The Consultative Committee for Space Data Systems

CCSDS

Advancing Spaceflight Technology For International Collaboration

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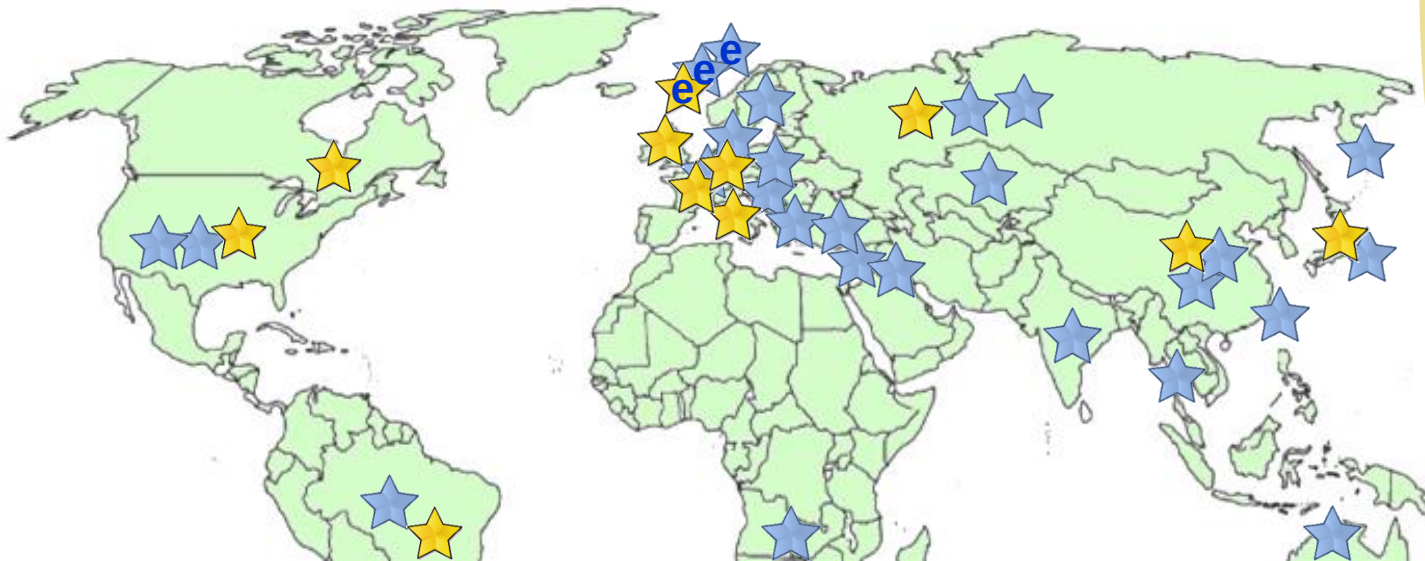
CCSDS Overview

- CCSDS = The Consultative Committee for Space Data Systems
- For international collaboration in spaceflight, the most critical enabling technology is ***communications and data systems***.
- The domain of CCSDS is ***interoperability*** for comm/data systems
- ***Interoperability*** translates to:
  - ***Operations --*** flexibility, capability and access to additional resources
  - ***Development*** - reduced risk, development time and project costs
  - For government, industry, agencies, vendors, programs and projects
- Historically, joint missions have tight schedules right after kickoff. Standards prepared in advance are more methodically developed for long-term benefits.
- CCSDS Started in 1982 developing at the lower layers of the protocol stack. The CCSDS scope has grown to cover standards throughout the ISO communications stack, plus other Data Systems areas (architecture, archive, security, XML exchange formats, etc.

CCSDS composition

- Produces International Voluntary Consensus Standards
- Agency-led international committee
  - Currently 11 Member agencies
  - Currently 28 Observer Agencies
  - Agencies represent 26 nations
  - Currently 141 Commercial Associates
  - ~160-180 attendees at Spring/Fall meetings
- Also functions as an ISO Committee
  - TC20/SC13 - Space Data & Info Transfer Systems



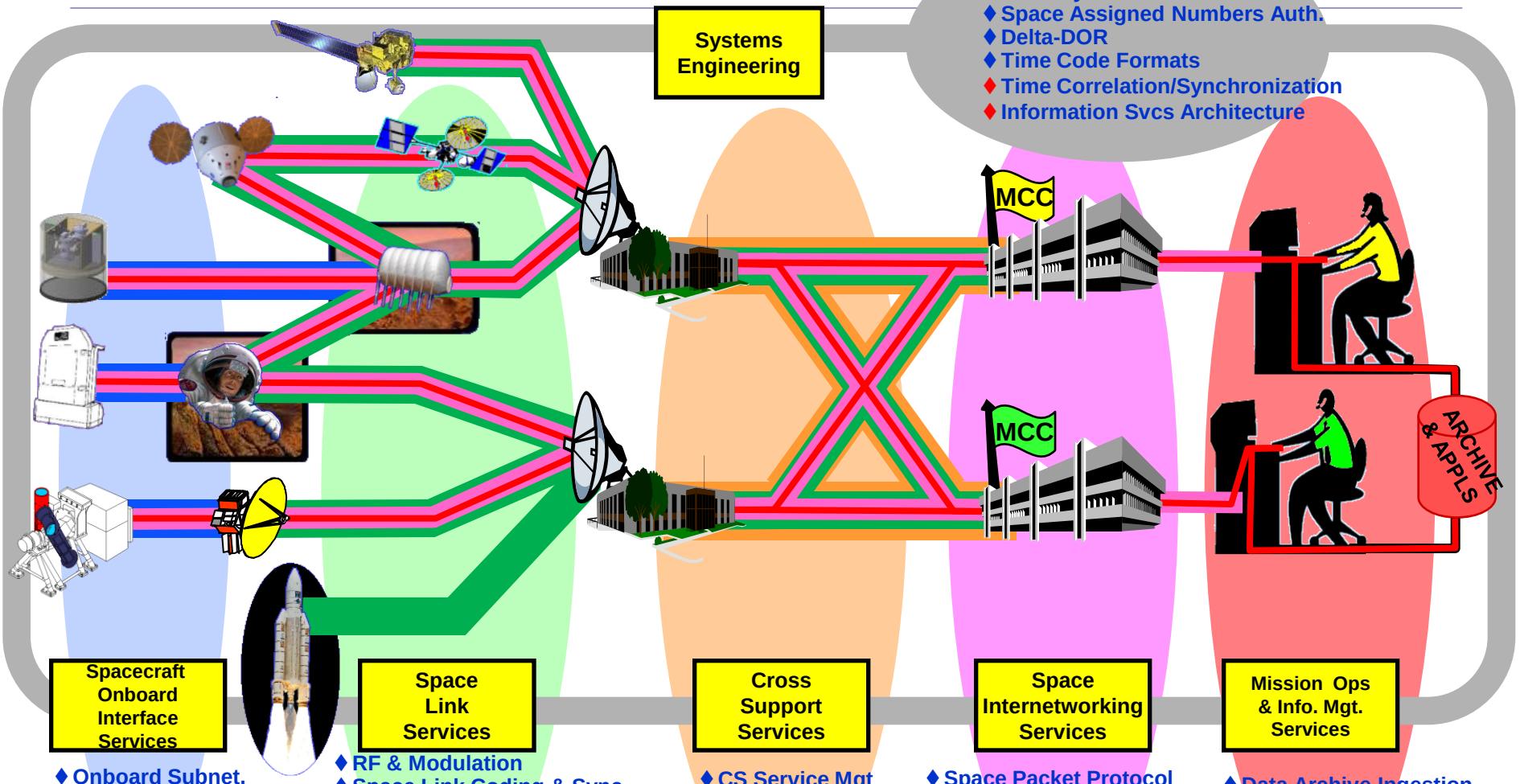
MEMBER AGENCIES

ASI/Italy
CNES/France
CNSA/China
CSA/Canada
DLR/Germany
ESA/Europe
FSA/Russia
INPE/Brazil
JAXA/Japan
NASA/USA
UKSA/UK

OBSERVER AGENCIES

ASA/Austria
BFSPO/Belgium
CAS/China
CAST/China
CLTC/China
CSIR/South Africa
CSIRO/Australia
DCTA/Brazil
DNSC/Denmark
EUMETSAT/Europe
EUTELSAT/Europe
GISTDA/Thailand
HNSC/Greece
IKI/Russia
ISRO/India
KARI/Korea
KFKI/Hungary
MOC/Israel
NCST/USA
NICT/Japan
NOAA/USA
NSARK/Kazakhstan
NSPO/Taipei
SSC/Sweden
SUPARCO/Pakistan
TsNIIMash/Russia
TUBITAK/Turkey
USGS/USA

CCSDS Overview



♦ Onboard Subnet. Services
♦ Onboard Application Services
♦ Wireless WG
♦ Onboard Plug-n-Play

♦ RF & Modulation
♦ Space Link Coding & Sync.
♦ Multi/Hyper Data Compress.
♦ Space Link Protocols
♦ Next Generation Uplink
♦ Space Data Link Security
♦ Planetary Communications
♦ Optical Coding and Mod

