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ISTSAT-1 Mission Data Handling Architecture

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Abstract

In this report we propose a solution to the Data Handling and Radio necessities of the ISTSAT-1.

The ISTSAT-1 is a CubeSat, a small space satellite being developed by students and professors from IST. The main mission of the ISTSAT-1 is to test a small form factor ADS-B signal receiver. ADS-B signals are sent periodically by airplanes in order for airplanes to be trackable. The satellite will be controlled by a Ground Station.

The ISTSAT-1's mission data handling architecture is a solution to the problem of handling the data captured by the satellite. This solution will allow for the characterization of the compact ADS-B receiver of the satellite. This architecture will also develop an intuitive user interface to display the captured data from the satellite. We also present a solution to the radio necessities of the Ground Station by use of Software Defined Radio.

Keywords: Satellite, ISTSAT-1, ground station, ADS-B, data handling, radio.

Resumo

Neste relatório, propomos uma solução para as necessidades de manuseio de dados e radio do ISTSAT-1.

O ISTSAT-1 é um CubeSat, um pequeno satélite espacial desenvolvido por estudantes e professores do IST. A principal missão do ISTSAT-1 é testar um receptor de sinal ADS-B de fator de forma pequeno. Sinais ADS-B são sinais enviados periodicamente por aviões para que os aviões possam ser rastreados. O satélite será controlado por uma estação terrestre.

A arquitetura de manipulação de dados da missão do ISTSAT-1 é uma solução para o problema de manipular os dados capturados pelo satélite. Esta solução permitirá a caracterização do receptor ADS-B compacto do satélite. Essa arquitetura também desenvolverá uma interface de usuário intuitiva para exibir os dados capturados do satélite. Também apresentamos uma solução para as necessidades de rádio da Estação Terrestre através do uso de Software Defined Radio.

Palavras-chave: Satélite, ISTSAT-1, estação terrestre, ADS-B, manuseamento de dados, radio.

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Acronyms

ADS-B Automatic Dependent Surveillance-Broadcast.

AMSAT Radio Amateur Satellite Corporation.

AUS Authentication Server.

AWS Amazon Web Services.

EGSE Electrical Ground Support Equipment.

ESA European Space Agency.

GENSO Global Educational Network for Satellite Operators.

GSS Ground Station Server.

GSSL Ground Station Server List.

INCP ISTnanosat Control Protocol.

ISS International Space Station.

MCC Mission Control Client.

PROBA Project for On-Board Autonomy.

RF Radio Frequencies.

SatNOGS Satellite Networked Open Ground Station.

SDR Software Defined Radio.

Chapter 1

Introduction

Ever since Commercial Aviation started taking off, the necessity for Aircraft coordination and tracking became crucial. In the early 1920's, before radar was invented the tracking of airplanes was done by each airplane itself using light beacons which demarked certain areas thus allowing pilots to track themselves. In the 1950's, after the invention of radars, airplanes started to get tracked by Air Traffic Control Towers. The Air Traffic Control Tower's purpose not only to track airplanes using radar but also to relay orders to airplanes in order to control their trajectories and organize aircraft traffic around airports. In their most basic form, radars work by transmitting an electromagnetic wave, this wave bounces on an object such as an airplane and the Radar receives this bounced electromagnetic wave and by calculating the delay between transmission and reception of the wave the radar is able to calculate how far apart the tracked object is and in which direction. The way radar works implies having very costly and large hardware, often in an elevated position, such as a tower. The necessity for a tower or expensive hardware limits the amount of coverage that is affordable to achieve by traditional radar.

In order to address the limitations of Radar a new technology was devised, Automatic Dependent Surveillance-Broadcast (ADS-B) [15]. ADS-B functions by having each Airplane carry an ADS-B transponder which periodically transmits a signal. This transmitted signal contains the location of the aircraft and other information such as speed of aircraft and speed of ascent/descent. By having monitoring stations that receive ADS-B signals, an Air Traffic Control center can monitor the air traffic within its assigned region without having to resort to radar. Due to the way in which ADS-B was designed it is possible for a station in ideal conditions to have a range of over 400km without a large hardware investment.

ADS-B signals are transmitted without any form of encryption or reception limitations. This allows anyone with a capable radio to receive the signals. This property of ADS-B signals has caused the creation of numerous websites which gather this information from all around the world such as FlightRadar24 [3] and FlightAware [1], Figure 1.1 shows an example of the information provided by FlightRadar24.

Most of the data that is being uploaded from all around the world for those ADS-B congregating websites is being uploaded from amateur radio operators. However, unlike in the past, where expensive and highly specified hardware was necessary in order to capture these signals, most of the captures are being made with what are called Software Defined Radio (SDR)

Figure 1.1: Screen-shot of the Flightradar24 website.

[12]. These radios differ from traditional radios by the fact that the way in which they function can be altered purely using software. This property of Software Defined Radio means that they are able to receive any frequency that is within its specified range and consequently able to demodulate any signal in that range utilizing software.

Another very common application of Software Defined Radios is to utilize them to receive signals from satellites in orbit. These satellites range from weather satellites, to many more examples such as Communication Satellites. A common trait of these previously mentioned satellites is that they are usually medium to large satellites [14]. These medium to large types of satellites are very costly to develop and to launch into space. As a response to these hurdles in the cost of reaching space and development a new type of satellite was devised: the CubeSat. A CubeSat [10] has much lower construction costs and lower launch costs which allows for a much bigger range of space satellite development.

ISTSAT-1 is a project that is being developed by students and faculty members at IST/ULisbon. The ISTSAT-1 is a satellite that is based on the CubeSat model. The main mission of the ISTSAT-1 project is to study the feasibility of monitoring aircraft utilizing ADS-B. Currently areas that are not within the range of terrestrial stations, such as oceans and very remote sparsely inhabited regions are unable to be tracked by ADS-B. This is the main limitation the ISTSAT-1 seeks to overcome, enabling the tracking at those locations from space. The ISTSAT-1 will build upon previous satellite missions that handled ADS-B technology such as the PROBA-V mission, the GOMX missions and others [5, 7, 9, 13]. The ISTSAT-1 will test a wide Field-of-View, small form factor ADS-B antenna and once operational the data recovered will be used to analyze several performance metrics including the probabilities of target acquisition, detection and identification [11]. The ISTSAT-1 satellite is also called the Space Segment.

Every satellite orbiting Earth needs a Ground Control Station responsible for sending telecommands to control it and receive telemetry gathered from its subsystems. In addition, mission data sent by the mission payload of the satellite has to be received and handled by specialized personnel and/or machinery on Earth; all these operations are usually carried out in the so called Mission Control Center which is part of the Ground Segment of spacecraft operations.

