Introduction to CCSDS Mission Operations (MO) Services Standards

Module 1 - Primer

European Space Operations Centre (ESOC)
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About the presenter

MARIO MERRI

- Education: “Laurea” in Electrical Engineering (Politecnico di Milano, Italy), Master and Ph.D. in EE (University of Rochester, NY, USA)
- Current position: Since 1989 with the European Space Agency (ESA), Darmstadt, Germany. Head of the Mission Operations Data Systems Division
- Role in CCSSD: Area Director of the Mission Operations and Information Management Services (MOIMS)

Introduction

- CCSDS and MO
- Aims of the training module

CCSDS


CCSDS.ORG
A few of the more than
300
missions
... that fly with
CCSDS
Images © the relevant Agency

Where MO Services are developed

Systems Engineering Area (SEA)
AD: Peter M. Shames

SEA DOCUMENTS

- **Systems Architecture Working Group (SEA-SA)** Chair: Peter Shames
- **Security Working Group (SEA-SEC)** Chair: Howard Weiss
- **Delta-DOR Working Group (SEA-D-DOR)** Chair: Mattia Mercolino
- **Time Management Birds of a Feather (SEA-TIME)** Chair: Peter Shames

Mission Operations and Information Management Services Area (MOIMS)
AD: Mario Merri

MOIMS DOCUMENTS

- **Data Archive Ingestion Working Group (MOIMS-DAI)** Chair: David Giaretta
- **Navigation Working Group (MOIMS-NAV)** Chair: David Berry
- **Spacecraft Monitor and Control Working Group (MOIMS-SM&C)** Chair: Dan Smith
- **Telerobotics Working Group (MOIMS-TEL)** Chair: David Mittman
- **Mission Planning & Scheduling Working Group (MOIMS-MP)** Chair: Mehran Sarkarati

Cross Support Services Area (CSS)
AD: Erik Barkley

CSS DOCUMENTS

- **Service Management Working Group (CSS-SM)** Chair: Erik Barkley
- **Transfer Services Working Group (CSS-CSTS)** Chair: Holger Dreihahn

Spacecraft Onboard Interface Services Area (SOIS)
AD: Jonathan Wilmot

SOIS DOCUMENTS

- **Application Support Services Working Group (SOIS-APP)** Chair: Jonathan Wilmot
- **Onboard Wireless Working Group (SOIS-WIR)** *Chair: Kevin Gifford*
- **Subnetwork Services Working Group (SOIS-SUBNET)** *Chair: Glenn Rakow*

Space Link Services Area (SLS)
AD: Gian Paolo Calzolari

SLS DOCUMENTS

- **RF Modulation Working Group (SLS-RFM)** Chair: Enrico Vassallo
- **Space Link Coding and Synchronization Working Group (SLS-C&S)** Chair: Massimo Bertinelli
- **Multispectral Hyperspectral Data Compression Working Group (SLS-MHDC)** Chair: Aaron Kiely
- **Space Link Protocols Working Group (SLS-SLP)** Chair: Greg Kazz
- **Space Data Link Layer Security Working Group (SLS-SEA-DLS)** Chair: Gilles Moury
- **Optical Communications Working Group (SLS-OPT)** Chair: Bernard Edwards

Space Internetworking Services Area (SIS)
AD: Scott Burleigh

SIS DOCUMENTS

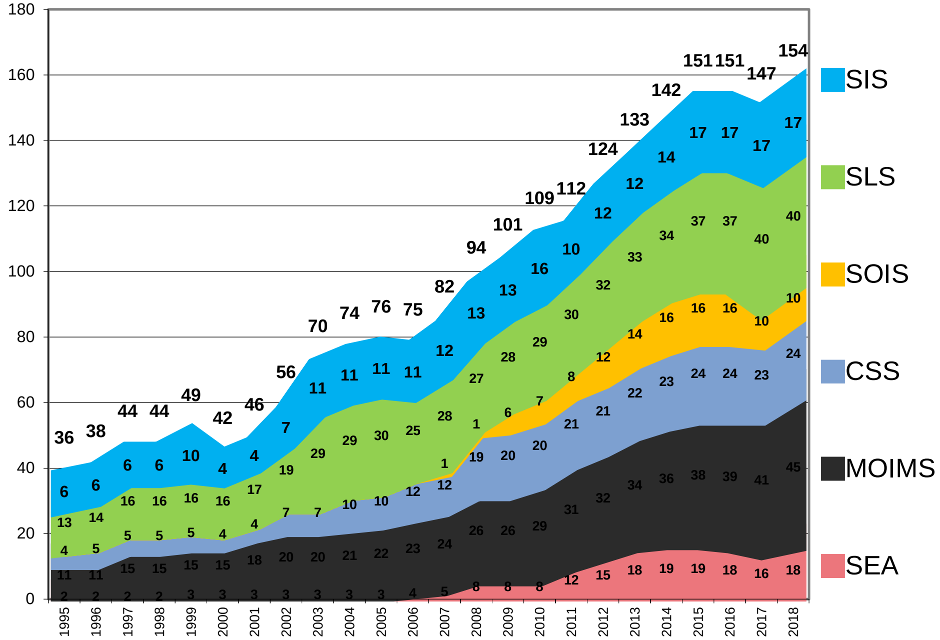
- **Motion Imagery and Applications Working Group (SIS-MIA)** Chair: Rodney Grubbs
- **Delay Tolerant Networking Working Group (SIS-DTN)** Chair: Keith Scott
- **Voice Working Group (SIS-VOICE)** Chair: Osvaldo Peinado
- **CCSDS CFDP Revisions Working Group (SIS-CFDPV1)** Chair: Scott Burleigh

cwe.ccsds.org

Mission Operations

CCSDS Overview

Active Publications



Currently Active Publications:

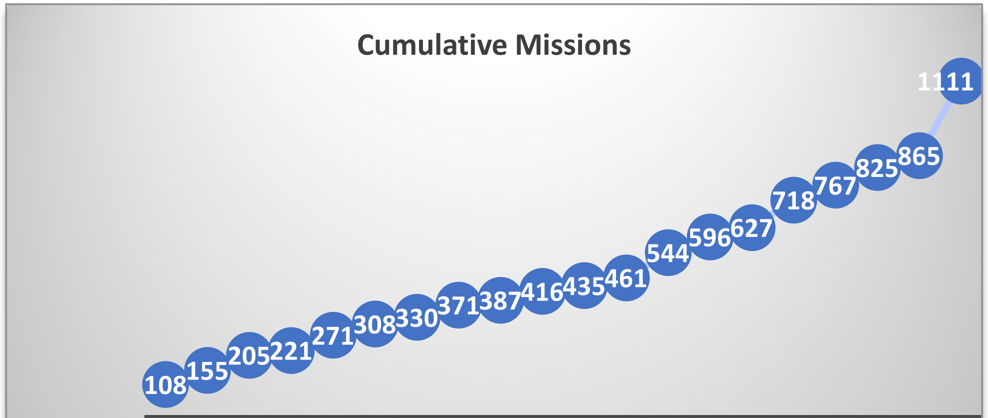
154 ***Normative (Blue & Magenta)*: 95**

***Informative (Green)*: 59**

Downloadable for free from www.ccsds.org

All major pubs since 1982: ~370
(Some were historical mission needs or superseded technologies)

1,111 space missions have adopted and used various CCSDS standards



	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	18
Missions	108	155	205	221	271	308	330	371	387	416	435	461	544	596	627	718	767	825	865	111

Mission Operations

Aims of the training module

- The Primer module is intended for anyone new to CCSDS MO
  - Its emphasis is more on the goals and benefits of MO rather than specific technical details
- The module will
  - Outline the fundamental issues that exist today
  - Walk through how MO solves these issues
- Cover the separation of
  - The MO Framework
  - The MO Services
    - And positioning of MO M&C Services in relation to the PUS standard
- The aim of the training is that you leave feeling you have a good grasp on the goals and approach of MO and how it would fit in your world

Part 1

- Issues that exist today
- Introduction to MO Services
- Benefits of MO Services
- Today's issues and the MO solution

A video

YouTube video link below:

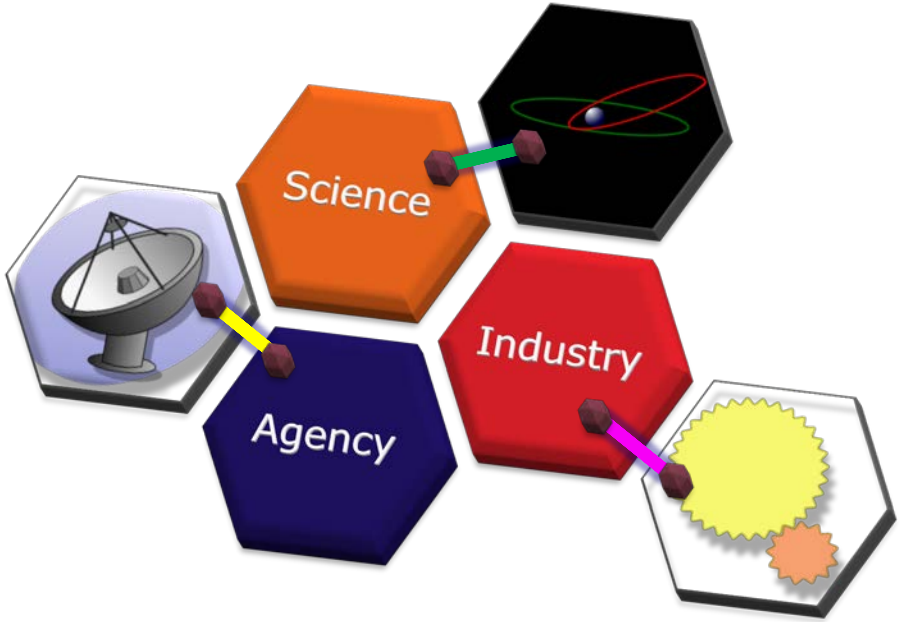
- https://www.youtube.com/watch?v=XdGeaJE7yEk

