Elysium Radio Data Link Layer - Space Data Link Protocols

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1 Overview

The Space Data Link Protocols (SDLP) are a group of CCSDS Recommended Standards defining the Data Link Layer services of a space link. They are used by many NASA and ESA missions. Four different SDLP standards exist - TM (Telemetry), TC (Telecommand), AOS (Advanced Orbiting Systems), and Prox-1 (Proximity-1 Space Link Protocol). The Elysium radio supports the TM and TC protocols, using TM for downlink (transmission) and TC for uplink (reception).

The Elysium does not currently support the Space data Link Security Protocol. If your mission requires the SDLS protocol, please contact Adamant to discuss adding suport.

Registers associated with the SDLP Data Link Layer subsystem can be found in Section 2. Channels, Errors, and Events associated with the SDLP Data Link Layer subsystem can be found in Section 3, Section 4, and Section 5, respectively.

1.1 TM Protocol

The TM protocol makes use of either one Master Channel or one or more multiplexed Virtual Channels to transfer fixed-length Transfer Frames over a Physical Channel. A Synchronization and Channel Coding Sublayer optionally encodes the TF using one of several types of FEC.

The Elysium makes use of 2 independent Virtual Channels, referred to as VC0 and VC1. Lower numbered VCs are treated as higher-priority channels. “Live” data (data coming in over the UART interface) uses VC0, while “logged” data being read out of on board storage uses VC1.

When used with the Space Packet Protocol Networking Layer, the Virtual Channel Packet service is used to transfer the Live packets over Virtual Channel 0. When used with other Networking Layer protocols, either the Virtual Channel Packet service with the Encapsulation packet standard or the Virtual Channel Access service may be used. The Virtual Channel Access service is always used to transfer “logged” telemetry on VC1. See the Standard for more details.

TM Transfer Frames are transmitted sequentially in order and without gaps. The timing of release is “mission-specific” according to the standard. The Elysium takes the approach that Transfer Frames are sent as quickly as possible for as long as there is data available to be sent. When all available data has been sent, the radio will cease transmission to conserve power. When data is being downlinked due to a GetTelem command, a single OID frame will be sent at the end of the Duration specified in the GetTelem command to signify the end of telemetry data.

OID frames will also be generated to serve as beacon frames in certain fault scenarios.

The TM Synchronization and Channel Coding Sublayer standard (CCSDS Recommended Standard 131.0-B-2) defines a large number of FEC encodings for use with TM space links. At present, only the rate 1/2 convolutional coding is supported. However, additional encodings are constantly under development. If your mission requires a particular FEC encoding, please contact Adamant to discuss adding support for it.

The data randomizer specified in the Synchronization and Channel Coding Sublayer is also optionally supported.

1.2 TC Protocol

The TC protocol makes use of either one Master Channel or one or more multiplexed Virtual Channels to transfer variable-length Transfer Frames over a Physical Channel. A Synchronization and Channel Coding Sublayer optionally encodes the TF using a modified BCH code for either error detection or error correction.

The TC protocol also specifies the optional use of Multiplexer Access Points (MAPs). The Elysium does not support the use of MAPs.

The Elysium makes use of a single Virtual Channel, referred to as VC0, for uplink data under the TC protocol.

When used with the Space Packet Protocol Networking Layer, the Virtual Channel Packet service is used to transfer the packets over the Virtual Channels. When used with other Networking Layer protocols, either the Virtual Channel Packet service with the Encapsulation packet standard or the Virtual Channel Access service may be used. See the Standard for more details.

The TC standard also makes reference to the COP-1 standard (CCSDS 232.1-B-2) which provides an ARQ functionality for TC frames by using the OCF field of the returning TM packets to serve as an acknowledgement function. The Frame Acceptance and Reporting Mechanism from COP-1 is optionally available on the Elyisum radio. The returned information occupies 8 bytes of each TM transfer frame. See the Standards for more details.

The TC Synchronization and Channel Coding Sublayer standard (CCSDS 231.0-B-2) specifies a modified BCH code for either error detection or error correction. The Elysium supports decoding of BCH-coded data in either error detection or error correction modes.

The data randomizer specified in the Synchronization and Channel Coding Sublayer is also optionally supported.

2 Registers

This section defines the registers in Table 1, which apply to the SDLP Data Link Layer.

