Executive Summary

The prime purpose of this paper is to start the drafting of a new general purpose CCSDS Data Link layer protocol; the Next Generation Space Link layer Protocol (NGSLP) that will provide the required services for all the CCSDS space links (ground to/from space and space to space links). The Protocol will be targeted for the emerging missions, both human and robotic, that will need to support the escalating data rates, identifying the ever growing number of new space vehicles, support Variable Code Modulation (VCM), independence of the frame and the code blocks, insertion of real-time messages. The protocol also provides the means to support multiple individually addressable VC Data Fields that can be associated with a single Virtual Channel and can be secured with a single Security Association. This new space data link layer protocol utilizes the proven features of the existing CCSDS protocols and adds options that can be used to tailor mission link layer protocol to the needs of specific links. In addition this paper references new coding options that offer significant performance gains for communications links that terminate in space vehicles.

NGSLP Format Description

This paper describes the Frame Format options and how they can provide the services that are provided on current links. It must be noted that the structure of the frame is such that it enables Transfer Frame, Insert Zone, and Operation Control Field services to be provided without any management information required for the Master Channel. The Transfer Frame structure is described in Figure 1.

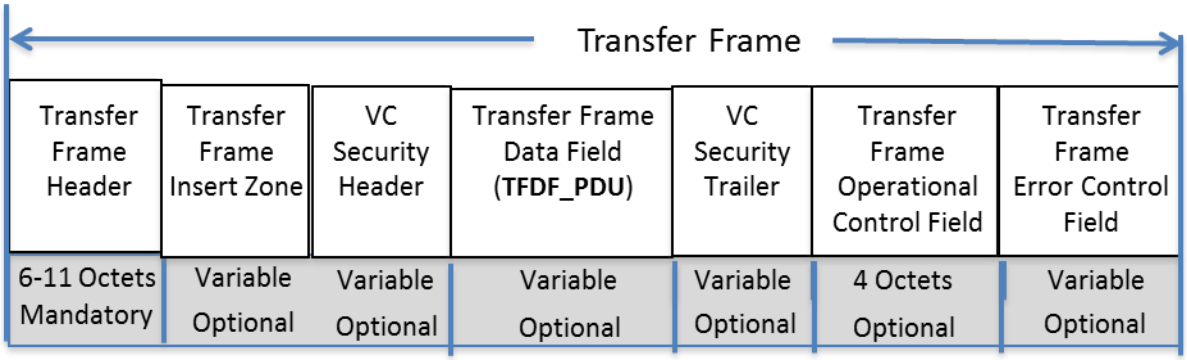


Figure 1 Transfer Frame Structure

The Transfer Frame consists of seven fields. The only required field is the Transfer Frame Header that is described in Figure 2.

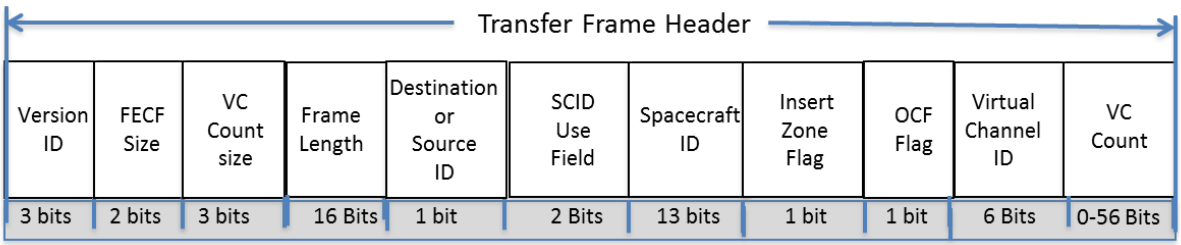


Figure 2. Transfer Frame Header Structure

The first field in the Transfer Frame is the Transfer Frame Header that contains 11 possible fields with only the VC Count field being optional. The functions associated with each field are described:

1) The Version ID field is compatible with the current CCSDS frame Version IDs and when it contains the value “110” it identifies the frame as being a NGSLP Frame.
2) The FECF Size field identifies whether an FECF is contained in the Frame and its size (the FEC algorithm is related to its size and will be describe in the Coding and Sync Specification.
3) The VC Count Size field identifies whether a VC Count Field is contained in the Frame and its size. The VC Count can be 0 to 7 bytes in length.
4) Frame Length Field provides for frame that can be up to 65,536 bytes in length.
5) Destination or Source Flag signals whether the SCID identifies the source of the frame of the SC entity to which the frame is being addressed.
6) SCID Use Field is provided for the mission developers to identify during what phase of the mission’s development the frame was created. The post-launch phase will be identified by the value “11”.
7) The SCID provides for 8192 SC IDs which is 8 time the number available in current formats.
8) Insert Zone Flag signals the presents or absence of an Insert Zone.
9) The OCF Flag signals the presents or absence of an OCF Field.
10) The VCID Field can identify 64 VCs.
11) The VC Count Field is an incrementing counter for a VC. The size of this field is identified by the VC Count Size field.

TRANSFER FRAME INSERT ZONE (TFIZ): The second field in the Transfer Frame is the Transfer Frame Insert Zone. The presence or absence of the TFIZ is signaled by the Insert Zone Flag. In order for all Master Frame Services to be data driven an Insert zone header is required that identifies its length at a minimum. It is herein suggested that it contains the source ID, if the frame is to be relayed to another SC and a contents type field. Any identification of the contents of the Insert Zone is left to the user. The maximum insert zone size is 255 bytes.

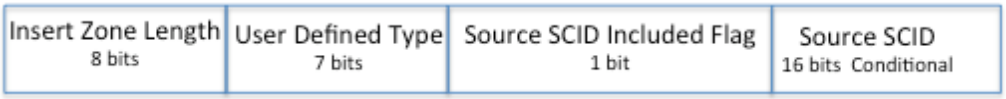
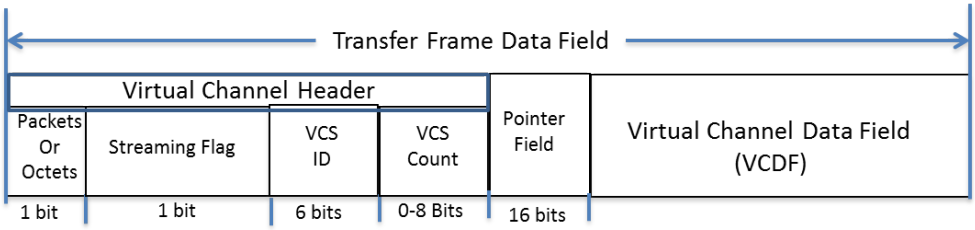


Figure Insert Zone Header

The third and fifth fields in the frame are optional and are used to provide security encoding for the frame. This service is usually provided on a VC basis. The contents of these fields will abide by the SDLS protocol.

The fourth field is the Transfer Frame Data Field whose structure is shown in Figure 3 and contains three optional field groups. The structure of the TFDF is managed for a VC.



1) The Virtual Channel Header is used to identify an included VC Sub Channel and supporting fields:
    a. The Packets or Octets Flag identifies the type of data contained within VCDF
    b. The Streaming Flag identifies the rules concerning how the data is included within the VCDF. When streaming is signaled, packets can flow across frame boundaries and/or user octet SDUs need not fill the VCDF.
    c. VC Sub channel ID field will identify the contained VC Sub channel.
    d. VC Count field will contain an 8 bit incrementing counter that is used to verify continuity of the VC Sub channel data stream.
2) The Pointer Field is used to point to the first byte of the first included packet header when packets are specified or points to the last octet of the user provided SDU in the VCDF.
3) The VCDF will contain the data to be transferred within the VC.

