The Consultative Committee for Space Data Systems

## MOIMS Document

# USE OF CCSDS STANDARDS FOR MISSION OPERATIONS INTEROPERABILITY IN THE LOP-G PROGRAM

## INFORMATIVE

## CCSDS 000.0-W-1

## WHITE BOOK

**May 2018**

# COVER LETTER

CCSDS Mission Operations and Information Management Services (MOIMS)

22 May 2018

Lunar Orbiter Platform – Gateway International Team

**Subject: Cover letter to the submission of the with paper "Use of CCSDS Standards for Mission Operations Interoperability in the LOP-G Program"**

To whom it may concern in the LOP-G Team

Mission operations is the program aspect that ties all systems and components together. As such, mission operations concepts and standards should be part of the very early planning phases of any mission. It is recommended that the International Deep Space Interoperability Standards document suite include a volume dedicated to mission operations interoperability standards applicable to both space and ground segment systems.

The Deep Space Interoperability Standards team should carefully consider adopting standards from the broad set of operations-related standards developed within the Mission Operations and Information Management Services (MOIMS) Area of the Consultative Committee for Space Data Systems (CCSDS).

MOIMS standards are dedicated to interoperability services and data formats defining a basic set of interfaces, interactions and services common in the Space and Ground domains. A general trend is the movement of intelligent applications from Ground to Space and the standards are an enabler for this movement due to their common nature and technology abstractions.

Reasons for early inclusion of CCSDS MOIMS standards in the Deep Space Programs include:

- Hard lessons learned in the early phases of the ISS. The lack of upfront definition of operations standards has resulted in a very complicated ground segment with duplication of the similar interfaces
- The set of MOIMS standards currently available includes key standards that are commonly used in most of space missions today.
- LOP-G is already considering several related CCSDS standards for communications and security, and the same rationale is applicable for the use of MOIMS Standards.
- MOIMS Services focus on the interface boundaries, with minimal invasion into the hosting systems. Therefore, they are easily usable on new or legacy and space and ground systems.
- MOIMS Standards simplify the integration of systems (legacy and new applications) and support heterogeneous communications protocols, therefore facilitating and simplifying inter-agency co-operation.

- MOIMS Standards are developed internationally and approved by the 11 CCSDS space agencies. They are the technical foundation for smooth international cooperation.
- Over time, mission operations concepts and procedure will mature and change, driving the LOP-G system in ways not currently considered. Mature interface and service standards can help simplify system redirection / expansion.
- The MOIMS service framework allows easy expansion of new capabilities as locally-defined services or as new Mission Operations (MO) standards through CCSDS. In particular, its modular architecture enables inclusion of new services at a very late stage of project development with no need to redesign the already developed components/applications.
- MOIMS standards facilitate unneeded software developments.

The MOIMS area is very interested in providing its set of standards to the LOP-G community. For this reason, should we identify the need of a specific standard that is not covered by the available set, we are ready to be flexible and, if agreed by the participating agencies, adapt the MOIMS workplan to the LOP-G needs. Clearly, LOP-G agency staff are welcomed to contribute to the work.

We also would like to re-mark the fact that the MOIMS includes the “Telerobotics Working Group” that unfortunately has been dormant for a couple of year due to lack of interest from the agencies. We think instead that standards in this field would be critical in a multi-asset and multi-organization set up as the LOP-G one. We would very welcome a revived interest by space agencies boosted by the LOP-G interest in order to re-start the work of this working group.

A whitepaper has been prepared to provide an overview of available mission operations standards that can directly benefit large missions such as the Lunar Orbital Platform – Gateway. The paper is attached and has been posted to the public CCSDS MOIMS Site at

https://cwe.ccsds.org/moims/docs/MOIMS%20Area/LOP-G/180525%20CCSDS%20MOIMS%20Input%20to%20LOP-G%20Final.pdf

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- Canadian Space Agency (CSA)/Canada.
- Centre National d'Etudes Spatiales (CNES)/France.
- China National Space Administration (CNSA)/People's Republic of China.
- Deutsches Zentrum für Luft- und Raumfahrt (DLR)/Germany.
- European Space Agency (ESA)/Europe.
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- Instituto Nacional de Pesquisas Espaciais (INPE)/Brazil.
- Japan Aerospace Exploration Agency (JAXA)/Japan.
- National Aeronautics and Space Administration (NASA)/USA.
- UK Space Agency/United Kingdom.

Observer Agencies

- Austrian Space Agency (ASA)/Austria.
- Belgian Federal Science Policy Office (BFSPO)/Belgium.
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- United States Geological Survey (USGS)/USA.

# EXEXUTIVE SUMMARY

The Consultative Committee for Space Data Systems (CCSDS) is a global organization which has been developing standards to address a wide range of space mission needs since 1982 [www.ccsds.org]. Within CCSDS, the Mission Operations and Information Management Services (MOIMS) Area addresses mission data systems standards ranging from navigation to planning and scheduling to mission monitoring and control and long-term data archiving.

