Federal Ministry
of Defence

Military Scientific Research Annual Report 2017

Defence Research for the German Armed Forces

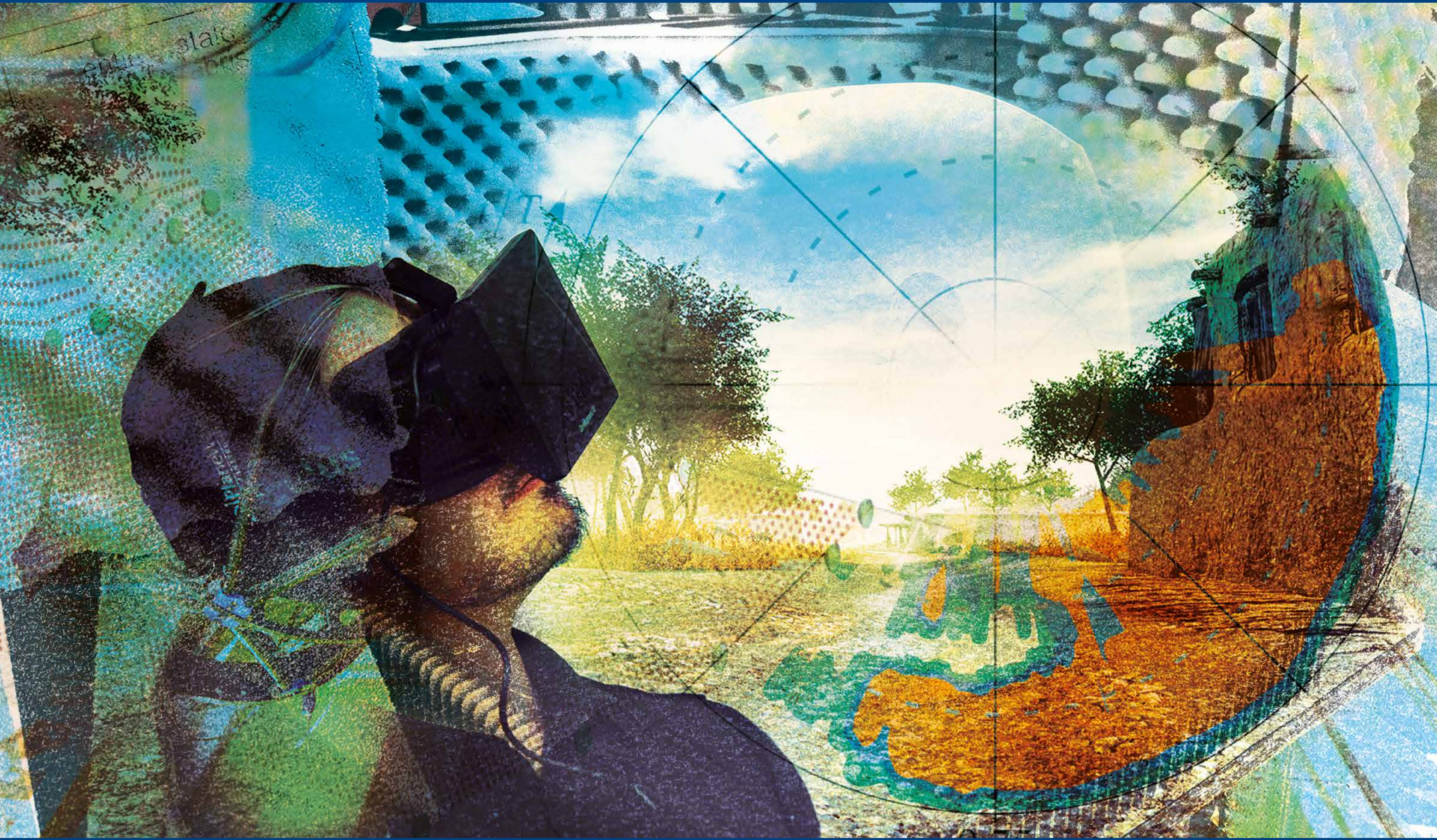
Bundeswehr
Wir. Dienen. Deutschland.

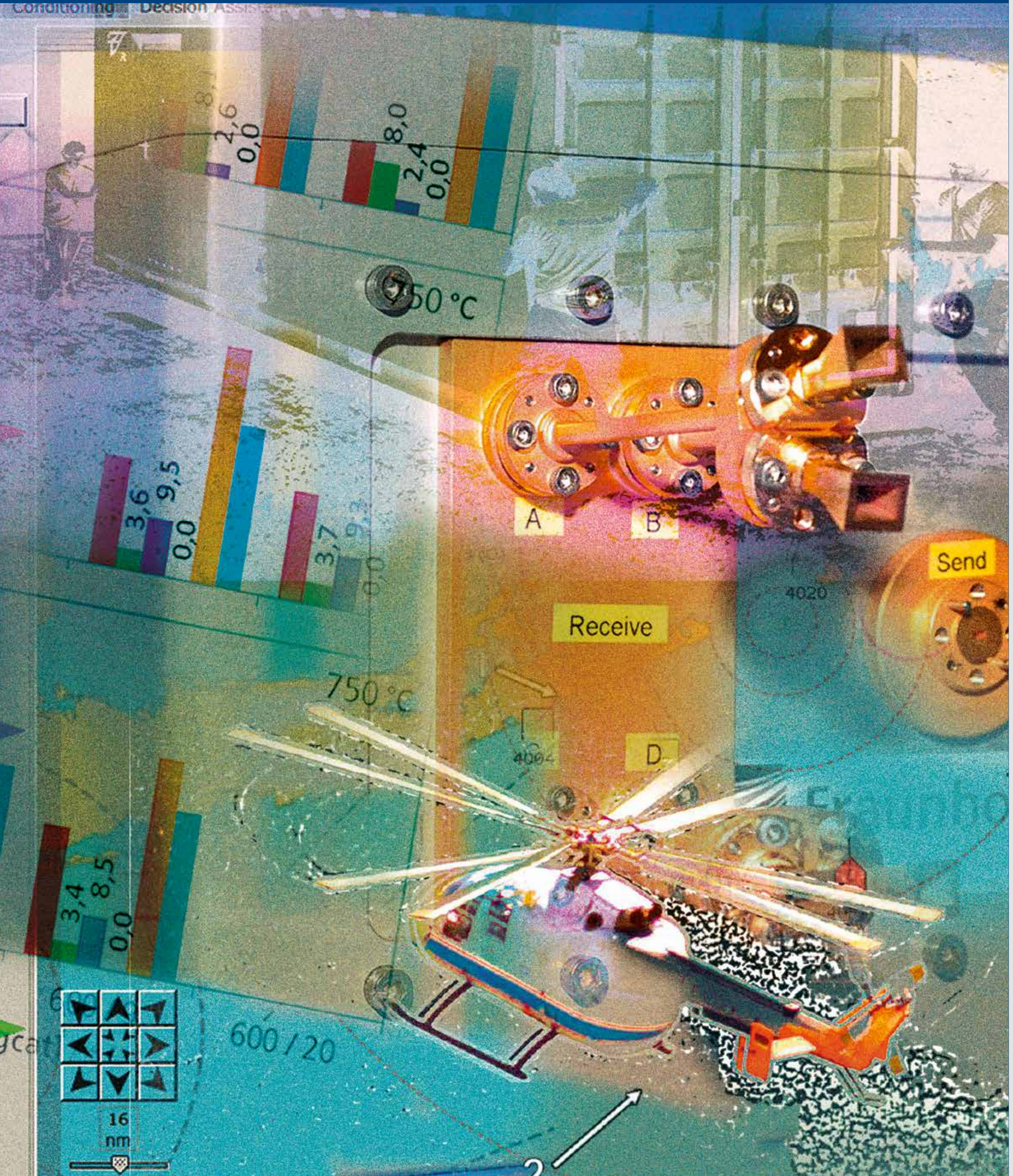
Federal Ministry
of Defence

Military Scientific Research Annual Report 2017

17

Defence Research for the German Armed Forces





2,6
0,0
8,0
2,4
0,0
750 °C
3,6
9,5
0,0
3,7
A
B
Send
Receive
4020
750 °C
D
3,4
8,5
0,0
600 / 20
16
nm

Ministerialdirigent Ralf Schnurr

Unterabteilungsleiter A II und Forschungsbeauftragter
Bundesministerium der Verteidigung

Defence Research for the German Armed Forces

As trend reversals take effect in regard to personnel, materiel and funding, the Bundeswehr is being positioned to face new challenges. The modernisation and procurement of defence equipment are focal issues for the Ministry of Defence. National and collective defence is also a topic increasingly in the spotlight – among other things in view of rapidly changing operational conditions.

Both for operations around the globe and for defence on the European continent, the Bundeswehr needs proper equipment – whether in the air, on land, in and on the water, or in cyberspace – to carry out its mission successfully and, while doing so, to protect the lives of its servicemen and women. In light of the limited predictability of future challenges, the Bundeswehr will require a wide range of capabilities to enable it to adequately shoulder the responsibilities of national and collective defence as well as international conflict prevention and crisis management.

The strategic direction of defence research and technology is also constantly reviewed and adapted in line with emerging requirements.

In the current issue the branches of research of the Federal Ministry of Defence present a selection of topics from the following fields:
- defence technology research
- military medical and military psychology research,
- military history and social science research,
- geoscientific research, and
- cyber and information technology research.

Ralf Schnurr

Access directly by clicking on the item

17

Part 2

Part 3

17

Part 4

Part 5

Part 6

1

Defence Technology Research

Defence research and technology (R&T) form the first link in a value chain, at the end of which the Bundeswehr should have the necessary equipment at its disposal, on time and reflecting mission requirements.

The broad spectrum of capabilities needed by the Bundeswehr calls for intensive monitoring and development of all fields of science and engineering relevant to defence applications.

Defence R&T activities provide the capability for analysis and assessment required for decision-making on equipment, i. e. by embracing findings from civilian research, by analysing technological developments for their future military usefulness or their threat potential, by identifying strategic fields of interest for the advancement of Bundeswehr capabilities and by driving relevant emerging technologies forward to the stage of production readiness at the proper time. Sovereignty in key national defence industry technologies needs to be preserved and strengthened.

Defence R&T work in Germany takes place

- at Bundeswehr research institutes and technical centres,
- within the scope of shared government funding at the Fraunhofer Society for the Advancement of Applied Research (Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V.), the German Aerospace Centre (Deutsches Zentrum für Luft- und Raumfahrt e. V. or DLR) and the French-German Research Institute of Saint-Louis (Deutsch-Französisches Forschungsinstitut Saint-Louis, or ISL), as well as
- in the context of project-funded research through the award of R&T contracts and grants to third parties, i. e. to industry and business, universities and non-university research institutes.

It is from these three working levels that examples of defence R&T activities in 2017 are presented in the articles which follow.

Dr. Jens Osterholz
Fraunhofer-Institut für Kurzzeitdynamik,
Ernst-Mach-Institut, EMI
Freiburg

info@emi.fraunhofer.de

M. Sc. Wolfgang Niklas
Fraunhofer-Institut für Kurzzeitdynamik,
Ernst-Mach-Institut, EMI
Freiburg

info@emi.fraunhofer.de

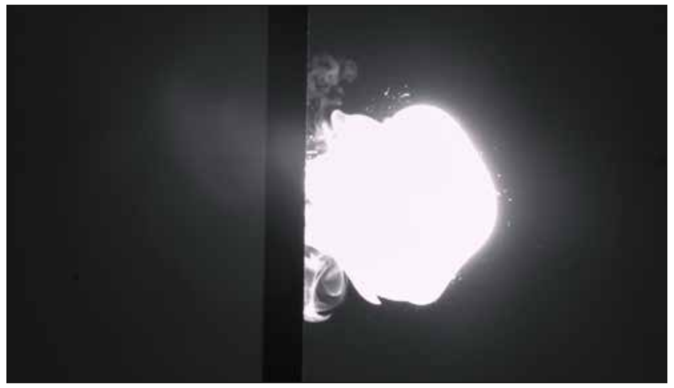
Analysing the safety for laser applications

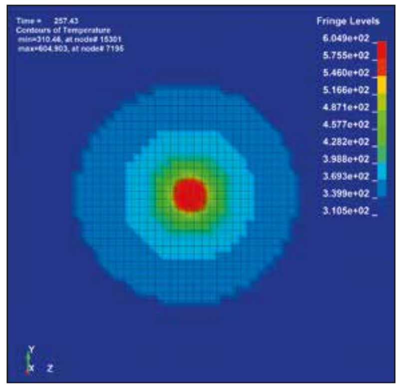
The Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institute (Fraunhofer EMI) carries out safety analyses in regard to applications involving distant use of intensive laser beams. Fraunhofer employs its capabilities to also investigate the effects of high-power lasers under laboratory conditions, and its expertise to conceptually develop risk-based analyses for implementation in software tools.

High-power lasers generate a strong local thermal energy input such as is used in industrial material processing – for example in laser-based cutting or welding. The properties of the laser beam also make it possible to direct the energy at an object with high precision also over long distances.

Electrically operated solid-state lasers have already been utilised by armed forces of other nations for several years, for instance to neutralise improvised explosive devices at a distance. Such use of lasers offers the advantage that neutralisation can be carried out from a safe distance without the need for soldiers to be in the immediate vicinity of the explosive device.

National studies on the potential of laser effectors (which are already undergoing development at various companies with a view to military applications) are also considering them particularly from the aspect of defence against drones (UAVs) in military scenarios. Cases have already been reported in which terrorist militias have also used UAVs to deliver explosive devices by air.





Dr.-Ing. Alexander Stolz
Fraunhofer-Institut für Kurzzeitdynamik,
Ernst-Mach-Institut, EMI
Freiburg

info@emi.fraunhofer.de

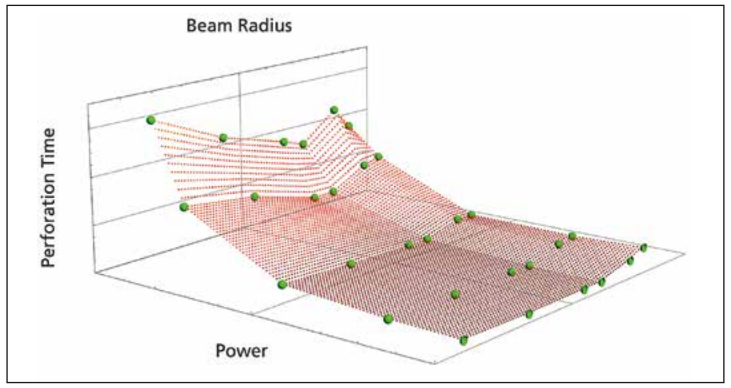
Dr. Matthias Wickert
Fraunhofer-Institut für Kurzzeitdynamik,
Ernst-Mach-Institut, EMI
Freiburg

info@emi.fraunhofer.de

To possibly use a laser effector in such scenarios, it is necessary to analyse exactly which phenomena have to be considered for their safe application and how they can be described quantitatively for a risk assessment. In this regard, Fraunhofer EMI is developing a safety analysis tool for the Bundeswehr (German Armed Forces) that can be used to identify areas of risk when using lasers, and to prepare appropriate protective measures. An important precondition for reliably identifying the relevant areas of risk is a detailed understanding of the temporal progression of the laser effects and the resulting reflection phenomena. At EMI the findings from laboratory tests and computer simulations are firstly being transposed into engineering models and then implemented in the safety analysis tool.

In addition to effects such as reflection and scattering of the laser beam at the material surface, it is necessary to consider the physical effects of the laser beam's propagation due to the atmosphere. This may also mean taking the influence of local density fluctuations in the atmosphere into account, beside the scattering and absorption. To legislate for such influencing factors, a close exchange is taking place among working groups and research institutes that are exploring the relevant processes involved during a laser beam's propagation in the atmosphere.

Once the software tool has been developed, it can be made available to the Bundeswehr for risk-based scenario analyses, similar to previous software solutions realised by Fraunhofer EMI.



Figures: Laboratory tests, computer simulations and application models for demonstrating laser/material interaction at Fraunhofer Ernst-Mach Institute

Dr. Diego Cristallini
Fraunhofer-Institut für Hochfrequenzphysik und Radartechnik FHR
Wachtberg

info@fhr.fraunhofer.de

Iole Pisciottano
Fraunhofer-Institut für Hochfrequenzphysik und Radartechnik FHR
Wachtberg

info@fhr.fraunhofer.de

DVB-S2-based passive radar imaging

Identifying non-cooperative targets of military relevance increasingly requires reliable and high-resolution radar imaging to do so. Passive radar operation offers inconspicuous surveillance in this regard. The SABBIA system developed by the Fraunhofer Institute for High-Frequency Physics and Radar Techniques (FHR) uses signals transmitted by satellites (DVB-S2) for the imaging of non-cooperative targets. SABBIA has a resolution capability of less than 2 metres and can also operate with different orthogonal polarisations.

Passive radar systems are steadily maturing as a defence technology. Beside conventional surveillance systems used in aerospace, new techniques have been developed over the past few years. Among them are passive radar imaging techniques such as SAR and ISAR, both of which are highly rated. The instantaneous signal bandwidth of such radars is generally dependent on the transmitting station or on the wavelength of the transmitter. Transmitters in the VHF range greatly limit these systems' bandwidth. Digital video broadcasting satellites (DVB-S and DVB-S2), in contrast, operate in the Ku band and offer a greater signal bandwidth, making it possible to achieve metre-range resolutions, which are an important prerequisite for (radar) imaging purposes. The use of DVB-S2 also offers two key benefits for military applications. Firstly, DVB-S2 signals provide broad illumination and are thus available over remote areas and open seas. Secondly, compared with conventional transmitters, it is much more difficult to disable the satellites in any war. A crucial drawback of DVB-S2-based passive radars, however, is the very low spectral power density at the receiver, which necessitates, among other things, the use of high-gain antennas and a long integration time in the signal processing.

Fig. 1: SABBIA system in operation

The long integration time, however, does not represent any major disadvantage for passive radar target imaging, as it is required for ISAR techniques anyway to achieve a high resolution in the cross-range.

Fraunhofer FHR has developed SABBIA, an experimental system, to enable passive radar imaging of non-cooperative airborne and maritime targets by exploiting DVB-S2 signals emitted from geostationary satellites such as ASTRA 19.2° E. The SABBIA system is based on two identically designed receiver frontends, as shown in Fig. 1. It comprises a so-called reference unit, for acquiring the direct satellite signal, and a tracking unit, which is used to receive the target echo. After analog-to-digital conversion, the signals from both frontends are recorded with the aid of high-speed data recorders.

The receiving unit consists of an 85 cm offset antenna, a custom-designed antenna horn developed at Fraunhofer FHR, and a special quad LNB that has a low noise factor as well as an internal low phase-noise oscillator and an external 10 MHz signal reference input.

Both receiving units are connected to a GPS/IMU (Inertial Measurement Unit) so as to receive precise information regarding location and antenna pointing direction. The quad LNB is capable of demodulating DVB-S2 signals with vertical and horizontal polarisations and in both high and low bands simultaneously, thus permitting full polarimetric operation of the system.

In 2017, field trials involving SABBIA were conducted as part of the EDA (cat. B) funded MAPIS (Multichannel passive ISAR imaging for military applications) project. During the trials a military vessel, Porpora (Fig. 2), was scanned as an ISAR image. The given bistatic geometry and orientation of the ship made it possible to image the target vessel from a so-called top, or bird's eye, view. The ship echo is squeezed in only one range cell due to the reduced signal bandwidth used during this first experiment, but is imaged in the cross-range direction (shown in Fig. 3 as a Doppler axis). From this it is possible to deduce the size of the target. This information is essential for target recognition and classification.

Fig. 2: Military vessel Porpora

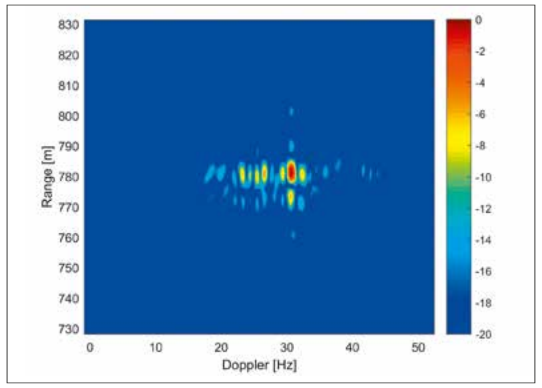


Fig. 3: DVB-S2-based passive ISAR image of the Porpora [dB] (obtained using the SABBIA system)

Dr. Michael Caris
Fraunhofer-Institut für Hochfrequenzphysik und Radartechnik FHR
Wachtberg

info@fhr.fraunhofer.de

Volker Port
Fraunhofer-Institut für Hochfrequenzphysik und Radartechnik FHR
Wachtberg

info@fhr.fraunhofer.de

Millimetre-wave radar for an active protection system

The Fraunhofer Institute for High Frequency Physics and Radar Techniques (FHR) conducts fundamental and applied research in the field of electromagnetic sensors. It develops concepts, methods and systems, particularly in the radar sector. The DUSIM radar sensor presented here is envisaged for integration into an active protection system.

Man-portable antitank weapons are available in great numbers on the global market nowadays. The high penetration power of these munitions in combination with the almost hemispheric threat level means that conventional ballistic protection technologies are scarcely able to provide adequate defence, in particular for light vehicles. What is needed, in fact, are active protection systems which detect and engage any incoming missile in good time before it can impact effectively. The performance capability of such a system depends on several factors: detection reliability, quality of the classification and 3D location, the time needed for processing the measurement data, and the initiation of an appropriate countermeasure. A key role falls to the sensor, which detects the approaching missile, provides information about its nature, and delivers data that allows highly precise determination of the flight parameters, which are then made available in real time to a fire control system. Its all-weather capability and ability to scan through dust clouds and sandstorms give radar technology several advantages over other sensors (e.g. electro-optical or infrared).

Fig. 1: DUSIM – four-channel radar frontend with an output power of 100 mW at a frequency of 94 GHz

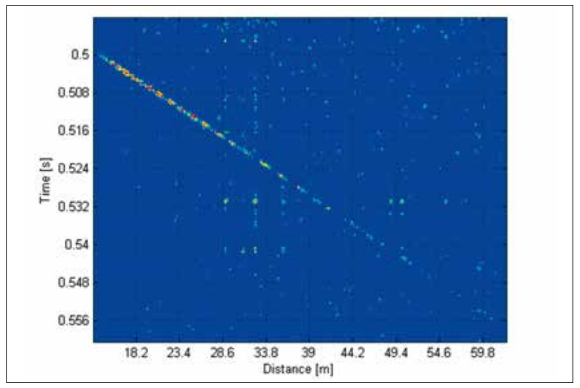


Fig. 2: Trajectory of a small-calibre projectile (MG3 7.62 x 51 mm)

A four-channel radar system for providing active protection over a surveillance range between 8 and 250 metres has been developed within the scope of the DUSIM (Dual Use Sensor for Mid-Range Applications) research project. It operates at a frequency of 94 GHz, with a low emission power of 100 mW, which makes the sensor difficult to detect for non-cooperative forces as well as non-hazardous for persons situated in close proximity (around two metres and more).

The frequency-modulated continuous wave signal (FMCW) with a bandwidth of 1 GHz enables a high range resolution of 15 cm. The core unit of the DUSIM radar frontend is a highly stable signal generation board, which generates a linear and phase-stable frequency ramp in the range of around 15.7 GHz. The signal is subsequently multiplied by six and amplified to the final output power. The frontend's four-channel receiver enables the sensor to localise approaching missiles with high accuracy by means of the mono-pulse principle. With the aid of the Doppler effect it is also possible to determine the velocity and flight direction of the threat. Immediate calculation of the flight track after successful detection is essential for any well-timed and targeted countermeasure. The most exact classification possible minimises the false alarm rate. The frontend shown in Fig. 1 weighs approximately 3 kg and has a size of 200 x 180 x 230 mm³.

The system has been successfully tested under realistic conditions in several measurement campaigns involving both small-calibre projectiles and armour-piercing ammunition. Results are shown in Figs. 2 and 3 as examples. In 2016 and 2017, additional experiments were conducted in a centrifuge facility at WTD 91 in Meppen, where different threats were moved under reproducible conditions along a circular path, during which the radar illuminated a tangential section of the trajectory. This enables the radar signatures of the projectiles to be measured very cost-effectively in a minimum of time. The high amount of measured data also allows a statistical analysis of the considered objects. Fig. 4 shows an excerpt from a typical centrifugal measurement.

The successful measurements show that the DUSIM radar sensor is suitable for use in an active protection system. The signal processing, e.g. localisation and classification of objects, offers potential for improvement. The area covered by the radar could also be expanded by increasing the output power (1 W is currently realistic).

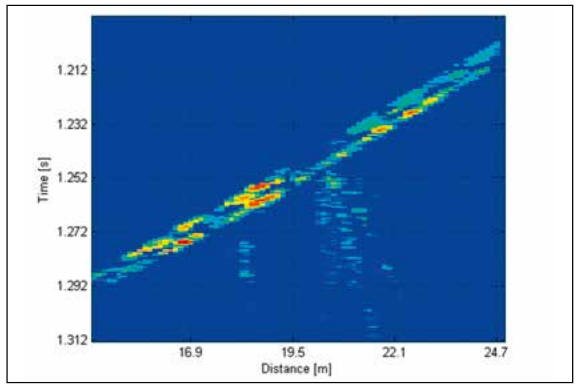


Fig. 3: Part of the trajectory of an RPG – the nose and tail (fin) of the missile are distinguishable

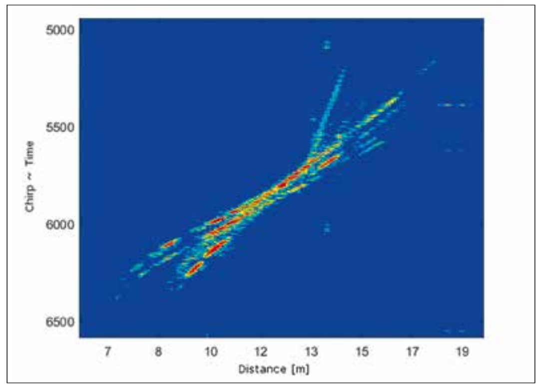


Fig. 4: Trajectory of a projectile in the centrifuge facility of WTD 91 in Meppen. Two scattering spots on the target object are visible, as well as other spots from the centrifuge itself which exhibit lower velocities

Dr. Thomas Alexander
Fraunhofer-Institut für Kommunikation,
Informationsverarbeitung und Ergonomie FKIE
Wachtberg

kontakt@fkie.fraunhofer.de

Virtual and Augmented Reality (VR/AR) in the Bundeswehr – a human-centred approach focusing on military applications

VR and AR technologies allow a realistic presentation of synthetic, computer-generated environments. They are generally available nowadays and efficient to use. But despite their potential for a broad spectrum of applications, there is no one-size-fits-all solution. An ergonomic, soldier-centric design makes it possible to draw on this potential.

Virtual Reality (VR) and Augmented Reality (AR) are meanwhile broadly available technologies enabling particularly realistic presentation and natural interaction with computer-generated, virtual environments. There are many possible applications for the Bundeswehr. A holistic ergonomic approach is crucial for an effective and efficient use of this technology.

A close involvement of the user into the virtual environment is helpful as immersion or a subjective feeling of presence is thereby achieved. This can, though, also induce negative effects such as headaches, nausea and simulator sickness. These topics have been a topic for a long time at the Fraunhofer Institute for Communication, Information Processing and Ergonomics (FKIE).

Technologies such as head-mounted displays or large-scale projections enable the user to be virtually present in the simulated environment, as if it were real. He/she is thus immersed more intensively than in a traditional simulation. Where Augmented Reality (AR) is concerned, the reality is superimposed by virtual elements that are added consistently

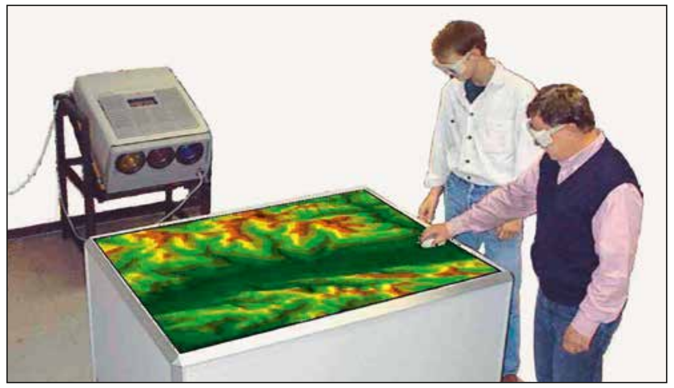


Fig. 1: Electronic Sandtable (ElSa) of FKIE for displaying tactical situation data (1999)

Fig. 2: Augmented Reality in an experimental setup (2015)

within the field of view. Both technologies allow users to experience situations completely, as in reality, but in a safe and controllable way.

Whereas a decade ago this involved the use of complex, monolithic systems, it is nowadays possible at relatively little expense. Developments in the commercial gaming and entertainment field, in particular, have led to suitable displays, graphic computers and interaction devices becoming broadly available.

Any reasonable application of VR in the Bundeswehr has to begin with a comprehensive analysis along with a contextual specification of the military application. This forms the basis for functional and technical requirements regarding the design of the VR/AR system. Further requirements are derived from the characteristics, capabilities and skills of the users. Taken together, this concerns, among other aspects, the image quality, resolution and latency of the system, as well as the stress experienced, feeling of presence, and symptoms of simulator sickness. To explore this, it is necessary to consider both the software (multimodality, presentation, etc.) and the system hardware (interaction devices, displays, etc.).

Possible fields of application in the Bundeswehr have been identified as education and training, enhancement of human mission performance, control of semi-autonomous systems and tele-presence, tele-maintenance, and technical design of future systems and platforms. In most of these applications, VR/AR can complement existing systems as a means of enhancing overall performance.

In military education and training, for example, VR systems can be used to prepare for live exercises. Exercise information can be imparted within the units beforehand to allow more efficient subsequent use of the time-, effort- and cost-intensive live training facility. This would be supplemented by feedback functions for more detailed after-action reviews.

AR systems can also enhance soldiers' perceptive performance by consistently superimposing friendly or hostile positions, identified dangers, and other relevant items of information in the field of vision, thus increasing situational awareness. It makes sense to limit the amount of information and visual clutter so as to prevent any distraction from the actual task in hand.

Similar potential exists for the other fields of application mentioned above.

Consideration given to ergonomic and human factors in an early definition and development phase of this new VR/AR technology will afford a key contribution in this regard and ultimately enable its practical and purposeful application within the Bundeswehr in future.

Fig. 3: See-through head-mounted display for presenting AR information (2016)

Fig. 4: Use of a head-mounted display for exploring environments in VR (2017)

Prof. Dr. Ulrich Schade
Fraunhofer-Institut für Kommunikation,
Informationsverarbeitung und Ergonomie FKIE
Wachtberg

kontakt@fkie.fraunhofer.de

Prof. Dr. Frank Kurth
Fraunhofer-Institut für Kommunikation,
Informationsverarbeitung und Ergonomie FKIE
Wachtberg

kontakt@fkie.fraunhofer.de

AI research in the context of security

This contribution takes a look at AI, of which there are numerous distinct variants. These are illustrated through references to current Bundeswehr-related research being conducted at the Fraunhofer Institute for Communication, Information Processing and Ergonomics (FKIE). The limits for applications involving AI are also outlined.

"Artificial Intelligence" (AI) is a term that is frequently misunderstood. When we currently speak of "AI", we mostly refer to "deep learning" applications, as these dominate public discourse, for instance due to the successes in mastering the game 'Go', in connection with autonomous driving, or also in the form of "Intelligent Personal Assistants" such as Siri or Alexa.

Essentially, AI applications can be viewed as categorisations or, more specifically, as classifiers. A classifier processes input, for example a picture or text, and delivers the corresponding output, such as the name of a person in the picture or the language of the text. Deep learning as a classifier is a very powerful tool from the family of so-called "neural networks", where the desired classification is learned on the basis of a huge 'corpus' of examples. The selection of the corpus and the learning itself are both time-consuming.

Generally, if the features used as the basis for an algorithm to successfully carry out classification are unknown to the developer, then the use of deep learning will be advisable as this method will extract the relevant features. One example of

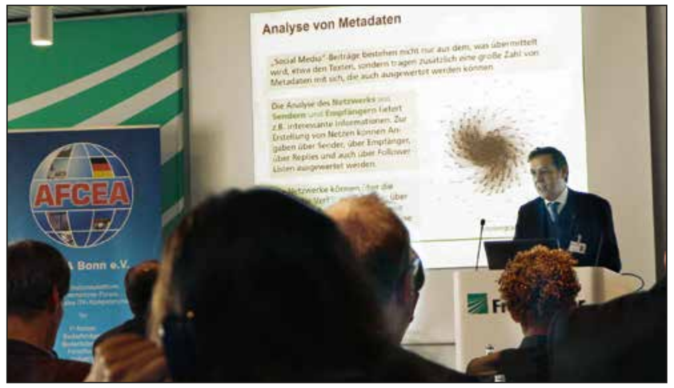


Fig. 1: Meta information for "social media" analysis: visualisation of communication relationships between members of the last Bundestag parliament (Source: © Fraunhofer FKIE)

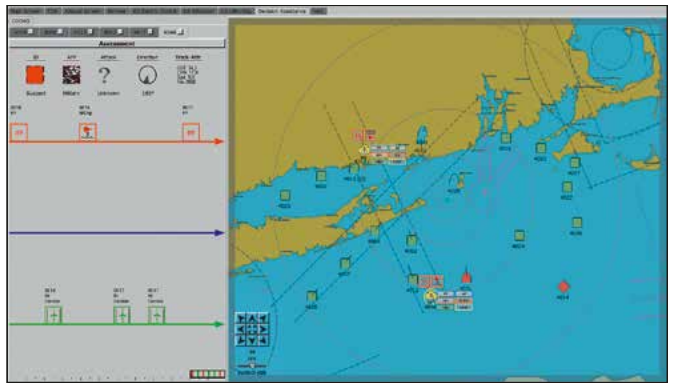


Fig. 2: Frigate's operational picture generated by means of rule-based AI (Source: © Fraunhofer FKIE)

such a "deep learning" application is the preselection and classification of demodulated radio signal data, as is being explored at the Institute.

If the features relevant for classification are known, however, the classifier can be developed using simpler machine learning methods. For example, the words used can serve as features for determining the language in which a text has been written. Also, metadata (time of publication, follower structure of the sender etc.) can, and should, be used as features for analysing "social media" posts. Such methods were a topic of an AFCEA future and technology forum entitled "Automated opinion influencing – manipulation in open media", hosted by FKIE in September 2017.

If the developer is also cognisant of the connections between the features and the classification, it will be possible to reflect that knowledge using rule-based AI. For instance, a frigate analyses its surrounding airspace and the objects within it so as to determine, through a complex system of rules, whether any object poses a threat. If it does, it is then displayed to the operator.

Generally speaking, AI applications are very suitable for use in the field of image analysis and, in many instances, also in the field of language analysis, as has been demonstrated at FKIE by the development of methods for robust speech classification for operational scenarios. But research regarding Siri, for instance, has shown that unusual vocabulary, complex syntactical structures and, in particular, a strong accent on the part of the speaker can lead to errors. For a voice control system, which is an application that can be realised fairly easily with AI methods, this means that a fixed vocabulary and a fixed syntactical structure might be necessary to offset the disadvantages caused by the din of battle and any other loud background noises.

The success of AI methods always depends on the relevance of the features and data being evaluated. The methods will not necessarily be flexible from the viewpoint of changes. For instance, a vehicle that has learned to drive autonomously on motorways in Germany will struggle to negotiate roundabouts in the UK, and a system that recognises familiar threats will then overlook a threat if it is new and unknown and deviates significantly in terms of the features on which recognition has previously been based. Adapting the methods through learning will be too slow for some applications and may require a lot of data to take account of the changes.

