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prepared by/préparé par Gian Paolo Calzolari (Editor)

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1 INTRODUCTION

This document constitutes the IOAG Service Catalog #1 that describes the cross-support services that will be provided by the ground tracking assets ¹ operated by the IOAG member agencies.

The IOAG Service Catalog #1 services provide space communication and navigation capabilities for interaction between a spacecraft control center and a spacecraft directly reachable via a ground tracking asset as shown in Figure 2-1. Measurements using the radio signal are provided as Radio Metric Services for the purpose of spacecraft navigation and communication operation in space.

Related to the provision of the above Space Communication and Radio Metric services is their Service Management, which is understood as all the interactions needed to make the service provision happen and to monitor it. For the simple ABA scenario addressed in Catalog #1, Service Management in addition interacts with the service provider as required to establish physical and link layer communications between the spacecraft and the ground tracking asset.

IOAG Service Catalog #1 is structured into “core” and “extended” services with the understanding that “core” services will be implemented by all IOAG Agencies by 2020, while “extended” services will be considered for bi-lateral cross supports. The IOAG agencies current capabilities are documented in the IOAG Communications Asset Table [XSCA].

The definition of IOAG Service Catalog #1 is likely to generate associated guidance of CCSDS work for those standards that are either in progress or to be started. These are mentioned as “to be written” in the list of applicable documents and their titles are therefore indicative and to be confirmed by CCSDS.

The IOAG Service Catalog #2 defines space communication services for in-space relay and network cross support scenarios which would enable future Solar System Internetworking. That catalog comprises typically DTN and/or IP technologies.

A future IOAG Service Catalog #3 is planned to define services at application level for end-to-end cross support scenarios or for interoperability within a Space and/or Ground system with contributions by several independent Agencies. That catalog will comprise typically Mission Operations software technologies.

Some agencies are currently implementing on their Ground Systems, the Mission Operation services that will be addressed in IOAG Service Catalog #3. There are on-going analysis for future implementations in Space assets.

¹ Ground Tracking Assets may be Ground Stations, Ground Data System or a combination of both.



1.1 Applicable Documents

1.1.1 GROUND LINK STANDARDS

[CLTU]	CCSDS 912.1-B Space Link Extension – Forward CLTU Service Specification. Blue Book.
[CFXS]	CCSDS 927.1-B Cross Support - Terrestrial Generic File Transfer – Blue Book. TBW
[CORS]	Offline Radio Metric Service - Blue Book. TBW
[CRTRM]	CCSDS 922.2-B Tracking Data Cross Support Transfer Service – Blue Book.
[DDORS]	CSTS Delta DOR Service - Blue Book. TBW
[EDM]	CCSDS 922.1-B Monitored Data - Cross Support Transfer Service - Blue Book.
[FCFS]	Forward CFDP-File Service – Blue Book. TBW
[FF]	CCSDS 922.3-B Cross Support Transfer Service – Forward Frame Service. TBW
[FPFS]	Forward Packets-File Service – Blue Book. TBW
[FSP]	CCSDS 912.3-B Space Link Extension – Forward Space Packet Service Specification. Blue Book.
[RAF]	CCSDS 911.1-B Space Link Extension – Return All Frames Service Specification. Blue Book.
[RCF]	CCSDS 911.2-B Space Link Extension – Return Channel Frames Service Specification. Blue Book.
[RCFS]	Return CFDP-File Service – Blue Book. TBW
[ROCF]	CCSDS 911.5-B Space Link Extension – Return Operational Control Fields Service Specification. Blue Book.
[RPFS]	Return Packets-File Service – Blue Book. TBW
[SCC]	Service Control Cross Support Transfer Service – Blue Book. TBW
[SM]	CCSDS 910.11-B Space Link Extension – Service Management. Blue Book.
[SM-ACC]	CCSDS 902.8-B Cross Support Service Management: Service Accounting. Blue Book. TBW

- [SM-ACP] CCSDS 902.5-B Cross Support Service Management: Service Agreement and Service Configuration Profile Data Formats. Blue Book. TBW
- [SM-AUT] CCSDS 902.10-B Cross Support Service Management: Management Services (Automation) . Blue Book. TBW
- [SM-CAT] CCSDS 902.7-M Cross Support Service Management: Service Catalog. Magenta Book. TBW
- [SM-ESF] CCSDS 902.6-B Cross Support Service Management: Event Sequence Data Format. Blue Book. TBW
- [SM-PDF] CCSDS 902.2-B Cross Support Service Management: Planning Data Formats. Blue Book. TBW
- [SM-SPF] CCSDS 902.4-B Cross Support Service Management: Service Package Data Formats. Blue Book. TBW
- [SM-SSF] CCSDS-902.1-B Cross Support Service Management: Simple Schedule Format Specification. Blue Book. TBW
- [SM-URF] CCSDS 902.9-B Cross Support Service Management: Service Management Utilization Request Format. Blue Book. TBW

1.1.2 SPACE LINK STANDARDS

- [AOS] CCSDS 732.0-B AOS Space Data Link Protocol. Blue Book.
Including the specifications to support the Space Data Link Security Protocol [SDLP].
- [CFDP] CCSDS 727.0-B CCSDS File Delivery Protocol (CFDP). Blue Book.
- [ENC] CCSDS 133.1-B Encapsulation Service. Blue Book.
- [OPT] Optical Coding and Modulation, i.e. the collection of:²
CCSDS 142.0-B Optical Communications Coding & Synchronization. Blue Book.
CCSDS 141.0-B Optical Communications Physical Layer. Blue Book.
- [PNR] CCSDS 414.1-B Pseudo-Noise (PN) Ranging Systems. Blue Book.

² The standards for Optical Coding and Modulation plan to eventually cover a number of different scenarios, namely High Photon Efficiency (HPE), Optical On Off Keying (OOK), and High Data Rate (HDR). As for other standards, Agencies may decide to support only a subset of those scenarios.

