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Blending Training of Students and Promotion of Space Technologies by Designing Satellite Communications

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Abstract: The purpose of this paper is to promote satellite communications by creating a communication and control platform that simplifies the interaction between the operator and the communication algorithms. The communication platform represents the application level of the nanosatellite communication stack and allows to provide the user with a simple and explicit graphical interface on the one hand and on the other hand it must automate, as much as possible, the nanosatellite communication process. The platform must allow users to receive useful information received from the nanosatellite, information on the status of the satellite and its subsystems, and to send to the nanosatellite the appropriate commands to configure it, reset it or request useful data. The general communication architecture with the nanosatellite is obtained after the implementation of the communication platform and the monitoring of the nanosatellites. In order to make the training process more efficient, it is proposed to apply the blending elearning approach. There are online courses on the elearning moodle TUM platform that reflect both the theoretical and practical part of satellite communications, which are mandatory for students studying these disciplines, as well as accessible to other students who want to get acquainted with modern satellite technologies.

Keywords: satellite communication, educational nanosatellite, ground station, blending training

I. INTRODUCTION

The National Center for Space Technologies (NCST) of Technical University of Moldova (TUM) has been oriented towards a series of nanosatellites, according to the international standard CubeSat. In 2019, the NCST team participated in the fourth round of the KiboCUBE Program with the "TUMnanoSAT" nanosatellite project proposal and won this competition for free launch by JAXA. This project includes the student-initiative design and fabrication of critical components, including the payload and CubeSat modules. From the other hand the satellite communication is also very important. The reception of the satellite telemetry data and

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payload data is achieved through a radio architecture. The functionality of a traditional radio architecture, within a satellite communication, is primarily based on hardware components, with minimal software configurability. Conventionally, they consist of: modulators, coders, amplifiers, filters, mixers, etc., dedicated to a certain mode of transmission. The software part is dedicated to the control of the interfaces with the communication network. Given that the hardware predominates in this model, a possible upgrade of the system would mean a total change of the model and a redesign of the system. SDR or Software Defined Radio solves this problem.

The discussed communication platform represents the application level of the nanosatellite communication stack and allows to provide the user with a simple and explicit graphical interface on the one hand and on the other hand it must automate, as much as possible, the nanosatellite communication process. The platform allows users to receive useful information received from the nanosatellite, information on the status of the satellite and its subsystems, and to send to the nanosatellite the appropriate commands to configure it, reset it or request useful data. Based on this communication platform, the students acquired experience with industrial level integration and testing procedures. Undergraduate teams working on TUMnanoSAT lead the design and fabrication of the payload, structure, and system integration, providing experience with systems engineering, technical writing, and various cross-disciplinary applications. Over fifty undergraduate students, several graduate students and faculty members from several departments were involved in this project in both the development and testing of the TUMnanoSAT nanosatellite subsystems to enhance understanding of the fundamentals of engineering.

In order to make the training process more efficient, it is proposed to apply the blending elearning approach. There are online courses on the elearning moodle TUM platform that reflect both the theoretical and practical part of satellite communications, which are mandatory for students studying these disciplines, as well as accessible to other students who want to get acquainted with modern satellite technologies.

II. RECEIVING STATIONS OF TUMNANOSAT

Successful missions require good communication with the ground segment. The satellite subsystem is based on the Endurosat UHF transceiver, based on the SI4463 integrated circuit from Silicon Labs. The basic features of the messages transmitted by TUMnanoSAT are:

- GMSK Modulation
- AX.25 protocol
- 9600 baud-rate
- NRZI and G3RUH Scrambled
- 1 W transmission power
- Beacon Frequency: 1/30 s
- Telemetry Frequency: On request

TUM Center of Space Technologies has 2 ground stations with the following architecture:

The ground stations are located at 200 km distance. Each station has two antennas assembly. The antennas, mounted on the mast, are connected with RF ecoflex cable to the LNAs (Low Noise Amplifiers). X-Quad 70cm and X-Quad 2m to LNA SP70 and LNA SP200 respectively. The next node connected from the LNAs consists of coaxial relays which split the signal for feeding it into the ICOM IC-9100 and USRP B200/E310 to be further processed. Besides the main RF connections there is also a data line connection from the PC Ground station to the signal processing units (ICOM and USRP) and a control line connection to the rotator controller and relays.

