# THE CCSDS RETURN ALL FRAMES SPACE LINK EXTENSION SERVICE

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## ABSTRACT

Existing Consultative Committee for Space Data Systems (CCSDS) Recommendations for Telemetry Channel Coding, Packet Telemetry, Advanced Orbiting Systems, and Telecommand have facilitated cross-support between Agencies by standardizing the link between spacecraft and ground terminal. CCSDS is currently defining a set of Space Link Extension (SLE) services that will enable remote science and mission operations facilities to access the ground termination of the Space Link services in a standard manner. The first SLE service to be defined is the Return All Frames (RAF) service. The RAF service delivers all CCSDS link-layer frames received on a single space link physical channel. The service provides both on-line and off-line data transfer modes to accommodate the variety of access methods typical of space mission operations. This paper describes the RAF service as of the Summer of 1994. It characterizes the behavior of the service as seen across the interface between the user and the service and gives an overview of the interactions involved in setting up and operating the service in a cross-support environment.

## INTRODUCTION

Widespread acceptance of existing CCSDS Recommendations on Telemetry Channel Coding (CCSDS, 1992a), Packet Telemetry (CCSDS, 1992c), Advanced Orbiting Systems (CCSDS, 1992d), and Telecommand (CCSDS, 1987a; CCSDS, 1992b; CCSDS, 1991; CCSDS, 1987b) has facilitated cross-support between Agencies by standardizing the link between a spacecraft and a ground terminal. However, significant impediments to cross-support remain because the scope of those Recommendations does not include the link between the ground terminal and other elements of the ground data system. CCSDS is addressing that lack through the definition of a set of Space Link Extension (SLE) services that will enable remote science and mission operations facilities to access the ground termination of the Space Link services in a standard way.

The most basic SLE service in the return (space-to-ground) direction is the Return All Frames (RAF) service. Provision of the RAF service involves the acquisition, demodulation, frame synchronization, and error detection/correction of all CCSDS link-layer frames of a physical channel, and the delivery of those frames across terrestrial networks to the users of the service. *Frame* is the term used in this paper as a common name for the various CCSDS data link protocol data units.[1] The users of the RAF service split the all-frames data stream into

[1]The Version 1 return link frame is formally known as the Packet Telemetry Transfer Frame, and the Version 2 frame is formally known as the (Coded) Virtual Channel Data Unit.

subsets based on master channels and virtual channels, and extract various data products from those channels, as defined in (CCSDS, 1992c; CCSDS, 1992d) and forthcoming Recommendations for other return SLE services.

The RAF service provides both *on-line* and *off-line* data transfer modes to accommodate the variety of access methods typical of space mission operations. An online service is one that delivers its service data to the user at (nearly) the same time that the data are received from the space link. An offline service is one in which the service data are delivered at some time after that at which the data crossed the space link.

CCSDS is in the process of defining the RAF service in detail. The RAF service is the first of the SLE services for which a draft Recommendation is being developed. CCSDS expects to submit the resulting Recommendation for review and approval by its member space agencies in 1995. Recommendations for the other SLE services will follow.

This paper describes the CCSDS Return All Frames SLE service as it is defined as of the Summer of 1994. First, the RAF service environment is presented. The environment identifies the various participants in the provision of the RAF service. Next, the behavior of the RAF service is described, in terms of the interactions between the user and provider of the service. Finally, the paper briefly introduces the formal techniques being used to describe the RAF and other SLE services.

## RAF SERVICE ENVIRONMENT

As defined in the SLE cross-support concept Green Book (CCSDS, 1994a) and presented in the companion SpaceOps '94 paper (Stallings et al., 1994), all SLE services are defined within the context of a *space mission* and an *SLE Component* that supports that mission. Figure 1 illustrates the Return All Frames service environment, which is a specific case of the general SLE service environment. In the terminology of the SLE reference model (CCSDS, 1994b), the various entities illustrated in Figure 1 are different types of *SLE objects*. The RAF Service User, the Mission Spacecraft, and the mission's Space Link Extension Utilization Management (SLE-UM - that part of mission management responsible for managing the acquisition and use of SLE services on behalf of the mission) are objects of the space mission. The SLE Component comprises those functions and systems that provide standard SLE services to the mission.

