UKube Payload Interface Document

Prepared by:	*S. Greenland, C. Warren*	*Date:*	
Checked by:	*C. Warren*	*Date:*	
Approved by:	*R. Wall*	*Date:*	
Authorised by:	*R. Wall*	*Date:*	

INTENTIONALLY BLANK

CONTENTS

TABLES

FIGURES

1 SCOPE

The UKube programme aims to develop and launch a CubeSat built by SME and universities together that tests new UK space technology, performs real science and provides training for the next generation of space professional, as well as outreach in the STEM subjects.

The purpose of this document is to define the interface requirements between the candidate payloads and the Cubesat platform. Conformity to these requirements is necessary for both the payload and platform (where relevant) systems.

2 DOCUMENTS

2.1 Applicable Documents

[AD-01] Cal Poly CubeSat Design Specification (CP-CDS) (Rev. 12)

[AD-02] Cal Poly 3 U CubeSat Acceptance Checklist (CP-CAC) (Rev. 12)

[AD-03] IADC Space Debris Mitigation Guidelines (IADC-02-01) (Rev. 2002-10)

[AD-04] GSFC General Environment Verification Standard (GSFC-STD-7000) (Rev. 2005-04)

[AD-05] IARU Amateur Satellite Frequency Coordination Request (IARU-ASFCR) (Rev. 2009-03)

[AD-06] IARU Amateur Radio Satellite (IARU-ARS) guidelines (Rev. 2006-10)

[AD-09] Clyde Space definition of Industrial Grade Non-Space Rated COTS (CS-NSP-STD-NSR) (Rev. A)

[AD-11] Clyde Space Request for Deviation / Wavier Procedure (CS-NSP-STD-WARP) (Rev. A)

[AD-14] I2C bus specification and user manual UM10204 (Rev. 03)

[AD-15] SPI Bus Specification (AVR151 setup and use of the SPI) (Rev. 2585C-AVR-07/08)

[AD-16] US DoD Interface Standard: Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment MIL-STD-461F

[AD-17] UKube-1 Payload Packet and Command Definitions (UKB1.TN.009) (Issue C)

[AD-18] Deleted

2.2 Reference Documents

[RD-1] CubeSat - A New Generation of Picosatellite for Education and Industry Low-Cost Space Experimentation

3 ACRONYMS LIST

CSK	PC/104 CubeSat Kit PC/104 (standard board format)
IARU	International Radio Amateurs Union
ITU	International Telecommunications Union
I2C	Inter-Integrated Circuit
MIC	Mission Interface Computer
PIR	Payload Interface Requirements
SPI	Serial Peripheral Interface

4 PAYLOAD INTERFACE CONTROL

4.1 Interface Concept

UKube-1 shall be a 3 U CubeSat nominally carrying three Primary Payloads (TBC, based upon payload selection). The baseline architecture is shown in Figure 4.1-2, with an external view of the spacecraft in Figure 4.1-1. Platform and Payload Modules will be stacked vertically (in the Z axis , as defined by Figure 4.1-4) within a single Primary Structure, interfaced using the CSK PC/104 format as defined in this PIR. This interface runs along the -Y face of the satellite carrying all standard data and power lines, and providing mechanical fastening through standoffs located in the four corners of the board.

The payload interface is shown in Figure 4.1-3. Solid lines are required interfaces, dashed lines are optional.. All data interfacing to the Payload will be via a Payload Controller, implemented by the Payload Provider and compatible to the Payload I2C and Comms SPI lines defined within this PIR. Power is provided to the Payload on three switchable and dedicated power lines; nominally 3.3 V, 5 V and 12 V. The mechanical, data and power functionality will be implemented within the Payload Interface Emulator supplied to successful payload applicants at Payload Kick-Off.

The Payload is managed by the Mission Interface Computer according to the Payload Operations Schedule, as described in AD-18.

