# Summary

This document provides details of downlink data for the AMSAT ESEO payload – based upon the FUNcube-1 spec for compatibility with the dashboard and data warehouse

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|  |  |

**Revision Record**

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| issue | date | total  pages | Authorisation | affected  pages | brief description of change |
| 1.1 DRAFT | 22.03.15 |  |  |  | Added details of where to look for extended sat-id. |
| 1.1 ESEO wip | 11.08.15 |  | Graham |  | Modified to reflect ESEO tlm. more work needed to finalise bit counts and channels in RT and WOD frames |
| 1.1f | 23.08.15 |  | Graham |  | Updated after discussions VZV/MRF and with FC team. pending further redefinitions on a skype Thursday 27th August |
| 1.1g | 24.08.15 |  | Duncan |  | Bit order defined – see section 2 |
| 1.1h | 28.08.15 |  | Graham |  | Revised after telcall. Agreed to concentrate on the RT and WOD coming from the EPS board directly and via the CAN bus from the RX & TX boards for the time being so that thermal testing can be undertaken asap  Also followed Duncan’s advice to make WOD frames parse better. |
| 1.1j | 28.08.15 |  | Graham |  | Various tweaks and move WOD frames |
| 1.1k | 18.06.16 |  | Chris, ALL |  | ESEO Workshop at Surrey Space Centre: Update RTT & WOD definitions for FSW & Dashboard |
| 1.1L | 28.06.2016 |  | Chris, David  (Skype) | ALL | Updated RTT, WOD, Schedule |
| 1.1M | 19.07.2016 |  | Chris, Pete |  | Defined 2B as payload\_header in 4k8 payload mode. Further edits from Skype call with team. |
| 1.1N | 16.11.2018 |  | Chris |  | Added temperature equations from 20 Nov 2018.  Added RF equations from ‘ESEO TLM ver 0.1e 04/10/2018.docx’  Corrected terminology in places. Added WOD eqns.  Issued as 1.21 |

**List of TBD’s and TBC’s**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *TBC/TBD* | *Location* | *Subject* | *Due date* | *Action by* |
| TBD |  | Internally generated CCT debug / status data |  | PB |
| TBC |  | Confirmation of platform EPS data via CAN |  | CPB, Done |
| TBD |  | Detail of data format and limits from science payloads. – e.g. How much memory holds current valid data. / Start - finish address |  | Internal |
| TBD |  | ESEO Platform Telemetry Equations |  | ESA |
| TBC |  | AMS Local Equations |  | CPB, Done |

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# List of Acronyms

ANT Antenna (board)

ADC Analogue to Digital Converter

ACS Attitude Control Subsystem

BCR Battery Charge Regulator

BPSK Binary Phase Shift Keying

CCT Command Control and Telemetry (board)

EPS Electrical Power Subsystem

FEC Forward Error Correction

MSE Material Science Experiment

PA Power Amplifier (board)

RF Radio Frequency (board)

RS Reed Solomon (error-correction code)

SW Software

TBC To Be Confirmed

TBD To Be Determined

TBW To Be Written

TCS Thermal Control Subsystem

TRX Transponder

# Overview

This document defines the data downlink format for the telemetry transmitted by the AMSAT payload on ESEO. Both the content of each downlink frame and the transmission order of the different frame types will be addressed.

The FEC encoding method and frame size remains unchanged from the original found here by James Miller:

<http://www.amsat.org/articles/g3ruh/125.html>

“The Telemetry uses 1200bps BPSK with both convolution and block coding based on the proven AMSAT OSCAR-40 FEC telemetry model. The encoding starts with a 256-byte (2048 bit) data frame, this is passed through a pair of RS (160,128) encoders, a scrambler, convolution encoder and the interleaver. This produces 5200 bits to transmit. Thus, ignoring pre- and post-amble, each data frame will take 4.3s to transmit”

|  |  |  |
| --- | --- | --- |
| ***8 bits***  ***Sat Id 8 bits Frame Type*** | ***432 bits***  ***Real Time Telemetry*** | ***1600 bits***  ***Payload*** |
| **2048 bits (256 byte) Frame** | | |

Each frame consists of an 8-bit satellite id and an 8-bit frame type indicator then 432 bits of real time data followed by 1600 bits of payload data. This results in the required total frame size of 2048 bits (256 bytes). The FEC encoded data (5200 bits) together with 700ms of idle tones fixes the frame transmission rate to one frame every five seconds.

