Satellite Control Software

TM & TC Packets Definition Recommendation

Proposed ECSS-E-70-41A tailoring

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23 March 2015

RECORD OF REVISIONS

ISS/REV	Date	Modifications	Created/modified by
1/0	25/11/2011	Initial release	Florian George
2/0	06/11/2013	Updated and issued for QB50 CDR	Stéphane Billeter / Muriel Richard
3/0	30/04/2014	Updated Service 13	Stéphane Billeter / Yann Voumard
3/1	14/07/2014	Packet Length corrected	Stéphane Billeter
3/2	17/07/2014	Add remarks about Extended Telecommands Add non-standard error codes for service 13	Yann Voumard
4/0	31/07/2014	First release of the software for the QB50 Teams	Stéphane Billeter
4/1	23/03/2015	Clarify the structure of the WOD, section 4.2.1.2 Remove obsolete comment, sections 2.2.2 and 7.3.6	Yann Voumard

REFERENCES

[N1]   ECSS-E-70-41A - Ground systems and operations – Telemetry and Telecommand packet utilization - 30 January 2003

[N2]   ECSS-E-ST-70-31C - Ground systems and operations - Monitoring and control data definition - 31 July 2008

[N3]   https://www.qb50.eu/index.php/requirements-and-reviews; INMS Interface Control Document, FIPEX Interface Control Document, MNLP Interface Control Document

ABBREVIATED TERMS

Ack   Acknowledgement

ADCS   Attitude Determination and Control System

APID   Application Process ID

bpp   Bits per pixel

CCSDS   Consultative Committee for Space Data Systems

COM   Communication [subsystem]

CRC   Cyclic Redundancy Code

ESA   European Space Agency

EPS   Electrical Power Subsystem

OBT   On-Board Time

PC   Parameter Code

PFC   Parameter Format Code

PL   Payload [subsystem]

PSS   Procedures, Specifications, Standards

PTC   Parameter Type Code

PUS   Packet Utilization Standard [N1]

SID   Structure Identification

UTC   Universal Time Coordinated

VC   Virtual Channel

INTRODUCTION

This document presents a recommendation of an ECSS-E-70-41A compliant TM&TC Packets Definition for a small CubeSat mission. The resulting protocol is a tailored version of the ECSS-E-70-41A [N1]. The full tailoring process is described in the ECSS-E-ST-70-31C [N2].

The assumed CubeSat has 5 subsystems: COM, EPS, CDMS, ADCS and Payload. The CDMS must be able to perform on-board scheduling of telecommand release.

The CubeSat must also receive and validate large files.

It is recommended to have a basic understanding the ECSS-E-70-41A before reading this document. The first chapters of the standard provide a good understanding of the general terms and concepts used here. For each service, it provides the full concept behind it. In addition, it is also interesting to compare the full untailored version of the services specification with their resulting tailored version presented in this document; leading to a better understanding of the tailoring process.

1 CONVENTIONS

1.1 Unsigned Integer values format convention

Hexadecimal values are always prefixed by the two characters "0x". Example 0x8000 is equal to the decimal value 32768.

1.2 Bit/Octet Numbering Convention

The following convention is used to identify each bit in a forward-justified N-bit field.

The first bit in the field to be transmitted (i.e. the most left-justified bit when drawing a figure) is defined to be "BIT 0"; the following bit is called "Bit 1" and so on up to "Bit N-1".

When the field is used to express a binary value (such as an integer), the Most Significant Bit (MSB) shall be the first transmitted bit of the field (i.e. "Bit 0"), i.e. in **big-endian** format.

An octet (i.e. a byte) is 8-bits length.

Bit 0   Bit N - 1

N-Bit Data Field

MSB
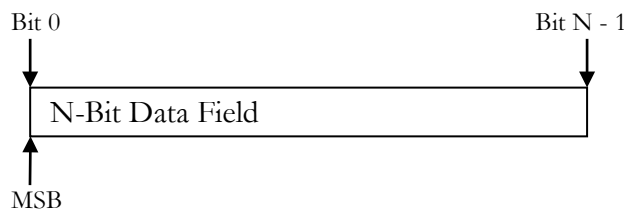
A short word is 16-bits length (i.e. 2 octets).

A word is 32-bits length (i.e. 4 octets).

A long word is 64-bits length (i.e. 8 octets)

Octet 0   Octet 1   Octet N-1

N-octets Data Field

Most Significant Octet
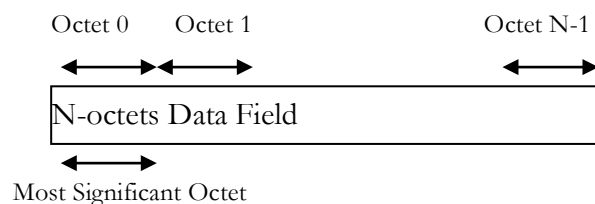
The above convention for identifying a bit is also used for identifying each octet in a forward-ordered N-octet field.

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2 PACKET STRUCTURE

All telecommand and telemetry packets shall confirm to the structure defined in ECSS-E-70-41A [N1]. Where applicable, optional fields and values for unneeded features for a small mission have been left out; exact parameter formats have been fixed.

2.1 Telecommand Packet Data Field Structure

2.1.1 CCSDS Header

Packet Header (48 Bits)							Packet Data Field (Variable)		
Packet ID				Packet Sequence Control		Packet Length	Telecommand Data Field Header	Application Data	Packet Error Control
Version Number	Type	Data Field Header Flag	APID	Sequence Flags	Sequence Count				
3	1	1	11	2	14				
16				16		16	24	Variable	16

#### 2.1.1.1 Packet Header (48 bits)

2.1.1.1.1 *Packet ID (16 bits)*

Version Number (3 bits): Value = 0.

Type (1 bit): Value = 1.

Data Field Header Flag (1 bit): Value = 1.