A typical Ground Station is composed of the following elements: an antenna system, a system that is able to receive satellite signals, a system that is able to transmit signals to the satellite, a system that handles telemetry and command of the satellite and finally a system that handles mission related data such as ADS-B signals in the case of ISTSAT-1.

1.1 Motivation

The satellite will be launched into space and delivered to the International Space Station (ISS). Once it is released from the ISS, its mission will begin. If there are no unexpected malfunctions with the ISTSAT-1 after a start-up procedure it will begin to attempt to communicate with the Ground Station. Once communication with the Ground Station is established it will begin its mission. The ISTSAT-1 satellite will not be picking up ADS-B signals without interruption but instead will be picking up signals at predetermined times which will correspond to specific regions of the planet. These predetermined times are sent by the Ground Station and put into practice by the satellite. Once the satellite is over one of the specified areas it will wake up and begin to capture ADS-B signals. After the reception in the specified area is completed, it will attempt to transmit the captured data to a Ground Station when it is able to do so.

After the Ground Station receives the data and decodes it, it is necessary for there to be a mechanism that takes in that data and processes it. This processing of data is crucial for the mission due to two main factors. The first factor is that only by verifying that the data is accurate are we able to prove that the satellite ADS-B receiver is functioning correctly. The second factor is that only by processing the data it is possible to characterize completely the compact ADS-B receiver the ISTSAT-1 team designed for this mission. The crucial mission parameters are the probabilities of target acquisition, detection and identification.

In order for the Ground Station to receive the previously mentioned signals, it is necessary to have working Radio Frequencies (RF) communications in the ground station. It is also necessary to have RF communications before launch, during the testing phase. It is necessary to have fully functioning RF communications in order to communicate with the satellite during testing due to a couple of factors. The main factor is that only by testing the RF communication portion of the Ground Station architecture are we able to prove that both the space and ground segments are able to communicate with each other. The other main factor is that only by having functional communications between the satellite and the ground station architecture are we able to fully test the satellite's functionality. To fully test the satellite's functionality it will be necessary to have a complete satellite responding to commands from the Ground Station and it is necessary to have the satellite receiving ADS-B signals.

1.2 Goals and Challenges

The main goal is to develop a data handling mechanism for ISTSAT-1's measured data which consists of ADS-B signals that have been received by the satellite. This processing of data will involve sorting and cleaning of the data to filter out any invalid ADS-B signals and to filter out any ADS-B signals that are not relevant. This goal also involves additional processing on the sanitized data to verify the data accuracy and to verify the performance of the satellite to the standards at which it was specified. Another sub-goal of the data handling mechanism is to develop a user interface which allows users to visualize the data received by the satellite in a more intuitive and easy to understand way such as overlaying the data globally based on the location that is being provided by each ADS-B signal.

In order to achieve the data handling mechanism goals, it is first necessary for the Ground Station to have the capability to receive the signals that are being sent by the satellite. In order to be able to receive these signals it is necessary to develop the radio frequency abilities of the satellite. To develop the RF capabilities of the ground station architecture, GNU-Radio [1] will be used. Using GNU-Radio we are able to decode all the modulations that are used by the Satellite and it also allows efficient integration with the rest of the Ground Station architecture.

After the development of the Ground Station's RF capabilities it will be necessary to test the Satellite using generated ADS-B signals, for this goal GNU-Radio will also be used. GNU-Radio will allow the generation of ADS-B signals that are designed to test the satellite in diverse conditions.

The main challenge that is being foreseen is the development of the data handling mechanism mentioned above. The main difficulty of development stems from the fact that this mechanism will have to be able to handle a large quantity of data in the form of ADS-B signals. Another factor in the challenge of developing such system is the difficulty in making positive matches between the received data and data from external sources such as FlightAware. This is being done in order to measure the accuracy and correctness of the received data. Another challenge in the development of the data handling mechanism is the development of the user interface in a way that it actually provides useful visualizations of the data. This user interface will be a challenge to develop due to the large number of predicted ADS-B signals that will be received. This large number of ADS-B signals means that the user interface system must handle this large number of data entries efficiently in order for it to be responsive.

The main challenges of the RF component being developed for the Ground Station is the implementation of the different modulations that the satellite is capable of transmitting and receiving. Another challenge of the RF component is to test it utilizing satellites that are already currently in orbit thus allowing us to test the component before the launch of the ISTSAT-1. The final challenge is to develop the capability to generate and transmit ADS-B signals in a way that we are able to specify the content of each ADS-B signal.

Another challenge is the integration of both the Data Handling mechanism and the RF component into the proposed Ground Station Stack. This stack will be explained in detail in Chapter 3.

The final challenge of both the data handling and the RF components triggered by the fact that there isn't a single isolated Ground Station but in fact a global network of Ground Stations. The ISTSAT-1 project is able to have a global network of Ground Stations due to the existence of projects that aim to provide global ground station networks for use by satellite operators. These global networks of Ground Stations will be further detailed in Chapter 2. This poses some additional challenges on the data handling component due to necessity of coordination and unification of data that is coming from multiple different Ground Stations. This also poses additional challenges on the RF component due to the fact that it will require adapting in order

[1] GNU-Radio is a piece of software that enables the control of Software Defined Radios

to be able to be installed at multiple non-heterogeneous Ground Stations.

1.3 Document Organization

This document is divided in six chapters.

Chapter 2 contains work related with this project. This related work consists of different existing projects that tackle the problem of distributed Ground Station Networks. In the same chapter we will also discuss other satellite missions that have involved the tracking of airplanes by use of ADS-B signals.

Chapter 3 contains our proposed solution to the problem we are trying to solve. In this chapter we explain the proposed Ground Segment architecture, user interface and RF component.

In Chapter 4 we are going to explain our proposed method of evaluating the effectiveness and quality of our proposed solution. This chapter will also propose a work plan for the development of the proposed solution.

Finally, in Chapter 5 we will give a conclusion of the work that is being proposed.

Chapter 2

Related Work

In this chapter we will take a look at the different aspects related with this project by looking at what has already been done in that subject. Our project will require the use of a Ground Station Network so we will first take a look at the multiple projects that already exist in the world of ground station networks. We will also take a look at the different projects that have already tackled the problem of tracking airplanes utilizing ADS-B from space.

2.1 Ground Station Networks

More and more universities and private companies are building CubeSats and other small form-factor satellites. While these satellites provide a reduced cost of access to space, they also have drawbacks. One major drawback of such small satellites is that they typically have limited capability of data transmission to earth. This means that when a satellite goes over a Ground Station, the amount of data that can be retrieved is very small since the time window over which the satellite is in range of the Ground Station is very short.