Additionally, it is possible to configure the spacecraft to downlink debug status information in Fitter message

slot 5.

# Frame Types

All data is transmitted MSB first i.e. in “network byte order” and the first 16 bits of each frame will indicate the Satellite Identification number as well as defining the contents of the final 1600 bits of the frame. i.e. Fitter message number or whole orbit data frame number. Values for Sat ID and frame type can be found in the Transmission Schedule table at the end of the document.

Frame types:

* Whole orbit data.
* Fitter messages.

The RF modes are:

* 0x00: Receive only, with data collection
* 0x01: Low power BPSK telemetry mode
* 0x02: High power BPSK telemetry mode
* 0x03: Low power transponder mode
* 0x04: High power transponder mode
* 0x05: Autonomous Mode

The data mode flag complements the RF mode to accommodate various RF and data combinations to act as a redundant communications link for ESEO. These are:

* 0x00: AMS + ESEO at 1k2 (default)
* 0x01: AMS + ESEO + Payload at 4k8

Depending of which RF and data modes are selected, the transmission sequence may vary.

In the first data mode, the usual FUNcube frame of RTT and WOD will be adhered to within the typical 5 second transmission schedule. But in the second data mode, the data rate is increased allowing 4 FUNcube frames to be transmitted in the 5 seconds – again, still following the transmission schedule. The first frame will still adhere to the RTT + WOD sequencing, but the next 3 frames will be of payload data. If payload data is not available to fill these three 256B data slots, AMS Payload data will be repeated. These will be collected on the ground via the FUNcube Dashboard.

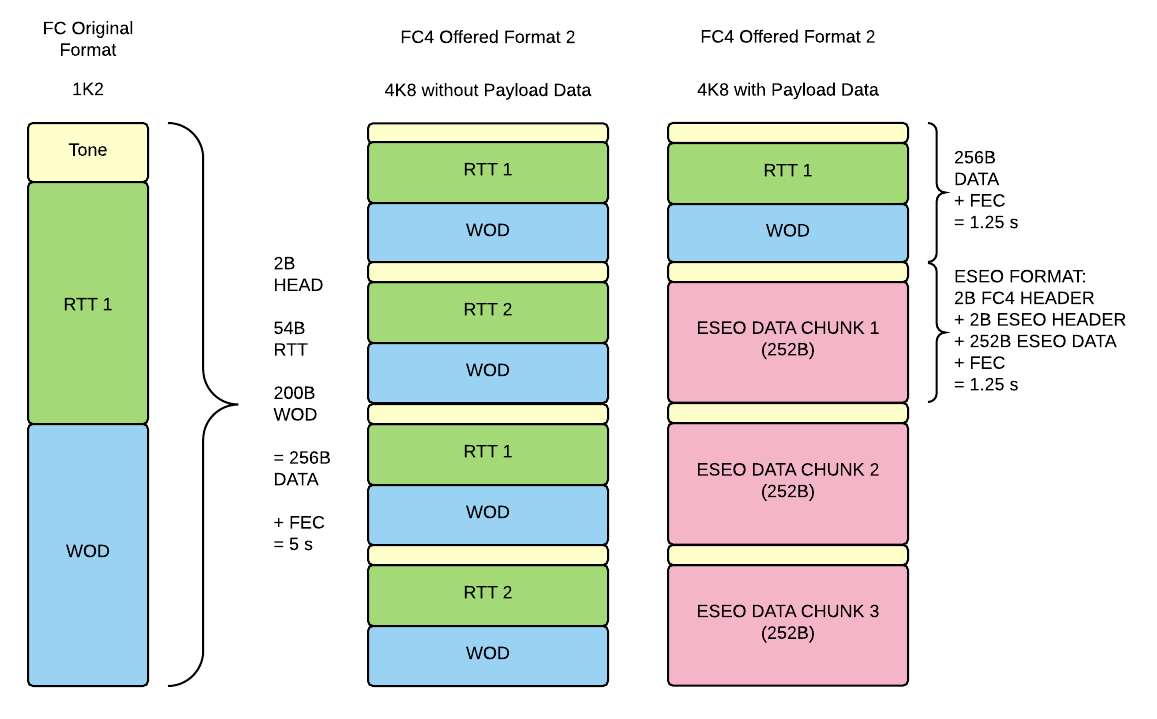


Figure 1. Offered 4k8 Mode: If Payload Data is empty / unused, the AMS will repeat existing telemetry

Real Time Telemetry

Each frame starts with Sat ID and frame type then 432 bits of real time data. This real-time data is updated every from sensors in the AMSAT Payload, from the AMSAT CCT board and from the ESEO platform housekeeping data.

