Qubik

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Libre Space Foundation

Apr 08, 2024

QUBIK MISSION

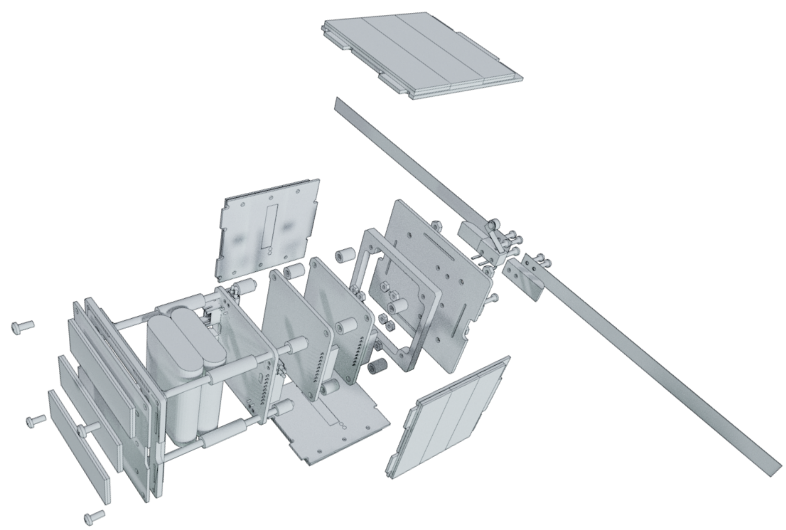
CHAPTER

ONE

INTRODUCTION

QUBIK mission is a twin PocketQube satellite mission, designed for amateur radio service and experiment. The science mission of QUBIK is to experiment with LEOP and passive RF orbit determination.

This is the main documentation of the project.



It is clear that in order to experiment with solutions addressing the *Objectives*, in-orbit-demonstrations should be in place, combining them with experiments on ground segments. Libre Space Foundation has chosen to self-fund an in-orbit demonstrator of an open source in-house developed pocketqube platform (QUBIK).

QUBIK enables us to lower the cost for a COMMS In-Orbit-Demonstrator and quickly get to orbit (expected Nov 2020) verifying some of our assumptions and test out different solutions to address the goals set. We envision QUBIK as a readily available, accessible and affordable platform for such small-scale, short-lived, small-payload experimentations. That said, LSF also owns and develops technologies and platforms for larger scale requirements (power, mass, operational) through a cubesat platfrom if needed in the near future.

1.1 Engage

1. Contact the team and keep in touch with mission operations in our QUBIK Matrix channel .
2. Help with the *Reception* of QUBIK signals once they are deployed.
3. Are you a radio amateur? *Command and Control* and control the QUBIK satellites.
4. See all our code and documentation in our open source repositories.

CHAPTER

TWO

OBJECTIVES

The objectives of the QUBIK mission can be categorized in two categories:

2.1 Satellite Identification and Tracking

2.1.1 GOAL1 : Unambiguously identify satellites as soon as possible after deployment

Launch and early operations phase is a time critical and time sensitive period for a satellite after deployment. It is important to establish communication with the satellite quickly after launch, to address possible issues (Communications or Attitude related) and start payload commissioning. To reliably communicate with the satellite, positive identification is crucial. The QUBIK satellites are designed to allow for easy RF identification during Launch and Early Operations Phase (LEOP). It is worth noting that with many more satellites using very low earth orbits lately (for debris mitigation and cost reasons) maximizing the available payload mission time is critical 1.

2.1.2 GOAL2 : Generate or update existing orbital elements based on Doppler curve tracking of satellite transmissions

Nano and micro-satellite operators are increasingly relying solely on external tracking of their satellite for a variety of reasons (saving on Attitude Determination and Control Systems - ADCS and operational expenses, power budget or COMMS budget). The only reliable available public resource for orbital elements has historically been the Combined Space Operations Center (CSpOC) (though their space-track.org2 dissemination website). With many nano and micro-satellites sharing the same launch vehicle, many are deployed together in the same orbit. The small radar cross section and crowding complicates tracking and identification by CSpOC, and it is not uncommon for initial orbital elements to be published with delays of up to a few weeks. Additionally, newly launched satellites on crowded launched are regularly mis-indentified, or not identified at all. For the QUBIK satellites, we will employ passive Doppler tracking through a global network of ground stations to independently determine orbital elements during LEOP.

2.1.3 GOAL3 : Explore the above goals in a scalable, distributed and open source, open data way consistent with the Libre Space Manifesto.

Libre Space Foundation vows to explore the above mentioned GOAL 1 and GOAL 2 in a way compatible with Libre Space Manifesto3. That essentially means that any technology developed (software, hardware) should be open source, and data captured should be readily available and distributed as open data, and any architecture deployed should be scalable and distributed.

2.2 Open Source Pocketqube Platform

2.2.1 GOAL4 : Create a re-usable open source Pocketqube Platform

Pocketqube as a format can be a versatile low-cost format for a satellite. Libre Space Foundation believes that by creating a complete open source stack of technologies around the Pocketqube format we can enable a wide variety of experiments, payloads, technology development and missions built at the state-of-the-art and not re-inventing the wheel. QUBIK serves as the realization of this vision.

CHAPTER

THREE

EXPERIMENTS

It is clear that in order to experiment with solutions addressing the goals set, in-orbit-demonstrations should be in place, combining them with experiments on ground segments. Libre Space Foundation has chosen to self-fund an in-orbit demonstrator of an open source in-house developed pocketqube platform (QUBIK).

QUBIK enables us to lower the cost for a COMMS In-Orbit-Demonstrator and quickly get to orbit (expected Nov 2020) verifying some of our assumptions and test out different solutions to address the goals set. We envision QUBIK as a readily available, accessible and affordable platform for such small-scale, short-lived, small-payload experimentations. That said, LSF also owns and develops technologies and platforms for larger scale requirements (power, mass, operational) through a cubesat platfrom if needed in the near future. Technical details and complete open source code and designs of the QUBIK satellites can be found in our repositories: https://gitlab.com/librespacefoundation/qubik

Experiment outline:

1. allow unambiguous identification of both QUBIK satellites from their radio frequency (RF) transmissions as received by SatNOGS ground stations
2. track both satellites, either linking observed Doppler curves to CSpOC produced orbital elements (two-line elements; TLEs), or otherwise determine orbital elements from the observed Doppler curves
3. explore approaches that could be applied in a large number of satellites, operating at the same or nearby frequencies.

Assumptions:

- both satellites are operational
- both satellites are transmitting at the same frequency and modulation
- both satellites are in close proximity during the initial orbital phases

3.1 Identification

Given the nature of the QUBIK platform and its capabilities, we chose to experiment in this 1st phase with Identification scenarios and experiments around radio beacons (and Telemetry transmissions). The possible identified RF identification experiments for this approach are:

1. **Beacon preamble/postamble**
    - Digital modulation schemes can use a preamble or a postamble to provide narrowband transmissions that can allow tracking from RF spectra, and differences in preamble/postamble length can be used to distinguish between satellites.
    - CONS: Preambles are often exactly the same, or quite similar in most of the framing schemes. Nominally it is a repeated sequence to allow for PA settling at the transmitter, while giving enough time at

the receiver for the AGC and any other tracking loop to lock. So preamble, per se, cannot be used for unambiguous identification.

Note: Experiment ID1 However, most of the framing schemes have after the preamble, a synchronization word also known as SFD. This is unique and allows a precise frame start recovery1. Putting some effort on the SFD selection (orthogonality, good auto-correlation) can be used pretty well for identification. The underlying assumption is that identification will require demodulation (but not decoding/deframing).

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2. **Beacon decoding**

   - A traditional approach would be to demodulate and then decode the signals captured, thus allowing for identification via a call-sign or address within the packets2.
   - CONS: This approach requires full demodulation and decoding data chain with all the required assumptions around SNR, Rx sensitivity etc. RF collisions on narrow non-spread-spectrum modulations would hinter demodulation and decoding.

Note: Experiment ID2 Essentially this approach is the typical approach taken from multiple missions using the SatNOGS Network. It requires no changes in our existing workflow and will be introduced in QUBIK as a control-case (since we are already utilizing this).

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3. **Beacon length**

   - Differences in beacon length can be used to distinguish between satellites.
   - CONS: The approach is not scalable for a large number of satellites. No experiment in the context of QUBIK will be selected for this approach.

4. **Beacon cadence**

   - Differences in beacon cadence (how often is a beacon transmitted) can be used to distinguish between satellites. This also provides an opportunity to prevent overlap between beacons from both satellites.
   - CONS: The approach is not scalable for a large number of satellites. No experiment in the context of QUBIK will be selected for this approach.

5. **Barker codes**

   - The use of Barker codes can provide monotonic identification right from the RF level performing only cross correlation at the raw signal. The advantages of this scheme is the lower SNR identification and decoding (identification can be performed in negative SNRs) . To introduce the Barker codes only bit level changes are required that can be easily implemented in any MCU.
   - PROS: Uniquely identify the spacecraft (or group of spacecrafts) right from the PHY without any decoding
   - CONS: Ground station should have multiple decoders operating in parallel. The number of the decoders maybe equal to the number of different code sequences. Since this is not a scalable approach we choose not to pursue this for our QUBIK experimentation.

6. **Spread spectrum low power beacon**

   - This experiment will use the RILDOS proposed protocol4, transmitting a beacon with a low transmission power. The idea is to benefit from the spread sequences of the protocol and retrieve a message from the spacecraft even in negative SNR environments. On top of that, the experiment will exploit possible techniques that can be applied on an SDR-based ground station, that can estimate the frequency drift between the spacecraft and the ground station. These techniques will be evaluated in terms of their accuracy and if RILDOS can be used for both identification and tracking.

- CONS: RILDOS requires 2 Mbps, but it will be tested in a lower bandwidth due to hardware restrictions. The basic features of the protocol should not be affected, but the performance in terms of BER is expected to be degraded. In addition, with spread spectrum approaches it is quite difficult to spot visually (spectrogram, waterfall) any kind of transmission. Therefore, debugging early after the deployment in space maybe quite challenging.

Note: Experiment ID 3 The QUBIK will integrate a simplified version of the RILDOS that will utilize the available bandwidth that the AX5043 IC provides. To restrict the time duration of the frame in a reasonable and meaningful value, the chip rate of the sequences will be reduced. This is expected to decrease the BER performance, but this can be compensated by increasing properly the Tx power. The ground station SDR software will implement a cross-correlation based approach to decode and identify the spacecraft.

Note: Experiment ID 4 In par with the decoding of the RILDOS, this experiment will try to exploit different techniques that can estimate the frequency offset between the spacecraft and the ground station. If the accuracy is suitable enough, RILDOS maybe used for both identification and tracking, reducing significantly the overall complexity of tracking and identification systems. This experiment is performed in the ground station only and can benefit from the transmissions of the ID 3 experiment.

3.2 Tracking

To allow tracking of both satellites through their Doppler curves, the transmitter frequency as a function of time needs to be measured. This can be determined directly from waterfalls (artifacts of SatNOGS Network observations), or through demodulation of transmissions. Tracking from waterfalls has the advantages that this will work for lower signal-strengths, and hence is likely to provide more measurements, but it has the disadvantage that for digital modulation schemes it is harder to obtain the transmitter frequency, especially for overlapping transmissions from both satellites.

1. **Modulation**
   - Any modulation scheme with narrow band features will provide the ability to track the satellites through waterfalls. CW would provide the highest accuracy at the expense of low bit rates.
2. **Beacon preamble/postamble**
   - Digital modulation schemes can use a preamble or a postamble to provide narrow provide narrowband features in the waterfalls. Examples are BPSK transmissions of FUNcube satellites, or FSK transmissions like those of UWE-4 or Firebird-4
3. **Residual carrier**
   - Residual carrier is a strong carrier on top of the modulation spectrum mask that runs for the entire frame duration. Normally is used to drive the PLL that tracks any frequency drift. This drift can be retrieved either from the RF level or visually.

Note: Experiment TR1 The RF IC of QUBIK (AX5043) does not support an optional residual carrier. An innovative approach we will be using is that QPSK with special precoding can be forced to use only two of the QPSK symbols. This produces a DC biased BPSK, which eventually will have a carrier at the center of the spectrum mask. The absence of a DC block filter on AX5043 makes this possible. Figure 4 and 5 illustrate experiment TR1 using a PQ9ISH-COMMS (the QUBIK mission COMMS) with unmodified and modified BPSK beacon, live captured using hardware in the loop, channel emulated using gr-leo1 and analyzed by strf2.

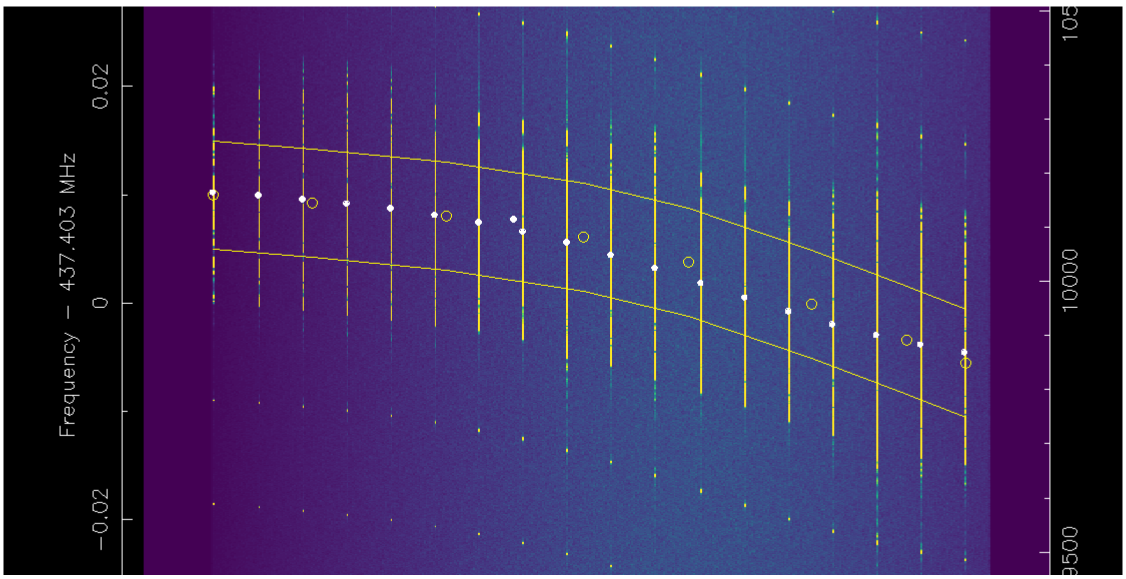

Fig. 1: Correct residual peak finding on a modified BPSK transmission.

CHAPTER

FOUR

RECEPTION

We are inviting all radio-amateurs and satellite enthusiasts around the world to help us receive QUBIK twins while in orbit. This is what you need to know about reception of QUBIK signals:

4.1 Beacons

QUBIK-1 and QUBIK-2 will be beaconing 30 minutes after deployment at the same frequency (this is part of the experimentation) 435.240 Mhz.