Table 1: SDLP Registers

Address	*Name*	*Description*
0xC0	TFLength0	Transfer Frame Length LSB
0xC1	TFLength1	Transfer Frame Length MSB
0xC2	TMFEC	Telemetry FEC Configuration Bitfields
0xC3	TCFEC	Telecommand FEC Configuration Bitfields
0xC4	Options	General Configuration Bitfields

Table 1: SDLP Registers

Address	*Name*	*Description*
0xC5	MaxPacketLength0	Maximum Packet Size LSB
0xC6	MaxPacketLength1	Maximum Packet Size MSB
0xC7	WindowLength	FARM Sliding Window Length
0xC8	MaximumInterval	FARM Maximum Reporting Interval
0xC9	IDs0	Spacecraft and Virtual Channel IDs LSB
0xCA	IDs1	Spacecraft and Virtual Channel IDs MSB
0xCB	FECLvl	FEC Error Reporting Level
0xCC	FECFLvl	FECF Error Reporting Level
0xCD	MissedFrameLvl	Missed Frame Error Reporting Level
0xCE	LockoutLvl	Lockout Error Reporting Level
0xCF	DoubleFrameLvl	Duplicate Frame Error Reporting Level
0xD0	InvalidIDLvl	Invalid ID Error Reporting Level
0xD1	ShortFrameLvl	Short Frame Error Reporting Level
0xD2	LongFrameLvl	Long Frame Error Reporting Level
0xD3	WaitLvl	Wait State Error Reporting Level
0xD4	SDLPErrRpt	SDLP Error Reporting Bitfields

2.1 TFLength[0-1]

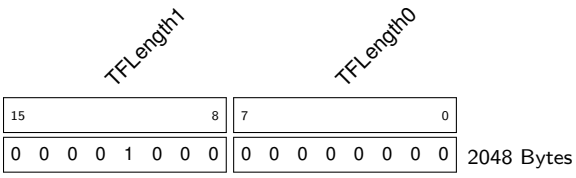
Address: 0xC0

Data Type: uint16_t

Description: The TFLength register contains the length of a downlink (TM) transfer frame as a 16-bit unsigned integer in bytes.

Diagram:

Register 2.1: TFLENGTH (0xC0)



Fields:

- TFLength1 - MSB - 0xC1
- TFLength0 - LSB - 0xC0

Recommended Value: 1024 bytes, unless required by FEC.

Notes: The valid range for this register is from 7 to 2048 bytes. Other restrictions may be imposed by the choice of error correction coding for the TM link.

2.2 TMFEC

Address: 0xC2

Data Type: Bitfields

Description: The TMFEC register contains the settings for Forward Error Correction coding for the TM link.

Diagram:

Register 2.2: TMFEC (0xC2)

Fields:

- FECF - Frame Error Control Field - 0xC2.7
- RS Errors - Reed-Solomon Error Correction - 0xC2.6
- RS Interleave - Reed-Solomon Interleaving - 0xC2.3
- Conv. Rate - Convolutional Coding Rate - 0xC2.0

Recommended Value: Rate 1/2 Convolutional coding, without Frame Error Control Field.

Notes: When the FECF bit is set, the Frame Error Control Field is used to detect errors in Transfer Frames on the TM channel. This setting is independent of other FEC settings.

The RS Errors bit controls the level of error correction provided by the Reed-Solomon encoding schemes. When the RS Errors bit is set, the RS code used can correct 16 symbol errors. When the RS Errors bit is not set, the RS code used can correct 8 symbol errors.

The RS Intervleave bitfield controls the level of interleaving being performed by the Reed-Solomon encoder. The values of this bitfield are as shown below.

000 - RS encoding is entirely disabled.

001 - Interleave depth of 1

010 - Interleave depth of 2

011 - Interleave depth of 3

100 - Interleave depth of 4

101 - Interleave depth of 5

110 - Interleave depth of 8

111 - Invalid - clipped to 110

The Conv. Rate bitfield specifies the rate used for the (possibly punctured) convolutional coding applied to TM frames. The values of this bitfield are as shown below.

000 - Convolutional coding is entirely disabled

001 - Coding is punctured to rate 7/8

010 - Coding is punctured to rate 5/6

011 - Coding is punctured to rate 3/4

100 - Coding is punctured to rate 2/3

101 - Unpunctured rate 1/2 coding is used

110 - Invalid - clipped to 101

111 - Invalid - clipped to 101

Both the convolutional and Reed-Solomon codes may be used simultaneously (concatenated coding). In this case, the Reed-Solomon code is the *outer* code, while the convolutional code is the *inner* code

See the TM Synchronization and Channel Coding standard for more details of the specific codes used.

Only rate 1/2 convolutional coding is supported at the time of this writer. Contact Adamant if you require support for punctured or Reed-Solomon coding.

2.3 TCFEC

Address: 0xC3

Data Type: Bitfields

Description: The TCFEC register contains the settings for Forward Error Correction coding for the TC link.