Standards from the MOIMS area are in use by many space organizations around the world. In the navigation area, data format standards cover common flight dynamics data and product exchanges and address space situational awareness needs, including conjunction assessment. The XML Telemetry and Command Exchange (XTCE) is used by many missions and commercial products to describe the telemetry and command formats for a mission. Mission Operations (MO) Services represent a full suite of service-oriented capabilities for data system development and inter-Agency interoperability with a vision that incorporates future trends of more seamless interactions between multiple space and ground system elements. Data Archive standards focus on long-term data preservation.

Addressing mission operations early in a program's concept development phase and identifying appropriate standards lead to more efficient, lower cost, and more capable operations of complex systems at the local-system level, the full mission level, or the enterprise level (multiple space assets and collaborative missions). Unfortunately, these aspects have not been considered in the current version of the New Deep Space Interoperability Standards that are being discussed between ISS Agencies (www.internationaldeepspacestandards.com).

This whitepaper provides a high-level overview of the CCSDS Mission Operations standards and discusses important benefits their use can have on missions, especially large scale multi-Agency programs with multiple space and ground assets and key needs for interactions between the participating systems. This paper is submitted as (significant) comment from the CCSDS MOIMS to the Deep Space Interoperability Standards as requested (due date end May18). It is hoped and expected that this document will generate interest in the Lunar Orbiter Platform – Gateway (LOP-G) international team and the CCSDS MOIMS is ready to support any discussion that might follow on.

# DOCUMENT CONTROL

| Document | Title and Issue | Date | Status |
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| CCSDS 000.0-W-1 | Use of CCSDS Standards for Mission Operations Interoperability in the LOP-G Program, Issue 1 | May 2018 | Final |

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# 1 INTRODUCTION

## 1.1 THE INTERNATIONAL SPACE STATION CASE

The International Space Station (ISS) can certainly be considered the first large international cooperative space programme, being a joint project among five participating space agencies: NASA, Roscosmos, JAXA, ESA, and CSA. With its first component launched into orbit in 1998, the ISS has allowed for the first time humans to live and work for long time in space. In this sense, it can be considered the precursor of any future international exploration programme. The various components of the ISS are operated and monitored by their respective space agencies at mission control centers across the globe, including[1]:

1. Roscosmos's Mission Control Center at Korolyov, Moscow Oblast, controls the Russian Orbital Segment which handles Guidance, Navigation and Control for the entire Station.,[97][219] in addition to individual Soyuz and Progress missions.
2. ESA's ATV Control Centre, at the Toulouse Space Centre (CST) in Toulouse, France, controls flights of the unmanned European Automated Transfer Vehicle.
3. JAXA's JEM Control Center and HTV Control Center at Tsukuba Space Center (TKSC) in Tsukuba, Japan, are responsible for operating the Kibō complex and all flights of the 'White Stork' HTV Cargo spacecraft, respectively.
4. NASA's Mission Control Center at Lyndon B. Johnson Space Center in Houston, Texas, serves as the primary control facility for the United States segment of the ISS and also controlled the Space Shuttle missions that visited the station.
5. NASA's Payload Operations and Integration Center at Marshall Space Flight Center in Huntsville, Alabama, coordinates payload operations in the USOS.
6. ESA's Columbus Control Centre at the German Aerospace Centre (DLR) in Oberpfaffenhofen, Germany, manages the European Columbus research laboratory.
7. CSA's MSS Control at Saint-Hubert, Quebec, Canada, controls and monitors the Mobile Servicing System, or Canadarm.

The full set of Space centers involved with the ISS programme is shown in Figure 1.


**Figure 1 - Space centers involved with the ISS programme (from[1]).**

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[1] "International Space Station," Wikipedia, URL: https://en.wikipedia.org/wiki/International_Space_Station [retrieved 06 February 2018].

It is evident how the task of monitoring and controlling the ISS is extremely challenging for both technical and political reasons. It is estimated that today more than 6000 people and several different ground systems are involved in this task. The implications of paying little attention at an early stage to the operational interoperability aspects and to agree among the international partners on common operational concepts to make the various components interoperable is evident in Figure 2, which is extracted by a NASA keynote presentation delivered at SpaceOps 2004[1] [2].