The satellites are programmed with a specific beaconing pattern to enable various *Experiments* for LEOP orbit determination and identification.

The default beaconing pattern is as follows:

	PA	Power	Telemetry Type	Modulation	Encoding	Baud	ms	sec delay
1	1	-2	Basic	GFSK	RS	9600	220	30
2	1	-2	Basic	BPSK-RES	CC12RS	9600	1300	30
3	1	-2	Basic	GFSK	RS	9600	220	30
4	1	-2	Basic	GFSK	CC12RS	9600	400	30
5	1	-2	Basic	GFSK	RS	9600	220	30
6	1	-2	Basic	BPSK-RES	CC12RS	9600	1300	30
7	1	-2	Basic	GFSK	RS	9600	220	30
8	1	-2	Basic	GFSK	CC12RS	9600	400	30
9	1	-2	Basic	GFSK	RS	9600	220	30
10	1	-2	Basic	BPSK-RES	CC12RS	9600	1300	30
11	1	-2	Basic	GFSK	RS	9600	220	30
12	0	15	Basic	RILDOS	RAW	125000	2500	30

All modulations regardless of their encoding and baud rate are CCSDS TM Space Data Link packets with a specific payload (the actual telemetry).

The Telemetry structure is as follows:

Category	Field	Details	Size		Unit
Power	Current	Instantaneous	16	s2	mA
Power	Voltage	Instantaneous	16	u2	mV
Power	Die Temperature	Instantaneous	8	s1	C
Power	Battery Temperature	Instantaneous	8	s1	C
Power	Current	Min	16	s2	mA

continues on next page

Table 1 – continued from previous page

Category	Field	Details	Size		Unit
Power	Voltage	Min	16	u2	mV
Power	Battery Temperature	Min	8	s1	C
Power	Current	Max	16	s2	mA
Power	Voltage	Max	16	u2	mV
Power	Battery Temperature	Max	8	s1	C
Power	Current	Average	16	s2	mA
Power	Voltage	Average	16	u2	mV
Power	Battery Temperature	Average	8	s1	C
Power	Time to empty		16	u2	min
Power	Remaining capacity		16	s2	mAh
Power	Full capacity		16	s2	mAh
Power	State of charge (%)		8	s1	%
Antenna	Antenna Deploy Test voltage	Acquired once on antenna deployment	16	s2	mV
Antenna	Antenna Deploy Test current	Acquired once on antenna deployment	16	s2	mA
Antenna	Antenna Deploy Test result	Acquired once on antenna deployment	8	u1	n/a
Antenna	Antenna Deploy average voltage	Acquired once on antenna deployment	16	s2	mV
Antenna	Antenna Deploy average current	Acquired once on antenna deployment	16	s2	mA
Antenna	Antenna Deploy duration	Acquired once on antenna deployment	8	u1	s
Antenna	Antenna Deploy status	Acquired once on antenna deployment	8	u1	n/a
Antenna	Antenna Deploy retries	Acquired during antenna deployment	8	u1	n/a
MCU	Uptime		32	u4	secs
MCU	Internal Temperature		8	s1	C
MCU	RTC Battery Voltage		16	u2	mV
Operational	First Deploy		8	u1	n/a
Operational	Antenna first Deploy		8	u1	n/a
Statistics	Reasons of reset		8	u1	
Statistics	Dropped Frames		16	u2	
Statistics	low_power_counter		16	u2	
Statistics	independent_watchdog_counter		16	u2	
Statistics	software_counter		16	u2	
Statistics	brownout_counter		16	u2	
Status	Power Save		8	u1	n/a
Status	Power Monitor Fail		8	u1	n/a
OSDLP	CLCW per VC		160	20	
Radio	Tx Frames		16	u2	
Radio	Rx Frames		16	u2	
Radio	Rx corrected bits		32	u4	
Radio	RSSI		8	s1	dB
Radio	Frequency tracking		16	s2	
Radio	AGC		8	s1	
Radio	Data rate Tracking		32	s4	
Radio	Phase Tracking		16	s2	
Radio	RF Freq Tracking		32	s4	
Radio	Rx-Tx turnaround		16	u2	ms

The kaitai struct for the whole PDU can be found here .

4.2 How to receive

The easiest way to receive is by setting up a SatNOGS station. SatNOGS is already setup for QUBIK tracking, demodulating, decoding and forwarding to the appropriate dashboard at dashboards.satnogs.org . Learn how to setup a SatNOGS station.

CHAPTER

FIVE

COMMAND AND CONTROL

5.1 Intro

QUBIK pocketqube twins are radio amateur service satellites that can be commanded by radio amateurs around the world. The purpose of documenting this functionality is to enable more radio amateurs around the world to gain hands-on experience with C&C of an actual satellite, testing their setups and having a rewarding experience.

Warning: Licensed radio amateurs only.

Before attempting to transmit any signals to QUBIK satellites please ensure that you are compliant with any local laws and regulations. If uncertain, reach out to your national radio amateur association.

5.2 Hardware setup

A typical command and control station for QUBIK satellites would include the following hardware components:

Components:

Part	Source-1	Source-2
PA		
RF Switch	https://gitlab.com/rf-modules/rf-switch	
LNA	https://gitlab.com/rf-modules/rf-low-noise-amplifier	https://www.wimo.com/en/lna-5000
Bias T	https://gitlab.com/rf-modules/bias-t	https://www.wimo.com/en/dcc-5000pro
Client	Follow instructions on the same page	
Antenna	https://www.wimo.com/en/x-quad	
Cabling		
Rotator	https://wiki.satnogs.org/Rotators	
SDR with Tx	PlutoSDR	USRP

NOTE: The RF-switch must switch from Rx to Tx and Tx to Rx at most in 10 ms.

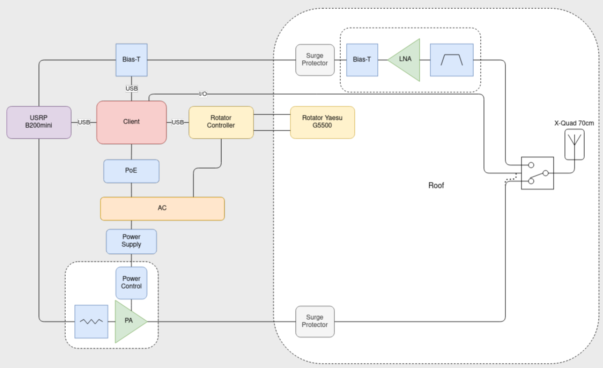

Fig. 1: one antenna setup

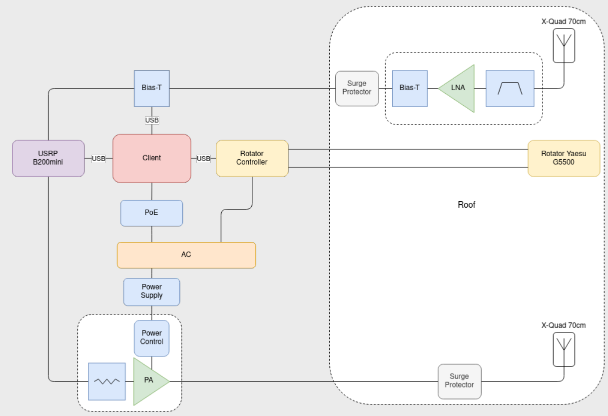

Fig. 2: two antennas setup

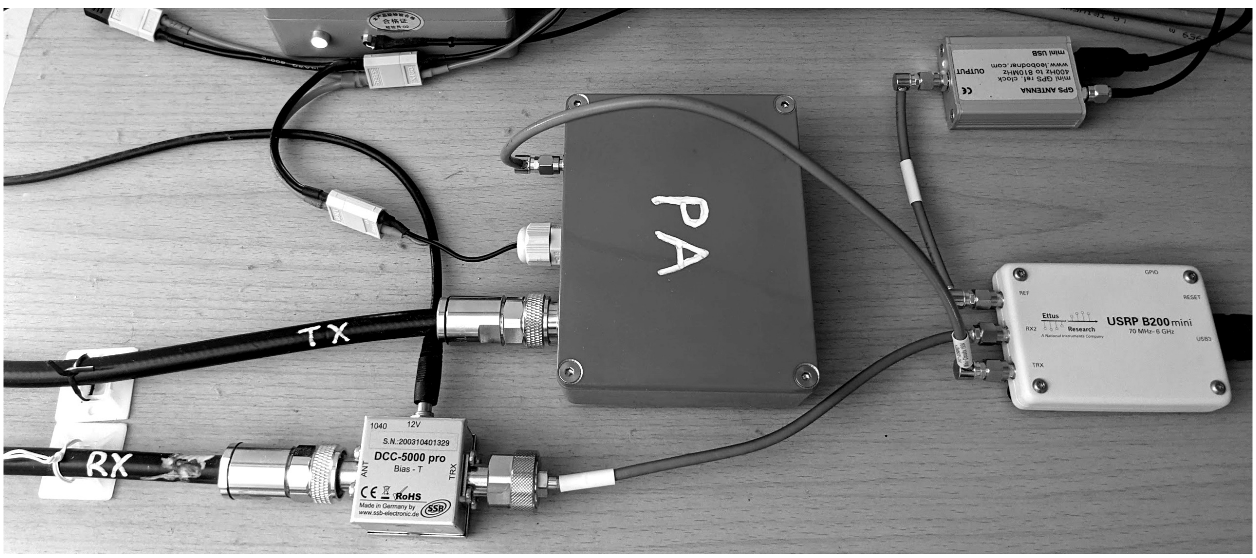

Fig. 3: Indicative QUBIK Tx setup.

5.2.1 Two Antennas Set-Up

This set-up uses the same components but with additional antenna for Tx. The problem with this set-up is the power that is received while the other antenna is transmitting.

A experiment with 2 x-quad antennas are done. The antennas are placed at distance of 1.7 m. The PA transmits 37 dBm before a cable of 5m and the antenna. The Rx antenna receives after a 2 m cable -8 dBm. The experiment took place in open air field and the measurement tool is a calibrated SA.

The results of experiment may not repeatable with other antennas.

The LNA can handle in the input the received power. The SDR either can handle the receiving power or the LNA gain when is OFF it is enough to protect the SDR.

5.2.2 Power Amplifier

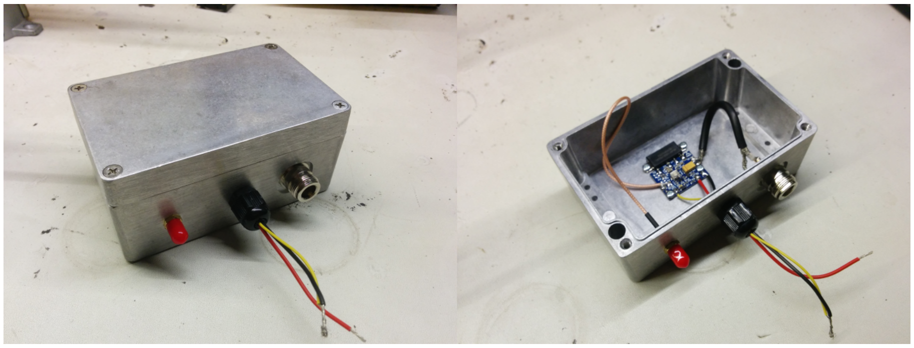

Fig. 4: PA Assembly

Part	Qty
Mitsubishi RA07H4047M RF Power Amplifier Module	1
SMA Female, Chassis Panel Mount	1
N-Type Female, Chassis Panel Mount	1
SMA Female, Chassis Panel Mount	1
RG-58 C/U MIL C17-F Coaxial Cable	~10cm
RG-316/U	~12cm
PG9 Cable Gland	1
Stranded Cable ~1.5mm^2 (16AWG) Black, Red, Yellow	1m
Screw M2.5 L6 DIN7985 INOX	4
Die-cast aluminum enclosure, 125x80x57 IP66 (or similar)	1

5.2.3 RA07H4047M Performance

Pin(mW)	Pout(W)	VDD (V)	VGG (V)	Pdc(W) at Tx	Pdc(W) at idle
12.6	6	12	3	12	3.3

5.2.4 RA07H4047M Modification

The RA07H4047M board needs to be modified to remove the input attenuator and work with the RF out of a USRP B200 directly.

The modification is the removal of R1 through R4 and replacement of R5 and R6 with 0Ohm resistors.

5.2.5 USRP B200mini - Power Calibration

The PA is drive by the USRP B200mini. Power Calibration of USRP by using SoapyUHD.

Setting [0, 89.75, 0.25] dB	Output (dBm)
12	-54
20	-45.8
32	-34
47	-19
63	-2.85
70	4.21
73	7
76	**10**
77	**11**
78	12
79	**13**
80	14
81	14.81
82	15.54
83	16.16
84	16.69
85	17.03
86	17.27

The absolute maximum input of RA07H4047M is 30 mW or 14 dBm.

5.2.6 Thermal Testing

Two temperatures sensors are placed in the enclosure. One sensor (T1) is placed at the bottom of the box near the PA module and the second (T2) at the lid of enclose.

The temperature at idle state of PA is stabilized at ~31.3°C after 50 minutes.

T1 (°C)	T2 (°C)	Time (min)	State
20.5	20.5	0	OFF
26.4	24.8	10	ON, Input terminated with 50Ohm, PDC = 3.324W @ 12V
28.5	26.9	20	
30	28.5	30	
30.8	29.3	40	
31.3	29.9	50	

Then a CW signal is applied to PA module.

T1 (°C)	T2 (°C)	Duration (min)	State
35.1	31.7	3	ON, Input +12 dBm, output 6W PDC = 12W @ 12V
33.5	32	10	ON, Input terminated with 50Ohm, PDC = 3.324W @ 12V
36.6	33.3	5	ON, Input +12 dBm, output 6W PDC = 12W @ 12V
37.8	34.3	2.5	ON, Input +12 dBm, output 6W PDC = 12W @ 12V
38.3	34.9	2.5	ON, Input +12 dBm, output 6W PDC = 12W @ 12V
35.7	33.6	10	ON, Input terminated with 50Ohm, PDC = 3.324W @ 12V

It seems that the PA module operates faraway from 90°C (maximum operating temperature). Also the temperature of PA module at idle is approximately +10°C above the environment temperature (20.5°C).