Fig. 3: Use of AI in the field of robust speaker classification (Source: © Fraunhofer FKIE)

Dr. Marcus John
Fraunhofer-Institut für Naturwissenschaftlich-Technische
Trendanalysen INT
Euskirchen

info@int.fraunhofer.de

Possible applications of cognitive computing as a means of technology foresight

For the purpose of technology foresight – the early detection and analysis of emerging technologies – a multitude of information, in form of texts or data, has to be perceived. Current developments in the field of cognitive computing offer increasing possibilities to support this process by means of IT-based methods and to make it more efficient. The Fraunhofer Institute for Technological Trend Analysis (Fraunhofer INT) is developing a suitable assistance system with this in mind.

Fraunhofer INT has been supporting the R&T (Research & Technology) planning process within the Bundeswehr for more than 40 years by compiling an overview of current developments in the domains of the natural sciences and technology for the purposes of technology foresight, and by analysing them with respect to their long-term relevance for the Bundeswehr. For this it is necessary to observe, where practicable, all relevant fields of science and technology continuously, in order to identify new topics and technologies as early as possible, for example, and also to register any breakthroughs in a particular area of research. For years, Fraunhofer INT has been regularly presenting the findings from this technology foresight process within the scope of a "Wehrtechnische Vorausschau" (Defence Technology Foresight) for the German Federal Ministry of Defence.

Scientific publications, patents and relevant internet pages form the knowledge base for this process. The number of publications alone is growing by more than 2.6 million per year. As part of the project presented here, an assistance system is being developed which will make it possible to tap into and analyse this enormous knowledge base with the aid of IT-based methods.

The system under development – referred to as KATI, or Knowledge Analytics for Technology & Innovation – is intended to assist the scientists at Fraunhofer INT in various tasks within the framework of technology foresight. Beside more efficient research and effective identification of key publications, it will include in-depth analyses. These will concern diverse aspects of topic content and questions regarding future developments, as well as the analysis of players in those fields, for the purpose of identifying suitable contacts or cooperation partners, for example.

A software package has been procured as part of the project for Fraunhofer INT to achieve this goal. This software is expected to make cognitive computing methods useful for technology foresight. Meant by this is the attempt to simulate human cognitive skills by means of computer algorithms. It will involve applying techniques from various domains of computer science. Computer linguistics methods will be used, for instance, to make text content accessible for analysis. This will be complemented by algorithms from the domains of data mining, machine learning and Big Data. These will be necessary for clustering large amounts of texts, identifying patterns within them, classifying them, and detecting anomalies.

Considerable adaptations will have to be made to the system, however, to be able to use it for the purpose of technology foresight. Aside from the shear amount of data, it will be a particular challenge processing information and texts from very greatly differing knowledge domains, each of which has its own vocabulary.

It has, therefore, firstly been a matter of storing the different required sources of information in a suitable data structure, for which purpose a so-called graph database is used since it is particularly well-suited for efficiently processing cross-linked bibliographic data from scientific publications and patents. A search engine developed for literature research will make this database accessible. In parallel with this, different metrics will be computed which will support the scientists at Fraunhofer INT in various research and analysis tasks. Beside analysing the players concerned (Fig. 2), the main focus has initially been on identifying key publications (Fig. 3).

In this way an analysis system has been developed which in future is to form the basis for a learning system (Fig. 1).

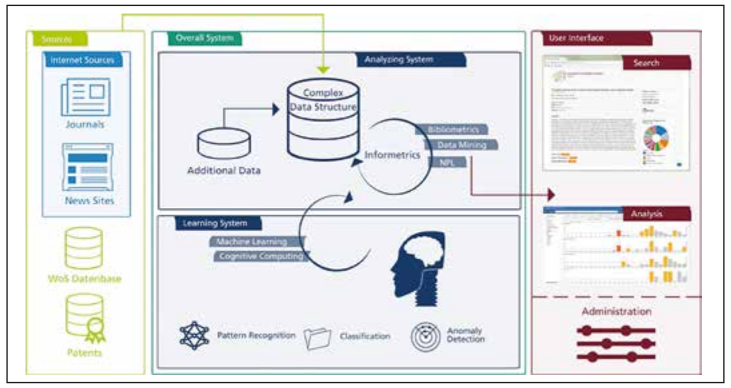


Fig. 1: Sketch of the planned system layout

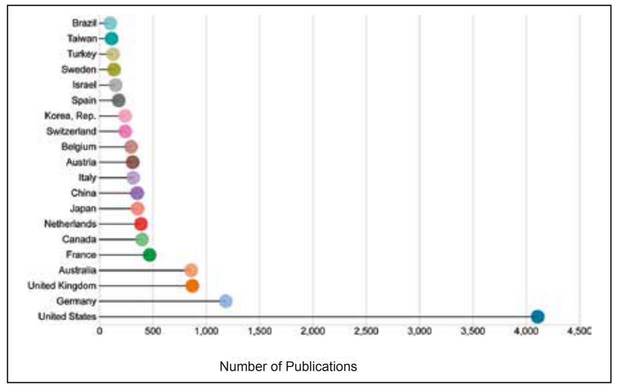


Fig. 2: Depiction of publication activities at national level.
Such depictions serve to identify the relevant players in a subject area

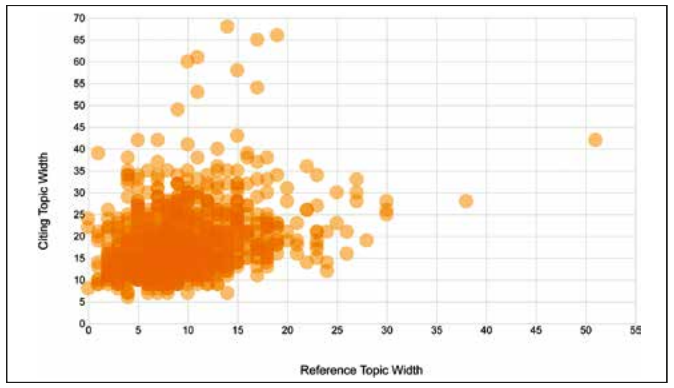


Fig. 3: This scatter plot shows, on the X-axis, the disciplinary width of the references cited in a scientific publication and, on the Y-axis, the disciplinary width of that author's references cited in papers. Such a display format is useful for identifying key publications

M. Sc. Marian Lanzrath
Fraunhofer-Institut für Naturwissenschaftlich-Technische
Trendanalysen INT
Euskirchen

info@int.fraunhofer.de

Dipl. Ing. Christian Adami
Fraunhofer-Institut für Naturwissenschaftlich-Technische
Trendanalysen INT
Euskirchen

info@int.fraunhofer.de

Research study ”UAS interaction studies CW and LPM“

Unmanned aerial systems (UAS) classified as LSS (Low, Small, Slow) pose a threat to military and civilian facilities due to their capabilities for reconnaissance and for carrying payloads (e. g. explosives). Neutralising them with conventional effectors requires considerable effort. Effectors based on sources of strong electromagnetic radiation (HPEM) represent a viable alternative.

The market for multirotor unmanned aerial systems such as quadcopters has seen a huge upsurge over the last few years. Particularly systems with a gross takeoff weight of less than 20 kilogrammes have found a mass market. These so-called SUA (Small Unmanned Aircraft) are categorised as nano- or micro-UAS by the military. Individuals, media professionals, industrial companies as well as authorities are especially appreciative of the opportunity they offer to capture aerial images. Operability has also improved over the past few years, even for inexperienced users, thanks to automatic altitude control, positioning and collision avoidance systems. If the battery power falls to low levels or the wireless connection to the controller is lost, the UAS will return automatically, supported by satellite navigation systems, to the takeoff point.

The combination of easy accessibility for amateur operators, capability to transport not insignificant payloads, and high freedom of movement afforded by a more open airspace offers the possibility to use UAS in diverse threat scenarios. Within the scope of a research study entitled “UAS interaction studies CW and LPM”, initiated by the Bundeswehr Research Institute

Fig. 1: Laboratory test setup at Fraunhofer INT
(Source: https://openclipart.org)

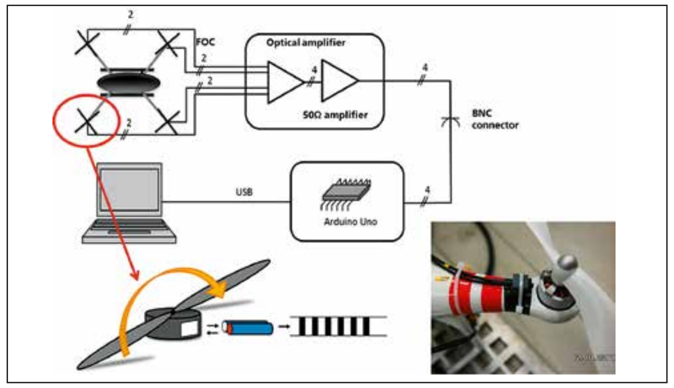


Fig. 2: Rotor speed monitoring system for laboratory tests

Dr. rer. nat. habil. Michael Suhrke
Fraunhofer-Institut für Naturwissenschaftlich-Technische
Trendanalysen INT
Euskirchen

info@int.fraunhofer.de

TRDir Dr. Martin Schaarschmidt
Wehrwissenschaftlichen Instituts für Schutztechnologien –
ABC-Schutz (WIS)
Munster

WISPosteingang@bundeswehr.org

for Protective Technologies and CBRN Protection (WIS) to explore suitable measures for countering UAS, a selection of 11 different UAS has been laboratory-tested at Fraunhofer INT in regard to their susceptibility to electromagnetic interference (Fig. 1). The electronics of the systems, which are developed mainly for the civilian market, are designed only for electromagnetic environments typically found in public spaces. Technical countermeasures which can generate electromagnetic fields beyond regulatory limits represent a valuable option for interdicting unauthorised use of UAS.

The electromagnetic interference exposure tests at the Fraunhofer INT laboratory employed a specially designed setup including video monitoring as well as a system based on photoelectric barriers developed to observe rotational speeds during exposure. The concept is shown in Fig. 2. This provided the means to accurately record any operating malfunctions of the UAS during exposure to narrow-band electromagnetic signals over a wide frequency range. The susceptibility profiles acquired for each UAS were subsequently analysed for structures and common features.

The selected UAS displayed vulnerabilities to pulsed low-power microwave (LPM) and continuous-wave (CW) signals throughout the tested frequency range, as shown in Fig. 3. The identified susceptibility thresholds, i. e. the electromagnetic field strengths needed to cause the UAS to malfunction or crash, depended on the polarisation of the electromagnetic field, the pulse parameters (duty-cycle ratio) and the frequency. Using this information as a basis, it is possible to derive first concepts for an effector system design. The lowest susceptibility thresholds were found during testing with CW signals, but, for mobile countermeasure systems of the same size with a large operating range, pulsed microwave signals are of greater interest because of their lower energy requirements and higher pulse output power. Suitably designed mobile effector systems with militarily relevant operating ranges are currently undergoing testing at WIS for their effectiveness against UAS (Fig. 4).

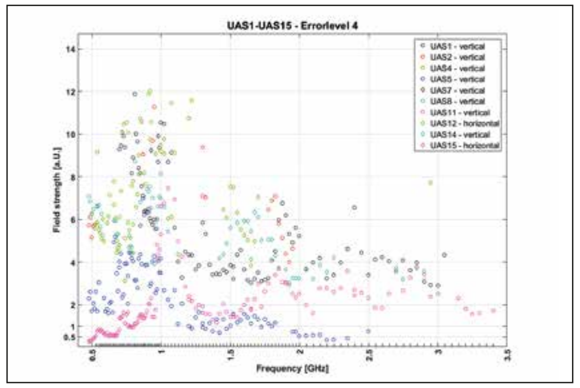


Fig. 3: Susceptibility test results for all UAS, and highest malfunction level

Fig. 4: Testing of a mobile effector system with a large operating range under free-field conditions at WIS

PD Dr. Rüdiger Quay
Fraunhofer-Institut für Angewandte Festkörperphysik IAF
Freiburg

info@iaf.fraunhofer.de

Dr. Erdin Ture
Fraunhofer-Institut für Angewandte Festkörperphysik IAF
Freiburg

info@iaf.fraunhofer.de

Flexible electronic countermeasures with special focus on jamming capabilities

In light of the constantly changing nature of, and strong increase in, electromagnetic threats, it is imperative to develop flexible solutions to counter radio-controlled improvised explosive devices, for example. Gallium nitride power amplifiers that are capable of providing highly-linear operation offer possibilities for new flexible architectures, which in turn, with sufficient power levels, will allow software-defined jamming of those threats.

Efficient generation of high levels of power while sustaining high linearity at the same time across a broad range of microwave frequencies is fundamentally important for the capabilities and protection of our armed forces. In the electromagnetic spectrum between 1 MHz and at least 6 GHz lie numerous civil and military radio applications, as well as a great number of wireless data links that can be easily acquired and used to trigger radio-controlled improvised explosive devices (RC-IEDs). With the number of threats constantly increasing, it is necessary for instance to deploy protective measures in the field to counter unmanned airborne vehicles (UAV). The key here is to flexibly deploy protection across the frequencies. Largely software-defined jamming is the vision for coping with the quickly changing military scenarios. However, radio frequency (RF) components are not typically available for wide multi-decade bandwidths and therefore not so easily made more flexible.

Recent findings from research based on gallium nitride (GaN) transistors can be used to realise power amplifiers and other key components (e.g. switches and receiving circuits), with a view to creating jamming architectures which allow constant adaptation to threats, ideally through software alone. The research described in this article is based on a cooperative effort involving, among others, Fraunhofer IAF and Fraunhofer FKIE, WTD81, Hensoldt, and United Monolithic Semiconductors (UMS).

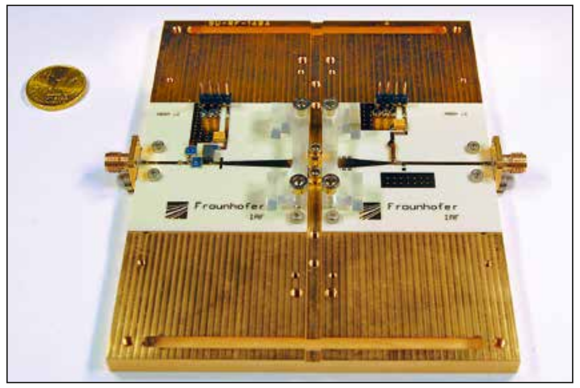


Fig. 1: Typical GaN transistor package (centre) forming the heart of the RF power generation

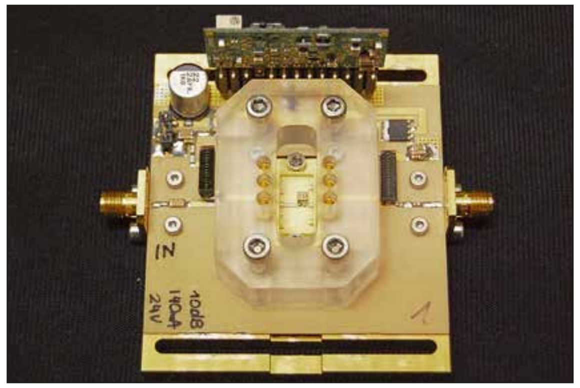


Fig. 2: Integrated linear gallium nitride broadband amplifier circuit

Shown as an example of such key components, in Fig. 1, is a so-called GaN powerbar – a very compact transistor device which can be used to generate power at frequencies between 10 MHz and 6 GHz. Such powerbars have to be adjusted to 50 Ohms of impedance, which is achieved through the hybrid circuits and passive elements around the transistor package (Fig. 1, centre). This need for adjustment normally stands in contradiction to the requirement for wideband operation, as adjustment is a frequency-dependent process. Therefore, hard-wired frequency adjustment cannot be applied for software-defined solutions. For this reason novel concepts for broadband components are needed, and any filtering should be avoided. There is, at the same time, a trade-off between wideband operation and efficiency. The supply of electric power is limited for any mobile platform, be it due to the generators or available battery capacity. Furthermore, flexible generation of radio frequency power will always lead to the generation of harmonic frequencies, which need to be suppressed without filtering, without impairing efficiency. Such an integrated linear GaN amplifier with multiple stages, which achieves good amplification in an efficient way, is depicted in Fig. 2, again integrated into a package. This driver delivers wideband signals with good gain and very high linearity over the entire bandwidth.

These and other GaN components can enable the jamming of RC-IEDs by means of jammer architectures that take account of the rapidly changing RC-IED threat scenarios. This approach is key, where the protection of armed forces is concerned, to creating flexible solutions on the fast-evolving market for mobile communication applications. Such protection includes developments regarding simple threats just as much as it does the developments associated with the more advanced mobile phone networks of the 3rd (UMTS), 4th (LTE) and, from 2020 onward, 5th generations, while older standards such as GSM (2nd generation) will also remain active. With that in mind, Fig. 3 shows an example of a new generation of flexible power amplifier modules capable of countering the possibilities offered by mobile communication technology and of protecting our armed forces in rapidly-changing scenarios.

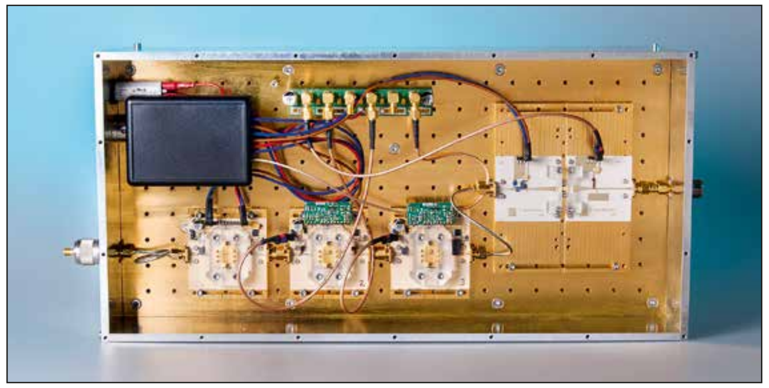


Fig. 3: Demonstrator of a newly-developed linear power amplifier

Sebastian Wurster
Fraunhofer-Institut für Chemische Technologie ICT
Pfinztal

info@ict.fraunhofer.de

Thomas S. Fischer
Fraunhofer-Institut für Chemische Technologie ICT
Pfinztal

info@ict.fraunhofer.de

Modelling, simulation and characterisation of the combustion behaviour of complex-shaped solid propellants

Solid propellants are an indispensable constituent for propulsion in current and future gun systems of the Bundeswehr. Fraunhofer ICT is exploring new algorithms and methods and developing software tools which will facilitate the modelling, simulation and characterisation of complexly shaped propellants.

To be able to model, simulate and characterise gun propellants during their design and development, it is necessary to describe the change in the propellants' geometry during the combustion process by means of a so-called form function. Currently used methods and models, however, have no or only very limited capability, for example, to simulate or characterise propellants irregularly formed through geometry variations ensuing from production irregularities. New production technologies such as 3D printing promise the possibility in future of producing complexly shaped propellants which hitherto used methods would be unable to describe or design.

Mindful of this, Fraunhofer ICT has developed the so-called "ICT Cellular Combustion Algorithm" (ICCA), which is also able to simulate form functions for randomly shaped solid propellants. The ICCA discretises the propellant geometry on a grid/mesh and describes the change in geometry with the aid of an algorithm based on cellular automata. The geometric input data for the ICCA simulations can be taken directly from computer tomographic images of a propellant grain. The simulation data produced by the ICCA can then be used to simulate the propellant combustion process, for instance in a gun or a closed vessel (bomb).

To describe the interior ballistics of complexly shaped propellants, however, it is necessary to know precisely not only the change in geometry during the combustion process but also the pressure-dependent linear burning rate, in other words the regression velocity of the burning surface. This involves the use of a pressure build-up model for a closed vessel, based on the ICCA, to fit experimental dynamic vivacity data. It is able to take account of additional effects such as heat loss, pressure-dependent thermodynamic parameters or a supplementary igniter charge. This so-called simulation-based burn rate measurement method can also characterise the combustion behaviour for complex propellant geometries, and precisely measure the burn rate at only a fraction of the hitherto needed amount of propellant and cost. For the JA2 gun propellant, for example, it has been demonstrated that a complete burn rate characterisation is possible with only 3 propellant grains (approximately 4.5 g) per test shot.

To make this know-how accessible and usable for the customer (i. e. government) and the defence industry, work is in progress on behalf of WTD 91 GF 410 to implement the algorithms in application software. ICCA-2D, for example, is being implemented in combination with a pressure build-up model for a closed vessel in a software tool called "Pulverabbrand" (Propellant Combustion". The 3D form function that it simulates will then be used to design gun propellants and ammunition. The ICCA will be implemented fully parallelised and thus allow high-resolution simulations with a minimum of computation time. Beside simulating the combustion of extrudable gun propellants with a complex cross-sectional geometry, the "Pulverabbrand" software tool will offer the capability to animate the change in geometry. This, in addition to use in research and development, will make it especially suitable for training and educational purposes.

The "Pulverabbrand" software tool is part of an interior ballistics software family which is being developed and nurtured at Fraunhofer EMI and ICT and includes the ICT Thermodynamic Code, the EMI interior ballistics codes SimIB-0D and 1D, as well as the interior ballistics design and analysis software "Ballistisches Analyse und Auslegungstool (BAA)" developed by ICT. The individual codes are partly interlinked by suitable interfaces, thus facilitating work involving different elements of the software and permitting a design and development process for new gun propellants that cuts time and costs.

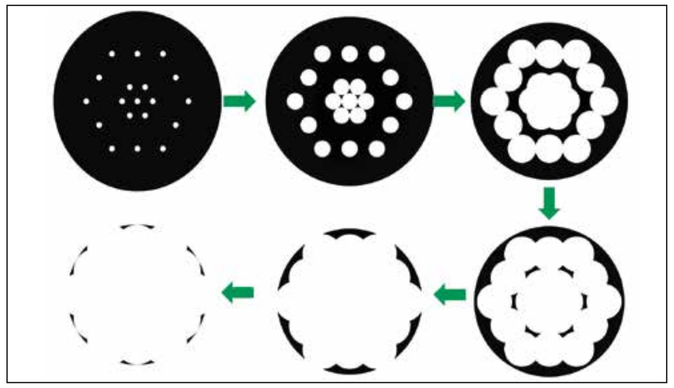


Fig. 1: Visualisation of the combustion process with the aid of the ICT Cellular Combustion Algorithm

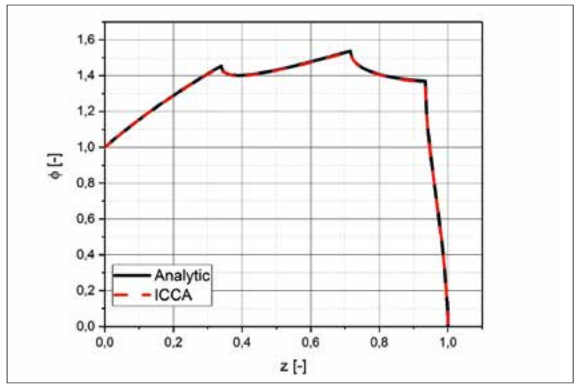


Fig. 2: Analytical and numerical form function in comparison with the ICCA validation

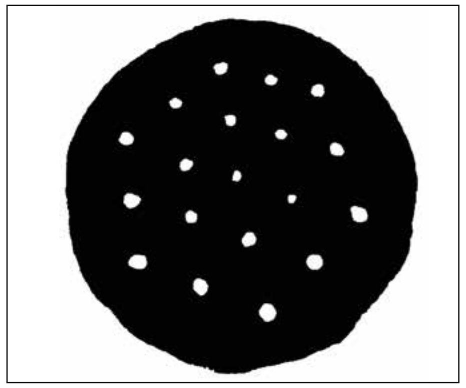


Fig. 3: Computer tomograhic propellant cross-section with geometry variations caused during production

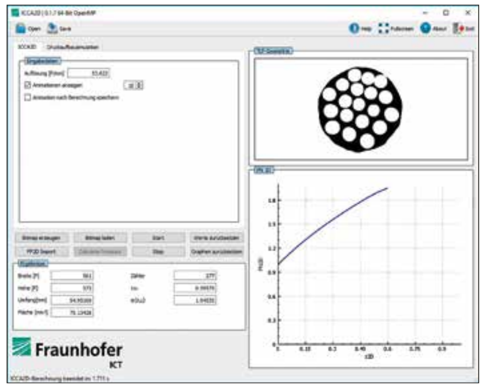


Fig. 4: Graphical user interface of the "Pulverabbrand" (Propellant Combustion) software tool

Dr. Ilja Kaufmann
Fraunhofer-Institut für Optronik, Systemtechnik
und Bildauswertung IOSB
Ettlingen

info@iosb.fraunhofer.de

Dr.-Ing. Markus Müller
Fraunhofer-Institut für Optronik, Systemtechnik
und Bildauswertung IOSB
Karlsruhe

info@iosb.fraunhofer.de

Counter-UAS: Image-based UAV detection and recognition

The Bundeswehr is increasingly having to address the threat posed by small unmanned aerial vehicles. Detection is a precondition for any countermeasures, with a multisensory approach proving indispensable. Fraunhofer IOSB, together with other institutes, is working to overcome this challenge through the development and cross-linking of active and passive optronic sensors.

Small remote-controlled and increasingly autonomous aerial vehicles, so-called "drones" or UAVs (Unmanned Aerial Vehicles), have become a mass phenomenon. National air traffic control organisation DFS (Deutsche Flugsicherung GmbH) estimates that in Germany alone 400,000 drones were sold in 2016, and a further 600,000 in 2017. These devices are used for private, industrial/commercial and official purposes. It is likely that their use for undesirable purposes will also increase. It can particularly be expected, for example, that during current and future Bundeswehr missions there will be greater hostile employment of mini-drones against friendly forces.

Before a drone can be effectively engaged, it must be reliably detected and identified. To handle such tasks it will be necessary to operate future-viable multisensor-based systems and also use new types of sensor technology. To cite one illustrative example, mini-drones are nowadays available that, to a certain extent, can circumvent obstacles independently (automatic obstacle avoidance). Systems will soon be available in large numbers that can autonomously navigate their way through woods and forests and, in many situations, operate without

Fig. 1: Gated viewing: background and visual obstructions can be physically suppressed, based on the runtime of light

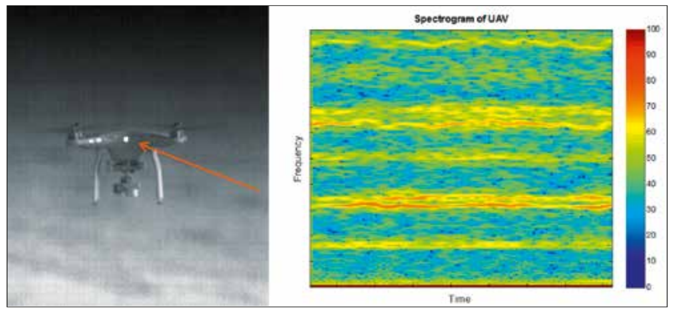


Fig. 2: Classification based on the vibration spectrum acquired by a laser Doppler vibrometer

radio and GPS links (vision-based drone navigation). Such a drone would begin operating from cover by means of an auto-timer and then, to accomplish its mission, would select the flight path previously stored in its memory and continuously compare it with current video data. Purely radio-based systems would not detect such a UAS.

Fraunhofer FKIE and Fraunhofer IOSB are participants in the "Defence Against UAS" research and development project of the BAAINBw, with work addressing sensor fusion, sensor data analysis, and laser Doppler vibrometry. Fraunhofer IOSB has, with its own research funding, also set up a laboratory system referred to as "MODEAS" (MOdulares DrohnenErfassungs- und AssistenzSystem, or Modular Drone Detection and Assistance System), through which a complete scanning and detection chain including target tracking was successfully finalised in late 2017.

The research domains of Fraunhofer IOSB encompass the entire optical wavelength range (UV to thermal infrared). Both passive and active sensor solutions are being developed, explored, and evaluated. Apart from visual-optical (VIS) and IR sensors, there are various active laser sensors that will play an important role in drone detection and recognition in the medium term. Two of these systems, gated viewing and laser vibrometry, are outlined in brief below.

In gated viewing, a camera sensor is activated for an extremely short, precisely defined period, ensuring that only that part of the light of an emitted laser pulse reflected from a specified distance interval is detected. Not only interfering background but also light scattered by fog or dust can thus be filtered out. The result is an almost perfectly segmented target signature, offering opportunities for automatic classification and payload estimation.

A laser Doppler vibrometer illuminates the target with a continuous laser beam. The movements (including vibrations) of a drone during operation modulate a slight frequency shift on the reflected laser beam due to the Doppler effect. The object vibrations can also be calculated from the modulation. It is possible to use the vibration spectrum for information on the type of drone and for payload estimation, for instance, and also for differentiation (between drone and birds).

In "MODEAS", Fraunhofer IOSB has created a laboratory system for the development and testing of in-house and external sensors as well as of sensor data evaluation methods. High-resolution visual-optical omnidirectional cameras give this system a detection range of up to 500 m for tracking UAV trajectories. Data from a tracking camera fitted with tele optics and further sensors permits classification of the target object.

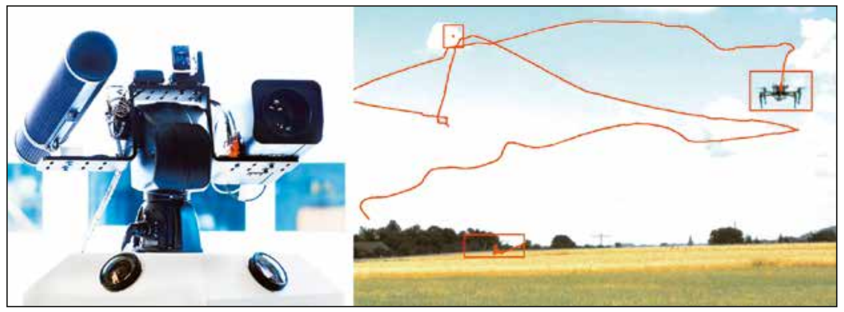


Fig. 3: MODEAS: detection and tracking, based on data from visual-optical omni-directional cameras, for parameterising high-resolution tracking sensors

Barbara Essendorfer, M.A.
Fraunhofer-Institut für Optronik, Systemtechnik
und Bildauswertung IOSB
Karlsruhe

info@iosb.fraunhofer.de

Supporting Joint ISR through Coalition Shared Data

Information superiority is a key factor in maintaining a nation's security. Sensors and information systems produce huge quantities of data, and the challenge is to have relevant information available in time. The Coalition Shared Data (CSD) concept permits efficient information management through standardised and coordinated services, interfaces and formats.

In recent decades, globalisation has created complex economic and sociological interdependencies. The nature of conflicts has changed, and nations are confronted with a great many new threat scenarios. Information superiority is a question of being able to have the right information at the right time and to draw the right conclusions from it. The advances in platform, sensor and network technologies and the development of storage capability make it possible to generate and store large volumes of data and to disseminate information in near real-time. Both aggressors and defenders are able to act remotely and to network via time and space. To make use of these new capabilities in complex operational scenarios where multiple nations and forces work together, it is necessary for systems and services to interact with one another in a well-defined interoperable way. Operational processes as defined in the context of Joint ISR (Intelligence, Surveillance and Reconnaissance) and the Intelligence Cycle (see AJP 2.1, 2.7 and AIntP-14) need to be supported.

The CSD concept offers an approach in this respect. It is based on STANAG 4559 and associated STANAG documents (NATO Standardization Agreements), process descriptions and doctrines (Fig. 1) and has been developed in multinational projects over several years. The results have been assimilated in the relevant standards and regulations.

The concept's starting point was the sharing of fixed, finished data such as reports, images and video clips. Over time this aspect has been extended to include the sharing of streaming data (e. g. videos, tracks). Today there is the ability to also share data generated in collaborative business processes, where multiple parties work collectively on an item of data (e. g. a task, or a request) within a clearly defined process (see AIntP-14). The concept is based on having a network of physically dispersed sites, which are connected via available network infrastructure (Fig. 2). The information generated at the sites is described with the aid of metadata. The metadata is disseminated at participating sites using appropriate synchronisation protocols. The actual information (data files) can be retrieved on demand, thus leading to a ubiquitous (global) information awareness throughout the network along with reduced network traffic. To further support information use tailored to operational requirements, analysis systems can, for example, add data and information extraction and fusion techniques (Fig. 3). Further sources can be connected through use of semantic world models, which describe the Joint ISR domain and the relevant missions.

The concept has been developed in a spiral approach and implemented by different providers. As a means of verification, its results have been tested in multiple interoperability exercises, such as MAJIIC (2) (Multi-intelligence All-source ISR Interoperability Coalition) and the Unified Vision exercise series. This has led to the CSD concept being operationalised by several nations and NATO.

Fraunhofer IOSB has developed systems and services for CSD on multiple levels and is now focusing its research in this area on improving the concept, as well as on aspects of data and information management. Additional interfaces and new services are being developed to enable the concept to be used for missions that combine various security domains, and to achieve multilevel security in an operational environment. The concepts are currently being adopted within the scope of Bundeswehr missions (e. g. MINUSMA) in cooperation with industry.

We would like to thank BAAINBw L5.4 and our national and international project partners for the support they have given to our work.

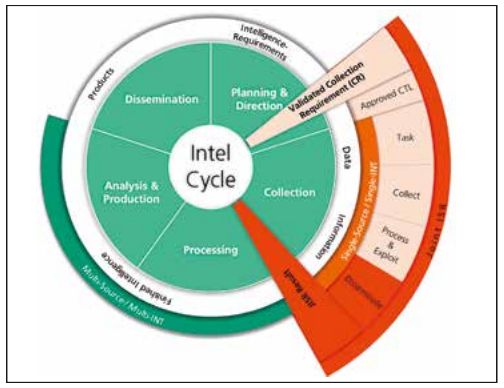


Fig. 1: Support for Joint ISR and the Intelligence Cycle through CSD. The aspects depicted in red are supported (primarily) by CSD, the focus being on disseminating information as required

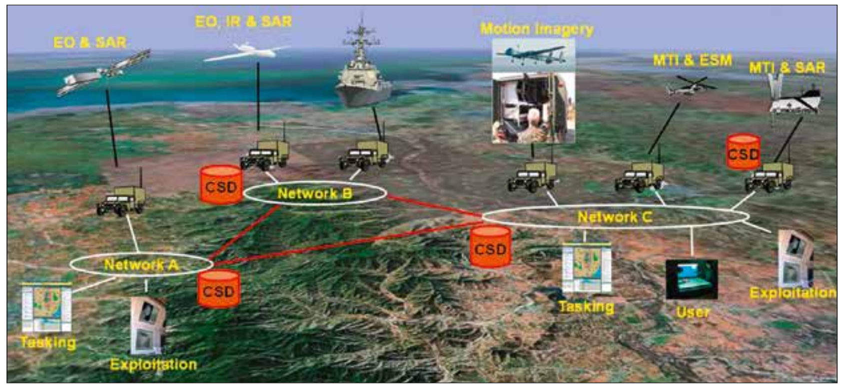


Fig. 2: Information dissemination in a CSD network

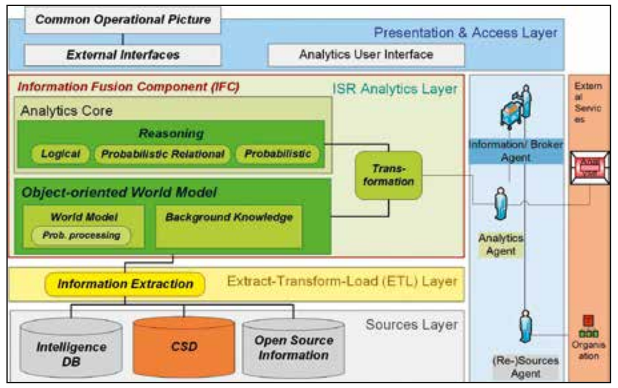


Fig. 3: Combination of external information sources and the CSD concept in the ISR analytics architecture developed by Fraunhofer IOSB at system level. The use of information agents permits the inclusion of additional external services

Prof. Dr.-Ing., M.S. Berend Gerdes van der Wall
Deutsches Zentrum für Luft- und Raumfahrt,
Institut für Flugsystemtechnik
Braunschweig

info-pks@dlr.de

Dr. habil. Anthony Gardner
Deutsches Zentrum für Luft- und Raumfahrt,
Institut für Aerodynamik und Strömungstechnik
Braunschweig

info-pks@dlr.de

Rotor technologies for military applications

The German Aerospace Center is developing components for future helicopter rotors. These technologies improve the aerodynamics of the helicopter to reduce noise and vibration and improve fuel efficiency. Currently three research areas are active: "Active rotor control", "Active twist rotors" and "Dynamic stall".