APID (Application Process ID) (11 bits): Value is mission specific. See chapter 4.2 in [N1].

2.1.1.1.2 *Packet Sequence Control (16 bits):*

Sequence Flags (2 bits): value = 11 (only using stand-alone packets)

Sequence Count (14 bits):

> This field is provided to identify a particular telecommand packet so that it can be traced within the end-to-end telecommand system. A separate sequence count shall be maintained by each telecommand source for each APID.

2.1.1.1.3 *Packet Length (16 bits):*

> The packet length field specifies the number of octets contained within the packet data field. The number shall be an unsigned integer "C" where:

> C = (Number of octets in packet data field) – 1

> NOTE: The actual length of the entire telecommand packet, including the packet header, is 6 octets longer. The largest telecommand packet length is 65'542 octets

2.1.2 Telecommand Data Field Header (24 bits)

CCSDS Secondary Header Flag	TC Packet PUS Version Number	Ack	Service Type	Service Subtype
Boolean (1 bit)	Enumerated (3 bits)	Enumerated (4 bits)	Enumerated (8 bits)	Enumerated (8 bits)

CCSDS Secondary Header Flag (1 bit): Value = 0

TC Packet PUS Version Number (3 bits): Value = 1

Ack (4 bits):

------1   (bit 3 of the Ack field set): acknowledge acceptance of the packet by the application process

----1--   (bit 2 of the Ack field set): acknowledge start of execution

--1----   (bit 1 of the Ack field set): acknowledge progress of execution

1------   (bit 0 of the Ack field set): acknowledge completion of execution (whether successful or failed)

See chapter 4.1 *Telecommand verification service (Service Type 1)* for details on the acknowledgements.

Service Type (8 bits):

This indicates the service to which this packet relates.

Service Subtype (8 bits):

Together with the service type, the subtype uniquely identifies the nature of the service request constituted by this telecommand packet.

Remark: The definition of service type and subtype is unique across all application processes.

2.1.2.1 Application Data (variable length)

The telecommand application data constitutes the data element of the service requests from the service user (e.g. the ground system).

2.1.2.2 Packet Error Control (PEC) (16 bits)

The packet's checksum using the CRC described in Annex A.1 of [N1].

2.2 Telemetry packet data field structure

2.2.1 CCSDS Header

Packet Header (48 Bits)						Packet Length	Packet Data Field (Variable)		
Packet ID				Packet Sequence Control			Telemetry Data Field Header	Source Data	Packet Error Control
Version Number	Type	Data Field Header Flag	APID	Grouping Flags	Source Sequence Count				
3	1	1	11	2	14				
16				16		16	64	Variable	16

2.2.1.1 Packet Header (48 bits)

2.2.1.1.1 Packet ID (16 bits)

Version Number (3 bit): Value = 0.

Type (1 bit): Value = 0.

Data Field Header Flag (1 bit): Value = 1.

APID (Application Process ID) (11 bits): Value is mission specific. See chapter 4.2 in [N1].

2.2.1.1.2 Packet Sequence Control (16 bits):

Grouping Flags (2 bits): value = 11 (only using stand-alone packet)

Source Sequence Count (14 bits):

A separate source sequence count shall be maintained by each APID and shall be incremented by 1 whenever it releases a packet. Therefore the counter corresponds to the order of release of packets by the source and enables the destination (e.g. the ground system) to detect missing packets. This counter should never re-initialize; however, under no circumstances shall it "short-cycle" (i.e. have a discontinuity other than to a value zero). The counter wraps around from $2^{14}-1$ to zero.

2.2.1.1.3 Packet Length (16 bits):

The packet length field specifies the number of octets contained within the packet data field. The number shall be an unsigned integer "C" where:

C = (Number of octets in packet data field) – 1

NOTE The actual length of the entire telemetry source packet, including the source packet header, is 7 octets longer C+7.

2.2.2 Telemetry Data Field Header (64 bits)

Spare	TM Source Packet PUS Version Number	Spare	Service Type	Service Subtype	Time
Fixed BitString (1 bit)	Enumerated (3 bits)	Fixed BitString (4 bits)	Enumerated (8 bits)	Enumerated (8 bits)	Absolute Time (40 bits)

Spare (1 bit): Value = 0

TM Source Packet PUS Version Number (3 bits): Value =1

Spare (4 bits): Value = 0

Service Type (8 bits):

This indicates the service to which this telemetry source packet relates.

Service Subtype (8 bits):

Together with the service type, the subtype uniquely identifies the nature of the service report constituted by this telemetry source packet.

Remark: The definition of service type and subtype shall be unique across all application processes and the combination of these fields can be used on the ground to determine the processing priority level.

Time (40 bits):

PTC 9 and PFC 16 described in chapter 7.3.6 Absolute Time (PTC = 9). PFC 16 is required due to the length of the QB50 mission and its epoch.

2.2.2.1 Source Data (variable length)

The telemetry source data constitutes the data element of the service reports to the service user (e.g. the ground system).

2.2.2.2 Packet Error Control (PEC) (16 bits)

The packet's checksum using the CRC described in Annex A.1 of [N1].

4 SERVICES

Services with a type less than 128 are standard PUS services tailored for this example mission. The telecommand verification service (Service Type 1) and the Housekeeping & diagnostic data reporting service (Service Type 3, in its most compact form) are present for any type of mission.

The function management service (Service Type 8) provides a straightforward way to execute simple on-board tasks without having to define mission-specific services. However it works only for on-board tasks that don't need to return telemetry more complex than simple execution verifications through Service Type 1 or housekeeping data through Service Type 3.

The on-board operations scheduling service (Service Type 11) and the on-board storage and retrieval service (Service Type 15) are the services implemented on the CDMS to interface with the simple on-board scheduling and data storage. They are of course tailored for the very basic needs of this small CubeSat mission.

The payload services (Service Type 128, 129 and 130) are mission-specific services needed to retrieve data from the payload. They are the transport mean for the science data.