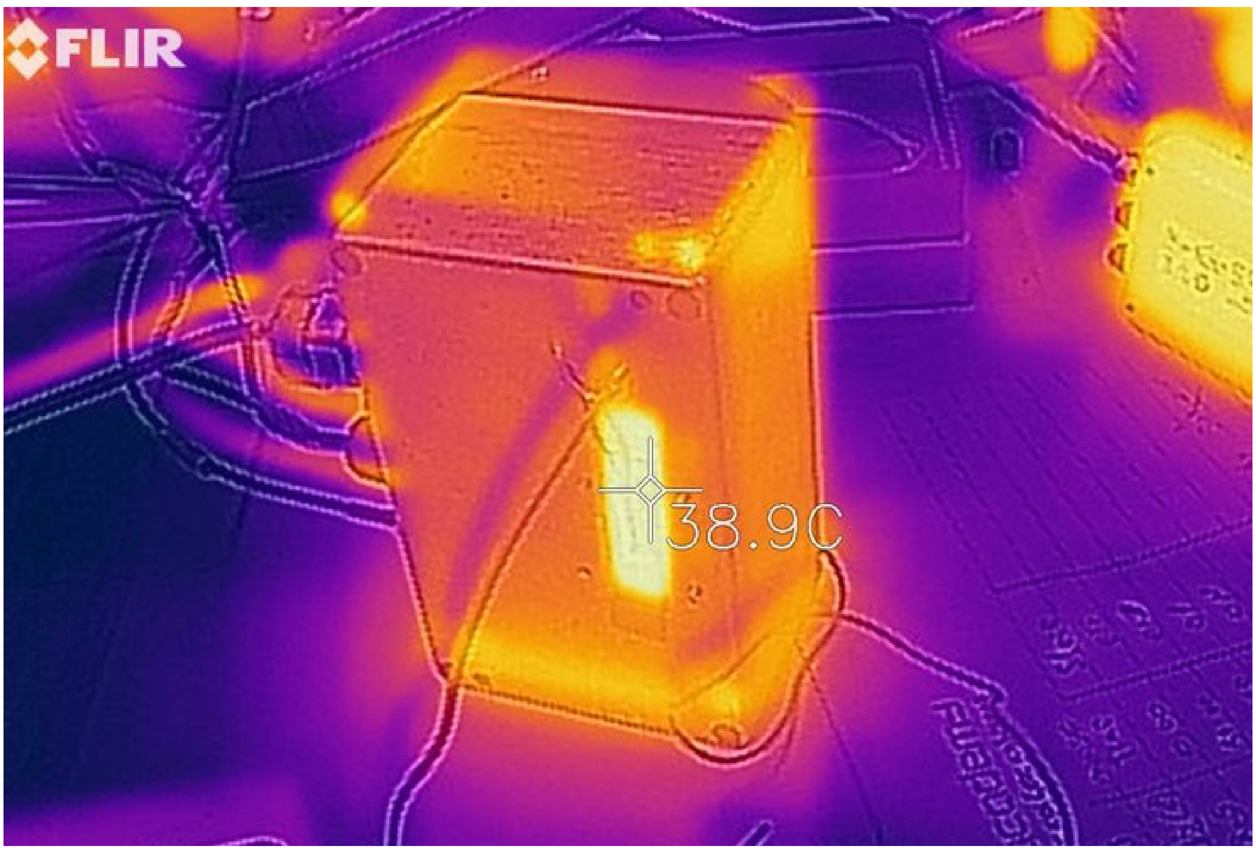

Fig. 5: Thermal Camera Result.

5.3 Software setup

In order to command and control a QUBIK satellite you will need a specific software stack to handle all the tasks necessary.

1. GNU Radio 3.8.2
2. gr-soapy (and appropriate SDR specific drivers)
3. gr-satnogs
4. Gpredict (for Doppler and rotator control)

5. QUBIK transceiver flow graph (The GNU Radio transceiver)
6. osdlp-operator (The command and control program)
7. qubik_listener (The packet forwarder to SatNOGS DB)

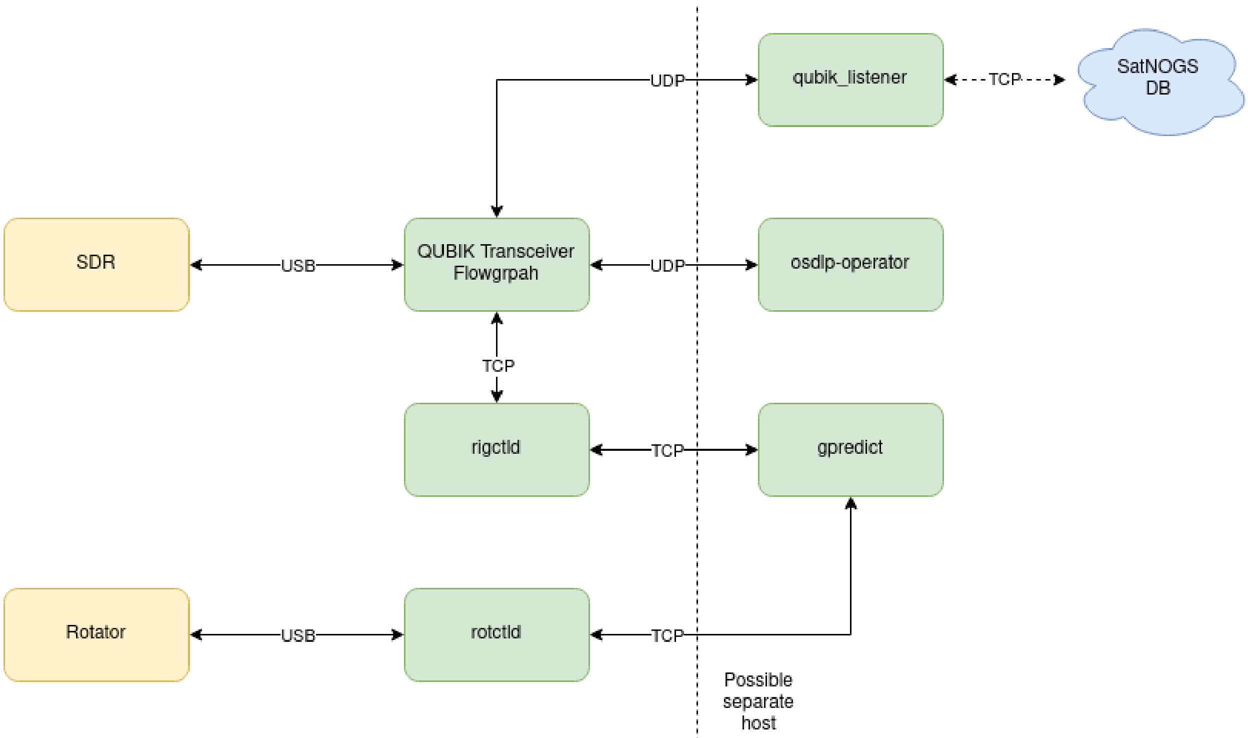

Fig. 6: QUBIK Command Software diagram

Tip: Your command software stack can be split in two different setups.

For example, a Rpi4 computer near the antenna with the SDR attached to it controlling also the rotator, while a second host over the network can handle the command and control software (osdlp-operator) and the Gpredict (for Doppler and rotator pointing calculations) for a pass. Of course those can be hosted under a single computer if cabling and secifics allow.

Tip: Setup your Gpredict Radio Interface with Radio Type: Full-Duplex and leave anything alse as default.

5.4 Running

When all hardware and software are ready and installed, just before AOS the following should happen:

1. Run `rigctld -T 127.0.0.1 -m 1 -v` to create a rigctl server to wait for incoming clients (transceiver and Gpredict)
2. Run the appropriate `rotctld` command to wait for incoming Gpredict connection
3. Run the `qubik_transceiver.py` with the appropriate arguments

- For PlutoSDR `./qubik_transceiver.py --soapy-rx-device 'driver=plutosdr' --antenna-rx 'A_BALANCED' --antenna-tx 'A_BALANCED'`
- For USRP use: `./qubik_transceiver.py --soapy-rx-device 'driver=uhd' --antenna-rx 'RX2' --antenna-tx 'Tx/Rx'`

4. Run the osdlp-operator with the fop configuration: `osdlp-operator fop_configuration.cfg`
5. Run `netcat -lu -p 16880` to see all debugging messages from osdlp-operator
6. Run `gpredict` and start the pass operations (Antenna and Radio control) for your selected QUBIK
7. Run `qubik_listener.py` to forward any received frames to SatNOGS DB (and see them locally)
   - Example for station `./qubik_listener.py --callsign SV1QVE --lon 36.970945N --lat 36.970945E`
8. Return to osdlp-operator and command QUBIK.

Note: If your running session is a testing one (with QUBIK EMs) you *need* to disable the rigctl message block from the qubik_transceiver flow graph, for your session to run. No need to Doppler compensate on ground.

CHAPTER

SIX

BUDGET

6.1 QUBIK RCS

Check the related issue https://gitlab.com/librespacefoundation/qubik/qubik-org/-/issues/18 for results.

6.2 Link Budget - Uplink

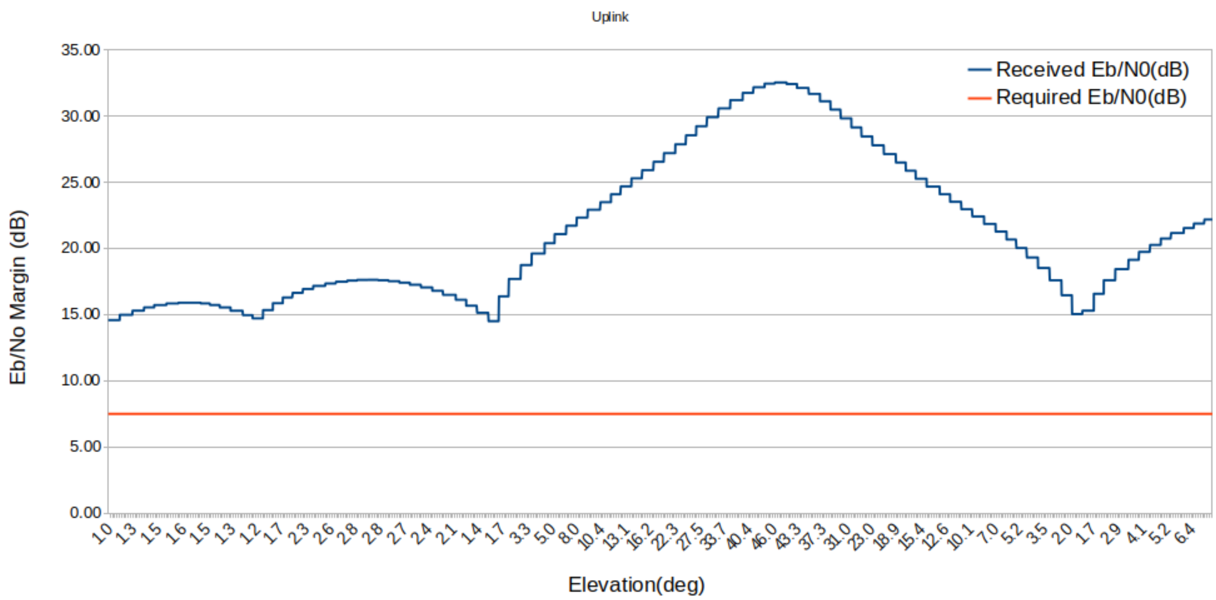

Fig. 1: QUBIK uplink budget

Transmitter - Parameters		Comment
Transmitter Frequency (MHz)	435.24	IARU Defined
Transmitter Power (dBm)	38.00	https://enigma-shop.com/index.php?option=com_hikashop&ctrl=produ
Transmitter Power (dBW)	8.00	Transmitter Power (dBm)-30
Antenna circuit loss(RFDN) (dB)	-2.00	TBD
Antenna gain (dBi)	14.95	Wimo X-Quad UHF
D3dB antenna (deg)	36.00	https://granasat.ugr.es/2013/11/ground-station-equipment/

Table 1 – continued from previous page

Transmitter - Parameters		Comment
Pointing accuracy (deg)	1.00	
EIRP(dBW)	20.95	Transmitter Power (dBW)+RFDN (dB)+Antenna gain (dBi)
EIRP(dBm)	50.95	Transmitter Power (dBm)+RFDN (dB)+Antenna gain (dBi)
Path - Parameters		
Elevation angle (deg)	6.96872	
Altitude (km)		
Slant Range (km)	1513.69	
Free Space Loss (dB)	-148.87	gr-leo calculations
Atmospheric/Ionospheric Loss (dB)	-1.58	gr-leo calculations
Rainfall Loss (dB)	-0.003	gr-leo calculations
Total Path Loss (dB)	-150.45	
Receiver - Parameters		
Polarization loss (dB)	-4.00	Assumption
Pointing loss (dB)	-3.00	From IARU link budget, for Theta2 = 60 deg
D3dB antenna (deg)	Omnidirectional	Dipole Lamda/2
Pointing accuracy (deg)	0.00	
Antenna circuit loss(RFDN) (dB)	-1.04	Connectors, BalUn, cable
Antenna gain (dBi)	2.15	Dipole Lamda/2
Total Antenna Gain(dB)	-5.89	Polarization loss (dB) +Pointing Loss(dB)+RFDN(dB)+Antenna Gain(
Antenna Noise Temp (K)	290.00	It is constant 290k for satellite
Received Signal (dBm)	-105.39	EIRP(dBm) + Total Path Loss (dB) + Total Antenna Gain(dB)
Receiver - Performance		
Front-End NF(dB)	7.00	Assumption from datasheet related with sensitivity for FSK w/o FEC
Front-End Noise Temp (K) at 290K	1163.44	290(k)*(10^(NF(dB)/10)-1)
Tsys(K)	1453.44	Antenna Noise Temp (K) + Front-End Noise Temp (K)
Tsys(dBK)	31.62	10*LOG10(Tsys)
G/T(dB/K)	-37.51	Total Antenna Gain(dB)-Tsys(dBK)
Noise Floor (dBm/Hz)	-166.98	10*LOG10(k*1000*Tsys(K))
MDS(dBm)	-114.571736674172	Noise Floor(dBm) + 10*LOG10(Required BW(Hz))
Symbol rate (samples/s)	9600.00	1200-9600
Channel symbol rate (dBHz)	39.82	10*LOG10(Symbol Rate(samples/s))
Implementation Loss (dB)	-1.00	
Received SNR (dB)	19.18	Received Signal (dBm)-(Noise Floor(dBm/Hz)+10*LOG10(Required B
Required SNR (dB)	10.00	
Received Es/N0(dB)	20.76	EIRP(dBW)+Total Path Loss(dB)+G/T(dB/K)+Impl. Loss(dB)-[k(dBW
RF Carrier Modulation, Type	FSK	
RF Carrier Modulation, Format	NRZ-M	
User Bit Rate, b/s	7200.00	Symbol Rate(samples/s)*Coding Rate*LOG2(Symbol M-arity)
Bit Error Rate	10^-5	ECSS-E-HB-50A
Data Coding, Type	RS(255,223)	We need for RS(255,223) concatenated or RS(128,96)
Required Bandwidth (Hz)	17400.00	Set by AX5043
Symbols M-arity	2.00	Due to FSK
Coding rate	0.75	For FSK and RS(255,223)
Received Eb/N0(dB)	22.01	Es/N0(Rx) -10*LOG10(LOG2(M))-10*LOG10(Coding Rate)
Required Eb/N0(dB)	7.50	Minus 2.5 from unencoded FSK-2
Margin (dB)	14.51	Received Eb/N0(dB)-Required Eb/N0(dB)

Spreadsheet calculator (it is better to download it)

6.3 Link Budget - Downlink

TBD

6.4 Energy Harvesting Power Budget

By using a python script to calculate the power coefficient and finally the power production of a satellite.

