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Global Satellite Tracking Initiative: Setting up ground stations to track satellites around the world

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ABSTRACT

The Global Satellite Tracking Initiative aims to facilitate students and young professionals setting up ground stations to download real-time data and images from satellites flying above their regions. The objective is to empower and build capacities among space enthusiasts around the world and to promote the space sector through hands-on activities and real space technologies related to satellite communications.

The Space Generation Advisory Council (SGAC) is an NGO that consists of a global network for students and young professionals interested in the space industry, with more than 15000 members globally from more than 150 countries. SGAC supports the United Nations Programme on Space Applications, with the vision of employing the creativity and vigor of youth in advancing humanity through the peaceful uses of space. SGAC organizes events worldwide, on a local, regional and international level, as well as several space-related projects within specific working groups.

SatNOGS is an integral part of the Libre Space Foundation, supporting the development of a global open source network of satellite ground stations. The projects supported are led by enthusiasts around the world operating ground stations, which can be openly accessed via an online portal.

Through the Global Satellite Tracking Initiative, SGAC and its partners will be providing all the resources, hardware, and know-how that is needed to set up several ground stations. A competition has been launched to select teams and individual space enthusiasts that will then be supplied with a kit and step-by-step instructions on how to build their own ground stations around the world..

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ACRONYMS/ABBREVIATIONS

SGAC Space Generation Advisory Council

GSTI Global Satellite Tracking Initiative

NOAA National Oceanic & Atmospheric Administration

ISS International Space Station

SDR Software Defined Radio.

INTRODUCTION

The Space Generation Advisory Council (SGAC) is the global network for students and young professionals interested in the space industry, with more than 15000 members globally from more than 150 countries. SGAC supports the United Nations Programme on Space Applications, with the vision of employing the creativity and vigor of youth in advancing humanity through the peaceful uses of space. SGAC organizes events worldwide, on a local, regional and international level, as well as several space related projects within specific working groups.

As members of SGAC, the authors determined that the organization could enhance its impact by engaging in hands-on activities for the benefit of young space enthusiasts around the globe. A proposal was submitted and the SGAC Global Satellite Tracking Initiative was selected to join the first cohort of the SGAC Incubator Programme [1].

The Global Satellite Tracking Initiative (GSTI) [2] aims to facilitate students and young professionals to set up ground stations and download real-time data and images from satellites flying above their regions. Due to the nature of the activities, the GSTI team got in touch with SatNOGS [3], an initiative by the Libre Space Foundation that operates an Open Source global network of satellite ground stations. The objective is that, once the GSTI teams have become familiar with the operation of the basic ground station kit provided by the GSTI, they keep developing their skills and capabilities while interacting with other space enthusiasts by joining SatNOGS operational collaborative network.

Selection process

The funding secured through the SGAC Incubator Programme, together with in kind contributions from partner organizations, allowed for the procurement and delivery of ten basic ground station kits. In order to choose ten teams from around the globe, a two-step selection process was launched in October 2021. The selection criteria used were:

Motivation: the responses ranged from university students trying to get involved in hands-on projects to local communities involved in scientific outreach interested in widening their portfolio of activities.

Feasibility: the answers received included individuals trying to set-up a ground station in their own backyard, as well as teams that had secured access to dedicated facilities already hosting telescopes and other receivers.

World Location: the teams were asked to explain why their geographical location was adequate for the project while being invited to check the existing coverage in the SatNOGS network. Applications from more than 60 different countries were received.

Outreach and impact: the responses went from university professors interested in offering their students a chance for practical training, to individuals in remote locations planning to help their local communities to be more engaged in science and technology.

The first step was an online application form, which allowed for a pre-selection of 20 teams among the close to 200 applications received. During December 2021, the GSTI team interviewed these 20 teams to come up with the 10 awardees. The selected team names and nationality are listed in Table 1 and their approximate geographical locations are shown in Figure 1.

