Instrument Large Data Product Format Specification

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Swift Instrument Large Data Product format Specification

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Signature Page

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REVISION SUMMARY			
REV	RELEASE DATE	BRIEF DESCRIPTION/REASON FOR CHANGE	EFFECTIVE PAGES
1.0		Initial Release	All

Term Definitions

ST-PDU	Swift Telemetry Protocol Data Unit
LDP	Large Data Product - A data product with length > 958 bytes
File	A large data product
Product Number	A sequential count of each file that is transmitted through a specific Application ID
Page Number	A sequential counter to identify a segment within a file
Observation Number	A data field composed of the Target ID and the Observation Segment
Target ID	An ID to identify the astronomical source that Swift is observing
Observation Segment	A number to identify which observation of a particular target is being accomplished
SDC	Swift Data Center
MOC	Mission Operations Center
GCN	Ground Communications Network

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1 Purpose

Swift instruments generate very large science data products (in the order of several Mega bytes). These data products shall be broken up into smaller segments in order to be transferred from the instruments to the spacecraft (over the Mil-Std-1553 Bus) and eventually downlinked to the ground data systems. The purpose of this document is to define a standard format for Swift large data products (LDP) and a segmentation scheme for routing the data through the system. Utilizing a common format for the segmentation will ensure a well-designed format, facilitate the process of data reconstruction on the ground and, hence, will save time, effort and cost.

Section 1 defines the purpose of this document. Section 2 indicates the path of the data from the instruments to the ground. Section 3 defines common formats for the large science data products. Section 3.1 describes two options for data products up to 64 Kbytes, and section 3.2 defines a common format for very large data products (sizes between 64 Kbytes and 60 Mbytes). Section 4 describes the segmentation schemes for the large data products. The CCSDS segmentation method is discussed in section 4.1 and a non-CCSDS method is introduced in section 4.2. A summary of the telemetry format being used by each instrument is provided in Appendix A.

2 Overview

Figure 1 illustrates the data flow diagram from the instruments to the Swift Data Center.

