QB50

System Requirements and Recommendations

Issue 7

13 February 2015

Issue No.	Issue Date	Revision Control
1	19 March 2012	
2	24 August 2012	
3	5 February 2013	
4	5 July 2013	
5	11 October 2013	- Updated QB50-SYS-1.4.1 to define WOD as the following set of parameters: time, spacecraft mode, battery bus voltage, battery bus current, current on regulated bus 3.3V, current on regulated bus 5.0V, communication subsystem temperature, EPS temperature and battery temperature. - Added a recommendation for downlink-only ground station network compatibility in the OBC / OBDH section. - Updated QB50-SYS-1.5.4 to indicate the information to be included in telemetry downstream. - Deleted QB50-SYS-1.5.10. The position accuracy requirement for the CubeSat is dependant upon the science sensor which it is carrying and it is specified in the corresponding ICD. - Updated QB50-SYS-1.5.11 to state the additional information that should be provided through the beacon. - Updated QB50-SYS-1.5.13 to state where the data type during downlink should be specified. - Replaced Mission Display Centre section with QB50 Storage Server on page 22 as it was more appropriate. - Updated QB50-SYS-1.7.9 to remove uncertainty in the type of data that is to be sent to the QB50 storage server by the teams. - Removed paragraph about Mission Display Centre as it is no longer relevant to this document. - Added QB50-SYS-1.7.10.

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Issue No.	Issue Date	Revision Control
		- Added a section on Science Operation Period containing 2 additional requirements: QB50-SYS-1.7.11 and QB50-SYS-1.7.12.
6	9 July 2014	- Included additional reference documents (Cyclone-4 User Manual, WOD packet format, Example umbilical connectors, SCS description and ICD) - Updated deployment system terminology from StackPack to QuadPack. - Updated CubeSat Access Hatch section to clarify that the access hatch is on the deployer and the access connector on the CubeSat is to be smaller such that it could fit through the hatch. To this end, a recommendation was added. - Added QB50-SYS-1.1.9. This was always a requirement but it was previously embedded within the text. - Updated Mass section to state the upper mass limits are from the QB50 Project, instead of the capabilities of the QuadPack. - Added remark after QB50-1.3.2. - Updated the Whole Orbit Data (WOD) section to clarify what is required for temperature values as part of the WOD. - Updated QB50-SYS-1.4.5 such that OBSW and mission support software is simplified to only OBSW. - Updated QB50-SYS-1.4.6 to clarify that the infinite loops mentioned in this requirement was referring to *unintentional* infinite loops. - Updated QB50-SYS-1.4.7 to state "implemented" instead of "foreseen". - Updated QB50-SYS-1.4.8 to be more clear on the type of software that is to be on the CubeSat.

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Issue No.	Issue Date	Revision Control
		- Updated Satellite Control Software section to remove DPAC and MCC and to indicate that the CubeSat teams will be interacting with a QB50 central server for data uploading. Also, the ICD for the SCS provided by EPFL should be consulted for teams that plan to use it. - Added a recommendation to avoid encapsulating one protocol within another. - Updated QB50-SYS-1.5.9. - Updated Thermal Control section to state that the thermal cycling levels are provided in Chapter 2 - Updated Apply Before Flight, Remove Before Flight items section to state that the RBF and ABF tags should fit through the access hatch and should be inserted / removed only after integration into the deployer. - Updated QB50-1.7.8 to specify what is meant by CubeSat name. - Removed all TBCs and TBDs from Chapter 1. - Revised entire Chapter 2, the system requirement numbering has been kept consistent with issue 5 when possible. - Added detailed quality assurance (QA) process in Chapter 3 - Unified names for QB50 central server and QB50 storage server, now are all named QB50 central server. - Updated Figure 3. - Added QB50-SYS-1.4.9 to clarify science data deletion. - Updated QB50-SYS-1.6.2. - Updated QB50-SYS-1.5.14.
7	2 February 2015	- Updated DPAC acronym and deleted MDC. - Reworded the “Important note” of Section 1 and added a reference to QB50 website.

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Issue No.	Issue Date	Revision Control
		- Updated Applicable & Reference documents (Issue numbers and dates). - Updated QB50-SYS-1.2.1, based on the Precursor campaign: higher tip-off rates, 3 days instead of 2. - Added Recommendation 13, based on the Precursor campaign. - Added Recommendation 14, based on the Precursor campaign. - Updated QB50-SYS-1.4.1: additional details in case the bus is not acquiring some values. - In Recommendation 10, replaced *QB50 central server* by DPAC. - In paragraph "Satellite Control Software" p.24, replaced *central server* by DPAC. - In Recommendation 12, removed *(1 week)*. - QB50-SYS-1.5.12 turned into Recommendation 15. - Added Recommendation 16, based on the Precursor campaign. - Updated QB50-SYS-1.7.1: the required lifetime is now 6 months instead of 3. - Subsection "QB50 Central server" p.30 became "QB50 Display, Processing, and Archiving Center (DPAC)". - Updated QB50-SYS-1.7.11: the duration for commissioning is now 1 month instead of 1 week. - Updated QB50-SYS-1.7.12, added QB50-SYS-1.7.13, Recommendation 17, and Figure 6: the concept of operations is modified (every second day but for a longer period). - Updated the introduction of Section 2 with orbital parameters. - Added requirement QB50-SYS-2.0.1. This requirement returns to the requirement of QB50 System Requirements and Recommendations Issue 5.

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Issue No.	Issue Date	Revision Control
		- In Table 6 (Acceleration test characteristics), the amplitude for qualification is modified to 13 g. - In Table 7 (Resonance survey test characteristics), a clarification note is added. - In Table 8 (Sinusoidal vibration test characteristics), the test profile is modified (frequency range extended to 125 Hz, amplitudes modified). - In Table 9 (Random vibration test characteristics), the duration is increased to 120 s for acceptance and protoflight tests. - In Table 9 (Random vibration test characteristics), the amplitude required for qualification is increased. - In Table 10 (Shock test characteristics), the test profile for protoflight is modified (lower loads). - Section 2.9 is thoroughly revised to lighten the required tests and provide guidelines for extensive EMC testing. QB50-SYS-2.9.1 updated, QB50-SYS-2.9.2 and Recommendation 18 added. - Modified introduction of Subsection 3.1.2, due to modification of Section 2.9. - New Subsection 3.1.7 with additional requirements and recommendations on functional tests. - Added QB50-SYS-3.1.2 and Recommendation 19 for continuous testing (with representative durations) of the flight software. - Added Recommendation 20 for representative testing of the ground station.

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Contents

List of acronyms

1U, 2U, 3U	1-Unit, 2-Unit and 3-Unit CubeSat sizes, respectively
ABF	Apply Before Flight
ACRR	Adjacent Channel Rejection Ratio
AMSAT	Amateur Radio Satellite
BPSK	Binary Phase Shift Keying
BRF	Body Reference Frame
CalPoly	California Polytechnical State University, SLO
CDR	Critical Design Review
CMD	Command
CSS	Command Sequence Script
CVCM	Collected Volatile Condensable Material
DC	Direct Current
DPAC	QB50 Display, Processing, and Archiving Centre
EGSE	Electronic Ground Support Equipment
EM	Electro-Magnetic
EMC	Electro-Magnetic Compatibility
EQM	Engineering / Qualification Model
ESD	Electro-Static Discharge
FIPEX	Flux-ϕ-Probe Experiment
FM	Flight Model
GS	Ground Station
GSE	Ground Support Equipment
HIL	Hardware-In-the-Loop
HDRM	Hold Down and Release Mechanism
IARU	International Amateur Radio Union
ICD	Interface Control Document
INMS	Ion/ Neutral Mass Spectrometer
ISIS	Innovative Solutions In Space BV
LEOP	Launch and Early Orbit Phase
LRF	Launcher Reference Frame
LV	Launch Vehicle
MM	Mass Memory
MNLP	Multi-Needle Langmuir Probe
MSSL	Mullard Space Science Laboratory

OBC	On-Board Computer
OBDH	On-Board Data Handling
OBSW	On-Board Software
NPU	Northwestern Polytechnical University, China
PCB	Printed Circuit Board
PDR	Preliminary Design Review
QA	Quality Assurance
QPSK	Quadrature Phase Shift Keying
RBF	Remove Before Flight
RE	Radiated Emission
RF	Radio Frequency
RFT	Reference Functional Tests
RS	Radiated Susceptibility
SA	Signal Answer
SCS	Satellite Control Software
SLO	San Luis Obispo, California, United States of America
SU	Sensor Unit
TBC	To Be Confirmed
TBD	To Be Determined
TCF	Thermal Cycling Functional
TT&C	Telemetry, Tracking and Command
TML	Total Mass Loss
UHF	Ultra High Frequency
VFT	Verification Functional Tests
VHF	Very High Frequency
VKI	von Karman Institute for Fluid Dynamics
WOD	Whole Orbit Data

Applicable documents

Reference No.	Document Name	Document Title
[A01]	QB50-INMS-MSSL-ID-12001 Issue 10	*QB50 INMS Science Unit Interface Control Document*, Mullard Space Science Laboratory (MSSL), 15 September 2014
[A02]	INMS Compliancy Matrix.xlsx	*QB50 INMS Compliancy Matrix*, Mullard Space Science Laboratory (MSSL), 15 September 2014
[A03]	ILR-RFS_FPXQB50_ICD-1000-10 Issue 2.4	*QB50 FIPEX Science Unit Interface Control Document*, Technische Universitat Dresden (TU Dresden), 30 September 2014
[A04]	FIPEX Compliancy Matrix.xlsx Version 2	*QB50 FIPEX Compliancy Matrix*, Technische Universitat Dresden (TU Dresden), 15 September 2014
[A05]	QB50-UiO-ID-0001 M-NLP Issue 4	*QB50 MNLP Science Unit Interface Control Document*, University of Oslo (UiO), 11 September 2014
[A06]	MNLP Compliancy Matrix.xlsx Version 2	*QB50 MNLP Compliancy Matrix*, University of Oslo (UiO), 15 September 2014

NOTE:

