

CCSDS Standardisation Roadmap for Future Space Missions

IPNSIG Academy, Thursday 14th March 2024

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Knowledge for Tomorrow



Outline

- CCSDS Introduction
- CCSDS Technical Activities
- Review of CCSDS SIS Area Activities



CCSDS Introduction



Knowledge for Tomorrow



CCSDS – Scope and Origins

- CCSDS = The Consultative Committee for Space Data Systems
- **Communications and data systems** standards.
- Since 1982 starting at the lower layers of the protocol stack.
- Now:
 - Throughout the entire ISO communications stack
 - Plus other Data Systems areas (architecture, archive, security, XML exchange formats, etc.
 - **End to end** data/comm architecture for any mission



Future Mission Drivers

PAST

PRESENT

DRIVERS FOR THE

FUTURE



Shuttle/SpaceLab
CCSDS packets



International Space Station
Adv. Orbital Sys (AOS)
Early DTN Prototyping

In Situ Exploration

- Human Expeditions
- Long Duration, High Reliability
- Mobile comm protocols
- Voice, Video, Medical handling
- Onboard Autonomy
- Highly integrated ops



Asteroid/Surface Exploration
Autonomy, High bandwidth
Multi-Agency Mission Ops



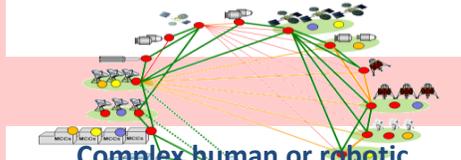
Brief Recon Flyby,
Short-Lived Probes
Direct-to-Earth links



Missions designed for orbital relays,
Longer duration

Complex Deep Space Missions

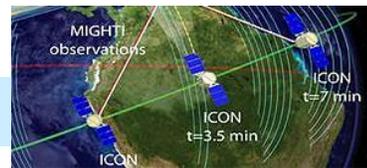
- Human or robotic exploration
- Longer Duration
- Mobile comm protocols
- Fully automated routing
- Network-Managed DTN
- Optical Communications



Complex human or robotic
Scenarios for remote surface missions
Fully automated Space Internetworking



Single-Spacecraft
Survey/Sensors



Spacecraft Constellations
and formation flying

Orbital Remote Sensing

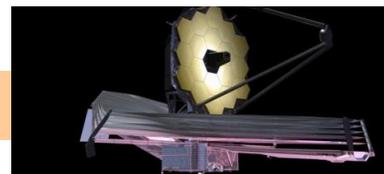
- Long Duration, high bandwidth
- High Spatial, Spectral, & Temporal Resolution
- Low Latency Comm
- Complex link topologies
- *SensorWebs for synchronized remote sensing*



Multi-Discipline and
Multi-Resource SensorWebs



Single-Spacecraft
Observatories in LEO



Greater Distances
Higher bandwidth

Next Generation Observatories

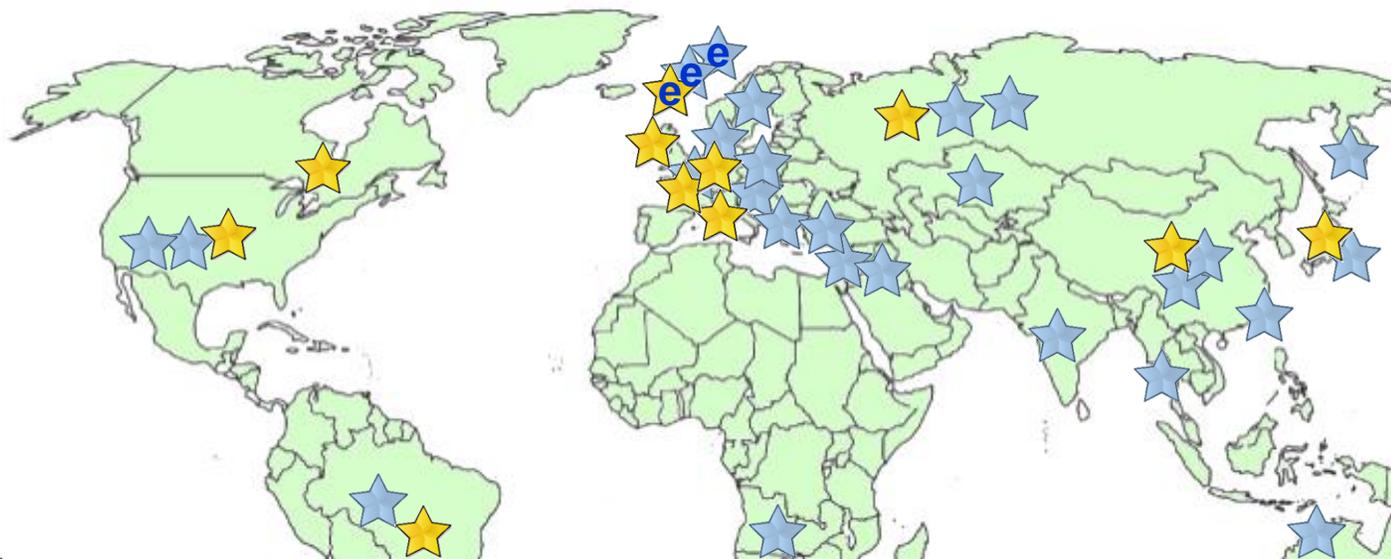
- More Capability
- Multiple Spacecraft drive network needs
- Even Greater Capacities require new coding schemes
- Located Even Farther from Earth



Next Generation
Observatory Complexes

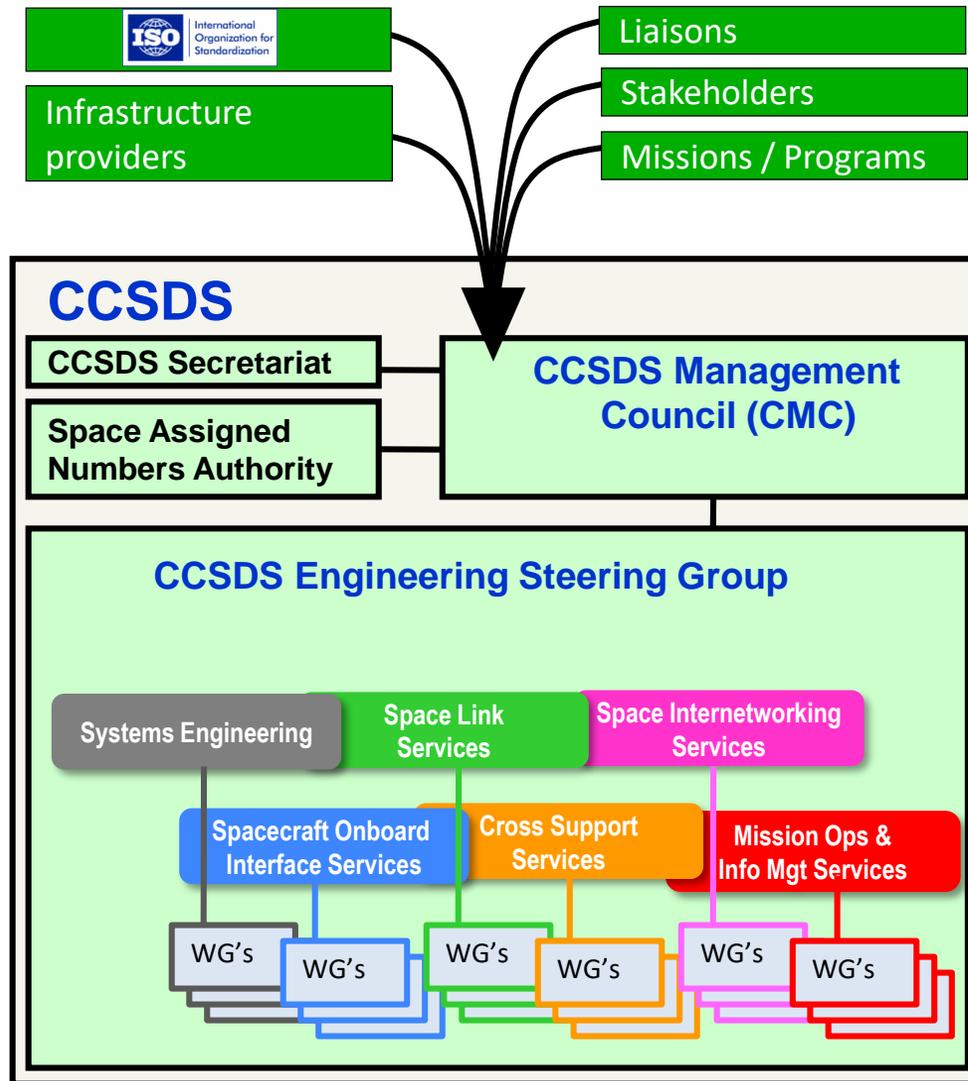
CCSDS Overview - Participation

- CCSDS – An Agency-Led International Committee
 - Currently 11 Member agencies
 - Currently 33 Observer Agencies
 - Agencies represent 27 nations (and 3 European orgs)
 - Currently 139 Commercial Associates
 - ~200-250 attendees at Spring/Fall meetings
- Also functions as an ISO Subcommittee
 - TC20/SC13 - Space Data & Info Transfer Systems
 - Represents 20 nations



| ★ | OBSERVER AGENCIES |
|---|--------------------|
| ★ | MEMBER AGENCIES |
| ★ | ASA/Austria |
| ★ | BFSP0/Belgium |
| ★ | CAS/China |
| ★ | CAST/China |
| ★ | CLTC/China |
| ★ | CSIRO/Australia |
| ★ | DCTA/Brazil |
| ★ | ASI/Italy |
| ★ | DNNSC/Denmark |
| ★ | EA/Europe |
| ★ | EUMETSAT/Europe |
| ★ | EUTELSAT/Europe |
| ★ | GISTDA/Thailand |
| ★ | HNSC/Greece |
| ★ | DLR/Germany |
| ★ | IKI/Russia |
| ★ | ESA/Europe |
| ★ | ISRO/India |
| ★ | FSA/Russia |
| ★ | KARI/Korea |
| ★ | KFKI/Hungary |
| ★ | INPE/Brazil |
| ★ | MOC/Israel |
| ★ | JAXA/Japan |
| ★ | NCST/USA |
| ★ | NASA/USA |
| ★ | NICT/Japan |
| ★ | NOAA/USA |
| ★ | UKSA/UK |
| ★ | NSARK/Kazakhstan |
| ★ | NSPO/Taiwan |
| ★ | SANSA/South Africa |
| ★ | SSC/Sweden |
| ★ | SSO/Switzerland |
| ★ | SUPARCO/Pakistan |
| ★ | TsNIIMash/Russia |
| ★ | TUBITAK/Turkey |
| ★ | USGS/USA |