Inputs:

```
# Put TLE
line1 = ('1 84001U          20001.00000000  .00000000  00000-0  50000-4 0 08')
line2 = ('2 84001  97.0000 156.0000 0001497   0.0000 124.0000 15.90816786 02')
satellite = twoline2rv(line1, line2, wgs72)
# Set the start day for simulation, Julian day
JD_ini = jday(2020, 4, 15, 8, 20, 0)
# Initialize parameters
total_time = 400  # in min
# Initialize angular velocities in rad/min
w_body = np.array([30.0, 10.0, 25.0])
# Initial angle conditions in deg
angle_body_curr = np.deg2rad([0.0, 0.0, 0.0])
# PV efficient in each side [xp, xm, yp, ym, zp, zm]
pv_eff = np.array([0.25, 0.25, 0.25, 0.25, 0.25, 0.25])
# Number of PV in each side [xp, xm, yp, ym, zp, zm]
pv_num = np.array([3.0, 3.0, 3.0, 3.0, 3.0, 3.0])
# Active area of each PV in mm^2, e.g. 45mmx15mm
pv_area = np.array([(45.0*15.0), (45.0*15.0), (45.0*15.0), (45.0*15.0),
                    (45.0*15.0), (45.0*15.0)])
# Solar irradiance (kW/m^2) in a specific orbit
si = 1.4
```

Note: solar cell is https://waf-e.dubudisk.com/anysolar.dubuplus.com/techsupport@anysolar.biz/O18Ae0B/DubuDisk/www/Gen3/SM141K04LV%20DATA%20SHEET%20202007.pdf

Results:

1. Mean Power coefficient of each side, [Xp_m, Xm_m, Yp_m, Ym_m, Zp_m, Zm_m]: [0.16756193891221607, 0.17041088209246041, 0.19111270153573892, 0.19375282007969838, 0.15851510079365622, 0.15893245086986432]
2. Total Mean Power coefficient, 1.0402858942836344
3. Mean Power of each side in mW, [Xp_m, Xm_m, Yp_m, Ym_m, Zp_m, Zm_m]: [118.7595242 , 120.77871268, 135.45112721, 137.32231123, 112.34757769, 112.64337455]
4. Total Mean Power in mW, 737.3026275735258

For 400 minutes or ~4 orbits

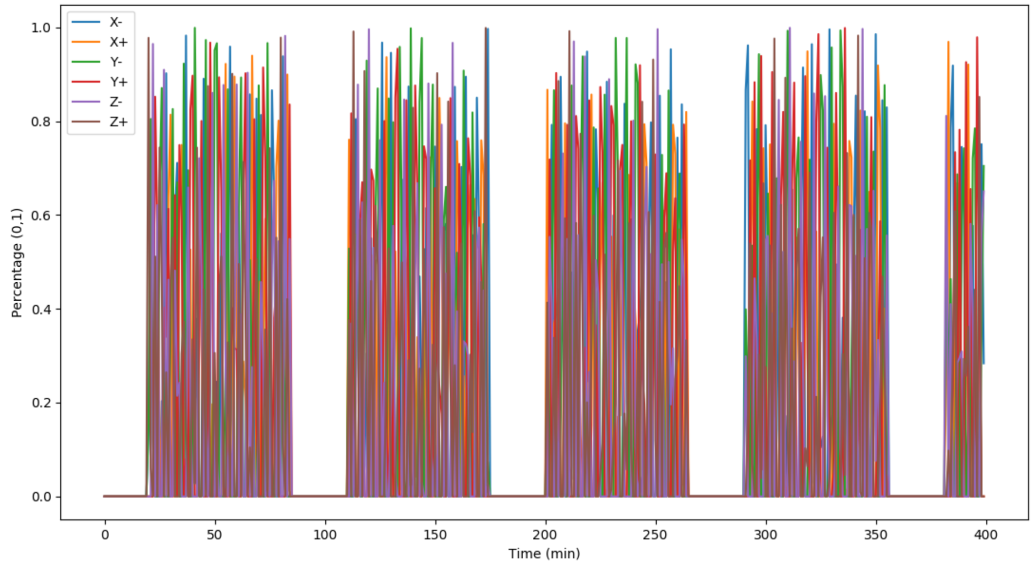

Fig. 2: QUBIK Power Budget

6.5 Power Budget

TBD

6.6 Data Budget

TBD

6.7 Mass Budget

TBD

6.8 Pointing Budget

Not applicable to QUBIK satellite due to missing determination and control attitude system.

CHAPTER

SEVEN

COMMS AND OBC

- Description
- Repository
- Releases

7.1 System Performance

- https://gitlab.com/librespacefoundation/pq9ish/pq9ish-comms-vu-hw/-/issues/48

7.2 System Assembly

Related issue:

- Before Gluing and coating a *dry fit* must be done

7.3 System Testing

Related documentation:

- https://gitlab.com/librespacefoundation/pq9ish/pq9ish-comms-vu-hw/-/wikis/home

CHAPTER

EIGHT

STRUCTURAL

- Description
- Repository
- Releases

8.1 System Perfomance

- Pass environmental tests.
- Document the CoM, https://gitlab.com/librespacefoundation/qubik/qubik-docs/-/issues/19

8.2 System Assembly

Related issue:

- https://gitlab.com/librespacefoundation/qubik/qubik-docs/-/issues/10
- https://gitlab.com/librespacefoundation/qubik/qubik-docs/-/issues/15
- https://gitlab.com/librespacefoundation/qubik/qubik-docs/-/issues/11
- https://gitlab.com/librespacefoundation/qubik/qubik-docs/-/issues/14
- https://gitlab.com/librespacefoundation/qubik/qubik-docs/-/issues/20
- Before Gluing and coating a *dry fit* must be done

8.3 System Testing

Related documentation:

- https://gitlab.com/librespacefoundation/qubik/qubik-structural/-/wikis/home
- Measure every mechanical part to be according to drawings

CHAPTER

NINE

BATTERY MANAGEMENT POWER SYSTEM

- Description: https://gitlab.com/librespacefoundation/qubik/qubik-bmps/-/issues/11
- Repository
- Releases

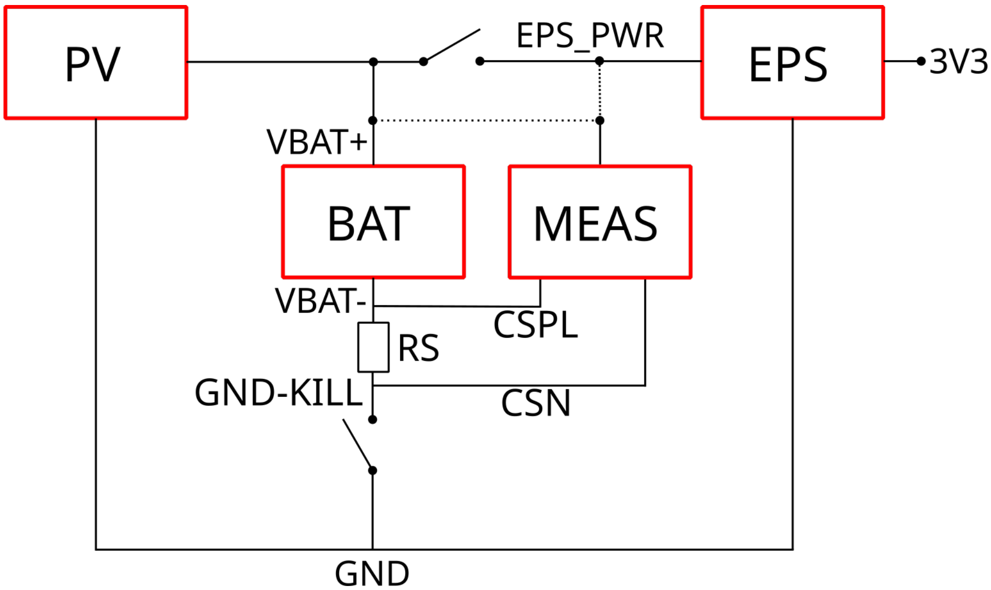

Fig. 1: Kill Switch Architecture.

9.1 System Perfomance

Related issues:

- https://gitlab.com/librespacefoundation/qubik/qubik-bmps/-/issues/21
- https://gitlab.com/librespacefoundation/qubik/qubik-bmps/-/issues/26
- https://gitlab.com/librespacefoundation/qubik/qubik-bmps/-/issues/20

9.2 System Assembly

Related issue:

- https://gitlab.com/librespacefoundation/qubik/qubik-docs/-/issues/13
- Before Gluing and coating a *dry fit* must be done

9.3 System Testing

Related documentation:

- https://gitlab.com/librespacefoundation/qubik/qubik-bmps/-/wikis/home

CHAPTER

TEN

SOLAR POWER BOARD

- Description
- Repository
- Releases

10.1 System Perfomance

Related issues:

- https://gitlab.com/librespacefoundation/qubik/qubik-spb/-/issues/23
- https://gitlab.com/librespacefoundation/qubik/qubik-spb/-/issues/14

10.2 System Assembly

Related issue:

- https://gitlab.com/librespacefoundation/qubik/qubik-docs/-/issues/12 and linked issues
- Before Gluing and coating a *dry fit* must be done

10.3 System Testing

Related documentation:

- https://gitlab.com/librespacefoundation/qubik/qubik-spb/-/wikis/home

CHAPTER

ELEVEN

CABLING

- Description
- Repository: a WireViz source file can be placed in this directory
- Releases

11.1 System Perfomance

Warning: Neither PVC bulk materials nor PVC plastic films shall be used in space applications, according to ECSS-Q-70-71A.

Note: Some wires like VBAT+ and VBAT- must be twisted. With the exception of the solar array, power lines shall be such that each line is twisted with its return, when the structure is not used as a return, as refered ECSS-E-ST-20C.

11.2 System Assembly

Note: Follow the NASA workmanship guide for cable lacing. Apply this in Main harness and COMMS Programmer cable. Use cyanoacrylate glue to solidify the knots in cable.

Note: Follow ECSS-Q-ST-70-08C for cabling assembly.

Note: The length of the wires mentioned below correspond to the length of the cable after the assembly. While cutting the wire, please add ~ 7mm of extra length.

- Color Abbreviations
  - RD -> Red
  - BK -> Black
  - BL -> Blue
  - YL -> Yellow

