CCSDS Mission Operations Services in Space

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The Spacecraft Monitoring & Control (SM&C) Working Group (WG) of the Consultative Committee for Space Data Systems (CCSDS) is working on the definition of a set of standard end-to-end services that can be used on ground, ground to space, and in space. The ambitious goal of the WG is to define standardised services which allow the construction of space systems using plug-in components that implement those services. The specification of standard services not only allows the rapid construction and deployment of new systems and configurations but also the selection of compliant implementations that are most appropriate for each particular deployment. As one of the expected deployments of the MO components is on-board the spacecraft, where there will need to communicate not only with ground based components but also between onboard components, careful study is required to ensure that the MO standards work appropriately in the on-board environment. This paper discusses the existing European space/ground services, the evolution of these to an MO based approach, the implications of MO based on-board implementations, and how other supporting standards and architectures (such as CCSDS SOIS and ECSS SAVOIR) can ease the transition.

I. Introduction

THE Consultative Committee for Space Data Systems (CCSDS) is an international standards organisation affiliated to the International Organisation for Standardisation (ISO). Its Spacecraft Monitoring & Control Working Group is developing a set of standardised Mission Operations (MO) Services that enable interoperable information exchange between collaborating agencies or organisations involved in the operations of space missions. The approach uses service-oriented concepts and focuses on meaningful (semantic level), end-to-end information exchange between software applications supporting mission operations functions. These applications may be distributed between organisations and also between a range of space and ground-based systems. The resultant MO Services will support both live information exchange and open access to operations history.

The focus of the working group to date has been in the definition of an extensible framework for the definition of such services that is independent of technology used to deploy the services. This allows for the evolution of implementation technology during the long lifetime of many space systems and also for the diversity of transport protocols that may be required to support communication in different environments.

The CCSDS Mission Operations Services Concept[1] identifies a range of application level services, including several that are relevant to the on board environment:

- Commanding & Telemetry (Monitoring & Control service)
- Remote Buffer Management

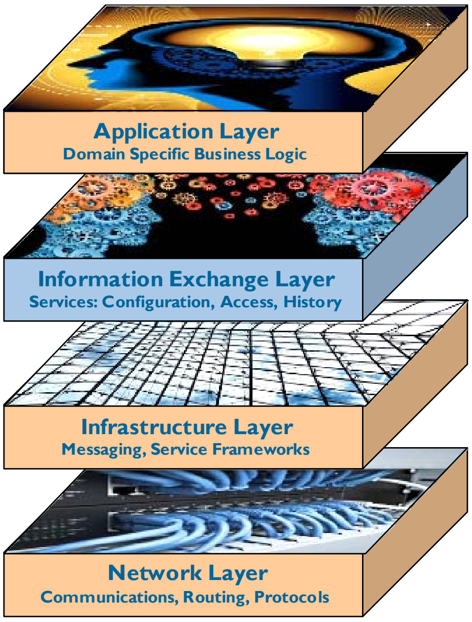

Figure 1. The CCSDS MO Service Layers. *Sits between mission operations applications and the technologies used to integrate them, supporting meaningful Information Exchange between applications.*

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- Data Product Management
- Software Management
- Navigation

In addition to these other services have been identified that may be applicable to future on board deployments:

- Planning Request
- Scheduling
- Automation

To date only the Monitoring & Control service has been developed, however as part of the CCSDS Technical Meeting held in Darmstadt, Germany in April 2012, a call for interest was issued to members of the Mission Planning community to initiate the process of service standardisation relevant to Space Mission Planning. Providing sufficient support is obtained from member agencies, the formal process of standardisation within CCSDS will then be initiated.

This paper provides background on the CCSDS Mission Operations Services and framework and the potential scope and benefits of MO services deployed on-board and outlines a future roadmap for achieving this.

II. Overview of CCSDS Mission Operations Service Concept

Mission operations functions are increasingly distributed more widely than a central Mission Control Centre (Fig. 2). There may be separate Payload Operations Centres, Payload Data Processing Centres, as well as Principal Investigator (PI) teams and end users. The spacecraft and payload manufacturers may play a continuing role from initial development into mission operations; and the increasing capability of on-board computers allows the migration of intelligence from ground to space-based systems. This distribution of functions often crosses organisational boundaries, due to the collaborative nature of space missions and requires interoperability between agencies. It can also highlight the boundaries between functions and systems within an organisation where intra-operability between major system components is desirable to enable re-use and rapid integration of mission systems.

