18th International Conference on Space Operations, Montreal, Canada, 26 - 30 May 2025.

SpaceOps-2025, ID # 351

Improve Your Voice Communication Skills – GSOC'S Tool for Individual Learning

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Abstract

Voice communication is widely used in space operations. The rules and guidelines are based on aviation and military communications. They are the cornerstone of communication in space operations as they help to ensure reliable and unambiguous information exchange for real-time operational environments. Especially when the protagonists of launches are spread across multiple locations or even continents, a basic communication protocol is crucial for the successful completion of missions.

At the German Space Operations Center (GSOC), ambitions rose to improve voice communication training to maintain a high level of proficiency even during prolonged periods of low activity in the control room. For this a voice loop communication training tool has been developed. It enables individualized training without dependencies on the schedule of the control room, the mission or the support team. In addition, this setup allows for more accurate monitoring of the learning progress, as the application points out errors continuously and more reliably than the current group training sessions.

It is envisioned to create an easily accessible environment to learn the basics as well as various advanced concepts of communication in space flight operations on an individual level.

The first step of this program is based on the survey platform LimeSurvey, which is used as an e-learning platform. The training will be divided into several lessons representing different skill levels and tailored to the intended short and concise training program.

The new opportunities for individualized training that supports each control room crewmember's schedule should initiate the evolution towards a comprehensive distribution of extensive and well-maintained skills applicable to a wide variety of satellite missions.

In this paper, the overall educational concept and its arrangement for different target groups and training purposes is presented, as well as the question types training the standards for voice communication that are intended to be established. As the tool is already in the evaluation phase, initial experiences of student groups using the program to support the conventional training will also be analyzed. After a final testing phase, the tool will become part of the advanced operations courses offered at GSOC.

Keywords: Spacecraft Operations, Voice Loop Communication, VoCS, Training, GSOC, DLR

Acronyms/Abbreviations

German Space Operations Center (GSOC)
Voice Communication System (VoCS)
Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center) (DLR)
Launch and Early Orbit Phase (LEOP)
Geostationary Orbit (GEO)
Low Earth Orbit (LEO)
DLR Project Executing Organization (DLR PT)

1. Introduction

Since the rise of commercial aviation, it became necessary to create a unified communication regime between pilots and ground controllers in order to avoid accidents.
Terrible incidents like the tragedy of Tenerife in 1977 killing 583 people [1], and almost-crashes like Nairobi in 1974 [1], heavily impacted by miscommunication between the involved parties, make the importance of a communication protocol even more transparent.
It is therefore not surprising that, when spacecraft operations entered the field, a comprehensive set of rules, not unlike the aviation guidelines, was put into play.
Mastering the skill of properly communicating within the guidelines of the voice protocol is seen as a key aspect of mission operations and is therefore part of every astronaut or control centre training.
In human space exploration missions, this training is conducted following internationally unified training standards set up by the operating space agencies and practiced exhaustively during the education programs. Active mission members will put these lessons to use on a daily basis, since all communication over the voice loops, apart from occasional media interviews, are following just this set of rules.
The satellite sector however faces a different situation due to its multi-mission setup, decentralized control centres, and vastly growing number of satellite customers aiming to incorporate mission operations into their portfolio.
A unified code of conduct for communication during satellite operations would therefore strengthen the connection between all contributors and furthermore allow for a higher interchangeability of operators during and across missions. It can, of course, be considered quite optimistic to believe that all of which can be brought into alignment when it fcomes to satellite operations, but setting a good example might convince others to follow that path as well.
Pursuing this mission comes with benefits as well, since offering superior training is vital for maintaining the claim of representing the most experienced and trusted contact point for satellite operations. This in turn will keep governmental projects as well as customers of high priority projects from mandate less experienced but more cost-efficient third-party services. Especially if space agencies cannot reach the mission quantity of private enterprises, operation quality becomes the deciding factor.
But even when focusing on the employees of space agencies – and DLR in particular – with their extensive experience and well-established training methods, new developments in mission operation call for a significant extension thereof. Mostly the multi-mission concept, in which experienced members take responsibilities in several projects in parallel, as well as a larger variety of mission concepts ranging from GEO satellites to CubeSats set boundaries on the logistics and time that can be dedicated to voice communication training.
Another aspect is the time intervals between satellite launches in mission operations [3], which cause a natural degradation of proficiency and training level, thereby intensifying the situation mentioned above.
At the same time, the lack of application prevents experienced crew members from passing on their in-depth knowledge to the next generation before eventually leaving the team.

