FOSSA Systems

Satellite Mission Statement

# Our Vision

Our vision is to build a picosatellite and put it in orbit around the Earth to inspire a new generation of engineers and scientists by providing a means of deploying user developed code in space.

We aim to achieve this using a satellite that will be able to operate JavaScript programmes developed by school and university members. We plan to host an inter-school/university competition and the winners will have their programs loaded onto the satellite along with prizes. All participants will have their names recorded on the system as it circles the globe.

We hope this proposal provides a mechanism to engage students in a wide variety of STEM subjects, Physics and Computer Science.

The team is currently developing a prototype which will be ready by the end of 2018. The aim being to have it fully tested on a weather balloon as a proof of concept. Our approach is to have the satellite build plan verified and validated by experienced personnel before taking it to launch. This phase of the project is already partially funded.

However, we are currently looking for support from third parties to help;

1. Deployment of the satellite on a balloon to test operability in space-like conditions.
2. Support in the delivery of the competition media to engage schools and universities in the project.
3. Fund the launch into space which is estimated at a cost of £25,000.

In return sponsors will receive priority attention for advertisement during the competition.

# The Team

We are a young and international (Spanish and British) development team consisting of Julian Fernandez, Richard Bamford and James Bateman.

Julian develops the hardware, engineers the builds, manages the legislation of aerospace licenses and rules.

Richard is the software developer who is responsible for the Arduino (Atmega) chips on board and the public relations of the project.

James handles the branding and management of the project’s public appearance.

# Development Time Plan

The picosatellite is a 5x5x5cm pocketqube called **“*FOSSASAT-1”***. It will be the first of its kind to feature deployable solar panels. Only 1 other picosatellite of this size has operated before.

We are confident that we can build a prototype that functions on a weather balloon. Once we have reached the limit of what we can do, we will contact Universities in Spain and Jodrell Bank Radio Telescope to hopefully get expert advice.

## Progress

Since the beginning of July 2018, we have already produced a prototype that will be tested onboard a weather balloon within the next month.

We blog all development progress on our website at <https://fossa.systems/news/>.

## Milestones

|  |  |  |
| --- | --- | --- |
| Milestone | Description | Date (Completed) |
| Beacon Arduino C system | The beacon is functional, it relays all the information specified in the requirements specification. | 20/07/2018 |
| Ground station Arduino C system | The ground station is functional and can receive all information transmitted by the Beacon (above) and transmit its own commands to the satellite. | 22/07/2018 |
| Arduino payload | This will be programmed with the competition winners javascript programs, which will be manually transpiled into C and security vetted. |  |
| Weather balloon test | The first serious test requiring security permits will be this, it will be hosted in Spain with the regulations fulfilled by Julian. |  |
| Sponsors and contact input | At this milestone we will go to our expert contacts (professors and engineers) to validate the build and entire project plan. |  |

# Brief System Overview

The entire system consists of the picosatellite and ground stations.

## Picosatellite

The picosatellite has 2 main modules; beacon and education payload.

The beacon is the module that transmits the system information such as; battery charging current, solar panel input voltages, reset count and deployment status to the ground stations via a LoRa package.

The education payload is an Atemega chip that will have the competition winners code on it, which can also transmit and receive messages - within the safety specifications. The programs will be analysed by our team and we will consult other experts to ensure safety and security.

## Ground Station

The ground station will be a system consisting of a LoRa transceiver and IO hardware which can downlink information from the picosatellite. No control is given to the ground stations other than pre-defined and security verified commands such as; ping.

# Technical System Design

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

## Introduction

Our main goal is to develop a cost-efficient aerospace platform for students to compete at an international level over to get their programs on-board and orbiting.

The system will critically power and communicate several student-designed circuits and programs with available ground stations along with system information.

Our system design must comply with our launch provider’s and the ITU’s requirements to receive launch approval.

Since no readily available pocketqube space proven components exist 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. We are purchasing off-the-shelf hardware and components and verifying that they are space-grade quality.

## Satellite Design

### Structure

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 60mm3 envelope including all deployable structures to avoid jamming the deployer. The deployment baseplate must be either 1.6mm FR4 board or 1.6mm space-grade anodized aluminium to avoid vacuum welding.

Considering these strict size 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.

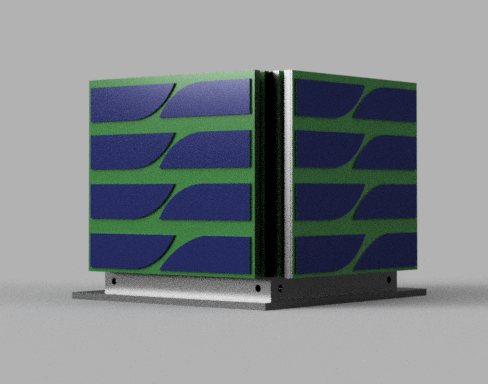


Figure : Prototype structure 3d CAD model

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.

### Communication

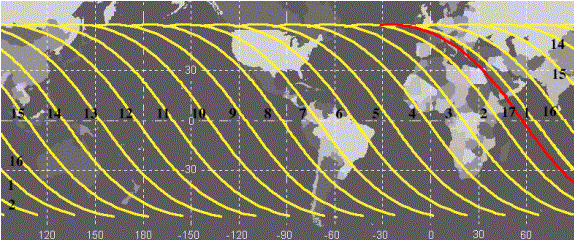
The main purpose of this satellite is to collect experiment information allowing students to participate in the aerospace sector; therefore, the proper communication between the satellite and ground stations are essential.

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 either, requiring us to have to use off the shelf parts.

Leveraging the IoT sector innovations; the communications network relies on the LoRa-WAN technology which has huge transmission ranges for very low power ratings.