CCSDS Structure and Organization



CCSDS Strategic Plan - The CCSDS Plan for the Future

Systems Engineering

1. Towards Cross-cutting functions and coherent architecture-wide integration

Spacecraft Onboard Interface Services

2. Towards standardized Onboard Interfaces and Services

Mission Ops & Info Mgt Services

3. Towards Standardized Mission Operations Services and complete Navigation Message Standardization

Cross Support Services

4. Towards an extensible Space Communications Cross Support Service Management and Transfer Services (Cross Support of Communications Assets)

Space Link Services

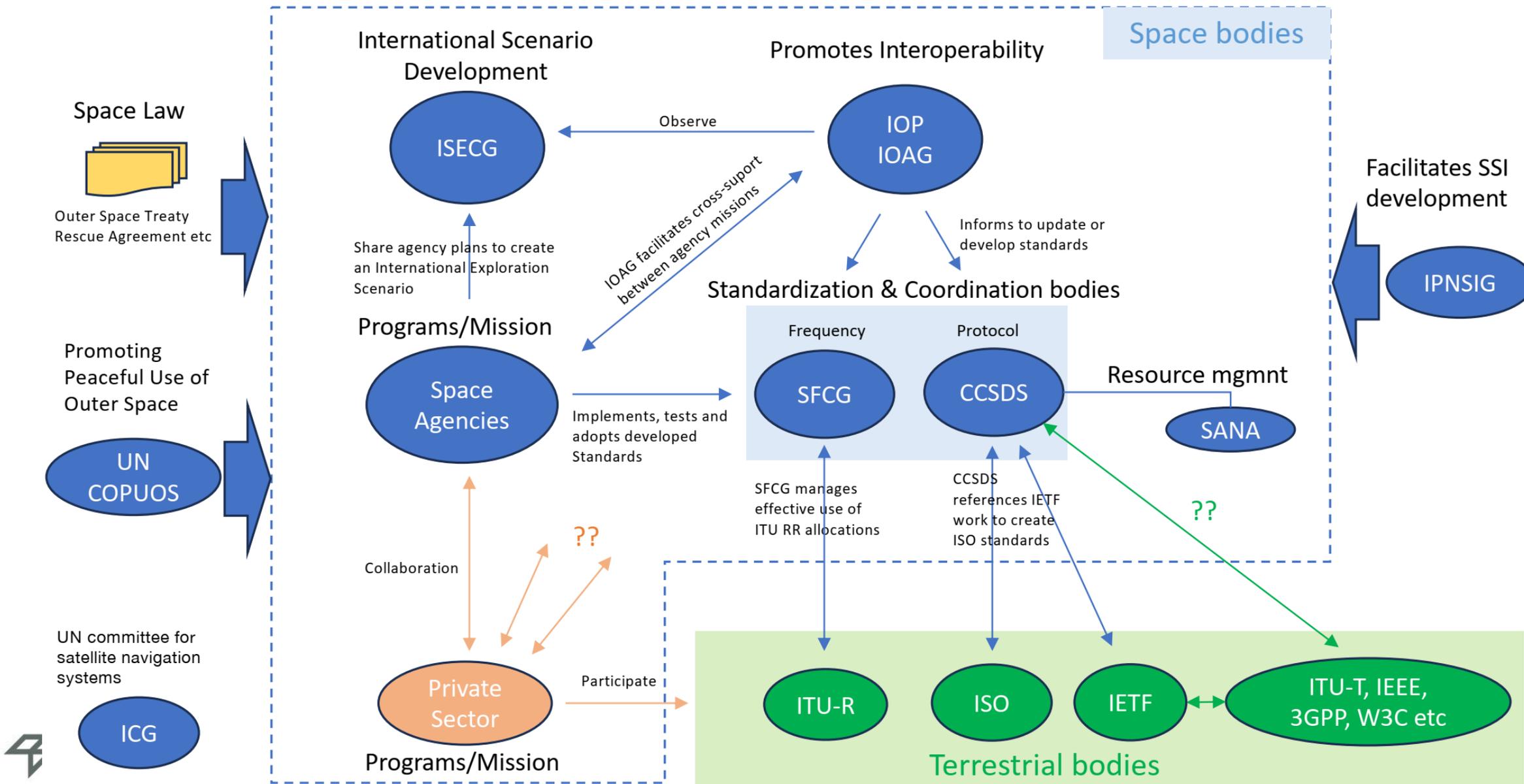
5. Towards an unified Space Data Link Protocol, optical links, new sync and channel coding schemes and compression

Space Internetworking Services

6. Towards standardized Space System Internetworking Services and the Solar System Internet (SSI)



Work-together with other Standardisation Bodies



CCSDS Overview

End-to-End Architecture

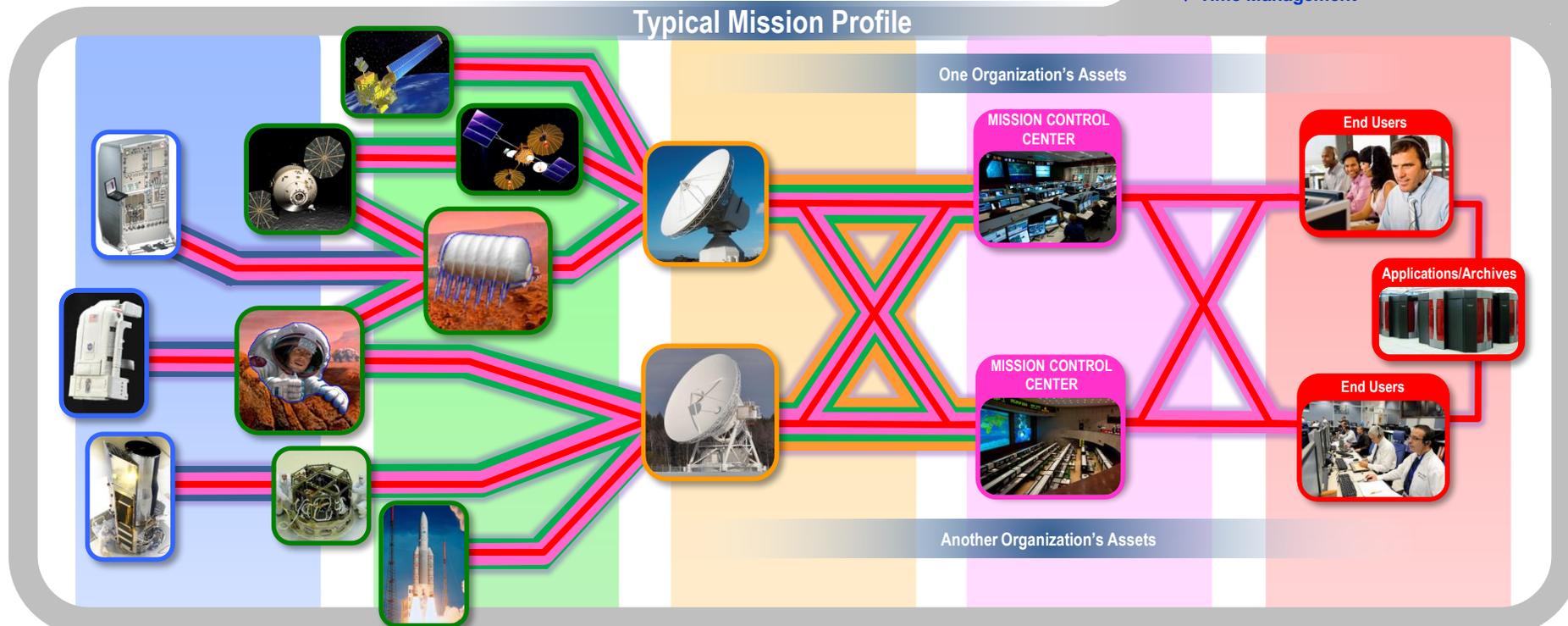
Six Technical Areas, Twenty-Six Teams

- ◆ Working Group (producing standards)
- ◆ Birds-Of-a-Feather stage (pre-approval)
- ◆ Special Interest Group (integration forum)

Systems Engineering

- ◆ System Architecture
- ◆ Security
- ◆ Delta-DOR
- ◆ Time Management

Typical Mission Profile



Spacecraft Onboard Interface Services

- ◆ Onboard Wireless WG
- ◆ Application Supt Services (incl. Plug-n-Play)
- ◆ Subnetwork Services

Space Link Services

- ◆ RF & Modulation
- ◆ Space Link Coding & Sync.
- ◆ Multi/Hyper Data Compress.
- ◆ Space Link Protocols
- ◆ Space Data Link Security
- ◆ Optical Coding and Mod

