# SSETI ESEO New Zealand Ground Station Project

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**Abstract:** The paper outlines the currently on-going project aimed at developing a fully operational Student Space Exploration and Technology Initiative (SSETI) New Zealand Ground Station for the European Student Earth Orbiter (ESEO) satellite scheduled for launching in 2009. The proposed ground station will provide additional satellite communication facilities enabling efficient data exchange with the ESEO when it is passing over the Pacific region, i.e., when its communication with the Europe-based Ground Stations is limited or not possible. The ground station will be linked to the Mission Control Centre in Europe via secure tunnels over the Internet to relay telemetry data and telecommand information.

Keywords Satellite Communications, Ground Station, Student Space Exploration and Technology Initiative, European Student Earth Orbiter

## 1. INTRODUCTION

The Student Space Exploration and Technology Initiative (SSETI) was founded in 2000 by the Education Department of the European Space Agency (ESA). The program now involves over 70 teams including hundreds of students from 25 universities from 16 European Countries, including Austria, Belgium, Denmark, France, Germany, Hungary, Italy, Norway, Poland, Portugal, Spain, Sweden, Switzerland, and United Kingdom as well as Canada and America [1]. The teams contribute to the development and implementation of different sub-systems of the satellites as well as to technical support to the project. Due to the distributed nature, the teams communicate through Internet Relay Chat (IRC), NewsGroup and FTP. The main SSETI program missions (projects) are:

- SSETI Express
- SSETI European Student Earth Orbiter (ESEO)
- SSETI European Student Moon Orbiter (ESMO).

In these team-based student projects, each team performs feasibility studies of their proposed subsystem and then designs and implements it with technical and managerial coordination of ESA. The SSETI initiative is a logically structured program where every mission is built upon the previous project and is a pre-cursor for the next one.

The SSETI Express was the first micro-satellite of the program. It was successfully launched into a Low Earth Orbit on 27th of October 2005 by a COSMOS-3M launcher from Plesetsk, Russia. In November 2005, the SSETI Express satellite was given the designation Express OSCAR XO-53.

The ESEO is the second project of the initiative. ESEO it is currently undergoing its development. Its launch is scheduled for the end of 2009.

The third satellite of the programs - ESMO is scheduled for launching to the lunar orbit in about

2011. Currently it is approaching the feasibility study phase. Additionally, a moon landing and exploration mission would be considered at the later stage based on the success of the above three missions as well as on financial/technical possibilities.

Aiming to contribute to the success of the SSETI program, Massey University is working towards developing and setting up a ground station to enable control, data downlink from and uplink to ESEO satellite (as well as to other relevant satellites in the future). This paper will provide overview of the ESEO satellite and outline the currently developed SSETI New Zealand ground station project

## 2. SSETI ESEO SATELLITE

The second satellite of the SSETI initiative - ESEO is currently under extensive development and implementation. Its assembly and testing is scheduled to be accomplished in 2008. It is planned that the ESEO will be launched by the Ariane 5 or by the Soyuz launch vehicles in 2009. The ESEO will be placed into a geostationary transfer orbit (in contrast to the low earth orbit of the first satellite - SSETI Express). The main parameters of the satellite are presented in Table 1 [1].

TABLE 1. ESEO Technical Data.

| | |
|---|---|
| Dimensions | 600x600x710mm |
| Mass | 120 kg |
| Altitude Determination System | Sun-sensors, Horizon-sensors, Magnetometers & a star tracker |
| Altitude Control System | Momentum wheel, cold gas attitude thrusters & a vector thrustcontrol main thruster |
| Orbit Control System | Cold gas |
| Propulsion | 181,300bar Nitrogen cold gas |
| On-board Data Transfer | CAN, RS232, RS242 |
| S-band Telemerty | 9.6Kbps (low gain), 128Kbps (high gain) |
| Power: Deployable Sun-tracking Solar-cell Panels | Average: 80W, Peak: 300W |
| Batteries | Li Ion, 150Wh |
| Power Bus | 28V Regulated |
| Thermal Control | Passive |

The ESEO will carry three cameras:

1. A narrow angle camera for Earth image capturing;
2. A micro camera for imaging satellites in space;
3. A star tracker for picturing stars.