Diagram:

Register 2.3: TCFEC (0xC3)

Fields:

- FECF - Frame Error Control Field - 0xC3.7
- Res. - Reserved. These bits are ignored. - 0xC3.3
- BCH Mode - BCH decoding mode - 0xC3.0

Recommended Value: Error correcting BCH coding, without Frame Error Control Field.

Notes: When the FECF bit is set, the Frame Error Control Field is used to detect errors in Transfer Frames on the TC channel. This setting is independent of other FEC settings.

The reserved bits are ignored - they may be safely set to any value.

The BCH Mode bitfield controls the operating mode of the BCH decoder. The values of this bitfield are as shown below.

00 - BCH encoding is not used, BCH decoder is entirely disabled

01 - BCH decoder operates in Triple Error Detection (TED) mode

10 - BCH decoder operates in Single Error Correction (SEC) mode

11 - Invalid - clipped to 11

See the TC Synchronization and Channel Coding standard for more details of the specific codes used.

2.4 Options

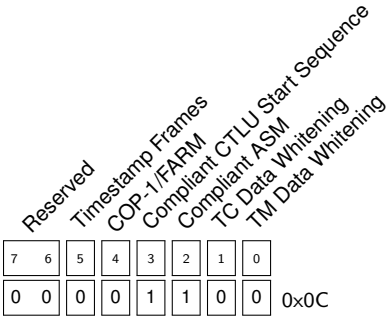
Address: 0xC4

Data Type: Bitfields

Description: The Options register contains the settings for optional components of both the TM and TC links, other than FEC.

Diagram:

Register 2.4: OPTIONS (0xC4)



Fields:

- Res. - Reserved. These bits are ignored. - 0xC4.6
- Timestamp Frames - Optional packet timestamping - 0xC4.5
- COP-1/FARM - Enable uplink delivery assurance - 0xC4.4
- Compliant CTLU Start Sequence - Standard uplink sync word - 0xC4.3
- Compliant ASM - Standard downlink sync word - 0xC4.2
- TC Data Whitening - Data whitening on uplink - 0xC4.1
- TM Data Whitening - Data whitening on downlink - 0xC4.0

Recommended Value: Data whitening on uplink and downlink, compliant sync words, FARM active, no timestamp.

Notes: The reserved bits are ignored - they may be safely set to any value.

When the Timestamp Packets bit is set, all TM frames sent by the Elysium will use the MC_FSH service to include a 4-byte timestamp of the Mission Time at which the frame was sent.

When the COP-1/FARM bit is set, the Frame Acceptance and Reporting Mechanism (FARM) specified in the COP-1 standard is used to allow for ARQ functionality on the uplink Virtual Channel. Note that the Communications Link Control Words (CLCWs) required by COP-1 are transmitted using the VC_OCF service on downlink Virtual Channel 0.

When the Compliant CTLU Start Sequence bit is set, the sync word used by the receiver to detect uplinked frames will be set to the standard value of 0xEB90 specified in the TC Synchronization and Channel Coding standard, regardless of the setting in the RXSync register.

When the Compliant ASM bit is set, the sync word added by the transmitter to allow the ground station to detect downlinked frames will be set to the value specified in the TM Synchronization and Channel Coding standard for the current FEC configuration, regardless of the setting in the TXSync register.

When the TC Data Whitening bit is set, the data dewhitening procedure specified in the TC Synchronization and Channel Coding standard will be applied to all received TC frames.

When the TM Data Whitening bit is set, the data whitening procedure specified in the TM Synchronization and Channel Coding standard will be applied to all transmitted TM frames.

See the relevant standards for more details.

2.5 MaxPacketLength[0-1]

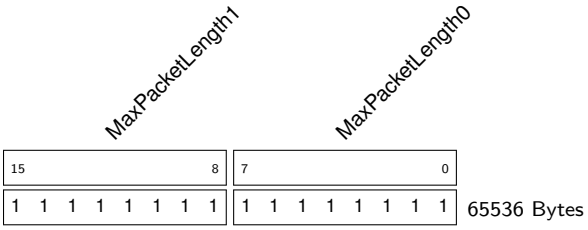
Address: 0xC5

Data Type: uint16_t

Description: The MaxPacketLength register contains the maximum length of a packet transferred over the SDLP Data Link Layer as a 16-bit unsigned integer in bytes, minus one.

Diagram:

Register 2.5: MAXPACKETLENGTH (0xC5)



Fields:

- MaxPacketLength1 - MSB - 0xC6
- MaxPacketLength0 - LSB - 0xC5

Recommended Value: Depends on Network Layer protocol - at least 1500 bytes for IP-based protocols, 8192 bytes for the Space Packet Protocol.

Notes: This register contains the maximum length of a packet *minus one*. That is, a value of 127 in this register allows a packet of length 128.

