International Software System Interoperability Standards (ISwSIS)

Draft – June 2019

REVISION AND HISTORY

REV.	DESCRIPTION	PUB. DATE
-	Baseline	XX-XX-XX

PREFACE

INTERNATIONAL SOFTWARE SYSTEM INTEROPERABILITY STANDARDS (ISWSIS)

This International Software System Interoperability Standards (ISwSIS) establishes a standard interface to enable collaborative endeavors utilizing different spacecraft in deep space.

Configuration control of this document is the responsibility of the Multilateral Coordination Board (MCB) The National Aeronautics and Space Administration (NASA) will maintain the ISwSIS under Human Exploration and Operations Mission Directorate (HEOMD) Configuration Management. Any revisions to this document will be approved by the MCB.

INTERNATIONAL SOFTWARE SYSTEM INTEROPERABILITY STANDARDS

CONCURRENCE

JUNE 2019

Associate Administrator for Human Exploration and Operations National Aeronautics and Space Administration	Date
Executive Director of Human Space Programs State Space Corporation Roscosmos	Date
Director of Human and Robotic Exploration European Space Agency	Date
Director General, Space Exploration Canadian Space Agency	Date
Deputy Director General Research and Development Bureau Ministry of Education, Culture, Sports, Science, and Technology	Date

TABLE OF CONTENTS

APPENDIX

TABLE

1.0 INTRODUCTION

This International Software System Interoperability Standards (ISwSIS) is the result of a collaboration by the International Space Station (ISS) membership to establish interoperable and compatible software terminology, interfaces and technologies to facilitate collaborative endeavors of space exploration in cislunar and deep space environments. These standards are available for international and commercial partnerships.

Standards that are established and internationally recognized have been selected where possible to enable compatible solutions from a variety of providers. Increasing functional commonality among providers while decreasing unique configurations has the potential to reduce the traditional barriers in space exploration. Standardizing interfaces reduces the scope of the development effort.

The information within this document represents a set of standards which, if accommodated in the system architecture, support greater efficiencies, promote cost savings, and increase the probability of mission success. These standards are not intended to specify system details needed for implementation nor do they dictate design decisions or features behind the interface, where specific requirements will be defined in applicable documents.

1.1 PURPOSE AND SCOPE

The purpose of this ISwSIS is to provide basic data interface standards that allow developers to independently design compatible cislunar and deep space spacecraft software systems. At the highest level, seamless data exchange and data interpretation between spacecraft and between spacecraft modules, where two or more modules comprise the spacecraft, is the objective.

The same data exchange and interpretation standards can apply to the software systems and subsystems residing within any one module, however there is latitude on the part of the spacecraft module developers to determine when and if the data standard is to apply.

Compatible software systems among software, hardware, and human interfaces for spacecraft systems, ground infrastructure, surface systems etc. is critical to the success of human exploration. Enabling the use of National Aeronautics and Space Administration (NASA), International Partner, commercial, and other software assets interchangeably, decreases development and procurement costs, and reduces operational and training complexity.

1.2 RESPONSIBILITY AND CHANGE AUTHORITY

Any proposed changes to this standard by the participating partners of this agreement shall be brought forward to the ISwSIS working group for review.

Configuration control of this document is the responsibility of the Multilateral Coordination Board (MCB). NASA will maintain the ISwSIS under Human Exploration and Operations Mission Directorate (HEOMD) Configuration Management. Any revisions to this document will be approved by the MCB.

2.0 DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The following documents include specifications, models, standards, guidelines, handbooks, and other special publications. The documents listed in this paragraph are applicable to the extent specified herein.