In the general case, the SLE Component may consist of multiple *SLE complexes*, where an SLE complex is a collection of SLE service capabilities operating in an integrated management domain (as seen by the SLE-UM). However, the RAF service, being the most basic SLE service, will be provided by a single SLE complex, referred to in this paper as the RAF Service Provider. Although the SLE service concept permits an SLE complex to be geographically-distributed, it is most convenient to think of the RAF Service Provider as being completely located at a ground station.

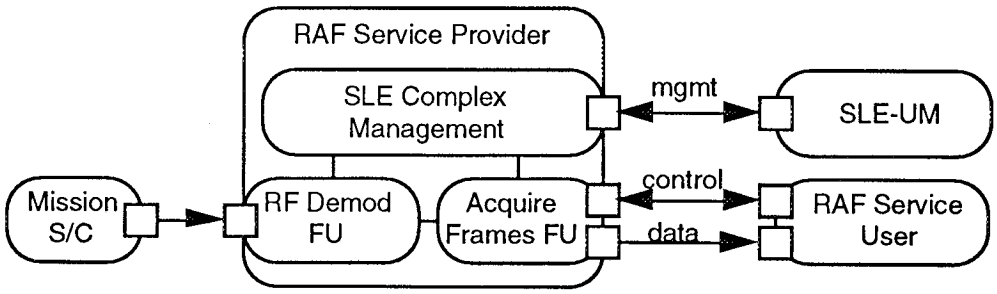


Figure 1. RAF Service Environment

The RAF Service Provider has an RF interface with the mission spacecraft, service control and data interfaces with the service user, and a management interface with the SLE-UM. The functions of the RAF Service Provider are formally modeled as two *functional unit* (FU) objects: the RF Demodulation (RFD) FU and the Acquire Frames FU. The RFD FU comprises the functions of acquiring the return RF signal from the mission spacecraft, and demodulating the signal to recover a stream of digital symbols. The Acquire Frames FU processes the symbol stream to synchronize upon and capture CCSDS frames, performs error detection and correction, and transfers the frames to the RAF Service User(s).[2] Frame synchronization and error detection and correction are performed in accordance with provisions of the Telemetry Channel Coding Blue Book (CCSDS, 1992a). The *SLE complex management* function of the RAF Service Provider coordinates the operation of the RFD FU and the Acquire Frames FU.

## BEHAVIOR OF THE RAF SERVICE

The CCSDS RAF service delivers all frames from a single space link channel, including fill frames (which by definition have no data content and exist only to maintain synchronization on the link). A *space link channel* is a physical channel carrying a synchronous stream of frames, separated by *attached sync markers.*

The wide variety of mission needs and Agency capabilities requires flexibility in the delivery of the RAF service. This flexibility manifests itself through different requirements/capabilities in the areas of:

- Received data quality: what constitutes data that are usable by/acceptable to the user of the service
- Data delivery: the combination of reliability, timeliness, and completeness that best fits the user's needs
- Service session initiation: whether the service session (i.e., the connection between the service user and service provider for the purpose of transferring service data) is initiated by the provider or the user
- Service status information: how much information about the progress of the service is needed/wanted by the user, and the mechanism for delivering that information

The following sections describes the options available in these areas.

### Received Data Quality Options

This area contains the options for service delivery that are affected by the quality of the frames acquired by the RAF Service Provider. These options are offered to meet the varying needs of the user community, and to match their ability to deal with errored data. Because this is the all *frames* service, each of these options deals with entities that have been frame synchronized and thus identified as frames.[3] The RAF service supports two options for received data quality: Correct Frames Only, and Correct and Errored Frames.

[2]Although only one RAF Service User is illustrated in Figure 1, there may be multiple users of RAF service receiving the same stream of data.