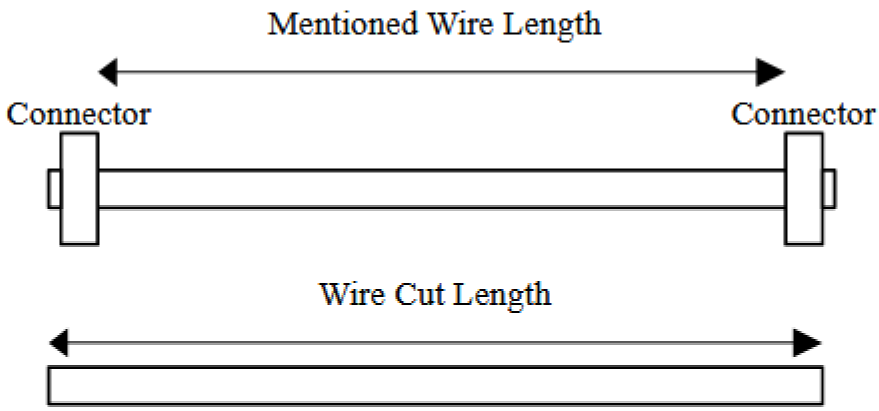

Fig. 1: Wire cutting

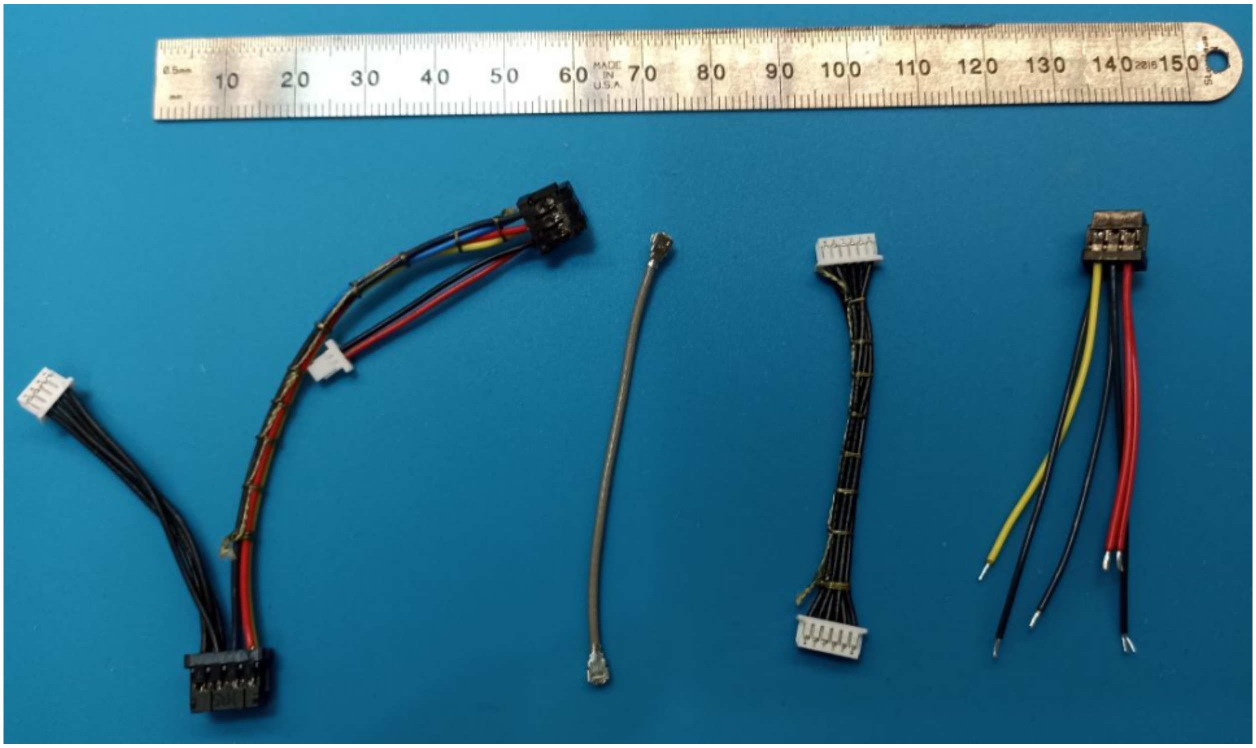

Fig. 2: QUBIK harnessing

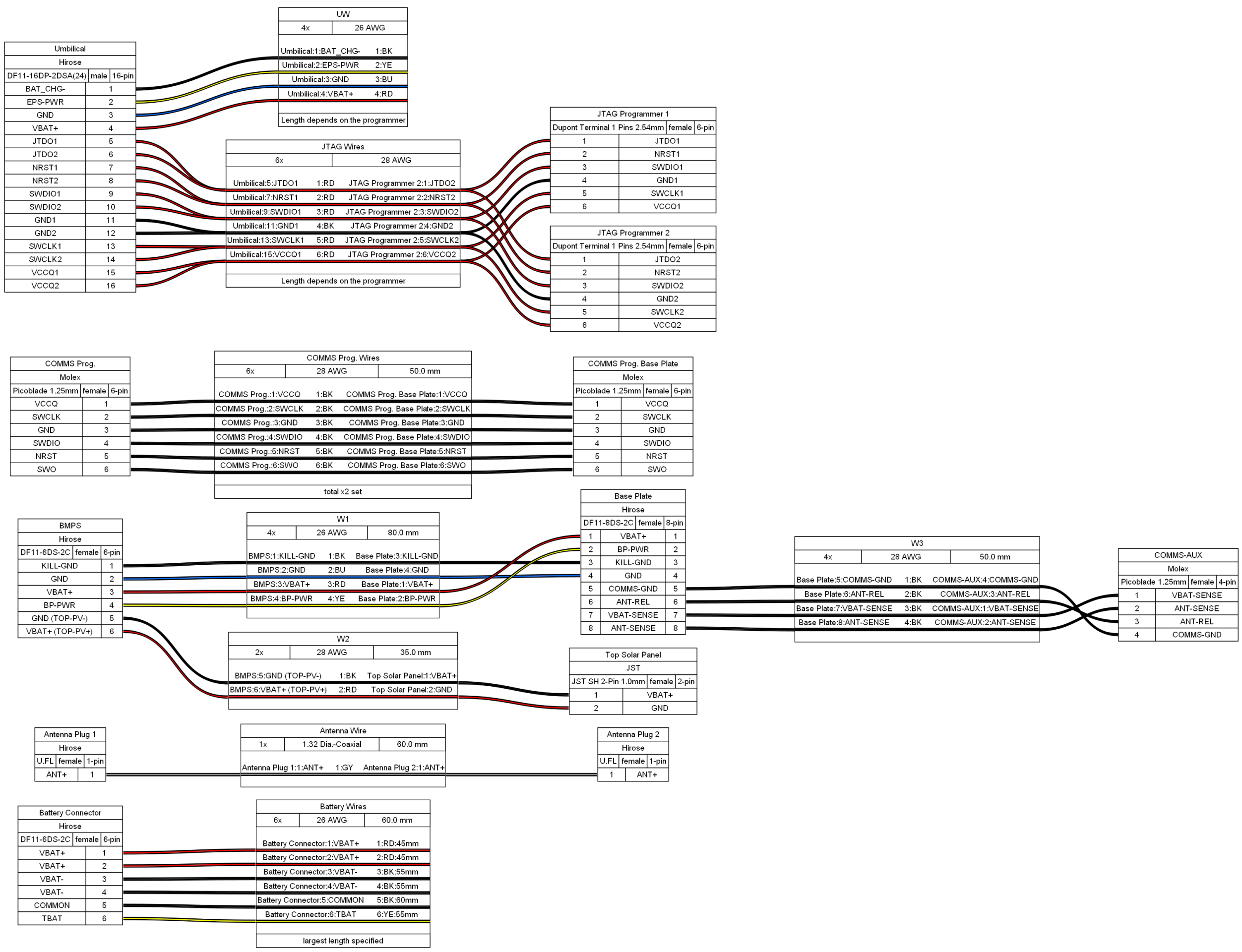

Fig. 3: WireViz Illustration

11.2.1 Battery cable

- DF11-6DS-2C
  - pin 1-2: VBAT+
  - pin 3-4: VBAT-
  - pin 5: COMMON (which is same with VBAT-)
  - pin 6: TBAT
  - Connector assembly - DF11-2428SC

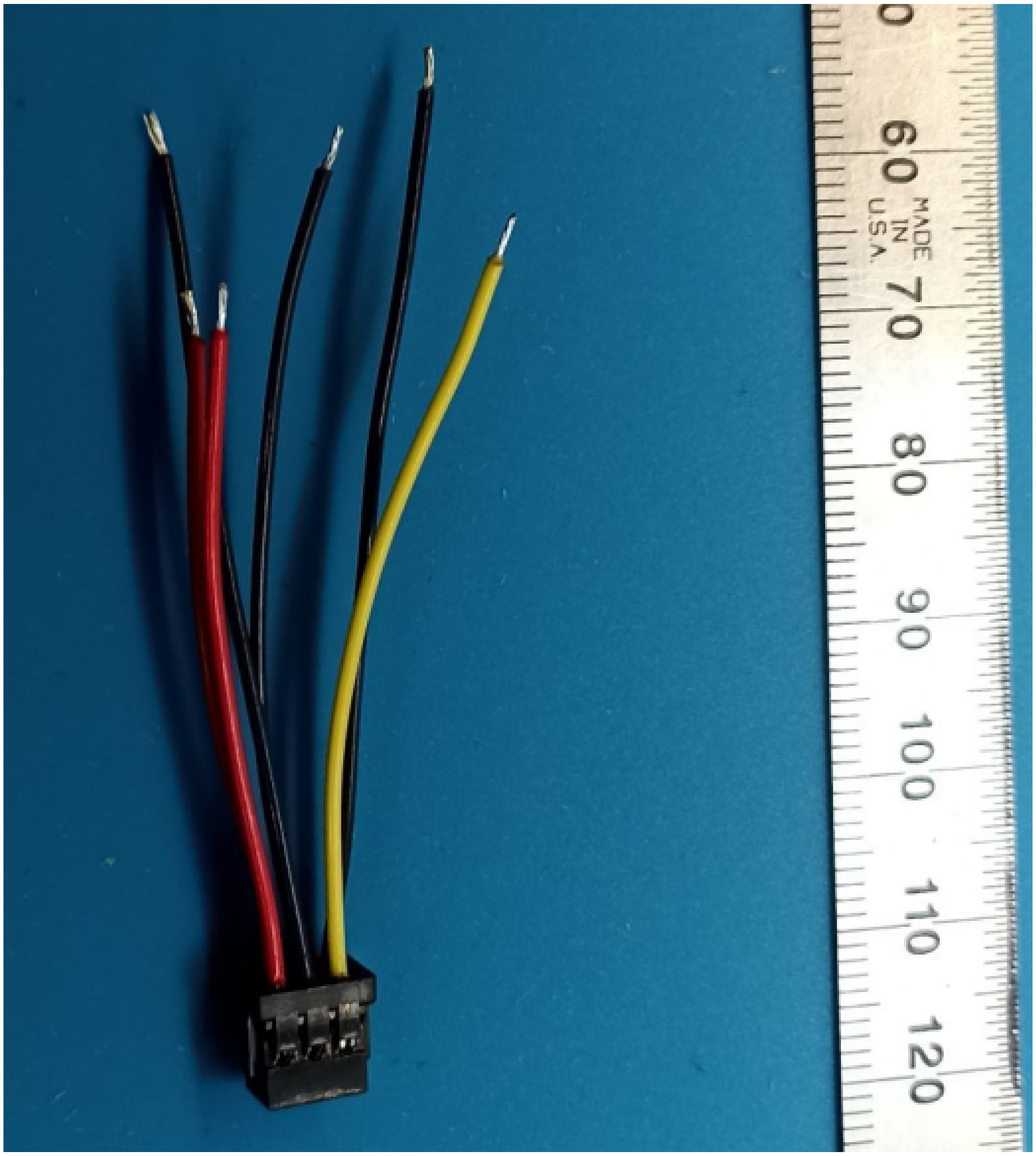

Fig. 4: Battery Cable

Note: As a convention we name (A) the battery attached on the BMPS board and (B) the other one.

Note: It is preferable to measure the colder battery, as cold is the more harsh condition for the battery performance.

Note: It is convenient to solder Common wire to (B) instead of (A).

Table 1: Battery Wiring

Connector	Pin Name	Pin Connector	Pin Battery	Wire
DF11-6DS-2C	VBAT+	1 - 2	A(+) - B(+)	26-AWG 45 mm (RD)
DF11-6DS-2C	VBAT-	3 - 4	A(-) - B (-)	26-AWG 55 mm (BK)
DF11-6DS-2C	Common	5	A(C) or B(C)	26-AWG 60 mm (BK)
DF11-6DS-2C	TBAT	6	A(T) or B(T)	26-AWG 55 mm (YL)

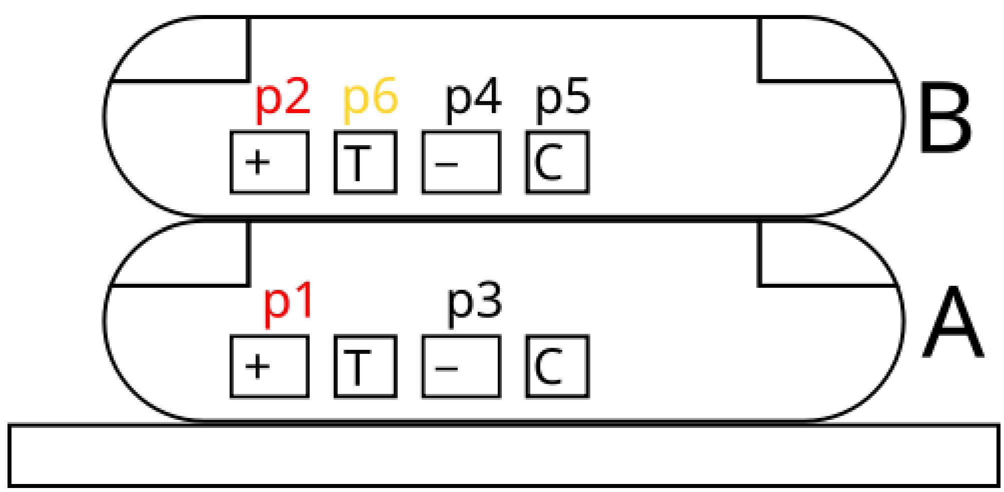

Fig. 5: Battery Stack

11.2.2 Antenna cable

- Length: 60mm
- U.FL-2LPHF6-066N1-A-60

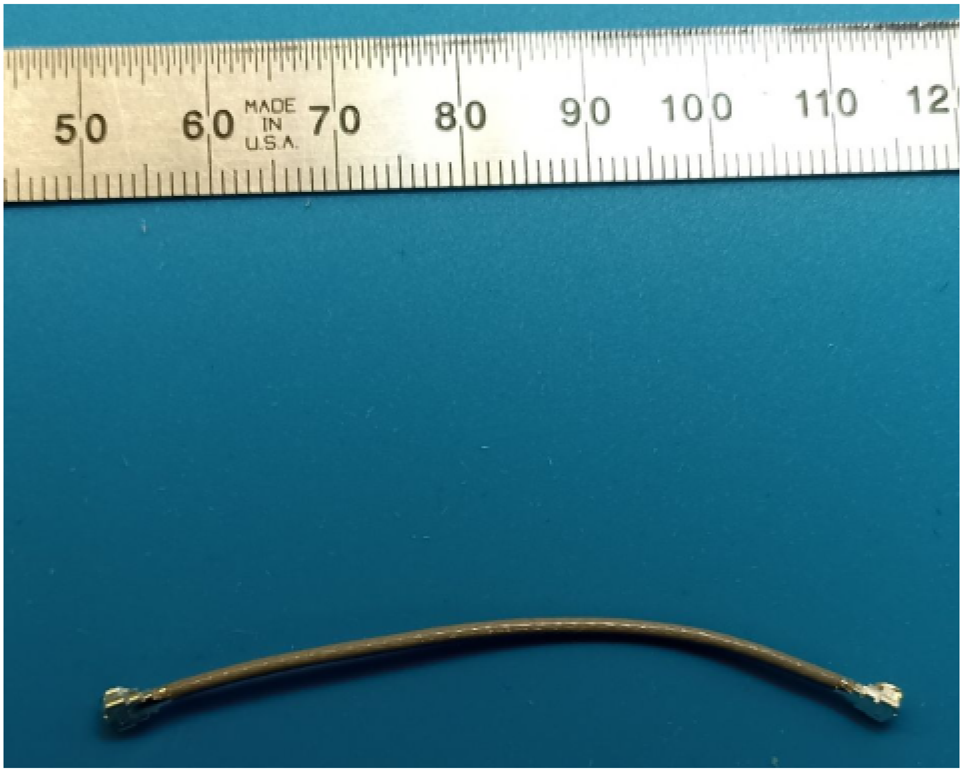

Fig. 6: Antenna Cable

11.2.3 Main harness

- Connectors:
  - DF11-8DS-2C
    - pin 1: VBAT+
    - pin 2: EPS-PWR
    - pin 3: KILL-GND
    - pin 4: GND
    - pin 5: COMMS-GND (GND that no connected to in base plate GND)
    - pin 6: ANT-REL
    - pin 7: VBAT-SENSE
    - pin 8: ANT-SENSE
    - Connector assembly - DF11-2428SC
  - DF11-6DS-2C

    * pin 1: KILL-GND
    * pin 2: GND
    * pin 3: VBAT+
    * pin 4: EPS-PWR
    * pin 5: GND (TOP-PV-)
    * pin 6: VBAT+ (TOP-PV+)
    * Connector assembly - DF11-2428SC
  - PicoBlade Female-to-PicoBlade Female 151340400
    * pin 1: VBAT-SENSE
    * pin 2: ANT-SENSE
    * pin 3: ANT-REL
    * pin 4: COMMS-GND (GND that no connected to in base-plate GND)
  - JST SH Connector Female 2-Pin 1.0mm
    * pin 1: VBAT+ (TOP-PV+)
    * pin 2: GND (TOP-PV-)
    * Connector assembly

Note: we need to cut one side and we put DF11-2428SCFA(04)

Table 2: Harness Wiring

Connector A	Pin A	Pin B	Connector B	Wire	Pin Name
DF11-8DS-2C	1	3	DF11-6DS-2C	26-AWG 80 mm (RD)	VBAT+
DF11-8DS-2C	2	4	DF11-6DS-2C	26-AWG 80 mm (YL)	EPS-PWR
DF11-8DS-2C	3	1	DF11-6DS-2C	26-AWG 80 mm (BK)	KILL-GND
DF11-8DS-2C	4	2	DF11-6DS-2C	26-AWG 80 mm (BL)	GND
DF11-8DS-2C	5	4	PicoBlade 1.25mm 4-p	28-AWG 50 mm (BK)	COMMS-GND
DF11-8DS-2C	6	3	PicoBlade 1.25mm 4-p	28-AWG 50 mm (BK)	ANT-REL
DF11-8DS-2C	7	1	PicoBlade 1.25mm 4-p	28-AWG 50 mm (BK)	VBAT-SENSE
DF11-8DS-2C	8	2	PicoBlade 1.25mm 4-p	28-AWG 50 mm (BK)	ANT-SENSE
DF11-6DS-2C	5	2	JST SH F 1.0 mm 2-p	28-AWG 50 mm (BK)	GND (TOP-PV-)
DF11-6DS-2C	6	1	JST SH F 1.0 mm 2-p	28-AWG 50 mm (BK)	VBAT+ (TOP-PV+)