4.1 Telecommand verification service (Service Type 1)

4.1.1 Service requests and reports

4.1.1.1   Telecommand acceptance

The reports of acceptance of a telecommand packet shall be as follows:

Telecommand Acceptance Report – Success (1, 1)

Telemetry source packet, source data:

Telecommand Packet ID	Packet Sequence Control
2 octets	2 octets

Telecommand Packet ID:

> This is a copy of the corresponding fields from the packet header of the Telecommand to which this verification packet relates.

Packet Sequence Control:

> This is a copy of the corresponding fields from the packet header of the Telecommand to which this verification packet relates.

Telecommand Acceptance Report - Failure (1, 2)

Telemetry source packet, source data:

Telecommand Packet ID	Packet Sequence Control	Code
2 octets	2 octets	Enumerated 2 octets

Code (PTC=1, PFC=16):

> The code indicates the reason for the failure of the telecommand at this verification stage.

At the acceptance stage, the following standard code values are defined:

0 = illegal APID (PAC error);

1 = incomplete or invalid length packet;

2 = incorrect checksum;

3 = illegal packet type;

4 = illegal packet subtype;

5 = illegal or inconsistent application data.

Other values of the code can be application process specific or command-specific (i.e. dependent on combinations of the type, subtype and individual command function).

4.1.1.2   Telecommand execution started

The reports of start of execution of a telecommand packet shall be as follows:

Telecommand Execution Started Report - Success (1, 3)

Telemetry source packet, source data: Same as for subtype 1.

Telecommand Execution Started Report - Failure (1, 4)

Telemetry source packet, source data: Same as for subtype 2.

4.1.1.3   Telecommand execution complete

The reports of completion of execution of a telecommand packet shall be as follows:

Telecommand Execution Completed Report - Success (1, 7)

Telemetry source packet, source data: Same as for subtype 1.

Telecommand Execution Completed Report - Failure (1, 8)

Telemetry source packet, source data: Same as for subtype 2.

4.2 Housekeeping & diagnostic data reporting service (Service Type 3)

4.2.1 Service requests and reports

4.2.1.1 Controlling the generation of housekeeping parameter reports

The requests to enable and disable the generation of one or more housekeeping or diagnostic parameters report definitions shall be:

Enable Housekeeping Parameter Report Generation (3, 5)

Name: TC_S3_EN_HK

Telecommand packet, application data:

Disable Housekeeping Parameter Report Generation (3, 6)

Name: TC_S3_DI_HK

Telecommand packet, application data:

SID
Enumerated 1 octet

SID (PTC=2, PFC=8):

SID for which to enable/disable report generation.

4.2.1.2 Reporting housekeeping or diagnostic data

The provider-initiated reports of the values of a set of housekeeping or diagnostic parameters shall be:

Housekeeping Parameter Report (3, 25)
Telemetry source packet, source data:

SID	Parameters
Enumerated 1 octet	Any

← Optionally repeated →

SID (PTC=2, PFC=8):

SID of the following reported parameters.

Parameters:

This field consists of one sequence of values of housekeeping parameters for real-time SIDs or a fixed array of sequences for archiving SIDs. In the latter case, the time field of the telemetry source packet refers to the capture time of the first sequence.

For ground system processing purposes, the SID, together with the application process ID and the nature of the packet (housekeeping or diagnostic) implicitly identifies the structure of the parameter field.

Remark*:* The housekeeping parameters and SIDs are mission-specific and shall be defined in an ICD of the CubeSat.

Example for the WOD as defined in the default Mission Information Base (qb50-base.xml):

		Dataset 1							
SID 0xFF	Spare	Mode	Bat. Voltage	Bat. Current	3V3 Bus Current	5V Bus Current	Temp. Comm	Temp. EPS	Temp. Battery
8 bits	7 bits	1 bit	8 bits	8 bits	8 bits	8 bits	8 bits	8 bits	8 bits

	Dataset 2								
Spare	Mode	Bat. Voltage	Bat. Current	3V3 Bus Current	5V Bus Current	Temp. Comm	Temp. EPS	Temp. Battery	…
7 bits	1 bit	8 bits	8 bits	8 bits	8 bits	8 bits	8 bits	8 bits	

Please note that the SID is present only once per packet and that each dataset is 8-bit aligned with padding bits at the beginning. This differs from the alignment presented in WOD Packet Format, Rev. 4. The time is obtained from the packet time field.

4.3 Function management service (Service Type 8)

4.3.1 Perform function

The request shall be:

Perform Function (8, 1)

Name: TC_S8_PERF_FUNCT

Telecommand packet, application data:

Function ID	Parameters
Unsigned Integer 1 octet	Any

←   Optional   →

Function ID (PTC=3, PFC=4):

The Function ID, together with the APID in the packet header, implicitly defines the presence and the structure the parameters which follow.

Parameters:

Optional structure of parameter to the function, the number of parameter, size and format are deduced from the Function ID.

Remark*:* The functions are mission-specific and shall be defined in an ICD of the CubeSat.

4.4 On-board operations scheduling service (Service Type 11)

4.4.1 Service requests and reports

4.4.1.1 Controlling the command schedule

4.4.1.1.1 *Controlling the release of telecommands*

The service requests to enable or disable the release of selected telecommands shall be:

Enable Release of Telecommands (11, 1)

Name: TC_S11_EN

Telecommand packet, application data: None

Disable Release of Telecommands (11, 2)

Name: TC_S11_DI

Telecommand packet, application data: None

4.4.1.2 Resetting the command schedule

The request shall be:

Reset Command Schedule (11, 3)
Name: TC_S11_RESET
Telecommand packet, application data: None.

When the service provider receives this request, it shall reset the command schedule as follows (this is considered to be the "default" starting state):

    a. It shall clear all entries in the command schedule. The command schedule shall be disabled.

    b. It shall reset the scheduling event information.

