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FUNcube – cosmic teaching aid

Summary: The author describes the use of amateur radio satellite FUNcube-1 (AO-73) for educational purposes. He discusses the issue of the hardware and the free software that is needed to implement activities in the project FUNcube. The author indicates the possibilities of their educational applications.

Keywords: satellites education, orbits education, space education; radio communication, amateur radio (HAM radio); support of STEM - science, technology, engineering and mathematics.

Today, even a child knows that satellites are placed in orbits that surround the earth, he or she is aware of the fact that low, high and geostationary earth orbits exist. Nowadays many people make use of these scientific achievements. However, they hardly ever think of the functioning essence of these devices. Telephony, television, satellite navigation appear to be well - known issues to everyone, these devices are easily accessible, they are "within arm's reach", nevertheless human knowledge about their functioning is often insufficient.

To comprehend the principles of the cosmic communication devices usage, ham radio operators' support might be needed. These people are pioneers in making use of the objects that are situated in outer space with the aim of communication. Four years after the artificial satellite Sputnik was successfully launched by the Soviet Union into the low earth orbit and a few months after the first human journey into outer space, took place (12 December 1961) the first Orbiting Satellite Carrying Amateur Radio was launched into space.

It was OSCAR-1. It was a 10 pound construction. Unfortunately, OSCAR-1 lasted only 21 days in an orbit before its batteries gave out[1]

Today, radio amateurs, ham radio operators, short wave listeners all over the world and they have a possibility to make use of many various-much more up-to-date cosmic radio stations ideas. The International Space Station is also equipped with the ham radio and it carries out a very popular project ARRISS – Amateur Radio on the International Space Station[2] A specialist group of ham radio enthusiasts do not only construct their devices, but they also talk about their experience with ham radio operators and even with people from all over the world, who do not get involved in the technical issues.

FUNcube – in English language it can be understood as a funny box, this is how the British and the Dutch constructors have defined their own project and their own satellite. These constructors constitute a team of the British and the Dutch volunteers with a small budget earmarked for their undertaking. These people are amateur radio operators (most of them have granted the license) and belong to AMSAT[3] an organization that deals with amateur radio communication with the use of the satellites. AMSAT organizations do not only focus on designing and building these satellites, but they also coordinate their functioning in the orbits and supervise the British Public Benefit Organization *Radio Communications Foundation.*

FUNcube is a type of miniaturized satellite for space research, called CubeSats. It usually has got a volume of exactly one liter (10 cm cube) and has a mass of no more than 1 kilogram. It is the smallest size, so -called one unit with (1U-*one unit*) - for this type of satellites.

CubeSats are usually made of units and components that are manufactured by specialist companies, that contributes to the low cost of their production, to the necessary tests that are carried out before

[1] Z. Bieńkowski: *Poradnik ultrakrótkofalowca*. Warsaw,1988, s 153-155
The Book is available at Academic Digital Library AGH;
http://winntbg.bg.agh.edu.pl/skrypty2/0067/; (4Septmebr 2014)

[2] The Global web page : *Amateur Radio on the International Space Station (ARISS)*; www.ariss.org/; (6 September,2014). Polish website : Official Polish website on *ARISS in polish* ariss.pzk.org.pl/; (6 September, 2014)

[3] *AMSAT North America | The Radio Amateur Satellite Corporation*; www.amsat.org; (8 September 2014).

launching them into outer space and to location on the proper orbit- in this case a small size and weigh of the object plays a prominent role.

This group of satellites also includes Polish artificial satellites[4]: PWSat made by students (it was launched into the orbit in 2012) and its sequel PWSat 2, that has been constructed and has been prepared to its mission in space by students of Space Club, that has been established at the Warsaw University of Technology[5].

The concept of CubeSats is often used in educational projects and dissertations at many schools, including universities and universities of technology all over the world. Some projects are left under construction and test procedures, that only prepare them to be put into action, however some of them are launched and go straight to the earth orbit in one part, except for the ones that fall into pieces on its way that in the consequence, move in the vicinity of cosmic space, this undertaking is possible to be performed on the basis of some projects *(California Near Space Project*[6] – or Polish project – *Copernicus*[7]) that make use of high-altitude or weather balloon.