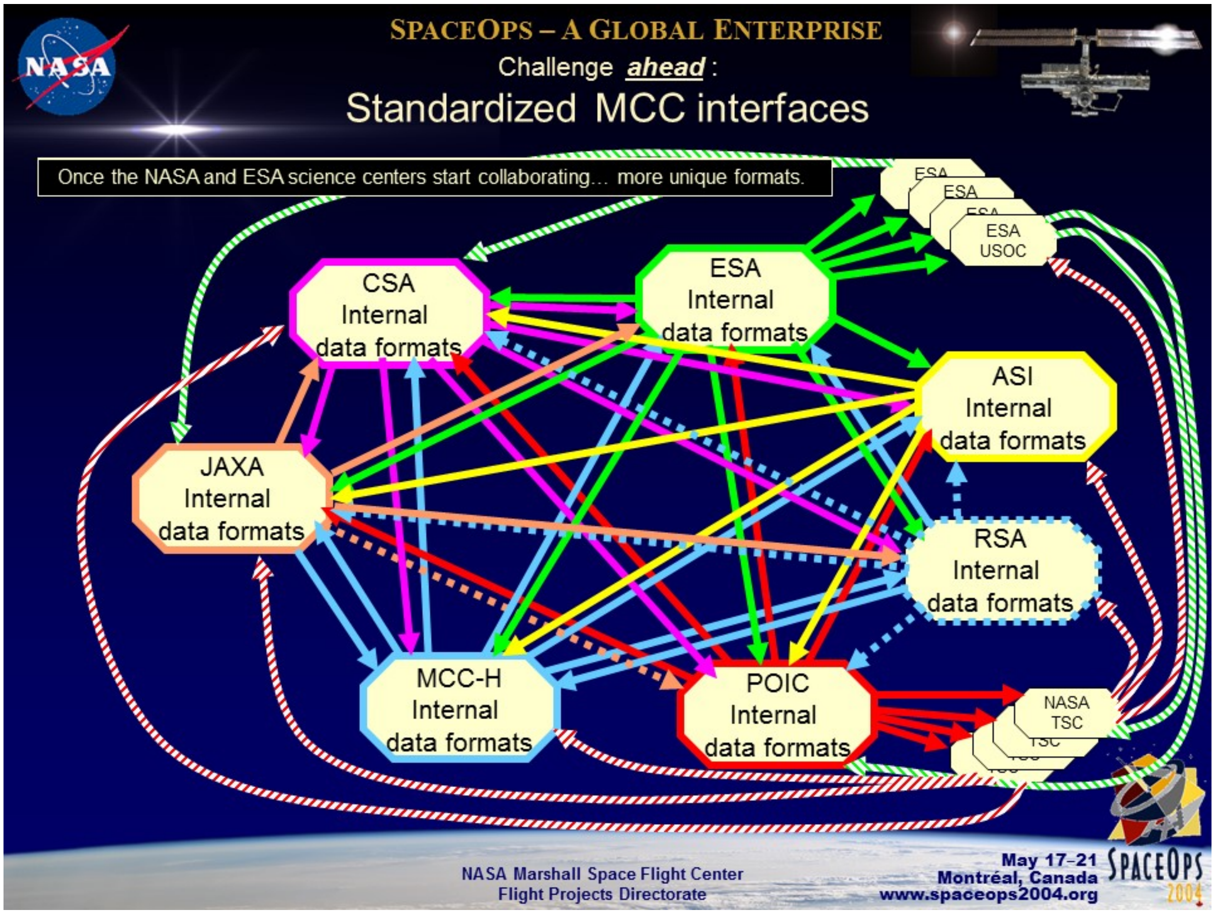



**Figure 2 - ISS "standardized" MCC interfaces (from[2]).**

The slide showed that the lack of standardization in the Mission Control Center interfaces resulted in an uncontrolled plethora of individual formats and protocols to exchange essentially the same type of information. The consequences are significant in terms of complexity, costs, size of teams, tools, maintainability and knowledge management, just to name a few. Considering that the ISS has a set up that is by far simpler than the foreseen future exploration programme (single spacecraft, 5 astronauts, low Earth orbit), how would that scale up to a more complex scenario that, for example, may involve several spacecraft orbiting Moon/Mars, human outposts and rovers on the planet? In this context, agreeing upfront on an efficient and

[1] "Ground System Technology Challenges in the ISS program: Challenges met and challenges ahead," Mike Kearney, NASA Marshall Space Flight Center, Keynote Speech at SpaceOps 2004, Montreal, Canada, May 2004

modern way to interoperate is a must, which will bring simplicity and cost effectiveness to the full programme.

## 1.2 INTEROPERABILITY BEYOND MECHANICAL AND COMMUNICATION INTERFACES

While the need for interoperability at mechanical interface and communication protocol level is today well understood and in the focus of engineering and design activities of most collaborative space missions, the operational aspects of interoperability of joint space assets is often neglected by space engineers and programme managers at early stages of mission design. The root of this observation lies in the general misconception that everything related to operations and in particular “software” can be dealt with later on and not a major concern to mission design. What is less appreciated in this context is the fact that mission operation capabilities, which are eventually exposed through software applications to operators, drive to a large extent the operational concept of collaborative missions, Hence the sustainability and the cost of operations. The differences in operational concepts, adopted protocols, tools and data formats drive directly the need for integration effort to overcome unnecessary diversity.

## 1.3 INTEROPERABILITY USE CASES

The ISS and future international orbiting platforms are model cases for operations standards. The diverse user base, multiple agencies collaborating, and specifically an openness for exchange or integration of equipment on board and on ground over the course of many years to service agency-, industry- and public experiments and applications are key beneficiaries of international and adaptable standards.

