System Design

The technical and functional aspects of the satellite are highlighted in this following document, divided into its respective satellite and ground station sections.

Introduction 1.

Initial Requirements 1.1

Our satellite has to accomplish a certain set of tasks in order to successfully carry out our desired mission, these requirements will be apparent in this document as all systems are designed and created accordingly.

Our main goal is to develop a cost efficient aerospace research platform for students to experiment on at an international level; this requires the ability to power and communicate several student-designed circuits with readily available ground station components.

We also must comply with our launch provider's and the ITU's requirements in order to receive launch approval.

No readily available pocketqube space proven components exist; therefore we must design and manufacture all parts of the satellites ourselves, this increases our level of customisability but also increases the risks involved with a failure.

Based off the previous conditions the following requirements are clearly stated throughout the development of this platform both on a software and hardware level.

Requirements 1.2

- Ability to disable the transmitter upon request (ITU requirement)
- Transmit data at a minimum distance of 600km from orbit (Downlink requirement)
- Power the satellite and its payload for the full duration of the mission, including a 35m eclipsed period during the 90m solar cycles.
- Reduce the research and development cost as much as possible.
- Use off the shelf parts available to the masses
- Keep a free open source software mentality throughout the project.
- Pocketqube format abides by launch provider rules (weight, size, etc.)

Given these requirements, the following initial prototype design has been created and is being developed as of the 08/18; design changes are subject to change and will be updated.

Satellite Design 2.

Structure 2.1

As stated in the requirements, we must abide by our launch provider's maximum weight and size regulations. We are restricted to 250g of weight and approximately a 60mm^3 size envelope including all deployable structures to avoid jamming the deployer. The deployment baseplate must be made out of either 1.6mm FR4 board or 1.6mm space-grade anodized aluminium to avoid vacuum welding.

Taking in consideration these strict requirements we have decided to mainly construct the satellite's structure using 1.6mm FR4 PCB board. Not only does this greatly simplify the manufacturing process of the structure, but it also allows us to use the structure as a PCB for circuits and components, therefore maximizing our available space and reducing overall weight.

The FR4 panels will be held together using a combination of milled aluminium brackets and M2 bolt fixing mechanisms. Similar designs have been successfully flown using this technique and we believe it will be able to resist the high structural stress involved with launching an object to space.

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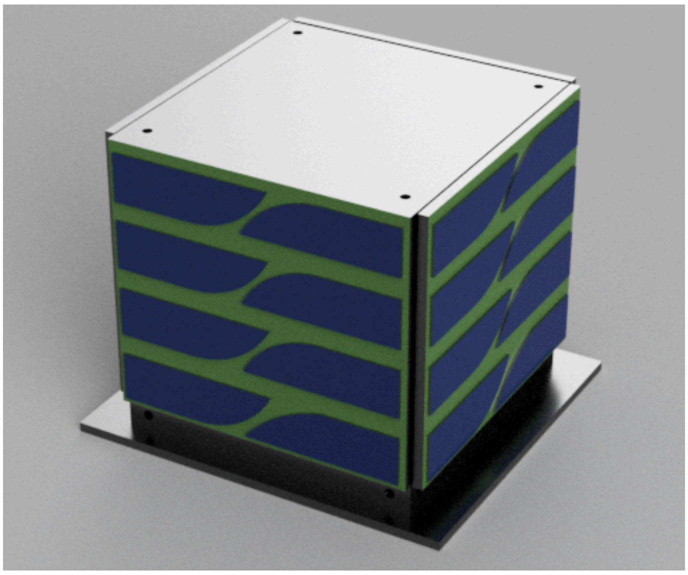

Figure 1: Prototype structure model

Communication 2.2

The main purpose of this satellite is to collect experiment information allowing students to participate in the aerospace sector; therefore the proper communication of the satellite with ground stations is essential.

The only functioning pocketqube satellite to be launched into orbit successfully proved the use of inexpensive off the shelf transceivers for space applications, no commercial pocketqube transceivers currently exist, leading us to have to use off the shelf parts anyways.

A relatively new sector that has recently gained popularity is the IoT sector; this network partly relies on the LoRa-Wan communications technology. This new technology allows the communication of nodes placed at far distances in urban and rural ground based areas.

Not only is this technology very power efficient and range effective, but it also allows the access to our satellite using currently existing IoT infrastructure and inexpensive <20$ off the shelf components.

This technology is commonly used on high altitude balloons and the current distance record stands at around 700km using a transmission power of 25mw on the SX1278 LoRa chip. This is well within our distance budget and considering our use of the full 100mw of transmit power provided by the SX1278 and additional higher gain antenna, the SX1278 should more than suffice to maintain our communication link.

This additional power also allows us to receive the packets using simple omnidirectional antennas. A LoRa device has never been flown in space to this date; a LoRa signal has been transmitted from space before though in the 160mhz band using a 225mw transmitter into a highly directional yagi antenna.

Several tests will need to be carried out in order to accurately calculate our link budget such as high altitude weather balloon tests. We also plan to transmit an RTTY and Morse code beacon in order to allow amateur radio operators to also listen to our satellite and decode information.