Issues that exist today

- Two main trends are becoming apparent in current and future missions

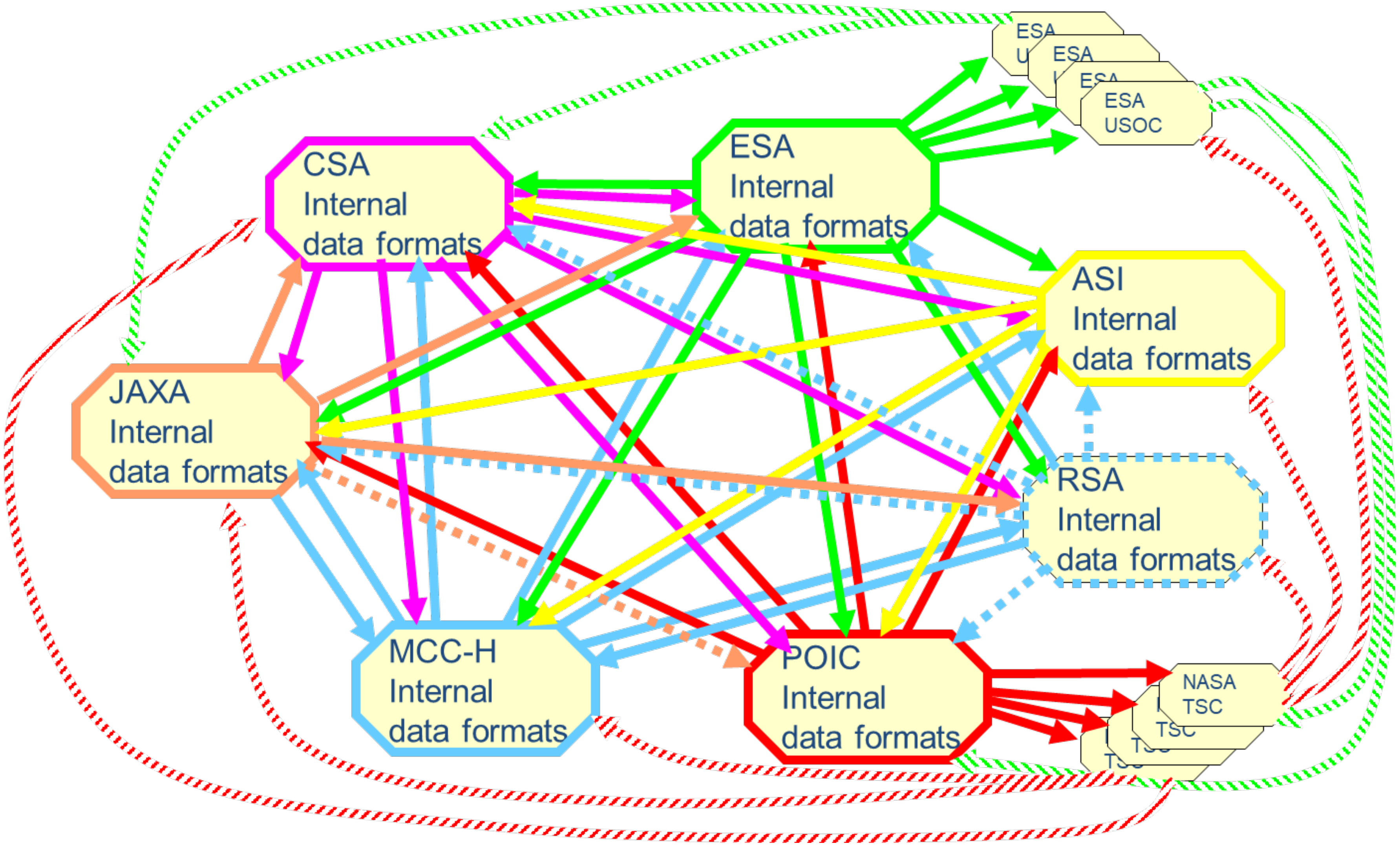
- An increase in mission complexity:
  - More organisations
  - More functions
  - More interfaces
  - More technologies

- With an increasing pressure to reduce costs



Example: ISS Ground Segment

- Picture shows (<u>only</u>) telemetry (TM) exchanges in the ISS ground segment
- Every coloured line corresponds to a different TM format
- High development, operation and maintenance costs!



Picture taken from keynote speech on ISS by Mike Kearney, NASA Marshall @ SpaceOps 2004!

Issues that exist today

- In today’s systems a lack of
  - Standardisation between and inside organisations
  - Combined with lack of re-use between missions
  - Has led to increased cost of
    - Development
    - Deployment
    - and operator training

- Whilst over the long lifetimes of space missions the inability to
  - Update technologies and infrastructure
  - Replace systems without major system redesign
    - Including vendor lock in
  - Has led to increased operational costs

- With the expected growth in mission complexity it is clear that future budget pressures are going to rise

CCSDS Mission Operations Services

- To alleviate this, CCSDS is standardising a set of services for Mission Operations
  - These services define a single specification for the exchange of similar information
- To support these standardised services CCSDS has also defined an open architecture and framework that is:
  - Independent from technology
  - Able to integrate new and legacy systems of different organisations
  - Designed to support the long lifetimes of space missions
  - Based on a Service Orientated Architecture (SOA)
- The CCSDS Mission Operations services provide the capability to hide the unavoidable difficulties that characterises the space environment whilst supporting future complexity needs

Interoperability Beyond Communication Layer

Data

Tell Mike to withdraw **1000 $** from Account **1234567**

How much is 1000$?

Which account is 1234567?

Application Layer

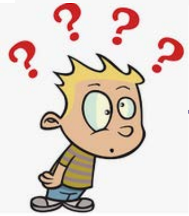
Tell Mike to **withdraw** 1000 $ from **Account** 1234567

Expected Behavior?

Do you expect a response ?

How fast do you expect a response

Possible Errors?



Who is Mike?!!!

Wrong Account Number!

No Money in the account!

Presentation (encoding)