In addition to this *QB50 System Requirements and Recommendation - Issue 7* document, CubeSats that carry the QB50 Science Unit have to adhere to their corresponding Interface Control Document (ICD) and their Compliancy Matrix, which are listed in this (Applicable documents) section. That is,

- CubeSats with an INMS shall also comply with [A01] - *QB50 INMS Science Unit Interface Control Document* and [A02] - *QB50 INMS Compliancy Matrix*
- CubeSats with a FIPEX shall also comply with [A03] - *QB50 FIPEX Science Unit Interface Control Document* and [A04] - *QB50 FIPEX Compliancy Matrix*

- CubeSats with a MNLP shall also comply with [A05] - *QB50 MNLP Science Unit Interface Control Document* and [A06] - *QB50 MNLP Compliancy Matrix*

Reference documents

Reference No.	Document Name	Document Title
[R01]	call_proposals_QB50.pdf	*Call for CubeSat Proposals for QB50*, von Karman Institute for Fluid Dynamics (VKI), Brussels, Belgium, 15 February 2012
[R02]	cds_rev12.pdf	*CubeSat Design Specification Rev. 12*, The CubeSat Program, Cal Poly SLO, 2009
[R03]	2_4_scholz.pdf [1]	*Recommended Set of Models and Input Parameters for the Simulations of Orbital Dynamics of the QB50 CubeSats* T. Scholz, C.O.Asma, A.Aruliah, 15 February 2012
[R04]	cyclone_4_users_guide.pdf	*Cyclone-4 Launch Vehicle Issue 1*, Alcantara Cyclone Space, Brasilia, Brazil, Oct 2010
[R05]	QB50 Whole Orbit Data - Iss4.pdf	*Whole Orbit Data Packet Format, Issue 4*, von Karman Institute for Fluid Dynamics (VKI), Brussels, Belgium, October 2014
[R06]	Umbilical_Options.pdf	*Examples of Umbilical Connectors*, Innovative Solutions in Space B.V (ISIS), Delft, Netherlands, 6 Dec 2013
[R07]	10 - QB50-EPFL-SSC-SCS-ICD-D2501-4-0.pdf	*SCS description and interface control document Issue 4*, Swiss Space Center Ecole Polytechnique Federale de Lausanne (EPFL), Lausanne, Switzerland, 31 July 2014

[1] This document is not fully up to date with respect to the orbit and the launch vehicle, however, the model is still valid

1 CubeSat System Requirements

IMPORTANT NOTE:

Please take the following points into account:

- In addition to the requirements stated in this document, **all QB50 CubeSats shall also comply with the requirements specified in CalPoly's CubeSat Design Specification, Rev 12** [R02]. However, if there is any contradiction (e.g mass), then the requirement in this document supersedes it. There does exist a CDS Rev 13 from Cal Poly, but the reference for QB50 CubeSats is the Rev 12.
- In addition to the requirements stated in this document, the CubeSat teams shall comply with the QB50 schedule and milestones (including reviews) as presented on the QB50 website (`https://www.qb50.eu`).
- VHF downlinks cannot be used.

1.1 Structural Subsystem

Dimension

Several standard CubeSat sizes are identified in "Units" relative to the original 1-Unit CubeSat. Only 2U and 3U CubeSats are anticipated for QB50. The dimensions are shown in Table 3.

QB50-SYS-1.1.1 CubeSats dimensions shall be as shown in Table 3.

Table 3: Generic CubeSat dimensions

Property	2U	3U
Footprint	$100 \times 100 \pm 0.1\ mm$	$100 \times 100 \pm 0.1\ mm$
Height	$227 \pm 0.1\ mm$	$340.5 \pm 0.1\ mm$
Feet	$8.5 \times 8.5 \pm 0.1\ mm$	$8.5 \times 8.5 \pm 0.1\ mm$
Rails	External edges shall be rounded $R \times 1mm$ or chamfered $45^\circ \times 1mm$	External edges shall be rounded $R \times 1mm$ or chamfered $45^\circ \times 1mm$

Reference Frame

QB50-SYS-1.1.2 **The CubeSats shall use the reference frame as shown in Figure 1 such that it will be in line with the reference frame of the deployment system.**

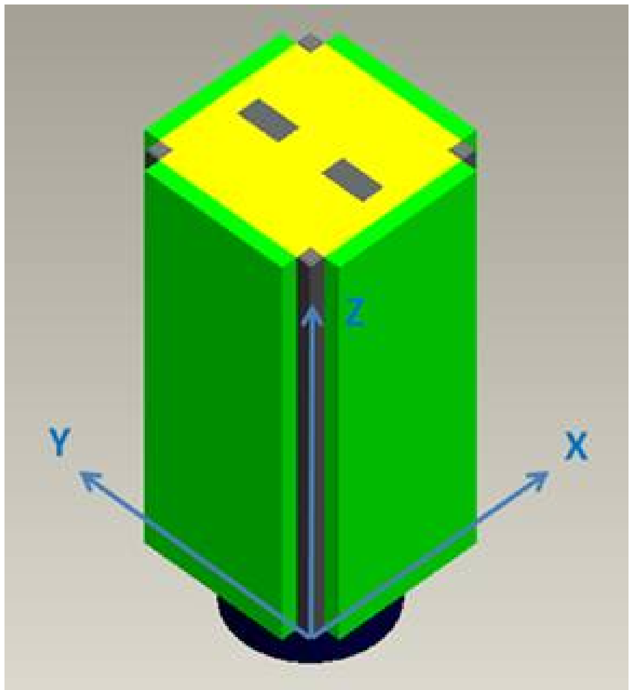

Figure 1: QB50 CubeSat reference frame

Extended Volumes

The QuadPack - the deployment system for the QB50 mission - can accommodate 2U and 3U CubeSats. It provides extra volume to accommodate deployables, appendices, booms, antennas and solar panels. It offers lateral clearance between the CubeSat lateral sides and the QuadPack side panels. Moreover the QuadPack provides the capability to accommodate CubeSats with both, front and back extended volumes. However, for the CubeSats carrying the Science Unit, only the front could be used as the back extended volume is allocated for the Science Unit.

Figure 2 shows the QuadPack extended volumes provided for the QB50 CubeSats; lateral extensions (-X, +X, -Y and +Y) are depicted in green, while front one (+Z) in yellow and back one (-Z) in blue.

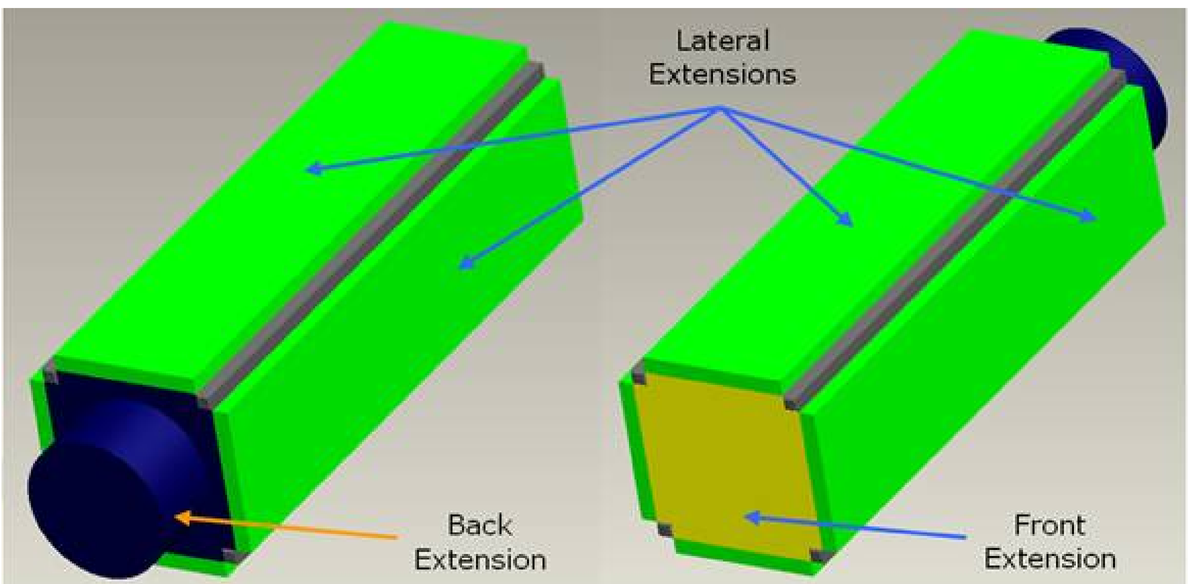

Figure 2: CubeSats lateral (green), front (yellow) and back (blue) extended volumes.

QB50-SYS-1.1.3 **In launch configuration the CubeSat shall fit entirely within the extended volume dimensions shown in Figure 3 for a 2U CubeSat or Figure 4 for a 3U CubeSat, including any protrusions.**

Figure 3 shows the maximum dimensions in millimetres allowed by the QuadPack for the QB50 2U CubeSat extended volumes. Note that these dimensions relate to the extended volumes of the CubeSat and not the height of the guide rails of the CubeSat. The height is still 227 mm as stated in Table 3.

Figure 4 shows the maximum dimensions in millimetres allowed by the QuadPack for the QB50

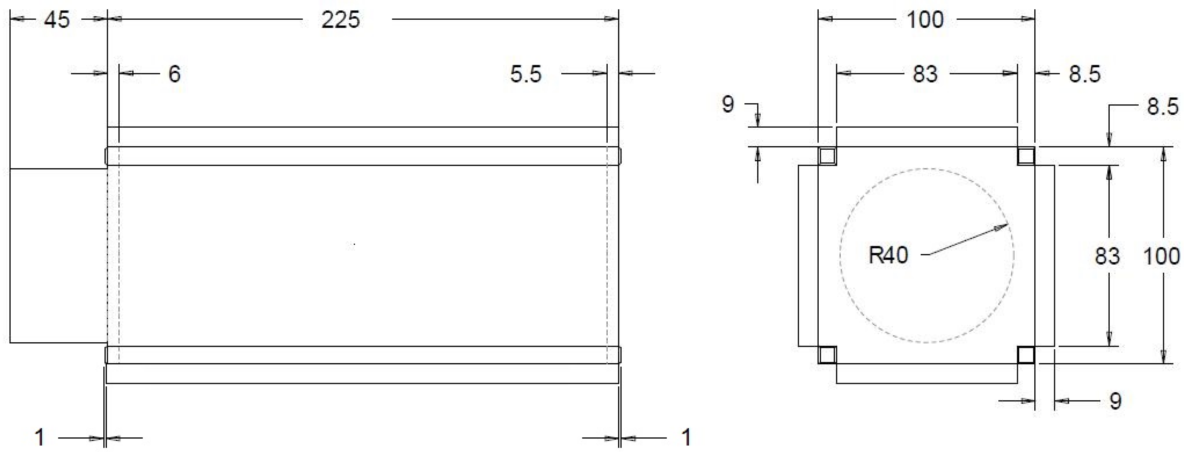

Figure 3: 2U CubeSat extended volume dimensions in millimetres.