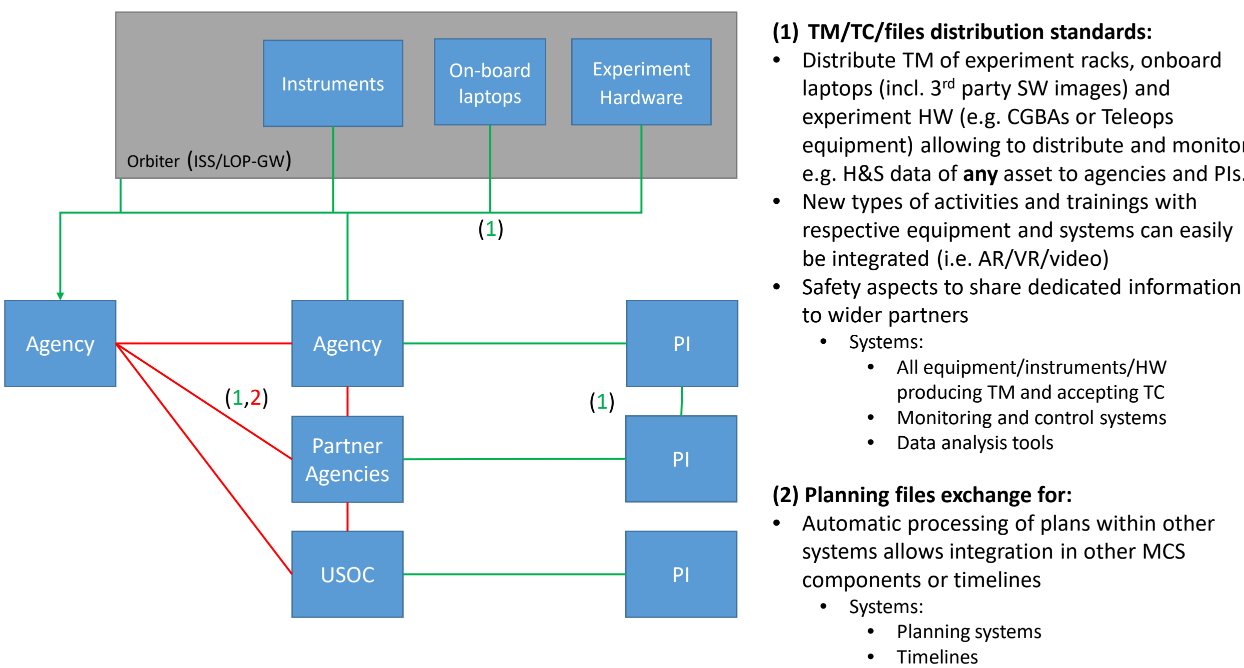



**Figure 3: Communicating building blocks**

Similar to ISS, the elements typically generating, receiving and distributing data are:

- On board equipment/racks produce telemetry and can be commanded remotely
- On board laptops or experiment equipment (teleoperations devices) produce telemetry and can be commanded
- Ground agencies can coordinate planning activities
- Ground agencies distribute experiment telemetry and route experiment commands
- Experimenters might collaborate and exchange information (telemetry, files)
- Experimenters might need to integrate new onboard equipment or equipment on ground
- Contingency cases: Agencies and Industry can ingest same data into infrastructure and systems to support activities and contingencies
- Data analysis, logging and storage of data with common/shareable tools
- Customized: Same data to all subscribed but definition and development of individual systems according to individual, required subset/view
- Different transport protocols available to offer same functionality over current and future protocols (Space link, IP based, Bundle protocol).

By using the CCSDS standards, the operators of the platforms can facilitate introduction of hardware or software applications, widen the supplier base and especially expand the services they can offer to the user community.

# 2 MISSION OPERATIONS TRENDS AND THE NEED FOR STANDARDS

The CCSDS organization strives to address the common challenges facing space organizations from around the world as they look to meet today's needs while evolving their vision for future missions. Different missions or mission elements often require the exchange of parameter values, data products, and alarms. They may need to direct the activities of another entity, develop cooperative and consistent activity schedules, or ensure mission data is available for years to come. At the same time, agencies may be on different technology refresh cycles, have their own heritage systems, and have different funding, security rules, and process regulations. Common standards help align mission and agency systems by aligning key interfaces per well-documented and proven approaches.

## 2.1 TRENDS AND CHALLENGES FOR MODERN SPACE MISSIONS AND PROGRAMS

- Collaborations and partnerships across nation space agencies and industry to meet shared or overlapping goals
- Participating organizations, each with its own heritage system, technology cycles and processes
- Missions that may operate several decades with maintenance and development needed throughout
- Evolvable mission concepts which could allow for the addition, deletion, or retasking of space assets
- Wide variety of both space and ground assets across many diverse organizations that can be of benefit for the duration of the program or to meet specific short-term needs under special circumstances.
- Mission operations trend of moving functions from ground to space, with new technologies reaching maturity.
- Increasing number of satellites to meet a goal. Examples include large constellations of cubesats, but also the idea of multiple large-scale missions which may have docking capabilities or work to create a large long-term space outpost.
- Increased need for security, resiliency, cross-support, and remote access or backup mission operations capabilities.
- Complex operations concept where control may be shared, or even change, between the space assets and the ground operations centers.
- Increased levels of autonomy and automation for both routine and contingency operations

CCSDS MOIMS Standard Services are very useful for many of the same reasons that other CCSDS standard are useful.

## 2.2 CCSDS MOIMS BENEFITS

- are internationally agreed by all CCSDS member agencies.
- are interface, interaction, and service standards, so have minimal requirements into systems
- provide a consistent basic capability set for mission operations.
- allow simplified system integration, with common interfaces.

- allow easy system expandability, in both intra and inter-agency scenarios.
- support system re-deployment and redirection.
- support technology evolution, as well as supporting legacy (via gateway) and new systems.
- provide a service framework for easy expansion of local and global services.
- support consistency of operational interactions across interoperating organizations.
- support consistency of security model and operational security controls.

