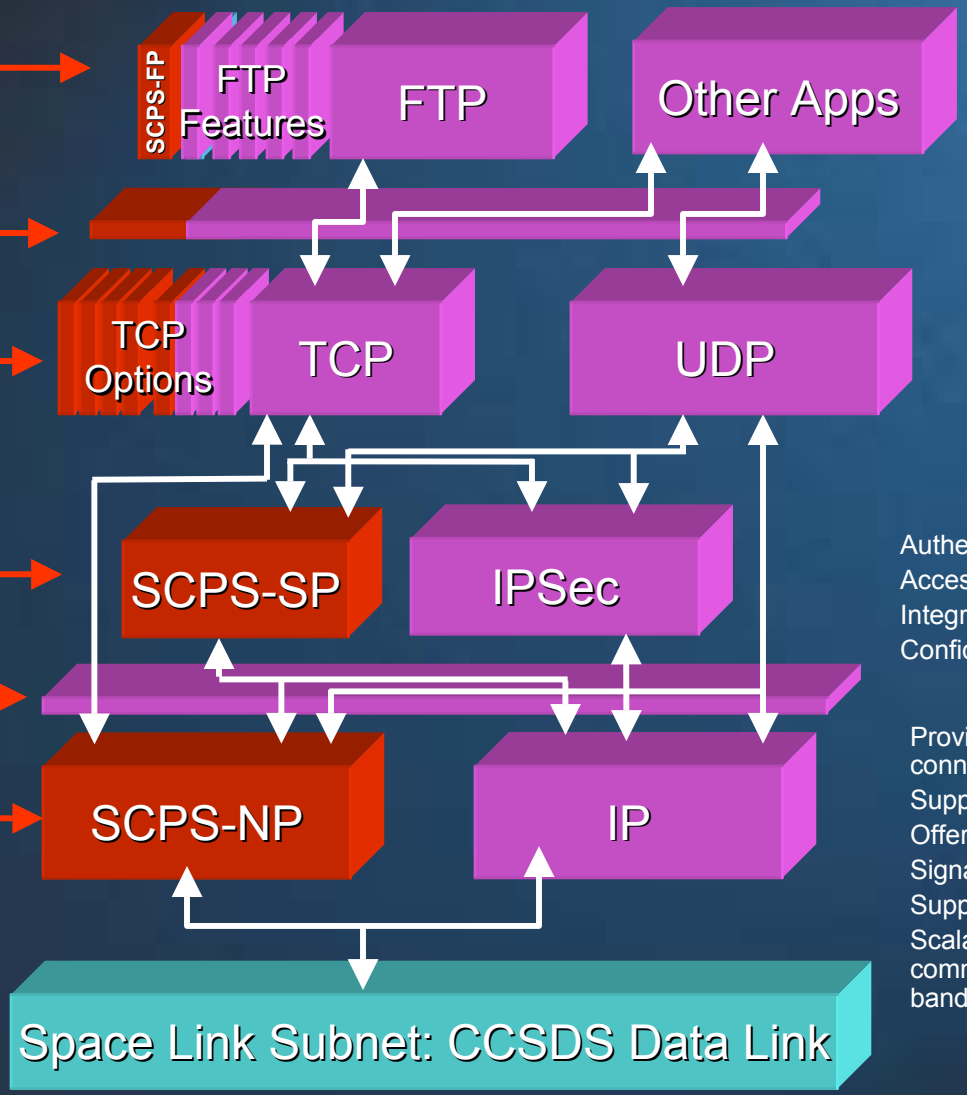
Space extensions to the Socket Interface

SCPS-TP "TCP Tranquility" options

Space-optimized IPSec variant

Common Network-Layer Interface

Space-optimized IP variant



Record read & record update;
File & record Integrity;
Automatic restart;
User suspend/resume;
Suppress ASCII reply codes.

Congestion control appropriate for mixed-loss environments (congestion, corruption, outage);
Selective negative acknowledgment;
Robust header compression;
Partial Reliability service (BETS);
Delimitation of record boundaries;
RFC 1323: Window scaling, time stamps, sequence number extension

Authentication: guarantee of the identity of a source;
Access Control: prevention of unauthorized access;
Integrity: protection against modification;
Confidentiality: protection from disclosure.

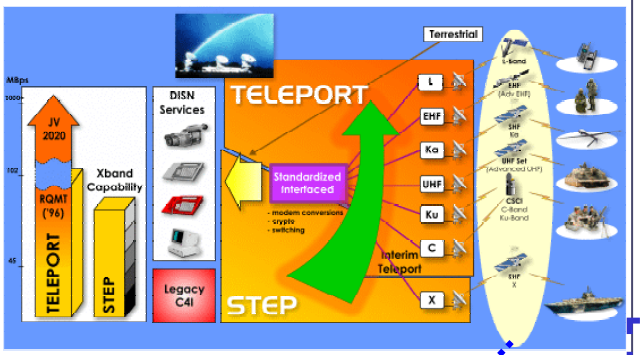
Provides both connectionless and managed-connection routing;
Supports precedence (priority) based handling;
Offer multiple routing options;
Signals errors to the layer above;
Supports packet lifetime control;
Scalable - tailor capability to need, e.g., high communications efficiency in constrained bandwidth conditions.

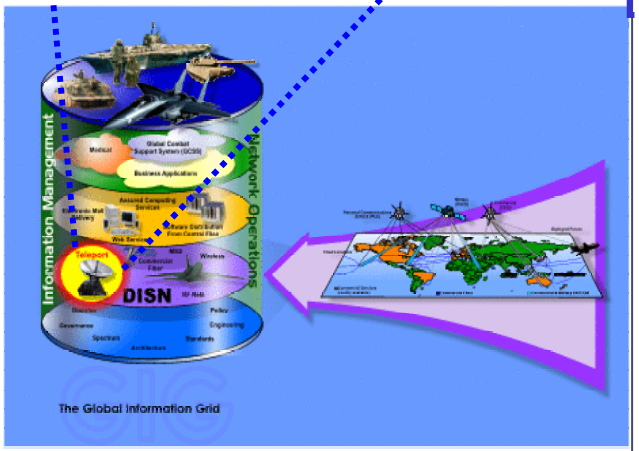
The CCSDS protocol suite supports either "native" or "space enhanced" Internet services, at the discretion of the Project organization

MILSATCOM

NPoM

Network Protocols over MILSATCOM





Space Communications Protocol Standards (SCPS) Approval

The Theater Joint Tactical Networks Configuration Control Board (TJTN-CCB) and Joint Staff have approved the Space Communications Protocol Standards—Transport Protocol (SCPS-TP) for Standardized Tactical Entry Point (STEP)/Teleport sites. SCPS-TP is one of several solutions to the Transmission Control Protocol (TCP) over satellite problem. In dealing with this problem the services investigated and implemented several solutions. These solutions, however, were largely proprietary, so a need developed to investigate and determine the best solution. SCPS-TP was shown to be the most effective and interoperable solution for TCP enhancements, according to extensive Joint Terminal Engineering Office (JTEO) testing performed for the 2002 Network Protocols over MILSATCOM (NPoM) working group. The SCPS-TP protocol was tested at both the Joint User Interoperability Communications Exercise (JUICE) and the Department of Defense Interoperability Communications Exercise (DICE). During both exercises, the SCPS-TP protocol performed well and demonstrated both TCP traffic enhancement capability and interoperability with other TCP devices. As a result of these efforts, the TJTN-CCB voted to standardize an SCPS-TP-enabled device for the STEP/Teleport Program; therefore SCPS-TP enabled TCP accelerators will be installed at each STEP site beginning in Fall 2003.