CCSDS 132.0-B-2	TM Space Data Link Protocol
CCSDS 133.0-B-1	Space Packet Protocol
CCSDS 133.1-B-2	Encapsulation Service
CCSDS 232.0-B-3	TC Space Data Link Protocol
CCSDS 232.1-B-2	Communications Operation Procedure-1
CCSDS 660.0-B-1	XML Telemetric and Command Exchange (XTCE)
CCSDS 876.0-R-2	Spacecraft Onboard Interface Services--XML Specification for Electronic Data Sheets

2.2 REFERENCE DOCUMENTS

The following documents contain supplemental information to guide the user in the application of this document. These reference documents may or may not be specifically cited within the text of this document.

No Number	Core Flight Software Source Code and Documentation Download Links
CCSDS 102.0-B.5	Packet Telemetry
CCSDS 103.0-B-2	Packet Telemetry Service Specification
CCSDS 203.0-B-1	Telecommand Part 3, Data Management Service, Architectural Specification
CCSDS 355.0-B-1	Space Data Link Security Protocol
CCSDS 701.0-B-3	Advanced Orbiting Systems, Networks and Data Links: Architectural Specification
CCSDS 727.0-B-4	CCSDS File Delivery Protocol (CFDP)
CCSDS 732.0-B-3	AOS Space Data Link Protocol

3.0 INTERNATIONAL SOFTWARE SYSTEM INTEROPERABILITY STANDARDS

3.1 GENERAL

The goal of establishing standards is to maximize the success of future human spaceflight missions conducted as international partnerships. The ability of components, systems, or vehicles delivered from multiple sources to work together as an effective system is important to the success of missions. Good collaboration can make technology development and system maturation more efficient, by sharing the lessons learned and failures that drive requirements. Using standard assumptions can also make development more efficient by making tests conducted by one partner relevant and valid to multiple partners.

This document focuses on factors that drive software system integration and performance, and on issues that most directly affect interoperability between systems.

3.1.1 DESCRIPTION

The following subsections describe or address the syntactic and semantic software system interface standards, as well as software production, product, and process standard rationale. Also defined is a Software Framework Standard for use by NASA, International Partners, and commercial entities developing cislunar spacecraft software systems.

The recommended standards set forth in this document will ensure the cislunar spacecraft are software compatible.

3.1.2 ENGINEERING UNITS OF MEASURE AND NOMENCLATURE

All dimensions are in International System of Units (SI units) (metric).

3.2 INTERFACES

This section describes areas to be implemented in cislunar spacecraft software systems; these are standards which are needed to ensure compatibility.

3.2.1 SYNTACTIC INTEROPERABILITY STANDARDS

Syntactic interoperability is generally defined as two or more software systems having the ability to communicate and exchange data. Most definitions of syntactic interoperability agree that the data can be exchanged, but not necessarily understood by the receiving software system(s). “Understanding” in this sense means the ability to parse the data, make decisions on that data, and provide specific actions or results to the sending software system or other software systems. As such, syntactic interoperability is the ability to accept and acknowledge data received, but no more.

There are several Consultative Committee for Space Data Systems (CCSDS) Blue Book standards that address syntactic interoperability supporting spacecraft data exchange. The CCSDS standards in this section specify the basis for spacecraft syntactic software interoperability standards at the spacecraft module level. Where mutually agreed, the communication between two units sharing an interface can use these CCSDS standards as the basis for syntactic interoperability within the module.

3.2.1.1 CCSDS 132.0-B-2, TM SPACE DATA LINK PROTOCOL

CCSDS 132.0-B-2, TM Space Data Link Protocol is a CCSDS telemetry standard designed to meet requirements for the efficient transfer of space application data. The standard supports space-to-ground or space-to-space communication links, i.e. "space links."

SWS-001 Spacecraft shall comply with a telemetry space data link protocol as defined in CCSDS 132.0-B-2, TM (Space Data Link Protocol.

Rationale: Compliance with the Telemetry Space Data Link Protocol (TM SDLP) standard provides standardization of telemetry formats between a spacecraft and the ground.