There are couple of ways to remedy this problem:

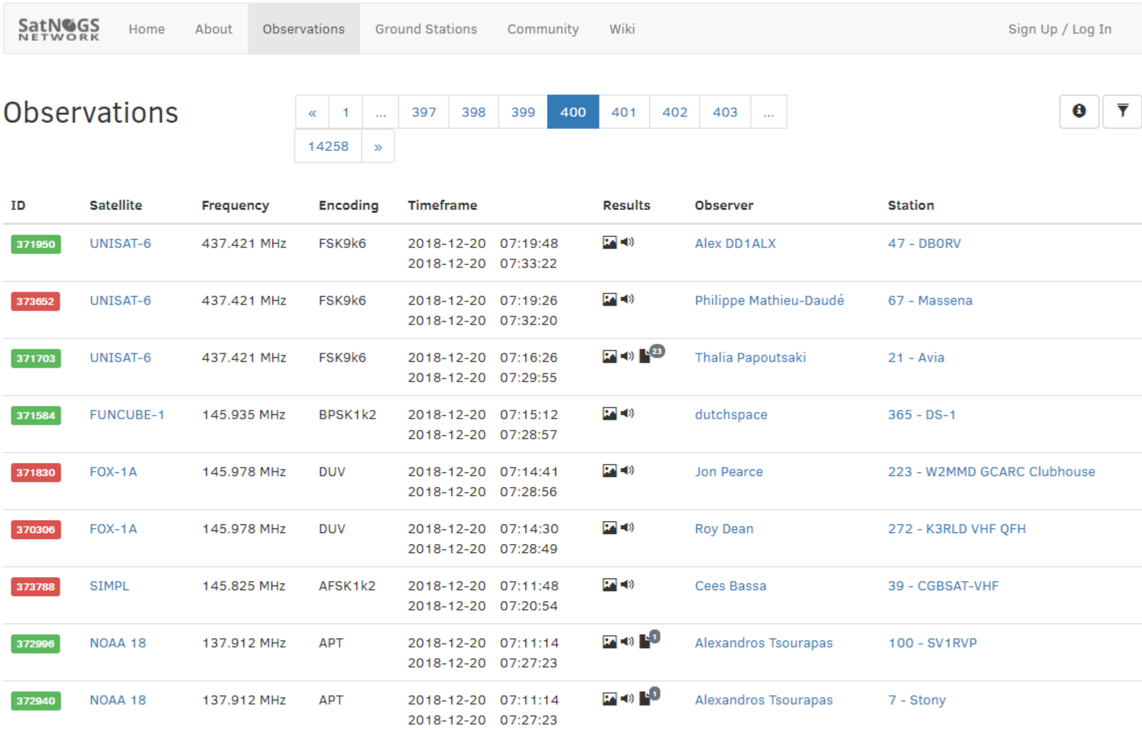
i Increase the data output rate at which the satellite transmits;

ii Transmit to multiple Ground Stations.

It is very difficult to increase the data output rate of small form factor satellites like CubeSats due to their low energy capabilities. The faster a satellite transmits the more power it consumes. Thus, we must look at ground station architectures that have more than one ground station. These ground station architectures that feature more than one ground station are typically a network that is managed by international space agencies or projects that are developed by non-governmental, community driven organizations. There are currently a few projects that tackle the Ground Station Network problem.

2.1.1 SatNOGS

Satellite Networked Open Ground Station (SatNOGS) [6] is an international open source networked ground station project which aims to create a global distributed network of ground stations for the purpose of only receiving data from satellites. The SatNOGS project aims to create


SatNOGS NETWORK | Home | About | Observations | Ground Stations | Community | Wiki | Sign Up / Log In

Observations

« 1 … 397 398 399 400 401 402 403 … 14258 »

ID	Satellite	Frequency	Encoding	Timeframe	Results	Observer	Station
371950	UNISAT-6	437.421 MHz	FSK9k6	2018-12-20 07:19:48 2018-12-20 07:33:22		Alex DD1ALX	47 - DB0RV
373652	UNISAT-6	437.421 MHz	FSK9k6	2018-12-20 07:19:26 2018-12-20 07:32:20		Philippe Mathieu-Daudé	67 - Massena
371703	UNISAT-6	437.421 MHz	FSK9k6	2018-12-20 07:16:26 2018-12-20 07:29:55	23	Thalia Papoutsaki	21 - Avia
371584	FUNCUBE-1	145.935 MHz	BPSK1k2	2018-12-20 07:15:12 2018-12-20 07:28:57		dutchspace	365 - DS-1
371830	FOX-1A	145.978 MHz	DUV	2018-12-20 07:14:41 2018-12-20 07:28:56		Jon Pearce	223 - W2MMD GCARC Clubhouse
370306	FOX-1A	145.978 MHz	DUV	2018-12-20 07:14:30 2018-12-20 07:28:49		Roy Dean	272 - K3RLD VHF QFH
373788	SIMPL	145.825 MHz	AFSK1k2	2018-12-20 07:11:48 2018-12-20 07:20:54		Cees Bassa	39 - CGBSAT-VHF
372996	NOAA 18	137.912 MHz	APT	2018-12-20 07:11:14 2018-12-20 07:27:23	0	Alexandros Tsourapas	100 - SV1RVP
372940	NOAA 18	137.912 MHz	APT	2018-12-20 07:11:14 2018-12-20 07:27:23	0	Alexandros Tsourapas	7 - Stony

Figure 2.1: SatNOGS network web page.

a ground station network utilizing a full stack of open source technologies and standards. This project also provides its users with a web platform where they are able to schedule any ground station on the SatNOGS network a time slot and instructions in order to receive signals from a specified satellite. These instructions include an envisaged orbit of the satellite in order to track it; this is a necessity in the case where rotators are utilized. These instructions also include a modulation and frequency at which the specific ground station must listen to. The project is divided into two main components, the Global Management Network and the Ground Stations.

Global Management Network The Global Management Network is composed of three components: the Network itself, the client and the Ground station.

- The SatNOGS network is a server that is responsible for managing the observations that have already been and will be performed and the creation of new ground stations. This management of observations includes: scheduling ground stations around the network for future observations and distributing already performed observations. The scheduling and distribution of observations is done through a SatNOGS web page. In Figure 2.1 we can see SatNOG's network page and a list of already performed observations from which we can download the observed signal, red ID tags mean that the signal reception was poor while green tags mean the reception was of good quality.
- The SatNOGS client is an embedded system run on the ground stations that receives scheduled operations from the Network and then records the observation as specified by the operation and sends the recorded observation back to the Network.