In 1991, a joint effort began among the National Aeronautics and Space Administration (NASA), the United States Strategic Command (USSTRATCOM) and the Jet Propulsion Labs (JPL) to develop an interoperable suite of end-to-end data protocols for satellite networks. Recognizing that there was a problem using TCP over high delay, high bit error rate links, a team of protocol engineers, drawn from the satellite community, started developing internet-over-satellite standards. This work resulted in the SCPS protocol suite, which not only is based on Internet protocols, but is also fully interoperable with Internet Engineering Task Force (IETF) standards.

Joint NASA-DOD SCPS Project 1991-1999

The SCPS consortium looked to establish the SCPS protocol suite as an international standard for the space networking community. The International Standards Organization (ISO), the Consultative Committee for Space Data Systems (CCSDS), and the U.S. Department of Defense (DoD) have adopted the SCPS protocol suite as a standard. The different organizations and their corresponding SCPS standards numbers are listed in Table 1.

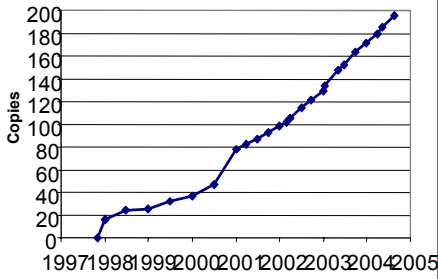
The SCPS Standards

SCPS Protocol	MILSATCOM	CCSDS	ISO
SCPS File Protocol	MIL-STD-2045-47000	717.0-B	15894
SCPS Transport Protocol	MIL-STD-2045-44000	714.0-B	15893
SCPS Security Protocol	MIL-STD-2045-43001	713.5-B-1	15892
SCPS Network Protocol	MIL-STD-2045-43000	713.0-B	15891

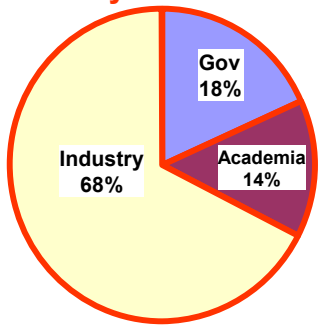
Table 1. SCPS Standards

Some vendors that have already implemented SCPS are: Comtech TurboIP, Lineo VPN Router w/ Skipware and the Xiphos XipLink Mini Gateway, with more on the way.

SCPS RI Distribution by Date

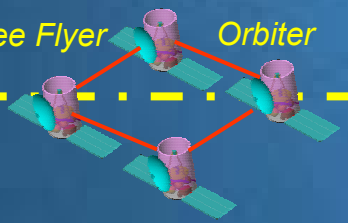


SCPS RI Distribution, by Sector



"Space Internet" CCSDS Protocol Scenario



Ground Operations | Long-Haul Space Backbone | Proximity Operations | Surface Operations

CCSDS Packet

CCSDS Long-haul Link

CCSDS Space Link Extension (SLE)

TCP, UDP

IPSEC

IP

Reliable File Transfer in disconnected, stressed, long-delay environments ?

FTP+

TCP+, UDP

IPSec,CCSDS SP

IP, CCSDS NP

CCSDS Long-Haul Link and Coding

Local Terrestrial Link

CCSDS Link + Physical Security

CCSDS Proximity Link and Coding

Local Terrestrial Wired

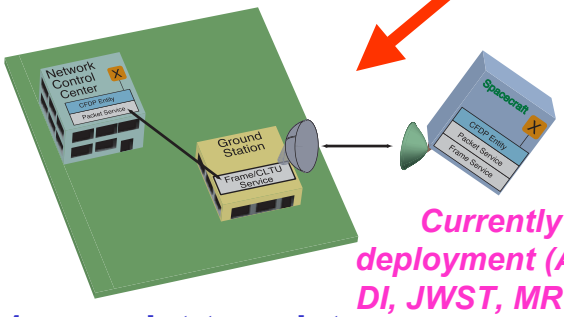
CCSDS S, X, Ka Band

CCSDS UHF

CCSDS UHF; local wired/ wireless

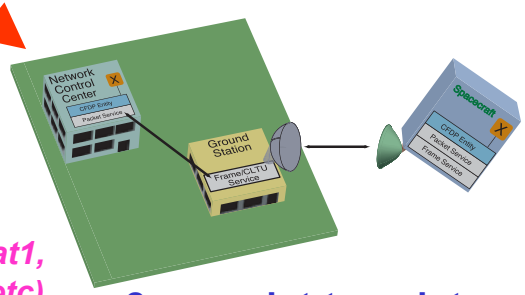
CCSDS File Delivery Protocol (CFDP)

Build 1 CFDP



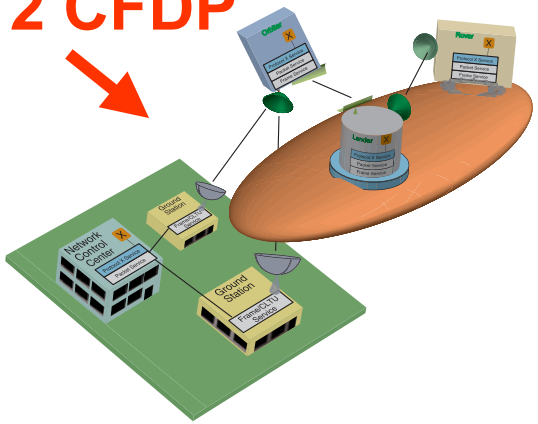
Currently in deployment (AISat1, DI, JWST, MRO, etc)