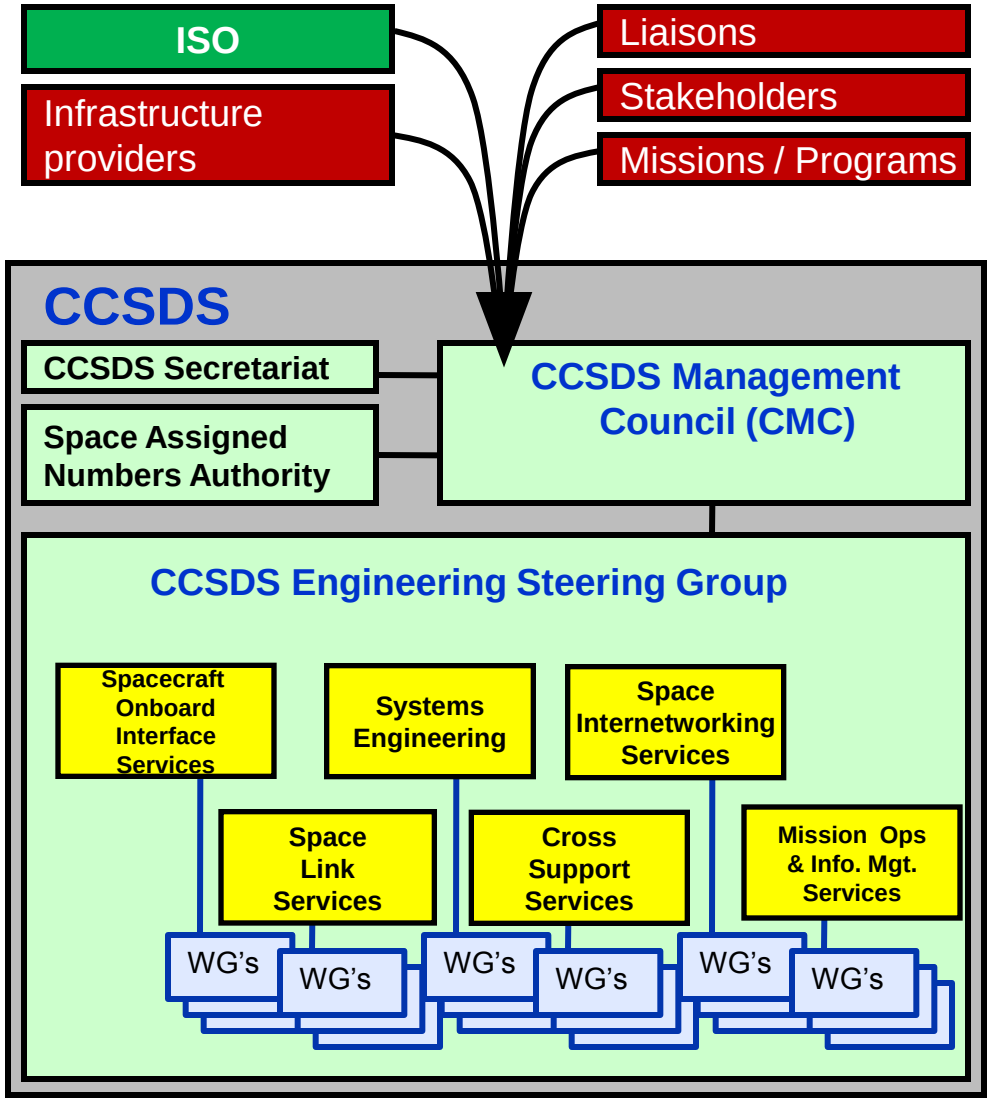
♦ CS Service Mgt
♦ CS Transfer Svcs
♦ Cross Support Architecture
♦ Reference Arch.

♦ Space Packet Protocol
♦ Asynch Messaging
♦ IP-over-CCSDS Links
♦ Motion Imagery & Apps
♦ Delay Tolerant Networking
♦ Voice

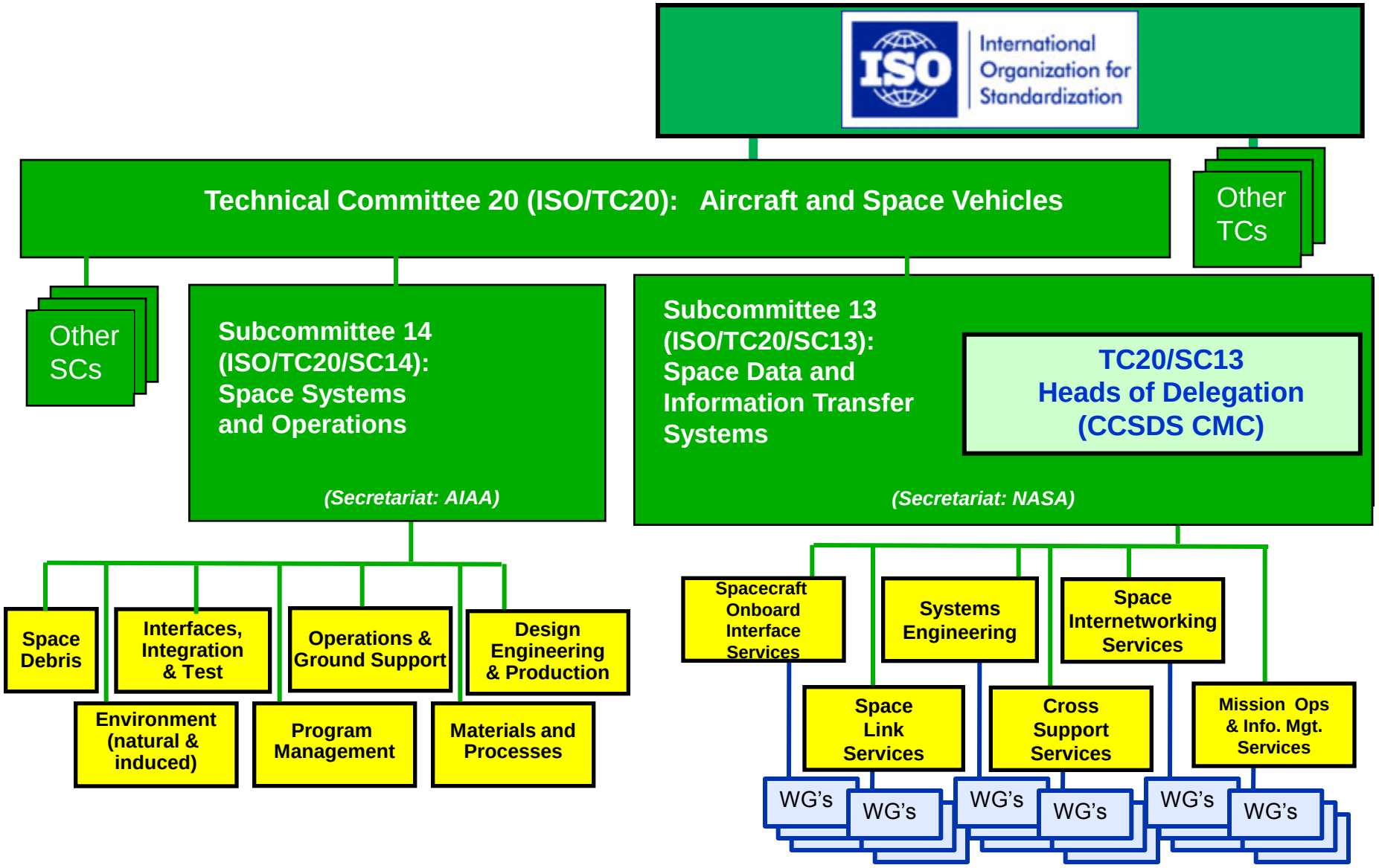
♦ Data Archive Ingestion
♦ Navigation
♦ Info. Pack. & Registries
♦ Spacecraft Monitor & Control
♦ Digital Repository Audit/Certification

Thirty-four working groups (some in formative stages ♦)