Tell Mike to withdraw 1000 $ from Account 1234567

告訴邁克從賬戶1234567中提取1000美元

マイクにアカウントから1000 $を引き出すように告げる1234567

أخبر مايك بالانسحاب 1000 $ من الحساب

Communication

CCSDS Mission Operations Services

Monitor and Control

Common Services

Mission Data Product Distribution

Telerobotics

Planning

Scheduling and Automation

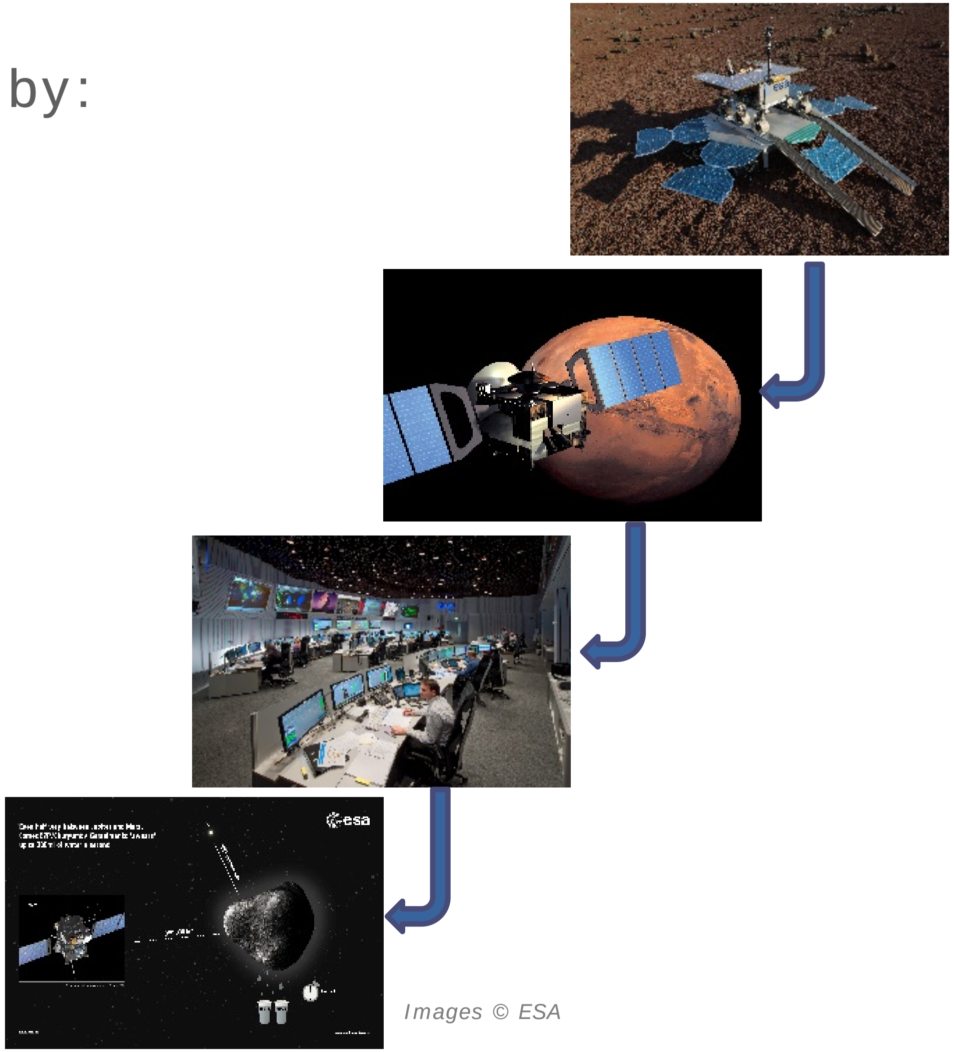
Navigation

Software Management

File Transfer and Management

CCSDS Mission Operations Services

- For instance, whether Parameters are being accessed by:
  - A rover on Mars,
  - A satellite orbiting Mars,
  - Or centres on Earth
- A standard service for Parameters means:
  - A relay satellite can receive the rovers parameters and forward it to Earth
  - A Mission Control Centre can receive and process the Parameters of the satellite or rover
  - An external institution can receive and process the Parameters
- Basically, the same service can be used by completely different systems in completely different situations



Images © ESA

Mission Operations

MO Services benefits

- By speaking a standard language different organisations around the world can interact more easily
  - Same words and grammar with defined meanings (the “what” and the “how”)
  - Difficult, this is why it should be done only once (via standardisation)

- This leads to
  - Minimisation of the number of different interfaces for the same functionality
  - Increased cooperation between organisations
  - Increased reuse from one mission to another
  - A reduction in cost

- This improved flexibility will allow
  - Increased distribution of functions between different organisations
    - Including the migration of functions between ground and space
  - Better able to cope with technology obsolescence/longevity

- Increased interoperability and reuse means
  - Faster times for deployment
  - More innovation
  - and always more competitive costs

MO Services benefits

- CCSDS has defined an open architecture and framework that is:
  - Able to integrate new and legacy systems of different organisations
  - Service Orientated
  - Independent from technology
  - Designed to support the long lifetimes of space missions

- The framework allows different systems to communicate and interact together, independently from their
  - Location
  - Programming language
  - Hardware platform
  - Communications technology

- This independence allows an organisation to choose
  - The technologies that are appropriate for them
  - Whilst still allowing bridging between these different choices where required

- It also increases long-term maintainability over the mission lifetime through replacement of both
  - Systems
  - Underline technology

Issues that exist today and MO

- So let's see how MO can help us
  - Let's review those two main issues again

- An increase in mission complexity due to the larger numbers of involved
  - Organisations
  - Interfaces
  - Functionalities
  - Technologies

- An increasing pressure to reduce costs

MO Provides

- Standardised services
- Separate from technologies

- Supports re-use
- Supports technology migration
- Supports automation

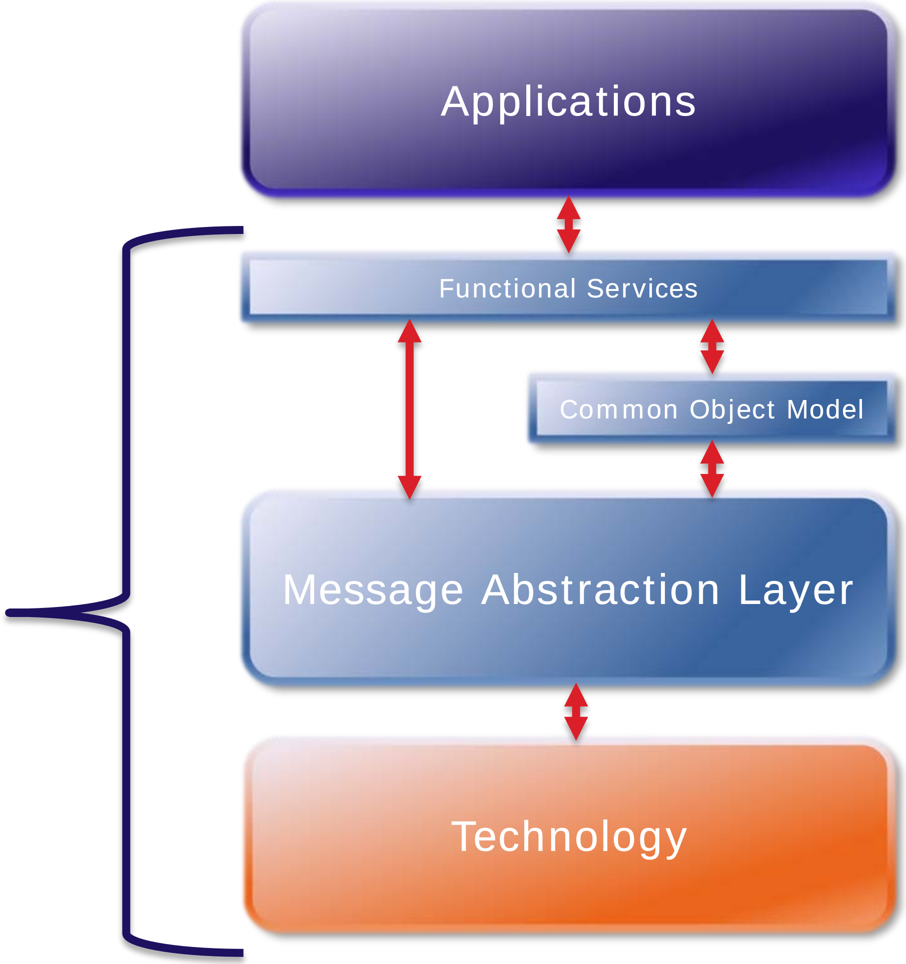
Part 2

- The MO framework
- The MO services
- MO and the future
- ECSS Packet Utilisation Standard

