



SSI Communication – Standardisation & Governance

A Perspective from the European
Space Agency

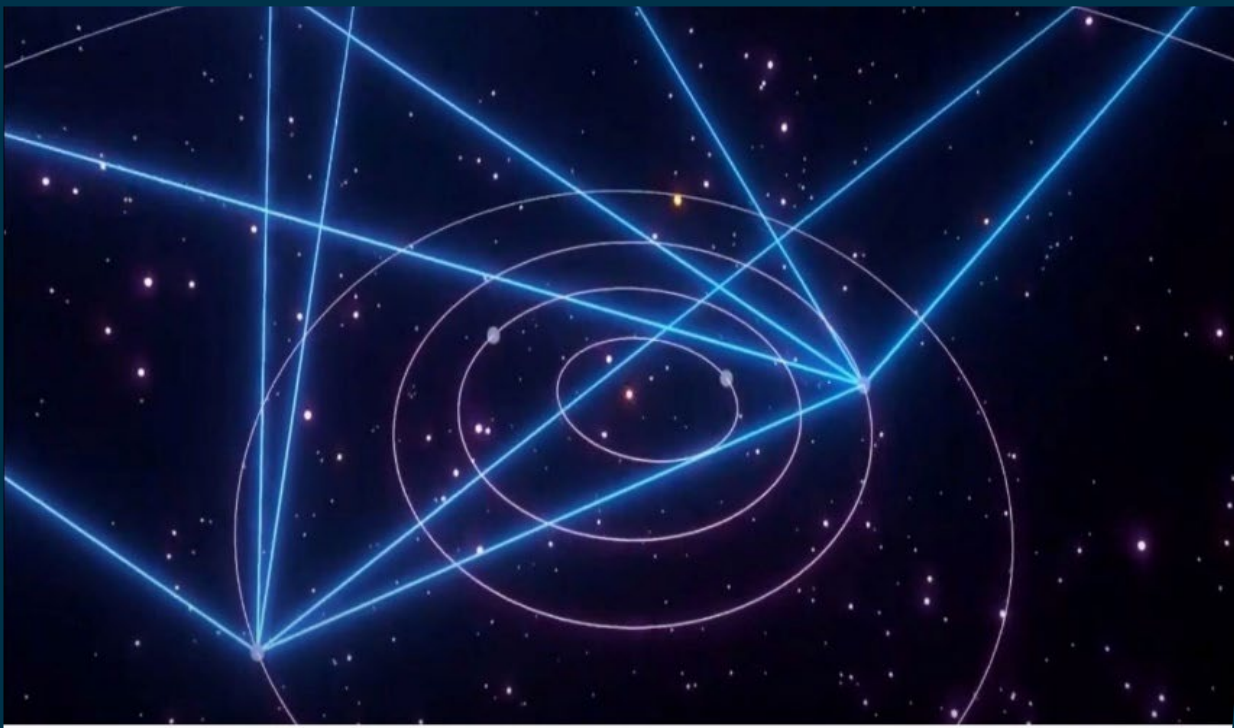
Felix Flentge

Space-Terrestrial Internetworking Workshop

15 September 2026

EUROPEAN SPACE AGENCY





ESA's Solar System Internet Vision

Establish a European **interoperable institutional** and **commercial** infrastructure with an appropriate **governance** and **operational concept** for providing network-based radio frequency and optical **communication** and **navigation** services to institutional and commercial missions in the solar system based on recognized international **standards** and in collaboration with **international partners**.

ESA Strategy 2040:

- Identifies strategic actions for Solar System Internet

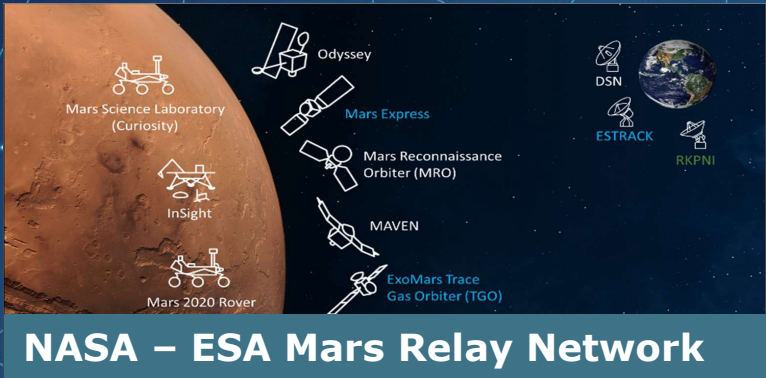
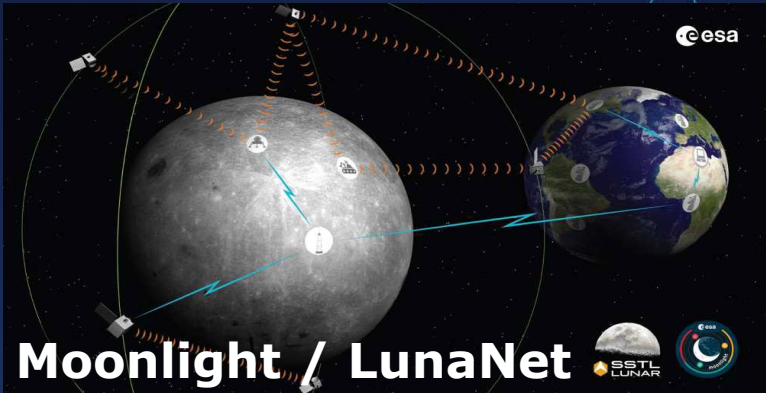
ESA Technology Vision 2040:

- Theme 'Solar System Internet, Navigation and Communication Technologies'

ESA and related networks – current & upcoming



ESA ESTRACK Augmented Network (including national & commercial assets)