[3]In particular, the RAF Service Recommendation does not provide for the delivery of data symbols or bits which cannot be frame synchronized. It is recognized that, in certain rare cases, anomalies in flight or ground systems may lead to conditions under which the RAF service can not deliver any data at all because the acquired data stream does not contain properly-formed frames. Implementors of the RAF service are well-advised to provide an 'escape mechanism' for the capture and possible delivery of such anomalous data to support troubleshooting and/or extraordinary data recovery methods. However, the handling of such anomalous situations is outside the scope of the RAF Service Recommendation.

The Correct Frames Only option causes only frames that have no detected errors to be delivered. This option is available only when it is known beforehand (either due to long-term service agreements or by schedule) that the frames on the channel are either all Reed-Solomon (R-S) -encoded or all cyclic redundancy code (CRC) -protected frames. R-S-encoded frames that successfully R-S decode are transferred, without the R-S check symbols, to the user. R-S-encoded frames that do not R-S decode are discarded. CRC-protected frames that show no CRC errors are transferred to the user as complete frames. CRC-protected frames that register CRC errors are discarded.

The Correct and Errored Frames option causes all frames to be delivered, regardless of received quality. This option exists for:

- Space link channels whose frames carry data which contains sufficient "internal coding" that the user is able to reconstruct (through mission-unique methods) the data content, or
- Space link channels that carry a mix of R-S- and CRC-encoded frames.

The Correct and Errored Frames option might also be useful in helping missions to identify flight system and ground system problems.

For space link channels that are known beforehand to carry only R-S encoded frames, frames that successfully R-S decode are transferred (without the R-S check symbols) to the user with the indication **R-S-good**, and frames that do not successfully R-S decode are transferred as complete, pre-decoded frames with the indication **R-S-bad**.

For space link channels that are known beforehand to carry only CRC encoded frames, frames that have no CRC errors are transferred to the user with the indication **CRC-good**, and frames that have CRC errors are transferred with the indication **CRC-bad**.

For space link channels that may be carrying mixed R-S and CRC encoded frames, frames that are successfully R-S decoded are transferred (without the R-S check symbols) to the user with the indication **R-S-good**. Frames that are not successfully R-S decoded are checked for CRC errors, using the as-received (pre-R-S-decoded) complete frames. Frames that have no CRC errors are transferred to the user with the indication **CRC-good**, and frames that have CRC errors are transferred with the indication **CRC-bad**.

CCSDS recommendations for processing RAF service into higher-strata services (such as SLE packet services) are predicated on the use of the Correct Frames Only option. Since processing of errored frames requires mission-unique methods, the ability to process such frames is by definition not a part of the standard SLE service suite.

**Data Delivery Options**

The data delivery options reflect different levels of reliability, completeness, and timeliness. When complete, the RAF service specification will define online and offline data delivery options. As of this writing, only two online options, Complete delivery and Timely delivery, have been defined.[4]

An RAF service instance with the Complete delivery option delivers the frames in the sequence received, with no ground-induced errors, with no frames omitted, and with possible large delays. The RAF Service Provider buffers the data to compensate for data rate mismatch and/or retransmissions. The user can specify a maximum delay, $T_{max}$. If $T_{max}$ is exceeded, the service informs the user that $T_{max}$ has been

[4]CCSDS has developed recommendations for the use of isochronous virtual channels (CCSDS, 1992d). As of this writing, CCSDS is determining if these recommendations result in a requirement for an isochronous delivery option for the RAF service. If so, it will be added to the online delivery options.

exceeded. When the delay drops below $T_{max}$, the service informs the user that the delay has been recovered.

An RAF service instance with the Timely delivery option delivers the frames in the sequence received, with no ground-induced errors, possibly with frames omitted, and with an upper bound on maximum delay, $T_{max}$. Due to the nature of the RAF service, the data rate of delivery of the RAF service is normally a steady-state rate equal to the rate of the underlying space link channel plus some SLE overhead increment. As long as the rate of the RAF service can be kept at or below this steady-state rate, frames will be forwarded without buffering in the RAF Service Provider. However, if frames begin to be buffered in the RAF Service Provider (for example, because of excessive retransmissions to the service user), their delivery latency will grow. If this latency exceeds the maximum delay parameter $T_{max}$, the RAF service drops an appropriate number of frames to drop below $T_{max}$ delay and informs the user that frames have been dropped.