The satellite will also be equipped with sensors, instrumentation and measurement devices aimed at measuring radiation levels and its effect on the on-board electronics, as well as detection of the plasma flow.

The communication system of ESEO is comprised of a transceiver module, microwave module and antennas. In the transceiver module, a UHF/S-Band linear transponder is being developed to handle telemetry on the downlink and telecommands on the uplink. The frequency and data rate of the ESEO communication system is presented below in Table 2.

TABLE 2. ESEO Communication Parameters.

| | | |
|---|---|---|
| Uplink: | 2025 – 2110 MHz | 4 Kbps |
| Downlink: | 2200 – 2290* MHz<br>*The downlink for radio amateurs will be in the 2400-2450 MHz range. | High rate: 153.6 Kbps<br>Low Rate : 9.6 Kbps (Primary)<br>2.4 Kbps (Secondary)<br>Implementation for the entire orbit (from 560 to 42,000km). |

There are in total nine on-board antennas in ESEO of two types: eight low gain antennas (LGA) for both uplink (receiving) and downlink (transmitting) – Figure 1 [1].

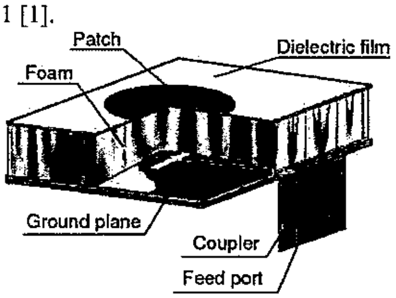


Figure 1. SSETI ESEO LGA Antenna Structure

There is also an inflatable high gain antenna (HGA) in the ESEO configured as a matrix patch antenna to be used for payload data transmission to a ground station – Figure 2 [1].

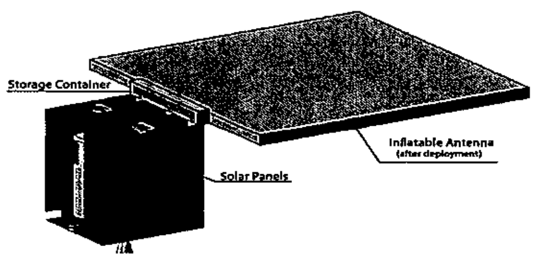


Figure 2. SSETI ESEO Inflatable Antenna Draft

The ESEO microwave module is employed for transmitting radio signals from LGAs to the transceiver and from the transceiver to LGAs and HGA. In addition the microwave module provides a constant RF output having power of 3 W.

## 3. SSETI GROUND STATIONS

A very substantial ground segment was developed by the collaborating teams to support the first SSETI mission - SSETI Express. It is expected that some part of this segment will be employed for the second SSETI mission along with new facilities purposely developed for the ESEO satellite. The SSETI Express ground segment includes the following main components [2]:

1. Primary Ground Station and Mission Control Computer (Aalborg, Denmark)
2. Secondary Ground Station (Svalbard, Norway)
4. Operations Team (Warsaw, Poland)
5. Telemetry Interface Database (Jouy En Josas, France).

The Primary (main mission) Ground Station in Aalborg is equipped with tracking antennas, an Ultra-High Frequency (UHF) radio, an S-Band to Very-High-Frequency (VHF) down-converter, a VHF radio, a Terminal Node Controller (TNC) and a controlling computer. It is the primary command station for controlling the spacecraft and for downlink of mission telemetry on both 437.25MHz and 2401.84MHz radio frequency channels.