The established classical voice trainings make use of a fully equipped control room setup allowing groups of trainees to follow a lecture style course with active practice sessions [4]. Those are mainly limited by the trainee and mentor group size, which need to be balanced between the simultaneous availability and frequency of training capabilities.
The jewel of spacecraft mission training are the large simulations of satellite launches, featuring the entirety of operational aspects needed for mission success [5]. Nonetheless, while proven to be the master class of mission practice, they seem to miss the mark when it comes to communication training, since the superordinate goal of mission accomplishments outweighs the voice call discipline.
As a result, it can be seen as a necessity to provide control room members with an opportunity to train voice protocols on their own. This would be especially useful in order to call out possible mistakes or to pass constructive criticism, since the human factor aspects present in classical group trainings can be avoided.
In conclusion this allows for a training progress tailored individually for the participants needs and strictly focussing on the development of exhaustive voice communication knowledge decoupled from the need to simulate a specific scenario or achieve mission goals.

In Chapter 2 of this paper, the underlying training setup and its implementation concerning the VoCS tool will be discussed. Chapter 3 will deal with the methodology of testing students, which used the tool as preparation for a GSOC LEOP simulation. The results of the afterwards collected feedback will be analysed in chapter 4. Finally, chapter 5 will give an outlook on a promising new communication training concept, which is currently developed at GSOC.

2. Setup and Methods

During the first phase of setting up the e-learning based VoCS tool, an analysis of the circumstances and capabilities of the classical training courses and sessions was conducted. An excerpt of the results compared to the intended features of the training tool is listed in table 1 below.

Table 1. Excerpt of classical and new training concepts.

Trainings	Methods	Group size	Duration of active participation
VoCS training course	Lecture course on voice communication. Short active voice loop practice. Direct consultation of experts.	8 – 18 participants	Approx. 10 minutes per hour.
LEOP simulation course	Simulating the first four hours of after satellite launch. Direct consultation of experts.	8 – 18 participants	Continuous communication split among all participants.
E-learning VoCS tool	Individual training. Application focused. Guided by scripts. Strict assessment and direct response to errors. High number of repetitions.	1 participant	Continuously in approx. 30-minute sessions.

With the intentions and circumstances well determined, focus was laid on the upcoming process steps while additions to the initial list were incorporated at later stages as well.

The training tool was developed using the DLR licence of the LimeSurvey online questionnaire software. This decision was made due to its high capabilities and the existing integration to the DLR environment. The licence is hosted by the DLR PT institute, which ensures that all processed data and settings are fulfilling compliance standards regarding user data. Nonetheless only anonymous information about the given answers were saved, since there is no interest in collecting user data at the current state of development. This might change if the tool is used for certification purposes in the future, however this will follow strict guidelines as well. Serving this idea, the tool provides a variety of options to regulate and track participants' answers, timestamps, IDs, and training repetitions.

The platform offers a large array of question types and was therefore the obvious choice for designing the new tool. Since it was later also used for employee certification in a different context, it happened to be well known within the institute, so that the introduction could be kept to a minimum. This, even though not considered from the beginning, can be seen as an additional benefit.

Originally invented as a survey tool, the overall setup allows for multiple-choice questions as well as any kind of enter-a-text and drag-and-drop interactions.
However, the undoubtedly biggest advantage is the possibility of embedding video, audio and image files in the questions. This makes the deployment of audio-based questions possible, which form a corner stone of VoCS training, since they are tremendously flexible in use.
As a classical example, an audio file is presented containing a word spelled out using the NATO alphabet. The participants can listen to the file multiple times before typing the answer using the input field.
Furthermore, one can utilize this to create one side of a conversation, so that the user can interact with the tool via typing or selecting the correct answers. This creates a chatbot like experience navigating through small communicative scenarios. This means that the participant does not simply answer a question but also has to provide meaningful answers to his fictional chatbot-college.