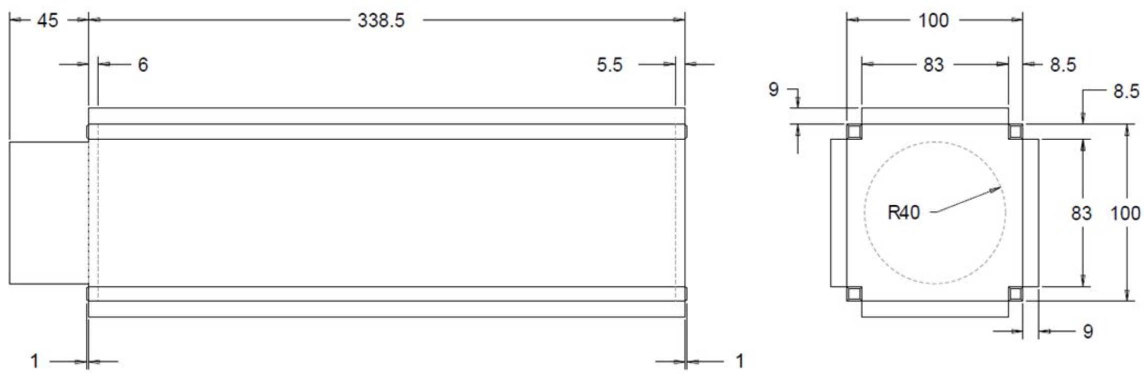

Figure 4: 3U CubeSat extended volume dimensions in millimetres.

3U CubeSat extended volumes. Note that these dimensions relate to the extended volumes of the CubeSat and not the height of the guide rails of the CubeSat. The height is still 340.5 mm as stated in Table 3.

CubeSat Access Hatches

QB50-SYS-1.1.4 **After integration into the QuadPack, the CubeSat shall only require access, for any purpose, through the access hatches in the door of the QuadPack. The position and dimensions of these hatches are shown in Figure 5.**

Remove Before Flight (RBF) tags should be able to be removed through these access hatches only. Likewise, Apply Before Flight (ABF) tags should only be accessible via these access hatches. These tags can only be removed / applied after integration into the QuadPack. Therefore they

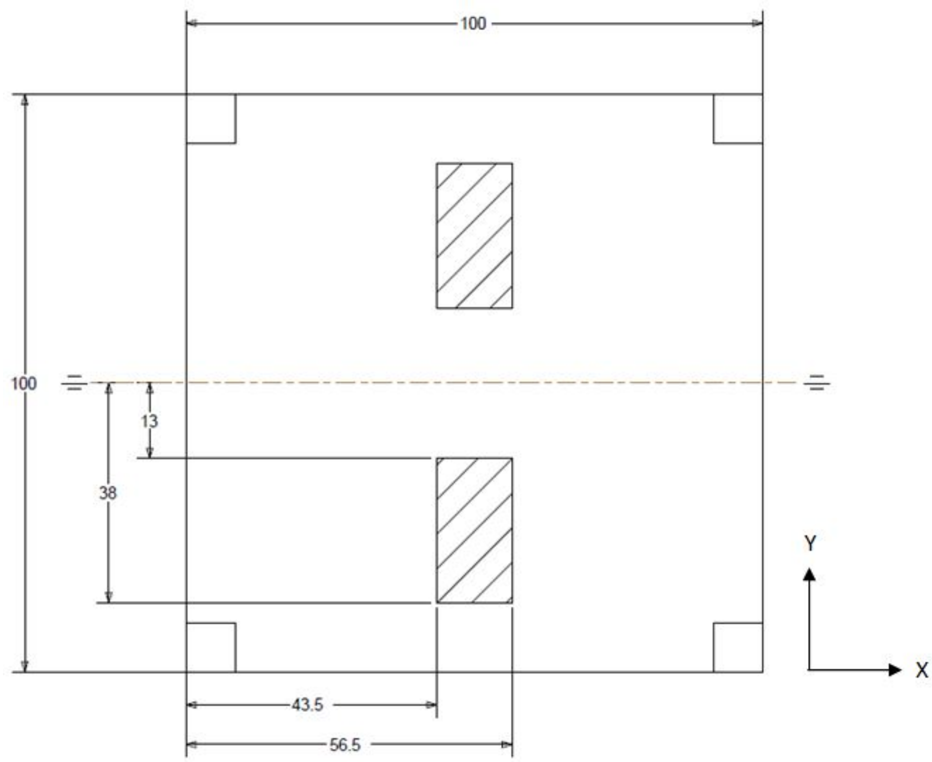

Figure 5: Definition of the CubeSat connector placement envelope on the +Z face.

should be able to fit within the specified dimension.

As the CubeSat can only be accessed / connected through the front door after integration into the QuadPack, the CubeSat connector has to be on the front side (+Z face), which is opposite to the Science Unit. Figure 5 defines the envelope within which these connectors could be placed on the CubeSat front side (+Z face). The teams can place their umbilical interface / connector within any of these two $25\ mm \times 13\ mm$ areas. This dimension is the projection of the access hatch of the QuadPack door on the CubeSat. The distance from the door to the CubeSat feet is approximately $1mm$.

Recommendation 8: **It is recommended to have a connector that is smaller than** $25\ mm \times 13\ mm$ **– which is the dimension of the access hatch – so that the connector could fit through it.**

Each CubeSat team is free to select the connector according to their needs as long as it complies with the front side available areas (and of course with the CubeSat envelope). A few examples of suitable connectors are specified in [R06].

QB50-SYS-1.1.9 **Due to the wide range of possible solutions each team shall supply the required Electrical Ground Support Equipment (EGSE) and harness.**

Due to time and space constraints, only one access opportunity after integration of the CubeSat into the QuadPack at ISIS will be granted to each team to perform all the required activities (data connectivity, battery charge, checkout, etc). Afterward, in a nominal situation, no battery charging or checkout will be performed. In a non-nominal situation, battery charging / checkout could be performed - given that a proper user manual and procedure, EGSE is available - by a QB50 Consortium member. Although, the Consortium Board cannot take responsibility for the health of the satellite.

Mass

As stated previously, the QuadPack is designed to accommodate both 2U and 3U CubeSats. Table 4 states the specifications for the maximum masses of the different QB50 CubeSat that is allowed by the QB50 Project.

QB50-SYS-1.1.5 The CubeSat mass shall be no greater than that shown in Table 4.

Table 4: CubeSat masses admitted by the QB50 Project

CubeSat Size	Maximum Mass
2U CubeSat	2.0 kg
3U CubeSat	3.0 kg

Centre of Gravity

QB50-SYS-1.1.6 The CubeSat centre of gravity shall be located within a sphere of 20 mm diameter, centered on the CubeSat geometric centre.

This is required in order to control misalignment of the QuadPack centre of gravity position on the launch vehicle.

Recommendation 1: For aerodynamic stability, it is recommended to have the CubeSat centre of gravity towards the face of the Science Unit (-Z face, which will be in the spacecraft ram velocity direction) with respect to the CubeSat geometric centre.

Deployment Switches

QB50-SYS-1.1.7 Deployment switches shall be non-latching (electrically or mechanically).

Material

QB50-SYS-1.1.8 The CubeSat rails and standoffs, which contact the QuadPack rails, pusher plate, door, and/or adjacent CubeSat standoffs, shall be constructed of a material that cannot cold-weld to any adjacent materials.

1.2 Attitude Determination and Control Subsystem (ADCS)

The ADCS is responsible for detumbling the satellite after deployment, pointing the satellite in a favourable attitude to meet the mission requirements as well as for recovering it from any spin ups during the mission. It is also responsible for determining the satellite's attitude. System level requirements that are applicable to the ADCS are the following:

QB50-SYS-1.2.1 **The CubeSat shall be able to recover from tip-off rates of up to $\pm 50°/s$ within 3 days (nominal conditions).**

Recommendation 13: **The CubeSat shall be able to recover from tip-off rates of up to $\pm 90°/s$ in off-nominal situation.**

The requirement and the recommendation above are both based on the lessons learned from the QB50 precursor flight.

QB50-SYS-1.2.2 **The Science Unit will be accommodated at one end of the CubeSat, on a $10\ mm \times 10\ mm$ face — the -Z face using the CubeSat reference frame as shown in Figure 1. The vector normal to this face shall be in the spacecraft ram velocity direction. The face shall not be available for solar cells, or for any other subsystem and nothing must forward this face.**

Recommendation 9: **Teams using on-board GPS receiver should foresee the usage of GPS orbital positions for improvement of early TLEs with high uncertainties during LEOP.**

Recommendation 14: **Magnetizable material shall not be used for CubeSat parts.**
This is because magnetizable materials may impact ADCS performances.

1.3 Electrical Power System (EPS)

The main purpose of the EPS is to provide enough electrical power to the rest of the subsystems such that the satellite is able to function during the entire length of the mission. The following are system level requirements that are applicable to the EPS:

QB50-SYS-1.3.1 **The CubeSat shall provide sufficient power at the appropriate voltage, either by solar array generation or battery, to meet the power requirements of all satellite subsystems in all modes of operation.**

QB50-SYS-1.3.2 **The CubeSat shall be able to be commissioned in orbit following the last powered-down state without battery charging, inspection or functional testing for a period of up to 8 months.**

This requirement should also be fulfilled even in the case that the batteries are completely drained.