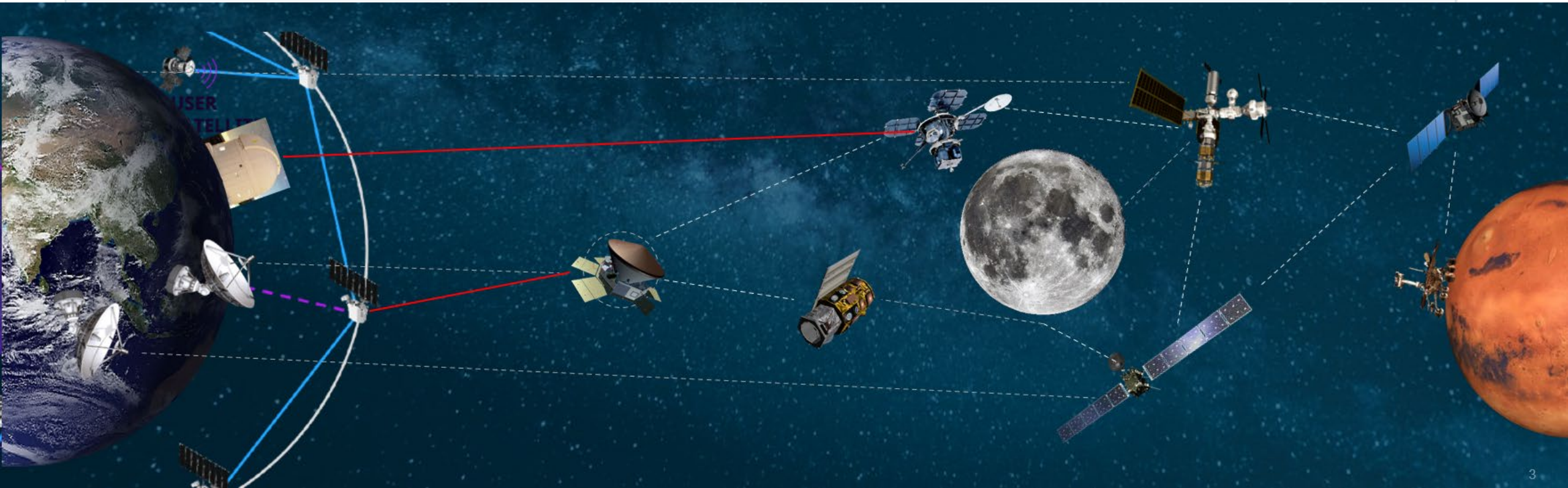
International Cross-Support

MARCONI / Lightship

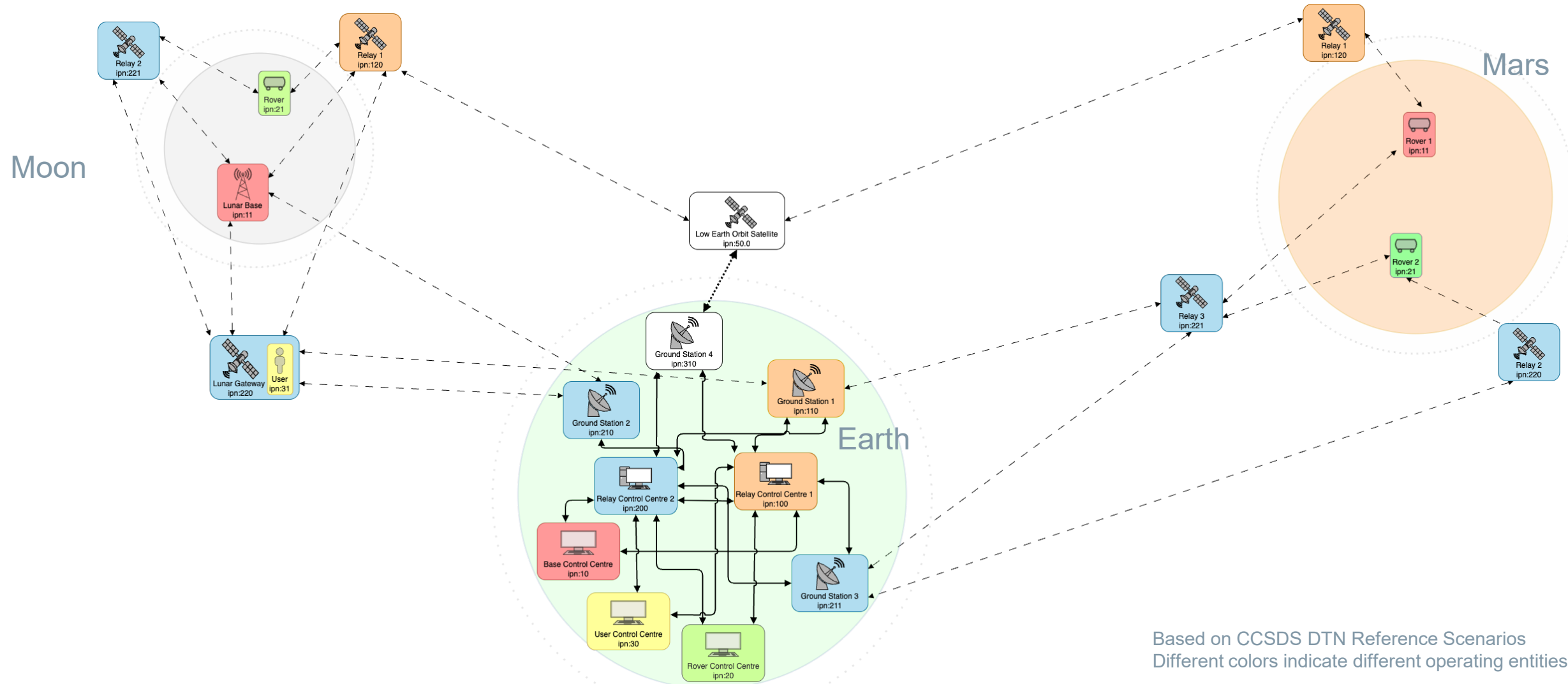
NASA – ESA Mars Relay Network

What is the Solar System Internet?

The **Solar System Internet** is a **network-of-networks** interconnecting space and ground infrastructures to provide standardised, **interoperable, delay- and disruption-tolerant communication and navigation services** across the Solar System.



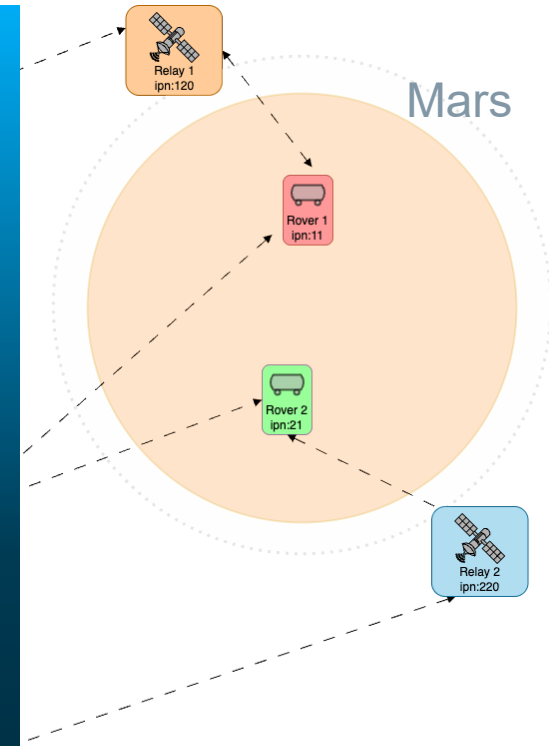
SSI – A Network of Networks



Key Characteristics:

- various users with different needs
- different providers
- heterogenous links & technology
- dynamic topology with disruptions and delays
- de-centralized planning, monitoring & control
- evolutionary growth