1. point-to-point, unacknowledged



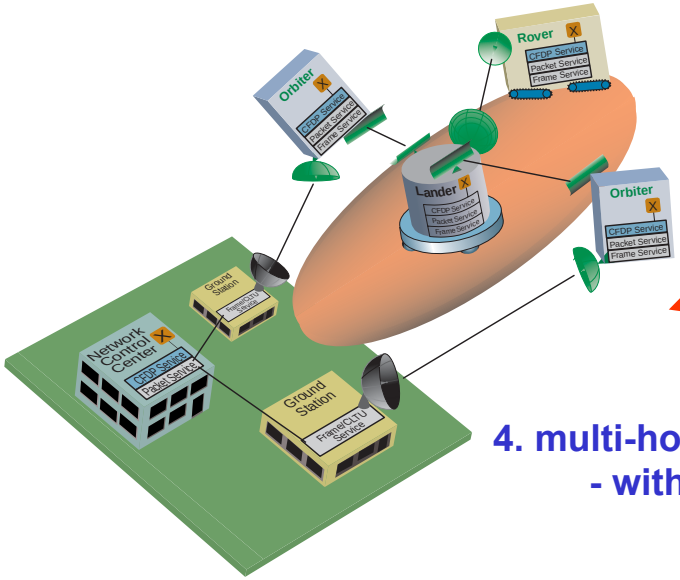
2. point-to-point, acknowledged

Build 2 CFDP



3. multi-hop, in series

Build 3 CFDP



4. multi-hop, in parallel
- without cross-links

"CFDP-Era" (2005+) CCSDS Protocol Scenario

Ground Operations

Long-Haul Space Backbone

Constellation

Free Flyer

Orbiter

Proximity Operations

Surface Operations

CCSDS File Delivery Protocol (CFDP)

CCSDS File Delivery Protocol (CFDP)

CCSDS Packet

CCSDS Long-haul Link

CCSDS Space Link Extension (SLE)

TCP, UDP

IPSEC

IP

Local Terrestrial Link

Local Terrestrial Wired

Is that all there is?