OPERATIONAL CONTROL FIELD: The sixth field is the Operational Control Field that is used for reporting on bi-directional traffic supporting the Go-Back-N frame retransmission protocol. This field is specified as a fixed 4 byte field that is compliant with all current CCSDS Link specifications.

FRAME ERROR CHECK FIELD: The seventh field is the Frame Error Check Field. This field is optional and is used to check that the received frame has not been corrupted in transit. The FECF Size Field identifies this fields length as either 0, 16, 24 or 32 bits in length. The 16 and 32 bit FEC algorithms are specified in the CCSDS Sync and Coding specifications.

Relationship of the Frame to the Code block

The introduction of high performance code in the 1980s brought a dynamic change to telemetry. The introduction and adoption of the convolutional –Reed Solomon code by the CCSDS lead to a flexibility in telemetry that was not envisioned to that point in time. No longer was telemetry susceptible to bit errors, no longer was telemetry constrained to commutation cycles, the new error free links lead to the introduction of packets and flexible data transfers. At the time hardware technology was not as advanced as it is today, thus telemetry frames was constrained to be synchronous to the Reed Solomon code block so

that frame delimiting could be obtained with the code block delimiting simplifying the process. In addition radio communications technology was still developing and the was thought to be a need for an isochronous insert zone that could provide a low rate audio channel for a manned mission. Technology has advanced and we await a new age of communications using lasers that will bring with it, very high data rates requiring longer frames and probably new codes. The constraint that straddles the frame to the code block is out dated. Coding has progressed to support very high rates and exceedingly low error rates and undecoded error rates. The unbinding of the frame from the code block provides new flexibility. There is no longer the need to have the frame size dictated by the code block nor is there a need to have all frame the same size. The ability, for instance, to insert a critical piece of information into a frame enabling its delivery with a minimum of latency could provide the communications necessary to monitor critical operation. The NGSLP protocol is designed to operate in this untethered environment requiring only the addition of a code block synchronization marker (CSM), but by constraining some flexibility this protocol can operate in the same manner (code block and frame synchronized) as the current CCSDS link layer protocols.

Tailoring the Frame to the operational needs of the link

Figure 4 highlights the 4 basic frame constructs that can be formed to provide the required services for a link. Note that inclusion of an Insert Zone field, Security Fields, an Operational Control field and / or a FECF can be accommodated in all the basic forms but these fields are not shown in the figure to reduce drawing complexity.

- These other optional frame fields are not shown in diagram: **Insert Zone, Security Fields, FEC and OCF**
- Data Construction Flags are: 1) Packets or Octets and 2) Streaming Data.

