Why Choose CCSDS SM&C for your next Ground Segment?

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Focus of the Abstract:

Today's ground segments consist very often of customized solutions that have been specifically developed and funded for a given mission. However, the recent developments in standardization are allowing the deployment of re-usable solutions across dissimilar systems.

The Consultative Committee for Space Data Systems (CCSDS) has been working on a set of emerging Spacecraft Monitoring & Control (SM&C) mission operations services that will allow future space systems to be assembled in an easy manner by means of pre-existing, possibly commercial, components and maintained with limited effort for long time. This also implies that the "boring" and repetitive part of each component will be standardized, thus leaving more resources for innovation and creativity that will bring smarter and smarter components.

[1] The SM&C WG has active participants from the following Space Agencies: ASI, BNSC, CNES, CSA, DLR, ESA, FSA, INPE, JAXA, NASA (GSFC and JPL).

What are the Limitations Today?

Today's ground segments consist very often of customized solutions that have been specifically developed and funded for a given mission. However, the recent developments in standardization are allowing the deployment of re-usable solutions across dissimilar systems. Still, re-usability is confined to specific areas and do not encompass yet the entire ground segment of space missions.

A recent worldwide success story in standardization is the Space Link Extension (SLE) developed by the Consultative Committee for Space Data Systems (CCSDS), which defines a set of standard services between mission control centre and ground station. This implies that Organization X can use the ground stations of Organization Y without the need of protocol and format gateways. This type of cross support has been pioneered by NASA and ESA in support of the ESA's Integral, Mars Express, and Rosetta missions with cost benefits to ESA projects. Today, several organizations have converted their ground stations to SLE, which has significantly increased the re-use of facilities and also boosted the commercial provision of such services.

Another clear success story, mainly European this time, is the Packet Utilization Standard (PUS). Prior to 1994, new space missions tended to re-develop each time the way of performing routine and troubleshooting operations and defined ex-novo the data structure of the telemetry sent from the spacecraft to the ground, and of the telecommands sent from the ground to the spacecraft. In 1994, the Packet Utilization Standard (PUS) was developed by ESA to define a common operational framework that is implemented via a standard set of monitoring and control services, each having a standard information model and data structures. Since then, most ESA missions, including all foreseen future spacecraft use the PUS, with significant technical quality and economic benefits for both the space and ground segments. Today, the PUS is part of the European Cooperation for Space Standardization (ECSS) suite of standards and is largely used by several other European space agencies.

What is the Lesson Learned?

From the two examples above it is clear that, if the space community agrees on the isolation and grouping of functionalities at the proper level of granularity and standardize their interface boundaries, then not only the complexity of a space system (space and ground segments) can be decomposed into simpler, well identified components, but it is also possible to build it up quickly and with less cost from a number of already available components. It must be stressed here that we are not advocating the existence of standard components, but rather of components with standard interfaces. In this way, we keep the door open to technical advancements and innovation as a component could be seamlessly replaced by another one providing similar services, but maybe with a much higher accuracy, using a smarter algorithm, or with more performance. Hopefully, this will boost the market to develop and commercialize more advance components. Examples of typical component could be a telemetry and commanding system, a mission planning system, or a flight dynamics system.

Another aspect that needs to be considered to make the approach introduced above more powerful, is the protection of the investments made from the erosion of time. As we all know, today's pace of technological evolution is very fast and certainly does not match with the typical long duration of space missions. Very often missions are forced to one or more costly migrations to more modern technologies during the lifetime. Typical examples are migration to new programming languages, operating systems, hardware platforms, communication protocols, etc..

What are the Basic Ideas Behind CCSDS SM&C?

Four years after its inception, the CCSDS Spacecraft Monitoring and Control (SM&C) working group has been able to cast its vision down into a concrete prospective, the SM&C framework, to the benefit of any organization responsible for the procurement and integration of ground segments for space missions. In our vision, future ground segments will consist of a network of loosely coupled components orchestrated by well defined and standard services. This model, otherwise called SM&C framework, is based on a Service Oriented Architecture, which is meant to largely simplify the job of ground segment procurement managers, including:

- Modular system integrating plug-in components (commercial and non-commercial)
- Independence from underlying technology
- Simplified maintenance via individual replacement of outdated components
- Interoperability with several suppliers of components and partner organizations.