TCP+, UDP

IPSec,CCSDS SP

CCSDS NP

IP, CCSDS NP

CCSDS Long-Haul Link and Coding

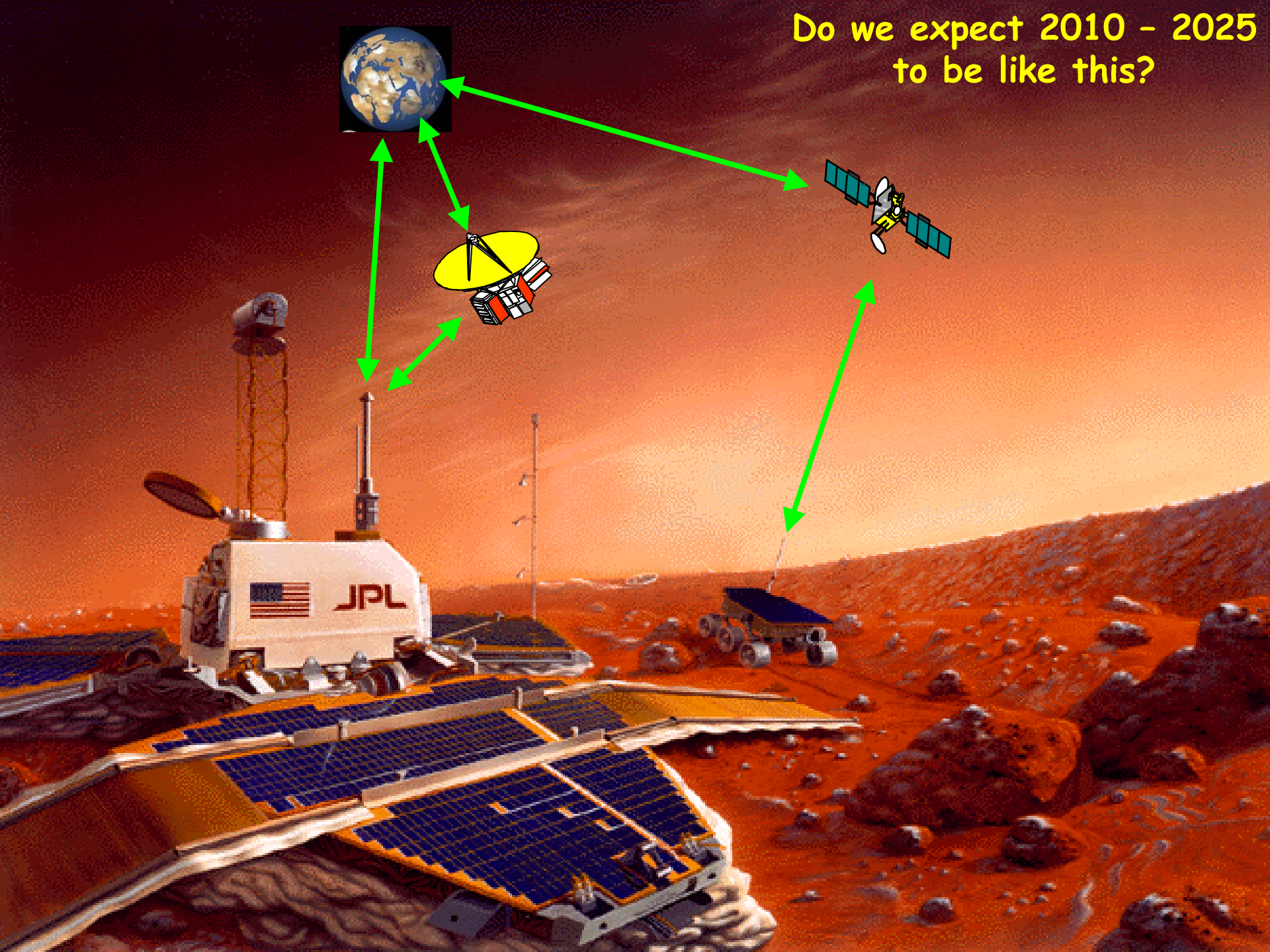
CCSDS Link + Physical Security

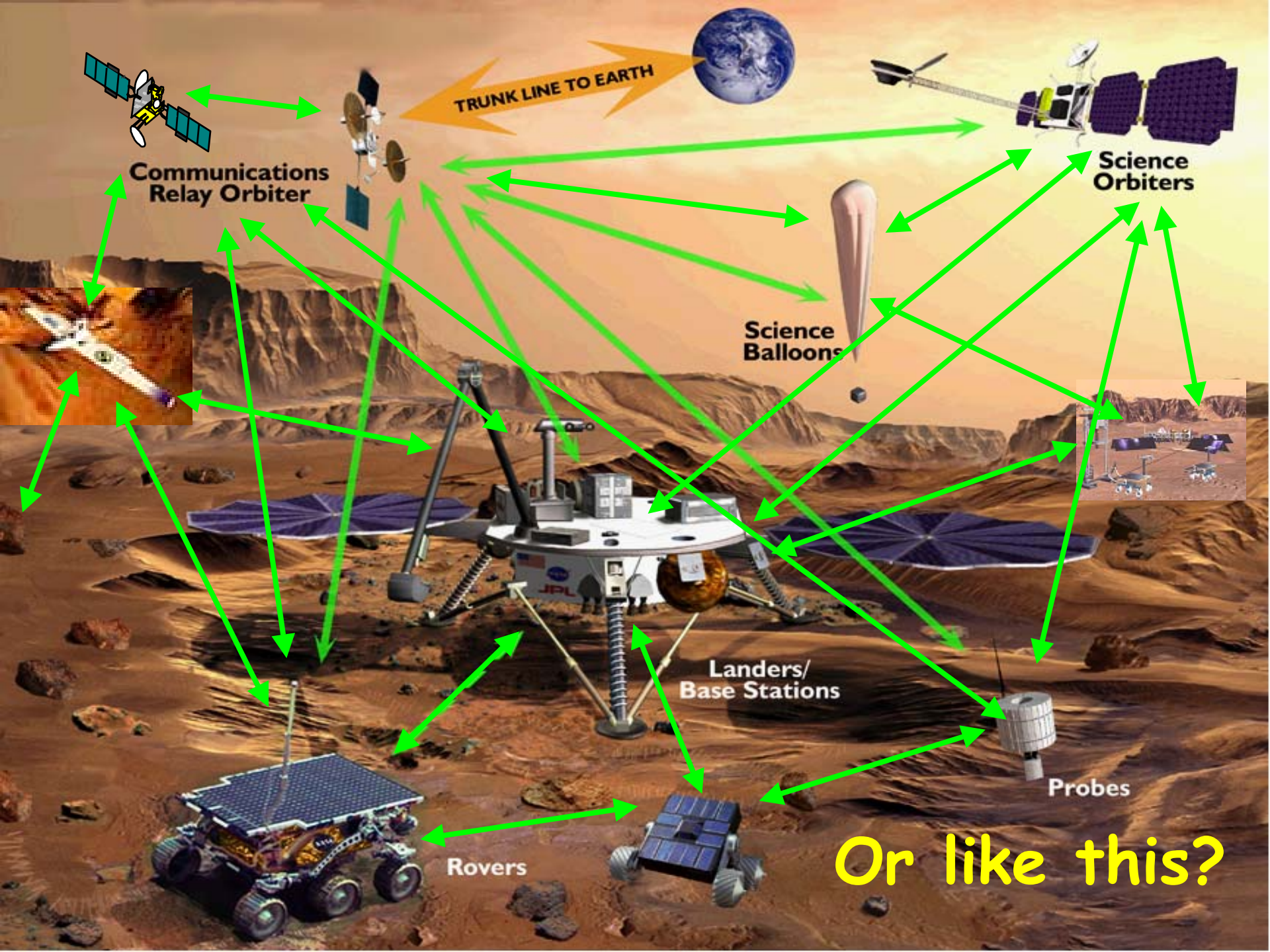
CCSDS Proximity Link and Coding

CCSDS S, X, Ka Band

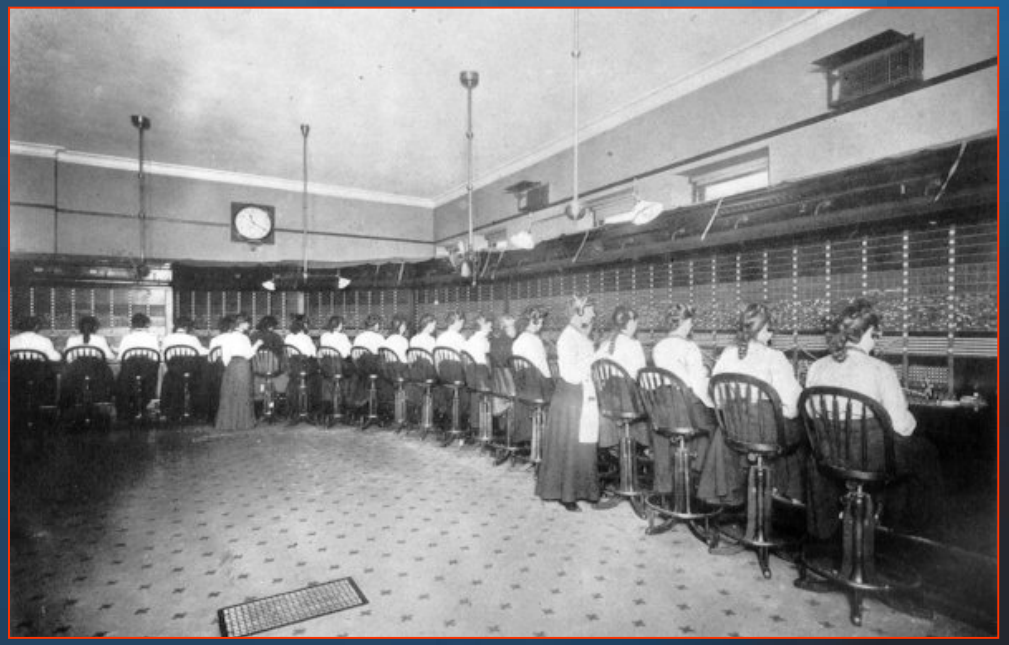
CCSDS UHF

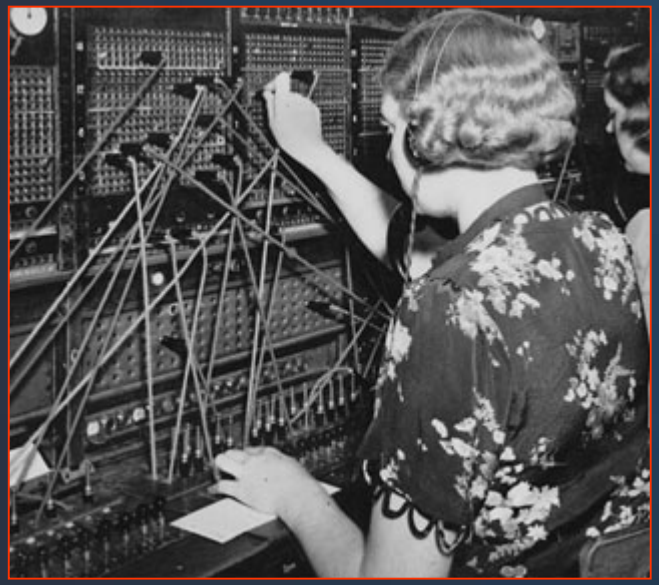
CCSDS UHF; local wired/ wireless


