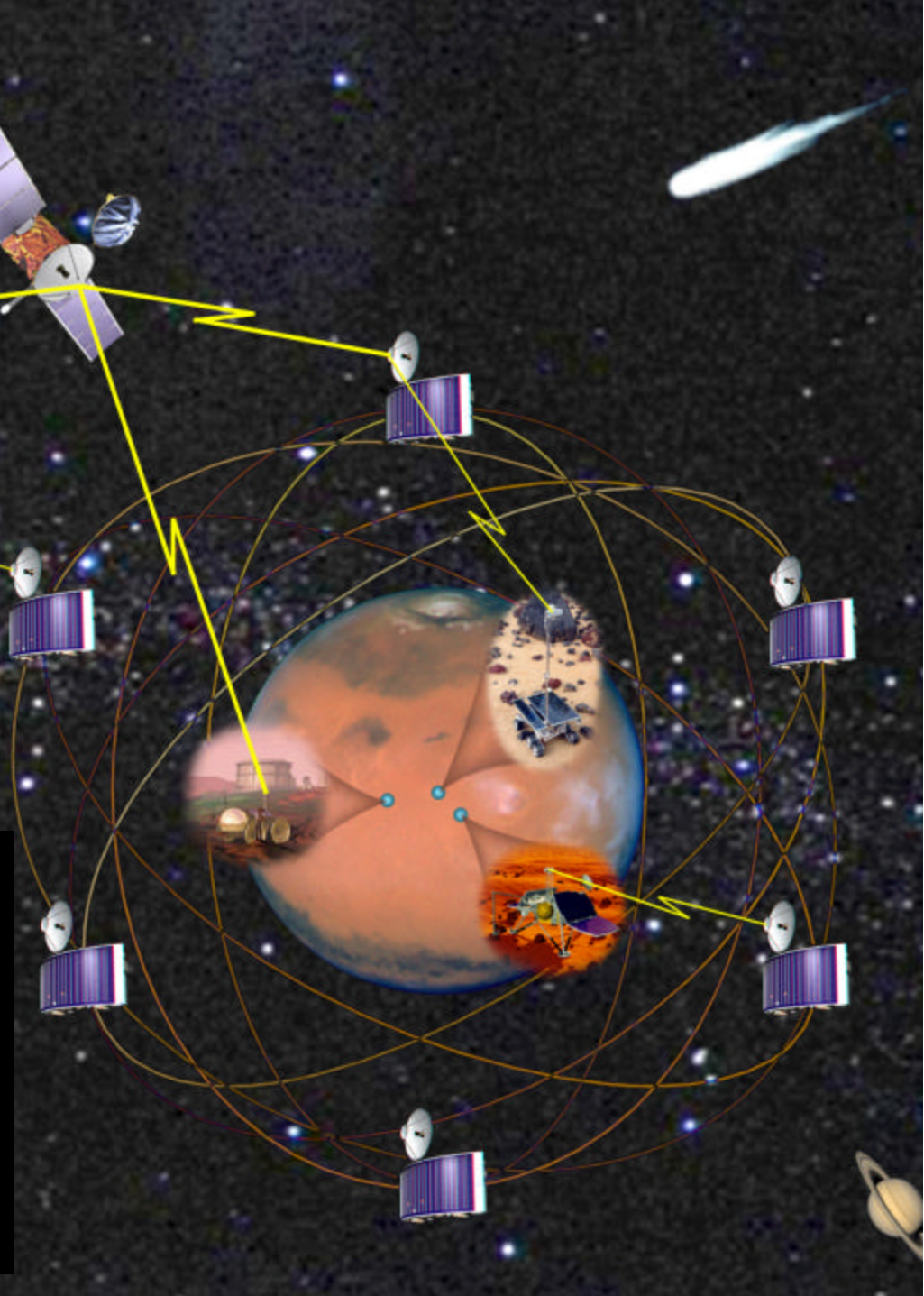




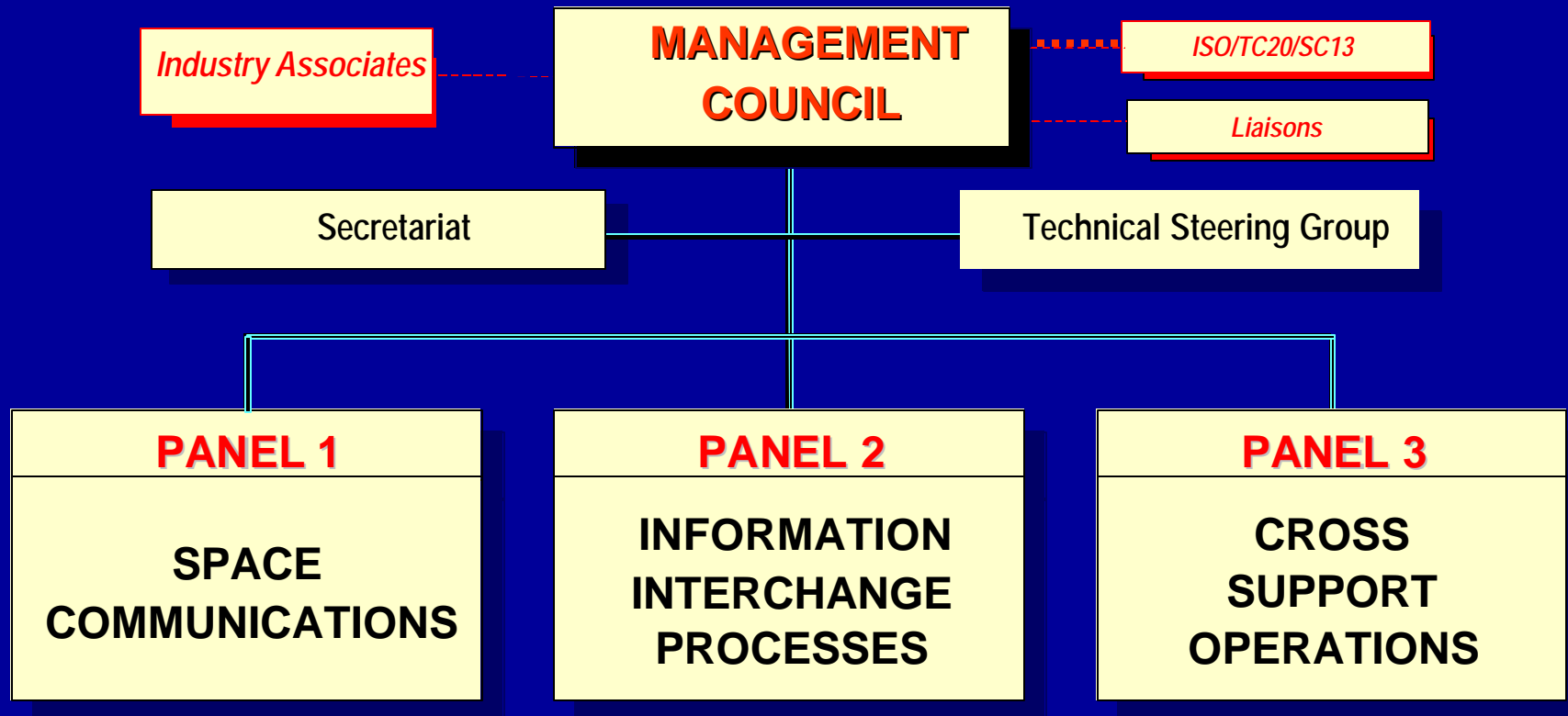
2000 Third Annual International Symposium
on Advanced Radio Technologies
Boulder, CO, 08 September 2000

Interplanetary Internet

Adrian J. Hooke
Jet Propulsion Laboratory
California Institute of Technology



Consultative Committee for Space Data Systems (CCSDS)



