# 1. Introduction

The purpose of this report is to consolidate the design of BLUEsat into a single document. The intention is that, by reading this particular report, the reader will be able to gain an overview of how BLUEsat has been designed and how the various sub-systems required for the satellite to work are intended to be integrated.

Whilst this report contains some amount of technical detail regarding the design of the satellite, it is not intended to be a fully detailed technical master file. The intention is that the report will be read from a systems engineering perspective. The rationale and overall design of each sub-system will be described such that the reader understands the nature of the satellite itself and how each system is related to each other. If further technical detail is required, other, more detailed design documents need to be consulted.

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# 3. System Overview

BLUEsat’s intended purpose is to service the Amateur Radio community whilst being a vehicle for experimental payloads. That is, the satellite is to assist in communications between members of the Amateur Radio Community worldwide, whilst also allowing simple payloads to conduct experiments in space.

To that end, the satellite is physically designed much like other Amateur Radio Microsatellites - with much inspiration taken from ECHOsat (AO-51). The satellite is composed of trays in which will contain communications peripherals and the processing units which are responsible for the (relatively) autonomous operation of the satellite.

## 3.1 Specifications

In order to function as a useful Amateur Radio Satellite, the satellite needs to be able to do the following (listed in increasing complexity but decreasing criticality)

1. Function as an Analogue Repeater
2. Function as a Digital Repeater
3. Be able to store and forward Data (PACsat)

On top of this, the satellite needs to survive autonomously in Low-Earth Orbit (at an altitude of approximately 750km). This means that that along with the above functionality, the satellite must

1. Be able to power itself
2. Survive in a Vacuum
3. Survive the Radiation in a Space Environment
4. Be able to evaluate its own state

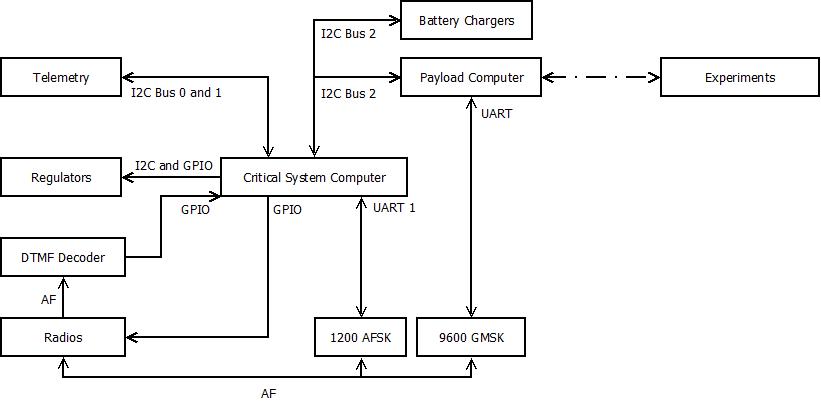
## 3.2 System Design

The satellite itself is split into two main systems, each with its own central processing unit - the Payload Systems and the Critical Systems.

The Critical Systems deal with the basic functioning and survival of the satellite, as well as performing basic Analogue repeating. Critical Systems is responsible for powering the different electrical systems, monitoring the health of the satellite and maintaining basic communications with Earth. To that end, the Critical Systems is composed of

* The Critical Systems Computer (CSC)
* Telemetry System
* Communications System
  + Radio Transmitter and Receiver
  + AFSK Modems
* Power Distribution System
* Solar Array and Battery Charging System,

The Payload system consists of the Payload Computer and the experimental Payloads themselves. The Payload computer is to act as an interface between the Satellite’s Payloads and the Critical systems. The Payload system was made distinct from the Critical Systems to allow for greater modularity in the overall design of the satellite. To this end, integration of payloads will not greatly affect the design of the critical systems of the satellite.



1. Figure .

\*diagram diagram diagram

# 4. Mechanical

The Satellite’s Mechanical design is based off of other similarly sized Amateur Radio Microsatellites, with particular inspiration taken from ECHOsat (AO-51). The satellite is composed of five square trays stacked vertically to create a 250x250x250mm cube with a Solar Panel on each of the 6 sides.

