QB50

System Requirements and Recommendations

Issue 5

11 October 2013

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. - Added a section on Science Operation Period containing 2 additional requirements: QB50-SYS-1.7.11 and QB50-SYS-1.7.12.

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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
BPSK	Binary Phase Shift Keying
BRF	Body Reference Frame
CalPoly	California Polytechnical State University, SLO
CDR	Critical Design Review
CVCM	Collected Volatile Condensable Material
DPAC	QB50 Data Processing and Archiving Centre
EGSE	Electronic Ground Support Equipment
EMC	Electro-Magnetic Compatibility
EQM	Engineering / Qualification Model
ESD	Electro-Static Discharge
FIPEX	Flux--Probe Experiment
FM	Flight Model
IARU	International Amateur Radio Union
ICD	Interface Control Document
INMS	Ion/ Neutral Mass Spectrometer
ISIS	Innovative Solutions In Space BV
LRF	Launcher Reference Frame
LV	Launch Vehicle
MDC	Mission Display Centre
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
QPSK	Quadrature Phase Shift Keying
RBF	Remove Before Flight
RF	Radio Frequency
SCS	Satellite Control Software

SLO	San Luis Obispo, California, United States of America
TBC	To Be Confirmed
TBD	To Be Determined
TT&C	Telemetry, Tracking and Command
TML	Total Mass Loss
UHF	Ultra High Frequency
VHF	Very High Frequency
VKI	von Karman Institute for Fluid Dynamics

Applicable documents

Reference No.	Document Name	Document Title
[A01]	QB50-INMS-MSSL-ID-12001_INMS_Interface _Control_Document _Issue_4.pdf	*QB50 INMS Science Unit Interface Control Document*, Mullard Space Science Laboratory (MSSL), 11 June 2013
[A02]	INMS Compliancy Matrix.xlsx	*QB50 INMS Compliancy Matrix*, Mullard Space Science Laboratory (MSSL), 14 June 2013
[A03]	ILR-RFS_FPXQB50_ICD-1000-01_Interface Control Document.pdf	*QB50 FIPEX Science Unit Interface Control Document*, Technische Universitat Dresden (TU Dresden), 19 June 2013
[A04]	FIPEX Compliancy Matrix.xlsx	*QB50 FIPEX Compliancy Matrix*, Technische Universitat Dresden (TU Dresden), 19 June 2013
[A05]	QB50-UiO-ID-0001 Issue 2 Rev DRAFT C.pdf	*QB50 MNLP Science Unit Interface Control Document*, University of Oslo (UiO), 11 June 2013
[A06]	MNLP Compliancy Matrix.xlsx	*QB50 MNLP Compliancy Matrix*, University of Oslo (UiO), 14 June 2013
[A07]	ISIS.QB50.StackPack.ICD v1.6 StackPack Interface Specification.pdf	*StackPack Interface Specifications v1.6*, Innovative Solutions in Space (ISIS), Delft, Netherlands, 25 April 2013

NOTE:

In addition to this *QB50 System Requirements and Recommendation - Issue 5* 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	*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]	ISIS.QB50.EL.001 v0.1 QB50 Environment Levels.pdf	*QB50 Environmental Levels*, ISIS, 1 May 2013

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.
- Some requirements from this document, which are still valid, such as TML $< 1\%$ and CVCM $<0.1\%$, have been removed as they are already part of the CalPoly CubeSat Design Specification. They have been removed from this document to avoid duplication.
- VHF downlinks cannot be used.
- The orbital sunlight period is likely to be at most 65% of the orbit period and may reduce at lower altitudes.

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 2.

QB50-SYS-1.1.1 CubeSats dimensions shall be as shown in Table 2.

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.