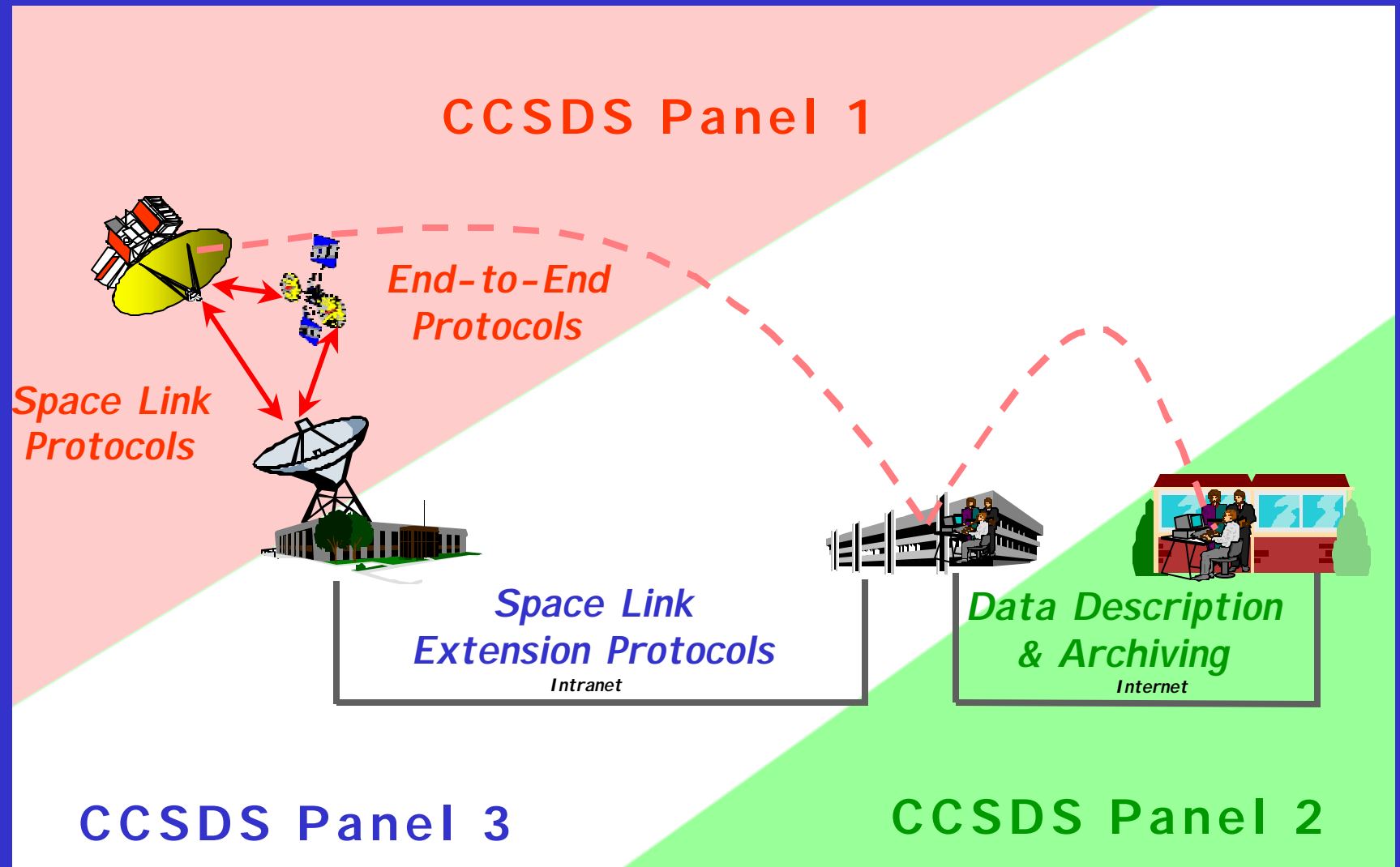
Member Agencies

ASI/Italy *ESA/Europe*
BNSC/UK *INPE/Brazil*
CNES/France *NASA/USA*
CSA/Canada *NASDA/Japan*
DLR/Germany *RSA/Russia*

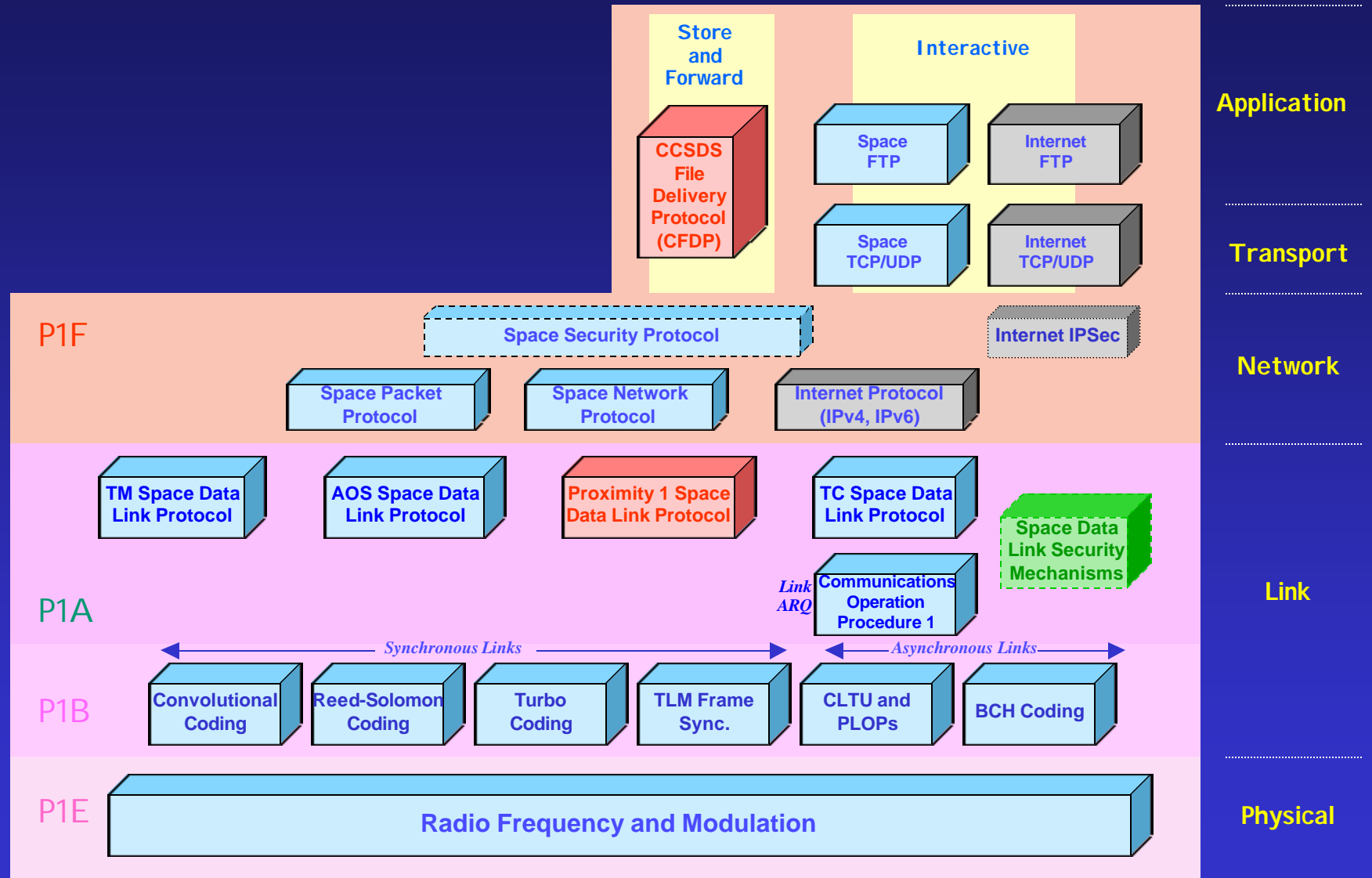
Observer Agencies

ASA/Austria *CTA/Brazil* *IKI/Russia* *NOAA/USA*
CAST/China *DSRI/Denmark* *ISAS/Japan* *NSPO/Taipei*
CRC/Canada *EUMETSAT/Europe* *ISRO/India* *SSC/Sweden*
CRL/Japan *EUTELSAT/Europe* *KARI/Korea* *TsNIIMash/Russia*
CSIR/South Africa *FSST&CA/Belgium* *KFKI/Hungary* *USGS/USA*
CSIRO/Australia *HNSC/Greece* *MOC/Israel*

CCSDS Panel Work



Current CCSDS Space/Ground Communications Protocol Stack



CCSDS Recommendation
 Draft CCSDS Recommendation
 CCSDS Report
 Internet RFC

CCSDS Implementations

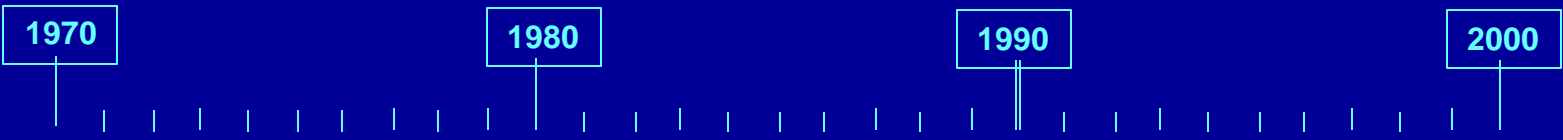


MISSIONS

151 Missions

PRODUCTS

10 COTS Spacecraft
16 COTS Space Products
2 COTS Ground Networks
28 COTS Ground Products



NASA Telemetry Standardization

"Packet" Spacecraft Telemetry and Telecommand

Basic Space/Ground Communications Standards for Space Missions

NASA/ESA Working Group



Consultative Committee for Space Data Systems (CCSDS)

