# Tracing gunfire – new tracking systems for shot localization

Today's technical aids still have problems locating people like snipers in built-up areas. Modern helicopters also lack early warning systems to alert pilots in dangerous situations of shots that have been fired. In cooperation with research partners, we at armasuisse Science and Technology are putting forward new methods for alerting and locating, and showing how our troops can be warned of snipers in future. We also test technology demonstrators with the use of innovative experiments.

**Text:** Dr Peter Wellig

Do you remember the tragic event in Las Vegas in October 2017 when an unknown man fired into a crowd of people? There was complete panic and total chaos everywhere. 58 people were fatally wounded and a further 869 sustained slight to serious injuries. The gunman was holed up in a hotel room and shot into the crowd of people from his balcony. However, for the first few minutes nobody knew where the gunfire was coming from, let alone how many shooters were involved.

**Tracking systems and their pitfalls**

It is also not always easy for soldiers in the Swiss Armed Forces to gain a quick overview of the current situation in an unknown area. They too would have problems locating a potential sniper, particularly in an urban environment. Aids such as microphone systems which record the shot or the acoustic event and locate the shooter do exist, but these only perform satisfactorily in areas where there are no buildings. This is due to the fact that in built-up areas sound waves bounce off

At the shooting trials on open ground in Thun, the specialists from the armasuisse S+T Test Center mounted the weapons on a gun carriage. The helicopter flew over volleys of gunfire and hovered near the ground at a steady height.

**MUZZLE BLAST AND SHOCKWAVE**
When a gunshot is fired, microphones usually measure a double blast, a punctual explosion - the muzzle blast, as well as a shockwave. The shockwave is caused by the supersonic projectile and propagate rapidly. However, the muzzle blast, on the other hand, spreads out at the speed of sound on a spherical surface. Acoustic sensing systems usually detect and process both signals, assuming that they can be distinguished and classified.

walls, making precise location impossible. Other technical aids for localisation are radar systems, visual cameras and thermal imaging cameras. However, these systems are also unsuitable in urban environments, as such areas are often complex and exact location is not possible.

**Locating people with an advanced microphone system**
We at armasuisse S+T are considering further developing microphone systems in order to locate snipers in urban areas. Existing systems in use today, consisting of microphones and electronics, can detect an acoustic event precisely. Unlike radar devices and cameras, microphones do not need to be specifically aligned, as they can perceive the sound of a report equally well from all directions. A microphone does not even need a direct view of the shooter, as a shot can even be heard if it is fired behind a house. To determine the exact direction of a shot and locate the shooter, several microphones always measure the report. As sound spreads out in waves, it first hits the nearest microphone, then the next nearest and so on. The time differences in measuring report enable the sound wave to be traced and the direction of the shot and the position of the shooter identified.

**Sound waves in urban terrain**
In an urban environment however, it is not just a single wave front from the acoustic event that hits the microphones, but hundreds or even thoudands of waves. This is due to sound waves bouncing off buildings. Thus, the muzzle blast cannot be clearly detected in such situations. The new method for localising a shooter is now to simulate the reflections and the complex way the sound wave spreads on a computer and compare it with the microphone measurements. This is precisely what our experts have been testing in the army training village at Walenstadt military base. Swiss Armed Forces snipers shot from streets and houses at a target slope on the edge of the training village. Microphones were spread around the training village and recorded the acoustic events. It was indeed possible, based on the computer simulations and acoustical events to identify the positions of the snipers in some cases to within one meter. The shot axis was correctly estimated in most cases with an uncertainty of less than 10°. The accuracy degraded when the shooter was outside the sensor network. However, the computer simulations required considerable processing power and the results were not known immediately. This is why we are now examining how a microphone system can directly determine a result in real time.

*Based on the computer simulations and acoustic events measured, it was possible to identify the positions of the snipers quite accurately.*

Members of the Armed Forces shot from streets and houses in the army village in Walenstadt. They used various rifles and even silencers.

*The loud noise from the helicopter drowns out the acoustic event. For this reason, very sensitive microphones are required.*

**Locating gunfire for helicopters**

Improved location and warning systems would also be extremely helpful in other cases, such as when flying a helicopter. Usually, the pilot does not hear if a shot flies in the direction of the helicopter or right past it. It would of course be important for the pilot to know where the gunfire is coming from, in order to fly in a safer direction. The challenge for a microphone-based solution in recognising gunfire, however, lies in the loud noise made by the helicopter, which drowns out an acoustic event. For this reason, very sensitive microphones are required. So sensitive that they function perfectly despite major noise and the strong vibrations of the helicopter and are able to detect a shot. Research company IAV Engineering from Tannay in the canton of Vaud, which specialises in these high-tech microphone systems, has built a technology demonstrator for the Cougar Swiss Army helicopter. The technology demonstrator consists of a box with microphones and electronics and is attached to the underside of the helicopter. The size of the box is 45 cm x 45 cm x 4.5 cm.

**Tests with a technology demonstrator**

In cooperation with other partners, we tested this technology demonstrator at armasuisse on open ground on the Thun military base. For example, experts from the armasuisse Test Center installed guns on a gun carriage, a mounting for weapons, on the ground. They were then able to shoot very accurately and safely past the helicopter. The engineers on the ground and in the helicopter from the Flight Testing unit at armasuisse coordinated the timing using radio devices. This enabled the chief test pilot from armasuisse to fly over volleys of gunfire on the defined flight paths at the right time. The microphone data recorded in the helicopter showed that gunfire could be clearly detected in various different flight manoeuvres. However, even in future the ability to detect shots and raise the alarm at very high air speeds will probably be limited.