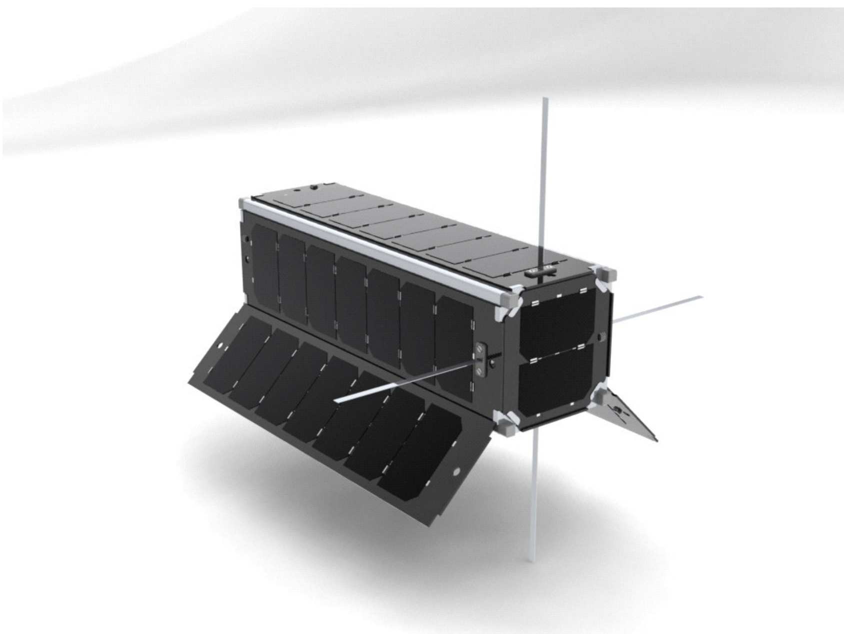

Figure 4.1-1: UKube1 External View

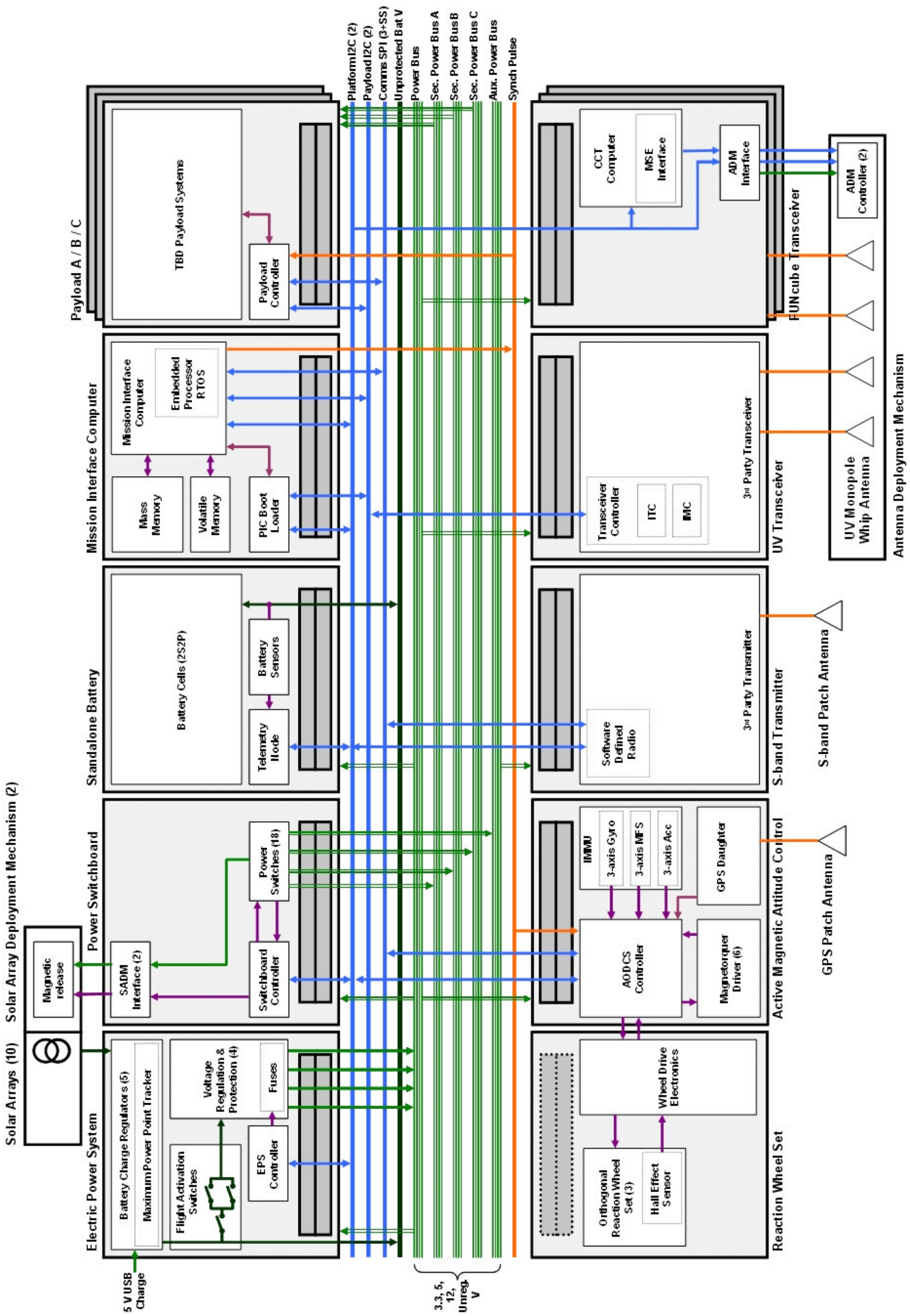

Figure 4.1-2: Baseline System Architecture

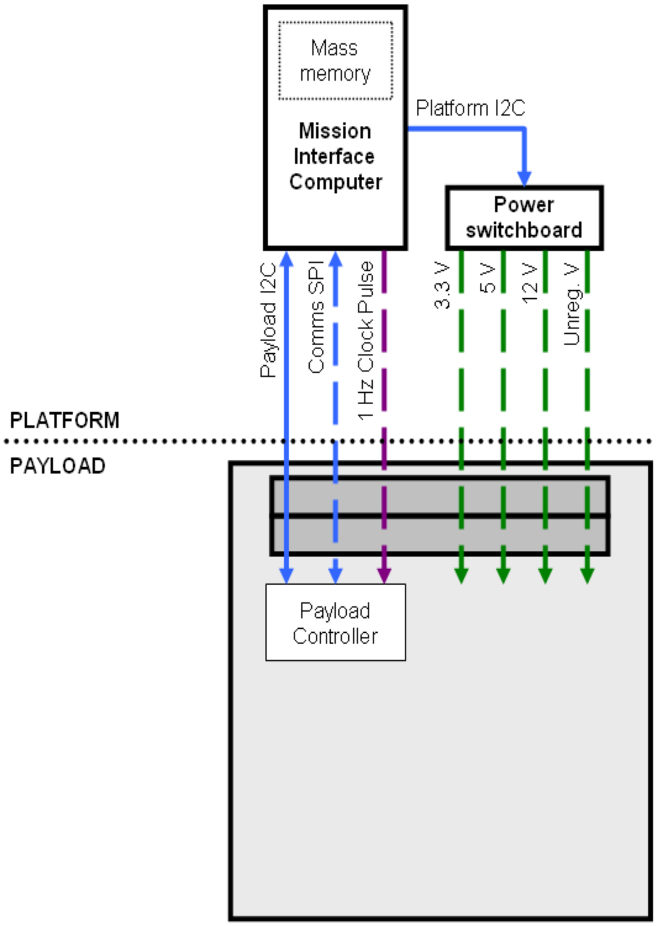

Figure 4.1-3: Payload Interface Architecture

PIR-321

The Payloads shall be accommodated in the positions shown in Figure 4.1-4.

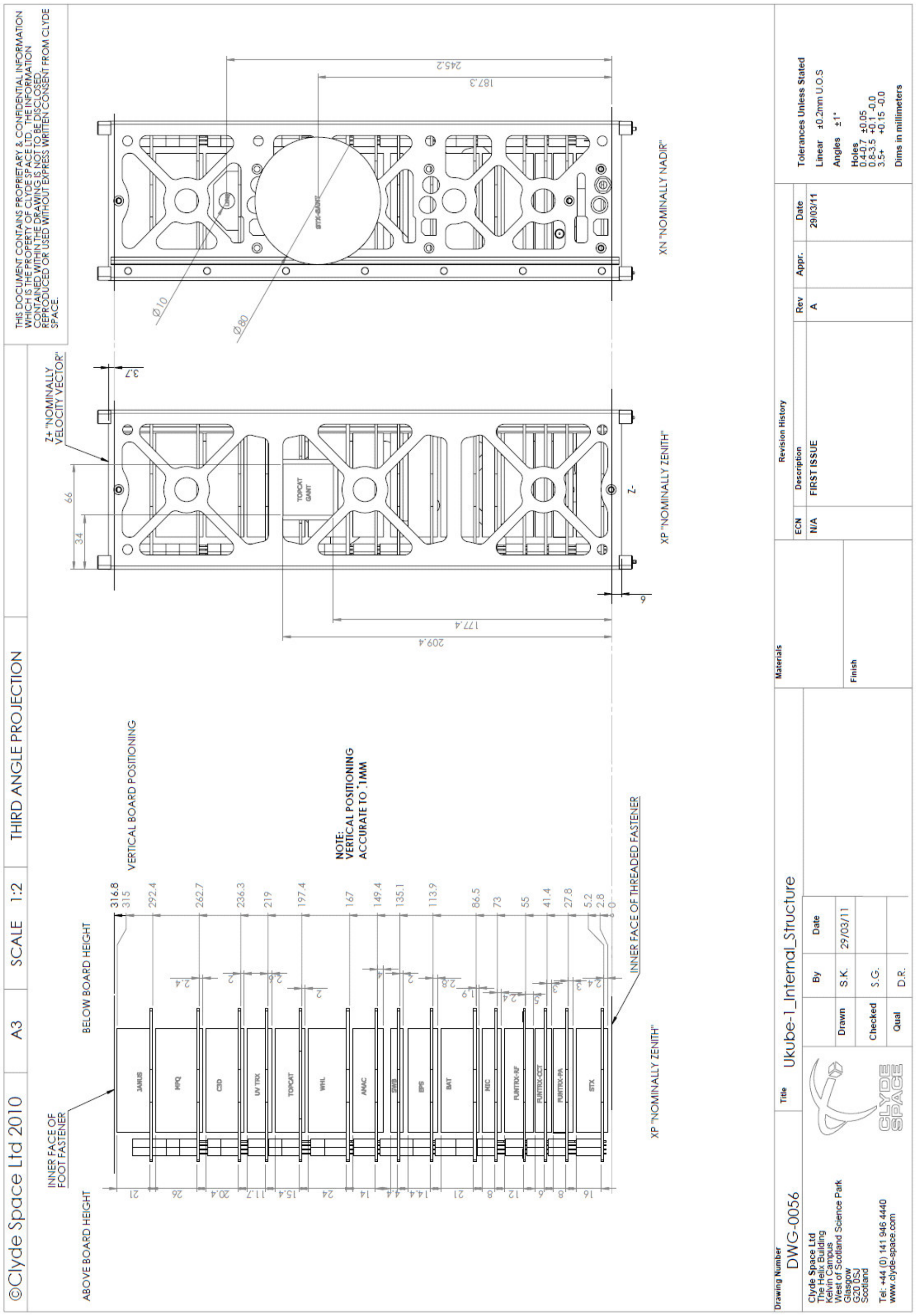

Figure 4.1-4: Payload Mechanical Configuration and Envelope

PIR-323

The Payloads shall support the cutouts shown in Figure 4.1-5.

Note: The cutaways are in the solar arrays and not in the Primary Structure and there is no cutaway assigned for MPQ boards.

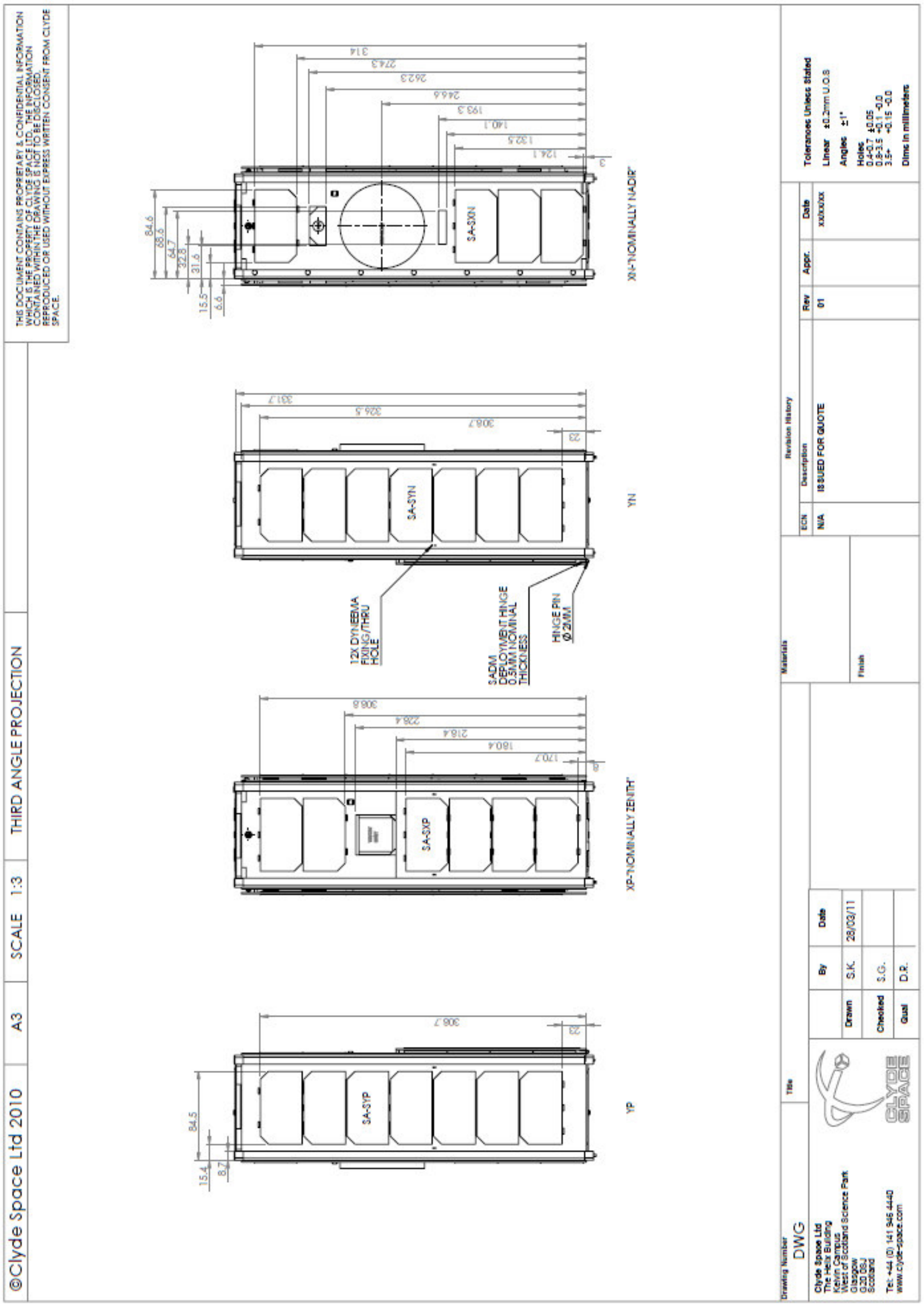

Figure 4.1-5: Cutaway Dimensions for Payload Boards

4.2 Mission Requirements

4.2.1 Operations Concept

The payload operations concept is described in [AD-18].