Table 2: 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 $45° \times 1mm$	External edges shall be rounded $R \times 1mm$ or chamfered $45° \times 1mm$

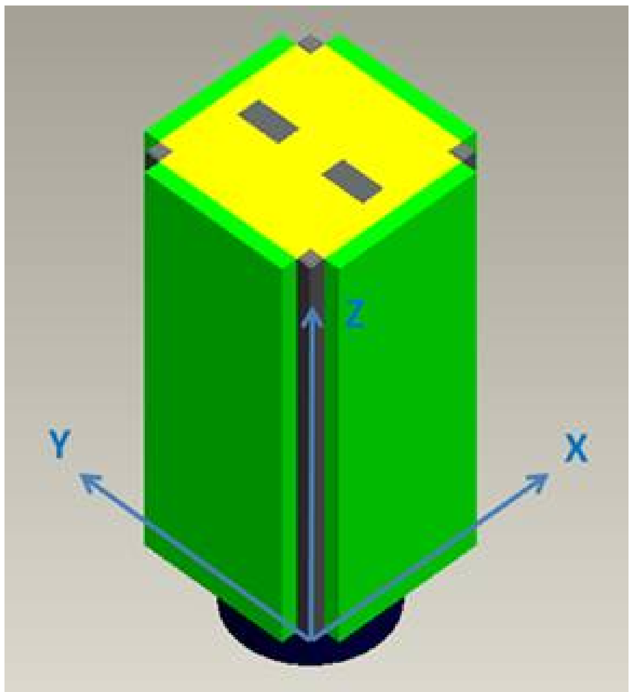

Figure 1: QB50 CubeSat reference frame

Extended Volumes

The StackPack - 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 StackPack Side Panels. Moreover the StackPack 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 StackPack 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.

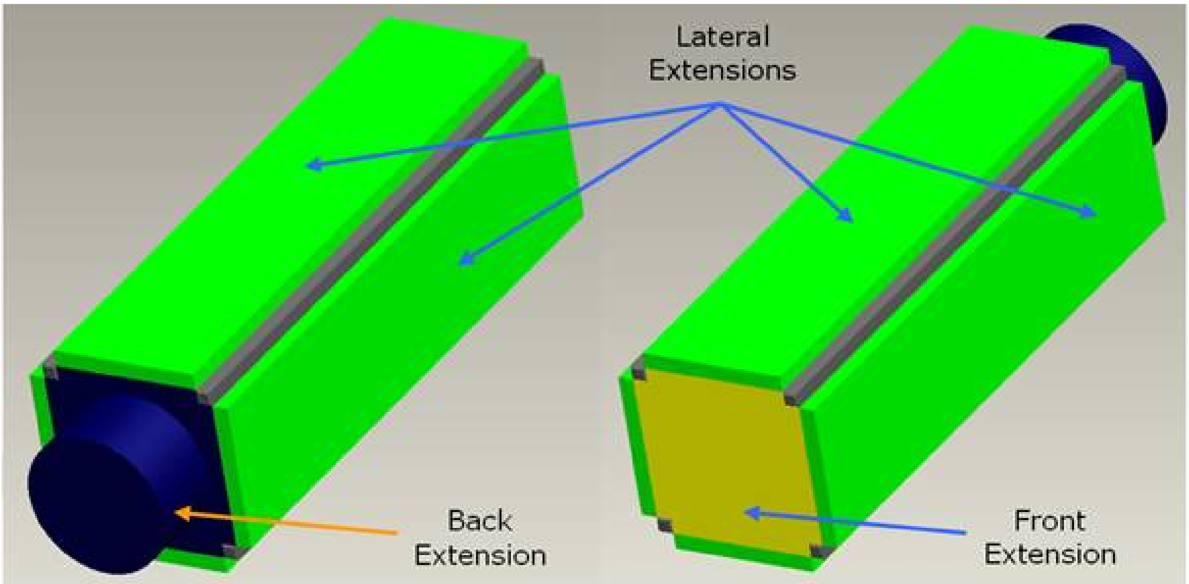

Figure 2: CubeSats lateral (green), front (yellow) and back (blue) extended volumes.