CCSDS Structure and Organization

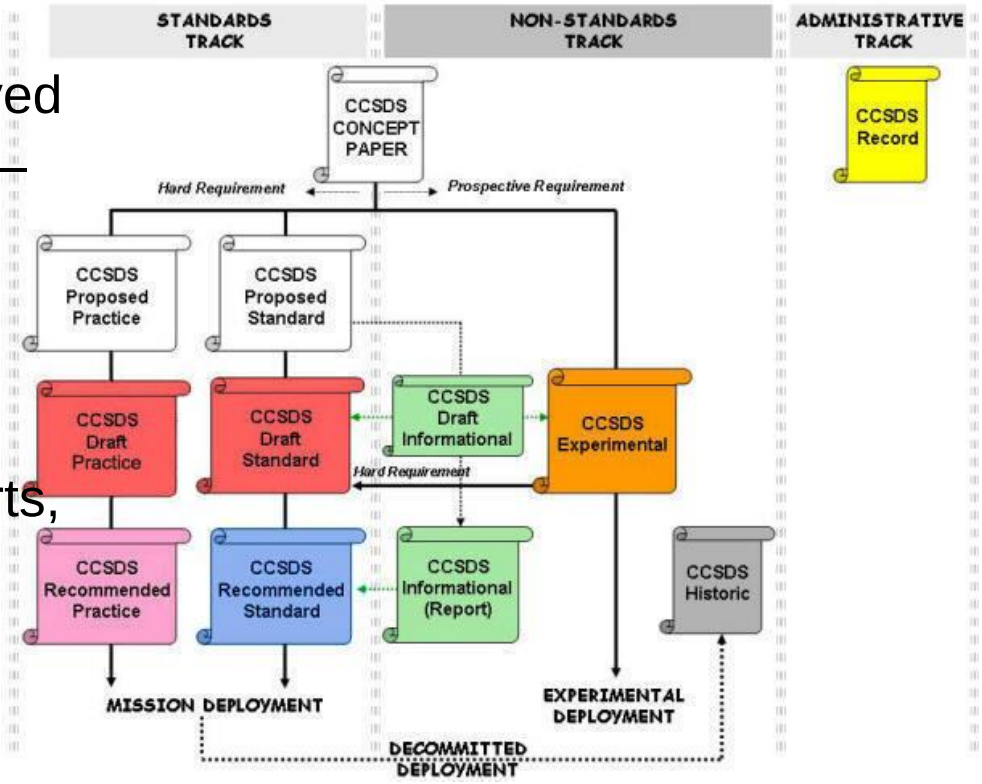


CCSDS Relationships with ISO

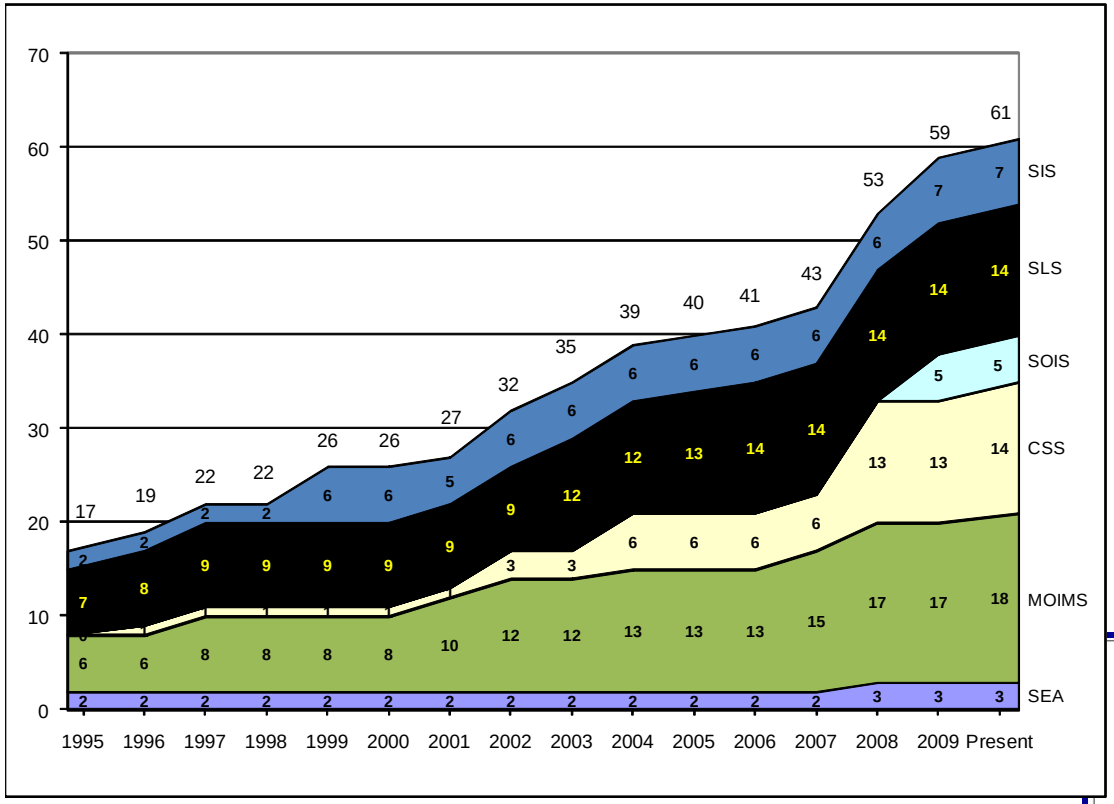


CCSDS Process – Colors of Books

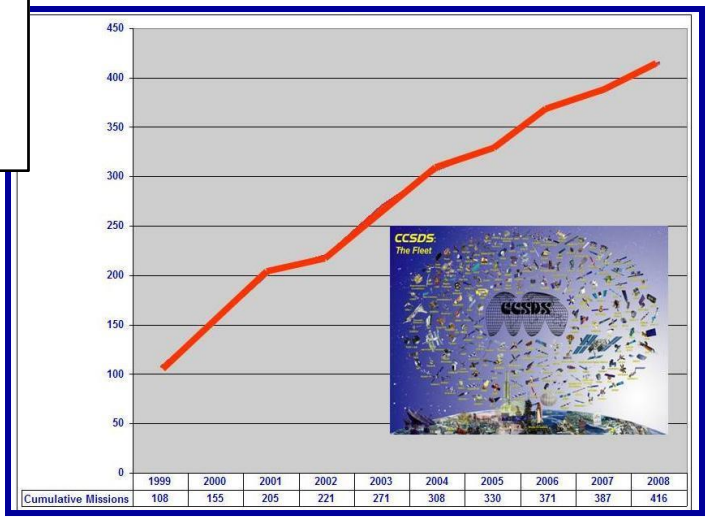
- Blue Books: Recommended Standards – Verified for Interoperable Implementations (with options specified)
- Magenta Books: Recommended Practices – Normative, but not for direct implementation
- Red Books: Drafts of Blue or Magenta books not yet approved
- Orange Books: Experimental – New Technology or Single-Agency
- Green Books: Informational, concepts, etc.
- Yellow Books: Technical reports, Procedures, etc.
- Silver Books: Historical (deprecated)



CCSDS Overview



61 Standards and Practices Currently Active



460+ missions

Access to CCSDS Publications
www.ccsds.org > Publications

About | Publications | Review Documents | Meetings | Press Room | Participation | Implementations | Search

CCSDS Approved Documents

- Blue: Recommended Standards
- Magenta: Recommended Practices
- Green: Informational Reports
- Orange: Experimental
- Yellow: Record
- Silver: Historical
- All Active Publications

Other

- Review Documents
- Reference Models
- Non-English Versions of Documents

Blue Books: Recommended Standards

CCSDS Recommended Standards (Blue Books) define specific interfaces, technical capabilities or protocols, or provide prescriptive and/or normative definitions of interfaces, protocols, or other controlling standards such as encoding approaches. Standards must be complete, unambiguous and at a sufficient level of technical detail that they can be directly implemented and used for space mission interoperability and cross support. Standards must say very clearly, "this is how you must build something if you want it to be compliant".

Currently 47 Books Listed

CCSDS 121.0-B-1
File size: 256,280 Bytes

Lossless Data Compression. **Blue Book. Issue 1. May 1997.**
This Recommendation defines a source-coding data-compression algorithm and specifies how data compressed using the algorithm are inserted into source packets for retrieval and decoding.This document has been reconfirmed by the CCSDS Management Council through November 2011. The current version of this document contains all updates through Technical Corrigendum 2, dated September 2007.
ISO Number : 15887

CCSDS 121.0-B-1 Cor. 1
File size: 84,329 Bytes

Technical Corrigendum 1 to CCSDS 121.0-B-1, Issued May 1997. **Blue Book. Issue 1 Cor. 1. November 2006.**
This Technical Corrigendum documents changes to CCSDS 121.0-B-1, Lossless Data Compression (Blue Book, Issue 1, May 1997)

CCSDS 121.0-B-1 Cor. 2
File size: 19,978 Bytes

Technical Corrigendum 2 to CCSDS 121.0-B-1, Issued May 1997. **Blue Book. Issue 1 Cor. 2. September 2007.**
This Technical Corrigendum documents changes to CCSDS 121.0-B-1, Lossless Data Compression (Blue Book, Issue 1, May 1997)

CCSDS 122.0-B-1
File size: 1,121,448 Bytes

Image Data Compression. **Blue Book. Issue 1. November 2005.**
This Recommended Standard defines an image-data compression algorithm applicable to digital data from payload instruments and specifies means to control compression rate and how