Extension of Standards for More Complex Space Missions

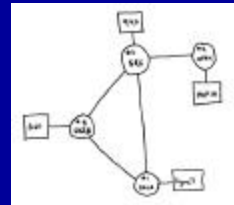
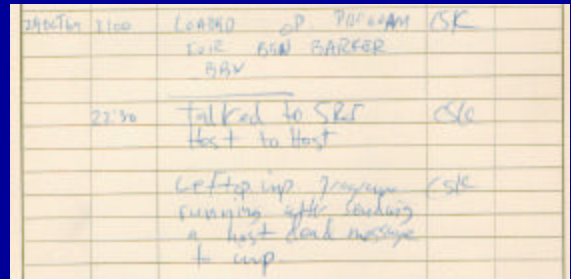
International Space Station

Extension of the Terrestrial Internet into Space

Evolution of space standards

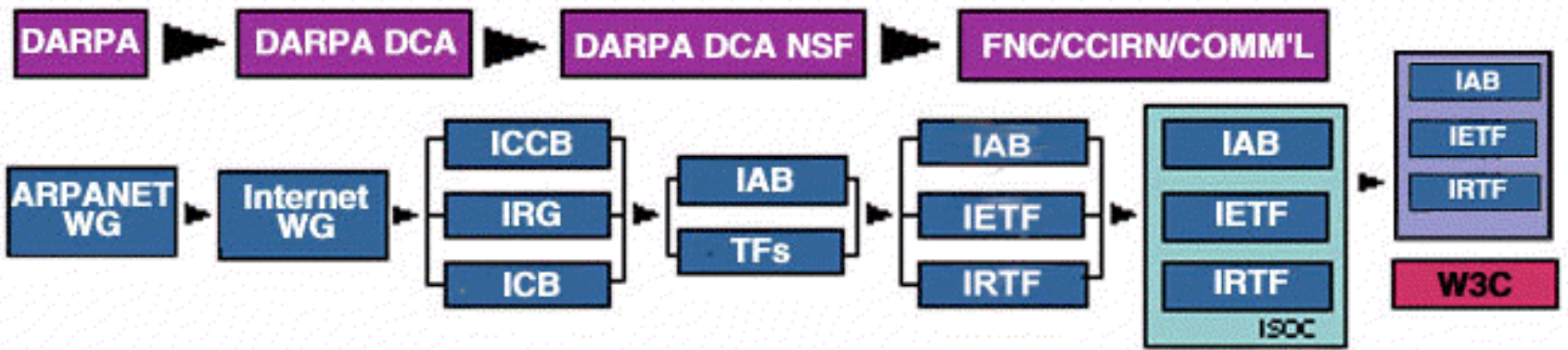
NASA/DOD Space Communications Protocol Standards (SCPS) Project

InterPlaNetary Internet (IPN)



Evolution of the terrestrial Internet





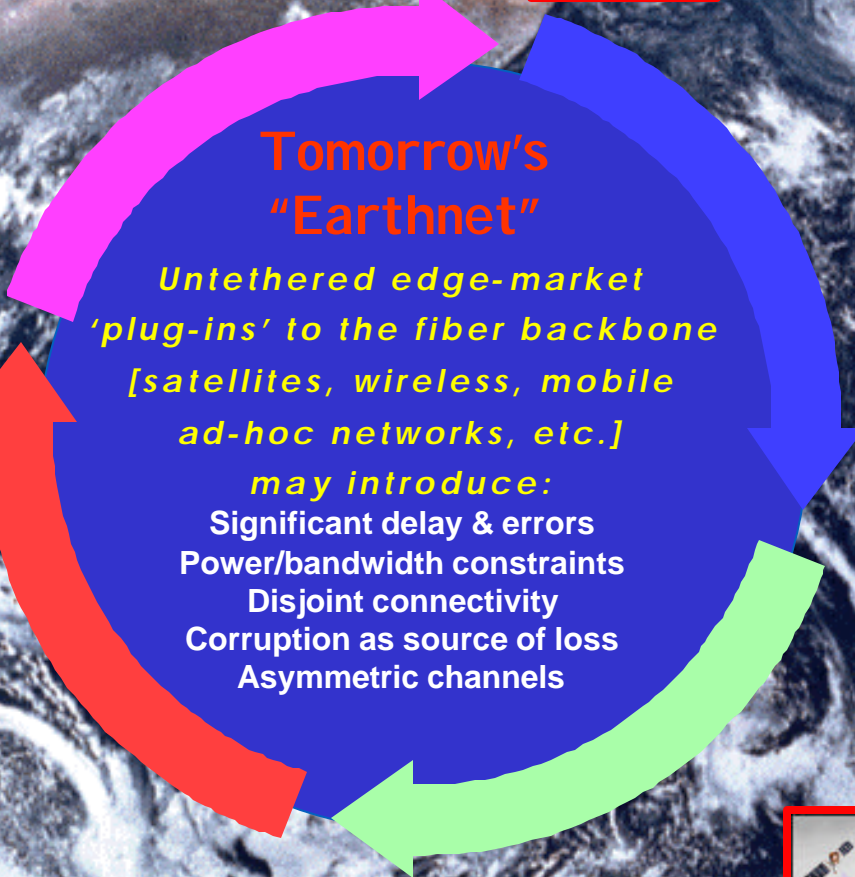
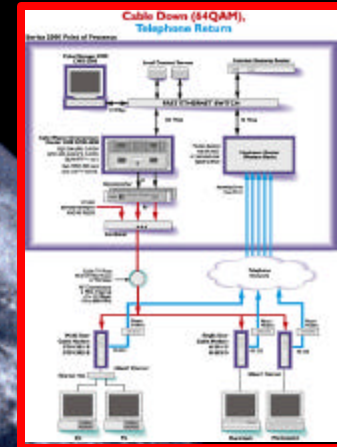
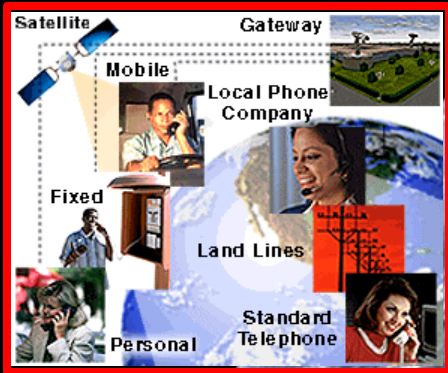
1968 ————— 1980 ————— 1986 ————— 1993 ————— 1996

Δ ARPANET Demonstrated
 Δ TCP/IP Invented
 Δ First Gateway
 Δ ARPANET Widely Used
 Δ MILNET/ARPANET Split
 Δ ARPANET Transition To TCP/IP
 Δ NSI-net Initiated
 Δ Multi-Protocol Environment
 Δ Many Thousands of Everything
 Δ Internet Society Founded
 Δ World Wide Web

Operational Networks On Internet	3	20	60	300	500	900	19,000	50,000
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**Today's
Internet:**
High rate fiber backbone
Negligible delay
Negligible errors
Symmetric data channels
Continuous connectivity
Loss = Congestion