Ground station have 2 possible variants of SDR configuration:

- The first choice is USRP B200 as a peripheral device and a PC as a processing device, connected through USB interface (preferably USB 3.0 for more bandwidth)
- The second choice is USRP E310 as both, peripheral device and processing device. USRP E310 uses its FPGA for digitizing the received data and its core for processing, working as a standalone device and mounted directly on antenna mast.

Regardless of the configuration of SDR that we choose, a software program is needed to process the data. The easiest way to create such software is to use GnuRadio Companion. In the figure 3 is presented flowgraph created in GNU Radio for communication with TUMnanoSAT, the telecommand part. ZMQ PULL Message Source is used as a socket for external application, then these messages are encoded in a AX.25 frame. Fixed Length Framer is modified digital block to create radio packet according to TUMnanoSAT Si4463 transceiver. Also Center of Space Technologies at Technical University of Moldova arranged a Mission Monitor and Control System where it is possible to see and control each antenna and get the information from a specific satellite. The software used for tracking is Gpredict. In Mission Monitor and Control System is integrated as well remote control of satellite communication ground stations [7] .

One of the biggest problems that face universities ground stations is their underutilization problem. Most of the time, ground stations sit unused due to short window of communication with satellite. The communications window for common CubeSats in the LEO is about 12 min per pass in the best-case scenario. In practice, however, the quality of a pass is very sensitive to the environmental factors as well as maximum elevation of the satellite as seen from the ground station. One of solution is, of course, utilization of networks that allow collaboration and collection of data between ground station operators. There are a lot of projects meant to make easier communication between stations [2].

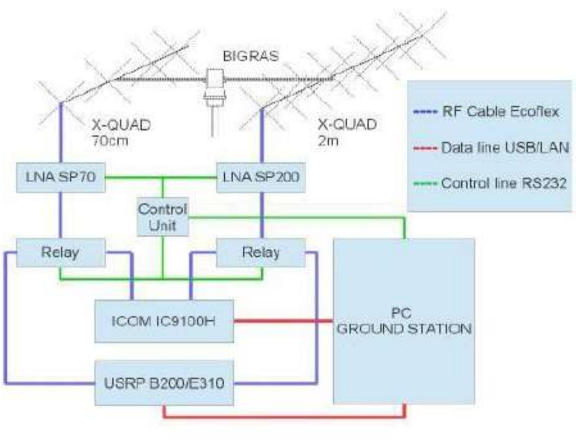

Figure 1. TUMnanoSAT ground stations architecture

Figure 2. Antennas assembly at TUM NCST

TUM Center of Space Technologies started to implement its own network of ground stations, during 2016-2018 under the project "Developing the Terrestrial Satellite Networks as a Platform for Cooperation with European Spatial Technology Partners" in partnership with the Space Sciences Institute (SSI) of Romanian Space Agency (ROSA). The idea of connecting ground stations through a virtual network of computers was developed within the project, which allows considerable extension of the radio visibility period of a satellite and, consequently, increasing the amount of data sent. Another opportunity is the simultaneous reception of data from a satellite via several ground stations, and storing them in the command center, where the data packages will merge. For the first stage were connected ground stations from TUM Center of Space Technologies and ground station from SSI of ROSA, Bucharest, Romania, based on which the interaction procedures were verified [5].

III. REMOTE CONTROL OF SATELLITE COMMUNICATION GROUND STATIONS

The TUM Center of Space Technologies network of ground stations is designed and constructed so as to ensure the communication among stations regionally / worldwide via the Internet. Ground stations can communicate via client applications with server components based on TCP / IP protocol. The architecture developed enables centralizing the data received from a satellite by different ground stations in the same database. Client applications can only communicate with the server, Server components having the administrative role. The Server component is the only link of the system which provides access to the database and is able to communicate with all client applications in the system. In order to implement the remote control of ground stations, the “client-server” classical architecture was taken as the basis consisting of three parts: a VPN server and a separate network device that interconnects the main server and the clients in a secure manner; the main high-performance server that manages the entire network and provides a web interface for end users; a number of clients PCs worldwide connected to the VPN network. Clients can be of two categories: the first category - only to access the web interface, and the second category - to connect the ground station to the network for its joint use [5-9].