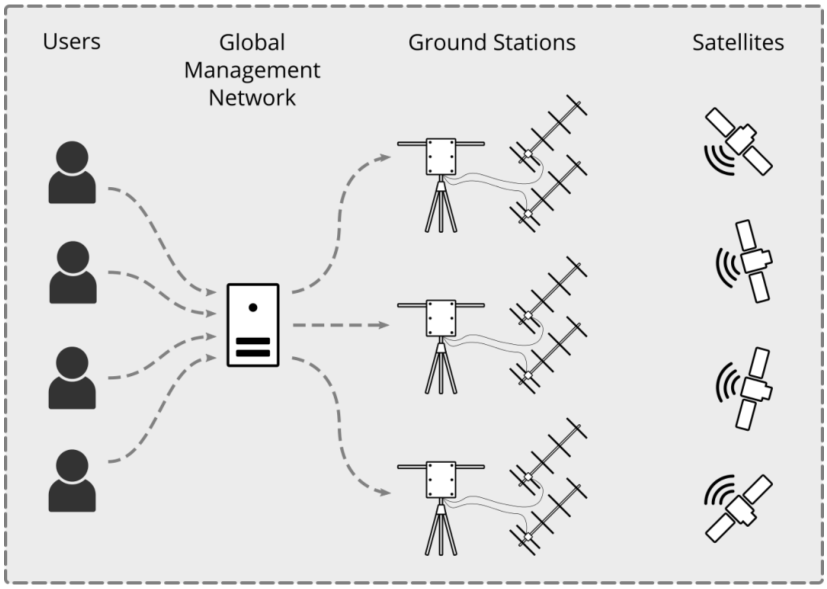


Figure 2.2: Diagram of SatNOGS Architecture.

This client runs on Linux computers, typically a Raspberry Pi [1].

- The SatNOGS Ground Station component of the network is the actual ground station hardware instrumentation which includes the electronics, antennas and rotators which we will discuss in greater detail in the following section. A diagram of the architecture can be seen in Figure 2.2

Ground Stations The Ground Stations of the SatNOGS architecture are controlled by the SatNOGS network client. The Ground Station is comprised of a signal receiver, an Antenna and possibly an antenna rotator.

- The Antenna can be of different form factors such as a directional antenna or an omnidirectional antenna. A directional antenna is an antenna that receives a signal from a specific region at which it is pointed at. In Figure 2.3 we can see a SatNOGS antenna setup utilizing rotators and directional antennas. An omnidirectional antenna is an antenna which can receive signals from all angles of the antenna or a very wide angle of reception. These antennas typically are not controlled by rotators. In Figure 2.4 we can see an example of an omnidirectional antenna.
- The signal receiver can be a Software Defined Radio (SDR) or standard amateur radios. While SDRs can be connected directly to the SatNOGS client, traditional radios cannot and must be connected using Ham Lib. Ham Lib provides drivers to bridge the connection between the client and the radio.
- The antenna rotator is the piece of hardware that points a directional antenna at a specific location. These rotators are also controlled by the SatNOGS client.

[1] A Raspberry Pi is a small and inexpensive linux computer. Due to its architecture it is has also very low power consumption

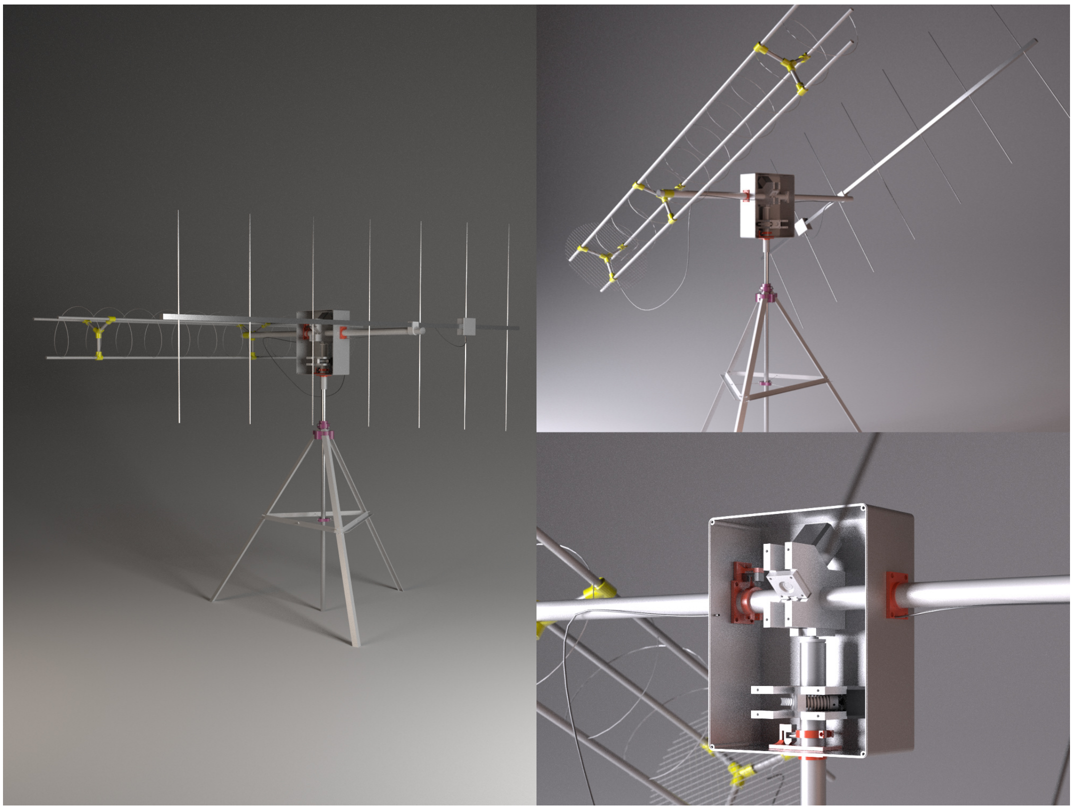


Figure 2.3: Example of antennas with a rotator from the SatNOGS Project.

Figure 2.4: Example of an omnidirectional antenna.

2.1.2 GENSO

Global Educational Network for Satellite Operators (GENSO) [16] is an international project managed and funded by the European Space Agency (ESA) which aims to create a global distributed network of ground stations for use by amateur satellite operators and for Radio Amateur Satellite Corporation (AMSAT) satellites. The purpose of the GENSO network is to increase the amount of data that can be received from a particular satellite. The GENSO network has three components: the Central Server, the Ground Station Server (GSS) and the Mission Control Client (MCC), as can be seen in Figure 2.5. We will now define the components of the GENSO network.