The valid range for this register is from 0 to 65535, or from 1 to 65536 bytes. Other restrictions may be imposed by the choice of Network Layer.

2.6 WindowLength

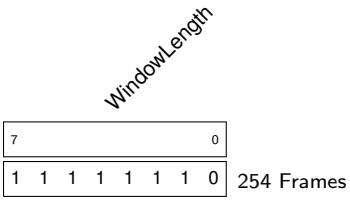
Address: 0xC7

Data Type: uint8_t

Description: The WindowLength register contains the length of the sliding window used by the FARM mechanism for ARQ functionality. It must be an even number.

Diagram:

Register 2.6: WINDOWLENGTH (0xC7)



Fields:

- WindowLength - Window length - 0xC7

Recommended Value: Depends on mission requirements - 16 is often appropriate.

Notes: This is the total window length used by the FARM. The window is divided into a positive and a negative region, with sequence numbers falling outside the window being in the Lockout region. Because of this, the length of the window must be an even number of bytes.

See the COP-1 standard for more details.

2.7 MaximumInterval

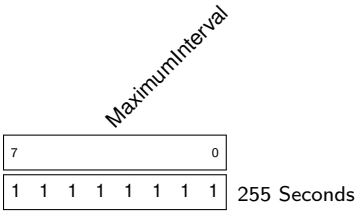
Address: 0xC8

Data Type: uint8_t (s)

Description: The MaximumInterval register contains the maximum length of time which the FARM may go without reporting back to the ground station through the Communications Link Control Word (CLCW).

Diagram:

Register 2.7: MAXIMUMINTERVAL (0xC8)



Fields:

- MaximumInterval - Maximum FARM reporting interval - 0xC8

Recommended Value: Depends on mission requirements - 16 is often appropriate.

Notes: If an uplink frame has been received and no downlink frame has been sent for the duration specified in this register, an Only Idle Data (OID) frame will be transmitted containing the required CLCW.

See the TC and COP-1 standards for more details.

2.8 IDs[0-1]

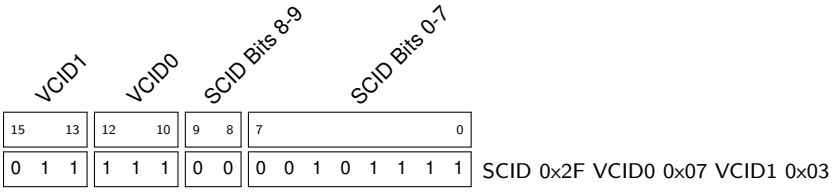
Address: 0xC9

Data Type: Bitfields

Description: The IDs register contains the Spacecraft ID and the Virtual Channel IDs used by the SDLP Data Link Layer.

Diagram:

Register 2.8: IDs (0xC9)



Fields:

- VCID1 - 3-bit Virtual Channel ID for VC1 - 0xCA.5
- VCID0 - 3-bit Virtual Channel ID for VC0 - 0xCA.2
- SCID - 10-bit Spacecraft ID - 0xC9

Recommended Value: N/A.

Notes: The same Spacecraft ID is used for both uplink and downlink.

The downlink Data Link Layer uses two Virtual Channels, identified by two 3-bit VCIDs, VCID0 and VCID1. The uplink Data Link Layer uses only one Virtual Channel, identified by one 6-bit VCID formed by concatenating VCID0 and VCID1 so that the most significant bit of VCID1 becomes the most significant bit of the new VCID and the least significant bit of VCID0 becomes the least significant bit of the new VCID.

2.9 FECLvl

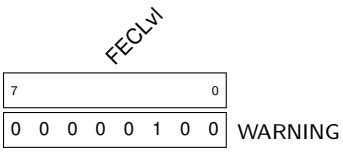
Address: 0xCB

Data Type: Priority Enumeration

Description: The FECLvl register controls the priority level of FEC error correction or detection events, if enabled by the FECRpt bit of the SDLPErrRpt register.

Diagram:

Register 2.9: FECLvl (0xCB)



Fields:

- FECLvl - Priority level of FEC error correction or detection errors - 0xCB

Recommended Value: WARNING

Notes: The acceptable values for this register are the valid values of the Priority Enumeration data type, a one-hot encoding using bits 0 through 4.

2.10 FECFLvl

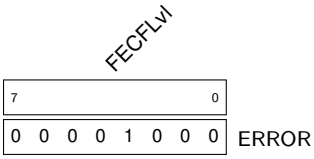
Address: 0xCC

Data Type: Priority Enumeration

Description: The FECFLvl register controls the priority level of FECF error detection events, if enabled by the FECFRpt bit of the SDLPErrRpt register.