- [RFM] CCSDS 401.0-B Radio Frequency and Modulation Systems--Part 1: Earth Stations and Spacecraft. Blue Book.
This standard includes numerous concise recommendations developed for conventional near-Earth and deep-space missions having moderate communications requirements. Section 2 focuses upon the technical characteristics of RF and modulation systems for Earth stations and spacecraft and it has been subdivided into six modules, each containing an individual subject:
1. Earth-to-Space Radio Frequency (Forward Link)
 2. Telecommand (Forward Link)
 3. Space-to-Earth Radio Frequency (Return Link)
 4. Telemetry (Return Link)
 5. Radio Metric
 6. Spacecraft (Transponder)
- It also includes policy constraints, and procedural elements relating to communications services provided by radio frequency and modulation systems.
- NOTE: IOAG Agencies integrated this document with the IOAG Report on Preferred Coding and Modulation Schemes [PC&M].
- [SDLP] CCSDS 355.0-B Space Data Link Security Protocol. Blue Book.
CCSDS 355.1-B Space Data Link Security Protocol: Extended Procedures. Blue Book. TBW
- NOTE: As implementation of security measures are normally left to bilateral agreements, the security options for Space Data Link Protocols are optional for core services.
- [SPP] CCSDS 133.0-B Space Packet Protocol. Blue Book.
- [TC-COP] CCSDS 232.1-B Communications Operation Procedure-1. Blue Book.
- [TC-DLP] CCSDS 232.0-B TC Space Data Link Protocol. Blue Book.
Including the specifications to support the Space Data Link Security Protocol [SDLP].
- [TC-S&C] CCSDS 231.0-B TC Synchronization and Channel Coding. Blue Book.
- NOTE: IOAG Agencies integrated this document with the IOAG Report on Preferred Coding and Modulation Schemes [PC&M].
- [TM-DLP] CCSDS 132.0-B TM Space Data Link Protocol. Blue Book.
Including the specifications to support the Space Data Link Security Protocol [SDLP].



- [TM-S&C] The collection of:
- CCSDS 131.0-B TM Synchronization and Channel Coding. Blue Book.
 - CCSDS 131.2-B Flexible Advanced Coding and Modulation Scheme for High Rate Telemetry Applications. Blue Book.
 - CCSDS 131.3-B CCSDS Space Link Protocols over ETSI DVB-S2 Standard. Blue Book.
 - CCSDS 431.1-B Variable Code and Modulation (VCM) Systems for CCSDS
- NOTE: IOAG Agencies integrated these documents with the IOAG Report on Preferred Coding and Modulation Schemes [PC&M].
- [USLP] CCSDS 732.1-B Unified Space Data Link Protocol. Blue Book.
Including the specifications to support the Space Data Link Security Protocol [SDLP].



1.1.3 DATA STRUCTURES STANDARDS

Some of the standards mentioned here below are widely used by the other applicable documents mentioned in this chapter and are listed here despite the fact that they may not be directly referenced in the rest of this document.

- [DDORO] CCSDS 506.0-M Delta-Differential One Way Ranging (Delta-DOR) Operations. Magenta Book.
- [DDRXF] CCSDS 506.1-B Delta-DOR Raw Data Exchange Format – Blue Book.
- [ODM] CCSDS 502.0-B Orbit Data Messages. Blue Book.
- [SLID] “Registries.” Space Assigned Number Authority.
<http://sanaregistry.org/r/>. This replaces CCSDS 135.0-B Space Link Identifiers. Silver Book.
- [TDM] CCSDS 503.0-B Tracking Data Message. Blue Book.
- [XNM] CCSDS 505.0-B-1 XML Specification for Navigation Data Messages. Blue Book.

Note: The XML Specification for Navigation Data Messages Recommended Standard is providing a different representation than [TDM] and [ODM] that define ASCII formats.

1.1.4 IOAG DOCUMENTS

- [XSCA] (IOAG) RF Communication Assets
http://sanaregistry.org/r/rf_assets/rf_assets.html
- [PC&M] IOAG Report: Recommendations on Preferred Coding and Modulation Schemes –Issue 1.0, 18 April 2016.

1.2 *Acronyms*

AOS	Advanced Orbiting Systems
CCSDS	Consultative Committee for Space Data Systems
CFDP	CCSDS File Delivery Protocol
CLTU	Communication Link Transmission Unit
COP	Command/Communication Operation Procedure
CSTS	Cross Support Transfer Services
DOR	Differential One-Way Ranging
DTN	Delay/Disruption Tolerant Network
HDR	High Data Rate
HPE	High Photon Efficiency



IOAG	Interagency Operations Advisory Group
IOP	Inter-Operability Plenary
IP	Internet Protocol
LEO	Low Earth Orbit
O3K	Optical On Off Keying
PN	Pseudo Noise
RF	Radio Frequency
SLE	Space Link Extension
SP	Space Packet
SSI	Solar System Internetworking
TBW	To Be Written (or to be published in case work is already ongoing)
TC	TeleCommand
TDM	Tracking Data Message
TM	TeleMetry
USLP	Unified Space data Link Protocol.

2 SCOPE OF CATALOG #1

Catalog #1 includes the ground based cross-support services currently available or envisaged in short time for supporting the scenario described in Figure 2-1. Such a scenario is sometimes referred to as an ABA scenario to show that an Agency B is providing services to Agency A Control Center for accessing an Agency A spacecraft.