Central Server The Central Server is responsible for network authentication and encryption, satellite list distribution, ground station monitoring, satellite operator status monitoring and compilation of network statistics. These tasks were selected due to their low processor requirements and low bandwidth requirements thus allowing the network to scale according to necessity. This central server is called the Authentication Server (AUS) and is comprised of several servers located in numerous countries around the world.

Ground Station Server (GSS) The GSS is the component at each ground station, this piece of software is responsible for moving the antenna by the use of a rotator and controlling the radio and tuning it into the correct frequency and modulation. The radios being utilized by the GENSO network are traditional amateur radios. In order to control the radios Hamlib is being used. Hamlib provides an abstraction layer that allows for the writing of custom drivers for radios to communicate using a standardized interface. GENSO also allows for individual radio operators to disconnect their ground station from its network while still using the radio and antenna rotator control components of GENSO.

Mission Control Client (MCC) The MCC is the application where the satellite operators actually control how the GENSO network handles their specified satellite. The MCC is responsible for indicating how the satellite is operating which means at which frequency and modulation the satellite is transmitting. The MCC is also responsible for allocating the appropriate time slot in the appropriate ground station in order to capture the optimal satellite pass. For each satellite there is only one MCC. When an MCC is created it is required to register on the AUS. Once the MCC is registered on the GENSO network it will receive the Ground Station Server List (GSSL) this list contains all the ground stations on the network, their locations, available frequencies and modulations on said ground station. The MCC is also responsible for updating the GENSO network on the satellite's status which includes the frequencies at which it is operating, the modulations and its location in orbit.

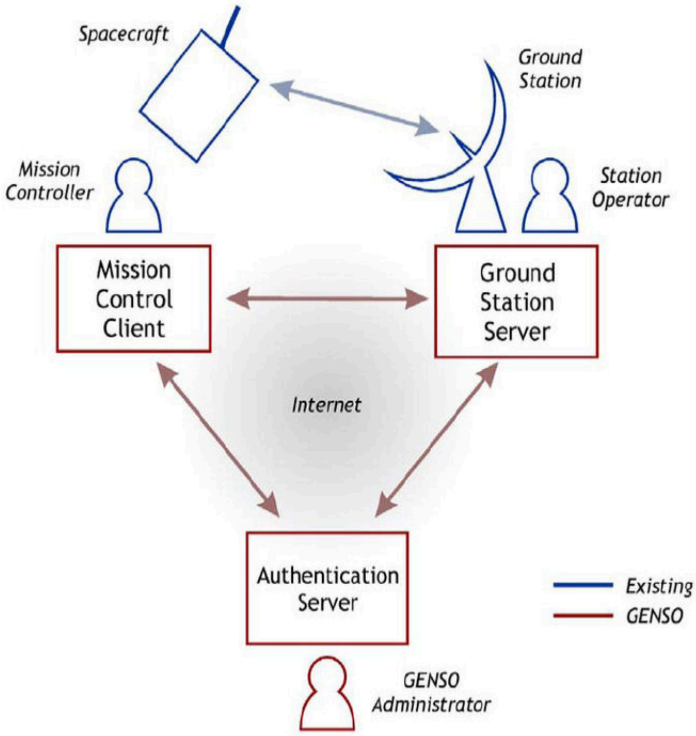


Figure 2.5: Diagram of GENSO Architecture.

2.1.3 AWS Ground Station

The Amazon Web Services (AWS) Ground Station network is a new commercial Ground Station Network created by the retail and cloud computing giant, Amazon [8]. This network intends to offer a global Ground Station Network as a service that a customer can pay for its use. The AWS Ground Station Network is mainly aimed at bigger entities such as large corporations or large space agencies like ESA. Unlike the previously mentioned Ground Station Networks, GENSO and SatNOGS, this proposed network is not only able to receive signals from a satellite but is also able to transmit signals to it. This advantage gives the AWS network a big improvement in usability compared to the previous ground station networks. Being able to control the satellite using a global ground station network makes controlling the satellite a much less delayed and much more reliable operation.

Another advantage of the AWS network is the fact that Amazon already has a global footprint which means that the network will always have a Ground Station in very close proximity to a satellite which is ready to receive and transmit signals. The expected use case of this network is portrayed in Figure 2.6.

Due to the fact that the AWS Ground Station network is a commercial solution, the details of the inner workings of the network are not published. Despite the inner workings of the network not being known, it shares similarities with the other ground station networks that came before it. The main similarity is the necessity to have to schedule a time-slot at one of the existing AWS Ground Station in order to receive the satellite data.

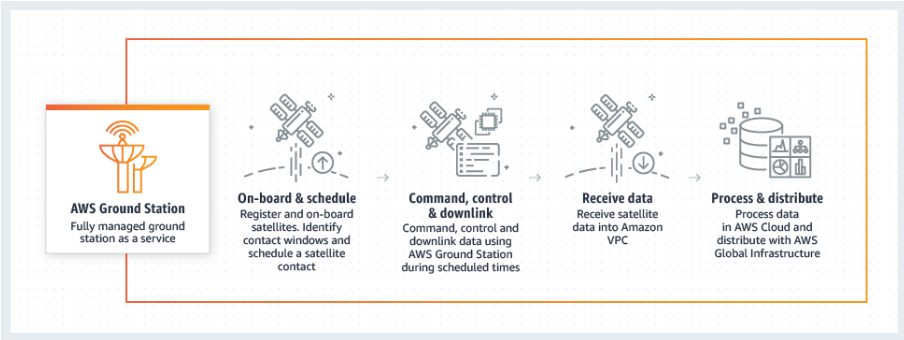


Figure 2.6: Expected use of the AWS Ground Station

2.2 Previous ADS-B Satellite Missions

The ISTSAT-1 mission is being built on top of experience gathered by other satellite missions that tackled the ADS-B monitoring problem. In the following section we will discuss a few of them.