Whole Orbit Data

This is intended to provide all the information required to demonstrate the physical and operational characteristics of the satellite over an entire orbit. The data will be sampled once per minute for 104 minutes and a full set of data is transmitted once every 24 frames or 2 minutes. Whole Orbit Data is received on the ground and presented in graphical form for educational outreach. Included are the battery voltage, system current and solar current collected together temperatures current and voltages from many subsystems.

Fitter Messages

These are the text messages received from ground stations to be periodically retransmitted within the 2 minutes telemetry sequence. Messages will not be broken up and sent over multiple frames, so the maximum length of a message is 200 bytes. The format of messages is transparent to the satellite, each received message will just be copied out verbatim.

Messages can be uploaded to specific AT32 memory slots with the slot id specified at upload time. After an upload attempt status bits in the Real Time Telemetry will be set to indicate the slot id and success or failure. An authentication (not encryption) scheme will be used to verify message validity.

# Extended Sat Id/Frame Types

To ensure the data format and transmission type can be used with multiple satellites the ID scheme allows the ground station to determine the Sat Identity.

The format of the first two bytes is shown below. Satellite ID and frame type information are contained within these 16 bits.

|  |  |
| --- | --- |
| Byte 0 | Byte 1 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sat ID | | Frame Type | | | | | | Sat ID | | | | | | | Frame Type | |
| S6 | S7 | F2 | F3 | F4 | F5 | F6 | F7 | | S0 | S1 | S2 | S3 | S4 | S5 | F0 | F1 |
| 1 | 1 | D | Variable | | | | | | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

The original two bits of Sat ID are the least significant bits of a byte of Sat ID data, and first six bits of Frame Type are now the least significant bits of a byte of Frame Type data. Frame Type 40 is used for debugging.

For ESEO payload transfer, F0 is set to 1 and the following 2B is for ESEO Science payload data which is a packet index (or counter) addressing 64 KB in 252B chunks (256B – 2B header – 2B packet index).

For satellites using this Extended Identification scheme, the overview diagram of a frame is:

|  |  |  |  |
| --- | --- | --- | --- |
| ***2 bits***  ***Sat Id 6 bits Frame Type*** | ***6 bits***  ***Sat Id 2 bits Frame Type*** | ***432 bits***  ***Real Time Telemetry*** | ***1600 bits***  ***Payload*** |
| **2048 bits (256 byte) Frame** | | | |

# Data Sources

AMSAT – The AMSAT payload via internal wiring and I2C

OBD – The main on-board data handling computer via CAN bus

STX – S Band transmitter

ACS – Attitude Control System

SSM – Sun Sensor main  
MWM – Momentum Wheel main

GPS – Global positioning system receiver

PMM – Power Management Unit main

# Data Collection/Transmission

This section details the rate at which data is collected and from which sensors. The table also defines the order and bit format for transmission.

**Real Time Telemetry: Total 448 bits / 56 bytes (inc 8 bits sat ID and 8 bits frame type)**

Collection Frequency: every 5 seconds (1K2) or 1.25 seconds (4K8)

Storage Count: 0 (real time!)