Do we expect 2010 – 2025
to be like this?
JPL

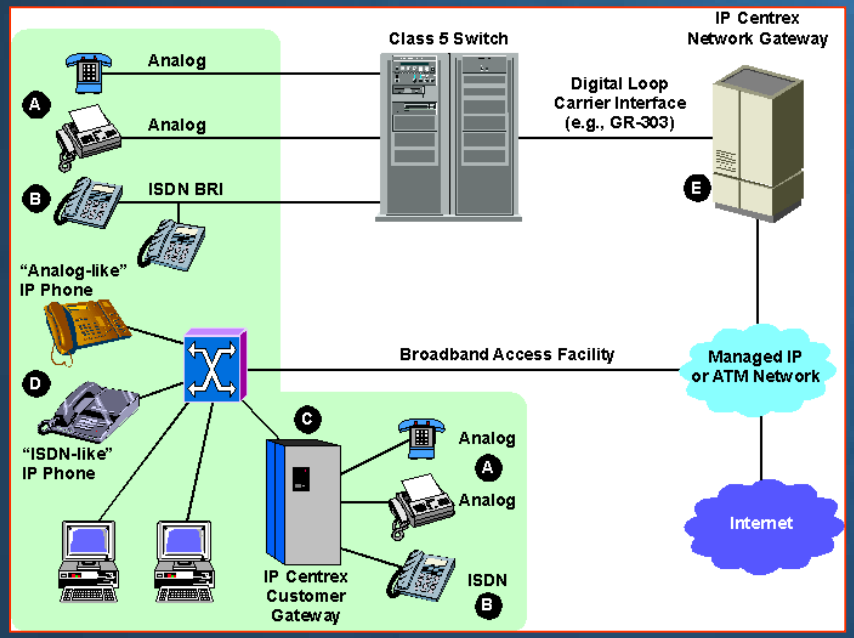

TRUNK LINE TO EARTH
Communications Relay Orbiter
Science Orbiters
Science Balloons
Landers/ Base Stations
Probes
Rovers
Or like this?

Will space operations of 2010 – 2025 look like this?



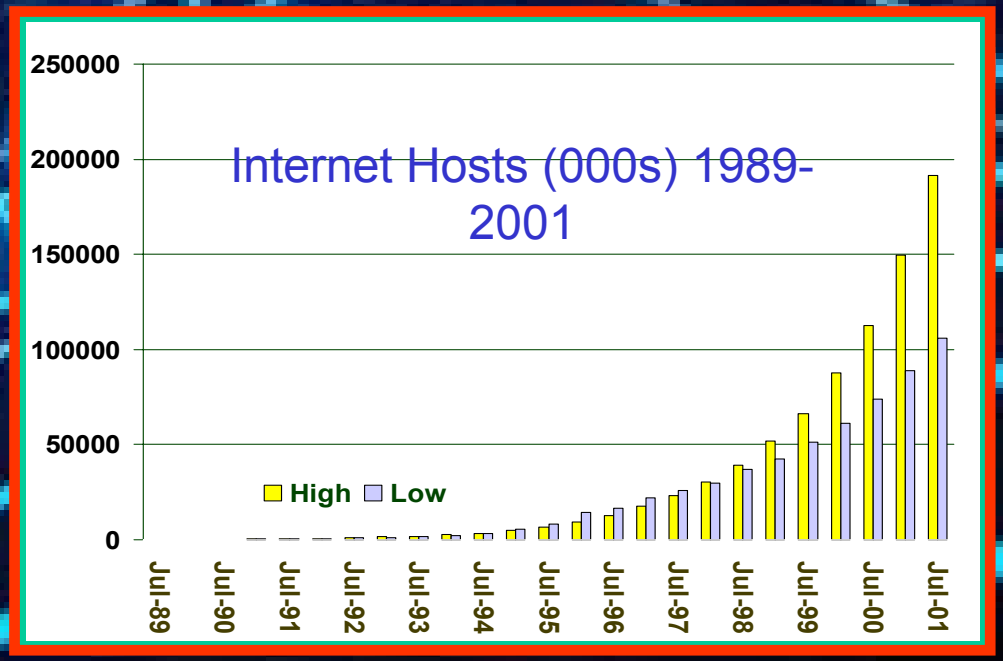


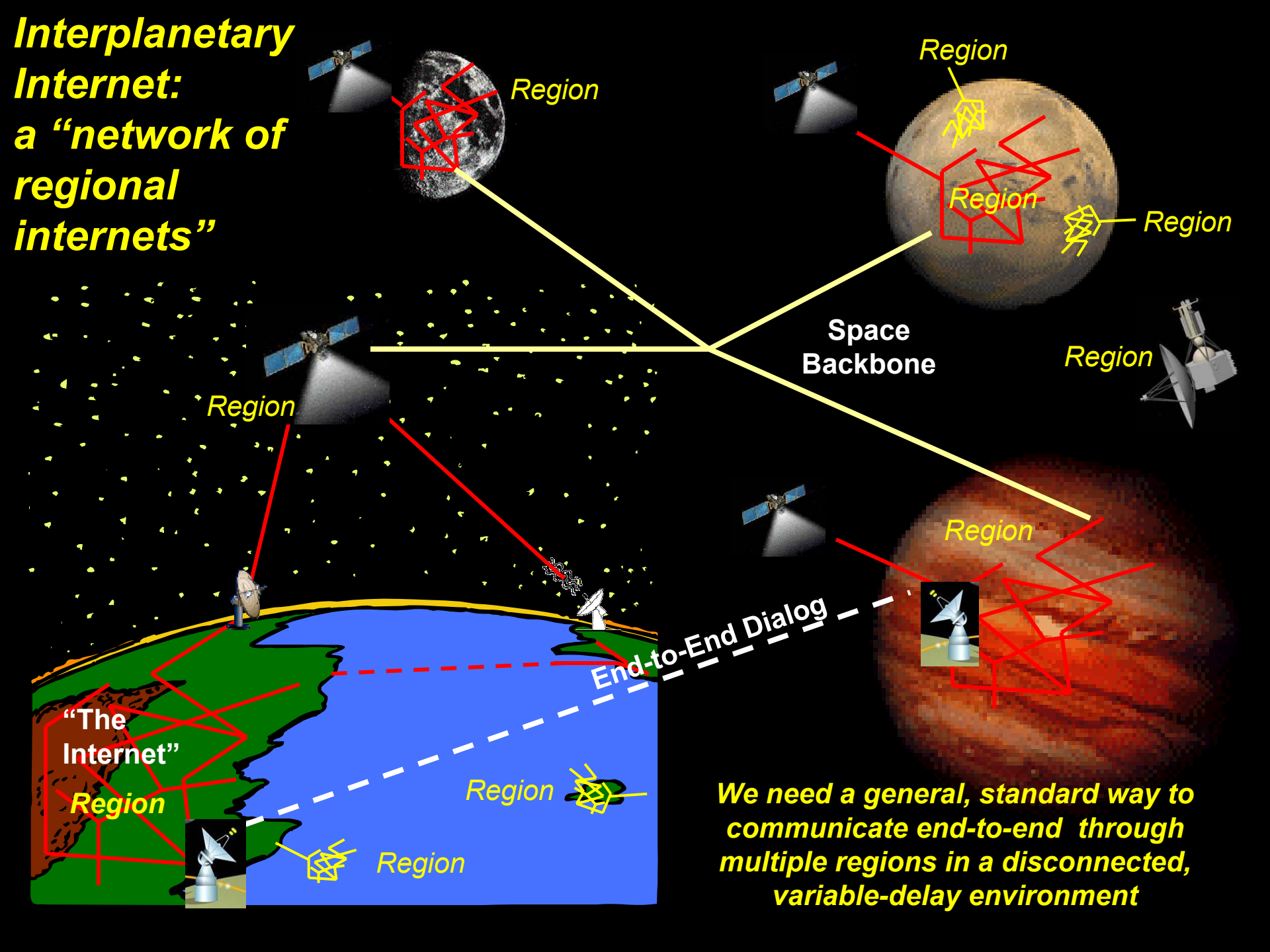
Or like this?