Primary Payload Operations are managed by the Payload Management (PM) software within the Mission Interface Computer (MIC), and controlled by interrupts from the rest of the operating system, in particular the Payload Scheduling software. Primary Payloads will only be operational in the spacecraft Mission Mode, or if specifically telecommanded.

Based upon the current Payload Schedule Script and confirmation of available onboard resources (generally power, but could also be data storage, etc.), the Payload Scheduling software will initiate an instance of the PM software to manage a particular payload.

The Payload will only be active during the sunlit side of the orbit.

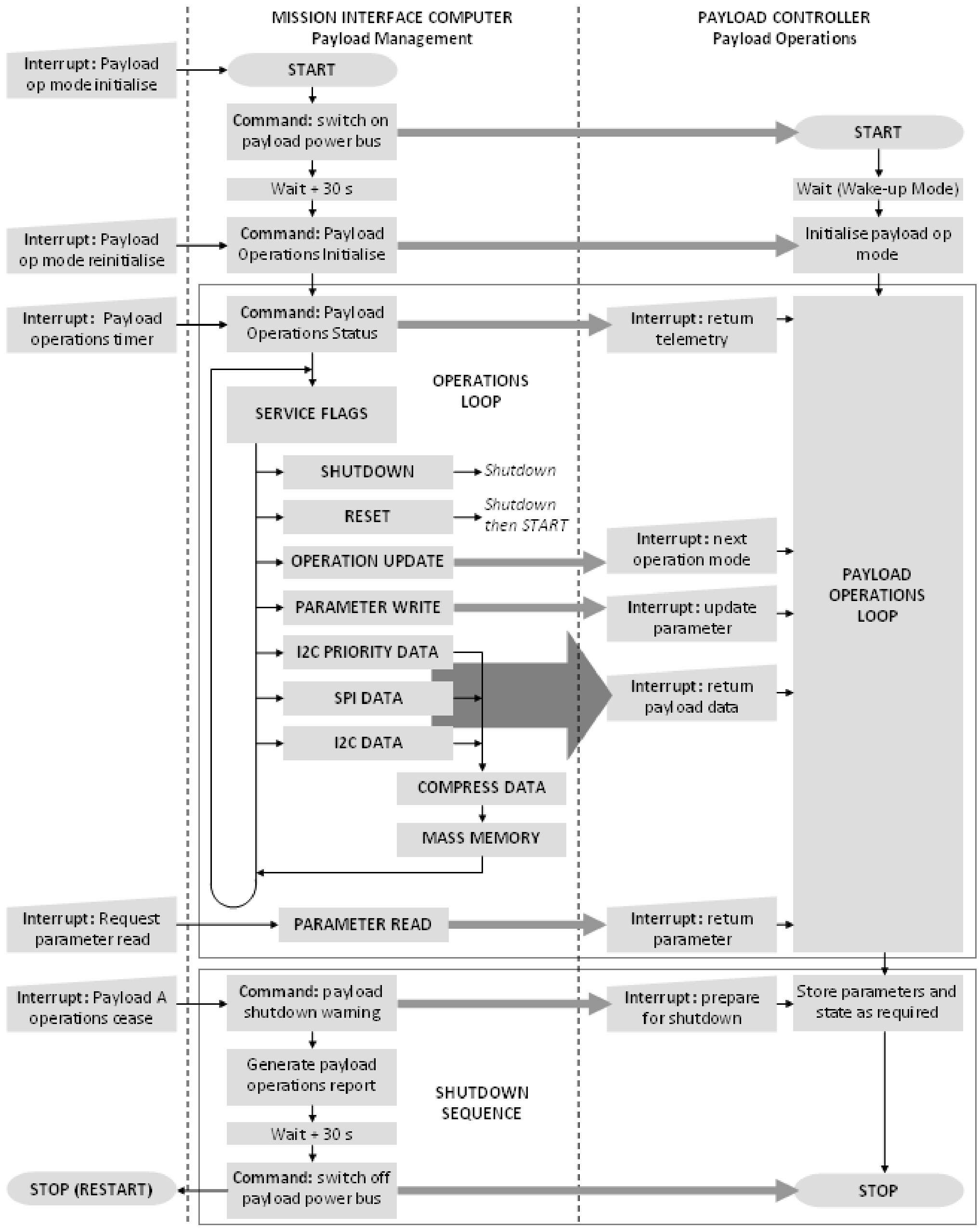

Figure 4.2-1: Payload Operations Flowchart

4.2.2 Lifetime

PIR-30

The Payload shall assume an in-orbit lifetime of 12 months.

PIR-31

The Payload design life shall be 36 months.

4.2.3 Orbit

PIR-33

The Payload shall be compatible orbits within the following range:

Altitude 300-800 km

Inclination 58-122 deg

Eccentricity < 0.001

The Payload should consider a nominal operating orbit to be a 600 km circular Sun-synchronous orbit with an inclination of 97.79 deg and a 11:00 LTAN.

The Payload should be compatible with an eclipse period of 2100 s or 0.40 of the total orbit period.

4.2.4 Orbit Determination

PIR-37

The Payload shall not require on-board orbit determination from the Platform.

PIR-38

The orbit determination required by the Payload shall not exceed an accuracy of 100 km from on-ground post-processing.

4.2.5 Timing

PIR-40

The Platform shall provide on-board time data to an accuracy of 10 s of Universal Time.

On-board time data is distributed by time-stamped telemetry packets on the payload data bus.

The Payload may access a 1 Hz synchronisation pulse.

4.2.6 Pointing and Stability Capability

PIR-43

The Payload shall not require specific pointing control to operate (e.g. Nadir pointing).

PIR-44

The Payload shall operate at spin rates up to 0.3 deg/s.

Platform Baseline design uses magnetorquers for 2-axis control about the Earth's magnetic (approximately Nadir towards equatorial regions). The anticipated control accuracy is +/- 5 deg. The Platform also will incorporate magnetic field sensors and rate gyros. Expected onboard pointing knowledge is +/- 1 deg and 0.1 deg/s.

4.2.7 Amateur Frequency Constraints

PIR-47

The Payload generated telemetry shall be unencrypted.

PIR-48

The Payload supplier shall publicly publish any telemetry packet protocols used by the Payload.

PIR-49

Any Payload with RF transmission capability shall not cause interference to the Platform communication system.

PIR-50

Any Payload with RF transmission capability shall conform with ITU regulations for amateur satellites, and be coordinated by the IARU.

PIR-51

Payloads with RF transmission shall have the capability to be shut down immediately upon command.

PIR-253

Licensing with the ITU for any active RF payload shall be the responsibility of the Payload Provider.

4.2.8 General Cubesat and POD Constraints

Payload Developers should be familiar with AD-01 and AD-02 regarding the CubeSat Design Specification. The requirements applicable to the payload are within the PIR.

The Spacecraft shall be a 3 U CubeSat mechanically conforming to the definition in the CubeSat Design Specification (AD-01 01 and Figure 4.2-2).

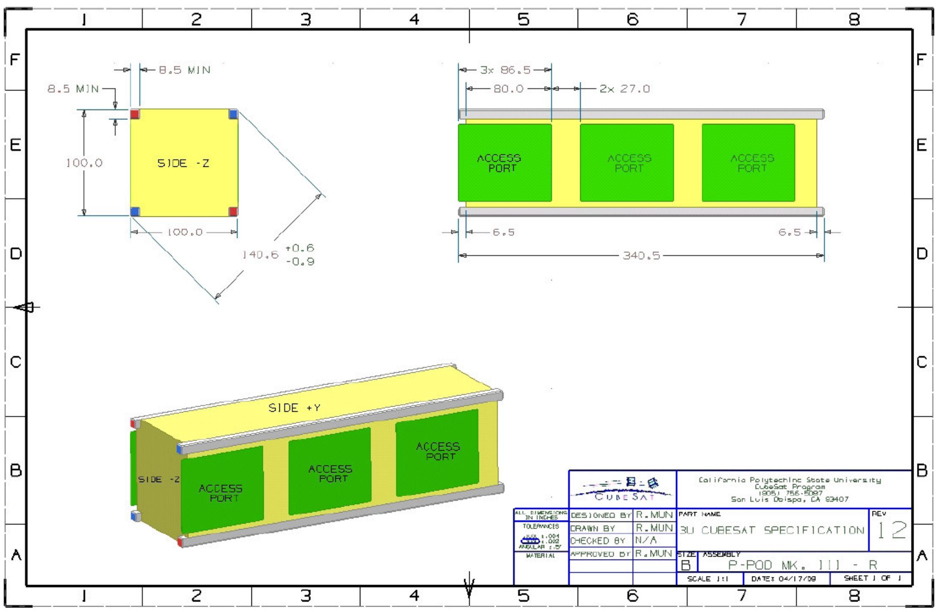

Figure 4.2-2: CubeSat Design Specification Mechanical Drawings

Information Deleted.

PIR-57

No access to the Payload shall be assumed after integration of the spacecraft with the POD.