The Mission Control Computer (MCC) serves as the interface between the operations team and the two ground stations (the main in Aalborg and the secondary one – in Svalbard). It is capable of controlling the uplink of detailed flight plans to the spacecraft and has a database where all downlinked telemetry is stored.

The Secondary (support) Ground Station in Svalbard is an assisting and back-up facility that provides additional UHF support for the telecommand uplink and mission telemetry downlink. Svalbard's extreme latitude has ensured 14 passes of the SSETI Express satellite per day, resulting in a high data return during the mission. This station is entirely remote controlled from the primary ground station in Aalborg. The MCC can be controlled remotely.

The Operations Team in Warsaw is responsible for defining the flight plans and commanding the spacecraft via the MCC and ground stations.

The Telemetry Interface Database (TIDB) in Jouy En Josas is a web-based facility aimed at the seamless dissemination of all mission telemetry (such as the temperature of subsystems and operating speed, etc.) from the MCC to SSETI Express teams, radio amateurs and the general public. Radio amateurs may also submit downlinked mission data to the TIDB.
The entire ground segment of SSETI Express has a rather sophisticated layout. In addition to the mentioned above primary components it includes a number of additional facilities in various countries in Europe as it can be seen from Figure 3 [3].

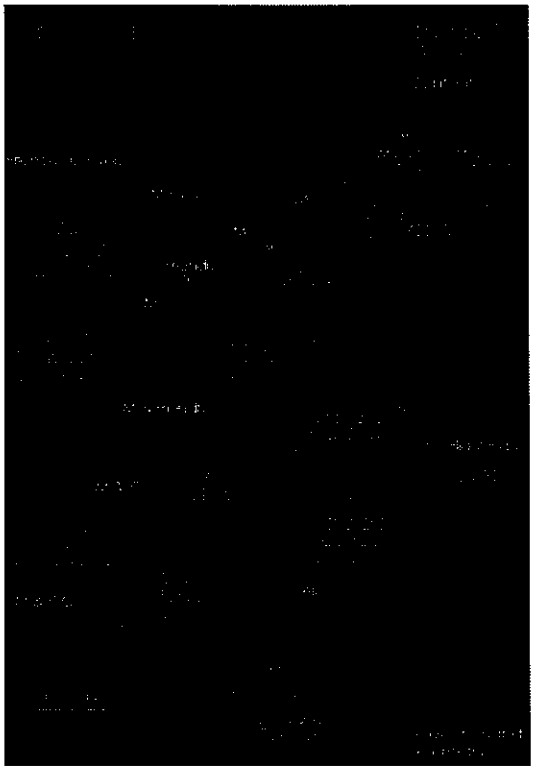

Figure 3. SSETI Express Ground Segment Layout

Unfortunately the ground segment doesn't provide any communication and control facilities either in the Southern hemisphere or over Pacific region. This was not a problem with the SSETI Express satellite that was clearly visible from European ground station locations. However, with the second SSETI mission - ESEO, where the satellite will be out of sight by the European stations for a rather substantial time, the need for an additional ground station has become apparent. This is where the Massey University team has made its proposal to SSETI to develop and host an additional communication and control facility in New Zealand for ESEO and other SSETI missions. The research and development towards implementation on the initiative has been under way since the beginning of 2007.

## 4. ESEO NZ GROUND STATION PROJECT

The New Zealand Ground Station for SSETI ESEO mission will meet the following main requirements:

- The Ground Station will track the ESEO satellite and communicate with the ESEO satellite with its onboard transceiver at any of the bit rates available at the satellite side.
- The Ground Station will exchange telemetry and telecommand data with the Mission Control Centre via secure connections over the Internet.

Since Massey University has three major campuses, three possible locations for the proposed SSETI Ground Station have been considered: Wellington, Auckland and Palmerston North.

The Wellington Campus has been selected to host the fully fledged SSETI ESEO New Zealand Ground Station that should be in full-scale operation at the time of the ESEO satellite launching (the choice has been mainly determined by the level of technical expertise and facilities available there). At the same time teams at other campuses will be involved in development of various subsystems of the ground station as well as in its integration and operation.