The CCSDS MO Services Concept introduced previously seeks to establish an extensible set of standard Mission Operations services to support inter- and intra-operability between applications at organizational, functional and system boundaries.

Standards already developed include a Reference Model[2]; a Message Abstraction Layer (MAL)[3]; and a Common Object Model (COM)[4]. Application level MO Services are defined in terms of the MAL and COM for specific types of mission operations information exchange. This

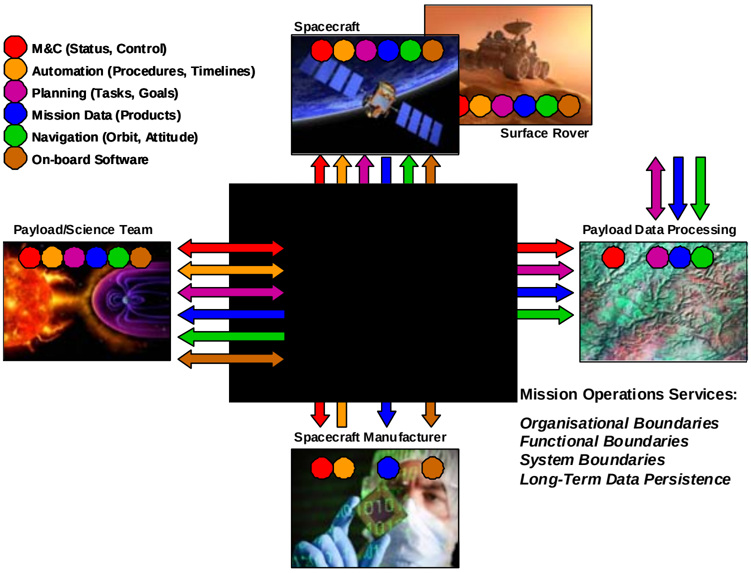

Figure 2. Distributable Mission Operations Functions. *Distribution of functions exposes potential MO services at interoperable boundaries between organizations/entities and systems, increasingly including the space segment itself.*

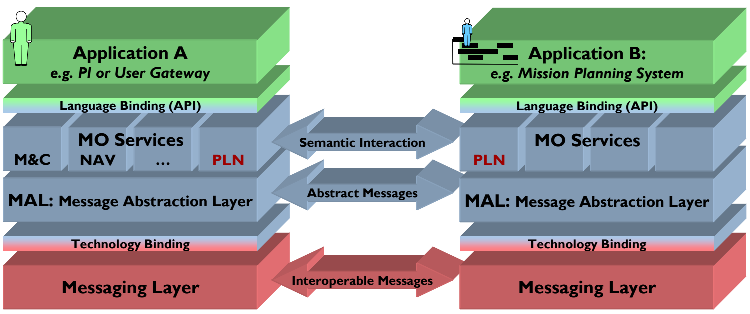

Figure 3. Layered MO Service Framework. *MO Services support semantic level interaction between mission operations applications. These are defined in terms of the Message Abstraction Layer that can be deployed over different messaging technologies. To allow deployed applications to interoperate, a common binding must be used.*

layered framework for service specification is illustrated in Fig. 3.

The MO Services themselves support meaningful message exchange between applications, independent of programming language or underlying message encoding and transport. An extensible set of MO Services can be defined, each based on a shared model for a particular class of information exchanged, together with the set of operations that the service consumer can invoke.

The COM provides a generic template for an MO service and the object classes it defines simplify the specification of individual MO services and ensure a harmonised approach across multiple services.

The MAL defines an abstract message structure and a set of standard interaction patterns for message exchange, including both request-response and publish-subscribe patterns. The MAL isolates services from deployment technology and may be "bound" to multiple message transport and encoding technologies - including both terrestrial technologies and space communications protocols. Two types of MAL binding exist:

- *Language Bindings* define how to express the API for a service in a particular programming language. This defines a transformation rather than a specific service API and therefore defines the API for all services specified in terms of the MAL. Communicating applications can be implemented in different languages and use different Language Bindings, but still interoperate as the underlying communication is defined in terms of the MAL.
- *Technology Bindings* define how the MAL messages and interaction patterns are implemented for a specific messaging technology. A common technology binding must be used to enable interoperability between applications, but which technology is used in deployment is transparent to the application layer and can be specific to deployment requirements. Bridging between technologies is also possible at the MAL layer. Standardisation of technology bindings allows for interoperability between independently developed systems, but private bindings can also be developed for intra-operability between applications within a single system context. All MO Services can be migrated to a different deployment technology through the definition or adoption of an alternative MAL technology binding.