Class 5 Switch
IP Centrex
Network Gateway
Analog
Analog
ISDN BRI
Digital Loop
Carrier Interface
(e.g., GR-303)
A
B
E
"Analog-like"
IP Phone
D
"ISDN-like"
IP Phone
Broadband Access Facility
Managed IP
or ATM Network
C
Analog
A
Analog
Internet
IP Centrex
Customer
Gateway
ISDN
B

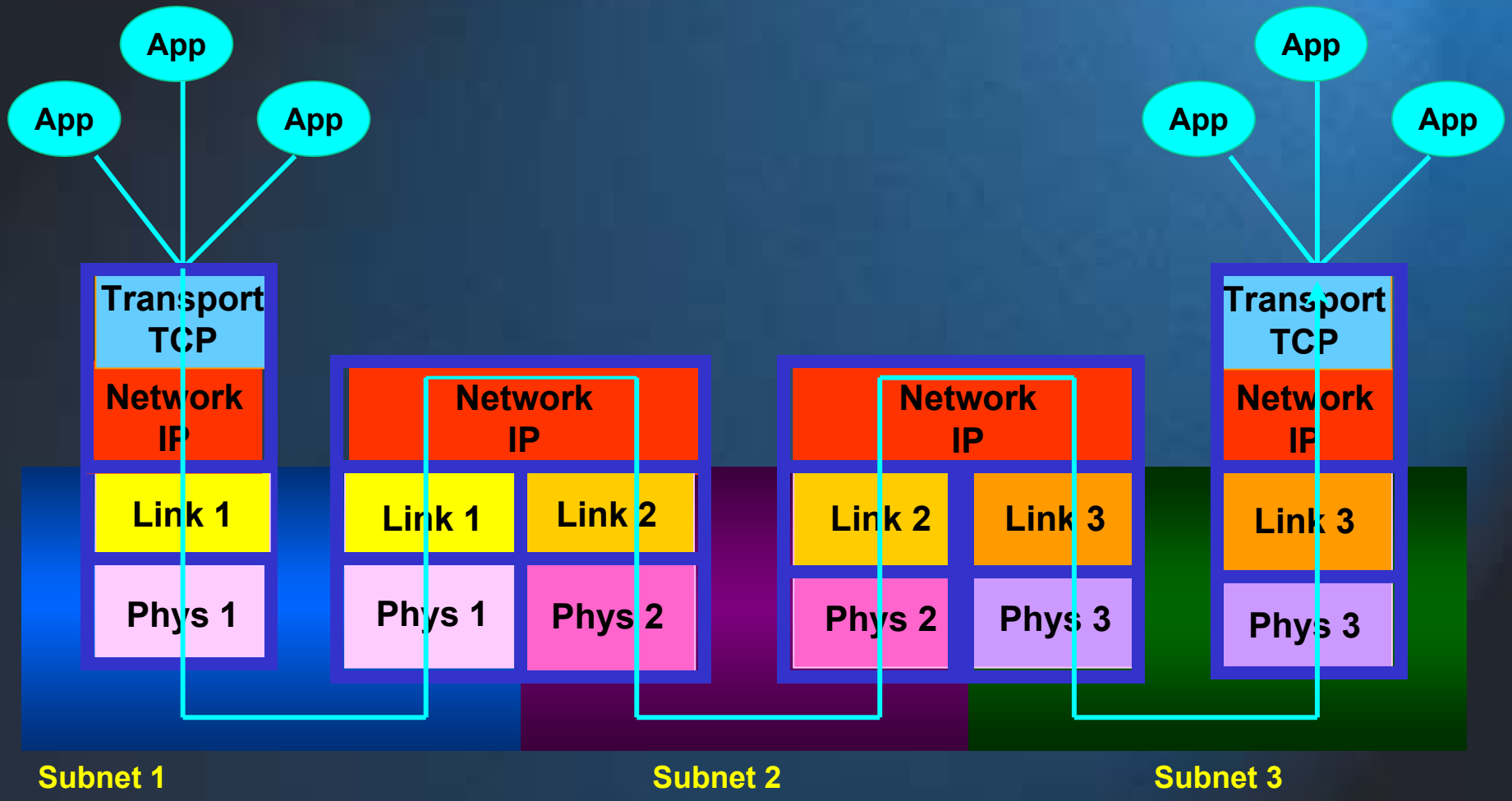
Do we have an underlying data communications architecture that can scale up?

i.e., do we have an Interplanetary Network architecture that can scale to handle disruptive developments?



