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The NASA Space Communications Data Networking Architecture

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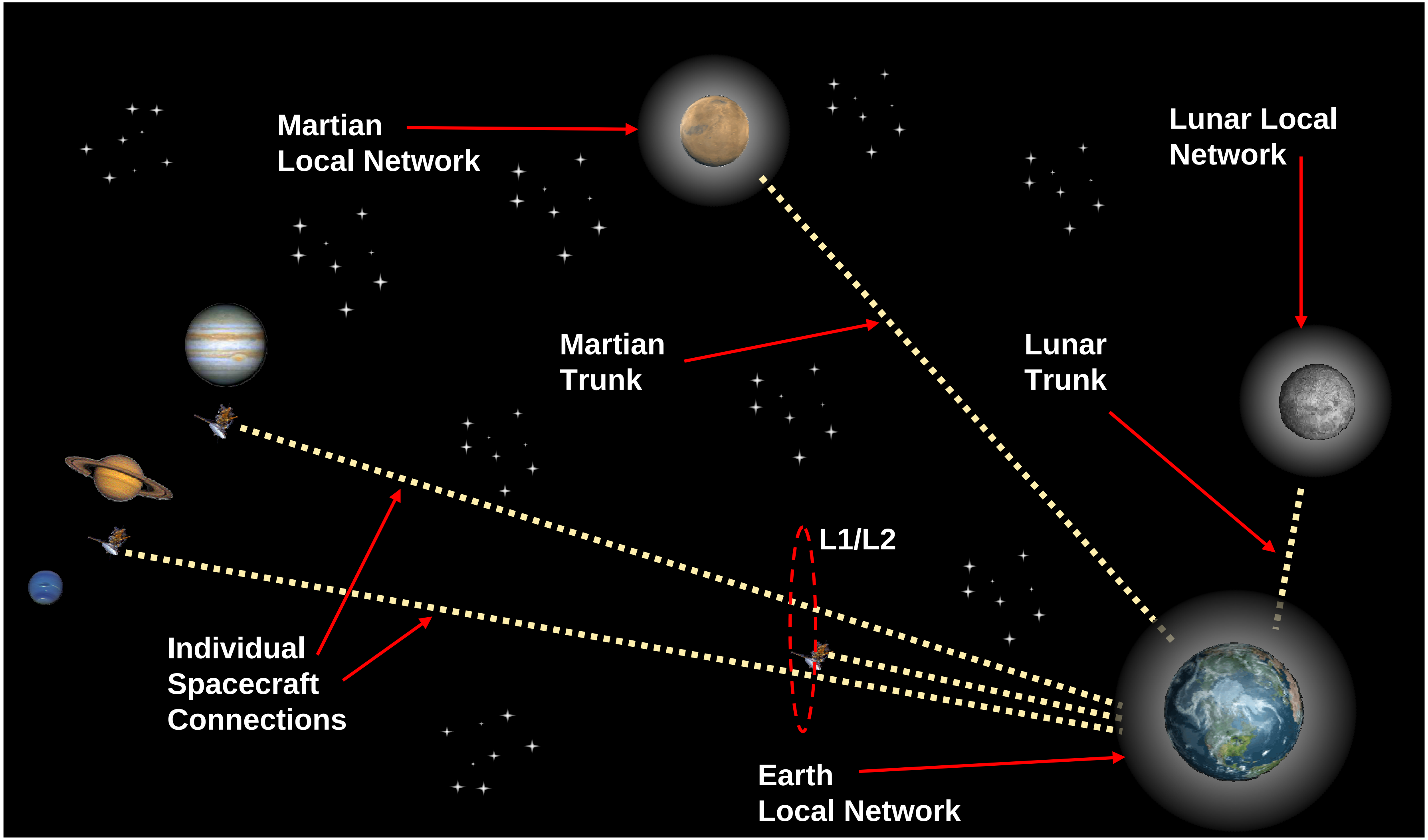
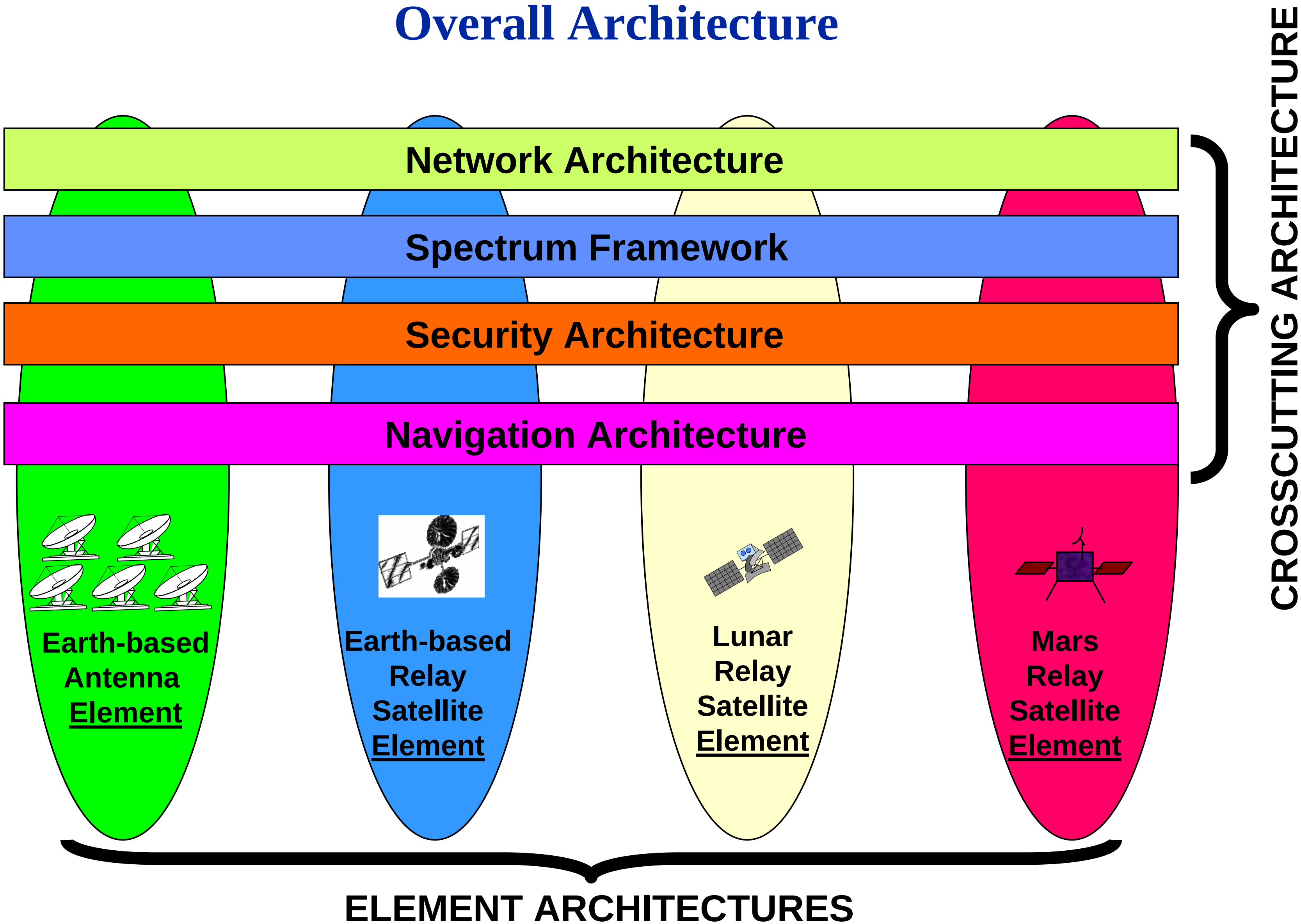
The NASA Space Communications Architecture Working Group (SCAWG)

