UKSEDS UKube1 payload ‘myPocketQub 442’ proposal

Introduction abstract

United Kingdom Students for the Exploration and Development of Space (UKSEDS) propose launching an open source myPocketQub IQEA with five experiments as a UKube1 payload.

The primary mission is to gain space heritage for myPocketQub IQEA. The secondary mission is to obtain results from each experiment. All aspects of the project are open source and will be documented on myPocketQub.com for anyone to follow.

A myPocketQub is a 46mm x 46mm x 46mm picosatellite platform (one eighth of the internal volume of a typical 1U CubeSat structure) with its sub-systems built into its solar panel walls leaving the centre free for multiple 32mm x 32mm x [Z]mm payloads.

A myPocketQub In-plane Qub with Experiment Array (IQEA) is a myPocketQub flat packed on a CubeSat PC/104 card with multiple positions for mounting standard myPocketQub payloads.

The five flight-ready experiment payloads are:

- OpenSpace365 – Arduino with sensors allowing 365 school pupils, university students and hobbyists to develop and fly virtual software payloads on-orbit for a day each for free
- OrbitView – imaging payload to capture 360 degree panoramas from multiple points on-orbit to allow anyone to ‘look out of the window’ of UKube1, Google Street View style
- Qubduino – Arduino with Field Programmable Gate Array (FPGA) to space qualify the FPGA, test self repairing algorithms and host advanced virtual payloads
- SuperLab – physics experiment to characterise superconductor materials
- SuperSprite – satellite on a chip proof-of-concept with solar cells, energy storage, micro-controller and transceiver

UKSEDS is an independent, student-based organisation which promotes the exploration and development of space with more than 150 members from more than a dozen British universities. Its members are major contributors to the flight-ready myPocketQub reference implementation.

For more information about this proposal, please email spaceprojects@ukseds.org

Technical details

Design of payload concept

United Kingdom Students for the Exploration and Development of Space (UKSEDS) is a society with student members drawn from space engineering and science departments across the United Kingdom. Its purpose is to:

- promote the exploration of space, and the research and development of space-related technologies
- provide a forum through which students can become involved in the international space community
- motivate students to excel in space-related fields
- share in the advancing knowledge and growing benefits to be reaped from space
- improve space-related education through both academic work and hands-on projects

Cost of access to space is a significant barrier to allowing these goals to be met, so members of UKSEDS have been developing a low cost open source platform to allow low cost payloads to be flown in space – myPocketQub. A myPocketQub has two standard formats:

1. the reference myPocketQub design, a 46mm x 46mm x 46mm free flying picosatellite designed to be launched from a MR-FOD deployer built into a small satellite, and
2. the myPocketQub IQEA, a CubeSatKit compatible PC/104 card version of the free flying reference design, designed to be installed in a standard CubeSat chassis either as the main avionics package or as a payload controller.

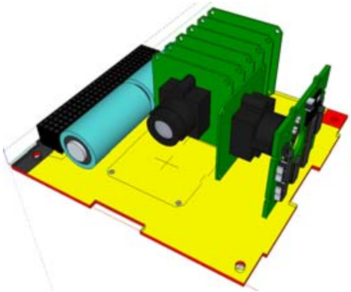
Both these formats are designed to provide the complete functionality of a nano or picosatellite including flight computer, communications and electrical power system and to provide these services to a number of payloads designed to be mounted within these structures – PocketPayloads.

PocketPayloads are 32mm x 32mm printed circuit boards with a four wire bus providing power (3.3V) and communications (I2C) to the payload. Typically designed to be multiples of 10mm tall / 10g mass (1PP), a 1PP PocketPayload can host surprisingly sophisticated experiments inexpensively. The goal of the PocketPayload concept is to allow multiple payloads to be densely packed within a free flying myPocketQub (up to four 1PP internally and four 0.5PP externally on a 1myP myPocketQub) or CubeSat or CubeLab (up to eighty one 1PP internally and eighteen 0.5PP externally per 1U CubeSat) such that the launch cost of an individual PocketPayload using mainstream launch options available today is less than GBP 1000 per PocketPayload.

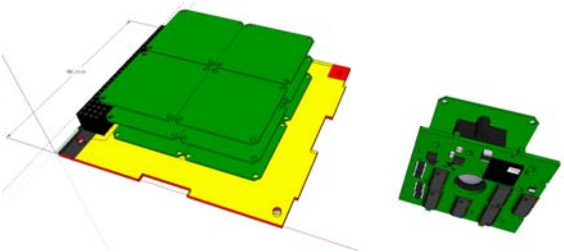
UKSEDS were kindly offered the opportunity to launch a free flying myPocketQub (to be called myPocketQub 441) to test this concept on a Russian launch at very short notice. A development team was put together and a flight ready system was developed on time in less than six months by members of UKSEDS to take advantage of this offer. Unfortunately, the cost of the third party liability insurance premium (more than GBP 100K) required by the Outer Space Act meant that UKSEDS was unable to accept the launch offer and launch the free flying version of the platform.

UKube1 provides the possibility of flying a myPocketQub IQEA configuration (without the crippling insurance premium problem) and with a number of exciting payloads including improved versions of payloads developed for myPocketQub 441 and some new payloads which were too big to fit on myPocketQub 441. In addition, flying a myPocketQub IQEA as part of UKube1 offers a number of advantages over the free flying myPocketQub thanks to the ability of UKube1 to use commercial-off-the-shelf systems for communications and other functions.

The myPocketQub IQEA is designed to be able to host PocketPayloads in parallel or perpendicular payload configurations:



Example of a myPocketQub IQEA with perpendicular payloads (preferred configuration)



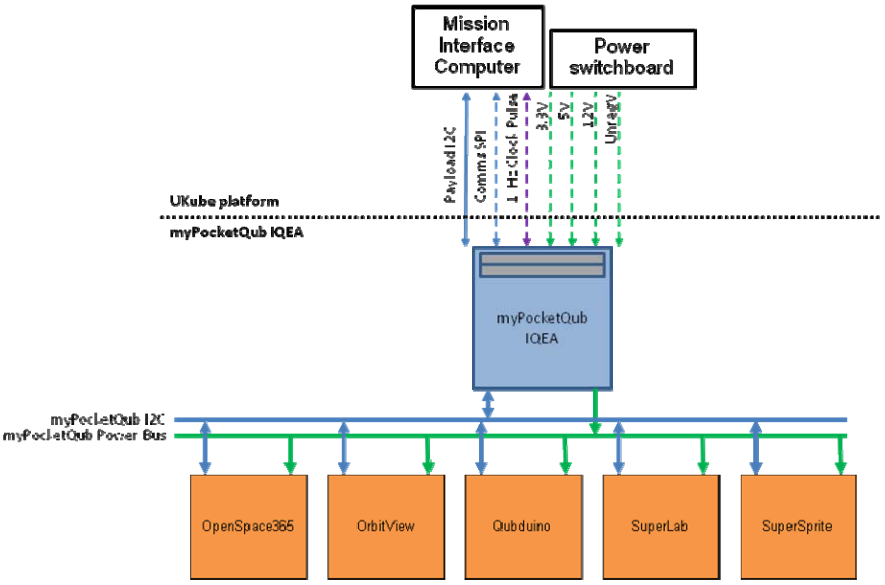
Example of a myPocketQub IQEA with parallel payloads and flying low profile sensor package