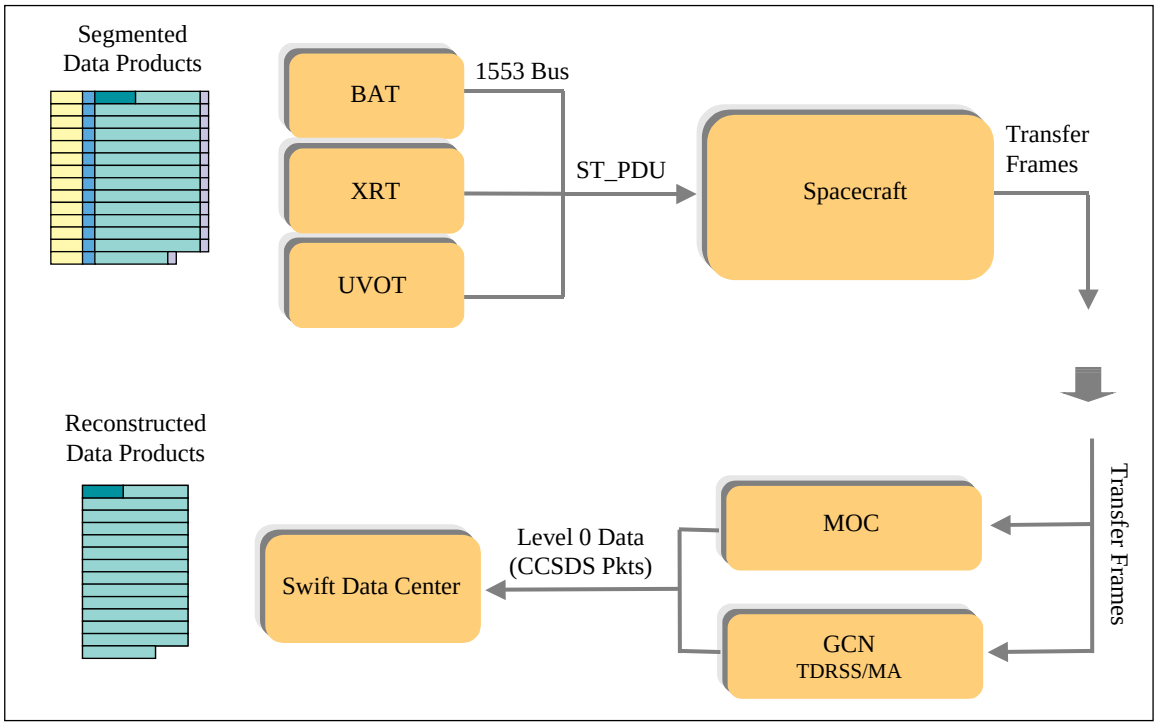

Figure 1: Data Flow Diagram

All data products are transmitted from instrument remote terminals to the S/C through ST-PDUs (960-byte data transfer blocks). Each block may contain one or more CCSDS telemetry packets. The spacecraft routes the telemetry packets to the appropriate destination and to the ground unaltered based on the telemetry packet's Application ID. The instruments must segment the large data products that do not fit in an ST-PDU block. The ground systems have the responsibility of reconstructing the un-segmented data products.

3 Science Data Products – Common Format

It is preferred that science data products include several common fields that facilitate sorting of the science data on the ground. These common fields form the Swift-standard Tertiary Header for science data products. This tertiary header (shown in Figure 2) is 16 bytes long and includes the following fields:

- Observation Number

  Observation Segment - (1 byte, most significant 8 bits)

  Target ID – (3 bytes, least significant 24 bits)

- Science data collection time (in S/C time)

  Seconds – (4 bytes)

  Sub-seconds - (2 bytes)

- Time Offset (UTCF)

  Seconds – (4 bytes)

  Sub-seconds - (2 bytes)

The CCSDS telemetry packets may not span across ST-PDUs. The data products that do not fit in a single ST-PDU shall be segmented into multiple CCSDS packets and transferred to the spacecraft through several ST-PDUs. Two common formats for Science data products are recommended in this document.

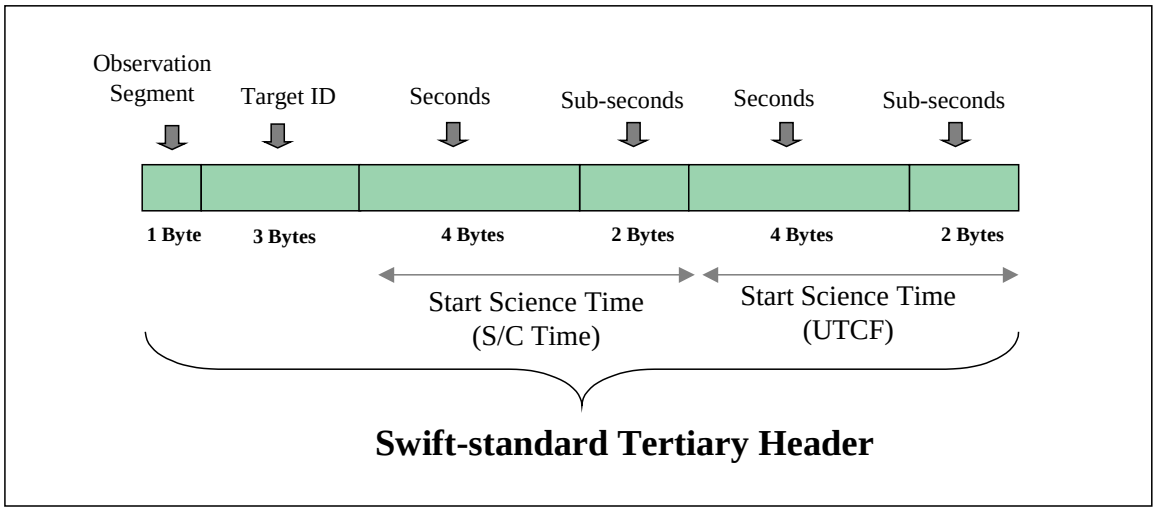

Figure 2: Structure of the Swift-Standard Tertiary Header

3.1 Standard Data Products

Standard data products can be up to 64 Kbytes. The standard data products that are larger than 958 bytes are broken up into multiple CCSDS telemetry packets of 958 bytes or less. These multiple packets may have different lengths. There are two options regarding the use of the tertiary header in these packets:

Option 1: Insert the tertiary header in each packet of the data product.