Table 1: Table 1: Selected Teams

Team Name	Country
Chasqui 2	Peru
Fly by encounters	Egypt
GST Benin	Benin
Hanos Orbit	Ethiopia
Ludibrium	Vietnam
Pacha	Bolivia
Rwanda Space Agency Team	Rwanda
SEDS-MSU	Zimbabwe
Team Deep Space	Philippines
Team Everest	Nepal

Figure 1. Selected teams

Ground Station Kit

The Ground Station Kit was defined with the objective of minimizing cost, size and complexity. This was intended to maximize the number of kits that could be delivered within the available financial envelope while allowing for a rewarding experience from the participating teams in receiving their first space data.

Kit Size and Content

The kit was designed to fit in a plastic container box of 30 x 20 x 10 centimeters. When assembled, the size of the system is enlarged primarily by the deployment of a V-dipole antenna, composed of two rods of 50 centimeters each at an angle of 120 degrees.

The components of the kit are listed below:

- Raspberry Pi 4 model B
- SANDISK Extreme class 10 microSDHC memory card of 32 Gigabytes
- RTL-SDR V3 dongle
- Dipole antenna base with 60 centimeters of RG174 coaxial cable
- Two telescopic antennas of 23 to 100 centimeters
- 3 meter RG174 extension coaxial cable
- Flexible tripod mount
- Suction cup mount
- 3-D printed dipole antenna support at an angle of 120 degrees

Figure 2. RTL-SDR dongle and antenna set

Power Requirements

The kit uses power output from a standard USB port. Most USB ports supply 5 Volts of electricity with a maximum current of 0.5 Amperes. This leads to an overall power output of 2.5 Watts.

Targeted Satellites and Applications

The main objective of this initiative is to acquire signals from orbiting spacecraft for educational, inspirational and capacity building purposes. For this reason, the targets for signal acquisition will be spacecraft emitting openly, including:

- National Oceanic and Atmospheric Administration (NOAA) satellites, which provide timely access to global environmental data. Frequency band of 137 megahertz.
- International Space Station (ISS), since it is deemed that listening to a spacecraft that permanently hosts humans in space will be very motivational. Frequency band of 144-146 megahertz.
- Educational and scientific satellites (especially CubeSats) in Low-Earth orbit. There is the potential of contributing to the Launch and Early Operations Phase through collaborative networks such as SatNOGS. Frequency band of typically 400 megahertz.

Receiving and Processing Satellite Data

The process of assembling and setting up an operational ground station can be challenging for people with no previous experience in using similar technologies. In order to flatten the learning curve and make the encouraging experience of receiving and processing data from orbiting satellites more accessible, the GSTI includes a set of instructions and exercises that enable a gradual approach.

The instructions of the SGAC Global Satellite Tracking Initiative Kit are divided in two procedures:

- Procedure-1 (basic): focused on receiving weather data from NOAA satellites using a personal computer.
- Procedure-2 (advanced): focused on setting-up a Raspberry Pi with SatNOGS software, leading to an autonomous online ground station.

GSTI is currently working with the selected teams to implement Procedure-1, which is summarized in this section.

ANTENNA SETUP AND PROCEDURE

Procedure-1 starts with the assembly of the kit components and the deployment of the V-dipole antenna. The two telescopic antennas need to be extended to 52 centimeters of length [5] and inserted through the dipole antenna support to secure the 120-degree angle before connection to the dipole antenna base. Figure 3 shows the system assembled on the flexible tripod mount.

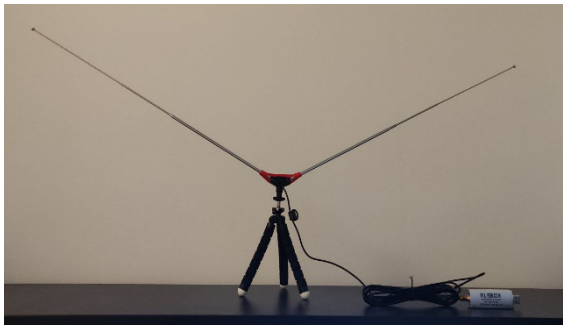

Figure 3. Antenna assembly

Downloading and installing the software

GSTI relies on the use of free-to-use software. The main software products required to complete Procedure-1 are:

- SDR# [4]: Software Defined Radio (SDR) software to tune into different frequencies.
- WXtoImg [5]: Fully automated weather satellite decoder.
- Satellite Tracking Software: Such as Orbitron (personal computer) [6] and Heavens Above (smartphone) [7], which facilitate the visualization of satellite orbit geometries and make it easier to understand where to point the antennas.