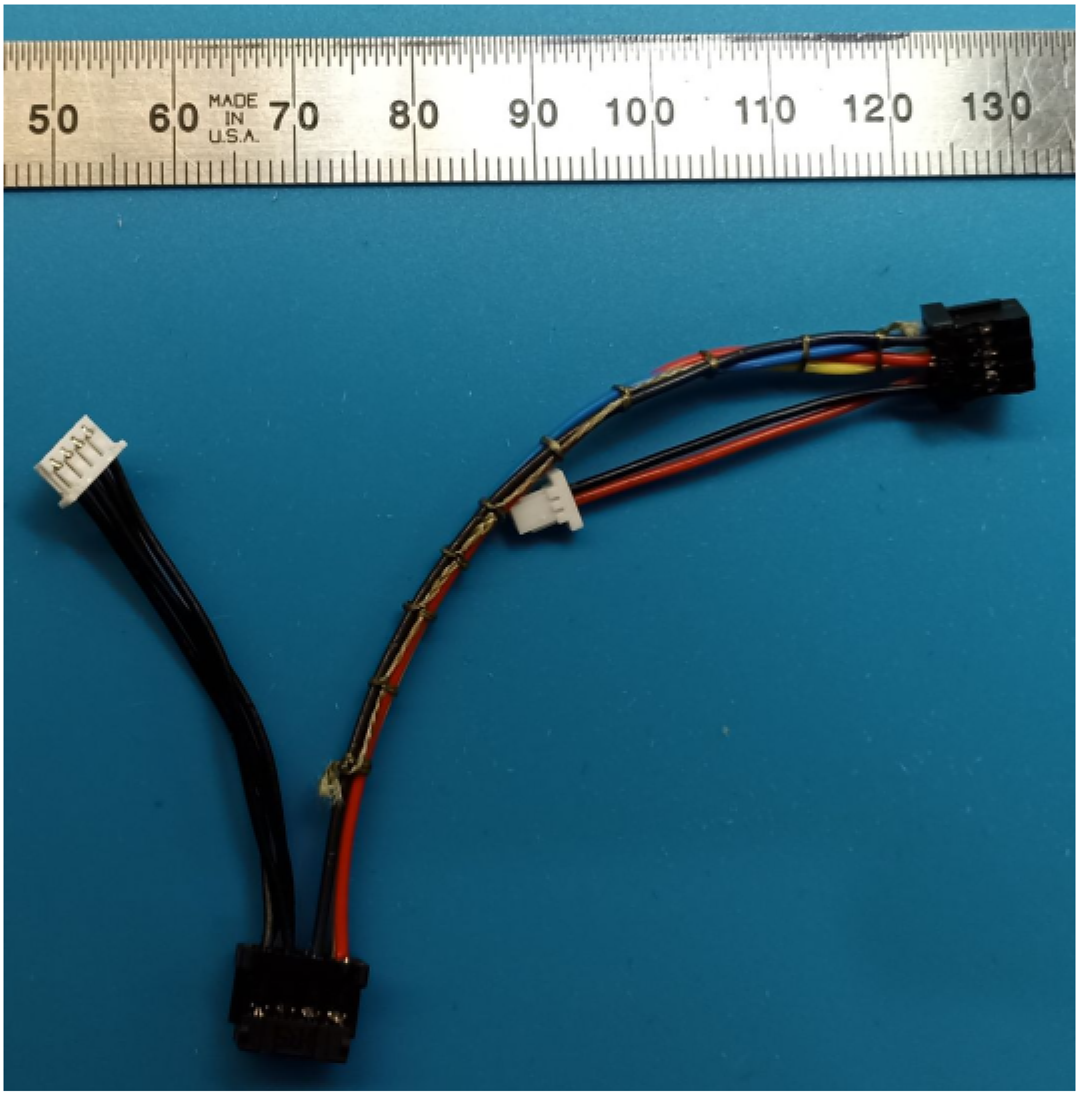

Fig. 7: Main Harness

11.2.4 COMMS Programmer cable

- Length: 50mm
- 1-pin is connected to 1-pin to other connector, so on one side we put new 1.25mm Pitch, PicoBlade Receptacle Crimp Housing.
- PicoBlade Female-to-PicoBlade Female 151340600

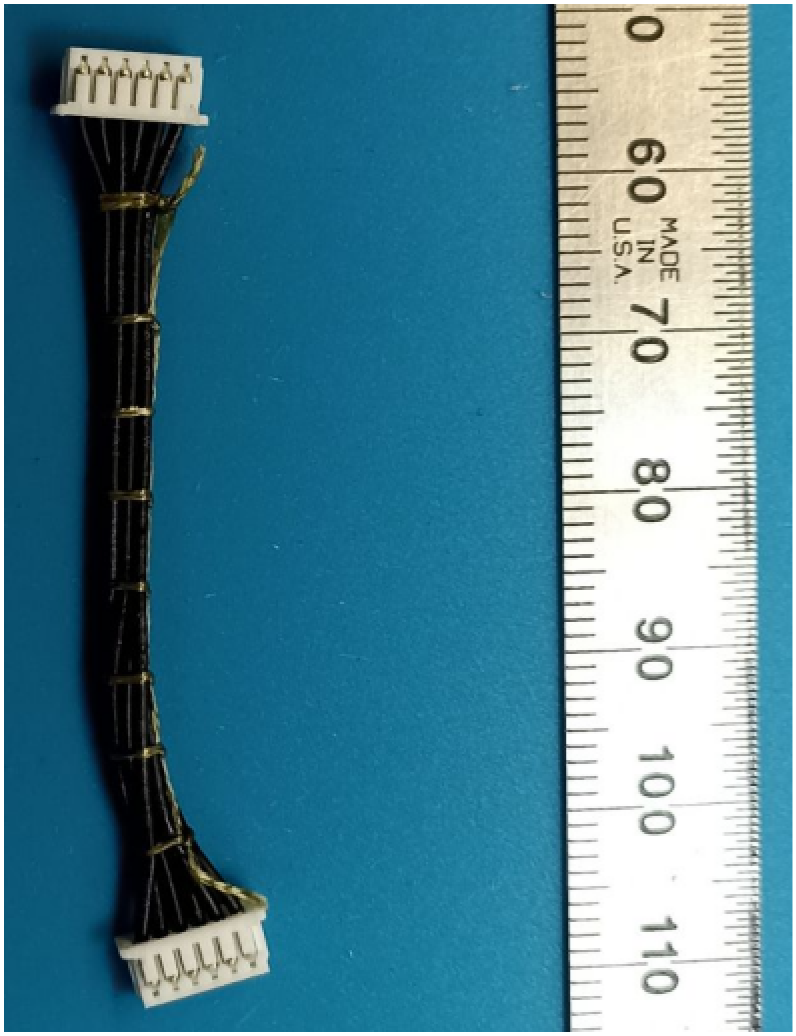

Fig. 8: COMMS Programming Cable

11.2.5 Umbilical

- Length: In depends on the programmer.
- pin1: VBAT-, black 26 AWG, when the switches is pushed, RBF in QUBIK
- pin2: EPS-PWR, yellow 26 AWG, when the switches is pushed, RBF in QUBIK
- pin3: GND, blue 26 AWG
- pin4: VBAT+, red 26AWG
- pin5: JTDO (COMMS), 28AWG red
- pin6: NC
- pin7: NRST (COMMS), 28AWG red
- pin8: NC
- pin9: SWDIO (COMMS), 28AWG red
- pin10: NC
- pin11: GND (COMMS), 28AWG black
- pin12: NC
- pin13: SWCLK (COMMS), 28AWG red
- pin14: NC
- pin15: VCCQ (COMMS), 28AWG red
- pin16: NC
- Connector assembly

11.3 System Testing

Related documentation:

- TBD

CHAPTER

TWELVE

PRE-ASSEMBLY

12.1 Dry-Fit

Follow the assembly guide **without** using glues (epoxy and Blue threadlocker). All the parts are ready and tested **without** glues and conformal coating.

Known issues:

- Collision between zip-ties of BMPS and ballast board. The guide of BMPS assembly includes the correct method.

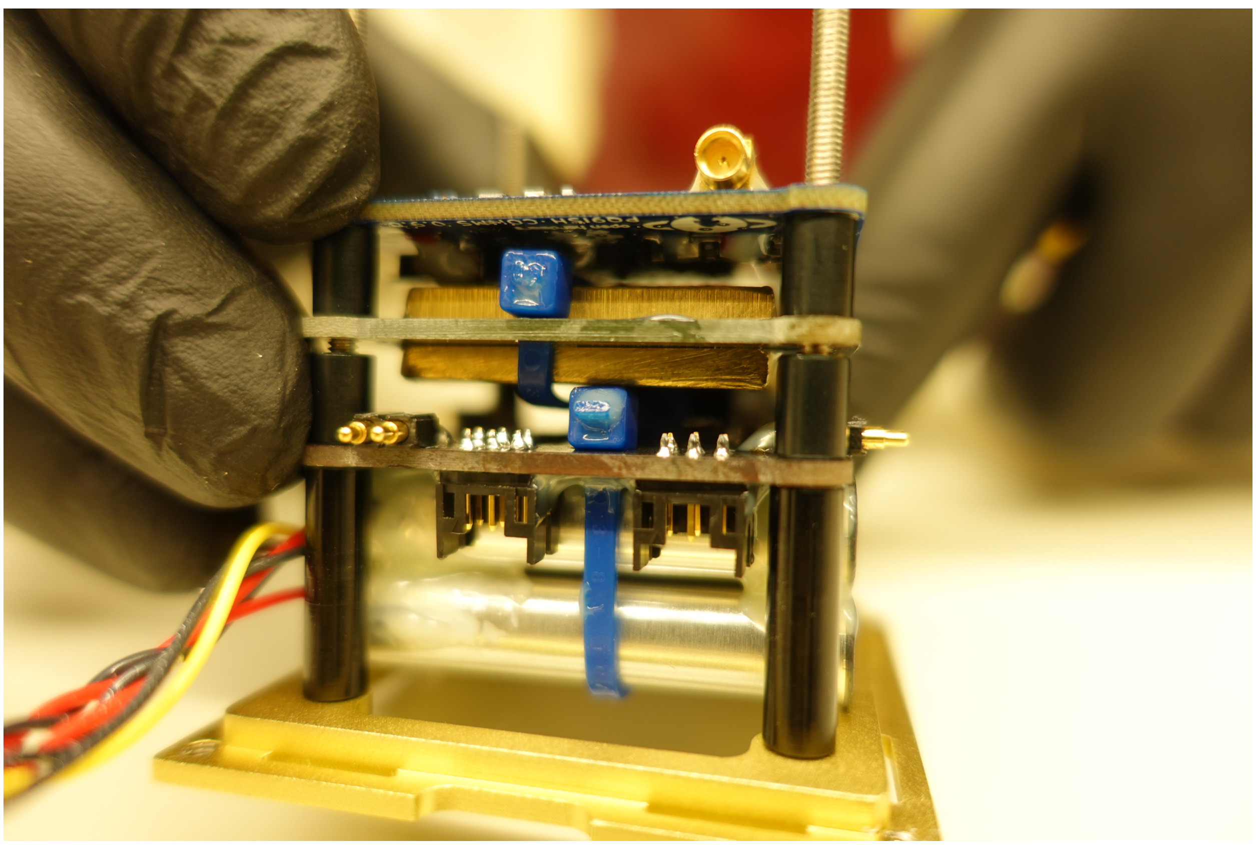

Fig. 1: Zip-ties collision

- collision between PQ9ish RF connector and antenna cable with side solar panel. In picture is appeared the spot of the antenna cable (near the number 16). A solution in case where the re-soldering of RF connector isn't possible (due to conformal or limited time)