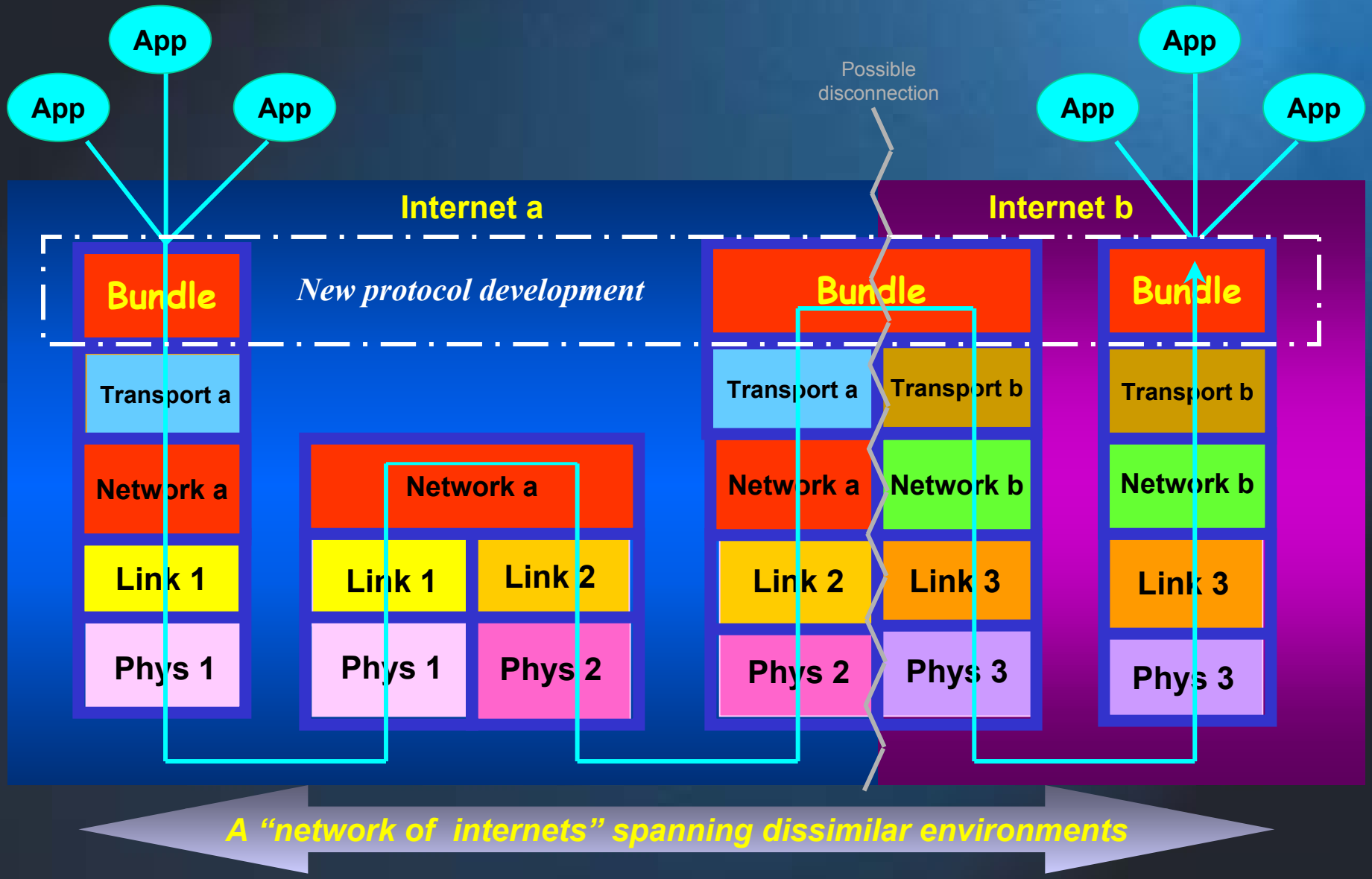

Interplanetary Internet: a "network of regional internets"
Region
Region
Region
Region
Region
Space Backbone
Region
Region
Region
End-to-End Dialog
"The Internet"
Region
Region
Region
We need a general, standard way to communicate end-to-end through multiple regions in a disconnected, variable-delay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

The Internet: a Network of Connected Sub-Networks

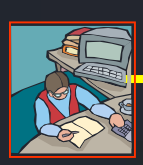


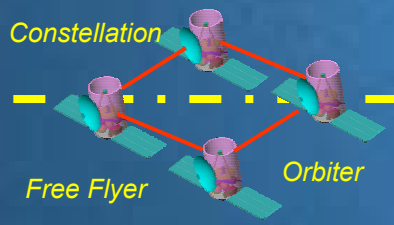
Bundles: A Store and Forward Application Overlay

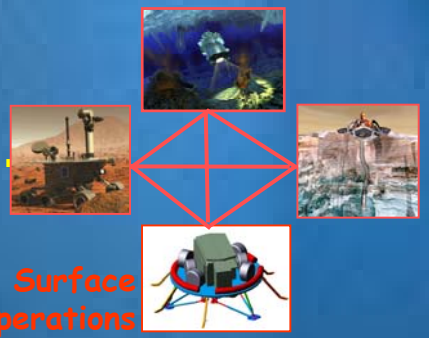
The "Thin Waist" of the Interplanetary Internet



2007-2012 "Bundling-era" Protocol Scenario





Ground Operations

Long-Haul Space Backbone

Proximity Operations

Surface Operations

CCSDS Middleware and Space Applications Services (CFDP, ftp, Messaging, Streaming, etc.)

CCSDS Disruption Tolerant Networking ("Bundling")

CCSDS Long-haul Link

CCSDS Space Link Extension (SLE)