For example, there is already a comprehensive Massey University Auckland Ground Station for Amateur Satellite (AMSAT) service with Callsign ZL1MUA operational at Auckland Campus. The ground station has an appropriate transceiver plus high gain, computer tracked antennas for the 2m V-band and 70 cm U-band. It also has a 1.2m parabolic dish antenna for 13cm S-band together with an S- to V-band converter (SSB 3000). Our Auckland ground station is fully compatible with the AMSAT communication system onboard the SSETI Express. We plan to extend the functionality of Wellington ground station to serve the AMSAT aspect of the ESEO project.

To meet the mission requirements, the SSETI ESEO New Zealand Ground Station will include the following major subsystems (Figure 4) [4]:

- Tracking and Signal Receiving/ Transmission
- Amplification
- Frequency Conversion
- Modulation and Coding
- Data Processing and Networking

### 4.1 *Tracking & Signal Receiving/ Transmission*

A highly directional antenna (metal parabolic dish) will be used for transmitting and receiving data in the UHF/S band spectrum. The antenna will be used in a duplex mode (i.e., simultaneous sending signals to, and receiving signals from, the satellite). The larger the dish the better the directional gain, so the better the signal received and sent. Thus the 3m antenna has been chosen (it is one of the existing and available antennas at the Wellington Campus).

The currently developed satellite tracking and antenna positioning tools will ensure the automatic following of the satellite in its orbit. The positioning motors will to be capable of adjusting both the azimuth and elevation of the dish. In the future, for a completely flexible system the Elevation control might need to be extended from 0-90 degrees and the Azimuth control - to provide a continuous 360 degrees rotation.

### 4.2 *Amplification.*

The transmitter pipeline requires a High Power Amplifier (HPA) to amplify the outgoing Telecommand signal so that it has enough power when reaching the satellite.

A nonlinear Low Noise Amplifier (LNA) is required to receive the Telemetry signal from the satellite. This amplifier has to be of required high sensitivity to receive the telemetry. In addition it has to be nonlinear so as not to introduce interference from the nearby high powered transmitting signal. The LNA is located close to the antenna to boost the received signal power while adding as little noise and distortion as possible so that the noise of all the subsequent stages is reduced by the gain of the LNA.

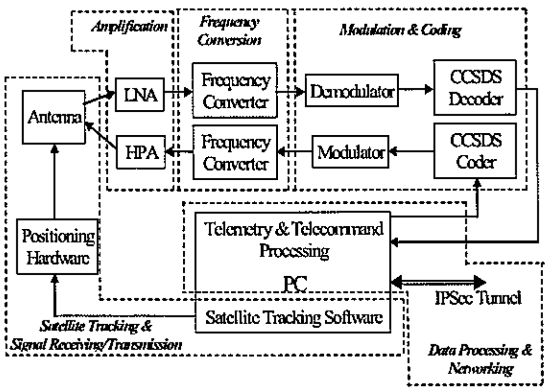


Figure 4. SSETI NZ Ground Station Architecture

### 4.3 *Frequency Conversion.*

This subsystem is employed in both the transmitter and receiver channels. However, it performs different operations in the pipelines: the frequency is up converted in the transmitter channel and is down converted in the receiver one. For ESEO mission the uplink frequency is between 2025-2110MHz, and the downlink frequency is between 2200-2290MHz. Before the downlink is demodulated, and after the uplink is modulated, the frequency converter needs to convert between these radio frequencies and the intermediate frequencies, much in the same way as a superheterodyne transceiver. An intermediate frequency of 70MHz will be used.