The trays will contain the electronic circuitry of the satellite. There are connectors attached to the backplane of the satellite in order to allow for connections between trays.The trays (from top to bottom) are assigned electronics as follows:

* Tray 5 - Radio Receiver and Hybrid Coupler
* Tray 4 - Payload Computer and Payload Systems
* Tray 3 - Batteries
* Tray 2 - Critical Systems and Power Systems
* Tray 1 - Radio Transmitter and Hybrid Coupler

\*\*\*diagram diagram diagram

Trays 5 and 1 have specialised mounting holes and covers in order to attach and shield the Radio units. Trays 4 and 2 are designed to maximise the amount of surface area available for printed circuit boards. Tray 3 is designed to allow for mounting of two battery packs that is to make up the battery array.

Once assembled, the trays allow for attachment of flat panels on each side, onto which the Solar Arrays will be mounted. The top and bottom panels will have allowance for Antennae footholds for radio transmission.

# 5. Critical Systems Computer

The critical systems on the satellite (being the Communications, Telemetry and Power systems) will be controlled via a central micro-controller and memory system complete with a multi-threaded Operating System. This central controlling system is called the Critical Systems Computer. This system is to be distinct from the Payload Computer, whose responsibilities lie solely in interfacing with the BLUEsat’s payloads.

The microcontroller central to the design of the Critical Systems Computer is the ARM7 LPC2468 manufactured by NXP Semiconductors. On this microcontroller, BLUEsat will run a distribution of the FreeRTOS (Free Real-Time Operating System), modified for the specific operational needs of the satellite.

Within the operating system, drivers and applications are intended to be run in order to control the critical systems of the satellite according to pre-defined constraints. These applications and drivers will be incorporated into the central computer ‘system’ according to the architecture outlined in the following pages.

The critical systems computer will run according to commands received from earth via transmission of nine digit codes transmitted in Dual Tone Multi Frequency (DTMF) format.

The following section will outline the hardware required to run the critical systems computer, the software architecture within its operating system and the specifications according to which applications in the Critical Systems Computer will be run.

## 5.1 LPC2468 Microcontroller

\*Why we chose LPC2468

\*Relevant feature sets

\*intention with design

## 5.2 Memory

## 5.3 The FreeRTOS and Software Architecture

For the sake of robustness, BLUEsat Software has been designed around the idea of static Operating System images. That is to say that for a given ‘image’, the satellite will function in a predetermined and unchanging manner according to a predefined set of stimuli. In order to change any of the core functions or procedures on the satellite, a new Operating System image needs to be ‘burnt’ or uploaded onto the satellite.

BLUEsat will be running a simple, lightweight, open-source operating system called the [Free Real Time Operating System (FreeRTOS)](http://en.wikipedia.org/wiki/FreeRTOS). The FreeRTOS itself provides no existing services other than a kernel.

Each peripheral hardware device running on BLUEsat will be controlled by a set of software drivers. Drivers abstract commands of devices and subsystems on the satellite (for example, polling data from the Telemetry system). They make up the basic interface and abstraction between the Critical Systems Computer and the rest of the hardware on the satellite.

In turn, these drivers are called upon according to a set of instructions defined by Applications. BLUEsat Applications will be written in order to address specific procedures required for particular operations that the satellite will need to do. For example, the Telemetry Application will need to poll data, raise flags on seemingly malfunctioning systems, compress this information within memory and pass it onto the communications system when commanded by Groundstation to do so.

The specifications for the functionality of each Driver and Application are included in this report specific to the subsystem that it addresses.

The software architecture has been designed around a central “command task”. The command task executes applications and exchanges data between them according to the current operating mode of the satellite. The priority with which certain applications are executed will be defined by either the operating mode of the satellite or direct commands from the Groundstation. This operating mode will be defined by a status manager which processes DTMF commands sent from the Groundstation by a BLUEsat administrator.

The full list of Operating Modes and what each mode entails is detailed below. A full list of the current list of DTMF commands is also given below.

\*add figure and flow diagram

## 5.4 DTMF Commands

\*NEED TO DEFINE

## 5.5 Operating Modes

\*NEED TO DEFINE

# 6. Power

The BLUEsat Power system is divided into three sub-systems, the Solar Array, the Battery Charge Regulator and Voltage Regulators.