The MO Framework

- Central concept is the MO framework
  - Defines the structure of an MO application
  - Provides generic model for data
    - Supports generic facilities such as archiving
  - Provides separation from technology

- It is defined by three published specifications
  - Reference Model
    - (CCSDS 520.1-M-1)
  - Message Abstraction Layer (MAL)
    - (CCSDS 521.0-B-2)
  - Common Object Model for data (COM)
    - (CCSDS 521.1-B-1)



Message Abstraction Layer (MAL)

- The MAL is the building block for all MO services

- Provides the ability to separate from technology
  - Technology independent XML notation used to describe:
    - Service behaviour
    - Available operations
    - Message structures

- Provides the ability to change that technology at any time
  - Mapping from the XML to your chosen technologies
  - Defines the required abilities of communication technologies

- Simplifies the task to develop communicating applications
  - Specifies a fixed behaviour for applications
  - Expected behaviour of service providers
  - Expected behaviour of service consumers

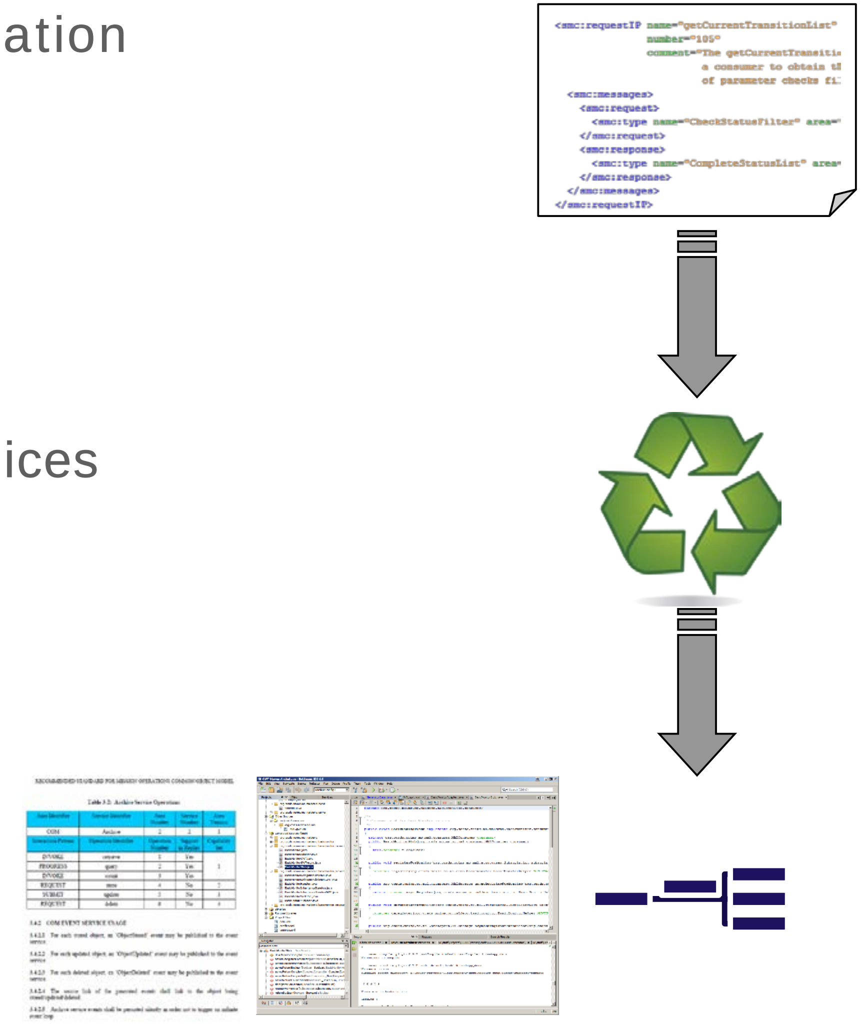
MAL mappings and transformations

- The MAL defines a standard and unambiguous XML notation for service specification

- Mappings define transformations from the XML to:
  - Language mappings for specific programming languages
  - Technology mappings for 'on-the-wire' transports/encodings
  - Bespoke mappings are also supported

- Mappings are not service specific they work for all services
  - Services are defined in terms of the MAL
  - Mappings are defined in terms of the MAL

- So, from this we can automatically and coherently generate:
  - Documentation
  - Programming language APIs
  - System databases
  - …



The MO Services

- So what services does MO intend to provide:

Monitor and Control

Common Services

Mission Data Product Distribution

Telerobotics

Planning

Scheduling and Automation

Navigation

Software Management

File Transfer and Management

Plus your own!