PIR-58

The total Payload stored energy shall not exceed 20 W.hr

The total stored energy for the Spacecraft shall not exceed 100 W.hr, to conform to P-POD requirements

PIR-60

The Payload shall not include any pyrotechnic devices.

PIR-61

The Payload shall not include pressure vessels with a mechanical safety factor less than 4, or pressurised above 1.2 standard atmospheres.

PIR-62

All Payload elements shall remain attached to the Spacecraft during launch, ejection and operation; no additional space debris shall be created.

PIR-63

The Payload Developer shall be responsible for ensuring the Payload complies with the current CubeSat Design Specification (AD-01).

The Platform Developer shall be responsible for ensuring the spacecraft complies with the current CubeSat Design Specification (AD-01).

The Spacecraft shall undergo inspection to confirm conformity to the CubeSat Acceptance Checklist (CAC) (AD-02).

The Spacecraft shall undergo random vibration following AD-04, or a launch vehicle specific standard if this becomes known.

The Spacecraft shall undergo thermal vacuum testing following AD-04, or a launch vehicle specific standard if this becomes known.

4.3 Physical Interfaces

4.3.1 Mass Properties

PIR-70

The Payload nominal mass allocation shall not exceed 310 g.

The total Spacecraft mass budget is limited to 4 kg.

PIR-72

The Payload centre of mass shall be within 10% of the geometric centre along the X and Y body axes, as given in Figure 4.3-1.

PIR-254

The Payload centre of mass shall be calculated by the Payload Provider and supplied to the Platform Provider, with respect to the geometric centre in the XY plane, and the top of the CSK PC/104 board in the Z direction.

4.3.2 Coordinate Systems

PIR-74

The spacecraft reference axis system defined in Figure 4.3-1 shall be assumed.

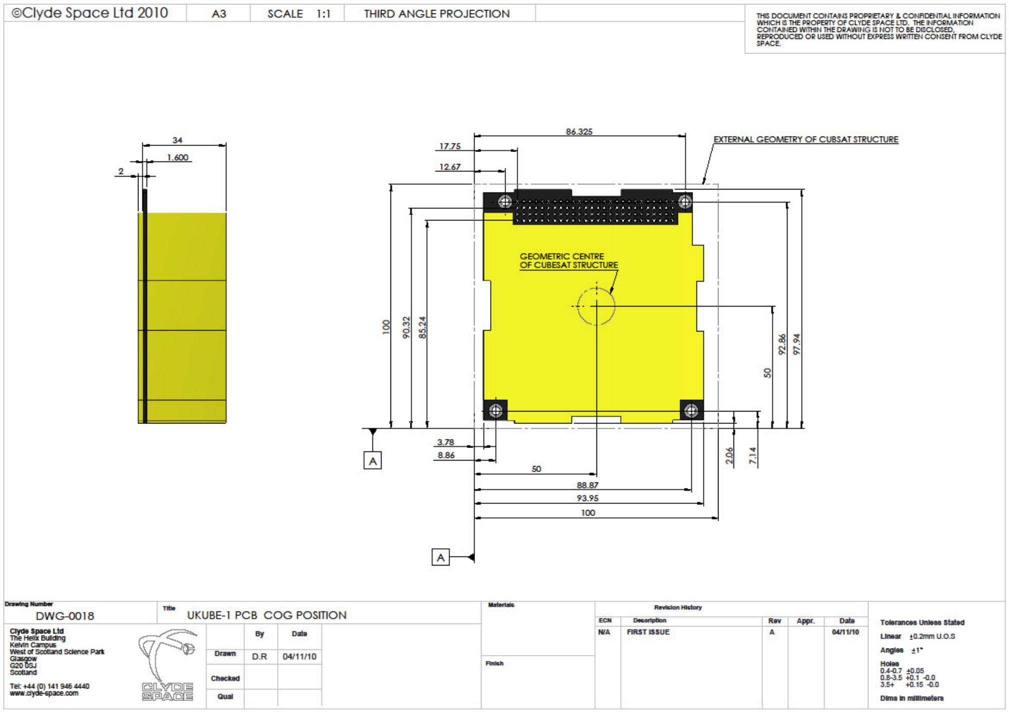

Figure 4.3-1: Spacecraft Reference Axis System Definition

4.3.3 Accommodation

PIR-77

The maximum height of the Payload shall not exceed 36 mm, as illustrated in Figure 4.1-4.

The Payload may consist of one or more PCB Modules with any number of daughter boards as shown in Figure 4.3-2.

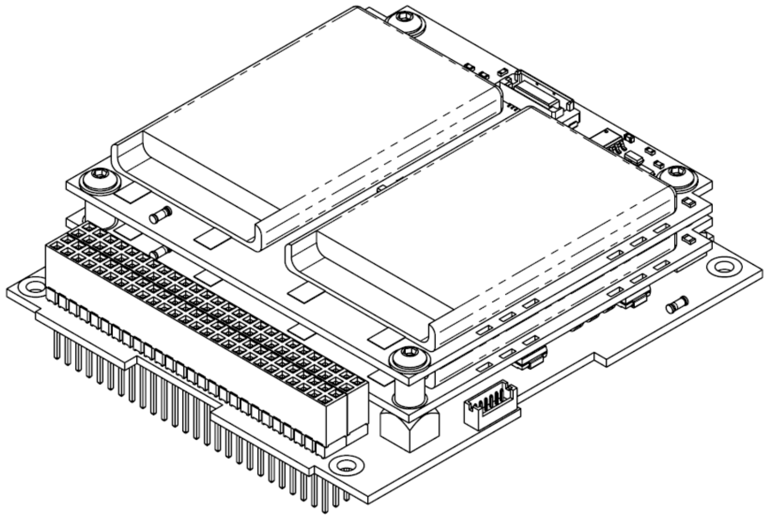

Figure 4.3-2: Typical module for the spacecraft, with example CSK PC/104 interfaces

PIR-81

Requirement Deleted

PIR-83

The Payload configuration within the spacecraft shall be stacked upon each other from the -Z face as shown in Figure 4.1-4.

PIR-85

Payload elements protruding beyond the Payload envelope, such as Deployables or Sensors, shall be identified to and authorised by the Platform Provider.

PIR-86

When stowed, Payload Deployables shall fit within the dimensions specified in Figure 4.3-1.

PIR-87

Deployables shall only be permitted to protrude from the +/-X, or + Y faces.

It is recommended that in the first instance deployables protrude from the +X face to minimise conflict with deployable solar arrays. The connector header runs up the -Y face making it less suited for mounting of protruding devices.

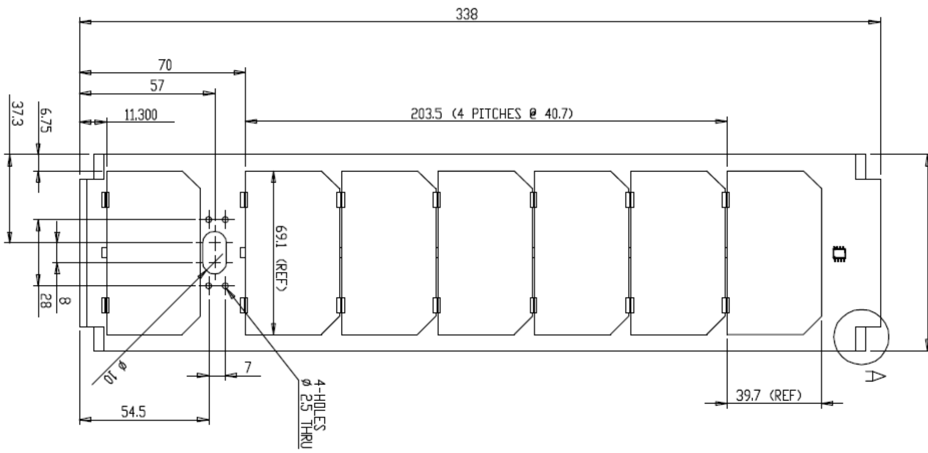

Figure 4.3-3: Example of solar cell arrangement for spacecraft, highlighting difficulty in accommodating surface protrusions

An exception may be granted for a single Payload for Deployables from either the +/- Z faces based upon the configuration specified in Figure 4.1-4.

PIR-91

Total surface area for Deployables or mounting of Sensors (for all Payloads) shall not exceed 20 x 75 mm on the +/-X and +/-Y faces.

Any Deployables and Sensors will impact upon the arrangement of solar cells on the spacecraft and therefore the required surface area should be minimised.

Developers using protruding Payload elements should refer to POD Constraints Requirements Section 4.2.8 and AD-01.

Additional requirements on specific Payloads may be imposed based upon systems level assessment of the Spacecraft.

PIR-241

The Payload Provider shall deliver a featured CAD model of the Payload for a virtual fit test 2 weeks prior to CDR.

The preferred format is Solidworks SLDASM or compatible.

4.3.4 Mechanical Interface

The standard method of mechanical fastening is the use of spacer screws between modules as described in Figure 4.3-1. Implementation of spacers beyond the screw holes noted in this figure is the responsibility of the Platform Provider.

Requirement Deleted

PIR-99

All dimensional tolerances shall be within +/- 0.1 mm.

PIR-100

The Payload shall be fixed at four points at the corners of the CSK PC/104 board as shown in Figure 4.1-4.

PIR-101

The mechanical interface shall not interfere with the Payload envelope specified in Figure 4.1-4.

4.3.5 Thermal Interface

PIR-103

The Payload shall be compatible with an operating temperature range of -20 to +65 degC.

PIR-104

The Payload shall be compatible with a survival temperature range between -30 to +75 degC.

PIR-105

The Platform shall not provide active thermal control for the Payload.