Cross Support Services

- ◆ CS Service Management
- ◆ CS Transfer Services
- ◆ Cloud Computing

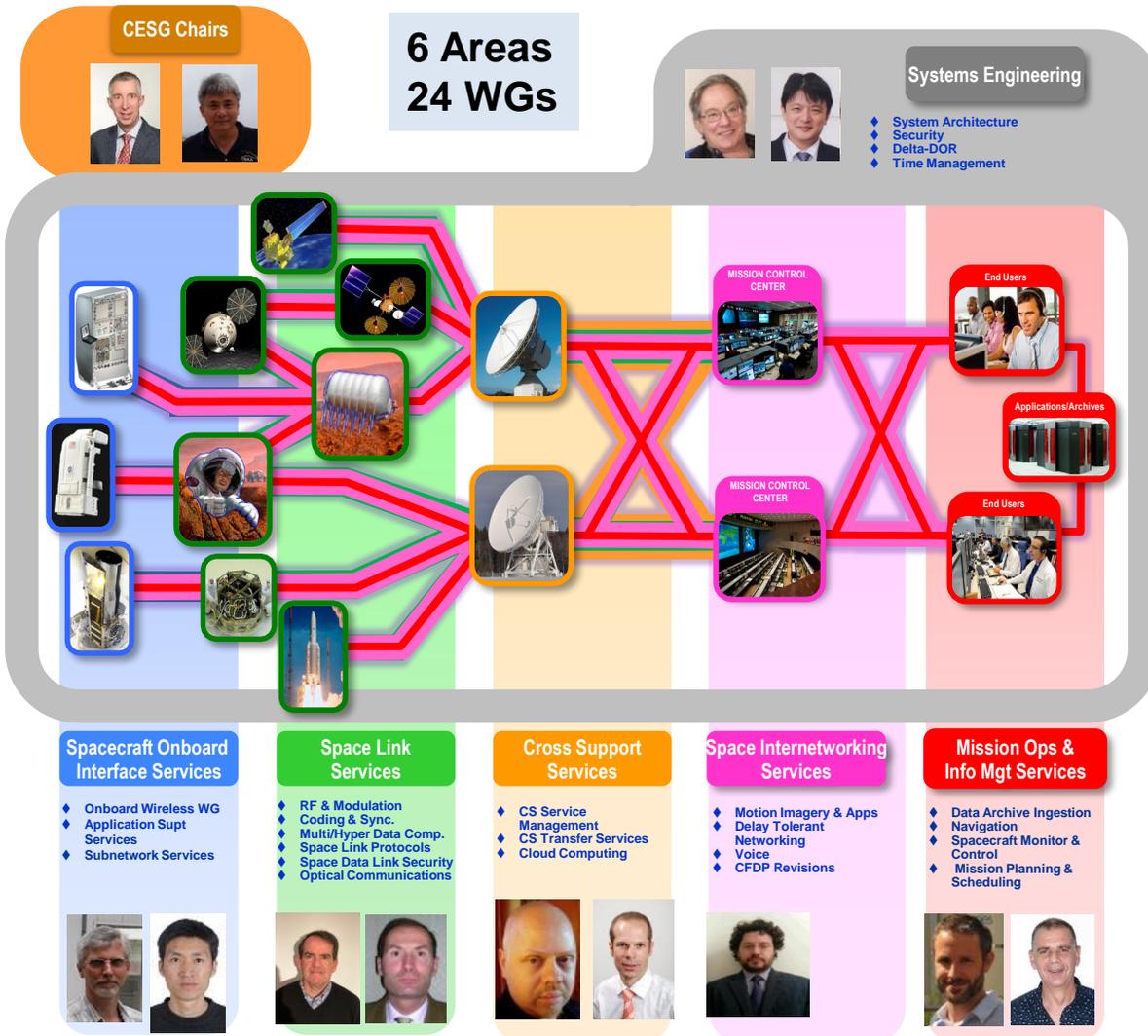
Space Internetworking Services

- ◆ Motion Imagery & Apps
- ◆ Delay Tolerant Networking
- ◆ Voice
- ◆ CFDP Revisions

Mission Ops & Info Mgt Services

- ◆ Data Archive Ingestion
- ◆ Navigation
- ◆ Spacecraft Monitor & Control
- ◆ Mission Planning & Scheduling

Members of the CESG



- | | |
|---|--|
| CESG Chair <i>Deputy</i> | K.-J. Schulz <i>Timothy Pham</i> |
| SE Area Director <i>Deputy</i> | Peter Shames <i>Hiroshi Takeuchi</i> |
| MOIMS Area Director <i>Deputy</i> | Daniel Fischer <i>Marc Duhaze</i> |
| CSS Area Director <i>Deputy</i> | Erik Barkley <i>Holger Dreihahn</i> |
| SLS Area Director <i>Deputy</i> | Ignacio Aguilar Sanchez <i>Gilles Moury</i> |
| SIS Area Director <i>Deputy</i> | Tomaso de Cola <i>Vinny' Ivica Ristovski</i> |
| SOIS Area Director <i>Deputy</i> | J. Wilmot <i>X. He</i> |



Field Guide to CCSDS Book Colors



BLUE BOOKS

Recommended Standards

Normative and sufficiently detailed (and pre-tested) so they can be used to directly and independently implement interoperable systems (given that options are specified).



ORANGE BOOKS

Experimental

Normative, but may be very new technology that does not **yet** have consensus of enough agencies to standardize.



MAGENTA BOOKS

Recommended Practices

Normative, but at a level that is not directly implementable for interoperability. These are Reference Architectures, APIs, operational practices, etc.



YELLOW BOOKS

Administrative

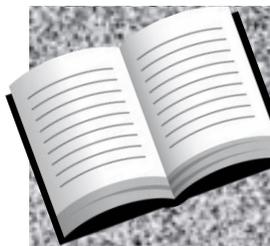
CCSDS Procedures, Proceedings, Test reports, etc.



GREEN BOOKS

Informative Documents

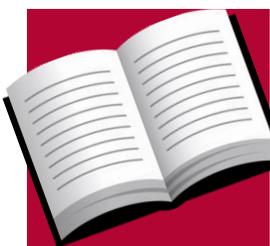
Not normative. These may be foundational for Blue/Magenta books, describing their applicability, overall architecture, ops concept, etc.



SILVER BOOKS

Historical

Deprecated and retired documents that are kept available to support existing or legacy implementations. Implication is that other agencies may not cross-support.



RED BOOKS

Draft Standards/Practices

Drafts of future Blue/Magenta books that are in agency review. Use caution with these... they can change before release.



PINK BOOKS/SHEETS

Draft Revisions For Review

Draft Revisions to Blue or Magenta books that are circulated for agency review. Pink Books are reissues of the full book, Pink Sheets are change pages only.

Online Resources

www.CCSDS.org

CWE.CCSDS.org

Public Website

- ✦ Overview info (About tab)
- ✦ Access to published standards (Publications tab)
- ✦ Comment on documents in review
- ✦ Meeting info & logistics
- ✦ Commercial implementations
- ✦ Missions that have adopted CCSDS
- ✦ New Work Items Announcements
- ✦ General Announcements (Blog)

Collaborative Work Environment

- ✦ Development environment for developing new standards
- ✦ Access to Areas' and WGs' materials (some private areas require ID/PW)
- ✦ Contact info for ADs and WG leads
- ✦ Access to schedule/status of current standards development projects

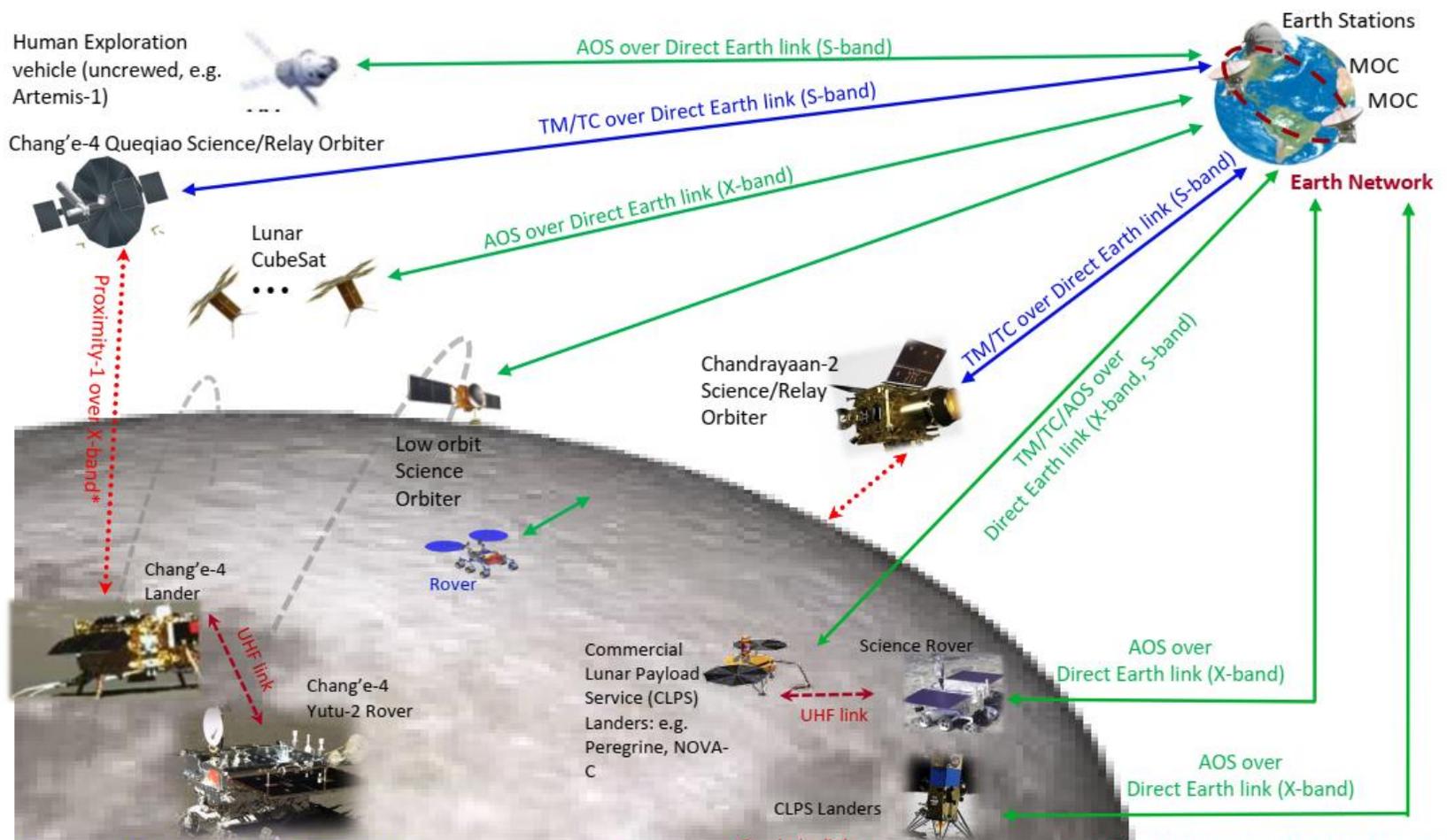
CCSDS Technical Activities



Knowledge for Tomorrow



Lunar Communication Architecture Review (up to year 2021)