4.4.1.3 Inserting telecommands in the command schedule

The request to insert (e.g. add) one or more telecommands in the Command Schedule shall be:

Insert Telecommands in Command Schedule (11, 4)

Name: TC_S11_INSERT

Telecommand packet, application data:

Absolute Time Tag	Telecommand Packet
Absolute Time 5 octets	Any TC

Absolute Time Tag (PTC=9, PFC=16):

> Time at which the telecommand packet shall be sent to its destination application process.

Telecommand Packet:

> This is a standard telecommand packet of any service type and subtype, (see sub clause 5.3 for the structure of a telecommand). This can be a telecommand destined for an on-board operations scheduling service, either this one or another instance of the same service implemented in another application process.

When this request is received, each telecommand in the request shall be processed in turn and, if no error is detected during its processing, it shall be added to the command schedule.

An error shall occur, if:

a.   the command schedule is full;

b.   the destination application process of the telecommand is invalid;

c.   the time specification refers to the past;

d.   the time specification is not supported by the service;

e.   a telecommand packet with the same APID and Sequence Count already exists in the scheduler;

4.4.1.4   Deleting telecommands from the command schedule

4.4.1.4.1   General

There are several ways of deleting a subset of the telecommands from the command schedule. The subsets are specified according to selection criteria.

> EXAMPLE *Telecommands whose absolute schedule time falls within a specified time period.*

If an error is detected during the processing of a request, nothing shall be deleted.

4.4.1.4.2   Deleting telecommands

The request to delete sets of telecommands from the command schedule shall be:

Delete Telecommands (11, 5)

Name: TC_S11_DEL_TC

Telecommand packet, application data:

APID	Sequence Count	Number of Telecommands
Enumerated 2 octet	Unsigned Integer 2 octets	Unsigned Integer 2 octets

APID (PTC=2, PFC=16):

  Application process ID of the first telecommand packet which shall be deleted.

Sequence Count (PTC=3, PFC=12):

  The sequence count of the first telecommand packet to be sent to the specified destination application process which shall be deleted.

  The (APID, Sequence Count) pair uniquely identifies a Telecommand packet.

Number of Telecommands (PTC=3, PFC=12):

  The number of successive telecommand packets sent by the source to the specified destination application process which shall be deleted.

When this request is received, all telecommands which satisfy the selection criteria defined by the APID, Sequence Count and the Number of Telecommands shall be deleted. An error shall occur if the first telecommand to be deleted is not found in the command schedule. If the Number of Telecommands exceeds the total number of commands that satisfy the selection criteria, then all commands that satisfy the selection criteria shall be deleted.

4.4.1.4.3   Deleting telecommands over a time period

The request shall be:

Delete Telecommands over Time Period (11, 6)

Name: TC_S11_DEL_TC_TP

Telecommand packet, application data:

Range	Time Tag 1	Time Tag 2
Enumerated 1 octet	Absolute Time 5 octets	Absolute Time 5 octets

←——— Optiona ———→
←——————— Optional ———————→
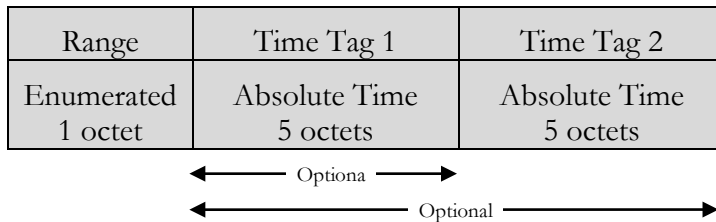
Range (PTC=2, PFC=8):

> This indicates that the time period is:
>
> a. from the beginning to the end of the command schedule if Range is "All" (value = 0); or
>
> b. between Time Tag 1 and Time Tag 2 inclusive if Range is "Between" (value = 1); or
>
> c. less than or equal to Time Tag 1 if Range is "Before" (value = 2); or
>
> d. greater than or equal to Time Tag 1 if Range is "After" (value = 3).

Time Tag 1 (PTC=9, PFC=16):

> The earliest absolute time if Range is "Between" or "After". The latest absolute time if Range is "Before". This parameter shall not be present if Range is "All".

Time Tag 2 (PTC=9, PFC=16):

> The latest absolute time if Range is "Between". This parameter shall not be present if Range is not "Between".

4.4.1.5   Time-shifting of telecommands in the command schedule

4.4.1.5.1   General

There are several ways of time-shifting a subset of the telecommands in the command schedule. The time-shift request shall contain the time offset to be added (which can be a positive or negative value) and shall specify the selection of telecommands to which this time-offset is applied.

If an error is detected during the processing of a request, nothing shall be time-shifted.

4.4.1.5.2   Time-shifting all telecommands

The request to time-shift all telecommands in the command schedule shall be:

Time-Shift All Telecommands (11, 15)

Name: TC_S11_SHIFT_ALL

Telecommand packet, application data

Time Offset
Relative Time 4 octets

Time Offset (PTC=10, PFC=10):

   The positive or negative interval of time of the time shift.

When this request is received, the release times for all telecommands in the command schedule which have an absolute release time shall be modified by adding the specified time offset.

Those telecommands whose absolute release times are not yet known are not time-shifted.

4.4.1.5.3   Time-shifting selected telecommands

The request to time-shift a selected subset of telecommands in the command schedule shall be:

Time-Shift Selected Telecommands (11, 7)

Name: TC_S11_SHIFT_TC

Telecommand packet, application data:

Time Offset	APID	Sequence Count	Number of Telecommands
Relative Time 4 octets	Enumerated 2 octet	Unsigned Integer 2 octets	Unsigned Integer 2 octets

Time Offset (PTC=10, PFC=10):

   The positive or negative interval of time of the time shift.

APID (PTC=2, PFC=16):

   Application process ID of the first telecommand packet which shall be time shifted.