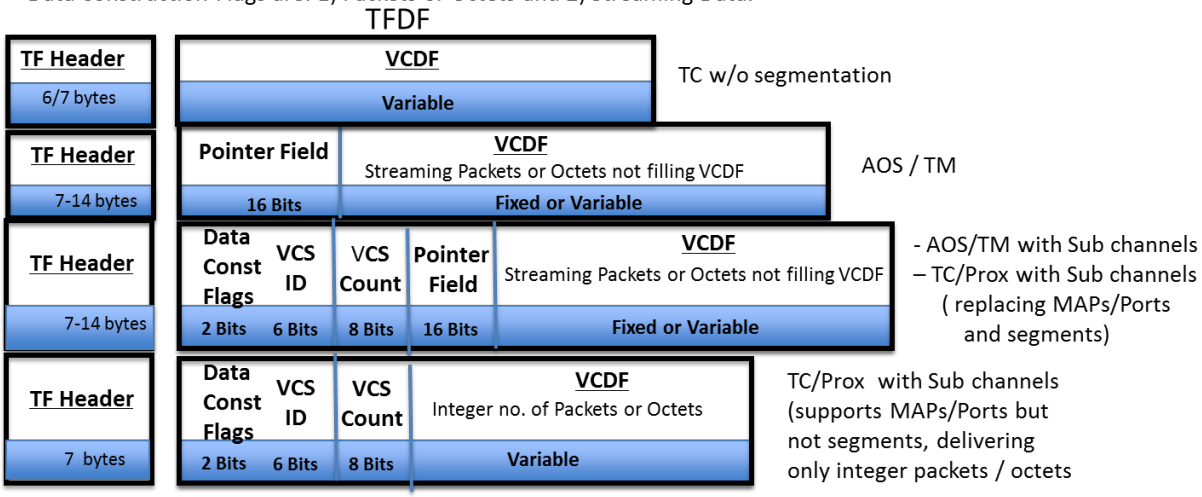


Figure 4 Basic NGSLP Frame Constructs

1) The first form is tailored for message transfers that support variable length frames as currently support Telecommand and Proximity exclusive of Segmentation and Ports. In the formation of hardware commands, for example, the sequence count field can be set to zero length and thus the required frame header would be just 6 bytes in length, the

rest of the frame could contain the user's complete message (control commands, packets or octets).

2) The second form is derived and consistent with the current TM and AOS protocols but could be considered for used for all links. This form allows the frame's message contents to cross frame boundaries eliminating the need for segmentation as currently available with the TC protocol. Thus when segmentation is required to provide a means to share link transport time then the second and third forms presented in Figure 4 can be used
3) The third form provides for VC Sub channels and allows messages to cross frame boundaries. By the use of VC Sub channels messages can be directed a particular element within the receiving system. This methodology allows for using a single VC for operational control (i.e. go-back-n protocol) and security processing before contents extraction and delivery to the designated element
4) The fourth form provides for VC Sub channels but limits the content of the frame to be an integer number of packets or constrains the frame to deliver the complete set of User provided octets. This methodology allows for using a single VC for operational control (i.e. go-back-n protocol) and security processing before contents extraction and delivery to the designated element.

How the NGSLP format replaces the current TC Format

Note: In all cases the services remain as they are in each particular link type.

1) There is no Bypass Flag and there is no Command Control Flag. These features are currently required because the VCID is used as a Physical Address ID denoting one of two receivers in order to simplify the "Go-Back-N protocol". Since the VCID is 6 bits in length and only one bit is being used then apportioning two of the VCID bits for replacement of the Bypass and Command Control bits provides the same capability.
2) The Version field has been enlarge to 3 bits but is compatible with all the CCSDS frame version numbers. Actually there are currently two version 1 formats; TC and TM share the same version ID.
3) The VCID field length is maintained while the SCID and Frame Length fields have been increased in size to accommodate future S/C needs.
4) The VC sequence count field has been made into a variable field and a VC Count length field has been added. The VC Count can be set 0 for emergency and or Bypass or Control Commands and from 0 to 7 bytes in length to support the needs of the link and for long term accounting.
5) The current TC specification requires the inclusion of a FEC field. However, when improved coding is provided on the link this field will no longer be required, A FECF Size field is provide to signal when an FEC field is included and to specify its length (and by default the FEC algorithm).
6) The Destination or Source Flag is currently not used for TC but is included proximity's bidirectional operational needs.

7) The inclusion of VC Sub channel is managed for a VC. This is provided as a replacement for 2 major reasons supporting TC. The first provides the means to use a single VC for Go-Back-N and security operations and providing a second address for routing the contained message to the desired element within the receiving S/C. The second provides the means the means to replace the current TC segmentation process with the streaming process that is used in TM and AOS.
8) The elimination of the requirement to synchronize the frame to the code block and use higher performing codes eliminates the need for fill when frame and code block are of different size and the need for a FEC field for reducing the command undetected error rate.