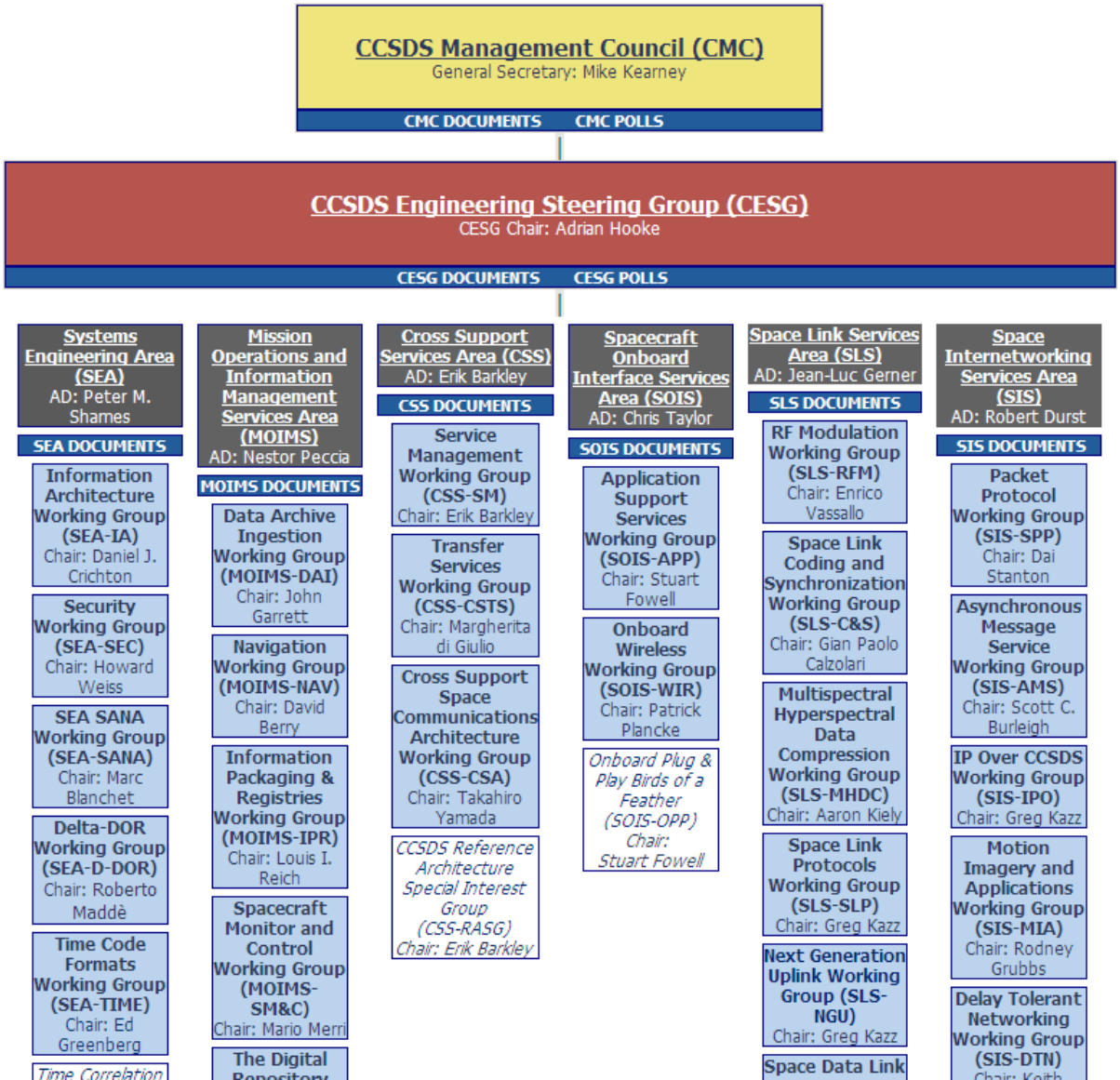
Access to CCSDS Technical WG info: www.ccsds.org > CWE

Welcome to the CCSDS Collaborative Work Environment (CWE)

The interactive graph to the right represents the CCSDS Technical Organization. The CCSDS Engineering Group (CESG) is composed of 6 areas. Within these areas there are Working Groups (WG), Birds of a Feather (BOF), and Special Interest Groups (SIG) that collaborate.

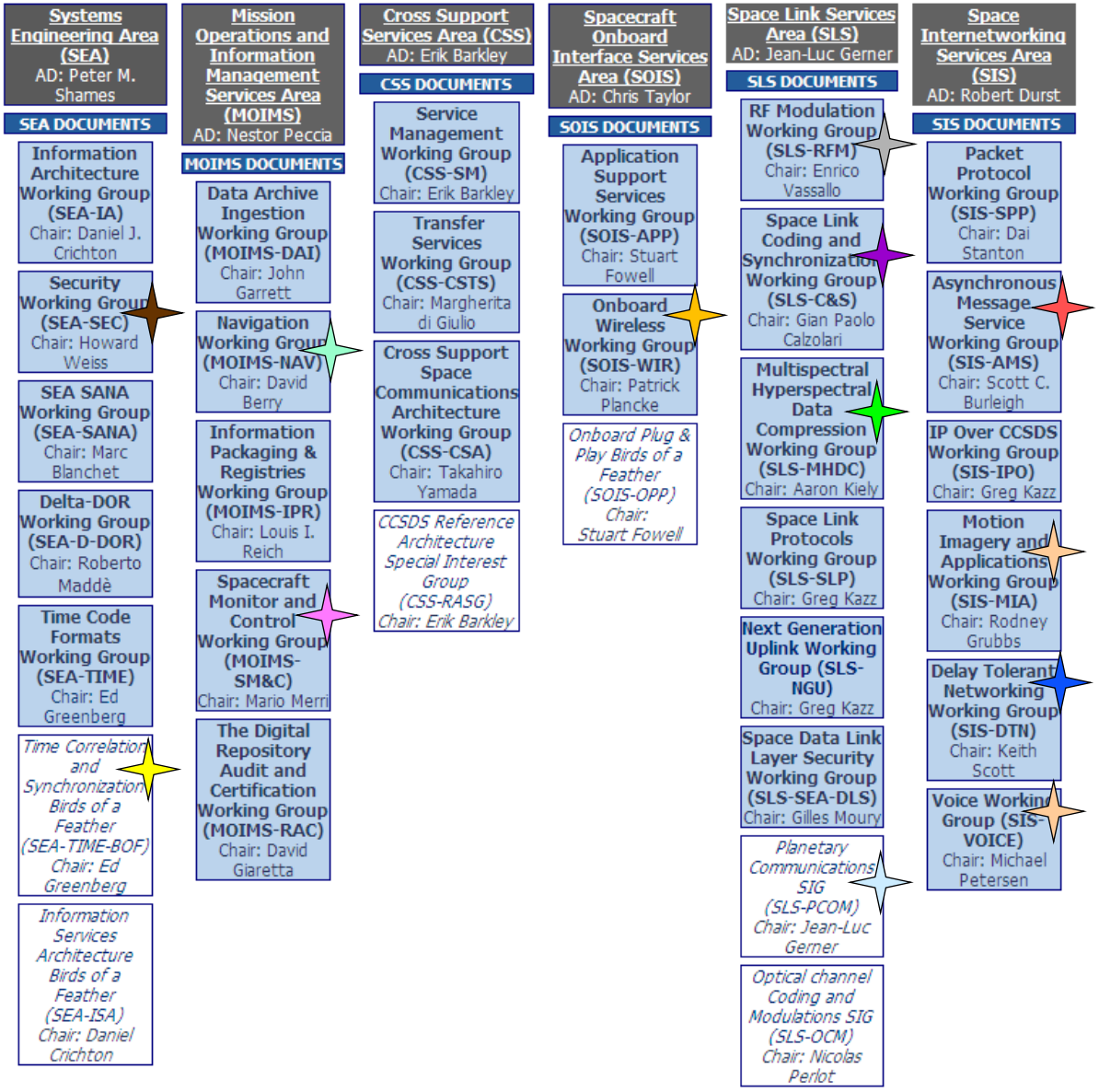
To access more information please click on the CMC, CESG, Area, WG, or BOF name.

To review the status of documents and projects being developed in these WGs, **Click Here**.



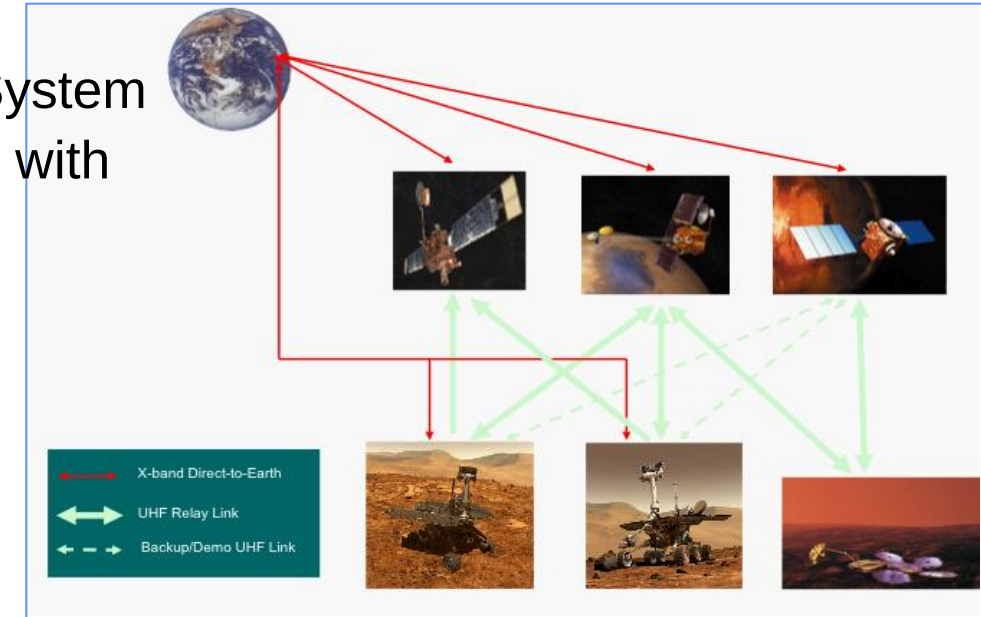
Sampling of Technical Topics (Cont.)