Sequence Count (PTC=3, PFC=12):

   The sequence count of the first telecommand packet to be sent to the specified destination application process which shall be time shifted.

   The (APID, Sequence Count) pair uniquely identifies a Telecommand packet.

Number of Telecommands (PTC=3, PFC=12):

   The number of successive telecommand packets sent by the source to the specified destination application process which shall be time shifted.

When this request is received the release times in the command schedule shall be time-shifted for those telecommands which meet the selection criteria defined by the specified APID, Sequence Count and Number of Telecommands. An error shall occur if the first telecommand to be time-shifted is not found in the command schedule. Those telecommands whose absolute release times are not yet known are not time-shifted.

4.4.1.6   Summary reporting of the command schedule

The request to obtain a summary report of all telecommands in the command schedule shall be:

Report Command Schedule in Summary Form (11, 17)

Name: TC_S11_REPORT

Telecommand packet, application data: None

When this request is received, a summary schedule report (see below) shall be generated containing all telecommands in the command schedule.

Summary Schedule Report (11, 13)
Telemetry source packet, source data:

N	Absolute Time Tag	APID	Sequence Count
Unsigned Integer 2 octets	Absolute Time 5 octets	Enumerate 2 octet	Unsigned Integer 2 octets

← Repeated N Time →

N (PTC=3, PFC=12):

  The number of telecommand in the schedule.

Absolute Time Tag (PTC=9, PFC=16):

   Time at which the telecommand packet shall be sent to its destination application process.

APID (PTC=2, PFC=16):

   Application process ID of the telecommand packet.

Sequence Count (PTC=3, PFC=12):

   Sequence count of the telecommand packet.

4.5 Large Data Transfer service (Service Type 13)

4.5.1 Service concept

This service allows transferring large data from the ground to the CubeSat.

It shall split the original Service Data Unit (SDU) in fixed size parts and send the parts one by one, and in order. Each part shall be transmitted within a single telecommand packet as illustrated below.

PH : Packet Header

DFH : Data Field Header
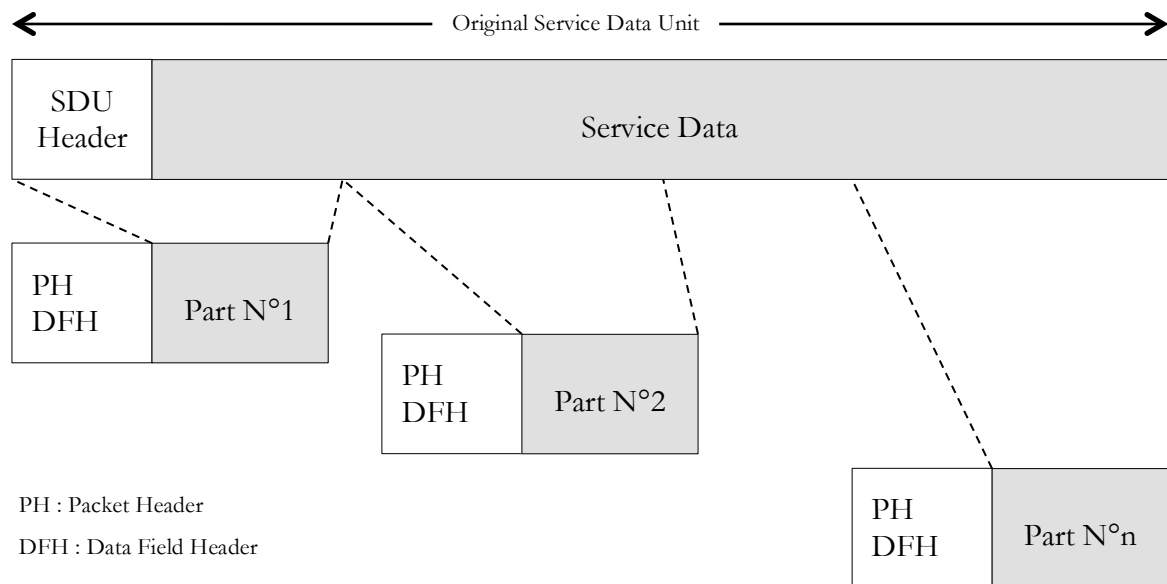
The sending and receiving sub-service providers shall use the same definition of the size of the parts (Parts Size). The parts shall have equal size (except possibly the last part), which shall be less than the maximum size of the source data field of a telecommand source packet.

The standard offers the use of "Extended Packets" exceeding the size limitation, 65535 octets, of regular packets. This is achieved via an additional UnitType field and a special interpretation of the Length field. This special type of packet is not supported by the SCS. There shall therefore not be a UnitType field preceding the regular telecommand structure.

4.5.1.1 Error Codes

In addition to the error codes defined in section 4.1.1.1 for the **Telecommand Acceptance Report - Failure (1, 2)**, the following service-specific codes are used for telecommands defined in this service:

6 = illegal transfer state.

7 = illegal sequence number.

8 = invalid data part (size).

4.5.2 Service requests and reports

4.5.2.1 Transferring the first part of a service data unit

Accept First Uplink Part (13, 9)

Name: TC_S13_UP_FP

Telecommand packet, application data:

Large Data Unit ID	Sequence Number	Service Data Unit Part
Enumerated 1 octet	Unsigned Integer 1 octet	Fixed Octet String

Large Data Unit ID (PTC=2, PFC=8):

> This uniquely identifies the service data unit which is the subject of the transfer.

> More specifically, this identifies the memory where the data should be transferred (this explain which script [value 0-2] is actually transferring.)

Sequence Number (PTC=3, PFC=4):

> This is a unique identification for this part of the service data unit. By convention, the sequence number of the first part shall be 1. The sequence number shall then be incremented by one for each part which is subsequently transferred.

Service Data Unit Part (PTC=7, PFC=variable):

> This is the first part of the service data unit. Its size shall always be equal to the part size in use.