The swashplate and control rods of a helicopter allow a cyclic or collective variation of the rotor blade pitch angle during the revolution of the rotor blades. A precise, locally variable control of each individual blade pitch angle can be achieved using "individual blade control". This allows the reduction of noise and vibration and an improvement in fuel efficiency. The target blade movements can be achieved by the use of active twist or multiple swashplates.

Active rotor control, using the multiple swashplate concept (META), is a patented invention of the DLR where full individual blade control can be achieved by only using actuators which are installed in the nonrotating system. An initial test of the META system in 2015 with a 4-Blade rotor was successfully performed, as was a second test in 2016 with a 5-blade rotor. The ability of the META system to significantly reduce noise and vibration while improving fuel efficiency was impressively demonstrated, and a static track and balance using the META system could also be executed. The rotor blades could be individually controlled for arbitrary pitch schedules, and also with harmonic motion in the range from 1-6 times the rotor

Fig. 1: META with a 5-blade rotor in the wind tunnel of DNW 2016

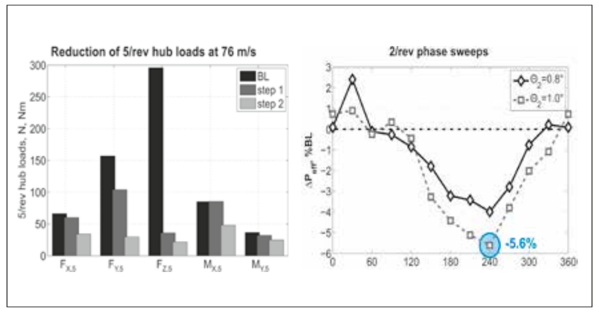


Fig. 2: Reduction of vibration and power requirement by META, test 2016

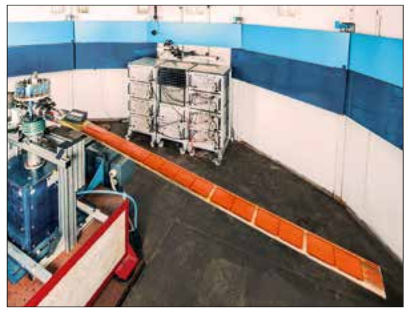


Fig. 3: Active twist rotor blade during whirl tower tests

Dr.-Ing. Johannes Riemenschneider
Deutsches Zentrum für Luft- und Raumfahrt,
Institut für Faserverbundleichtbau und Adaptronik
Braunschweig

info-pks@dlr.de

rotation frequency. Since the META system is entirely installed in the nonrotating system, the rotor and all rotating parts remain unchanged, suggesting META as a retro-fit to existing helicopters.

Active twist rotors consist of a passive rotor blade structure combined with piezoelectric actuators which are integrated into the structure of each rotor blade and can change the twist of the blade. This requires a new blade design taking the actuators into account. The target of a ± 2° twist at the blade tip while protecting the delicate ceramic actuators from the high centrifugal loads is non-trivial. In 2017 a blade was designed and built which used a special stiffening of the trailing edge to reduce the total strain in the blade (and thus also in the actuators) to under 0.1%. Whirl-tower tests on the rotor blade demonstrated that this low strain could be preserved while achieving blade tip twists of ± 2° at control frequencies of 2 – 4/rev. It could be shown that the actuator concept is robust enough to be undamaged by a wind tunnel test, and thus a full set of rotor blades is currently being built to demonstrate the improved aerodynamic performance.

Research into Dynamic stall on rotorcraft delivers an important contribution to the performance improvement of future military rotorcraft. In fast forward flight, or highly loaded maneuvering flight, a part of the flow on the retreating main rotor blade is subjected to stall. In the regions of dynamic stall, large load reversals and pitching moment peaks appear. Modern helicopters limit the flight envelope to avoid flight conditions with more than minimal amounts of dynamic stall on the rotor blades, in order to avoid structural damage to the blades and to the rotor hub. The research in the working package "The Virtual Aerodynamic Rotorcraft" also includes activities to characterize the flow field of a helicopter in flight. The main rotor blade tip vortices can cause dynamic stall when a highly loaded rotor blade approaches them. The DLR uses experimental and numerical tools for the basic investigation and understanding of dynamic stall and blade tip vortices. A further activity is the control of dynamic stall.

Fig. 4: Active twist blade tip deflections under actuation

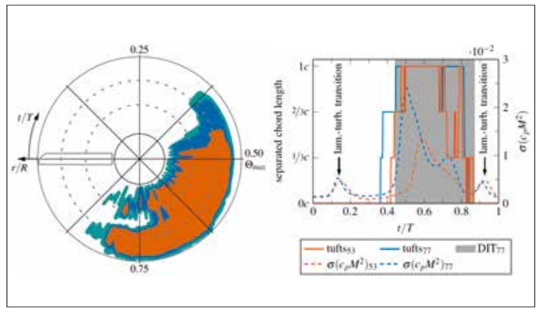


Fig. 5: Stall detection using tufts (left) and comparison with pressure measurements (right) from a dynamic stall experiment

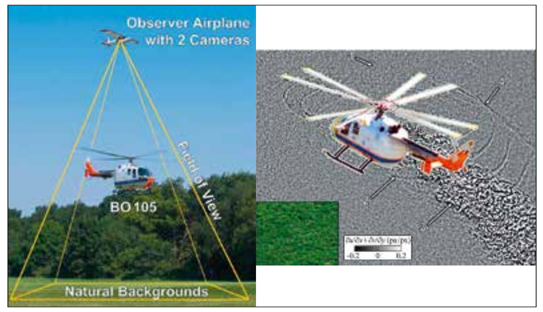


Fig. 6: Measurement of rotor blade tip vortices in flight by a chase aircraft

Dr. rer. nat. Doris Keye-Ehing
Deutsches Zentrum für Luft- und Raumfahrt,
Institut für Luft- und Raumfahrtmedizin
Hamburg

info-pks@dlr.de

Dipl.-Psych. Wiebke Melcher
Deutsches Zentrum für Luft- und Raumfahrt,
Institut für Luft- und Raumfahrtmedizin
Hamburg

info-pks@dlr.de

Requirement profiles for operators of unmanned aircraft systems

Unmanned aircraft systems are becoming more important as military equipment and are generating new activity profiles. The German Aerospace Center is drawing up scientifically based requirement profiles for operators of unmanned aerial vehicles so that, in future, the relevant human factors can be considered in personnel selection, training and stress management.

As a leading-edge technology, unmanned aircraft systems (UAS) are nowadays an integral part of the military equipment in service with the Bundeswehr. Their use is helping to accomplish Bundeswehr missions efficiently and increase the security of armed forces personnel. Since the introduction of UAS in the Bundeswehr, their deployment has steadily grown, as has also the demand for suitable operating personnel. Because of the further increasing need for UAS operators and the hitherto lack of knowledge regarding possibly required qualifications, the Department of Aviation and Space Psychology of the DLR, in cooperation with the German Air Force's Centre of Aerospace Medicine, has been tasked with conducting a scientific study to empirically analyse and determine the qualification requirements for UAS operators.

The primary goal is to scientifically determine specific requirement profiles for UAS operating personnel as well as to identify any differences in the requirements for manned and unmanned military aviation. The study will differentiate between different UAS (Heron, Luna, KZO, Aladin) and the positions for operating them (operator/pilot vs. sensor operator/aerial image analyser),

Fig. 1: KZO ground control station / Copyright: © Bundeswehr / Neumann

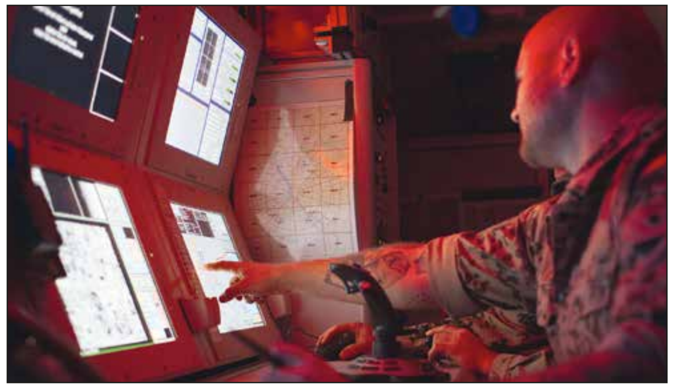


Fig. 2: Operator and sensor operator, Luna ground control station / Copyright: © Bundeswehr / Marc Tessensohn

Dr. Hinnerk Eißfeldt
Deutsches Zentrum für Luft- und Raumfahrt,
Institut für Luft- und Raumfahrtmedizin
Hamburg

info-pks@dlr.de

Dr. Anja Schwab
Zentrum für Luft- und Raumfahrtmedizin der Luftwaffe
Fürstenfeldbruck

zentrlurmedlws1presseoea@bundeswehr.org

since different systems can require different operating concepts, which in turn can also result in different requirement profiles. The study will thus deliver information on relevant human factors which should be considered in personnel selection, training and stress management for future UAS operators.

Methodological implementation starts with job shadowing in order to identify the different operating positions and associated tasks. Experienced UAS operators as well as pilots of manned aircraft are currently filling out a standardised questionnaire about the requirements of their activity. As experts, these servicemen and women will consider abilities that their activities require in the cognitive, psychomotor and sensory domains, as well as interactive and social skills. First results regarding UAS operators suggest that it is possible to deduce general requirements, such as high mental resilience, high level of reliability and high selective awareness, irrespective of the UAS system or operating position. Position-specific requirements have also been identified. For UAS pilots, for example, system monitoring and timely problem recognition are central requirements, while for sensor operators and image analysers good visualisation skills and perceptual speed are particularly relevant.

Based on these methods and analyses, requirement profiles can be defined scientifically for future UAS operators of the Bundeswehr and hence contribute valuable information for the conceptualisation and evaluation of diagnostic procedures in the selection of personnel. The questionnaire results will also enable first comparative analyses of the requirement profiles for manned and unmanned aviation and thus provide relevant information on common features as well as differences in selection and training.

Fig. 3: Operator, Heron system / Copyright: © 2016 Bundeswehr / Christian Thiel

Dr.-Ing. Patrick Gruhn
Deutsches Zentrum für Luft- und Raumfahrt,
Institut für Aerodynamik und Strömungstechnik
Köln

info-pks@dlr.de

Dr.-Ing. Christian Schnepf
Deutsches Zentrum für Luft- und Raumfahrt,
Institut für Aerodynamik und Strömungstechnik
Göttingen

info-pks@dlr.de

Use of flight dynamics simulations in the analysis of missile threats

Flight dynamics simulations play an important role in the analysis and evaluation of missile performance and are, therefore, also used in the assessment of potential threats. Within the scope of government-funded research, the German Aerospace Center (DLR) is developing tools and methods to simulate missile trajectories as well as intercept possibilities, where appropriate.

Technically analysing and evaluating missiles that pose a potential threat, such as ballistic missiles, involves relying on a multitude of different sources and methods. Several fundamental questions regarding flight performance – for instance, range and possible payload – can be answered by means of engineering methods (provided that suitable information about the system under consideration is available). If, however, greater accuracy or more information is required, it is then necessary to do as realistic a reconstruction of the missile as possible and also to use methods of a higher quality for trajectory simulation.

As part of government-funded research on the topic of missile technologies, the DLR's Institute of Aerodynamics and Flow Technology has developed a flight dynamics simulation tool (Flight Dynamic Simulator, or FDS) to simulate missile reference missions. Implemented in Matlab/Simulink®, this tool calculates missile trajectories in all six degrees of freedom (6DoF). Through inclusion of a further (interceptor) missile, the tool also offers the possibility to conduct closed-loop simulations of complete missile intercept scenarios. This is shown schema-

tically in Fig. 1. Lessons learned in the development of the FDS are also being taken into account in DLR's contribution to the Interceptor Simulation (ISim) being developed for the 20.x.03 missile technology field of the Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support (BAAINBw). ISim is intended as a modular, multiple-application simulation toolbox for analysing and evaluating missiles, as well as for their design, planning and realisation.

The quality of the employed input data has a substantial effect on the modelling results. For this reason, use is made of data delivered not only by means of conventional design tools but also by high-quality experimental methods (wind tunnel tests) and/or numerical flow calculations (CFD). Shown as an example in Fig. 2 are the Mach number and wall pressure distribution for a re-entry vehicle which have been calculated with the aid of the CFD code 'TAU', also developed by DLR. Fig. 3 shows the numerically calculated pressure distribution of the nozzle flow field of a ballistic missile controlled by jet vanes (thrust vector control, TVC). The coefficients gained from these numerical calculations are input as characteristic data in the flight dynamics simulation, where they serve to improve the prediction of the occurring aerodynamic and control forces.

In Fig. 4 a comparison of two trajectory calculations – for a short-range ballistic missile equipped solely with thrust vector control, and for a separable re-entry vehicle – is shown as an example. It displays curves for altitude and Mach number, the one using a 'simple' (panel) model to predict TVC forces, and the other using the (more sophisticated) numerical data from CFD calculations. Many other parameters can be gleaned from the flight dynamics simulations, as well. Particularly when combined with variational calculi and Monte-Carlo simulations, it is also possible, for example, to evaluate missile precision or, when simulating the interception process, to estimate the chances or probability of successful interception.

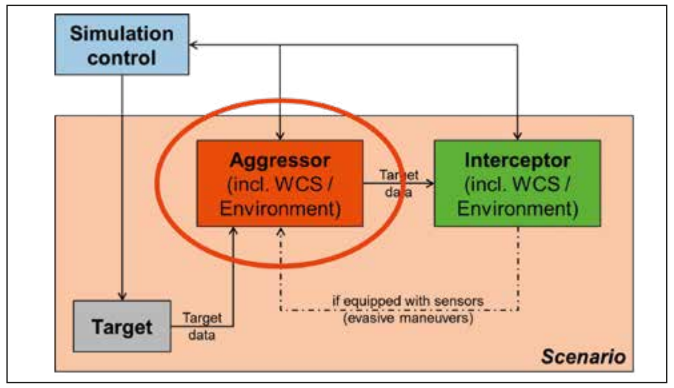


Fig. 1: Schematic view of closed-loop simulation

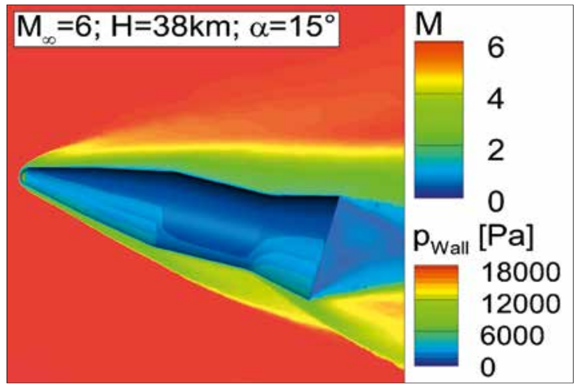


Fig. 2: Numerical simulation of a re-entry vehicle, Mach number and wall pressure distribution

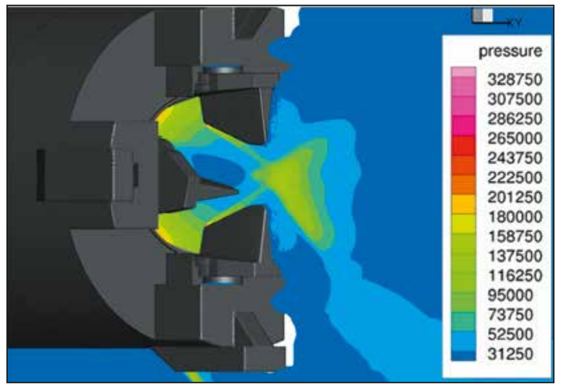


Fig. 3: Numerical simulation of thrust vector control (TVC), static pressure distribution

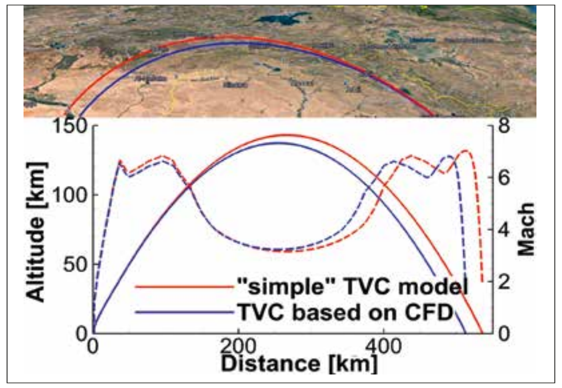


Fig. 4: Comparison of trajectories for different TVC models

Thomas Hasenohr
Deutsches Zentrum für Luft- und Raumfahrt,
Institut für Technische Physik
Stuttgart

info-pks@dlr.de

Dr. Leif Humbert
Deutsches Zentrum für Luft- und Raumfahrt,
Institut für Technische Physik
Stuttgart

info-pks@dlr.de

STAR-C: Transportable laser ranging system from DLR for measuring orbits of space debris

A transportable laser ranging system – STAR-C – is being developed to accurately measure distances to and between space debris in low Earth orbit. These measurements will allow precise determination of those objects' orbits particularly with respect to imminent collisions. Its containerised design enables it to be used anywhere in the field.

Space infrastructure and satellite operation are facing a growing threat due to a steady increase in the space debris population. This applies especially to certain heavily populated orbital paths within low Earth orbit (LEO) up to altitudes of 2,000 km. The US Space Surveillance Network, a global network of approximately 30 contributing sensors consisting of radar facilities for the surveillance of objects in LEO and telescopes to observe objects in higher orbits, monitors this population and maintains a comprehensive debris catalogue. The catalogue contains data on the orbits of more than 20,000 objects 10 centimetres in size or larger and is made available to satellite operators. Often, however, this data is not accurate enough to be able to plan suitable avoidance manoeuvres if collisions with satellites are imminent. Laser ranging, familiar from the field of satellite geodesy, offers the possibility to measure an orbital object's distance with a very high accuracy of a just few centimetres during a station pass. Such a high accuracy will allow precise determination of any object's orbit.

For these reasons, DLR is conducting research and development work involving laser ranging systems to measure distances to

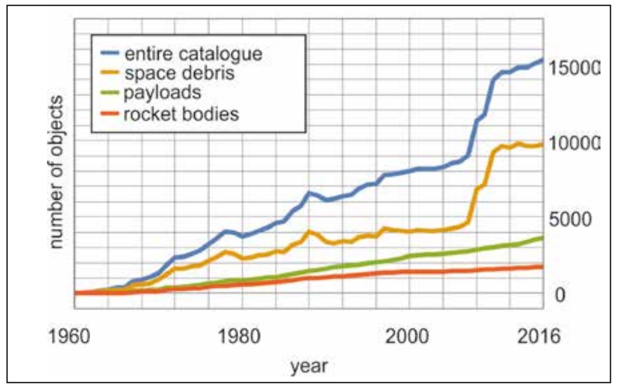


Fig. 1: Annual growth in the number of space debris objects larger than 10 cm

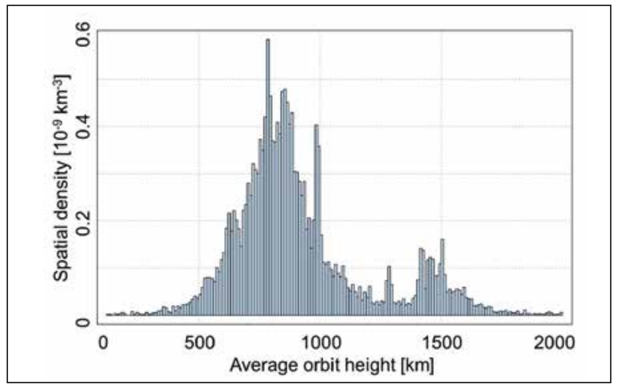


Fig. 2: Spatial density of objects larger than 10 cm in LEO

Wolfgang Riede
Deutsches Zentrum für Luft- und Raumfahrt,
Institut für Technische Physik
Stuttgart

info-pks@dlr.de

and between space debris in LEO. To permit location-independent operation, a transportable containerised solution in the shape of a 20 ft. ISO container has been selected (STAR-C: Surveillance, Tracking and Ranging Container), which, if need be, can operate autonomously with a power generating unit. The functional principle is based on an elevating device, which raises a platform carrying an alt-azimuth mount, a laser transmitter and a receiver telescope above the roof level of the container, allowing panoramic observation or so-called all sky tracking (including low elevations). The elevating device is decoupled from the actual structure of the container, thus avoiding any transmission of vibrations. The large mass of the device, weighing 4.5 tonnes, has a stabilising effect and dampens vibrations during operation in the field. The laser-based passive optical tracking of objects is performed using a closed-loop tracking algorithm, which keeps the 17-inch aperture telescope on target to within a few arcseconds. Such high dynamical pointing accuracy is essential for directing the collimated laser beam onto the distant object while at the same time detecting backscattered photons with the receiving telescope. The photons are detected by means of a sensitive single-photon detector. The laser system in use at present is also located on the platform, and the laser light is guided along the rotational axes of the mount via a Coudé train, delivering near-infrared laser pulses with a duration of a few nanoseconds.

The system is currently being evaluated in field tests, with automated operation being envisaged for the future. Used as a module in a geographically dispersed laser ranging network, this technology will afford a significant contribution to collision avoidance and to maintaining the space debris catalogue.

Fig. 3: STAR-C (Surveillance, Tracking and Ranging Container), showing elevated platform

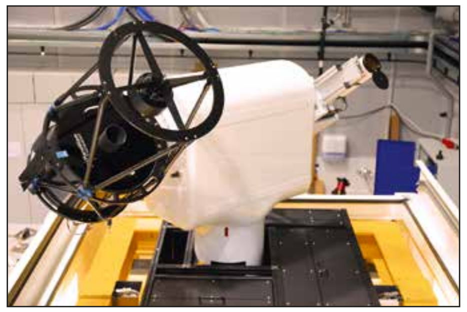


Fig. 4: Mount on the (raised) platform, bearing transmitter (right, in the background) and receiver telescope (left)

Fig. 5: Field installation of STAR-C using a heavy-duty crane (Copyright: DLR/Eppler)

Dipl.-Ing. Michael Hanke
Deutsches Zentrum für Luft- und Raumfahrt (DLR),
Institut für Faserverbundleichtbau und Adaptronik
Braunschweig

info-pks@dlr.de

Sarah Froese, B. Eng.
Deutsches Zentrum für Luft- und Raumfahrt (DLR),
Institut für Faserverbundleichtbau und Adaptronik
Braunschweig

info-pks@dlr.de

Eurofighter airbrake – a demonstration of advanced composite design

Within the framework of a government-funded guiding concept entitled "FFS – Advanced Aerostructures", the DLR Institute of Composite Structures and Adaptive Systems, together with partners AIRBUS Defence and Space, Airbus Central R&T and the Bundeswehr Research Institute for Materials, Fuels and Lubricants (WIWeB), has developed an advanced composite and adhesively viable design for aircraft components and demonstrated it in the case of a typical Eurofighter component, the Airbrake B ground demonstrator model.

The primary objective has been to significantly increase the cost efficiency of military aircraft structures, in which respect it has been possible to demonstrate a cost-saving potential of around 40 % through bionically inspired bonded designs as well as suitable materials and manufacturing technologies. While this very forward-looking fibre composite version has not yet attained TRL-6 (Technology Readiness Level 6) maturity, an earlier yet secondary bonded model (A model) of the original airbrake, based on the structural concept of the series-produced airbrake, will this year be undergoing a flight test campaign on Instrumented Production Aircraft # 3 (IPA3) under the supervision of the Bundeswehr Technical Centre for Aircraft and Aeronautical Equipment (WTD 61) after approval by the German Military Aviation Authority (LufABw) in Manching.

Especially the assembly and joining technology plays a crucial role in realising high-performance and, at the same time, cost-efficient lightweight CFRP structures for modern combat aircraft. The development and establishment of a robust secondary bonding technology is, for those reasons, the purpose of joint activities being undertaken as part of the FFS guiding concept. Bonded structures in differential design are manufactured as smaller, usually less complex components, in contrast to integral structures, and are subsequently joined in a separate bonding process step. This reduces the production costs (lamination costs of complex structures and tooling costs) as well as the risk of expensive integral structures being rejected (in the curing process). A particular challenge where bonding technology is concerned is ensuring a suitable and contamination-free adhesive surface in order to guarantee robust adhesion.

The goal of this collaborative work is to demonstrate the entire process chain for an actual typical secondary bonded component (the A model). The structure selected as an example is the airbrake of the Eurofighter Twin Seater. The A-shaped main stiffening elements in the serial component, the spars, are produced through co-curing technology. While the structural concept of the serial component will be retained and only Eurofighter-specific, fly-ready materials, additives and processes used, the assembly process for the main spar of the A-model will be done by secondary bonding. Complete production and military approval (by the German Military Aviation Authority according to Eurofighter standard) of the flight demonstrator are envisaged including, therefore, demonstration of TRL-6 technology maturity.

Already in parallel with the production of the flight demonstrator, the DLR had designed a variety of new design methods in a consistent, weight-neutral design-to-cost approach. In contrast to the previously presented A-model, the aim of this B-model was to explore new, more cost-efficient design concepts as a means of reducing manufacturing time and costs. At the end of the evaluation and selection process, the decision was made to use a double-shell design in which two flexible shells were pasty-bonded with a continuous adhesive joint, resulting altogether in a stable airbrake component. The two CFRP shells made from cost-efficient, well-drapable dry fibre materials are produced in a liquid resin infusion process and supplemented only with three 3D-printed metal load introduction devices (AddCompS™ – Additive Composite Structures).

Particularly by reducing the number of parts from around 40 to 5 and by dispensing with hundreds of rivets, it has been possible to demonstrate a significant cost-savings potential. In addition, the cost-efficient production technology for the outer and stiffening shell, in combination with the semi-analytical design methodology approach for bonded structures (SAADA Joint – Semi-Analytical Approach for the Design of Adhesive Joints), will have significant cost-reducing implications for future military aircraft structures.

Fig. 1: Eurofighter airbrake, a demonstrator structure for "Structural Bonding Technology" (Source: Airbus)

Fig. 2: Final Eurofighter airbrake A-model (Source: Airbus)

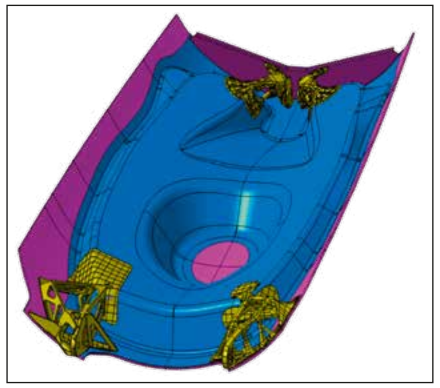


Fig. 3: Engineering design of the airbrake demonstrator B-model

Fig. 4: Eurofighter airbrake demonstrator B-model

Fig. 5: Detailed view of a 3D-printed load application armature for thin-walled CFRP shell structures

Dr. Loïc Bernard
Deutsch-Französisches Forschungsinstitut
Saint-Louis (ISL), Frankreich

isl@isl.eu

Armin Schneider
Deutsch-Französisches Forschungsinstitut
Saint-Louis (ISL), Frankreich

isl@isl.eu

Development of meta-surface antennas for projectile applications

Guided munitions require powerful communication systems for transmitting on-board sensor data and for receiving GNSS signals. Under development for this purpose are dedicated conformal antennas and transceivers, which have to withstand extreme conditions such as accelerations up to 50000 g during gun firing and roll rates up to 1000Hz during flight.

The French-German Research Institute (ISL) is conducting studies aimed at increasing the range of projectiles, so as to effectively combat stationary as well as moving targets at distance. To additionally avoid or minimise collateral damage, precision needs to be increased (also for munitions already in service), which requires the ability to guide the projectiles. The navigation electronics of guided projectiles are based on inexpensive, freely available (off-the-shelf) and, where possible, ITAR-free components as well as civil GNSS receivers. Such freely available components, however, are not designed for the high demands involved and therefore have to be carefully selected and gun-hardened. ISL has a dedicated facility enabling it to carry out acceleration tests up to 60000 g (to validate electronics, mechanical and/or optical components), and an external proving ground comprising two firing ranges for performing free-flight tests under realistic conditions.

Transmitter/receiver antennas for telemetry and GNSS can be integrated both into the projectile fuse and into the projectile body. In recent years there has also been exploration of integrating classical patch antennas into the rear part of projectiles

Diameter	Patch	Meta-surface
32 mm	52 MHz	90 MHz
20 mm	not working	21 MHz
16 mm	not working	22 MHz

Fig. 1: Bandwidth of classical patch and meta-surface antennas (integrated into a cavity)

Fig. 2: Circular patch antennas (left) and meta-surface antennas (right) integrated into a cavity

for telemetry applications, which of course requires special protection for the antennas during firing/launch. Where smaller-calibre projectiles are concerned, the size of such antennas also has to be reduced, which decreases the available bandwidth. If the antenna diameter falls below a critical minimum size in relation to the wavelength in use, the antenna structure will then no longer have a resonance frequency and be able to emit. Patch antennas with a diameter less than 20 mm, for example, no longer function at a frequency of 2.3 GHz.

Meta-surface antennas are similar in design to classical patch antennas. They comprise, however, not one homogeneous conductive surface but several periodic structures. If these structures are smaller than 0.1 of the wavelength (λ), they are referred to as meta-surface antennas. The advantage of such antennas is that the fabrication process is practically identical to that for classical patch antennas. In addition, they are much smaller geometrically for the same frequency, and the available bandwidth is also considerably larger.

Meta-surface antennas have been the subject of world-wide research in the past two decades, but mainly with regard to relatively large lateral dimensions. The particular feature of our research work is the integration of meta-surface antennas into very small (relative to the wavelength) metallic cavities (rear part of a projectile). Several antennas in different sizes between 0.12 and 0.6 λ have been realised for square, rectangular and circular cavities for telemetry applications (2.3 GHz and 5.2 GHz) and for GNSS reception (1.575 GHz). The radiation patterns of these antennas are very similar to those of classical patch antennas (broadside) The antennas have been validated successfully in numerous free-flight tests at the Institute's own test site using small-calibre projectiles (25 mm and 28 mm) with roll rates up to 700Hz and accelerations up to 20000 g.

Current research is concentrating on integrating conformal meta-surface antennas into cylindrical or conical structures and on developing compact dual-band and broadband antennas (with circular polarisation) for GNSS applications. The following table shows the bandwidths measured for different patch and meta-surface antennas for a frequency of 2.3 GHz.

Fig. 3: 25 mm 'long range projectile' with a meta-surface antenna integrated into the rear part

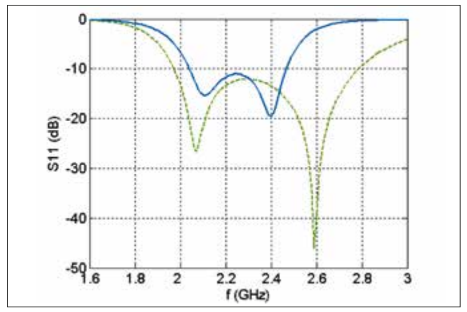


Fig. 4: Bandwidth of a classical stacked patch antenna (blue) and of a meta-surface antenna (green)

Dr. Michaela Knoll
Wehrtechnische Dienststelle für Schiffe und Marinewaffen,
Maritime Technologie und Forschung (WTD 71)
Eckernförde

WTD71posteingang@bundeswehr.org

ORR Dr. Stefan Ludwig
Marinekommando
Rostock

marine@bundeswehr.org

Automatic detection of marine mammals in acoustic and visual recordings

Anthropogenic underwater noise generated, for example, by the use of active sonar systems can cause harm to marine mammals. Suitable measures to minimise risk need to be developed with the aim of avoiding arbitrary restrictions on sonar use. Projects concerning the detection of marine mammals as well as in support of protective measures for whales are being conducted jointly by WTD 71 and Helmut Schmidt University / Bundeswehr University, Hamburg.

On several occasions there has been a close temporal and spatial link between whale strandings and the use of active sonar systems by NATO naval units during exercises. These incidents have caused concern within navies and in public, as well as within governmental and non-governmental organisations. European legislation such as the Marine Strategy Framework Directive requires Member States to prevent environmental harm being caused by underwater noise and to achieve a good environmental status. While active sonar systems are an essential element of naval capabilities, it is also essential to strike the right balance between protection of the maritime environment and the operational necessity to use sonar.

The whale strandings linked to the use of sonar on exercises have mainly involved deep-diving beaked whales, although the whale species most frequently encountered in the North Sea, the harbour porpoise (Fig. 1), is also highly sensitive to underwater noise.

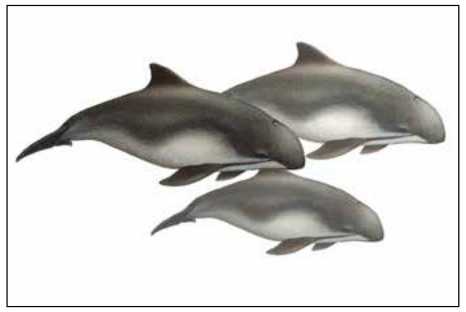


Fig. 1: The harbour porpoise is the most frequently occurring whale species in the North Sea and the only one indigenous to the Baltic Sea. The illustration inclusive of rights of use for the Bundeswehr was provided by Mr Wurtz (Artescienca)

Fig. 2: Acoustic recording tower, including hydrophone chain, buoyancy element and glass floatation ball, moored in the North Sea close to the FINO3 research platform*

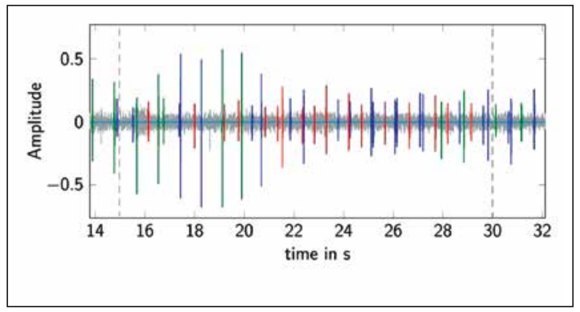


Fig. 3: Automatic detection of sperm whale clicks in acoustic recordings obtained in the Mediterranean Sea. The clicks were attributed to three different individuals (blue, red, green). The study was carried out by Messrs Simkus and Obaldia of Helmut Schmidt University under the direction of Dr Nissen of WTD 71

Prof. Dr. Ing. habil. Udo Zölzer
Helmut-Schmidt-Universität / Universität der Bundeswehr Hamburg
Hamburg

pressestelle@hsu-hh.de

In recent years, various military organisations around the world have set up teams to carry out or organise requisite research work, since the precise relation between the whale strandings and sonar use is still unknown. These teams also provide support to navies in assisting the navies to plan sonar exercises and in drawing up suitable risk mitigation guidelines based on the latest research findings, so that no arbitrary restrictions on active sonar use are imposed. Knowledge of the distribution and habitat use of marine mammals in potential sonar exercise areas is essential. It is also necessary to quickly detect, localise and classify any whales that are present, to be able to initiate protective measures in good time.

In projects jointly undertaken by WTD 71 and Helmut Schmidt University, sound measurements (Fig. 2) from various regions have been analysed with regard to whale clicks. With the aid of the Teager-Kaiser Energy Operator, clicks in the acoustic recordings are detected, and reflections are identified and eliminated through cross correlation analysis. Specific characteristics are assigned to each registered click, thus allowing identification of single individuals and prediction of the number of animals present (Fig. 3). This procedure for determining the presence of whales can be applied not only to acoustic recordings of underwater moorings but also to hydrophone data obtained on-line on vessels.

A joint study aimed at automatic detection of harbour porpoises in optical recordings of the sea surface near the FINO3 research platform in the North Sea (Fig. 4) has shown the FAST (Features from Accelerated Segment Test) algorithm to be suitable for detecting mammals. The algorithm however fails under bad environmental conditions such as rough sea and rain and produces many false alarms. An improvement of the detection rate has been achieved by using convolutional neural networks (Fig. 5). Pre-trained neural networks and a simple customised network are being tested in this connection. Although the latter, with a detection rate of 84 %, falls to achieve the detection rates of the pre-trained networks, the computations are much faster. An augmented test data set, in which a differentiation is made between sea gulls, buoys, harbour porpoises and water, attains habour porpoise detection rates of up to 94 %.