Figure 3. Mission Monitor and Control System

Currently, the VPN server runs on the computer MikroTik Cloud Router with advanced performance - a high level of flexibility and a wide range of possibilities. The main server is running on the "blade" type server Sun Microsystems and Ubuntu Server LTS is used as operating system and provides a range of personalized services developed for the remote control of ground stations. For the purpose of redundancy, a second "blade" type server is installed, identical to the main one. The client computer can be any type of PC, from a medium performance SBC to a "high-end" desktop computer. The choice depends on the purpose of the end user, which may consist of access to the web interface and / or connection to the ground station. At the current stage of implementation, the client software for the connection to the ground station has been tested successfully on a Raspberry PC SBC module and a desktop PC, which is running an Ubuntu distribution, but it can run any other operating system: Microsoft Windows, Mac OS X, GNU / Linux and even on BSD derivatives.

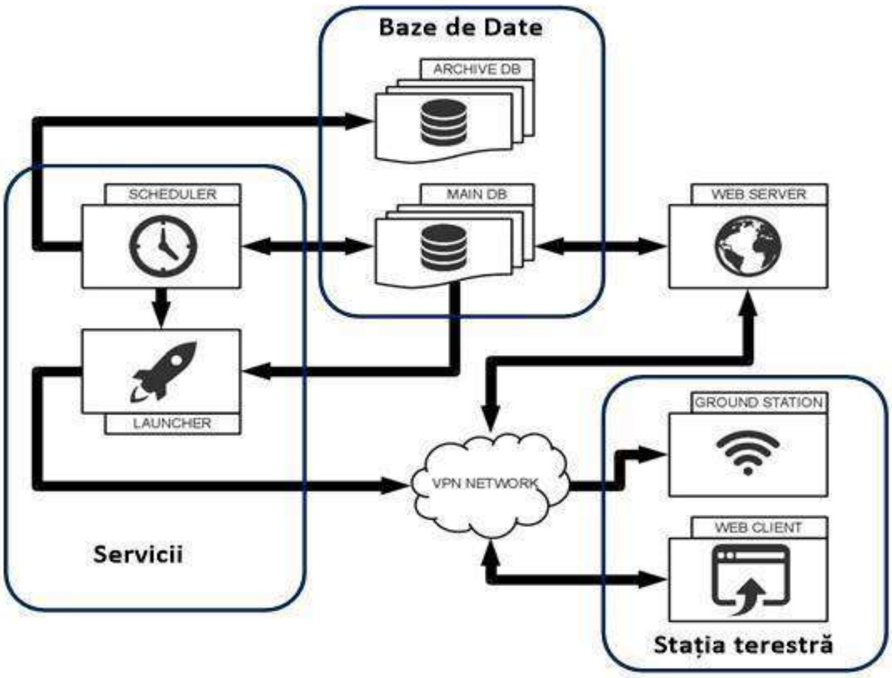

Figure 4 Server components of remote control of the ground stations.

The Software "server-side" component was developed at NSTC that provides the following services and / or certain functional destinations [10-13]:

- **Main DB –** the main database for storing data necessary for current operations (data stored for a short period of time);
- **Scheduler** – monitors the main DB for current data, making decisions based on previously acquired data - appealing the **Launcher** or sending data to the **DB archive**; maintaining and updating TLEs and future observations based on updated information;
- **DB archive –** database in which previous data is stored in the long term;
- **Web Client –** GUI component, enables end users to interact with the system in order to schedule new observations or remove old ones, view information about the connected ground stations etc. (only accessed by clients of the VPN network);
- **Web Server –** ensures the functionality of the Web Client component and access to databases;
- **Launcher –** is the service that communicates with clients (those with the ground station connected), sending them commands required to fulfil specific tasks based on some parameters provided by Scheduler;
- **Ground Station –** is the end point of the system that receives and executes the requested commands.
- **VPN network –** client-server communication via secured VPN network tunnel; **Server Link –** the client receives all commands from the server-side component.