Should active thermal control be required by the Payload, this must be included within the Payload power budget allocation.

4.3.6 Electrical Interface

PIR-109

The Payload shall interface to the Platform computer via two parallel SAMTEC ESQ-126-38-G-D connectors or equivalent as shown in Figure 4.1-4. (See Appendix A for details).

PIR-257

The Payload shall interface to the Payload I2C data bus for command and control.

The Payload may interface to the Comms SPI data bus for higher rate data transfer.

PIR-263

Requirement Deleted.

PIR-262

The Payload Provider shall indicate the Power Lines that will be required for their Payload.

PIR-261

The maximum number of Power Lines per Payload shall not exceed four.

The following power lines are available to the Payload: 3.3V, 5V, 12V and Unregulated V. The unregulated voltage floats at the battery voltage, 7.5-8.3 V.

The Platform Provider shall allocate Slave Select and Power Lines based upon the requirements of the Payload.

Description	Designation	HEADER 1		Designation	Description
		H1.01	H1.02		
		H1.03	H1.04		
		H1.05	H1.06		
		H1.07	H1.08		
TOPCAT Comm SPI Slave Select	COMM_SS0	H1.09	H1.10		
C3D Comm SPI Slave Select	COMM_SS2	H1.11	H1.12	COMM_SS3	MPQ442 Comm SPI Slave Select
		H1.13	H1.14		
		H1.15	H1.16		
		H1.17	H1.18		
		H1.19	H1.20		
Comm SPI Clock	COMM_SCLK	H1.21	H1.22	COMM_MISO	Comm SPI Master In, Slave Out
Comm SPI Master Out, Slave In	COMM_MOSI	H1.23	H1.24		
		H1.25	H1.26		
		H1.27	H1.28		
		H1.29	H1.30		
		H1.31	H1.32		
		H1.33	H1.34		
		H1.35	H1.36		
		H1.37	H1.38		
		H1.39	H1.40		
		H1.41	H1.42		
		H1.43	H1.44		
Payload I2C Data	PAY_SDA	H1.45	H1.46		
Payload I2C Clock	PAY_SCL	H1.47	H1.48		
		H1.49	H1.50		
		H1.51	H1.52		

Description	Designation	HEADER 2		Designation	Description
TOPCAT 3V3	TOPCAT_3V3	H2.01	H2.02	JANUS_3V3	JANUS 3V3
C3D 3V3	C3D_3V3	H2.03	H2.04		
MPQ442 Supersprite enable (HIGH: Enable)	MPQ442_SS_3V3	H2.05	H2.06		
		H2.07	H2.08		
		H2.09	H2.10	TOPCAT_5V	TOPCAT 5V
JANUS 5V	JANUS_5V	H2.11	H2.12	C3D_5V	C3D 5V
		H2.13	H2.14		
		H2.15	H2.16		
		H2.17	H2.18		
C3D BATV	C3D_BATV	H2.19	H2.20	MPQ442_BATV	MPQ442 BATV
		H2.21	H2.22	C3D_12V	C3D 12V
TOPCAT 12V	TOPCAT_12V	H2.23	H2.24	JANUS_12V	JANUS 12V
		H2.25	H2.26		
		H2.27	H2.28		
Ground	GND	H2.29	H2.30	GND	Ground
		H2.31	H2.32	GND	Ground
		H2.33	H2.34		
		H2.35	H2.36		
		H2.37	H2.38		
		H2.39	H2.40		
		H2.41	H2.42		
		H2.43	H2.44		
		H2.45	H2.46		
		H2.47	H2.48		
		H2.49	H2.50		
		H2.51	H2.52		

Figure 4.3-4: Payload Pin Allocations

PIR-294

When switched off payload shall draw zero power.

It should be noted that the IO pins on the payload controller may still be active when the payload power is off. In order to ensure that the payload complies to PIR-(above) the route between the data IO and the power lines must be isolated. A typical solution is the use of enable buffers as demonstrated on the Interface Emulator.

PIR-110

Should additional interfaces be required for on-ground testing, these shall be implemented within the Payload budget at a location agreed with the Platform supplier.

4.3.6.1 Power Electrical Interface

PIR-112

The Payload sunlit average power requirement shall not exceed 400 mW over the sunlit period of the orbit.

Please note this is not the orbit average power.

PIR-113

The Payload shall not be active during eclipse.

PIR-114

The Payload shall not require power until it is switched on by the Platform.

PIR-115

Power line isolation by the Platform shall not damage or otherwise stress the Payload.

The Platform may isolate all power lines to the Payload to minimise power consumption, such as in eclipse. In nominal operations a warning shall be issued to the Payload Controller 30 s before shut down,allowing the Payload to save its status. This cannot be gauranteed in all scenarios however.

PIR-118

The Payload peak power draw in any operational mode shall not exceed 2000 mW.

PIR-119

The Platform shall provide 3.3 V, 5 V and 12 V regulated voltage power lines.

PIR-120

The regulated voltage shall be within +/-1% of stated value across the full load range.

Should additional regulated voltage power lines be required by the Payload, the regulation shall be performed at Payload level.

PIR-122

The Platform shall provide an unregulated floating voltage power line (7.5-8.3 V).

The unregulated voltage power line floats at the battery voltage.

PIR-124

The maximum steady state current shall not exceed 600 mA on any power line.

PIR-125

The inrush or transient current shall not exceed 2 A over 1 ms.

PIR-126

All supplied power lines shall have overcurrent protection. This will be set 10% above the peak current draw reported by Payloads.

The maximum steady state current on any power line will not be allowed to exceed 4 A.

PIR-299

The Payload power pin allocation shall correspond to Table 4.3-1.

Designation	Owner	Pin
TOPCAT_3V3	TOPCAT	H2.01
JANUS_3V3	JANUS	H2.02
C3D_3V3	C3D	H2.03
MPQ442_SS_3V3	MPQ442	H2.05
TOPCAT_5V	TOPCAT	H2.10
JANUS_5V	JANUS	H2.11
C3D_5V	C3D	H2.12
C3D_BATV	C3D	H2.19
MPQ442_BATV	MPQ442	H2.20
C3D_12V	C3D	H2.22
TOPCAT_12V	TOPCAT	H2.23
JANUS_12V	JANUS	H2.24

Table 4.3-1: Payload Power Pin Allocations

4.3.6.2 Data Handling Electrical Interface

The data handling will be between the Payload Controllers and the Mission Interface Computer.

All Data Buses willl be controlled by the Mission Interface Computer.

PIR-266

All Payloads shall implement a Payload Controller for data handling with the Platform.

PIR-131

Payload Telemetry and Telecommand shall use the Payload I2C data bus.

PIR-132

Payload Mission Data for Mass Memory or Downlink shall use the Payload I2C or Comms SPI data buses.

PIR-133

The data rate on the Payload I2C data bus shall be 100 kbps I2C as defined in AD-14.

PIR-303

The I2C addresses for the payload shall correspond to those shown in Table 4.3-2.

System	Address	Device	PLT I2C	PAY I2C	Notes
CDH	0x11	MIC-FPGA	x	x	
	0x12	MIC-SP	x	TBC	
PWR	0x21	EPS	x		
	0x22	BAT	x		
	0x23	Reserved	x		Additional battery
	0x24	SWB	x		Only single address need for switching
COM	0x31	Reserved		x	UVTRX if on I2C (else uses UART)
	0x32	FUNTRX-CCT	x		
	0x33	STX	x		
GNC	0x41	AMAC	x		
STM	0x51	ADM-A	x		Routed on Platform I2C
	0x52	ADM-B			Internal to FUNTRX-CCT
PAY	0x61	JANUS		x	
	0x62	TOPCAT		x	
	0x63	MPQ442		x	
	0x64	MPPT		x	
	0x65	NEPEX		x	
	0x66	C3D		x	
	0x67	UKATC		x	
	0x71	Platform Emulator	NA	NA	Not flight
	0x72	Payload Emulator	NA	NA	Not flight

Table 4.3-2: Payload I2C Address Allocation

PIR-134

The data rate on the Comms SPI data bus shall be 1 Mbps SPI as defined in AD-15.

PIR-135

All Data Bus voltages shall be 3.3 V.

PIR-136

Pull-up resistors for all signal lines shall not be implemented on the Payload.

Pull-up resistors for the signal lines will be implemented by the Platform.

PIR-138

Data Buses shall interface to a single Payload Controller.

Specification of the Payload Controller is at the discretion of the Payload Provider, subject to meeting the requirements defined here.

PIR-140

The Payload Controller shall handle all Payload Data Bus interactions.

PIR-141

The Payload Controller shall be a Slave device on all Data Buses.

PIR-305

The Payload utilise the CSK PC/104 header allocation listed in Table 4.3-3.

INTERNAL MODULE	HEADER	STANDOFF
	Samtec Part No.	Toby Part No.
JANUS	ESQ-126-38-G-D	TBD
MPQ442	ESQ-126-39-G-D + (2 x SSQ-126-22-G-D)	BS-L28-TA-M3
C3D	ESQ-126-39-G-D + SSQ-126-22-G-D	2x (BS-L12-TA-M3)
TOPCAT	ESQ-126-39-G-D + SSQ-126-22-G-D	BS-L20-TA-M3

Table 4.3-3: CSK PC/104 Header Connector Allocation

Note, C3D are assessing standoff options for their boards to accommodate aluminium baseplate and additional top PCB into the stack.

4.3.6.3 Connectors and Harness

PIR-143

Requirement Deleted

PIR-144

Requirement Deleted

Two SAMTEC connectors will be supplied by the Platform Provider to the Payload Provider as part of the Interface Pack. A DXF drawing layout and CAD model of the PCB is available in the data pack supplied with this PIR.

