Can Harmonization be Achieved via Standardization?: New Concrete Opportunities from the CCSDS Mission Operations Services

CCSDS Spacecraft Monitoring & Control Working Group (SM&C)
Mario Merri (ESA), Chair

GSAW, Los Angeles, USA - 1 Mar 2011
Putting Together Mission X

- Mission X
  - Spacecraft & Launcher
  - Ground Stations
  - Mission Control System (Command and Control)
  - Flight Dynamics System
  - Mission Planning System
  - Automation System
  - Data Distribution System

Harmonisation via CCSDS MO Services
Welcome to the CCSDS Mission Operations Applications Store

...please select the segment on the left pane
CCSDS MO app store

**Ground Segment**
- Ground Station
- Mission Control System
  - Flight Dynamics System
  - Mission Planning System
  - Automation System
  - Data Distribution System

**Space Segment**
- In-CONTROL
  - Category: MCS
  - Released: 1 Jan 2014
  - **Free**
- You-Control-It
  - Category: MCS
  - Released: 30 Sep 2015
  - $$$
- M&C Suite
  - Category: MCS
  - Released: 30 Sep 2015
  - $$$

All these applications are CCSDS MO certified.
Assembling Mission X Ground Segment from (Harmonised) Components

- Application-Level Components communicate via standardised Services
- Services are supported by a distributed Infrastructure
- Reusable components “Plug-in” via Service Interfaces to the Infrastructure
- Both Components and Infrastructure are replaceable with minimum impact to rest of system

Harmonisation via CCSDS MO Services
CCSDS Spacecraft M&C (SM&C) Working Group

- Established December 2003
- ESA Chair (Mario Merri); UKSA Deputy
- Active Participation of 10 Space Agencies
- One of the Most Active CCSDS Working Groups
- Establishing a Service Oriented Architecture for Mission Operations
  - Monitoring & Control
  - Planning, Scheduling and Automation
  - Navigation
  - On-board Software / Configuration Management
- Multiple Prototypes – now going operational at NASA/JSC for ISS
Distributable Mission Operations Functions

- M&C (Status, Control)
- Automation (Procedures, Timelines)
- Planning (Tasks, Goals)
- Mission Data (Products)
- Flight Dynamics (Orbit, Attitude)
- On-board Software

Mission Operations Services:
- Organisational Boundaries
- Functional Boundaries
- System Boundaries
- Long-Term Data Persistence

Harmonisation via CCSDS MO Services
Characteristics of Mission Operations Services

- Service Oriented Architecture (SOA) for Spacecraft Mission Operations
  - Application Level Services for Mission Operations
  - Enable Plug-in Components: Applications & Infrastructure
  - Semantic Interaction: Information not Data
  - Extensible Framework: Common and Generic Elements
  - Distributable: Independent of Deployment Architecture
  - Protocol Agnostic: Independent of Transport Technology
  - Language Neutral: Independent of Deployment Language
SOA: Integrated Systems vs. Modular Components

In traditional modular system design, components can be integrated into just one system. With SOA, more loosely coupled components can be assembled into a range of similar systems.
End-to-End Services and Layering

End-to-End Communication:
Standard Pattern of Interaction (I invite, Respond)

- Mission Operations
- Transport Layer: Packaging
- Physical Communications Infrastructure
- Mission Operations

I shall Invite my Lady to a Feast
Thou art Invited to a Banquet
I shall Invite my Sweetheart to a Ball
Thou art Invited to a Banquet

My Lord has invited me to a Feast
My Beau has invited me to a Ball
My Boyfriend has invited me to a Party

Hey, Babe, Wanna Come to a Party?
Hey, Babe, Wanna Come to a Party?

You Have Mail
My Boyfriend has invited me to a Rave

U 12 Come 2 Rave?
Mission Operations Framework Layers

- **Application Layer**
  - Common Services: Directory, Login, ...
  - Functional Services: M&C, Automation, Scheduling, Time, ...