Fig. 4: Camera attached to the railing of the FINO3 research platform for the visual detection of harbour porpoises *

* The data recordings were carried out under the direction of Dr Gerdes of WTD 71 for Forschungs- und Entwicklungszentrum Fachhochschule Kiel GmbH as part of a project sponsored by Germany's Federal Ministry for Economic Affairs and Energy

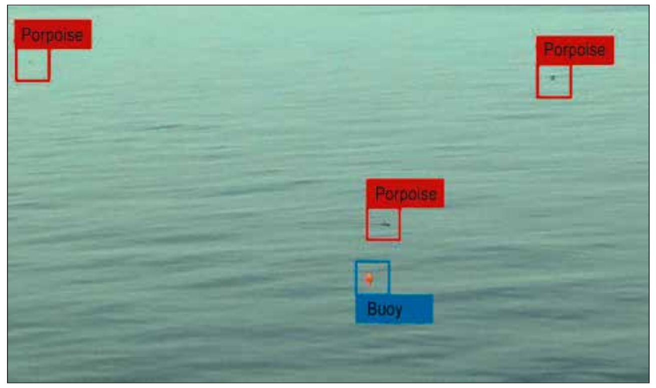


Fig. 5: Automatic detection of harbour porpoises and a buoy in an image section obtained on 7.7.2013 05:05 UTC with the camera attached to the FINO3 research platform. The study was carried out by Dr Wulf and Mr Bhattacharya of Helmut Schmidt University

Dr.-Ing. Lars Ole Fichte
Helmut-Schmidt-Universität /
Universität der Bundeswehr Hamburg
Hamburg

forschung@hsu-hh.de

Prof. Dr. rer. nat. Marcus Stiemer
Helmut-Schmidt-Universität /
Universität der Bundeswehr Hamburg
Hamburg

forschung@hsu-hh.de

Dr. med. Andreas Lamkowski
Institut für Radiobiologie der Bundeswehr
München

InstitutfuerRadiobiologie@bundeswehr.org

Dipl.-Ing. Matthias Kreitlow
Wehrwissenschaftliches Institut für Schutztechnologien –
ABC Schutz (WIS)
Munster

WISPosteingang@bundeswehr.org

Biological dosimetry for electromagnetic fields

Bundeswehr personnel are exposed to electromagnetic fields in various situations. The Bundeswehr Institute of Radiobiology, the Bundeswehr Research Institute for Protective Technologies – NBC Protection (WIS), and the Chair for the Theory of Electrical Engineering at Bundeswehr University, Hamburg, are employing genetic research methods to assess such exposure in greater depth.

On out-of-area missions, servicemen and women of the Bundeswehr face a high threat potential posed, for instance, by so-called improvised explosive devices (IEDs), which are often detonated remotely via radio signals. To prevent their detonation, specialised forces are equipped with jamming devices, which are carried in a backpack system and block enemy forces from remotely triggering the IEDs. By doing this, these specialists are automatically exposed to radio frequency (RF) electromagnetic fields emitted by the jammers. According to the current state of research, exposure poses no health risks as long as established threshold values are not exceeded.

Hitherto, however, there have been no methods of biological dosimetry that allow validation of electromagnetic exposure beyond known (thermal) effects. Research has hence been focused on any interactions between electromagnetic waves and biological cells by monitoring the cells' reaction at the genome level by means of gene expression analysis, the aim being to study the usability of such an analysis as a biological dosimetry method.

The present study seeks to clarify if cell reactions can be influenced or triggered even by moderate field intensities, as emitted by jammers used in the Bundeswehr, and whether they lie below permissible thresholds. In the high-frequency (RF) range, these thresholds are derived from the medically tolerable rise in tissue temperature. Gene expression analysis provides the possibility to evaluate whether there are other electromagnetic field influences beside the increase in tissue temperature. Every external stimulus leads, within the cell, to the genetic material (DNA) being accessed and the genetic information being transferred to the transcriptome.

Any stimulus of relevance for the cell leads to its alteration, and any further cellular reactions are based on the information stored in it. If the cell is exposed to an electromagnetic field, the transcriptome is then compared with that of non-exposed cells.

Blood samples from five test persons (donors) have been exposed in an experimental pre-study (Fig. 1) to RF fields in an open waveguide operated by WIS (Fig. 2) for different durations (30, 60, and 90 min). A first evaluation (Fig. 3) has so far yielded no validated evidence of any cellular effects beside a rise in temperature. Source: "Lamkowski et al. 2018: Radiat Res. 2018 May;189(5):529-540. Gene Expression Analysis in Human Peripheral Blood Cells after 900 MHz RF-EMF Short-Term Exposure". Additional systematic tests involving other exposure situations are currently under preparation in the ongoing project. Should it be possible to detect electromagnetic influences in this data, then gene expression analysis can be used further to develop a biological dosimetry method.

For the future there are plans to depict every exposure scenario relevant to service personnel on missions by means of suitable test environments, and to systematically carry out exposure experiments. Fig. 4 shows an electromagnetic reverberation chamber of variable geometry that is to be used for that purpose. It has been integrated into an incubator to offer the exposed cells optimum environmental conditions and to minimise any external influences interfering with the highly sensitive measurements.

Fig. 1: Test set-up

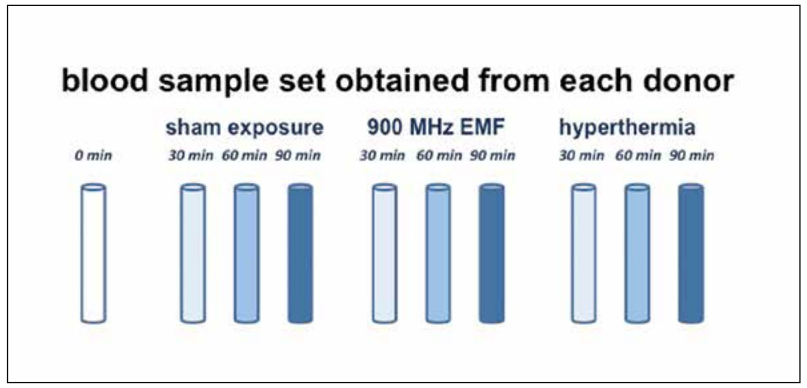


Fig. 2: Modified from Lamkowski et al. 2018 (Radiat Res. 2018 May;189(5):529-540)

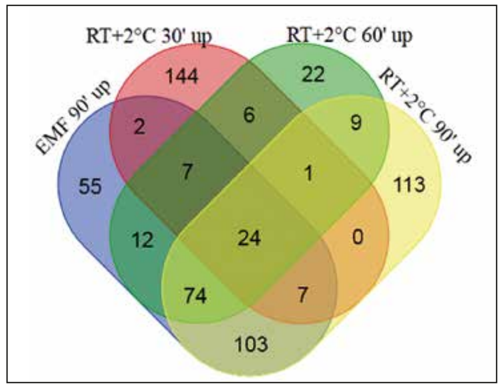


Fig. 3: Venn diagram of different exposure test variants (90 min with electromagnetic fields, and 30, 60, 90 min test duration without field exposure, with 2°C increase in temperature). The figures indicate the number of up-regulated genes in comparison with the control [group]. A subsequent validation revealed no significant thermal effect

Fig. 4: Exposure device integrated into an incubator

Univ.-Prof. Dr. rer. pol.
Klaus Beckmann
Helmut-Schmidt-Universität /
Universität der Bundeswehr Hamburg
Hamburg

forschung@hsu-hh.de

Prof. Dr. rer. nat. habil.
Armin Fügenschuh
Helmut-Schmidt-Universität /
Universität der Bundeswehr Hamburg
Hamburg

forschung@hsu-hh.de

M.Sc. Fabian Gnegel
Helmut-Schmidt-Universität /
Universität der Bundeswehr Hamburg
Hamburg

forschung@hsu-hh.de

M.A. Timo-Christian Heger
Helmut-Schmidt-Universität /
Universität der Bundeswehr Hamburg
Hamburg

forschung@hsu-hh.de

Capability development and armed forces planning in the context of multinational cooperation

This short contribution describes a study aimed at presenting, analysing and evaluating military capabilities in the context of the Framework Nation Concept. The data model that has been developed can be used to optimise force structures and to explore capability gaps, for which an IT-supported demonstrator has been created.

Since the end of the 1980s, the Bundeswehr has been promoting the development of multinational force and capability structures. In light of recent events there has been a shift in thinking, and NATO, at its summit meetings in Wales in 2014 and Warsaw in 2016, consequently determined to revert to its original role as defined in Article 5 of its Treaty. To add to a series of other initiatives being undertaken in and by NATO, the EU or individual member states, Germany initiated the so-called Framework Nation Concept (FNC) in 2013.

The Directorate-General for Planning at Germany's Federal Ministry of Defence (FMoD) commissioned a study entitled "European Capabilities 2030 and their Usability for the Creation of Larger Formations within the Framework Nations Concept (FNC)", which, based on an agreed set of comparative criteria, aimed to systematise, model and evaluate the capabilities of potential nations. The data and evaluation model then had to be implemented in an IT-supported demonstrator so that it would not only be possible to access the data, but both the model and the database could also predict future developments and additional requirements. And, the demonstrator

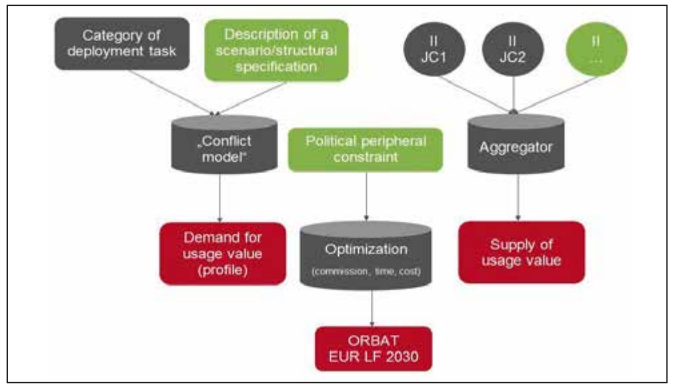


Fig. 1: Model structure

Generalmajor a.D.
Georg Nachtsheim
Helmut-Schmidt-Universität /
Universität der Bundeswehr Hamburg
Hamburg

forschung@hsu-hh.de

Dipl.-Vw. Lennart Reimer
Helmut-Schmidt-Universität /
Universität der Bundeswehr Hamburg
Hamburg

forschung@hsu-hh.de

Oberst i.G. Priv.-Doz.
Dr. Manuel Schulz
Helmut-Schmidt-Universität /
Universität der Bundeswehr Hamburg
Hamburg

forschung@hsu-hh.de

Ingmar Vierhaus
Helmut-Schmidt-Universität /
Universität der Bundeswehr Hamburg
Hamburg

forschung@hsu-hh.de

should ultimately serve to compile optimum Larger Formations (Orders of Battle, or ORBATs) within the FNC and offer support in detecting and evaluating capability gaps.

ORBATs comprise components from different military services, branches and nations ("Joint Components", or JCs.). Entries in the database reflect such JCs, usually of battalion size, which may consist of air force, navy and specialised elements, as well as of individual systems and their crews. The structure of the comparative criteria is similar to the Capcodes used by NATO, but has been radically simplified to facilitate practical application and optimisation. The economically driven evaluation concept is based on a comparison of supply and demand for military capabilities. (Fig. 1).

A browser-based database system has been developed in which all JCs, ORBAT requirements and political constraints (for example, a minimum or maximum number of different nations) have been input. The ORBAT, comprising the JCs, is designed to service endogenous and exogenous demand attributes, which all the JCs within the ORBAT then have to supply.

Exogenous demand describes the task that the ORBAT is required to perform, while endogenous demand relates to the resources required from other JCs, such as medical or logistical support. Beside the simple addition of force numbers, consideration can be given to mutual reinforcement of the JCs in instances where they complement one another as combined weapons systems, or also to force degradations when frictional losses occur (due to different language, doctrine, or lack of mutual coordination).

The planning problem to be resolved is a complex issue of optimisation in which a human planner would quickly lose sight of the bigger picture. Thanks to support provided by mathematical optimisation procedures, it is possible after brief computation to determine an optimum ORBAT comprising around 4,000 JCs, each of which is described by over 70 attributes, or, where there is demonstrably no ORBAT that fulfills all the requirements, to identify the capability gaps.

Prof.in Dr. Bettina Schaar
Universität der Bundeswehr München,
Neubiberg

sportmethodik@unibw.de

M. Sc. Anna Schlumberger
Universität der Bundeswehr München,
Neubiberg

sportmethodik@unibw.de

Developments in the promotion of job-related physical fitness in the German Army

The study described here examines different work-related activities and quantifies the specific physiological demands on servicemen and women in the German Army from the perspective of sports science. The aim is to determine the current status and, on that basis, develop scientifically driven training recommendations to improve soldiers' fitness levels in the German Army.

Due to the changing role of the Bundeswehr, the demands on its servicemen and women are also evolving. These progressive changes will make it indispensable in future to have a scientifically based concept in place for purposefully improving soldiers' physical fitness. With that in mind, the first goal of this study has been to draw up selected physiological requirement profiles for job-related activities in the German Army. This has involved the formation of five study groups sourced from selected branches of service, namely randomised servicemen and women from infantry, combat support, military logistics, armoured units, and basic military training recruits. Beside the recording of job-related performance requirements and resultant physical exertions in the different groups, an analysis of soldiers' current physical fitness levels is taking place. The findings from the follow-on deficit analysis will be used to draw up training recommendations with a view to optimum tolerance of work-related demands, stresses and strains.

A "Participant's Observation Sheet" has been developed and used as a research tool for recording the physical stresses and strains of the servicemen and women involved. It gives

Fig. 1: Lactate testing under field test conditions

Fig. 2: Preparations for cardiorespiratory exercise testing

Dipl.-Sportwiss. Saskia Klughardt
Universität der Bundeswehr München,
Neubiberg

sportmethodik@unibw.de

structured consideration to those physical stresses and strains based on "functional units" (Knebel, 1994) and documents part- and whole-body movements. It also records other factors such as additional burdens caused by equipment, as well as movement patterns and durations. This research tool is suitable for recording both daily and operationally specific physiological requirement and stress/strain profiles.

As a further part of this study there have been guideline-based interviews with experts and persons of authority in the sports field within the Bundeswehr, the aim being to validate and expand upon the findings gleaned from participants' observations by drawing on their expertise.

The last part of the study is devoted to collecting data on the soldiers' current physiological and metabolic fitness levels. This is being conducted on the basis of standardised spiroergometric tests (= gold standard for cardiorespiratory performance diagnostics in sports science) under field conditions. The collection of data is still in progress.

The first available findings from the interviews and from the participants' observations indicate, from a sports science viewpoint, significant differences in the stress/strain and requirement profiles between the five examined branches of the Army. It may be surmised on the basis of these findings that a differentiated, individualised training concept is urgently needed to ensure a suitable improvement in the physical fitness of Army servicemen and women and, as a result, optimally meet the various indicated physiological demands. The final report containing all the results (and recommendations for training) is expected in mid-to-late 2018.

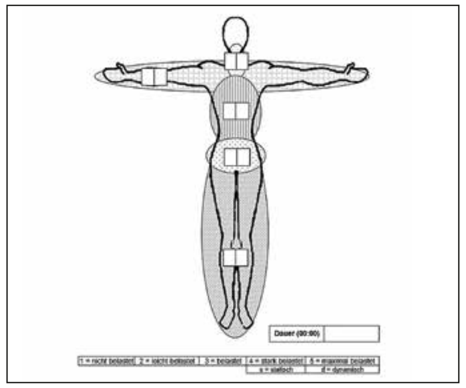


Fig. 3: Excerpt from "Participant's Observation Sheet"

Prof. Dr. Manfred Keuser
Universität der Bundeswehr München
Neubiberg

info@unibw.de

Tobias Zircher
Universität der Bundeswehr München
Neubiberg

info@unibw.de

Alexander Berg
Wehrtechnische Dienststelle für Schutz- und Sondertechnik (WTD 52)
Oberjettenberg

WTD52posteingang@bundeswehr.org

Use of steel fibre reinforced concrete in out-of-area missions

Military facilities of the Bundeswehr have for years, during out-of-area missions, faced a steadily growing threat from terroristic attacks. Structural protection measures are an important element of a holistic security concept for ensuring personnel safety and for protecting mission-relevant materiel.

The structural design of protective components has to ensure direct protection and, if used in an overall structure (e. g. wall, ceiling, columns), guarantee that the global load-bearing effect is maintained. The addition of steel fibres significantly improves the post-cracking behaviour and ductility of concrete components. Moreover, the fibres lead to a substantial reduction in the spalling of secondary debris, which is ejected from the matrix on the protective side at high speeds when impacted by ballistic attack or contact detonations and poses a hazard to personnel and materiel.

In a study initiated by WTD 52, a concept is being developed for the production of protective concrete components using resources (personnel, materials, equipment) locally available in the conflict areas so that, in future, only the steel fibres have to be delivered to the mission country. During this study, 45 square panels, each with an edge length of 2.0 m, have been produced both from standard concrete and from steel fibre reinforced concrete in strength class C 25/30 using different types of fibres, reinforcement systems and component thicknesses, for contact detonation tests. In Mix 1, a concrete containing flue ash and superplasticiser was used. In the other mixes (Mix 1 and Mix 3), these materials were replaced by cement and water so as to have the simplest possible mixture.

All the panels of test series 1 and 3 contain a double-layer, crosswise reinforcement system (Ø 16/10). The panels of test series 2 have no additional steel reinforcement, so that the influence of the fibres on debris ejection can be precisely examined. Contact detonation experiments have been carried out at WTD 52 using these test specimens. The contact detonation generates a pressure shock wave on the side of the contact explosion (impacted/loaded surface) which runs through the panel and is reflected as a tensile wave on the rear side (protective/unloaded surface). When the tensile stresses exceed the concrete's tensile strength on the protective side, a crater-shaped area becomes detached from the panel.

After complete evaluation of test series 1 to 3, it has been found that the mixtures without steel fibres (Mixes 1.1, 2.1 and 3.1) display maximum break-out volumes on the protective/unloaded side (Fig. 2). The addition of steel fibres significantly reduces the occurrence of debris ejection and amount of debris ejected on the protective/unloaded side, thus having a positive effect on personnel and materiel safety.

In the course of this study, steel fibre reinforced concrete mixtures have been developed for different aggregates and cements feasible for use in mission countries. The three different steel fibre types (Fig. 3) have shown themselves to be suitable for the production of protective components, and their processing to be possible without any restrictions. The study findings have confirmed the suitability of steel fibre reinforced concrete for protective components, as well as the ability to produce them in mission areas.

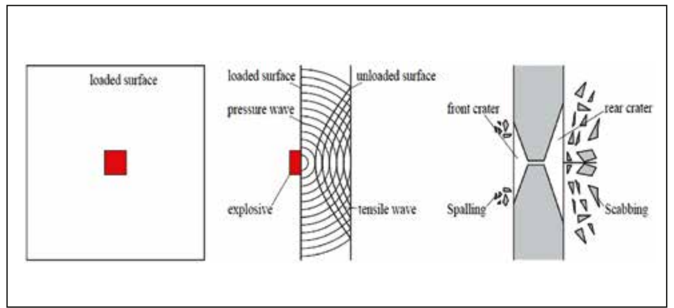


Fig. 1: Schematic diagram of contact detonation

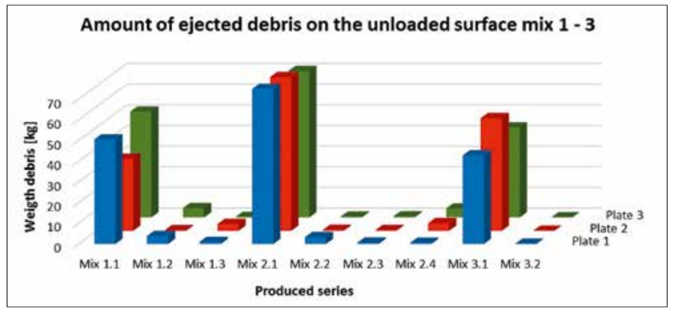


Fig. 2: Amount of debris ejected on the protective/unloaded side, Mix 1 to Mix 3

Ingredients·concrete·mixture	**Mix°1**	**Mix°2-3**
Cement·II/A-M(V-LL)42,5N	330·kg/m³	---
Cement·II/A-M(V-LL)32,5N	---	400·kg/m³
Flue·ash	70·kg/m³	---
Aggregate·0/4·NfGK	893·kg/m³	770·kg/m³
Aggregate·0/8·NgGK	132·kg/m³	224·kg/m³
Aggregate·8/16·NgGK	629·kg/m³	609·kg/m³
Water	224·kg/m³	250·kg/m³
Water/cement·ratio	0,65	0,625
superplasticizer	1,32·kg/m³	---
Steel·fibre·KH·DE60/0,9°N	78,5·kg/m³·(Mix·1.2)	78,5·kg/m³·(Mix·2.3,·3.2)
Steel·fibre·KH·DE35/0,55°N	78,5·kg/m³·(Mix·1.3)	78,5·kg/m³·(Mix·2.2)
Steel·fibre·Dramix·4D-65/60BG	---	78,5·kg/m³·(Mix·2.4)
Plate·thickness	30°cm	30°cm
Consistency	F4	F4

Fig. 3: Concrete composition, Mixes 1 – 3

Jun.-Prof. Dr.-Ing. Christian Hofmann
Universität der Bundeswehr München
Neubiberg

info@unibw.de

Univ.-Prof. Dr.-Ing. Andreas Knopp, MBA
Universität der Bundeswehr München
Neubiberg

info@unibw.de

Secure satellite communication for the Bundeswehr

The Bundeswehr currently operates a satellite communication system comprising two of its own satellites in geostationary orbit as a way to ensure strategic and tactical communication for out-of-area missions. Greater protection of the existing system as well as of future satellites against intentional and non-intentional interference is the subject of a study being conducted by Bundeswehr University, Munich.

The Institute of Information Technology at Bundeswehr University, Munich, is conducting a study for Section I6.3 of the Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support with regard to greater overall protection for the Bundeswehr's satellite communication system (SATCOMBw) against interference and jamming.

The Bundeswehr currently operates two geostationary satellites to ensure strategic and tactical communication for out-of-area missions. The satellites act as relay stations in space for radio communication between two ground stations, which have to be located within the footprint of the satellites' beam. Both satellites offer more than one footprint, or beam, as they are also referred to: a beam over Germany to ensure communication with the home country, steerable beams for the mission countries, and global beams for global communication. In contrast to terrestrial communication where effective jamming requires a jammer to be located very close to the receiver, satellite communication is vulnerable to jamming also over large distances. A jammer transmitting towards the satellite has to be located within the footprint, or can also cause interference from outside the footprint through enhanced transmission power. Jammers transmitting towards the receive antenna of an earth station, however, need to be located relatively close to the receive antenna, similar to jammers for terrestrial links. Large ground stations with highly directional antennas are less vulnerable to such jammers, whereas mobile terminals with small-diameter antennas are very easy to jam.

The study analyses the level of protection that the SATCOMBw system has in relation to conceivable intentional and non-intentional interference and discusses the technical possibilities an adversary would need to have at its disposal to cause effective jamming. It also explores technical means for monitoring for, detecting and localising jammers.

Technical and organisational measures for protecting the current SATCOMBw system are additionally recommended. As protection in the presence of jamming requires extra bandwidth and power resources, hardening of the system leads in most cases to a lowering of the usable data rate. The user then has to prioritise his connections. One important outcome of the study is that, for this purpose, the user receives an estimation of the remaining user data rate as a function of the severity of the jamming attack. Technical solutions commercially available for the ground segment, such as frequency hopping and spread spectrum, are also being explored with a view to further improving the protection of satellite links in future beyond what is currently in place.

Lastly, the study gives anti-jamming recommendations concerning the space segment, which are to be taken into consideration in the design for the upcoming regeneration of the Bundeswehr's satellites. Smaller beams, for instance, will improve not only protection against jammers but also the user data rate of the satellite through frequency re-use. Adaptive satellite antenna arrays with a variable footprint are also under consideration for their ability not only to localise jammers but also block out the jamming signal.

The study findings will enable the Bundeswehr to assess not only what is required to enhance jamming protection but also the level that is achievable. The identified technical solutions will, moreover, enable the procurement agencies to formulate suitable selection criteria for their procurement decisions, with a view to providing the desired level of security against interference, thereby ensuring the best possible protection for the Bundeswehr's tactical and strategic satellite communications when on out-of-area missions.

Fig. 1: A small jammer (right) transmitting at relatively low power in the direction of the receiving ground station antenna (left) can severely affect satellite communication

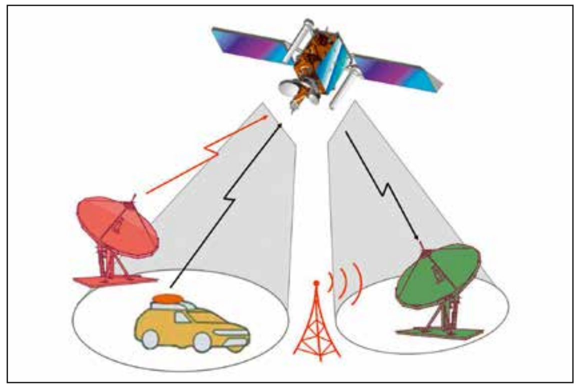


Fig. 2: Satellite communication jammers (in red) can either transmit towards the satellite (uplink jammer) or towards the receiving ground station (downlink jammer)

Fig. 3: Bundeswehr satellite ground station in Gerolstein

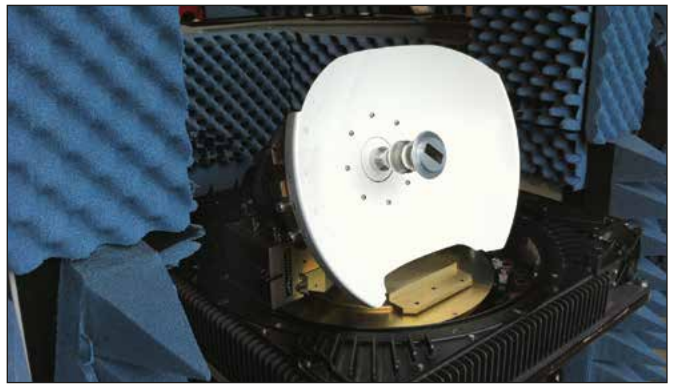


Fig. 4: Small antennas such as this vehicle-mounted automatically aligning reflector are particularly vulnerable to jamming attacks

M. Eng. Benjamin Künzel
Research Center RISK
Universität der Bundeswehr München
Neubiberg

info@unibw.de

M. Sc. Thomas Hertle
Research Center RISK
Universität der Bundeswehr München
Neubiberg

info@unibw.de

Dr.-Ing. Lars Rüdiger
Research Center RISK
Universität der Bundeswehr München
Neubiberg

info@unibw.de

Univ.-Prof. Dr.-Ing. habil. Norbert Gebbeken
Research Center RISK
Universität der Bundeswehr München
Neubiberg

info@unibw.de

Software-aided assessment of bridges and modernization of the standards for makeshift bridges of the Bundeswehr

The decision-making on the mobility of military forces is based on a quick and reliable determination of the load-bearing capacity of bridges. An in-house software for bridge classification is a supporting tool for that task. Additionally, the use of makeshift bridges may be necessary to ensure mobility in mission. Further development of the corresponding standards for makeshift bridges is essential.

The engineering corps is an indispensable element for ensuring the mobility of troops during missions. Key tasks of military engineers are to enable mobility of their own troops and to reduce the mobility of the opposing forces. Both options serve to increase the survivability of the allied troops. In order to fulfill these tasks, the soldiers of the Bundeswehr have a variety of technical systems at hand. In bridge constructions, these include fixed bridges, such as foldable fixed bridges or the makeshift bridge construction kit, and a range of swimming bridge systems including the improved foldable swimming bridge and the floating bridge Amphibie M3. As a timber construction, the makeshift bridge construction kit still is a particularly economical solution, which can remain on site for civilian use. In certain cases, it might be more advantageous to use existing bridges (Fig. 1) instead of deploying specific equipment to erect a new bridge. In such a scenario, the load-bearing capacity of the existing bridge must be evaluated swiftly and with little effort. This is where specifically developed engineering tools, e. g. the bridge assessment software BRASSCO-NG, come into play. The makeshift bridge construction kit is currently being modernized, and the assessment software is being advanced at the Chair of Structural Mechanics of the UniBwM.

The main task in bridge construction is to cross a terrain gap or an obstacle with a suitable structure. For makeshift bridges as well as for existing bridges, the bearable loads must be known. The required load-bearing capacity of a bridge is mainly driven by the dead load of the crossing vehicles. For the assembly of makeshift bridges, a sophisticated, modular construction kit provides instructions facilitating bridge building by local resources. This allows for a variable design while guaranteeing an optimal use of the given resources. In case of existing bridges, the software has to provide the flexibility to cover a majority of bridge types and structural systems. A clear graphical user interface guides the user to the required input. Conservative assumptions have to be made for missing bridge data. The military load classes (MLC) that are permitted to cross the existing bridge result out of this.

Recent research on these two issues focuses on precise determination of the loads at work and on the implementation of the current design codes, e.g. Eurocodes. For the revision of the makeshift bridge construction kit, numerical parameter studies reflecting close-to-reality bridge physics are being conducted (Fig. 4). To validate and calibrate the results, stress tests are being performed (Fig. 2) on experimental set-ups (Fig. 3) such as the Bundeswehr Technical Center for Land-Based Vehicle Systems, Engineer and General Field Equipment (WTD 41).

Both examples illustrate how challenging the field of military engineering has become over the last decades. The increasing computational power of hardware of mobile devices also enables engineers to extend the programing of engineering tools. By close collaboration between research and development, managing agencies and end users, practicable and customized solutions are being developed for use by the Army Corps of Engineers of the Bundeswehr and its international allies in future missions.

Fig. 1: Example of an improvised bridge

Fig. 2: Aerial view of the WTD 41 test-site

Fig. 3: On-site assembly of structural components

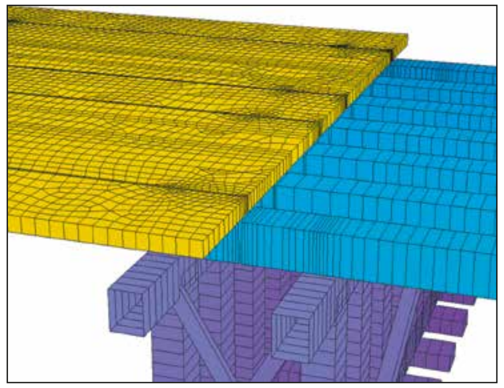


Fig. 4: Numerical model of the makeshift bridge

Dipl.-Ing. Alexander Nekris
Deutsch-Französisches Forschungsinstitut
Saint-Louis (ISL), Frankreich

isl@isl.eu

Dr.-Ing. habil. Patrick Gnemmi
Deutsch-Französisches Forschungsinstitut
Saint-Louis (ISL), Frankreich

isl@isl.eu

Numerical simulations of plasma discharges in supersonic flows

The trajectory of high-velocity missiles or projectiles can be corrected by generating electrical discharges on their surfaces via a plasma actuator. For a more effective investigation of the physical processes that occur in this connection, a numerical algorithm is under development as a means of simulating plasma discharges in supersonic flows.

The trajectory of high-velocity missiles or projectiles can be corrected by altering the pressures exerted on their surfaces during flight. The resulting force alters the flying angle of the projectile and ultimately leads to a deviation from its original trajectory. Work is underway at ISL on a new technique whereby the trajectory correction is realised by means of a direct current (DC) plasma actuator, which induces power-controlled electric discharges on demand between the electrodes installed flush with the projectile surface. The generated plasma leads to local alterations in the pressure distribution on the surface. The absence of moving mechanical components, and good reproducibility of the discharges, are only a few of many advantages offered by this technique. A series of experiments in wind and shock tunnels have already demonstrated that DC plasma actuators are capable of producing a sufficient angular deviation on projectiles and can thus be used for guidance purposes.

There has already been experimental work to explore some of the physical processes that come about during the interaction of the plasma discharge with the supersonic flow. Further theoretical investigations and numerical simulations are needed to increase the knowledge on this subject. A numerical model could, in addition, help to efficiently optimise the plasma source (actuator). The objective of the presented work is to develop a numerical algorithm for modelling such phenomena.

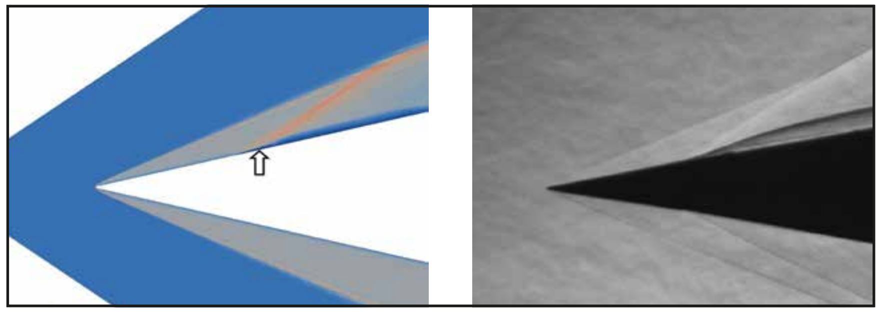


Fig. 1: 2D simulation of the density field around a wedge-shaped profile at a velocity of Mach 4.5; the location of the electric (plasma) discharge is marked with an arrow (left). A comparable experiment was conducted on a cone in a wind tunnel (right)

Univ.-Prof. Dr.-Ing. Christian Mundt
Universität der Bundeswehr München
Neubiberg

info@unibw.de

An electric (or plasma) discharge is a complex multi-physical system combining electrodynamics, fluid dynamics and chemical (reaction) kinetics. The discharge is maintained by the voltage applied at the plasma actuator electrodes. The occurring plasma forms an intensive heat source, leading to a local increase in pressure (Fig. 1). The small volume of increased pressure acts as a virtual obstacle, inducing perturbations and ultimately causing an angular deviation of the projectile. The very high temperatures in the plasma discharge lead to an ongoing ionisation of the air between the actuator electrodes, so that the air remains electrically conductive and the electric arc is sustained.

The new numerical algorithm essentially consists of three modules. The first module is responsible for the chemical kinetics and calculates the reaction rates for chemical processes such as dissociation and ionisation (taking place in the plasma discharge). The second module numerically solves the fluid dynamics equations, thus delivering information about the pressure, velocity and temperature of the air flowing around the projectile. The third module calculates the electric and magnetic fields in the simulation. The new algorithm has been developed on the basis of OpenFOAM, which is an open-source toolbox. OpenFOAM uses the finite volume method (FVM) to discretise partial differential equations and is applied mainly in the field of computational fluid dynamics (CFD).

Currently, two-dimensional simulations are being conducted involving a simple wedge-shaped geometry (Fig. 2), which permits faster debugging and validation of the algorithm. Once the development stage has been concluded, there are plans to conduct three-dimensional simulations of an electric discharge in a supersonic flow. For validation, the simulation data will be compared with the experimental measurement data.

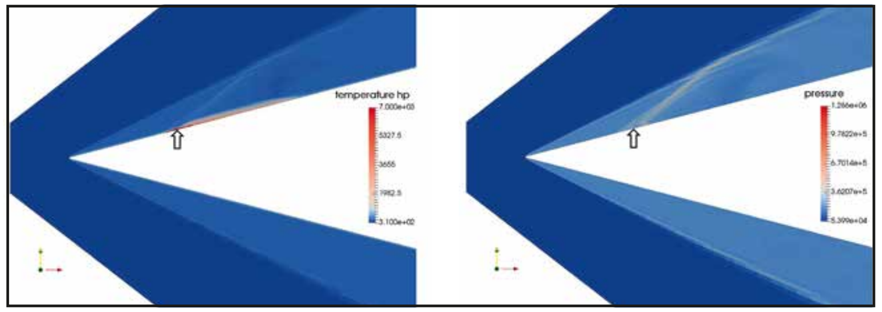


Fig. 2: 2D simulations of the temperature (left) and pressure (right) fields around a wedge-shape profile at a velocity of Mach 4.5; the location of the electric (plasma) discharge is marked with an arrow

Jakob P. Haug, M. Sc.
Institut für Strahlantriebe
Universität der Bundeswehr München
Neubiberg

isa@unibw.de

Univ.-Prof. Dr.-Ing. Reinhard Niehuis
Institut für Strahlantriebe
Universität der Bundeswehr München
Neubiberg

isa@unibw.de

Detailed analyses of the flow field in a modern engine intake system

Fully integrated intake systems offer a way to reduce the radar signature of flight systems. Predicting the complex flow field in such intake systems requires precise numerical simulation tools. Vortex generators are one possibility to positively influence the complex flow field. The Institute of Jet Propulsion is conducting numerical and experimental studies in this regard.