QB50-SYS-1.3.3 **The CubeSat shall be powered OFF during the entire launch and until it is deployed from the deployment system.**

1.4 On-Board Computer (OBC) and On-Board Data Handling (OBDH)

As the 'brain' of the satellite, the OBC/OBDH subsystem is responsible for communicating with the rest of the subsystems and for relaying information between them. The following are system level requirements that are applicable to the OBC/OBDH subsystem:

Whole Orbit Data (WOD)

QB50-SYS-1.4.1 **The CubeSat shall collect whole orbit data and log telemetry every minute for the entire duration of the mission, where whole orbit data is defined as the following set of parameters: time, spacecraft mode, battery bus voltage, battery bus current, current on regulated bus 3.3V, current on regulated bus 5.0V, communication subsystem temperature, EPS temperature and battery temperature. If the bus is not acquiring some of this data, the WOD shall contain a 0 instead. The WOD packet format is documented in the reference document [R05].**

For the temperature values, an average should be used if there are multiple measurements available. For example, the temperature of the microcontroller on the EPS board or the average of the boost converters should be used for the EPS temperature.

QB50-SYS-1.4.2 **The whole orbit data shall be stored in the OBC until they are successfully downlinked.**

This is so that the information could be used to determine the causes of any problems in the case of a CubeSat anomaly.

Recommendation 10: **The correctness of received WOD packages should be verified by teams on ground (e.g. using parameter range checks) prior to submission to the DPAC.**

Clock

QB50-SYS-1.4.3 **Any computer clock used on the CubeSat and on the ground segment shall exclusively use Coordinated Universal Time (UTC) as time reference.**

QB50-SYS-1.4.4 **The OBC shall have a real time clock information with an accuracy of 500ms during science operation. Relative times should be counted / stored according to the epoch 01.01.2000 00:00:00 UTC.**

This requirement requests real time clock *information* and not necessarily a real time clock on board the CubeSat. The use of a GPS or an uplink clock synchronization command could provide such information.

Inhibit Override

QB50-SYS-1.4.5 **The onboard software (OBSW) shall not be allowed to override hardware inhibits such as the deployment switch. (This is not applicable during check-out via umbilical cord).**

Deadlock Prevention

QB50-SYS-1.4.6 **The OBSW shall protect itself against *unintentional* infinite loops, computational errors and possible lock ups.**

Defensive Programming

QB50-SYS-1.4.7 **The check of incoming commands, data and messages, consistency checks and rejection of illegal input shall be implemented for the OBSW.**

OBSW Code

QB50-SYS-1.4.8 **The OBSW programmed and developed by the CubeSat teams shall only contain code that is intended for use on that CubeSat on ground and in orbit.**

Scientific Data

QB50-SYS-1.4.9 **Teams shall implement a command to be sent to the CubeSat which can delete any SU data held in Mass Memory originating prior to a DATE-TIME stamp given as a parameter of the command.**

Satellite Control Software

The Satellite Control Software (SCS) is a software package provided by the QB50 Project that could be implemented by the CubeSat teams on their own ground stations. Each team can have access to the SCS package for use in ground stations under a bilateral license agreement. The SCS will provide:

- Ground station interface software
- TM/TC Front End
- CubeSat Control System
- Operations User Interfaces software
- Communications handling with the QB50 DPAC for science and WOD data uploading

It is not a requirement to use the SCS provided by EPFL, and teams may use an alternative solution to meet the data downlink requirement. The DPAC supports file uploading and data uploading via the web interface.

If utilized, the SCS provided by EPFL will allow the CubeSat teams to assist each other with any difficulties with the common interface and will provide the CubeSat teams with a lighter software development. This will contribute to the overall project success by offloading some ground tasks that teams might not have expertise in.

Another advantage is that the teams will benefit from compatibility with other teams and could collaborate on their on-board software implementations. This option also facilitates the possibility of using other teams ground stations. The software provided is extremely flexible and individual teams can integrate their own specifics at many levels, for instance integrating their own payload-specific data processing or visualization.

The SCS provided by EPFL has specific packet format and frame protocol which is defined in SCS description and Interface Control Document [R07]. And teams that choose to use it will need to comply with its requirements.

Recommendation 11: It is recommended to avoid encapsulation of one protocol within another (e.g. AX.25 in CSP) to avoid increased overhead.

Ground Station Network

Recommendation 2: It is recommended for the CubeSats to have the capability to schedule future autonomous downlinks such that it would be compatible with potential downlink-only ground station networks.

1.5 Telemetry, Tracking & Command

Downlink

QB50-SYS-1.5.1 VHF shall not be used for downlink.

QB50-SYS-1.5.2 If UHF is used for downlink, the CubeSat shall use a downlink data rate of at least 9.6 kbps.

QB50-SYS-1.5.3 If UHF is used for downlink, the transmission shall fit in 20 kHz at -30 dBc, measured without Doppler, but over the entire operating temperature range.

This will help ensure that each satellite can be quickly identified even at the start of the mission when many or all of the spacecraft may be overhead a single ground station.

QB50-SYS-1.5.4 **All CubeSats shall have and make use of its unique satellite ID in the telemetry downstream.**

Recommendation 3: **It is recommended to implement BPSK or QPSK downlinks because of their spectral efficiency.**

Recommendation 4: **It is recommended to use different bands for uplink and downlink.**

Uplink

QB50-SYS-1.5.5 **If VHF is used for uplink, it shall have a data rate no greater than 1.2 kbps.**

QB50-SYS-1.5.6 **If UHF is used for uplink, it shall have a data rate no greater than 9.6 kbps.**

QB50-SYS-1.5.7 **All CubeSats shall have the capability to receive a transmitter shutdown command at all times after the CubeSat's deployment switches have been activated from QuadPack ejection.**

QB50-SYS-1.5.8 **Once a transmitter shutdown command is received and executed by the CubeSat, a positive command from the ground shall be required to re-enable the transmitter. Power reset (e.g. following eclipse) should not re-enable the transmitter.**

QB50-SYS-1.5.9 **The CubeSat provider shall have access to a ground station which has the capability and permission to send telecommands through an uplink to control its satellite.**

QB50-SYS-1.5.10 ***Requirement deleted from Issue 4***

QB50-SYS-1.5.11 **The CubeSat shall transmit the current values of the WOD parameters and its unique satellite ID through a beacon at least once every 30 seconds or more often if the power budget permits.**

Recommendation 12: **The beacon should be transmitted every 10 seconds during LEOP phase to allow for multiple receptions of the beacon during a pass. This procedure will assist the orbit determination and the identification of each Cubesat.**

QB50-SYS-1.5.12 *Requirement turned into a recommendation from Issue 7.*

Recommendation 15: **If UHF is used for uplink, the radio receiver shall have an Adjacent Channel Rejection Ratio (ACRR) of at least 100 dB.**

This is to avoid possible blocking of the receiver or interference from nearby QB50 satellites. Teams should also be aware that such operation will require very quick ($< 2ms$) changeover time between transmit and receive when working with short frames.

Downlink / Uplink Framing Protocol

QB50-SYS-1.5.13 **The CubeSat shall use the AX.25 Protocol (UI Frames). The data type during downlink shall be specified in the Secondary Station Identifier (SSID) in the destination address field of the AX.25 frame. Science data shall be indicated using 0b1111 and Whole Orbit Data with 0b1110.**

Since the identifier describing the source and the destination in the address field of the frames shall be unique for each CubeSat and its ground station within QB50, the satellite ID for each CubeSat can be assigned by the QB50 Project to the CubeSat teams after the frequency allocation and coordination process. The radio call sign for the operating ground station will have to be obtained locally by each team.

QB50-SYS-1.5.14 **User-friendly and documented software consisting of a) CubeSat data Frames Decoder b) CubeSat data Packet Decoder and c) CubeSat data Viewer that complies with radio amateur regulations shall be made available to VKI 6 months before the nominal launch date. This documented software will be made available to the public following the AMSAT regulations.**

The data viewer can be skipped, if a documented spreadsheet/csv (incl. column header information) file will be generated by the decoder software, so the data can be viewed with external software e.g. Excel.

1.6 Thermal Control

QB50-SYS-1.6.1 **The CubeSat shall maintain all its electronic components within its operating temperature range while in operation and within survival temperature range at all other times after deployment.**

The operational and survival temperature range for components will vary between teams based on hardware specification. The thermal cycling levels for environmental testing are provided in Chapter 2 of this document.

QB50-SYS-1.6.2 **The CubeSat shall survive within the temperature range of $-20°C$ to $+50°C$ from the time of launch until its end of life.**

Recommendation 16: **Due to the lessons learned from the QB50 precursor campaign, it is recommended for all QB50 CubeSats to have a battery heater.**

1.7 General

Lifetime

QB50-SYS-1.7.1 **The CubeSat shall be designed to have an in-orbit lifetime of at least 6 months.**

Material Degradation

QB50-SYS-1.7.2 **The CubeSat shall not use any material that has the potential to degrade in an ambient environment during storage after assembly, which could be as long as approximately 2 years.**

Conformal Coating

Recommendation 5: **All electronic assemblies and electronic circuit boards should be conformally coated.**

Conformal coating is a standard low-cost protection process for printed circuit boards (PCBs). It provides electrical insulation, protection against harsh elements such as solvents, moisture, contamination, dust or debris that could damage the electronic component.

Environmental

QB50-SYS-1.7.3 **The CubeSat shall withstand a total contamination of 3.1 mg/m^2 at all phases of the launch vehicle ground operation and in flight.**

QB50-SYS-1.7.4 **The CubeSat shall withstand a maximum pressure drop rate of 3.92 kPa/sec.**

Cleanliness, Handling, Storage and Shipment

The whole set of QB50 CubeSats will undergo checkout and integration into the QuadPack at ISO Class 8 clean room ISIS facility.

QB50-SYS-1.7.5 **If a CubeSat has any special requirement in terms of cleanliness, handling, storage or shipment, these shall be communicated to the QuadPack integrator (ISIS) and also be approved by ISIS, 12 months before delivery of the CubeSat and also highlighted in the User Manual.**

The requirement(s) shall be well justified and explained in the proposal in order to be studied and possibly taken into account. The acceptance of any special requirement is not granted in advance.