- **MO Services Layer**
  - Common Object Model: Identify, Definition, Occurrence, Status

- **Message Abstraction Layer**
  - Messaging Abstraction Layer: Generic Interaction Patterns, Access Control, Quality of Service

- **Transport Layer**

Harmonisation via CCSDS MO Services
Mission Operations Services Interoperability and Portability

Language Binding

Interoperability Requires Wire Protocol

Technology Binding: Encoding (e.g. XML) Transport (e.g. FTP)
MAL Protocol Bridging

- Applications hosted in different transport technology environments:
  - ESA / NASA
  - Space / Ground
  - CORBA / JMS

- Mission Operations Services transparently bridged at MAL layer
  - Supports all Services overlaid on MAL
  - Supports all Applications built on those Services
Clever Engineering of the MO Services

- Technology and location independent
  - Application computer language
  - Transport and encoding
  - Interoperable
  - On Ground and/or space
  - Discoverable: not duplicated via directory service

- Implementing common features in the same way
  - Messages (standard header, construction rules)
  - Interaction patterns (Send, Submit, Request, Invoke, Progress, Publish-subscribe)
  - Data types
  - Error handling
  - Common service template (archiving/retrieval, activity monitoring, events, configuration)
  - Common services (e.g. directory, login,…)
API Standardisation

- Approach Compatible with Model Driven Development and Autocoding
- Extensible Approach: Only one Magenta Book required per Language

Harmonisation via CCSDS MO Services
Specific MO Service Definition

- **Requires:**
  - Definition of Information Model (Service Objects)
  - Definition of Service Operations (mapped to Interaction Patterns)
  - Service Configuration (Object Definitions) [for Service Deployment]

- **Does not Require:**
  - Message Encoding/Binding to Messaging Technology
    
  - Specific Definition of API
    
  - Definition of Service Discovery, Login, Authentication, etc.
    
  - Specification of dedicated Service History Model
    
Harmonisation via CCSDS MO Services
CCSDS Mission Operations Book Structure and Status

Published Books:
- MO Concept
- Reference Model
- MAL

Draft Books:
- Java API
- COM
- Common Services
- M&C Services
- Space Packet Binding

Planned Books:
- Motion Imagery Service
- JMS Binding
- C++ API

- Green Book = Informational
- Magenta Book = Recommended Practice
- Blue Book = Standard

Harmonisation via CCSDS MO Services
Example: Mission Planning and Service Orchestration

Planning Request
Orbital Event
Contact Scheduling
Activity Scheduling

End-Users Operations Other MPS

On-board Software Management

Ground Station Complex

Mission Planning Engine

Orbital Events

Orbital Event Service

Manoeuvres

Software Loads

Planning Request Service

Ground Schedule

On-board Schedule Management

Scheduling Service

Ground Schedule Execution

Flight Dynamics
MAL Prototyping Validation

- Mandatory CCSDS (ESA-CNES) Prototype
  - Completely automated
  - 16840 individual tests!
  - The two implementations interoperated perfectly!

- NASA/JSC-DLR Prototype
  - DLR’s MCS (SCOS 2000) and JSC Simulator (legacy systems!)
  - Conclusion: "**DLR GSOC and NASA/JSC successfully exchanged actions, parameters and alerts .... The interoperability prototype demonstrated that the Message Abstraction Layer is transport and technology agnostic and that space agencies can use the Mission Operations standards for interoperability among existing legacy systems. ... our findings provide support for the overall viability of the standards.**"

- ISS will be first operational user of MO Services
  - Decision: PLATO (Power Level Analysis Tool @ NASA/JSC) to be a client of the M&C Parameter service. Operational as of 2012
**Conclusion**

- MO service’s underlying framework (RM, MAL) is ready
- M&C and Common Services books are in advanced status and will come next, hopefully by the end of the year
- Next MO services to be tackled depend on the interests and needs of the community
  - Planning?, Flight Dynamics?
  - Suggestions and active participation of interested groups are welcome
- MO service standardisation provide the framework that will allow real harmonisation of services (and components) for mission operations
Let MO Services do the boring part of the job so that YOU can focus on the smart part