Another type of audio related question are image-search questions, in which the question is presented in an audio file with the important information transmitted using the NATO alphabet. The user then must compose the NATO spelling into meaningful words, which then state a request concerning a presented image. The user will in turn give an answer matching the request, in contrast to blindly summarising the audio input.
The illustration below shows an example of such an exercise, while figure 2 takes a closer look at the referred image.

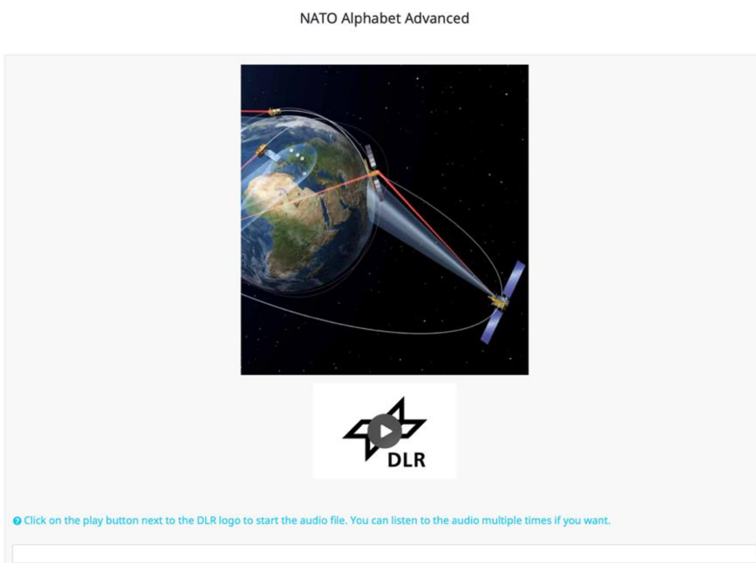

Fig. 1. User interface of an exercise within the training tool. Clicking on the DLR logo will start the audio file. The answer can be entered in the field below the blue instruction guide.

The audio file's content reads: "Multiply the number of Sierra Alpha Tango Echo Lima Lima India Tango Echo Sierra with the number of Sierra Tango Alpha Tango India Oscar November Sierra on the picture."
The participant can listen to the audio file multiple times to collect the important information. In this case the words "satellites" and "stations" are of special interest. To find the correct answer the picture in figure 2 needs to be inspected as well.

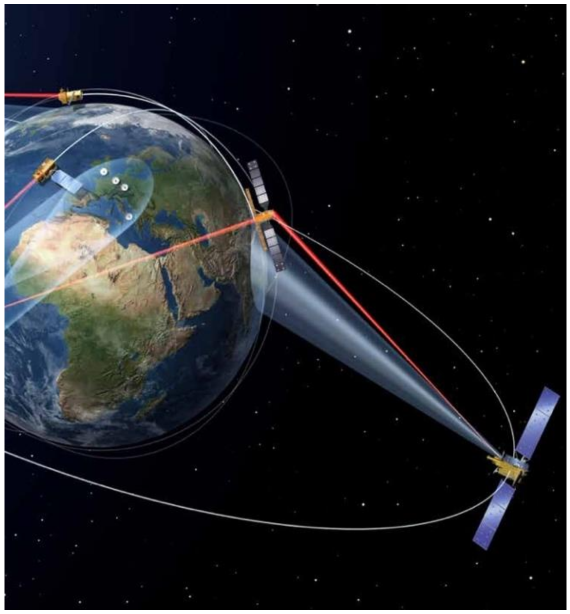

Fig. 2: Illustration of satellite connections. Used as an example image for training purposes within the tool.