**Service Session Initiation Options**

Service session initiation options describe the different options by which user and provider connect to support the provision of RAF service. When complete, the RAF service specification will define options for initiating online and offline service sessions. As of this writing, only the online options have been defined, which are Online Provider-Initiated and Online User-Initiated.

The Online Provider-Initiated option allows the RAF Service Provider to set up the connection to the user, based on the schedule for the activation of the space link. The preconditions for providing an instance of RAF service using this option are: (1) that the RAF Service Provider has in its configuration data base the identification, addressing information, startup data quality options, and startup data delivery options for the user(s) of the RAF service, (2) that the RAF Service Provider has been scheduled to receive the space link channel associated with the RAF service instance, and (3) that the RAF Service Provider has been scheduled to provide an RAF provider-initiated service instance to the particular user(s).

As controlled by the scheduled start time of the service instance, the RAF Service Provider connects to the service user(s) and verifies the user's ability to receive the service. Once the service session has been initiated, either user or provider can terminate the session, but the nominal responsibility for closing the session lies with the service provider, which it does after the space link channel has been deactivated and all received data has been delivered to the user.

The Online User-Initiated option allows the RAF Service User to set up the connection to the RAF Service Provider within a time window previously scheduled with respect to the scheduled activation of the space link. The preconditions for providing an instance of RAF service using this option are (1) that the RAF Service Provider has in its configuration database the identity of users permitted to receive the RAF service, (2) that the RAF Service Provider has been scheduled to receive the space link channel associated with the RAF service instance, and (3) that the RAF service provider has been scheduled to provide an RAF user-initiated service instance to the user. The user-initiated service instance can be scheduled to begin at any time after some specified time prior to the start of the space link session (the start time of the schedule window is determined on an agency/mission basis). The end time of the scheduled service instance can be scheduled at any time from the scheduled start of the service instance up until some specified time after the scheduled end of the space link session.

To initiate RAF service using the Online User-Initiated option, the service user connects to the Service Provider, in the process identifying and authenticating itself as a legitimate user of the RAF service associated with a particular space link channel. Service session requests associated with a specific space link session are valid

only during the scheduled service instance. If a service user attempts to initiate the service session before the start time of the service instance, the service session initiation attempt will be denied by the RAF Service Provider. A service user may initiate a service session at any time during the scheduled service instance. This includes service sessions that are initiated after the start of the associated space link session. Service sessions may be suspended and resumed during the scheduled service instance. Figure 2 illustrates the relationships among the space link session, scheduled service instance, a possible service session, and the resulting period of data transfer for the Online User-Initiated option. According to the figure, the service session is initiated after the start of the scheduled service instance, but before the actual start of the space link session. In this example, the service instance is scheduled to go some time beyond the end of the space link session to allow for a long buffer drawdown when a Complete delivery option is selected. The actual service session extends beyond the end of the space link session, but terminates before the scheduled end of the service instance. The resulting period of data transfer begins at the start of the space link session and ends at the end of the service session.

Once the user-initiated service session has been initiated, either user or provider can terminate the session, but the nominal responsibility for closing the user-initiated session lies with the service user. However, if the service session extends until the end of the scheduled service instance, the service session is terminated by the RAF Service Provider.

**Service Instance Status Information.** Service instance status information is provided to the SLE-UM and the user of the service during the execution of the service instance. Service instance status information is conveyed to the RAF service user for the purpose of providing information necessary for the proper interpretation and processing of the RAF service data units. Service instance status information is conveyed to the SLE-UM for the purpose of correlating the performance of the RAF service with the performance of the underlying RF link and the performance of multiple higher-strata services that are derived from the data contained in the frames delivered by the RAF service.