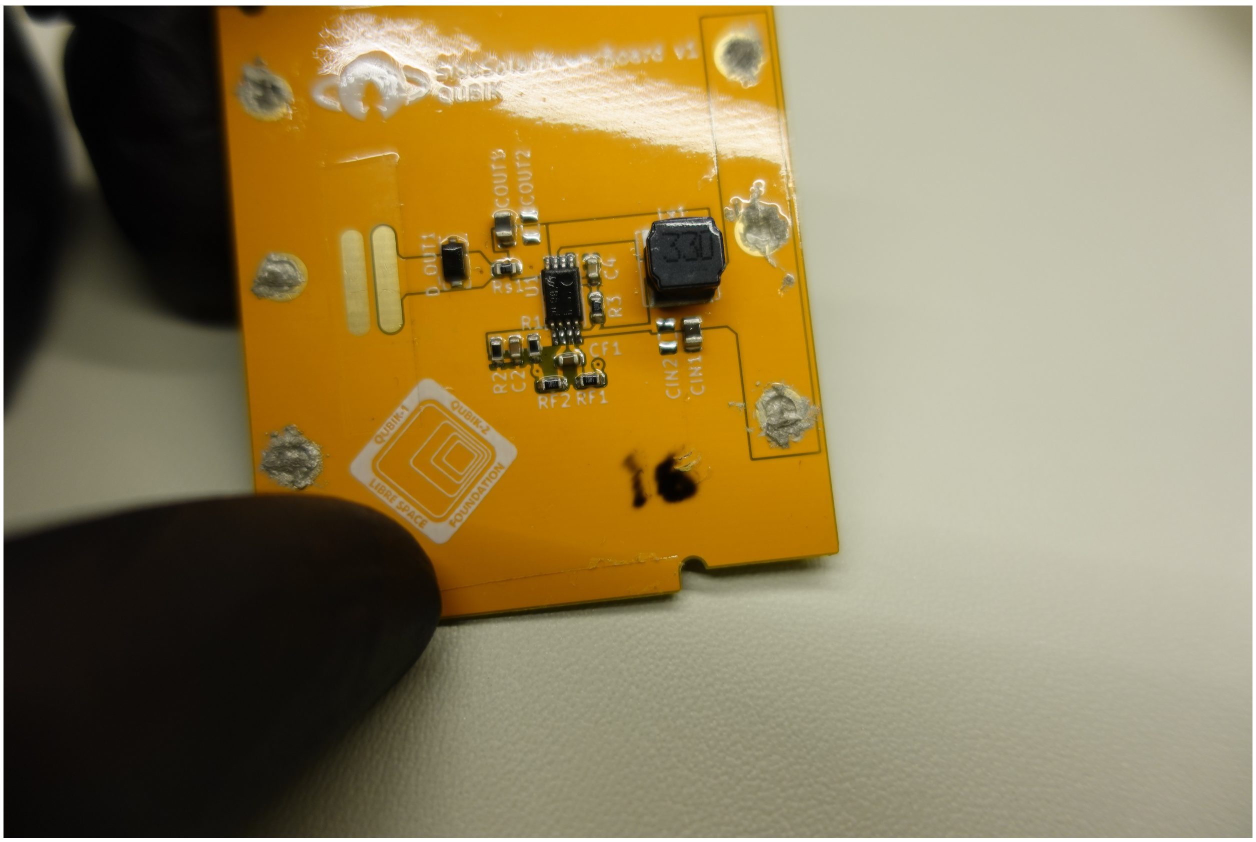

Fig. 2: RF connector and side panel collision

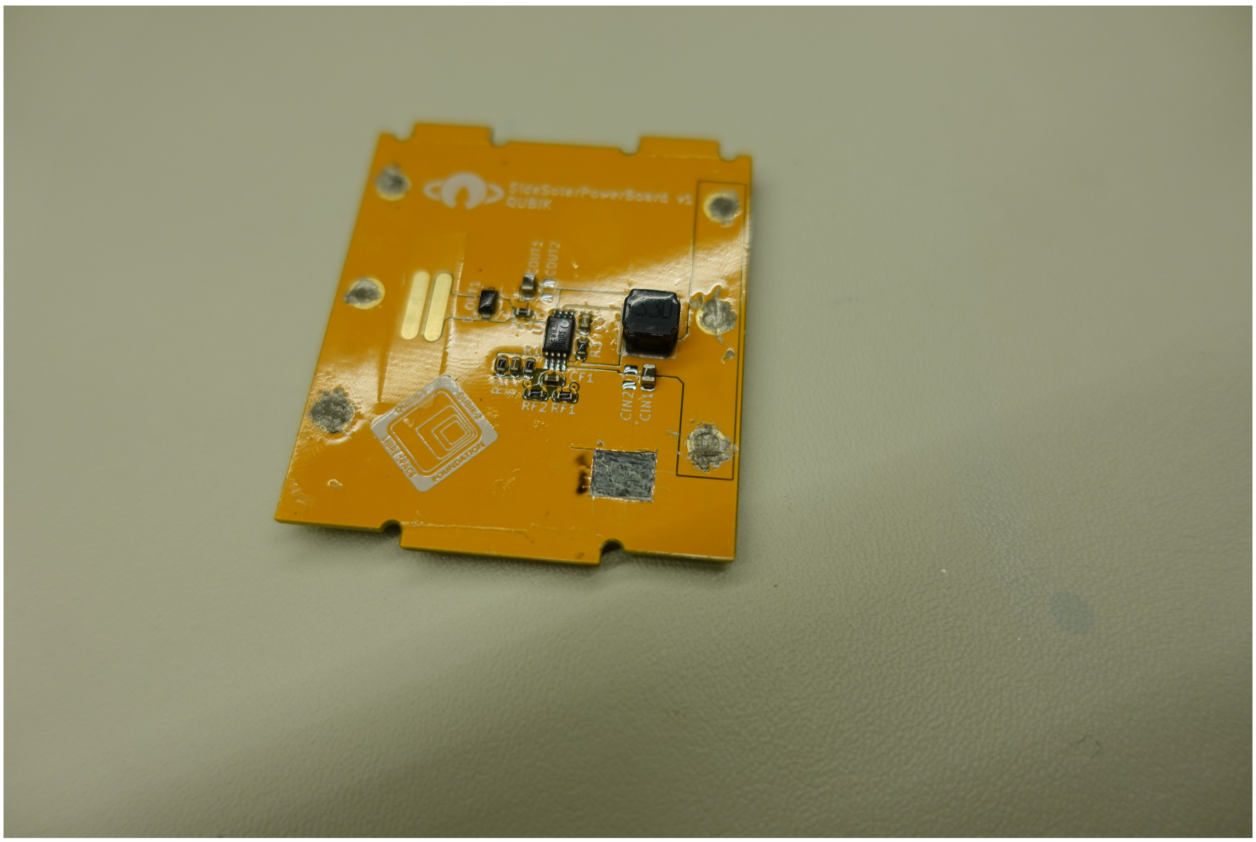

Fig. 3: RF connector and side panel collision

- Check the countersink of top frame with the screw M2.5x60 DIN965

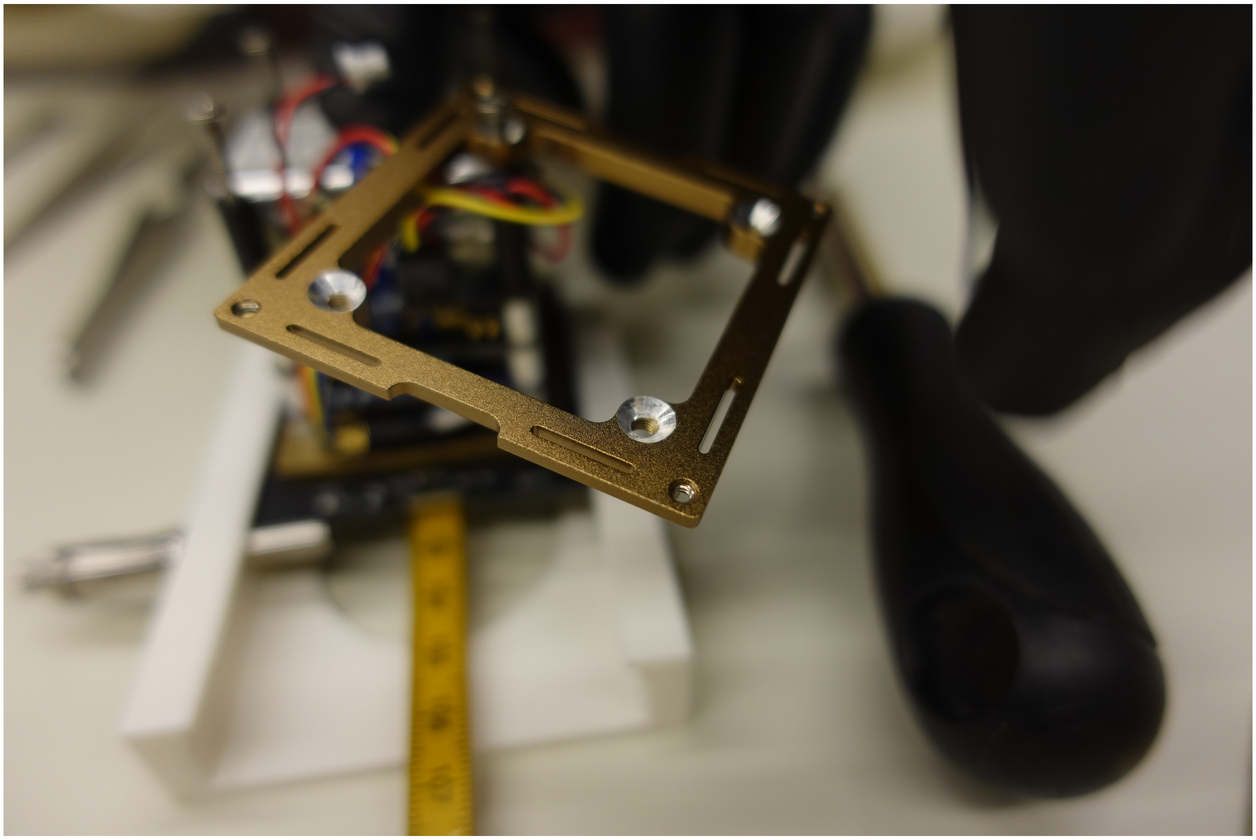

Fig. 4: Fixed countersink of top frame

- Check the soldering pad height in PQ9ish bus to be according to PQ9 standard.

This problem might drive to not connect properly the sub systems. Also pay attention in the maximum cycles of connector-SQT-109-03-L-S which are 100 in dry fit and final assembly process.

It is important to check every change in structural and perform a dry fit after it. Also the meaning of dry fit is to check the assembly before applying glues and conformal coating.

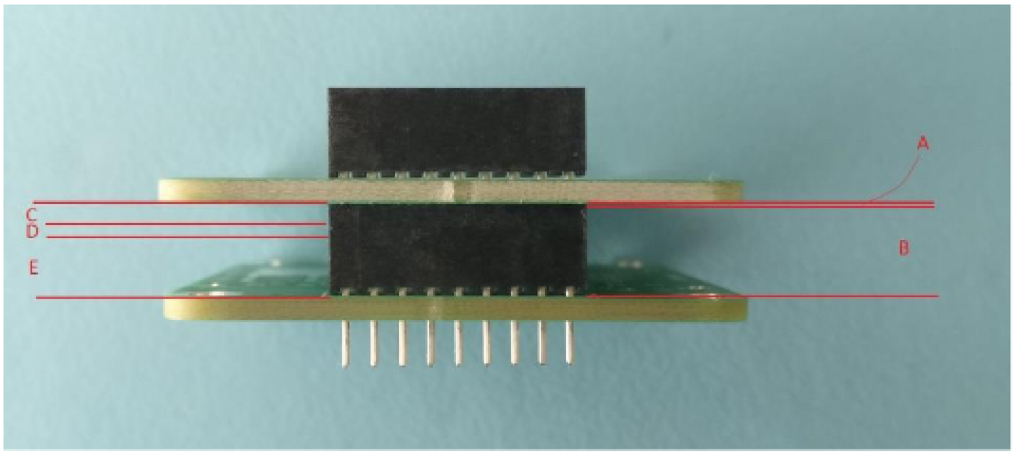

Figure 3: Out-of-plane constraints example (option I)

Table 1: Values of maximum component height and insertion depth (option I)

Symbol	Description	Value [mm]
A	Maximum soldering pad height	0.65
B	Connector height	6.35
C	Maximum height of components placed underneath upper PCB	2.00
D	Margin between components of two adjacent PCBs	1.00
E	Maximum component height	4.00
t_{PCB}	PCB thickness	1.60
$L_{pins,small}$	Pin length of the small connector	5.28
l_{depth}	Pin Insertion Depth	3.03

Fig. 5: Proper soldering pad height

CHAPTER

THIRTEEN

USER MANUAL

13.1 Integration procedure

1. Remove QUBIK from Dev tray

Note: Secure with a Kapton tape the kill switches on base plate.

1. Weight QUBIK
2. Insert QUBIK to RBF tray and secure it in place with the securing pin
3. Prepare the antennas as in QUBIK assembly guide
4. Connect COMMS programming device to umbilical and provide 3.3V power to umbilical in order to activate COMMS board
5. Reset COMMS parameters as described in Parameter storage reset procedure
6. Disconnect umbilical

13.1.1 Transfer to deployer

1. Remove securing pin
2. Slide QUBIK until base plate protrudes 5mm from RBF tray
3. Insert protruding base plate to deployer keeping RBF tray in contact with the deployer

1. Slide QUBIK into the deployer

13.2 Material List

Metals

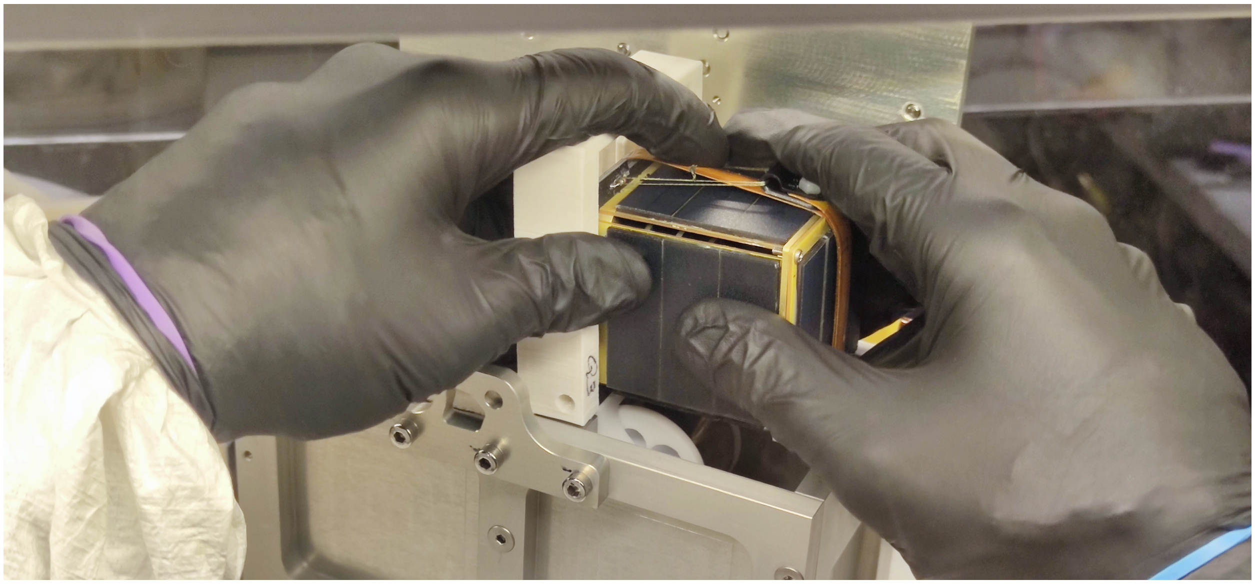

Fig. 1: Slide QUBIK in to deployer

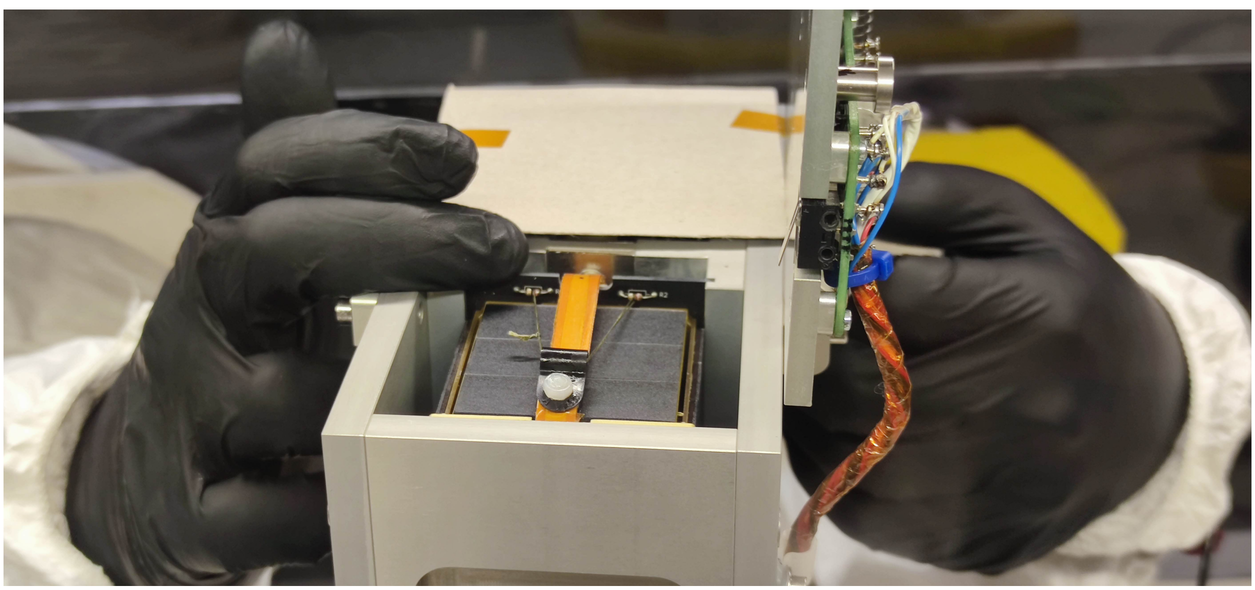

Fig. 2: QUBIK inside the deployer

PART NAME	FILE NAME	QTY	MASS per unit (gr)	MASS TOTAL (gr)	MATERIAL	SURFACE COATING
Top Plate	solar-power-board-top-mount.FCStd	1	10	10	AL6061	Anodized
Screw M2.5L60 DIN965	screw-M2_5-L60-DIN965.FCStd	4	1.7	6.8	Stainless Steel	N/A
Bottom Plate	plate.FCStd	1	9	9	AL6061	Anodized
Screw M2L6 DIN7985	screw-M2-L6-DIN7985.FCStd	4	(Included in Sub-Assemblies)	(Included in Sub-Assemblies)	Stainless Steel	N/A
Antenna	antenna.FCStd	1	(Included in Base Plate PCB)	(Included in Base Plate PCB)	Steel	Electrostatic Paint
Nut M2.5 DIN934	nut-M2_5-DIN934.FCStd	4	(Included in Sub-Assemblies)	(Included in Sub-Assemblies)	Stainless Steel	N/A
Screw M2L10DIN7985	screw-M2-L10-DIN7985.FCStd	8	(Included in Sub-Assemblies)	(Included in Sub-Assemblies)	Stainless Steel	N/A
Nut M2DIN934	nut-M2-DIN934.FCStd	8	(Included in Sub-Assemblies)	(Included in Sub-Assemblies)	Stainless Steel	N/A
PQ9ish-Bus Spacer	pq9-spacer.FCStd	12	0.4	5	AL6061	Anodized
Dummy Mass	assembly-dummy-mass.FCStd	1	45	45	Bronze	N/A
Sony NP-BX1 Battery	NP-BX1.FCStd	2	24.9	49.8	Lithium	N/A
PQ9ish-Bus Battery Spacer	pq9-battery-spacer.FCStd	4	1	4	AL6061	Anodized
M2x0.45x1D HELICOIL insert	N/A	4	(Included in Sub-Assemblies)	(Included in Sub-Assemblies)	Stainless Steel	Dry Film Lubricant
M2.5x0.45x1.5D HELICOIL insert	N/A	4	(Included in Sub-Assemblies)	(Included in Sub-Assemblies)	Stainless Steel	Dry Film Lubricant