Diagram:

Register 2.10: FECFLVL (0xCC)



Fields:

- FECFLvl - Priority level of FECF error detection errors - 0xCC

Recommended Value: ERROR

Notes: The acceptable values for this register are the valid values of the Priority Enumeration data type, a one-hot encoding using bits 0 through 4.

2.11 MissedFrameLvl

Address: 0xCD

Data Type: Priority Enumeration

Description: The MissedFrameLvl register controls the priority level of FARM missed frame detection events, if enabled by the MissedFrameRpt bit of the SDLPErrRpt register.

Diagram:

Register 2.11: MISSEDFRAMELVL (0xCD)

Fields:

- MissedFrameLvl - Priority level of FARM missed frame detection errors - 0xCD

Recommended Value: ERROR

Notes: The acceptable values for this register are the valid values of the Priority Enumeration data type, a one-hot encoding using bits 0 through 4.

2.12 LockoutLvl

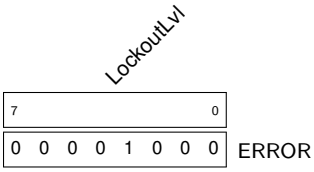
Address: 0xCE

Data Type: Priority Enumeration

Description: The LockoutLvl register controls the priority level of FARM lockout events, if enabled by the LockoutRpt bit of the SDLPErrRpt register.

Diagram:

Register 2.12: LOCKOUTLVL (0xCE)



Fields:

- LockoutLvl - Priority level of FARM lockout errors - 0xCE

Recommended Value: ERROR

Notes: The acceptable values for this register are the valid values of the Priority Enumeration data type, a one-hot encoding using bits 0 through 4.

2.13 DoubleFrameLvl

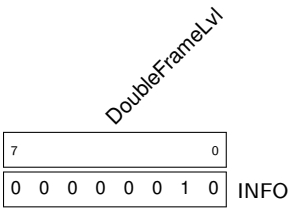
Address: 0xCF

Data Type: Priority Enumeration

Description: The DoubleFrameLvl register controls the priority level of FARM multiple reception events, if enabled by the DoubleFrameLvl bit of the SDLPErrRpt register.

Diagram:

Register 2.13: DOUBLEFRAMELVL (0xCF)



Fields:

- DoubleFrameLvl - Priority level of duplicate frame reception errors - 0xCF

Recommended Value: INFO

Notes: The acceptable values for this register are the valid values of the Priority Enumeration data type, a one-hot encoding using bits 0 through 4.

2.14 InvalidIDLvl

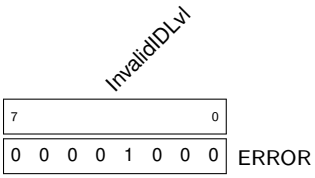
Address: 0xD0

Data Type: Priority Enumeration

Description: The InvalidIDLvl register controls the priority level of invalid Transfer Frame ID reception events, if enabled by the InvalidIDRpt bit of the SDLPErrRpt register.

Diagram:

Register 2.14: INVALIDIDLVL (0xD0)



Fields:

- InvalidIDLvl - Priority level of invalid Transfer Frame ID reception errors - 0xD0

Recommended Value: ERROR

Notes: The acceptable values for this register are the valid values of the Priority Enumeration data type, a one-hot encoding using bits 0 through 4.

2.15 ShortFrameLvl

Address: 0xD1

Data Type: Priority Enumeration

Description: The ShortFrameLvl register controls the priority level of invalid Transfer Frame length events where fewer bytes are received than indicated by the Transfer Frame Length field, if enabled by the LengthRpt bit of the SDLPErrRpt register.

Diagram:

Register 2.15: SHORTFRAMELVL (0xD1)

Fields:

- ShortFrameLvl - Priority level of short Transfer Frame reception errors - 0xD1

Recommended Value: ERROR

Notes: The acceptable values for this register are the valid values of the Priority Enumeration data type, a one-hot encoding using bits 0 through 4.

2.16 LongFrameLvl

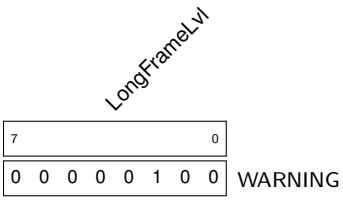
Address: 0xD2

Data Type: Priority Enumeration

Description: The LongFrameLvl register controls the priority level of invalid Transfer Frame length events where more bytes are received than indicated by the Transfer Frame Length field, if enabled by the LengthRpt bit of the SDLPErrRpt register.

Diagram:

Register 2.16: LONGFRAMELVL (0xD2)



Fields:

- LongFrameLvl - Priority level of long Transfer Frame reception errors - 0xD2

Recommended Value: WARNING

Notes: The acceptable values for this register are the valid values of the Priority Enumeration data type, a one-hot encoding using bits 0 through 4.