- Chartered to develop a space communications and navigation architecture to support NASA Science and Exploration missions through the 2030 time frame.
- Membership from across all NASA
- Initial architecture recommendation report was completed in May 2006

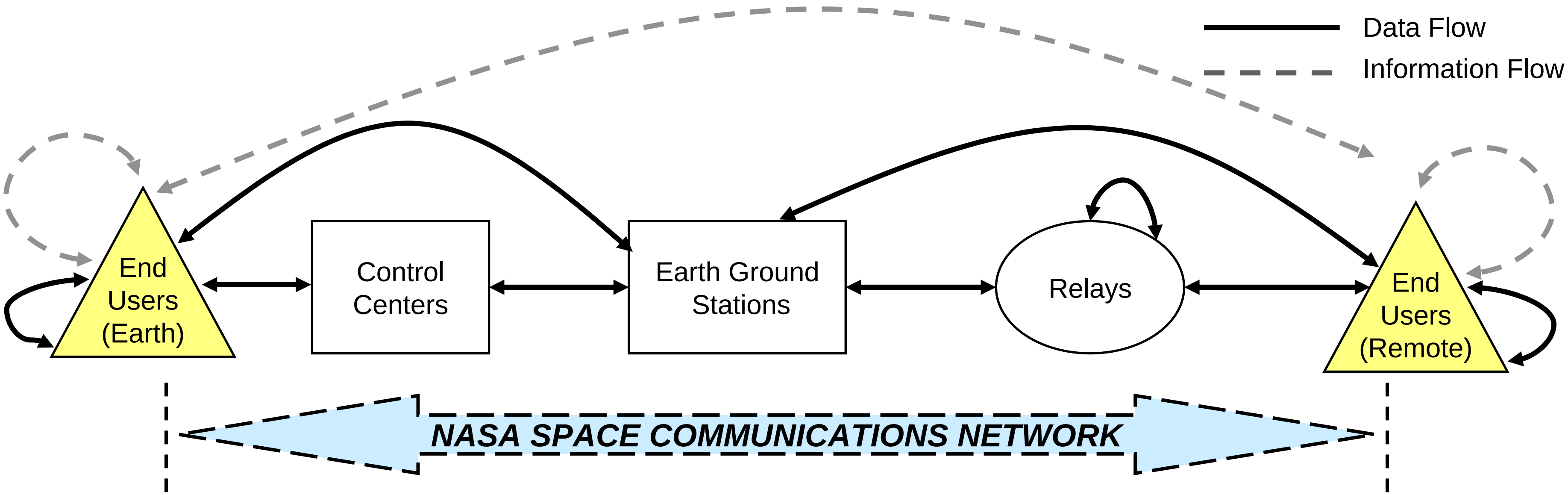
Top Level Conceptual Communication Architecture ~2030



Overall Architecture



Scope of the Space Communications Network



- End users interconnected logically via a series of physical layer "hops"
- Information exchange between users flows logically (dashed lines) from source to destination independent of the underlying network structure.
- The individual hops connect adjacent elements of the architecture and feature:
  - Terrestrial links connecting users to control centers, users to ground stations, or control centers to ground stations.
  - In-space links connecting ground stations to remote user vehicles, ground stations to relays, relays to relays, relays to remote user vehicles, remote vehicles to remote vehicles, or interconnecting end systems within remote vehicles.

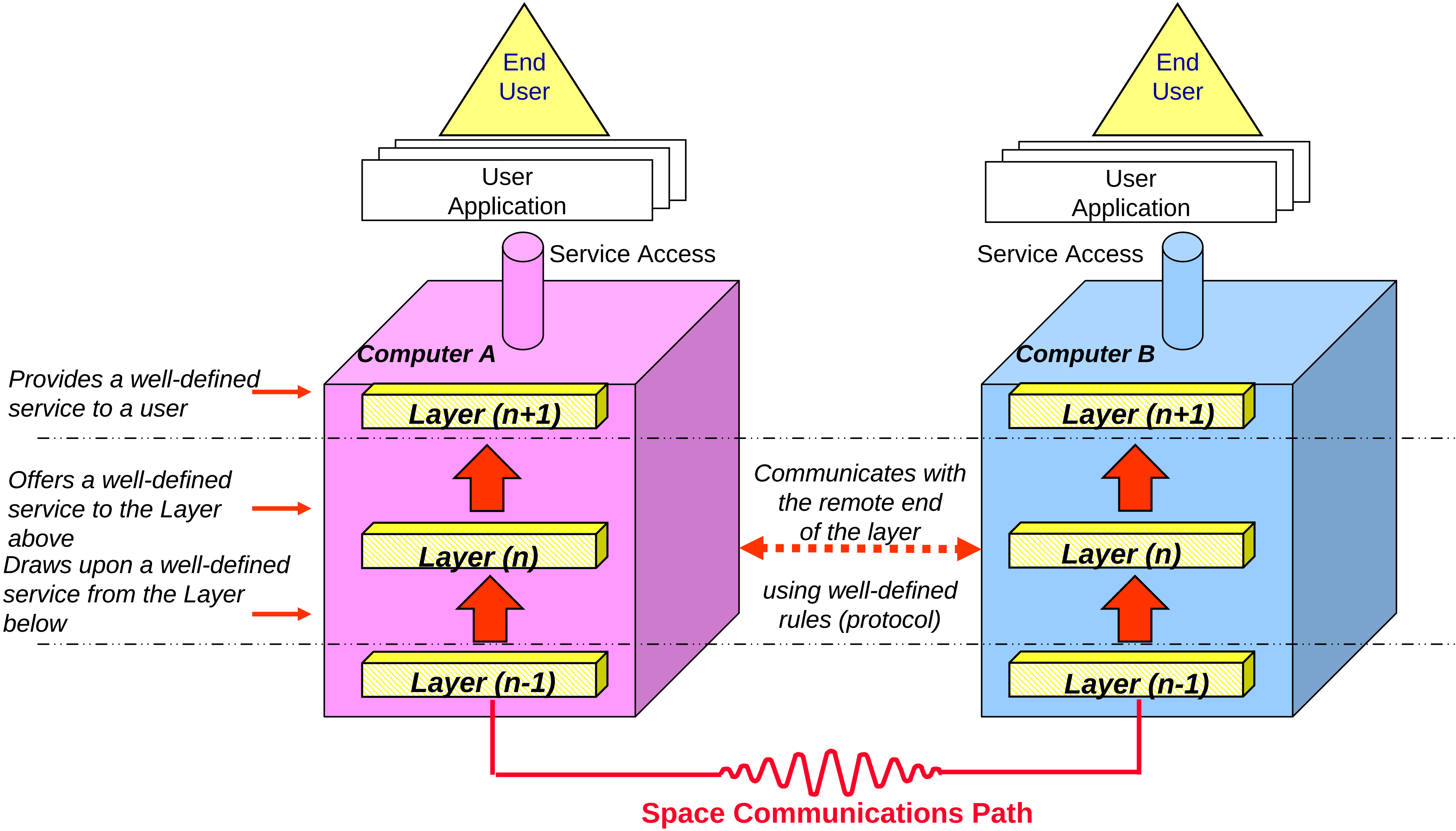
Driving Requirements on the Networking Architecture

