Cosmic Call Tech – A hands-on space radio workshop for students in secondary education

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Abstract

The DLR_School_Lab Braunschweig, Germany, organized an amateur radio contact with an astronaut on board the International Space Station (ISS) for students from five different schools for the third time. While the contact itself was always an exciting event for the participating students our goal was to increase the sustainability in learning with a deeper understanding of the technology used for the radio contact. As a result, we present our concept for engaging with the students and preparing them for the actual radio contact with an inexpensive hands-on space radio workshop that was conducted remotely via video conferencing and thus is independent in regard to distance between the lecturer and the group.

During the workshop the students built their own ground station to receive amateur radio satellites and the ISS. Due to the COVID-19 pandemic the workshop could not be conducted fully as an in-person learning experience.

To overcome this obstacle, we chose a hybrid approach. Each session started with a short introductory lecture using a video conferencing software. After the introduction the students worked in groups following a written guide which we provided. During the rest of the session we assisted online in case of any questions or technical difficulties. We also supplied the schools with a Raspberry Pi single board computer, an inexpensive software defined radio and some coaxial cables for building antennas. The tasks necessary building the ground station included setting up the hardware, configuring the software and building antennas.

The written guide gave detailed information on how to complete the individual steps. It also provided some optional more in-depth information on propagation of electromagnetic fields, antenna theory and orbital mechanics to accommodate the range of participating school forms with different levels of proficiency and wide range of age of the students participating.

The students were very motivated to take part in this workshop, even as an extracurricular activity during their spare time. The students as well as the teachers involved also highlighted the interesting and useful lectures and the professional support via video conferencing software. This kind of hybrid approach was a new and innovative learning experience for the schools.

Our workshop offered the students an introduction to radio technology and space which would be otherwise beyond most teachers' knowledge and capabilities. We demonstrated that such a workshop can be realized over distance besides pandemic conditions broadening the field of schools that can be involved.

Keywords

Amateur Radio, Education, International Space Station, Software Defined Radio

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Acronyms/Abbreviations

ARISS	*Amateur Radio on the International Space Station*
DLR	*Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)*
DVB-T	*Digital Video Broadcast – Terrestrial*
ESA	*European Space Agency*
ISS	*International Space Station*
SBC	*Single Board Computer*
SDR	*Software Defined Radio*
STEM	*Science, Technology, Engineering and Math*

1. Introduction

1.1. The DLR_School_Labs

Germany has a growing need for professionals especially in the fields of science, technology, engineering and math (STEM) [1]. To promote the topics of STEM to students in secondary education the German Aerospace Center (DLR) currently operates fifteen out-of-school learning laboratories partly in cooperation with universities distributed all over Germany. These laboratories enable the students to gain first hand experiences with experiments related to the research topics of DLR (aerospace, space, transportation, energy, security and digitalisation) often with high-end equipment which is not available in schools, e.g. a wind tunnel or high-end flight simulators. It has been be shown that the DLR_School_Labs succeed in promoting interest in STEM [2].

1.2. Amateur radio on the International Space Station – Enabling ham radio contacts for students

Starting with the crewed operations on the International Space Station (ISS) the educational payload Amateur Radio on the International Space Station (ARISS) was deployed. Since then many radio contacts between students on the ground and astronauts on orbit took place and inspired thousands of students in the STEM field [3]. These radio contacts require a direct line-of-sight between the ground station antenna and the ISS. Therefore, these contacts usually last approximately ten minutes due to the movement of the ISS from horizon to horizon.

Schools and organisations can apply for such an amateur radio contact with an astronaut on orbit. They can decide if they want to use the telebridge infrastructure provided by ARISS so the equipment needed by the schools is reduced to just a telephone. Alternatively, the schools can use their own radio equipment often in cooperation with local amateur radio enthusiasts. Selected applicants are then carefully guided through the preparation process up to the actual contact by experienced ARISS mentors. The astronaut's time is a very precious good and ARISS does everything possible for the contact being a success.

1.3. Past ARISS contacts carried out by the DLR_School_Lab Braunschweig

The DLR_School_Lab Braunschweig carried out three successful radio contacts with the ISS so far. For each contact four or five cooperating schools were invited to select students asking the astronaut interesting questions. From this pool twenty questions in total were selected evenly distributed over the participating schools.

The first contact took place in 2014 with European Space Agency (ESA) astronaut Alexander Gerst during his "Blue Dot" mission. The second contact was part of Alexander Gerst's mission "horizons" in 2018. The most recent ARISS call took place in December 2021 as part of ESA astronaut Matthias Maurer's mission "cosmic kiss".