Exercise 1

The first exercise invites users to connect the RTL-SDR V3 dongle to their personal computer and configure it as the source within SDR# to listen to a local radio station. This helps the users to become familiar with the SDR# software, its configuration options and user interface.

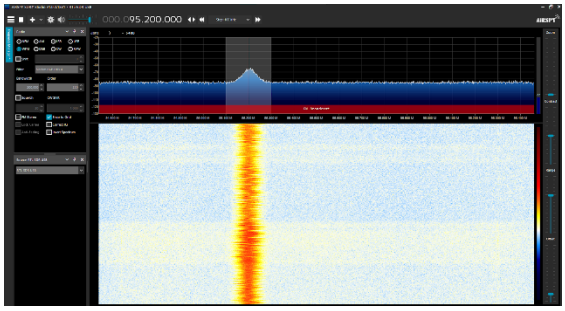

Figure 4. Local radio station signal in SDR#

Exercise 2

The second exercise focuses on decoding an image from the audio recording of a satellite signal [8]. This allows users to verify that they have understood how to carry out the record and image decoding functions in WXtoImg before attempting to capture a satellite pass.

Exercise 3

The last exercise of Procedure-1 consists of downloading an image from an operational NOAA satellite. The main steps are:

1. Plan a pass based on your geographical location and local time, making use of one of the suggested satellite tracking software products.
2. Configure SDR# to tune into the right frequency depending on the target satellite [9]:
    a. NOAA 15: 137.6200.
    b. NOAA 18: 137.9125.
    c. NOAA 19: 137.1000.
3. Record the pass and decode the images using WXtoImg.

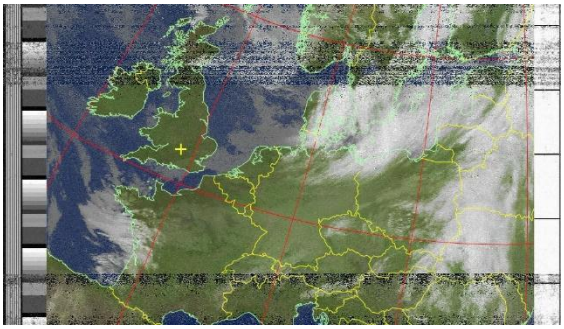

Figure 5. Decoded NOAA image using WXtoImg

RESULTS & SUCCESS STORIES

Team selected and worldwide impact

The SGAC Global Satellite Tracking Initiative received applications from close to 200 teams of space enthusiasts from more than 60 different countries. Due to funding constraints, only 10 of those teams are receiving a ground station kit.

During the months following the selection (March, April, May 2022), the focus of the GSTI team was sending the ground stations kits to the 10 selected teams. Several challenges were faced as costs for shipment were higher than expected and unexpected customs fees issues had to be addressed, which delayed expected delivery dates and ground stations set up by the various teams.

Team success story - Hanos Orbit

Hanos Orbit is a team of young professionals and students from Ethiopia with the vision to contribute to the development of the private Ethiopian Space Industry. It is composed of professionals from various fields of Engineering, GIS, Space Science and Business. They have been working on various capacity building and outreach activities at different capacities with the Ethiopian Space Science Society (ESSS), Space Generation Advisory Council (SGAC), and other stakeholders at local and international levels, nurturing their future spin-off, Hanos Orbit.

After receiving the ground stations kit and successfully setting up the antenna as described in the previous section, the team went carefully through the instructions from Procedure-1.