Not only is this technology very power efficient and range effective, but it also allows communication to our satellite from currently existing IoT infrastructure and the transceiver is inexpensive < $20.

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 which is well within our distance budget. Considering our capability to power the SX1278 at the rated 100mW and our use of a high gain antenna the satellite can communicate across massive distances.



Our solar panel and power management circuits allow us to receive the packets using simple omnidirectional antennas on the satellite.

A LoRa device has never been flown in space to this date but a LoRa signal has been transmitted from space before. It used the 160Mhz band with a 225mW transmitter and was received on Earth by a highly directional yagi antenna.

Several tests will be carried out to accurately calculate our uplink and downlink budget:

1. High-altitude weather balloon.
2. Hill saddle LOS – will the connection persist even when there is a hill blocking LOS.

The simplicity of the receiver components and build guarantees that the barrier to creating a ground station is very low therefore high school students could create one as a school project.

### Power

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. To accommodate 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 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 to account for the reduced power generated.

### Beacon

An Atmega 328P-AU powered beacon will be integrated into the satellite to provide a vital debugging tool for the satellite and transmit system information to the ground stations. It will be a completely redundant system separated from the payload to avoid critical full system failures and will feature uplink capabilities such as; disabling its transmitter or executing 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

Upon launch, the satellite’s antenna must be stowed inside the specified envelope to avoid deployment failures. Similarly, to other Cubesat and Pocketqube missions we will be using a half wave 433mhz antenna constructed out of metal carpenters’ tape, that will provide the satellite with a simple and efficient antenna capable of being deployed on its own without exterior mechanisms such as springs.

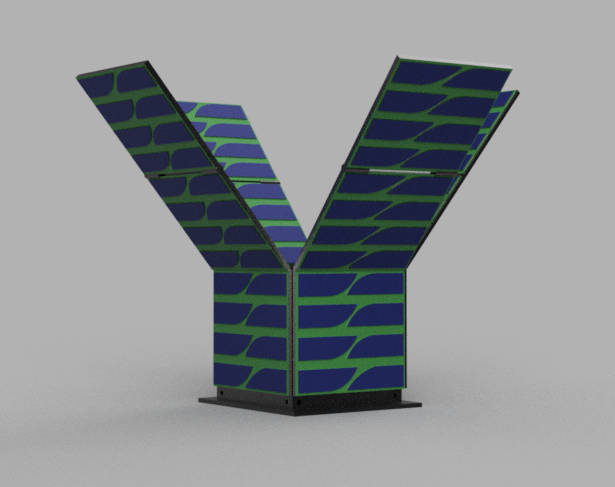
The solar panels will be deployed using miniature metal hinges and custom torsion springs. the solar panels and the antenna will be “released” from the satellite’s body using a combination of nylon wire serving as a retainer and a resistor to melt the respective wire.

Figure : Satellite with solar panels deployed 3D CAD model.

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.

### Payload

The satellite’s payload will be connected to a variety of sensors including;

1. Spectrum analysers.
2. Radiation sensors.
3. Several Arduino Atmega 1284 nodes carrying students code.

We will provide the hardware solution for their Atmega node and a software submission system which consists of:

1. Online JavaScript payload simulator
2. Online JavaScript program submission (zip file contents)

Once all the submissions have been judged, we will manually transpile (convert) the JavaScript programs into C code.

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

## Ground Station Design

The ground station will be primarily focused around a LoRa receiver with a highly usable user interface. Wi-Fi functionality will be included to easily relay decoded packets to a common database consisting of ground stations from all over the world.

The price and size of the ground stations allows us to distribute them to educational institutes all over the world, expanding space exploration participation to the masses to hopefully get them excited about STEM subjects.

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

## Requirements

### Hardware

1. Ability to disable the transmitter upon request (ITU requirement)
2. Transmit data at a minimum distance of 600km from orbit (Downlink requirement)
3. Power the satellite and its payload for the full duration of the mission, including a
4. 35m eclipsed period during the 90m solar cycles.
5. Reduce the research and development cost as much as possible.
6. Use off the shelf parts available to the masses
7. Keep a free open source software mentality throughout the project.
8. Pocketqube format abides by launch provider rules (weight, size, etc.)

### Software

1. Both ground station and satellite can communicate.
2. Ground station automatically tunes itself.
3. Satellite sends information and tuning packings periodically.
   1. Info at 400ms intervals.
   2. Tuning at 1s intervals.
4. Students have a friendly and easy to use environment for building their javascript programs.
   1. Online simulator
   2. Online submissions

### Legal

1. ITU regulation specifications
   1. Transcevier on the satellite can be switch off and switch on remotely.
   2. Communications via uplink are rigidly defined and checked by experts.
2. Checking that communicating hardware is verified by FOSSA and Co.

# Finances

## Sponsors

So far, we have 2 sponsors able to supply us with PCBs:

1. PCBWay
2. JLCPCB

But we are looking to other companies to help with our budget.

## Budget

|  |  |
| --- | --- |
| Items | Amount |
| Research and development | $500 |
| Prototype construction | $900 |
| Licenses and general administration fees | $500 |
| Marketing and public relations | $500 |
| Launch | $25,000 |
| Total | **$27,400** |

# Development Ethics

Our focus as a development team is to engineer solutions that push our skills and the satellite to the limit, while retaining a KISS (keep it simple stupid) philosophy.

# Competition Plan

### Rules

1. Teams of any sizes are allowed.

### Prizes

We want to leverage our sponsors to help us provide some great prizes to the students that win the competition, currently we have no prizes to offer but these will be crucial rewards – along with the code on the satellite – for the competition.

### Programming Environment

Each participant will be able to run Javascript code on an online simulator. Once we have all the projects and their associated media like flyers, description or documentation we will then vet each submission and convert it to C code manually.