- Provide multi-mission data communication services for:
  - Legacy missions
  - New Science missions
  - New Exploration missions
- Support internetworked space and ground elements
- Provide data communication service “on-ramps” for future government and, potentially, commercial service providers
- Accommodate both scheduled and unscheduled communications
- Accommodate both continuous and intermittent connectivity
- Provide service over space data links characterized by:
  - Both large and small signal propagation latencies
  - Both uni-directionality and bi-directionality
  - Both low and high bit error rates
- Support data flows that:
  - Originate at arbitrary user locations on Earth and in space
  - Terminate at arbitrary user locations or sets of user locations (i.e., multi-point delivery) on Earth and in space
  - Traverse N-hop transmission paths where N > 1

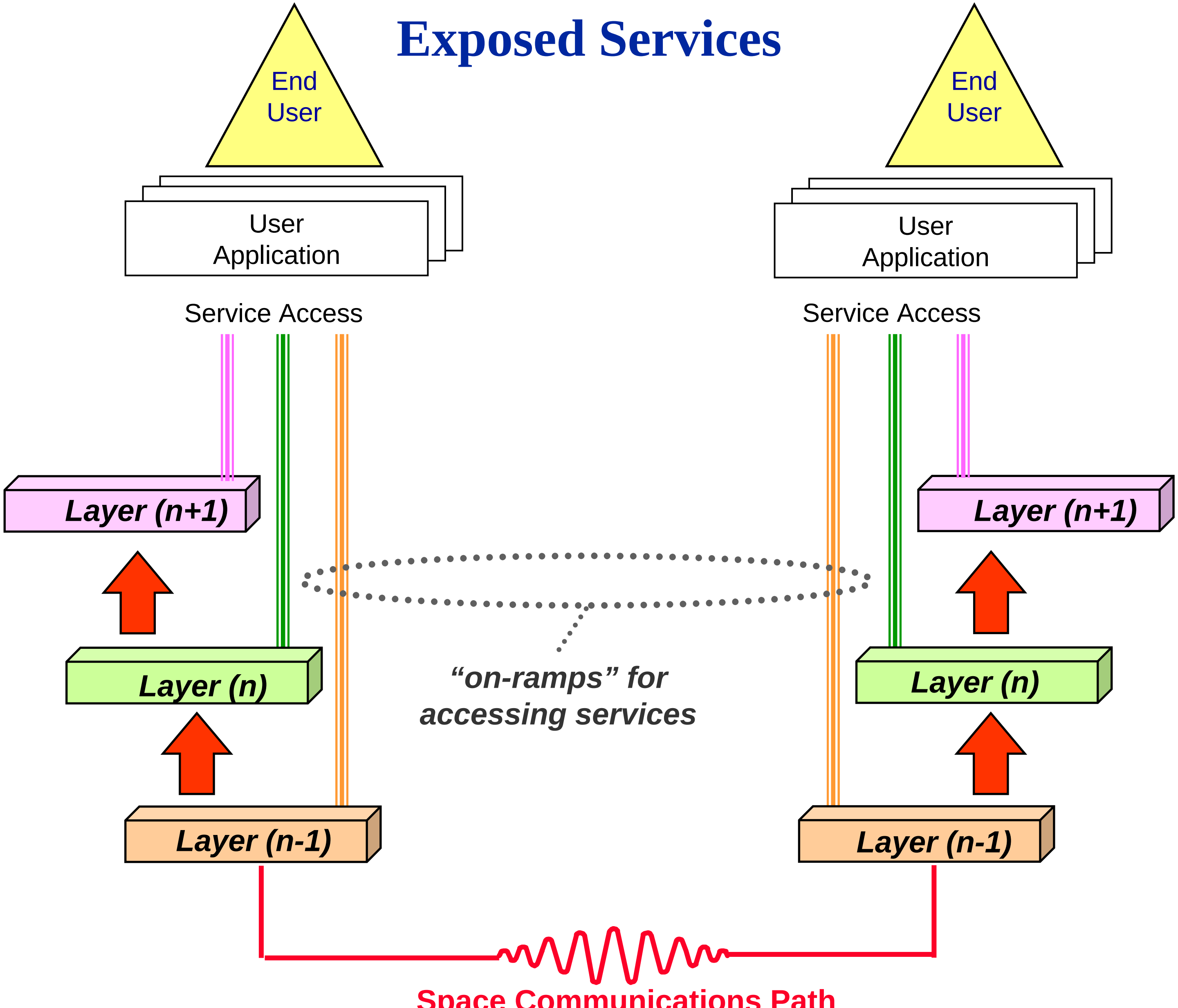
Driving Requirements on the Networking Architecture (cont'd)

- Support transmission of the following types of data:
  - Command
  - Telemetry
  - Files (including web pages)
  - Messages (e.g., electronic mail)
  - Voice
  - Video
  - Range safety
- Provide the following qualities of data communication service (not necessarily in all combinations):
  - Isochrony
  - Reliability
  - Transmission order preservation
  - Timeliness
  - Priority
- Provide data communication performance metrics and accountability