# 3 MISSION OPERATIONS (MO) SERVICES

*Responsible CCSDS Working Group: Spacecraft Monitor and Control Working Group (MOIMS-SM&C) and the Mission Planning and Scheduling Working Group (MOIMS-MP).*

Mission Operations (MO) Services is a standardized set of service specifications and supporting software technologies which aim to enable significant improvements to the operational capabilities of space missions. The broad collection of services supports both interoperability between Agencies and also promotes software reuse inside Agencies.

The MO Standards are based on a service oriented approach, and follow a well-defined consistent service framework. They define a single mechanism by which information and interactions between agencies is both defined and exchanged.

The standards are designed to be usable in both the space and ground domain, and are abstracted from the underlying communication/transport technologies used. For example they define the concept of a telemetered parameter and its information separately from how it is exchanged, allowing the exchange technology to change over time or deployment as required.

The scope of the functional services is sufficiently broad to allow users to select just the services needed for a simple interface between two organizations, for full shared-operations missions, or even for the development of a new mission operations control center.

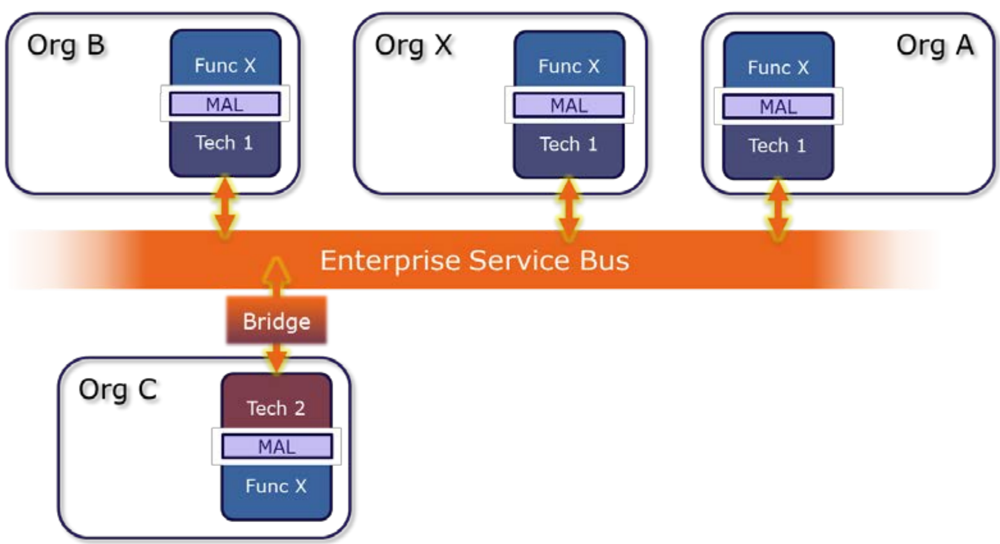
## 3.1 CONCEPTS

The MO services are, conceptually, split into three layers. The first layer is the service specification itself, this defines the information the service is concerned with (parameters, planning requests, events etc.) and the interactions that may be associated with that data (submit planning request, request parameter data etc.). These specifications are defined in a formal (computer readable) language, abstracted away from any specific technology. It is complete enough to describe the information being exchanged without having to be fixed (at this point) to the physical representation (no bits and bytes); this is the second layer called the Message Abstraction Layer (MAL). Finally there is a mapping from the abstraction layer onto whatever technology is required, be that a specific communication technology (the bits and bytes on the wire as it were) or a specific programming language (to provide high level application programming interfaces if that is so desired).

The layering is shown below:


It should be noted that this is a conceptual layering that has no need to be represented in software. Taking a service specification (the top layer) and mapping it directly to a communications technology (such as CCSDS space packets) gives you the definition of the data messages required for the specific service using CCSDS space packets. This forms a simple, traditional, ICD that can be used between cooperating agencies; one side can work using just the data formats given in the ICD whilst the other may use a MO compliant software stack to raise those data formats up to high level software APIs. Neither is aware of the choices of the other and neither is affected by the choices of the other.


The separation of the information exchanged from the manner in which it is exchanged also means that you can change the technology you are using without affecting the functions inside the Agency that is using that information. It also makes supporting heterogeneous communication technologies much simpler (see diagram below).




A cleaner, leaner and simpler architecture based on the example diagram above could be the one used by LOP-G rather than the more chaotic one shown in Figure 2.