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.**

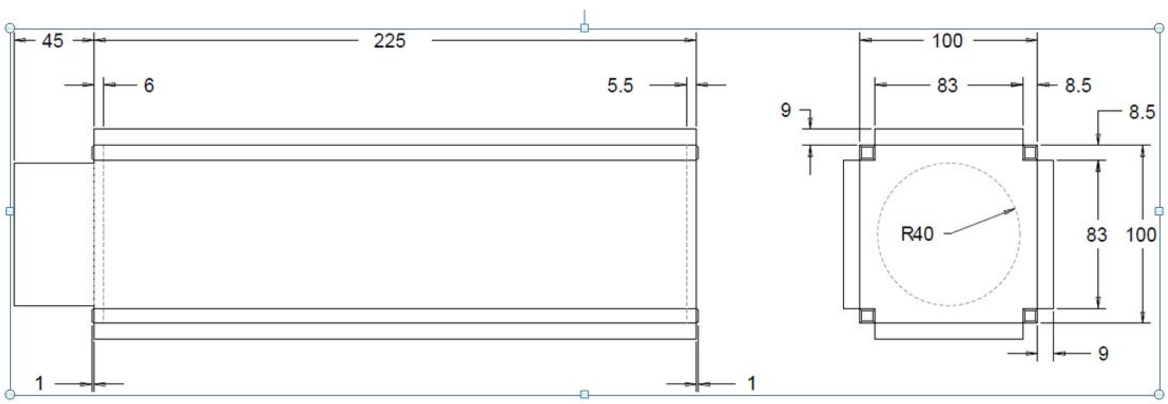

Figure 3: 2U CubeSat extended volume dimensions in millimetres.

Figure 3 shows the maximum dimensions in millimetres allowed by the StackPack 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 2.

Figure 4 shows the maximum dimensions in millimetres allowed by the StackPack for the QB50 3U CubeSat extended volumes. Note that these dimensions relate to the extended volumes of the

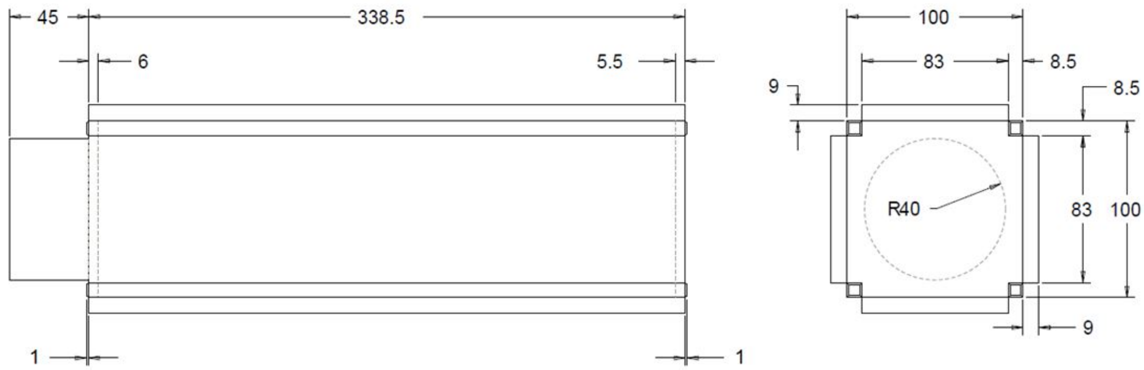

Figure 4: 3U CubeSat extended volume dimensions in millimetres.

CubeSat and not the height of the guide rails of the CubeSat. The height is still 340.5 mm as stated in Table 2.

CubeSat Access Hatches

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

As the CubeSat can only be accessed / connected through the front door after integration into the deployer, the access hatches on the CubeSat have to be on the front side (+Z face), which is opposite to the Science Unit. Figure 5 defines the position of these access hatches on the CubeSat front side (+Z face). The teams can allocate their umbilical interface / connector through any of these two $25\ mm \times 13\ mm$ areas.