And, of course, all the above will be achieved for just a fraction of the cost, the schedule, and the risks of the pervious architectures. To achieve this, three main elements have been devised.

The first key element of our standardization effort is the ability to define the messages to be exchanged between components that implemented the services exclusively in a set of standard interaction patterns. These are defined in the SM&C Message Abstraction Layer (MAL), a standard that provides a generic mechanism to all application-level services to allow for language and message transport independence. Obviously, for a real implementation a language mapping is required that maps the MAL messages into the required software

language, e.g. Java or C++. By the same token, a transport mapping is also required to specify the transport technology, e.g. the Java Message Service (JMS), and the encoding technology, e.g. the Extensible Markup Language (XML).

The second fundamental element is a number of SM&C Mission Operations (MO) services have been identified which specify the boundaries of the component. The currently identified MO services are: Core Monitoring & Control, Time, Software Management, Planning, Scheduling, Automation, Data Product Management, Location, Flight Dynamics, Operator, and Remote Buffer Management. All SM&C MO services are defined exclusively in terms of the MAL, which makes them language, platform, and encoding agnostic.

The third element is that a set of facilities has been identified that is common to all Mission Operations services. These Common Services include services such as Directory, Login, Configuration, Interaction, Retrieval and Replay and, being services, are themselves defined in terms of the MAL.

How does it Work in Practice?

The following practical cases examples are provided to allow a better understanding of the advantages in the approach.

Interoperability: Missions are increasingly collaborative, using assets from different agencies and organizations. Each organization will have its own infrastructure and cannot afford to develop bespoke operational systems for each new mission. For example, an academic institution may have a payload instrument on-board a spacecraft operated by a space agency. The interoperable interface between the two organizations could be implemented through a set of standard services: the submission of planning requests; access to payload telemetry; and visibility of the operational schedule. The SM&C framework will offer a range of mission operations services that apply at different functional distribution boundaries, allowing organizations to interoperate at different abstractions of control and data: telecommand or operational planning request; telemetry parameter or schedule status.

Modular systems and plug-in components: An open service framework will allow organizations, including operating agencies and commercial vendors, to develop software components that support standard service interfaces with other components. In this way they can be rapidly assembled into a mission operations system. A particular TM/TC processor may be selected because it supports the space-ground protocol used by the space segment, but this can be rapidly integrated with components offering particular solutions for Operator Displays, Analysis, Mission Planning, Flight Dynamics and Automation without any software tailoring. This will allow the most appropriate tools to be selected for a given mission. In this way individual components can be optimized to bring particular benefits: for example, one Mission Planning tool may be designed to support optimal scheduling in a resource constrained mission – another to support rapid transactional response in a less constrained mission. As each mission has its own unique set of characteristics, there is no “one size fits all” system – but a broad range of systems can be rapidly assembled from a set of components supporting standard interfaces. This approach also allows any one component to be replaced by another without major disruption to the overall system – e.g. to enhance capability, address obsolescence, or reduce cost of ownership.

Technology Independence and Long-term Maintainability: Space missions and their operations infrastructure can have a lifetime measured in decades. They can often outlive the technologies used during initial deployment. It should be possible to take advantage of new technologies without throwing away the investment made in applications specific to mission operations. SM&C offers two levels of technology independence: transport/encoding and language. Service standardization is implementation neutral – technology and language bindings must be applied to render the service for use in a specific context. The MAL can be deployed over any underlying transport protocol, but to ensure interoperability with independently developed applications, communicating entities must use the same transport and encode the MAL messages in the same way. In one infrastructure a Mission Planning component may communicate with other components, such as Flight Dynamics, Mission Control, through SM&C services implemented over CORBA (IDL and GIOP), but the same tool can be used in another environment where services are implemented as XML over SOAP. All that is required is to exchange the MAL implementation – no change is required to the Mission Planning application itself. Applications access services through APIs specific to a programming language – a language binding specifies how the abstract service should be cast as an API for that language. This allows a component to be exchanged for another implemented in another language.

Conclusions

The SM&C MO services will allow future space systems to be assembled in an easy manner and maintained with limited effort for long time. The end result is that the “boring” and repetitive part of the components is standardized, thus leaving more energy to focus on the more noble and creative part of the component.