This combination of packet transmission types and the simplicity of their receival guarantees that we will gather data from the satellite at an international level covering a large part of the world.

Power 2.3

With such a small surface area to use for solar cells, we are very limited with our power consumption. This constraint would greatly reduce the interval rate at which we could carry out the experiments and transmit information. We have therefore decided to implement deployable solar cells in our design, therefore nearly tripling the solar power have access to.

We will be using high efficiency TrisolX triple junction solar cells due to their availability, price and efficiency. Similarly to other Cubesats and Pocketqubes we will also be using Li-Ion battery technology to provide power to the system during the 35 minute eclipsed period.

The satellite will use SPV1040 MPPT charge controllers for each axis totalling up to 3, thus maximizing efficiency between shaded panels. A simple linear voltage regulator will be used to regulate the incoming voltage from the battery and provide a 3.3v power rail, this could seem counterintuitive at first but it hugely simplifies the design and offers little to no efficiency downgrade compared to complicated and sensitive step down converters.

The solar panels will each count with their respective blocking and bypass diodes in order to avoid reverse current and power draw from shaded non-active cells, this also allows the panel to function properly in the case of a solar cell failure by simply bypassing the failed cell. This is an important safety feature taking in consideration we predict the solar cells will be the first to fail.

The power system is designed in such a way that it will function regardless of the state of the deployable solar panels, thus ensuring a successful communication with a ground station to carry out emergency deployment manoeuvres. If the power system senses that it has not deployed the solar cells, the transmission interval will be increased in order to account for the reduced power generated.

Beacon 2.4

An Atmega 328P-AU powered beacon will be integrated into the satellite in order to provide a vital debugging tool for the satellite and transmit vital information about its current state. It will be a completely redundant system separated from the payload in order to avoid critical full system failures and will feature uplink capability in order to disable its transmitter or execute deployment manoeuvres in case of emergency. This beacon will also transmit the satellite's identification at a high power in order to determine its exact frequency.

Deployable structures 2.5

Additionally to the deployable cells stated in the power section, the satellite's antenna must also be stowed inside the specified size enveloped during launch in order to avoid deployment jamming.

Similarly to other Cubesat and Pocketqube missions we will be using a half wave 433mhz antenna constructed out of metal carpenters tape, this will provide the satellite with a simple and effective antenna capable of being deployed on its own without exterior mechanisms such as springs.

The solar panels will be deployed using a set of metal hinges and torsion springs. Both the solar panels and the antenna will be "released" from the satellite's body using a combination of nylon wire serving as a retainer and a resistor in order to melt the respective wire.

This deployment will be controlled by a timer chip and a set of micro switches that will ensure the antenna and solar panels are deployed after being released into orbit. The antenna is placed in such a way that it will function regardless of the deployment state of the solar panels, thus guaranteeing proper communication with a ground station to carry out an emergency deployment manoeuvre.

Antenna deployment is our main priority and will be the first to take place.

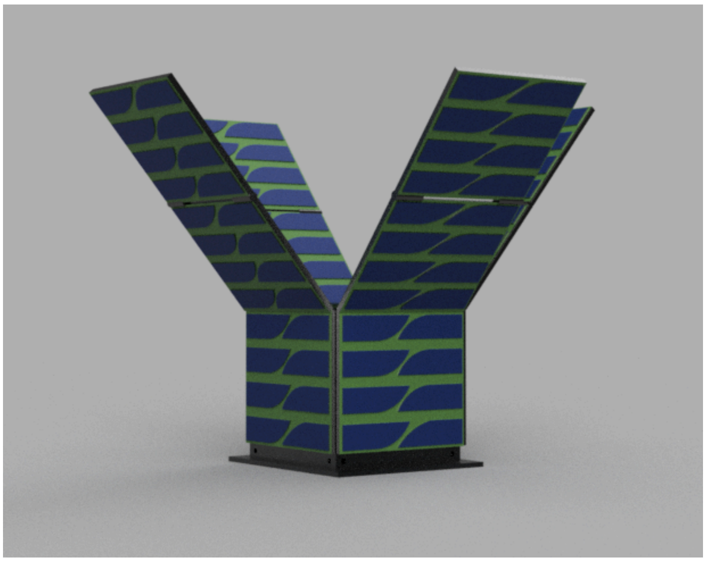

Figure 2: Satellite with solar panels deployed.

Payload 2.6

The satellite's payload will count with a variety of sensors (spectrum analysers, radiation sensors, etc.) connected to several Arduino Atmega 1284 nodes carrying out student's experiment, we will provide the power and communication for the experiments and will coordinate the required sensors and functionality with the students.

This payload will also have the functionality to disable the transmitter as required by ITU regulations.

Ground Station Design 3.

The ground station will be primarily focused around a LoRa receiver with an easy to user interface. Wi-Fi functionality will most likely be included in order to easily upload decoded packets to a common database made up of ground stations from all over the world.

The price and size of the ground stations allows us to massively distribute them to educational institutes from all over the world, expanding space exploration participation to the masses.

A website will be created in order to simplify the process of tracking the satellite during its passes and input its decoded data.