Internationally Interoperable Data Systems
Critical Enabler for Collaborative International Exploration

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IOP / IOAG History

IOP-1 Held in 1999
- To foster strategic space operations planning and interoperability
- Chartered the IOAG
  - Translates IOP guidance into interoperable architectures

IOP-3 held in 2013 / CNES
- For a history of the IOP/IOAG’s first decade
- For information on IOP-3 see the IOP website or
  - “Results from the recent Interoperability Plenary-3, and the implication on future interoperability for global space communication and operations architectures”
IOP / IOAG Organization
IOP-3 Results

The IOAG received a strong endorsement of all of its Recommendations and Liaisons Including:

1. Defining a path forward for global interoperability in:
   - Space Internetworking
   - Optical Communications Links
   - Mission Operations Systems
   - Low Earth Orbit 26GHz

2. Mandate for Effective Liaisons with
   - CCSDS
   - SFCG
   - ICG
   - ISECG
IOAG CCSDS Product Agreement (ICPA)
CCSDS Overview - Participation

✦ CCSDS – An Agency-Led International Committee
  ✦ Currently 11 Member agencies
  ✦ Currently 29 Observer Agencies
  ✦ Agencies represent 27 nations (plus European orgs)
  ✦ Currently 151 Commercial Associates
  ✦ ~160-180 attendees at Spring/Fall meetings

✦ Also functions as an ISO Subcommittee
  ✦ TC20/SC13 - Space Data & Info Transfer Systems
  ✦ Represents 20 nations
CCSDS Overview

Currently Active Publications: 137
Normative (Blue & Magenta): 86
Informative (Green): 50
Experimental (Orange): 1

Downloadable for free from www.ccsds.org
All major pubs since 1982: ~283
(Some were historical mission needs or superseded technology)

694 space missions have adopted and used various CCSDS standards
Overview - End-to-End Architecture
Mission Benefits of Using Interoperable Data System Standards

• Lowers **Cost** of space communication and mission systems
  – Major companies produce subsystems which meet them
  – Compatible ground systems can fill in the gaps
  – Facilitates implementation of complex international mission systems

• Lowers **Risk** for space mission operation
  – Robust coverage for critical human exploration needs or events
  – Facilitates seamless backup mission systems

• Enables **Collaborative** space missions with other nations
  – **Aligned with NASA’s Strategic Plan**
  – Example: "trading" a ride for an instrument for cross support communications
Agency Benefits of Using Interoperable Data Systems Standards

- Internationally Interoperable standards have enabled $100s$ of $M$ in cross support for NASA and Partners
- Promotes robust global interoperability
- Saves money for NASA and partners
- Key to enabling missions such as:
  - Mars Science Laboratory / NASA
  - MOM / ISRO
  - HTV, ALOS II / JAXA
  - MARS InSight / NASA
- Essential element in successful implementation of the Global space operations Architecture
  - Critical to meeting SCaN Driving Requirements
As a first step, the current ISECG Global Exploration Roadmap has included in Chapter 3, “A Long-Range Human Exploration Strategy,” a section on Standards to Promote Interoperability:

“Agencies participating in IOAG, SFCG, and CCSDS have collaborated on establishing data communications and mission operations architectures, coordinating spectrums for space communications, and technical standards for cross support which take advantage of current and anticipated state-of-the-art technologies. These teams have developed service catalogs and technical standards which respond to the anticipated needs of future exploration missions. These services and standards will enable highly internetworked mission operations and facilitate the integration of new partners into complex human space exploration missions.”

The IOAG agencies look forward to working with you to create the future for Human Space Exploration!
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BACK-UP
IOAG Service Catalog #1
Issue 1, Revision 3, Approved 04 March, 2010

IOAG Service Catalog #1 addresses current mission scenarios where access is provided to a single space/ground data link.

a) Forward Data Delivery Services Group
b) Return Data Delivery Services Group
c) Radio Metric Services Group
d) Service Management functions

**CORE SERVICES:**
- Forward CLTU Service (SLE Forward CLTU)
- Return All Frames Service (SLE Return All Frames)
- Return Channel Frames Service (SLE Return Channel Frames)
- Validated Data Radio Metric Service (CSTS Offline Radio Metric, over CSTS File Transfer)

**EXTENDED SERVICES:**
- Forward Space Packet Service (SLE Forward Space Packet, existing)
- Forward Synchronous Encoded Frame Service (SLE Forward Synchronous Encoded Frame) → For AOS Frames (mainly)
- Forward File Service (CSTS Forward File Service, over CSTS Transfer File)
- Return Operational Control Field Service (SLE Return OCF, existing)
- Return Unframed Telemetry Service (CSTS Return Unframed Telemetry) → no TM format
- Return File Service (CSTS Return File, over CSTS File Transfer)
- Raw Data Radio Metric Service (CSTS Real Time Radio Metric)
- Delta DOR Service (CSTS D-DOR Data, over CSTS File Transfer)
IOAG Service Catalog #2 addresses space communication services for in-space relay and network cross-support scenarios which would enable future Solar System Internetworking (SSI).