Layered Service Architecture



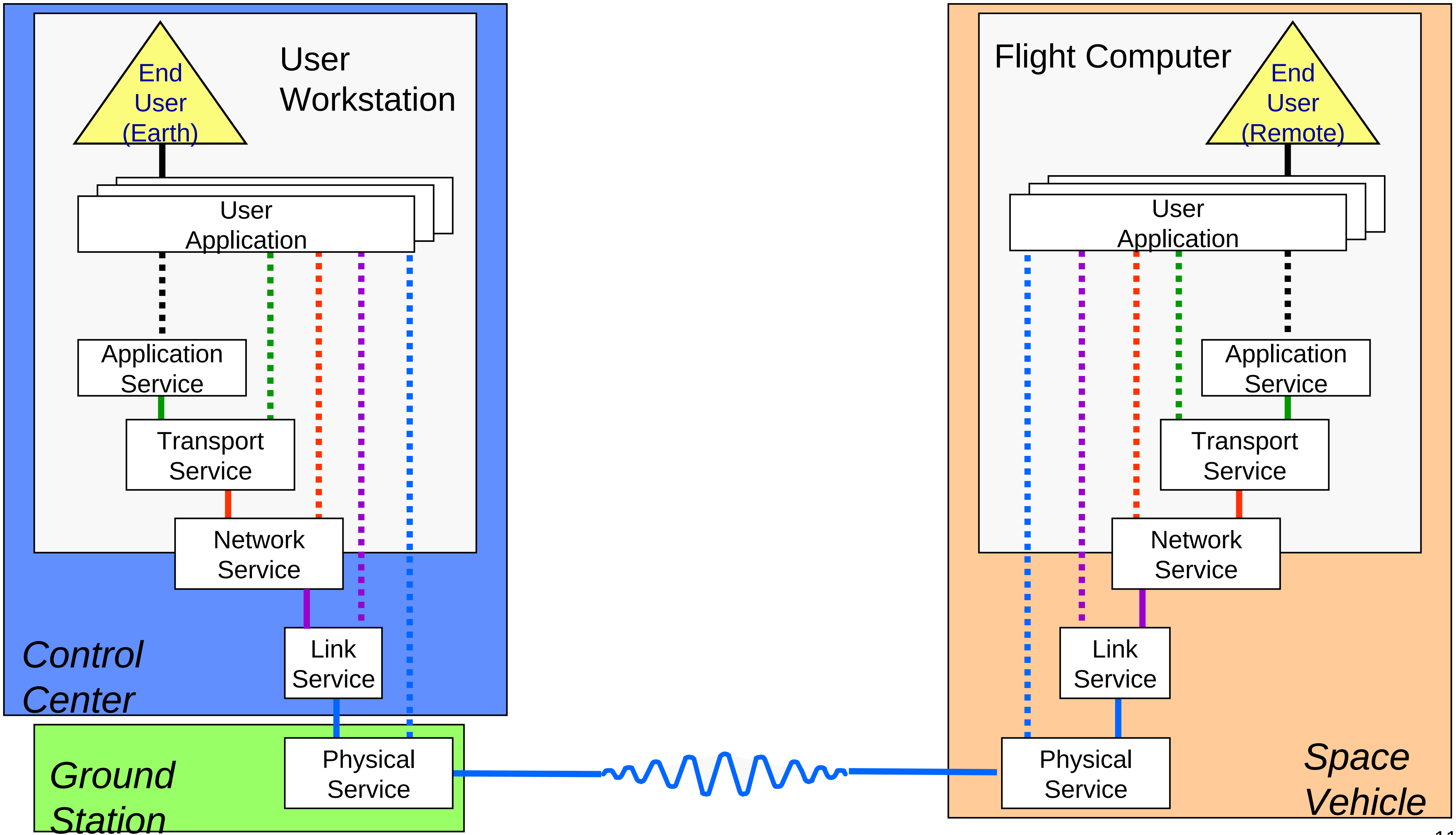
Exposed Services



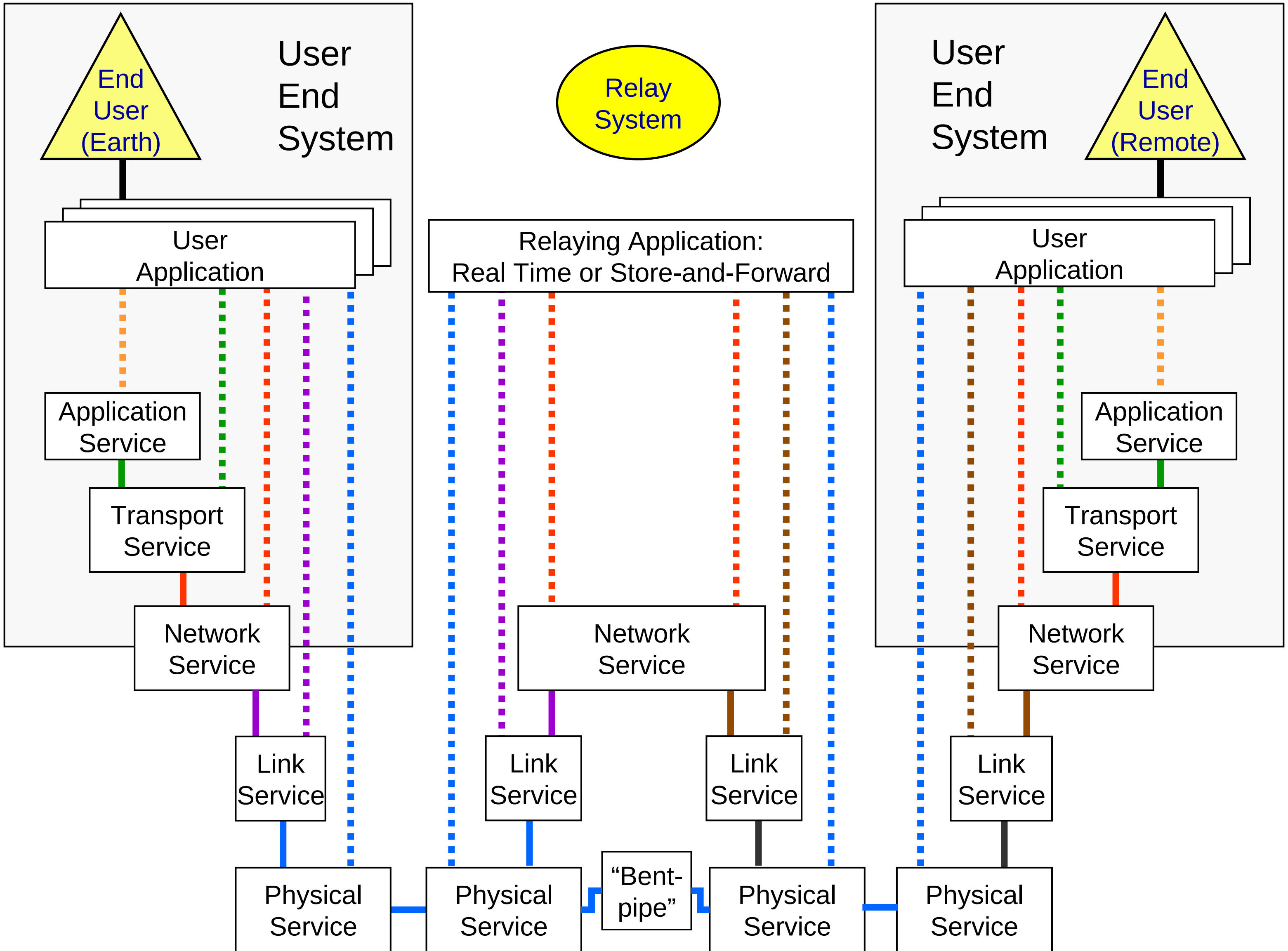
“On-Ramps” Enable Key Capabilities

- Basic emergency commanding can be done by bypassing all but the most rudimentary communications services
- Legacy systems, which do not necessarily conform to all the standard service layers, may be accommodated