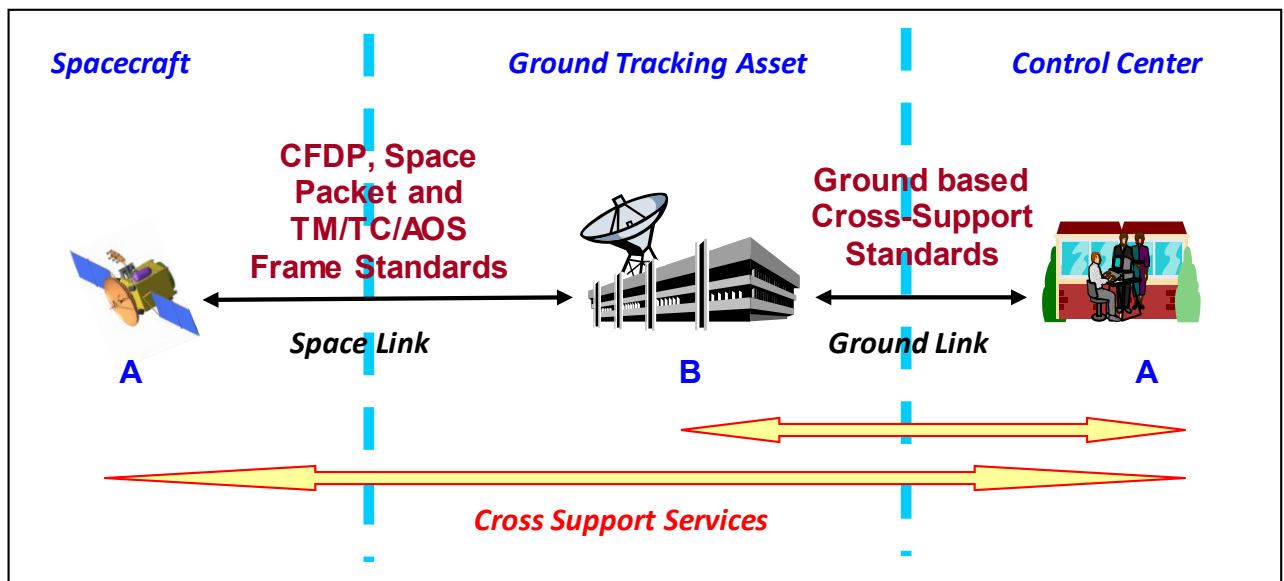


Figure 2-1 ABA Scenario for Catalog #1

As depicted in Figure 2-1, there are two kinds of links (and then two types of interfaces) involved in this scenario: the Space Link (Interface) between the Spacecraft and a Ground Tracking Asset and the Ground Link (Interface) between the Ground Tracking Asset and the Spacecraft Control Center.

On the Space Link, services are based on a set of standards applicable to the transfer of data over this connection, while on the Ground Link the services are defined by a set of standards defining a set of Cross Support Transfer Services (named Space Link Extension services in their simplest form). In addition both kinds of links (and then two types of interfaces) rely on a set of other standards for data structures. The relevant standards are defined by CCSDS.

For the Space Link Interface a very comprehensive list of CCSDS Recommendations is available covering RF and Modulation, Coding and Synchronization and Link Layer Protocols. However those Recommendations are not necessarily fully supported by the plurality of the IOAG agencies (e.g. GMSK modulation, turbo codes, regenerative ranging, forward AOS).

The Cross Support Transfer Services provide the Control Center either with access to information traveling on the Space Link or with access to other information not traveling on the Space Link (but possibly derived from/related to the space link). Therefore the IOAG Service span either between



the Control Center and the Spacecraft or between the Control Center and the Ground Tracking Asset as shown by the yellow arrows in the figure.

The Ground Link Interface services fall into the following categories:

1. Cross Support Transfer Services / Space Link Extension Services.
2. “Service Management” Functions.

The Cross Support Transfer Services (CSTS) and the Space Link Extension (SLE) Services define ground link interface between a Control Center and a Ground Tracking Asset.

The “Service Management” functions include

- a. assessment of service suitability by verification of the Provider’s Service Catalog,
- b. the establishment of a Service Agreement between User and Provider of Cross Support, possibly including configuration profiles to execute the supports,
- c. the Service Planning and Scheduling
- d. the Service Execution, and
- e. the Service Accounting

2.1 Definition of Service

A service is a self-contained function, which accepts one or more requests and returns one or more responses through a well-defined, standard interface. A service does not depend on the context or state of other services or processes (although it may utilize other services via their interfaces). Services are specified from the user's point of view, i.e., in terms of "what it provides" rather than "how it is performed" or "what does the job". Therefore, a service is solely specified in terms of its behavior and performance without reference to a particular implementation.

The services described in this catalog are those services supporting mission operations and relevant to an operational context where a service provider (e.g., a tracking station or a communications network) exists and it provides communications and tracking supports to a service user, i.e., a flight project’s mission control center. Figure 2-2 describes the “service provider – service user” relationship in the service paradigm.

The service is the "whole job" in the operations sense. It will thus typically involve a combination of software components, computing and communications hardware, personnel and the procedures they follow, as well as facilities. Further, the service is also the "whole job" in the life-cycle sense. The design, implementation, integration, verification and validation activities needed to supply the service are an inherent part of it.



This catalog describes a set of standard service types provided by the IOAG member agencies for cross support purposes. The individual service types as defined are distinguished from one another by the functions provided, level of processing involved, and/or the type(s) of source data. Of these service types a few that are minimally required of all member agencies are considered “Core Services”, whereas those to be provided only on a voluntary, bi-lateral agreement basis are “Extended Services”.



3 CATALOG #1 SERVICES

A given IOAG Service can be built on top of a number of combinations of Space Link Interface standards and Ground Link Interface standards as shown in Table 3-1. Both types of standards rely on Data Structure standards that are not shown in the table.

The following groups of IOAG Services have been identified within IOAG Service Catalog #1. Each group includes several service types.

- Forward Data Delivery Services Group. These services allow transfer of data from a control center to a spacecraft.
- Return Data Delivery Services Group. These services allow transfer of data from a spacecraft to a control center.
- Radio Metric Services Group. These services allow the results of radio metric measurements to be provided to a control center.

In addition Service Management functions are defined. They allow for interaction between the space agencies in order to coordinate the provision of the above space communications and radio metric services. Moreover, these functions allow the results of radio link status to be provided to a control center.

Based on the criticality, availability, and performance attributes associated with the provision of services, there exist at least three service modes:

- (a) Nominal service mode: The mode in which the services are provided to a user mission operating under nominal, routine conditions.
- (b) Mission critical service mode: The mode in which the services are provided to support a user mission during its mission critical events. Typical mission critical events are, but not limited to, launch, orbit insertion, trajectory correction maneuver, and entry/descent/landing. In this mode, success or failure in service provision may be critical to the mission, the service availability may have to be guaranteed to the user mission, and the performance of service execution may be more demanding than that in nominal service mode.
- (c) Emergency service mode: The mode in which the services are provided to a user mission that has declared its spacecraft in an emergency state, i.e., the state caused by the occurrence of an anomaly in the spacecraft, including the failure of a spacecraft component, that, if not corrected, will result in the spacecraft's inability to meet the mission objectives. In this mode, success or failure in service provision is critical to the mission, the service availability must be very high, and the performance of service execution, in some aspect, may be more stringent than that in nominal service mode.

The rows marked by light green shadow in Table 3-1 indicate core services for IOAG Service Catalog #1 while the white rows indicate extended services.