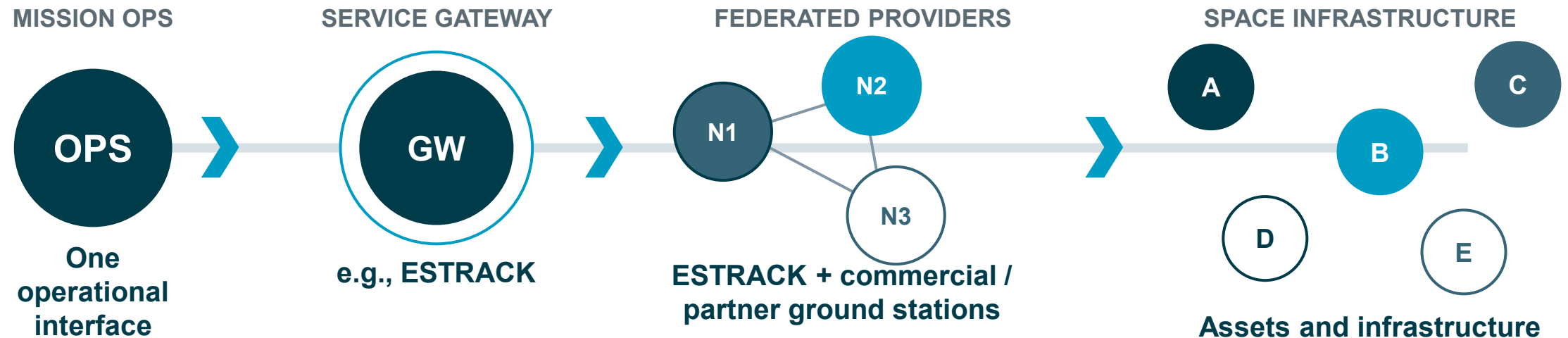
→ **ONE SSI based on interoperability & compatibility**



CCSDS DTN Reference Scenarios
Colors indicate different operating entities

Spacecraft Operator View: Operate the constellation as one delay-tolerant network

The operator buys an outcome: timely delivery through one service gateway—or a reserved direct-access slot when operations demand it.



ROUTINE / NETWORK-CENTRIC OPERATIONS

Command products reach the target asset(s) within an agreed service time; telemetry returns through the same networked service.

CRITICAL OR CONTINGENCY OPERATIONS

Direct spacecraft access remains available during an agreed or pre-planned time slot, with explicit fallback rules.

Operational contract: delivery-time objective, end-to-end status visibility, and a defined direct-access fallback.

A standards-compliant node does not automatically provide an interoperable service.

- BPv7, extensions and supporting protocols provide a common technical foundation
- Independent, interoperable implementations are available
- Operational interoperability also requires
 - Coordinated Concept of Operations (including distributed planning)
 - Link interoperability (technology, protocols, configuration)
 - Agreed identifiers & policies
 - Service Level Agreements and “user awareness”
 - Reliability & Trust

Questions that remain

- How to enable compatible and interoperable communication services?
- Who selects the protocols, profiles, procedures, policies and configuration?
- Who governs change and operation?
- Who validates interoperability?

International Governance, Standardisation & Coordination (Lunar Only)

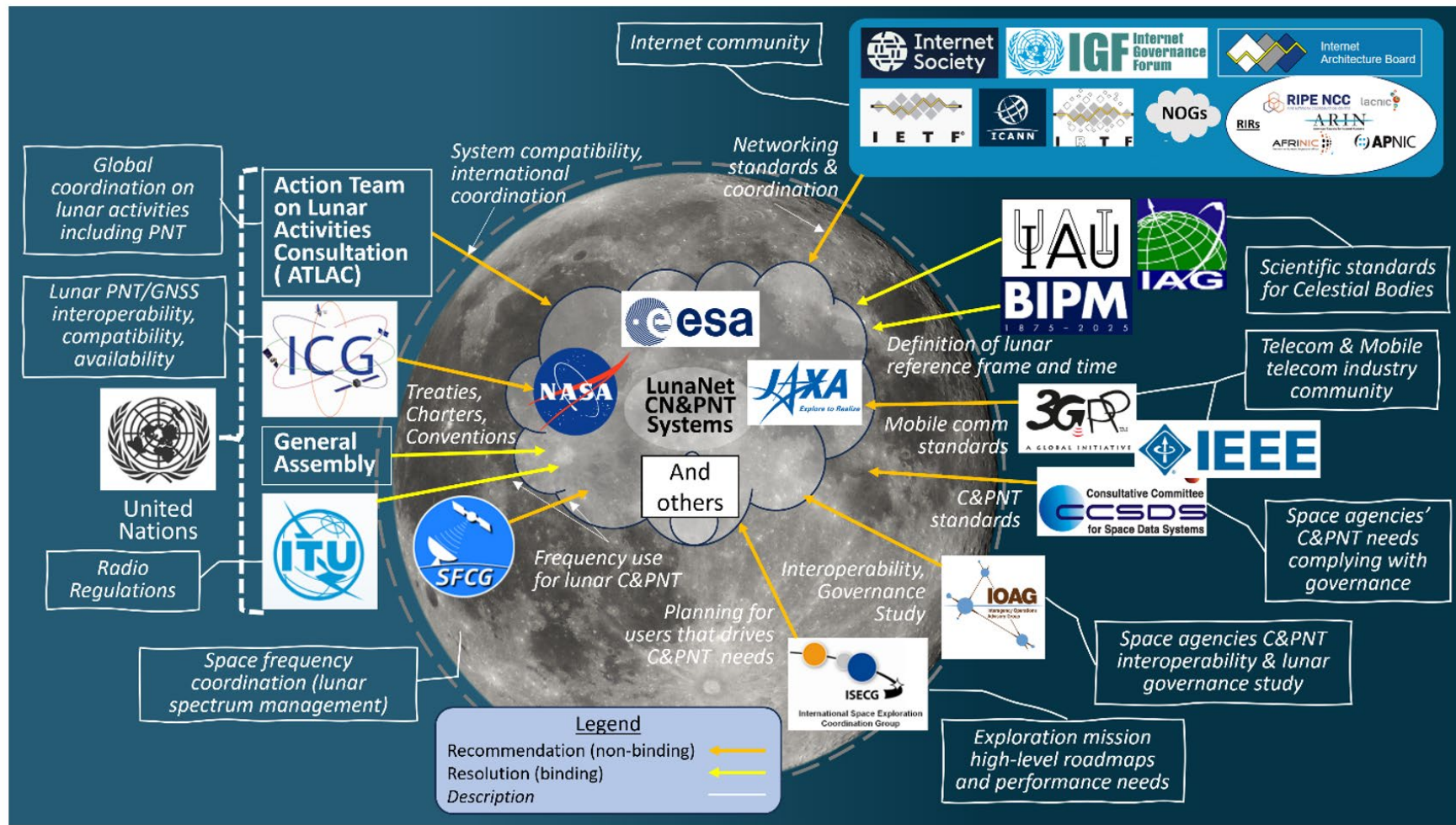
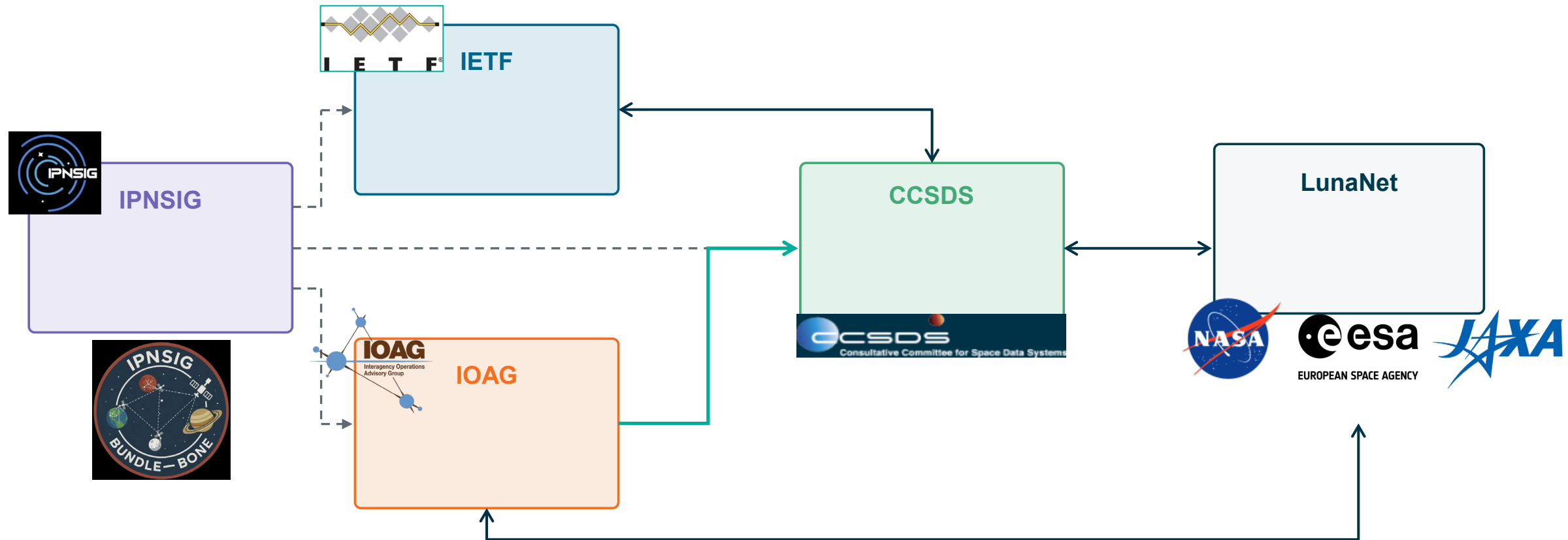