The perpendicular payload configuration allows an array of up to ten 1PP standard sized PocketPayloads to be placed perpendicular to the myPocketQub IQEA main board as if they were stacked in a free flying myPocketQub.

The parallel payload configuration allows either a 2x2 or 3x3 array of PocketPayloads to be stacked parallel to the myPocketQub IQEA main board within a standard CubeSat chassis. The 3x3 array does not permit the use of a CubeSatKit compatible connector to achieve the highest density of payloads, therefore we propose using a 2x2 configuration if chosen for UKube1.

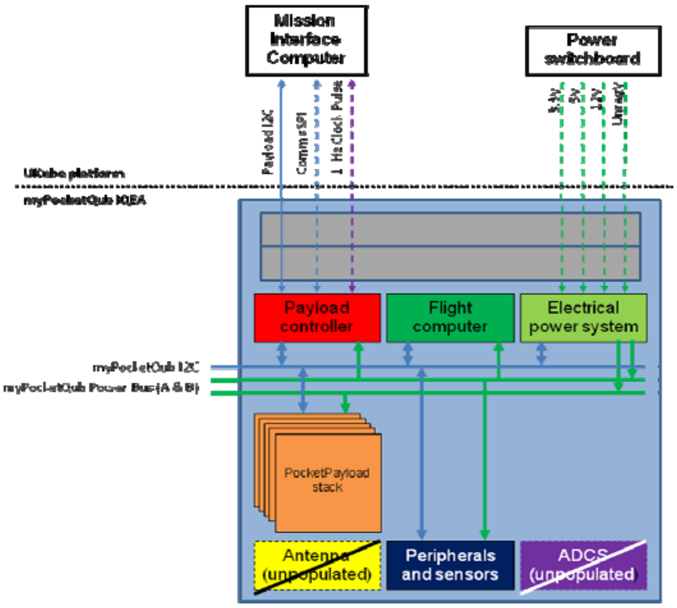
UKSEDS is proposing to fly either a perpendicular payload configuration (preferred) or a parallel payload configuration depending on the needs of the other payloads on UKube1. If the location labeled PAYLOAD C in figure 4.1-4 of UKUBE.RS.001 ISS02 is available for myPocketQub 442, then we propose flying a perpendicular payload configuration with a deployable imaging system to allow 360 degree panoramas of UKube1 and its surroundings to be made. If the location PAYLOAD C is not available, then we propose flying a parallel payload configuration with low profile sensors which can be attached to any external UKube1 surface.

Overview



It is proposed that the myPocketQub 442 UKube1 payload consist of a myPocketQub IQEA plus five individual payloads as shown in the block diagram and described in the following sections.

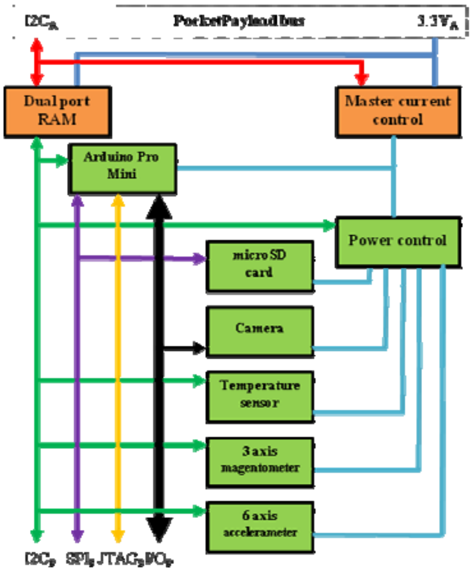
myPocketQub IQEA



The myPocketQub IQEA will use the standard free flying myPocketQub systems including the Arduino based flight computer, electrical power system (input power coming from the CubeSatKit compatible connector rather than solar panels) and peripheral and sensor subsystem. These systems are normally built into the walls of a free flying myPocketQub, but are flattened onto a PC/104 card to form a myPocketQub IQEA. The radio module will be replaced with a payload controller configured to appear as a radio to the myPocketQub IQEA and as the specified payload controller to UKube1. The areas of the board reserved for the attitude determination and control system, antenna and solar cells (underside) will be left unpopulated.

The primary goal is to demonstrate the first successful operation of a myPocketQub IQEA in space. Secondary goal is to demonstrate its utility as a PocketPayload payload adaptor, also demonstrating the ability of a UKube to support two full size UKube payloads and up to twelve PocketPayloads.

OpenSpace365



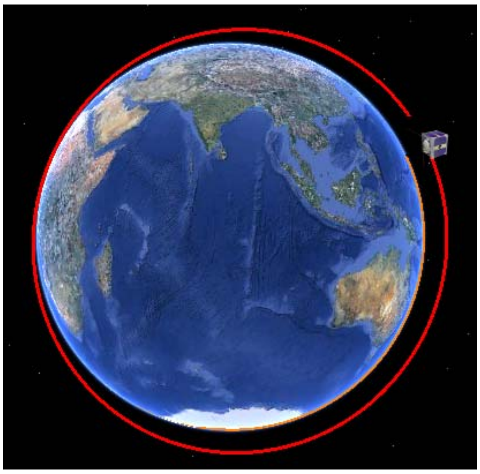
OpenSpace365 is a PocketPayload based on the open source Arduino Pro Mini board which we intend to allow up to 365 people to use to run their own software in space for one day each.

The board has a microcontroller, 32KB of program memory, 2KB SRAM, a 2GB micro SD card, a VGA quality camera, temperature sensor, three axis magnetometer, six axis accelerometer and a power controller. It is isolated from the PocketPayload bus by a dual port RAM and master current controller to protect the rest of the system from malicious payloads.