## 3.2 PROVIDED STANDARD SERVICES

The following services have already been published as standards by CCSDS:

| Service | Description | Specification document |
|---|---|---|
| **Archive** | A simple service for access to data archives | MO Common Object Model[1] |
| **Activity Tracking** | A tracking service for monitoring the execution of remote activities (Actions, Procedures, Plans etc.) | |
| **Event** | A basic event distribution service | |
| **Alert** | Specific alert capability that builds on the Event service | MO Monitor & Control Services[2] |
| **Parameter** | Single parameter remote monitoring and distribution | |
| **Aggregation** | Parameter value collection requesting and reporting | |
| **Action** | Remote command execution requests | |
| **Check** | Parameter value limit checking | |

The following service publication is imminent:

| Service | Description |
|---|---|
| **Directory** | A service for the lookup of other service providers |
| **Login** | Login and logout session management |
| **Configuration Management** | Distribution and management of configurations |

The following services are currently being worked on:

| Service | Description |
|---|---|
| **Mission Data Product Distribution (MDPD)** | A standard service-based interface at the backend of one control center to request/distribute mission data products, including telemetry (in various formats, e.g. frames, packets, parameters), commanding information, and any other relevant mission product (e.g. orbit files, mission planning files, time correlation information, reports, …). It also supports streaming capability. |
| **Planning Request** | Asynchronous submission of Planning Requests, associated responses and their subsequent management and status feedback. Update (editing) of the executing Plan at activity level. Update of Planning Events and resources. |

[1] https://public.ccsds.org/Pubs/521x1b1.pdf
[2] https://public.ccsds.org/Pubs/522x1b1.pdf

| Service | Description |
|---|---|
| | A Planning Request may reference a Plan (output from an earlier planning process), in which case the provided feedback includes the status of the Plan in terms of its contained activities and other items. |
| **Plan Distribution & Retrieval** | Provides distribution and access to Plans generated by the planning function. |
| **Planning Process Management** | Management of the planning process itself - initiation, status feedback and control. Also supports provision of Plan status updates by a third party. |
| **Plan Execution Management** | Control and management of the execution of a plan, including actions to Start/Stop and Pause/Resume execution. |

The following services are planned for future production:

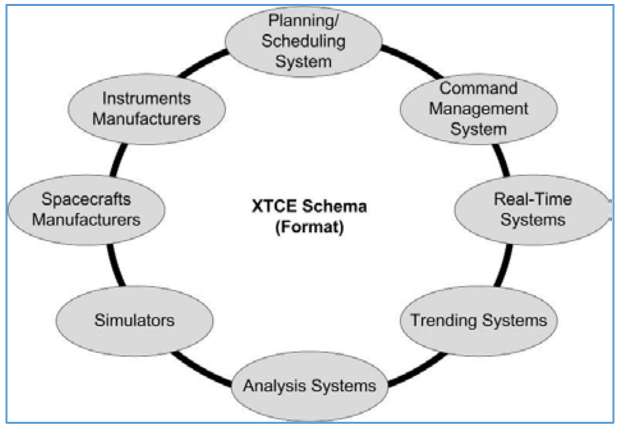
| Service | Description |
|---|---|
| **Automation Control** | Control and monitoring of remote automation procedures |
| **File System and Transfer Management** | Management of remote file systems and file transfers. NOTE: the actual file transfer is delegated to the relevant technology such as FTP or CFDP |
| **Time Management** | Time synchronization management and time distribution |
| **Navigation** | Services wrapped around the Navigation products (see Flight Dynamics standards below) for their request and delivery. |

# 4 XML TELEMETRIC AND COMMAND EXCHANGE (XTCE) STANDARD

*Responsible CCSDS Working Group: Spacecraft Monitor and Control Working Group (MOIMS-SM&C). The XTCE standard is an Object Management Group (OMG) Space Domain Task Force product that has been adopted by the CCSDS MOIMS group.*

The XML Telemetry and Command Exchange (XTCE)[1] standard facilitates the exchange of spacecraft telemetry and command definitions between organizations and systems during any mission phase. The use of a common non-proprietary format minimizes the need for customized import/export tools and allows for the rapid integration and validation of mission databases and updates.

1 https://public.ccsds.org/Pubs/660x0b1.pdf




It can be used to exchange a database between spacecraft manufacturers, payload/instrument manufacturers, and different systems of the ground segment as seen in figure to the right. It can also be used as an exchange mechanism between different development teams or between missions, which enhances database reuse. Many commercial product vendors' tools accept XTCE files as inputs and many space organizations and contractors routinely use XTCE as their common format for describing their telemetry and command formats.

# 5 FLIGHT DYNAMICS STANDARDS

*Responsible CCSDS Working Group: Navigation Working Group (MOIMS-NAV).*

The MOIMS Navigation Working Group provides a discipline-oriented forum for the development of technical flight dynamics standards (orbit/trajectory, attitude, tracking, maneuver, pointing, orbital events, conjunction assessment, etc.). Interagency partnering in mission operations is increasingly widespread.

## 5.1 CONCEPTS

Standardization of navigation data formats facilitates interoperability between space agencies, where navigation functions for a mission of agency A could be performed by agency B, or vice-versa; or where navigation functions might be cooperatively partitioned across two or more agencies.

The objective of all navigation data messages is to minimize the burden during a mission's implementation phase by giving a specification and unambiguous interpretation of the input and output data for common navigation processes. Each standard is developed to communicate the necessary data elements in a compact format that is readable to the human eye, as well as readable by computers to enable automation of navigation processes. The navigation standards define the message format and content, but not the method of message transmission between exchange partners. The transmission method or mechanism agreed by the exchange partners could be based on a CCSDS data transfer protocol, a file-based transfer protocol such as SFTP, stream-oriented media, service-based, or other secure transmission mechanism.