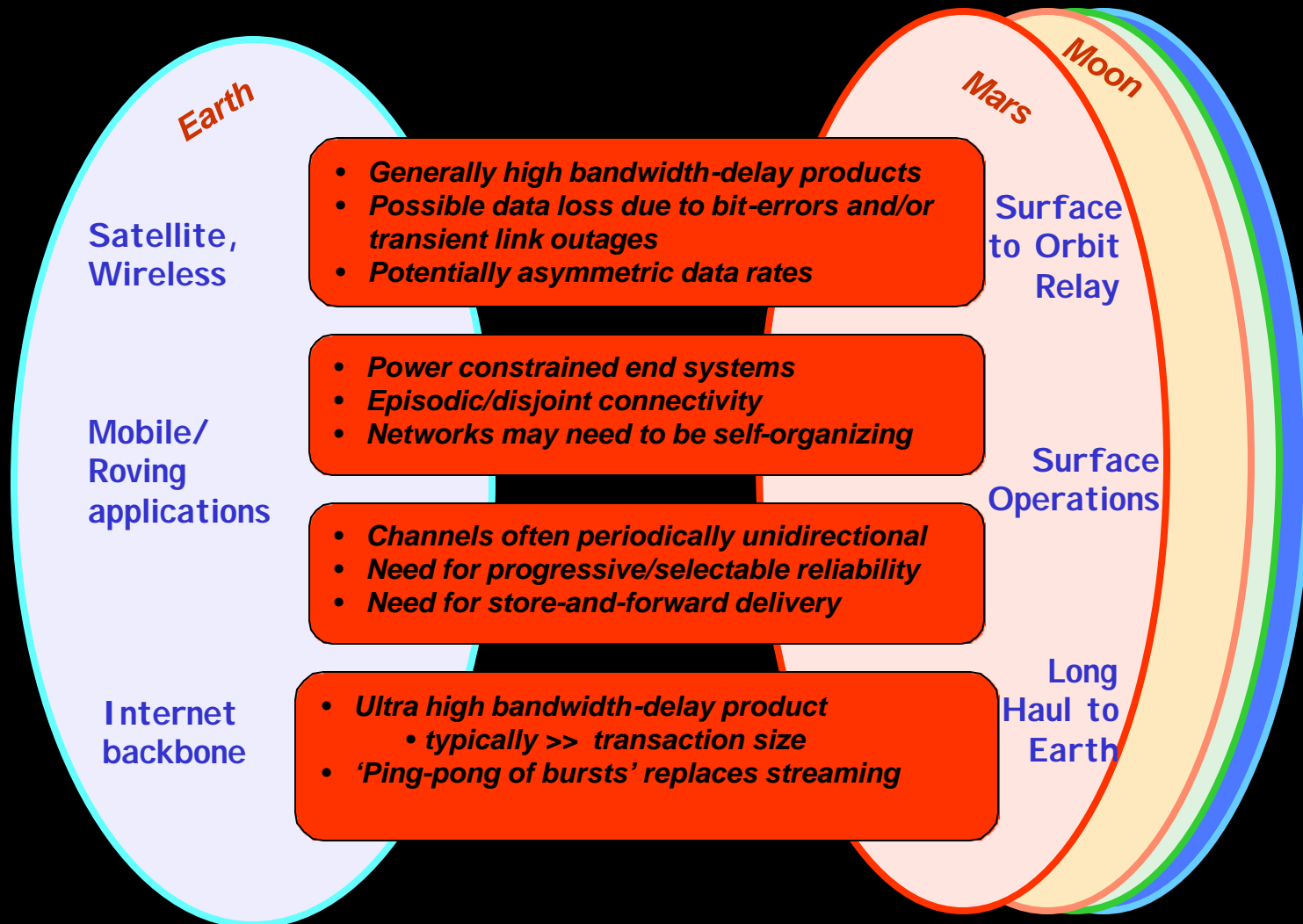
Tomorrow's "Earthnet"

Untethered edge-market 'plug-ins' to the fiber backbone [satellites, wireless, mobile ad-hoc networks, etc.]

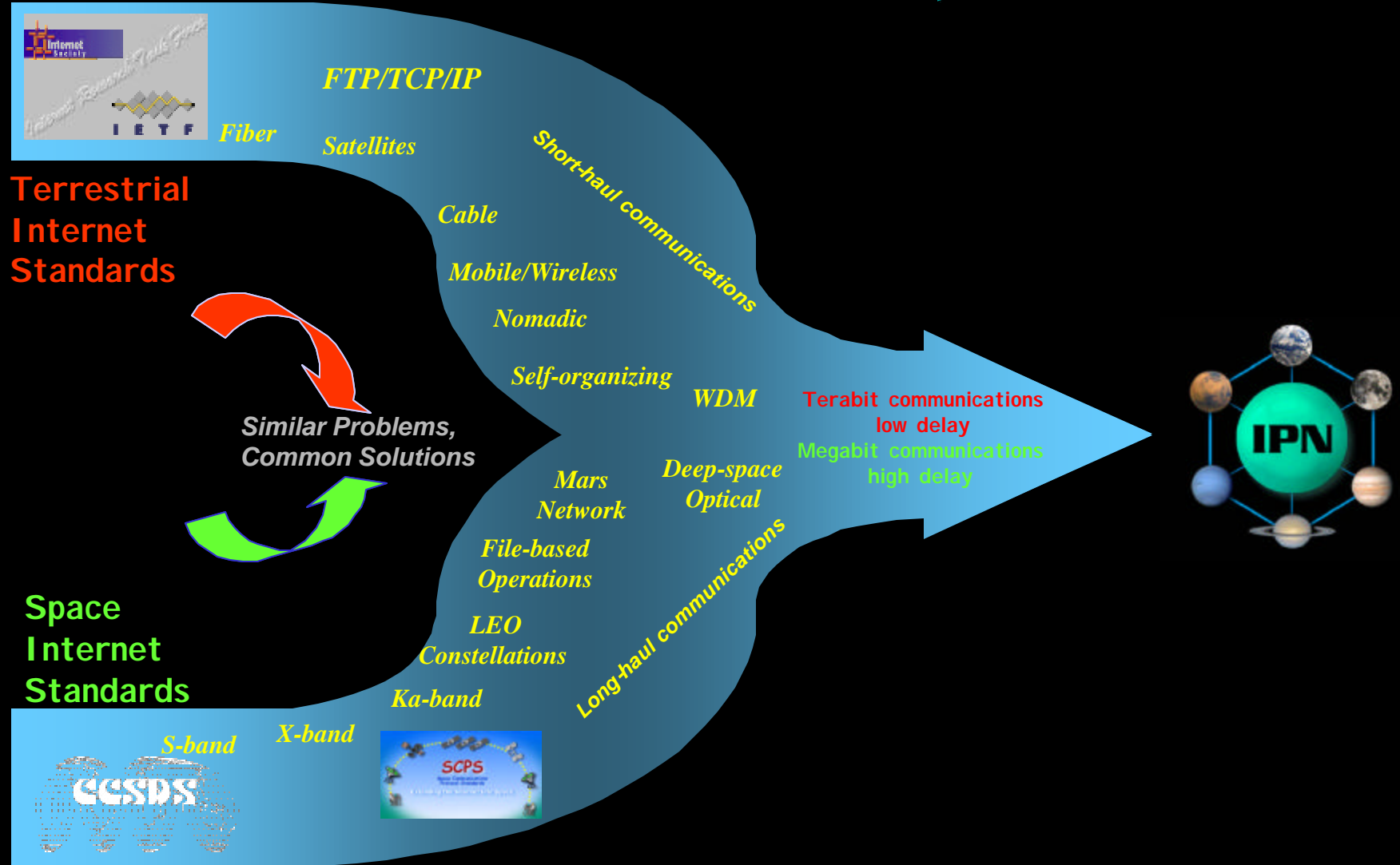
- may introduce:*
- Significant delay & errors
 - Power/bandwidth constraints
 - Disjoint connectivity
 - Corruption as source of loss
 - Asymmetric channels



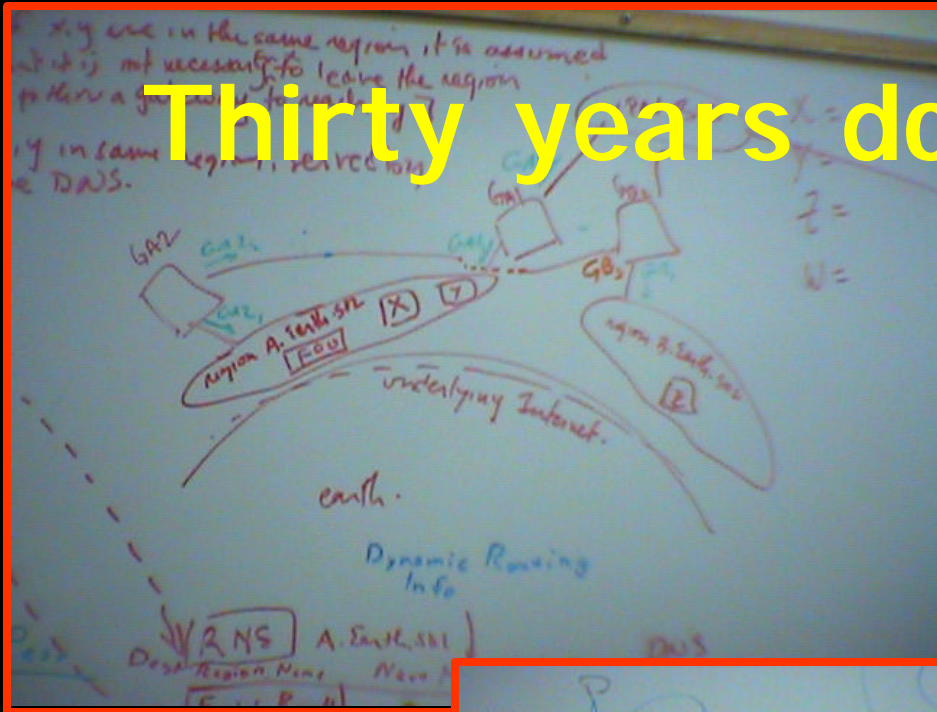
A Candidate Sharing of Issues and Technologies



IPN Leverage



Thirty years down the road....