- Different organizations (e.g., future commercial providers) may “drop in” their services as a confederated contribution to the overall end-to-end network.

Mapping of Abstract Layers to Mission Facilities



Layered Services in a Space Relay Data Flow



Options Considered for Service Infrastructure Standardization

- At the Physical Layer (Bit/Symbol stream services only).
- Up to the Link Layer, with access to a standard Physical layer.
- Up to the Network Layer, with access to standard Link and Physical layers.
- Up to the Transport Layer, with access to standard Network, Link and Physical layers.
- Up to the Application Layer, with access to standard Transport, Network, Link and Physical layers.

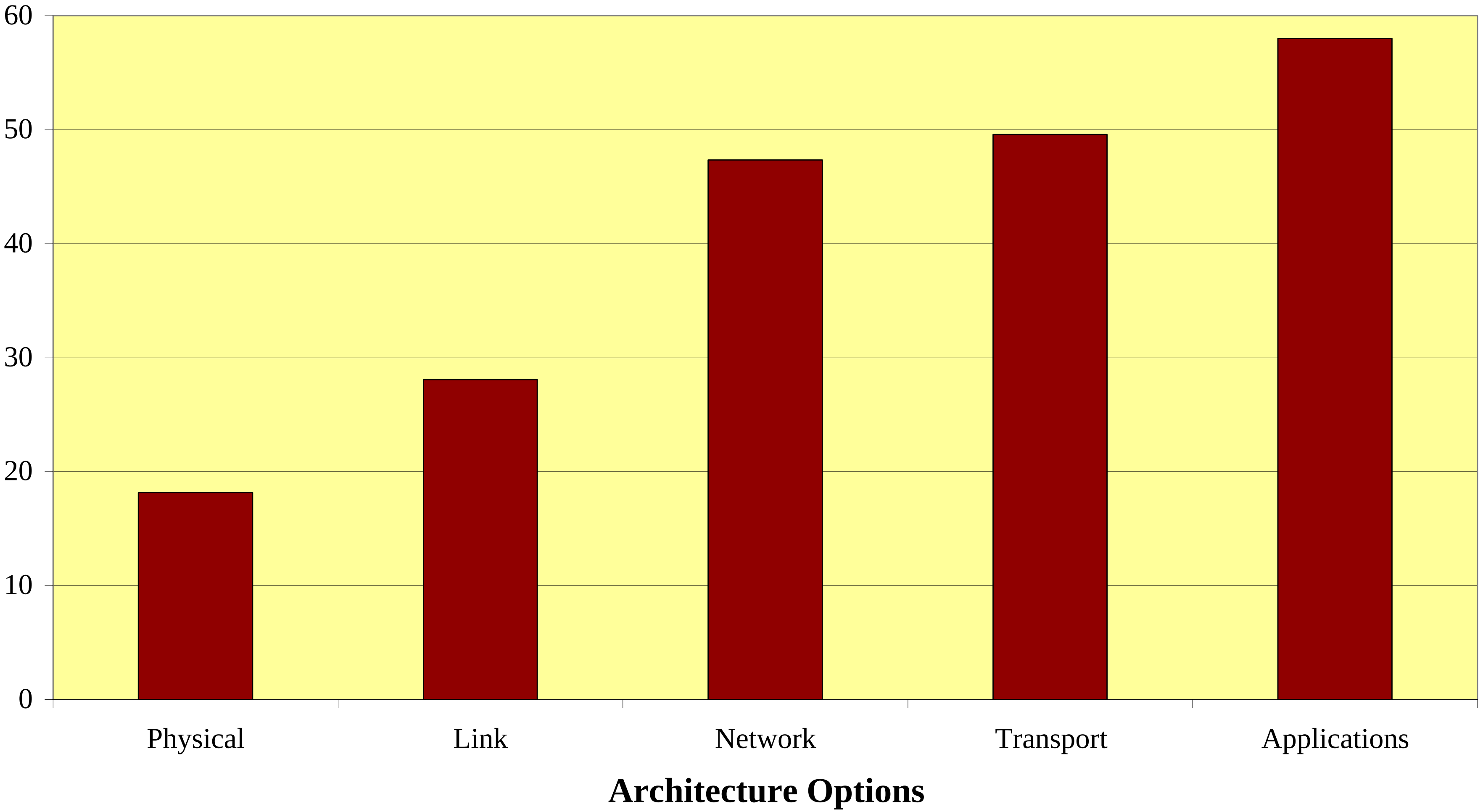
Figures of Merit (FOM) Utilized in Trade Study