- Topics to be discussed:
  - DTN WG
  - AMS WG
  - Multi/Hyperspectral Data Compression
  - Coding and Synch
  - RF & Modulation
  - Onboard Wireless
  - Spacecraft Monitor & Control
  - Navigation WG
  - Security WG
- New work items briefly mentioned
  - Optical Coding and Modulation SIG
  - Planetary Comm BOF
  - Time Correl/Sync BOF
  - Voice/Video WGs



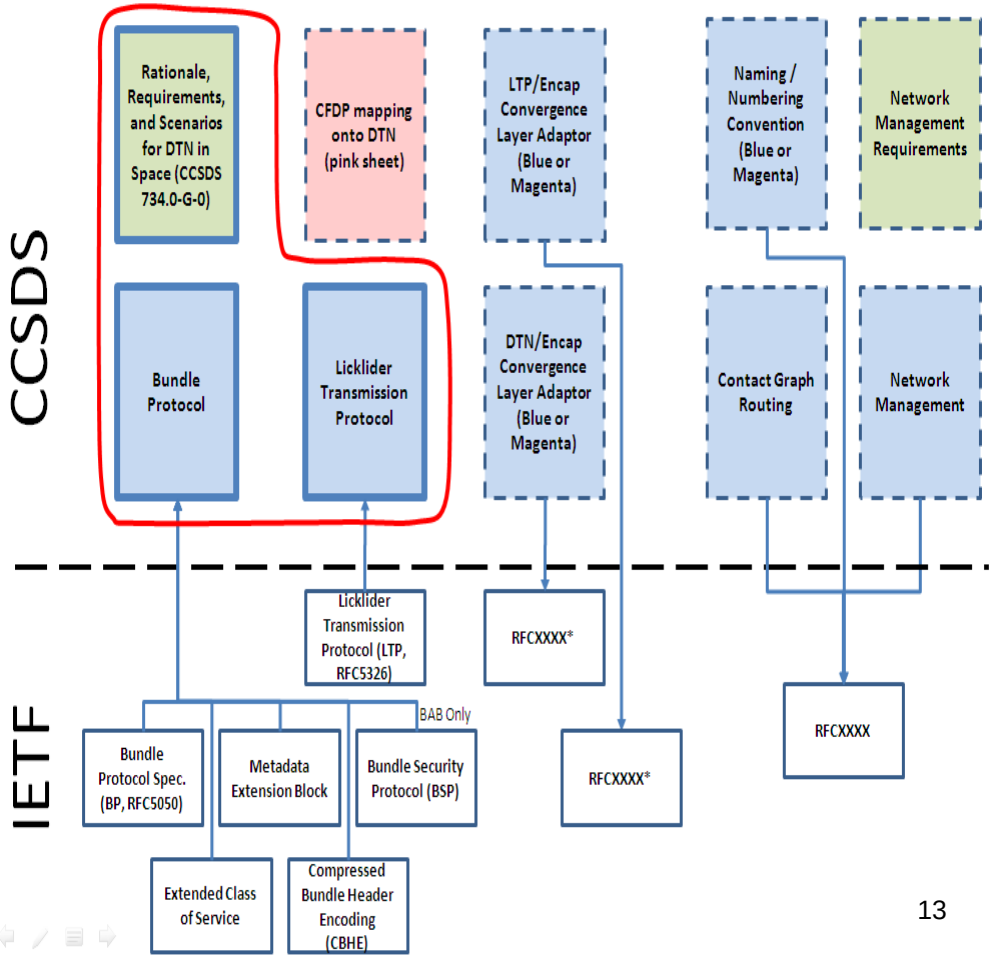
Delay Tolerant Networking

- The DTN Working Group is laying the foundation for the Solar System Internetwork (SSI)
  - Provides automated routing (like current Internet), but compared to current IP technology:
    - Adds Delay tolerance for deep space delays
    - Delivers more data, faster in disrupted near-earth environment
- Past Progress and Current Work
  - Current green book almost finalized. Establishes Rationale, Develops Scenarios, explores candidate technologies
  - In work: DTN Bundle Protocol (BP) specification and Licklider Transport Protocol (LTP).
- Future work – Complete Solar System Internetwork (SSI) infrastructure with
  - Network Management
  - Naming/Numbering conventions
  - Contact Graph Routing
  - File Delivery Protocol (CFDP)



Delay Tolerant Networking (cont.)

- DTN efforts use terrestrial internet work of the IRTF as a "springboard" for the Solar System Internetwork
  - Great example of strategy for "paced" development of Space Communications infrastructure following terrestrial and commercial technology development
  - Adopt/Adapt/Develop strategy

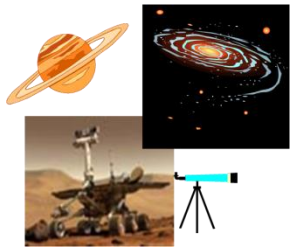


Asynchronous Message Service (AMS)

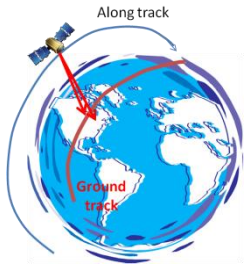
- The AMS Working Group is standardizing messaging middleware for flight mission communications.
  - AMS provides “message bus” functionality for flight missions, including both publish/subscribe and client/server interaction models.
  - Unlike JMS or DDS, AMS is *a wire protocol rather than a service spec*
    - Conformant implementations are interoperable, no gateways needed.
  - Unlike AMQP, AMS is *peer-to-peer, not reliant on a message broker*
    - High performance, fault tolerant.
  - Unlike RTPS, AMS is *designed to run efficiently over space links*
    - Uses a built-in delay-tolerant and disruption-tolerant multicast tree.
- Overall benefit: Loosely-coupled, simplified interfaces
  - Overall reduction in system complexity
- Past Progress and Current Work
  - Final Red Book has passed Agency review, but more interoperability testing is needed before Blue Book is published.
- Reference implementation is available as open source, included in JPL’s “ION” software distribution at: http://www.openchannelfoundation.org/projects/ION/

Multi/Hyperspectral Data Compression

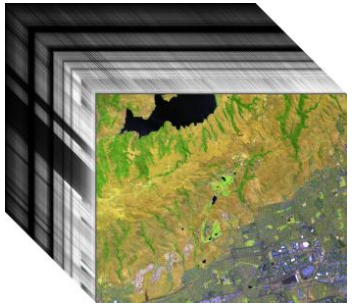
- The Multispectral & Hyperspectral Data Compression (MHDC) and previous Data Compression (DC) working groups
  - Develop standards for lossy and lossless data compression, primarily for imagery
  - Pay close attention to hardware implementation complexity – focus is spacecraft onboard compression
- Past Progress and Current Work
  - 121 Blue Book (1997): general-purpose lossless compressor based on Rice coding, implementation > 25 missions
  - 122 Blue Book (2005): lossy and lossless 2D image compression using advanced wavelet-based techniques, applicable to frame sensors and push-broom sensors, implementation > 3 missions
  - 123 Blue Book (in progress): lossless compression for multispectral and hyperspectral (i.e., 3D) image compression
- Future work
  - Lossy compression for multispectral and hyperspectral imagers



frame sensors



Push-broom sensors



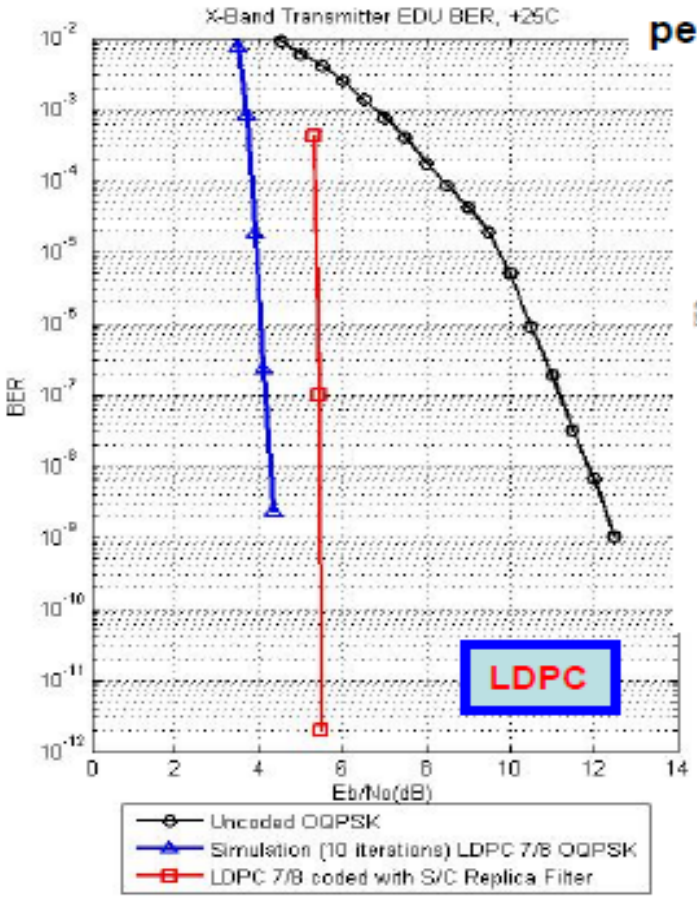
Hyperspectral imagers can produce enormous data volumes