The goal is to allow school pupils, university students and hobbyists to write software for an inexpensive and readily available open source environment on the ground and to run these programs in space – we call these virtual payloads. We do not know what sort of virtual payloads people will write, but with a good selection of sensors and storage and a freely available development environment we look forward to finding out. A web site will be set up to allow virtual payloads to be submitted for flight. They will be reviewed for merit and then scheduled to be run on the spacecraft on a first come first served basis when an opportunity permits.

The primary goal for this mission is to demonstrate one piece of software written by a non space professional running in space. The secondary goal is to run 365 programs over the course of a year.

OrbitView



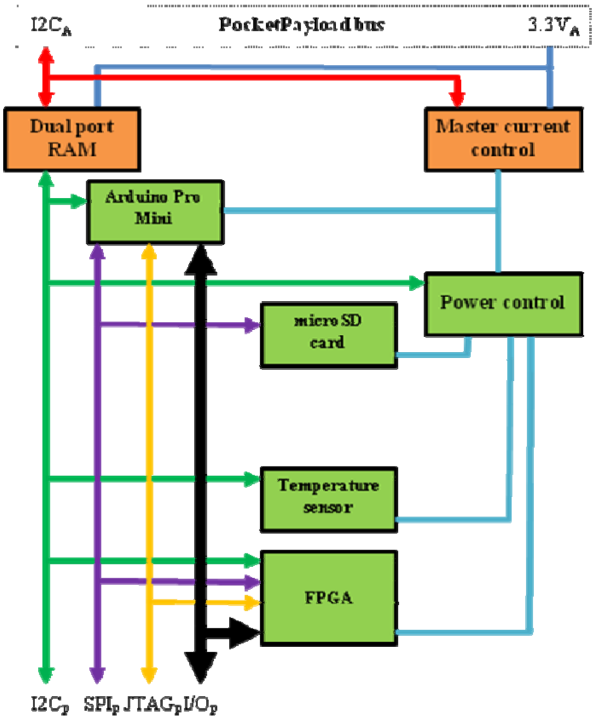
OrbitView is an imaging PocketPayload designed to capture 360 degree panoramas from multiple points on-orbit to allow anyone to 'look out of the window' of UKube1, Google Street View style, via a web interface. The payload will be configured to capture data from one complete orbit on to its 2GB micro SD card and then send this data down over a period of months to the web servers. Users of the web interface will see an orbit track which they can click on to view a panorama at a specific point. The hardware is the same as the OpenSpace365 payload with the addition of a second camera if permitted.

If myPocketQub 442 can fly in the PAYLOAD C position, it will be able to deploy an 18mm diameter parabolic mirror positioned in front of a static camera. The mirror will deploy approximately 50mm outside the main CubeSat structure using a spring loaded mechanism released by nichrome cutters melting monofilament restraints. This mirror will allow images of the CubeSat and its surroundings to be captured. A second static camera will be positioned to image the field of view blocked by the parabolic mirror and to act as a backup imaging source in case the parabolic mirror fails to deploy.

If myPocketQub is only able to fly on UKube1 in a payload slot that does not permit the deployable parabolic mirror to be used, then the OrbitView payload will use the low profile camera proposed as the backup imaging source in the deployable scenario. As UKube1 will be spinning slowly, this will still permit the parabolic imagery to be created, however, imaging of UKube1 itself will not be possible other than any incidental structures such as antennas that might be in the field of view.

The primary goal is to obtain a single panorama, the secondary goal is to obtain multiple panoramas from multiple points on the same orbit.

Qubduino



The Qubduino payload is an Arduino with a Field Programmable Gate Array (FPGA) intended to space qualify the FPGA, test self repairing algorithms and host advanced virtual payloads.

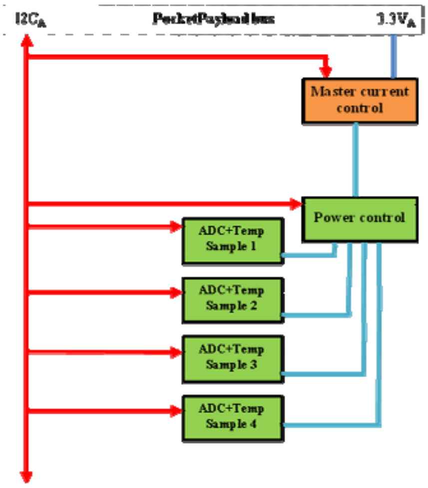
The primary goal is to fly a member of the Xilinx Spartan-6 low-power FPGA family (the XC6SLX16) to test its suitability for use in spacecraft in the future.

The secondary goal is to test a number of self repairing algorithms (known as FPGA scrubbers) on orbit. These algorithms allow errors in the FPGA configuration induced by the radiation environment to be corrected on the fly.

Finally, if both of the other goals have been achieved, the payload may be made available on the same basis as the OpenSpace365 payload for advanced virtual payloads.

SuperLab

High temperature superconductors were discovered in 1986 and despite 25 years of intensive research an understanding of the microscopic mechanism that leads to the superconducting pairing has not been achieved. Low temperature experiments require the use of He-based cryostats: these are expensive devices. Irradiation-induced disorder studies require radioactive sources combined with low-temperature refrigeration systems: these are sophisticated setups available in a small number of research facilities worldwide.



This experiment is a feasibility test for carrying out temperature dependent conductivity measurements in space as a function of irradiation-induced disorder. The temperature cycle will depend on the type of orbit (sample position with respect to the Sun and satellite position with respect to Sun-Earth line), and disorder will be induced by the high energy particles present in space that will hit the sample.

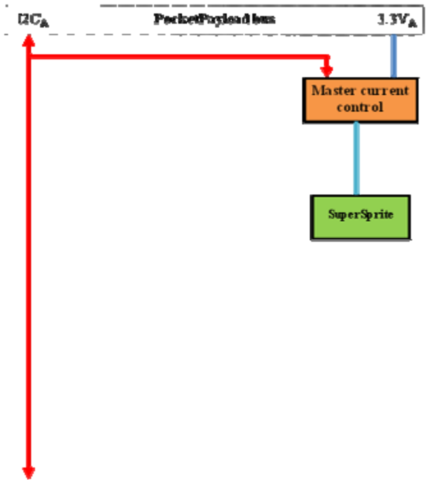
The primary goal is to test the survival of sample and electric contacts to launch and orbiting and the reliability of the resistivity measurement method.

The other payloads described so far are 'smart' payloads with onboard processing that are isolated from the myPocketQub IQEA flight computer. The secondary goal of this payload is to assess the flight computer overhead of managing a real world 'dumb' payload with readings and measurements managed directly by the flight computer.