| **Bit total** | **Frame Type**  **+ SAT ID** | **Data Source** | **Data Type** | **Data Channel Name** |
| --- | --- | --- | --- | --- |
| 8 | 1 & 2 | Local | UNSIGNED8 | SAT ID 2 bits, Frame type 6 bits |
| 16 | 1 & 2 | Local | UNSIGNED8 | SAT ID 6 Bits, Frame type 2 bits |
| 24 | 1 & 2 | *AMSAT CCT* | UNSIGNED8 | EPS DC/DC Converter output voltage (10b)  0.100\*x V |
| 32 | 1 & 2 | *AMSAT CCT* | UNSIGNED8 | EPS DC/DC Converter output current (10b)  5.131579\*x mA |
| 40 | 1 & 2 | *AMSAT CCT* | UNSIGNED8 | EPS DC/DC Converter temperature (10b)  y = -0.7796212\*x + 98.19402 degC |
| 48 | 1 & 2 | *AMSAT CCT* | UNSIGNED8 | EPS Enclosure temperature (10b)  y = -0.7385868\*x + 97.74249 degC |
| 56 | 1 & 2 | *AMSAT CCT* | UNSIGNED8 | CCT Processor temperature (10b)  y = -0.7725984\*x + 94.95152 degC |
| 64 | 1 & 2 | *AMSAT CCT* | UNSIGNED8 | EPS 3.3 V Voltage (10b)  0.031141509\*x V |
| 72 | 1 & 2 | *AMSAT CCT* | UNSIGNED8 | EPS 3.3 V Current (10b)  3.75\*x mA |
| 80 | 1 & 2 | *AMSAT CCT* | UNSIGNED8 | EPS Transponder 6/9 V Voltage (10b)  0.0885753425\*x V |
| 88 | 1 & 2 | *AMSAT CCT* | UNSIGNED8 | EPS Transponder 6/9 V Current (10b)  y = (x-2) \* 2.5941175 mA |
| 96 | 1 & 2 | *AMSAT CCT* | UNSIGNED8 | EPS 9 V Voltage (10b)  0.088171498\*x V |
| 104 | 1 & 2 | *AMSAT CCT* | UNSIGNED8 | EPS 9 V Current (10b)  2.52778\*x mA |
| 112 | 1 & 2 | *AMSAT TX* | UNSIGNED8 | VHF transmitter forward power  y = 0.0136x2 + 0.4995x + 1E-12 |
| 120 | 1 & 2 | *AMSAT TX* | UNSIGNED8 | VHF transmitter reflected power  y = 0.0136x2 + 0.4995x + 1E-12 |
| 128 | 1 & 2 | *AMSAT TX* | UNSIGNED8 | FM power amplifier temperature (10b)  y = -0.789929\*x + 97.5934 degC |
| 136 | 1 & 2 | *AMSAT TX* | UNSIGNED8 | BPSK power amplifier temperature (10b)  y = -0.8104347\*x + 91.93637 degC |
| 144 | 1 & 2 | *AMSAT TX* | UNSIGNED8 | BPSK power amplifier current (10b)  y = 2.18x mA |
| 152 | 1 & 2 | *AMSAT TX* | UNSIGNED8 | BPSK 3.3V supply current (Osco + driver amp)  y = 0.8x V |
| 160 | 1 & 2 | *AMSAT RX* | UNSIGNED8 | L-Band transponder receiver RSSI (10b)  (See end of table) |
| 168 | 1 & 2 | *AMSAT RX* | UNSIGNED8 | L-Band command receiver RSSI (10b)  (See end of table) |
| 176 | 1 & 2 | *AMSAT RX* | UNSIGNED8 | L-Band command receiver Doppler (10b)  (See end of table) |
| 184 | 1 & 2 | *AMSAT RX* | UNSIGNED8 | L-Band CMD receiver oscillator temperature (10b)  y = -0.8592393\*x + 94.30121 degC |
| 192 | 1 & 2 | *AMSAT CCT* | UNSIGNED24 | Sequence number |
| 216 | 1 & 2 | *AMSAT CCT* | UNSIGNED8 | Last Command |
| 224 | 1 & 2 | *AMSAT CCT* | UNSIGNED3 | RF Mode:  0x00: Receive only, with data collection  0x01: Low power BPSK telem mode  0x02: High power BPSK telem mode  0x03: Low power transponder mode  0x04: High power transponder mode  0x05: Autonomous Mode |
| 227 | 1 & 2 | *AMSAT CCT* | UNSIGNED2 | Data Mode:  0x00: AMS + ESEO data mode at 1k2 (default)  0x01: AMS + ESEO data + Payload mode at 4k8 |
| 229 | 1 & 2 | *AMSAT CCT* | 1 | Payload Transfer Status:  0x00: Get data from payload  0x01: Downlink data to ground |