3.2.1.2 CCSDS 133.0-B-1, SPACE PACKET PROTOCOL

CCSDS 133.0-B-1, Space Packet Protocol, specifies the protocols, services, and procedures pertaining to the CCSDS Packet. These specifications correspond with CCSDS Source Packet specifications contained in CCSDS 102.0-B.5, Packet Telemetry, CCSDS 103.0-B-2, Packet Telemetry Service Specification, CCSDS 203.0-B-1, Telecommand Part 3, Data Management Service, Architectural Specification, and CCSDS 701.0-B-3, Advanced Orbiting Systems, Networks and Data Links: Architectural Specification.

SWS-002 Spacecraft shall comply with a space packet protocol as defined in CCSDS 133.0-B-1, Space Packet Protocol.

Rationale: Compliance with the Space Packet Protocol standard provides standardization of space packets as provided on the software buses.

3.2.1.3 CCSDS 133.1-B-2, ENCAPSULATION SERVICE

CCSDS 133.1-B-2, Encapsulation Service, specifies a communications service to be used by space missions to transfer protocol data units that are not directly transferred by the space data link protocols over a ground-to-space or space-to-space communications link. It defines another option to encapsulate packets to interface devices to the CCSDS data link protocols (Telemetry (TM), Telecommand (TC), Advanced Orbiting Systems (AOS), etc.).

SWS-003 Spacecraft shall comply with the encapsulation service as defined in CCSDS 133.1-B-2, Encapsulation Service.

Rationale: Compliance with the Encapsulation Service standard defines another option to encapsulate packets and to interface devices (e.g. Power & Data Units) to the CCSDS data link protocols (TM, TC, AOS, etc.).

3.2.1.4 CCSDS 232.0-B-3, TC SPACE DATA LINK PROTOCOL

CCSDS 232.0-B-3, TC Space Data Link Protocol is a CCSDS telecommand standard designed to meet requirements for the efficient transfer of space data via command. The standard supports space-to-ground or space-to-space communication links, i.e. “space links.”

SWS-004 Spacecraft shall comply with a command space data link protocol as defined in CCSDS 232.0-B-3 TC Space Data Link Protocol.

Rationale: Compliance with the Telecommand Space Data Link Protocol (TC SDLP) standard provides standardization of command format between a spacecraft and the ground.

3.2.1.5 CCSDS 232.1-B-2, COMMUNICATIONS OPERATION PROCEDURE-1

CCSDS 232.1-B-2, Communications Operation Procedure-1 is a closed-loop procedure executed by the sending and receiving ends of the TC SDLP, allowing Type-A Transfer Frames to be accepted by the receiving end only if the frames are received in strict sequential order.

The standard enables correct data frame delivery at the receiving end, without omission or duplication, and in the same sequential order in which the frames were received from the sending end.

SWS-005 Spacecraft shall comply with a communications operation procedure as defined in CCSDS 232.1-B-2, Communications Operation Procedure-1.

Rationale: Compliance with the Communications Operation Procedure-1 (COP-1) standard provides ensures correct data frame delivery between a spacecraft and the ground.

3.2.1.6 NETWORK BYTE ORDER

SWS-006 All messages on the spacecraft will be in Network Byte Order.

Rationale: Network Byte Order is a common format for data networking involving the internet protocol suites, i.e. Internet Protocol version 4 (IPv4) Internet Protocol version 6 (IPv6), Transmission Control Protocol (TCP), and User Datagram Protocol (UDP). Network Byte Order is consistent with the internet protocols required in the International Communication System Interoperability Standards (ICSIS) and is the data format used on the Orion Data Network (ODN).

3.2.2 SEMANTIC INTEROPERABILITY STANDARDS

Semantic interoperability is largely understood to be the ability of two or more software systems to interpret information exchanged between them in a meaningful and accurate manner, thereby producing useful results. The ability to produce useful results, as defined by the end users of each software system involved, is the key driving concept behind semantic interoperability. Not only does a software system have to receive and acknowledge the data, it must have the ability to parse the data, make decisions on that data, and provide specific actions or results to the sending software system or other software systems.