IOAG Service Group	IOAG Service Types	Space Link Interface Standards	Ground Link Interface Standards
Forward Data Delivery Services	Forward CLTU Service	- Radio Frequency and Modulation [RFM] ³ - TC Synchronization and Channel Coding [TC-S&C]	SLE Forward CLTU Service [CLTU]
	Forward Frame Service	- Radio Frequency and Modulation [RFM] ⁴ - TM Synchronization and Channel Coding [TM-S&C] - AOS Space Data Link Protocol [AOS] - Unified Space Data Link Protocol [USLP]	CSTS Forward Frame Service [FF]
	Forward Frame Optical Service	- Optical Coding and Modulation [OPT] - AOS Space Data Link Protocol [AOS] - Unified Space Data Link Protocol [USLP]	CSTS Forward Frame Service [FF]
	Forward Space Packet Service	Those for “Forward CLTU Service” plus: - TC Space Data Link Protocol [TC-DLP] - Unified Space Data Link Protocol [USLP] - Communications Operation Procedure-1 [TC-COP]	SLE Forward Space Packet Service [FSP]

³ With respect to Forward IOAG Service(s), the applicability of this recommendation is limited to the sections for the recommendations about “Earth to Space RF” and “Telecommand”.

⁴ With respect to Forward IOAG Service(s), the applicability of this recommendation is limited to the sections for the recommendations about “Earth to Space RF” and “Telecommand”.



	Forward CFDP-File Service	Those for “Forward CLTU Service” plus: • Space Packet Protocol [SPP] • Encapsulation Service [ENC] • CCSDS File Delivery Protocol [CFDP]	• Forward CFDP-File Service [FCFS], over • Cross Support - Terrestrial Generic File Transfer [CFXS]
	Forward PACKETS-File Service	Those for “Forward CLTU Service” plus: • Space Packet Protocol [SPP] • Encapsulation Service [ENC]	• Forward Packets-File Service [FPFS], over • Cross Support - Terrestrial Generic File Transfer [CFXS]

IOAG Service Group	IOAG Service Types	Space Link Interface Standards	Ground Link Interface Standards
Return Data Delivery Services	Return All Frames Service	- Radio Frequency and Modulation [RFM] ⁵ - TM Synchronization and Channel Coding [TM-S&C]	SLE Return All Frames [RAF]
	Return All Frames Optical Service	Optical Coding and Modulation [OPT]	SLE Return All Frames [RAF]
	Return Channel Frames Service	Those for “Return All Frames Service” plus: - TM Space Data Link Protocol [TM-DLP] - AOS Space Data Link Protocol [AOS] - Unified Space Data Link Protocol [USLP]	SLE Return Channel Frames [RCF]
	Return Channel Frames Optical Service	Those for “Return All Frames Optical Service” plus: - TM Space Data Link Protocol [TM-DLP] - AOS Space Data Link Protocol [AOS] - Unified Space Data Link Protocol [USLP]	SLE Return Channel Frames [RCF]
	Return Operational Control Field Service	Those for “Return Channel Frames Service”	SLE Return Operational Control Field [ROCF]
	Return CFDP-File Service	Those for “Return Channel Frames Service” plus: - Space Packet Protocol [SPP] - Encapsulation Service [ENC] - CCSDS File Delivery Protocol [CFDP]	- Return CFDP-File Service [RCFS] over - Cross Support - Terrestrial Generic File Transfer [CFXS]

⁵ With respect to Return IOAGService(s), the applicability of this recommendation is limited to the sections for the recommendations about “Space to Earth RF” and “Telemetry”.



	Return PACKETS-File Service	Those for “Return Channel Frames Service” plus: • Space Packet Protocol [SPP] • Encapsulation Service [ENC]	• Return Packets-File Service [RPFS] over • Cross Support - Terrestrial Generic File Transfer [CFXS]
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IOAG Service Group	IOAG Service Types	Space Link Interface Standards	Ground Link Interface Standards
Radio Metric Services	Validated Data Radio Metric Service	- Radio Frequency and Modulation [RFM] ⁶ - Pseudo-Noise (PN) Ranging Systems [PNR]	- Offline Radio Metric Service [CORS] over - Cross Support - Terrestrial Generic File Transfer [CFXS]
	Raw Data Radio Metric Service	Those for “Validated Data Radio Metric Service” ⁷	Tracking Data Cross Support Transfer Service [CRTRM]
	Delta DOR Service	Radio Frequency and Modulation [RFM] ⁸	- CSTS D-DOR Data Service [DDORS] over - Cross Support - Terrestrial Generic File Transfer [CFXS]

Table 3-1 Catalog #1 Services

⁶ With respect to Radio Metric IOAG Service(s), the applicability of this recommendation is limited to the sections for the recommendations about “Radio Metric”.

⁷ With respect to the “Validated Data Radio Metric Service”, the Delta DOR recommendation of [RFM] is not applicable to “Raw Data Radio Metric Service”.

⁸ With respect to Radio Metric IOAG Service(s), the applicability of this recommendation is limited to the Delta DOR related sections for the recommendations about “Radio Metric”.



4 DESCRIPTION OF CATALOG #1 SERVICE GROUPS AND TYPES

Catalog #1 includes three groups of Services:

- Forward Data Delivery Services Group
- Return Data Delivery Services Group
- Radio Metric Services Group

4.1 *Forward Data Delivery Services Group*

The Forward Data Delivery services allow a Control Center to forward messages to a remote spacecraft as shown in Figure 2-1.

4.1.1 FORWARD CLTU SERVICE TYPE

This Service enables a mission to send Communications Link Transmission Units (CLTUs) to a spacecraft. It relies on the following Space Link Interface Standards and Ground Link Interface Standards.

- Radio Frequency and Modulation [RFM] limited to modules for “Earth-to-Space Radio Frequency (Forward Link)” and “Telecommand (Forward Link)”
- TC Synchronization and Channel Coding [TC-S&C]
- SLE Forward CLTU Service [CLTU]

4.1.2 FORWARD SPACE PACKET SERVICE TYPE

This Service enables a mission to send Space Packets to a spacecraft, possibly with the benefits given by the Communications Operation Procedure-1. It relies on the same Space Link Interface Standards applicable to “Forward CLTU Service” (see 4.1.1) plus the following Space Link Interface Standards and Ground Link Interface Standards.