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). Due to the wide range of possible solutions each team shall supply the required EGSE and harness. One (TBC) access opportunity after integration of the CubeSat into the deployer at ISIS will be granted to each team to perform all the required activities (data connectivity, battery charge, checkout, etc). Afterwards only battery charging will be performed.

Mass

As stated previously, the StackPack is designed to accommodate both 2U and 3U CubeSats. Table 3 states the specifications for the maximum masses of the different QB50 CubeSat that can be

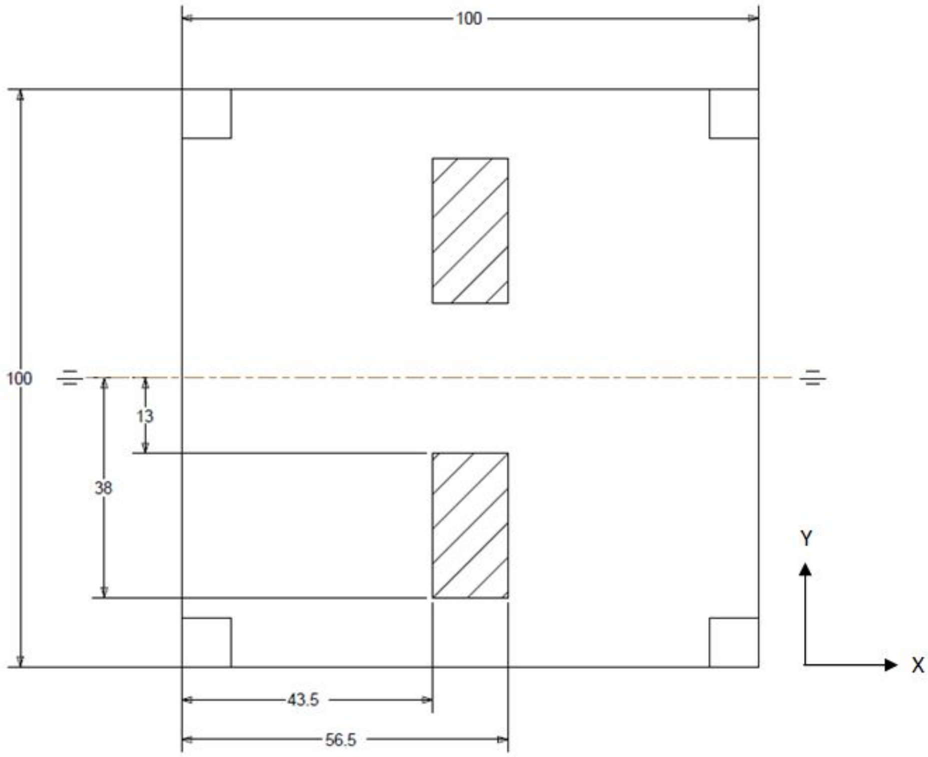

Figure 5: Definition of QB50 CubeSat access hatch on the +Z face .

accommodated in the StackPack.

QB50-SYS-1.1.5 **The CubeSat mass shall be no greater than that shown in Table 3.**

Table 3: CubeSat masses admitted by the StackPack for QB50

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, centred on the CubeSat geometric centre.**

This is required in order to control misalignments of the StackPack 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 deployer 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 satellites 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** $10°$ **/ sec (TBC) within 2 days.**

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.**

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.**

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. The WOD packet format is provided as an Annex to this document.**

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.

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 (TBC) 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) and mission support software 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 and mission support software shall protect itself against 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 foreseen for the OBSW and mission support software.**

OBSW Code

QB50-SYS-1.4.8 **The OBSW shall only contain code that is intended to be used in orbit.**

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 Data Processing and Archiving Centre (DPAC) and Mission Control Centre (MCC)

It is not a requirement to use the SCS, and teams may propose an alternative solution provided it meets the requirements for controlling the satellite and communicating with the DPAC and MCC.

If utilized, the SCS 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.

For the teams who chose to use the QB50 SCS, the packet and frame protocol is defined and the teams will need to comply with it.