TCP, UDP

IPSEC

IP

Local Terrestrial Link

Local Terrestrial Wired

CCSDS NP

Long-haul Link ARQ

CCSDS Long-Haul Link and Coding

CCSDS Link + Physical Security

CCSDS S, X, Ka Band; Optical

TCP+, UDP

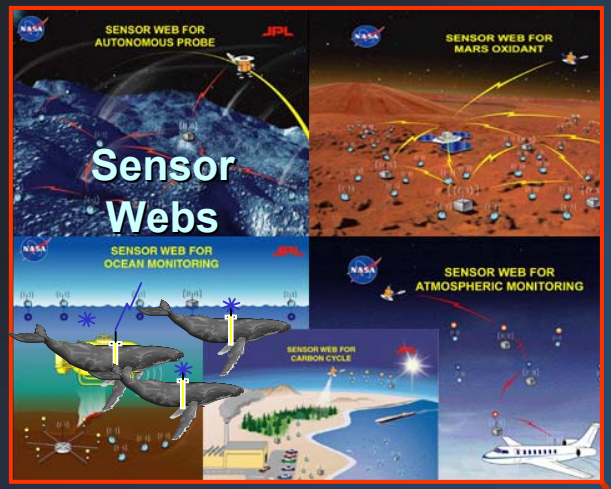
IPSec,CCSDS SP

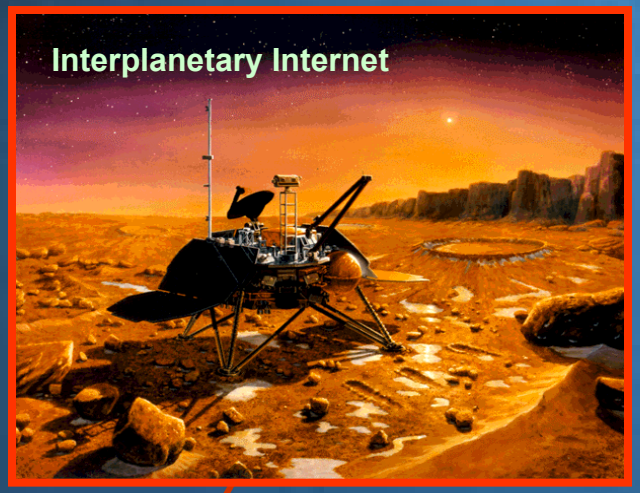
IP, CCSDS NP

CCSDS Proximity Link and Coding

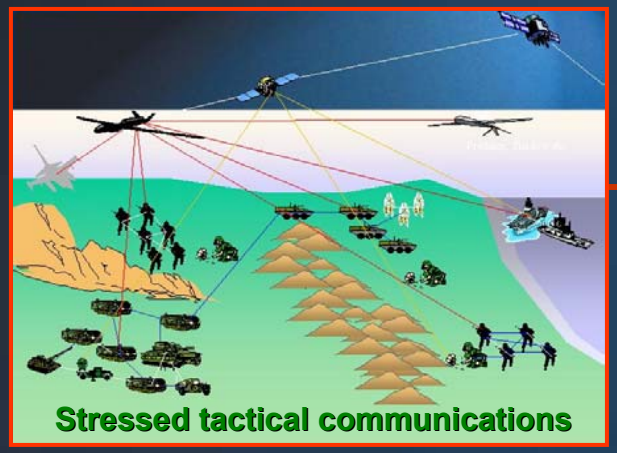
CCSDS UHF

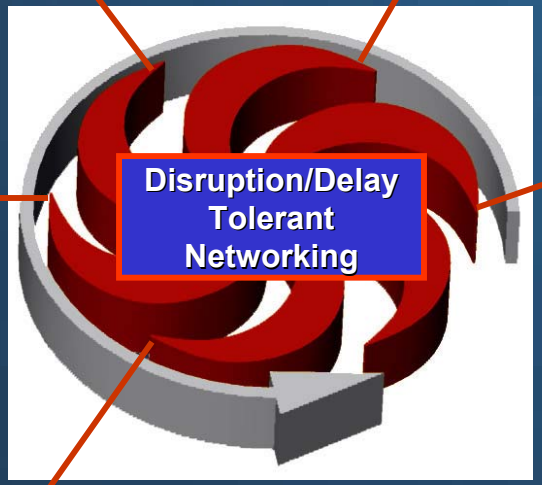
local wired/ wireless

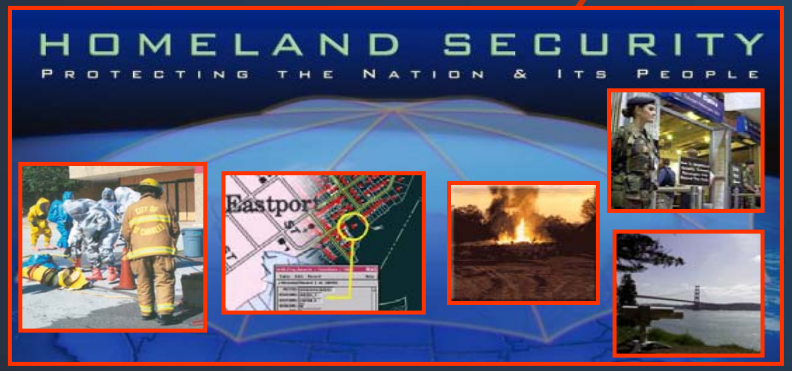




- "Non-chatty" message-oriented communications
- Store-and-forward between nodes
- Routing algorithms cognizant of scheduled connectivity
- Use transport and network technologies appropriate to the environment
- Integral infrastructure protection







Disruption Tolerant Networking:
A new DARPA initiative

BAA04-13
Proposer Information Pamphlet (PIP)

for

Defense Advanced Research Projects Agency (DARPA)
Advanced Technology Office (ATO)

Disruption Tolerant Networking (DTN)

Technical POC: Preston Marshall, DARPA/ATO

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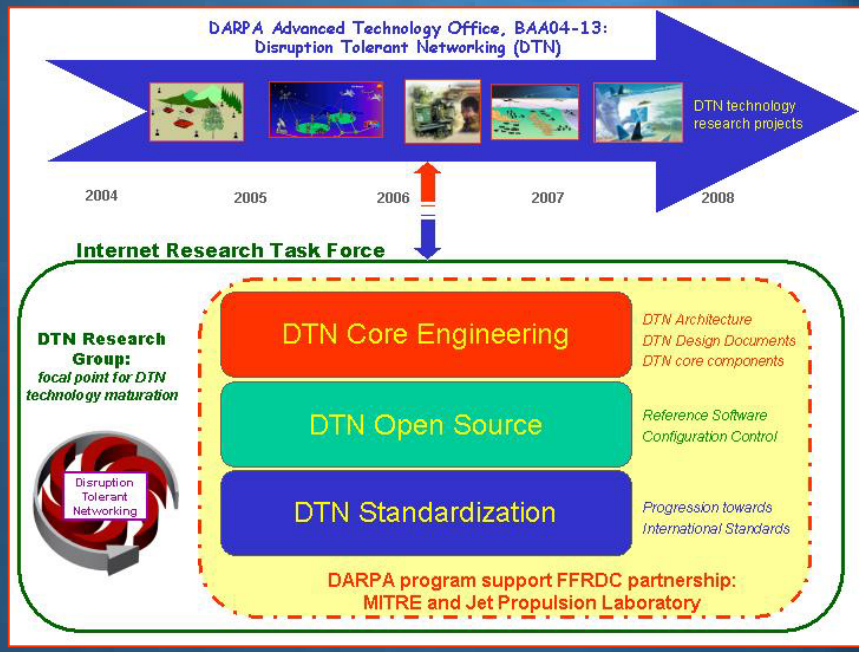

2. OVERVIEW OF DISRUPTION TOLERANT NETWORKING

2.1. PROGRAM OVERVIEW

The DTN program will develop and demonstrate technology that will provide network services when no end-to-end path exists through the network, and additional network behavior and functionality are required as DoD transitions from conventional networks to more dynamic, self-forming, peer to peer architectures, such as Mobile Ad-Hoc Networks (MANETs). This program builds on protocol development and work performed by DTNRG program. The DTNRG program's goal is to provide delay tolerance by organizing information flow into bundles. These bundles are to be routed through an "intelligent" network that can manage the delivery of the bundles to the maximal extent permitted by the available topology. This method will allow messages to pass through the network with successive nodes (or regions) assuming delivery responsibilities. This approach is in contrast to current layer 3 approaches which are based on an end-to-end model in which the sending and receiving nodes mutually assume all responsibility for delivery. In the DTN program, features appropriate to military application of the underlying delay tolerant mechanism will be researched. These technology needs are further described in the research areas outlined in paragraph 2.1.1. DTN should be designed to be as Layer 3 Protocol independent as possible, and should address terrestrial, airborne and space environments.

Phase 1 (September 2004 - November 2005) proposal selection began by DARPA in late July…….

……. DTN is on its way.

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