- TC Space Data Link Protocol [TC-DLP]
- Unified Space Data Link Protocol [USLP]
- Communications Operation Procedure-1 [TC-COP]
- SLE Forward Space Packet Service [FSP]

4.1.3 FORWARD SYNCHRONOUS ENCODED FRAME SERVICE TYPE

This Service has been removed from IOAG Service Catalog 1. Eventually two Forward Frame Services (RF and Optical) have been added.

4.1.4 FORWARD FILE SERVICE TYPES

These Services enable a mission to send either a file or Space/Encapsulation Packets to a spacecraft through the file uplink by an authorized Ground Tracking Asset. Within Catalog #1, usage of this

service is limited to a spacecraft directly reachable from a Ground Tracking Asset (i.e. single hop space link) as per Figure 2-1.

For these file services, it is expected that CCSDS may develop use cases for different mission profiles and possibly derive different solutions so as to minimize the number of options for a said profile (e.g. Deep Space vs. Exploration vs. LEO).

Remark - While Forward/Return CFDP-File services do not need to define the structure of the file transferred from the Control Centre to the Ground Tracking Asset, the Forward/Return Packets-File services require that the internal structure of the file is defined.

4.1.4.1 Forward CFDP-File Service Type

This Service enables a mission to send a file to a spacecraft. It relies on the same Space Link Interface Standards applicable to “Forward CLTU Service” (see 4.1.1) plus the following Space Link Interface Standards and Ground Link Interface Standards.

- Space Packet Protocol [SPP]
- Encapsulation Service [ENC]
- CCSDS File Delivery Protocol [CFDP]
- Forward CFDP-File Service [FCFS] over
- Cross Support - Terrestrial Generic File Transfer [CFXS]

Remark - The two File Services listed above are “to be written”. It is assumed that a generic file transfer service allowing to transfer files between two units, i.e. [CFXS], will be available.

It shall also be noted that, in case CFDP Class 2 (i.e. Reliable Transfer) or CFDP Class 1 (Unreliable Transfer) with closure⁹ is required, the Ground Tracking Asset shall be able to receive in the downlink the relevant CFDP messages (e.g. NAKs, EOF) and process them uplinking the related CFDP PDUs (e.g. retransmissions). Usage of COP-1 may also be required for Telecommand and, in such a case, the Ground Tracking Asset shall be able to receive in the downlink the CLCW messages and process them e.g. retransmitting TCs.

Considering that capabilities for reliable transfer, unreliable transfer with closure and COP-1 usage can be very demanding, it is expected that support of reliable transfer and COP-1 usage will be optional in the CCSDS Standard(s) TBW (i.e. the expected minimum required capability should be unreliable transfer over simplex path without COP-1 usage).

In addition to the generic service, there is however the need to provide the Ground Tracking Asset with ancillary information about the processing to be performed as well as providing the Control Center with Ground Tracking Asset report. The ancillary information is expected to include e.g.

- configuration parameters for CFDP, and whether

⁹ CFDP Class 1 provides for the unreliable delivery of bounded or unbounded data files from the source to the destination over simplex or duplex paths. Class-1 procedures may be exercised over simplex transmission paths unless transaction closure is requested, in which case duplex transmission paths are required.

- the CFDP PDUS shall be embedded either in Space Packets or Encapsulation Packets ¹⁰, and how
- they will be forwarded to the spacecraft within TC Frames (e.g. VCs, MAPs, COP-1 usage, Priorities, etc.).

The ancillary information and the reporting will be provided as part of Service Agreement, and/or via Service Management services, and/or via a more “specialized” file service (i.e. [FCFS]) and/or via metadata transferred with [CFXS]. As long as details on the [CFXS] and [FCFS] are not fully defined by CCSDS, both standards are mentioned in this document.

4.1.4.2 Forward PACKETS-File Service Type

This Service enables a mission to send Space/Encapsulation Packets to a spacecraft. It relies on the same Space Link Interface Standards applicable to “Forward CLTU Service” (see 4.1.1) plus the following Space Link Interface Standards and Ground Link Interface Standards.

- Space Packet Protocol [SPP]
- Encapsulation Service [ENC]
- Forward Packets-File Service [FPFS] over
- Cross Support – Terrestrial Generic File Transfer [CFXS]

It shall also be noted that COP-1 usage may also be required and, in such a case, the Ground Tracking Asset shall be able to receive in the downlink the CLCW messages and process them e.g. retransmitting TCs.

Considering that capabilities for COP-1 usage can be very demanding, it is expected that support of COP-1 usage will be optional in the CCSDS Standard(s) TBW (i.e. minimum required capability no COP-1 usage).

Remark - The two File Services listed above are “to be written”. It is assumed that a generic file transfer service allowing to transfer files between two units, i.e. [CFXS], will be available.

In addition to the generic service, there is however the need to provide the Ground Tracking Asset with ancillary information about the processing to be performed as well as providing the Control Center with Ground Tracking Asset report. This ancillary information is expected to include e.g.

- how the Space/Encapsulation Packets will be forwarded to the spacecraft within TC Frames (e.g. VCs, MAPs, COP-1 usage, Priorities, etc.).

The ancillary information and the reporting will be provided as part of Service Agreement, and/or via Service Management services, and/or via a more “specialized” file service (i.e. [FPFS]) and/or via metadata transferred with [CFXS]. As long as details on the [CFXS] and [FPFS] are not fully defined by CCSDS, both standards are mentioned in this document.

¹⁰ For Catalog #1, CFDP runs single hop in ABA scenario, therefore the ground tracking asset shall support the packet service used in the spacecraft and this can be either [SPP] or [ENC].

4.1.5 FORWARD FRAME SERVICE TYPE

This Service enables a mission to send fixed length AOS or USLP Transfer Frames to a spacecraft. It relies on the following Space Link Interface Standards and Ground Link Interface Standards.

- Radio Frequency and Modulation [RFM] limited to modules for “Earth-to-Space Radio Frequency (Forward Link)” and “Telecommand (Forward Link)”
- TM Synchronization and Channel Coding [TM-S&C]
- AOS Space Data Link Protocol [AOS]
- Unified Space Data Link Protocol [USLP]
- CSTS Forward Frame Service [FF]

4.1.6 FORWARD FRAME OPTICAL SERVICE TYPE

This Service enables a mission to send fixed length AOS or USLP Transfer Frames to a spacecraft over an Optical link. It relies on the following Space Link Interface Standards and Ground Link Interface Standards.