In order to accomplish semantic interoperability in an efficient and effective manner, identification of a standard that allows for the definition and interpretation of data exchanged between spacecraft and within a spacecraft will be required. Data definitions for inter-module and module-to-ground data exchange will need to be centralized to support interface compatibility and to simplify the process of managing data products across module interface boundaries.

Currently CCSDS has developed syntactic interoperability standards and is progressing towards a semantic interoperability standard that can be adopted and tailored to meet specific software interoperability needs. A management process for governance of tailoring, inclusion of new dictionary terms, modification of terms, and assessment of impacts across spacecraft modules associated with modification of terms, etc. will be established to ensure efficient and effective management of the standard.

3.2.2.1 CCSDS 876.0-R-2, SPACECRAFT ONBOARD INTERFACE SERVICES--XML SPECIFICATION FOR ELECTRONIC DATA SHEETS

CCSDS 876.0-R-2, Spacecraft Onboard Interface Services--XML Specification for Electronic Data Sheets, is a CCSDS Red Book standard specifying the Spacecraft Onboard Interface Services (SOIS) compliant services to be provided in support of software applications. This CCSDS standard defines the Extensible Markup Language (XML) Specification for SOIS Electronic Data Sheet (SEDS) for Onboard Devices.

Definition of the standard encompasses the XML representation of the functional interfaces offered by protocols used to access the data interfaces. Descriptions in machine-readable format can be processed by a toolchain to facilitate the various phases in the life of a space vehicle.

SWS-007 Spacecraft shall utilize XML specification for electronic data sheets standard as defined in CCSDS 876.0-R-2, Spacecraft Onboard Interface Services--XML Specification for Electronic Data Sheets.

Rationale: Compliance with the XML-based Electronic Data Sheet (EDS) specification provides a means for electronically defining and describing data across spacecraft interfaces, with visiting spacecraft, and with the ground. Definition of the data will allow inter-module processing in support of autonomous operations, thereby providing control authority to spacecraft software systems. Note: CCSDS 876.0-R-2, Spacecraft Onboard Interface Services--XML Specification for Electronic Data Sheets is currently a CCSDS draft or "Red Book" standard and will become a recommended or "Blue Book" standard sometime in the future.

SWS-008 Spacecraft software shall utilize the specification for Dictionary of Terms for EDS as defined in CCSDS 876.1-R-2, Spacecraft Onboard Interface

Services – Specification for Dictionary of Terms for Electronic Data Sheets.

Rationale: Compliance with the dictionary of terms for EDS specification provides a means for semantic interoperability of data across spacecraft. Consistent use of the common semantic attributes and quantity types enables the use of data discovery and standardized preservation of the relationship between data points. Note: CCSDS 876.1-R-2 is currently a CCSDS draft or "Red Book" standard and will become a recommended or "Blue Book" standard sometime in the future. Tailoring of the standard will be required.

3.2.2.2 CCSDS 660.0-B-1, XML TELEMETRIC AND COMMAND EXCHANGE (XTCE)

The XTCE data specification provides an information model and data exchange format for telemetry and commanding definitions in all phases of the spacecraft, payload, and ground segment life cycle. Use of XTCE will assist with building plugins for command and data dictionaries, which in turn will output CCSDS XTCE compliant information.

SWS-009 Spacecraft shall utilize XCTE specification for defining and describing an information model and data exchange format as defined in CCSDS 660.0-B-1, XML Telemetric and Command Exchange (XTCE).

Rationale: Compliance with the XTCE standard specification provides the standard for electronically defining and describing an information model and data exchange format. Definition of the data will support inter-element data exchange in support of autonomous operations, thereby providing control authority to spacecraft software systems.

3.2.3 FLIGHT SOFTWARE FRAMEWORK STANDARD

NASA's Core Flight System (cFS) is a NASA asset for Spacecraft Flight Software Reuse (http://cfs.gsfc.nasa.gov/). cFS is a productized real-time flight software framework developed over several years by the Goddard Space Flight Center (GSFC) to serve as a reusable software base for spacecraft missions, test missions, and real-time systems.