Recommendation 6: **The CubeSats should have a dedicated case for transport and storage.**

Apply Before Flight, Remove Before Flight items

QB50-SYS-1.7.6 **Apply Before Flight (ABF) items, including tags and/or labels, shall not protrude past the dimensional limits of the CubeSat extended volumes (as defined in Figure 3 and Figure 4) when fully inserted.**

QB50-SYS-1.7.7 **All Remove Before Flight (RBF) items shall be identified by a bright red label of at least four square centimetres in area containing the words "REMOVE BEFORE FLIGHT" or "REMOVE BEFORE LAUNCH" and the name of the satellite (CubeSat QB50 ID) printed in large white capital letters.**

Both ABF and RBF tags that needs to be applied or removed should fit through the access hatch to ensure a powered off state of the CubeSat. It should be inserted or removed after integration into the QuadPack. Therefore, these labels should be able to fit through an area of $25\ mm \times 13\ mm$ as that is the dimension of the access hatch.

Naming

QB50-SYS-1.7.8 **The CubeSat QB50 ID (e.g. BE05) shall be printed, engraved or otherwise marked on the CubeSat and visible through the access hatch in the door of the QuadPack.**

QB50 Display, Processing, and Archiving Center (DPAC)

QB50-SYS-1.7.9 **The CubeSat provider shall transfer the whole orbit data and science data to the DPAC within 24 hours following reception on the ground.**

QB50-SYS-1.7.10 **All of the whole orbit data and science data downlinked to the ground shall be stored in the individual CubeSat server up to 6 months after the completion of the mission.**

Model Philosophy

Recommendation 7: **It is recommended for CubeSat teams to adopt the Engineering Qualification Model - Flight Model (EQM-FM) approach in building their CubeSat.**

A qualification model (QM) is a prototype which is will undergo qualification test. A QM could serve as a spare part replacement and moreover could be used to troubleshoot if a complex problem occurs. This is especially useful if the problem occurs while the FM CubeSat is not accessible - such as at the launch site, or in orbit. Hardware costs are usually low compared to the overall cost.

Most launch vehicle providers prefer that the payload uses an EQM-FM approach. As such, the levels for the qualification and acceptance testing are already available. Chapter 2 provides the envelope of the qualification and acceptance testing levels. Even though Cyclone-4 is the selected LV, the envelope environmental levels will be required to be used to ensure a robust design.

The ProtoFlight testing levels are an intermediate level between qualification and acceptance. More details on the ProtoFlight testing levels are given in the description of each mechanical test to be performed (see Chapter 2).

Science Operation Period

QB50-SYS-1.7.11 **CubeSats carrying the standard atmospheric sensors shall be able to commence the science payload operations within one month after deployment in orbit.**

QB50-SYS-1.7.12 **The standard atmospheric sensors shall be operated every second day for a period of 60 days, starting one month after deployment in orbit.**

QB50-SYS-1.7.13 **The science operation phase shall be resumed after the CubeSat constellation has reached an altitude of approximately 300 km. This event will be notified by VKI two weeks ahead of the event. The standard atmospheric sensors shall be operated every second day for a period of 60 days.**

Recommendation 17: **The standard atmospheric sensors shall be operated every day during the science phases, also in between the two science phases and after the second science phase to maximize the science return.**

Figure 6 summarizes this approach for the operation of the science unit.

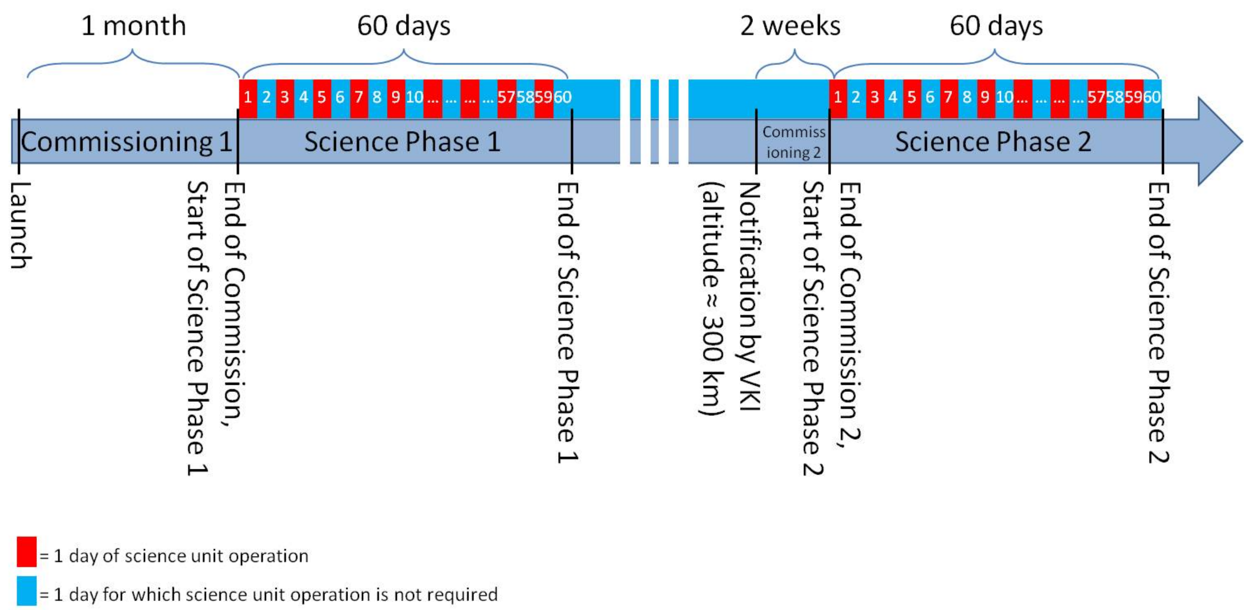

Figure 6: Approach for the operation of the science unit.

2 Qualification and Acceptance Testing Requirements for Launch

The CubeSat orbit is a circular orbit with an altitude of 400 km ±20 km, an inclination of 98.18±1°, and a local time of ascending node (LTAN) TBD. Due to the secondary payload status inherent to CubeSats, flexibility regarding the orbit (and especially the LTAN) is required, resulting in the following requirement [2].

QB50-SYS-2.0.1 **The CubeSat shall be compatible with any local time of ascending node (LTAN).**

This chapter describes the case qualification and acceptance testing requirements for EQM-FM (Engineering/Qualification Model and Flight Model) or PFM (Proto-Flight Model) test philosophy.

For qualification of the CubeSat design, an EQM of the CubeSat has to be subjected to the required qualification tests at qualification levels and durations as defined in this chapter. For acceptance of the CubeSat, the FM of the CubeSat has to be subjected to the required acceptance tests at acceptance levels and durations as defined in this chapter. The mentioned values correspond to the ones required by the Launch Vehicle Provider.

IMPORTANT: All the CubeSats shall be subjected to the most severe level imposed by the launch vehicle, characteristics of which are defined in the corresponding subsections, in all three mutually perpendicular directions X, Y, Z of the satellite {BRF}.

IMPORTANT: To ensure the correct vibration loads, each CubeSat shall be tested while it is integrated into a TestPOD. Because the ISIS QuadPack will be equipped with a custom designed dynamic rail, all the mechanical testing performed using a TestPOD without dynamic rail are conservative.

At this stage, it is recommended for the teams to identify the facilities in which they will perform the following tests for their CubeSat.

[2] This requirement returns to the requirement of QB50 System Requirements and Recommendations Issue 5.

Table 5: Summary of required mechanical testing

Test category	Qualification	Acceptance	Protoflight	Testing method
Quasi-Static and G-Loads	X	-	X	FEM simulation + Test
Natural Frequencies / Resonance Survey	X	X	X	FEM simulation + Test
Sinusoidal	X	X	X	FEM simulation + Test
Random	X	X	X	FEM simulation + Test
Shock	X	-	X	Test

2.1 Acceleration (Quasi-static)

Table 6 states the characteristics of the acceleration (quasi-static) test and indicates whether or not it is required.

QB50-SYS-2.1.1 CubeSat shall pass the acceleration (quasi-static) test as per Table 6.

Table 6: Acceleration (quasi-static) test characteristics

	Qualification	Acceptance	Protoflight
Reference Frame	{BRF}	{BRF}	{BRF}
Direction	X, Y, Z		X, Y, Z
Amplitude	13 g		10.8 g
Method	Test	Not Required	Test

2.2 Resonance Survey

Table 7 states the characteristics of the resonance survey test and indicates whether or not it is required. During the test, the CubeSat shall be integrated into a TestPOD which is attached to an absolute rigid base. It is required (see QB50-SYS-2.2.2) to run a resonance survey test before and after running a test at full level. By comparing the results of the resonance survey tests, a change in CubeSat integrity due to settling or possible damage can be found.

QB50-SYS-2.2.1 **The CubeSat shall pass a resonance survey test, the characteristics of which are stated in Table 7 and the lowest natural frequency of the FM of the CubeSat shall be $>$ 90 Hz.**

QB50-SYS-2.2.2 **Two resonance surveys shall be performed during the mechanical test campaign. One before and one after running a test at full level (sine, random and shock on all the three axes).**

Table 7: Resonance survey test characteristics

	Qualification, Acceptance or Protoflight	
Resonance survey test	Required	
Reference Frame	{BRF}	
Direction	X, Y, Z	
Type	Harmonic	
Sweep rate	2 oct/min	
Profile	**Frequency**, *[Hz]*	**Amplitude**, *[g]*
	5	0.15*
	100**	0.15*

*Depending on the test equipment higher value could be required in order to properly identify the natural frequencies of the CubeSat.

**The resonance survey shall be extended up to a frequency permitting to properly identify the first natural frequency of the CubeSat.

2.3 Sinusoidal Vibration

Table 8 states the characteristics of the sinusoidal vibration test and indicates whether or not it is required.