The ground segment shall use this request to send the first part of the data to be uplinked.

On reception of the part, the receiving sub-service provider shall update its context and initiate a reception timer.

4.5.2.2 Transferring an intermediate part of a service data unit

Accept Intermediate Uplink Part (13, 10)

Name: TC_S13_UP_IP

Telecommand packet, application data:

Same as for (13, 9).

The ground segment shall use this request to send an intermediate part of the data to be uplinked.

The sending sub-service provider shall initiate an acknowledgement timer if this part is the last part which can be sent in the current sliding window.

On reception of the part, the receiving sub-service provider shall update its context and initiate a reception timer.

4.5.2.3 Transferring the last part of a service data unit

Accept Last Uplink Part (13, 11)

Name: TC_S13_UP_LP

Telecommand packet, application data:

Same as for (13, 9).

The ground segment shall use this request to send the last part of the data to be uplinked.

The sending sub-service provider shall always initiate an acknowledgement timer.

On reception of the part, the receiving sub-service provider shall update its context and immediately notify the sending sub-service provider of what is the "last successfully received part" at this point.

4.5.2.4 Transfer abort initiated by the sending end

Abort Reception of Uplinked Data (13, 13)

Name: TC_S13_UP_ABORT

Telecommand packet, application data:

Large Data Unit ID	Reason Code
Enumerated 1 octet	Enumerated 1 octet

Reason Code (PTC=2, PFC=8):

> This indicates the reason for the transfer abort. Codes are to be defined by the teams to fit with their on-board software.

4.5.2.5 Acknowledging the successful reception up to a part

Uplink Reception Acknowledgement Report (13, 14)

Name: TM_S13_PART_SUCCESS

Telemetry source packet, source data:

Large Data Unit ID	Sequence Number
Enumerated 1 octet	Unsigned Integer 1 octet

The receiving sub-service provider shall use this notification to indicate to the sending sub-service provider that it has successfully received all parts of the large service data unit up to and including the part with the indicated sequence number.

4.5.2.6 Transfer abort initiated by the receiving end

Reception Abort Report (13, 16)

Name: TM_S13_UP_ABORT

Telemetry source packet, source data:

Large Data Unit ID	Reason Code
Enumerated 1 octet	Enumerated 1 octet

Reason Code (PTC=2, PFC=8):

This indicates the reason for the transfer abort. Codes are to be defined by the teams to fit with their on-board software.

4.6 On-board storage and retrieval service (Service Type 15)

4.6.1 Service requests and reports

4.6.1.1 Controlling the storage

The requests shall be:

Enable Storage in Packet Stores (15, 1)

Name: TC_S15_EN

Telecommand packet, application data:

Disable Storage in Packet Stores (15, 2)

Name: TC_S15_DI

Telecommand packet, application data:

Store ID
Enumerated 1 octet

Store ID (PTC=2, PFC=8):

The identifier of the on-board packet store.

4.6.1.2 Downlinking the contents of a packet store for a specified time period

4.6.1.2.1 Downlinking the full contents of the packet store

Downlink Packet Store Contents for Time Period (15, 9)

Name: TC_S15_DWL_PKT

Telecommand packet, application data:

Store ID	Time Span
Enumerated	Enumerated

1 octet	1 octet

Store ID (PTC=2, PFC=8):

The identifier of the on-board packet store.

Time Span (PTC=2, PFC=8):

Value = 0 (All)

4.6.1.2.2 Downlinking the packets stored during a time range

Downlink the packets stored between Storage Time 1 and Storage Time 2 inclusive.

Downlink Packet Store Contents for Time Period (15, 9)
Name: TC_S15_DWL_TP
Telecommand packet, application data:

Store ID	Time Span	Storage Time 1	Storage Time 2
Enumerated 1 octet	Enumerated 1 octet	Absolute Time 5 octets	Absolute Time 5 octets

Store ID (PTC=2, PFC=8):

   The identifier of the on-board packet store.

Time Span (PTC=2, PFC=8):

   Value = 1 (Between)

Storage Time 1, Storage Time 2 (PTC=9, PFC=16):

   The absolute times defining the boundaries of the range of packets to be downlinked. The format and length of these parameters are described in chapter 7.3.6 *Absolute Time (PTC = 9)*.

4.6.1.2.3 Downlinking the packets stored before an absolute time

Downlink the packets stored less than or equal to Storage Time 1.

Downlink Packet Store Contents for Time Period (15, 9)
Name: TC_S15_DWL_BEFOR
Telecommand packet, application data:

Store ID	Time Span	Storage Time 1
Enumerated 1 octet	Enumerated 1 octet	Absolute Time 5 octets

Store ID (PTC=2, PFC=8):

   The identifier of the on-board packet store.

Time Span (PTC=2, PFC=8):

   Value = 2 (Before)

Storage Time 1 (PTC=9, PFC=16):

   The absolute time defining the boundary of the range of packets to be downlinked. The format and length of this parameter is described in chapter 7.3.6 *Absolute Time (PTC = 9)*.

4.6.1.2.4   Downlinking the packets stored after an absolute time

Downlink the packets stored greater than or equal to Storage Time 1.

Downlink Packet Store Contents for Time Period (15, 9)
Name: TC_S15_DWL_AFTER
Telecommand packet, application data:

Store ID	Time Span	Storage Time 1
Enumerated 1 octet	Enumerated 1 octet	Absolute Time 5 octets

Store ID (PTC=2, PFC=8):

  The identifier of the on-board packet store.

Time Span (PTC=2, PFC=8):

  Value = 3 (After)

Storage Time 1 (PTC=9, PFC=16):

  The absolute time defining the boundary of the range of packets to be downlinked. The format and length of this parameter is described in chapter 7.3.6 *Absolute Time (PTC = 9)*.

Remark: The telemetries stored are downlinked directly into a dedicated virtual channel, exactly as received by the packet store.