### 4.4 *Modulation and coding.*

Modulation and coding is required in the uplink and the downlink for telecommand data transmission and telemetry data reception, respectively.
The uplink has a data rate of 4 Kbps and the modulation is PCM(NRZ-L)/PSK/PM, where PCM(NRZ-L) is for Pulse Code Modulation with Non-Return-to-Zero-Level, PSK for Phase Shift Keying, and PM for Phase Modulation. The sub-carrier used for PSK is 16 KHz sine wave. The PSK signal is modulated onto the carrier by PM with a modulation index of 0.8 radians and the PM signal has an approximate bandwidth of 74 KHz. BCH (Bose, Ray-Chaudhuri, and Hocquenghem) coding [5] is applied to the telecommand data before the modulation.

The downlink has two data rates depending on the distance between the satellite and the Ground Station: high data rate of 153.6 Kbps and low data rate of 9.6 Kbps (primary) or 2.4 Kbps (secondary). Correspondingly there are two types of modulation: PCM(NRZ-L)/PSK/PM with 38.4 KHz sine wave subcarrier and modulation index of 1.3 radians for low data rate, and PCM(NRZ-L)/BPSK for high data rate. The bandwidth is 168 KHz for low data rate and 307 KHz for high data rate. The telemetry data is protected by convolutional coding as inner coder and Reed-Solomon coding [5] as outer code with interleaving of depth of 5.

As an additional functionality enhancing research and development project an application of Software Defined Radio (SDR) is being considered for this subsystem. Universal Software Radio Peripheral (USRP) is used for analog-to-digital conversion, down conversion and decimation and filtering the signal before sending it to the computer.
The USRP motherboard requires an appropriate daughterboard for the specific needs of this project with regard to the operating frequency and bandwidth of the SSETI satellite transmitter.

One of the options under consideration is to feed the IF/Baseband signal from a satellite receiver (off-the-shelf one or custom designed by a sub-group of the Massey SSETI team), to the SDR if an appropriate daughterboard cannot be used. GNU radio, a free software toolkit, is considered as an interface between the USRP and the PC while Python [6] is employed as the programming language.

### *4.5 Data Processing and Networking*

The processor (a high-specification PC) is employed in this subsystem. It must be fast enough to acquire and process both telemetry and telecommand data at the specified data rate. It has to be able to handle image data as well as measurement data once decoded. The processor will be linked to the network so the information will be relayed between the SSETI ESEO New Zealand Ground Station and the European SSETI partners.

The satellite tracking software is also run on the processor to track the satellite accurately in real-time with regular update of the Two-Line Element (TLE) data of the satellite.

An add-on to the project is a currently developed suite of software to interact with the Telemetry Interface Database (TIDB) in Europe using secure connections across the Internet.
The first step is development of a simple "listener" to the TIDB data feeds implemented by socket listening software. Once it is completed, the performance tests would then be carried from various computer platforms.

The next step is building this into a larger application that functions essentially as a "virtual ground station" listener to the satellite. In is planned that the software will be expanded then to allow commands to be sent to the satellite.

## 5. CONCLUSIONS

This paper briefly introduces the Student Space Exploration and Technology Initiative. It also outlines the Massey University project on establishing a New Zealand satellite ground station aimed at using for communication and control of SSETI European Student Earth Orbiter (ESEO) scheduled for launch in 2009. The project development is currently under way and we plan to keep our colleagues in the country updated on its progress through presentations at the future ENZCon conferences as well as through publications.

## 7. ACKNOWLEDGMENTS

We would like to acknowledge continuing and crucially valuable support and encouragement we have received from many SSETI and ESA teams and individuals, including:

- Professor Pawel Kabacik, Wroclaw University of Technology, Poland – Leader of the COMM_PL SSETI team;
- Mr. Per Berglund, ESEO Project Coordinator, European Space Agency;
- Mr. Roger Walker, ESEO Project Manager, European Space Agency;
- Ms. Erica Peterson, SSETI Secretary;
- Mr. Holger Endt, Coordinator of SSETI project at TU Munich;
- Mr. Martin Pfannenstein, Coordinator of ESEO German Ground Station team, TU Munich

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