QB50-SYS-2.3.1 **The CubeSat shall pass the sinusoidal vibration tests as per Table 8.**

Table 8: Sinusoidal vibration test characteristics

	Qualification		Acceptance		Protoflight	
Sine vibration test	Required		Required		Required	
Reference Frame	{BRF}		{BRF}		{BRF}	
Direction	X, Y, Z		X, Y, Z		X, Y, Z	
Sweep rate	2 oct/min		4 oct/min		4 oct/min	
Profile	**Frequency**, *[Hz]*	**Amplitude**, *[g]*	**Frequency**, *[Hz]*	**Amplitude**, *[g]*	**Frequency**, *[Hz]*	**Amplitude**, *[g]*
	5 - 100	2.5	5 - 100	2	5 - 100	2.5
	100 - 125	1.25	100 - 125	1	100 - 125	1.25

2.4 Random Vibration

Table 9 states the characteristics of the random vibration test and indicates whether or not it is required.

QB50-SYS-2.4.1 The CubeSat shall pass the random vibration tests as per Table 9.

Table 9: Random vibration test characteristics

	Qualification		Acceptance		Protoflight	
Random vibration test	Required		Required		Required	
Reference Frame	{BRF}		{BRF}		{BRF}	
Direction	X, Y, Z		X, Y, Z		X, Y, Z	
RMS acceleration	8.03 g		6.5 g		8.03 g	
Duration	120 s		120 s		120 s	
Profile	**Frequency**, *[Hz]*	**Amplitude**, *[g^2/Hz]*	**Frequency**, *[Hz]*	**Amplitude**, *[g^2/Hz]*	**Frequency**, *[Hz]*	**Amplitude**, *[g^2/Hz]*
	20	0.01125	20	0.007	20	0.01125
	130	0.05625	50	0.007	130	0.05625
	800	0.05625	200	0.035	800	0.05625
	2000	0.015	640	0.035	2000	0.015
			2000	0.010		

2.5 Shock Loads

Table 10 states the characteristics of the shock test and indicates whether or not it is required. The CubeSat shall withstand, without any degraded performance, the shock levels indicated in Table 10. The shock test is applied 2 times along each of the 3 axes.

QB50-SYS-2.5.1 **The CubeSat shall pass the shock tests as per Table 10. The shock loads shall be applied two times along each axis.**

Table 10: Shock test characteristics

	Qualification		Acceptance	Protoflight	
Shock test	Required		Not Required	Required	
Reference Frame	{BRF}			{BRF}	
Direction	X, Y, Z			X, Y, Z	
Q-factor	10			10	
Number of shocks	2			2	
Profile	**Frequency**, *[Hz]*	**Spectrum**, *[g]*		**Frequency**, *[Hz]*	**Spectrum**, *[g]*
	30	5			
	100	100		100	30
	700	1500		1000	700
	1000	2400		2000	700
	1500	4000		5000	400
	5000	4000			
	10000	2000			

2.6 Mechanical Test Pass Criteria

In addition to having successfully passed the mechanical test as per QB50-SYS-2.1.1, QB50-SYS-2.2.1, QB50-SYS-2.3.1, QB50-SYS-2.4.1 and QB50-SYS-2.5.1, the following requirement must be satisfied to consider the vibration test passed.

QB50-SYS-2.6.1 **The variation of natural frequencies measured in the two resonance surveys as per QB50-SYS-2.2.2 shall be lower than 5%.**

2.7 Thermal-Vacuum Test

Table 11 states the characteristics of the thermal vacuum cycling test and indicates whether or not it is required.

QB50-SYS-2.7.1 **The CubeSat shall pass the Thermal Vacuum Cycling tests as per Table 11.**

Table 11: Thermal Vacuum Cycling test characteristics

	Qualification	**Acceptance**	**Protoflight**
TVac test	Required	Not Required	Required
Min temperature	-20±2^{o}C		-20±2^{o}C
Max temperature	50±2^{o}C		50±2^{o}C
Temperature variation rate	≥1^{o}C/min		≥1^{o}C/min
Dwell time	1 hour at extreme temperatures		
Vacuum	10^{-5} mBar		10^{-5} mBar
Cycles	4		4

2.8 Thermal-Vacuum Bake Out

Table 12 states the characteristics of the thermal vacuum bake out test and indicates whether or not it is required.

QB50-SYS-2.8.1 **The CubeSat shall pass the Thermal Vacuum Bake Out tests as per Table 12.**

Table 12: Thermal Vacuum Bake Out test characteristics

	Qualification	Acceptance	Protoflight
TVAC test	Not Required	Required	Required
Max temperature		50±2^{o}C	50±2^{o}C
Temperature variation rate		≥1^{o}C/min	≥1^{o}C/min
Vacuum		10^{-5} mBar	10^{-5} mBar
Duration		3 hours after thermal stabilization	

Remarks:

- Test to be run in thermal vacuum chamber with test model in full assembly configuration;
- Outgassing pass criteria: TML $< 1\%$;
- Pre TVAC and post TVAC test required before and after thermal vacuum tests (as per Table 13).

2.9 EMC Testing

The EMC tests are required in order to ensure that a single satellite element does not generate interferences with other spacecraft components.

QB50-SYS-2.9.1 **CubeSats subsystems and components shall not have electromagnetic emissions generating self-interferences with other subsystem/components.**

QB50-SYS-2.9.2 **If during the functional test a potential self-interference will be identified, a complete EMC test in anechoic chamber shall be performed. Test levels and procedures are reported in Sections 2.9.1 and 2.9.2.**

Recommendation 18: **As per QB50-SYS-2.9.2, the verification of EMC through a dedicated test is not mandatory if no self-incompatibility is detected. Nevertheless EMC testing is strongly recommended: it can be done according to test levels and procedures defined in Sections 2.9.1 and 2.9.2, for radiated emission and radiated susceptibility**

2.9.1 Radiated Emission

Radiated emission (RE) test shall be done in anechoic chamber at ambient temperature and pressure.
CubeSats shall pass electric field RE testing as per Table:

EM Test	Frequency Range	Limit	Remarks
RE Electric Field	30 MHz - 1 GHz	$50 dB\mu V/m$ at all frequencies	Procedures: refer to *ECSS-E-ST-20-07C*

Test for DC Magnetic Field Radiated Emission is recommended (even if not mandatory). This test can be useful for characterization of CubeSat magnetic features (generated and residual magnetic dipole, permanent or induced magnetic field of components, etc.).
In case, the test should verify a maximum DC magnetic emission according to the following features:

EM Test	Frequency Range	Limit	Remarks
RE Electric Field	DC	$0.2 \mu T$ at 1m distance from each face	Procedures: refer to *ECSS-E-ST-20-07C*

2.9.2 Radiated Susceptibility

Radiated susceptibility (RS) test shall be done in anechoic chamber or reverberation chamber at ambient temperature and pressure.
CubeSats shall pass electric field RS testing as per Table :

EM Test	Frequency Range	Value	Remarks
RS Electric Field	30 MHz - 10 GHz	$10 V/m$ outside the main frame or at proximity of beams	Procedures: refer to *ECSS-E-ST-20-07C*
		$1 V/m$ inside the main frame[3]	

[3] Optional requirement, depending on accessibility of internal parts for measurements.

Pass criteria for CubeSat is to successfully perform functional EMC test as per section 3.1.2, without any degraded performance of electronic subsystems (especially high frequency electronics) under the EM environment defined above.

Test for low frequencies magnetic field RS is recommended but not mandatory. The test can be performed with Helmoltz coils only, according to MIL-STD-461F, section 5.19.4.

3 Quality Assurance and Reporting

3.1 Functional Tests

High level functional tests on CubeSats subsystems and assemblies are required for validation. Functionality of the components shall be verified in different moments during the acceptance campaign. Six different sets of functional tests have been identified and listed in Table 13.

QB50-SYS-3.1.1 The Cubesat functionalities shall be verified using the functional test sets reported in Table 13.

REMARK: The way to accomplish each functional test is left intentionally to each Team. It can be a direct verification (e.g. digital scopes) or an indirect verification (e.g. OBC values reading). It is forbidden at any time to disassemble or manipulate the QB50 Sensor Unit Hardware.

IMPORTANT: In case one or more functional tests cannot be performed because they are not applicable to the specific Cubesat hardware, a waiver is required.

Table 13: Functional Test Sets

Set	Test Set	Description	When
1	Reference Functional Tests (RFT)	This sequence of tests shall be the reference for CubeSat performances and term of comparison for tests performed in the following phases.	• Beginning of acceptance campaign or protoflight testing campaign.

Continued on next page

Table 13 – *Continued from previous page*

Set	Test Set	Description	When
2	Electromagnetic Compatibility Functional Tests	Electromagnetic Compatibility Functional Tests (EMC) shall ensure that CubeSat components do not generate EM fields interfering with other components or subsystems. The EMC test shall measure the emitted signals and check the performances of the subsystems. Only a subset of the RFT is required as part of EMC functional tests.	• During EMC tests.
3	Pre Thermal Vacuum Tests (Pre-TVAC)	Tests to be performed, before both Thermal Vacuum Cycling and bake out. Those set of tests shall be compared with the tests performed at the end of TVAC test campaign (phase 5, post TVAC).	• Before running Thermal Vacuum Bake out; • Before running Thermal Vacuum Cycling.
4	Post Thermal Vacuum Tests (post TVAC)	Tests to be performed after both Thermal Vacuum Cycling and bake out. The purpose is to verify that the thermal loads and the vacuum environment do not modify system performances or functionalities. Results of tests shall be compared with set 4 tests (pre TVAC).	• After running Thermal Vacuum Bake out; • After running Thermal Vacuum Cycling.

Continued on next page

Table 13 – *Continued from previous page*

Set	Test Set	Description	When
5	Thermal Cycling Functional Tests (TCF)	Tests to be performed during Thermal Vacuum Cycling at temperatures plateau to check the functionality of systems in that conditions. This class of tests shall be performed at least once during hot and cold temperatures plateaus.	• During thermal cycling tests.
6	Verification Functional Tests (VFT)	The verification functional tests are requested to verify functionality of the satellite when a certain phase of the acceptance or protoflight test campaign is completed. They can be used as additional pass/fail criteria. The results of the Verification Functional Tests shall be compared with RFT results.	• End of complete acceptance or protoflight test campaign.