- Optical Coding and Modulation [OPT] limited to the parts for Earth-to-Space (Forward) Link
- AOS Space Data Link Protocol [AOS]
- Unified Space Data Link Protocol [USLP]
- CSTS Forward Frame Service [FF]

4.2 *Return Data Delivery Services Group*

The Return Data Delivery services allow a Control Center to receive messages that a remote spacecraft sent to a supporting Ground Tracking Asset as shown in Figure 2-1.

4.2.1 RETURN ALL FRAMES SERVICE TYPE

This Service enables a mission to send Telemetry Frames received over an RF link (formatted according to Packet Telemetry or AOS standards or privately formatted) to a Control Center. It relies on the following Space Link Interface Standards and Ground Link Interface Standards.

- Radio Frequency and Modulation [RFM] limited to modules for “Space-to-Earth Radio Frequency (Return Link)” and “Telemetry (Return Link)”
- TM Synchronization and Channel Coding [TM-S&C]
- SLE Return All Frames [RAF]

NOTE: IOAG Agencies are expected to consider also the IOAG Report on Preferred Coding and Modulation Schemes [PC&M].



4.2.1.1 Return All Frames Optical Service Type

This Service enables a mission to send Telemetry Frames received over an Optical link (formatted according to Packet Telemetry or AOS standards or privately formatted) to a Control Center. It relies on the following Space Link Interface Standards and Ground Link Interface Standards.

- Optical Coding and Modulation [OPT] limited to the parts for Space-to-Earth (Return) Link
- SLE Return All Frames [RAF]

4.2.2 RETURN CHANNEL FRAMES SERVICE TYPE

This Service enables a mission to send Telemetry Frames received over an RF link (formatted either according to Packet Telemetry or AOS standards) to a Control Center. It relies on the same Space Link Interface Standards applicable to “Return All Frames Service” (see 4.2.1) plus the following Space Link Interface Standards and Ground Link Interface Standards.

- TM Space Data Link Protocol [TM-DLP]
- AOS Space Data Link Protocol [AOS]
- Unified Space Data Link Protocol [USLP]
- SLE Return Channel Frames [RCF]

4.2.2.1 Return Channel Frames Optical Service Type

This Service enables a mission to send Telemetry Frames received over an Optical link (formatted either according to Packet Telemetry or AOS standards) to a Control Center. It relies on the same Space Link Interface Standards applicable to “Return All Frames Optical Service” (see 4.2.1.1) plus the following Space Link Interface Standards and Ground Link Interface Standards.

- TM Space Data Link Protocol [TM-DLP]
- AOS Space Data Link Protocol [AOS]
- Unified Space Data Link Protocol [USLP]
- SLE Return Channel Frames [RCF]

4.2.3 RETURN OPERATIONAL CONTROL FIELD SERVICE TYPE

This Service enables a mission to send Operational Control Fields (extracted from frames formatted either according to Packet Telemetry or AOS standards) to a Control Center. It relies on the same Space Link Interface Standards applicable to “Return Channel Frames Service” (see 4.2.2) plus the following Space Link Interface Standards and Ground Link Interface Standards.

- SLE Return Operational Control Field [ROCF]

4.2.4 RETURN UNFRAMED TELEMETRY SERVICE TYPE

This Service has been removed from IOAG Service Catalog 1.

4.2.5 RETURN FILE SERVICE TYPES

These Services enable an authorized Ground Tracking Asset to send either a file or Space/Encapsulation Packets received from a spacecraft to a Control Center. Within Catalog #1, usage of this service is limited to a spacecraft directly reachable from a Ground Tracking Asset (i.e. single hop space link) as per Figure 2-1.

For these file services, it is expected that CCSDS may develop use cases for different mission profiles and possibly derive different solutions so as to minimize the number of options for a said profile (e.g. Deep Space vs. Exploration vs. LEO).

Remark - While Forward/Return CFDP-File services do not need to define the structure of the file transferred from the Control Centre to the Ground Tracking Asset, the Forward/Return Packets-File services require that the internal structure of the file is defined.

4.2.5.1 Return CFDP-File Service Type

This Service enables a mission to receive a file sent from a spacecraft to a Ground Tracking Asset. It relies on the same Space Link Interface Standards applicable to “Return Channel Frames Service” (See 4.2.2) plus the following Space Link Interface Standards and Ground Link Interface Standards.

- Space Packet Protocol [SPP]
- Encapsulation Service [ENC]
- CCSDS File Delivery Protocol [CFDP]
- Return CFDP-File Service [RCFS] over
- Cross Support - Terrestrial Generic File Transfer [CFXS]

Remark - The two File Services listed above are “to be written”. It is assumed that a generic file transfer service allowing to transfer files between two units, i.e. [CFXS], will be available.

It shall also be noted that, in case CFDP Class 2 (i.e. Reliable Transfer) or CFDP Class 1 (Unreliable Transfer) with closure¹¹ is required, the Ground Tracking Asset shall be able to generate the related CFDP messages (e.g. NAKs, EOF) and uplink the relevant CFDP PDUs with or without COP-1 usage.

Considering that capabilities for reliable transfer, unreliable transfer with closure, and COP-1 usage can be very demanding, it is expected that support of reliable transfer and unreliable transfer with closure will be optional in the CCSDS Standard(s) TBW (i.e. the expected minimum required capability should be unreliable transfer over simplex path, as they do not imply COP-1 usage).

¹¹ CFDP Class 1 provides for the unreliable delivery of bounded or unbounded data files from the source to the destination over simplex or duplex paths. Class-1 procedures may be exercised over simplex transmission paths unless transaction closure is requested, in which case duplex transmission paths are required.

In addition to the generic service, there is however the need of providing (in advance) the Ground Tracking Asset with ancillary information about the processing to be performed as well as providing the Control Center with Ground Tracking Asset report. The ancillary information is expected to include e.g.

- configuration parameters for CFDP, and whether
- the CFDP PDUS are expected either in Space Packets or Encapsulation Packets ¹², and how
- they were sent by the spacecraft within TM/AOS Frames.

The ancillary information and the reporting will be provided as part of Service Agreement, and/or via Service Management services, and/or via a more “specialized” file service (i.e. [RCFS]) and/or via metadata transferred with [CFXS]. As long as details on the [CFXS] and [RCFS] are not fully defined by CCSDS, both standards are mentioned in this document.