Coding & Modulation for Ka Band

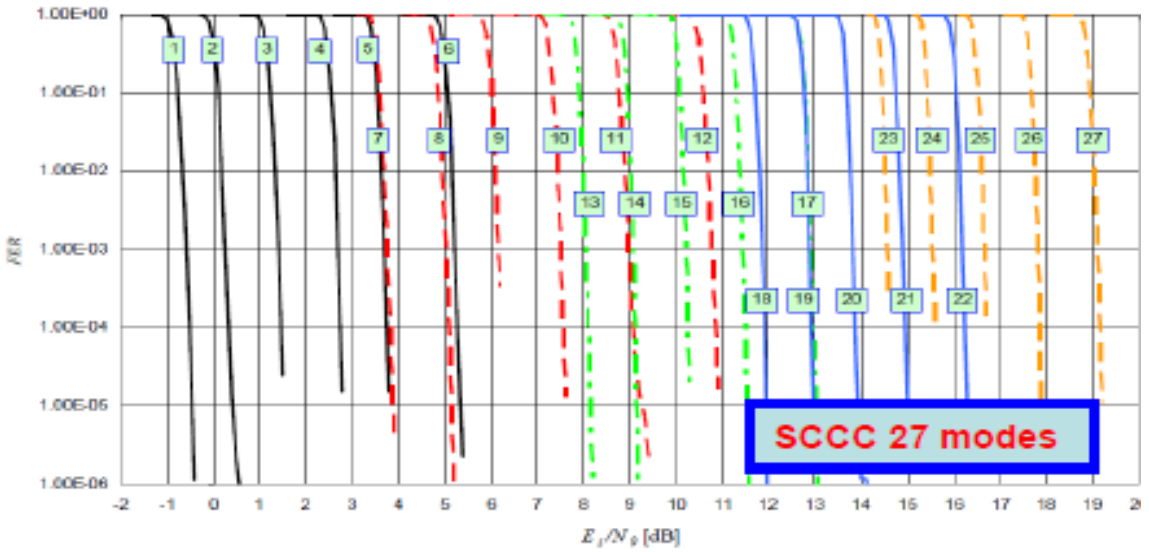
- The RF & Mod and Coding & Sync Working Groups are laying the foundation for the future missions operating at Ka band frequencies
  - Ka band is the answer to the increasing demand in bandwidth but … is very sensitive to atmospheric conditions
    - For deep space, Earth station diversity permits the use of conventional fixed Coding and Modulation
    - In disrupted near-earth environment, Variable/Adaptive Coding & Modulation (VCM & ACM) deliver more data, faster
    - VCM/ACM -- physical layer complement to Network layer DTN
  - Amplitude Phase Shift Keying modulations (8/16/32APSK) and advanced coding (SCCC, LDPC) for efficiently supporting fixed and variable/adaptive CodMod over satellite nonlinear channels
- Past Progress and Current Work
  - Two Orange Books adopted. Three Red Books under completion. Provide standards for fixed CodMod and for VCM/ACM, together with recommended practice
- Future work: Publication of the two Blue Books and the Magenta Book addressing coding and modulation for Ka band links and related topics

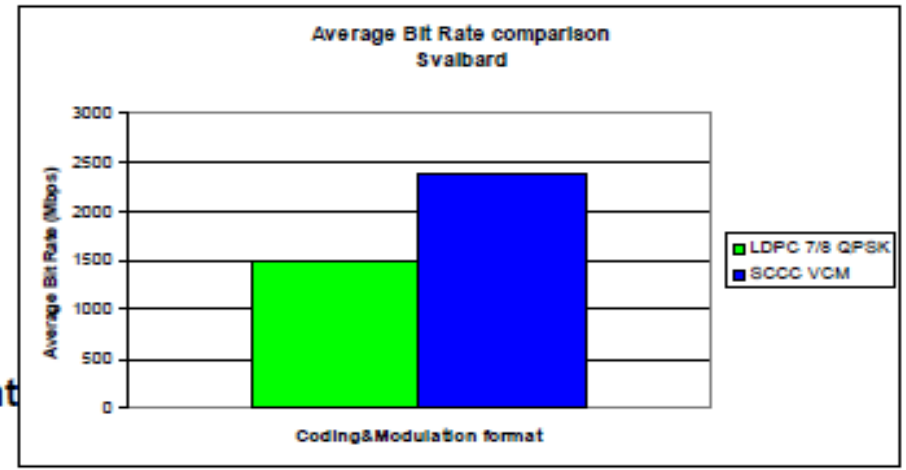
Coding & Modulation for Ka Band

- Conclusion: State-of-the-art coding and modulation techniques will be offered by CCSDS for future space missions at Ka band (26 GHz, 32 GHz)



LDPC and SCCC close-to-Shannon performance in plain environment





SCCC VCM high performance in disrupted near-earth environment

Onboard Wireless Working Group

- Overview of Onboard Wireless activity
  - Provides standards-based resources to achieve interoperable wireless network communication:
    - Wireless communications is an enabling technology for both manned and unmanned spacecraft Delivers more data, faster in disrupted near-earth environment

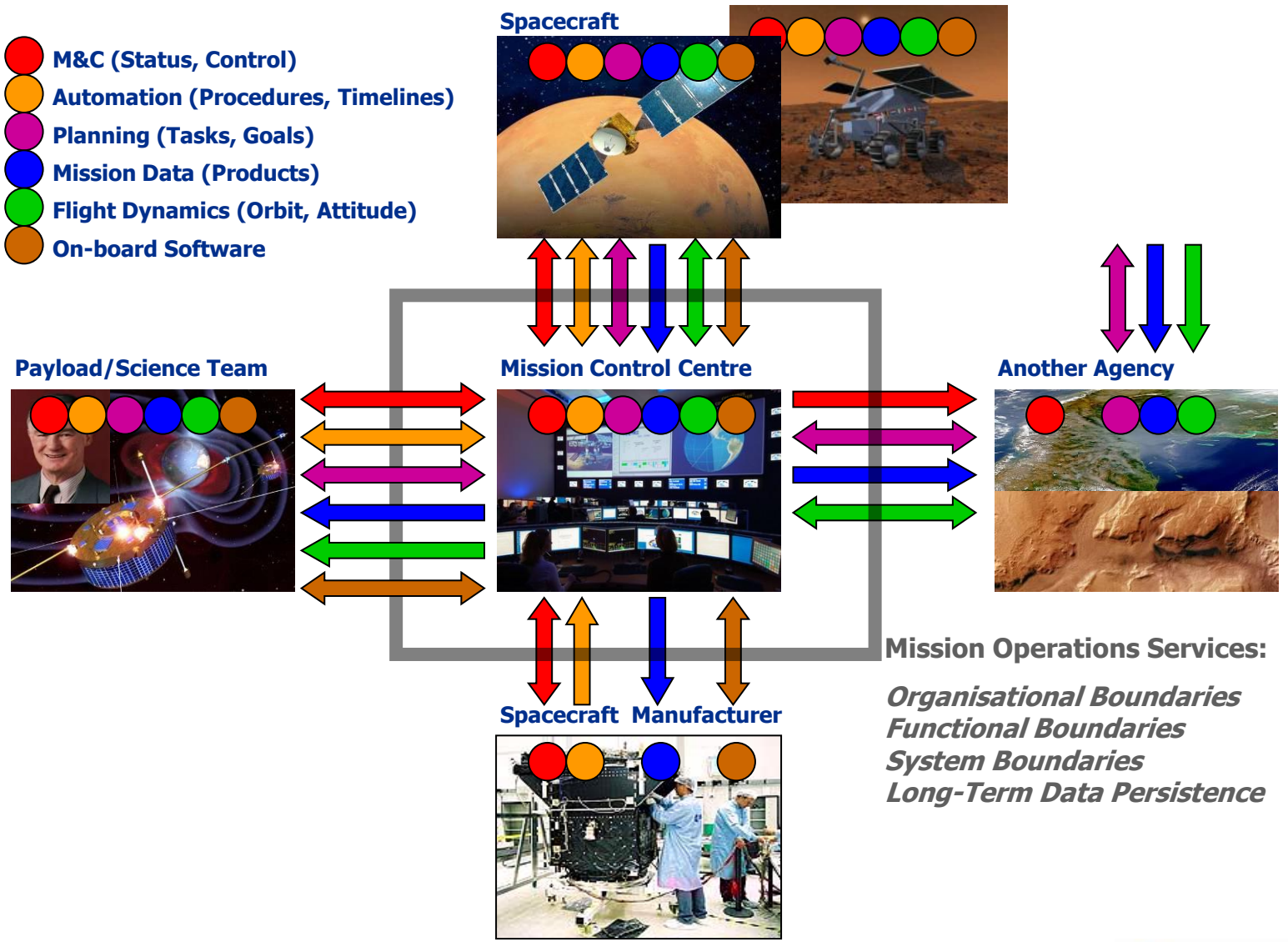
- Past Progress
  - Current Green Book completing publication process
    - Examines the possibilities and advantages of the application of *wireless communications technology* to space missions

- Current / Future Work
  - Magenta Book: *RFID-Based Inventory Management Systems*
    - Improve ground system and spaceflight vehicle inventory tracking & visibility
  - Magenta Book: *Low Data-Rate Wireless Communications for Spacecraft Monitoring and Control*
    - targeted towards low data-rate and low-power applications transmitting in the 850 MHz – 950 MHz and 2.45 GHz (ISM) radio frequency band