To make military flight systems more difficult to detect in future, it will be indispensable to use compact and highly bent engine intake systems. Strong curvature of the flow path upstream of the engine avoids direct line of sight onto the rotating parts of the engine and thus greatly reduces the radar signature, but induces strong flow distortions which may unfavourably affect the engine's performance and stability.

The Bundeswehr Technical Centre for Aircraft and Aeronautical Equipment (WTD 61), in collaboration with the Institute of Jet Propulsion at Bundeswehr University Munich, has successfully completed research projects aimed at exploring the flow field in such compact and highly bent intake systems and is following them up with further research. This collaboration has led to the development and construction of the MEIRD (Military Engine Intake Research Duct, Fig. 1), among others, which features a combined swirl and pressure distortion typical of military intake systems. Modern numerical methods have been used to precisely predict the flow field inside the intake duct. To validate and ensure high accuracy of the numerical flow data, experimental investigations (Fig. 2) have been conducted in parallel,

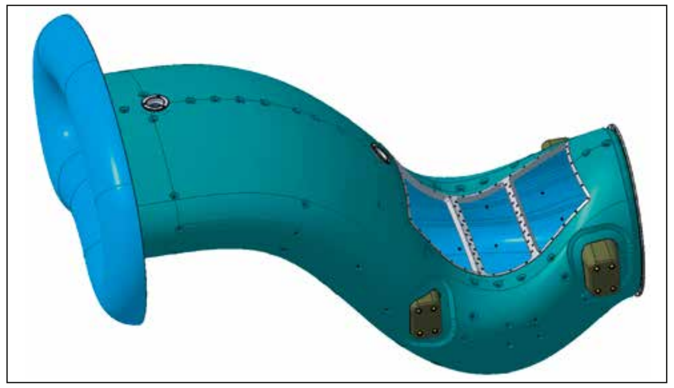


Fig. 1: CAD model of the MEIRD intake system with three adapter openings for removable panels e.g. for flow control

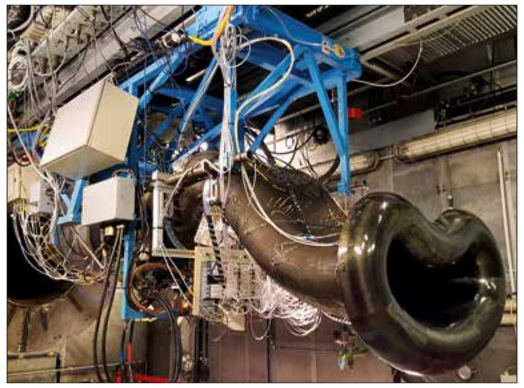


Fig. 2: Experimental set-up with installed MEIRD intake system and Larzac 04 test engine in the engine testing facility at the Institute of Jet Propulsion

Hptm Dr.-Ing. Marcel Stößel
Wehrtechnische Dienststelle für Luftfahrzeuge und Luftfahrtgerät der Bundeswehr (WTD 61)
Manching

WTD61posteingang@bundeswehr.org

for which a total of 143 static pressure taps, in addition to other measuring sensors, have been installed along the wall of the MEIRD.

Various numerical parameters as well as turbulence models have been used for the numerical simulations with subsequent checking and assessing of the results on the basis of experimental data. The focus was especially put on the distortion pattern at the outlet of the MEIRD and on the accompanying flow phenomena, as the latter exert a particular influence on the engine's performance. Two different vortex systems have been found to display the most prominent flow phenomena (Fig. 3). The first one is generated in the front part of the duct and consists of two twin vortices in the lower side wall area. The second vortex system develops from a large flow separation at the strongly curved upper wall in the rear part of the intake. It similarly consists of a large twin vortex and dominates the distortion pattern at the duct's outlet plane, impacting the engine operation.

In addition to the two vortex systems, the highly bent geometry of the MEIRD causes strong local pressure and velocity gradients to develop, via which both mentioned vortex systems are coupled indirectly and influence one another. Through the experimental investigations it has been possible to establish a sophisticated numerical setup for conducting a detailed flow field analysis in the MEIRD research intake duct.

As is generally known, it is possible to use passive measures, such as vortex generators, to homogenise the flow in the outlet plane of the intake duct. Several variants of such vortex generators have been used and tested in the MEIRD adapter openings envisaged for that purpose (Fig. 4). Their configurations consist of multiple guide vanes, which are arranged in varying number and with varying geometric parameters on the removable cover panels. These first configurations have already been able to influence the flow locally (directly upstream of the large flow separation) and significantly reduce the distortion pattern in the duct's outlet plane.

The results obtained so far hold promise of further potential improvements, in which respect both numerical and experimental investigations are currently ongoing.

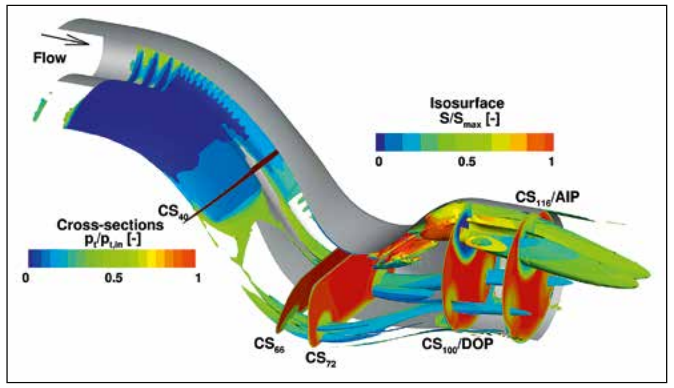


Fig. 3: Flow phenomena within the MEIRD based on data from numerical simulations

Fig. 4: Adapter cover panel with vortex generators installed in the adapter frame of the MEIRD

Thomas Lehmacher
Wehrwissenschaftliches Institut für Schutztechnologien –
ABC-Schutz (WIS)
Munster

WISPosteingang@bundeswehr.org

Wolfram Berky
Fraunhofer-Institut für Naturwissenschaftlich-Technische
Trendanalysen INT
Euskirchen

info@int.fraunhofer.de

Alternative neutron detection methods as protection for armed services personnel

The growing number of international operations involving the Bundeswehr is steadily raising the probability of contact with radioactive or nuclear material during missions. Substances emitting neutrons pose a major hazard. A focal point of interest where sensitive detection of neutrons is concerned is alternative materials with a high neutron efficiency and a wide availability.

The increasingly complex missions of the Bundeswehr call for equipment which reliably and swiftly warns of possible hazards posed by warfare agents (in this case: radioactive materials) but is also economical and technically manageable. Although detecting ionising radiation currently seems to be of subordinate importance, it can quickly become more relevant because of the modernisation of already existing nuclear weapons and the development of new carrier systems. Moreover, there is the constantly growing risk of terrorist attacks on facilities which use nuclear materials for energy generation or store them after disposal.

The equipment and systems fielded in the Bundeswehr to detect neutrons, based on proven Helium-3 (^{3}He) technology, is in principle well-suited for the purpose, but far too few systems are available and are generally reserved for a small group of specialists. To be able to ensure adequate availability of detectors in the field, there is the need to analyse and evaluate efficient and economical alternatives to the existing equipment and systems so that effective area protection (camps, airports, and other sensitive areas) can be provided.

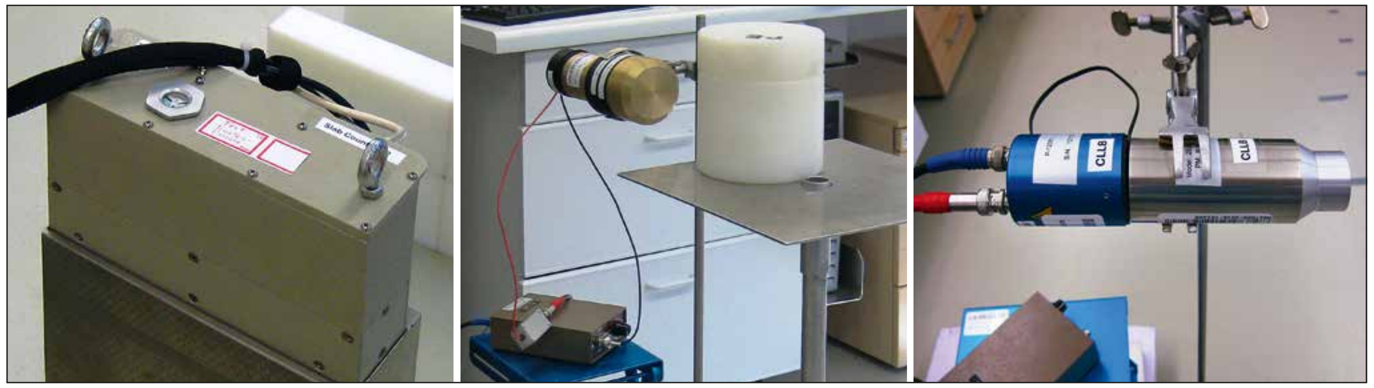


Fig. 1: Typical measurement situation with a ^{252}Cf neutron source. Left: Slab counter (^{3}He), Centre: CLYC detector (^{6}Li), Right: CLLB detector (^{6}Li) (photos: Fraunhofer INT)

"Alternative methods for neutron detection" have been examined in a first step as part of a research project undertaken by the Bundeswehr Research Institute for Protective Technologies and CBRN Protection (WIS) in cooperation with the Fraunhofer Institute for Technological Trend Analysis (Fraunhofer INT). This was begun with literature research to identify the best alternative material to ^{3}He.

Lithium-6 (^{6}Li) has been identified and examined in greater detail in measurements and tests with the aid of detectors available on the market ($^{6}LiF/ZnS$, CLYC and CLLB), and the detectors characterised as thoroughly as possible. In Fig. 1 the detectors are shown in a typical measurement situation with a californium 252 (^{252}Cf) neutron source, while Fig. 2 shows the signal rate of an $^{6}LiF/ZnS$ detector as a function of the distance to the source. The latter indicates that, to detect neutrons over greater distances, very sensitive detectors are needed. A highly sensitive measuring system has been realised for Fraunhofer INT's measurement vehicle (DeGeN) with standard ^{3}He material, which is used as a reference for new detector materials. Calculations of this system's detection threshold for different vehicle speeds and distances to the neutron sources (in this case americium/beryllium (Am/Be) and ^{252}Cf) are visualised in Fig. 3. The measurements conducted with the DeGeN car in this project show a good correlation with the calculations.

This project has looked at alternative detector materials to the currently used ^{3}He, as the latter is becoming scarcer and more expensive. Systems based on ^{6}Li, especially the $^{6}Li/ZnS$ detector newly acquired and characterised in this project, show better neutron detection efficiency even than the current ^{3}He reference detector.

Other alternatives that use new materials, such as CLYC (Cs_2LiYCl_6:Ce) and CLLB ($Cs_2LiLaBr_6$:Ce) detectors, additionally have the ability for gamma detection and even surpass the performance of a sodium iodide (NaI) detector. Fig. 4 shows the energy spectrum of a ^{252}Cf source and illustrates the simultaneous detection of neutrons and gammas using the CLYC detector.

Because of the promising results and ongoing development in the field of alternative neutron detection technologies, further research activities are envisaged with the aim of ensuring efficient protection for armed forces personnel in complex nuclear scenarios.

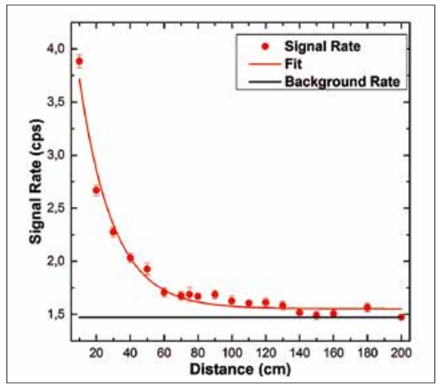


Fig. 2: Signal rate of an LiF/ZnS detector as a function of the distance to the ^{252}Cf neutron source

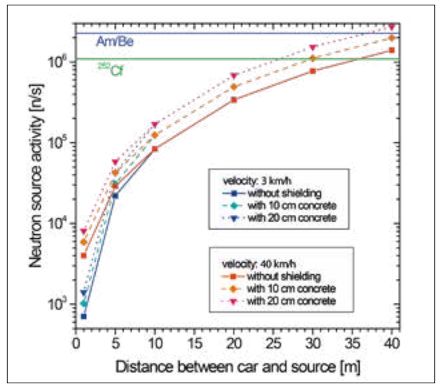


Fig. 3: Calculations of the detection thresholds for a vehicle-bound neutron detection system (in this case: slab counter (^{3}He)). The emission rates of the neutron sources used in the measurements (^{252}Cf and Am/Be) are shown for comparison purposes

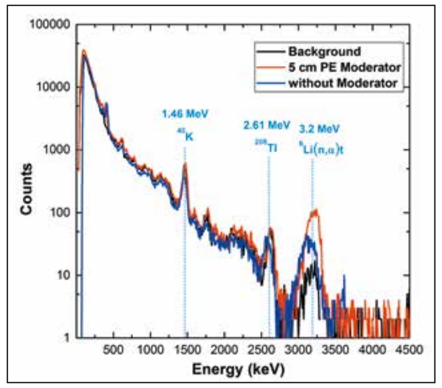


Fig. 4: Energy spectrum of the CLYC detector with simultaneous detection of neutrons and gammas by a ^{252}Cf source

Dipl- Phys. Frank Wilsenack
Wehrwissenschaftliches Institut für Schutztechnologien –
ABC-Schutz (WIS)
Munster

WISPosteingang@bundeswehr.org

Dipl.-Ing. (FH) Thomas Wolf
Wehrwissenschaftliches Institut für Schutztechnologien –
ABC-Schutz (WIS)
Munster

WISPosteingang@bundeswehr.org

Hyperspectral IR spectroscopy as a means of realising distance-capable area protection

Networks of point detectors are laborious to operate and difficult to protect outside of secured areas. An alternative is the use of standoff detection technologies. The Bundeswehr Research Institute for Protective Technologies and CBRN Protection (WIS) explores various standoff sensor technologies for detecting clouds of hazardous chemical substances. This will permit to gain a longer warning time ahead and a faster compilation of the situation picture with less effort.

Operations undertaken by the Bundeswehr in war zones and crisis areas involve the also installation and hence the protection of military camps. For one does this require protection against ballistic attack and explosives. But this holds true as well for the protection against chemical weapons, which despite the banning and outlawing of chemical warfare agents (CWA) have been put to use again in recent years by governments and terrorists. Beside classic CWA there is growing use of easy-to-obtain toxic industrial chemicals (TICs). The mandate upper limit imposed in each case may additionally restrict the deployment of CBRN reconnaissance forces. Therefore the area protection is only practicable by using automated, standoff-capable detection devices.

Thus far, detection devices fielded in the Bundeswehr allow detection only at their point of use (point detectors). Even given the current state of the art and with reasonable effort, setting up a network of such point detectors (which is something as yet to be realized) would not lead to provide adequate warning times to establish a threat-adapted level of protection.

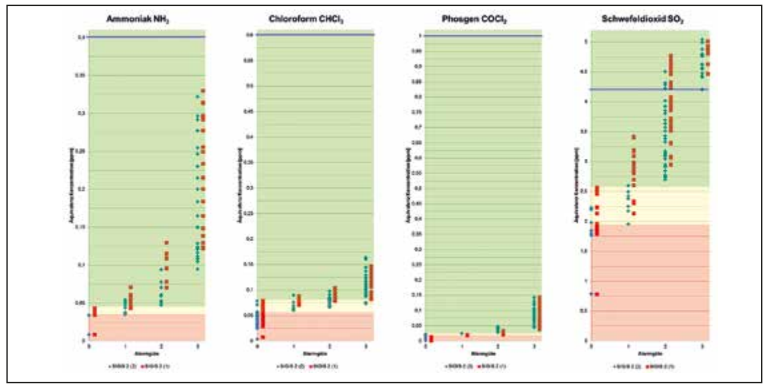


Fig. 1: Measurement results determine the identification detection limits of randomly selected chemical warfare agents and hazardous substances in the laboratory
(blue line: lower limit of detection according to specifications; green area: concentration range in which both systems always identify true/positive; yellow area: concentration range in which there was partly no true/positive identification; red area: concentration area without any true/positive identification)

Fig. 2: Verification of the standoff detection of gaseous hazardous substances from a distance by outdoor measurements at the WIS site

For some time now, WIS has been working on the concept of standoff-capable detection systems. In the past it has also participated in the development of a passive, hardened standoff detector (RAPID). This infrared spectroscopy-based sensor type measures along a line which is ultimately limited by the horizon and hyperspectrally covers a full spectrum in the wavelength range of 8 – 12 microns. This spectrum is subsequently analyzed and compared against a device-based spectrum library, in which all relevant hazardous substances (except for non-infrared active halogens) can be stored.

Passive detectorscan determine the direction from which the threat emanates, but they cannot provide any information about either the distance or the concentration distribution in the hazardous-substance cloud. With the intention of overcoming these limitations, which are important when weighing up any alarm, WIS presented a concept at the 2015 CBRN Symposium in Berlin. This was based on triangulation by several hyperspectral plane array detectors and wouldallow the determination of the distance and of the concentration in the hazardous-substance cloud. WIS is conducting research within the scope of R & T projects into hyperspectral focal plane array detectors, which additionally have the capability to measure 256 x 256 channels at the same time. This allows them to observe a large solid/spatial angle and thus a large area in an environmental direction simultaneously.

To be able to provide an initial, fast and, above all, reliable solution, where military camp protection is concerned, WIS proposed, on the basis of the knowledge gained in the projects, a first implementation of a triangulation solution with the use of two single-segment SIGIS 2 detectors. This proposal was translated into a procurement in cooperation between the Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support (BAAINBw), the Bundeswehr, Bruker and WIS, and then tested and qualified at the WIS in 2017 as “proof of concept”. Following the initial training of the system’s future users at WIS, the system has been set up and commissioned by a WIS staff member in northern Iraq, where it is still in operation.

Using the results achieved so far as a basis, WIS is currently conducting intensive research on a much faster plane array detector-based area protection system. Beside its higher detection speed, this system would offer additional options for reducing false alarm rates and for compiling a more accurate situation picture.

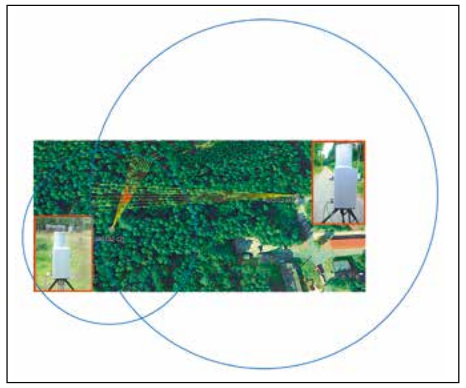


Fig. 3: Verification for the correct localization of a test cloud released at WIS using triangulation based on measurements from two coupled SIGIS 2 systems

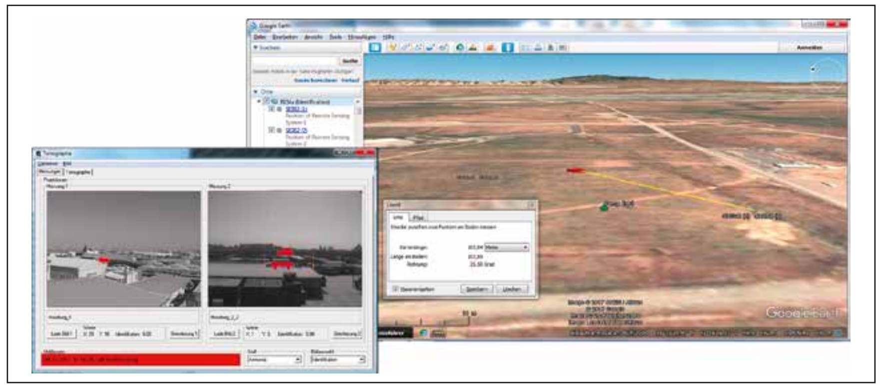


Fig. 4: Identification and localization of a hazardous-substance cloud by the standoff detection system installed in northern Iraq

RDir Prof. Dr. Sebastian Eibl
Wehrwissenschaftliches Institut für Werk- und Betriebsstoffe (WIWeB)
Erding

wiweb@bundeswehr.org

Impact of improvised fire accelerants on carbon fibre reinforced polymer material (CFRP)

The Bundeswehr Institute for Materials, Fuels and Lubricants (WIWeB) conducts various research projects as part of its responsibility for technology, safety and reliability of materials and POL (petroleum, oil and lubricant) products. In one project focusing on "In-service properties of carbon fibre reinforced polymer materials (CFRP)", it is exploring aspects such as climatic influence and lightning strikes, detection and repair of damage, and the impact of improvised fire accelerants.

Carbon fibre reinforced polymer materials (CFRP) are used in modern Bundeswehr aircraft because of their very good lightweight characteristics. But, in contrast to metallic materials, CFRP display less thermal stability and inferior reaction-to-fire properties.

The goal of the featured project is to assess the vulnerability of CFRP structures in case of arson attacks carried out with improvised fire accelerants (e. g. "Molotov cocktail"). It involves not only determining the residual strength after thermal exposure, but also gaining a deeper insight into the degradation mechanisms of the resin matrix and laminate structure.

For this purpose, experiments have been conducted on real aircraft components, and on laboratory samples from all the CFRP systems relevant to the Bundeswehr, using cone calorimetry. The research is concentrating on how different amounts of fire accelerants influence varyingly thick laminates and sandwich structures with respect to the heat released during exposure to fire, temperature development, degradation of the resin matrix, susceptibility to delamination, and residual strength for horizontally and vertically aligned samples, etc. Several techniques available at WIWeB have been used, such as mechanical testing to determine the residual interlaminar shear strength. Ultrasonic testing, infrared spectroscopy and computer tomography allow non-destructive characterisation of the polymer and laminate degradation. Special care has been taken so that the improvised fire accelerants contain ingredients that are inexpensive and generally available.

Basic correlations are observed between specific fire scenarios and resultant thermal damage. The more fire accelerant is applied, and the thinner the CFRP laminate is, the more pronounced is the observed thermal damage, as would be expected. This makes sandwich structures particularly susceptible due to their comparatively thin CFRP top layers. The damage caused by a given amount of fire accelerant is more severe for a vertically aligned sample compared with a sample that is horizontally aligned, as there is a better transfer of heat from the flame to the CFRP. The protective effect of various surface layers such as typical lacquers, copper lightning-protection meshes and intumescent coatings is additionally being explored.

In their current state, CFRP and, particularly, sandwich structures have to be considered prone to damage if subjected to arson attacks carried out with improvised fire accelerants. The obtained results provide a basis to define criteria that predict the failure of CFRP structures in case of arson attack. It is also possible to estimate for diverse threat scenarios whether CFRP structures are suitable for purpose. These findings will permit precise optimisation of the CFRP material with regard to its reaction-to-fire properties and the impact of improvised fire accelerants. One specific approach in this respect is to integrate intumescent fire protection coatings on CFRP sandwich structures. Newly developed analysis techniques based on infrared spectroscopy are able to non-destructively estimate the residual strength and the temperature that develops with thermally exposed CFRP material. In case of damage involving a non-obvious/moderate need for repair, these techniques make it possible to decide on what further course of action to take.

The overriding objective of the research project is to assess hazards emanating from thermally exposed CFRP and to eliminate uncertainties associated with their military use. Service personnel will have practical methods placed at their disposal to ensure sustained operational readiness of the weapons systems, and the Bundeswehr will thus have an independent assessment capability that it urgently needs.

Fig. 1: Application of an improvised fire accelerant to a CFRP helicopter component

Fig. 2: Combustion of an improvised fire accelerant on a horizontally aligned CFRP panel in a cone calorimeter

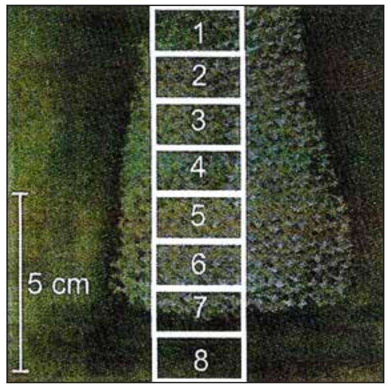


Fig. 3: A 2 mm thick CFRP panel after vertical exposure to 10 g fire accelerant (positions of samples for testing residual strength are marked)

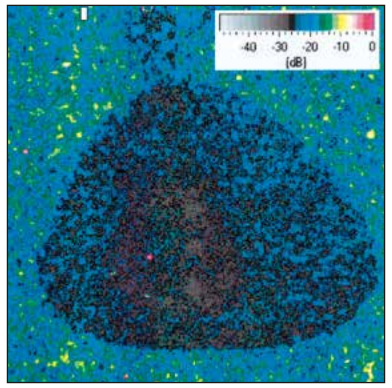


Fig. 4: Accompanying ultrasonic scan showing massive delaminations

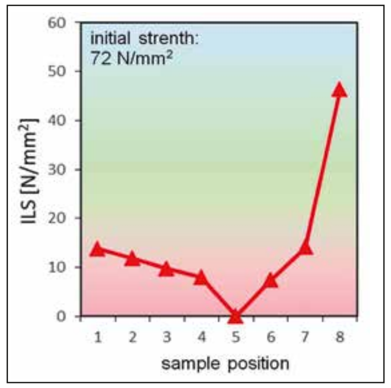


Fig. 5: Accompanying curve of the interlaminar shear strength (ILS) as a function of the sample position (see Fig. 3)

ORR Dr. Raman Tandon
Wehrwissenschaftliches Institut für Werk- und Betriebsstoffe (WIWeB)
Erding

wiweb@bundeswehr.org

OFA Dr. Andreas Werner
Zentrum für Luft- und Raumfahrtmedizin der Luftwaffe – FG I 1
Königsbrück

zentrlurmedlwi1diagnostik-forschung@bundeswehr.org

Telemonitoring by means of smart textiles in the field of CBRN protection – mobPhysioLab®

The mobile physiological laboratory (mobPhysioLab®) is a modular system that can collect and process physiological and environmental data. It allows the monitoring of armed services personnel during real operations. Integrating mobPhysioLab® sensors into a textile has significantly improved the usability of the system and created a smart textile with great potential applicability.

The mobPhysioLab® is a mobile system used to study stress situations of individuals in different working environments. The monitoring technology has been in use for years in the fields of aviation medicine and industrial medicine as well as in research (even in space: ISS). Unlike conventional methods, the system permits continuous non-invasive measurement of physiological data using innovative medical technology. It consists of flexible individual components which combine psycho-physiological measurement methods with the collation of environmental parameters using state-of-the-art information technology. It permits both physiological data collection and subject-specific studies of individuals under harsh environmental conditions, such as persons wearing CBRN protective suits.

Wearing such protective clothing can be extremely strenuous for emergency response forces, this applies especially to impermeable suits worn in warm/hot and particularly damp environments. The aim, by physiologically monitoring emergency response forces, is to adapt the times spent in insulating protective clothing to individual performance and to extend or

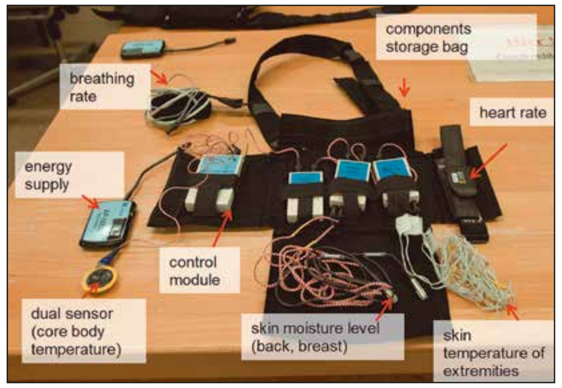


Fig. 1: HealthLab (master and several satellites), showing measurement options, ranging from physiological parameters to cable solutions

TROARin Karola Hagner
Wehrwissenschaftliches Institut für Schutztechnologien - ABC-Schutz (WIS)
Munster

WISposteingang@bundeswehr.org

shorten them as required, so as to preclude health risks for those wearing the clothing.

To date, wear time for protective clothing has been limited to 30 minutes (for occupational health and safety reasons). Medical specialists have previously had to attach all sensors manually to each person being monitored by the mobPhysioLab®. Within the scope of combined R&T activities involving the Air Force Centre of Aerospace Medicine, the Bundeswehr Research Institute for Protective Technologies and CBRN Protection (WIS) and the Bundeswehr Research Institute for Materials, Fuels and Lubricants (WIWeB), a technology demonstrator has been developed for a smart textile which either has attachment points for mobPhysioLab® sensors in the correct positions in the textile material or has fully integrated sensors.

Smart textiles are garments equipped with electrical functions or incorporating conductive materials capable, for example, of interacting with the environment, or have integrated sensors, or are able to react to influences or hazards near-by. Thanks to the integration of the mobPhysioLab® system into the clothing, users only have to don the textile in order to be monitored online by a physician via telemetric transmission. This has greatly increased user friendliness. As a result, medically trained specialists only have to verify the correct positioning of the sensors. The data is transmitted by radio or WLAN. At present it is possible to monitor 5 persons simultaneously. The parameters can be transmitted over a distance of up to 5 km and be updated every 5 seconds, thereby ensuring monitoring over a large radius. This can also be used by mission commanders for command and control purposes.

The technology demonstrator in its present configuration has already been tested successfully in a field trial in Canada during the "Precise Response" exercise. All test persons gave positive feedback.

Fig. 2: At present, each individual sensor is manually connected via cable and secured with tape

Fig. 3: Prototype of a smart textile, with sensors and cables integrated into the textile

OLt Maximilian Krönert, M. Eng.
Wehrwissenschaftliches Institut für Werk- und Betriebsstoffe (WIWeB)
Erding

3D-Druckzentrum@bundeswehr.org

TRAmtm Markus Rebhan, M. Eng.
Wehrwissenschaftliches Institut für Werk- und Betriebsstoffe (WIWeB)
Erding

3D-Druckzentrum@bundeswehr.org

Pilot project on local additive manufacturing of spare parts

The potential uses of 3D printing technologies for the local manufacturing of spare parts are to be explored as part of research work on 3D printing. This has led to the operation of a 3D printer including work environment in Mazar-e-Sharif. The pilot project will serve to gain initial experience in the usefulness of this innovative manufacturing technology in theatre.

The project is being realised across major organisational elements in close cooperation between the Bundeswehr Logistics Command (BwLOGCOM), the Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support (BAAINBw) and the Bundeswehr 3D Printing Centre at the Bundeswehr Research Institute for Materials, Fuels and Lubricants (WIWeB) in Erding. It is serving as a subproject in the further development of the Bundeswehr logistics system.

The 3D Printing Centre, activated in February 2017, makes technical expertise available and is responsible for material procurements. Selecting a suitable 3D printer at the start of the project was an important milestone. A 3D plastics printer for professional/industrial applications was chosen on the basis of different criteria and lessons learned with various 3D printing technologies at the 3D Printing Centre. A concept for a “3D printing container” was also developed to house the phone booth-sized 3D printer and the workstations for up- and down-stream activities. The system comprising the 3D printer and work environment was first set up in Erding and subjected to

Fig. 1: The “3D printing container” houses computer workstations for component design and for operating the 3D printer, as well as workbenches for finishing the manufactured plastic components

Fig. 2: Printed to order: an additively manufactured protective cover (left) replaces the broken plastic cover (right), which had previously been removed from the oil burner of a warm-air space heater

TROS Philipp Ficker
Wehrwissenschaftliches Institut für Werk- und Betriebsstoffe (WIWeB)
Erding

3D-Druckzentrum@bundeswehr.org

TORR Dipl.-Ing. Constantin Deschner
Wehrwissenschaftliches Institut für Werk- und Betriebsstoffe (WIWeB)
Erding

3D-Druckzentrum@bundeswehr.org

thorough testing. In view of the harsh environmental conditions in theatre (such as high level of dust exposure), the system was then modified by the staff of the 3D Printing Centre.

The preparation of digital 3D geometry models for selected spare parts was initiated in parallel with the adaptation of the hardware. Spare parts that are difficult to source were first of all identified from logistic data; other spare parts were suggested by field units. Assessment whether a spare part is suitable for additive manufacturing was based on the expertise of the 3D Printing Centre. Relevant factors in this context include the size and function of the component, environmental conditions, as well as the required material properties. The digital 3D models and the first test prints were prepared by a mixed civil-military project team at the 3D Printing Centre.

A container was set up for this project at Camp Marmal with the assistance of a logistic company in theatre. After the arrival of the 3D printer in northern Afghanistan, personnel from the 3D Printing Centre were on site to install and start up the 3D printer in the container. Later, roughly a year after the launch of the project, the 3D printer container was handed over to the operators.

Its operators are soldiers from the in-theatre contingent who are trained at WIWeB for this additional activity prior to being deployed abroad. The training covers, for example, operation and maintenance of the 3D printer, troubleshooting, component design, and properties of plastic materials.

During the course of the project the team at the 3D Printing Centre will also be assisting those soldiers over a distance of 4600 km in solving technical problems, in assessing spare parts for their suitability for additive manufacturing, and in component designs. Complex components can, moreover, be additively manufactured in Germany and then shipped to the theatre of operations.

“Does this sophisticated technology work in harsh environments?” “How fast can spare parts be manufactured locally?” “Who should operate a local 3D printer and who should prepare the required 3D model data?” These are some of the questions that are to be answered during the initial one-year project period.

Fig. 3: Produced by 3D printer: quick replacement for a broken headphone piece

Fig. 4: “We'll just print it“ is the motto of the pilot project spanning different organisational element boundaries in which the Bundeswehr is gaining initial experience in local additive manufacturing

Dipl.-Inform. Christian Winkens
Institut für Computervisualistik
Universität Koblenz-Landau
Koblenz

agas@uni-koblenz.de

Univ.-Prof. Dr.-Ing. Dietrich Paulus
Institut für Computervisualistik
Universität Koblenz-Landau
Koblenz

agas@uni-koblenz.de

Enhanced environment perception using hyperspectral camera data

Autonomous navigation by vehicles in structured and unstructured environments has been a focus of robotics research for some years. Due to the complexity and diversity of environments, there are challenges that have not yet been completely mastered. Novel hyperspectral imaging is opening up new possibilities and areas of application in this connection.

Autonomous navigation generally requires suitable perception of the environment involving a combination of corresponding sensors and software. Current research vehicles operated by automobile manufacturers utilise 3D laser scanners for environment perception. During data evaluation, drivability is usually inferred only from the geometric nature of the environment. Colour cameras and laser scanners are suitable only to a limited extent for autonomous driving in unstructured environments, as they are unable to fully capture the complexity and the spectrum of the environment. Colour cameras are based on humans' colour perception and use only three channels to capture information from the visible range of light.