4.6.1.3   Transfer abort

The report to notify of that a transfer abort during a download operation shall be:

Abort transfer (15, 128)
Name: TC_S15_ABORT
Telecommand packet, application data:

Store ID
Enumerated 1 octet

Store ID (PTC=2, PFC=8):

  The identifier of the on-board packet store.

5.1 Payload Services (Service Type 128, 129 & 130)

5.1.1 Scope

The Payload Services are mission-specific services add-on to the standard ECSS-E-70-41A services. In the QB50 project, each team has one of three Science Units (SU):

- INMS
- FIPEX
- MNLP.

The payload of the CubeSat is one of those three units and for each unit a new service was defined. It allows each unit to define specific structure of data to be downlinked.

5.1.2 Service concept

The payload of the CubeSat provides raw data from the SU. The data structure of each SU is described in the specific ICD of the SU (INMS, FIPEX, MNLP). [N3]

The service is a response to a request to download science data.

The service 15 allows manipulating the on-board memory and storage. It can be used to store science data and retrieve it on ground through. The mission-specific services only define the content of the downlinked packets.

5.1.3 INMS Payload (Service Type 128)

5.1.3.1 Download data

The telemetry to get a science available data packet which is on-board should be:

Downlink Data (128, 1)
Name: TM_S128_DOWNLINK
Telemetry source packet, source data:

SCIENCE DATA
521 octets

SCIENCE DATA (PTC=7, PFC=521):

   Fixed size data field. The detail of the parameter is described in the ICD of the INMS [N3].

5.1.4 FIPEX Payload (Service Type 129)

5.1.4.1 Download data

The telemetry to get a science available data packet which is on-board should be:

Downlink Data (129, 1)
Name: TM_S129_DOWNLINK
Telemetry source packet, source data:

<table>
<tr><td>SCIENCE DATA</td></tr>
<tr><td>255 octets</td></tr>
</table>

SCIENCE DATA (PTC=7, PFC=255):

Fixed size data field. The detail of the parameter is described in the ICD of the FIPEX [N3].

5.1.5 MNLP Payload (Service Type 130)

5.1.5.1 Download data

The telemetry to get a science available data packet which is on-board should be:

Downlink Data (130, 1)
Name: TM_S130_DOWNLINK
Telemetry source packet, source data:

<table>
<tr><td>SCIENCE DATA</td></tr>
<tr><td>511 octets</td></tr>
</table>

SCIENCE DATA (PTC=7, PFC=511):

Fixed size data field. The detail of the parameter is described in the ICD of the MNLP [N3].

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7   ANNEX A: PARAMETER TYPES

7.1   Introduction

Each field in a telecommand or telemetry packet described in this document is designed to hold a parameter value. Each parameter field has a type, defining the set of values that can be assigned to the parameter. The parameter types used by the mission are defined below.

This annex defines the physical encoding rules for each type, i.e. the permitted lengths of the parameter fields and the internal format used to encode values. This annex does not define the conversion of data parameters into physical or engineering units or user messages.

When defining telecommand and telemetry packets only parameter types defined in this section shall be allowed.

7.2   Encoding Formats of Parameter Types

The parameter type defines the range of possible parameter values. A given parameter type can vary in format and length. Each combination of parameter type and encoding format has an associated parameter code, which defines the type and its physical encoding.

The parameter code shall be used whenever a definition of a parameter field is required. The parameter codes shall be applicable to both telecommand and telemetry data.

The parameter code PC, is defined as follows:

Parameter Type Code (PTC)	Parameter Format Code (PFC)
enumerated	enumerated

The parameter code is written as (PTC, PFC) in the next subchapter.

7.3 Parameter Type Definitions

7.3.1 Boolean (PTC = 1)

PFC = 0

This is a one-bit parameter, with two distinguished values only, involved in logical operations where:

value 1 denotes "TRUE"

value 0 denotes "FALSE".

7.3.2 Enumerated Parameter (PTC = 2)

PFC = 1, 2, 3, 4, 8, and 16: length in bits of the parameter values

This is a parameter, with discrete integer values only, involved in logical and comparative expressions (but not in numeric and relational expressions). The values that such a parameter can take are discrete and unordered. Each value has a meaning which is interpreted as a character string value. An error code is a typical example (e.g. 0 means "unchecked", 3 means "invalid").

7.3.3 Unsigned Integer (PTC = 3)

The values that this parameter can take are positive and can be involved in arithmetical, relational and comparative expressions. An unsigned integer shall be encoded with Bit-0 being the most significant bit (MSB) and Bit-N-1 the least significant bit (LSB).

The formats of an unsigned integer shall be:

Format Code	Format Definition	Lowest Value	Highest Value
$0 \leq PFC \leq 12$	PFC +4 bits, unsigned	0	$2^{PFC+4}-1$ (15 to 65 535)
PFC = 13	3 octets, unsigned	0	$2^{24}-1$ (16 777 215)
PFC = 14	4 octets, unsigned	0	$2^{32}-1$ ($\approx 4{,}3*10^9$)
PFC = 15	6 octets, unsigned	0	$2^{48}-1$ ($\approx 2{,}8*10^{14}$)
PFC = 16	8 octets, unsigned	0	$2^{64}-1$ ($\approx 18{,}5*10^{18}$)

7.3.4 Signed integer parameter (PTC = 4)

The values that such a parameter can take are positive or negative and can be involved in arithmetical, relational and comparative expressions.

- If Bit-0 = 0, the value shall be positive following the unsigned integer convention.

- If Bit-0 = 1, the value shall be negative and the field is the 2's complement of the positive value.