Figure 13: International organizations currently involved in lunar foundational elements.

Source: IOAG-CSLG Preliminary Study Report- 2026

International Governance, Standardisation & Coordination (Communication)

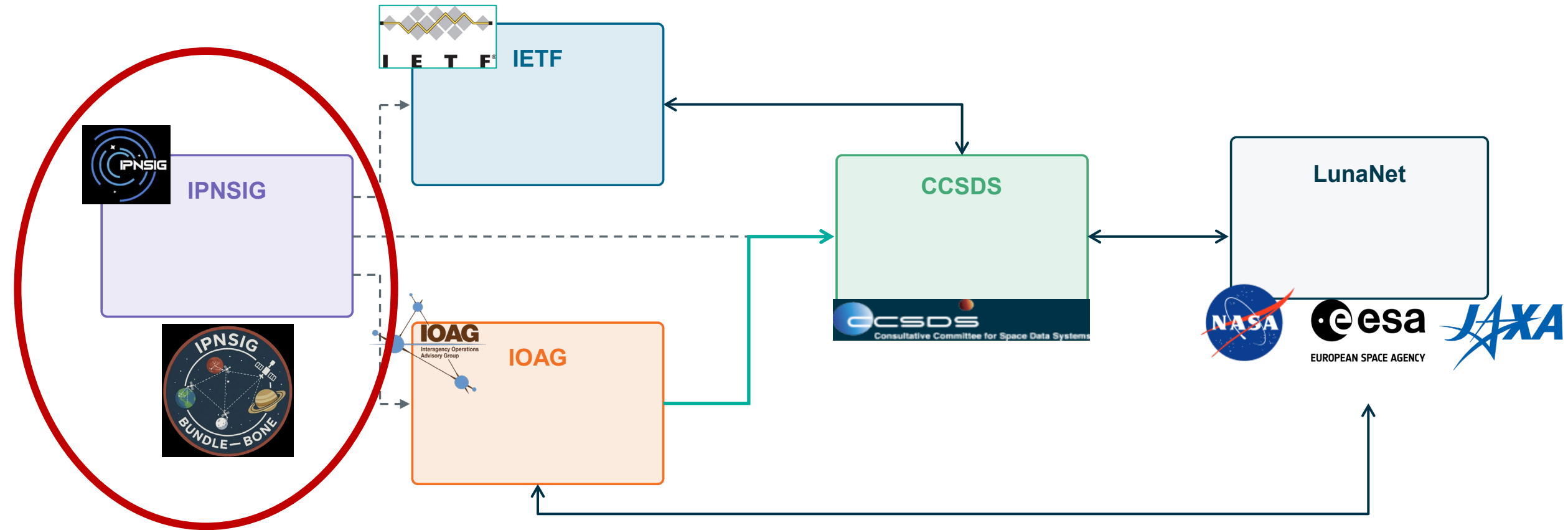
“Simplified View”



COMMON OUTCOME: interoperable services across independently operated networks

International Governance, Standardisation & Coordination (Communication)

“Simplified View”



COMMON OUTCOME: interoperable services across independently operated networks

Contribution



- Long-term Solar System Internet vision
- Architecture and multistakeholder governance principles
- Attention to fairness, transparency, interoperability and security
- Community participation beyond institutional / commercial space (Project's Working Group)
- Public Outreach
- Education via IPNSIG Academy

ESA perspective

- **IPNSIG Architecture & Governance Report increased the visibility of SSI at ESA top Management Level**
- Important forum for shaping the direction of travel
- Bridging between technical, academic and policy communities
- Not a replacement for agency cross-support agreements or operational authority

IPNSIG asks: what kind of Solar System Internet do we want to build?