**Findings and benefits**

Using new and improved microphone systems and computer simulations, together with out-of-the-ordinary experiments, armasuisse and its research partners were able to successfully demonstrate how our troops can be warned against fire in future. The knowledge gained will also help us to test systems procured in the future.

**INTERVIEW WITH THE CHIEF TEST PILOT OF ARMASUISSE, RUDOLF ENGELER**

**Mr Engeler, you were involved as the helicopter pilot in the flight tests over the open ground at Thun. Shots were fired close to the helicopter. What was important for you when preparing and performing these out-of-the-ordinary tests?**
The flight tests have to be carried out safely and the risks identified and mitigated in advance, for instance by ballistic protection on the helicopter, the crew wearing protective vests and keeping to minimum heights and distances. Arranging, coordinating and professionally carrying out the tests with the specialists from armasuisse S+T was crucial.

**Did you hear the shots during the flight manoeuvres? And if you did, were you able to tell the direction the shots were coming from just by listening?**
The shots from the 12.7mm sniper rifle could be heard from close by, but due to the considerable noise level of the helicopter the source could not be localised. This experience underscores the need for a reliable hostile fire indicator.

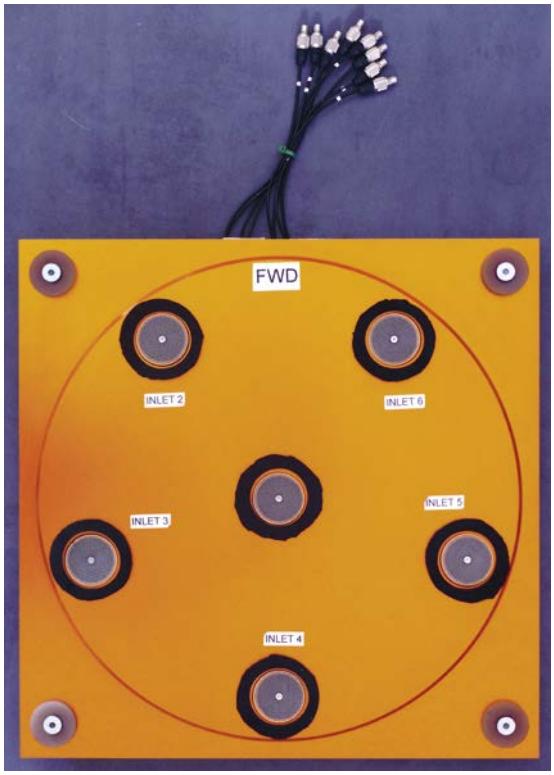
**What criteria should a warning system for rifle shots meet to support you as a pilot? And how do you rate the results of the technology demonstrator used in Thun?**
For a warning system to be reliable, it must be able to give alerts in real time and at distances which still allow for evasive manoeuvres. For this, the crew's human-machine interface has to allow immediate situational awareness, for example, using clear display devices and 3D audio. It must also have a high probability of detection and at the same time a low rate of false alarms.

The system tested on the flight did not yet have a real-time display, but the results of the post-flight evaluation are promising.

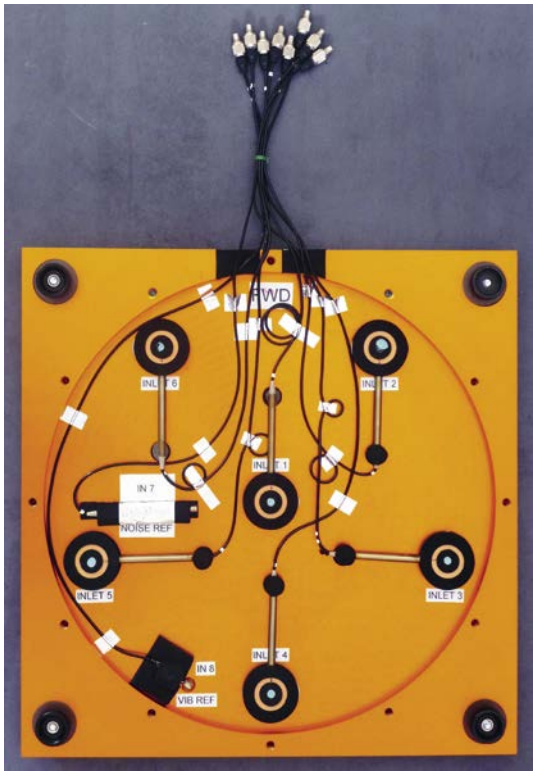
**DR PETER WELLIG**
Head of research programme

Dr. Peter Wellig has headed the research programme "Reconnaissance and Surveillance" at armasuisse Science and Technology since 2008. The focus of "Reconnaissance and Surveillance" is on new ways of acquiring information, for example for airspace surveillance or for weather-independent imagery reconnaissance. The programme is also exploring new ways to detect and locate threats, such as from drones and snipers. Technological developments in detectors, artificial intelligence and data communication will make it possible to detect and track targets better than can be done today, even under difficult conditions such as cloud, rain and with few people. However, the performance limits of these technological developments need to be assessed and possible countermeasures examined.

The technology demonstrator was attached to the underside of the helicopter.




Exterior view of the technology demonstrator. It can be deployed in all flight and weather conditions.




Interior view of the technology demonstrator. The integrated microphones capture the bullet report and identify the direction of origin of the sound.