PIR-267

The connector shall be a stack-through connector as defined in Figure 4.3-5.

PIR-268

The connector shall interface to a through hole array of 4 x 26 on the PCB substrate, located as defined in Figure 4.1-4.

A DXF drawing layout and CAD model of the PCB is available in the data pack supplied with this PIR.

PIR-269

The connector shall use a through hole pitch of 0.1" as defined in Figure 4.1-4.

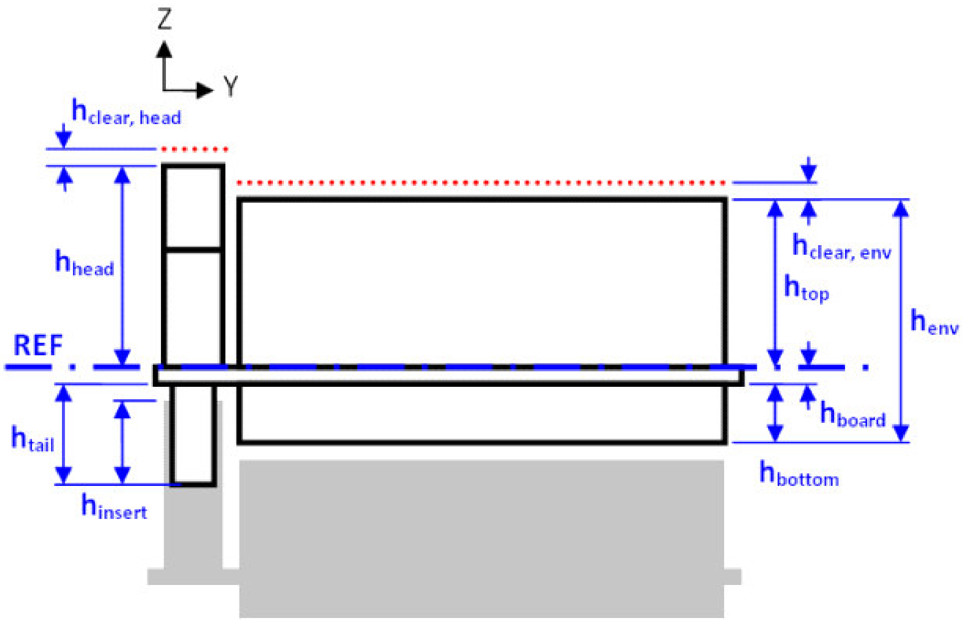

Figure 4.3-5: SAMTEC Connector Mechanical Interface Drawing

PIR-146

Any additional connections (such as to a surface mounted sensor) shall be identified by the Payload Provider to, and authorised by, the Platform Provider.

PIR-147

Any additional connections shall be the responsibility of the Payload Provider.

4.3.6.4 Additional Interfaces

Formatted: Bullets and Numbering

PIR-310

The TOPCAT Payload shall interface to the AMAC module from the GPS receiver by 4 differential lines.

PIR-309

The TOPCAT Payload shall inform the Platform if GPS lock cannot be acquired.

PIR-311

The JANUS payload shall have no other interfaces.

PIR-312

The C3D payload shall have access to SAA knowledge (computed on ground or otherwise).

PIR-314

The C3D payload shall have an Image capture trigger when Earth pointing.

PIR-313

The C3D payload shall have distribute 2 RADFET sensors on the spacecraft.

Proposed locations are internal face of SA-SZN and between the BAT and MIC boards.

PIR-316

The MPQ442 payload shall have a SuperSprite enable switch.

PIR-317

The MPQ442 payload shall be provided with eclipse status.

PIR-318

The MPQ442 payload shall have a Deployable camera (TBC, based on S-band feedback).

PIR-319

The MPQ442 payload shall have a SuperSprite radio (TBC, based on comm impact assessment).

PIR-320

The MPQ442 payload shall have the Ability to pass reprogramming data directly to payload (TBC).

4.4 Functional Interfaces

4.4.1 Operations

Spacecraft operations shall be handled by designated Operations Providers using amateur frequencies. Nominally, these are assumed to be UK universities, however secondary ground stations across the world are preferable for enhanced coverage. The Primary Ground Station shall take the lead in operating the Spacecraft and take responsibility to upload Payload Schedule Files to the Spacecraft. The Payload Schedule Files shall be supplied as required by the Payload Provider, in a format specified by the Primary Ground Station. At the next available opportunity this Payload Schedule File shall be uplinked to the Spacecraft. All data returned from the Spacecraft shall be publicly available via the internet.

PIR-151

Payload developers shall command their own payloads via Schedule Files to be sent to spacecraft operator.

PIR-152

The format of the Schedule Files shall be provided by the Primary Ground Station supplier.

PIR-153

The data volume required by the Payload for successful completion of the mission shall not exceed 100 kbit per orbit.

UKube-1 baseline system incorporates a 1 Mbps S-band Transmitter for Payload Data downlink. Following verification of the link in orbit, the anticipated data downlink for the payload will exceed 10 Mbit per orbit.

PIR-154

The data volume required by the Payload for Telecommand Uplink shall not exceed 10 kbit per orbit.

PIR-155

Payload data dissemination shall be by web interface defined by the Primary Ground Station.

PIR-156

The Payload Provider shall provide a publicly available decoder for interpreting Data returned.

PIR-157

The Payload Provider shall be responsible for interpreting the Data returned.

PIR-158

The Payload shall not be powered until commanded on by the Platform.

PIR-159

All deployables such as booms and antennae shall not deploy until commanded by the Platform.

4.4.2 Data Handling

4.4.2.1 General

PIR-162

The Platform shall not provide any processing capability for the Payload.

To minimise integration issues all processing is performed by the Payload. Requests for the Mission Interface Computer to perform additional processing or compression may be considered by the Platform Provider.

PIR-272

The Mission Interface Computer shall provide basic lossless data compression for all Payloads prior to downlink.

PIR-273

The Payload shall have a minimum of 256 Bytes for storage of Payload Data locally.

PIR-164

The Payload use of Platform mass memory shall not exceed 256 Mbytes before compression.

The Payload may opt out of compression.

Please note the limited allowable data volume for downlink per orbit, as defined in PIR-153.

PIR-166

The Payload use of any one data bus shall not exceed 10% loading based on the data rates specified in PIR-133 and PIR-134.

As a Slave device, the Payload Controller may only respond to commands on the Data Buses. These allow telemetry or mission data to be returned from the Payload.

4.4.2.2 Payload Data Bus

PIR-169

The Payload I2C Data Bus shall use the Packet standard as defined in AD-17.

PIR-170

The Payload shall respond to all commands received on the Payload I2C within 2 ms.

PIR-171

At a minimum, the following telecommands shall be implemented on the Payload I2C data bus:

- *Payload Operation Initialise*
- *Payload Operation Status*
- *Payload Operation Update*
- *Payload Parameter Write*
- *Payload Parameter Read*
- *Payload Priority Data Transfer*
- *Payload Data Transfer*
- *Payload SPI Data Transfer*
- *Payload Shutdown*

PIR-291

If no parameter writes are required, the payload shall respond with 0x00 for the value.

PIR-287

The polling frequency for operation status shall be greater than 1 s.

The Platform shall send a command for Payload Operation Status to each Payload at a frequency of at least once every 60 s when operational. This allows the Payload to inform the Platform of data waiting and request updates of up to 8 parameters. Should faster polling be required this may be considered by the Platform Provider.

PIR-275

Should the Payload be unable to respond to the command, then the Payload Controller shall respond with an Error Code defined by the Payload Provider in accordance with AD-17.

PIR-173

Requirement Deleted

PIR-174

Requirement Deleted

4.4.2.3 Comms SPI Data Bus

The Comms SPI Data Bus is an optional higher rate data bus for use by the Payload.

PIR-176

The maximum clock for SPI is 1 MHz

The Comms SPI Data Bus is clocked at 1 MHz, giving a data rate when active of 1 Mbps when transmitting or receiving. However, delays in processing after each Byte of data reduce the effective data rate. The typical effective data rate is expected to be over 700 kbps, with a delay between Byte transactions of 3 us.

The Comms SPI Data Bus may be requested to operate at a lower data rate for specific Payloads, subject to approval by the Platform Provider.

PIR-177

The Comms SPI Data Bus shall use the Packet standards defined in AD-17.

PIR-278

Each Payload Controller shall interface to a unique Slave Select line as specified in Table 4.4-1.

System	Line	Device	Pin	Notes
COM	SS	STX	H1.24	Data Stream for downlink
PAY	SS0	TOPCAT	H1.09	Data Packet for mass memory
	SS1	JANUS	H1.10	NOT REQUIRED
	SS2	MPQ442	H1.11	Data Packet for mass memory / reprogramming
	SS3	C3D	H1.12	Data Packet for mass memory
	SS4	TBD	H1.13	Data Packet for mass memory
GNC	SS5	Reserved for AMAC	H1.14	Data Packet for mass memory

Table 4.4-1: Slave Select Pin Allocations

Data file transfer is expected to be by pin H1.23 through the MOSI SPI line. MPQ442 will use this interface for transfer of data files.

Information Deleted

The Slave Select line is used to identify the which device should respond to the Master on the Comms SPI Data Bus. When the Slave Select line is enabled, the Payload should stream data onto the Comms SPI Data Bus according to the SPI Data Transfer Settings. The SPI Data Transfer Settings are defined by command through the Payload I2C Data Bus to the Payload Controller in accordance with AD-17.

PIR-180

Requirement Deleted

The Platform Provider shall supply an Interface Emulator for at least the data handling functionality of the Platform-Payload Interface.