What is desirable is a higher spectral resolution so that a wider spectrum can be recorded and the reflection characteristics of the observed objects be analysed more precisely. It is in that regard that the latest developments in camera technology may be useful, enabling simple and fast acquisition of hyperspectral image data. The camera sensor is fitted with pixel-accurate filters so that each pixel reacts sensitively to a certain wavelength range. Such hyperspectral cameras thus deliver a more

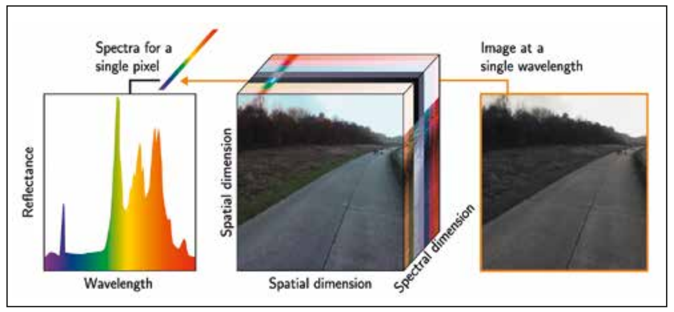


Fig. 1: Diagram of a hypercube with hyperspectral data

Fig. 2: Sample image from the data set created by AGAS. A colour image calculated from hyperspectral data with accompanying semantic annotation

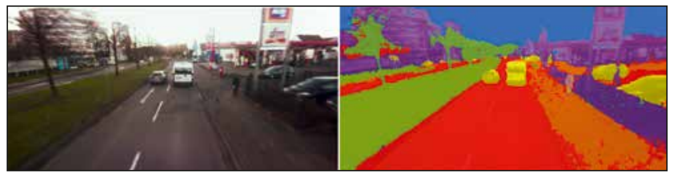


Fig. 3: Result of the semantic scene analysis based on VIS data, using machine learning. On the left, a calculated colour image and, on the right, the result of the pixel-based classification

detailed insight into the nature of the environment than would otherwise be possible with colour cameras.

The Active Vision Group (AGAS) at the University of Koblenz-Landau has explored the potential of this new camera technology for environment perception in the context of an R&D study, using two Ximea cameras for the purpose. The first camera, of model type MQ022HG-IM-SM4X4-VIS (VIS), is equipped with a special 4 x 4 macropixel pattern – i. e. 16 spectral bands – and captures the visible light spectrum in the range from around 400 – 675 nm. The second camera, of type MQ022HG-IM-SM5X5-NIR (NIR), has a 5 x 5 macropixel pattern and 25 channels for the range of 675 – 975 nm and thus covers both the visual red spectrum and parts of the near infrared range.

Various machine learning methods have been examined with a view to analysing this high-dimensional data. The aim is to assign a class to each pixel of the captured image and, from that, derive the driveability class, in which respect the AGAS has developed a new data set with hyperspectral data so as to train models and compare them with the use of colour cameras. The adapted methods have yielded very convincing results, especially when based on near-infrared data, which is partly due to the special absorption properties of chlorophyll. Plants in particular take on their green colour thanks to chlorophyll. Overall, it has been possible to improve the outcome and stability of the semantic scene analysis by using hyperspectral data.

Especially when it comes to classifying different materials in the environment, the use of special spectral markers provides the possibility to separate vegetation from other materials effectively and without any training. This can offer considerable advantages in autonomous navigation, as it is very easy to distinguish between navigable paths and impassable vegetation. This can potentially simplify the task of autonomous navigation. The study has also shown that the combination of spectral and laser-based 3D environment information is a promising approach in terms of environment perception.

The findings from this study are being applied in a project entitled "Technology Carrier Unmanned Land Vehicle (TULF)". Thanks to such enhanced environment perception it will be possible to decide in future whether an obstacle is a solid rock that has to be bypassed, or a shrub that can potentially be driven over.

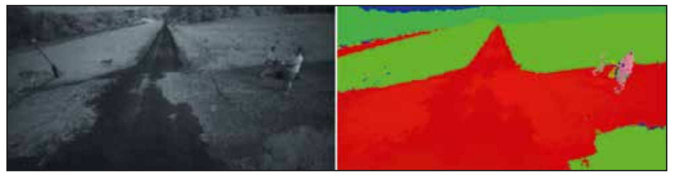


Fig. 4: Result of the semantic scene analysis based on NIR data, using machine learning. On the left, a channel from the NIR data as a grey-scale image and, on the right, the result of the pixel-based classification

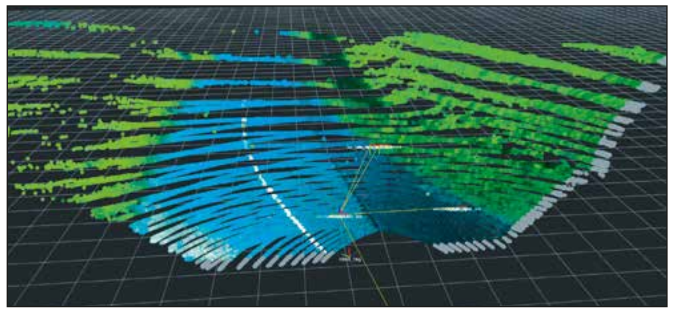


Fig. 5: Fusion of 3D laser and hyperspectral data. The 3D laser points are coloured according to the information from the VIS camera

Fabian Peifer B.Eng.
Institut für Fahrzeugtechnik
Hochschule Trier
Trier

kinetose@hochschule-trier.de

TRDir Dr.-Ing. Johannes Kloppenburg
Wehrtechnische Dienststelle für Landgebundene Fahrzeugsysteme, Pionier- und Truppentechnik (WTD 41)
Trier

WTD41posteingang@bundeswehr.org

Improving performance through optimised workplace design

In military vehicles, working with digital control and display elements while driving is an everyday normality. Using them during passive movement can often lead to symptoms of nausea, dizziness and fatigue, thus significantly limiting human performance. Such limitation of crewmember performance can have crucial impacts on the success of a mission.

The Institute of Automotive Technology at Trier University of Applied Sciences, in cooperation with the Bundeswehr Technical Centre for Ground Vehicle Systems, Engineer and General Field Equipment (WTD 41), is examining the occurrence of these symptoms in crews of military land vehicles. Commonly referred to as 'motion sickness', kinetosis occurs as a protective reaction when there is a disconnect between visually perceived movement and the vestibular system's sense of that movement. The research project is investigating the causes and factors influencing the development of kinetosis. The aim is to improve the interior design of vehicles and, in consequence, the performance of crewmembers.

A test rig has been developed and, last year, was modified at the Institute of Automotive Technology as a means of exploring influencing factors reproducibly and effectively (Fig. 1). A test subject sits off-centre, and without any outward view, in a darkened cabin that is rotatable about the vertical axis. During the rotational movements the subject is required to do various tasks. These tasks involve head movements, often causing dizziness. This test setup is based on previous medical studies

of the vestibular system, which plays a prominent part in triggering kinetosis.

This test procedure also allows the simulation of real conditions in vehicles. The various positioning of individual workplace screens and controls permits a wide variety of head movement measurements. Whether such head movements lead to dizziness depends on individual susceptibility of the person concerned as well as, to a significant degree, the type and direction of movement. Clinical studies have identified screen arrangements that can have a critical impact. This is information that can serve to improve the design of mobile workplaces.

An inventory of the vehicles currently in service with the Bundeswehr is being conducted with respect to such individual workplace characteristics triggering kinetosis. Last year, measurement runs were carried out in PUMA AIFVs. Beside analysis of the individual workplace designs, there were human-relevant vibration analyses, including measurement of temperature and noise to determine the resulting impact on the crew.

Additional physiological measurements performed on the test subjects have made it possible to correlate the reactions of the human body with the stimuli experienced. The physiological measurements conducted on the test rig and during measuring runs included parameters such as heart rate, skin conductance, respiratory rate and skin temperature (Fig. 2). This data permits objective measurement of even minimal physiological responses.

Another finding from this research is that the present standards for evaluating whole-body vibrations in military land vehicles are inadequate. The guidelines specify methods for evaluating the kinetogenic stimuli of vibrations. They include filtering and weighting collected measurement data according to special procedures. The weighting serves as a basis for demonstrating whether a vibration has a critical or noncritical impact on humans.

Current procedures for assessing kinetogenic stimuli are based on studies in the maritime field where the vibrations and impacts on the crews are significantly different to those in land vehicles. The acceleration-time curve given in Fig. 3 shows the actually measured vibrations (in blue) compared with their weighting based on the current standard guidelines (in red). The extreme contrast between the real vibrations and the weighted values indicates that further research into the kinetogenic assessment of whole-body vibrations in military land vehicles is needed.

Fig. 1: Rig for testing motion sickness at Trier University (without external walls)

Fig. 2: Physiological measurement (right) during a test drive

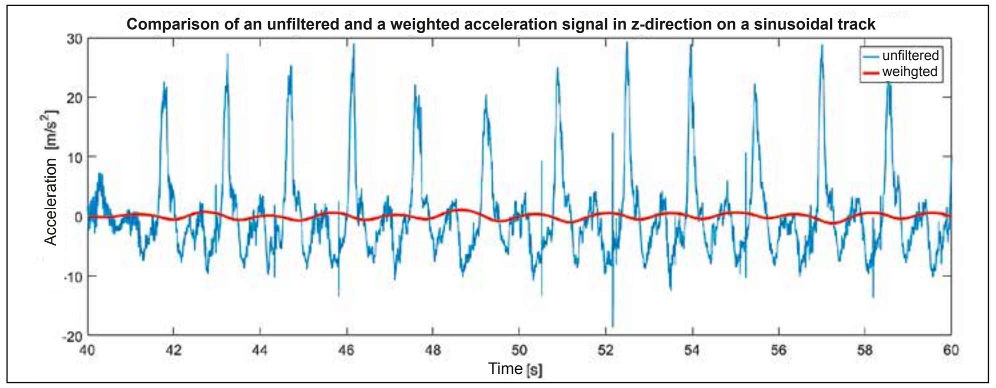


Fig. 3: Comparison between unfiltered accelerations in a PUMA AIFV (blue) and the signal weighted on the basis of standard guidelines (red)

TRDir Wolfgang Scheidler
Wehrtechnische Dienststelle für Luftfahrzeuge und Luftfahrtgerät der Bundeswehr (WTD 61)
Manching

WTD61posteingang@bundeswehr.org

Dipl.-Ing. Dr. Franz Madritsch
Ingenieurbüro für interdisziplinäre technische Projekte und Expertisen
Aicha

madritsch@madritsch.de

Mode N – a terrestrial navigation system to modernise conventional aeronautical radio navigation

Mode N is a concept that will permit the gradual replacement of the technically obsolete and inefficient DME/ TACAN systems with modern, effective and reliable navigation technology. The new technology based on SSR/Mode S signals and formats will broaden capabilities whilst reducing the bandwidth required in the L spectral band and presents the opportunity to free up the frequency spectrum for other services.

Mode Navigation (Mode N) represents a terrestrial alternative to satellite-based GNSS. In a similar manner to GNSS, multiple ground stations emit time-referenced radio signals, which can be processed in an airborne receiver by measuring the time difference of arrival (TDOA) to determine the precise position and time. Relatively short distances and a relatively high transmission power make it possible to realise much more robust signal transmission compared with GNSS. Mode N ground stations broadcast their navigational information (i. e. a unique ID, geolocation coordinates, antenna height, and transmission time) periodically using a modified Mode S message format. All Mode N ground stations are to be synchronised in time with each other through primary and secondary time sources as well as through mutual reception of synchronisation messages. Since the TDOA measurement is computed via the Mode N avionics system onboard aircraft, it is possible to use Mode N as a passive navigation system for military applications.

The development of this concept has its roots in an initiative launched by Germany's air traffic control authority Deutsche Flugsicherung GmbH (DFS) to create a high-performance follow-up system to the obsolete DME/TACAN. With the freeing-up of a large frequency spectrum in the L band currently occupied by DME channels, that spectrum could then be used efficiently for additional services. Mode N and DME can be operated in parallel with one another, thus enabling a smooth transition from one system to the other. Spoofing resistance and selective availability will be possible through suitable encryption.

The present research is focusing on the military aspects of such a system, which will be taken into consideration together with other possible requirements in the overall system concept.

A development laboratory for software defined radio (SDR) has been set up at the Bundeswehr Technical Centre for Aircraft and Aeronautical Equipment (WTD 61) to enable early technical assessment of the system and to develop and evaluate functionalities relevant to military requirements. The current state of development of Mode N has been realised in this laboratory in co-operation with DFS. Following application, the radio permit required for experimental radio transmissions has been granted to WTD 61.

The laboratory setup comprises software defined radios, high-performance PCs and laptops, signal generators, oscilloscopes and standard measuring equipment. A GPS-disciplined quartz oscillator with 8 parallel outputs serves in this development stage as a time reference and distribution system within the laboratory. Use of primary time standards is envisaged for achieving independence from GNSS.

Using SDR monitored and controlled from PC platforms, it is now possible to generate and receive Mode N signal waveforms. The research so far has focused on signal generation and reception with different signal and sampling rates, as well as on precise synchronisation of SDR devices. Suitable encryption and key-management methods have been examined so as to realise robust and secure signal transmission. IFF NATO standards have also been researched in this connection and consideration given to possible synergies regarding integrated key-management.

As a follow-on step, the experimental laboratory is to be developed into a site for testing, evaluating and advancing Mode N, the aim being initially to establish an area for ground tests within WTD 61 and later a larger area for flight tests with Mode N signal coverage. The requisite ground stations will be erected on buildings and premises of WTD 61 and DFS.

The medium-term objective is to establish a complete Mode N system for carrying out testing, evaluation, standardisation and further development in Manching.

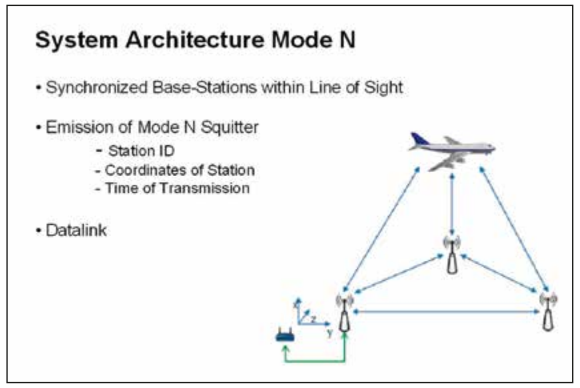


Fig. 1: Principle of Mode N: an adequate number of ground stations transmit a modulated signal from known positions at defined times. The aircraft's onboard receiver is able to determine its position and the exact time from the time difference of arrival (TDOA) (image courtesy of DFS)

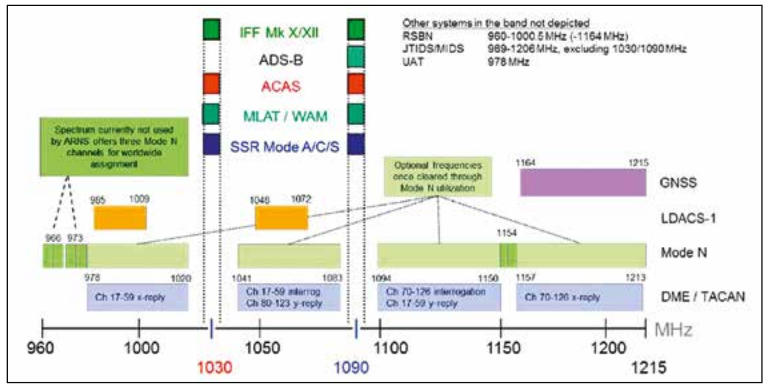


Fig. 2: Current and planned use of the L band; the overloading of frequencies 1030 and 1090 MHz by various services is clearly evident (image courtesy of DFS)

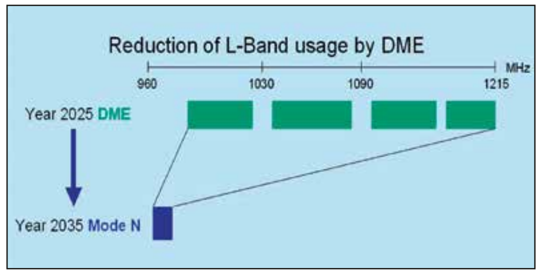


Fig. 3: The Mode N concept allows a flexible transition from the outdated DME to the innovative terrestrial navigation system, whilst freeing up a large part of the frequency spectrum in the L band (e.g. in the period from 2025 to 2035)

Fig. 4: SDR test laboratory for the experimental evaluation of Mode N and the exploration and consideration of military requirements

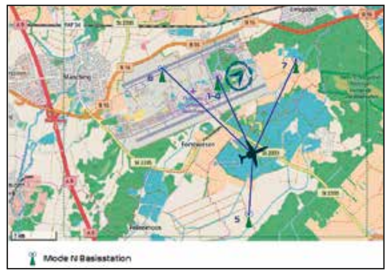


Fig. 5: Test range for Mode N under construction; the Bundeswehr Technical Centre for Aircraft and Aeronautical Equipment (WTD 61) is currently building an experimental range at and around Manching Airport for the ground and flight testing of Mode N. Map based on data of OpenStreetMap-Database. License: Open Database License (ODbL)

Dr. Ivor Nissen
Wehrtechnische Dienststelle für Schiffe und Marinewaffen,
Maritime Technologie und Forschung (WTD 71)
Kiel

WTD71posteingang@bundeswehr.org

Dr. Justus Fricke
Wehrtechnische Dienststelle für Schiffe und Marinewaffen,
Maritime Technologie und Forschung (WTD 71)
Kiel

WTD71posteingang@bundeswehr.org

Cooperative identification underwater by means of IFS

Uncooperative identification lies at the end of a long and complex process chain: from detection in time and space, to filtering for irrelevant signature characteristics – so-called false alarms – to reliable identification of an object. Yet, an alternative approach is also feasible.

Among the familiar methods used for cooperative identification are ID and credit cards, or digital procedures for automatic identification friend or foe (IFF) for aircraft, or the automatic identification system (AIS) for ships. An object becomes a subject by cooperating and by actively contributing to its own identification. It is associated with expressions such as trustworthiness (safety, security, privacy, reliability, and resilience).

Electro-magnetic waves do not propagate well underwater, making it necessary to use acoustic waves for identification procedures. Submarines are optimised in regard to their acoustic signature, and any active emission of sound negates that advantage. The capability to communicate with a low probability of detection (privacy) is, therefore, essential so that submarines do not relinquish the mantle of invisibility that is afforded by the ocean. There again, robustness (reliability, resilience) is needed but, in communications, low probability of detection and robustness are conflicting requirements. A higher signal-to-noise ratio means less decoding errors, but is also more overt. From a scientific viewpoint, underwater communication with a low probability of detection through hiding the signal (covertness) is an interesting challenge. The lack of 'signal hiding places' often leaves only the noise floor at the location of the reconnaissance unit, or steganography, as an alternative. The scientific problem has hence consisted in defining a low probability of detection underwater, in objectively benchmarking different approaches, and in achieving demonstrable implementation.

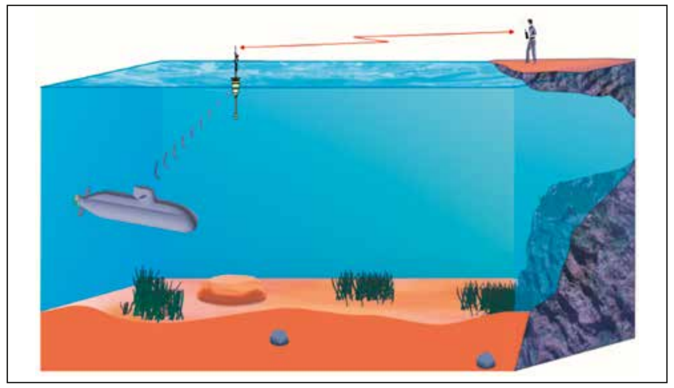


Fig. 1: Taxi call as an example of 'air-sub cooperation'.
Low probability of detection is essential for this application

In 2006, the Centre of Excellence for Operations in Confined and Shallow Waters (COE CSW) in Kiel and the then Institute for Underwater Acoustics and Geophysics (FWG), now WTD 71, started to define the underlying process chain – referred to, in computer science, as initiator-responder (IN-RES) processes – and to underpin it technologically. With feasibility having been demonstrated with the assistance of the German Navy, WTD 71 and industrial enterprises in multiple benchmarks as well as in a series of tests on military exercises, a NATO standardisation document classified as secret has been put forward.

NATO standard STANAG 1481 (IFS – Identification of Friendly Submarine) describes the IN-RES process, from bit transmission in the form of a tactical underwater communication through to underwater application, including unified presentation within the command and control system. A submarine in this context is not limited to a submarine boat. Applications such as diver homing, remote switching of barriers, secure access to harbours, ASW, or water-space management are possible for various submerged units, whether manned or unmanned. IFS is not IFF, since an automatic response from manned submerged craft is not sensible. In this respect the commander has the last word and will decide whether a response is to be transmitted.

"All-weather detection and localisation of threat subs and secure identification and recognition of own subs in littorals" is the guiding principle realised through this STANAG, providing navies with the first tactical digital waveform of communication underwater, with a low probability of detection as a new capability, and represents a major step toward 'digitisation underwater'. from which further applications will emerge.

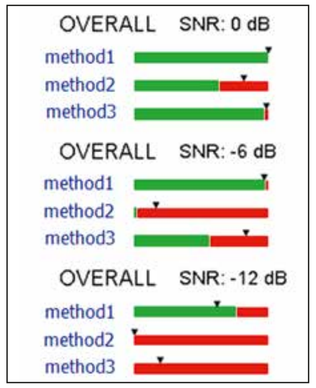


Fig. 2: Benchmark analysis of bit errors (error-free = triangle on the right) and packet errors (error-free = green), by means of 2336 measured and archived water sound propagation channels for three (different) digital transmission methods, with regard to robustness for non-positive signal-to-noise ratios

TORR Markus Pettinger
Wehrtechnische Dienststelle für Informationstechnologie und Elektronik
(WTD 81)
Greding

WTD81posteingang@bundeswehr.org

Bi-spectral detectors for the short and medium wavelength infrared range (SWIR/MWIR)

Bi-spectral infrared detectors allow spatially and temporally coincident detection of events in two spectral bands, thus dispensing with the effort involved in sensor-related image processing to synchronise both spectral channels. SWIR/MWIR sensors are suitable for thermal imagers, for precise, jamming-resistant guided missiles, and for specialised space-based missile early warning systems.

Since 2015, national IR detector manufacturer AIM Infrarot-Module GmbH (AIM) has been conducting research into bi-spectral SWIR/MWIR detectors made from semiconductor composite material cadmium-mercury telluride (HgCdTe). Beside a high photonic yield, this material offers the possibility to adjust the sensitivity of the detector for each individual spectral band, from the visible to the far infrared, through precise composition of the Hg, Cd and Te elements. The other relevant crystal properties, in particular the lattice constant, remain largely the same for almost every composition. This is essential for the cultivation of high-quality detector crystals. Faults in the lattice structure will cause increased detector noise and defects. HgCdTe is uniquely suitable for the growth of high-quality bi-spectral detector crystals thanks to the unchanging lattice constant and varying composition (Fig. 1).

Bi-spectral detectors allow spatially and temporally coincident detection of objects and events, rendering image processing to synchronise both spectral channels unnecessary. Compared with two separate detectors, they have the advantage of requiring only one set of optics, cooling housings and evaluation electronics for both spectral ranges. The new generation of bi-spectral thermal imagers can be manufactured to be compact, small and lightweight, with a low power requirement. This offers advantages for automated image processing and object detection. The spectral bands can also be processed separately, and the best spectral range selected if visibility is poor.

Research on bi-spectral detectors in the medium and long wavelength infrared ranges at AIM and the Fraunhofer Institutes began in the 1990s. Findings from that work were then applied to the SWIR/MWIR spectral bands. By 2017, good results with the first detectors were already being achieved in the laboratory.

Fig. 2 shows raw images in SWIR (left) and MWIR (right) taken by a bi-spectral detector, the resolution being 320 x 256 pixels with a pixel pitch of 30 µm. The number of defective pixels is already very low at 0.3 % and can be corrected with conventional image processing. It has been possible to adjust the spectral sensitivity so precisely that at maximum sensitivity neither spectral range influences the other (Fig. 3). This is a fundamental requirement for bi-spectral operation. The photonic yield of the detector is over 60 %. Fig. 4 shows the detector modules for laboratory and test operation. Further research work will be aimed at increasing the resolution, reducing the grid size and detector errors, and optimising the operating parameters.

Seeker heads equipped with bi-spectral detector arrays are more resistant to interference, flares and optronic countermeasures, thus increasing the precision and reliability of guided missiles. No bi-spectral detectors are used as yet in guided missiles, but modern seeker heads such as IRIS-T and RAM are already designed so that SWIR/MWIR detectors can be retrofitted in future system enhancements.

One planned application is space-based missile early warning. This will involve putting two satellites into a geosynchronous orbit for the permanent surveillance of conflict areas. The characteristic emission of missile engine exhaust plumes can, given spatial and temporal coincidence of the measurement, be clearly distinguished from other terrestrial emissions in the MWIR, as well as from solar-induced clutter in the SWIR spectral range. An aim of the current research project on bi-spectral SWIR/MWIR detectors is to have sensor technology of sufficient maturity available by 2022. The launch of the satellite mission is scheduled for 2025.

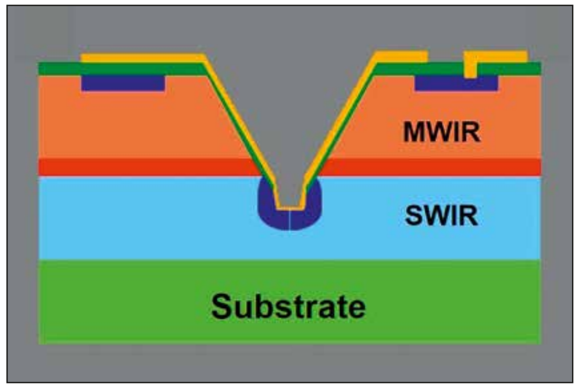


Fig. 1: Diagram of a detector pixel with applied contact points (yellow), passivation (green), separating layer (red), and spectral sensitivity range (orange/blue)

Fig. 2: Images taken by a bi-spectral detector at 130 Kelvin operating temperature, left: SWIR, right: MWIR

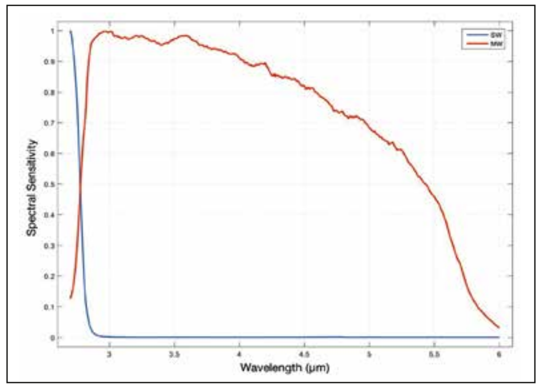


Fig. 3: Spectral sensitivity at wavelengths from 2.7 µm (SWIR) to 6.0 µm (MWIR); the sharp transition between the channels prevents spectral crosstalk

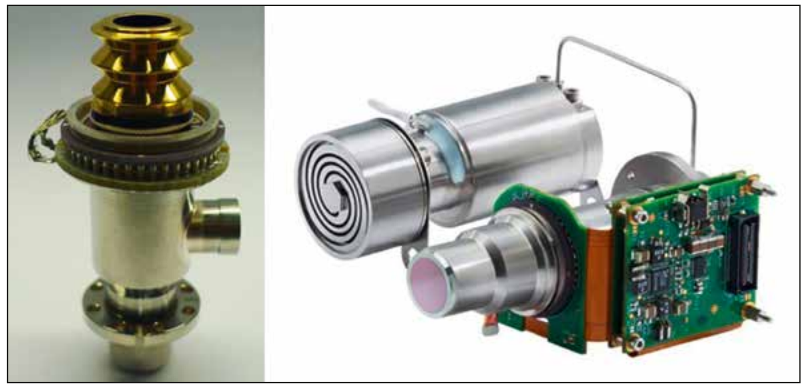


Fig. 4: Detector modules for laboratory and test operation

Dipl. Chem. Dr. Manfred Kaiser
Wehrtechnische Dienststelle für Waffen und Munition (WTD91)
Meppen

WTD91posteingang@bundeswehr.org

Predicting the ballistic stability of gun propellants with the aid of IR spectroscopy

Knowing the thermal and ballistic stability of gun propellants is important for using munitions safely and efficiently. The chemical stability of propellants is very well known and routinely checked, but little is known about their ballistic stability, which in Germany has been increasing in importance for some years because of its armed forces conducting out-of-area missions.

Ballistic stability is of major importance when munitions are used on out-of-area missions in hot climatic zones. Rolled ball propellants are used in small-calibre ammunition, such as for the German G36 or American AR15 rifle. The interior ballistic performance of the employed propellant is improved by adding a deterrent, which is applied to the propellant's surface by means of diffusion processes to control the propellant's combustion and is present on the surface down to a certain depth.

The process for manufacturing ball propellants is well-known, and the combustion characteristics can be easily adjusted (for different ammunition types) by modifying their shape and surface. This surface modification usually involves impregnation with a deterrent. The deterrent's concentration gradient ensures an almost constant pressure during the combustion process, thus compensating for the propellant's diminishing surface area due to an increasing burn rate.

As the propellant ages, its concentration gradient changes through diffusion of the deterrent, in which case the burn rate increases at the beginning of the combustion process,

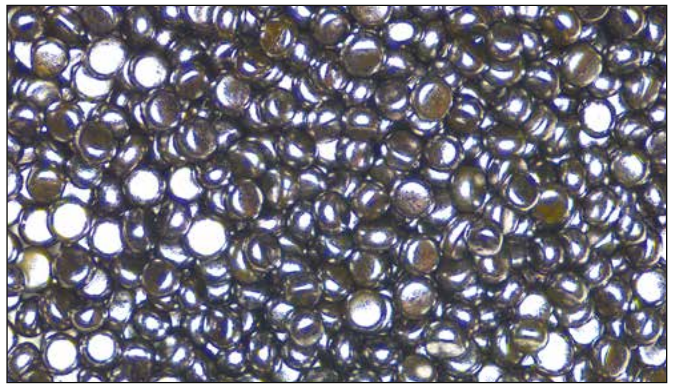


Fig. 1: Rolled ball propellant

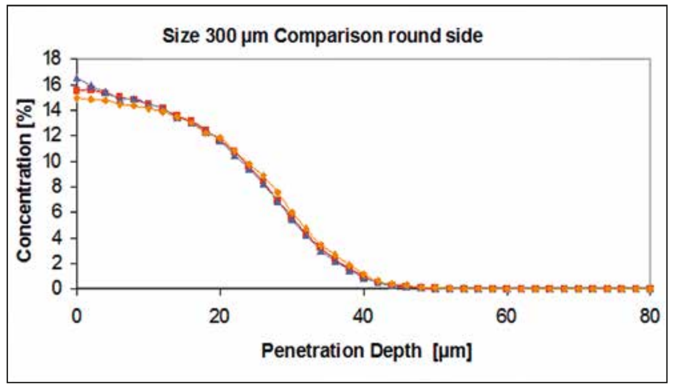


Fig. 2: Concentration profile of deterrent in a propellant grain

leading to a higher maximum pressure. Excessive maximum pressure can lead to weapon damage or malfunctions.

The service life of propellants depends on various factors. Two of these factors are chemical and ballistic stability. Ballistic stability is incontrovertibly linked to diffusion processes of the applied deterrent. To determine the diffusion constants, the propellant grains are embedded in an epoxy resin glue. Once the epoxy resin has hardened, the sample is cut into thin slices using a microtome, and the slices are then examined by means of space-resolved infrared microscopy. The measured spectra form the basis for determining the concentration profiles.

By evaluating deterrent concentration profiles as a function of storage time and storage temperature it is possible to determine deterrent diffusion constants for different temperatures. The activation energy for the diffusion process can then be calculated from the diffusion constants.

With this knowledge it is possible to calculate the ballistic life time of the propellant for different temperatures. It can be shown that the maximum pressure in the weapon is dependent on the deterrent concentration on the propellant grain surface. Below a certain concentration on the propellant grain surface, the burn rate becomes too high and the maximum pressure allowed in the weapon is exceeded.

Future investigations will employ the help of data loggers to monitor real temperature profiles of ammunition. The intention is to develop computer programmes to calculate ballistic stability using real temperature profile data from data loggers and the known temperature dependence of diffusion constants.

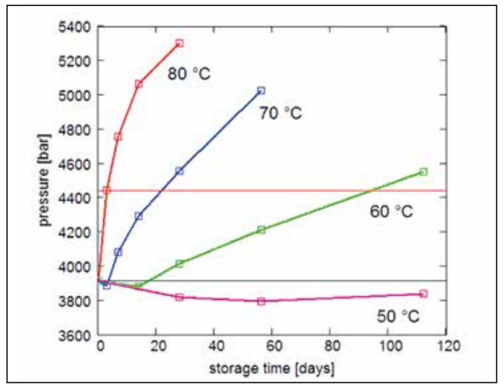


Fig. 3: Maximum pressure in the weapon after storage of the ammunition at different temperatures (red line: critical maximum pressure)

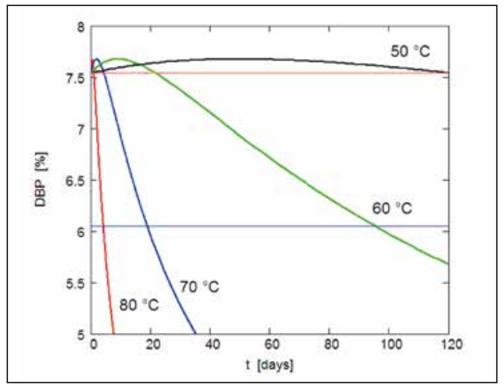


Fig. 4: Calculated surface concentration of deterrent for different storage temperatures as a function of storage time (blue line: critical minimum concentration)

2

Military Medical and Military Psychology Research

Service in the military involves a range of health risks. The mission of the Bundeswehr Medical Service is to protect and restore the health of the servicemen and -women entrusted to its care in this challenging environment. Military medical research is indispensable for maintaining and improving its capability to perform that mission. In the following, the research institutes of the Bundeswehr Medical Service present examples of their research and its practical applications.

The Bundeswehr Institute of Radiobiology is conducting a scientific analysis of the Chernobyl disaster, among other topics. In the past it has been difficult to demonstrate the link between exposure to ionising radiation and the increased occurrence of certain tumours. Identification of particular patterns of genetic changes has now helped to elucidate these causal relationships.

Ricin is a toxin of plant origin that can be extracted even with little equipment and expertise, which is why there is increased risk of it being used in terrorist attacks. The Bundeswehr Institute of Microbiology presents methods for quickly detecting or ruling out contamination with / exposure to ricin, where necessary.

The Bundeswehr Institute of Pharmacology and Toxicology presents a new detector for identifying nerve agents as well as highly toxic pesticides that have a comparable mechanism of action on the skin. In view of recent incidents in the Syria conflict in which nerve agents have been used, and due to persisting asymmetric threats, having the capability to quickly investigate and diagnose related symptoms is particularly important.

The newly established Bundeswehr Institute of Preventive Medicine is continuing research work in the fields of military ergonomics and performance physiology which was previously conducted at the Central Institute of the Bundeswehr Medical Service Koblenz. In this year's contribution, the Institute's scientists report on a method for measuring finger strength, which is a key aspect related to the safe and effective use of firearms.

Service in the Navy's diving units can involve the use of what is referred to as hyperbaric or pressurised oxygen. This can result in the human organism's exposure to oxidative stress. The Naval Institute of Maritime Medicine presents new research into reducing oxidative stress through the use of plant-based ingredients called flavonols and thus helping to protect long-term health and fitness for duty.

Flying duties in highly agile modern-day combat aircraft requires great physical resilience of flight crews. The G-forces to which they are subjected particularly affect the muscles of the neck and shoulders. The Air Force Centre of Aerospace Medicine describes a training programme specially developed to counter this type of strain. The effectiveness of the programme has been studied using the human centrifuge at the Königsbrück training centre.

The Centre of Military Mental Health of the Bundeswehr Hospital in Berlin reports on structural and physiological changes in the human brain resulting from psychological trauma. Awareness of such changes is key to early diagnosis and treatment and helps to improve the support for servicemen and -women who suffer from mental trauma.

Oberfeldveterinär Dr. med. vet. Heiner von Buttlar
Institut für Mikrobiologie der Bundeswehr
München

InstitutfuerMikrobiologie@bundeswehr.org

Detecting ricin

Biological toxins are an important group of substances that have the potential to become biological warfare agents. Especially highly poisonous ricin, the toxin produced from Ricinus communis, or castor oil plants, has already been used on several occasions for bioterrorist purposes. An accurate ricin detection method for the timely verification of any such attack against members of the Bundeswehr in Germany or on out-of-area missions is therefore essential.