All three contacts were conducted using the purposely on-site installed radio equipment. Planning these contacts involved a steep learning curve. The administrative workload for a successful contact was more or less constant for all three radio contacts. From an operator's point of view the technical preparations before the radio contacts decreased with increasing knowledge and experience for each contact.

The preparation of the first contact in 2014 was mainly driven by the selection and permanent installation of the radio equipment followed by intensive training for the operators.

For the second contact in 2018 the technical preparations were focused on optimising the process and some operator training. The resources not needed for setting up the radio equipment were used to create a video stream of the event. This stream was distributed over social media channels but also using amateur radio television in cooperation with the amateur radio group of the *Technische Universität Braunschweig*. These channels enabled even more students and amateur radio enthusiasts to attend the event.

For all three contacts the participating students prepared the radio contacts in class but in 2014 and 2018 the students experience was mostly limited to an exciting one-day event. For the most recent contact in 2021 our goal was to increase the engagement of students with regard to radio technology before the contact and possibly inspire them to continue with their own projects using the gained knowledge.

2. Project description "Cosmic Call Tech"

Most of modern radio technology appears like a black box for students. It is not part of the curriculum in physics or informatics while being ubiquitous in our world at the same time. With our project "Cosmic Call Tech" we wanted the students to discover radio technology as a hands-on experience enabling them to use the gained knowledge to follow their own projects and enrich the ARISS experience. To achieve this, we enabled the participating students to build a single board computer-based receiver which could be used to listen to ARISS contacts and small satellites.

The project was planned considering the types of participating schools (*Gymnasium*, *Integrierte Gesamtschule* and *Realschule*, see [4] for further details on the German school system) and the age of the students. The youngest students participating were in the 8th grade (13-14 years) and the oldest students were attending the 13th grade (18-19 years).

The project was structured to be worked on once a week for 45-90 minutes over a course of six to eight weeks. This mode enabled schools to use this project within the regular lectures, as a compulsory selected practical training or as an extracurricular activity during the students' free time.

2.1. Aims of the project

We wanted to create a lasting and sustainable learning experience. Using a space-themed setting enhanced the attraction of the students' interest as this is widely regarded as something special that only large space agencies do. We also wanted the students to use a broad range of capabilities (e.g. software configuration and manual building) with the intention that as many students as possible will find their place in the project and are eager to actively participate. A qualitative and quantitative differentiation was especially important because of the wide range of ages and the different forms of schools that took part in the project. The students heading for *Abitur* graduation in the 13th grade do have more previous knowledge than an 8th grade student attending a *Realschule*.

2.2. Online guided lessons and support

Each of the topics was introduced by a short online lecture of no more than fifteen minutes. These lectures were used to give the students an overview and a classification of the importance of the topic as well as explaining the goals and tasks ahead in this lesson. This was conducted by one of two DLR_School_Lab - team members so that the students had a constant contact person they could relate to.

After the lecture the students started working on the project on their own with the in-classroom support by their teacher. We stayed connected via video conferencing software during the rest of each session. This allowed us to provide low threshold support as the required skills to troubleshoot or answering questions which arose while working often beyond the teachers' knowledge.

2.3. Script - step by step to success

We supplied the participating schools with a PDF-document covering the topics and giving detailed instructions on what to do. This document was structured into six chapters corresponding to the topic of each week. Besides the instructions more in-depth theoretical aspects, e.g. on antenna theory and movements of satellites, were covered, too. These parts were completely optional so that progressing in the project was possible even when skipping these sections. This scheme allowed differentiation and a hands-on connection to aspects covered in the upper secondary curriculum (e.g. waves and oscillations, electromagnetic fields, circular movements and force equilibriums).

2.4. Hardware

The available information technological infrastructure available in German schools differs a lot. For simplification we decided to use a comparatively cheap single board computer (SBC) as a hardware base together with an inexpensive DVB-T USB key used as a software defined radio (SDR). This selection allowed us to prepare a unified guide on how to configure the device and maximise the student's success.

Each school was supplied with one set of the needed hardware but most schools bought some additional hardware so that even more students were able to work simultaneously.

2.4.1. RaspberryPi

The RaspberryPi 4B with 8 GB memory was chosen as the base SBC. This version of the hardware was easily available and proved to being capable enough for the task of decoding the signals from the SDR. As the RaspberryPi 4B has only Micro-HDMI outputs we included an adapter cable from Micro-HDMI to normal HDMI so that the schools could use a regular monitor or projector as a display.