2.2.1 PROBA-V Mission

The PROBA-V (Vegetation) was the 4th satellite in ESA's Project for On-Board Autonomy (PROBA) series [11]. The main mission of the satellite was to test a new type of vegetation measuring optical instrument, but also contained a new ADS-B receiver and antenna. The main goal of the inclusion of the ADS-B instrumentation was to measure the performance of capturing ADS-B signals from space. In the end the PROBA mission was able to track aircraft, those of which can be seen in Figure 2.7. The most important information to take way from the PROBA mission to the project that is being proposed are the ADS-B performance parameters defined in the mission. These performance parameters are relevant to the goal of measuring the performance of the satellite. The parameters are the following:

Probability of Target Acquisition This performance parameter results from the comparison of reference traffic and detected aircraft tracks by the satellite. The reference traffic was aircraft traffic obtained by terrestrial means such as a radar. This parameter was calculated as a percentage ratio between the actual number of targets detected and the expected number of targets to be detected within a certain area or time of observation.

Probability of Detection This performance parameter is the percentage ratio between the actual number of ADS-B messages received and the expected number of ADS-B messages from the reference traffic.

Probability of Target Identification This performance parameter is the percentage ratio between the actual number of aircraft identified and the expected number of aircraft which should have been identified.

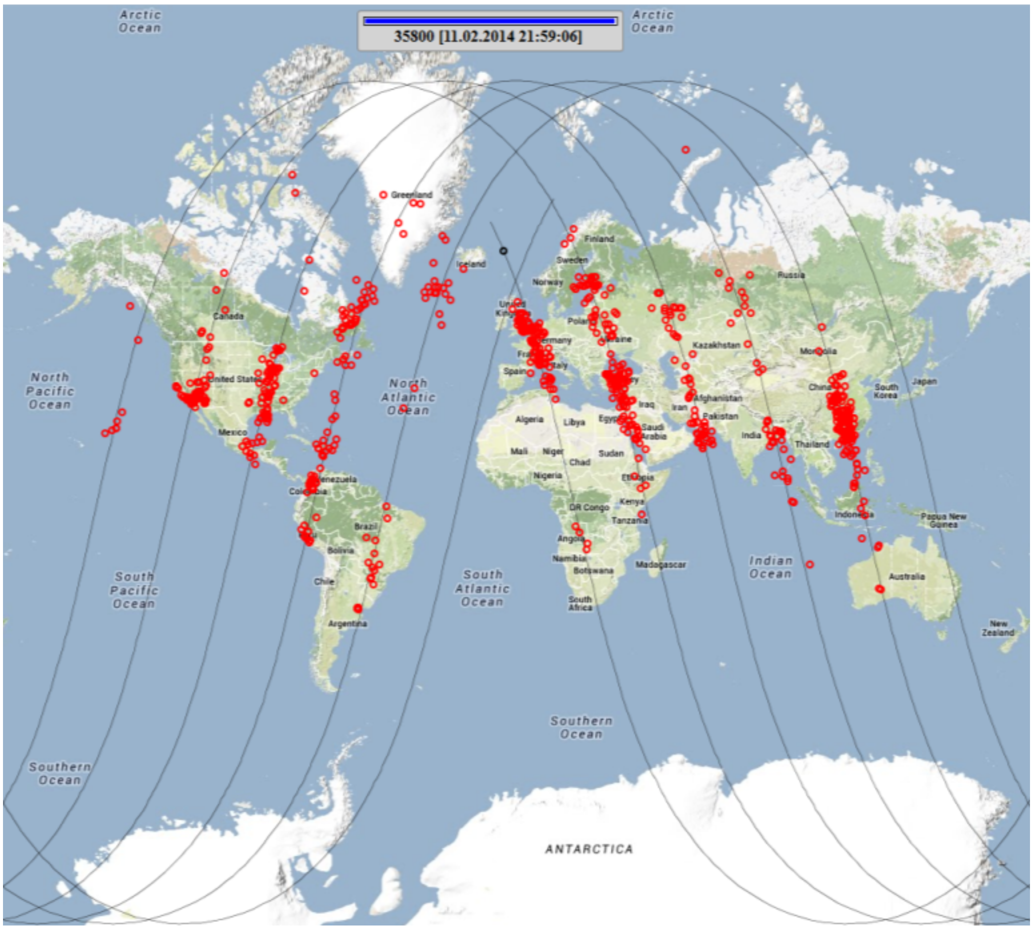


Figure 2.7: Aircraft observed by PROBA-V

Probability of Identification This performance parameter is the percentage ratio between the actual number of identification messages received and the expected number of identification messages.

Chapter 3

Proposed Solution

In order to accomplish the previously specified goals the following elements are required: a Ground Station Architecture, a Ground Station Software Stack, a data handling mechanism and a user interface. We will now describe each of the elements in detail.

3.0.1 Ground Station Architecture

ISTSAT-1's ground station architecture is comprised of the following elements: Antenna, Radio, PC, Server and Ground Station Network.

The radio component is composed of two main radios, a Software Defined Radio which can handle all RF modulation types that are used by the satellite and a more traditional amateur radio which can only handle simpler RF modulation types. Both types of radios are connected to a PC which has the capability of decoding the signals transmitted by the satellite.

The PC also has the capability of controlling the radios and the antenna rotator depending on what the necessities are at the moment. The signals that are transmitted to and from the satellite utilize the ISTnanosat Control Protocol (INCP) protocol. The INCP protocol was designed by the ISTSAT-1 team to fit the specific needs of the mission.

The Server communicates with the PC and provides the following services: a graphical user interface for the control of the satellite for telemetry and command and a data processing component which will handle the ADS-B mission data. There is also a Ground Station Network component which consists of other Ground Stations that are connected to a network which is available to access through the Internet. This Ground Station Network component is managed by the PC.

There is also another component called the Electrical Ground Support Equipment (EGSE), this component is responsible for providing an interface with which the PC can verify in the internal status of the satellite. The EGSE component is required in order to test the satellite. The EGSE component is utilized during testing to verify the result of sending particular command to the satellite. The EGSE component of the Ground Station is only to be used during testing phases. A diagram of this Ground Station network can be seen in Figure 3.1.