The formats of a signed integer shall be:

Format Code	Format Definition	Lowest Value	Highest Value
$0 \leq PFC \leq 12$	PFC +4 bits, signed	-2^{PFC+3} (-8 to -32 768)	$2^{PFC+3}-1$ (7 to 32 767)
PFC = 13	3 octets, signed	-2^{23} (-8 388 608)	$2^{23}-1$ (8 388 607)
PFC = 14	4 octets, signed	-2^{31} ($\approx -2,15*10^9$)	$2^{31}-1$ ($\approx 2,15*10^9$)
PFC = 15	6 octets, signed	-2^{47} ($\approx -1,4*10^{14}$)	$2^{47}-1$ ($\approx 1,4*10^{14}$)
PFC = 16	8 octets, signed	-2^{63} ($\approx -9,2*10^{18}$)	$2^{63}-1$ ($\approx 9,2*10^{18}$)

7.3.5 Octet String (PTC = 7)

PFC = 0:   A variable-length octet string.

PFC > 0:   A fixed-length octet string with a number of octets equal to PFC.

The values that such a parameter can take are variable-length or fixed-length sequences of octets, each octet being an ordered sequence of eight bits. The meaning and interpretation of a value shall be application process specific.

A variable-length octet-string parameter shall be of the form:

n	O_1	O_2	- - - - -	O_n
Unsigned Integer	octet	octet		octet

Where:

O1....On   are octets;

n   indicates the number of octets which follow.

A fixed-length octet-string parameter is of the form:

O_1	O_2	- - - -	O_n
1 octet	1 octet		1 octet

Where:

O1....On   are octets;

n   is the number of octets and is equal to PFC.

7.3.6 Absolute Time (PTC = 9)

PFC = 16:   The CUC format with ((PFC +1) / 4, rounded down coarse time, (PFC +1) % 4 of fine time) thus 4 octets of coarse time and 1 octet of fine time.

The value of an Absolute Time parameter field shall be a number of seconds and fractions of second from a given Agency epoch. It shall be a positive time offset.

CUC format

The full CUC Format shall be as follows:

C_1	C_2	C_3	C_4	F_1
1 octet	1 octet	1 octet	1 octet	1 octet

The time in seconds from the given Agency epoch is given by:

$t = C_1 * 256^3 + C_2 * 256^2 + C_3 * 256 + C_4 + F_1 * 256^{-1}$

7.3.7 Relative Time (PTC = 10)

PFC = 10:   The CUC format with ((PFC +3) / 4, rounded down) thus 3 octets of coarse time and ((PFC +1) modulo 4) thus 1 octet of fine time.

The value of a Relative Time parameter field shall be a number of seconds and fractions of a second from the occurrence time of an event whose identification can be derived from other parameters in the packet (e.g. identifying a type of on-board event) or a number of seconds and fractions of a second between two absolute times. It can be a positive or negative time offset.

The full CUC Format shall be as follows:

C_2	C_3	C_4	F_1
1 octet	1 octet	1 octet	1 octet

A time offset in seconds is given by:

$t = C_2 * 256^2 + C_3 * 256 + C_4 + F_1 * 256^{-1}$

where C_2 is in the range -128 to 127.

A negative time offset is expressed as the "2's complement" of the corresponding positive time offset

8   ANNEX B: SERVICE TYPE AND SUBTYPE ALLOCATION

[1]: to reduce on-board complexity, the ADCS and Payload subsystems don't support the telecommand packet format but have their own interface. The CDMS translate the Function Management Service telecommands packets to internal function calls and generates the corresponding acknowledgments; but this is done transparently from the point of view of the ground and there those subsystem can be used as a telecommand destination and appear as a source of telemetry.

Telecommand/Telemetry Service	COM	EPS	CDMS	ADCS	PL
Service 1: Telecommand verification service					
TM 1, 1 Telecommand Acceptance Report - Success	Yes	Yes	Yes	Yes[1]	Yes[1]
TM 1,2 Telecommand Acceptance Report - Failure	Yes	Yes	Yes	Yes[1]	Yes[1]
TM 1, 3 Telecommand Execution Started Report - Success	Yes	Yes	Yes	Yes[1]	Yes[1]
TM 1, 4 Telecommand Execution Started Report - Failure	Yes	Yes	Yes	Yes[1]	Yes[1]
TM 1, 7 Telecommand Execution Completed Report - Success	Yes	Yes	Yes	Yes[1]	Yes[1]
TM 1, 8 Telecommand Execution Completed Report - Failure	Yes	Yes	Yes	Yes[1]	Yes[1]
Service 3: Housekeeping & diagnostic data reporting					
TC 3, 5 Enable Housekeeping Parameter Report Generation			Yes		
TC 3, 6 Disable Housekeeping Parameter Report Generation			Yes		
TM 3, 25 Housekeeping Parameter Report	Yes	Yes	Yes	Yes[1]	Yes[1]
Service 8: Function management					
TC 8,1 Perform Function	Yes	Yes	Yes	Yes[1]	Yes[1]

Service 11: On-board operations scheduling

TC 11, 1 Enable Release of Telecommands			Yes		
TC 11, 2 Disable Release of Telecommands			Yes		
TC 11, 3 Reset Command Schedule			Yes		
TC 11, 4 Insert Telecommands in Command Schedule			Yes		
TC 11, 5 Delete Telecommands			Yes		
TC 11, 6 Delete Telecommands over Time Period			Yes		
TC 11, 15 Time-Shift All Telecommands			Yes		
TC 11, 7 Time-Shift Selected Telecommands			Yes		
TC 11, 17 Report Command Schedule in Summary Form			Yes		
TM 11, 13 Summary Schedule Report			Yes		

Service 15: On-board storage and retrieval service

TC 15, 1 Enable Storage in Packet Stores			Yes		
TC 15, 2 Disable Storage in Packet Stores			Yes		
TM 15, 8 Packet Store Contents Report			Yes		

Service 128: Payload Service

TC 128,1 Downlink data			Yes		

Service 129: Payload Service

TC 129,1 Downlink data			Yes		

Service 130: Payload Service

TC 130,1 Downlink data			Yes		