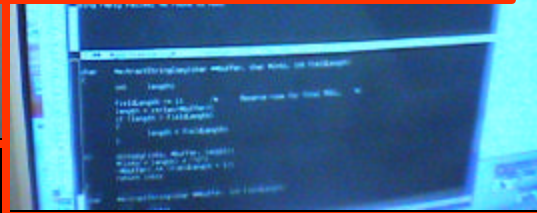
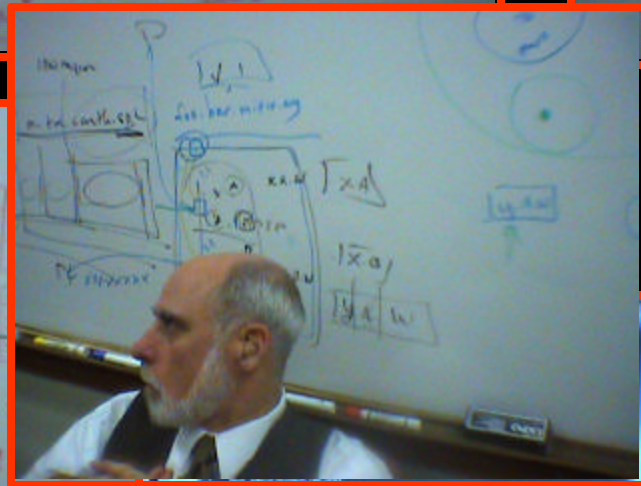


Handwritten notes on a whiteboard:

DNS

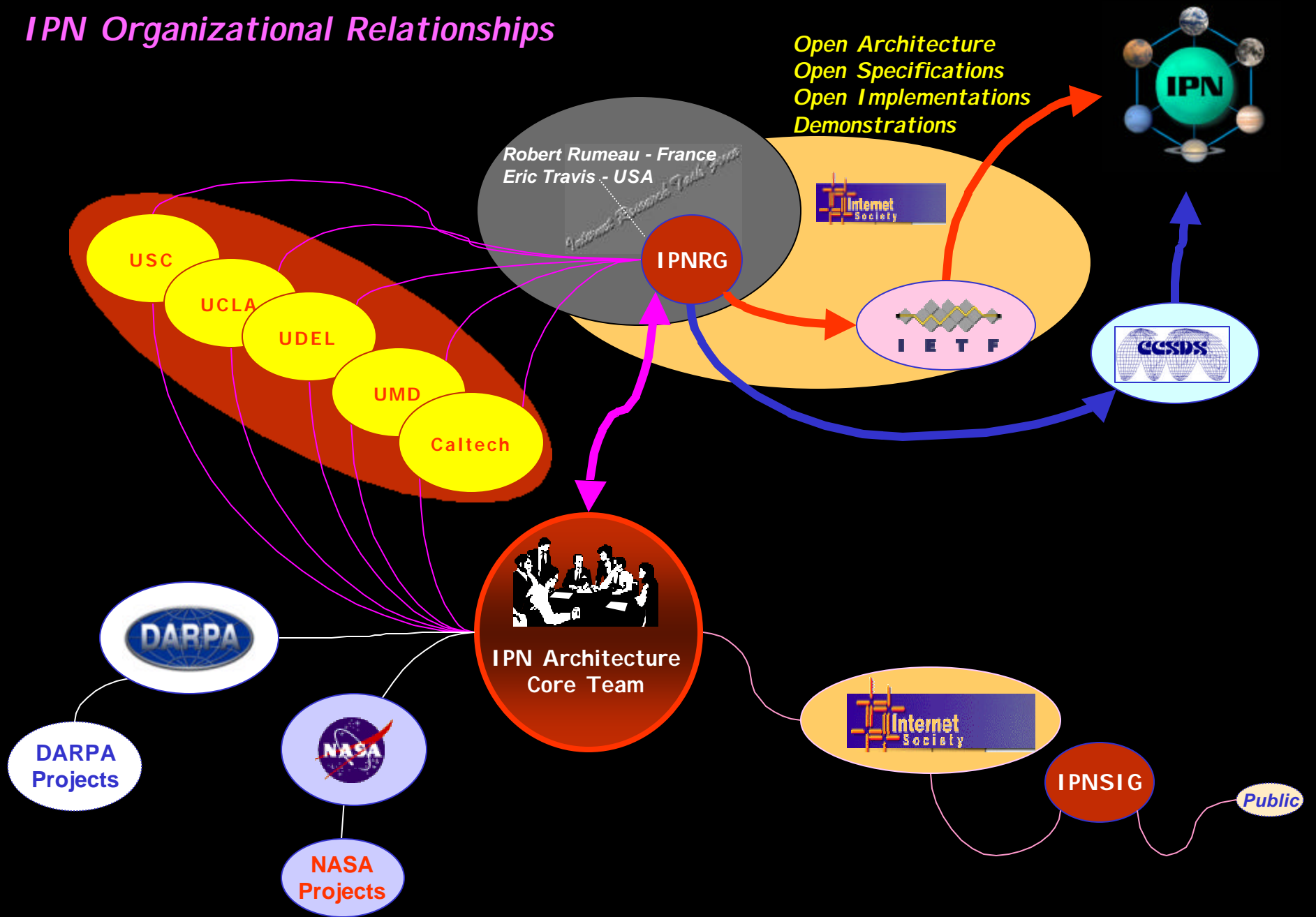
Region Name	Next Hop	Priority
EAST.SOL	GAZ	
WEST.SOL	GAT	

It's ok for not every machine



IPN Organizational Relationships

Open Architecture
Open Specifications
Open Implementations
Demonstrations

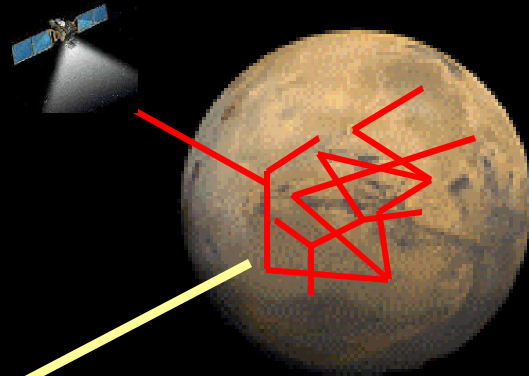
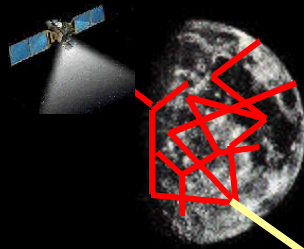


The Basic IPN Concept:

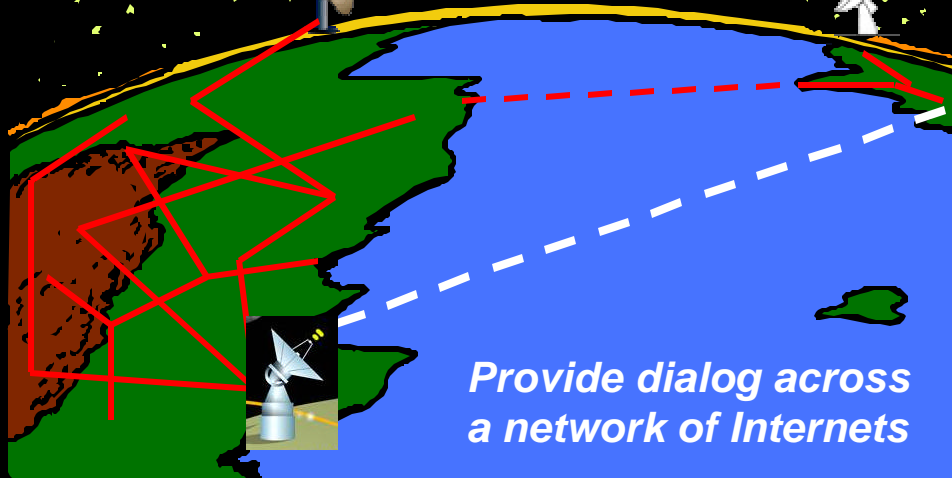
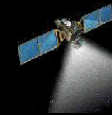
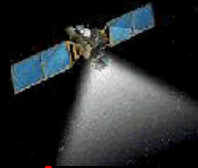
Construct a "Network of Internets"

- Deploy standard internets in low latency remote environments (e.g., on other planets, on remote spacecraft)
- Connect these distributed internets via an interplanetary backbone that handles the high latency deep space environment.
- Create gateways and relays to interface between low and high latency environments

Deploy standard internets in low latency remote environments (e.g., on other planets)