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 deployer 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 and to upload and execute timed Instrument Command Files. The format of these commands is TBD.**

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.**

QB50-SYS-1.5.12 **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.**

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.

QB50-SYS-1.6.2 **The CubeSat shall survive within the temperature range of $-10°C$ (TBC) to $+50°C$ (TBC) from the time of launch until its deployment from the deployment system.**

1.7 General

Lifetime

QB50-SYS-1.7.1 **The CubeSat shall be designed to have an in-orbit lifetime of at least 3 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 (TBC before CDR) 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 (TBC before CDR).**

Cleanliness, Handling, Storage and Shipment

The whole set of QB50 CubeSats will undergo checkout and integration into the StackPack 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 deployer integrator (ISIS BV) 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 printed in large white capital letters.**

Naming

QB50-SYS-1.7.8 **The CubeSat name shall be printed, engraved or otherwise marked on the CubeSat and visible through the access hatch in the door of the deployer.**

QB50 Storage Server

QB50-SYS-1.7.9 **The CubeSat provider shall transfer the whole orbit data and science data to the QB50 storage server 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. The following chapter provides the envelope of the qualification and acceptance testing levels as these are already known.

The ProtoFlight testing levels will mostly likely be at an intermediate level between qualification and acceptance. However, these levels are not yet known as the ProtoFlight approach has to be requested and agreed with the selected launch vehicle provider. Once the LV is selected, the levels for the ProtoFlight Testing can be made available.

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 week after deployment in orbit.**

QB50-SYS-1.7.12 **CubeSats carrying the standard atmospheric sensors shall operate it for a period of at least 2 months.**

2 Qualification and Acceptance Testing Requirements for Launch

The following launch vehicles (LVs) are being considered for QB50: Cyclone-4, Dnepr, PSLV-5, Rockot and Soyuz. The final decision for the selection of the launch vehicle (LV) is pending approval by EC/ REA.

It will most likely be a sun-synchronous circular orbit with an altitude of 350 - 400km (TBC before CDR) $\pm$7km, an inclination of 98.6$\pm 0.08°$, eccentricity of $\pm$0.04, and a local time of descending node of TBD.

As it is not certain what the final selection will be, a launcher envelope is provided to which the CubeSats should be designed. This chapter describes the the worst case qualification and acceptance testing requirements among the five considered launch vehicles for EQM-FM test philosophy (Engineering/Qualification Model and Flight Model).

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 values required by the Launch Vehicle Provider; The CubeSat teams can multiply these values by their own safety factor.

The orientation of the satellite reference frame {BRF} with respect to the launch vehicle reference frame {LRF} is generally not known sufficiently ahead of time. And since this may vary from team to team, 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}.

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

2.1 Acceleration (Quasi-static)

Table 4 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 4.**

Table 4: Acceleration (quasi-static) test characteristics

	Qualification	**Acceptance**
Acceleration (quasi-static) test	Required	Not Required
Reference Frame	{BRF}	
Direction	X, Y, Z	
Amplitude	12 g	

2.2 Resonance Survey

Table 5 states the characteristics of the resonance survey test and indicates whether or not it is required. During the test, the CubeSat shall be attached to an absolute rigid base. It is common practice 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 5 and the lowest natural frequency of the FM of the CubeSat shall be $>$ 90 Hz.**

Table 5: Resonance survey test characteristics

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

2.3 Sinusoidal Vibration

Table 6 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 6 (TBC before CDR).**

Table 6: Sinusoidal vibration test characteristics

	Qualification		**Acceptance**	
Sine vibration test	Required		Required	
Reference Frame	{BRF}		{BRF}	
Direction	X, Y, Z		X, Y, Z	
Sweep rate	2 oct/min		4 oct/min	
Profile	**Frequency**, *[Hz]*	**Amplitude**, *[g]*	**Frequency**, *[Hz]*	**Amplitude**, *[g]*
	5	1.3	5	1
	8	2.5	8	2
	100	2.5	100	2

2.4 Random Vibration

Table 7 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 7 (TBC before CDR).**

2.5 Shock Loads

Table 8 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 8. The shock test is applied 2 times along each of the 3 axes.