SuperSprite

The Sprite Satellite Project is a project from the Cornell University Space Systems Design Studio working towards packaging the traditional spacecraft systems (power, propulsion, communications, etc.) onto a single silicon microchip – a 'chipsat'.

Prototypes of the Sprite concept implemented from a very small number of discrete parts that fit in a 16cm^2 footprint are scheduled to fly in space shortly. However, these prototypes are limited to very short periods of operation (less than a second), and, although they have 11mW transceiver hardware on board, they will only transmit a simple beacon.



We propose modifying the design to allow transmission and reception of signals in the 70cm amateur radio band and to permit operation for longer periods of time. In addition, we propose reducing the footprint to less than 4cm^2 to allow the SuperSprite to fit around the OrbitView camera lens. This will allow the total footprint of the myPocketQub sensors on the external panels of UKube1 to be less than 5cm^2. Although the SuperSprite will be a completely self contained satellite, a power control or 'kill switch' operated by the myPocketQub IQEA will be implemented as a backup in case the receiver fails so that transmissions can be commanded to cease.

The primary goal of this payload is to demonstrate a chipsat with transmit and receive ability.

Outline development plan

The six main components of the project (myPocketQub IQEA plus five payloads) are already substantially complete. The only major area of development will be the UKube Payload Controller module and protocols specified by the UKube Payload Interface Requirements document and the parabolic mirror deployment mechanism. There may also need to be minor modifications to the myPocketQub IQEA PC/104 card to support the UKube pin assignments. It is expected that these modules will be quickly developed by repurposing an existing hardware design. As the myPocketQub IQEA is designed to be capable of being a self contained spacecraft in its own right, we expect to make minimal demands of the UKube platform, asking only for power, communications and mechanical support.

All custom hardware and software development is carried out in house by the UKSEDS team. Manufacturing of flight ready hardware has been or will be carried out by members of the UKSEDS team, technicians from UKSEDS team member's institutions or reputable electronics assemblers.

The Project Lead will be in overall charge of the project and will liaise with the Engineering Lead, the Payload Coordinator and the Validation/QA Lead to address any issues as they arise. The Project Lead will also be available for technical support and advice throughout the project.

The Engineering Lead will manage the team working on the myPocketQub IQEA including the UKube payload interface module. Comprehensive documentation will be produced for each component and also for the overall integrated payload. All technical documentation will be reviewed by the Engineering Lead.

The Payload Coordinator will manage five payload team leads, with each payload being subject to technical review and sign off by the Engineering Lead as various milestones are reached. The five payload teams will work in parallel to prepare the payloads for integration with the myPocketQub IQEA. Each payload team will have its own team lead.

The Validation/QA Lead will have final responsibility for ensuring total compliance with the specifications as set out in the UKube Payload Interface Requirements. All team members will also be familiar with the specification requirements and the Engineering Lead's reviews will pay close attention to compliance.

Assembly, Integration, Validation and Testing (AIV&T) plan for payload

The necessary equipment for testing electronics and software (with the exception of the UKube platform test environment) have already been obtained by UKSEDS. Members of its teams from each institution have been trained in its use at a workshop. A standard verification protocol and test rig for testing boundary conditions, error conditions, burn in and so forth will be provided to the team leads.

For more complicated mechanical and other tests, as the team is made up of members from well equipped universities that have kindly offered access to their facilities to support this project, we have access to clean rooms, thermal vacuum, vibration testing and other facilities as required in multiple locations.

Engineering models of the myPocketQub IQEA and the individual payloads will be assembled, integrated, validated and tested in house at locations provided by each of the team leads. Where a particular facility is not available in house, the Project Lead has identified one facility for each test that will act as a group facility for the teams. Individual team leads will be responsible for verification and testing to ensure that their element of the payload is fully compliant with all requirements as set out in the Payload Interface Requirements document and other appropriate documentation. Additional tests will also be carried out as considered appropriate. Verification and testing will also be reviewed by the Engineering lead and Validation/QA lead at both the modular and fully integrated levels. All hardware and software will be subject to rigorous review and testing.

Assembly, integration, validation and testing of the flight model will take place at each facility identified as the group facility when the flight model is prepared.

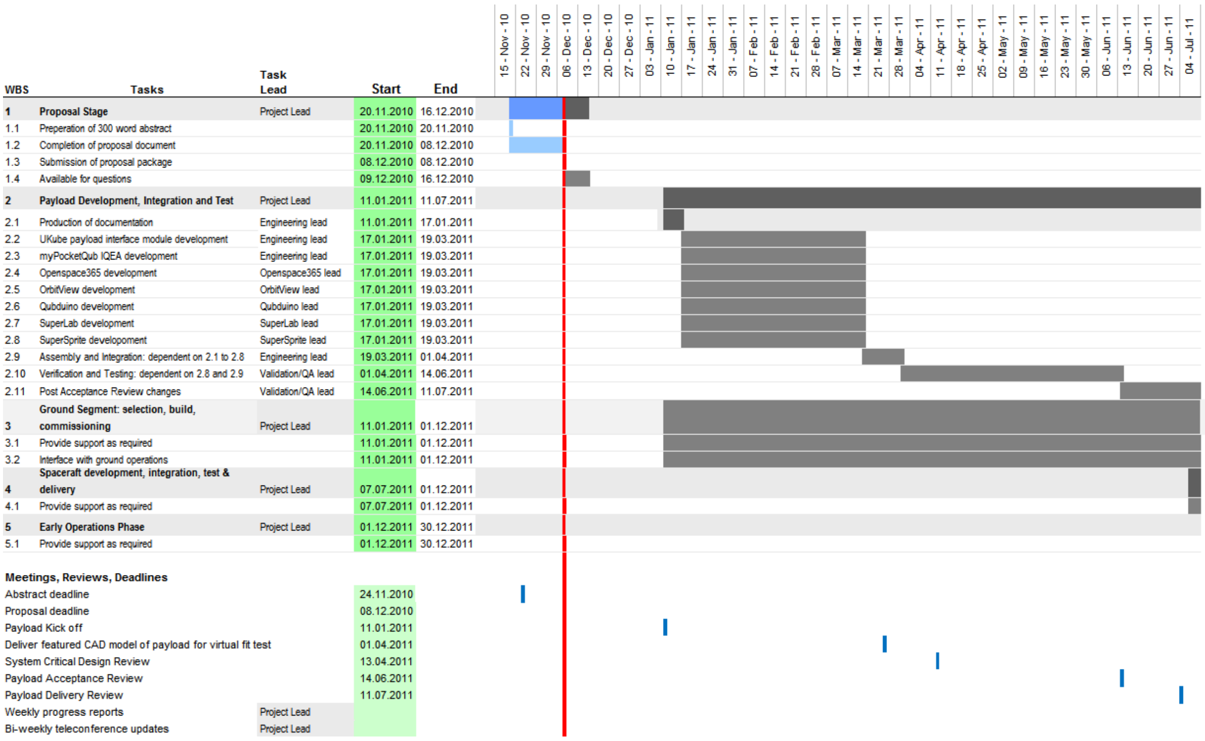
Management details

Demonstration of feasibility

The Gantt chart below illustrates our overall development plan which comfortably allows us to meet all deadlines as required. No major development is required and all deadlines and milestones can easily be met. The payload will be delivered complete and functioning with suitable operating manuals. Ongoing support will be available as required.