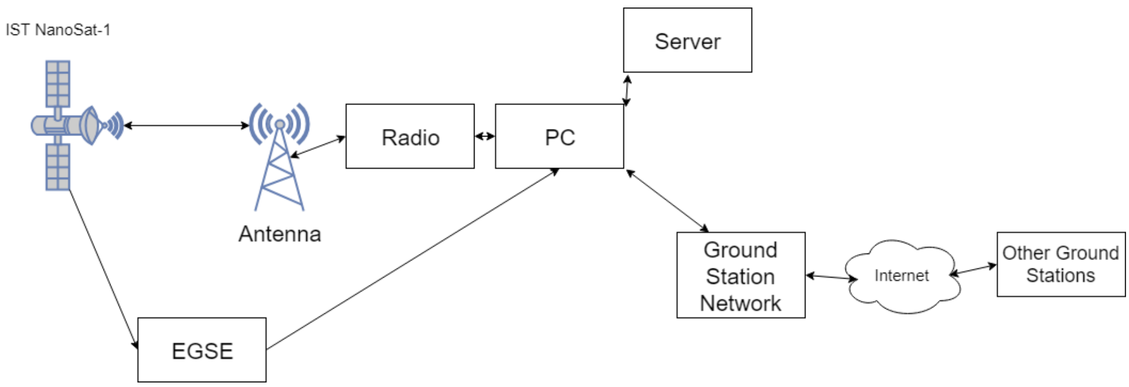


Figure 3.1: Diagram of the ISTSAT-1 Ground Station Architecture

3.0.2 Ground Station Software Stack

The Ground Station Software Stack integrates all of the Ground Station components into a single architecture. The stack is composed of the following components:

- The physical Radio layer is comprised of a Software Defined Radio (SDR) and a traditional Amateur Radio both of which are responsible for receiving the signals captured by the antenna and transforming them into digital signals. In order to program the radio layer's SDR GNU-Radio will be utilized. GNU-Radio is a piece of software capable of controlling SDR's and is extremely flexible. This flexibility allows us to integrate the SDR with the rest of the Ground Station Software Stack without much difficulty.
- The logical Radio layer is the actual digital signal that is being transmitted. This layer uses the AX.25 protocol. This protocol encapsulates the data being transmitted into packets and enables more robust transmission and reception of data from the satellite.
- The middleware layer is comprised of the INCP protocol which defines the structure of the messages being transmitted from and towards the satellite. The types of messages in the INCP protocol include: commands, diagnostics, errors and data retrieval.
- The Ground Station Network Layer is a global network of Ground Stations from where signals can be received.
- Telemetry and Telecommand are at the last layer of the stack and they are responsible for the management and well being of the satellite. Telemetry is detailed information about the status of the satellite's subsystems. Telecommand are the instructions that actually control the satellite and help to maintain it.
- Mission Data are ADS-B signals that have been captured by the satellite. These signals will be processed by the data handling mechanism that will be detailed further in section 3.0.3.

A diagram of the Ground Station Stack Architecture can be seen in Figure 3.2

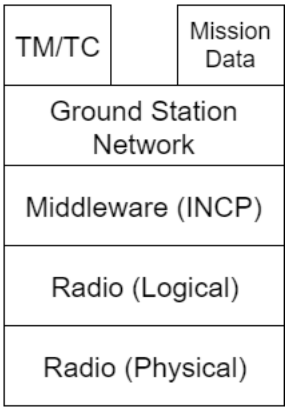


Figure 3.2: Diagram of Ground Station Stack

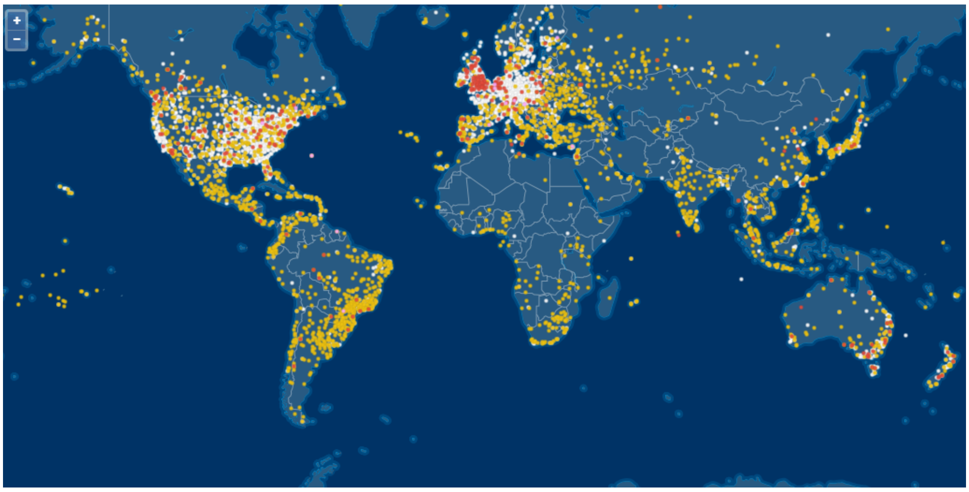


Figure 3.3: FlightAware's Coverage of ADS-B reception

3.0.3 Data Handling Mechanism

To perform the processing of the data we require not only the mission data but also reliable data from a 3rd party source, as we have seen in section 1.2. The 3rd party source selected for the data handling mechanism is FlightAware's FlightXML API [2]. This API allows us to query FlightAware's DB of received ADS-B signals. Due to the fact that FlightAware is comprised of a very large network of proven ADS-B receivers it provides a reliable source of ADS-B information. In Figure 3.3 we can see the coverage map of FlightAware's ADS-B reception, each dot represents an ADS-B receiver. By utilizing this information and cross-referencing it with the received ADS-B signals from the satellite we are able to characterize completely the ADS-B receiver designed for this mission.

3.0.4 User Interface

In order to build the user interface a web server will be utilized. This server will display a web page which contains a global map. This map will contain the locations that are reported by the ADS-B signals that the satellite has received. The map will also display the location of the satellite in real-time. It will be possible to zoom in or out of the map and look at specific

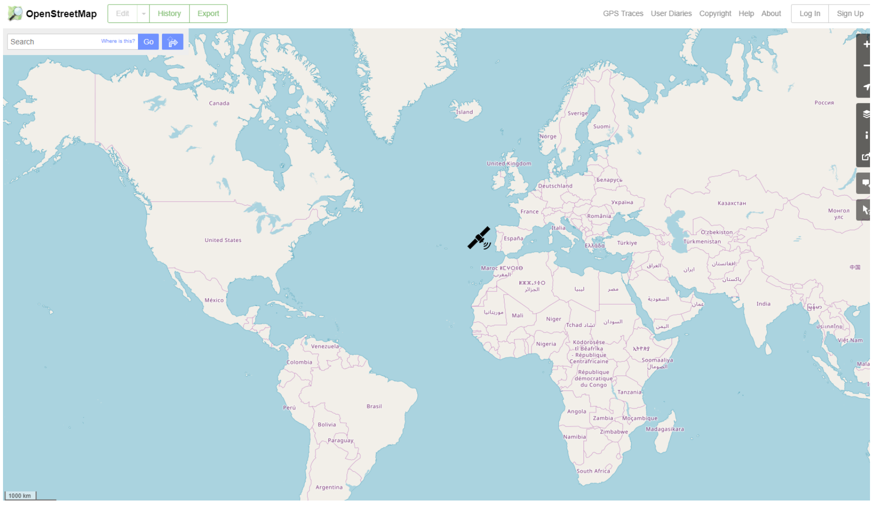


Figure 3.4: Mock-up of User Interface utilizing OpenStreetMap

locations. It will also be possible to filter out ADS-B signals based on: time intervals in which they were recorded, show only signals that were unreported by any other ADS-B tracking station on FlightAware's network, show only ADS-B signals that were confirmed with FlightAware's network and finally to disable all ADS-B signals from appearing. In order to display the map OpenStreetMap's API will be utilized [4]. This API allows for the generation of custom maps which in the case of this project will be populated with ADS-B signals and the satellite's location. In Figure 3.4 we can see a mock-up example of the user interface, utilizing OpenStreetMaps, showing the location of the satellite in relation to the globe.

