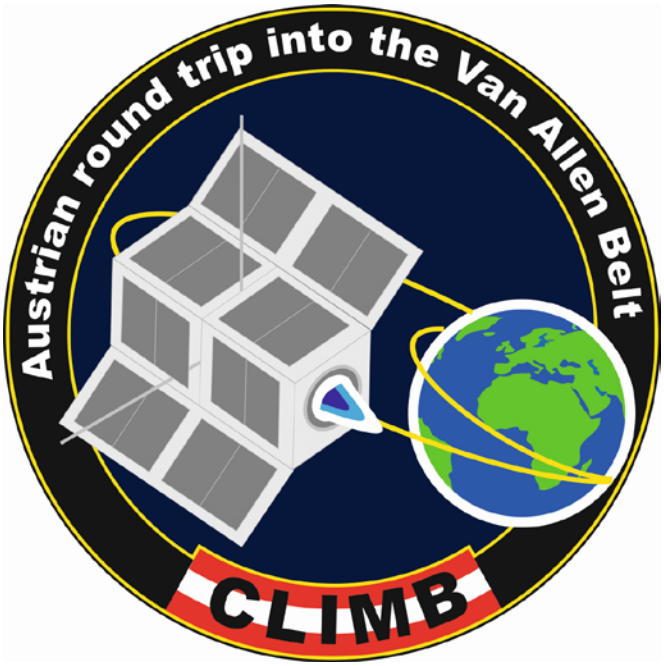

Manual for Radio-Amateurs

**for receiving and decoding
UHF (435-438 MHz) telemetry data of the
CLIMB satellite**

**This document is a preliminary version
and may be changed without notice!**

DOCUMENT CHANGE RECORD	
Project: CLIMB - Communication	
Change Status Log:	
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Abbreviations

ADCS	Attitude Control System
AID	Address Identifier
CALL	Call Sign (Ham Radio Call Sign) of the satellite
CRC	Cyclic Redundancy Checksum
E-Beacon	EPS-Beacon
EPS	Electrical Power System
FEC	Forward Error Correction (RS Code)
GPS	Global Positioning System
GS	Ground Station
IARU	International Amateur Radio Union
ILEOP	Initial Launch and Early Orbit Phase
LEOP	Launch and Early Orbit Phase
MCC	Mission Control Center
OBC	Onboard Computer
O-Beacon	OBC-Beacon
PCB	Printed Circuit Board
PID	Protocol Identifier
RS	Reed Solomon
RSSI	Received Signal Strength Indication
RTC	Real Time Clock
S-Beacon	STACIE-Δ-Beacon
SDC	Space Data Center
Side-P	Side Panels
STG-A	Space Tech Group Austria
STACIE-Δ	Space Telemetry And Command Interface UHF
TRX	Transceive, Transceiver
TX	Transmit, Transmitter
TT-64	Thomas Turetschek 64 byte protocol
WOD	Whole Orbit Data

1 Radio Engineering Parameter of CLIMB (UHF)

The satellite Pegasus is a 2U CubeSat with 2 redundant TRX modules on one PCB. This communication module is called STACIE-Δ. The two 90° crossed dipole antennas are used independently by the two TRX modules. STACIE-Δ is supplied by the two independent power busses of the satellite. Thus, the communication system of Pegasus is operating independently and redundantly.

Downlink Frequency	(435-438 MHz)
TX power max	30dBm, 1W
Modulation	GFSK
Polarisation	Linear
Protocol	TT-64

