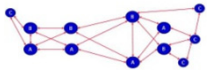

SISG

IOAG Space Internetworking Strategy Group

CNES DLR ESA JAXA NASA

Operations Concept for a Solar System Internetwork

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Jet Propulsion Laboratory, California Institute of Technology

Michel Denis
European Space Operations Centre

Lena Braatz
Booz Allen Hamilton

Introduction

- The Interagency Operations Advisory Group (IOAG) has established a Space Internetworking Strategy Group (SISG)
  - The SISG was chartered to provide recommendations to the IOAG for a strategy to implement space internetworking
  - One element of this work involves the development and documentation of an operations concept for a solar system internetwork (SSI)
- In 2009-2010, the SISG worked to establish this SSI operations concept, leading to the release of "Operations Concept for a Solar System Internetwork (SSI)" in Oct 2011

SISG Membership

- Co-chairs:
  - Wolfgang Hell – ESA ESOC
  - John Rush – NASA HQ
- Members:
  - Francois Allard – ESA ESTEC
  - Erik Barkley – NASA JPL
  - Lena Braatz** - NASA/Booz Allen Hamilton
  - Fred Brosi – NASA/GST
  - Scott Burleigh – NASA JPL
  - Gian Paolo Calzolari – ESA ESOC
  - Vint Cerf - NASA/Google
  - Matthew Cosby – UK Space Agency/QinetiQ
  - Michel Denis* - ESA ESOC
  - Robert Durst – NASA/MITRE
  - Chad Edwards* - NASA JPL
  - Roy Gladden – NASA JPL
  - Adrian Hooke – NASA HQ
  - Dave Israel – NASA GSFC
  - Narita Kaneaki - JAXA
  - Greg Kazz – NASA JPL
  - Mike Kearney – NASA MSFC
  - Paolo Maldari – ESA ESOC (ret)
  - Jane Marquart – NASA GSFC
  - Gilles Moury - CNES
  - John Pietras – NASA/GST
  - Martin Pilgram - DLR
  - Luca Salotti - ASI
  - James Schier – NASA HQ
  - Michael Schmidt – ESA ESOC
  - Klaus-Juergen Schulz – ESA ESOC
  - Keith Scott – NASA/Mitre
  - Peter Shames – NASA JPL
  - Jason Soloff – NASA JSC
  - Wallace Tai – NASA JPL
  - Chris Taylor - ESA ESTEC
  - Takahiro Yamada - JAXA

Participation from ESA, NASA, ASI, CNES, DLR, JAXA, et al.