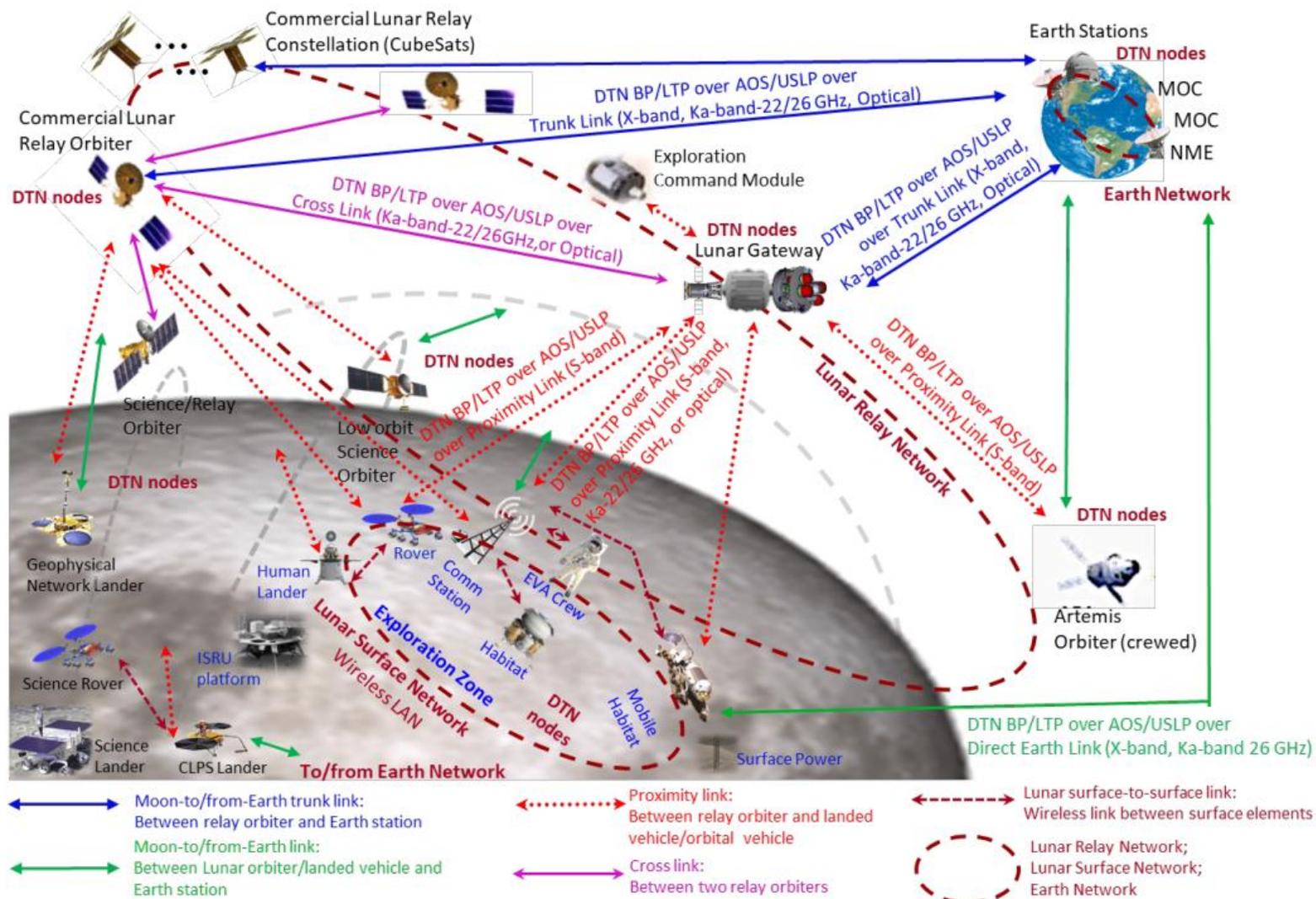


↔ Moon-to/from-Earth trunk link: Between relay orbiter and Earth station
↔ Moon-to/from-Earth link: Between Lunar orbiter/landed vehicle and Earth station
⋯↔ Proximity link: Between relay orbiter and landed vehicle/orbital vehicle
↔ Lunar surface-to-surface link: Wireless link between surface elements

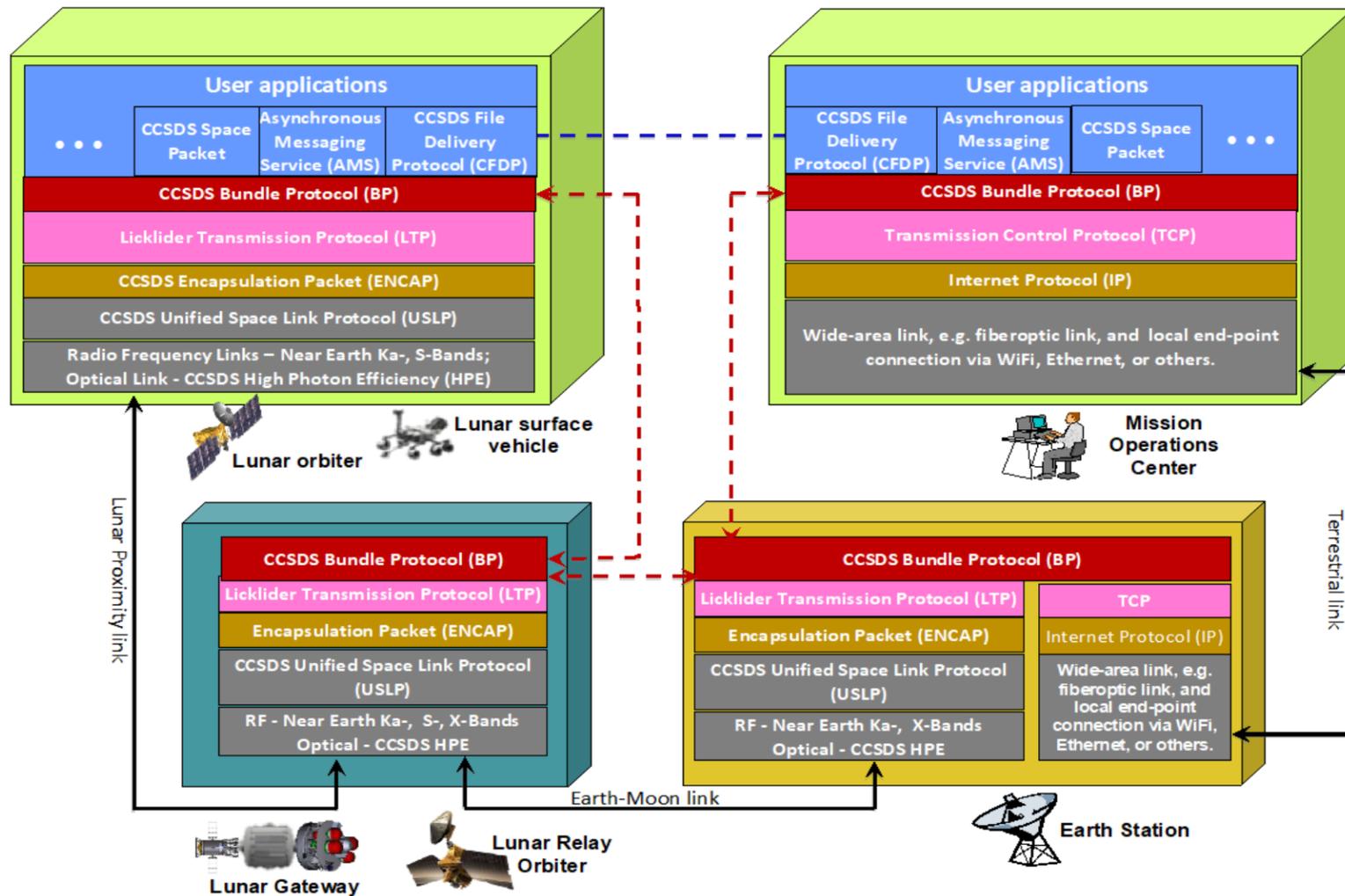
* Note: X-band for Lunar proximity link is strongly discouraged as it violates ITU's Shielded Zone of the Moon (SZM) protection



Lunar Communication Architecture Vision (up to year 2030)

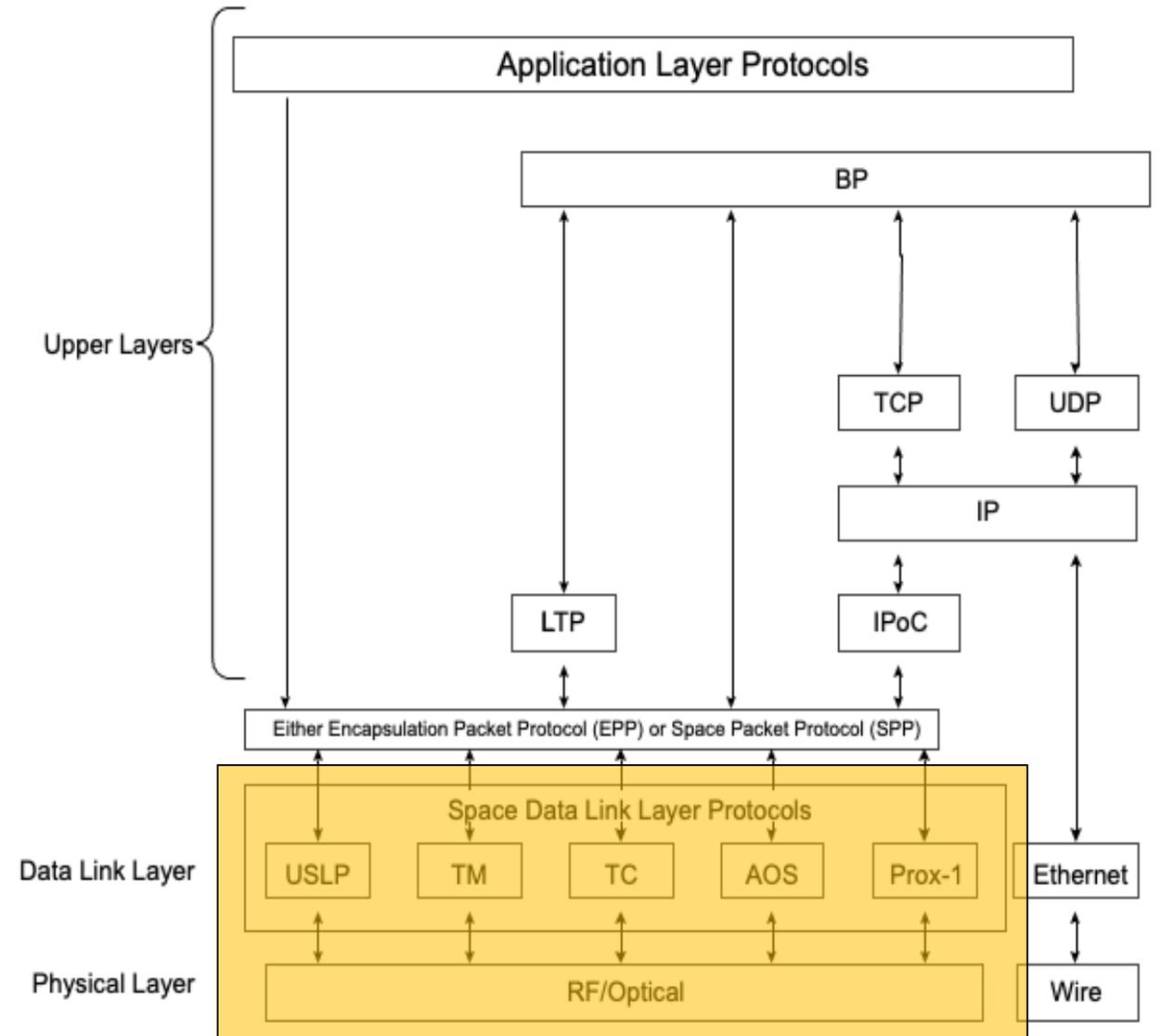


Candidate Protocol Architecture



CCSDS Protocol Stack

- The Space Data Link Protocols (SDLPs) are protocols of the Data Link Layer of the OSI Basic Reference Model
- They were designed by CCSDS to meet the requirements of space missions for efficient transfer of space application data of various types and characteristics on space links.
- Designed CCSDS SDLPs can meet diverse requirements in terms of reliability and QoS, in relation to the specific link and scenario taken as reference
- The CCSDS Protocol stack has defined five different SDLPs:
 - USLP, TM, TC, AOS, and Proximity-1
 - Each SDLP can operate on top of RF and optical physical links, whose specification is provided in standalone CCSDS standards