The Solar Array consists of six solar panels consisting of xx Gallium Arsenide (GaAs) cells. These six panels will sit on each of the six sides of the satellite (see [[#Mechanica]]).  This array will feed power into the Battery Charge Regulator which regulates power into the battery array. The battery array currently consists of four strings of x Nickel Metal Hydride (NiMH) batteries. Power from this battery array then gets passed to the Voltage regulators, which distribute power to the different subsystems of the satellite.

The power system has been designed such that the Critical Systems computer is able to monitor and modify the state of the charging circuit, as well as being able to shut off power to different parts of the satellite.

\*find out how many solar cells on each panel

\*find out how many batteries in each string

## 6.1 Solar

The satellite will use Gallium Arsenide Solar Cells arranged in 6 Panels on each side of the satellite.

## 6.2 Battery Charge Regulator

## 6.3 Voltage Regulator

***Obsolete – please fix.***

*Voltage regulators act as the interface between the supply bus and BLUEsat's [Subsystems](https://www.bluesat.unsw.edu.au/index.php/BLUEsat_Project_Systems). Voltage Regulation serves to provide these subsystems with their respective supply voltages. For example with a 30VDC supply bus, a certain subsystem might require a 9VDC supply and so this function is carried out by the voltage regulator, which will step the voltage down.*

[*Solar*](https://www.bluesat.unsw.edu.au/index.php/Solar) *panels and on-board batteries deliver electrical energy to the satellite via the supply bus. Due to fluctuations in solar exposure, resulting from the satellite's constantly changing attitude, solar panels could provide anywhere between 0~33VDC, thus rendering the supply bus unregulated. A supply bus regulated at ~29VDC (The voltage level that provides max. power from solar cells) is achieved by implementing Buck-Boost Regulators. In this case, only Buck voltage regulators will be required since subsystem buses are at lower voltages than the supply bus.*

*Furthermore, the critical systems computer will also need to be able to shut off certain devices (for example, the Radio Transmitters) in the event of device failure. The Voltage regulators will supply this capability.*

*The voltage regulators have been designed such that they*

* *Handle a voltage input of 0~33VDC*
* *Output Voltages of 3.3V, 5V, 9V, or 13.6V for the four subsystem busses*
* *Can handle a load of 0.5A (the maximum load to the Radio Transmitter)*
* *Have a high switching frequency ''(reducing component sizes; specifically inductor, thus smaller circuit)''*
* *Have a Thermal Shutoff & Current Limit  as safety features*

*To this end, the design is centred around the LM2676 Step-down voltage regulator. The four circuits designed allow for a step down voltage from the specified supply voltage to the output voltages listed above. The circuit includes BLAH BLAH and BLAH so that BLAH BLAH and BLAH can occur.*

\*fix above paragraph.

\*add circuit diagram

A full list of voltage regulators is given below:

\*LIST GOES HEAR!

All 14 voltage regulators have been designed into an array that will sit in Tray 4 of the satellite, so that the critical systems of the satellite can remain centralised into one location.

# 7. Communications

BLUEsat will communicate with Earth via VHF radio transmitters and UHF radio receivers. Digital data from the Critical Systems Computer and Payload Computer will be modulated by AFSK (Audio Frequency Shift Keying) and GMSK (Gaussian-Minimum Shift-Keying) modems, respectively, for transmission or reception by the radios.

In addition to this the satellite will also process commands in the form of nine digit numbers, transmitted in DTMF (Dual-Tone Multi-Frequency) form. These commands will be decoded by a DTMF decoder for processing by the Critical Systems computer.

These communication lines will be controlled by a central switching circuit. This switching circuit will be used to implement a hierarchy according to which communication lines need to be used to transmit and receive.

## 7.1 Radio Modules

## 7.2 Antennae

## 7.3 AFSK Modem

## 7.4 GMSK Modem

## 7.5 Beacon

The beacon was designed by a random polish guy. As such we think the circuitry incorporates some form of explosive, and we are afraid to launch the satellite with it on. However, he wields a mighty hammer everytime he comes into groundstation, so we fear going against his word.

# 8. Telemetry

# 9. Payloads

## 9.1 Payload Computer

## 9.2 EDAC

## 9.3 Namuru