> This format is recommended for the data products that have fixed structure. Inserting the tertiary header in every packet requires more bandwidth; however, if a portion of data is lost during transmission, the partial data products received on the ground will contain enough information within them for data retrieval; i.e. the loss of some segments will not result in loss of the whole product.

Option 2: Insert the tertiary header in the first packet of the product only.

> This format is appropriate for the data products that do not have fixed structure such as compressed science data. This format is also recommended when data bandwidth or data storage space is concerned. A shortcoming of this method is that if the first packet of the group is lost the rest of the data is not retrievable; i.e. the loss of some packets will result in a loss of the whole group of packets in that product.

3.2 Large Data Products (Files)

Files are data products that are larger than 64 Kbytes. Files are composed of file header and data content. The header of a file has the following structure:

- File Size (in total number of pages) – (2 bytes - handles files with size up to ~60 Mbytes)
- Swift-standard Tertiary Header – (16 bytes)
- Non-standard Header – (variable length)

The non-standard section of the file header may be defined differently for different files, and it may have spare fields for future expansion. There is no limit on the length of the file header. Figure 3 illustrates the structure of a file header.

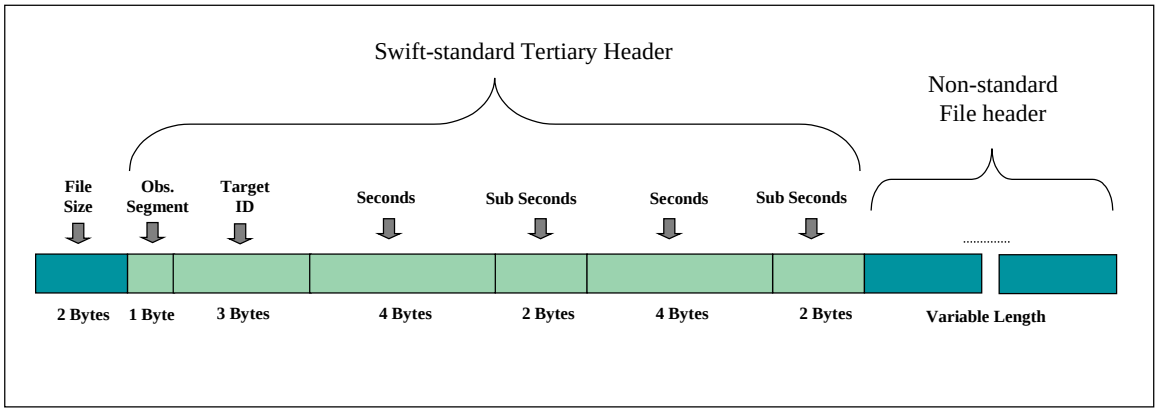

Figure 3: Structure of a file header

4 Segmentation Methods

Maximum length of a CCSDS telemetry packet that can be transferred over the 1553 from an instrument to the spacecraft and to the ground is 958 bytes. Larger science data products are broken into CCSDS telemetry packets of 958 bytes or less.

The CCSDS secondary header of the packets that contain segments of a large data product shall include the packet generation time in Spacecraft Time. This is the time at which the raw data is removed from the raw data queue and encapsulated into a CCSDS packet. The format of the time fields is specific to Swift and is defined in the 1553 Bus Protocol Interface Control Document.

The information in the CCSDS primary and secondary headers is used on the ground for Level Zero data processing. The ground system uses two criteria to sort the packets. The first is the secondary header time and the second is the Packet Sequence Count. It is acceptable for several consecutive packets to have the same secondary header time as long as they have a different sequence count; hence, no two packets shall have the same Application ID, CCSDS secondary header time, and sequence count.

The use of a checksum for individual packets of a large data product is optional; however, it should be consistent within the Application ID. The purpose of the checksum

is to provide the capability for detecting errors that may have been introduced into the telemetry packet during the data handling process.

The checksum algorithm is a byte-by-byte addition of the whole telemetry beginning at the first byte of the primary header. The result is stored as a 16-bit value following the last byte of the telemetry data. The length field in the primary header should be set to include the checksum bytes.

There are two options for segmenting large data products. These are discussed below.

4.1 CCSDS Grouping Feature

This feature may be used for data products up to 64 Kbytes in size. The instrument sets the Packet Sequence Control field (the Sequence Flags and the Sequence Count – see Figure 4 for the structure of the CCSDS telemetry packet) of the CCSDS primary header to control the reconstruction of the large telemetry packet on the ground. This method is described in the CCSDS 102.0-B-5 Blue Book.