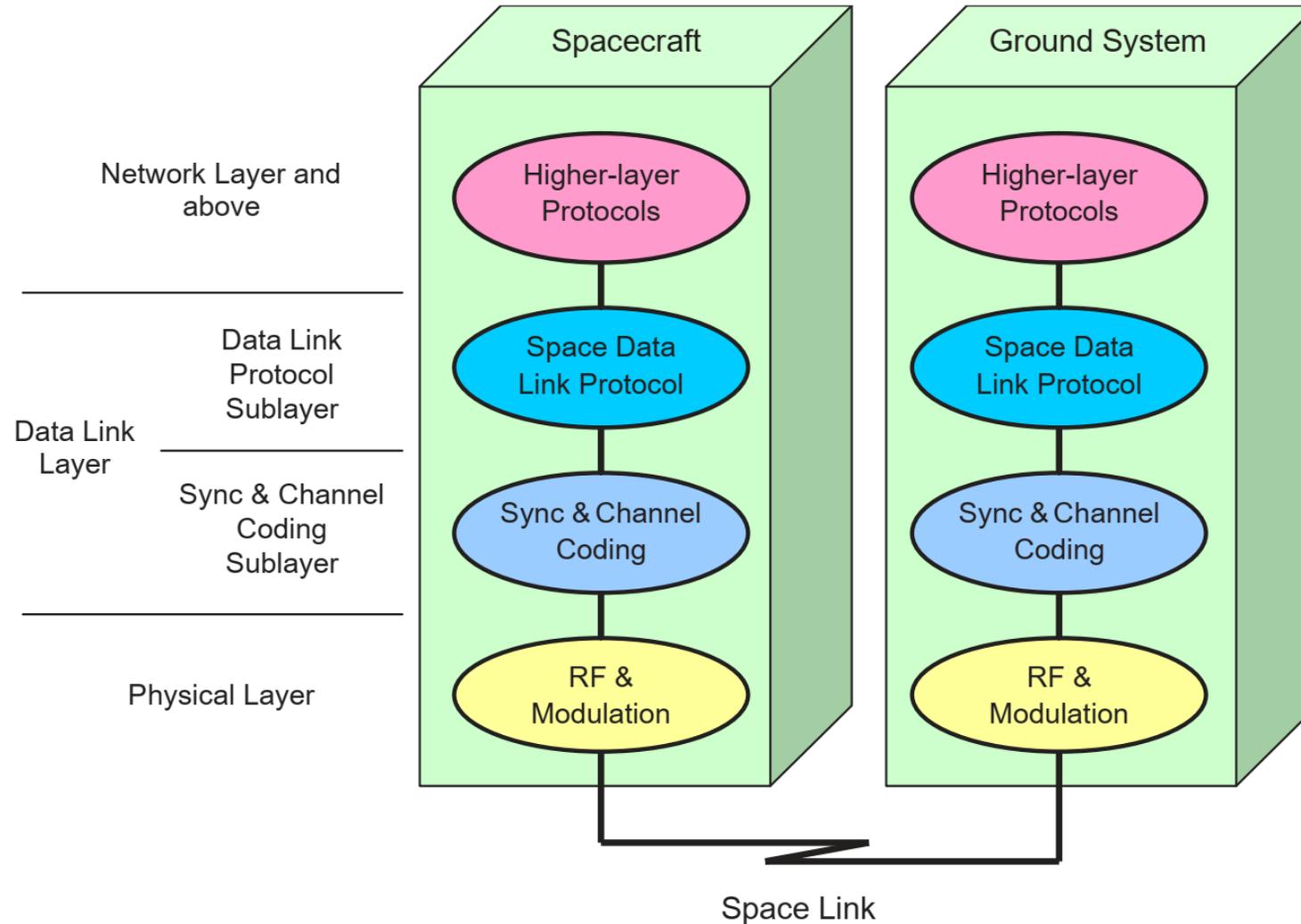


CCSDS Protocol Stack

- CCSDS defines two Sublayers in the Data Link Layer of the OSI Model:
 - Data Link Protocol Sublayer
 - It specifies methods of transferring data units provided by the higher layer over a point-to-point space link using data units known as Transfer Frames
 - Synchronization and Channel Coding Sublayer.
 - It specifies methods of synchronization and channel coding for transferring Transfer Frames over a space link.
- The SLDP can provide security measures by means of the SDLS protocol:
 - Optional (i.e., use driven by mission requirements)
 - Functionalities (authentication and confidentiality) embedded in the header of frames
 - No profile defined yet for CCSDS Proximity-1



CCSDS Protocol Stack



CCSDS Recommendations

- Space datalink protocols:
 - CCSDS 132.0-B-3, TM Space Data Link Protocol
 - CCSDS 232.0-B-4, TC Space Data Link Protocol
 - CCSDS 232.1-B-2, Communications Operation Procedure-1
 - CCSDS 211.0-B-6, Proximity-1 Space Link Protocol-Data Link Layer
 - CCSDS 732.0-B-4, AOS Space Data Link Protocol
 - CCSDS 732.1-B-2, Unified Space Data Link Protocol
 - CCSDS 355.0-B-2 Space Data Link Security Protocol
 - CCSDS 355.1-B-1 Space Data Link Security Protocol--Extended Procedures
- Coding and Synchronisation sublayer protocols:
 - CCSDS 131.0-B-3 TM Synchronization and Channel Coding
 - CCSDS 231.0-B-4, TC Synchronization and Channel Coding
 - CCSDS 131.3-B-2 CCSDS Space Link Protocols over ETSI DVB-S2 Standard
 - CCSDS 211.2-B-3, Proximity-1 Space Link Protocol--Coding and Synchronization Sublayer
 - CCSDS 142.0-B-1 Optical Communications Coding and Synchronization
 - CCSDS 131.2-B-2 Flexible Advanced Coding and Modulation Scheme for High Rate Telemetry Applications
 - CCSDS 431.1-B-1, Variable Coded Modulation Protocol



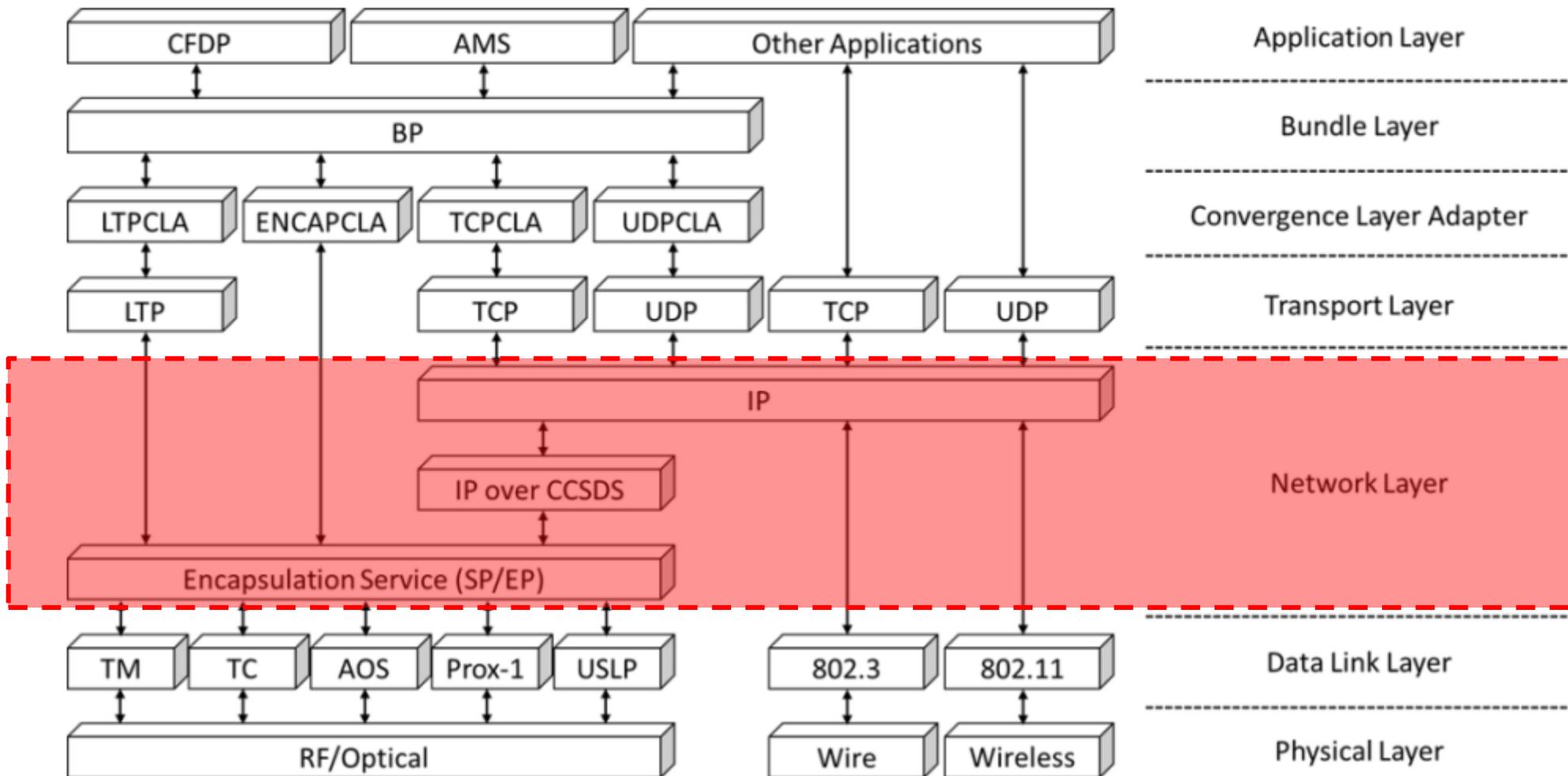
CCSDS Recommendations

- Physical layer:
 - CCSDS 401.0-B-32 Radio Frequency and Modulation Systems—Part 1: Earth Stations and Spacecraft
 - CCSDS 414.1-B-3 Pseudo-Noise (PN) Ranging Systems
 - CCSDS 415.1-B-1 Data Transmission and PN Ranging for 2 GHz CDMA Link via Data Relay Satellite
 - CCSDS 211.1-B-4, Proximity-1 Space Link Protocol--Physical Layer