## 5.2 PROVIDED STANDARDS

The following recommendations have already been published as standards by CCSDS:

| Standard | Description |
|---|---|
| **Orbit Data Messages**[1] | Specifies message formats for use in transferring spacecraft trajectory information between space agencies and commercial or governmental spacecraft operators |
| **Attitude Data Messages**[2] | Specifies two standard message formats for use in transferring spacecraft attitude information between space agencies. |
| **Tracking Data Message**[3] | Specifies a standard message format for use in exchanging spacecraft tracking data between space agencies |
| **Pointing Request Message**[4] | Defines a standardized format that allows space agencies and operators to exchange information about requested changes to the attitude of the spacecraft or to an articulated spacecraft component |
| **Conjunction Data Message**[5] | Specifies a standard message format for use in exchanging spacecraft conjunction information between data originators of conjunction assessments, satellite owner/operators, and other authorized parties |
| **Navigation Data Messages / XML Specification**[6] | Describes an integrated XML schema set that is suited to interagency exchanges of navigation data messages |

Note that CCSDS published standards are reviewed every five years. The three actions to be considered in the five-year review are 'reconfirm', 'retire', or 'revise', as applicable. Currently some of the above published standards are in the process of being revised to respond to requests for changes from users, or to accommodate new use cases.

The following recommendations are currently in development:

| Standard | Description |
|---|---|
| **Navigation Events Message** | Will specify a standard message format for use in exchanging information regarding orbital events which will occur or have occurred, generally related to a spacecraft |
| **Re-Entry Data Message** | Specifies a standard message format for use in exchanging predictions as to when a space object will re-enter the central body it has been orbiting, and issue appropriate warnings |

[1] https://public.ccsds.org/Pubs/502x0b2c1.pdf
[2] https://public.ccsds.org/Pubs/504x0b1c1.pdf
[3] https://public.ccsds.org/Pubs/503x0b1c1.pdf
[4] https://public.ccsds.org/Pubs/509x0b1.pdf
[5] https://public.ccsds.org/Pubs/508x0b1e2.pdf
[6] https://public.ccsds.org/Pubs/505x0b1.pdf

# 6 LONG-TERM DATA PRESERVATION STANDARDS

*Responsible CCSDS Working Group: MOIMS Area, Data Archive Interoperability Working Group (MOIMS-DAI).*

Information is often the only output produced by spacecraft. MOIMS-DAI standards and recommendations of best practice address the how to ensure that the information, created at great expense, can be exploited immediately and into the future when it may be combined with many other sources of information.

The data, i.e. the bits, from the spacecraft must be accompanied by appropriate metadata in order to be exploitable and organisations must then ensure that the information is available into the, perhaps indefinite, future.

MOIMS-DAI standards, which are used globally across disciplines, address the whole process as illustrated in the diagram.