The history of Funcube project dates back to October 2009, when the British team of volunteer workers from AMSAT-UK in collaboration with Radio Communications Foundation (RCF) worked a new amateur satellite concept FUNcube, consisting of FUncube-1 and FUNcube-2 projects, the latter will be launched to the orbit in the future as a follow-on, moreover FUNcube-2 is going to be a part of the bigger, triple satellite called U Kube-1 (3U).

An independent work of the British Consortium turned out to be too expensive in the end. One of the major obstacles concerned the cost of the British Cosmic Agencies license receiving, therefore the Dutch support of AMSAT-NL seemed to be inevitable, in this way the satellite has been registered as the Dutch spacecraft. The Dutch partners have contributed largely to the FUNcube technical construction, because they

[4] *PWSat2 – th Polish satellite made by students* www.pw-sat.pl; (8 September 2014).
[5] Students' Space Club; www.ska.pw.edu.pl; (8 September 2014).
[6] *California Near Space Project | Silicon Valley, California*; http://www.cnsp-inc.com/; (8 September 2014).
[7] *Copernicus Project .:. FIRST pOLISH Near Space Program*; http://copernicus-project.org/; (8 September 2012)

financed the process of some creation of crucial components. It is very significant that they also signed a contract that guaranteed launching the satellite to the orbit.

The satellite was successfully launched from Russia on a DNEPR rocket on November 21st 2013. Nowadays, it goes around the earth nearly 15 times during day and night, it takes place 670 kilometers above the earth, and its orbital period equals to 97 minutes and 26 seconds. FUNcube-1 appears on the list of amateur radio satellites as A0-73. From the very beginning - as the first assumptions indicated - FUNCube project **has been referred to schools.** The major aim of this satellite has been connected with making children and teenagers more interested in radio communication, exploration and knowledge expansion about outer space, physics and electronics. According to its authors this project has a positive impact on learning Science and Mathematics in the context of STEM (*Science, Technology, Engineering, Mathematics*.)

FUNcube creators' assumptions can be classified as the philosophy of the popularizing activities that are realized by the cosmic agencies all over the world, including European Cosmic Agency (ESA). Teachers who are interested in implementation of the cosmic space issues to their work have many possibilities to do it. Therefore, they are recommended to visit social web portals like ESA[8] or American NASA[9]. The main task of the FUNcube-1 (AO-73) is to transmit the telemetry data, that can be easily received and decoded by schools, universities and other educational institutions all over the world.

The FUNcube project is addressed, to its free of charge use all over the world and for every level of education. In Special handbook[10] there are various aspects of the satellite use mentioned an issue of the software that is used during different school activities is also discussed. Different aspects connected with telecommunication, tele-information services and the theories of electromagnetism, radio waves, are also emphasized there, as well as some geographical issues (countries, places, the weather etc). In this book some other information can be also found, for example,

[8] *European Space Agency Teachers Corner*; www.esa.int/Education/Teachers_Corner; (9 September 2014).