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- **Supporting transition towards operational networks via Bundle Bone Initiative**

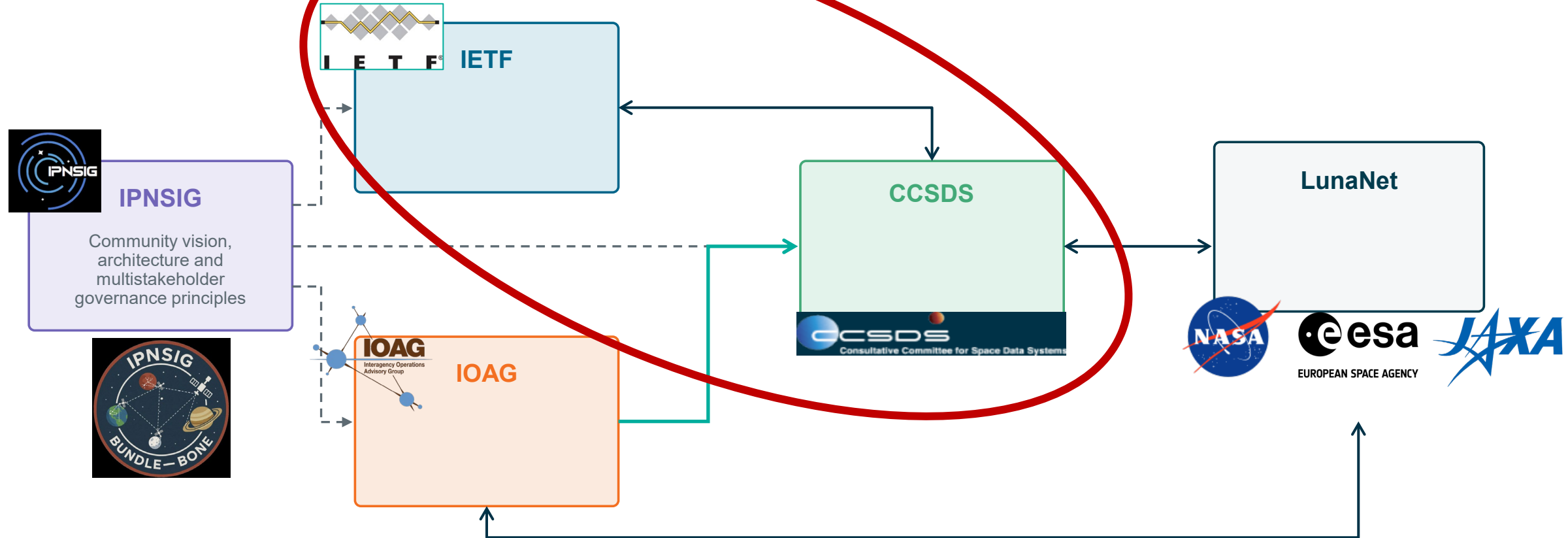
ESA perspective

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- Important forum for shaping the direction of travel
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- Not a replacement for agency cross-support agreements or operational authority
- Supporting international interoperability testing

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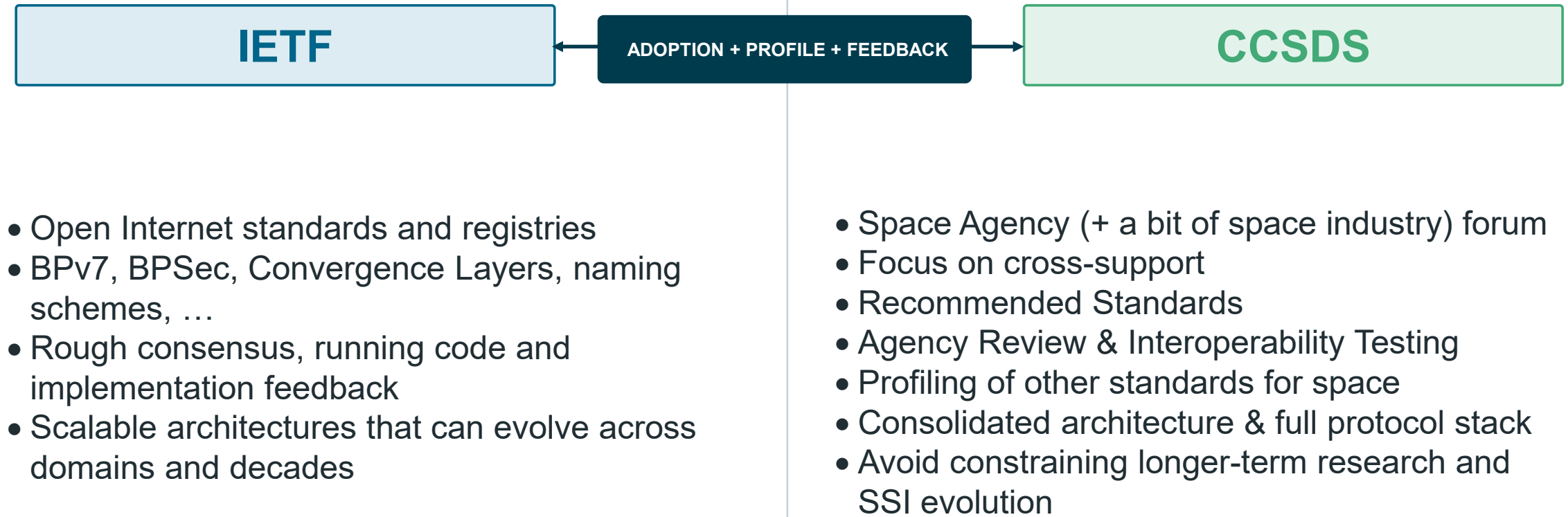
International Governance, Standardisation & Coordination (Communication)

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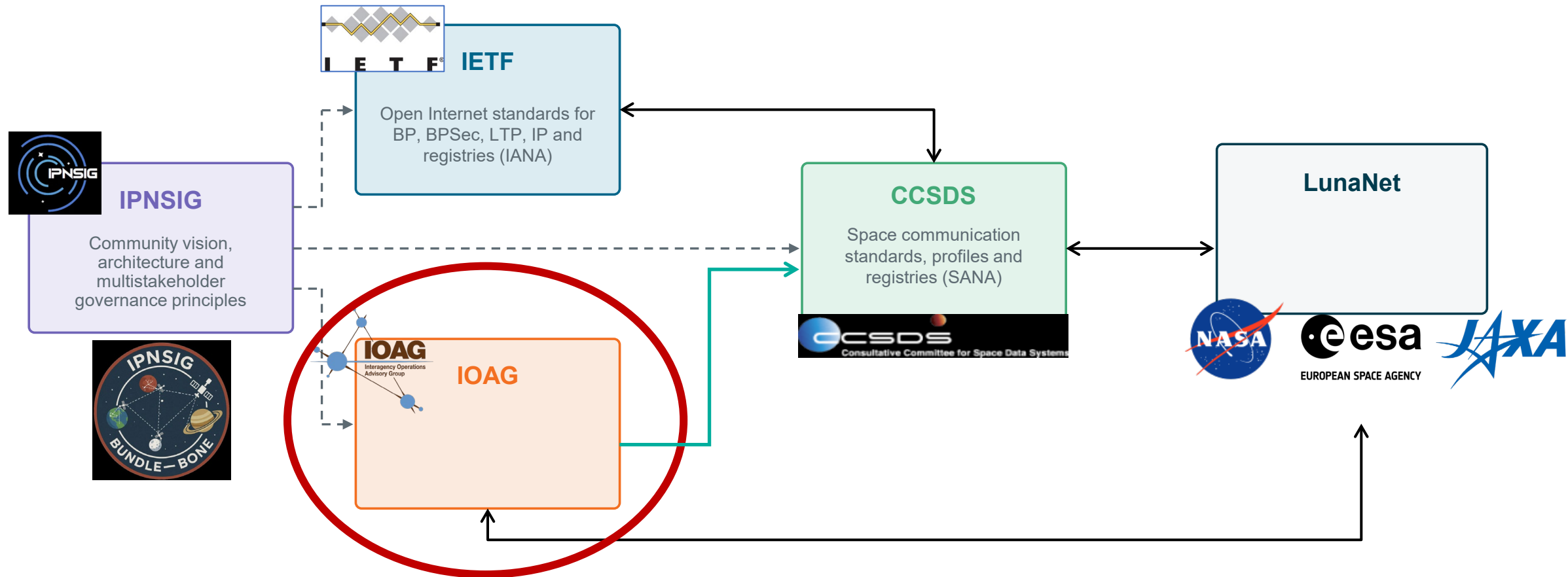
IETF & CCSDS: Collaborative & Complementary Standardisation