IV. DATA MANAGEMENT FOR INFORMATION RETRIEVAL IN GROUND STATIONS NETWORKS

Monitoring ground stations are not built typically parallel because, on the one hand, the beam of radio waves from the satellite is relatively narrow and, on the other hand, the development of several backup ground stations for a space agency can be very expensive. Networks of educational ground stations can share resources to ensure simultaneously the reception of the data stream from a single satellite. The reception from a “downlinks” satellite offers both opportunities and challenges. The opportunity is to get redundant data from ground stations, and the challenge lies in the need to develop a system that requires the use of appropriate methods of management and data synchronization.

Data management has evolved from the idea of combining multiple data streams from the same satellite, received at a number of geographically distributed ground stations. Theoretically, these data streams received in parallel by ground stations should be identical, but in reality they differ for several reasons. For example, the interaction time of each satellite and ground station differs depending on the route. When two routes overlap, the ground stations being geographically spaced apart, there is a small period of time during which only one of them will be in contact with the satellite. Thus, each station receives different sets of data frames. To solve this problem ground stations of the network must be synchronized between them, to command data frames received on a common time scale worldwide. This supposes both synchronizing computer clocks and timing of subsequent data streams.

V. Blending Training of Students to promote Space Technologies

In the last time it is observed a slowing interest of pupils and students towards a research or engineering career. In the same time there was noticed an underperformance of current students in engineering and science. Analyzing the reasons for this poor performance, there were identified several key factors including the quality and incompleteness of academic programs, the existing gap in scientific knowledge among school teachers, the lack of information, motivation, environment and opportunities for children and students regarding the science and technology. Space endeavors and related technologies are a constant and strong catalyser for human scientific development and can be successfully used to attract the interest towards science and engineering of a larger number of people from four target groups at different education levels: children, high school students, students and master degree students, PhD students.

As a global approach project includes raising awareness about space field, generating relevant project ideas and their implementation, creating a favorable environment for personal scientific development among the target groups. The outreach activities are differentiated for each group taking into account their education levels and backgrounds. For the first group, it is intended to draw the attention towards the space science through movies and lectures held at the planned planetarium located in the observatory at NCST-TUM. Furthermore, for those interested there will be available online lectures and contest proposals placed on the planned website platform.

In order to initiate the 2-nd group in the space technology there were planned the online lectures on relevant science areas such as of physics, mathematics and programming, followed by the proposals to use the gained knowledge in practical activities related to aircraft flights and mechanics of celestial bodies, assembling simple Robo-KITs, aircraft and copters KITs and even classroom satellites (CubeSat format). To boost and maintain the motivation there are planned contests and summer schools. The general scope of activities planned for this target group consists in increasing the number of high school students with an interest towards university education in the specialties related to space science and engineering.

For the current university students, the proposed activities include online and video lectures on advanced topics not covered by standard curriculum such as microcontrollers and electronics used in spacecraft and satellites, satellite design, attitude control and stabilization etc, generating project proposals (including license and Master Degree theses) related to space science and their implementation, summer schools and workshops with invited speakers from the consortium partners. The biggest motivation will be to have the opportunity to participate in the design and elaboration of SATUM. The partners involved in the project will compliment each other in creating and implementing the educational content, and sharing their expertise and knowledge.

Regarding the PhD students, it is necessary to prepare intriguing research topics, provide an adequate environment, equipment and assistance and offer the possibility of bringing their ideas to life. The partners also can be involved in co-advising joint Doctoral Degree theses. All information about recent developments of space science and technology, online and video lectures, contest conditions, assistance will be integrated on the to be developed website platform that will allow effectively and efficiently share resources, communicate with target groups, disseminate results and distribute the project information to the press and the public.