Ricin is produced from castor oil seeds (Fig. 1) and accounts for up to 2 % of the weight of the plant's seeds.

Ricinus communis is cultivated agriculturally, especially in subtropical regions, because the main constituent of the seeds – castor oil – is used in the chemical and pharmaceutical industries. Castor oil plants are also widespread as ornamental variants in temperate zones. The oilcakes remaining after oil extraction are highly poisonous and are mostly used as organic fertiliser. Neither cultivation, nor processing, nor trading of castor oil plants or seeds is monitored, meaning that access to the raw material to produce toxins is not regulated and there is a corresponding risk of misuse.

Structurally, ricin is a so-called ribosome-inactivating protein (RIP). After cellular uptake, ricin inhibits protein biosynthesis by impairing ribosomal function, which ultimately leads to the death of the cell.

Fig. 1: Castor oil seeds

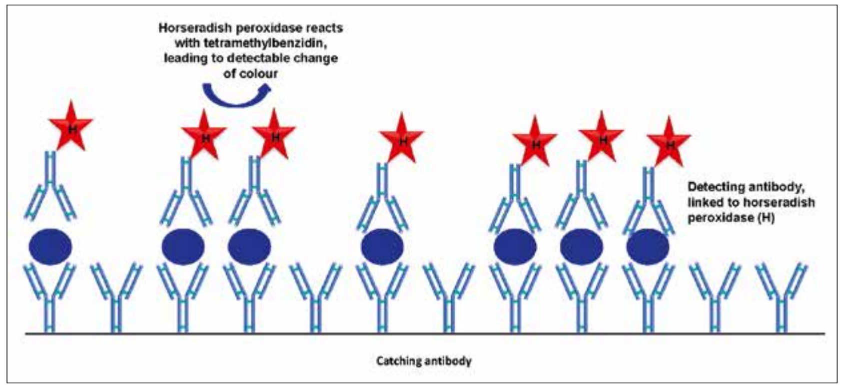


Fig. 2: Schematic diagram of a basic ELISA system

Since 1940, ricin has been an important part of many bioweapon programmes and therefore proscribed under the conventions on the prohibition of biological and chemical weapons. One past example of bioterrorist misuse is letters containing ricin that were addressed to the President of the USA, among others, in 2013.

Such examples underscore the necessity for a robust ricin verification procedure enabling early detection of released toxin.

Rapid test systems which can be used without any laboratory infrastructure are already available for such purpose, but they are much less sensitive and meant preferably as laboratory-based detection methods.

One of these laboratory-based detection methods is the so-called enzyme-linked immunosorbent assay (ELISA), whereby ricin is isolated from a sample by means of specific antibodies bound in 96 plastic well plates and then sensitively verified with the aid of further specific and enzyme-linked antibodies (Fig. 2).

In the approach under consideration here, a ricin-specific monoclonal antibody is used to 'catch' the ricin. This test has displayed a high specificity and also been able to differentiate between ricin and structurally closely related proteins. The influence of the sample material (e.g. beverages, food) in which the presence of ricin has had to be verified (referred to as the matrix effect) has been found to be low. Even detection in dairy products, which are well-known for their disruptive influence on the verification of ricin, has been possible with this test approach.

In order to increase the sensitivity of the test, it has subsequently been combined with an upstream enrichment procedure, to also enable the testing of larger sample volumes. In this so-called "on-bead-ELISA" approach (Fig. 3), the ricin in the sample is marked by the monoclonal antibody, and this antigen-antibody complex is then specifically enriched by means of magnetic beads. The detection of the ricin bound to the magnetic beads then takes place with the aid of an enzyme-marked antibody, which, if ricin is present in the sample, causes a typical change of colour in the assay.

Testing in different food products and clinical matrices such as serum and plasma has demonstrated its applicability with relevant sample material. Especially where food products are concerned, the test has been shown to be capable of detecting very low ng/ml concentrations, which would allow the safety assessment of foodstuffs.

Test systems are thus available for specific ricin detection using standard laboratory equipment. And with the necessary infrastructure also being available in mobile laboratories, this approach is also feasible in a mobile setting.

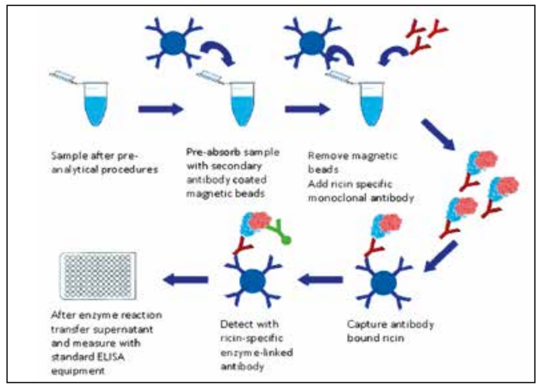


Fig. 3: Schematic diagram of the on-bead ELISA approach

Oberstarzt Prof. Dr. Franz Worek
Institut für Pharmakologie und Toxikologie der Bundeswehr
München

InstitutfuerPharmakologieundToxikologie@bundeswehr.org

Oberfeldarzt Priv.-Doz. Dr. Timo Wille
Institut für Pharmakologie und Toxikologie der Bundeswehr
München

InstitutfuerPharmakologieundToxikologie@bundeswehr.org

Skin contamination detector for nerve agents and pesticides

Detecting skin exposure caused by nerve agents and pesticides poses a major diagnostic challenge, but is essential for initiating life-saving measures. In order to close this capability gap, the Bundeswehr Institute of Pharmacology and Toxicology has developed a simple-to-use, highly sensitive and generic skin contamination detection method called the OP Skin Disclosure Kit.

Recent, repeated use of chemical warfare agents in Syria and Iraq has drastically underlined the perpetual threat to military forces and civilian populations. Persistent nerve agents and pesticides constitute a particular problem since such compounds are difficult to detect with the detection systems currently available. This applies especially to detecting skin contamination caused by these agents. The dosage of VX agent calculated to be lethal for humans is a few milligrams, and any exposure to these highly toxic compounds requires immediate countermeasures, such as skin decontamination.

With the aim of closing the existing capability gap, the Bundeswehr Institute of Pharmacology and Toxicology has developed a skin contamination detection method with the following features:
Capable of detecting all nerve agents and pesticides toxic to humans; highly sensitive; swift and easy to use; low in weight, size and cost.

The primary intention in this regard has been to detect skin contamination caused by nerve agents and pesticides so as to be able to initiate suitable early countermeasures.

To meet this requirement, a test principle based on an enzyme reaction has been selected. The use of human acetylcholinesterase, which is the enzyme inhibited by nerve agents and pesticides, thus triggering the acute toxic effects, forms the basis for the high sensitivity to, and detection of, all nerve agents and pesticides toxic to humans. It enables the OP Skin Disclosure Kit to detect nerve agent quantities that are a factor of 10,000 below the lethal dose. Use of a secondary colour reaction that can be analysed with the aid of a score sheet (score 0 – 4) delivers a test result within 3 minutes. No complex technical devices are needed as the evaluation takes place visually.

The OP Skin Disclosure Kit consists of four components with a total weight of 20 grams and a size of ~ 10 x 15 cm, hence allowing soldiers and emergency response personnel to carry the kit on them without adding greatly to their weight burden, and can be used immediately if need be. Its simple handling involves only a short induction, e.g. in the form of a training video.

Available as a prototype at present, the kit is soon to be manufactured in larger quantities at a facility of the Bundeswehr Medical Service and fielded in keeping with the Bundeswehr's operational concept. This will present the possibility to close a substantial capability gap when it comes to providing medical protection against chemical agents and help to optimise medical care for military personnel and the general population.

Fig. 1: Prototype of the OP Skin Disclosure Kit, with dimensions of ~ 10 x 15 cm and a total weight of 20 g

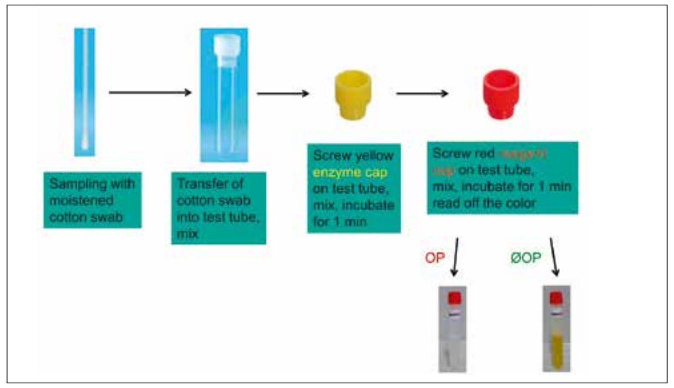


Fig. 2: Schematic diagram showing the application of the OP Skin Disclosure Kit, including sampling, reaction with test enzyme and reagents, and visual scoring

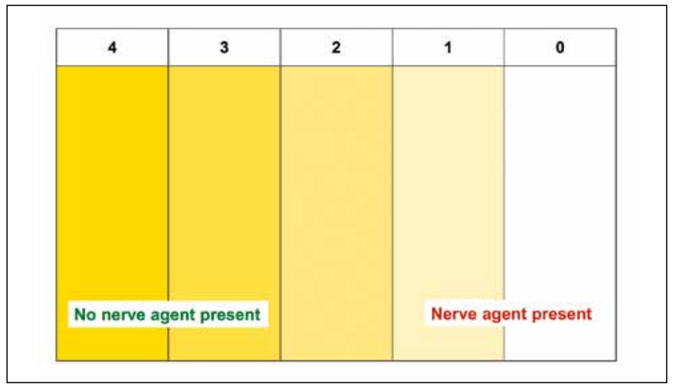


Fig. 3: Score sheet for the visual rating of colour reactions (score 0 – 4)

OSA Dr. Kai Nestler
Institut für Präventivmedizin der Bundeswehr
Abteilung A: Gesundheits- und Leistungsförderung
Koblenz

InstPraevMedA@bundeswehr.org

OFA Dr. Ulrich Rohde
Institut für Präventivmedizin der Bundeswehr
Abteilung A: Gesundheits- und Leistungsförderung
Koblenz

InstPraevMedA@bundeswehr.org

Physical challenges involved in marksmanship training – development of a measuring method to acquire data on finger strength

Diminishing finger strength impairs shooting ability during pistol marksmanship training. A newly developed measuring method makes it possible for the first time to assess muscular fatigue of the trigger finger. In addition to monitoring training **measures, the method may find use in future for ergonomic developments and for diagnosing finger and hand trauma.**

Many everyday tasks require not only fine coordination but also sufficient hand and grip strength. This is put to use in the field of clinical medicine to observe the course of degenerative illnesses and for the regeneration of finger and hand trauma. As a predictor this method also provides reliable information about morbidity and mortality rates.

Grip strength is the predominant performance-limiting factor in many core military skill sets.

Diminishing grip strength will impair casualty evacuation by stretcher, for example, before the performance limit of the cardiovascular system is at all reached.

Sufficient finger and hand strength is also needed for pistol firing and is crucial for individual mission capability and self-defence. The ability to shoot is, therefore, a so-called "individual basic skill" which all active soldiers are required to master. Pistol firing is practised regularly for this reason as part of the Bundeswehr's new deployment-oriented marksmanship training concept (Fig. 1). This comprises various series of shots,

Fig. 1: New marksmanship training concept of the Bundeswehr. Repeated series of pistol shots can lead to finger muscle fatigue

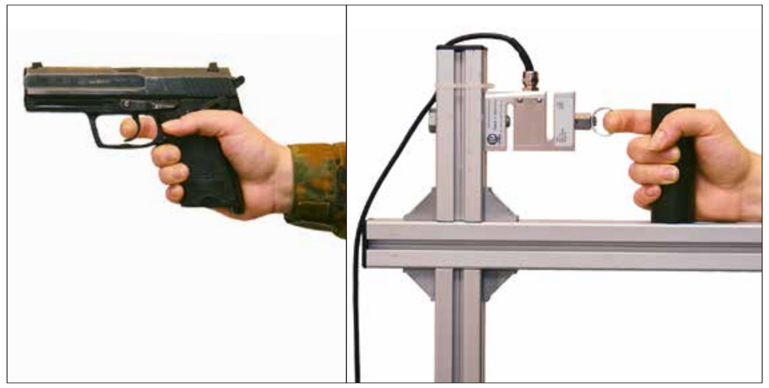


Fig. 2: The gauge for gathering finger strength data has been adapted to the dimensions of the P8 pistol

Dr. Alexander Witzki
Institut für Präventivmedizin der Bundeswehr
Abteilung A: Gesundheits- und Leistungsförderung
Koblenz

InstPraevMedA@bundeswehr.org

OTA Prof. Dr. Dr. Dieter Leyk
Institut für Präventivmedizin der Bundeswehr
Andernach

InstPraevMedA@bundeswehr.org

which are repeated several times. It can lead to muscular fatigue of the trigger finger, problems as regards safe firing, decreasing precision, and even failure to achieve the training objective.

To date, there have been no practical methods available for measuring such strains so as to gather data on the flexion forces of individual fingers. That is why, for example, there is only very little information on maximum force and its distribution in military collectives. As firing a P8 requires forces of approximately 58 N to pull the trigger, it is not surprising that diminishing finger strength is partly to blame when a soldier fails to pass his or her marksmanship training.

The aim of the research project at the Institute for Preventive Medicine has hence been to develop a reliable and valid method for gathering data on finger strength. This has led to a measuring device that is adjustable in terms of height and spacing. In the accompanying isometric maximum force test, the finger is flexed in a ring directly connected to a force gauge (Fig. 2). There are also software modules (Fig. 3) designed to record and evaluate high-definition force and time sequences (1000 Hz). Trial measurements have demonstrated compliance with the highly demanding test quality criteria. Suitability as an applied performance diagnostic technique has also been successfully demonstrated, making it possible to record in detail the change in finger strength during marksmanship training.

Prospectively, the measuring method will consequently be suitable for monitoring training measures. Comparative finger strength data can also be used for any ergonomic developments in which materiel has to be operated manually. It will provide the possibility for more precise and specific diagnoses in the field of clinical military medicine, as well as for analysing the course of finger and hand trauma treatments. In principle, the method is not limited to one finger, but can be extended and adapted for use on digits DIII-DV, although there is still a need to develop gender- and age-standardised value tables.

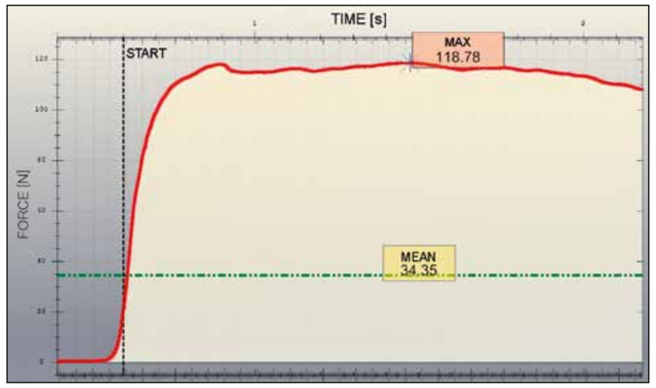


Fig. 3: Automated analysis of high-definition force-time sequences, with maximum force indicated; useful for assessing finger muscle fatigue

ORR Dr. rer. nat. Annette Arndt
Bundeswehrkrankenhaus Ulm
Ulm

BwKrhsUlm@bundeswehr.org

OFA Dr. med. Stefan Eder
Institut für Radiobiologie der Bundeswehr
München

InstitutfuerRadiobiologie@bundeswehr.org

Genetic biomarkers in papillary thyroid cancer tissue of a Ukrainian post-Chernobyl patient cohort

Identifying an association between the development of a tumour and previous occupational radiation exposure represents a major challenge for medical consultants, because radiation-specific biomarkers in tumour tissue have been unavailable so far. This has prompted a study in which tissue specimens removed from Ukrainian papillary thyroid cancer patients have been analysed using molecular-genetic methods.

Even 30 years after the Chernobyl reactor accident in April 1986 in Ukraine, its scientific evaluation is still ongoing. In the 1990s, a striking increase in the risk of illnesses involving papillary thyroid carcinoma (PTC) was reported particularly among children and adolescents in the regions affected by the nuclear fallout, primarily Ukraine, Belarus and Russia. The intake and accumulation of radioactive iodine I-131 in the thyroid gland, which is metabolically active during childhood and adolescence, is deemed a significant risk factor for the malignant degeneration of thyroid gland cells. Numerous scientific working groups around the globe have since been looking to identify genetic or protein-based biomarkers as a means of differentiating between malignant thyroid cancer tumours that have developed by chance and those attributable to previous radiation exposure.

Sporadic thyroid tumours rank among the rather rare tumour diseases and occur predominantly at older ages. Molecular-genetic studies revealed that point mutations in particular gene sequences of the thyroid cells are responsible for tumourigenesis, inducing uncontrolled proliferation and greater survivability of the degenerated cells. Point mutations involve e. g. single nucleotide substitutions within the coding region of a gene leading to amino acid exchanges in the respective gene product.

Ionising radiation, such as that released during the decay of incorporated radioactive iodine, is known to induce DNA double-strand breaks, the probability of which becomes higher with increasing radiation dose. Faulty cellular DNA repair mechanisms may as a consequence lead to an inaccurate joining-together of chromosomal break ends and thus to a "rearrangement" of genes, some of which in the worst case are thought to be responsible for the development of cancer.

In the present study, the frequency of ALK and RET gene rearrangements in a total of 76 tissue specimens taken from Ukrainian PTC patients with known I-131 thyroid doses were analysed by means of fluorescence in situ hybridisation (FISH) and immunohistochemistry (IHC), as shown in Fig. 1. All patients were younger than 18 years of age at the time of the reactor accident. Additionally, tumour tissue of 19 PTC patients born years after the accident was studied. Due to the isotope's relatively short physical half-life of approximately 8 days these patient samples were considered unexposed to radioactive iodine I-131 and thus, served as a control. In a further approach, the occurence of BRAF and RAS gene point mutations – two frequently mutated genes in sporadic thyroid cancer – was determined by pyrosequencing.

The findings failed to substantiate any association between the radiation dose and frequency of BRAF/RAS point mutations. Regarding the frequency of ALK and RET rearrangements, on the other hand, a statistically significant association with the radiation dose was found (Figs. 2 and 3). In particular, it was possible for the first time to demonstrate an increased frequency of ALK rearrangements in children and adolescents with thyroid cancer following radiation exposure.

In summary, the scientific findings strengthen the hypothesis that gene rearrangements occurring in papillary thyroid cancer tissue indicate causation of previous radiation exposure.

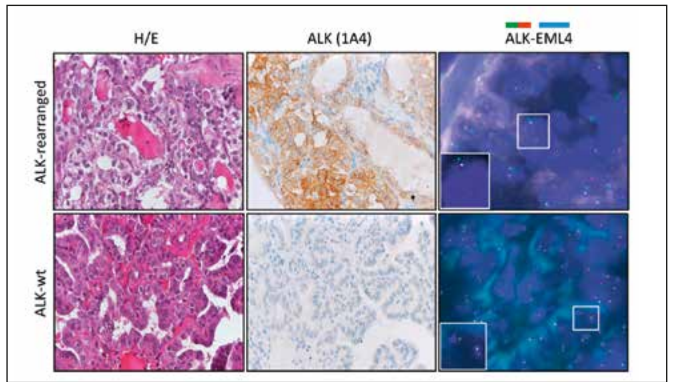


Fig. 1: Microscope images of papillary thyroid cancer tissue including confirmed ALK rearrangement (using immunohistochemistry and FISH

modell	dose categories (mGy)	OR	95 % CI	
BRAF/RAS mutations	0	1,00		
	>0-100	1,53	0,45	5,17
	>100-500	0,36	0,09	1,52
	>500	0,58	0,13	2,50
ALK & RET rearrangements	0	1,00		
	>0-100	1,85	0,32	10,69
	>100-500	5,19	1,00	26,92
	>500	6,18	1,10	34,68

Fig. 2: Summary of the odds ratios for point mutations and ALK/RET rearrangements

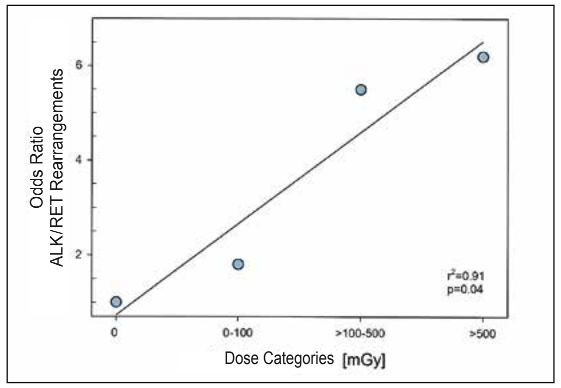


Fig. 3: Linear dose-effect model for ALK/RET rearrangements

Oberstarzt Priv.-Doz. Dr. Peter Zimmermann
Psychotraumazentrum der Bundeswehr
Berlin

BwKhrsBerlinPsychotraumazentrum@bundeswehr.org

Oberstarzt Dr. Gerd Willmund
Psychotraumazentrum der Bundeswehr
Berlin

BwKhrsBerlinPsychotraumazentrum@bundeswehr.org

Brain structure and physiological changes in the context of critical trauma incidents

When treating disorders ensuing from deployment-related trauma, early diagnosis and initiation of therapy are essential. Biomarkers and imaging techniques are currently being explored with particular regard to their use in treating post-traumatic stress disorder. The aim is to identify predictors in the field of imaging as well as biomarkers that facilitate faster diagnosis.

Mental illnesses often take a chronic course, which then restricts the possibilities for rehabilitation and reintegration into active duty. Efforts are needed in order to improve the early detection of mental illnesses, especially in light of the increasing frequency of out-of-area deployments, the known high prevalence of mental illnesses, and the greatly increased vulnerability to subsequent post-traumatic illnesses as a result.

Previous studies involving the Bundeswehr's Psychotrauma Centre (PTC) have shown, though, that a large proportion of the service personnel who fall victim to post-traumatic stress disorder (PTSD) during deployments abroad omit to seek any professional, psychotherapeutic assistance within the first 12 months after returning home. Experiencing the effects of (self-) stigmatisation appears to be an important factor in this omission.

Where the assessment of treatment processes and results is concerned, biological parameters, or so-called biomarkers, look set to play a greater role in future. It is a known fact that

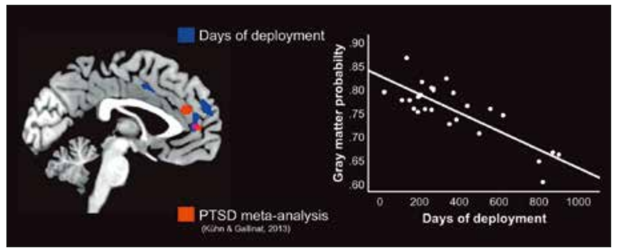


Fig. 1: The analysis suggests a negative correlation between the grey matter volume and the total duration of all the deployments of the test persons. This has been demonstrable especially in meta-analytically identified ROI (regions of interest)

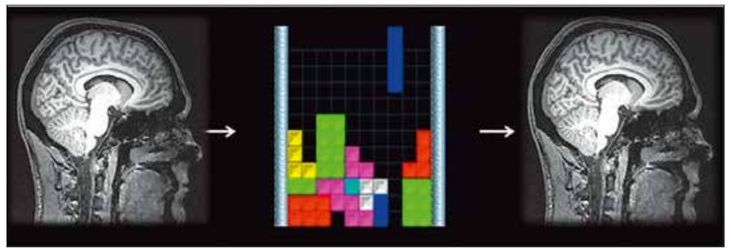


Fig. 2: In a controlled therapy study, the cerebral effects of daily video gaming have been explored during trauma-confrontational psychotherapy involving soldiers suffering from PTSD

Prof. Dr. Simone Kühn
Max-Planck-Institut für Bildungsforschung
Berlin

info@mpib-berlin.mpg.de

Prof. Dr. Jürgen Gallinat
Klinik für Psychiatrie und Psychotherapie
Universitätsklinikum Eppendorf
Hamburg

info@uke.de

post-traumatic mental disorders have extensive effects on central hormonal and neuroimmunological regulatory processes in the human body.

In addition to studies on neuroimmunological and physiological parameters, the Bundeswehr has initiated imaging studies to explore the suitability of MRI imaging as a method for the early identification and evaluation of therapies. In a controlled pilot study involving service members with deployment-related PTSD as well as healthy trauma-exposed combat soldiers, for instance, it has been demonstrated that glutamate concentrations increase significantly with the intensity of the stress caused by combat engagements and with the overall stress level for all the test persons. Moreover, the severity of the PTSD symptoms has, to a significant degree, been positively linked to GABA concentration.

The duration of deployments appears to have an impact on the extent of cerebral changes. During the same pilot study, a negative correlation has been demonstrated between the duration of military deployments and the grey matter volume in the ventromedial prefrontal cortex (vmPFC) and dorsal anterior cingulate cortex (ACC). A negative correlation has also been found between deployment-related grey matter volumes and psychological symptoms, but not between military deployment as such and psychological symptoms (Butler et al., 2017). Controlled longitudinal studies, i.e. after inpatient psychotherapy, have also revealed a significant increase in the volume of the hippocampus region, in keeping with a possible reversibility.

A randomised controlled study conducted by the working group has investigated the influence of video games on inpatient treatment for 40 soldiers suffering from post-traumatic stress disorder. Here, too, significantly stronger growth of the hippocampus volume has been found in the video-gaming group compared with the control group. It has also been possible to demonstrate a reduction in the overall severity of PTSD and of trait anxiety.

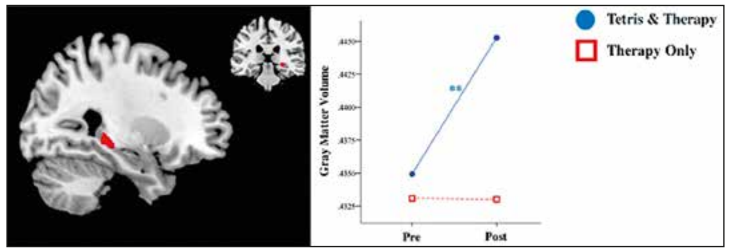


Fig. 3: The video-gaming intervention group with diagnosed PTSD showed a significant increase in grey matter in voxel-based volumetry

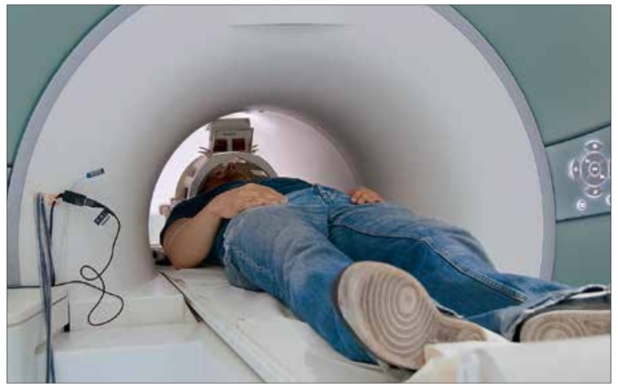


Fig. 4: In all the sub-projects, soldiers have been examined at several points in time in modern 3t MRI scanners

Photos made available courtesy of Max Planck Institute for Human Development, Berlin

OLt zS M.Sc. Monika Rausch
Zentrum für Luft- und Raumfahrtmedizin der Luftwaffe
Fürstenfeldbruck

ZentrLuRmedLwifachabtltrforschungwissuerprob@bundeswehr.org

OFA PD Dr. Carla Ledderhos
Zentrum für Luft- und Raumfahrtmedizin der Luftwaffe
Fürstenfeldbruck

ZentrLuRmedLwifachabtltrforschungwissuerprob@bundeswehr.org

OTA PD Dr. Frank Weber
Zentrum für Luft- und Raumfahrtmedizin der Luftwaffe
Fürstenfeldbruck

ZentrLuRmedLwifachabtltrforschungwissuerprob@bundeswehr.org

Prof. Dr. Billy Sperlich
Julius-Maximilians-Universität Würzburg
Würzburg

sportwissenschaft@uni-wuerzburg.de

Strain on neck and shoulder muscles due to acceleration forces and influencing this through a specific training programme – examinations in a human training centrifuge

Neck complaints induced by flying duties are a problem familiar to jet pilots. Particularly +g acceleration in combination with heavy helmets and night vision goggles (NVG) exerts strain on the cervical spine. For this reason, the Air Force Centre of Aerospace Medicine and its cooperation partners are analysing the strain on the muscles concerned during flight operations and exploring how to influence this by means of specific training programmes.

The technologisation of modern helmet systems is enhancing system performance. But, at the same time, the increase in weight is placing greater strain on the spine, particularly the cervical spine. Aeromedical research is hence focusing on analysing the strained muscular system with the objective of finding out whether training specifically intended to strengthen the neck and shoulder muscles is able to reduce the physiological cost of G-forces. The term "physiological cost" denotes the exertion a muscle has to undergo in order to perform the work it is required to.

In a pre-post test design study, 18 test persons (of whom 12 in a training group and 6 in a control group) were subjected to a 12-week training phase and to standardised exposure to G-forces in a human training centrifuge. In addition to anthropometric data and data regarding sporting behaviour, the maximum strength of the neck muscles was measured before and after the training phase.

Data collection in the human training centrifuge took place as follows. The test persons each completed three rides in the centrifuge, first at + 1.4 Gz (baseline) and then at +3 Gz, in three different settings: without a helmet, with a helmet, and with a helmet and NVG. During the rides, a surface electromyogram of muscles in the neck and shoulder areas was recorded (Fig. 2). The participants were then given a questionnaire on how the strain was felt.

To be able to compare the electromyogram data inter-individually, the "MVC normalisation" procedure is applied: the muscle under consideration is first of all contracted voluntarily to the maximum extent. Using surface electrodes, the muscle action potentials (measured in µV) are registered as field potentials. The area below the curves of the maxima of the action potentials is determined over a period of 1,000 ms. The resulting value (dimension $\mu V^2/ms$) is referred to as physiological cost and used as a reference value for the further comparisons in the course of the examination (Fig. 3).

Muscle development training was chosen as the form of training, with a view to building up strength by increasing the muscle's cross-sectional area. The training devices were easy to stow away and transport, so that training could take place independently of location and be space-saving.

It was found that, when the cervical spine was in a neutral position, muscular activity increased significantly, as did the physiological cost as a result, for all the muscles considered when accelerating from the baseline (+1.4Gz) to +3 Gz. When the head was turned at + 3 Gz, the physiological cost – as well as the subjective feeling of strain – increased many times over compared with the initial value, particularly in the neck. The post-test showed the positive influence of the training on maximum strength and general well-being. The electromyogram demonstrated objectively that the physiological cost during the flight-like strain in the centrifuge for the training group was lower after the intervention than before, meaning that the muscular system had to exert less effort for the same task.

The study shows the potential for keeping flying personnel healthy by means of flight-specific functional strength training that focuses on building up the spine-stabilising muscle system. With regard to future developments, interdisciplinary synergies are to be used and combined, including, for example, findings from the fields of ergonomics, performance physiology and training science.

Fig. 1: The different settings during the ride in the human centrifuge (photos: Monika Rausch)

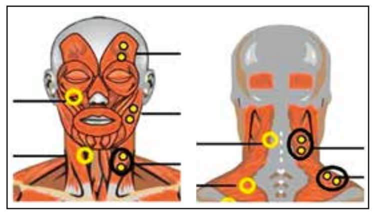


Fig. 2: Depiction of the muscles for which the physiological cost was recorded during the rides in the human training centrifuge. From left to right: sternocleidomastoid muscle, erector spinae muscle C4, descending part of the trapezius muscle

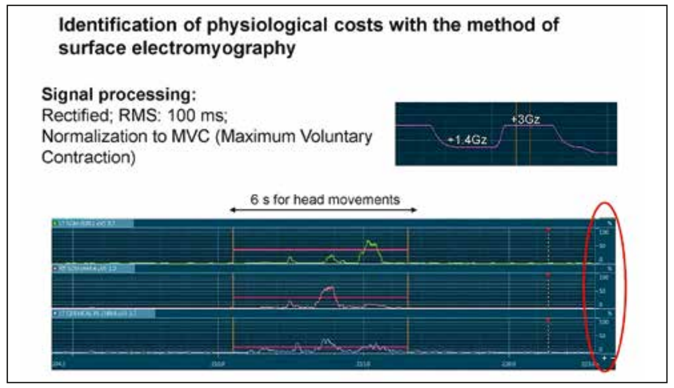


Fig. 3: Signal processing of surface electromyography by means of MVC normalisation ("MyoResearch" software, Noraxon)

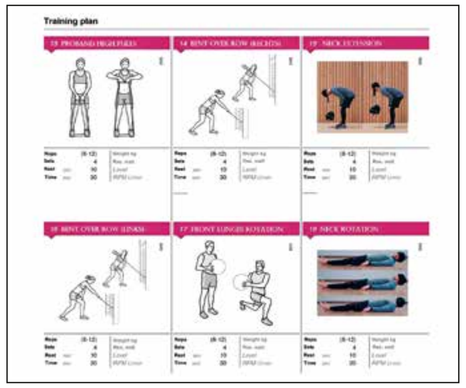


Fig. 4: Excerpt from the training plan (produced using "evoletics" software)

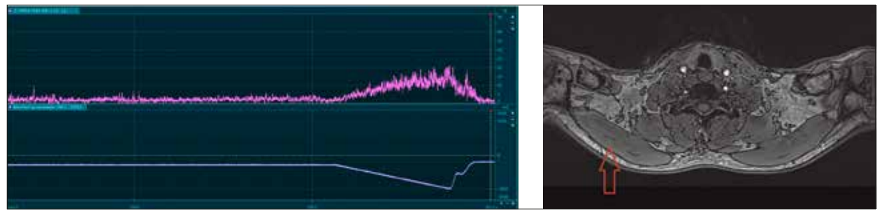


Fig. 5: Left: processed electromyogram signal of the descending part of the trapezius muscle (L/H side) when testing the natural G-tolerance of a test person in the human training centrifuge. The increase in muscular activity with increasing Gz acceleration is clearly perceptible.
Right: axial MRI image of the neck. The arrow marks the descending part of the trapezius muscle from which the electromyogram was recorded

Dr. rer. nat. Wataru Kähler
Schifffahrtmedizinisches Institut der Marine
Kiel

schiffmedinstm@bundeswehr.org

Dipl. Biol. Frauke Tillmans
Schifffahrtmedizinisches Institut der Marine
Kiel

schiffmedinstm@bundeswehr.org

OSA Dr. med. S. Klapa
Schifffahrtmedizinisches Institut der Marine
Kiel

schiffmedinstm@bundeswehr.org

FLA Prof. Dr. med. Andreas Koch
Schifffahrtmedizinisches Institut der Marine
Kiel

schiffmedinstm@bundeswehr.org

M. Sc. Bente Grams
Christian-Albrechts-Universität zu Kiel
Kiel

mail@uni-kiel.de

Potential use of flavonols in reducing oxidative stress in hyperoxia-exposed service personnel and patients

Quercetin, a natural dietary antioxidant, might prove helpful in reducing hyperoxia-induced oxidative stress. The effectiveness of water-soluble quercetin-3-glucuronide (Q3G) in protecting against oxidative DNA damage has been explored and visualised in single-cell gel electrophoresis using human PBMCs under extreme hyperoxic stress (400 kPa O2, 3h). The results show that, dependent on the dose, Q3G reduces oxidative DNA damage.

Recent scientific literature has increasingly drawn attention to unphysiologically high oxidative stress, since the reactive oxygen species (ROS) this generates can, from a medical perspective, be made responsible for a variety of illness symptoms. With the overburdening of the body's own defence system in particular having been intensively studied in this context in the past, the focus of research in the last several years has shifted towards antioxidants, which are able to eliminate unphysiologically high ROS concentrations and thus reduce oxidative stress. Whereas only direct interactions or reaction cascades between antioxidants and ROS have mainly been investigated, more and more antioxidants are being identified nowadays which, due to their biochemical characteristics, not only serve as targets for ROS but exhibit multifactorial properties.