The Payload Coordinator will liaise on a day-to-day basis with development teams to ensure that progress is as scheduled. The Payload Coordinator, Engineering Lead and Project Lead will be in regular contact to address any potential issues on a timely basis. Weekly progress reports will be provided and the Project Lead will attend the bi-weekly teleconference updates. All are experienced in managing geographically dispersed teams.

The overall team is highly motivated and includes experienced professionals returning to the academic world with track records of successful on time delivery of complicated technical projects as well as those at the beginning of their career. Most of the students involved intend making a career in the space industry and are keen to develop appropriate curriculum vitae. Only team members with the necessary time available throughout the development period have been permitted to take part in the project. We also have the support of lecturers and tutors, providing us with access to skills and facilities as required.



WBS	Tasks	Task Lead	Start	End
1	**Proposal Stage**	Project Lead	20.11.2010	16.12.2010
1.1	Preperation of 300 word abstract		20.11.2010	20.11.2010
1.2	Completion of proposal document		20.11.2010	08.12.2010
1.3	Submission of proposal package		08.12.2010	08.12.2010
1.4	Available for questions		09.12.2010	16.12.2010
2	**Payload Development, Integration and Test**	Project Lead	11.01.2011	11.07.2011
2.1	Production of documentation	Engineering lead	11.01.2011	17.01.2011
2.2	UKube payload interface module development	Engineering lead	17.01.2011	19.03.2011
2.3	myPocketQub IQEA development	Engineering lead	17.01.2011	19.03.2011
2.4	Openspace365 development	Openspace365 lead	17.01.2011	19.03.2011
2.5	OrbitView development	OrbitView lead	17.01.2011	19.03.2011
2.6	Qubduino development	Qubduino lead	17.01.2011	19.03.2011
2.7	SuperLab development	SuperLab lead	17.01.2011	19.03.2011
2.8	SuperSprite developoment	SuperSprite lead	17.01.2011	19.03.2011
2.9	Assembly and Integration: dependent on 2.1 to 2.8	Engineering lead	19.03.2011	01.04.2011
2.10	Verification and Testing: dependent on 2.8 and 2.9	Validation/QA lead	01.04.2011	14.06.2011
2.11	Post Acceptance Review changes	Validation/QA lead	14.06.2011	11.07.2011
3	**Ground Segment: selection, build, commissioning**	Project Lead	11.01.2011	01.12.2011
3.1	Provide support as required		11.01.2011	01.12.2011
3.2	Interface with ground operations		11.01.2011	01.12.2011
4	**Spaceraft development, integration, test & delivery**	Project Lead	07.07.2011	01.12.2011
4.1	Provide support as required		07.07.2011	01.12.2011
5	**Early Operations Phase**	Project Lead	01.12.2011	30.12.2011
5.1	Provide support as required		01.12.2011	30.12.2011

Meetings, Reviews, Deadlines

Abstract deadline		24.11.2010
Proposal deadline		08.12.2010
Payload Kick off		11.01.2011
Deliver featured CAD model of payload for virtual fit test		01.04.2011
System Critical Design Review		13.04.2011
Payload Acceptance Review		14.06.2011
Payload Delivery Review		11.07.2011
Weekly progress reports	Project Lead	
Bi-weekly teleconference updates	Project Lead	

Risk assessment and mitigation approach

The involvement of students in this project could be a cause for concern as there may be a high churn rate. However, having access to a large pool of students means that should an individual be unable to fulfill their commitment we have others willing and able to take over their role giving the team resilience and flexibility. We have addressed the risk of involving inexperienced students by having a highly experienced, professional management team. We have also taken care when selecting the student team to include those who have demonstrated reliability through testing and track record.

The part time nature of the team could also be seen as a risk. To mitigate this, our detailed schedule includes interim milestones which will allow us to deliver ahead of target at each stage and will give us advanced warning of any potential delays. Our internal target date for completion of the payload prior to validation and testing is 1 April 2011.

The involvement of students from a range of Universities gives us access to test facilities, however there is a risk that these may not always be available at a time convenient to us. We have mitigated this risk by building sufficient slack into our timetable to allow for delays and scheduling required access as early in the project as possible. In addition, we have multiple sources of all the facilities that we require.

Most of the components of the payload have already been developed and are awaiting assembly. Many have already undergone vibration and vacuum testing. There is minimal significant further hardware development required. The minor adjustments required to ensure that the payload fits the specification requirements can be completed within the six month timetable. Materials have been selected using standard commercial-off-the-shelf sources and we have kept in mind the required lifetime of the payload when selecting materials and components.

The SuperSprite experiment makes use of radio frequency. To mitigate the risk of interference, the Project Lead will liaise with Clyde Space, including discussing the possibility of a full spectrum review of the completed satellite. A kill switch will also be provided as a final safety measure.

UKSEDS has a good track record of delivering its projects on time and at short notice whilst involving and managing large numbers of its members drawn from geographically dispersed locations. These projects have included technical projects such as the myPocketQub reference implementation and organizing large national conferences and workshops, a professional quality publication and maintaining and managing the demands of a large and growing membership.

Funding brought to the project

This project is self funding and does not require a Knowledge Transfer Partnership (KTP). The team members are donating their time free of charge and sponsorship has been obtained from a substantial number of companies and organisations who have provided parts, equipment, small grants and use of facilities to help develop the myPocketQub platform. The total cost of materials to build the flight model will be less than five thousand pounds and this has already been raised in cash and kind from sponsors.

Identified individuals

The project team is led by experienced professionals who are used to meeting tight deadlines and delivering in a demanding commercial setting. The team includes more than two dozen students from more than six universities, giving them the opportunity to work on a real space project and gain valuable experience and access to resources at other institutions. The experienced management team will monitor progress and be available to step in as required, thus ensuring that there is no risk to the flight project.