To power the SBC the original RaspberryPi USB power supply unit was used to guarantee stable operations.

2.4.2. Software Defined Radio

For receiving the radio signals regular USB receiver keys for terrestrial digital television (DVB-T) were used. These inexpensive devices consist of a tuner chip and a software defined radio chip with USB interface to pass the data to the host computer. The SDR chip samples the signal to generate its in-phase and quadrature components which can be used to demodulate the signal using software.

We chose DVB-T USB keys with a Realtek RTL2832U tuner chip because this tuner is supported by most of the available software and it offers a radio reception from about 60 MHz up to 1700 MHz. Our kit included also a small antenna with a suitable SMA connector for the first reception experiments. As intended, the small antenna provided only a very limited gain and was only useful to receive strong local radio sources.

2.4.3. Half-wave dipole antenna

When trying to receive the ISS or a small satellite a better antenna with more gain is needed. The project included the instructions to build a half-wave dipole for the 2 m band (144 MHz). This corresponds to the band used for the downlink from the ISS (145.800 MHz). This antenna is very easy to build and provides sufficient gain to successfully receive the ISS. The most complicated to build part is the connecting pigtail cable with a SMA connector on one end because a special crimping tool is needed. We provided each school with a few coaxial cables with a crimped connector.

2.4.4. J-pole antenna

While the half-wave dipole is very well suited for the 2 m band a lot of small satellites also use the 70 cm band (430 MHz). The instructions included a so-called J-pole antenna ([5]) which is suitable for 2 m and 70 cm. Building this antenna was more ambitious but it was not mandatory for the progress of the project.

2.4.5. Software stack

The software stack consisted of a Raspbian Linux operating system ([6]) and OpenWebRX ([7]) as demodulating software and graphical front end. OpenWebRX works as a web application and is used with a web browser. After downloading and setting up everything the RaspberryPi was configured to start OpenWebRX automatically as a service after booting. The integrated wireless hardware was then re-configured to work as an access point so that the students could connect with a tablet or smartphone to the RaspberryPi and open the web application provided by OpenWebRX. With this setup it was easily possible to going outdoors and powering the RaspberryPi with a battery pack in order to receive weaker signals.

3. Results and Discussion

All participating students successfully completed the project. Several students were able to listen to the downlink from the ISS with their self-built receiver and antenna combination during the actual ARISS call with astronaut Matthias Maurer. The teachers reported their students were very excited when they heard the astronauts voice with their own receivers and self-built antennas.

At the end of the project we collected feedback from the students and their teachers. The students enjoyed the project and highlighted that they learned something new and interesting. The students as well as the teachers also perceived the support via video conferencing software as very helpful. Even though some teachers wished it to be in-person instead of using video conferencing. Nevertheless, several teachers told us that this low threshold support using video conferencing was an actual enabler for such a project because they did not have the knowledge needed and it worked out really well.

We received some remarks on the readability of the script as it was sometimes difficult for the students to distinguish between an “O” and “0” (zero) for the configuration of the RaspberryPi. We will revise the script to increase the readability for the configuration of the RaspberryPi as this caused a non-working configuration in one case that had to be troubleshooted.

The involved teachers fed back that the project was not only interesting but useful for their students as it motivated them to engage with STEM even further. The extent and topical depth of the project was perceived as adequate.

It was highlighted that the broad range of skills used by the students made the project inclusive for the students and promoted teamwork and enabled them for their own future projects. Some of the teachers also reported that they want to continue to build on space as a theme for their regular lectures (e.g. building a Mars rover in manual training lectures).

4. Conclusions and Outlook

We presented a hands-on space radio workshop for students in secondary education based on a RaspberryPi SBC and a digital TV USB key used as a software defined radio to receive signals from the ISS.

From the received feedback we conclude that we succeeded in creating an enjoyable, lasting and sustainable learning experience for the students involved. As there was no negative feedback stating the project was boring, too complicated or overwhelming we infer that our differentiation worked as intended.

The overall positive feedback encouraged us to repeat the project with other schools detached from seldom ARISS calls. We demonstrated that it is possible to conduct the workshop remotely by video conferencing enabling this kind of content for schools that are not close nearby. We are also considering to offer this project within the frame of a holiday program for students as an in-person project at the DLR_School_Lab Braunschweig while continuing to offer it in the described hybrid format.

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