IETF: Broad Solar System Internet focus – CCSDS: near-term cross-support needs

International Governance, Standardisation & Coordination (Communication)

“Simplified View”



IOAG: from mission needs to interagency interoperability

IOAG coordination value



For SSI communication

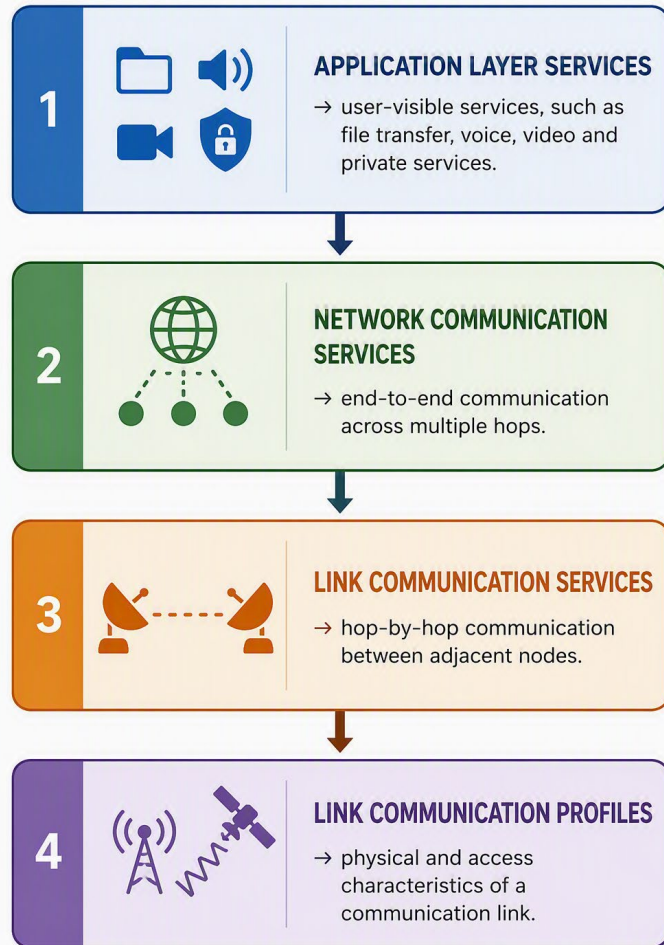
- Forum for agencies to identify common needs
- Agreement on cross-support services and interoperability
- Service catalogues and architecture studies
- Coordination of interoperability demonstrations
- Operations / Programme Participation
- Interoperability Plenary with agency top management to set priorities

- Maintain a coherent service architecture
- Coordinate user and provider needs
- Identify gaps and initiate standards work (IOAG-CCSDS Product Agreement)
- Feed operational experience back into standards
- Demonstrate practical interoperability between agencies' (operational) networks

SSI Communication Service Concept

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SSI SERVICE ARCHITECTURE

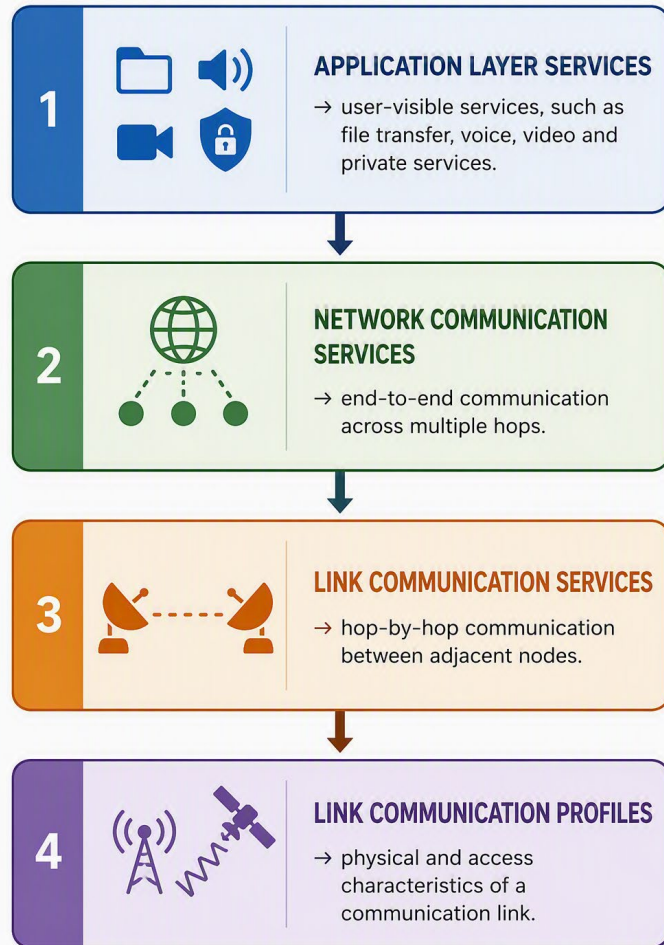


Concept aligned with IOAG Service Catalog #2.

