SpaceOps Workshop 2011: Plan Management Systems

CCSDS Mission Operations Services and Potential Standardised Mission Planning Services

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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
Welcome to the CCSDS Mission Operations Applications Store

...please select the segment on the left pane
All these applications are CCSDS MO certified
Introduction

CCSDS  Consultative Committee for Space Data Standardisation
ISO Affiliated International Standardisation Body
11 Member Space Agencies:

1. CCSDS SM&C Working Group
2. Introduction to the Mission Operations Service concept
3. Potential Services to support Mission Planning
CCSDS Spacecraft M&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**

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

- **Payload/Science Team**

- **Mission Control Centre**

- **Spacecraft Manufacturer**

- **Payload Data Centre**

**Mission Operations Services:**
- Organisational Boundaries
- Functional Boundaries
- System Boundaries
- Long-Term Data Persistence
SM&C 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.
Service-Oriented Architecture: Plug-in 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
Mission Operations: Coarse-Grained Components

- On-board Schedule Handling
- Operator Displays
- Mission Planning
- TM/TC Processing
- Flight Dynamics
- Automation
- Infrastructure

- SOA can be applied at multiple levels of decomposition / granularity
- SM&C is concerned only with the top-level building blocks of a Mission Operations System
- Services defined at natural Distribution and potential Interoperability Boundaries
- Implementation of Components [or groups of Components] is not constrained
- Components compliant with Standard Services are potentially reusable in other contexts
SM&C Mission Operations [MO] Services

Mission Exploitation

- Mission Planning
- Mission Data Processing
- Mission Operations Planning
- Analysis & Reporting
- Spacecraft M&C Proxy
- OB Procedure Proxy
- OB Schedule Proxy
- OB Data Product Proxy
- OB Software Proxy
- OB Software Management
- Flight Dynamics
- SLE-Man
- Operator Interaction
- Operations Automation
- OB Schedule
- OB Procedure
- OB Data Product
- OB Software
- OB Schedule Execution
- OB Procedure Execution
- Station Scheduling
- Station M&C
- Tracking & Ranging
- Ground Station

User

- External User
- OB Software
- OB Data Product
- OB Schedule
- OB Procedure
- OB Software Management
- Flight Dynamics
- SLE-Man
- Operator Interaction
- Operations Automation
- OB Schedule
- OB Procedure
- OB Data Product
- OB Software
- OB Schedule Execution
- OB Procedure Execution
- Station Scheduling
- Station M&C
- Tracking & Ranging
- Ground Station

Spacecraft
End-to-End Services and Layering

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

Transport Layer: Packaging

Mission Operations

Physical Communications Infrastructure

Mission Operations

I shall invite my Lady to a Feast

Thou art Invited to a Banquet

My Lord has invited me to a Feast

I shall invite my Sweetheart to a Ball

Thou art Invited to a Banquet

My Beau has invited me to a Ball

I’ll invite my Girlfriend to a Party

Hey, Babe, Wanna Come to a Party?

Hey, Babe, Wanna Come to a Party?

My Boyfriend has invited me to a Party

I’ll invite my Girlfriend to a Rave

U 12 Come 2 Rave?

You Have Mail

My Boyfriend has invited me to a Rave

She has accepted

I Graciously Accept

She has been invited to a Feast

Thou art Invited to a Banquet

My Lord has invited me to a Feast

I shall invite my Sweetheart to a Ball

Thou art Invited to a Banquet

My Beau has invited me to a Ball

I’ll invite my Girlfriend to a Party

Hey, Babe, Wanna Come to a Party?

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You Have Mail

My Boyfriend has invited me to a Rave
MO Framework Layers

- **Application Layer**
- **Consumer/Provider**

- **MO Services Layer**
  - **Common Services**
    - Directory, Login, ...
  - **MO Functional Services**
    - Core, Automation, Scheduling, Time, ...