The Image shows a total of four satellites connected with red lines as well as four ground stations spread across Europe. Following the instructions of the audio file, a simple calculation – four times four – gives the correct answer for the exercise. Correspondingly, the participant would have to enter "sixteen" or an equivalent spelling into the intended field at the bottom of the page.
On top of this, all questions can be equipped with a customizable timer, so that time pressure can be trained as well, e.g. in preparation for a satellite mission with time critical procedure steps.
Additionally, also question types centred around pronunciation can feature a flawed voice call which then has to be analysed regarding its built-in mistakes.

In any case, the individual questions' content was created following the insights from [1, 2, 3, 4] and a multitude of meetings and interviews with experienced mission operations members. The resulting lessons cover the entire spectrum of voice loop communication guidelines. This includes learning the basic concepts of callsigns, responsibilities and the NATO alphabet but also mastering the correct application of terminology like "copy" (received your message) and "wilco" (will comply). Additionally, the structure of voice call sequences between multiple stations in the control room will be trained. This starts with understanding the necessary rules for correct message transmission and continues with maximizing communication efficiency in an environment of high information traffic. Ultimately, advanced concepts for dealing with the eventualities of voice call interruptions and miscommunications are exercised as well.

The methods discussed so far are mainly focussing on the testing and active practice part of voice communication training, as this is seen to be its most important factor. The reader might however rightfully question the usefulness of this endeavour, if beginners and out-of-practice experts have no option to gather trainable knowledge in the first place. This requirement is met in two ways, one within and one separate from the LimeSurvey tool.
The classical external supplements are utilizing a summary of the VoCS protocol scripts and PowerPoint presentations used during the in-person trainings at GSOC [3, 4]. This is only natural as the collective knowledge of decades of satellite mission operations is culminated in those sessions. This knowledge was then thoughtfully arranged to form well-rounded and comprehensive scripts and guidelines for the course members. To meet the standards of training courses offered at GSOC, these scripts are continuously maintained and updated to match the developments of the field. This includes the implementation of new courses or exploring the potential of new operational software.
Out of those, a variety of excerpts will be manufactured containing suitable information to fit the scope of each individual e-learning session. Such scripts are then distributed among the recipients of the invitation links to the online training and are best used on-the-go while working with the training tool.

The second way of presenting the information needed for voice communication practice is directly implemented into the training survey. It will be displayed as information sheets quite similar to PowerPoint slides in between the question groups.
These slides may contain important information needed to solve the upcoming exercises when the information cannot be read out as easily from the external scripts or might point to a specific subtlety of voice loop communication.
They are also put to use for giving context to a series of questions in order to guide the participants view of the exercise.
The most advanced usage is, however, the utilization of audio files in a phonetic context. Since pronunciation is a valuable ingredient to voice communication, it is seen to be very beneficial to provide correct voice calls as a benchmark. Especially when communicating numbers, the training of abstract guidelines will benefit tremendously when examples of wrong and right pronunciation can be listened to shortly after another.

As mentioned above, the VoCS tool offers a variety of methods and concepts exceeding the classical training setup to counteract its shortcomings and account for the developments in the field. Nonetheless it is crucial to avoid ambiguities with the existing courses, since it would counteract the original intent to promote a unified understanding of voice loop communication. In consequence, the script and training tool originate from the large experience base influencing the VoCS training and presented in the lecture courses at GSOC [3, 4], while breaking new ground regarding knowledge transfer.

After setting up multiple prototypes for a large variety of audiences and proficiency levels over the course of half a year, the phase of collecting training data and feedback had begun. Following multiple feedback and development rounds inside organizational groups within GSOC, a set of training sessions was created to be tested among students taking in-person courses at GSOC in Oberpfaffenhofen. The results and methodology of these evaluation will be discussed in the next chapter.

3. Methodology of Testing among Students

In order to test the training program, a specifically designed training session was created and distributed among multiple student groups. The participants were taking part at one of GSOC's simulation training courses containing at least a one-hour VoCS training course and a four-hour LEOP simulation. The content was created to serve as a first introduction to the topic, preferably consumed prior to the in-person VoCS lecture, but also perfectly suitable as repetition before the LEOP simulation. Most of the students had a profound background in satellite operations since they joined the course as members of a satellite operating chair at their university or aimed to build up a satellite program in the future. But every group also contained less experienced students, which completed the same e-learning exercises and in-person events, only varying in the amount of support during the events at GSOC.