- a) Forward + Return Internetworking for DTN
- b) Forward + Return Internetworking for IP
- c) Forward Last Hop Delivery + Return First Hop Delivery (e.g.: non networked commanding or essential telemetry)
- d) Radiometric services (e.g.: Proximity-1 radio metric data)
- e) Time Synchronization Service
- f) SSI Network Management functions
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).

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

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

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.

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

YELLOW BOOKS
Administrative
CCSDS Procedures, Proceedings, Test reports, 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.

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.
IOAG Top Priorities:
Game changing / Critical needs

- Coordination on Space Debris
- Increase to very high data rates
- Service Management of the Service Catalogs
- End-to-end file transfers
- Security
- Coordination on solar system and exploration missions
- Mission Operations

- Conjunction data message: standard in final production at CCSDS
- LDPC codes (3 mission models): standards available now from CCSDS
- Service Management: standard "under revision“ at CCSDS
- CFDP: standard available and implementation standards (CFDP over xxx) in final production in CCSDS
- Space Data Link Security: standard in preparation at CCSDS.
- Delta DOR: standards available and others in preparation at CCSDS
- Mission Operations Core Services: standards available and others in preparation at CCSDS
IOP, IOAG, and CCSDS Overview

Technology Drivers and Strategy Groups

Timeline

Capitalizing on advanced technology when the timing is right.

Timeline not to scale

1982  Late 80’s  Early 90’s  1999  2007  2008  2009  2010  2011  2012  2013

IOP

IOAG  Bilateral ITCOPs

LEO26SG  Ka-Band Comm Strategies

OLSG  Optical Comm Strategies

MOSCG  Mission Ops Strategies

SISG  Internetworking Strategies

CCSDS

Technology Drivers

Advancements in all comm layers (RF, Modulation, Coding, Networking) And application functions (Messaging, SOAs, etc.)
How Does A MO Service Oriented Architecture Work?

Service Oriented Architecture is widely used in other industries.

Discovery of Services (allows automated access)
How Can This CCSDS MO Service Architecture Work?

Cross-support is based on operational configuration and on security \[ \rightarrow \text{NOT} \] on a new software development project.
Liaison with the ICG

GNSS Space Service Volume: Navigation Beyond LEO

- 100s of space missions rely on GNSS for navigation
- IOAG established a liaison to the ICG
  - Represent these equities
  - Foster interoperability for space users
- While most space missions using GNSS today are in Low Earth orbit and covered by the Terrestrial service volume
- Future missions will use
  - SSV for Medium Altitudes:
    - 3,000 to 8,000 km altitude
    - One-meter orbit accuracies are feasible
  - SSV for GSO/HEO Altitudes:
    - 8,000 to 36,000 km altitude

IOAG has observer status in the ICG
SSI Architecture Documentation

IOAG-SISG Documents
- 2010

SSI Architecture Documents
- 2012-2013

CCSDS Standards
- 2013-...

Recommendations on a Strategy for Space Internetworking, (IOAG document)

Operations Concept for a Solar System Internetwork (SSI) (IOAG document)

Rationale, Scenarios, and Requirements for DTN in Space (CCSDS Green Book)

Solar System Internetwork (SSI) Architecture (CCSDS Green Book)

BP (CCSDS Blue Book) LTP (CCSDS Blue Book)

Space Communications Cross Support Architecture (CCSDS Magenta Book)
CCSDS Response to IOAG
Solar System Internet (SSI) Package

Recommendations on a Strategy for Space Internetworking

Operations Concept for a Solar System Internetwork (SSI)

Rationale, Scenarios, and Requirements for DTN in Space (CCSDS 734.0-G-1)

Solar System Internetwork (SSI) Architecture (CCSDS 730.1)
Current Status: White
Target: Green by 2013

Licklider Transmission Protocol for CCSDS (CCSDS 734.1)
Current Status: Red-2
Target: Blue by 2013

Space Communications Cross Support Architecture Description Document (CCSDS 901.0)
Current Status: CESG Poll Completed
Target: Green by PENDING

Bundle Protocol for CCSDS (CCSDS 734.2)
Current Status: Red-1
Target: Blue by 2013

Space Communications Cross Support Architecture Requirements Document (CCSDS 901.1)
Current Status: White
Target: Magenta by 2013

Bundle / DTN Security not shown (not yet in CCSDS Programme of Work)
CCSDS Overview
Organizational Interrelationships

IOAG provides to CCSDS the IOAG priorities and guidance for future communications/operations plans.

CCSDS Participants bring in other agencies/industry inputs, mission needs and technology drivers.

CCSDS participant inputs bring in needs of individual organizations.

CCSDS MEMBER AGENCIES (11) direct inputs
OBSERVER AGENCIES (28) direct inputs
MISSIONS AND PROGRAMS with direct funding

Study Groups
- SISG
- OLSG
- MOSCG
- LEO26SG

SFCG, ICG, and other peer groups

Close Coordination for Discipline Topics