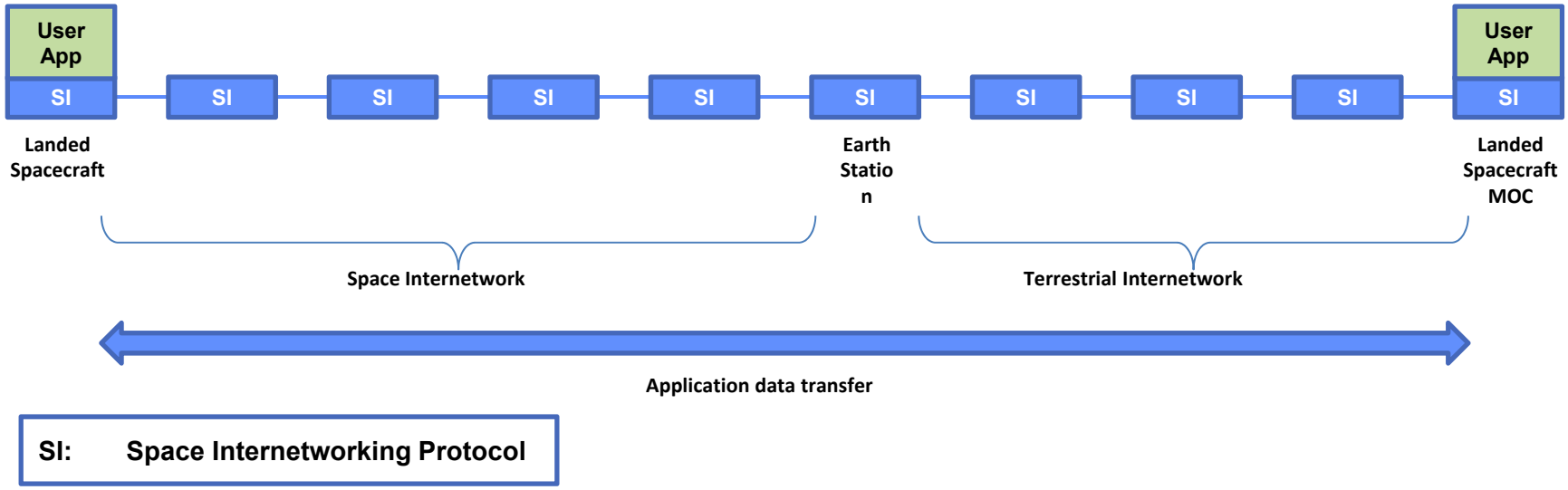
* Co-author ** Editor

The Need for an SSI

- To date, most space communications scenarios have involved simple point-to-point links
  - Supported via standardized CCSDS link layer protocols (e.g., TM/TC, AOS)
- Future space exploration scenarios will move beyond this simple point-to-point paradigm:
  - More complex topologies involving multiple spacecraft
  - Data flowing over multiple hops via intermediate relay spacecraft
  - Data flowing to multiple destinations, with data-driven routing

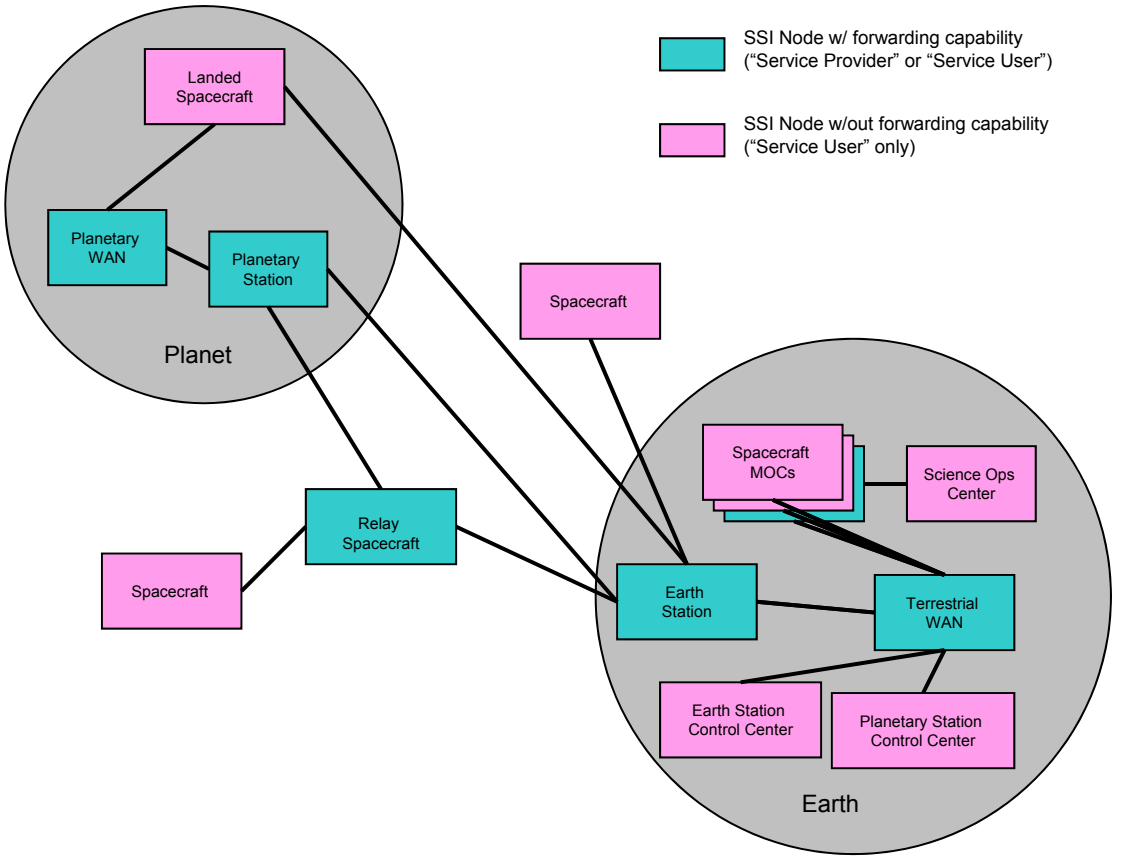
The Need for an SSI (cont'd)

- The SSI drives the need for a **functional network layer**
  - Like terrestrial Internet, provides a simple, standardized network interface
  - A pair of applications at disjoint nodes would be able to seamlessly exchange data, with the network layer handling the intermediate routing