Project lead:	Michael Johnson, Director of Space Projects, UKSEDS
50% FTE	Physicist/Software developer, was CEO of a number of software companies and has more than twenty years experience managing technical projects

Engineering lead: 25% FTE	Johannes van der Horst, PhD student, University of Southampton Experienced embedded systems engineer with proven track record of delivering innovative hardware designs including the myPocketQub platform
Payload coordinator : 25% FTE	Nancy Hine, Undergraduate student, Open University Now studying Physical Science, was a senior manager at Ernst & Young responsible for co-coordinating multi-site teams to meet tight client deadlines
Validation/QA lead: 10% FTE	Roger Duthie, Ph.D. student, UCL / Mullard Space Science Laboratory Physicist and Chair of UKSEDS

Payload leads (each 10% FTE)

OpenSpace365 lead:	Toivo Hartikainen, M.Sc. student, Cranfield University
OrbitView lead:	Dale Potts, Ph.D. student, UCL / Mullard Space Science Laboratory
Qubduino lead:	Alex Hocking, Undergraduate student, Open University
SuperLab lead:	Alessandro Narduzzo, Lecturer, University of Bath
SuperSprite lead:	Tom Nordheim, Ph.D. student, UCL / Mullard Space Science Laboratory

Market or mission opportunities

The myPocketQub project aims to deliver clear benefits to the UKSEDS membership and the wider United Kingdom space community through a combination of innovative platform and payloads, open source hardware and software and the inherent educational benefits.

The myPocketQub IQEA and PocketPayloads that are proposed, potentially provide the basis for reducing the cost of access to hands on space projects by another order of magnitude even compared to the already low cost of CubeSats. The individual benefits of the payloads have been described earlier in this document, but the industry wide benefits of essentially removing cost as a barrier to entry to space research are clear. The ability for any university student that wants to, to be able to work on hardware that will actually fly in space and, through the use of virtual payloads, for individual school pupils and hobbyists to do likewise, should be an educational game changer.

The open source nature of the project means that any British company or individual can start new projects from a solid base which has flown in space and is known to work. The benefits of open source in terms of improving the pace of innovation and making robust infrastructure open to all, has been widely demonstrated by software projects such as Linux and is ripe for bringing to the space industry. We expect myPocketQub to be the catalyst for a number of open source space spinouts.

Terms for supporting Spacecraft integration phase

We will provide comprehensive documentation covering individual experiments, the integrated payload and interface with the spacecraft. The modular design and minimal integration requirements should ensure that there are few, if any, integration issues. We will provide assistance as required during the Spacecraft Development, Integration and Test Phase and the Early Operations Phase. We will be available for on-site consultation if required. All reasonable requests will be complied with. The Project Lead should be approached in the first instance if further assistance is required during the post delivery phases. He will then either provide the required assistance himself or coordinate a team response.

Why choose to fly this proposal?

If chosen to fly, the UKSEDS UKube1 myPocketQub 442 payload will enable any university student, school pupil or hobbyist to contribute to space research. By making a low cost open source platform available that anyone can duplicate, contribute to and improve on, we hope that myPocketQub can be the first step on the way to ubiquitous access to space in the same way that the very first low cost microcomputers eventually lead to ubiquitous access to computing with the consequential universal economic, scientific and cultural benefits.

Annex 1: Compliance Analysis of Payload Interface Requirements

ID	Requirement	Compliance	Compliance Comment
PIR-30	The Payload shall assume an in-orbit lifetime of 12 months.	Yes	
PIR-31	The Payload design life shall be 36 months.	Yes	
PIR-33	"The Payload shall be compatible orbits within the following range: Altitude 300-800 km Inclination 58-122 deg Eccentricity < 0.001"	Yes	
PIR-37	The Payload shall not require on-board orbit determination from the Platform.	Yes	
PIR-38	The orbit determination required by the Payload shall not exceed an accuracy of 100 km from on-ground post-processing.	Yes	
PIR-40	The Platform shall provide on-board time data to an accuracy of 10 s of Universal Time.	Yes	
PIR-43	The Payload shall not require specific pointing control to operate (e.g. Nadir pointing).	Yes	
PIR-44	The Payload shall operate at spin rates up to 0.3 deg/s.	Yes	
PIR-47	The Payload generated telemetry shall be unencrypted.	Yes	
PIR-48	The Payload supplier shall publicly publish any telemetry packet protocols used by the Payload.	Yes	All software (including telecommand sequences) will be open source and published
PIR-49	Any Payload with RF transmission capability shall not cause interference to the Platform communication system.	Yes	The SuperSprite transceiver is only 11mW so the chance of interference is small, however it will be provided with a kill switch and can operate in receive only mode
PIR-50	Any Payload with RF transmission capability shall conform with ITU regulations for amateur satellites, and be coordinated by the IARU.	Yes	A draft IARU coordination form has been prepared
PIR-51	Payloads with RF transmission shall have the capability to be shut down immediately upon command.	Yes	SuperSprite can be so commanded via its own transceiver or via a payload controlled kill switch
PIR-253	Licensing with the ITU for any active RF payload shall be the responsibility of the Payload Provider.	Yes	SuperSprite will operate in the amateur bands and will be coordinated via the IARU
PIR-57	No access to the Payload shall be assumed after integration of the spacecraft with the	Yes	

	POD.		
PIR-58	The total Payload stored energy shall not exceed 20 W.hr	Yes	Stored energy is expected to be less than 3 W.hr.
PIR-60	The Payload shall not include any pyrotechnic devices.	Yes	If a configuration with a deployable parabolic mirror is possible then it would be released using nichrome cutters but we do not consider these pyrotechnic.
PIR-61	The Payload shall not include pressure vessels with a mechanical safety factor less than 4, or pressurised above 1.2 standard atmospheres.	Yes	
PIR-62	All Payload elements shall remain attached to the Spacecraft during launch, ejection and operation; no additional space debris shall be created.	Yes	
PIR-63	The Payload Developer shall be responsible for ensuring the Payload complies with the current CubeSat Design Specification (AD-01).	Yes	
PIR-70	The Payload nominal mass allocation shall not exceed 310 g.	Yes	
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 PIR-75.	Yes	
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.	Yes	
PIR-74	The spacecraft reference axis system defined in Figure PIR-75 shall be assumed.	Yes	
PIR-77	The maximum height of the Payload shall not exceed 36 mm, as illustrated in Figure PIR-84.	Yes	
PIR-81	Requirement Deleted	N/A	
PIR-83	The Payload configuration within the spacecraft shall be stacked upon each other from the -Z face as shown in Figure PIR-84.	Yes	
PIR-85	Payload elements protruding beyond the Payload envelope, such as Deployables or Sensors, shall be identified to and authorised by the Platform Provider.	Yes	The payload has been designed to be able to operate without such elements but operation will be enhanced if a number of limited elements of this type are permitted
PIR-86	When stowed, Payload Deployables shall fit	Yes	