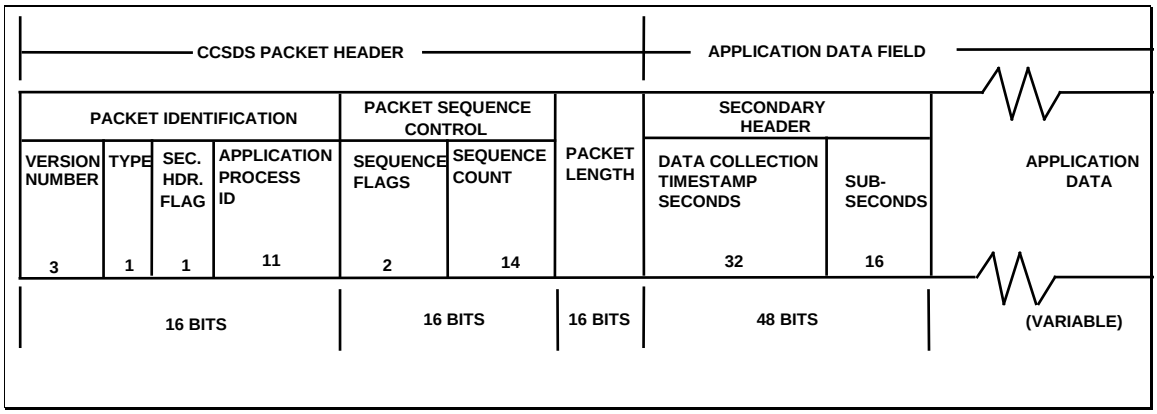

Figure 4: CCSDS Telemetry Packet Structure

The segmented data products will be merged on the ground by either the ITOS ground system or by a software utility at the SDC. The merged data products for this method of segmentation will be CCSDS packets. Different Application IDs shall be assigned to the merged packets. The Sequence Flags field shall be set to "11h" indicating a complete reconstructed packet. The Sequence Count field of a merged packet shall be copied from the first packet of the group. Note that this field will not be continuous for the merged packets and hence cannot indicate the loss of data. The Packet Length field of the merged packet shall indicate the length of the Application Data field of the merged packet minus 1. Note that the length of the merged data is limited by the size of this field (64 Kbytes). The secondary header of the merged packet shall be copied from the first packet of the group. The application data in the merged packet will be a concatenation of

the data in each packet following the secondary header. Tertiary headers will be considered as application data; i.e. if they exist in all the segments they will all be copied to the merged data product and if it exists only in the first segment of the product it will appear only once in the merged data product.

4.2 Swift-specific Segmentation Method

This method is a non-standard segmentation method and is not tied to the CCSDS headers. The intent is to define a common process that would work for all three instruments and hence to simplify the science data extraction process on the ground.

This method of segmentation should be used for data products that are larger than 64 Kbytes. These data products are segmented into smaller pieces and transferred through multiple CCSDS telemetry packets. The segments of a file may be of arbitrary lengths.

The header of the file may span across multiple segments of the file. Since it is possible to lose some portion of a large data product, the CCSDS packets that contain the header will be transferred one more time when all segments of the file are transferred. This will increase the probability of receiving the header information on the ground. The sequence count and the CCSDS secondary header of the packet shall be updated when it is transferred for the second time. The following specifies the segmentation fields:

- **Product Number**

The Product Number is a 16 bit big-endian unsigned integer that provides a sequential count of each file that is transmitted through a unique Application ID. This field is inserted into all segments of a file and will be static for all segments associated with that file. The range of this number is from 0 to 65535.

The size of this data field is large enough for the Swift science data products, and with the current design of the data structures, the Product Number will not roll over within the content of the science data recorders. Nonetheless, it is acceptable for this field to roll over within the content of a data recorder since the combination of the Product Number and the time stamp of the packet will certainly be unique for the life of the mission, and there would be no ambiguity in data reconstruction process.

- **Page Number**

The Page Number is a 16 bit big-endian unsigned integer that identifies a segment within a file. This field is inserted into all segments of a file. A file will be reconstructed on the ground by concatenating its segments according to the page number of the segment. The range of this number is from 1 to 65535, and it handles files with size up to ~60 Mbytes.