| 230 | 1 & 2 | *AMSAT CCT* | 1  1  1 | FM Transponder Status:  ESEO Eclipse State (0 = no, 1 = yes)  Autonomous Mode State (0 = A, 1 = B)  CTCSS Detect State (0 = OFF, 1 = ON) |
| 233 | 1 & 2 | *AMSAT CCT* | 1 | Safe mode state |
| 234 | 1 & 2 | *AMSAT CCT* | 1 | In Safe mode (over temperature protection - Traco) |
| 235 | Only 1 | *ESEO OBC* | UNSIGNED16 | PMM\_VOLTAGE\_SP1\_STRING\_1  Solar panel voltage for eclipse detection |
| 251 | Only 1 | *ESEO OBC* | UNSIGNED16 | PMM\_VOLTAGE\_SP2\_STRING\_1 |
| 267 | Only 1 | *ESEO OBC* | UNSIGNED16 | PMM\_VOLTAGE\_SP3\_STRING\_1 |
| 283 | Only 1 | *ESEO OBC* | UNSIGNED8 | ESEO OBD\_MODE  0x00: OBDH power up  0x01: AOCS initialization  0x02: AOCS damping  0x04: AOCS normal SUN  0x08: AOCS normal ECLIPSE  0x10: Safe mode S1: minor main bus power down  0x20: Safe mode S2: sever main bus power down  0x40: Safe mode S3: major main bus power down |
| 291 | Only 1 | *ESEO OBC* | UNSIGNED20 | ESEO OBD\_EQUIPMENT\_STATUS:  0: TMTC main ON/OFF  1: TMTC redundant ON/OFF  2: Power Management Unit main ON/OFF  3: Power Management Unit redundant ON/OFF  4: Sun sensor main ON/OFF  5: Sun sensor redundant ON/OFF  6: Earth sensor ON/OFF  7: Magnetometer main ON/OFF  8: Magnetometer redundant ON/OFF  9: Magnetic Torquer main ON/OFF  10: Magnetic Torquer redundant ON/OFF  11: Momentum Wheel main ON/OFF  12: Momentum Wheel redundant ON/OFF  13: TRITEL ON/OFF  14: Langmuir Probe ON/OFF  15: uCAM ON/OFF  16: De-orbit mechanism ON/OFF  17: AMSAT-UK ON/OFF (Always on)  18: S-Band ON/OFF  19: GPS receiver ON/OFF |
| 311 | Only 1 | *ESEO OBC* | UNSIGNED8 | OBD\_WD\_RESET\_COUNT |
| 319 | Only 1 | *ESEO OBC* | REAL32 | ACS\_OMEGA\_P (Roll, deg/s) |
| 351 | Only 1 | *ESEO OBC* | REAL32 | ACS\_OMEGA\_Q (Pitch, deg/s) |
| 383 | Only 1 | *ESEO OBC* | REAL32 | ACS\_OMEGA\_R (Yaw, deg/s) |
| 415 | Only 1 | *ESEO OBC* | UNSIGNED8 | STX\_TEMP\_4 (S-band Amplifier temperature) |
| 423 | Only 1 | *ESEO OBC* | UNSIGNED8 | PMM\_VOLTAGE\_MB (16b) (Main Bus Voltage) |
| Total | 431 bits | Spare = 1 bits |  |  |
| 235 | Only 2 | *ESEO OBC* | REAL32 | ACS\_ORBIT\_x (Orbital position) |
| 267 | Only 2 | *ESEO OBC* | REAL32 | ACS\_ORBIT\_y |
| 299 | Only 2 | *ESEO OBC* | REAL32 | ACS\_ORBIT\_z |
| 331 | Only 2 | *ESEO OBC* | UNSIGNED16 | PMM\_AMSAT\_CURRENT (16b) (AMSAT Switch current) |
| 347 | Only 2 | *ESEO OBC* | UNSIGNED8  (was 16) | MWM\_VOLTAGE (Momentum wheel Measured DC-link voltage) |
| 355 | Only 2 | *ESEO OBC* | UNSIGNED16 | MWM\_CURRENT (Momentum wheel Measured current) |
| 371 | Only 2 | *ESEO OBC* | UNSIGNED16 | MWM\_OMEGAMESURED (Measured rotation speed) |
| 387 | Only 2 | *ESEO OBC* | SIGNED16 | MPS\_HPT01 (High Pressure Transducer measures tank pressure) |
| 403 | Only 2 | *ESEO OBC* | SIGNED12 | PMM\_TEMP\_SP1\_SENS\_1 (Temp. of the solar panel 1) |
| 415 | Only 2 | *ESEO OBC* | SIGNED12 | PMM\_TEMP\_BP1\_SENS\_1 (Temp. of battery pack 1) |
| Total | 427 bits | Spare = 5 bits |  |  |