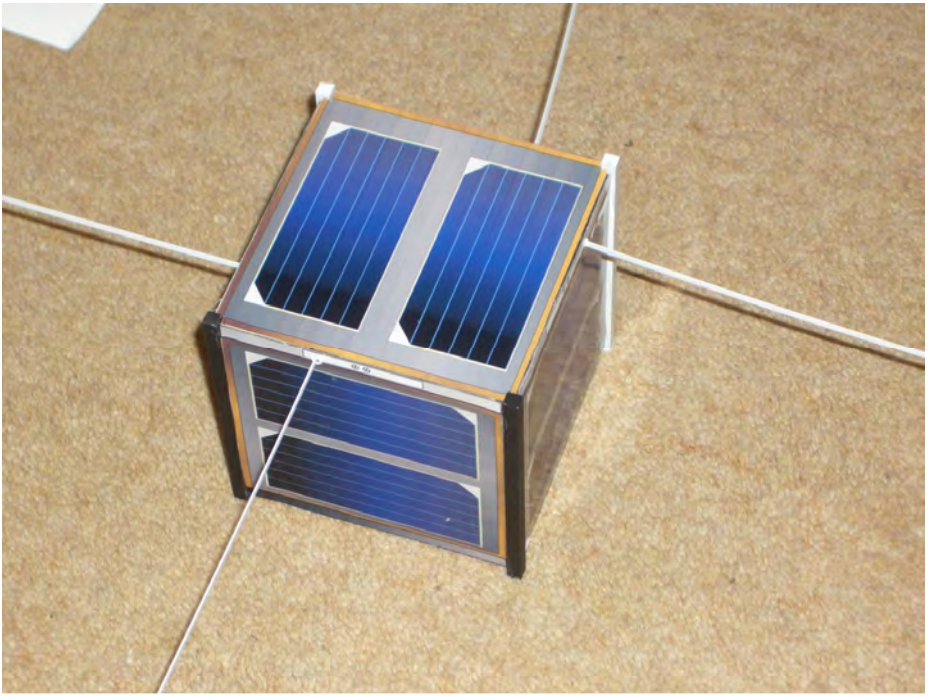
[9] *NASA Education*; www.nasa.gov/audience/foreducators; (9 September,2014).

[10] R.W.L. Limebear, C. Mercier: *The AMSAT-UK FUNcube Handbook*. First Edition, AMSAT-UK, November 2013, s. 9.

connected with a size comparison of the micro satellite (10 centimeters long on its side) with International Cosmic Station (its size is compared to five double-decker buses). There are also suggestions on battery functioning and the solar system, including radiation.

The possibilities of the small satellite are great, one of them is connected with the system of sending short text messages. This information can be useful to schools, teachers and students, moreover, it is worth mentioning that these text messages can also comprise greetings, congratulations etc. They may look like popular text messages; however, they reach all the recipients, who decode FUNcube signals. These messages are named *Fitter Messages*, and they have their own section in computer software.

Pict. 1. A model of the satellite FUNcube-1 (AO-73) that is ready to work



Source: *www.funcube.org.uk*
– a paper model to single-handedly making(also during the didactic activities) you can download it at:
http://funcubetest2.files.wordpress.com/2011/03/fc_model_graphics.pdf

The satellite works in two major modes. Their efficiency primarily depends on - (*in automatic model of working)* - lightening it with the solar light. When it is located in the range of solar radiation, it manages to fulfill its educational mission. When it is covered by the earth shadow, the device changes the mode of the transponder (receiver-transmitter) that can be used by ham radio users with the license in order to have phonic (audio) and telegraphic (with the use of the Morse code) communication. Not only was an issue of the cosmic segment taken into consideration in this project, but also a very important part of this undertaking was connected with the **fit-out of the ground stations** which include various equipment and computer software that could be used in educational institutions that are financially restricted. A cheap and easy to use device has been developed for this purpose. This device plugs into the USB port of a computer and functions as the communications' receiver (*SDR – Software Defined Receiver),* moreover, special software that enables telemetry signals decoding has been developed. The same function may be executed by some television sets that plug into the USB port of a computer (for example, the ones with the chipset RTL2832U+R820T) particularly, when the cost of the purchase does not exceed a much in computer shops and the hardware is available for free in online marketing.

Information and other instructions can be found online at various web pages and different internet forums, and when it comes to selecting the equipment installation a customer can count on the support of specialists, either. Another advantage of obtaining digital signals with the use of the computer receiver is connected with the lack of advanced antenna systems. Many elaborations and guidebooks that deal with this subject are published by amateur radio operators online, these e-books can be very useful to students and teachers at design and technology lessons, for example.