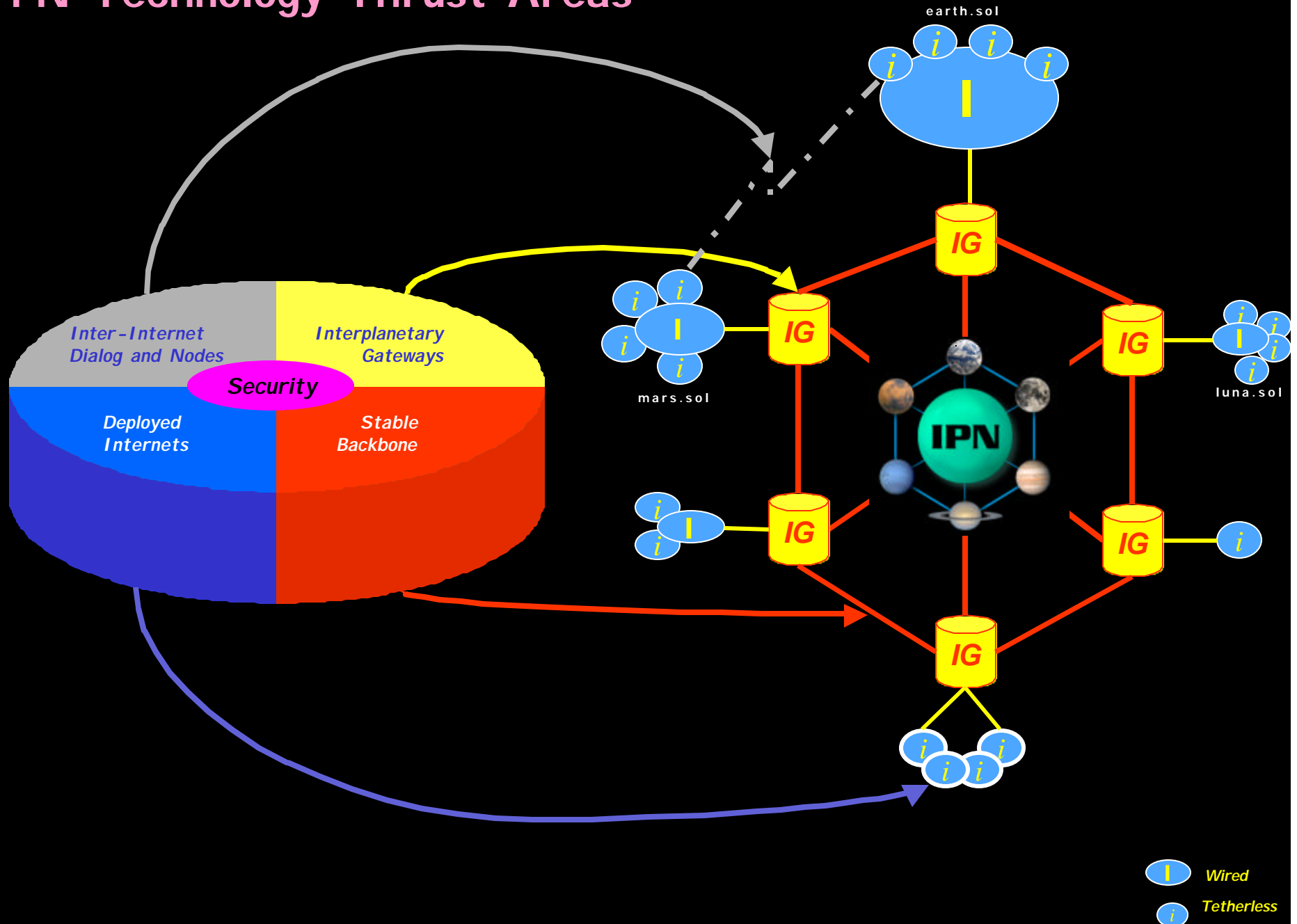
Connect distributed internets via an interplanetary backbone

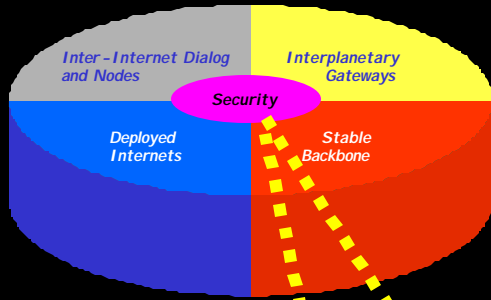


Provide dialog across a network of Internets

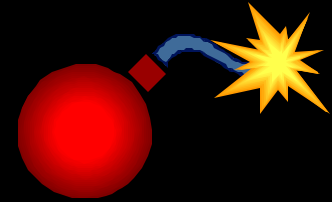
The Basic IPN Concept:
construct a "Network of Internets"