General Description of the SSI

- Service User nodes
  - Reside at periphery of SSI
  - Can access SSI service, but cannot provide network layer forwarding capability
- Service Provider nodes
  - Can provide network layer forwarding capability



Key SSI Principles: Management

- **Asset Responsibility**: Each agency is responsible for the planning, control, and operations of its own assets
- **Communications Protocols**: The operations concept shall, as far as possible, be independent of the communications protocols below the network layer
- **Addressing**: Asset addressing must be constructed and managed at the network level; the SSI will require an entity to manage and maintain a repository of addresses.
- **Network Services**: The defining characteristic of the SSI end state operations concept is the presence of a functional network layer in the protocol stack; application layer functionality is only present at the endpoints of an end-to-end service
- **Interoperability**: To provide a functional network layer in the protocol stack, all nodes that agree to provide SSI services will offer an agreed set of interoperable IP and/or DTN protocol services

Key SSI Principles: Planning

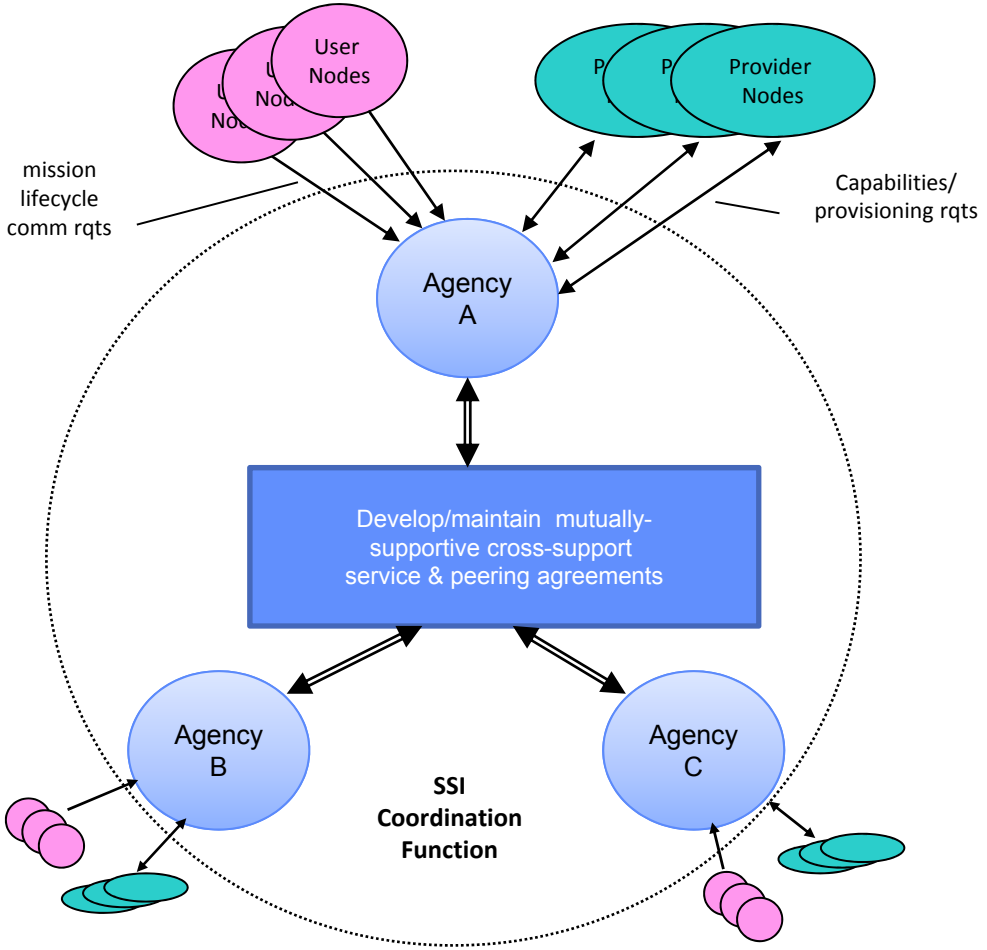
- **Network Planning and Management**: The SSI requires network planning and management functions to develop the network contact plan and execute network services
- **Overall Planning**: The planning entities of the provider and user agencies must coordinate at long-term (typically geometry or flight dynamics), medium-term (typically resources or mission planning), and short-term (typically service request and delivery) levels
- **Contact Plan**: Network planning and execution in the SSI end state hinge on a network contact plan, which establishes the temporal windows and communications capabilities (e.g., bandwidth) of individual node-to-node network links
- **Peering Agreements**: Peering agreements will be used to implement interagency interfaces within the SSI. When planning mission communications, an individual user will arrange for service with its agency-level provider, who will, in turn, employ peering agreements to arrange end-to-end data flows that use different agencies' provider nodes.