Equations for Transponder RSSI, Command RSSI and Command Doppler:

Transponder RSSI // Transponder RSSI  
double[,] valToAdc = { { -120, double.MinValue }, { -120, 108 }, { -118, 110 }, { -116, 112 }, { -115, 114 }, { -114, 116 }, { -113, 117 }, { -112, 118 }, { -111, 120 }, { -110, 122 }, { -109, 123 }, { -108, 124 }, { -107, 126 }, { -106, 128 }, { -105, 130 }, { -104, 131 }, { -103, 133 }, { -102, 134 }, { -101, 136 }, { -100, 137 }, { -99, 139 }, { -98, 140 }, { -96, 144 }, { -94, 147 }, { -92, 151 }, { -90, 154 }, { -88, 157 }, { -86, 159 }, { -84, 161 }, { -82, 163 }, { -80, 165 }, { -78, 168 }, { -76, 171 }, { -74, 174 }, { -72, 176 }, { -70, 178 }, { -68, 179 }, { -66, 180 }, { -64, 181 }, { -64, double.MaxValue } };  
  
Command RSSI // Command RSSI  
double[,] valToAdc = { { -120, double.MinValue }, { -120, 93 }, { -118, 95 }, { -117, 96 }, { -116, 98 }, { -114, 100 }, { -113, 101 }, { -112, 103 }, { -111, 104 }, { -109, 106 }, { -108, 108 }, { -107, 109 }, { -106, 110 }, { -105, 111 }, { -104, 113 }, { -103, 114 }, { -102, 116 }, { -101, 117 }, { -100, 118 }, { -99, 119 }, { -98, 121 }, { -96, 124 }, { -94, 127 }, { -92, 130 }, { -90, 133 }, { -88, 135 }, { -86, 136 }, { -84, 138 }, { -82, 140 }, { -80, 142 }, { -78, 145 }, { -76, 147 }, { -74, 150 }, { -72, 152 }, { -70, 153 }, { -68, 155 }, { -64, 156 }, { -64, double.MaxValue } };  
  
Command Doppler// Command Doppler  
double[,] valToAdc = { { -9.0, double.MinValue }, { -9.0, 140 }, { -8.0, 139 }, { -7.0, 138 }, { -6.0, 136 }, { -5.0, 134 }, { -4.0, 131 }, { -3.0, 128 }, { -2.0, 124 }, { -1.0, 120 }, { 0.0, 115 }, { +1.0, 110 }, { +2.0, 105 }, { +3.0, 100 }, { +4.0, 95 }, { +5.0, 91 }, { +6.0, 87 }, { +7.0, 84 }, { +8.0, 82 }, { +9.0, 80 }, { +10, 78 }, { +11, 77 }, { +12, 76 }, { +12, double.MaxValue } };