4.2.5.2 Return PACKETS-File Service Type

This Service enables a mission to receive (in a file) Space/Encapsulation Packets sent from a spacecraft to a Ground Tracking Asset. It relies on the same Space Link Interface Standards applicable to “Return Channel Frames Service” (See 4.2.2) plus the following Space Link Interface Standards and Ground Link Interface Standards.

- Space Packet Protocol [SPP]
- Encapsulation Service [ENC]
- Return Packets-File Service [RPFS] over
- Cross Support – Terrestrial Generic File Transfer [CFXS]

Remark - The two File Services listed above are “to be written”. It is assumed that a generic file transfer service allowing to transfer files between two units, i.e. [CFXS], will be available.

In addition to the generic service, there is however the need of providing (in advance) the Ground Tracking Asset with ancillary information about the processing to be performed as well as providing the Control Center with Ground Tracking Asset report. This ancillary information is expected to include e.g.

- whether the file contains Space Packets or Encapsulation Packets, and how
- the Packets were sent by the spacecraft within TM/AOS Frames.

The ancillary information and the reporting will be provided as part of Service Agreement, and/or via Service Management services, and/or via a more “specialized” file service (i.e. [RPFS]) and/or via metadata transferred with [CFXS]. As long as details on the [CFXS] and [RPFS] are not fully defined by CCSDS, both standards are mentioned in this document.

¹² For Catalog #1, CFDP runs single hop in ABA scenario, therefore the ground tracking asset shall support the packet service used in the spacecraft and this can be either [SPP] or [ENC].



4.3 *Radio Metric Services Group*

The Radio Metric services allow a Control Center to receive data involved in orbit computation for a remote spacecraft.

4.3.1 VALIDATED DATA RADIO METRIC SERVICE TYPE

This Service enables a Control Center to receive the data involved in orbit computation as received and validated by a Ground Tracking Asset. Validated data include range, Doppler, and Pseudo-Noise ranging results as well as correlated Delta-DOR data. Such data are provided to a Control Center within files assembled by the Ground Tracking Asset. This Service relies on the following Space Link Interface Standards and Ground Link Interface Standards.

- Radio Frequency and Modulation [RFM] limited to module for “Radio Metric”
- Pseudo-Noise (PN) Ranging Systems [PNR]
- Offline Radio Metric Service [CORS] over
- Cross Support - Terrestrial Generic File Transfer [CFXS]

Remark - The [DDORO] Recommended Practice addresses Delta-DOR aspects as e.g., configuration requirements for interagency Delta-DOR measurement; interagency exchange of measurement data; parameters that are necessary in order to correlate and process the data at one of the agencies; interagency transfer of the generated observables; and the end-to-end flow of control.

Remark - The two standards [CORS] and [CFXS] are “to be written”. It is assumed that a generic file transfer service allowing to transfer files between two units, i.e. [CFXS], will be available and - on top of or within this generic service – “specialized” file services or metadata will allow requesting the dedicated processing for the file being transferred. Therefore, it is expected that either the Offline Radio Metric Service or metadata provided with [CFXS] will allow the Ground Tracking Asset to inform the Control Center about file contents (i.e. Tracking Data Messages (TDM) according to the [TDM] or [XNM] standards specifying a format for use in exchanging spacecraft tracking data).

4.3.2 RAW DATA RADIO METRIC SERVICE TYPE

This Service enables a Control Center to receive the data involved in orbit computation as soon as they are received/built by a Ground Tracking Asset. Such data are provided to a Control Center via streaming interface sending CSTS messages embedding the TDM formatted data received by the Ground Tracking Asset. It relies on the same Space Link Interface Standards applicable to “Validated Data Radio Metric Service” (See 4.3.1) – with the exception of the Delta DOR recommendation of [RFM] - plus the following Space Link Interface Standards and Ground Link Interface Standards.

- Tracking Data Cross Support Transfer Service [CRTRM]

4.3.3 DELTADOR SERVICE TYPE

This Service enables a Control Center to receive Delta-DOR raw data¹³ or Open Loop Recording data¹⁴ acquired by a Ground Tracking Asset. Such data are provided to a Control Center within files assembled by the Ground Tracking Asset. It relies on the following Space Link Interface Standards and Ground Link Interface Standards.

- Radio Frequency and Modulation [RFM] limited to Delta DOR related sections in the module for “Radio Metric”
- CSTS D-DOR Data Service [DDORS] over
- Cross Support - Terrestrial Generic File Transfer [CFXS]

Remark - The [DDORO] Recommended Practice addresses Delta-DOR aspects such as:

- configuration requirements for interagency Delta-DOR measurement;
- interagency exchange of measurement data;
- parameters that are necessary in order to correlate and process the data at one of the agencies;
- interagency transfer of the generated observables;
- and the end-to-end flow of control.

Remark - The CSTS D-DOR Data Service [DDORS] is “to be written”. It is assumed that a generic file transfer service allowing to transfer files between two units, i.e. [CFXS], will be available and - on top of or within this generic service – “specialized” file services/metadata will allow requesting the dedicated processing for the file being transferred. In this case, it is assumed that the CSTS D-DOR Data Service [DDORS] will implement delivery of D-DOR “raw data” or Open Loop Recording data stored according to [DDRXF].

¹³ Note that this service only provides Delta-DOR raw data while Delta-DOR correlated data are provided via the “Validated Data Radio Metric Service”.

¹⁴ In fact, the data format defined in [DDRXF] can also be used to store Open Loop Recording data.

5 SERVICE MANAGEMENT FUNCTIONS

Services provided by an IOAG member agency are requested and controlled via a standard service management function. Service management by itself is not a service. It is a function performed cooperatively by both the tracking network (on the service provider's side) and the mission operations center (on the service user's side). It includes:

- Allocation and scheduling of space communication resources and assets during the service commitment and planning phases.
- Configuring, monitoring, and controlling the communication assets during the service provision phase (i.e., before, during, and after a communication contact).
- Reporting of service execution results.

The service management interfaces employed by some of the above tasks will be in compliance with any of the standards in the set of the CCSDS Cross Support Service Management Specifications; i.e. [SM], [SM-ACC], [SM-ACP], [SM-AUT], [SM-CAT], [SM-ESF], [SM-PDF], [SM-SPF], [SM-SPF], [SM-SSF], [SM-URF].

