CHALLENGES OF SPACE MISSION INTEROPERABILITY

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The Spectrum Problem

Multiple spacecraft clustered on or about Mars …

… result in all spacecraft in view of Earth lying in the beamwidth's of all Earth stations with view of Mars.
If non-orthogonal telemetry spectra overlap, mutual interference is likely. So, these spectra must be sufficiently separated.
The First Step In Interoperability

International coordination of spacecraft frequency assignments for Moon & Mars missions

To achieve this, the Space Frequency Coordination Group (SFCG) has formed a Lunar-Martian Spectrum Coordination subgroup. All Agencies are strongly encouraged to support this group in order to provide the necessary foundation for Communications Interoperability.
What is “Interoperability”? 

The technical capability of two or more systems or components to exchange information and to use the information that has been exchanged.

[IEEE 90] Institute of Electrical and Electronics Engineers.  
IEEE Standard Computer Dictionary:  
The Key to Interoperability: Standardization of Space Communications Services and Protocols

Key Concepts: Standard Services

- **User Application**: Service Access
  - **Layer (n+1)**: Offers a well-defined service to the Layer above
  - **Layer (n)**: Uses a well-defined service from the Layer below
  - **Layer (n-1)**

- **Computer A**
- **Computer B**: Service Access
  - **Layer (n+1)**: Communicates with the remote end of the layer using well-defined rules (protocol)
  - **Layer (n)**
  - **Layer (n-1)**

Space Communications Path

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Layering Permits Interoperability to Evolve: Smooth Introduction of New Technologies

Computer A

User Application

Service Access

Layer (n+1)

New Layer (n)

Layer (n-1)

Communicates with the remote end of the layer using well-defined rules (protocol)

Offers a well-defined service to the Layer above

Uses a well-defined service from the Layer below

Computer B

User Application

Service Access

Layer (n+1)

New Layer (n)

Layer (n-1)

Space Communications Path
An agreement between two or more organizations to exploit the technical capability of interoperability for mutual advantage, such as one organization offering support services to another in order to enhance or enable some aspect of a space mission.
Potential Space Communications and Navigation
Cross Support Interfaces

1. Space – Ground Link
2. Space – Near-Earth Relay Link
3. Ground Station – Control Center
4. Control Center – User
5. Surface – Planetary Relay Link
6. Surface – Surface
7. Vehicle – Vehicle Link
8. Payload – Spacecraft
9. End-to-End

Payload - Spacecraft
  Short range wired or wireless
Vehicle - Vehicle
  Short/medium range wireless
Surface - Surface
  Short/medium range wired or wireless
Surface - Relay
  Medium range wireless
Space - Relay
  Medium range wireless
Space - Ground
  Long-haul wireless

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Stages of Cross Support

1. **Harmony**
   - Space organizations conduct independent, interference-free operations

2. **Cooperative Cross Support**
   - One organization helps another to execute its mission

3. **Confederated Cross Support**
   - Multiple organizations contribute independent pieces to a mission
     - 3A: preplanned
     - 3B: ad-hoc “Plug-and-Play”
Stage 1: Harmony

Organizations operate independently and without interference, as a result of coordinated spectrum allocations and utilization.
Stage 2: Cooperative Cross Support

Standard Service Interfaces

Organization A

Organization B

Organization B provides communications and navigation services to assist Organization A with the execution of its independent missions

Organization A
Multiple organizations each contribute assets towards the execution of a more complex mission than any could individually undertake.
Stage 3B: Confederated Cross Support, Plug-and-Play

Organizations rapidly support unplanned or contingency operations, via self-configuring communications systems.
Current State of International Cross Support

Emerging Stage 3a:
Relay interoperability (e.g. Mars Express support to Phoenix and MER)

Currently mainly at Stage 2:
point-to-point interoperability

Next step: end-to-end (Internetworking) interoperability
International Coordinating Bodies for Interoperability and Cross Support

**Inter Operability Plenary (IOP)**
- Convened in Paris, June 1999
- Attended by ESA, France, Germany, Italy, Japan, USA
- Reached international agreement on the need for space mission interoperability, and terms of reference for the IOAG

**Interagency Operations Advisory Group (IOAG)**
- Convened by the Interoperability Plenary in February 2000.
- Members are ESA, France, Germany, India, Italy, Japan, USA
- High level management coordination forum; meets ~once/year

**Consultative Committee for Space Data Systems (CCSDS)**
- Chartered in Toulouse, October 1982
- Members are Brazil, Canada, ESA, France, Germany, Italy, Japan, Russia, UK, USA
- International space data standards authority; meets ~twice/year, 150+ attendees

**Space Frequency Coordination Group (SFCG)**
- Chartered in 1980
- Members are Argentina, Australia, Austria, Brazil, Canada, China, ESA, EUMETSAT, France, Germany, India, Italy, Japan, Korea, Malaysia, Netherlands, Russia, Spain, Sweden, Taiwan, UK, Ukraine, USA
- International spectrum utilization authority; meets ~once/year
IOAG’s Definition of Interoperability

• The mechanisms by which two or more heterogeneous systems can directly interact and exchange information without any customization or human pre-configuration of the interface between them.

• *It is a goal to achieve plug-and-play operations where all that is required is for each of the systems to use an agreed communications medium, after which the systems configure each other for the purpose of exchanging information and subsequently effect such exchange automatically.*
The Goal: International Level 3B Plug-and-Play
The Goal: International Level 3B Plug-and-Play
Summary

• Progress towards international interoperability during the past 20+ years has been good
  • A mature international coordinating and development infrastructure (IOAG, CCSDS, SFCG) exists

• The need for future interoperability is accelerating
  • Many countries are now interested in exploring the same places

• It is an opportune time to consider convening the second Interoperability Plenary, with expanded membership, to chart the course for the next 20 years
  • If we don’t, everyone may waste resources by re-inventing communication and navigation systems that should be standardized and routine
Discussion?
Supplementary material