4.4.3 Software Interfaces

PIR-183

Packet encoding and formats shall be as defined in AD-17, the standard format for data packets is given in Figure 4.4-1.

PIR-288

All packets containing Payload Data shall contain 256 Bytes of payload data.

All data packets should be padded to the maximum possible length of the response, not 256 bytes. For example, the response to the status command should be padded to 19 bytes (the 17 normal bytes plus two for the CRC) even if it is sending an error condition (2 command bytes, 1 error byte and possibly 2 CRC bytes). A Payload Data transfer always reads 260 bytes.

There is no short packet reception for SPI Payload Data transfer. The MIC will always read 260 Bytes. If the payload sends less than 260 bytes the extra info will be indeterminate, but will fail a CRC check.

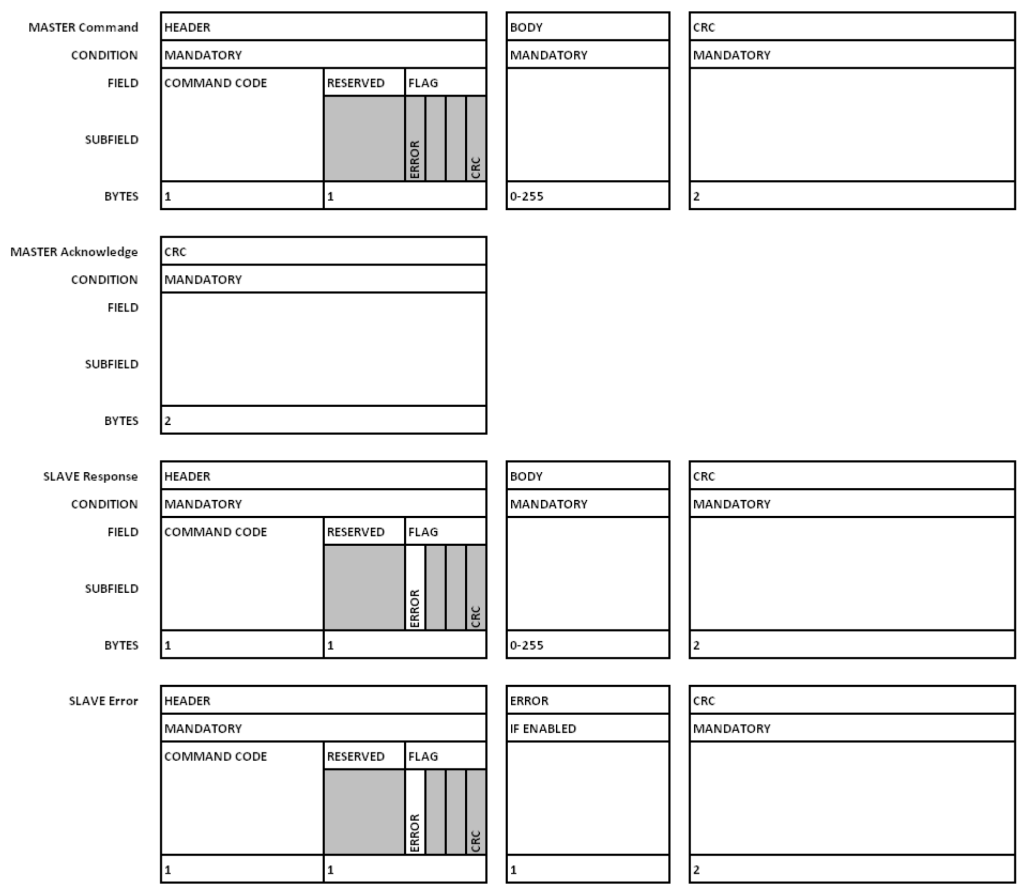

Figure 4.4-1: Standard Packet Definition

PIR-292

The payload shall not use the MOSI line.

I2C uses 7 bit addressing. Payloads addresses are identified by 0x6_.

PIR-184

Requirement Deleted

Payload Software with the Payload may be defined by the Payload Provider as required, provided data handling interfaces as defined in this document are adhered to.

PIR-280

The Payload Provider shall specify any additional commands required, to be agreed by the Platform Provider.

4.5 Environmental Requirements

4.5.1 Mechanical Environment

PIR-188

The Payload shall meet the random vibration requirements of AD-04, or a specific launch vehicle if this becomes known (see Figure 4.5-1).

Table 2.4-3
Generalized Random Vibration Test Levels
Components (STS or ELV)
22.7-kg (50-lb) or less

Frequency (Hz)	ASD Level (g^2/Hz)	
	Qualification	Acceptance
20	0.026	0.013
20-50	+6 dB/oct	+6 dB/oct
50-800	0.16	0.08
800-2000	-6 dB/oct	-6 dB/oct
2000	0.026	0.013
Overall	14.1 G_{rms}	10.0 G_{rms}

The acceleration spectral density level may be reduced for components weighing more than 22.7-kg (50 lb) according to:

	Weight in kg	Weight in lb	
dB reduction	= 10 log(W/22.7)	10 log(W/50)	
$ASD_{(50\text{-}800\ Hz)}$	= 0.16•(22.7/W)	0.16•(50/W)	for protoflight
$ASD_{(50\text{-}800\ Hz)}$	= 0.08•(22.7/W)	0.08•(50/W)	for acceptance

Where W = component weight.

The slopes shall be maintained at + and - 6dB/oct for components weighing up to 59-kg (130-lb). Above that weight, the slopes shall be adjusted to maintain an ASD level of 0.01 g^2/Hz at 20 and 2000 Hz.

For components weighing over 182-kg (400-lb), the test specification will be maintained at the level for 182-kg (400 pounds).

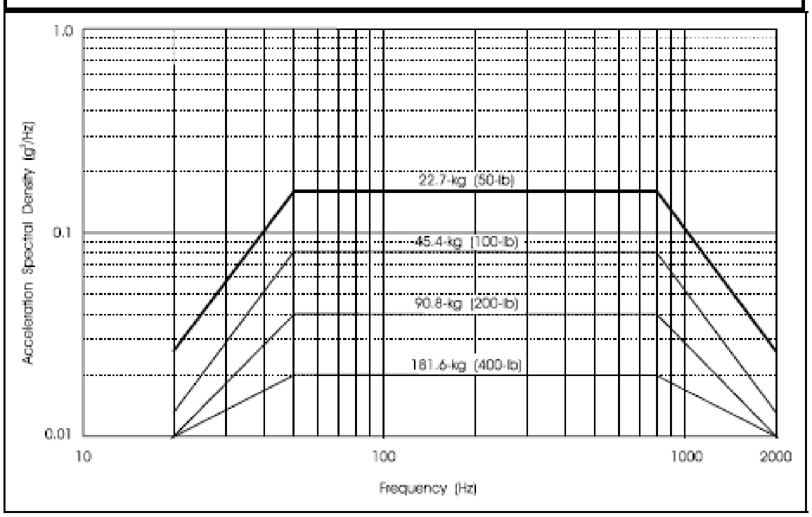

Figure 4.5-1: Random Vibration Environment

PIR-190

The designed for natural frequency of the Payload shall exceed the resonances of the launch vehicle by a factor of two.

PIR-191

The minimum designed natural frequency of the Payload shall exceed 150 Hz.

PIR-192

Any vibration resonances or shock to which a subsystem may be particularly susceptible shall be identified by the Payload developer.

4.5.2 Thermal Environment

PIR-194

The Payload shall meet the thermal cycle described in Figure 4.5-2, or a specific spacecraft-orbit thermal cycle if this becomes known.

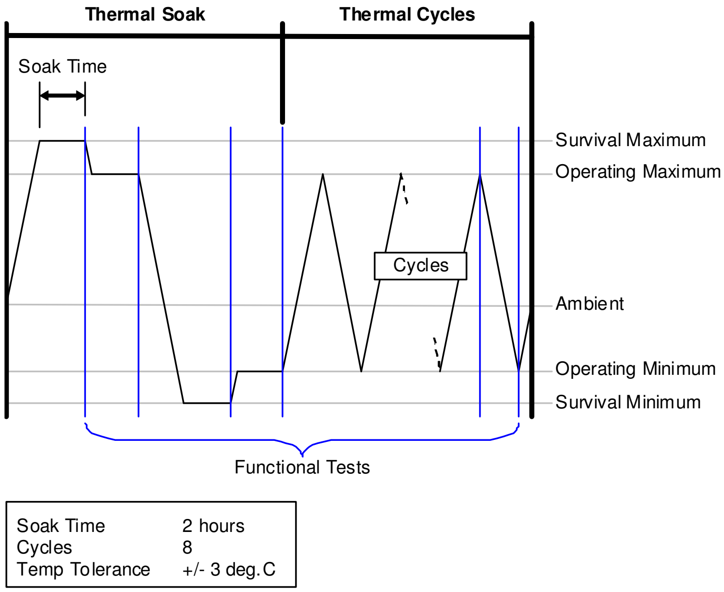

Figure 4.5-2: Thermal Cycle Environment

4.5.3 Radiation Environment

The Total Ionising Dose (TID) expected during the mission lifetime is not expected to exceed 15 krad.

Should higher radiation tolerances be required by the Payload, spot shielding may be implemented within the Payload budget.

PIR-200

Payload components shall be selected for fault tolerance with respect to Single Event Effects and Total Irradiated Dose as described in AD-09, as far as is practicable.

4.5.4 Electromagnetic Environment

PIR-202

The Payload shall not connect Structure and Ground.

PIR-297

Payloads shall electrically isolate the mechanical fixing points of the CSK PC/104 format board.