The MO Framework and bespoke services

- MO framework also supports bespoke services
  - These are the services that you define for your:
    - Infrastructure
    - Missions
    - Agency
    - Anything else you identify

- If you define your bespoke services use the MO framework!
  - In the same way the standard services provide future proof technology separation
  - The services specific to your environment can also benefit too

Ingredients for MO Service deployment

Example: Java application to monitor a Remote Object that supports MO M&C Service communicating by means of binary messages over TCP/IP

- M&C Service blue book (defined in terms of MAL)
- MAL Java API magenta book
- MAL binding to TCP/IP transport & binary encoding

Consumer Application
(Java)

M&C Service API
(auto-generated Java code)

Message Abstraction Layer
(Java code from GitHub)

MAL binding to Binary over TCP/IP API
(auto-generated Java code)

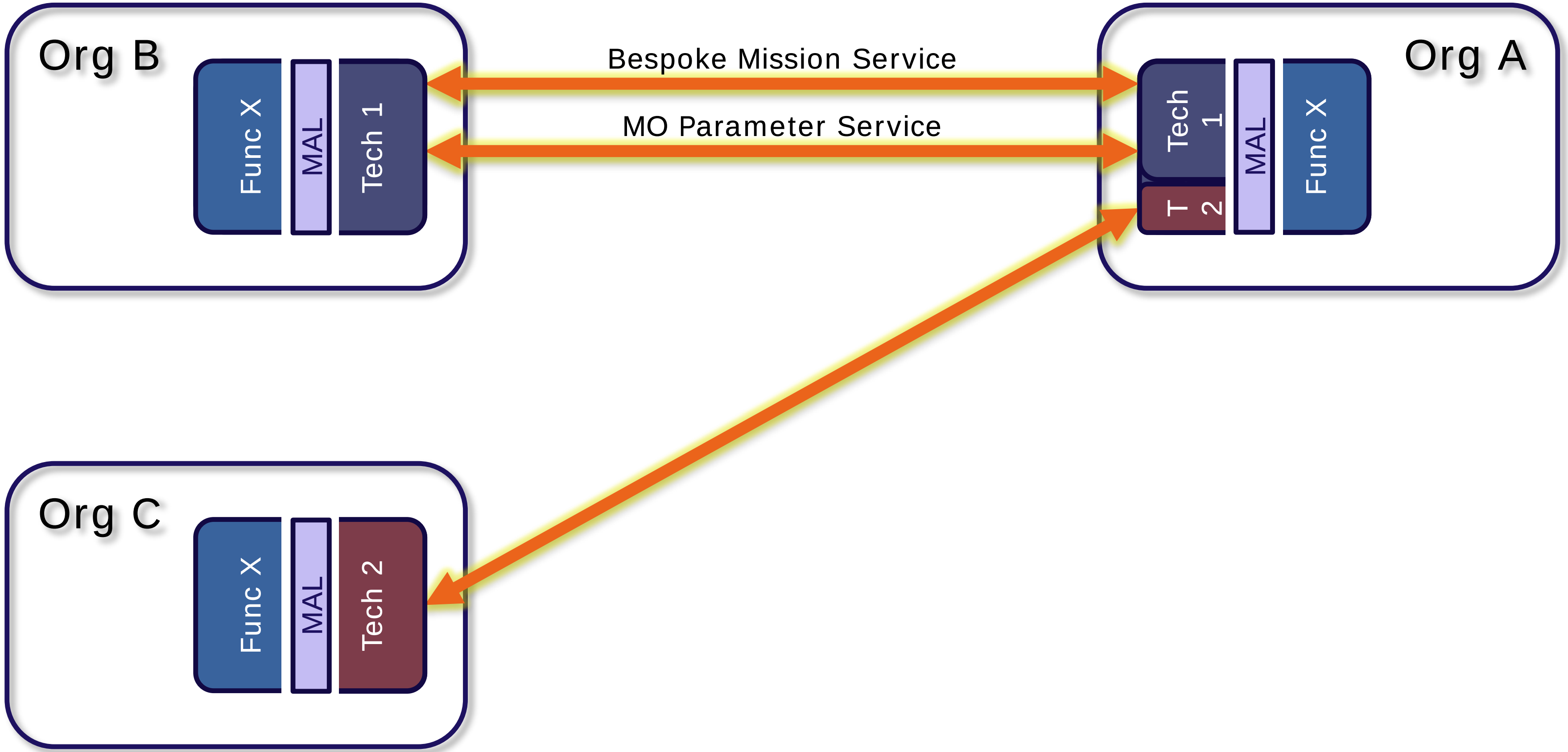
Binary Encoded messages
over TCP/IP

Provider App
Remote Object

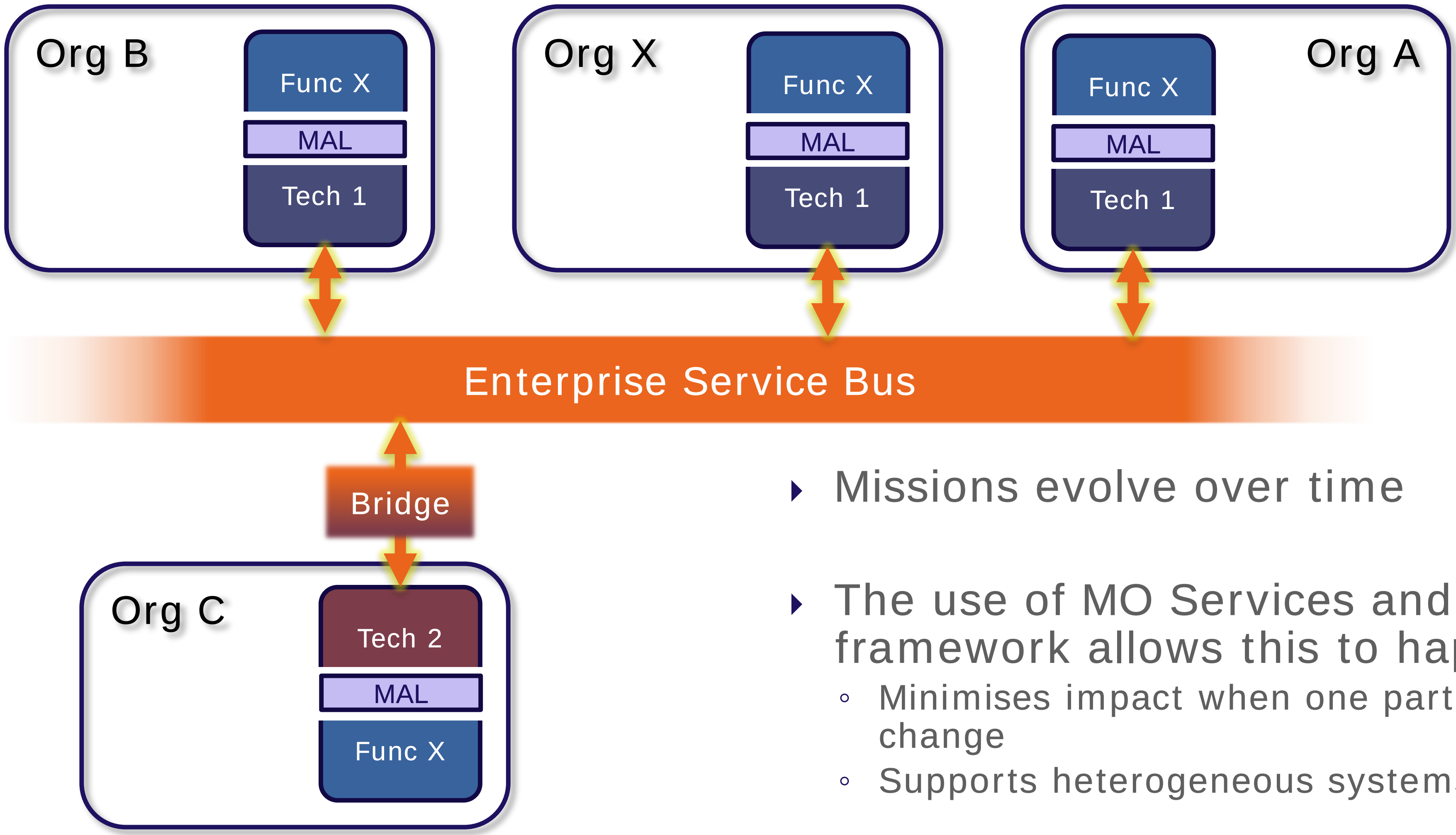
MAL messages to/from
Provider Application