For the VoCS tool testing a subgroup of the exercises was created and curated according to the estimated proficiency levels of the participants. Apart from little deviations due to the removal of small mistakes and bugs, the training scope was kept constant, so that the test results are reasonably comparable. Each instance of the training tool was reachable via an internet link and was accessible without a password or individual login-key. To ensure a closed testing group, the link was only sent to confirmed participants of the in-house trainings and feedback forms were only collected from attendees of the LEOP simulation at GSOC.
In addition to the link, a short summary script was distributed, to give helpful insights on the training concepts and provide the rules to solve the exercises in case the participants were less experienced than previously assumed.

In order to leave enough time for individual practice, the link was distributed among all participants at least one week ahead of the LEOP simulation, which takes place at the end of the student course.
A total of three test rounds were conducted with 16 participants contributing to the final feedback statistics.
The participation at the online training was voluntary and following the privacy policy only the timestamps and anonymized answers were tracked. As a result, LimeSurvey's build in statistics tool was not sufficient to give a reliable result, since this setup did not allow to determine whether the link was distributed outside the originally intended focus group.

Therefore, an analogous feedback form was set up, consisting of six questions regarding the perceived impact of the online training as well as the student's experience prior to participating at the courses offered by GSOC.
The printed forms were then distributed after the final simulation so that the students could immediately fill out the feedback and hand it in anonymously. The questions asked them to reflect on the impact that the e-learning had on their performance, but also to compare it to the in-person VoCS lecture and advice during the simulation.
Of course, it was not possible to have a control group participate at the LEOP simulation without an in-person VoCS training as the development of the e-learning tool could not impede the learning progress. As mentioned above it was not feasible to restrict access to the e-learning for some participants either, since the participants numbers would have been too low to provide a proper statistical meaning.
In consequence, all answers are based on the student's self-assessment and the comparison of e-learning and classical training courses – and have to be analysed in this context.
At this stage of development, however, the main focus did not lay on the quantitative evaluation of the training tool, but the improvement of the training experience. Therefore, face-to-face feedback and creative suggestions were clearly considered to be more important, when trying to match the trainees needs most effectively.
With this in mind, the results of the student feedback will be discussed in the following chapter 4.

4. Feedback Results and Discussion

The feedback sheets contained a number of statements, which then could be evaluated with "I fully agree", "I agree", "I disagree" or "I fully disagree". Next to the four statements listed below, two additional questions about the affiliation and study level of the participants were asked. However, since those parameters are not contributing to the VoCS tool performance test, the reminder of the paper will focus on the statements below.

Statement 1: Using the training tool, I was able to spend more time on handling the tasks during the simulation, as I did not need to focus on the communication protocol as much.

Statement 2: The additional preparation with the online tool did help me participating in the simulation more actively.

Statement 3: I would recommend the online tool to my study fellows as a preparation for their satellite mission operations.

Statement 4: Specifically, for my voice loop communication: the preparation with the online tool was more helpful than the in-person VoCS training course and advice during the simulation.

As mentioned above, statement 1 and statement 2 are both relying on the student's self-assessment, while statement 4 aims to compare the results with the tool's in-person counterparts. Statement 3 should give context to the tool's suitability for satellite operations in general, especially outside the predefined GSOC courses.

Table 2. Combined feedback results from three different student groups participating at the LEOP simulation.

	I fully agree	I agree	I disagree	I fully disagree
Statement 1	7 (43.8%)	8 (50,0%)	1 (6.2%)	0 (0%)
Statement 2	9 (56,2%)	7 (43.8%)	0 (0%)	0 (0%)
Statement 3	10 (62.5%)	6 (37.5%)	0 (0%)	0 (0%)
Statement 4	0 (0%)	4 (25.0%)	9 (56,2%)	3 (18.8%)

Result in absolute numbers (and relative numbers).