Chapter 4

Evaluation Methodology

Since the launch of ISTSAT-1 into orbit not being scheduled to happen before the expected finish date of this thesis' date there is the necessity to have extra testing mechanisms in order to evaluate the performance of the proposed solution before launch. The first mechanism is the generation of ADS-B signals. These signals will be transmitted at the satellite and simulate normal aircraft traffic signals that the satellite will receive. These signals will be generated using GNU-Radio and this mechanism will be connected to the Ground Station in order to coordinate the tests. The second mechanism is the use of the EGSE component of the ground station. This mechanism will allow for the verification of signal reception of both ADS-B signals and signals sent from the Ground Station.

There are two main evaluation objectives that we have to define. The main evaluation objective we must accomplish is evaluating the performance of the satellite's ADS-B data collection. The second evaluation objective that must be performed is the evaluation of the performance of the RF component that was developed.

4.0.1 Evaluating ADS-B Collection Performance

The evaluation of ADS-B collection performance will be done utilizing some of the performance parameters that were utilized in the PROVA-V mission [11]. The parameters that are of most importance to the ISTSAT-1 mission are the probability of detection and probability of identification. The probability of detection and the probability of identification are calculated using the following formulas:

$$\text{Probability of Detection} = \frac{\text{\# of received ADS-B signals}}{\text{\# of expected ADS-B signals}} \times 100$$

$$\text{Probability of Identification} = \frac{\text{\# of identifying messages}}{\text{\# of expected identifying messages}} \times 100$$

4.0.2 Evaluating RF Component Performance

In order to evaluate the performance of the developed RF component we will utilize 2 SDR radios and test the transmission between them. In order to simulate the distortion, noise and signal power loss GNU-Radio's built in tools for noise generation, signal distortion and power reduction will be utilized. We will perform signal transmission tests at expected mission conditions and measure the number of signals transmitted and the number of signals received and calculate the ratio of successful transmission. The formula for this calculation is the following:

$$\text{Transmission Success} = \frac{\text{\# of received signals}}{\text{\# of transmitted signals}} \times 100$$

4.1 Work Plan

In this section we will describe the work plan for the proposed work.

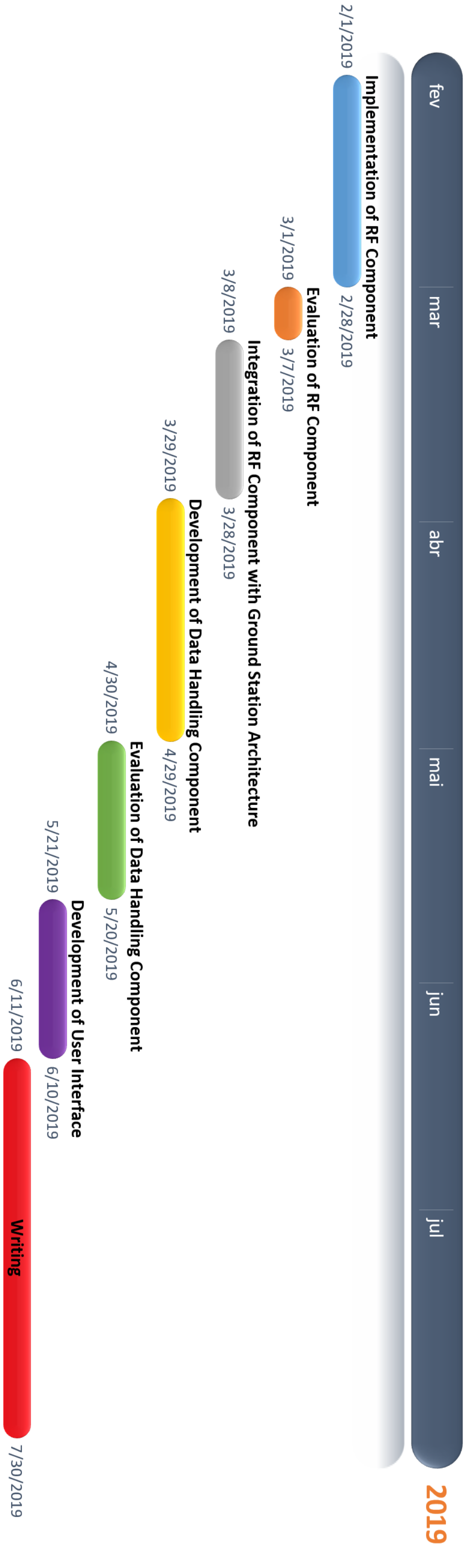
There are weekly software development meetings in IST Taguspark with ISTSAT-1's team. Work will begin on February 1st and will end on 30th of July. The work is divided into 7 parts. Firstly, we will implement the RF component due to it being necessary in order to accomplish the remainder of the proposed work. Secondly, we will evaluate the performance of the implemented RF component. Following will be integration of the RF component with the Ground Station Architecture. Then we will develop the Data handling Component followed by its evaluation. We will then develop the User Interface. Finally, we will write the dissertation document. In Appendix A we can see a Gantt chart of the proposed work plan.

Chapter 5

Conclusion

In this report we propose a solution to the Data Handling and RF necessities of the ISTSAT-1. We also took a look at existing projects in the field of ground station networks and existing projects that tackle ADS-B reception from space. We proposed a solution of the Data Handling necessities of the ISTSAT-1 mission that fits with ISTSAT-1's Ground Station architecture. This Data Handling solution will serve not only to process the data and verify the feasibility of the ISTSAT-1 mission but also to provide a graphical user interface that displays the received data in a more user-friendly way. We also proposed a solution of the RF necessities of the mission. This proposed solution utilizes software defined radio in order to provide the necessary RF functionality which will be integrated into the Ground Station architecture.

Appendix A - Work Plan



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