- **Operational Efficiency**: The proportion of mission operations activity that must be performed by humans over the entire mission lifecycle, regardless of location.
- **Robustness**: A compound FOM consisting of:
  - The ease with which additional elements can be added to a mission or mission set (**scalability**)
  - The ease with which new operational capabilities can be introduced into mission operations systems (**evolvability**)
  - The ease with which data paths through the network can be changed in response to changing mission requirements (**adaptability**)
  - The proportion of the operational time in which the network operates without error (**reliability**)
  - The ease with which errors can be remedied (**maintainability**)
  - The proportion of wall clock time in which the network operates (**availability**).
- **Infrastructure Capability**: (Communication Infrastructure Development and Maintenance Efficiency): The ease with which mission functionality is developed and maintained over the entire mission lifecycle, at vehicle end user terminals (spacecraft, aircraft, etc.); at ground stations and relay points; and Earth end user terminals (control centers, science centers, test facilities).

Figures of Merit (cont'd)

- **Ease of Transition**: The ease with which the option can be implemented within NASA, including the acquisition of new equipment, development of new technology, and training of mission operators.
- **Interoperability**: The ease with which users are able to complete all negotiations required to achieve successful and secure communication of mission information among both NASA and non-NASA assets and facilities.
- **Resource Utilization**: Total value of user data delivered, given fixed resources. These resources include link utilization, available memory, available power, visibility windows, and launch mass.

Weighted FOM Scores



Trade Study Conclusions

- Standardization should reach at least to the Network layer, although the benefits of standardization continue to increase above this layer. The Network layer is the “thin waist” of interoperability.
- In order to support Network layer standardization, standardization of the underlying Physical and Link layers is required when different organizations act as the termini for the individual data links in the end-to-end path.
- The choice for a Network layer standard is assumed to be the Internet Protocol, IP
- However, the complete IP suite cannot be sustained across the entire Networking Architecture, an enhanced version of Network service – such as Disruption Tolerant Networking (DTN) – should be developed

Next Steps

- Detailed protocol selection trade-offs
- Standard options at each layer based on existing and developing CCSDS and IETF standards with guidance for option selection by missions
- Implementation of networking architecture across NASA’s Space Communications Architecture

Acronym List

CCSDS	Consultative Committee for Space Data Standards
DTN	Disruption Tolerant Networking
FOM	Figure of Merit
GSFC	Goddard Space Flight Center
HQ	Headquarters
IETF	Internet Engineering Task Force
IP	Internet Protocol
JPL	Jet Propulsion Laboratory
NASA	National Aeronautics and Space Administration
SCAWG	Space Communications Architecture Working Group