Since 2012, NASA has assessed and matured cFS for broad use, advanced the cFS product line and supported agency-wide and industry investment in software reuse. cFS is fully tested, documented, and operational as a Technology Readiness Level 9 (TRL 9) product, supporting the Lunar Reconnaissance Orbiter (LRO) spacecraft and a host of other operational missions.

The following list summarizes key cFS capabilities pertinent to this standard:

- Supports numerous hardware platforms, operating systems, and software architectures.
- Scalable to support a variety of space missions and space-related projects.

- Provides a spacecraft flight software command, control, and communication framework based on a common message distribution capability.
- Complies with CCSDS TM SDLP, TC SDLP, COP-1, and CCSDS File Delivery Protocol (CFDP) standards, and supports the CCSDS XML EDS standard.
- Provides an Orion/ Space Launch System (SLS) Command, Control, Communications and Information (C^3I) compliant data converter/translator.
- Provides a common developer toolset for application development and integration.
- Controlled and released as a single product line supported and configuration managed by NASA.

SWS-010 Spacecraft module software systems shall utilize the cFS as the standard software framework.

Rationale: cFS provides a common software framework for command, control, and communication software and a platform for the integration of applications that can be shared across spacecraft modules and applications that are hosted on two or more modules, such as a spacecraft's Vehicle System Manager (VSM).

3.2.4 PRODUCTION, PRODUCT, AND PROCESS STANDARDS

The development of ISwSIS addressed three other areas from which other software standards may evolve. These include:

a) Production standards providing engineering and management requirements for the development of software products over the complete software lifecycle. These standards and/or requirements typically specify procedures, architecture, design, activities, and tasks used to specify, develop, assure, and maintain software developed or acquired.

b) Product standards which define the operational behavior of a software product. For example, the "look and feel" of display images or intonation of audio output. Such standards are applicable to human/space system interaction, providing uniform technical requirements for the design, selection, and application of crew-centric software, processes, and procedures.

c) Process standards covering software requirement, design, code, integration, test, and verification processes, procedures, methods, and tools. Also included are support processes and tools for software configuration management, development and test environments, simulators, etc.

Recognizing that software organizations developing spacecraft software systems and products already meet or will meet specific goals associated with existing software development environments, standards, or models such as the Capability Maturity Model Integration (CMMI) Institute's Capability Maturity Model Integration-Development

(CMMI-DEV)®, no software engineering production standards, product standards, process standards, languages, toolchains, etc. will be identified, levied, or proposed.

Instead, the software development organizations from the various space agencies will leverage their existing software engineering requirements, standards, certified/assessed processes, practices, and tools, and apply them as needed. Management of the software development and verification organizations, and products will be the responsibility of the software organizations contributing to cislunar spacecraft software products and systems, in accordance with a spacecraft-level Software Management Plan.

This approach eliminates the need for ongoing assessment, agreement, adaptation, and adoption of common software processes, development environments, languages, and tools across disparate organizations. This will minimize overhead and eliminate cross-agency and cross-organizational learning curves.

Agreement on delivery media, installation instructions, user's guides, etc. may require further discussion and decision. Identification of common software product requirements and software development best practices are acceptable approaches to achieve commonality.

3.3 PERFORMANCE

The specific performance parameters and requirements will be captured in the Interface Control Documents (ICD)s, Software Requirements Specifications (SRS)s, Human Systems Integration Requirements (HSIR)s, and crew information requirements to support safety and performance. The standards required for interoperability are defined in this document.

3.4 VERIFICATION AND TESTING

It is the responsibility of the spacecraft software developer to perform verification and validation. The majority of the standards will be verified using a combination of interface/compatibility testing (including human-in-the-loop usability and performance assessments), demonstration, and analysis at the subsystem and system level.