When complete, the RAF service Recommendation will define status information associated with both online and offline service instances. As of this writing, only the online service instance status information has been addressed.

Service instance status information falls into three categories:

- Annotation data, which are appended to the frames themselves

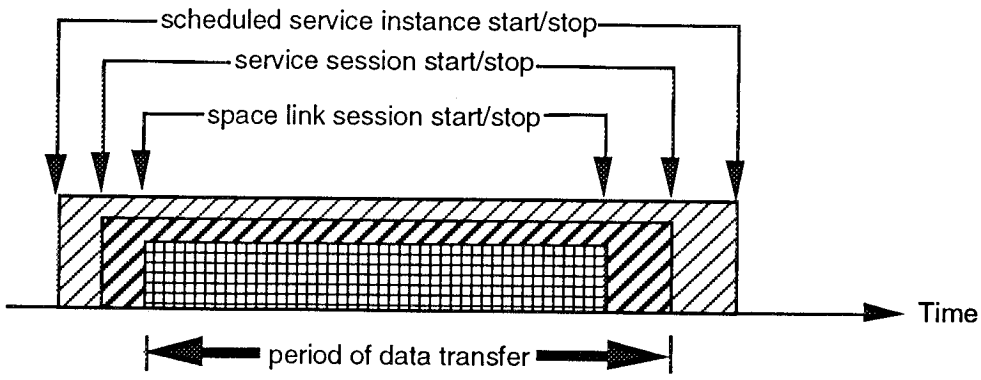


Figure 2 Relationships among Space Link Session, Scheduled Service Instance, Service Session, and Period of Data Transfer for the Online User-Initiated Mode

- Frame-sequence-dependent status data which conveys information about events of interest occurring between specific frames
- Frame-sequence-independent status data which conveys information about trends that transcend individual frames

Annotation and frame-sequence-dependent data are conveyed to the service user so that the user may correctly interpret and process the sequence of frames received. Frame-sequence-independent data are of interest to both the user of the service and to the SLE-UM: to the user, they serve as a means of accounting for the service received; to the SLE-UM, they are a source of information that can be correlated with status information about related services and RF links.

The core annotation data to be appended to every frame consists of:

- The ground receipt time of the frame
- The sequence quality of the frame (i.e., the indication of whether the frame is the direct successor of the previous frame on the space link channel)
- The quality of the frame (e.g., R-S bad, CRC good)

In addition to the above core annotation data, CCSDS is investigating methods to allow service providers to flexibly add annotation data that may be required on a mission or Agency basis.

The frame-sequence-dependent information that has been thus far identified consists of:

- Loss-of-synchronization notifications that inform the user in a timely fashion that frames are missing because of loss of synchronization (and not, for instance, because of failure of ground processing or communications)
- Data delivery threshold notifications:
  - When the Complete data delivery option is in effect, the service informs the user when a user-specified delay threshold has been exceeded, and again (if and) when the delay has been recovered.
  - When the Timely data delivery option is in effect, the service informs the user when a user-specified data latency threshold has been exceeded, and the number of frames that have been discarded in order to ensure the delivery of "fresh" data.

As of this writing, frame-sequence-independent status information is still being defined in the categories of periodic reports, event notifications, post-pass debriefing reports, and journals.

## FORMAL SPECIFICATION OF THE RAF SERVICE

The SLE services, including the RAF service, are formally defined within a framework based on the International Organization for Standardization's (ISO) Abstract Service Definition Conventions (ASDC) (ISO/IEC, 1992). ASDC provides a conceptual model for constructing systems of *abstract-objects* which interact with each other via *abstract-ports*. The interactions are defined in terms of *abstract-operations*, and *abstract-services* are defined in terms of groupings of *abstract-operations* over one or more *abstract-ports*. ASDC provides a rich set of concepts and conventions for defining the various roles that the components of the SLE architecture may play, such as *user/provider*, *initiator/responder*, *invoker/performer*, and *consumer/supplier*. ASDC also provides a formal specification methodology using Abstract Syntax Notation #1 (ASN.1) *macros*, which serve as templates for the definition of the various elements of the model.