	within the dimensions specified in Figure PIR-75.		
PIR-87	Deployables shall only be permitted to protrude from the +/-X, or + Y faces.	Yes	To protrude from +X face.
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.	Yes	The total surface area for the optional Deployables and sensors is estimated to be 20mm x 25mm
PIR-241	The Payload Provider shall deliver a featured CAD model of the Payload for a virtual fit test 2 weeks prior to CDR.	Yes	
PIR-99	All dimensional tolerances shall be within +/- 0.1 mm.	Yes	
PIR-100	The Payload shall be fixed at four points at the corners of the CSK PC/104 board as shown in Figure PIR-84.	Yes	
PIR-101	The mechanical interface shall not interfere with the Payload envelope specified in Figure PIR-84.	Yes	If the optional Deployables and sensors are integrated on the payload board then the payload is compliant. If, to help fit in with other payloads, it is more convenient for these to be located away from the payload then a small wiring harness will be required to connect them to the payload.
PIR-103	The Payload shall be compatible with an operating temperature range of -20 to +65 degC.	Yes	
PIR-104	The Payload shall be compatible with a survival temperature range between -30 to +75 degC.	Yes	
PIR-105	The Platform shall not provide active thermal control for the Payload.	Yes	
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 PIR-84. (See Appendix A for details).	Yes	
PIR-257	The Payload shall interface to the Payload I2C data bus for command and control.	Yes	
PIR-263	The Payload shall interface to the Ground line within the pin allocation shown in Figure PIR-258.	Yes	
PIR-262	The Payload Provider shall indicate the Power Lines that will be required for their Payload.	Yes	The payload will be designed to be able to draw power from any of the Power Lines
PIR-261	The maximum number of Power Lines per	Yes	

	Payload shall not exceed four.		
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.	Yes	
PIR-112	The Payload sunlit average power requirement shall not exceed 400 mW over the sunlit period of the orbit.	Yes	
PIR-113	The Payload shall not be active during eclipse.	Yes	This can be implemented, but the mission would be improved if the payload is permitted to be active during eclipse as long as it relies on its own battery and does not attempt to interact with the rest of the spacecraft
PIR-114	The Payload shall not require power until it is switched on by the Platform.	Yes	
PIR-115	Power line isolation by the Platform shall not damage or otherwise stress the Payload.	Yes	
PIR-118	The Payload peak power draw in any operational mode shall not exceed 2000 mW.	Yes	
PIR-119	The Platform shall provide 3.3 V, 5 V and 12 V regulated voltage power lines.	Yes	
PIR-120	The regulated voltage shall be within +/-1% of stated value across the full load range.	Yes	
PIR-122	The Platform shall provide an unregulated floating voltage power line (7.5-8.3 V).	Yes	
PIR-124	The maximum steady state current shall not exceed 600 mA on any power line.	Yes	
PIR-125	The inrush or transient current shall not exceed 2 A over 50 ms.	Yes	
PIR-126	All supplied power lines shall have overcurrent protection.	Yes	
PIR-266	All Payloads shall implement a Payload Controller for data handling with the Platform.	Yes	
PIR-131	Payload Telemetry and Telecommand shall use the Payload I2C data bus.	Yes	
PIR-132	Payload Mission Data for Mass Memory or Downlink shall use the Payload I2C or Comms SPI data buses.	Yes	
PIR-133	The data rate on the Payload I2C data bus shall be 100 kbps I2C as defined in AD-14.	Yes	
PIR-134	The data rate on the Comms SPI data bus shall be 1 Mbps SPI as defined in AD-15.	Yes	

PIR-135	All Data Bus voltages shall be 3.3 V.	Yes	
PIR-136	Pull-up resistors for all signal lines shall not be implemented on the Payload.	Yes	
PIR-138	Data Buses shall interface to a single Payload Controller.	Yes	
PIR-140	The Payload Controller shall handle all Payload Data Bus interactions.	Yes	
PIR-141	The Payload Controller shall be a Slave device on all Data Buses.	Yes	
PIR-143	Requirement Deleted	N/A	
PIR-144	Requirement Deleted	N/A	
PIR-267	The connector shall be a stack-through connector as defined in Figure PIR-270.	Yes	
PIR-268	The connector shall interface to a through hole array of 4 x 26 on the PCB substrate, located as defined in Figure PIR-84.	Yes	
PIR-269	The connector shall use a through hole pitch of 0.1" as defined in Figure PIR-84.	Yes	
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.	Yes	The payload can operate without any additional connections. However, if to assist with packaging with other payloads it would be helpful for the payload sensors to be located elsewhere, a small six wire wiring harness can be used
PIR-147	Any additional connections shall be the responsibility of the Payload Provider.	Yes	
PIR-151	Payload developers shall command their own payloads via Schedule Files to be sent to spacecraft operator.	Yes	
PIR-152	The format of the Schedule Files shall be provided by the Primary Ground Station supplier.	Yes	
PIR-153	The data volume required by the Payload for successful completion of the mission shall not exceed 100 kbit per orbit.	Yes	
PIR-154	The data volume required by the Payload for Telecommand Uplink shall not exceed 10 kbit per orbit.	Yes	
PIR-155	Payload data dissemination shall be by web interface defined by the Primary Ground Station.	Yes	
PIR-156	The Payload Provider shall provide a publicly available decoder for interpreting Data returned.	Yes	This information will be posted on the myPocketQub.com web site
PIR-157	The Payload Provider shall be responsible for interpreting the Data returned.	Yes	An open source data interpretation program will be

			made freely available
PIR-158	The Payload shall not be powered until commanded on by the Platform.	Yes	
PIR-159	All deployables such as booms and antennae shall not deploy until commanded by the Platform.	Yes	
PIR-162	The Platform shall not provide any processing capability for the Payload.	Yes	
PIR-272	The Mission Interface Computer shall provide basic lossless data compression for all Payloads prior to downlink.	Yes	
PIR-273	The Payload shall have a minimum of 256 Bytes for storage of Payload Data locally.	Yes	
PIR-164	The Payload use of Platform mass memory shall not exceed 256 Mbytes before compression.	Yes	
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.	Yes	
PIR-169	The Payload I2C Data Bus shall use the Packet standard as defined in AD-17.	Yes	
PIR-170	The Payload shall respond to all commands received on the Payload I2C within 100 us.	Yes	
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"	Yes	
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.	Yes	
PIR-173	Requirement Deleted	N/A	
PIR-174	Requirement Deleted	N/A	
PIR-176	The Comms SPI Data Bus shall operate at 1 Mbps.	Yes	
PIR-177	The Comms SPI Data Bus shall use the Packet standards defined in AD-17.	Yes	
PIR-278	The Payload Controller shall interface to a unique Slave Select line in the connector as	Yes	