In addition, an engineering data delivery service is planned in IOAG Service Catalog # 1, to deliver in near real time to the users, the status of the space link or of the related processing equipment.

For configuring of the tracking asset in terms of antenna pointing the [ODM] or [XNM] standards will be applied.

5.1 *Service Management Functions Group*

The Service Management functions allow a Control Center to agree, to plan and to execute the services required from a Ground Tracking Asset provider, as shown in Figure 2-2.

	IOAG Service Function	Space Link Interface Standards	Ground Link Interface Standards
Service Management Functions	Assessment of service suitability	• N/A	• Service Catalog [SM-CAT]
	Service Agreement Development	• N/A	• Service Agreement and Configuration Profile Data Formats [SM-ACP]
	Request the information required to provide a cross support	• N/A	• Utilization Request Format [SM-URF]

	Planning Information	N/A	Planning Data Formats [SM-PDF]
	Event Sequences	N/A	Space Link Event Sequence Data Format [SM-ESF]
	Service Package	N/A	Service Package Data Formats [SM-SPF]
	Schedule and unallocated times	N/A	Simple Schedule Format Specification [SM-SSF]
	Service accounting	N/A	Service Accounting [SM-ACC]
	Management Service (Automation)	N/A	Management Services (Automation) [SM-AUT]

Table 5-1 Catalog #1 Service Management Functions

5.1.1 ASSESSMENT OF SERVICE SUITABILITY

This service function enables a User of services to evaluate the suitability of a Provider of Cross Support Services, to provide the required supports, based on the study of its Service Catalog. The Service Catalog is used before the Service Agreement Development phase. Therefore it is expected that the [SM-CAT] (Service Catalog) will define the data format for defining the agency services.

5.1.2 SERVICE AGREEMENT DEVELOPMENT

This service function enables a User of services to establish an agreement with a Provider of Cross Support Services Data for a specific phase of a mission. Such agreement may contain the configuration profiles for expressing the configuration of cross supported services. Configuration profiles may also be used in the Planning Activity of the Service Agreement Period. Therefore it is expected that the [SM-ACP] (Service Agreement and Service Configuration Profile Data Format) will define the data format for expressing the configuration of cross supported Telemetry, Tracking, and Commanding services.

5.1.3 REQUEST THE INFORMATION REQUIRED TO PROVIDE A CROSS SUPPORT

This service function enables a User of services and a Provider of Cross Support Services Data to exchange the information required in the frame of a Service Agreement. Such exchanges may concern requests for Planning, Service Packages, Reports (e.g.: accountability or schedule) or

Submission (e.g.: Trajectory prediction). Therefore it is expected that the [SM-URF] (Utilization Request Format) will define the data format to indicate requests for planning data, schedules, submission of trajectory data, submission of service configuration profiles, etc.

5.1.4 PLANNING INFORMATION

This service function enables a User of services to give a Provider of Cross Support Services information that will constrain the planning activities of the support. Such information may include the provisional plans, the constraints on the communication geometry, the boundaries on data rates and volumes, the Radio Frequency Interferences, the resource conflicts and possibly, the cost estimates. Therefore it is expected that the [SM-PDF] (Planning Data Format) will define such data format to indicate communication geometry for a particular mission given a trajectory or return data volume estimates.

5.1.5 EVENT SEQUENCES

This service function enables a User of services to give a Provider of Cross Support Services information on a time ordered sequence of Space Link Events. Such information may include events such as start/stop of return or a forward carrier, start/stop times of data transport availability, configuration changes with the space link or the transport. Therefore it is expected that the [SM-ESF] (Space Link Event Sequence Data Format) will define such data format for expressing, for instance, events in a long-signal delay propagation environment to properly coordinate Telemetry, Tracking, and Commanding services.

5.1.6 SERVICE PACKAGE

This service function enables a User of services to describe the services that are scheduled. Such information may include real time Space Link services, retrieval services or offline services. Therefore it is expected that the [SM-SPF] (Service Package Data Format) will define such data format for expressing a committed package of services.

5.1.7 SCHEDULE AND UNALLOCATED TIMES

This service function enables a Provider of Cross Support Services to describe the resources that are scheduled in support of a mission and the unallocated times that remain free for utilization. Such information includes the start / stop times of the activities in the Service Packages. Therefore it is expected that the [SM-SSF] (Simple Schedule Format Specification) will define such data format to indicate schedule of services for missions relative to an agencies tracking assets and also to indicate unallocated times

5.1.8 SERVICE ACCOUNTING

This service function enables a Provider of Cross Support Services to report on the volumes and the quality of the services provided to a User of such services. The Service Accounting is used after the provision of the services phase. Therefore it is expected that the [SM-ACC] (Service Accounting) will define the data format for providing accounting of services rendered.



5.1.9 MANAGEMENT SERVICES (AUTOMATION)

This service function enables the transmission of automated management functions between a Provider of Cross Support Services and a User of such. Therefore it is expected that the [SM-AUT] (Management Services Automation) will define the data format for providing full management service (i.e., automation).

5.2 *Engineering Monitoring Data Delivery*

IOAG Service Catalog #1 foresees one Link Monitoring function (see Table 5-2) to allow a Control Center to receive data monitoring the status of the space link between a Ground Tracking Asset and a remote spacecraft. Such monitoring data are not limited to the status of the space link and they may also include information about space link related status and/or processing of the equipment at the Ground Tracking Asset.

IOAG Service Catalog #1 also foresees a control function (see Table 5-2) that provides a Control Center with the capabilities to request control directives at a ground station and/or to perform configuration changes in near-real time in response to unplanned events involving the spacecraft.

The Engineering Monitoring Data Delivery relies on the following Ground Link Interface Standards.

- Monitored Data - Cross Support Transfer Service [EDM]
- Service Control - Cross Support Transfer Service [SCC]

	IOAG Service Function	Space Link Interface Standards	Ground Link Interface Standards
Service Management Functions	Engineering Monitoring Data Delivery	• N/A	• Monitored Data - Cross Support Transfer Service [EDM]
	Service Control	• N/A	• Service Control - Cross Support Transfer Service [SCC]

Table 5-2 Catalog #1 Service Execution Functions