Key SSI Principles: Execution

- **Monitoring/Reporting**: The SSI providers shall provide the user MOC with feedback on the progress and success of the intermediate steps in the relaying process.
- **Transparency**: Each node agreeing to participate in the network shall be indifferent and transparent to any contents of the transferred data units
- **Integrity**: The SSI shall be capable of delivering complete, gap-free data products between any two nodes
- **User Emergency**: The SSI shall allow for defining and using, under pre-agreed conditions, a path from the user MOC to the user node that is completely deterministic in geometry and timing (e.g., to recover from anomalies in the network and/or the user node)
- **Routing Functions**: The SSI end state operations concept supports data flow over multiple possible network data paths
  - Forwarding of information is based on static or dynamic routing tables in the network-layer protocol with forwarding decisions based on information in the network-layer Protocol Data Units (as opposed to being driven by metadata or manually sequenced operations)

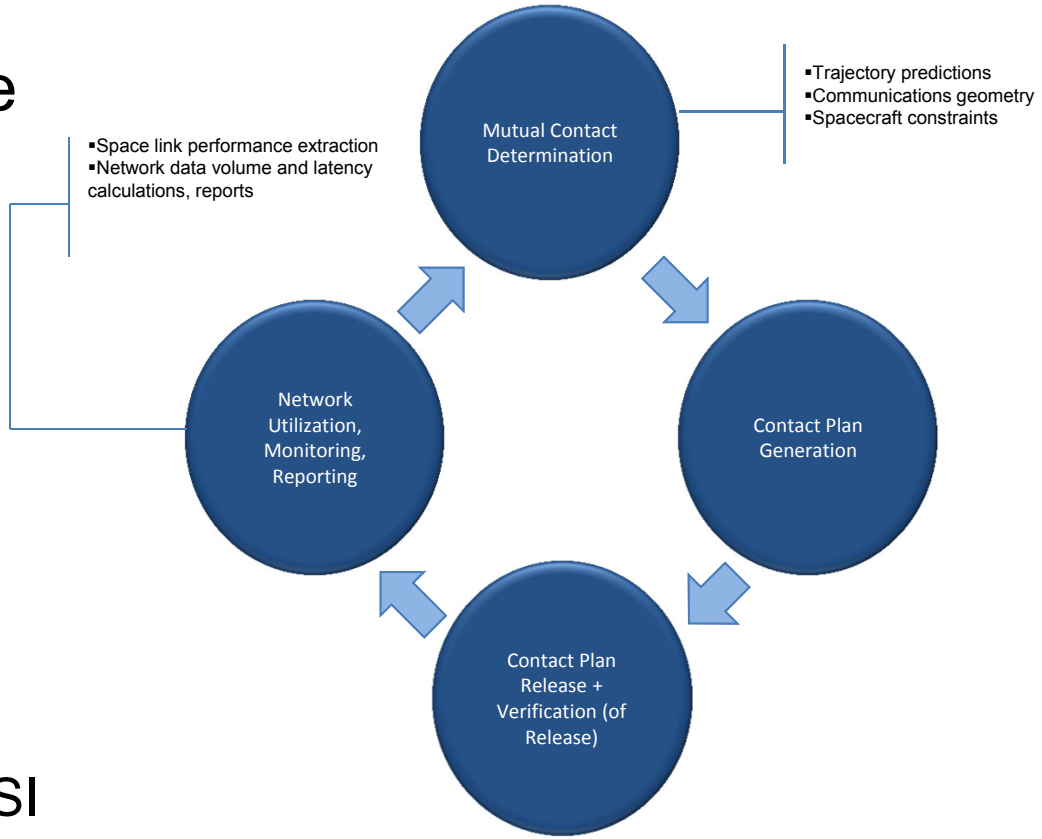
Overview of SSI Coordination

- The SSI is a confederation of network elements from multiple international space agencies
  - Each agency serves as an "SSI Service Provider" for its user nodes (like a terrestrial ISP)
  - "Peering agreements" are used to access services from other providers