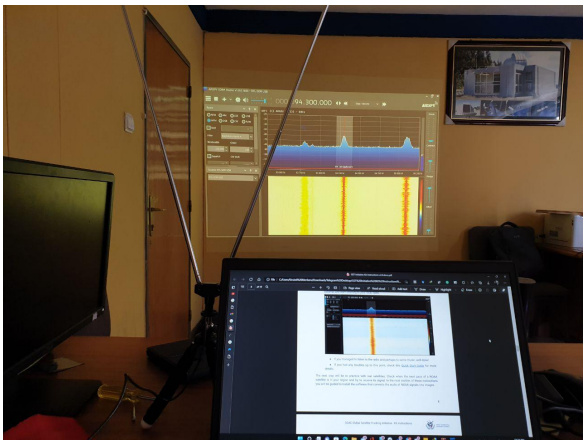

Figure 6: Antenna setup by Hanos Orbit team

As per the last exercise of Procedure-1, which consists of downloading an image from an operational NOAA satellite, Hanos Orbit team has been able to download their very first picture of the country and surroundings using NOAA 18 satellite.

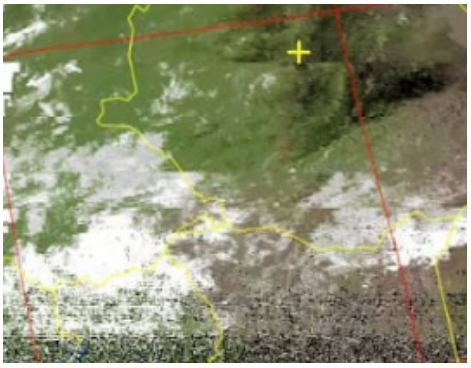

Figure 7: First picture from part of Ethiopia based on exercice 3

Next steps

All the teams are currently in the process of setting up their ground stations kits and getting familiar with the different exercises including in the Procedure-1. The objective of this initiative is to provide knowledge and hands-on experience through the use of hardware to countries with limited resources. The selected teams have already been grateful to SGAC for this initiative as they confirmed the possibility of doing more outreach to their respective universities using the materials. We are waiting for all the teams to go through the exercises and gather the pictures from their respective countries, but it is already considered a successful initiative.

Acknowledgements

The SGAC Global Satellite Tracking Initiative would not have been possible without the support of our partners, who have facilitated access to hardware, knowledge and resources:

- SatNOGS, an integral part of the Libre Space Foundation, is designed as an open source participatory project based on the users operating a ground station that is accessed via a web page.
- RTL-SDR.COM is a blog all about low cost software defined radios and their applications. They also manufacture and sell the RTL-SDR V3 and various low cost SDR accessories.

- SDR-Technologies is a French company specialised in Software Defined Radio based ground stations for satellite communications.
- GPIO Labs builds high performance, user-friendly RF modules. Application areas include radio astronomy, satellite communication, airplane tracking, agriculture, test & measurement and more.
- Pimoroni Ltd is a hobbyist electronics company based in Sheffield, Yorkshire, UK.

Here you have some examples of references.

1. SGAC Incubator Programme Website: www.spacegeneration.org/sgac-incubator-program, last visited: 20th March 2022.
2. SGAC Global Satellite Tracking Initiative Website: www.spacegeneration.org/sgac-incubator-program/2021-cohort/global-satellite-tracking, last visited: 20th March 2022.
3. RTL-SDR.COM Website: www.rtl-sdr.com/simple-noaameteor-weather-satellite-antenna-137-mhz-v-dipole, last visited: 20th March 2022.
4. Airspy Website: www.airspy.com/download, last visited: 20th March 2022.
5. Wraase Website: www.wraase.de/wxtoimg, last visited: 20th March 2022.
6. Stoff Website: www.stoff.pl, last visited: 20th March 2022.
7. Heavens Above Website: www.heavens-above.com, last visited: 20th March 2022.
8. RTL-SDR.COM Website: www.rtl-sdr.com/rtl-sdr-tutorial-receiving-noaa-weather-satellite-images, last visited: 20th March 2022