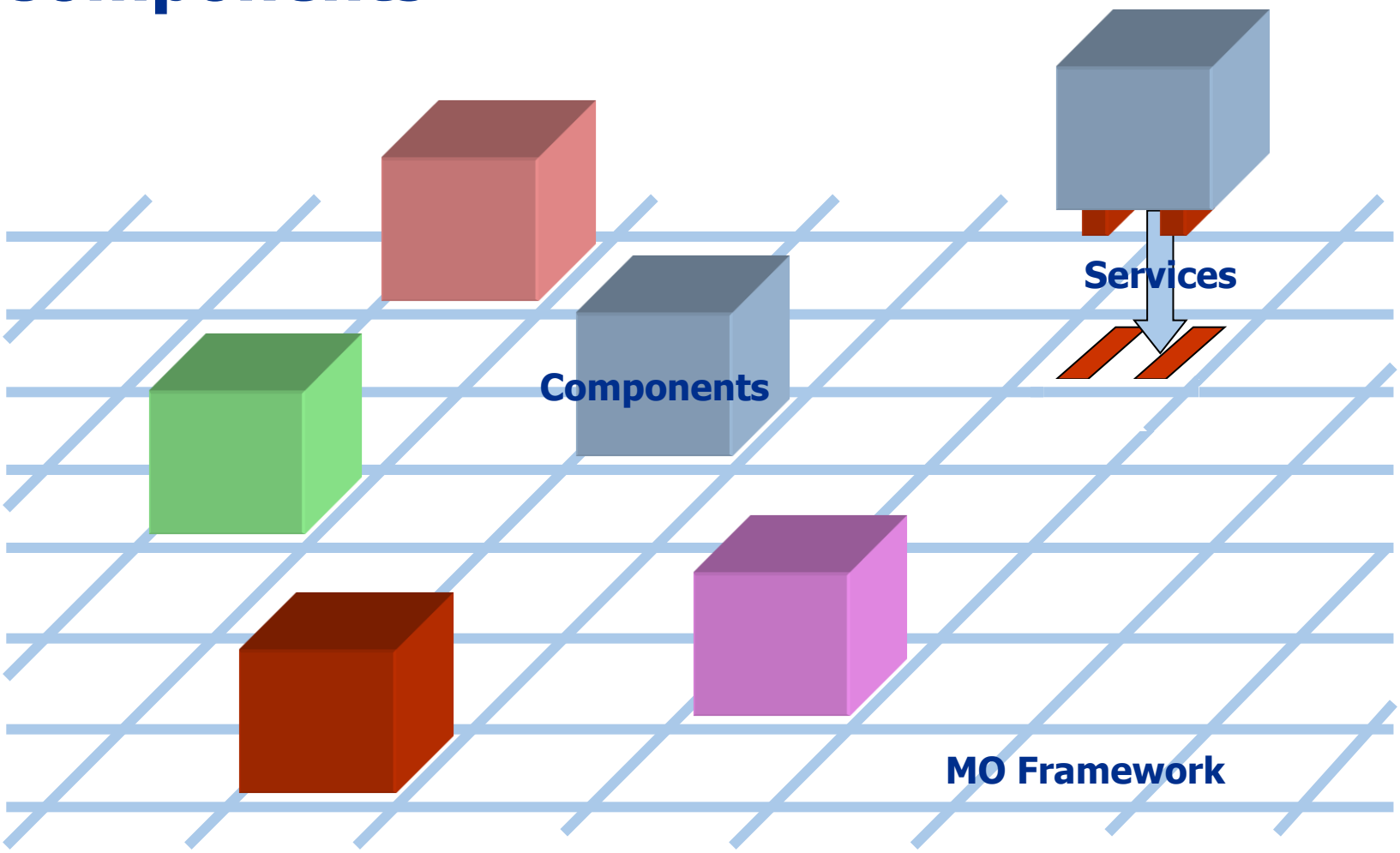
Spacecraft Monitor and Control

- Emphasis is on standardizing certain functions that are in every missions -- *Application level*
- Capitalizes on industry approach of a SOA
  - SOA = Service Oriented Architecture
- Need for functions to be location transparent, so service interface in many locations should be standard
- Define providers and consumers of service
  - Information transferred between the two contains semantics
- Result: Plug-in architecture.
  - Components plug into services
  - Provides application portability as well as interoperability
- Initial focus of effort: Ground MCCs. Eventually will include flight systems that provide services