3.1.1 Reference Functional Tests (RFT)

This set of functional tests shall be performed before running the acceptance or protoflight test campaign. The results will be taken as reference for CubeSat performances. The following subsystem shall be test:

- **OBC** - On Board Computer and Data Handling
- **COMM** - Communication Subsystem
- **EPS** - Electrical Power Subsystem
- **ACS** - Attitude Determination and Control Subsystem
- **Structure** - All structural requirements are linked to deployable mechanism. In case of deployables which cannot be refurbished, the functionality of the HDRM can be shown

with a dummy device. ***If it is not present any deployable mechanism, please ignore this subsystem and no waiver is required.***

- **Payload** - Considering as Payload any other instrument or electronic board which is not a QB50 Sensor Unit. ***If it is not present any Payload, please ignore this subsystem and no waiver is required.***
- **Sensor Unit** - ***If it is not present any QB50 Sensor Unit, please ignore this subsystem and no waiver is required.***

Table 14: Reference Function Test

Subsystem	Test ID	Test/Verification Description
OBC	OBC01	Verify that EPS supplies power to OBC board(s).
	OBC02	Verify that OBC receives power and commands through umbilical connector.
	OBC03	Verify that OBC transmits data to COMM subsystem.
	OBC04	Verify that OBC receives and stores in the memory data from COMM subsystem.
	OBC05	Verify that OBC can access and read data stored in memory.
	OBC06	Verify that OBC can read, store and transmit to COMM subsystem, data coming from sensors or subsystems boarded.
	OBC07	Verify that OBC sends activation command to deployables (such as booms, antennas, panels etc.) not before than 30 minutes after deployment switches activation.
	OBC08	Verify that OBC activates RF transmitters not before than 30 minutes after deployment switches activation.
COMM	COM01	Verify antenna connection.
	COM02	Verify that antennas receive signals from COMM subsystem.
	COM03	Verify that antennas transmits signals to COMM subsystem.
	COM04	Verify that antennas receives signals from external sources.
	COM05	Verify that antennas transmits signals to external receivers.
	COM06	Verify power supplying to the transceiver.
	COM07	Verify that COMM subsystem receives signals from OBC.

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Table 14 – *Continued from previous page*

Subsystem	Test ID	Test/Verification Description
	COM08	Verify that COMM subsystem transmits signals to OBC.
	COM09	Verify that transceiver decodes the received signals into the expected data format.
	COM10	Verify that transceiver encodes the received signals from OBC into the expected data format.
	COM11	Verify transceiver modulation.
	COM12	Verify the capability to shut down the transmitter after receiving the transmitter shutdown command.
	COM13	Verify that a power reboot doesnt re-enable the transmitter after receiving the shutdown command.
	COM14	Verify the capability to re-enable the transmitter after receiving a specific enabling command.
	COM15	Verify and record that the transceiver operates in the expected (and officially IARU assigned) frequencies both in Tx and Rx.
	COM16	Verify beacon timing and transmitted data.
	COM17	Verify and establish communications with the ground station.
EPS	EPS01	Verify that batteries can be charged through the external umbilical connector.
	EPS02	Verify battery voltage both with GSE and by telemetry data reading.
	EPS03	Verify battery full charge and discharge cycle.
	EPS04	Verify battery voltage both with GSE and by telemetry data reading after a complete charge and discharge cycle.
	EPS05	Verify battery temperature readings by telemetry.
	EPS06	Verify batteries connection.
	EPS07	Verify 3.3V regulator output voltage level.
	EPS08	Verify 5V regulator output voltage level.
	EPS09	Verify that solar panels provides expected voltage and power outputs when enlightened.
	EPS10	Verify that solar panels can recharge the batteries.

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Table 14 – *Continued from previous page*

Subsystem	Test ID	Test/Verification Description
	EPS11	Verify the functionality of RBF or ABF devices.
ACS	ACS01	Verify that power is supplied to ADCS board(s).
	ACS02	Verify capability to enable/disable power to ADCS.
	ACS03	Verify magnetic field intensity measurements of magnetometers.
	ACS04	Verify that power is supplied to magneto-torquers.
	ACS05	Verify the capability to enable/disable power to coils.
	ACS06	Verify polarity of magneto-torquers.
	ACS07	Verify that all magneto-torquers magnetic field and/or dipole intensity has no more than a 10% variation from the calculated one.
	ACS08	Verify that ADCS sensors data are consistent (gyroscopes, accelerometers, etc).
	ACS09	Verify power supplying to GPS antenna.
	ACS10	Verify GPS telemetry.
	ACS11	Verify that power is supplied to momentum wheels.
	ACS12	Verify that the momentum wheels are operational and the commanded rotational speed has no more than 10% variation from the expected one.
Structure	STR01	Verify that all hold on and release mechanisms (HDRM) will be activated not before than 30 minutes after deployment switch activation and no elements will be deployed before.
	STR02	Verify that power is supplied to HDRM.
	STR03	Verify functionality of HDRM.
	STR04	Verify all deployable mechanisms are capable deploy from the folded position and lock into the operational position.
Payload	PLU01	Verify power supplying to the payload.
	PLU02	Verify that payload unit receives signals from OBC.
	PLU03	Verify that payload unit sends data to OBC in the expected format with expected content.

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Table 14 – *Continued from previous page*

Subsystem	Test ID	Test/Verification Description
	PLU04	Verify that OBC is capable to enable/disable power to the payload unit.
	PLU05	Verify that OBC is capable to activate/deactivate/swap different operative modes of the payload unit.
Sensor Unit	SEU01	Verify power supplying to the payload.
	SEU02	Verify that payload unit receives signals from OBC.
	SEU03	Verify that payload unit sends data to OBC in the expected format with expected content.
	SEU04	Verify that OBC is capable to enable/disable power to the payload unit.
	SEU05	Verify that OBC is capable to activate/deactivate/swap different operative modes of the payload unit.
	SEU06	Verify that the OBC can read/switch correctly between the different time tagged scripts.
	SEU07	Verify that OBC/SU handles single script at end-of-day time-roll-over.

3.1.2 Electromagnetic Compatibility Functional Tests

Test to be performed only if QB50-SYS-2.9.2 applies or if a full EMC test campaign is executed (as per recommendation 18). To be performed in adequate facilities which can shield external EM fields, at ambient pressure and temperature (please refer to sections 2.9.1 and 2.9.2).

Table 15: EMC Functional Tests

Subsystem	Test ID	Test/Verification Description
OBC	OBC01	Verify that EPS supplies power to OBC board(s).
	OBC03	Verify that OBC transmits data to COMM subsystem.

Continued on next page

Table 15 – *Continued from previous page*

Subsystem	Test ID	Test/Verification Description
	OBC04	Verify that OBC receives and stores in the memory data from COMM subsystem.
	OBC05	Verify that OBC can access and read data stored in memory.
	OBC06	Verify that OBC can read, store and transmit to COMM subsystem, data coming from sensors or subsystems boarded.
COMM	COM01	Verify antenna connection.
	COM02	Verify that antennas receive signals from COMM subsystem.
	COM03	Verify that antennas transmits signals to COMM subsystem.
	COM06	Verify power supplying to the transceiver.
	COM07	Verify that COMM subsystem receives signals from OBC.
	COM08	Verify that COMM subsystem transmits signals to OBC.
	COM09	Verify that transceiver decodes the received signals into the expected data format.
	COM10	Verify that transceiver encodes the received signals from OBC into the expected data format.
	COM11	Verify transceiver modulation.
	COM15	Verify that the transceiver operates in the expected (and officially assigned) frequencies both in Tx and Rx.
EPS	EPS02	Verify battery voltage both with GSE and by telemetry data reading.
ACS	ACS01	Verify that power is supplied to ADCS board(s).
	ACS02	Verify capability to enable/disable power to ADCS.
	ACS05	Verify the capability to enable/disable power to coils.
	ACS08	Verify that ADCS sensors data are consistent (gyroscopes, accelerometers, etc).
Payload	PLU01	Verify power supplying to the payload.
	PLU02	Verify that payload unit receives signals from OBC.
	PLU03	Verify that payload unit sends data to OBC in the expected format with expected content.
	PLU05	Verify that OBC is capable to activate/deactivate/swap different operative modes of the payload unit.
Sensor Unit	SEU01	Verify power supplying to the payload.

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Table 15 – *Continued from previous page*

Subsystem	Test ID	Test/Verification Description
	SEU02	Verify that payload unit receives signals from OBC.
	SEU03	Verify that payload unit sends data to OBC in the expected format with expected content.
	SEU05	Verify that OBC is capable to activate/deactivate/swap different operative modes of the payload unit.

3.1.3 Pre Thermal Vacuum Tests

Test to be performed before thermal vacuum tests (cycling or bake out).

Table 16: Pre Thermal Vacuum Functional Test

Subsystem	Test ID	Test/Verification Description
OBC	OBC01	Verify that EPS supplies power to OBC board(s).
	OBC02	Verify that OBC receives power and commands through umbilical connector.
	OBC03	Verify that OBC transmits data to COMM subsystem.
	OBC04	Verify that OBC receives and stores in the memory data from COMM subsystem.
	OBC05	Verify that OBC can access and read data stored in memory.
	OBC06	Verify that OBC can read, store and transmit to COMM subsystem, data coming from sensors or subsystems boarded.
	OBC07	Verify that OBC sends activation command to deployables (such as booms, antennas, panels etc.) not before than 30 minutes after deployment switches activation.
	OBC08	Verify that OBC activates RF transmitters not before than 30 minutes after deployment switches activation.
COMM	COM01	Verify antenna connection.