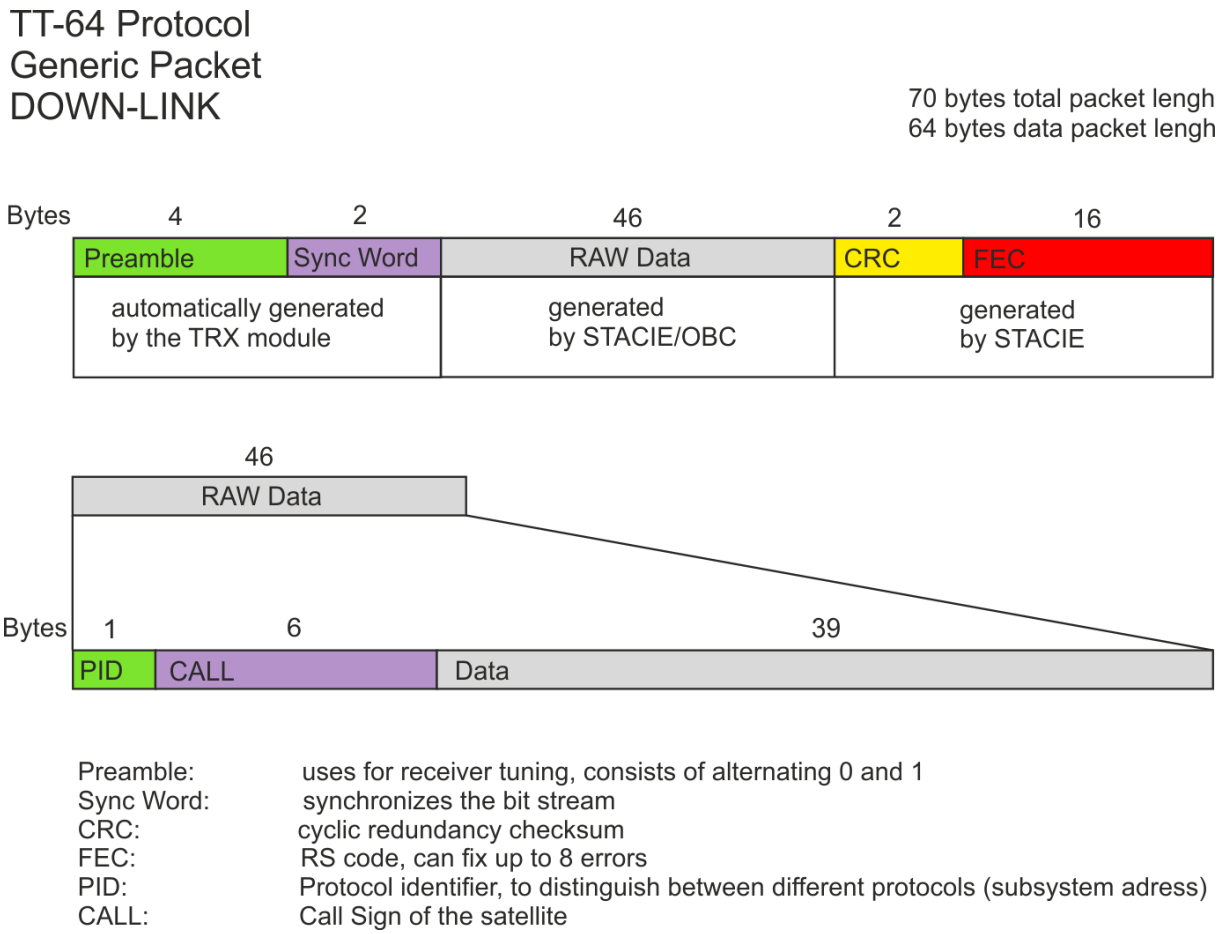
2 TT-64 Protocol

The TT-64 protocol regulates the data transfer between the satellite and the GS in both directions (air interface). The TT-64 protocol supports the time division multiplex method (semi duplex communication).

A complete data packet consists of a 70 bytes string, whereas 6 bytes are created automatically by the TRX module of the communication interface STACIE for synchronizing and receiver tuning. The remaining 64 bytes are data bytes. The last 18 bytes are used for CRC and FEC.

2.1 Down-Link

From the 46 bytes of data, 1 byte must be the PID and 6 bytes the CALL. The CALL is the official call sign of the satellite.



Preamble:	uses for receiver tuning, consists of alternating 0 and 1
Sync Word:	synchronizes the bit stream
CRC:	cyclic redundancy checksum
FEC:	RS code, can fix up to 8 errors
PID:	Protocol identifier, to distinguish between different protocols (subsystem adress)
CALL:	Call Sign of the satellite

2.2 PID Regulation

The PID regulates if the OBC or STACIE is the responsible subsystem of the data packet, the direction of the packet and an assignment to a special beacon.
With the PIDs it is possible to distinguish between the different beacons and route them to the beacon dependent decoding operations.

Assigned PIDs

Content	hex	binary

2.3 CALL

The assigned call sign of the satellite CLIMB is

Symbol						
Hex						
Binary						

2.4 FEC and CRC

In principle there is no need to use FEC and CRC for receiving and decoding the beacons. Anyway, if CRC and FEC are not used by the decoding operation, there is no indication of errors in the raw data.

CRC
The Cyclic Redundancy Checksum (CRC) is a standard
CRC16 Checksum

FEC
The Forward Error Correction (FEC) is a Reed Solomon (RS) code with the following Specifications:
RS(n=64,k=48)
Generator-polynomial-coefficients:
[79,44,81,100,49,183,56,17,232,187,126,104,31,103,52,118]
It is possible to repair 8 errors per 64bit packet.