Distributable MO Functions

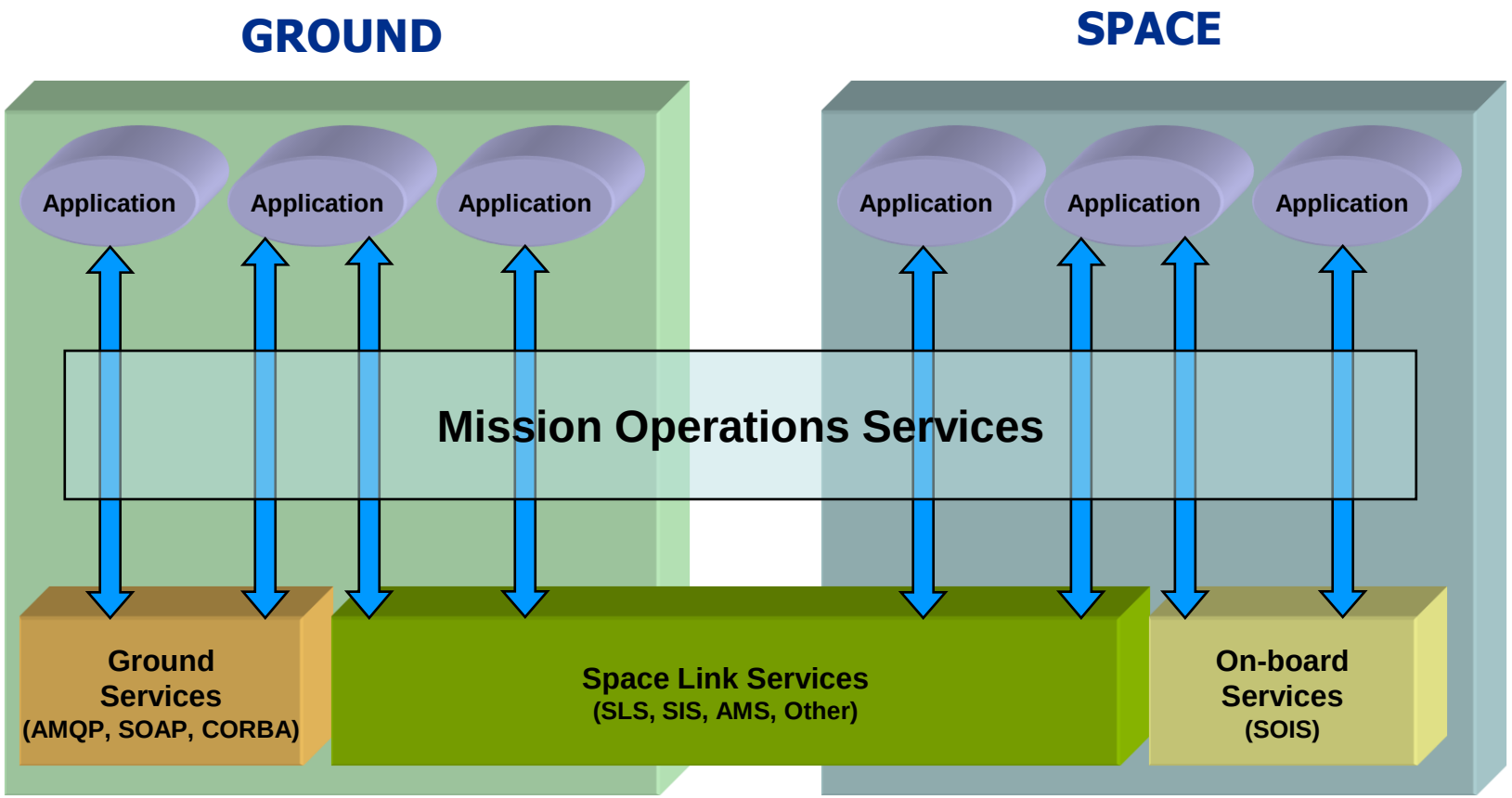


Service-Oriented Architecture: Plug-in Components

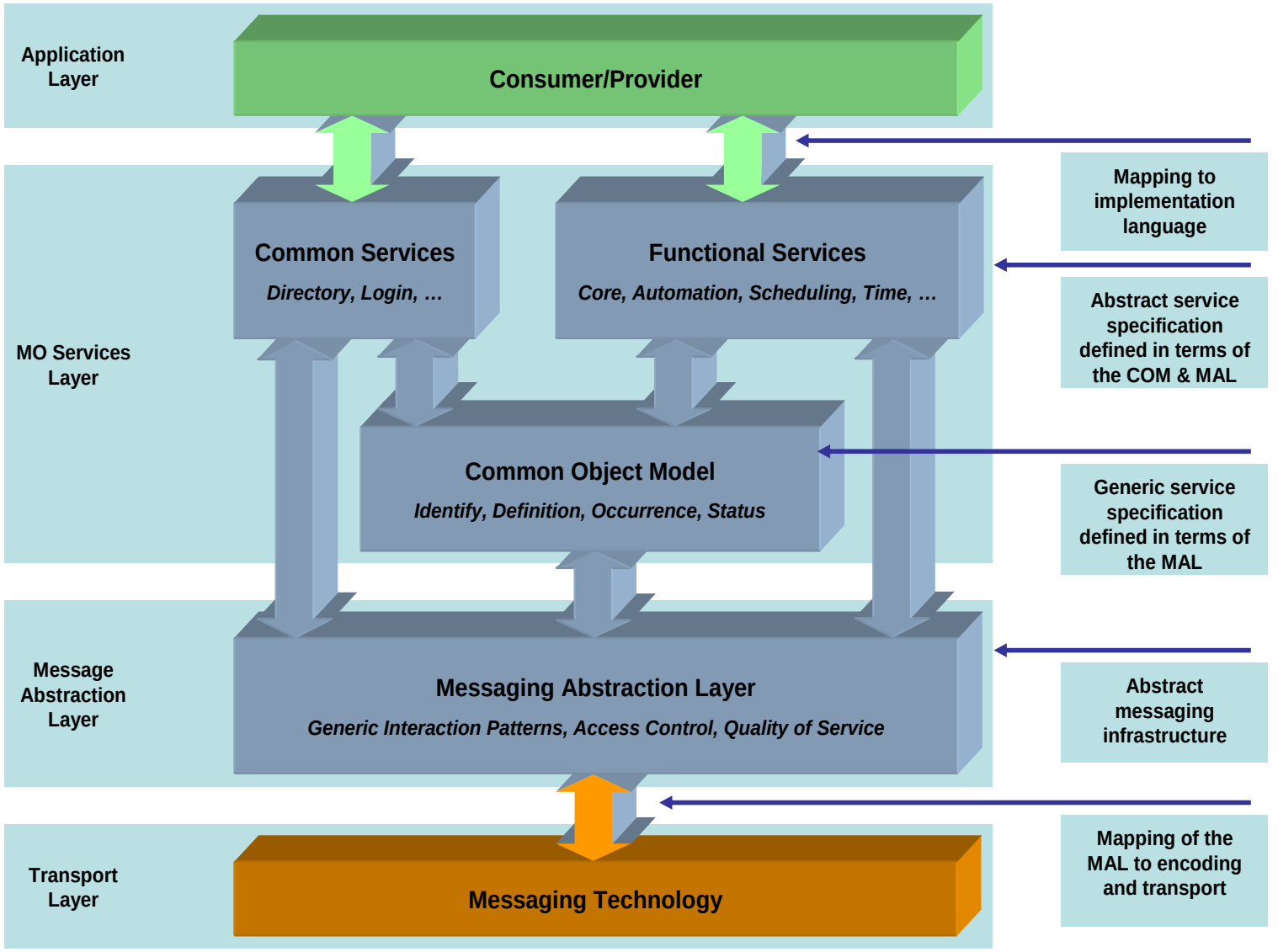


MO Service Deployment Options

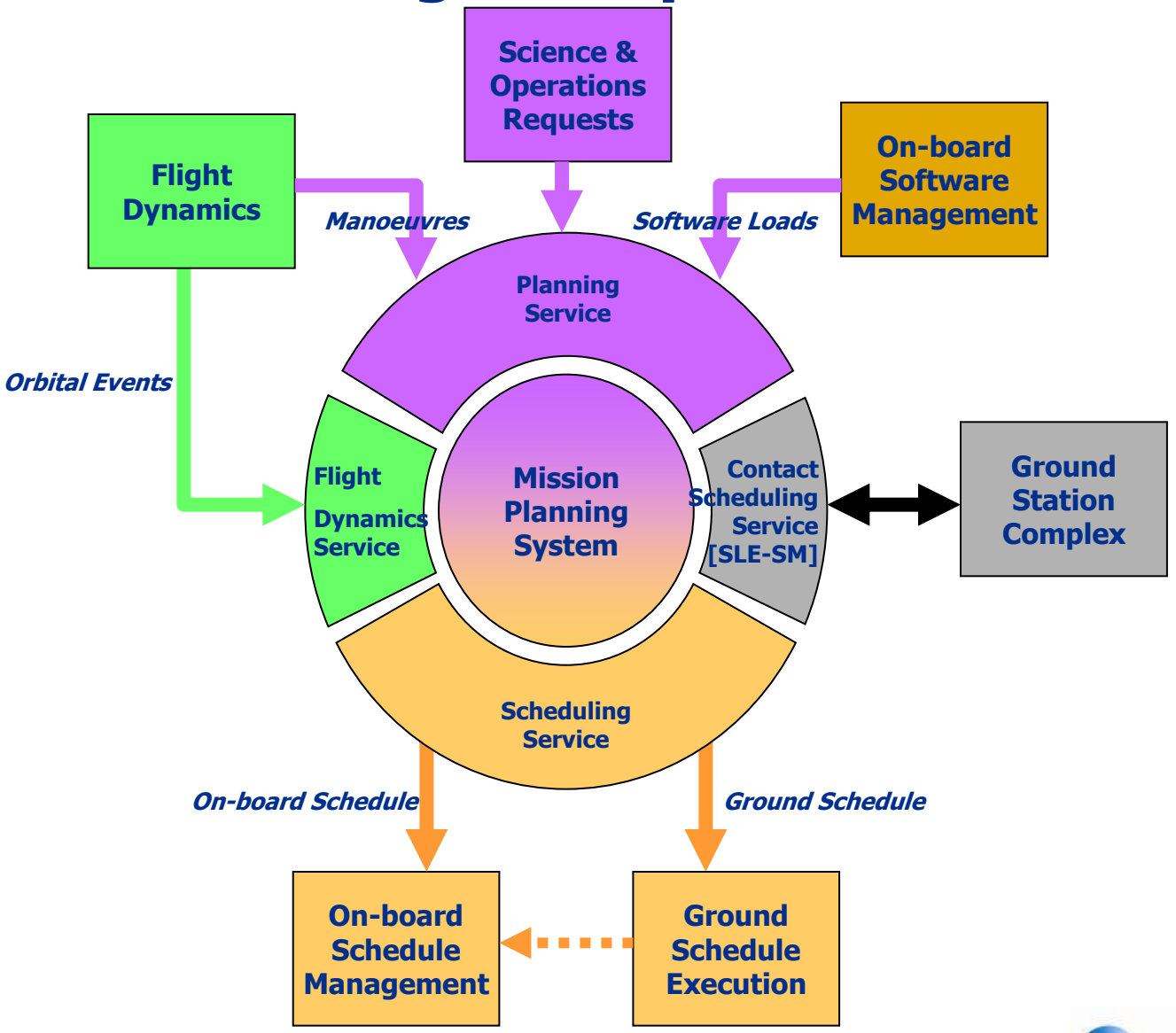
Mission Ops Services reside between the comm system and the applications



MO Service Layering



Orchestrating MO Services: Mission Planning Example



Navigation WG

- The Navigation Working Group is chartered to develop standards covering spacecraft orbits, attitudes, and tracking
- Past Progress and Current Work
  - Orbit Data Messages (version 2.0 published 11/2009)
    - Three standard message formats for exchanging orbit descriptions
      - Orbit Parameter Message (OPM) is a state vector (position and velocity at epoch; must be propagated)
      - Orbit Mean Elements Message (OMM) is an orbit state (mean Keplerian elements; must be propagated)
      - Orbit Ephemeris Message (OEM) is an ephemeris (position and velocity at multiple epochs; must be interpolated)
  - Tracking Data Message (version 1.0 published 11/2007)
    - Message format for exchanging tracking data; supports widely used tracking data types: Doppler, range, angle, ΔDOR, ancillary information
  - Attitude Data Messages (version 1.0 published 05/2008)
    - Two message formats for exchanging spacecraft attitude descriptions
      - Attitude Parameter Message (APM) is an attitude state at epoch, must be propagated
      - Attitude Ephemeris Message (AEM) a series of attitude states at multiple epochs, allows modelling of any number of torques, must be interpolated
  - Navigation Green Book (version 3.0 published 05/2010)
    - Contains technical background related to the Nav WG Recommendations
- Future work – Adressing gaps in existing standardization
  - Planned are several messages relating to spacecraft perturbations, pointing requests, conjunction assessment, orbital events, maneuver planning/tracking

Security Working Group

- The CCSDS Security Working Group:
  - Develops CCSDS security recommendations (standards)
  - Develops security guides and informative documents
  - Provides security advice and guidance to CCSDS working group for security factors and practices in other CCSDS standards.
- Documents developed:
  - Green Book on use of security in CCSDS
  - CCSDS Security Architecture
  - Algorithm trade studies for encryption and authentication
  - System interconnection guide
  - Threat guide
- On-going work:
  - Encryption and authentication algorithm standard
  - Key management guide and standard
  - Mission planner's security guide
  - Network layer security profile
  - Information security glossary

Other New Work Areas

- Optical Coding and Modulation BOF
  - Considering whether it is time for an Optical Comm standard
  - Would support Mars-Earth, LEO-GEO, LEO DTE scenarios
  - Interesting work in optical coding and modulation for interoperability
- Planetary Communications BOF
  - Will address comm on planetary surfaces
    - Lunar/Mars, Robotic/Human, Orbiters/Rovers/Habitats, etc.
  - Currently surveying agencies for mission plans and needs
- Time Correlation and Synchronization BOF
  - Exotic technical problem - establishing time on distant spacecraft
  - Applies spacecraft-to-spacecraft, space-to-MOC, etc.
- Voice and Video WGs
  - Classic problem of Voice/Video degradation from analog/digital conversions during cross support (mostly human spaceflight programs)
  - Plan to establish “profiles” of cross-supported commercial standards
- More participation in these freshly-forming topics is encouraged.

Drinking from a fire hose?

Concluding Information

- Recent Membership News
  - Thailand, Turkey, Kazakhstan admitted as observer agencies
  - Nigeria and Egypt expressing interest

- Next Tech WG meeting: October 25-29, 2010
  - At British Standards Institute, London, UK
  - Hosted by UK Space Agency
  - Visit www.ccsds.org for info
  - Management meeting the following week includes joint meeting with the Interagency Operations Advisory Group (IOAG).

- Spring 2011: May 16-20, 2011
  - DIN facility, Berlin DE
  - Hosted by DLR
  - Management meeting the following week includes joint meeting with ISO TC20/SC14

Concluding Information

- Take-home message: Still much work to be done
  - As technology changes, new standards must emerge
  - This ***enables interoperability*** between international agencies
  - New technologies will enable new mission concepts, sometimes unanticipated benefits.

- Even if a mission has no int'l interoperability goals, missions should comply with standards to enable contingency (rescue) operations. Examples:
  - 1995 - NASA DSN "rescue" of UK's STRV vehicle
  - 2008 - NASA DSN "rescue" of ESA's XMM-Newton mission

- **When mankind reaches other planetary surfaces, we can't afford to not have standardization.**
  - It's too far away to have the inefficiencies of incompatible systems.
  - It's too far away to not use the help of other agencies on that new planet.