Table 7: Random vibration test characteristics

	Qualification		Acceptance	
Random vibration test	Required		Required	
Reference Frame	{BRF}		{BRF}	
Direction	X, Y, Z		X, Y, Z	
RMS acceleration	8.03 g		6.5 g	
Duration	120 s		60 s	
Profile	**Frequency**, *[Hz]*	**Amplitude**, $[g^2/Hz]$	**Frequency**, *[Hz]*	**Amplitude**, $[g^2/Hz]$
	20	0.009	20	0.007
	130	0.046	50	0.007
	800	0.046	200	0.035
	2000	0.015	640	0.035
			2000	0.010

QB50-SYS-2.5.1 **The CubeSat shall pass the shock tests as per Table 8 (TBC before CDR).**

Table 8: Shock test characteristics

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

2.6 Thermal Cycling

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

QB50-SYS-2.6.1 The CubeSat shall pass the Thermal Cycling tests as per Table 9 (TBC before CDR).

Table 9: Thermal Cycling test characteristics

	Qualification	Acceptance
Thermal Cycling test	Required	Required
Values	TBD	TBD

2.7 Thermal Vacuum

Table 10 states the characteristics of the thermal vacuum test and indicates whether or not it is required.

QB50-SYS-2.7.1 The CubeSat shall pass the Thermal Vacuum tests as per Table 10 (TBC before CDR).

Table 10: Thermal Vacuum test characteristics

	Qualification	Acceptance
Thermal Vacuum test	Required	Required
Values	TBD	TBD

2.8 EMC / ESD

Table 11 states the characteristics of the EMC / ESD test and indicates whether or not it is required.

QB50-SYS-2.8.1 The CubeSat shall pass the EMC / ESD tests as per Table 11 (TBC before CDR).

Table 11: EMC / ESD characteristics

	Qualification	**Acceptance**
EMC / ESD test	Required	Required
Values	TBD	TBD

Annex 1

Whole Orbit Data Packet Format

<table>
<tr><td>(Logo)</td><td>DOCUMENT REVISIONS TRACEABILITY SHEET</td></tr>
<tr><td>Rev. 1</td><td>Date: 27 September 2013</td></tr>
<tr><td colspan="2">Changes:
-none, new issue</td></tr>
<tr><td>Rev. 2</td><td>Date:</td></tr>
<tr><td colspan="2">Changes:
-</td></tr>
</table>

Table of Contents

1. Purpose

This document defines the data packet format to be implemented on the QB50 CubeSats for the transmission of the Whole Orbit Data.

2. Definitions

Whole Orbit Data (WOD) is a set of and important house-keeping data (HSK) data collected over the whole orbit once a minute. The parameters (satellite mode, battery voltage, battery current, regulated bus currents, temperature of COMM system, EPS and batteries) are defined as important by QB50 and serve the purpose to identify the health status of the CubeSat over the mission period. The WOD shall be send by the teams to the QB50 server (**QB50-SYS-1.7.9** [1]).

3. Acronyms

EPS	Electrical Power System
HSK	House-Keeping Data
MCU	Micro-Controller Unit
OBC	On-Board Computer
WOD	Whole Orbit DATA
PCB	Printed Circuit Board
SU	Science Unit

4. Whole Orbit Data Format

The whole orbit data consists of

- the CubeSat status (mode)
- raw battery voltage
- battery bus current
- 3V3 bus current
- 5V bus current
- temperature of the COMM system
- temperature of EPS
- temperature of batteries

These shall be collected over the whole orbit with a frequency of 1/60 Hz (once a minute, **QB50-SYS-1.4.1** [1]). The data shall be stored on-board, transmitted to ground and send to the QB50 storage server using the whole orbit data packet format specified in Table 4-1.