 - CCSDS 141.0-B-1 Optical Communications Physical Layer
- Others:
 - CCSDS 130.0-G-3 Overview of Space Communications Protocols
 - CCSDS 130.2-G-3 Space Data Link Protocols--Summary of Concept and Rationale



CCSDS Protocol Stack



Network Layer Protocols within CCSDS

- IP (v4 or v6, as defined within IETF)
 - Support of IP-based streams in CCSDS available by means of the IPoC (IP over CCSDS) shim layer
→More details in the next slides of this section
- Space Packet Protocol:
 - Capability to transfer space application data over a path that involves a ground-to-space or a space-to-space communications link
 - Used at application layer to directly embed user data for later transmission over CCSDS space links
 - Used as shim layer to act as „intermediate“ between upper layer and CCSDS Space Link Protocols
→More details in the next slides of this section
- Encapsulation Packet Protocol:
 - Function of encapsulating the PDU generated by the higher layers of the CCSDS protocol stack into the underlying CCSDS Space Link Protocols
→More details in the next slides of this section
- All protocols are best effort and delegate reliability, congestion/flow control functionalities to the other protocol layers of the CCSDS protocol stack
- QoS management is also outside the core functionalities and can be provided by other CCSDS protocols



CCSDS Recommendations

- CCSDS 133.1-B-3, Encapsulation Packet Protocol
- CCSDS 133.0-B-2, Space Packet Protocol
- CCSDS 702.1-B-1, IP over CCSDS Space Links
- CCSDS 130.0-G-3, Overview of Space Communications Protocols



Review of CCSDS SIS Area Activities

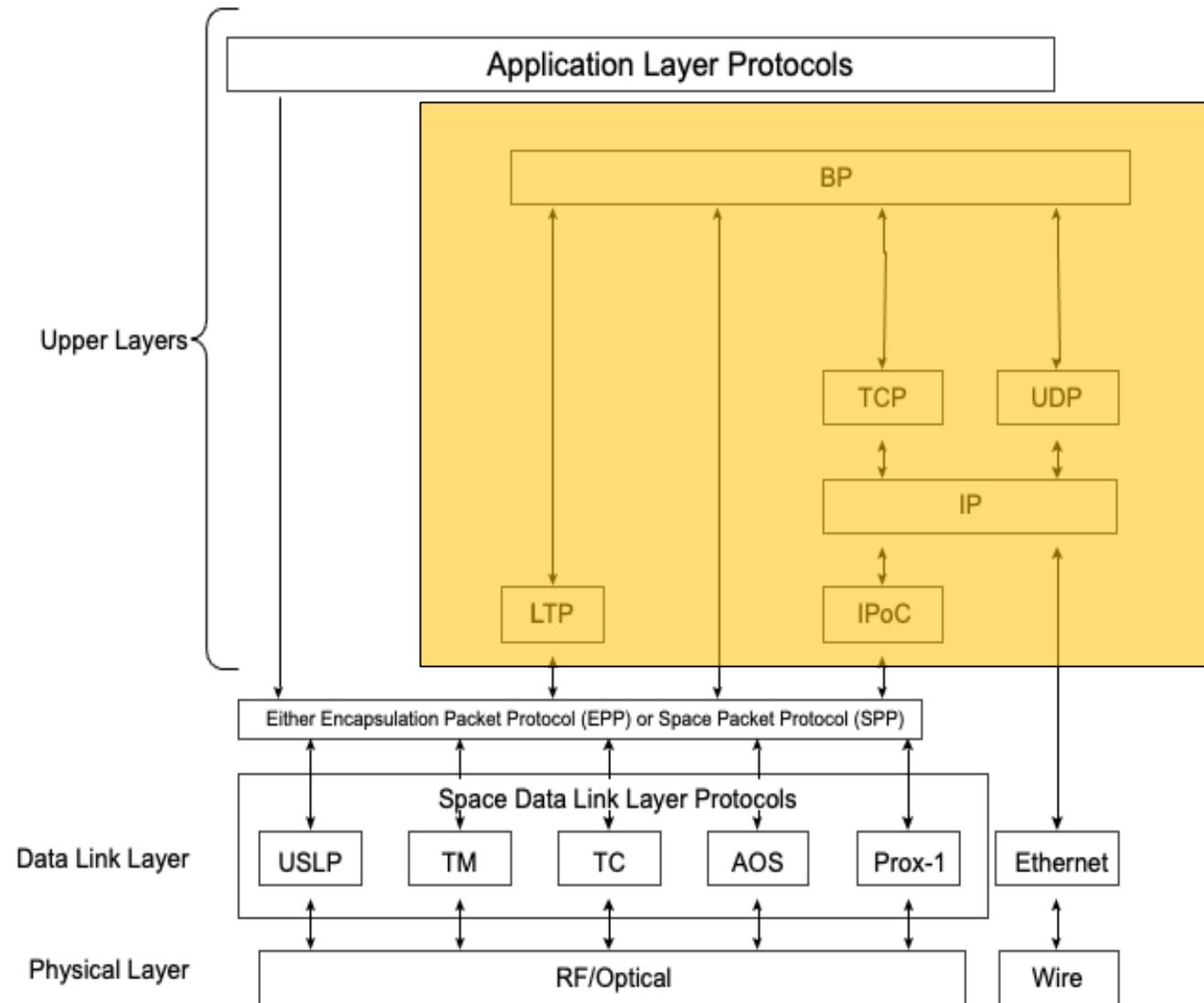


Knowledge for Tomorrow

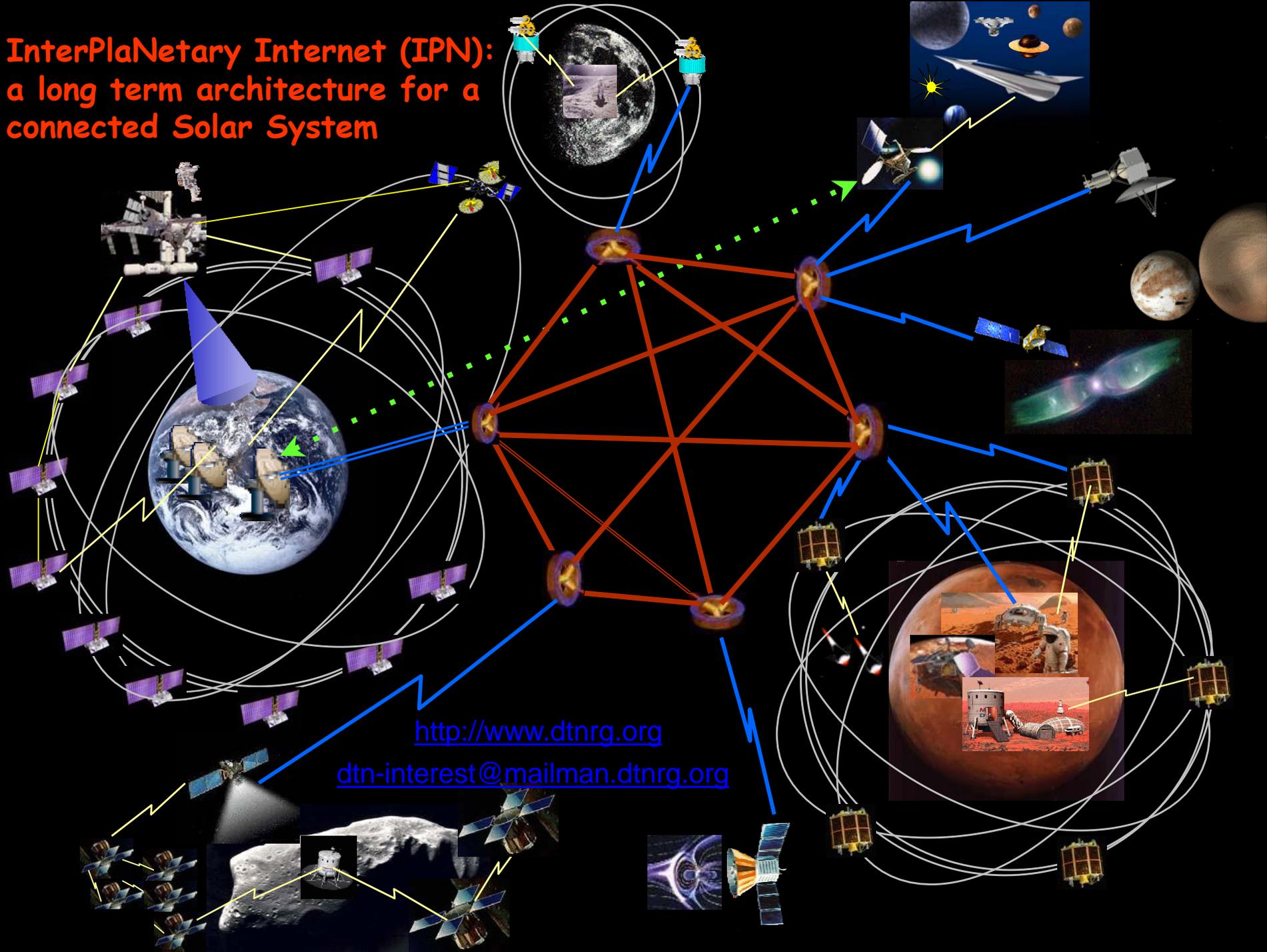


CCSDS Protocol Stack

- Internetworking services are offered by the Delay-Tolerant Network (DTN) architecture to allow for operations in complex missions
- Different features are therein offered:
 - Store-forward operations
 - Routing/forwarding
 - Quality of service
 - Management
 - Security
 - Optional reliability
 - Interface to upper layer services
- DTN is encompassed of two main protocols:
 - Bundle Protocol (BP)
 - Licklider Transmission Protocol (LTP)
- DTN is also the baseline for the Solar System Internet (SSI)