4.0 FUTURE TOPICS FOR POSSIBLE STANDARDIZATION

For purposes of this document, future topics will be listed on an “as identified” basis and worked as actions to affect the body of the document.

APPENDIX A - ACRONYMS AND ABBREVIATIONS

AOS	Advanced Orbiting Systems
C^3I	Command, Control, Communications and Information
CCSDS	Consultative Committee for Space Data Systems
CFDP	CCSDS File Delivery Protocol
cFS	Core Flight Software
CMMI	Capability Maturity Model Integration
CMMI-DEV	Capability Maturity Model Integration-Development
COP	Communications Operation Procedure
EDS	Electronic Data Sheet
FEL	First Element Launch
GSFC	Goddard Space Flight Center
HEOMD	Human Exploration and Operations Mission Directorate
HSIR	Human Systems Integration Requirements
ICD	Interface Control Document
ICSIS	International Communication System Interoperability Standards
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
ISS	International Space Station
ISwSIS	International Software System Interoperability Standards
LRO	Lunar Reconnaissance Orbiter
MCB	Multilateral Coordination Board
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
ODN	Orion Data Network
SDLP	Space Data Link Protocol
SEDS	SOIS Electronic Data Sheet
SLS	Space Launch System
SOIS	Spacecraft Onboard Interface Services
SRS	Software Requirement Specification
TBD	To Be Determined
TBR	To Be Resolved
TC	Telecommand
TCP	Transmission Control Protocol
TM	Telemetry
TRL	Technology Readiness Level

UDP	User Datagram Protocol
VSM	Vehicle System Manager
XML	Extensible Markup Language
XTCE	XML Telemetric and Command Exchange

APPENDIX B - GLOSSARY

ALLOCATION

The portioning of resources and accommodations to the ISS users. Total ISS resources and accommodations are allocated between system and utilization. Utilization resources and accommodations are allocated between International Partners.

ASSEMBLY PHASE

Refers to the time period starting with First Element Launch (FEL) and ending with the landing of the last flight in the assembly sequence.

CARGO CARRIER

Element of a transportation vehicle that provides capability to carry cargo.

MODULE

A major individual piece of flight hardware that fulfills a specific function for cislunar or deep space missions. For example, a habitat module providing crew accommodations and work space. A spacecraft may be comprised of one or more modules.

SOFTWARE SYSTEM

The term “software system” refers to one or more software configuration items designed to support a system within a module or to operate the spacecraft. Software systems may be developed by NASA, International Partners, or commercial companies.

SPACECRAFT

A vehicle that delivers crew and cargo from Earth to cislunar or deep space locations, or between cislunar or deep space locations.

APPENDIX C - OPEN WORK

Table C-1 lists the specific To Be Determined (TBD) items in the document that are not yet known. The TBD is inserted as a placeholder wherever the required data is needed and is formatted in bold type within brackets. The TBD item is numbered based on the section where the first occurrence of the item is located as the first digit and a consecutive number as the second digit (i.e., <TBD 4-1> is the first undetermined item assigned in Section 4 of the document). As each TBD is solved, the updated text is inserted in each place that the TBD appears in the document and the item is removed from this table. As new TBD items are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBDs will not be renumbered.

TABLE C-1 TO BE DETERMINED ITEMS

TBD	Section	Description

Table C-2 lists the specific To Be Resolved (TBR) issues in the document that are not yet known. The TBR is inserted as a placeholder wherever the required data is needed and is formatted in bold type within brackets. The TBR issue is numbered based on the section where the first occurrence of the issue is located as the first digit and a consecutive number as the second digit (i.e., <TBR 4-1> is the first unresolved issue assigned in Section 4 of the document). As each TBR is resolved, the updated text is inserted in each place that the TBR appears in the document and the issue is removed from this table. As new TBR issues are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBRs will not be renumbered.

TABLE C-2 TO BE RESOLVED ISSUES

TBR	Section	Description

APPENDIX D - SYMBOLS DEFINITION

N/A