2.17 WaitLvl

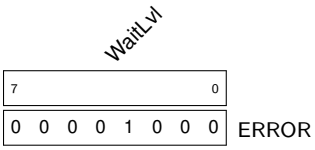
Address: 0xD3

Data Type: Priority Enumeration

Description: The WaitLvl register controls the priority level of FARM insufficient buffer events, if enabled by the WaitRpt bit of the SDLPErrRpt register.

Diagram:

Register 2.17: WAITLVL (0xD3)



Fields:

- WaitLvl - Priority level of FARM insufficient buffer errors - 0xD3

Recommended Value: ERROR

Notes: The acceptable values for this register are the valid values of the Priority Enumeration data type, a one-hot encoding using bits 0 through 4.

2.18 SDLPErrRpt

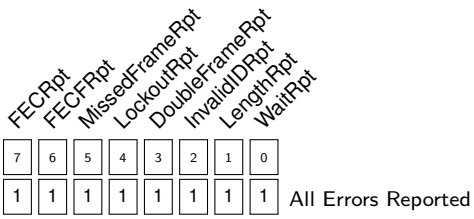
Address: 0xD4

Data Type: Bitfields

Description: The SDLPErrRpt register contains a number of bitfields controlling the reporting of errors within the SDLP Data Link Layer.

Diagram:

Register 2.18: SDLPERRRPT (0xD4)



Fields:

- FECRpt - Enables reporting of FEC error correction or detection - 0xD4.7
- FECFRpt - Enables reporting of FECF error detection - 0xD4.6
- MissedFrameRpt - Enables reporting of missed frame errors - 0xD4.5
- LockoutRpt - Enables reporting of FARM lockout errors - 0xD4.4
- DoubleFrameRpt - Enables reporting of repeat frame reception errors - 0xD4.3
- InvalidIDRpt - Enables reporting of invalid Transfer Frame ID errors - 0xD4.2
- LengthRpt - Enables reporting of incorrect Transfer Frame Length errors - 0xD4.1
- WaitRpt - Enables reporting of FARM insufficient buffer errors - 0xD4.0

Recommended Value: If the spacecraft contains a flight computer which is capable of taking action to correct errors, in general all errors should be reported.

Notes: When the FECRpt bit is set, anytime the FEC decoder decoding the binary BCH coding on the uplink channel corrects or detects an error, the decoder will report an error with the priority level defined in the FECLvl register.

When the FECFRpt bit is set, anytime the Frame Error Control Field check on the uplink channel detects an error, an error will be reported with the priority level defined in the FECFLvl register.

When the MissedFrameRpt bit is set, anytime the FARM on the uplink channel detects a missed frame, an error will be reported with the priority level defined in the MissedFrameLvl register.

When the LockoutRpt bit is set, anytime the FARM on the uplink channel receives a Transfer Frame which sends it into the Lockout state, an error will be reported with the priority level defined in the LockoutLvl register.

When the DoubleFrameRpt bit is set, anytime the FARM on the uplink channel detects a repeat frame, an error will be reported with the priority level defined in the DoubleFrameLvl register.

When the InvalidIDRpt bit is set, anytime a Transfer Frame is received on the uplink channel which has an invalid SCID or VCID, an error will be reported with the priority level defined in the InvalidIDLvl register.

When the LengthRpt bit is set, anytime a Transfer Frame is received on the uplink channel which contains a number of bytes different than the number specified in the Transfer Frame Length field, an error will be reported. The error will have the priority level defined in the ShortFrameLvl register if fewer bytes are received than expected, or the priority level defined in the LongFrameLvl register if more bytes are received than expected.

When the WaitRpt bit is set, when the FARM on the uplink channel receives a Transfer Frame for which no buffer is available, sending the FARM state machine into the Wait state, an error will be reported with the priority level defined in the WaitLvl register.

3 Channels

Table 2: Channels

ID	*Name*	*Data Type*
0x70	FEC Corrections/Detections	uint8_t
0x71	FECF Detections	uint8_t
0x72	Receiver Frame Sequence Number V(R)	uint8_t
0x73	Missed Frames	uint8_t
0x74	Double Receptions	uint8_t
0x75	Type-A Frames Received	uint8_t
0x76	Type-B Frames Received	uint8_t

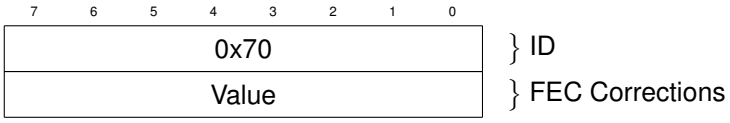
3.1 FEC Corrections/Detections

Channel ID: 0x70

Data Type: uint8_t

Description: The FEC Corrections/Detections Channel reports the number of FEC corrections or detections (depending on the value of the BCH Mode field of the TCFEC register).