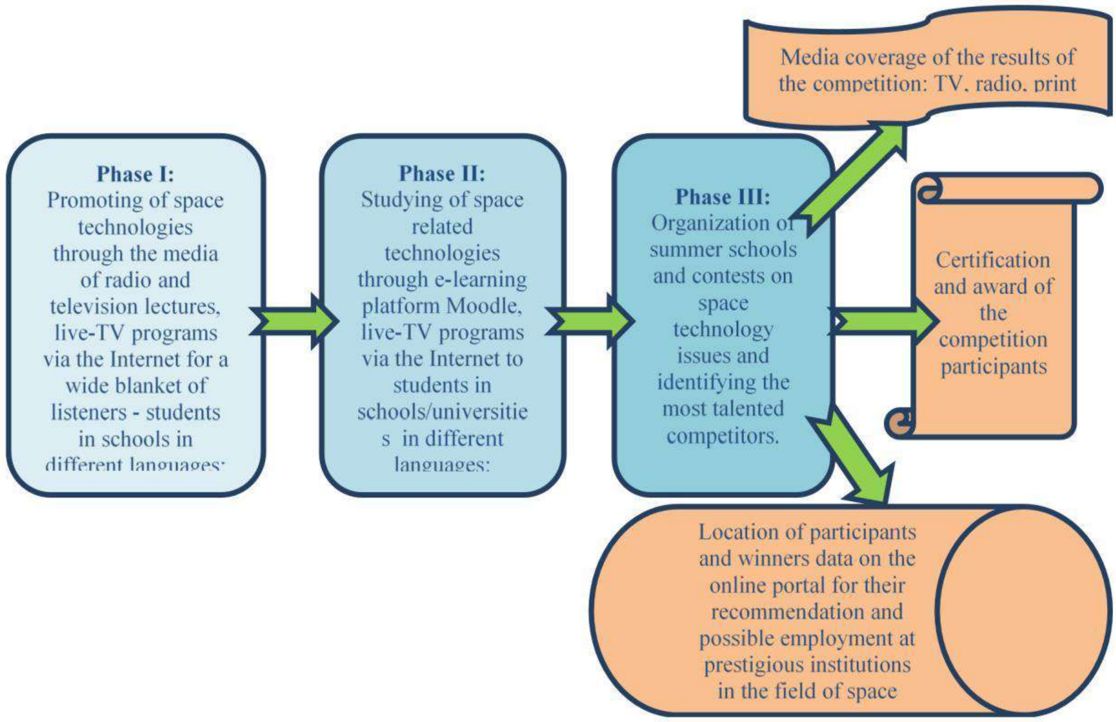

Figure 5. The scheme to promote the space technologies for the I level - pupils in schools and level II - students from universities.

In order to achieve the main goal of this proposal - excluding the lack of scientists, engineers and technicians on the area of space research and development by dissemination of experiences in the space domain and to contribute to building of long-term partnerships between peoples from different Europe countries there are planned activities that can act as catalyzers in motivating pupils and students at different ages and education levels: **Phase I:** Promoting of space technologies through the media of radio and television lectures, live-TV programs via the Internet for a wide blanket of listeners - students in schools in different languages: Romanian and English as possible. **Phase II:** Studying of space related technologies through e-learning platform Moodle, live-TV programs via the Internet to students in schools/universities in different languages: Romanian and English as possible [15-16]. **Phase III:** Organization of summer schools, workshops and contests on space technology issues and identifying the most talented competitors. Training cycle ends with a media coverage as party competition and awarding participants. An important point is to create a "database" of participants with recommendations for their admission at prestigious institutions and/or companies engaged in space research and technology development.

VI. CONCLUSION

TUM Center of Space Technologies developed a terrestrial infrastructure with a modern approach in the communication procedures with the microsatellites using Software Defined Radio technology for communication. SDR provides a new approach to designing a network of ground stations satellite, an approach that brings primarily significant reduction in design complexity and cost and offers a flexible environment, versatile radio architecture development. There were identified a several key factors including the quality and incompleteness of academic programs, the existing gap in scientific knowledge among school teachers, the lack of information, motivation, environment and opportunities for children and students regarding the science and technology. The implementation of project results will improve the quality of teaching by providing all study materials and imposing a study discipline as well as for parttime studies, continuing education and full-time studies.

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