Mission Operations

An example deployment



An example deployment (alternative view)



- Missions evolve over time
- The use of MO Services and the framework allows this to happen
  - Minimises impact when one part needs to change
  - Supports heterogeneous systems

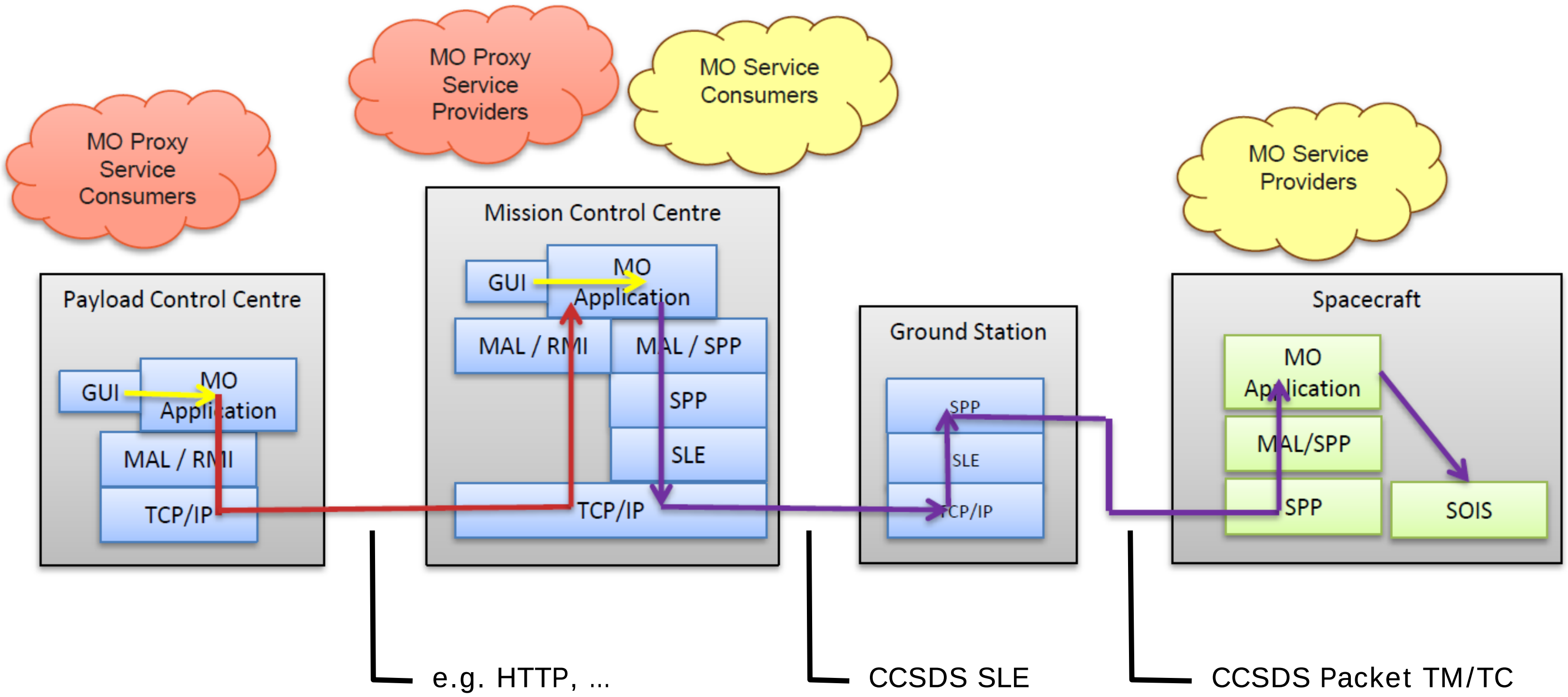
The MO Service Vision

- First priority is to use them ground-to-ground (easier), but long-term goal is to use them on-board and on the space-to-ground link as well

- The project manager of a future mission will
  - Select the CCSDS MO services needed by his missions
  - Define bespoke (mission-specific) services using the MO Framework

- Benefits
  - CCSDS MO services: specs and related software already validated and available for immediate re-use
  - Bespoke services: all MO services benefits extend to them as well
  - Re-use of avionic software
  - Re-use of ground infrastructure software for mission operations
  - Re-use of ground operational concept and procedures
  - Easy maintenance for long duration missions