3 Beacons

There exist 3 different types of beacons, the E-Beacon (EPS Beacon), the S-Beacon (STACIE Beacon) and the O-Beacon (OBC-Beacon).
2 Subsystems are able collecting telemetry data and give the command for transmitting it, the OBC and STACIE. In normal operation mode, only the OBC Beacon will be transmitted. The other beacons are only sent on request from the GS.
As long as the OBC has not taken over the command (ILEOP) or is in a sleep (safe) mode (or is not working), STACIE is sending 2 beacons alternately, the E-Beacon and the S-Beacon.

3.1 E-Beacon

The E-Beacon consists of the EPS telemetry. STACIE collects this telemetry from the EPS over the I^2C interface between EPS and STACIE. The OBC is not involved in this action.
The E-Beacon is only sent, if the OBC operation status does not allow sending O-Beacons.
The PID is 0xC1
Data Packet

Data sequence of the E-Beacon

Byte #	Name	Unit	Format	bit	Description
0	PID			8	0xC1 (EPS-Beacon ID)
1	CALL			8	
2	CALL			8	
3	CALL			8	
4	CALL			8	
5	CALL			8	
6	CALL			8	
7					
8					
9					
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	CRC			16	
	FEC			128	

3.2 S-Beacon

The S-Beacon consists of the STACIE telemetry. The telemetry is generated and stored in the communication subsystem STACIE and immediately available by internal storage.
The OBC is not involved in this action. The S-Beacon is only sent, if the OBC operation status does not allow sending O-Beacons. If O-Beacons or other packets from the OBC are sent, a S-Beacon is sent after every 30th packet sent by the OBC.

The PID is 0xC0

Data Packet

Data sequence of the S-Beacon

Byte #	Name	Bit	Value	Description
0	PID	1	0xC0	Stacie Beacon ID
1	Call Sign	6		
2	Call Sign			
3	Call Sign			
4	Call Sign			
5	Call Sign			
6	Call Sign			
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	CRC	2		
	FEC	16		

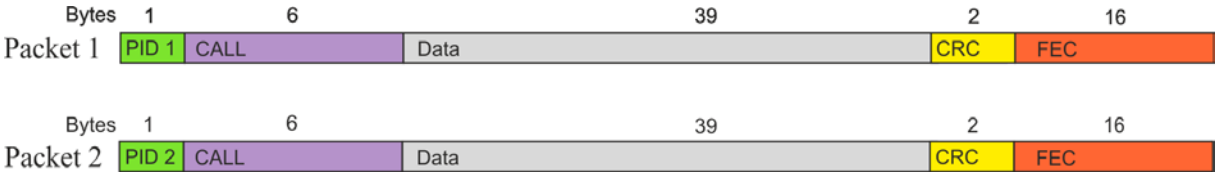
3.3 O-Beacon

The O-Beacon consists of OBC, STACIE, EPS, µPPT, GPS and ADCS telemetry. The OBC is collecting and storing the telemetry of the different subsystems. The OBC is sending the collected data in two packets to STACIE, which is adding the CRC and the FEC before it is transmitting it.

Each packet has its own PID, thus if one packet is lost, the other packet can be decrypted by the GS.
The PID of the first packet is 0x53 and of the second packet 0x56.
Telemetry marked with WOD (Whole Orbit Data) in the commend fields is telemetry, which is required by QB50. The WOD telemetry is also displayed in the public area of the MCC.
In the subsystem section of the table, there is written from which subsystem the telemetry is collected.

The O-Beacon 1 consists mainly of the EPS telemetry and some telemetry of STACIE and from the OBC.
The O-Beacon 2 consist mainly of the GPS data, ADCS and Side Panels data and a huge amount of OBC status parameter (Boolean).

Data Packets



OBC BEACON 1/2						
#	Name	Unit	Format	Bit	Commend	Subsystem
0	PID			8	0x53 (OBC-Beacon ID 1)	
1	CALL			8		
2	CALL			8		
3	CALL			8		
4	CALL			8		
5	CALL			8		
6	CALL			8		
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	CRC			16		
	FEC			128		

	OBC BEACON 2/2					
#	Name	Unit	Format	Bit	Commend	Subsystem
0	PID			8	0x56 (OBC-Beacon ID 2)	
1	CALL			8		
2	CALL			8		
3	CALL			8		
4	CALL			8		
5	CALL			8		
6	CALL			8		
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	CRC			16		
	FEC			128		