- **COM**
  - Common Object Model
    - Identify, Definition, Occurrence, Status

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

- **Transport Layer**
  - Messaging Technology

- **Mapping to implementation language**
- **Abstract service specification defined in terms of the COM & MAL**
- **Generic service specification defined in terms of the MAL**
- **Abstract messaging infrastructure**
- **Mapping of the MAL to encoding and transport**
SM&C Components

**Language Binding**

**Interoperability**
Requires Wire Protocol

**Technology Binding:**
- Encoding (e.g. XML)
- Transport (e.g. FTP)

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MAL Generic Interaction Patterns

Services defined in terms of a set of Operations:

- Each defined by a “conversation” between Consumer and Provider
- Messages are specific to Service and Operation but the Pattern of Message Exchange is common across many Operations
- By defining Generic Interaction Patterns, specification and implementation of individual services is simplified

MAL Identifies 6 Patterns:

- SEND
- SUBMIT
- REQUEST
- INVOKE
- PROGRESS
- PUBLISH-SUBSCRIBE
Service Objects: correspond to meaningful Mission Operations information – specific to the Mission Operations service

Service Information Model

Service Interaction: the sequence of message exchange between Service Provider and Consumer

Interaction Patterns
Service Information Model and History

- **Entity**: any Service Object *Parameter, Command, Orbital Event, Planning Request* ...
- **Definition**: configuration data defining the above
- **Occurrence**: invocation of a Dynamic Object *Command, Orbital Event, Planning Request*
- **Status**: update (event) in response to an operation or spontaneous behaviour
Referencing Service History

Who?

Origin
Commands originating from this Entity by Originator

Planning Request

Scheduled Task

Procedure

Command

What?

Commands of this Type (ID), by Domain

Where?

Commands at this Time, by Session

Identity

Time

When?
MAL Protocol Bridging

Applications hosted in different Infrastructure Environments:
- Space / Ground
- ESA / NASA
- CORBA / JMS

Mission Operations Services transparently bridged at MAL Layer
- Supports all Services overlaid on MAL
- Supports all Applications built on those Services
API Standardisation

- Approach Compatible with Model Driven Development and Autocoding
- Extensible Approach: Only one Magenta Book required per Language
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
    *Standard Technology Binding applies to all MO Services*
  › Specific Definition of API
    *Standard Language Transform applies to all MO Services*
  › Definition of Service Discovery, Login, Authentication, etc.
    *Covered by SM&C Common Service Specifications*
  › Specification of dedicated Service History Model
    *Covered by SM&C Common Object Model*
SM&C Standards Book Structure

Existing Books:
- MO Concept Reference Model
- MAL

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

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

 Exists

Green Book = Informational
Magenta Book = Recommended Practice
Blue Book = Standard
MO Planning Services

- Opportunity to Define
- Potential to Standardise
- MO Provides Existing Standardisation Framework

What is a Planning Request?
- Task or Goal Oriented
- One-off, Repetitive, or Series
- Scoped by Time-window; Position/Area; Resource Availability

What is a Plan / Schedule?
- Operations; Events; Visibility/Contact; Resources; Configuration;
- Timeline
- Position Based Schedule
- To-do List
- Standing-Orders:
  - Repeat Pattern/Cycle of Operations (Time or Position based)
  - Rules (based on Time, Event, Condition)

What other Services would an MPS Use/Provide?
- Orbital Events
- Resource Availability
- Automation
Mission Planning and Service Level Interactions

Planning Request
Orbital Event
Contact Scheduling
Activity Scheduling

End-Users Operations Other MPS

On-board Software Management

Orbital Events

Mission Planning Engine

Orbital Event Service

Scheduling Service

Ground Schedule

On-board Schedule Management

On-board Schedule

Ground Schedule Execution

Contact Scheduling Service [SLE-Man]

Ground Station Complex

Flight Dynamics

Manoeuvres

Software Loads

Orbital Event Service

Mission Planning Engine

Ground Ops
Concept for Planning & Automation Services

Planning Request Service
• Planning Requests:
  - Simple/Compound
  - Single Event/Series
  - Temporal Constraints (When)
  - Location Constraints (Where)

Schedule Execution Service
• Schedule (Timeline) or To Do List:
  - Events; Visibilities; Contacts; Availabilities
  - Tasks
  - Activities
  - Configuration Changes
  - Assignment of Operational Responsibility

Procedure Execution Service
• Procedures:
  - Automated Process or Function
  - Parallel Threads of Execution
  - Executable Steps
  - Conditional Execution and Waits
  - Failure Recovery

Mission Planning
- Operations Planning: Level 1
- Operations Planning: Level n

Interaction Service
• Interactions:
  - Alarms and Messages
  - Remote Notification (e.g. SMS)
  - Request to Operator
  - Operator Responses

Operations Automation
- Schedule Execution
- Procedure or Function Execution

User and Operations Tasking
Operations Team

Core M&C Service
• Parameters
• Actions
• Alerts

Controlled System

Operations Team

Via GUI

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