How the NGSLP format replaces the current TM Format

1) The Version field has been enlarge to 3 bits but is compatible with all the CCSDS frame version numbers.
2) The allowable frame length and the SCID fields have been increased in size to accommodate future S/C needs.
3) The VC sequence count field has been made into a variable field and a VC Count length field has been added. The VC Count can be set from 0 to 7 bytes in length to support the needs of the link and for long-term accounting.
4) The current TM specification provides for the inclusion of a FEC field but its presence is managed while NGSLP provides a field in the frame header signals when an FEC field is included and specifies its length (and by default the FEC algorithm).
5) The current TM format has a Master Channel and a MC counter. These where both dropped in the generation of the AOS format. These two fields are not included in the NGSLP format. It is possible in the NGSLP format to use the Transfer Frame Insert Zone to contain a counter for that purpose.
6) The TM frame format contains a single byte for the VC counter while the NGSLP format allows the VC count to be up to 7 octets in length. The VC counter provides for continuity checking of the VC. A VC Sub channel counter is also provided for continuity checking of a VC Sub channel. The VC Sub channel counter is one octet in length.
7) Both the TM and NGSLP include an OCF flag in the frame header to signal the inclusion of an OCF SDU.
8) TM provides a flag to signal the inclusion of a secondary header; NGSLP provide for the inclusion of an Insert Zone that could have the same functionality.
9) The Synch and packet order flags and segment length fields have been eliminated because their inclusion was there to support tape recorder playbacks. Tape recorders have been replaced with mass memories that do not need those function flags.
10) The First Header Pointer field has been moved from the Frame header to the TFDF. The Pointer Field in the TFDF is the First Header pointer when packet data is to be transported in the VC. Note that the Pointer field points to the last valid octet within the data field if packets are not being transferred in the VCDF.
11) The use of VC Sub channels provides the means to use a single Security Association for multiple user data streams and/or provide a second address for routing the contained VCDF

data to the desired element within the receiving entity. A VC Sub channel counter is provided to provide a continuity check for VC Sub channel contents

12) The constraints in the TM format/protocol require the frame to be synchronized to the codeblock. This has ramifications in the construction of the frame and as such there are rules that effect the inclusion of a secondary header and an OCF. These rules require that if a VC is to have either a Secondary header or an OCF that those must be constant for the mission phase. By disconnecting the frame from the code block both the insertion of the secondary header (replaced by the Insert Zone) and the OCF can be added to a frame when needed. The secondary header terminology is replace by an insert zone and the secondary header flag is renamed the Insert Zone inclusion flag. A length field has been added to accommodate a variable length frame as necessary. An example where a variable length frame is necessary is when an Insert Zone or OCF is added to the frame on an as needed basis while the basic frame information content size is unchanged.

How the NGSLP format replaces the current AOS Format

1) The Version field has been enlarge to 3 bits but is compatible with all the CCSDS frame version numbers.
2) The allowable frame length and the SCID have been increased in size to accommodate future S/C needs.
3) The VC sequence count field has been made into a variable field and a VC Count length field has been added. The VC Count can be set from 0 to 7 bytes in length to support the needs of the link and for long-term accounting. The current AOS format has a 3 byte count plus an additional field that extends the count by a 4 bits.
4) The current AOS specification provides for the inclusion of a FEC field but its presence is managed while NGSLP provides a field in the frame header signals when an FEC field is included and specifies its length (and by default the FEC algorithm).
5) The current AOS does not have a Master Channel and a MC counter. These where included in TM but were dropped in the generation of the AOS format. These two fields are not included in the NGSLP format.
6) AOS provides for the inclusion of an Insert Zone but its presence is managed and must be present for a phase in the mission. NGSLP provide for the inclusion of an Insert Zone that could have the same functionality but its presence is signaled. If there is a requirement to have an isochronous insert zone then it constrains the frame to have a fixed size and the insert zone to appear in every frame, even Idle frames. The elimination of the requirement to have the frame synchronized to the code block and no requirement for isochronous data allows this field to be inserted when necessary without affecting the frame VC construction rules.
7) The AOS protocol provides 3 mechanisms for inserting data into the information field of the frame. These methods provide for multiplexing packets, including user octets or user bitstream data. The NGSLP format provides for packets and octet (VCA) services. The different construction rules however are managed and not signaled. The NGSLP protocol uses the management option if VC Sub channel are not used but adds a flag to identify packet or octet service when VC Sub channels are included. The bitstream service could be

provided by added management rules that prepend the user's bit SDU with a 3 bit field that indicates the number of valid bits in the last user octet.