	specified by the Platform Provider.		
PIR-180	Requirement Deleted	N/A	
PIR-183	Packet encoding and formats shall be as defined in AD-17, the standard format for data packets is given in Figure PIR-279.	Yes	
PIR-184	Requirement Deleted	N/A	
PIR-280	The Payload Provider shall specify any additional commands required, to be agreed by the Platform Provider.	Yes	
PIR-188	The Payload shall meet the random vibration requirements of AD-04, or a specific launch vehicle if this becomes known (see Figure PIR-189).	Yes	
PIR-190	The designed for natural frequency of the Payload shall exceed the resonances of the launch vehicle by a factor of two.	Yes	
PIR-191	The minimum designed natural frequency of the Payload shall exceed 150 Hz.	Yes	
PIR-192	Any vibration resonances or shock to which a subsystem may be particularly susceptible shall be identified by the Payload developer.	Yes	None
PIR-194	The Payload shall meet the thermal cycle described in Figure PIR-195, or a specific spacecraft-orbit thermal cycle if this becomes known.	Yes	
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.	Yes	
PIR-202	The Payload shall not connect Structure and Ground.	Yes	
PIR-203	The Payload shall conform to the single point grounding scheme defined in Figure PIR-204.	Yes	
PIR-205	The Payload shall not produce peak to peak noise or ripple over 50 mV on any power line across all frequencies.	Yes	
PIR-206	The Payload magnetic dipole shall not exceed 0.001 A.m2.	Yes	
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.	Yes	
PIR-211	The Payload shall be compatible with a maximum depressurisation rate of 50 mbar/s from 1000 mbar to negligible.	Yes	
PIR-213	The Payload shall use industrial grade non-	Yes	

	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.	Yes	
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 %.	Yes	
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.	Yes	
PIR-217	The Payload shall cause negligible additional risk to the launch vehicle and any primary or secondary payloads.	Yes	
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.	Yes	No RFD required
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.	Yes	No RFW required
PIR-220	Any Flight Hardware shall be stored in electrostatic discharge and vibration / shock protected containers.	Yes	
PIR-223	The Payload shall be interfaced to an Interface Emulator for Platform-Payload pre-integration testing by the Payload Provider.	Yes	
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."	Yes	
PIR-226	Requirement Deleted	N/A	
PIR-227	Requirement Deleted	N/A	
PIR-230	Payload Acceptance Testing shall be performed in advance of delivery for Platform-Payload integration by Payload Provider.	Yes	
PIR-281	All boards shall be conformally coated prior to delivery.	Yes	

PIR-231	The Payload shall undergo thermal bakeout for a minimum of 2 hours at least +75 deg.C prior to any conformal coating.	Yes	
PIR-232	The Payload shall undergo thermal cycle testing to Figure PIR-195.		
PIR-233	The Payload shall undergo random vibration testing to Figure PIR-189.	Yes	
PIR-234	The Payload shall undergo random vibration testing to Figure PIR-189.	Yes	
PIR-236	Following each test, a functional test shall be performed to verify continued functionality of the Payload	Yes	
PIR-238	The Payload shall validate compliance to environmental requirements as specified in Section PIR-186 through test in advance of delivery.	Yes	
PIR-239	Testing shall be documented and repeatable.	Yes	
PIR-240	Payload shall verify against compliance matrix supplied by the AIVT Engineer.	Yes	

Compliance options Yes/No

If compliance is not known yet against a specific requirement, select "No" , but annote Comment field to that effect.

Annex 2: Response to Clarification Request 13th December 2010

Responses to clarification requests received from Caroline Harper, UK Space Agency by email on the 13th December 2010. Outline answers to the queries were required by 12pm on 15th December 2010.

CR1: Uploaded data rate

Can you estimate the uploaded data rate required for participants that want to participate in the orbit experiment? Do you have a strategy for packeting the request?

The proposed UKSEDS UKube1 payload 'myPocketQub 442' consists of a myPocketQub IQEA with five PocketPayload daughterboards. The system is controlled by 128 bit packets wrapped inside the UKube data communications protocol. Packets are buffered such that they can arrive in any order and at any data rate including over many days if necessary. An ideal upload data rate for typical operations is expected to be about 4kbit per day for the whole myPocketQub 442 payload. However, we can cope with substantially less and can use more if it is available.

Module	**Typical data upload per day**	
	Packets	**kbit**
myPocketQub IQEA	8	1
OpenSpace365	8	1
OrbitView	<4	<0.5
Qubduino	8	1
SuperLab	<1	<0.1
SuperSprite	<1	<0.1
Total	**<30 packets per day**	**<3.8kbit per day**

The PocketPayload OpenSpace365 allows programs written by third parties to be run in space. These programs can be a maximum of 32KB (we expect 8KB to be typical) and are stored on a microSD card which can be updated in flight. We expect to launch the microSD card with sufficient programs stored to be able to run one per day for several months. We will upload additional programs in any upload data allocation we are permitted above the ideal 4kbit per day upload data rate. If we use approximately 4kbit upload for telecommand every day and we are allocated 10kbit upload a day (single orbit) that leaves 6kbit for program upload which would allow an additional 8KB program to be uploaded approximately every eleven days. If we can upload 10kbit of data every orbit and there are at least seven orbits that can be used for upload per day, then we can upload a new program every day. Data compression is likely to improve these figures by a third or more.

CR2: Modularity of payload

Are any elements of the payload available individually, for example the Orbit View payload element?

Yes - the payload breaks down into the myPocketQub IQEA adaptor (a PC/104 card) and five PocketPayload (32mm x 32mm) daughterboards attached by a simple four wire bus (3.3V power+I2C).

One or more PocketPayloads could fly alone but will need to interface with UKube. The myPocketQub IQEA does this, but could be replaced by a custom payload adaptor in PC/104, PocketPayload or another format. For example, we could supply a printed circuit board design which could be integrated on another printed circuit board flying on UKube such as the FUNcube CCT board.

However, we would prefer to fly the myPocketQub IQEA and the five PocketPayloads as a complete payload if possible, as we believe all the payloads make significant contributions and we wish to involve the maximum number of UKSEDS members in the project as possible.