Format:



Notes: This counter increases monotonically until it rolls over from 255 to 0.

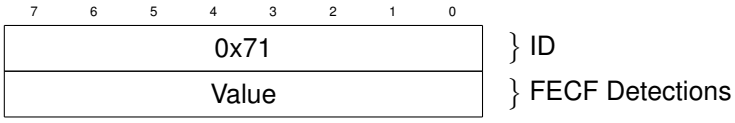
3.2 FECF Detections

Channel ID: 0x71

Data Type: uint8_t

Description: The FECF Detections Channel reports the number of errors detected by the CRC value stored in the Frame Error Control Field of uplink frames, if enabled by the FECF field of the TCFEC register.

Format:



Notes: This counter increases monotonically until it rolls over from 255 to 0.

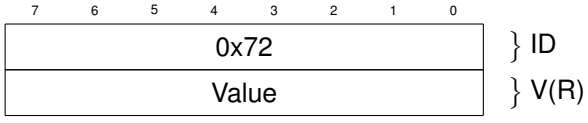
3.3 Receiver Frame Sequence Number V(R)

Channel ID: 0x72

Data Type: uint8_t

Description: The Receiver Frame Sequence Number Channel contains the Receiver Frame Sequence Number, called V(R) in the TC and COP-1 standards. This is the value of Frame Sequence Number, or N(S), expected to be seen in the next Type-AD Transfer Frame on the uplink Virtual Channel.

Format:



Notes: This counter increases monotonically as Transfer Framse are accepted until it rolls over from 255 to 0 or is modified by a “Set V(R)” command as defined in the COP-1 standard.

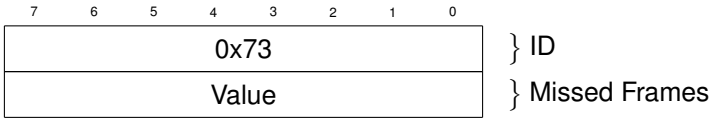
3.4 Missed Frames

Channel ID: 0x73

Data Type: uint8_t

Description: The Missed Frames Channel contains the number of frames that have been missed on the uplink channel as detected by the FARM.

Format:



Notes: When a Transfer Frame is received which has a sequence number greater than the current value of V(R), this counter is increased by the difference between the received sequence number N(S) and the current value of V(R).

This counter increases monotonically until it rolls over from 255 to 0.

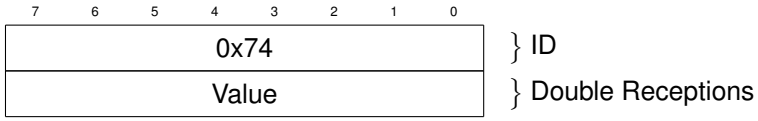
3.5 Double Receptions

Channel ID: 0x74

Data Type: uint8_t

Description: The Double Receptions Channel contains the number of frames that have been received twice on the uplink channel as detected by the FARM.

Format:



Notes: When a Transfer Frame is received which has a sequence number less than the current value of V(R), this counter is increased by one.

This counter increases monotonically until it rolls over from 255 to 0.

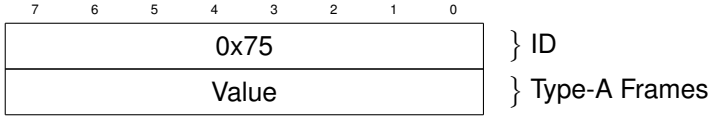
3.6 Type-A Frames Received

Channel ID: 0x75

Data Type: uint8_t

Description: The Type A Frames Received Channel contains the number of Type-A frames that have been received on the uplink channel.

Format:



Notes: This counter is incremented only when a Type-A frame is fully accepted (i.e., has passed all frame validation checks).

This counter increases monotonically until it rolls over from 255 to 0.

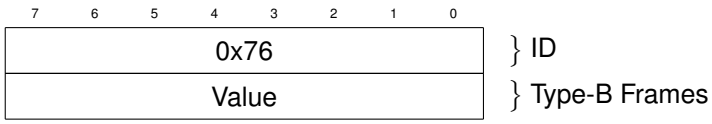
3.7 Type-B Frames Received

Channel ID: 0x76

Data Type: uint8_t

Description: The Type B Frames Received Channel contains the number of Type-B frames that have been received on the uplink channel.

Format:



Notes: This counter is incremented only when a Type-B frame is fully accepted (i.e., has passed the Frame Error Control Field check, if enabled).