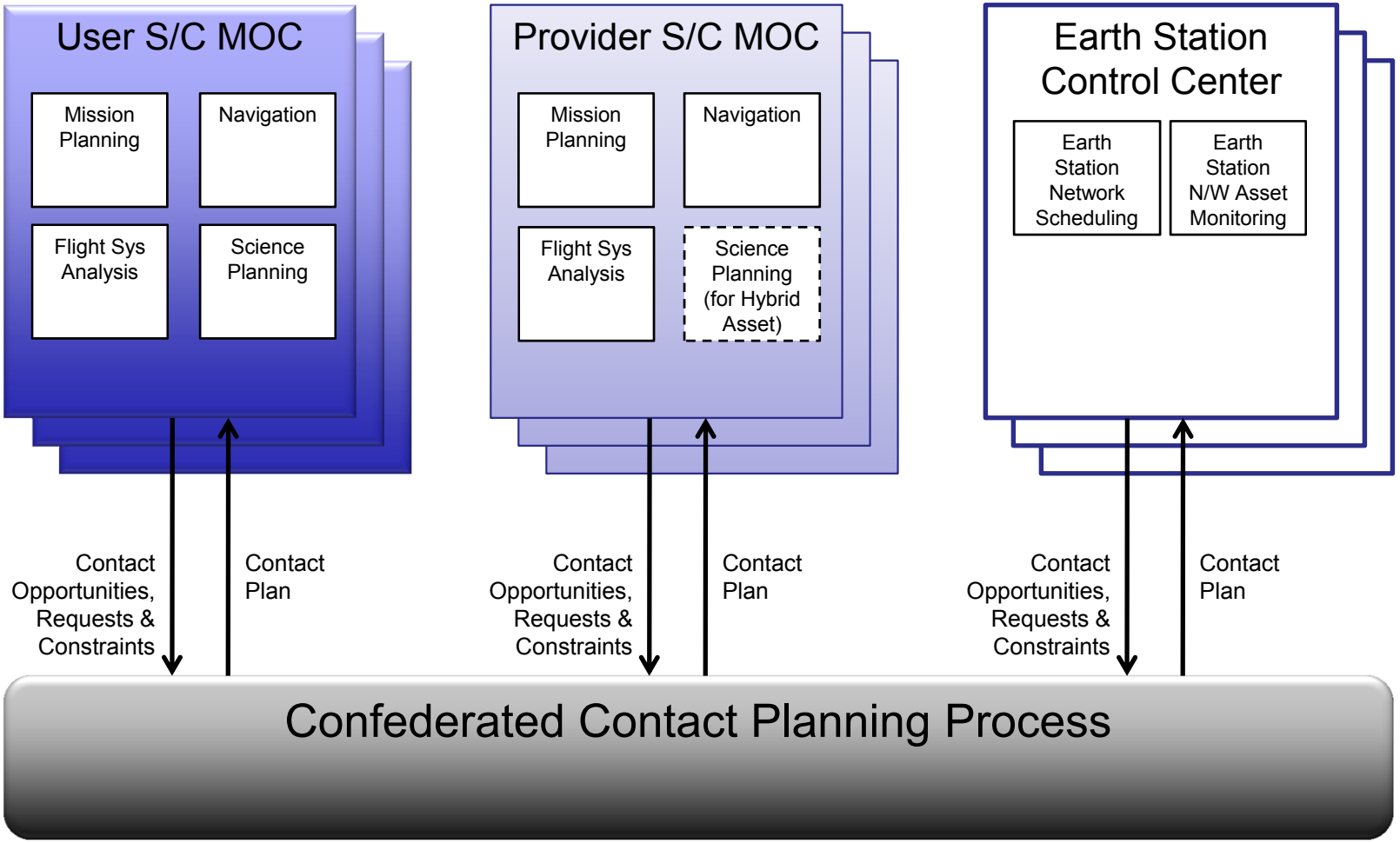


SSI Contact Planning Process

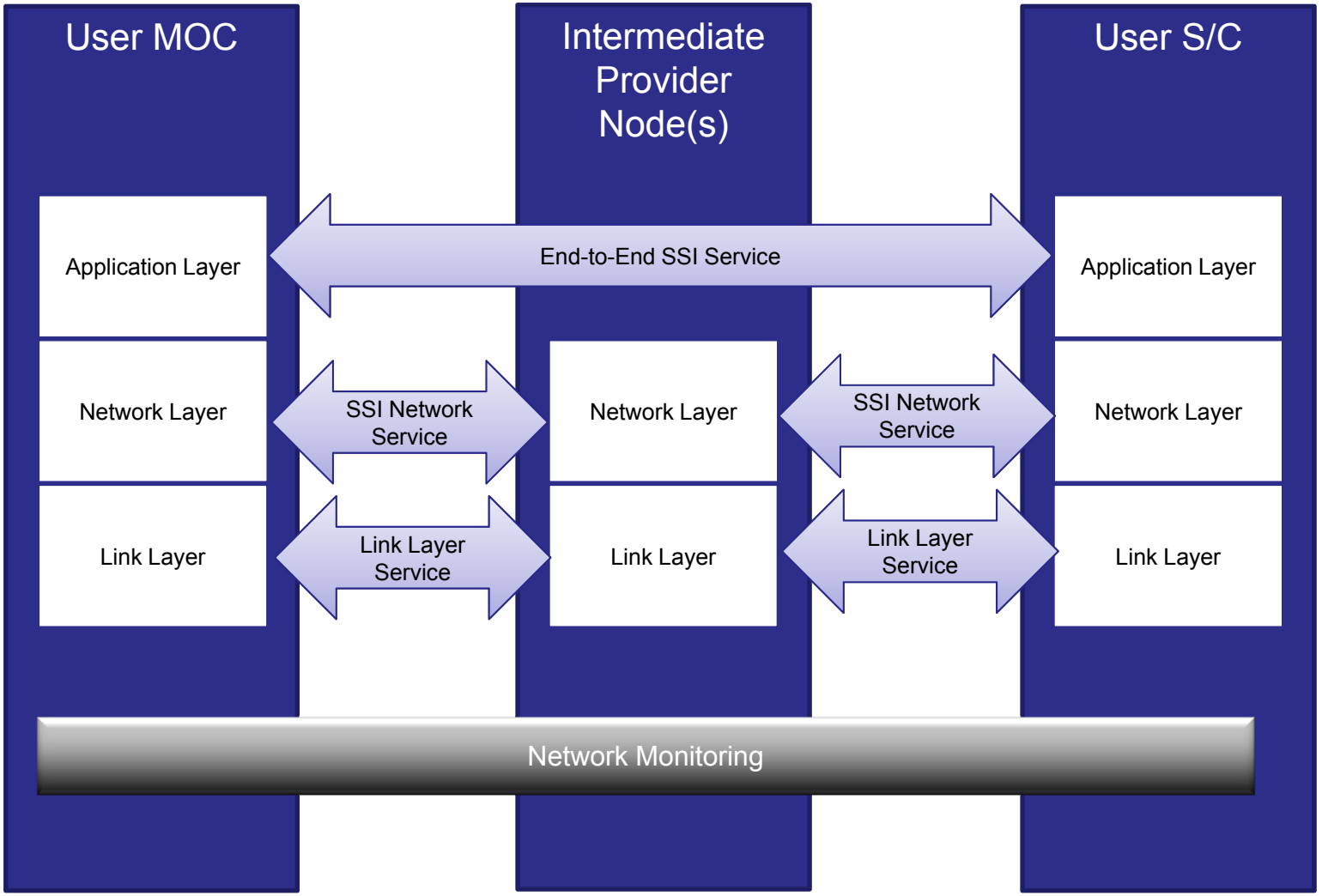
- A key element of SSI operations involves the development and distribution of a contact plan
  - Describes the temporal connectivity and bandwidth capabilities of the network
  - Is essential to enable routing and forwarding decisions by individual SSI nodes in support of end-to-end network data delivery



SSI Contact Planning Process



SSI Run-Time Operations



Conclusions

- The IOAG's Space Internetworking Strategy Group has established an **operations concept for a solar system internetwork**
  - Provides robust and efficient end-to-end data services **spanning terrestrial and space links up to interplanetary scales**
  - **Utilizes a standard network layer** (IP or DTN)
  - Incorporates many aspects of the terrestrial Internet, while reflecting the unique challenges of space communications
- A key aspect of the SSI operations concept involves the development and dissemination of the **contact plan** describing the temporal connectivity of SSI nodes and the bandwidth characteristics of individual links
  - Once this contact plan has been established, network communication can proceed in a highly automated fashion, with intermediate nodes using knowledge of the contact plan to drive forwarding and routing decisions

BACKUP

Acknowledgments

- The authors thank all the members of the Space Internetworking Strategy Group for their many valuable inputs in reviewing and refining this SSI operations concept

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