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Table 16 – *Continued from previous page*

Subsystem	Test ID	Test/Verification Description
	COM02	Verify that antennas receive signals from COMM subsystem.
	COM03	Verify that antennas transmits signals to COMM subsystem.
	COM04	Verify that antennas receives signals from external sources.
	COM05	Verify that antennas transmits signals to external receivers.
	COM06	Verify power supplying to the transceiver.
	COM07	Verify that COMM subsystem receives signals from OBC.
	COM08	Verify that COMM subsystem transmits signals to OBC.
	COM09	Verify that transceiver decodes the received signals into the expected data format.
	COM10	Verify that transceiver encodes the received signals from OBC into the expected data format.
	COM11	Verify transceiver modulation.
	COM12	Verify the capability to shut down the transmitter after receiving the transmitter shutdown command.
	COM13	Verify that a power reboot doesnt re-enable the transmitter after receiving the shutdown command.
	COM14	Verify the capability to re-enable the transmitter after receiving a specific enabling command.
	COM15	Verify that the transceiver operates in the expected (and officially assigned) frequencies both in Tx and Rx.
	COM16	Verify beacon timing and transmitted data.
EPS	EPS02	Verify battery voltage both with GSE and by telemetry data reading.
	EPS05	Verify battery temperature readings by telemetry.
	EPS07	Verify 3.3V regulator output voltage level.
	EPS08	Verify 5V regulator output voltage level.
ACS	ACS01	Verify that power is supplied to ADCS board(s).
	ACS02	Verify capability to enable/disable power to ADCS.
	ACS04	Verify that power is supplied to magneto-torquers.
	ACS05	Verify the capability to enable/disable power to coils.
	ACS08	Verify that ADCS sensors data are consistent (gyroscopes, accelerometers, etc).

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Table 16 – *Continued from previous page*

Subsystem	Test ID	Test/Verification Description
	ACS09	Verify power supplying to GPS antenna.
	ACS11	Verify that power is supplied to momentum wheels.
	ACS12	Verify that the momentum wheels are operational and the commanded rotational speed has no more than 10% variation from the expected one.
Structure	STR01	Verify that all hold on and release mechanisms (HDRM) will be activated not before than 30 minutes after deployment switch activation and no elements will be deployed before.
	STR03	Verify functionality of HDRM.
Payload	PLU01	Verify power supplying to the payload.
	PLU02	Verify that payload unit receives signals from OBC.
	PLU03	Verify that payload unit sends data to OBC in the expected format with expected content.
	PLU04	Verify that OBC is capable to enable/disable power to the payload unit.
	PLU05	Verify that OBC is capable to activate/deactivate/swap different operative modes of the payload unit.
Sensor Unit	SEU01	Verify power supplying to the payload.
	SEU02	Verify that payload unit receives signals from OBC.
	SEU03	Verify that payload unit sends data to OBC in the expected format with expected content.
	SEU04	Verify that OBC is capable to enable/disable power to the payload unit.
	SEU05	Verify that OBC is capable to activate/deactivate/swap different operative modes of the payload unit.

3.1.4 Post Thermal Vacuum Tests

Tests to be performed after thermal vacuum test campaign. Results shall be compared with results of pre TVAC tests. Sequence of post TVAC tests is the same as the pre TVAC (Section 3.1.3).

3.1.5 Thermal Cycling Functional Tests (TCF)

Tests to be performed in vacuum conditions in a thermal vacuum chamber. The test sequence shall be run at least once for maximum and minimum temperature plateaus during thermal cycling tests.

Table 17: Thermal Cycling Functional Test

Subsystem	Test ID	Test/Verification Description
OBC	OBC01	Verify that EPS supplies power to OBC board(s).
	OBC02	Verify that OBC receives power and commands through umbilical connector.
	OBC03	Verify that OBC transmits data to COMM subsystem.
	OBC04	Verify that OBC receives and stores in the memory data from COMM subsystem.
	OBC05	Verify that OBC can access and read data stored in memory.
	OBC06	Verify that OBC can read, store and transmit to COMM subsystem, data coming from sensors or subsystems boarded.
	OBC07	Verify that OBC sends activation command to deployables (such as booms, antennas, panels etc.) not before than 30 minutes after deployment switches activation.
	OBC08	Verify that OBC activates RF transmitters not before than 30 minutes after deployment switches activation.
COMM	COM01	Verify antenna connection.
	COM02	Verify that antennas receive signals from COMM subsystem.
	COM03	Verify that antennas transmits signals to COMM subsystem.
	COM06	Verify power supplying to the transceiver.
	COM07	Verify that COMM subsystem receives signals from OBC.

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Table 17 – *Continued from previous page*

Subsystem	Test ID	Test/Verification Description
	COM08	Verify that COMM subsystem transmits signals to OBC.
	COM09	Verify that transceiver decodes the received signals into the expected data format.
	COM10	Verify that transceiver encodes the received signals from OBC into the expected data format.
	COM11	Verify transceiver modulation.
	COM12	Verify the capability to shut down the transmitter after receiving the transmitter shutdown command.
	COM13	Verify that a power reboot doesnt re-enable the transmitter after receiving the shutdown command.
	COM14	Verify the capability to re-enable the transmitter after receiving a specific enabling command.
EPS	EPS02	Verify battery voltage both with GSE and by telemetry data reading.
	EPS05	Verify battery temperature readings by telemetry.
	EPS07	Verify 3.3V regulator output voltage level.
	EPS08	Verify 5V regulator output voltage level.
ACS	ACS01	Verify that power is supplied to ADCS board(s).
	ACS02	Verify capability to enable/disable power to ADCS.
	ACS04	Verify that power is supplied to magneto-torquers.
	ACS05	Verify the capability to enable/disable power to coils.
	ACS08	Verify that ADCS sensors data are consistent (gyroscopes, accelerometers, etc).
	ACS09	Verify power supplying to GPS antenna.
Payload	PLU01	Verify power supplying to the payload.
	PLU02	Verify that payload unit receives signals from OBC.
	PLU03	Verify that payload unit sends data to OBC in the expected format with expected content.
	PLU04	Verify that OBC is capable to enable/disable power to the payload unit.
	PLU05	Verify that OBC is capable to activate/deactivate/swap different operative modes of the payload unit.
Sensor Unit	SEU01	Verify power supplying to the payload.

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Table 17 – *Continued from previous page*

Subsystem	Test ID	Test/Verification Description
	SEU02	Verify that payload unit receives signals from OBC.
	SEU03	Verify that payload unit sends data to OBC in the expected format with expected content.
	SEU04	Verify that OBC is capable to enable/disable power to the payload unit.
	SEU05	Verify that OBC is capable to activate/deactivate/swap different operative modes of the payload unit.

3.1.6 Verification Functional Tests (VFT)

The VFT is requested to be performed at the end of the acceptance or protoflight to verify full functionality of the CubeSat. The test sequence is the same as the RFT (Section 3.1.1).

3.1.7 Additional requirements and recommendations on functional tests

QB50-SYS-3.1.2 The satellite flight software shall be tested for at least 14h satellite continuous up-time under representative operations.

This is because a typical time between ground station passes is 12h.

Recommendation 19: The satellite flight software shall be tested for at least 30h satellite continuous up-time.

This is because a science script lasts for 24h.

Recommendation 20: The ground station shall be tested with a satellite in orbit (preferably using the QB50 Precursor satellites) for up and downlink to verify, among others, the tracking procedure.

3.2 End-to-End HIL Test

QB50-SYS-3.2.1 **CubeSats boarding the QB50 Sensors Unit shall perform an End-to-End test, to verify the functionality of the sensors and the interfaces with the CubeSat subsystems. Detailed procedure will be given in the User Manual shipped with the Sensor Unit hardware. An overview of the testing procedures is listed below as example.**

A test should be structured as follows on an engineering model (or equivalent) fully representative of the flight model with Sensor Unit (with dummy sensor head, if present). The content of scripts to be run by the CubeSat team will be given by the SU provider. To consider the Sensor Unit End-to-End HIL test as successful, the following tasks shall be accomplished based on continuous operation of the CubeSat:

1. Load 7 scripts to the CubeSat via radio link, and show that each of the 7 scripts runs at the correct date and time. For testing purposes, the start time of each script shall 10 mins from the last script start time.
2. A script shall be loaded to the CubeSat and left to run past midnight (UTC time) to prove that it correctly handles continuous operation, and roll-over to the next day.
    - The OBC shall run this script at the correspondent tagged times, interpreting the OBC commands to power the SU ON/OFF and forwarding the SU commands to the Science Unit.
    - Data packets shall be generated by the SU, received by the OBC and stored in the CubeSat memory.
    - SU data shall be downlinked via the CubeSat radio link to the ground station (or equivalent) when commanded (if power requirements allow then during SU operation, or else when SU is OFF).
3. Two scripts shall be loaded to the CubeSat and left to run to show that the first script is replaced by the second script at the correct date and time (at midnight in this test), as given in the script header information.
    - The OBC shall run these scripts at the appropriately tagged times, interpreting the OBC commands to power the SU ON/OFF and forwarding the SU commands to the Science Unit.

- Data packets shall be generated by the SU, received by the OBC and stored in the CubeSat memory without overwriting SU data that has not been transmitted to the ground station
- SU data shall be downlinked via the CubeSat radio link to the ground station when commanded (if power requirements allow then during SU operation, or else when SU is OFF). This should include SU data from a previous day.

4. A command sent to the CubeSat, shall delete any SU data in MM-#1 prior to a given DATE-TIME stamp.
5. Demonstrate that SU data in MM-#2 can be downloaded via radio link. (This could be the data deleted from MM-#1 previously).

The data received shall then be compared with the expected values. List of test commands and relative expected answers will be provided with the Sensor Units, together with a detailed test procedure, description of needed GSE, pass/fail criteria etc. In addition to the End-to-End tests, depending on the boarded SU, some other functional test could be required (e.g. to test for correct SU data headers, or that the OBC is capable to read, process, store and send to COMM an unexpected signal coming from the SU, or system robustness with respect to inconsistent signals, etc.).

3.3 Test Reporting

The following verification campaign reports are requested:

1. Qualification Campaign Report/Acceptance campaign report (or alternatively Protoflight test campaign report)
   - Requirements
   - Description of test sequence
   - Test timing and deviations from the expected schedule
   - Test summary (brief informations about all the performed tests)
   - Statement of pass/fail criteria
   - Non-conformance report

- CubeSat uptime log (number of hours the CubeSat has been on during the acceptance/protoflight test campaign)
- CubeSat reboots log (number of Satellite Reboots during the entire acceptance/protoflight test campaign)

2. Detailed test report for all the executed tests, at all level (qualification, protoflight or acceptance).

    - Requirements
    - Test facilities description
    - Test Setup and Configurations
    - Loads adopted
    - Test flow
    - Test results
    - Pass/fail statement with respect to requirements
    - Non-conformance report and solutions