CCSDS has adapted the ASDC to the SLE environment, defining special subtypes of abstract-objects such as SLE complexes and functional units. CCSDS has also adapted the ASDC ASN.1 macros to include parameters peculiar to the SLE environment. The SLE reference model (CCSDS, 1994b) documents the SLE adaptation of ASDC.

Among other things, the reference model defines the set of ASN.1 macros that must be populated for each of the SLE service specifications. Thus, the CCSDS RAF Recommendation will contain ASN.1 macro-based specifications that complement the "plain English" definition of the RAF service.

## SUMMARY

CCSDS is currently defining the Return All Frames service, one of a family of Space Link Extension services that will enable remote science and mission operations facilities to access the ground termination of the CCSDS Space Link services in a standard way. The RAF service provides all CCSDS frames received on a single space link channel. Provisions in the current draft of the RAF service specification include different service options to allow users to tailor the service to individual processing capabilities and operational philosophies. Several forms of service status information are provided to report on the status of individual frames, time-critical events, and long-term service trends. Current plans are for the CCSDS Return All Frames Service Specification Recommendation to be submitted for CCSDS member Agency approval in 1995.

## REFERENCES

CCSDS. (1987a, January). *Recommendation for Space Data System Standards. Telecommand, Part 1 - Channel Service: Architectural Specification.* CCSDS 201.0-B-1, CCSDS Secretariat, National Aeronautics and Space Administration, Washington, DC.

____. (1987b, January). *Recommendation for Space Data System Standards. Telecommand, Part 3 - Data Management Service: Architectural Specification.* CCSDS 203.0-B-1. CCSDS Secretariat, National Aeronautics and Space Administration, Washington, DC.

____. (1991, October). *Recommendation for Space Data System Standards. Telecommand, Part 2.1 - Command Operation Procedures.* CCSDS 202.1-B-1. CCSDS Secretariat, National Aeronautics and Space Administration, Washington, DC.

____. (1992a, May). *Recommendation for Space Data System Standards. Telemetry Channel Coding.* CCSDS 101.0-B-3. CCSDS Secretariat, National Aeronautics and Space Administration, Washington, DC.

____. (1992b, November). *Recommendation for Space Data System Standards. Telecommand, Part 2 - Data Routing Service: Architectural Specification.* CCSDS 202.0-B-2. CCSDS Secretariat, National Aeronautics and Space Administration, Washington, DC.

____. (1992c, November). *Recommendation for Space Data System Standards. Packet Telemetry*, CCSDS 102.0-B-3, CCSDS Secretariat, National Aeronautics and Space Administration, Washington, DC.

____. (1992d, November). *Recommendation for Space Data System Standards. Advanced Orbiting Systems, Network and Data Links: Architectural Specification.* CCSDS 701.0-B-2. CCSDS Secretariat, National Aeronautics and Space Administration, Washington, DC.

____. (1994a, November). *Report Concerning Space Data System Standards. Cross Support Concept, Part 1: Space Link Extension Services.* CCSDS xxx-W-1. CCSDS Panel 3 plenary meeting, Goddard Space Flight Center, Greenbelt, MD.

____. (1994b, November). *Recommendation for Space Data System Standards. Space Link Extension Reference Model.* CCSDS xxx-W-1. CCSDS Panel 3 plenary meeting, Goddard Space Flight Center, Greenbelt, MD.

ISO/IEC. (1992, March). *Information technology - Text communication - Message-Oriented Text Interchange*

*Systems (MOTIS) - Part 3: Abstract Service Definition Conventions, Technical Corrigendum 1*. ISO/IEC 10021-3.

Stallings, W. & Kaufeler, J.-F. (1994, November). Cross Support Overview and Operations Concept for Future Space Missions. *Proceedings of the Third International Symposium on Space Mission Operations and Ground Data Systems*. Goddard Space Flight Center, Greenbelt, MD.

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