**Whole Orbit Data:**

Collection Frequency: Every 60 seconds

Storage Count: 100 (minutes)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Total Bits** | **Frame Type** | **Bits per src** | **Data Source** | **Bits Per Channel** | **Data Channel Name** |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***298***  ***Bits***  ***x***  ***100***  ***=***  ***3725 bytes*** | ***Whole Orbit Data***  ***298 bits*** | 88 | AMSAT  EPS | UNSIGNED8  UNSIGNED8  UNSIGNED8  UNSIGNED8  UNSIGNED8  UNSIGNED8  UNSIGNED8  UNSIGNED8  UNSIGNED8  UNSIGNED8  UNSIGNED8 | A: CCT Processor Temp. (10b)  y = -0.7725984\*x + 94.95152 degC  B: Enclosure temp. (10b)  y = -0.7385868\*x + 97.74249 degC  C: DCDC Converter temp. (10b)  y = -0.7796212\*x + 98.19402 degC  D: DCDC Supply Current (10b)  5.131579\*x mA  E: DCDC Supply Voltage (10b)  0.100\*x V  F: EPS 6/9V Transponder supply voltage (10b)  0.0885753425\*x V  G: EPS 9V Voltage (10b)  0.088171498\*x V  H: EPS 3V3 Voltage (10b)  0.031141509\*x V  I: EPS 6/9V Transponder supply current (10b)  y = (x-2) \* 2.5941175 mA  J: EPS 3V3 Current (10b)  3.75\*x mA  K: EPS 9V Current (10b)  2.52778\*x mA |
| 32 | AMSAT  L-RECEIVER | UNSIGNED8  UNSIGNED8  UNSIGNED8  UNSIGNED8 | L-Band transponder RSSI freq. (10b)  (See end of table)  L-Band command Doppler (10b)  (See end of table)  L-Band command RSSI (10b)  (See end of table)  L-Band command oscillator temp. (10b)  y = -0.8592393\*x + 94.30121 degC |
| 48 | AMSAT VHF TRANSMITTER | UNSIGNED8  UNSIGNED8  UNSIGNED8  UNSIGNED8  UNSIGNED8  UNSIGNED8 | A: BPSK PA temp. (10b)  y = -0.8104347\*x + 91.93637 degC  B: Forward power (10b)  y = 0.0136x2 + 0.4995x + 1E-12  C: Reverse power (10b)  y = 0.0136x2 + 0.4995x + 1E-12  D: BPSK PA Current (10b)  y = 2.18x mA  E: FM PA Current (10b)  y = 2.18x mA  F: FM PA temp. (10b)  y = -0.789929\*x + 97.5934 degC  G: <Unused>  H: <Unused> |
| 50 | AMSAT  CCT | UNSIGNED8  UNSIGNED4  UNSIGNED8  UNSIGNED13  UNSIGNED4  UNSIGNED13 | Command Watchdog time remaining (hours)  No. of uplink packets received (16b)  RAM Memory Error Count  CAN Bus Communications Status Packet 1:  ESEO Master, CANopen Transactions (32b)  AMS Master, Payload Number (4b),  AMS Master, CANopen Transactions (32b) |
| 48 | ESEO CAN  (EPS) | SIGNED8  SIGNED8  SIGNED8  SIGNED8  UNSIGNED16 | From AS-12\_0005-SYS-PLA-OBDH-AR-03.pdf:  PMM\_TEMP\_SP1\_SENS\_1 (16b), Solar panel 1 temperature  PMM\_TEMP\_SP2\_SENS\_1 (16b)  PMM\_TEMP\_SP3\_SENS\_1 (16b)  PMM\_CURRENT\_BP1 (16b), Battery pack 1 current  PMM\_VOLTAGE\_MB (16b), Main Bus Voltage |
| 32 | ESEO  CAN  (ADCS) | SIGNED32 | Absolute angular rotation (use ACS P, Q, R) |
| **(37.25 Bytes \* 100 Storage Count) = 3725 bytes** | | | | | |
|  | | | | | |
| **4000 bytes / 200 (payload size) = 20= Transmitted in 20 payloads** | | | | | |

Equations for Transponder RSSI, Command RSSI and Command Doppler:

Transponder RSSI // Transponder RSSI  
double[,] valToAdc = { { -120, double.MinValue }, { -120, 108 }, { -118, 110 }, { -116, 112 }, { -115, 114 }, { -114, 116 }, { -113, 117 }, { -112, 118 }, { -111, 120 }, { -110, 122 }, { -109, 123 }, { -108, 124 }, { -107, 126 }, { -106, 128 }, { -105, 130 }, { -104, 131 }, { -103, 133 }, { -102, 134 }, { -101, 136 }, { -100, 137 }, { -99, 139 }, { -98, 140 }, { -96, 144 }, { -94, 147 }, { -92, 151 }, { -90, 154 }, { -88, 157 }, { -86, 159 }, { -84, 161 }, { -82, 163 }, { -80, 165 }, { -78, 168 }, { -76, 171 }, { -74, 174 }, { -72, 176 }, { -70, 178 }, { -68, 179 }, { -66, 180 }, { -64, 181 }, { -64, double.MaxValue } };  
  