The assessment of statement 1 indicating that 93.8% of participants felt like they were able to focus more on content related tasks during the simulation, since they were less occupied by the correct transmission of their voice call.
Together with the even more overwhelming results of statement 2, the e-learning tool seems to be a much-needed extension to the existing training regime, enabling the users to focus and actively contribute to the tasks during the LEOP simulation.
It is also insightful to bring the results into context when taking a look at statement 4, clearly highlighting the importance of in-person information exchange. Even though the amount of invested time per trainee is significantly lower, direct interaction is still a fundamental cornerstone of the training progress. This explains that 75% of the participants experience the classical trainings as more helpful than the e-learning but also shows the greatest potential for improvement when aiming to bring the tool towards the next step of development.
Finally, the evaluation of statement 3 states great approval to the tool as well, since it indicates that all participants would recommend the tool to their colleges as preparation for satellite missions.

Furthermore, in order to get an even better understanding of the evaluation's context, a quick assessment of the preexisting knowledge and experience of the participants was collected using the feedback form.

Table 2. Practical experience in satellite operations prior to the simulation.

	In great detail	Occasionally	Rather limited	Not yet
Qualification	9 (56.2%)	2 (12.5%)	3 (18.8%)	2 (12.5%)

Result in absolute numbers (and relative numbers).

While spread across the entire spectrum, it can be stated that over half of the participants had exhaustive practical knowledge in the field of satellite operations and only 12.5% of trainees were completely new to the topic.
Here should the connection with statement 3 not remain unnoticed, since it suggests that for the entire qualification range, participants believe the tool to have a beneficial impact on the mission preparation of their colleagues.

These results conclude the statistical investigation of the VoCS training tool used in preparation to a LEOP simulation, indicating it to be a great use case and much desired extension to the existing voice communication courses. However, it also shows the shortcomings of the e-learning based version of the individual training tool, since it cannot compensate for the personal interaction and support during a GSOC event. To ensure the user can benefit from the best aspects of both worlds, a new generation of voice loop communication trainings is currently developed at GSOC and will be portrayed in chapter 5.

5. The educational context and future developments

In practice, this voice tool is not an isolated concept but has to be seen as one of many projects forming the GSOC academy, the centralized training institution of satellite missions at GSOC. As such, the tool is currently part of in the initial education of new employees at DLR and is also used in preparation for simulations of any kind. In future, the range of application might be extended to the certification processes as well. Settings could be adjusted, so that questions can be repeated only once per session and participant. This allows for an accurate tracking of answer and time scores, which can form the basis of a grading and certification system also available for online usage and remote testing. However, these plans are also influenced by the development of a second level voice tool at GSOC.
As already hinted at in previous chapters, the e-learning based VoCS training tool was a mere first step towards the vision of true individual learning. This vision incorporates AI, namely a locally hosted speech-to-speech solution, that allows the users to actively train a given satellite operation scenario.
Contrasting the question-style training in the portrayed tool, a realistic environment to specifically train voice communication guidelines is envisioned.

The core of the tool will be formed by a specifically finetuned LLM, which will be accompanied by a speech-to-text and a text-to-speech module to enable a control-room-like conversation.
Retrieval-augmented generation (RAG) will then guide the LLM through the flight procedures incorporating the benefits of simulation training with the strict implementation of voice loop communication discipline. In a first step, only procedure parts with two active control room members will be trained, but it is planned to extend the program such that the tool will be able to take the roles of multiple control room members.
To further enrich this experience, the voice console interface used by the operating satellite mission teams will be integrated as the main user interface of the training tool.
This next level tool is already under construction and will hopefully be presented at SpaceOps27.

Acknowledgements

We thank the members of our partner groups at GSOC for the insightful feedback on voice communications in satellite operations as well as the student groups for testing the tool's prototypes.
Special thanks to Wolfgang Kling for the recommendation and introduction to LimeSurvey which turned out to be exactly the powerful platform to build our training tool that we were looking for.

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