Non-Metals

PART NAME	FILE NAME	QTY	MASS per unit (gr)	MASS TOTAL (gr)	MATERIAL	SURFACE COATING
Side Solar Panel	assembly-solar-power-board.FCStd	4	7	28	PCB	422B - Modified Conformal Coating
Top Solar Panel	assembly-solar-power-board-top.FCStd	1	11	11	PCB	422B - Modified Conformal Coating
Solar Cell	SM141K04LV.F(	15	2.3	35	Monocrystalline Silicone solar cell	N/A
Base Plate PCB	assembly-base-plate.FCStd	1	28	28	PCB	422B - Silicone Modified Conformal Coating
Antenna Mount	antenna-mount.FCStd	2	(Included in Base Plate PCB)	(Included in Base Plate PCB)	Teflon	N/A
Antenna Cable Mount	antenna-cable-mount.FCStd	1	(Included in Base Plate PCB)	(Included in Base Plate PCB)	Nylon	N/A
Antenna Cable	N/A	1	(Included in Base Plate PCB)	(Included in Base Plate PCB)	Dyneema(0.14m	N/A
Nut M3 Nylon	nut-M3-nylon.FCStd	1	(Included in Base Plate PCB)	(Included in Base Plate PCB)	Nylon	N/A
Slotted Screw M3L6 Nylon	screw-M3-L6-nylon-slotted.FCStd	1	(Included in Base Plate PCB)	(Included in Base Plate PCB)	Nylon	N/A
PQ9ish COMMS	pq9-comms.FCStd	1	10	10	PCB	422B - Silicone Modified Conformal Coating
PQ9ish EPS	pq9-eps.FCStd	1	15	15	PCB	422B - Silicone Modified Conformal Coating
Power and Signals Harness, 5853 BL005 Alpha Wire	N/A	1	(Included in Sub-Assemblies)	(Included in Sub-Assemblies)	PTFE	N/A
RF Harness, 83284 009100 Belden Wire & Cable	N/A	1	(Included in Sub-Assemblies)	(Included in Sub-Assemblies)	Fluorinated Ethylene Propylene (FEP)	N/A
Cable tie, 111-006659 Hellermann Tyton	N/A	4	(Included in Sub-Assemblies)	(Included in Sub-Assemblies)	E/TFE	N/A

Adhesives

PART NAME	FILE NAME	QTY	MASS per unit (gr)	MASS TOTAL (gr)	MATERIAL	SURFACE COATING
Loctite 9497	N/A	1	N/A	N/A	Epoxy Adhesive	N/D
Loctite 9466	N/A	1	N/A	N/A	Epoxy Adhesive	N/D
MG Chemicals 8331	N/A	1	N/A	N/A	Silver Conductive Epoxy Adhesive	N/D
Kapton Tape, 3M 1218	N/A	1	N/A	N/A	Polyimide Film Tape with Acrylic Pressure-Sensitive Adhesive	N/D
Loctite 243	N/A	1	N/A	N/A	Acrylic	N/D
MG Chemicals						SILICONE CONFORMAL COATING SPRAY

CHAPTER

FOURTEEN

INTERFACES

14.1 Payload

TBD

14.2 Umbilical

TBD

14.3 QUBIK Envelop

TBD

CHAPTER

FIFTEEN

ENVIRONMENTAL AND FUNCTIONAL TESTING

15.1 Vibration test

Perform Resonance survey, Sine, Quasi-static and Random vibration on the Satellite as specified in ECSS-E-ST-10-03C. Equipment for testing:

1. Shaker table
2. Adapter plate to mount DUT on shaker table in X, Y and Z configuration

15.2 Test profiles for vibration test

The Satellite must be tested at qualification levels following ECSS-E-ST-10-03C standards with profiles shown in the Tables below:

Resonance survey profile	
Frequency	Level (g)
5 - 2000	0.4

Sine Vibration		
Frequency	Level (g)	Sweep Rate (oct/min)
5 - 100	2.5	2
100 - 125	1.25	2

Quasi Static		
Frequency	Level (g)	Full Cycles
50	9.6	6

Random Vibration			
Frequency	Level (g2/Hz)	Overall (g rms)	Test Time (s)
20	0.006	10	120
20 - 120	0.006 + 6 dB/oct	10	120
100 - 700	0.04	10	120
700 - 2000	0.04 - 6 dB/oct	10	120
2000	0.006	10	120

15.3 Test sequence

Z test sequence		
Test ID	Test Name	Profile
1	Resonance Survey MGSE Z	Resonance Survey
2	Initial Resonance Survey Z	Resonance Survey
3	Sine Vibration Z	Sine Vibration
4	Quasi Static Shock Z	Sine Shock
5	Random Vibration Z	Random Vibration
6	Final Resonance Survey Z	Resonance Survey

X/Y Test sequence		
Test ID	Test Name	Profile
7	Resonance Survey MGSE Y/X	

Y AXIS		
Test ID	Test Name	Profile
8	Initial Resonance Survey Y	Resonance Survey
9	Sine Vibration Y	Sine Vibration
10	Quasi Static Shock Y	Sine shock
11	Random Vibration Y	Random Vibration
12	Final Resonance Survey Y	Resonance Survey

X AXIS		
Test ID	Test Name	Profile
8	Initial Resonance Survey X	Resonance Survey
9	Sine Vibration X	Sine Vibration
10	Quasi Static Shock X	Sine shock
11	Random Vibration X	Random Vibration
12	Final Resonance Survey X	Resonance Survey

Expected Result:

1. The first modal frequency in each axis should be greater than 200Hz
2. The difference in the first modal frequency between the pre- and post-resonance survey should be under 5%

3. Visual inspection of the device after vibration should not show any signs of damage
4. Functional tests should be passed successfully before and after the vibration test

15.4 Bake - Out procedure

Perform the Bake-out procedure for the Satellite as specified in LSP-REQ-317_01A:

- For proto-flight testing, Satellite should be baked in 10^{-4} Torr and 70°C for three hours after the temperature stabilization
- Satellite should be switched off (kill switches pressed) throughout the procedure
- Satellite should be weighed before and after the procedure, and the difference in mass should be less than 1% for the test to be successful
- Battery voltage should be measured before and after the test, and the difference should be less than 1%
- Satellites should be able to pass the functional tests after the bake-out test successfully

15.5 Functional testing

PREREQUISITES: The Satellite must be as it is, in the deployer, ready to be in orbit. This means that:

- It is in stowed configuration
- Identify which Satellite you are testing and mark its Tx and Rx frequencies as well as the SCID
- The firmware must be the final flight firmware
- The batteries must be fully charged
- The ground station (or ground support equipment) must be ready to communicate with the Satellite, and the logging system to be ready to record
- A 500W lamp and the tripod are ready to operate as a solar illuminator or "sun"
- A thermal camera is ready to record the temperatures while the satellite is under the "sun" and while the thermal knives are working

15.6 Ground Station test setup

Setup the ground station by following the instructions in the Link. The default setup is for pluto SDR and the satellite flashed with QUBIK 1 firmware, different setups can be found under the "docker-env_files" folder.

OVERVIEW:

- Start satellite operations in a state similar to being ejected on orbit
- Use ground station or ground support equipment to communicate, upload commands, and download data
- Command satellite to perform common operations
- Run a typical payload collection scenario and download the data. Confirm it is valid
- Use a solar illuminator if possible (or a charging source that is cycled in accordance with the expected orbit day/night cycle) to simulate in-orbit battery charge/discharge
- Allow the test to run as long as possible (several days to a week)

Time Sequence:

Time	State
T-hold of time	Activate satellite. Start counting down for the hold of time to start normal operation
T-2 min	Start thermal camera recording of thermal knifes
T+0	Antenna release
T+5 min	OSDLP operation of Satellite
T+10 min	Light up one panel each time for one minute and check the corresponding current value in telemetry. Iterate for all five panels
T+15 min	End of test

Simple telemetry request:

1. Select `2 | Request TM`
2. Select `3 | Initiate with Set V(R) (Sends a command. Good for ping)` and set `V(R)` to 0
3. Select `r | [osdlp] Resume`. Until a proper frame arrives, the rest of the commands may not appear. If this is not happening, return to 1 or check for the lock flag
4. Select `1 | Request TM`. Telemetry should arrive, and the sequence number should be increasing
5. Repeat step 4 multiple times. Check that the sequence number increases
6. Select `2 | Request Manifesto` and make sure that the Manifesto arrives
7. Terminate the session for the VCID 2 using the `2 | t | [osdlp] Terminate local osdlp service (Reset)`
8. Return to the VCID selection menu by selecting `0 | Return to the VCID selection menu`

Simple Management:

1. Select `0 | management`
2. If the Lock flag is not set, select `3 | Initiate with Set V(R) (Sends a command. Good for ping)` and set the `V(R)` to 0. Otherwise, initiate an unlock first
3. Select `r | [osdlp] Resume`.Commands should be available only if step 2 were successful
4. Select `2 | Request periodic telemetry attributes`. You should receive the corresponding frame, and the sequence number should be increasing
5. Repeat step 4 multiple times. Check that the sequence number increases
6. Terminate the session for the VCID 2 using the `t | [osdlp] Terminate local osdlp service (Reset)`
7. Return to the VCID selection menu by selecting `0 | Return to the VCID selection menu.`

Test the locking and unlocking procedure:

For this test, we will lock the satellite by force and then unlock it. For this particular example, the locking will be done on the Request TM VCID 2, but it can also be tested on the Management VCID 0.

1. Select `2 | Request TM`
2. If the Lock flag is not set, `select 3 | Initiate with Set V(R) (Sends a command. Good for ping)` and set the `V(R)` to 0. Otherwise, initiate an unlock first
3. Select `r | [osdlp] Resume`. Commands should be available only if step 2 were successful
4. Select `1 | Request TM`. Telemetry should arrive, and the sequence number should increase

5. Repeat step 4 multiple times until the sequence number reaches a number > 10 (the window that the OSDLP allows for out-of-order frames)
6. Kill the OSDLP session. Note that you have to close and restart the `netcat`
7. Re-open OSDLP and select the same VCID used in step 1. For this example, the `2 | Request TM`
8. Select `2 | Initiate no CLCW (Don't expect anything. Begin Tx)` . This will use the sequence number 0, because we just started again the osdp-operator
9. Select `1 | Request TM`
10. From now on, the VC 2 should be in Lockout mode, and the corresponding flag should be true
11. Select `r | [osdlp] Resume`. With the VC locked, this should return you to the initialization option menu
12. To start the unlock procedure, select the `4 | Initiate with Unlock. (Another command. Also good for ping)`
13. Check the telemetry and identify that the lockout flag is set to false, otherwise, go to step 12
14. With the VC unlock, normally, the `s | [osdlp] Set new V(S) (Local frame sequence number)` would be sufficient. However, due to a bug in the osdlp-operator this is not yet possible. For this reason, terminate the session using the t | [osdlp] Terminate local osdlp service (Reset)
15. Select `3 | Initiate with Set V(R) (Sends a command. Good for ping)`` and set a new `V(R)`, for example 0
16. Select `r | [osdlp] Resume`. If everything went well, the available MAP options should appear
17. Select `1 | Request TM` and check if you receive the requested frame
18. Repeat 17 and check that everything performs well
19. Select `t | [osdlp] Terminate local osdlp service (Reset)`

Change TRX delay:

1. Select `0 | Management`
2. If the Lock flag is not set, select `3 | Initiate with Set V(R) (Sends a command. Good for ping)` and set the `V(R)` to 0. Otherwise, initiate an unlock first
3. Select `r | [osdlp] Resume`. Commands should be available only if step 2 were successful.
4. Select `5 | Set TRX delay`
5. The new TRX delay should be available on the telemetry. Until this is available through Grafana, the last 10 bytes of the telemetry hex output should start with `0x00 0x64`

15.7 Day In The Life (DITL) Testing

This test, as described in Cubesat 101, validates that satellite software is nominally functional, and that the combination of hardware and software can perform its basic mission. The operation of satellite is documented and the same operation is expected when the satellite is in the orbit.

Time Sequence

Time	State
T+0 | Start counting down for 30 minutes to start normal operation	
T+28 min | Prepare the camera to record the antenna deployment, prepare the thermal camera to evaluate the thermal knife operation	
T+30 min | Antenna release	
T+1 h | 5 min OSDLP operation or Ground station testing of QUBIKs 2 min 30 s each from one station	
T+1 h 5 min | 5 min under lamp 1 min per panel	
T+2 h | 5 min OSDLP operation or Ground station testing of QUBIKs using 2 stations	
T+2 h 5 min | 5 min under lamp 1 min per panel	
T+3 h | 5 min OSDLP operation or Ground station testing of QUBIKs using 2 stations	
T+3 h 5 min | 5 min under lamp 1 min per panel	
T+4 h | 5 min OSDLP operation or Ground station testing of QUBIKs using 2 stations	
T+4 h 5 min | 5 min under lamp 1 min per panel	
T+4 h 10 min | End of test	

The start/stop of test must be logged. For each step follow previous sections.

- search