All Swift science data products are smaller than 60 Mbytes. Therefore, a 16-bit Page Number will not roll over within a science data file.

- **File Size (in total number of pages)**

The file size is also a 16 bit big-endian unsigned integer that identifies the total number of segments within a file. This field is part of the file header. The range of this number is from 0 to 65535. If the file begins to be transmitted prior to knowing the file size, this field shall contain a value of zero when the beginning file header is constructed and transmitted; however, this field shall contain the correct file size when the ending file header is transmitted at the end (i.e., after all segments of the file have been transferred).

Figure 5 provides an overview of the process for this segmentation method.

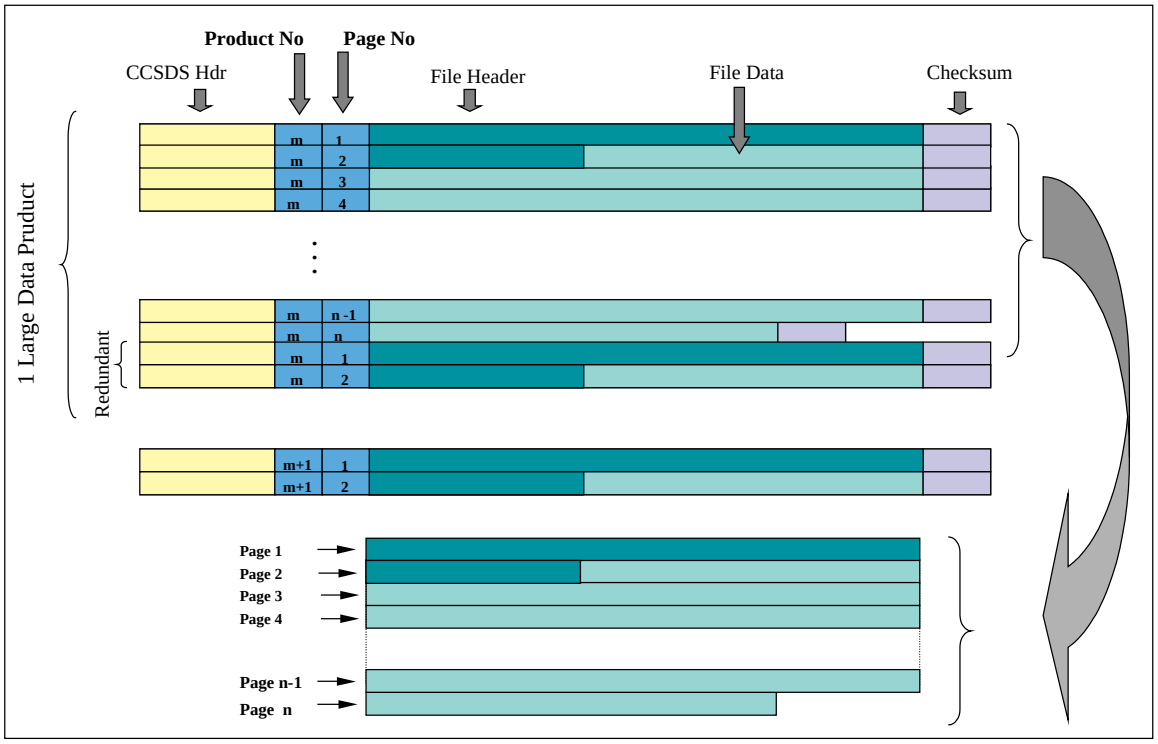

Figure 5: Overview - Swift-specific Segmentation Method

This method of segmentation is preferred for large science data products. The data products that are segmented with this method of segmentation will be reconstructed at the Swift Data Center (SDC). The CCSDS headers and the segmentation fields will be removed when reconstructing the large data products.

Appendix A – Swift Science Data Formats

The following table summarizes the telemetry format being used by each instrument. Details of each format are described in the body of the document.

Instrument	Data Product	Telemetry Format		
		Standard Data Format		LDP Format
		Option 1	Option 2	
BAT	Science Files			X
	Engineering Files			X
XRT	TDRSS Messages > 958 bytes	X		
	Large Science Data Products			X
UVOT	Images (Compressed image rows)		X	
	CCD Frames		X	