Command RSSI // Command RSSI  
double[,] valToAdc = { { -120, double.MinValue }, { -120, 93 }, { -118, 95 }, { -117, 96 }, { -116, 98 }, { -114, 100 }, { -113, 101 }, { -112, 103 }, { -111, 104 }, { -109, 106 }, { -108, 108 }, { -107, 109 }, { -106, 110 }, { -105, 111 }, { -104, 113 }, { -103, 114 }, { -102, 116 }, { -101, 117 }, { -100, 118 }, { -99, 119 }, { -98, 121 }, { -96, 124 }, { -94, 127 }, { -92, 130 }, { -90, 133 }, { -88, 135 }, { -86, 136 }, { -84, 138 }, { -82, 140 }, { -80, 142 }, { -78, 145 }, { -76, 147 }, { -74, 150 }, { -72, 152 }, { -70, 153 }, { -68, 155 }, { -64, 156 }, { -64, double.MaxValue } };  
  
Command Doppler// Command Doppler  
double[,] valToAdc = { { -9.0, double.MinValue }, { -9.0, 140 }, { -8.0, 139 }, { -7.0, 138 }, { -6.0, 136 }, { -5.0, 134 }, { -4.0, 131 }, { -3.0, 128 }, { -2.0, 124 }, { -1.0, 120 }, { 0.0, 115 }, { +1.0, 110 }, { +2.0, 105 }, { +3.0, 100 }, { +4.0, 95 }, { +5.0, 91 }, { +6.0, 87 }, { +7.0, 84 }, { +8.0, 82 }, { +9.0, 80 }, { +10, 78 }, { +11, 77 }, { +12, 76 }, { +12, double.MaxValue } };

**Fitter Messages:**

Collection Frequency: N/A

Storage Count: 4

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Total Bits** | **Frame Type** | **Bits per source** | **Data Source** | **Bits Per Channel** | **Data Chanel Name** |
| ***1600 bits***  ***200 bytes*** | ***Fitter Message Data*** | **1600** | **RAM** | 1600 | Fitter message |
| **(200 Bytes \* 4 Storage Count) = 800 bytes** | | | | | |
| **800 bytes / 200 (payload size) = 4 = Transmitted in 4 payloads** | | | | | |

# Transmission Schedule

The above data collection strategy results in:

20 Whole orbit frames

4 Fitter message frames

Each frame also contains the Real Time Telemetry information. The order of frames will be as shown below:

|  |  |  |
| --- | --- | --- |
| **Frame Type** | **Frame Type** | **Frame id** |
| RTT1 + Fitter Message | FM1 | 01 |
| RTT2 + Whole Orbit | W01 | 02 |
| RTT1 + Whole Orbit | W02 | 03 |
| RTT2 + Whole Orbit | W03 | 04 |
| RTT1 + Whole Orbit | W04 | 05 |
| RTT2 + Whole Orbit | W05 | 06 |
| RTT1 + Fitter Message | FM2 | 07 |
| RTT2 + Whole Orbit | W06 | 08 |
| RTT1 + Whole Orbit | W07 | 09 |
| RTT2 + Whole Orbit | W08 | 10 |
| RTT1 + Whole Orbit | W09 | 11 |
| RTT2 + Whole Orbit | W10 | 12 |
| RTT1 + Fitter Message | FM3 | 13 |
| RTT2 + Whole Orbit | W11 | 14 |
| RTT1 + Whole Orbit | W12 | 15 |
| RTT2 + Whole Orbit | W13 | 16 |
| RTT1 + Whole Orbit | W14 | 17 |
| RTT2 + Whole Orbit | W15 | 18 |
| RTT1 + Fitter Message | FM4 | 16 |
| RTT2 + Whole Orbit | W16 | 20 |
| RTT1 + Whole Orbit | W17 | 21 |
| RTT2 + Whole Orbit | W18 | 22 |
| RTT1 + Whole Orbit | W19 | 23 |
| RTT2 + Whole Orbit | W20 | 24 |

In 1K2 mode, each frame requires 5 seconds to transmit the sequence of frames and will repeat every 120 seconds (two minutes).