Example of Simple Deployment



ECSS Packet Utilisation Standard

- In Europe there is an existing service-based standard for mission operations
  - It is called the Packet Utilisation Standard, or PUS
  - It is maintained by a European standards body called ECSS
    - European Cooperation on Space Standardization (ECSS)
- The PUS is used in many European, and wider, missions:
  - It has been around since 1994
  - It is well understood
  - It defines a strong Concept of Operations
    - This is very good for operator familiarity and training
  - It had a significant update in 2015 (PUS C)
- However:
  - It is fixed to CCSDS Space Packets
    - Not optimal for use outside the spacelink
  - Not machine readable
    - Auto generation of code difficult
  - Low level
    - Interaction behaviour between TC/TM implied in associated text
    - Makes automation more complex
- PUS has a good concept, but an implementation focussed on the spacelink

CCSDS MO and ECSS PUS

- The CCSDS working group used PUS as our starting point
  - Built upon the large experience gained using PUS
  - Uses the same, strong, concept of operations
    - But is flexible to work with your concept
  - Worked to resolve the limitations of PUS

- MO Services are aimed at a wider domain and have been designed to be used:
  - On-ground
  - On-board
  - and not just across the spacelink

- MO Services take advantage of more modern ideas:
  - The specifications are independent of transport and encoding technology
    - The MAL ensures this
  - Machine readable XML specifications
    - Allows easy auto-generation of mission artefacts
  - Clear relationship between what needs to be sent and what will be received in return
    - The MAL enforces this and is captured in the XML
    - Reduces complexity for automation of operations

- MO Services cover more functions
  - E.g. planning, navigation, telerobotics, …

CCSDS MO Books and status

INFORMA-TIONAL	Mission Operations Services Concept	CCSDS 520.0-G-3	PUBLISHED	ESA
	Telerobotic Operations	CCSDS 540.0-G-1	PUBLISHED	NASA
	Mission Planning and Scheduling	CCSDS 529.0-G-1	PUBLISHED	ESA
FRAMEWORK	Reference Model	CCSDS 520.1-M-1	PUBLISHED	ESA
	Message Abstraction Layer (MAL)	CCSDS 521.0-B-2	PUBLISHED	ESA/CNES
	Common Object Model (COM)	CCSDS 521.1-B-1	PUBLISHED	ESA/CNES
FUNCTIONAL SERVICES	Monitor & Control	CCSDS 522.1-B-1	PUBLISHED	ESA/DLR
	Common Services	CCSDS 521.0-B-2	AGENCY REVIEW	ESA/CNES
	Mission Data Product Distribution	CCSDS 522.2-R-1	AGENCY REVIEW	ESA/CNES
	Planning and Scheduling	CCSDS	ON-GOING	ESA/DLR
	File Transfer & Management	CCSDS	ON-GOING	ESA/CNES
	Automation		PLANNED	
	Navigation		PLANNED	
	Software Management		PLANNED	
	...			
LANGUAGE BINDINGS	Java API	CCSDS 523.1-M-1	PUBLISHED	CNES
	C++ API	CCSDS 523.2	PUBLISHED	NASA
TECHNOLOGY BINDING AND ENCODING	Space Packet Transport & Binary Encodings	CCSDS 524.1-B-1	PUBLISHED	CNES/DLR
	TCP/IP Transport & Split Binary Encoding	CCSDS 524.2-B-1	PUBLISHED	ESA/CNES
	HTTP Transport & XML Encoding	CCSDS 524.3	PUBLISHED	ESA/NASA
	ZeroMQ Message Transport Protocol	CCSDS 524.4	AGENCY REVIEW	CNES/ESA

- Informational/Concept
- Draft Standard or Recommended Practice
- Standard
- Recommended Practice

Book editor+prototype1/prototype2

MO and the future

- So what does the future hold for MO
  - More importantly what does the future of MO hold for you?

- Basically more!
  - More service specifications
  - More programming languages supported
  - More communications technologies supported
  - More free software
  - More support from industry

- This means
  - More re-use
  - More simplified migration of technology over time
  - Rapid development of missions for less
  - More cost savings

- More for less

Operational Use of MO Services

- METERON (ISS Utilisation)
  - MO Services are already deployed on ISS!
  - Since 2015, 5 experiments with Astronaut on ISS driving rover on the ground
  - Use MO Services over DTN
  - Could re-use the same control system to operate 5 different rovers

- OPSSAT
  - First ESA 3-U cubesat fully based on MO Services (ground-ground, space-ground, space-space)
  - Launch Q4/2019

- Major on-going ground segment initiatives
  - EGS-CC selected ground-ground interfaces based on MO Services
  - CNES next generation control system infrastructure (ISIS) based on MO Services
  - DLR plan to use MO services as backbone service bus to integrate functions in an EGS-CC based MOC

Summary

Summary

- Two main trends are becoming apparent in current and future missions:
  - An increase in mission complexity
  - An increasing pressure to reduce costs

- In today's systems a lack of
  - Standardisation between and inside organisations
  - Combined with lack of re-use between missions
  - Has led to increased cost of development, deployment and operator training

- Whilst over the long lifetimes of space missions the inability to
  - Update technologies and infrastructure
  - Replace systems without major system redesign
    - Including vendor lock in
  - Has led to increased operational costs

- To alleviate this CCSDS is defining and standardising:
  - A set of services for Mission Operations
  - A open framework, independent from technology

- These provide:
  - Increased interoperability and reuse
  - Improved flexibility
  - Independence from location, programming language, hardware platform and communications technology

The CCSDS Mission Operations services provide the capability to hide the unavoidable difficulties that characterises the space environment whilst supporting your future complexity needs

Providing the foundations for your creativity

Links

General

CCSDS Website

http://www.ccsds.org/

MO in Wikipedia

http://en.wikipedia.org/wiki/CCSDS_Mission_Operations

MO Viewer

https://esa.github.io/mo.viewer.web

Open Source Software

ESA on GitHub

https://github.com/esa

ESA MO OSS Wiki

https://github.com/esa/CCSDS_MO/wiki