IPN Technology Thrust Areas



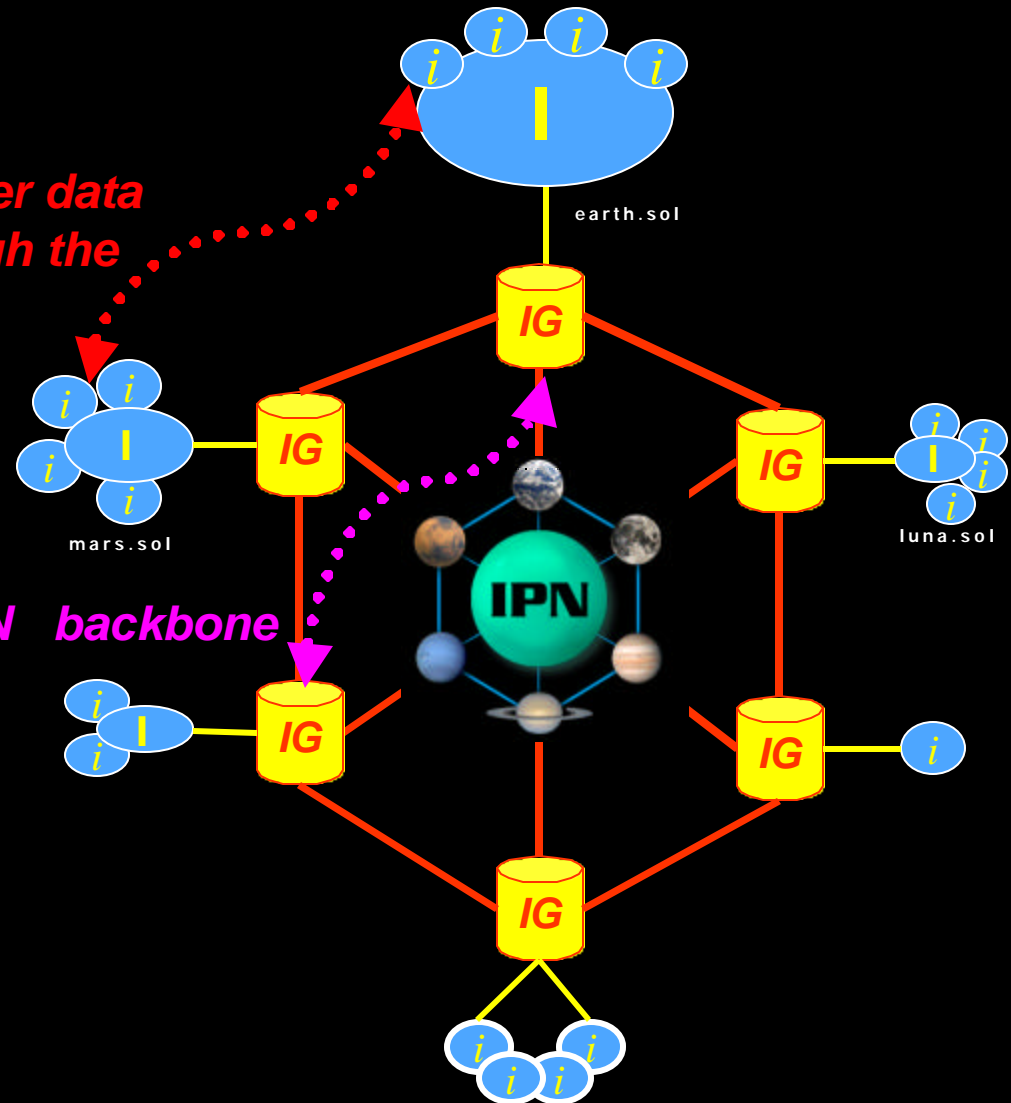


IPN Security

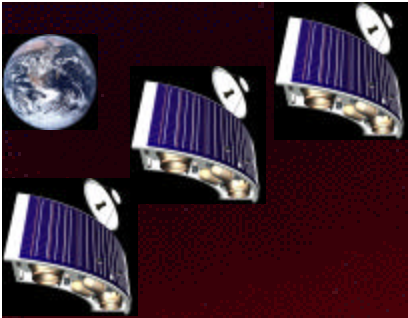


Security of user data flowing through the IPN

Security of the IPN backbone

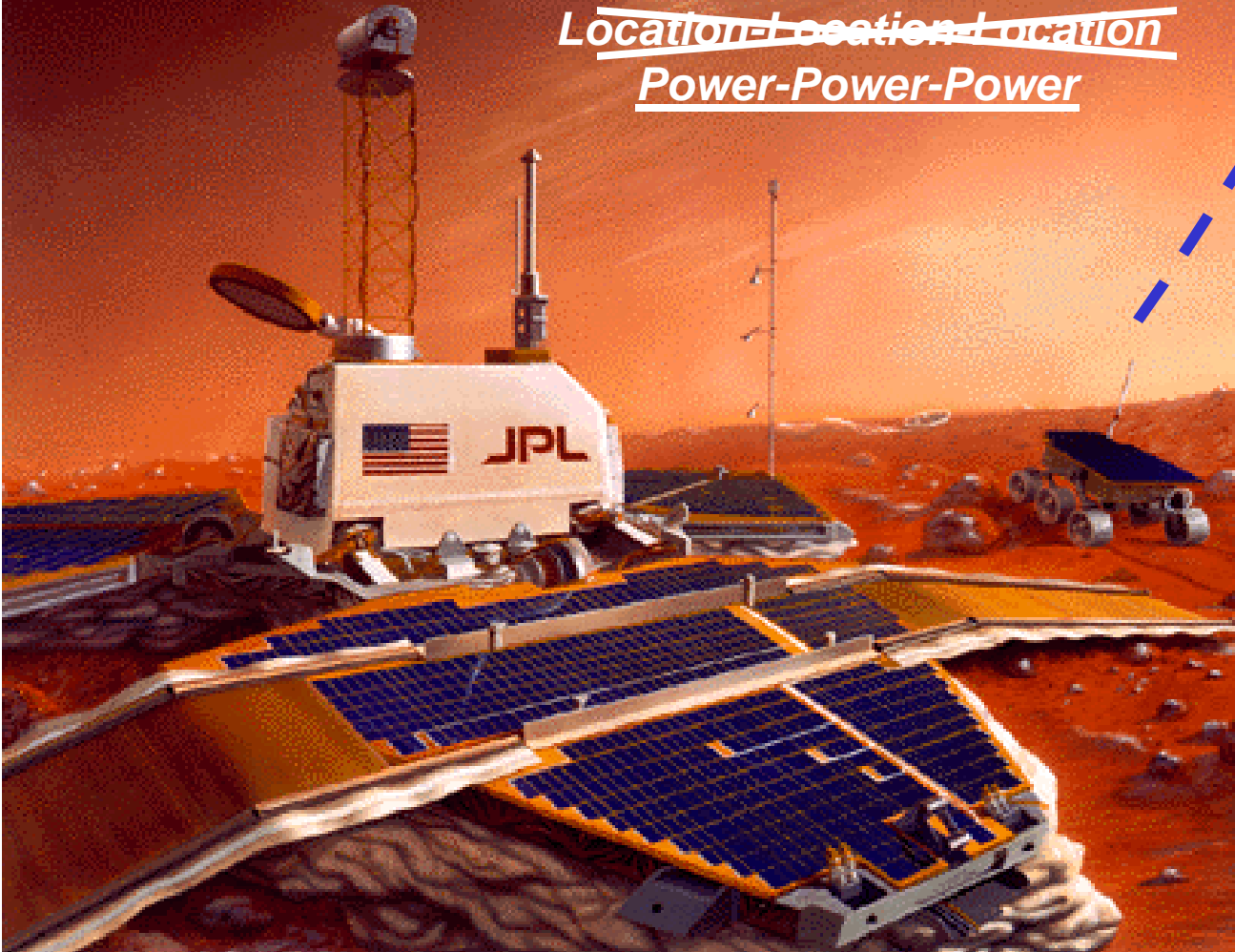
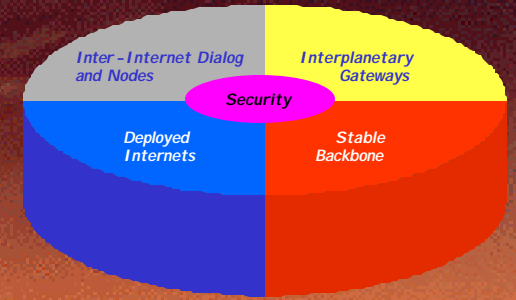


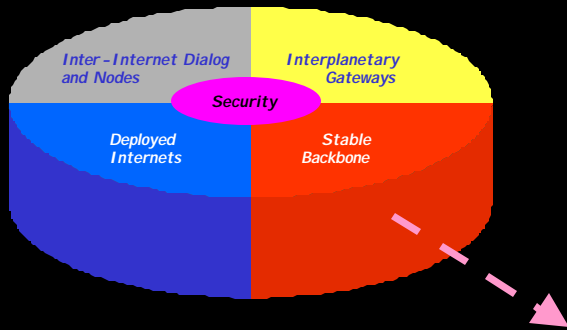
- **access control** to the IPN will be required because space-based assets will have limited available resources.
- **authentication** will be required to perform access controls.
- **data integrity** will be required to assure that what was sent *is* received.
- **data privacy** will be required to assure that unauthorized users cannot obtain information.



Deployed In-Situ Internets

Untethered
Mobile
Mass constrained
~~Location-Location-Location~~
Power-Power-Power





What's a Backbone?

- ***A set of high-capacity, high-availability links between network traffic hubs***
 - Terrestrial backbone links are between hubs like Houston and Chicago.
 - Interplanetary backbone links are between hubs like Earth and Mars.

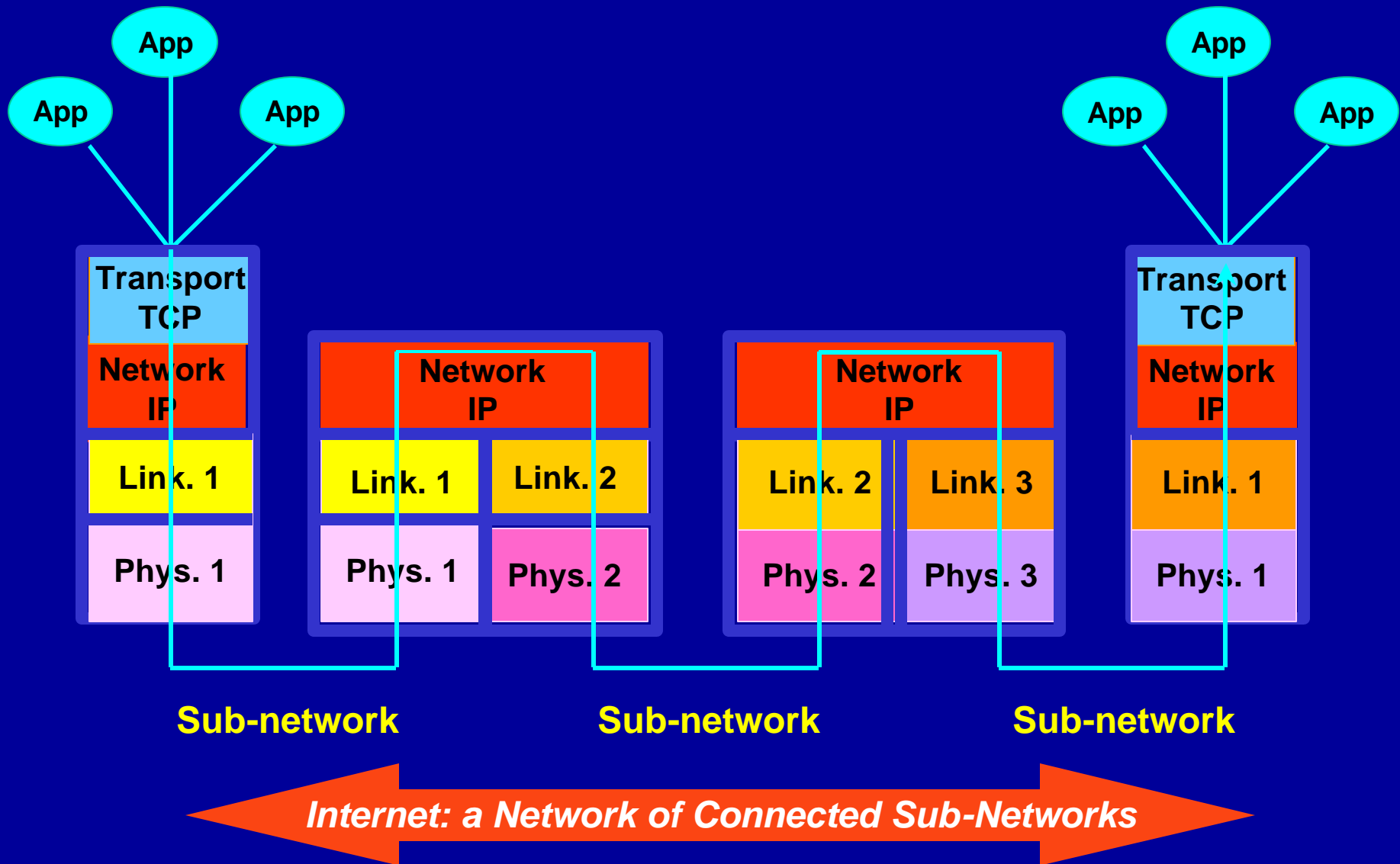
On the Interplanetary Backbone:

- ***Communications capacity is expensive***
 - Bits count
- ***Round Trips hurt***
 - Interactive protocols don't work
 - *Internet protocol suite doesn't scale well with increasing latency*
 - *Negotiation is impractical*
 - *Reliable in-order delivery takes too long*
 - *Protocols need to be connectionless*
 - *Congestion control and flow control are difficult*
 - *Reliance on forward coding versus retransmission for error recovery*
- ***Custodial store-and-forward data transfer is fundamental***
 - “Chatty Telephony” gives way to “Bundled Mail” as the model of operations

Resulting Backbone Differences

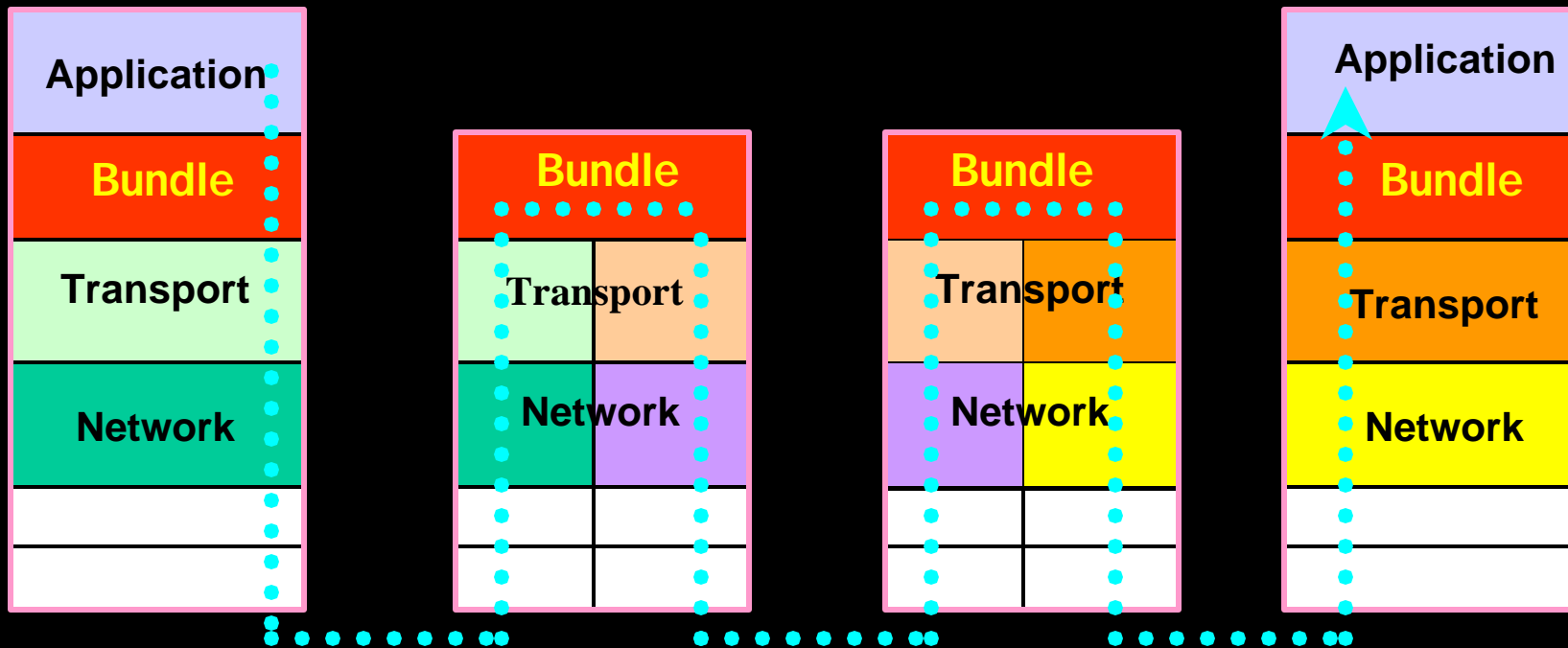
	<u>Terrestrial Backbone</u>	<u>Interplanetary Backbone</u>
<i>Transport</i>	TCP	“Bundling”
<i>Network</i>	IP	IP, NP, None?
<i>Link</i>	SONET	CCSDS
<i>Physical</i>	Optical fiber	R/F or laser

IP: the "Thin Waist" of the Earth's Internet



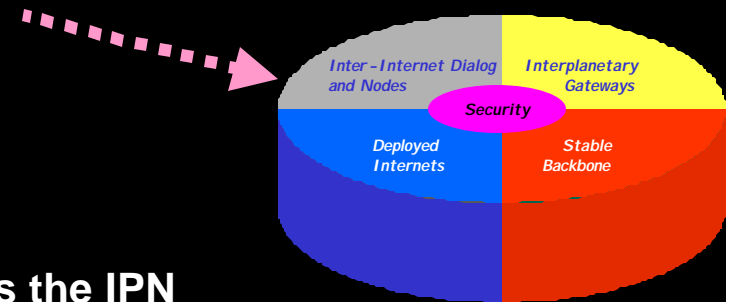
Bundles: A Store and Forward Overlay - the "Thin Waist" of the Interplanetary Internet

Network of disconnected Internets spanning dissimilar environments



Bundling supports end-to-end transfer across a "network of disconnected Internets" having heterogeneous network protocol stacks

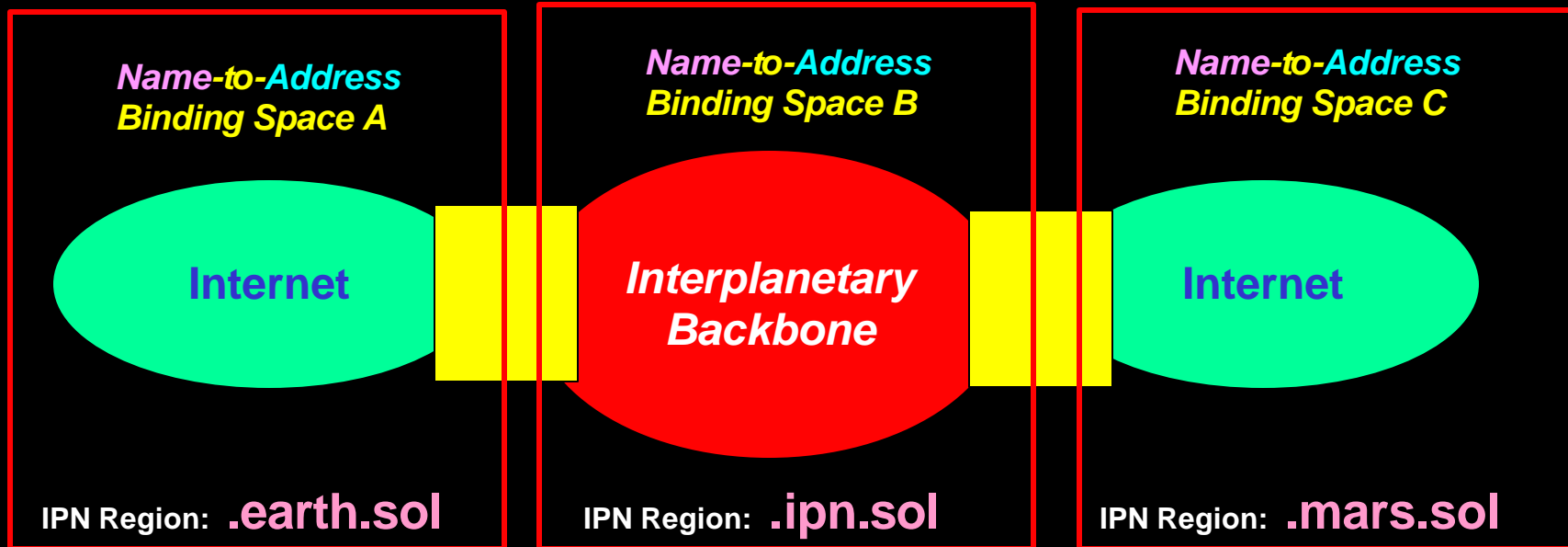
Bundling: Design Principles



- Names are the means of reference
 - Names have two parts: a routing part (specifies the IPN region) and an administrative part (specifies the DNS name)
 - Routing between IPN regions based upon routing part of the name
- Late-Binding
 - Separate **addressing** domains for each internet; administrative **names** converted to local **addresses** in destination IPN region
- Indirection
 - Inherent dependence on intermediate relay agents
- Custodial transfer
 - “Bundles” are the common end-to-end transfer mechanism

Single Name Space, Late Name-to-Address Binding(s)

Name Space - Common Across All Internets



Name:
{routing part: earth.sol,
admin part: <http://www.bughunter.org>}

Local Address: 137.79.10.232

Name:
{routing part: mars.sol,
admin part: <http://www.rockshop.com>}

Local Address: 137.79.10.232

Interplanetary Internet Deployment Plan



Interplanetary Internet, "2020"