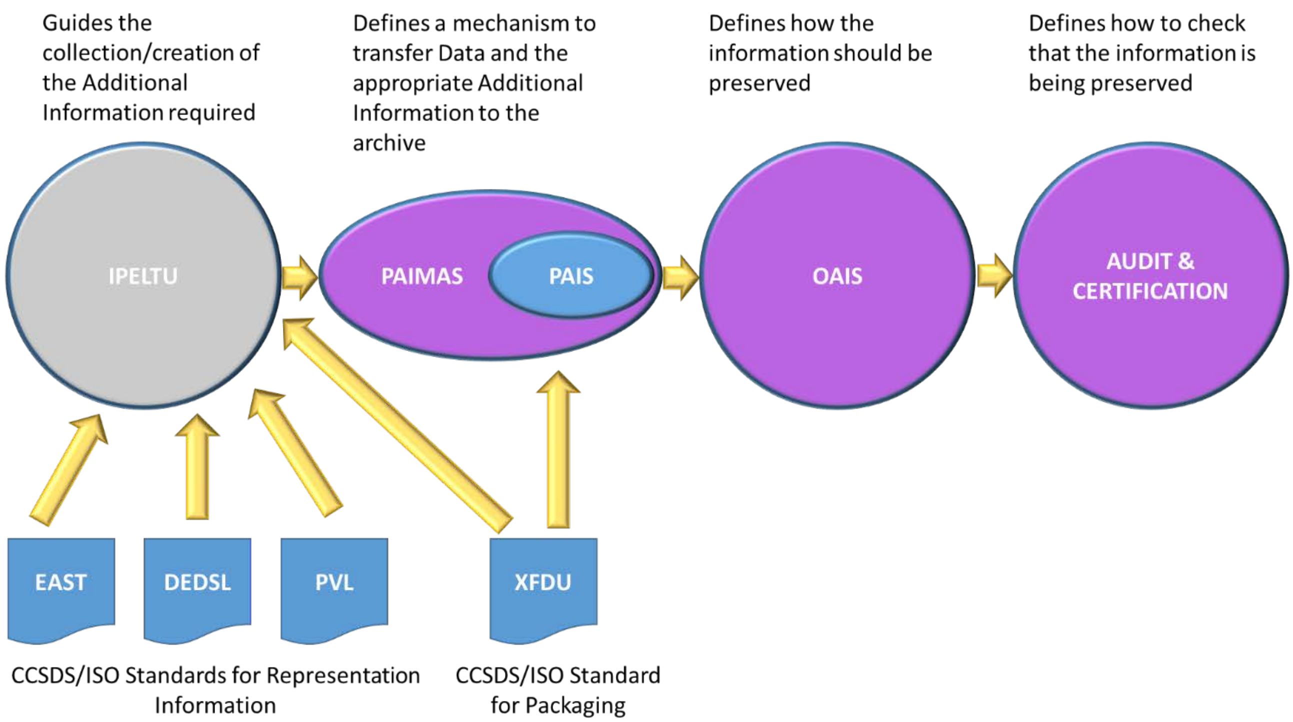



**Figure 4 Relationship between MOIMS-DAI standards**

The metadata (Additional Information) to be collected throughout the project, from its inception, through its operations and beyond, is described in *Information Preparation to Ensure Long Term Usability* (IPELTU, in preparation). The *Producer-Archive Interface Methodology Abstract Standard* (PAIMAS) defines a methodology for transferring data from an Information Producer to an Archives based on the four following phases: Preliminary, Formal Definition, Transfer, Validation. Required activities during each phase are identified.

The *Producer-Archive Interface Specification* (PAIS) provides the abstract syntax and an XML implementation of descriptions of data to be sent to an archive. These descriptions are negotiated agreements between the data Producer and the Archive and facilitate production of agreed data by the Producer and validation of received data by the Archive. The Recommended Standard includes an abstract syntax and one possible concrete implementation for the packages.

The *Audit and Certification of Trustworthy Digital Repositories* Recommended Practice provides metrics for use in assessing the trustworthiness of digital repositories or archives.

In addition there are other CCSDS/ISO standards that may be used to create Representation Information (the *Parameter Value Language* (PVL), the *Data Description Language EAST Specification* [9] and the *Data Entity Dictionary Specification Language* (DEDSL) and also to package information the *XML Formatted Data Unit* (XFDU). There are many other techniques for creating Additional Information but these are outside the scope of this document.

New standards are in the pipeline to specify how archives can interoperate and provide information to users.

# 7 TELEROBOTICS STANDARDS

*Responsible CCSDS Working Group: MOIMS Area, Telerobotics Working Group (MOIMS-TEL). Current in dormant status.*

The MOIMS Telerobotics Working Group was established in 2013 by the CCSDS to respond to the request from member agencies. The group produced the Telerobotic Operation[1] report to roadmap the intended work.

Unfortunately, since 2016 the working group lost momentum due to lack of interest from the agencies and is kept by the CCSDS in dormant status for a couple of year. We believe instead that standards in this field would be critical in a multi-asset and multi-organization set up as the LOP-G one. We would very much welcome a revived interest by space agencies boosted by the LOP-G interest in order to re-start the work of this working group.

[1] https://public.ccsds.org/Pubs/540x0g1.pdf

# 8 SUMMARY AND AVAILABLE RESOURCES

The use of data standards for the key mission operations interfaces of major missions provides many benefits in the areas of cost and risk reduction, operations concept evolution, and inter-agency interoperability. Whether incorporated via communications between system gateways or incorporated natively into newly developed systems, the benefits can be very large. The Mission Operations and Information Management Services (MOIMS) Area of the Consultative Committee for Space Data Systems (CCSDS) offers the broadest set of such standards in the world and should be carefully considered beginning in the earliest phases of major new missions.

For additional information, visit the CCSDS website for more information and to download any of the published standards or contact the CCSDS MOIMS Area Director, Dr. Mario Merri. Note that prototype software aligned with many of these standards is available on GitHub.

https://public.ccsds.org/ main CCSDS website

https://public.ccsds.org/Publications/default.aspx for all published CCSDS documents

https://public.ccsds.org/Publications/MOIMS.aspx for all published MOIMS documents

http://en.wikipedia.org/wiki/CCSDS_Mission_Operations MO in Wikipedia

https://github.com/esa Open Source Software on GitHub

https://github.com/esa/CCSDS_MO/wiki MO OSS Wiki

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# ANNEX A

# ACRONYMS

| | |
|---|---|
| API | Application Programming Interface |
| CCSDS | Consultative Committee for Space Data Systems |
| DEDSL | Data Entity Dictionary Specification Language |
| HTTP | Hypertext Transfer Protocol |
| ICD | Interface Control Document |
| IPELTU | Information Preparation to Ensure Long Term Usability |
| ISS | International Space Station |
| LOP-G | Lunar Orbiter Platform - Gateway |
| MAL | Message Abstract/Abstraction Layer |
| MO | Mission Operations |
| MOIMS | Mission Operations and Information Management Services |
| PAIMAS | Producer-Archive Interface Methodology Abstract Standard |
| PAIS | Producer-Archive Interface Specification |
| PVL | Parameter Value Language |
| SFTP | Secure File Transfer Protocol |
| SM&C | CCSDS Spacecraft Monitoring and Control |
| TC | Telecommand |
| TCP | Transmission Control Protocol |
| TM | Telemetry |
| UDP | User Datagram Protocol |
| URI | Universal Resource Identifier |
| UTC | Universal Coordinated Time |
| WG | Working Group |
| XFDU | XML Formatted Data Unit |
| XML | eXtensible Markup Language |
| XTCE | XML Telemetry and Command Exchange |