8) The Frame Retransmission frame is not included because it utility has not been validated to date.
9) The use of VC Sub channels provides the means to use a single Security Association and provide a second address routing the contained message to the desired element within the receiving entity. A VC Sub channel counter is provided to provide a continuity check for VC Sub channel contents
10) The constraints in the AOS format/protocol that requires the frame to be synchronized to the codeblock has ramifications in the construction of the frame and as such these rules effect the inclusion of a insert zone and an OCF. These rules require that if a VC is to have an Insert Zone that it must be constant for the mission phase. By uncoupling the frame from the code block both the insertion of an Insert Zone and the OCF can be added to a frame when needed, and the inclusion of these fields is signaled by flags in the frame header. A length field has been added to accommodate a variable length frame as necessary. An example where a variable length frame is necessary is when an Insert Zone or OCF is added to the frame on an as needed basis while the basic frame information content size is unchanged. The elimination of the coupling of the frame and code block also eliminates the need for fill frames when the ground station does not have a frame ready. This capability to use Idle bits rather than an Idle frame can reduce the latency caused by a ground event that delays the delivery of a frame (in a CLTU using SLE CLTU service) across the Internet.
11) The manned missions are planning to use the AOS protocol emergency uplink. The current design is trying to minimize the decoding hardware on the S/C. The current specification requires all frames to fit into one code word (using LDPC 1024 bit code word). It would be easy to change the code block size at different rates if necessary by concatenating code word to form a larger code block using an integer number of code words the same decoder would be used only when the process looks for the CSM would change.

How the NGSLP format replaces the current Proximity Format

Note: The Proximity format was derived from the TC format

1) There is no Quality of service indicator (similar to the Bypass Flag in TC) and there is no PDU Type ID (similar to control command in TC) in the NGSLP format. These fields are required in the Proximity Format because there is but a single bit provided for Physical Address ID (VCID in TC), which is named that because of the way the field is used. It denotes which of two receivers is to process the frame. Since the NGSLP frame provides for a VCID that is 6 bits in length and if only one bit is being used then apportioning two of the VCID bits for replacement of the Quality of Service Indicator and PDU Type ID fields provides the same capability.
2) The Version field has been enlarge to 3 bits but is compatible with all the CCSDS frame version numbers. Actually there are currently two version 1 formats; TC and TM share the same version ID.

3) The VCID field length is maintained while the SCID and Frame Length fields have been increased in size to accommodate future S/C needs.
4) The VC sequence count field has been made into a variable field and a VC Count length field has been added. The VC Count can be set 0 when it is not required, and set to the desired size when required.
5) The current Proximity specification requires the inclusion of a FEC field. However, when improved coding is provided on the link this field will no longer be required, a FECF Size field is provide to signal when an FEC field is included and to specify its length (and by default the FEC algorithm).
6) The Destination or Source Flag is required and provided
7) A VCS Flag is also included to signal the inclusion of VC Sub channel. This is provided as a replacement for 2 major reasons supporting Proximity. The first provides the means to use a single VC for Go-Back-N and security operations and providing a second address routing the contained message to the desired element within the receiving entity. The second provides the means the means to duplicate current Proximity segmentation process and/or to transform the segmentation process into the streaming process that is used in TM and AOS.
8) The elimination of the requirement to synchronize the frame to the code block and use higher performing codes eliminates the enable the flexible use of an insert Zone and OCF. Instead of the OCF (carrying a PLCW) to be in a separate frame the OCF can be included in any frame when needed.
9) The remainder of the Proximity protocol can be accommodated by the NGSLP format.
10) If a frame relay service were to be provided via an Orbiter, the data routing would use the Destination SCID in the Transfer frame Header and could add the Source SCID in the Insert Zone thus informing the recipient of the frame of its origination.