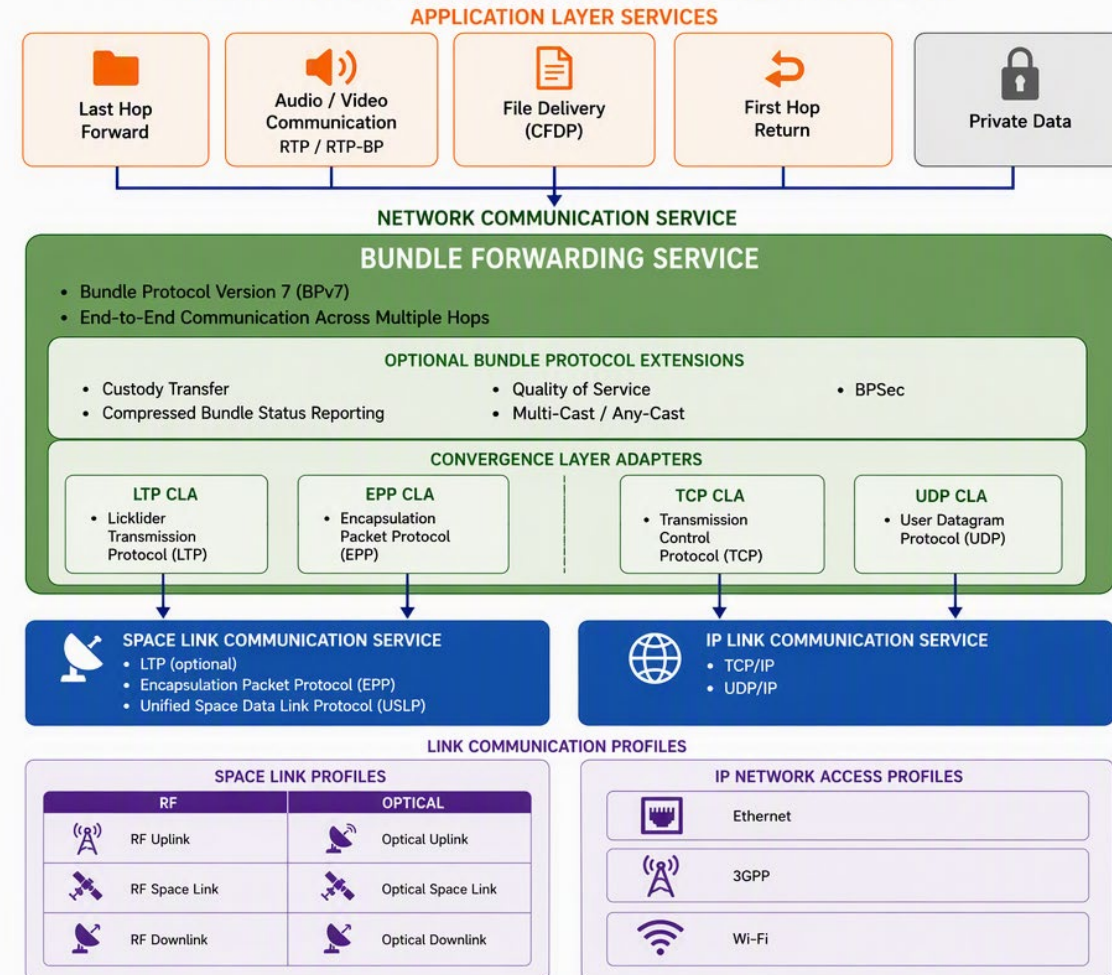
SSI Communication – DTN Bundle Protocol (Inter-)Networking

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SSI SERVICE ARCHITECTURE



BUNDLE FORWARDING SERVICE ARCHITECTURE

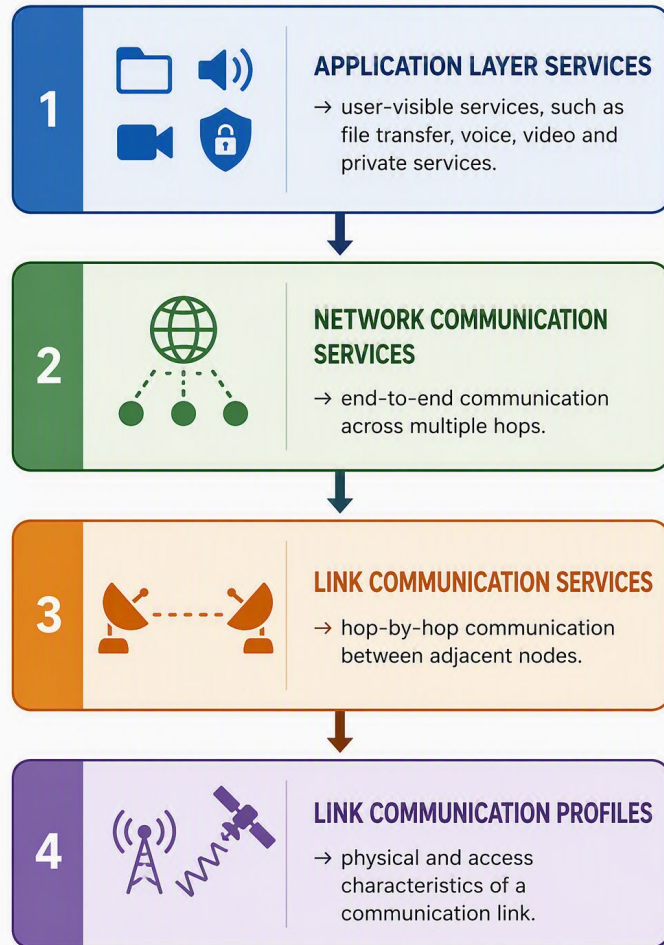


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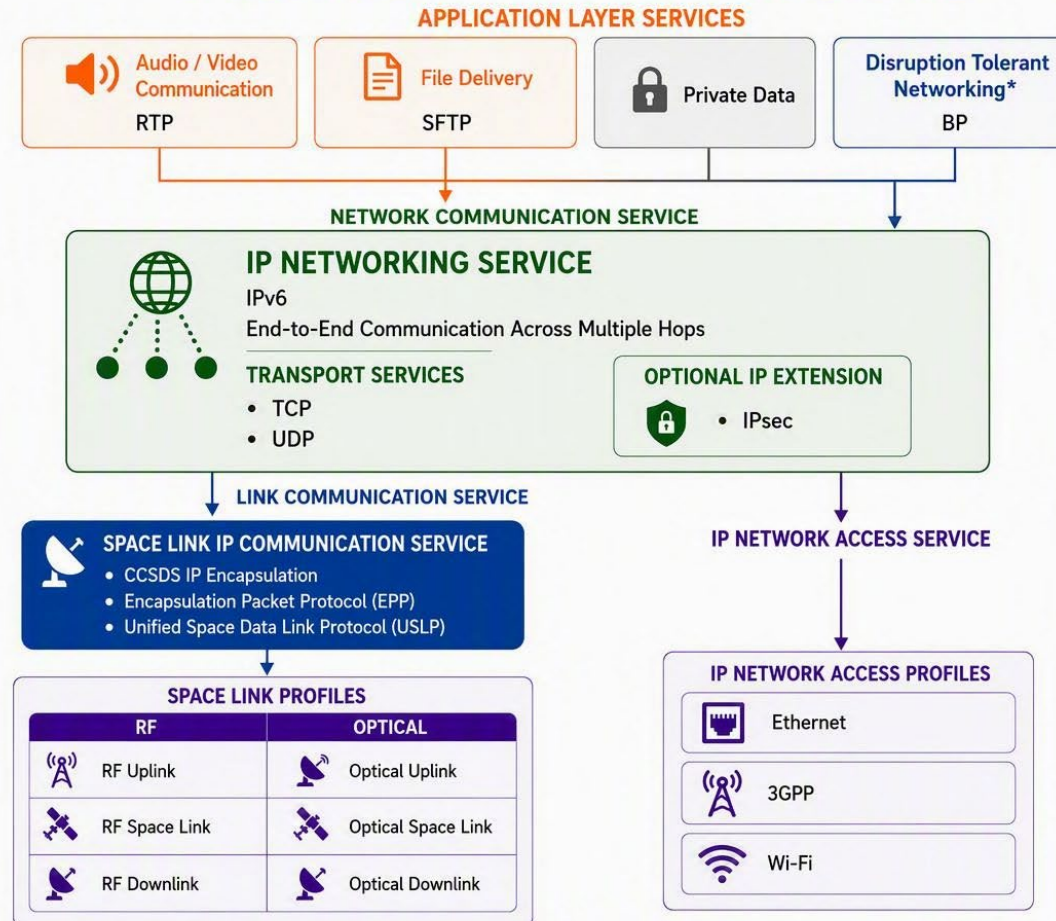
SSI Communication – (local) IP Networking