The mechnical standoffs are frame grounded and must not be interfaced to in order to prevent current loops.

PIR-203

The Payload shall conform to the single point grounding scheme defined in Figure 4.5-3.

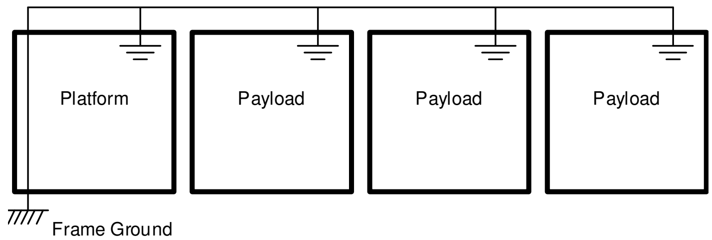

Figure 4.5-3: Grounding Scheme

PIR-205

The Payload shall not produce peak to peak noise or ripple over 50 mV on any power line across all frequencies.

PIR-206

The Payload magnetic dipole shall not exceed 0.001 A.m2.

Relevant EMC standards are provided by AD-16

PIR-208

Potential for spurious emissions in the frequency range 10 kHz to 4 GHz shall be avoided by the design, as far as is practicable.

In particular, Payload should be aware of spurious emissions in expected communication frequencies: 100 kHz; 1, 145, 435, 2400 MHz.

4.5.5 Depressurisation Environment

PIR-211

The Payload shall be compatible with a maximum depressurisation rate of 50 mbar/s from 1000 mbar to negligible.

4.6 Product Assurance Requirements

PIR-213

The Payload shall use industrial grade non-space rated COTS components and materials or above and conform to AD-09.

PIR-214

Payload component and material selection process shall conform to AD-09.

PIR-215

The Payload shall use materials which conform to NASA outgassing requirements; Total Mass Loss (TML) < 1.0 %, Collected Volitile Condensible Material (CVCM) < 0.1 %.

Small deviations to this requirement are expected, but must be approved by the Platform Provider.

PIR-216

Payload shall be capable of being stored in a launch ready configuration for 120 days without maintenance and with no degradation to its functionality.

PIR-217

The Payload shall cause negligible additional risk to the launch vehicle and any primary or secondary payloads.

PIR-218

The Payload Supplier shall submit a Request for Deviation (RFD) against any requirement which cannot be met by design in accordance with the approval process defined in AD-11.

PIR-219

The Payload Supplier shall submit a Request for Waiver (RFW) against any requirement which is not successfully met during verification, in accordance with the approval process defined in AD-11.

PIR-220

Any Flight Hardware shall be stored in electrostatic discharge and vibration / shock protected containers.

5 VERIFICATION OF REQUIREMENTS

5.1 Testing Required

PIR-223

The Payload shall be interfaced to an Interface Emulator for Platform-Payload pre-integration testing by the Payload Provider.

An Interface Emulator will be supplied at Payload Kick-Off by the Platform Provider for mechanical, electrical, and data handling functional check-out.

PIR-225

The Interface Emulator shall be used for verification by test of the following requirements at a minimum

Full compliance: PIR-83, 100, 131, 133, 134, 135, 169, 171, 257, 262, 263.

Partial compliance: PIR-124, 125, 132, 138, 140, 141, 166, 170, 176, 267, 275, 278.

PIR-226

Requirement Deleted

PIR-227

Requirement Deleted

5.1.1 Payload Acceptance Testing

PIR-230

Payload Acceptance Testing shall be performed in advance of delivery for Platform-Payload integration by Payload Provider.

PIR-281

All boards shall be conformally coated prior to delivery.

PIR-231

The Payload shall undergo thermal bakeout for a minimum of 2 hours at least +75 deg.C prior to any conformal coating.

Humiseal 1B31 Acrylic, or equivalent may be used for conformal coating. Note that the CVCM for this epoxy is 0.11%, with respect to PIR-215, however the WVR is 0.09%.

PIR-232

The Payload shall undergo thermal cycle testing to Figure 4.5-2.

PIR-233

The Payload shall undergo random vibration testing to Figure 4.5-1.

PIR-234

The Payload Provider shall undergo any additional tests required by Engineering Management as the result of an identified risk (e.g. EMC).

Other tests necessary may include magnetic and EMC tests.

PIR-236

Following each test, a functional test shall be performed to verify continued functionality of the Payload

The Payload Flight Model will undergo EMI testing at spacecraft level.

PIR-238

The Payload shall validate compliance to environmental requirements as specified in Section 4.5 through test in advance of delivery.

PIR-239

Testing shall be documented and repeatable.

PIR-240

Payload shall verify against compliance matrix supplied by the AIVT Engineer.

CHANGE LOG

Note:

This log is autogenerated from Doors. Special symbols may not be rendered correctly and hence the main body of the document shall always take precedence for requirements. Thus it should only be used as a guide to the modifications in the document and not as a substitute.

Modified Objects

The following table shows the new and old values of each modified attribute.
The codes used in the object type (OT) column are: Rq = Requirement, Inf = Information, Hd = Heading, TC = Table Cell, Ah = Applicability Matrix Heading, Ar = Applicability Matrix Requirement

Identifier	Attribute	OT	New Text	Old Text
PIR-84 section 4.1	OLE	Inf	Figure/Table modified	
PIR-126 section 4.3.6.1	Object Text	Rq	All supplied power lines shall have overcurrent protection. This will be set 10% above the peak current draw reported by Payloads.	All supplied power lines shall have overcurrent protection.
PIR-258 section 4.3.6	OLE	Inf	Figure/Table modified	
PIR-263 section 4.3.6	Object Text	Rq	Requirement Deleted.	The Payload shall interface to the Ground line within the pin allocation shown in Figure 4.3-4.
PIR-278 section 4.4.2.3	Object Text	Rq	Each Payload Controller shall interface to a unique Slave Select line as specified in Table 4.4-1.	The Payload Controller shall interface to a unique Slave Select line in the connector as specified by the Platform Provider.
PIR-285 section 4.1	Object Type	Inf	Information	TBD
PIR-286 section 2.2	Object Type	Inf	Information	TBD

Inserted Objects

Identifier	Object Type	Text
PIR-299 section 4.3.6.1	Requirement	The Payload power pin allocation shall correspond to Table 4.3-1.
PIR-300 section 4.3.6.1	Information	Table 4.3-1: Payload Power Pin Allocations
PIR-301 section 4.4.2.3	Information	Table 4.4-1: Slave Select Pin Allocations
PIR-302 section 4.4.2.3	Information	Data file transfer is expected to be by pin H1.23 through the MOSI SPI line. MPQ442 will use this interface for transfer of data files.
PIR-303 section 4.3.6.2	Requirement	The I2C addresses for the payload shall correspond to those shown in Table 4.3-2.

Identifier	Object Type	Text
PIR-304 section 4.3.6.2	Information	Table 4.3-2: Payload I2C Address Allocation
PIR-305 section 4.3.6.2	Requirement	The Payload utilise the CSK PC/104 header allocation listed in Table 4.3-3.
PIR-306 section 4.3.6.2	Information	Table 4.3-3: CSK PC/104 Header Connector Allocation
PIR-307 section 4.3.6.2	Information	Note, C3D are assessing standoff options for their boards to accommodate aluminium baseplate and additional top PCB into the stack.
PIR-308 section 4.3.6.4	Heading	Additional Interfaces
PIR-309 section 4.3.6.4	Requirement	The TOPCAT Payload shall inform the Platform if GPS lock cannot be acquired.
PIR-310 section 4.3.6.4	Requirement	The TOPCAT Payload shall interface to the AMAC module from the GPS receiver by 4 differential lines.
PIR-311 section 4.3.6.4	Requirement	The JANUS payload shall have no other interfaces.
PIR-312 section 4.3.6.4	Requirement	The C3D payload shall have access to SAA knowledge (computed on ground or otherwise).
PIR-313 section 4.3.6.4	Requirement	The C3D payload shall have distribute 2 RADFET sensors on the spacecraft.
PIR-314 section 4.3.6.4	Requirement	The C3D payload shall have an Image capture trigger when Earth pointing.
PIR-315 section 4.3.6.4	Information	Proposed locations are internal face of SA-SZN and between the BAT and MIC boards.
PIR-316 section 4.3.6.4	Requirement	The MPQ442 payload shall have a SuperSprite enable switch.
PIR-317 section 4.3.6.4	Requirement	The MPQ442 payload shall be provided with eclipse status.
PIR-318 section 4.3.6.4	Requirement	The MPQ442 payload shall have a Deployable camera (TBC, based on S-band feedback).
PIR-319 section 4.3.6.4	Requirement	The MPQ442 payload shall have a SuperSprite radio (TBC, based on comm impact assessment).
PIR-320 section 4.3.6.4	Requirement	The MPQ442 payload shall have the Ability to pass reprogramming data directly to payload (TBC).
PIR-321 section 4.1	Requirement	The Payloads shall be accommodated in the positions shown in Figure 4.1-4.

Identifier	Object Type	Text
PIR-322 section 4.1	Information	Note: The cutaways are in the solar arrays and not in the Primary Structure and there is no cutaway assigned for MPQ boards.
PIR-323 section 4.1	Requirement	The Payloads shall support the cutouts shown in Figure 4.1-5.
PIR-324 section 4.1	Information	Figure 4.1-5: Cutaway Dimensions for Payload Boards

Deleted Objects

33 differences found

Requirement/Section Cross Reference

Page numbers are the pages where the sections start

INTENTIONALLY BLANK

DOCUMENT CHANGE DETAILS

DISTRIBUTION LIST