The FUNcube project s*oftware*[11] decodes telemetry data and displays them by the means of the user special graphic interface.The data comprise information of the external and internal surfaces of the satellite heat that is provided by its sensors.

[11] FUNcube *Telemtry Dashboard*; http://funcube.org.uk/working-documents/funcube-telemetry-dashboard/; (9 September 2014.)

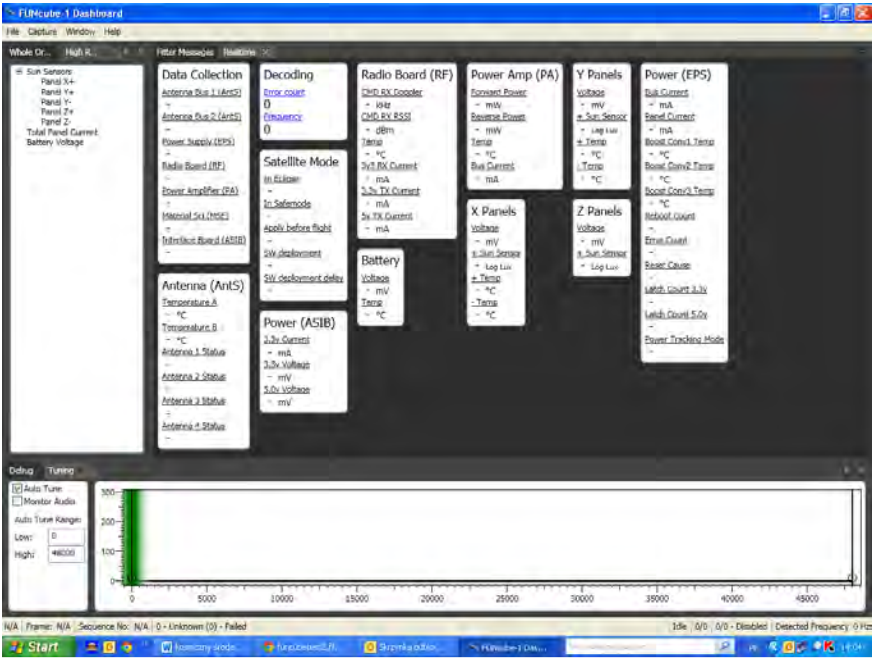
Furthermore, the voltage and the electric power of the solar cells and FUNcube batteries data are also collected, other exploitation information are included either.

The data that seems particularly interesting from the educational point of view are concerned with *Material Science Experiment* (MSE), in other words „*Leslie's Cube*" - it is a metal box with four differently painted sides. It demonstrates the absorption and emission of the solar radiation in space, this is achieved by sending information about current temperature of all sides of the box.

Additionally, the software enables to display information that relates to the orbital period of the satellite around the earth, including its exposure to the sun light and the time of eclipse. It also helps to correlate the solar activity with the effectiveness and directionality of antenna systems data etc.

The data are shown by means of the software-user graphic interface called *the Dashboard; the name was given by its creators.*

Pict. 2. The image of the major graphic screen of the user interface – The FUNcube Telemetry Dashboard



Source: www.funcube.org.uk

In relation to the fact, that the satellite is in a permanent move and goes around the earth on its own orbit, it is essential to become familiar with the current location of it. The web page about the FUNcube project and its bookmark delivers necessary information about the location of AO-73 on the map[12]

Sometimes, it is possible to use more advanced computer system that can work both offline and online[13] to perform this activity.

In the second case, computer system by – Sebastian Stoff - *Orbitron*[14] can be used

The author claims: *Orbitron is a satellite tracking system for radio amateur and observing purposes. It's also used by weather professionals, satellite communication users, astronomers, UFO hobbyist and even astrologers. Application shows the positions of satellites at any given moment (in real or simulated time). It's free (Cardware) and it's probably one of the easiest and most powerful satellite trackers, according to opinions of thousands of users from all over the world. Try it, if you like it tell your friends about it and send me a postcard* [15].