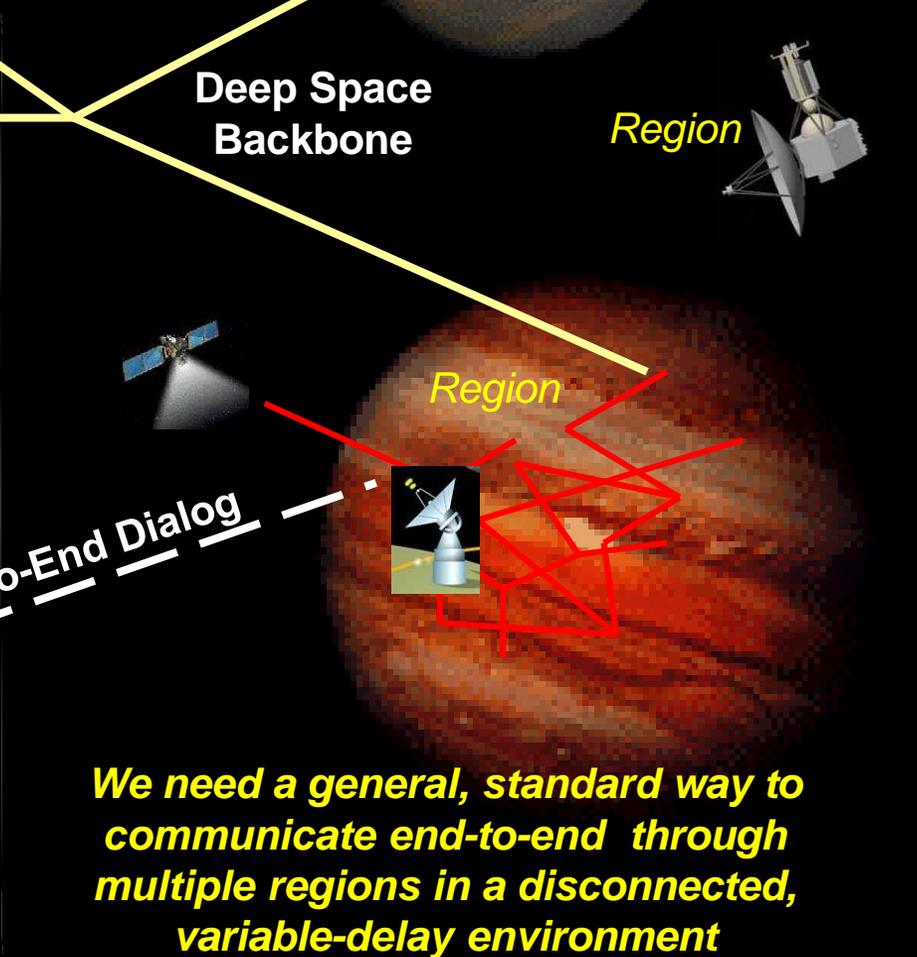
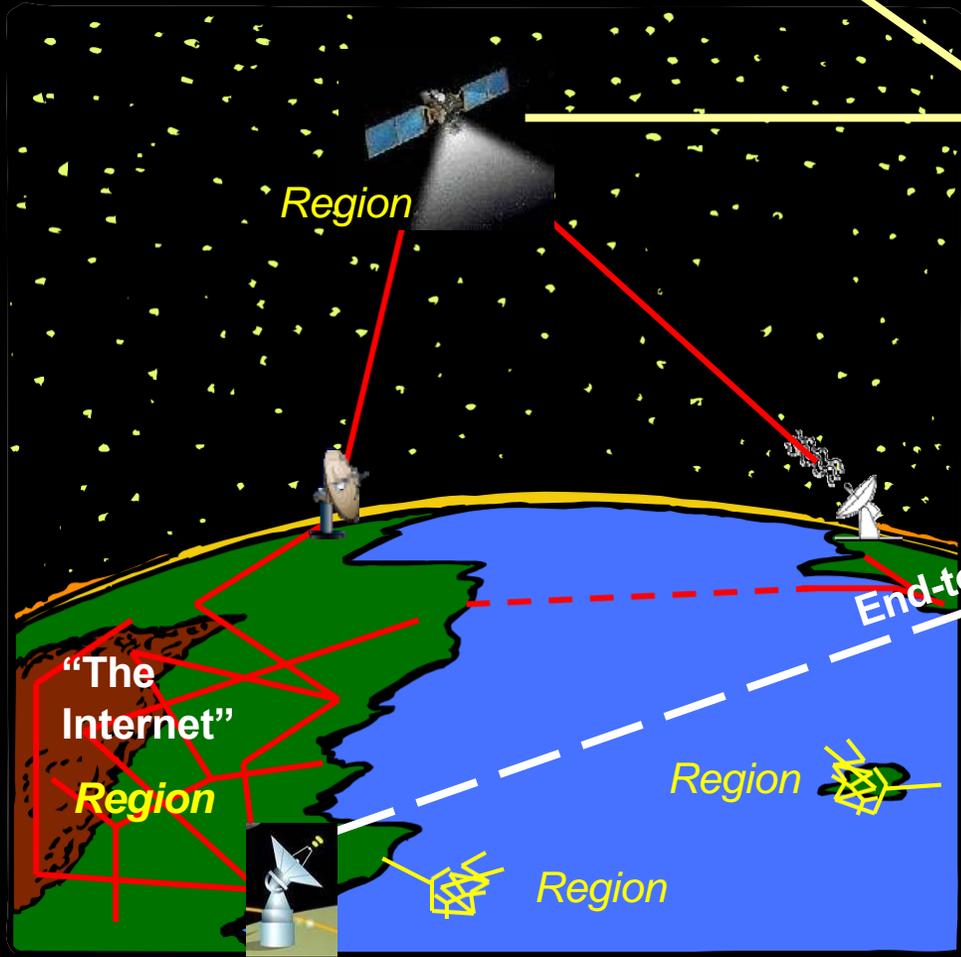


InterPlaNetary Internet (IPN): a long term architecture for a connected Solar System



<http://www.dtnrg.org>
dtn-interest@mailman.dtnrg.org

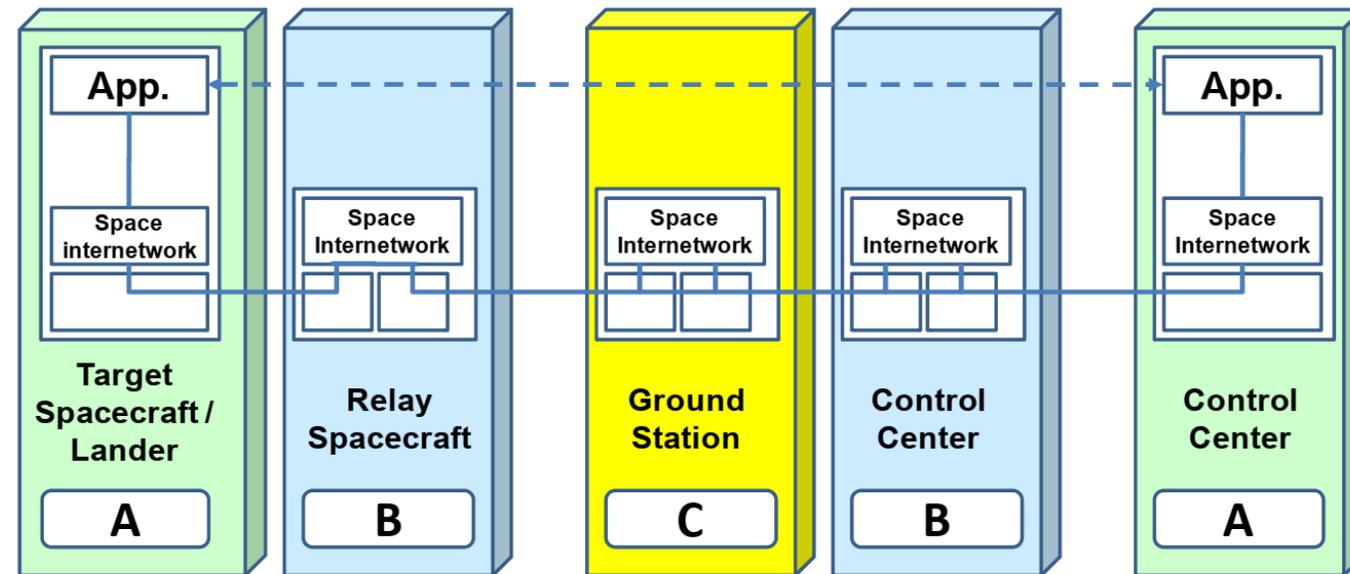
Interplanetary Internet: a "network of regional internets"



We need a general, standard way to communicate end-to-end through multiple regions in a disconnected, variable-delay environment