This counter increases monotonically until it rolls over from 255 to 0.

4 Errors

Table 3: Errors

ID	*Error*
0xB0	FEC Correct/Detect
0xB1	FECF Detect

Table 3: Errors

ID	*Error*
0xB2	Missed Frame
0xB3	Lockout
0xB4	Double Reception
0xB5	Invalid Frame ID
0xB6	Frame Too Short
0xB7	Frame Too Long
0xB8	Wait

4.1 FEC Correct/Detect

Error ID: 0xB0

Description: The FEC Correct/Detect error indicates that the Forward Error Correction decoder on the uplink channel has corrected or detected an error (depending on the value of the BCH Mode field of the TCFEC register).

Fault Response? Transfer Frame discarded.

Recommended Priority: WARNING for correction, ERROR for detection.

Priority Register: FECLvl

4.2 FECF Detect

Error ID: 0xB1

Description: The FECF Detect error indicates that the Frame Error Control Field check on the uplink channel has detected an error.

Fault Response? Transfer Frame discarded.

Recommended Priority: ERROR

Priority Register: FECFLvl

4.3 Missed Frame

Error ID: 0xB2

Description: The Missed Frame error indicates that the FARM on the uplink channel has detected one or more missing frames.

Fault Response? None.

Recommended Priority: ERROR

Priority Register: MissedFrameLvl

4.4 Lockout

Error ID: 0xB3

Description: The Lockout error indicates that the FARM on the uplink channel has received a Transfer Frame with a sequence number outside of the sliding window and gone in the Lockout mode.

Fault Response? Transfer Frame discarded. No further Transfer Frames are accepted until the Unlock command described in the COP-1 standard is received.

Recommended Priority: ERROR

Priority Register: LockoutLvl

4.5 Double Reception

Error ID: 0xB4

Description: The Double Reception error indicates that the FARM on the uplink channel has received a Transfer Frame with a sequence number less than the expected sequence number - that is, a Transfer Frame which has already been received.

Fault Response? Transfer Frame discarded.

Recommended Priority: INFO

Priority Register: DoubleFrameLvl

4.6 Invalid Frame ID

Error ID: 0xB5

Description: The Invalid Frame ID error indicates that the radio has received a Transfer Frame with an invalid Spacecraft ID (SCID), Master Channel ID (MCID), or Virtual Channel ID (VCID).

Fault Response? Transfer Frame discarded.

Recommended Priority: ERROR

Priority Register: InvalidIDLvl

4.7 Frame Too Short

Error ID: 0xB6

Description: The Frame Too Short error indicates that the radio has received a Transfer Frame whose Length field contains a value larger than the number of received bytes.

Fault Response? Transfer Frame discarded.

Recommended Priority: ERROR

Priority Register: ShortFrameLvl

4.8 Frame Too Long

Error ID: 0xB7

Description: The Frame Too Long error indicates that the radio has received a Transfer Frame whose Length field contains a value smaller than the number of received bytes.

Fault Response? Excess bytes discarded.

Recommended Priority: WARNING

Priority Register: LongFrameLvl

4.9 Wait

Error ID: 0xB8

Description: The Wait error indicates that the radio has received a valid Transfer Frame, but no buffer space is available to store the Transfer Frame. If the FARM is active, the FARM state machine transitions to the Wait state.

Fault Response? Transfer Frame discarded

Recommended Priority: ERROR

Priority Register: WaitLvl

5 Events

Table 4: Events

ID	*Event*
0xF0	Receiver Sequence Number V(R) Changed

Table 4: Events

ID	*Event*
0xF1	Unlock
0xF2	Buffer Release

5.1 Receiver Sequence Number V(R) Changed

Event ID: 0xF0

Description: The Receiver Sequence Number V(R) Changed Event indicates that the current value of the Receiver Sequence Number - V(R) as defined in the COP-1 standard - has changed in a discontinuous way due to a “Set V(R)” command as defined in the COP-1 standard.

Notes: The new value of V(R) can be retrieved from the Receiver Frame Seuqence Number V(R) channel.

5.2 Unlock

Event ID: 0xF1

Description: The Unlock Event indicates that the FARM state machine has received the “Unlock” command as defined in the COP-1 standard and exited the Lock state, if required.

Notes: This event is reported whenever the Unlock command is received, regardless of whether the FARM state machine is in the Lock state.

5.3 Buffer Release

Event ID: 0xF2

Description: The Buffer Release Event corresponds to the Buffer Release Signal defined in the COP-1 standard and indicates that buffer space is now available for new Transfer Frames to arrive. The FARM state machine has also exited the Wait state.

Notes: This event is reported only when the FARM state machine is active.

A Revision History

1. Initial release