Orbitron not only tracks the fake orbital objects but also determines the location of the natural satellite- the moon in relation to the earth direction. Sun location can be also simulated, as well as defining the areas of our planet that are lit by it. The way this issue can be used in didactic process depends only on teachers' creativity and ingenuity. The possibility of showing data in real-time system or simulating them whenever it is required makes this system unique.

FUNcube project program has not been finalized, its concept is still under development. Satellites originators launch other objects that orbit the earth, another spacecraft called FUNcube-3 was safely launched on June 19th 2014 and located into the orbit on January 19 2014.

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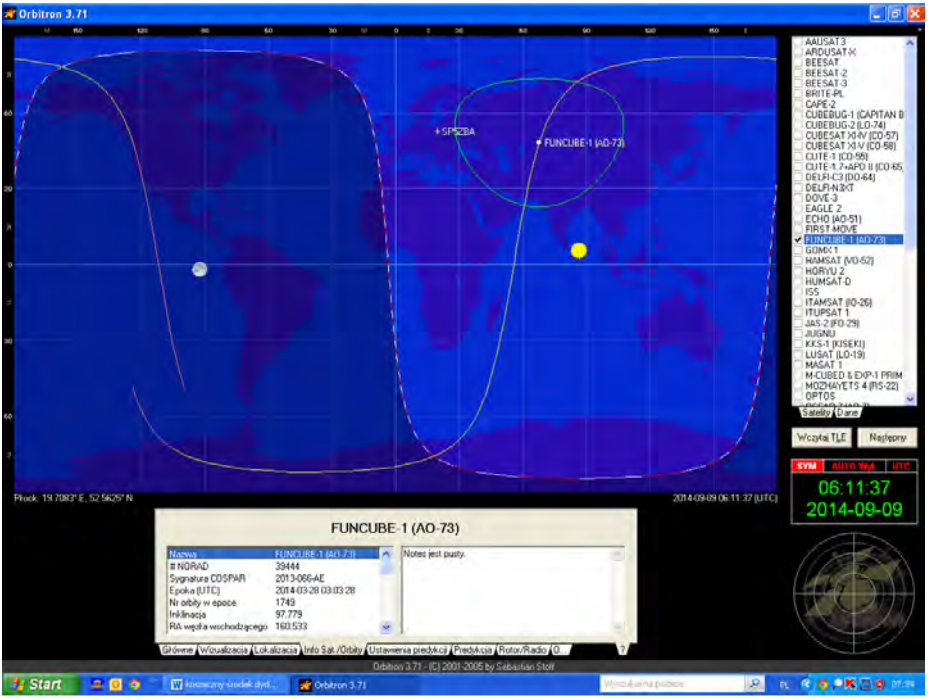
[12] *Satellite Position*; http://warehouse.funcube.org.uk/satmap.html?satelliteId=2; (10 September 2014)

[13] f.ex..: *AMSAT - AMSAT Online Satellite Pass Predictions*; http://www.amsat.org/amsat-new/tools/predict/index.php; (10 September 2014)

[14] *Satellite Tracking System: Orbitron by Sebastian Stoff*; http://www.stoff.pl/

[15] *Orbitron – the home web page* http://www.stoff.pl/orbitron/summary.php?plk; (10 September 2014)

Pict. 3. The image of the Orbitron system that shows the location of the FUNcube-1 satellite project (AO-73)



*I **Source** : www.stoff.pl*

In amateur radio nomenclature it is European OSCAR 79 or EO-79. *OSCAR* is a shortened from of English phrase *Orbiting Satellite Carrying Amateur Radio*. Although, this satellite concentrates only on its scientific purposes now, an amateur radio transponder is also expected to become operational soon. The next FUNcube-4 satellite project is underway. FUNcube-4 project is supported by the European Space Agency and its Education Resource Office. This object is larger and it weighs approximately 20 kilograms. It is going to incorporate experimental payloads from number of universities around Europe. FUNcube-4 will provide similar telemetry to its predecessors but should have a more powerful transmitter and thus be even easier to hear at schools and universities.