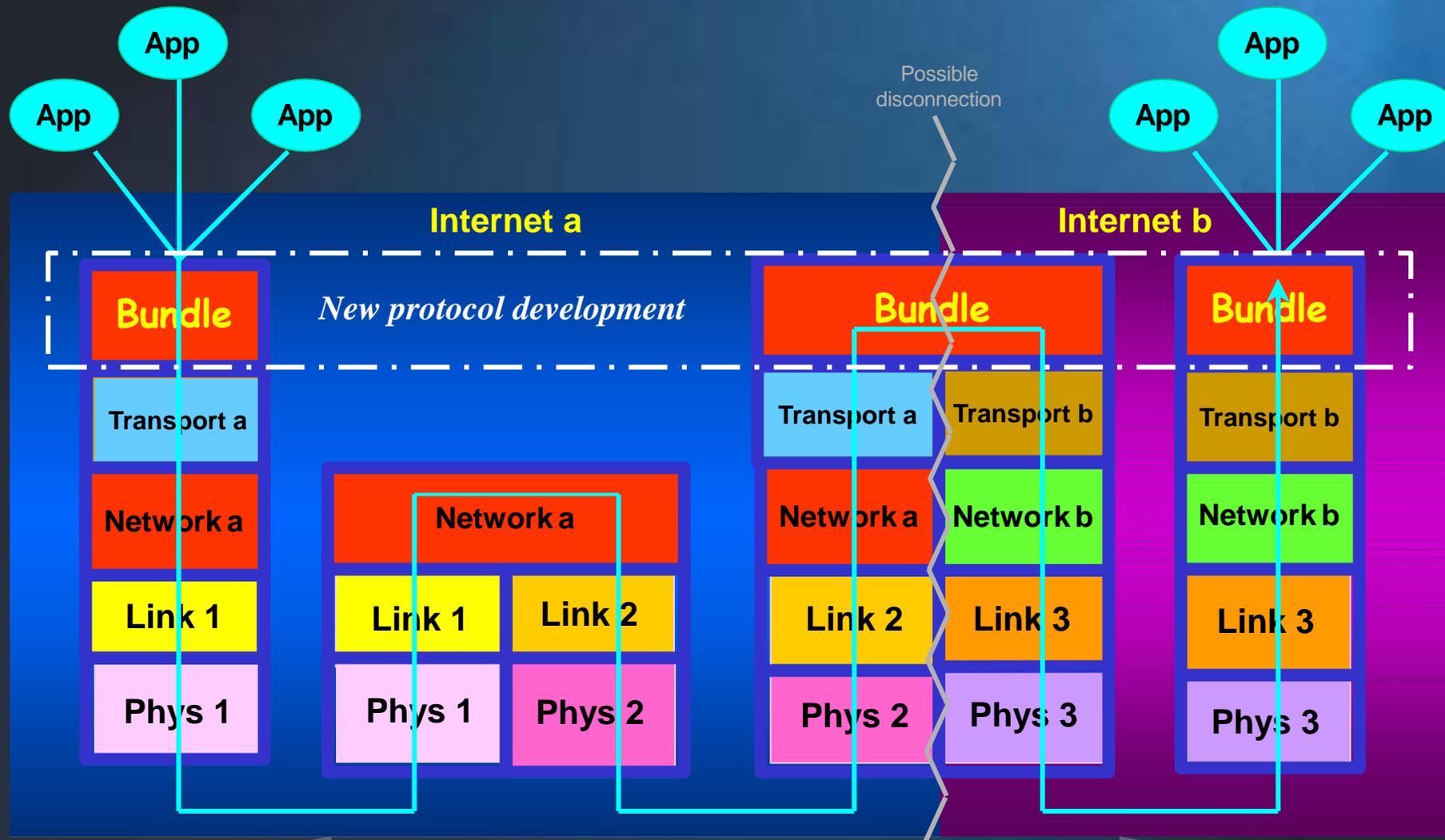
Internetworking Service Requirements

- An Optionally Reliable End-to-End Application Data Unit Delivery Service
- Ability to Handle Arbitrarily Sized Application Layer PDUs
- End-to-End SDU Delivery in the Presence of Delays/Disruptions
- Data Accountability
- Optional Reliability
- Prioritized Data Delivery
- Data Link Layer Agility
- Compatibility with the Terrestrial Internet
- Security
- Management
- Support for Higher-Layer Services



Bundles: A Store and Forward Application Overlay

The "Thin Waist" of the Interplanetary Internet



CCSDS Recommendations

- CCSDS 730.1-G-1, Solar System Internetwork (SSI) Architecture
- CCSDS 734.0-G-1, Rationale, Scenarios, and Requirements for DTN in Space
- CCSDS 734.1-B-1, Licklider Transmission Protocol (LTP) for CCSDS
- CCSDS 734.2-B-1, CCSDS Bundle Protocol Specification
- CCSDS 734.3-B-1, Schedule-Aware Bundle Routing



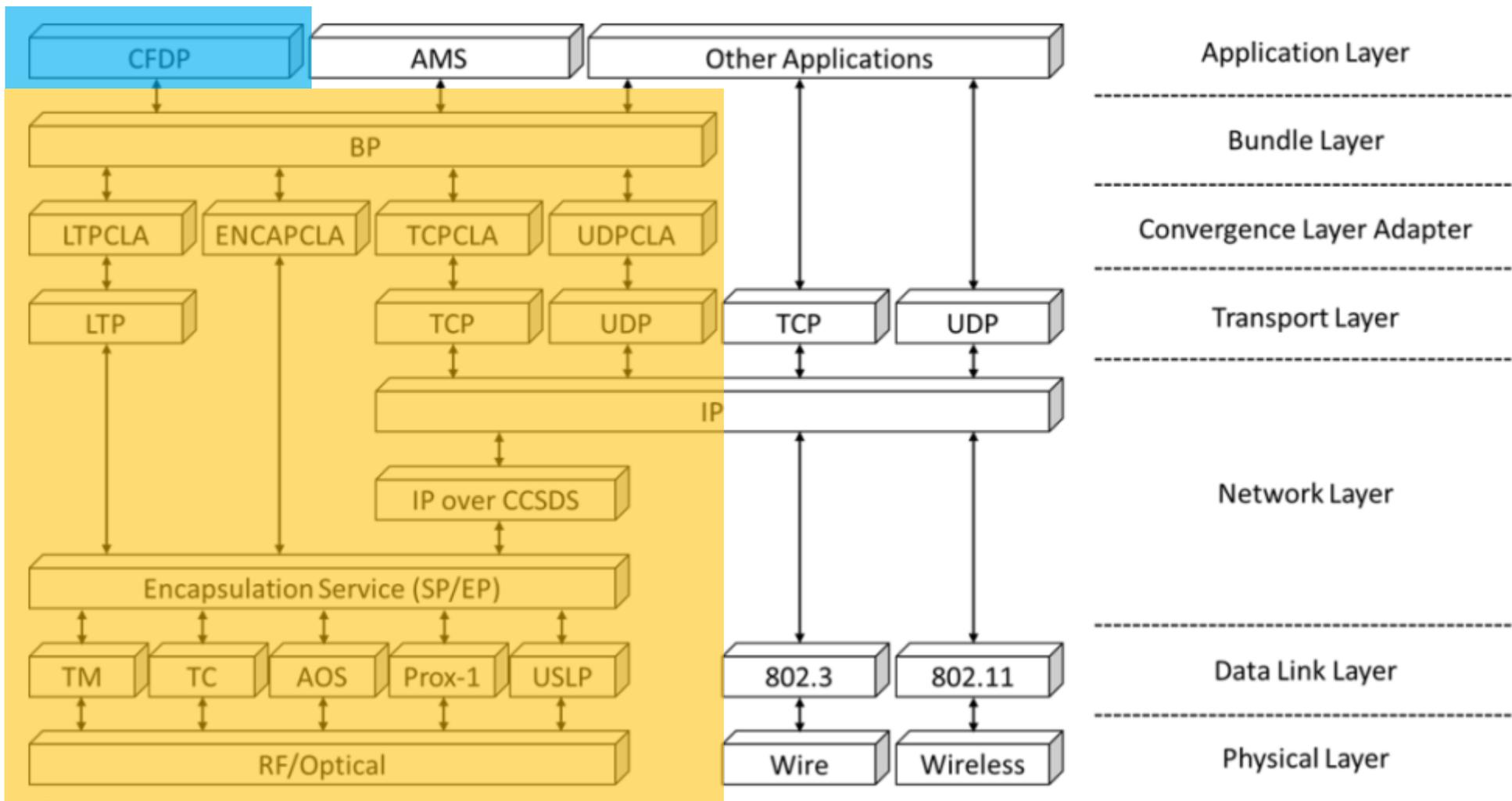
Convergence Layer Adapters (CLAs)

- Convergence Layer Adapters (CLAs) are necessary to support mission operations both in space and on the ground.
- There are many possible convergence layer protocols to support the various communications interfaces with which the Bundle Protocol may interact.
- So far CCSDS/IETF define the following CLAs:
 - LTP
 - TCP
 - UDP
 - Encapsulation Packet/Space Packet Protocol



CFDP in the CCSDS Protocol Stack

DTN detailed view



CFDP – Design Goals

- CFDP provides the capability to transfer 'files' to and from a spacecraft mass memory.
- The content of the files may be anything from a conventional timeline update to an unbounded SAR image.
- Files can be transferred reliably, when it is guaranteed that all data will be delivered without error, or unreliably, when a 'best effort' delivery capability is provided.
- Files can be transmitted with a unidirectional link, a half-duplex link, or a full-duplex link, with near-Earth and deep-space delays.
- File transfer can be triggered automatically or manually.



CCSDS recommendations

- CCSDS 727.0-B-5, CCSDS File Delivery Protocol (CFDP)
- CCSDS 720.1-G-4, CCSDS File Delivery Protocol (CFDP)—Part 1: Introduction and Overview
- CCSDS 720.2-G-4, CCSDS File Delivery Protocol (CFDP)—Part 2: Implementers Guide
- CCSDS 722.1-M-1, Operation of CFDP over Encapsulation Service



Ongoing work in SIS area

- Update to Bundle Protocol Specification
 - CCSDS profile of BPv7 IETF RFC
 - Ongoing finalization of the book revision according to the received comments
 - Preparation of the interoperability testing
- Bundle Protocol Security Protocol (BPsec) for CCSDS
 - CCSDS profile of Bpsec IETF RFC
 - Ongoing finalization of the book revision according to the received comments
- Licklider Transmission Protocol - 5-year Review
 - Ongoing finalization of the book update upon CESG review comments



Ongoing work in SIS area

- CCSDS File Delivery Protocol (CFDP) - Pink Sheets
 - Ongoing update of existing v5 towards v6
 - Aim it to clarify some parts of the specification and making optional features which are not anymore considered essential for future missions
- CFDP Unitdata Transfer Layers
 - Ongoing update of the existing version
 - Extension of UT layer so as to include also TCP, UDP, BP, LTP and SPP



Ongoing work in SIS area

- **Compressed Bundle Status Reporting and Custody Signaling**
 - Definition of mechanisms to efficiently report on bundle status (e.g. received, transmitted, etc.).
 - Support for end-to-end retransmission and/or in-network reliability (custody transfer).
- **DTN Multipoint Delivery**
 - Multipoint naming scheme (IMC) that builds on the IPN naming scheme
 - Definition of Bundle Protocol extensions. The Bundle Protocol extensions include a Multicast Extension Block and a Multicast Briefing Administrative Message.
- **High Performance Reliability Protocol (HPRP)**
 - Support for reliable or unreliable delivery of blocks of data over space-to-ground, ground-to-space, and space-to-space links.
 - Efficient segment-level re-transmission mechanism, suitable for highly asymmetrical data rates with large round-trip delays (inter-planetary communications) and ultra-high-rate links with very small latencies (near-Earth/Cislunar communications).
 - Design tailored to high-speed processing on typical flight hardware including FPGA and ASIC
 - HPRP protocol is an evolution of the LTP, though not backward compatible



New items to start soon

- **Bundle Protocol Quality of Service Extensions**

- Definition of quality of service (QoS) extensions for Bundle Protocol → a new BP extension block and related policies.
- Definition of different traffic priorities as well as possibly other flavors/levels of QoS.

- **DTN Network Management**

- Logical architecture of the DTN network management ecosystem
- Data model used to express management directives
- Structured syntax used to identify model objects
- Transport encodings and a binding to carrying those encodings over the Bundle Protocol
- **Existing blue/green book on this subject will be disbanded soon**

- **Bundle in Bundle Encapsulation**

- Service for the transportation of a bundle within another bundle.
- Specification of the service as a convergence layer protocol for BPv7.



Thank you for the attention!

For any questions → tomaso.decola@dlr.de



Knowledge for Tomorrow