Table 4-1 Whole Orbit Data Packet Format

Whole Orbit Data Packet (1856 bits)				
Time	Data set 1	Data set 2	…	Data set 32
32 bits	57 bits	57 bits	1653 bits	57 bits

The packet consists of 32 data sets (32 measurements covering 32minutes) and the time of the first measurement (data set 1). Using the specified frequency and the time for consecutive packets, the time of the intermediate measurements can be precisely reconstructed. The size of generated WOD packets during a day will be approximately 84kbits (10kB) assuming the frequency of 1Hz. If a packet is requested for transmission without 32 data sets available, the packet shall be filled with trailing zero up to the next complete octet to archive a packet length of multiple octets. For example, a packet with only one data set will be completed by 0b000000 (seven zeros), for 11 data sets, 5 zeros (0b00000) have to be appended to archive a length of 664 bits or 83 octets.

A data set consists of the battery voltage, battery bus and regulated bus currents beside temperatures obtained at the same time from different systems. The format of one data set is given in the following Table 4-2.

Table 4-2 Data set format

Data set X (57 bits)							
Mode	Bat. bus voltage	Bat. bus current	3V3 bus current	5V bus current	Temp. Comm	Temp. EPS	Temp. Battery
1 bit	8 bits	8 bits	8 bits	8 bits	8 bits	8 bits	8 bits

In the following, the parameters are described in more detail and the used encoding or conversion formula is given:

The *Time* flag holds the number of seconds passed from the reference epoch of QB50 (01/01/2000 00:00:00 UTC, **QB50-SYS-1.4.4** [1]) as defined in the requirements document. A *32-bit unsigned integer* is used to represent the elapsed seconds.

The *Status* bit indicates the operational status of the CubeSat. If the satellite is in normal operation mode with science unit (SU) functional, the bit shall be set to 0b1. If the CubeSat is in safe mode or no science measurements can be performed, the bit shall be set to 0b0.

The *Battery Voltage* contains the measured raw battery voltage value in Volt using an *8-bit unsigned integer* for representation. Following equation shall be used on-board of the CubeSat to convert the floating-point voltage level to unsigned integer.

$$U_{UI8} = \min(0, \max(2^8\text{-}1, \text{floor}((20 * U) - 60))) \quad (1)$$

This allows monitoring voltages in the range from 3V to 15.75V with a resolution of 50mV.

The *Battery Bus Current* represents the battery (dis-)charge rate at the time-point of the measurement. Using information of the active sub-systems, the incoming power can be derived from the current. The measured current shall be converted to an 8-*bit unsigned integer* using the following equation.

$$I_{UI8} = \min(0, \max(2^8\text{-}1, \text{floor}(127 * I) + 127)) \quad (2)$$

This allows monitoring currents from -1A to 1.008A with a resolution of 7.87mA.

The *3V3* and *5V bus current* represents the power consumption on-board of the CubeSat. The sub-system status and activities can be derived from the consumption by comparison with ground-tests or datasheet values. The currents shall be converted to an 8-bit unsigned integer using the following equation.

$$I_{UI8} = \min(0, \max(2^8\text{-}1, \text{floor}(40 * I))) \quad (3)$$

This allows monitoring currents from 0A to 6.375A with a resolution of 25mA.

The *Temperature COMM/EPS/Battery* fields represent the measured temperatures in ºC at the specific locations on the communication system (MCU or PCB temperature), EPS (MCU or PCB temperature) and battery surface temperature. An *8-bit unsigned integer* shall be used for the transmission obtained with the following equation for the conversion.

$$T_{UI8} = \min(0, \max(2^8\text{-}1, \text{floor}((4 * T) + 60))) \quad (4)$$

This allows monitoring temperature levels from -15ºC to 48.75ºC with a resolution of 0.25ºC.

5. Bibliography

[1] F. Singarayar, “QB50 System Requirements and Recommendations, Issue 5,” Von Karman Institute for Fluid Dynamics, Sint-Genesius Rode, 11 October 2013.