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SSI SERVICE ARCHITECTURE



IP NETWORKING SERVICE ARCHITECTURE

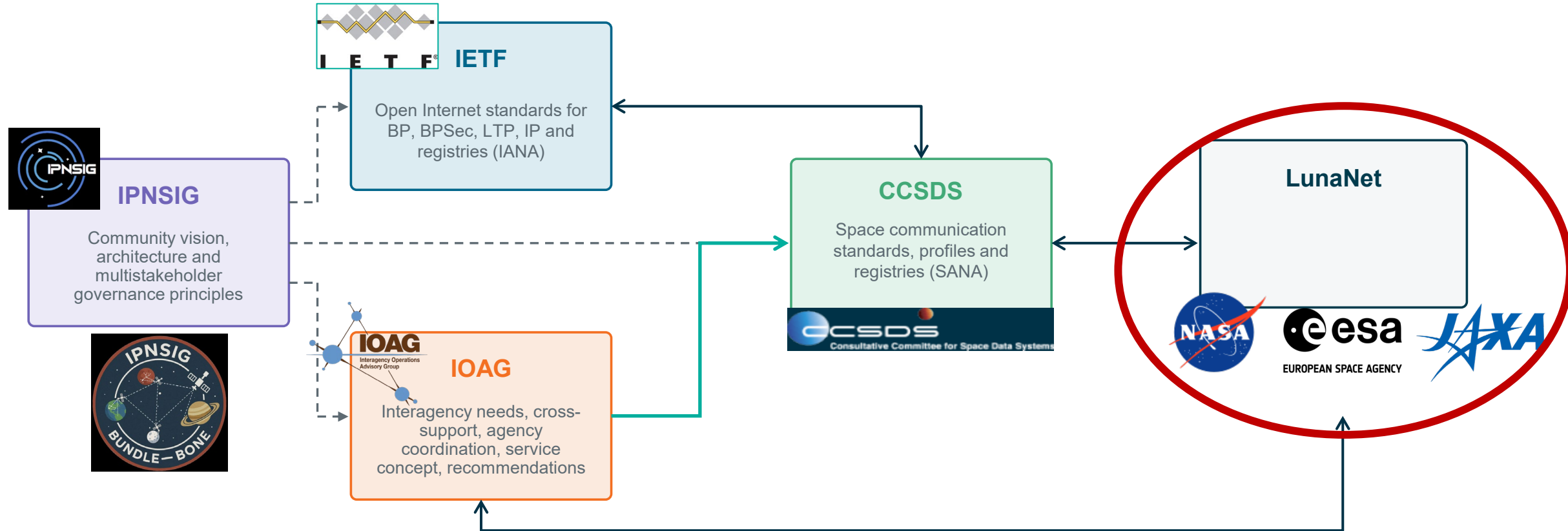


* Only via IP Network Access; not for Space Data Links.

Concept aligned with IOAG Service Catalog #2.

International Governance, Standardisation & Coordination (Communication)

“Simplified View”



COMMON OUTCOME: interoperable services across independently operated networks

- Coordination between Agencies (NASA, ESA, JAXA) with programmes implementing lunar communication & navigation infrastructure
- Communication heavily based on IOAG work and CCSDS standards
- Working Groups covering System, Communication, Navigation, Security, ConOps and Data Services (includes DTN)
- Down selection & additional specification of CCSDS standards
- Coordination with CCSDS via CCSDS LunaNet WG
- Multi-level review process (IOAG, CCSDS, Agencies, Industry)
- Current focus on User – Provider Interfaces (ground & space) – no specification of provider internal implementation
- Sufficient level of detail to guarantee inter-provider compatibility (& interoperability)
- Provider – Provider and wireless surface communication expected in future releases

LunaNet is a practical regional implementation of SSI principles, not the final global SSI architecture.

Protocol baseline

- BPv7
- No BP-layer fragmentation
- Support for the usual extension blocks

Terrestrial convergence

- TCPCLv4
- TLS support
- (UDPCL)

BPSEC

- Optional for Provider
- No messing-up with user-provided BPSEC blocks (→ BIBE)

Naming

- Three-element IPN encoding
- Fully qualified node numbers

Reliability / Reporting

- Custody and compressed reporting
- BPv7 status reports (NOT for routine operations)
- Echo service

Routing

- Requirements for node registration
- Routing LNSP-specific

Space convergence

- EPP and LTP
- Red (reliable) LTP sessions - only

QoS

- User Quality of Service Block, or
- Policy-based Qos

Future Work

- Provider-to-Provider Interfaces
- BPSEC Authentication

MODE 0

User-independent IP use

IP remains opaque to the provider and is carried through Frame Relay Service

MODE 1

End-to-end IP encapsulation

Provider transports user IP packets received via IPSEC tunnel to user's space asset without general routing of the user network

MODE 2

Interconnected IP networking

User and provider networks interconnect and route user IP traffic

Five communities, one interoperability challenge

IPNSIG

Shared vision and governance principles

IETF

Open, scalable protocol foundation

CCSDS

Near-term space interoperability and cross-support

IOAG

Cross-support needs, interagency service concepts and coordination

LunaNet

User Compatibility & Provider Interoperability for Moon

The SSI will not be governed as one network. It must be governed so that many networks can deliver interoperable services.

- Use open international standards wherever possible
- For DTN, keep IETF and CCSDS specifications aligned
- Use IOAG to define interoperable architectures & services and provide input into standardisation
- Standardise interfaces and observable behaviour, not internal implementation
- Validate with independent implementations and multilateral (operational) demonstrations
- Contribute to the education of the next generation
- Keep active research questions open until evidence supports convergence

**Interoperability now.
Scalability and
architectural evolution
over time.**

**The objective is an
interoperable foundation on
which future research,
products and services can
build.**

THANK YOU!



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