III. Potential Scope and Benefits of MO Mission Services Deployed On-Board

The deployment of standardised interoperable interfaces between Operating Agencies and Spacecraft and internally on-board would in itself bring a number of benefits. Each organization would be able to develop or integrate their own multi-mission systems that can then be rapidly support compliant Spacecraft. It does not preclude the re-use of legacy Spacecraft, an adaptation layer on the ground is required to support it, rather than many mission-specific bespoke interfaces. In the on-board environment, where software development costs are considerably higher due to platform constraints and reliability requirements, any level of software reuse can bring immense savings. This needs to be balanced against how much software is actually reusable, but for clearly defined functions such as on-board software management (patching, dumping, checking) a standard interface between space and ground can lead to great savings through re-use.

Adaptation from the standard interfaces provided by the MO Services to the particular on-board environment is still needed however, for example how a particular on-board file store is implemented, but standardising the interface presented to other components on-board and also the ground allows existing compliant ground software and on-board equivalents to be re-used. When combined with other standardisation efforts focused on on-board architectures, such as CCSDS SOIS and ECSS SAVOIR, the actual implementation can be completely re-used as the internal API is standardised by the on-board architecture.

The MO Mission services are specified in a machine readable format, this in combination with standardised transformations to programming languages and communication technologies means that automatic code generators can be developed that generate the API code for specific languages that map directly down to the required communication technology for efficiency. These APIs present a high level interface to application developers, both on ground and on-board, and massively simplify the development task required. The generated code hides from the application developer the code required to map their high level API call into an appropriate form for communicating with the relevant component, whether that is an XML message ground to ground, a Space packet for crossing the Space link, or some equivalent on-board communications network. The API call is the same regardless.

IV. Future roadmap for On-Board MO Services

The path to having a fully validated implementation of the MO framework on-board requires some work. Firstly a mapping to a traditional on-board programming language, such as C, is required. Secondly a mapping to appropriate communications technologies such as Space packets on the space link or some on-board network protocol such as Spacewire is also required. These mappings do not exist currently.

The actual services themselves need to be defined, validated, and implemented for a specific mission using the above technologies before they can be used. These unknowns, combined with the in development nature of the standards, make it difficult for missions to accept these forthcoming standards on their spacecraft.

However, several smallsat and cubesat missions are currently in development or being proposed that would support the current experimental nature of the MO Services and its framework. These spacecraft will allow the deployment of implementations that demonstrate MO Services, over existing technologies, in a non-critical environment gaining vital flight experience.

One such proposed mission is ESA’s OpsSat. OpsSat is a small cubesat that supports very high uplink and downlink speeds (S-Band and X-Band), large on-board memories, multiple redundant computers, and is explicitly designed for the testing of experimental software and operations concepts. Due to its completely safe hardware design the on-board software has been removed from the critical path and therefore can be completely replaced at any time without endangering the mission, in fact this is its expected mode of operation.

It is through activities such as OpsSat that MO services, the framework and technologies that support it, will achieve acceptance and the benefits that will bring.

Appendix A
Acronym List

API	Application Programming Interface
CCSDS	Consultative Committee for Space Data Systems
COM	[CCSDS MO] Common Object Model
ISO	International Organization for Standardization
M&C	Monitoring and Control
MAL	[CCSDS MO] Message Abstraction Layer
MO[S]	[CCSDS] Mission Operations [Services]
NAV	[CCSDS MO] Navigation Services
PI	Principal Investigator
PLN	[CCSDS MO] Mission Planning Services
SLE	[CCSDS] Space Link Extension Standards
TM/TC	Telemetry / Telecommand

References

[1]Mission Operations Services Concept, Informational Report (Green Book), CCSDS 520.0-G-3, December 2010, http://public.ccsds.org/publications/archive/520x0g3.pdf

[2]Mission Operations Reference Model, Recommended Practice (Magenta Book), CCSDS 520.1-M-1, July 2010, http://public.ccsds.org/publications/archive/520x1m1.pdf

[3]Mission Operations Message Abstraction Layer, Recommended Standard (Blue Book), CCSDS 521.0-B-1, September 2010, http://public.ccsds.org/publications/archive/521x0b1.pdf

[4]Mission Operations Common Object Model, Draft Recommended Standard (Red Book), CCSDS 522.0-R-2, September 2011, http://public.ccsds.org/sites/cwe/rids/Lists/CCSDS%205220R2/Attachments/522x0r2.pdf