One of these antioxidants is quercetin (3,3‘,4‘,5,7-pentahydroxyflavone), which belongs to the group of flavonols and is present in high concentrations in plant-based foodstuffs such as onions and apples. Because of its chemical structure (Fig. 1), it has the ability to emit electrons without changing structure or losing stability.
Its protective function against oxidative stress through direct interaction with ROS has already been demonstrated in numerous instances, while various other mechanisms of action are the subject of ongoing extensive discussion.

As part of a preventive medical study aimed at examining the potential use of antioxidants to help service personnel exposed to elevated levels of oxygen (e.g. combat swimmers and mine clearance divers; Fig. 2), an initial research experiment was conducted to explore, in vitro, the ability of a water-soluble human metabolite of quercetin, quercetin-3-glucuronide (Q3G) (Fig. 3), to influence oxidative DNA damage in human lymphocytes.

An experimental and hyperbaric chamber-based hyperoxic stress model (HBO) (400 kPa / 3 h O_2) was used to generate reactive oxygen species (ROS) endogenously in the lymphocytes, after pre-incubation with various Q3G concentrations. The ROS-mediated DNA damage was then quantified with the aid of a fluorescence microscopic method (so-called "comet assay"). The results show (Fig. 5) that all the administered concentrations of Q3G (1, 10, 50 and 100 µM) reduce the extent of ROS-mediated DNA damage in comparison with the untreated control specimen (0 µM), dependent on the dose. The most relevant reduction percentage of damaged nuclei (– 13 %) was found after a 30 min incubation with 1 µM Q3G, which corresponds to a high physiological plasma concentration. The experimental findings indicate that Q3G pre-treatment has a protective effect on human lymphocytes against endogenously generated ROS.

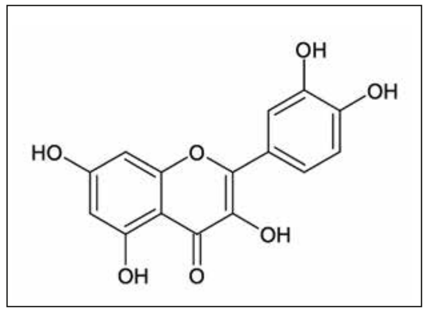


Fig. 1: Quercetin, a foodstuff-derived antioxidant, present particularly in apples and onions

Fig. 2: Combat swimmer of the German Navy

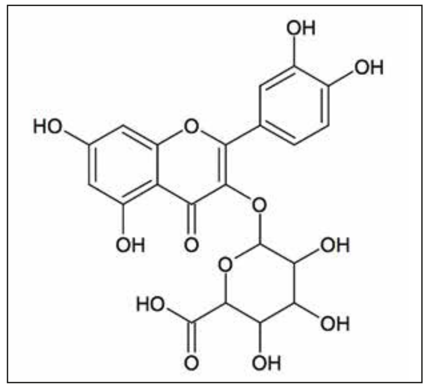


Fig. 3: Chemical structure of the water-soluble human metabolite Quercetin-3-glucuronide (Q3G)

Fig. 4: Experimental pressure chamber for in-vitro experiments under hyperoxia

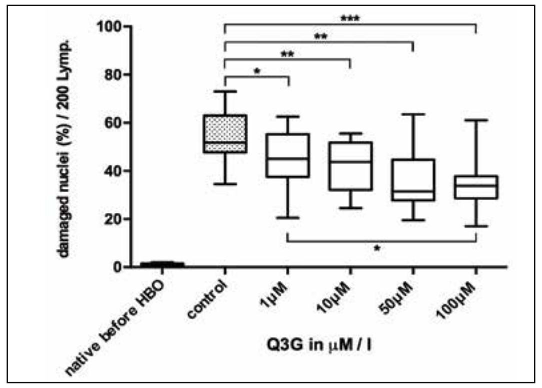


Fig. 5: The diagram shows the percentage of DNA-damaged nuclei after 30 min of pre-incubation with Q3G and 400 kPa / 3h O_2. The statistical significance has been adjusted according to Bonferroni

ORR Dr. Stefan Röttger
Streitkräfteamt, Gruppe Angewandte Militärpsychologie und Forschung
Bonn

SKAAbtPersGdsFordGrpMilPsych-Forschg@bundeswehr.org

LRDir PD Dr. Jens T. Kowalski
Streitkräfteamt, Gruppe Angewandte Militärpsychologie und Forschung
Bonn

SKAAbtPersGdsFordGrpMilPsych-Forschg@bundeswehr.org

Optimisation of tactical breathing techniques for coping with mental stress situations

Tactical breathing techniques help soldiers to control their physiological excitement in combat and threat situations and to remain as effective as possible despite the stress experienced. In a joint study carried out by the Armed Forces Office and Helmut Schmidt University, the effectiveness of classical Combat Tactical Breathing has been examined in comparison with a simpler breathing technique.

Stress that develops in threat situations can affect military personnel‘s effectiveness. One possibility of mitigating stress reactions is to use breathing techniques – a principle already applied over centuries in marksmanship or in Asian martial arts. The reason why breathing techniques are frequently used to reduce tension and excitement is that breathing is easy to control and also has an effect on cardiac activity and blood pressure. This coupling of breathing and circulation leads, among other things, to respiratory sinus arrhythmia (RSA), i. e. to an acceleration of the heart rate when inhaling, and to a deceleration of the heart rate when exhaling. A slowing-down of breathing can also reduce the heart rate to a certain degree.

One breathing technique that is commonly used especially in the armed and security forces in North America is Combat Tactical Breathing (CTB). It involves dividing the breathing process into four phases: inhale – hold – exhale – hold, so that each phase takes four seconds.

This leads overall to a deceleration in breathing, as a result of which a slowing-down of the heart rate can also be expected.

Fig. 1: Combat exercise as an example of active stress management.
© Bundeswehr / Navy PIC

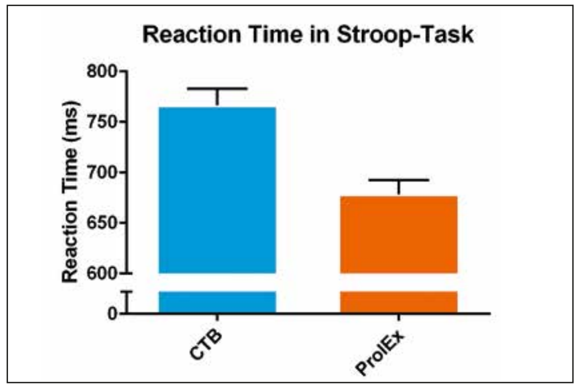


Fig. 2: Reaction times of participants in handling the Stroop task when using tactical breathing techniques. ProlEx allowed significantly faster reaction times.

Leutnant Dominique Gerber
Helmut-Schmidt-Universität / Universität der Bundeswehr Hamburg
Hamburg

pressestelle@hsu-hh.de

Professor Thomas Jacobsen
Helmut-Schmidt-Universität / Universität der Bundeswehr Hamburg
Hamburg

pressestelle@hsu-hh.de

To date, however, there has been no scientific proof of the effectiveness of this breathing technique.

Prolonged Exhalation (ProlEx) is a breathing technique that is not very widespread in the military context, yet very easy to apply. It utilises the effect of RSA, in which the breathing phase associated with a deceleration of the heart rate is prolonged. The effectiveness of this breathing technique for handling pain has already been demonstrated. ProlEx also seems to be more compatible with the physical stresses frequently occurring in military threat situations than CTB, which requires a holding of breath for several seconds.

This prompted a laboratory experiment to compare the effectiveness of ProlEx and CTB. The participants in the experiment were required to handle the so-called Stroop task, in which colour words are displayed in a colour deviating from the meaning of the word. The participants had to indicate the colour or the meaning of the word as quickly as possible by pressing a key and, in doing so, make no mistakes. Stress during the performance of the task was created in the form of time constraints and noise. To help manage the stress, the participants were to use the CTB technique once, and the ProlEx technique once.

The participants' subjective perception of that stress, and the variability of the heart rate as an indicator of parasympathetic activity of the autonomous nervous system, were identical for both breathing techniques. The use of CTB, however, led to a lower heart rate compared with ProlEx, while ProlEx allowed faster yet no less precise handling of the Stroop task than CTB.

The results suggest that prolonged exhalation may be used as a simpler alternative to CTB, especially when a quick response to the surrounding situation, i.e. active stress management, is called for. Where passive stress management is concerned, i. e. in situations in which stronger concentration on one's own breathing is possible (for example, during breaks in combat), it seems to be more effective to use the CTB breathing technique. These findings can now be verified in more realistic studies.

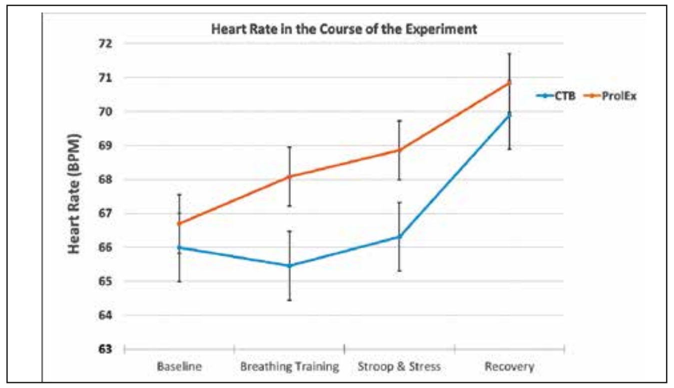


Fig. 3: Heart rate of participants in the course of the experiment.
When the CTB technique was used, the heart rate was significantly lower during the breathing training and during task handling under stress.

Fig. 4: Break in combat as an example of passive stress management.
© Bundeswehr / Sebastian Wilke

3

Military History and Social Science Research

The Bundeswehr Centre of Military History and Social Sciences (ZMSBw) undertakes military historical and socio-scientific research on behalf of the Federal Ministry of Defence with a view to actively shaping the public debate about military and security issues in Germany through its academic findings. The ZMSBw researches German military history in accordance with the generally accepted methods and standards applied in the science of history, taking into account the interrelationships between the military, politics, economy, society and culture. Through its social science research the ZMSBw contributes to the continued development of the social sciences as well as to academically based political consultations. The intertwined nature of the science of history and the social sciences broadens the range of opportunities in the field of research and in the application of its findings in history education.

The contribution made by the ZMSBw helps to better understand the role of armed forces in a pluralistic society. The social sciences, being thematically interlinked with military history, feed into the research on, and interpretation of, new conflicts and special operational scenarios of the Bundeswehr.

Through their work the researchers at the ZMSBw are members of the academic community. They foster and maintain contacts with organisations, institutions and agencies at home and abroad as well as with university and non-university research facilities. Of increasing importance is cooperation with other Bundeswehr institutions engaged in training, research and education. The ZMSBw supports Bundeswehr missions through historical and social science analyses.

Oberstarzt Prof. Dr. Ralf Vollmuth
Zentrum für Militärgeschichte und Sozialwissenschaften
der Bundeswehr (ZMSBw)
Potsdam

ZMSBwEingang@bundeswehr.org

The Medical Service makes history

For a long time, the history of the Medical Service and of military medicine attracted little attention in German military and medical historiography circles. A historical, critical debate on relevant topics took place only on the margins. In view of these research desiderata, a new structural element came into being at the Bundeswehr Centre of Military History and Social Sciences (ZMSBw) in 2016 and has since flourished.

In 2011 it was verified in valid academic terms that there had previously been hardly any systematic studies on the history of the Medical Service and of military medicine, especially in the context of German military history after 1945. After the creation of an initial temporary position in the research branch dedicated to "Military History after 1945", there has, since 1 July 2016, been a position occupied at research branch level at ZMSBw by a 'Commissioner of the Surgeon General of the Bundeswehr for History, Theory and Ethics of Military Medicine'. This title has been introduced by analogy with the interdisciplinary field of "History, Theory and Ethics of Medicine" offered at universities.

The spectrum of research on military medical history and ethics is very wide-ranging and enshrined in Special Publication C1-821/0-4001 'Forschungskorridore im Sanitätsdienst der Bundeswehr' (Lines of Research in the Bundeswehr Medical Service), which, on the basis of capability gaps, largely identifies the research and development activities undertaken in the Bundeswehr Medical Service. The "History and Ethics of Military Medicine" is identified as a separate line of research, along with fields such as radiobiology, microbiology, or pharmacology and toxicology.

Fig. 1: An army surgeon removing an arrow, from: Hans von Gersdorff, Feldbuch der Wundarznei, Strasbourg 1517, Bl. 38r

Fig. 2: Hospital huts, by Louis Stromeyer, in the Battle of Langensalza 1866, from: Louis Stromeyer, Erfahrungen über Schusswunden im Jahre 1866 [...], Hanover 1867, p. 35

The large variety of content and topics can only be hinted at and ranges from the history of events, institutions and organisations, to medical subjects. In the medium term, apart from a few smaller projects, the focus will initially be on three main topic areas:

The high relevance of the first main topic area – historical culture and historical awareness in the Bundeswehr Medical Service – has been underscored not least of all by the recent debate on cultivation of tradition and by the Bundeswehr Guidelines on Tradition and the Cultivation of Tradition in the Bundeswehr. Of particular importance in this connection is the assessment of the medical service of the Wehrmacht, the question of ideological, institutional and personnel continuities, discontinuities and breaks, as well as their consequences for the cultivation of traditions and professional identity in the Bundeswehr Medical Service.

Precisely this professional identity forms the second main topic area, which practically exemplifies, in terms of content, the synthesis of the three sub-disciplines: the history, theory and ethics of military medicine. It encompasses historical, military, medico-ethical as well as action- and value-theoretical discussions on widely differing aspects and levels, such as international humanitarian law, issues of professional law, codes of conduct, the dichotomy of being a physician and an officer, the physician-patient relationship, and other areas of everyday (military) medical life.

The third main topic area is included as part of a major project of ZMSBw to recount a German-German military history of the Cold War from 1970 to 1990. The study, which takes a comparative look at the Bundeswehr Medical Service and the medical service of East Germany's National People's Army (NVA), focuses not only on aspects such as organisation, structure, training and other determinants of medical care. Its aim (based on the hypothesis that medical care, being shaped by attitude toward patients and people as well as by medico-ethical implications, is a sensitive indicator of how an army treats its military personnel) is particularly to explore questions concerning the inner structure and inner state, as well as how people were regarded and treated in the two German armies.

Other main activities, additional to research, lie in the conceptual and coordinative domains, such as consultation and assessment, committee work, as well as the coordination, implementation and supervision of research projects. Networking with other scientists and academics within the Bundeswehr and in the civil sector is important so as to broaden the basis for research on military medical history and to enhance the effective role of this structural element at ZMSBw.

Fig. 3: Surgery at a field hospital in World War I.
Source: Collection of military history exhibits, Bundeswehr Medical Academy

Fig. 4: Tradition in the Medical Service – quo vadis.
This collage of different terms and names symbolises the recent debate on tradition in Germany (chart: Mees/Vollmuth)

Dr. Markus Steinbrecher
Zentrum für Militärgeschichte und Sozialwissenschaften
der Bundeswehr (ZMSBw)
Potsdam

ZMSBwEingang@bundeswehr.org

German attitudes towards collective defence – selected results of the 2017 ZMSBw population survey

The results of the 2017 ZMSBw population survey show that Germans generally support collective defence and solidarity with Germany's allies. However, where it is a question of specific defence responsibilities, such as Enhanced Forward Presence in the Baltic states, there is a lack of support within the population.

Potsdam-based ZMSBw conducts a population survey annually for the German Ministry of Defence concerning public attitued towards security and defence policy in Germany. This survey has been conducted regularly since 1996 and constitutes the longest time series for public opinion surveys in Germany on the subject of foreign and security policy. The 2017 ZMSBw population survey comprised 2,508 personal interviews with citizens randomly selected in Germany.

Central topics of the survey included security and threat perceptions of German citizens, as well as their attitudes towards foreign and security policy commitments of the Federal Republic of Germany. The attitudes of the population towards the Bundeswehr and its out-of area missions and deployments were also analysed. Further topics related to the public's perceptions of the Armed Forces and to questions on public acceptance of the Bundeswehr. The attractiveness of the Bundeswehr as an employer was also addressed.

A particular topic of the 2017 survey was the position of the German population on collective defence within the NATO framework. The survey asked, on the one hand, how the population generally regards collective defence and solidarity with Germany's allies. Respondents also had to evaluate specific collective / Alliance defence measures such as participation of the Bundeswehr in the NATO battle group in Lithuania as part of "Enhanced Forward Presence", in the surveillance of Baltic airspace, and in general NATO troop reinforcements in Central and Eastern Europe.

The rationale behind these questions is whether Germany shows the same willingness for mutual defence as its partners did for the Federal Republic of Germany during the Cold War confrontation. Particularly important in this regard is whether the German population is willing to provide assistance for Alliance partners.

As Fig. 1 shows, 72 percent of Germans would deploy the Bundeswehr to assist an ally who is under attack, while 68 percent would be in favour of helping an ally that is threatened, and 66 percent would deploy the Armed Forces militarily against countries which threaten Germany or its allies. General measures taken within the scope of collective defence or in solidarity with Germany's allies thus find extensive support.

Specific collective defence tasks and responsibilities shouldered by the German Armed Forces as part of NATO's Enhanced Forward Presence or troop reinforcements in Eastern Europe, however, lack support within the population, as indicated in Figs. 2 and 3. Only 34 percent support increased NATO military presence in Eastern Europe. And only 29 percent are in favour of Germany supporting the Baltic States militarily so that they are able to defend themselves against Russia. These specific commitments of the Federal Republic of Germany in the Baltic states are also supported by, at most, one third of the respondents. There is, therefore, a clear discrepancy in public opinion between general and specific attitudes towards collective defence.

In further analyses the researchers in the Military Sociology Department of ZMSBw explored the reasons and motives for the differences that were found, with the results showing that, among other things, the view towards Russia is a crucial explanatory factor. The complete findings from these analyses are given in a short report as well as in the research report on the 2017 ZMSBw population survey, both of which can be downloaded (in German) from the website of ZMSBw (www.zmsbw.de). Further detailed analyses can be found in the edited volume "Freiheit oder Sicherheit?" published in the autumn of 2018.

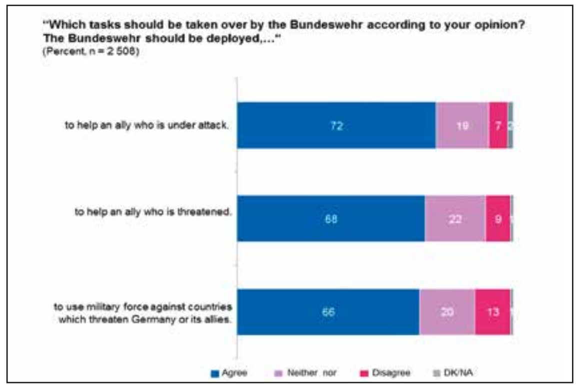


Fig. 1: : Attitudes in Germany towards collective defence in general

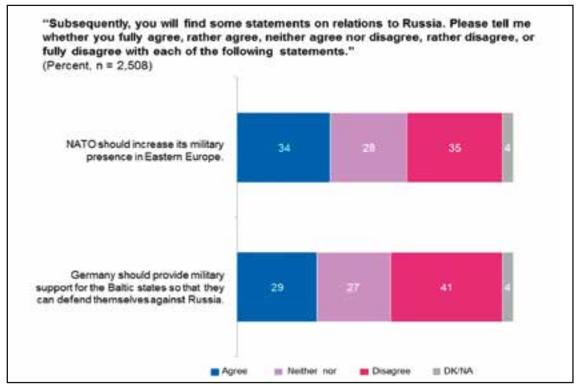


Fig. 2: Attitudes in Germany towards specific collective defence measures

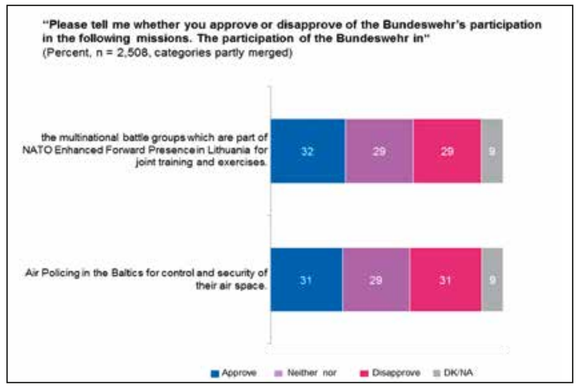


Fig. 3: Attitudes in Germany towards Bundeswehr deployments in Central and Eastern Europe

4

Geoscientific Research

Geofactors are of key significance for all military capabilities and operations. The diverse and challenging responsibilities of the Bundeswehr mean that there is continuing growth in demand for valid information on the spatiotemporal variability of geospatial factors. This applies both to international crisis management operations and to national and collective defence, which is now being more greatly accentuated and includes deterrence measures being undertaken by NATO and the EU on the periphery of the Alliance, or also to humanitarian emergency and disaster relief.

The Bundeswehr Geoinformation Centre (BGIC) is the central institution of the Bundeswehr with geoscientific expertise. It always provides up-to-date science-based information for all geospatial activities of the Federal Ministry of Defence and the Bundeswehr and addresses both short-term and medium-to-long-term tasks and issues. The geoscientific research activities are concentrated within the Applied Geosciences Directorate.

Acting as an interface between science and practice, the Applied Geosciences Directorate does the scientific groundwork for the transfer of knowledge and expertise for military use by the Bundeswehr. The demand for research and development ensues from the necessity to

- identify mission-relevant geofactors and environmental influences at all times and at all locations and to asses their impacts on the conduct of operations,
- provide current and quality-assured geoinformation in preparation for operations and in-theatre deployment, and
- render geoscientific advice and support to field forces and the Federal Ministry of Defence).

Such comprehensive geoinformation support is ensured through the research and development work carried out in 18 geoscientific disciplines.

The following articles highlight three examples of geoscientific research conducted in 2017. They are indicative of the wide range of geoinformation support required by the Bundeswehr in international crisis management as well as for national and collective defence.

Dr. Nadine Klauke
Zentrum für Geoinformationswesen der Bundeswehr
Euskirchen

ZGeoBwChdSt@bundeswehr.org

Forecasting bird concentrations in airspace – improving air safety during Bundeswehr missions abroad

Major bird concentrations pose a risk to air traffic and jeopardise both operational readiness and pilot safety. To optimally minimise this hazard, a forecast model designed and tested for Germany as a means of predicting bird presence in airspace is being developed further and put to use for Bundeswehr theatres of operations.

In military aviation there are frequent collisions with birds which can cause substantial human injury and financial damage. A daily estimate of birds present in airspace is greatly beneficial for planning and conducting operations, as their presence in airspace will vary enormously according to season, even during the bird migration periods in spring and autumn.

The Bundeswehr already has a procedure in place for forecasting the bird strike risk over German territory. It offers 24-h predictions of the potential occurrence of avian movements in airspace and, hence, of the risk of bird strike incidents. The basis for the risk calculation is the meteorological situation and, derived from that, how the birds will likely behave. Besides the seasonal, longer-term changes in the meteorological conditions, it is the daily weather situation that influences the concentration of birds in airspace, especially during the migration periods. The model does not calculate the absolute number of birds in airspace, but estimates the bird strike risk.

Fig. 1: Remnants of an F-16 jet of the Israeli Air Force after collision with a golden eagle (Aquila chrysaetos). From Vogel & Leshem (2009)

Fig. 2: Bird strike risk forecast for the Baltic region (left) and the Middle East (right). The risk level may range from low to very high. The theatre of operations is divided into forecast areas, reflecting not only the meteorological conditions but also known bird migration routes

Bird migration and the periodic occurrence of massive bird concentrations in airspace is a global phenomenon, meaning that the danger of an aviation accident happening due to a collision with a bird is not limited to Germany or central Europe. In implementing the standing operational task of “Baltic Air Policing”, the German Air Force has been repeatedly required at multi-month intervals to ensure NATO airspace safety and security in the Baltic region. The risk of aviation accidents occurring due to collisions with birds is particularly high as the Baltic region, and especially the coastal zones, are part of the eastern Atlantic flyway. The region is a resting spot for several million birds on their way from their Arctic breeding grounds to their winter habitats in central and southern Europe. Circumstances are similar in the Middle East region, where the Bundeswehr has been deployed on Operation “Counter Daesh” since 2016. This is one of the most frequented migration routes worldwide with, in spring and autumn, up to 500 million birds migrating along the Mediterranean coast and the Jordan Valley alone. From 1972 to 1995 the Israeli Air Force registered several thousand bird strikes, resulting in at least 7 total losses and three fatalities (Fig. 1).

To minimise the hazard of bird strike incidents during missions abroad, a forecasting procedure has been developed for these theatres of operations which provides mission personnel with a risk estimate at both the spatial and temporal level (Fig. 2). The forecast model designed for each deployment area is essentially based on the model that has already been in operational use for Germany for years. The evaluation of the magnitude of single meteorological parameters and the occurrence of birds expected as a result have been adapted according to local conditions. The passage of birds in the Middle East, for instance, is dominated by bird species which depend strongly on thermal lift along their route – so-called soaring birds. Accordingly, unlike in the forecasting procedure for Germany, the development of the thermal conditions over the course of the day plays a vital role when it comes to bird strike risk calculation and forecasting for the Middle East during the migration periods.

The modelling of bird strike risk forecasts for Bundeswehr mission areas is an automated process which uses dedicated software developed specially by BGIC (Bundeswehr Geoinformation Centre) (Fig. 3). It permits a relatively speedy continuation and update of the forecast in line with the spatial and temporal demands of the operation.

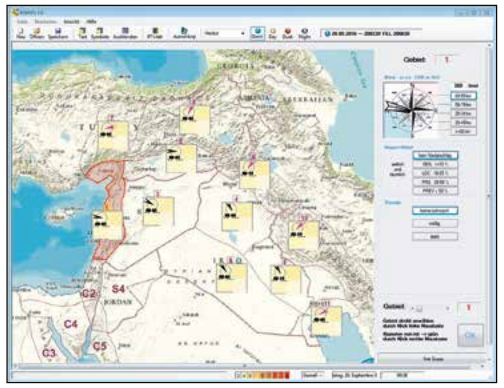


Fig. 3: Software interface for calculating a bird strike risk forecast, exemplified by a forecast for the Middle East

ORR Dr. Christian von Rüsten
Zentrum für Geoinformationswesen der Bundeswehr
Euskirchen

ZGeoBwV8atmosphaerenphysik@bundeswehr.org

Development of a process to calculate infrared transmission

The Bundeswehr Geoinformation Centre provides infrared transmission data for various purposes and applications. It can be subsequently used for orientation in terrain, especially at night and / or during poor visibility.

A utilisable thermal image signature relies on distinct terrain temperature contrasts generated, for instance, by different heat capacities of objects (e. g. armoured vehicle, or meadow). Before such a signal reaches the sensor, it must pass through the atmosphere, which dampens the signal to the extent that, what arrives at the sensor, is only a remainder of what was transmitted. Water vapour and carbon dioxide in particular allow only certain wavelength ranges to pass through, such as the mid-wave (3 – 5 µm) and long-wave (8 – 13 µm) windows.

IR transmissivity is influenced not only by air humidity but also by precipitation, dust and aerosol particles. In comparison with the visible spectral band, humidity and rain have a stronger dampening effect on transmission in the infrared range, while dust exhibits a much weaker dampening influence. This offers the advantage in a desert that when using IR, for example, it is possible to identify a helicopter through the dust cloud it raises (Figs. 1 and 2). Whereas the helicopter is almost invisible to the naked eye, it stands out relatively distinctly in the infrared image.

Fig. 1: Visual image: helicopter hidden in its dust cloud
(Source: Attack Helicopter Regiment 36, Fritzlar)

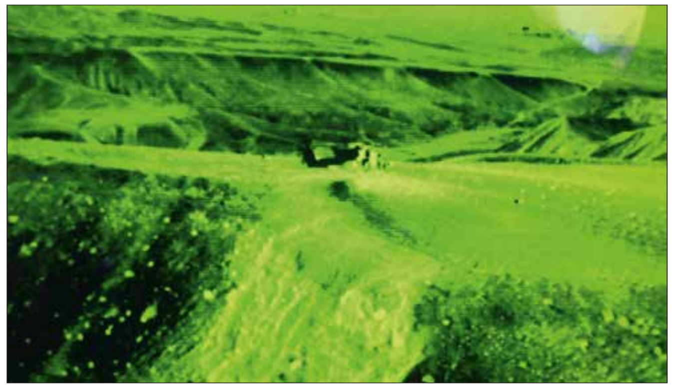


Fig. 2: Infrared image of the same scene: helicopter well-recognisable
(Source: Attack Helicopter Regiment 36, Fritzlar)

In central Europe, however, humidity exerts a greater influence, causing aerosol particles to swell up, for instance, and thus lead to clearly reduced transmission. This reduction is somewhat more substantial in the long-wave than the mid-wave range, meaning that the use of infrared equipment during precipitation and / or fog yields hardly any improvement.

The passage of the radiation from the ground through the atmosphere to the sensor can be calculated, for example, using the Modtran radiative transfer model by inputting the required geometrical path, wavelength range and relevant meteorological parameters. Precipitation and dust also need to be included in the calculations.

These calculations can be automated using a weather forecast model such as ICON or ECMWF. Calculation at a grid point involves very lengthy computing time, however, with it therefore being recommendable, where large areas in global operations are concerned, to run the computation on parallel processors. Multiple grid points can then be processed in one time step.

R&D efforts are currently in progress with the aim of achieving optimum parameter settings and programming-specific optimisations, to be able to provide global transmission forecasts for the use of infrared devices at the operational level. This involves the integration and testing of a new version of the Modtran radiative transfer model.

Shown as an example in Fig. 3 are current IR transmission calculations. Value ranges of the longwave IR transmission are represented as identically coloured isosurfaces against the map background. Meteorological stations are also included for better orientation. The precipitation intensity (mm / hr) still has to be multiplied by the transmission at present as a factor. If the precipitation intensity is high, then the residual transmission will be very low. The value range may vary, depending on the theatre of operations, sensor and flight hardware. Important empirical knowledge still has to be gathered, therefore, through use around the world.

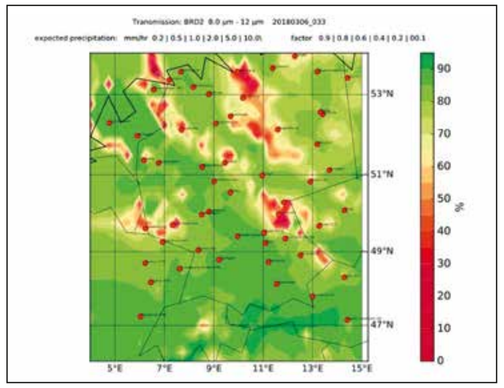


Fig. 3: IR transmission forecast dated 06. 03. 2018
(Source: BGIC V (8))

ORR'in Dipl.-Geoökol. Petra Zieger
Zentrum für Geoinformationswesen der Bundeswehr
Euskirchen

ZGeoBwEingang@bundeswehr.org

Trafficability and soil moisture

"CCMod2 Overview" has been developed as a prototype tool for the production of trafficability maps. Based on formulas used for the NATO Reference Mobility Model (NRMM), the newly designed tool helps to compute overview maps for the three scenarios of "dry", "medium" and "wet" for entire mission countries.

Cross-country movement is a key factor in the planning of armed forces operations (Fig. 1). CCMod2 is a tactical tool capable of making three-day trafficability forecasts and is characterised by its link to the numerical weather forecast issued by the German Meteorological Service (DWD) and to a hydrological model, HYDRUS1D. This tool can be used for an area measuring around 100,000 km² and is based on the trafficability formulas of the NATO Reference Mobility Model (NRMM). It is currently undergoing a validation process.

In the past, various users have frequently called for CCMod2 trafficability maps for entire mission countries as a way of supplementing the tactical CCMod2. The Bundeswehr Geoinformation Centre (BGIC) already makes manually prepared cross-country mobility maps available to mission forces as part of its region-based advisory services. The underlying goal is to automate map production by using the CCMod2 algorithms and to make the maps available through the GIS portal of the BGIC on the Bundeswehr intranet.

Fig. 1: Cross-country deployment of tracked vehicles (Source: BGIC)

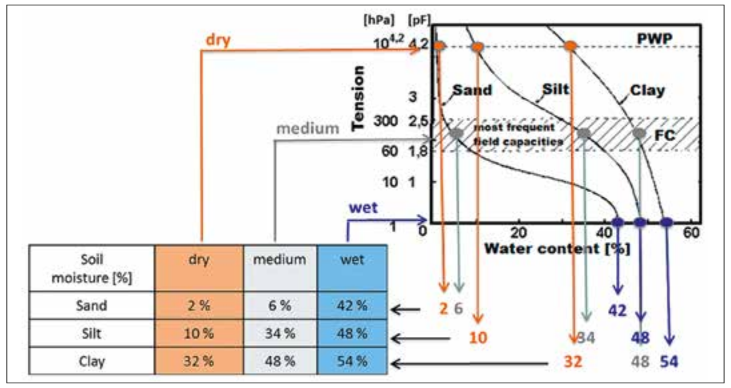


Fig. 2: Derivation of soil moisture maps from soil properties (water retention curve) (Source: BGIC)

The CCMod2 overview maps additionally offer the possibility to identify potential no-go areas in advance, for which it is then sensible to employ the tactical CCMod2 to incorporate an actual 3-day weather forecast.

Regional trafficability will change considerably over the course of a year on account of the prevailing climate as well as the weather. The CCMod2 Overview tool has therefore been designed to compute three scenarios – "dry", "medium" and "wet" – based on the water retention curve of the soil (Fig. 2).

The information base in use at present is the Harmonised World Soil Database (HWSD), as this raster data is globally available and contains information on soil type, bulk density, stone content, and organic matter. Silty and clayey soils, when wet, offer much worse trafficability than sandy soils. By contrast, sandy soils, when extremely dry, also present challenging conditions for trafficability. A high proportion of organic matter (swamps, in extreme cases) hampers trafficability, whereas a high bulk density and stones improve it. These different soil physics relevant for cross-country movement are consistently taken into account in the CCMod2 algorithm for regions throughout the world.

The correlation between soil moisture and soil moisture tension in percent by volume (referred to as soil water characteristics or water tension curve) allows consideration of the different properties of the soils during hydration and dehydration (Fig. 2). In an automated process based on this approach it is possible to compute potential soil moisture and trafficability maps for "dry", "medium" and "wet" scenarios for entire mission countries in no more than a few minutes (Fig. 3).

In addition to vegetation / land use and slope of the terrain, there is the possibility to take vehicle-specific properties (climbing capability, overturn angle, weight, vehicle cone index (VCI)) into account in the trafficability maps by choosing a vehicle from a list (Fig. 4).

The next step will involve supplementing the maps with climate data that gives a reference point for every sub-area of a theatre of operations (e.g. for degree cells) regarding how probable a particular scenario will be in the month concerned.

Similar to the tactical CCMod2, the CCMod2 Overview tool draws on the formulas of the current NATO Reference Mobility Model (NRMM). In the long term, however, it is likely that NATO will realign its trafficability approach (Next-Generation NRMM), such that the activities of the relevant NATO working group are being followed with interest.

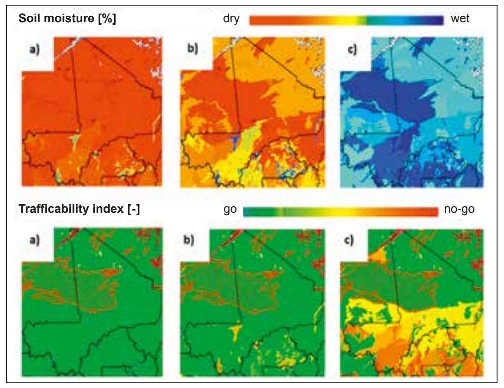


Fig. 3: Soil moisture and trafficability for 3 moisture scenarios in Mali: a) dry, b) medium, c) wet (Source: BGIC)

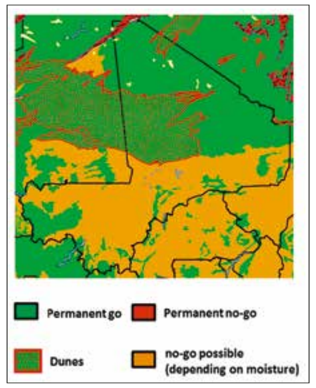
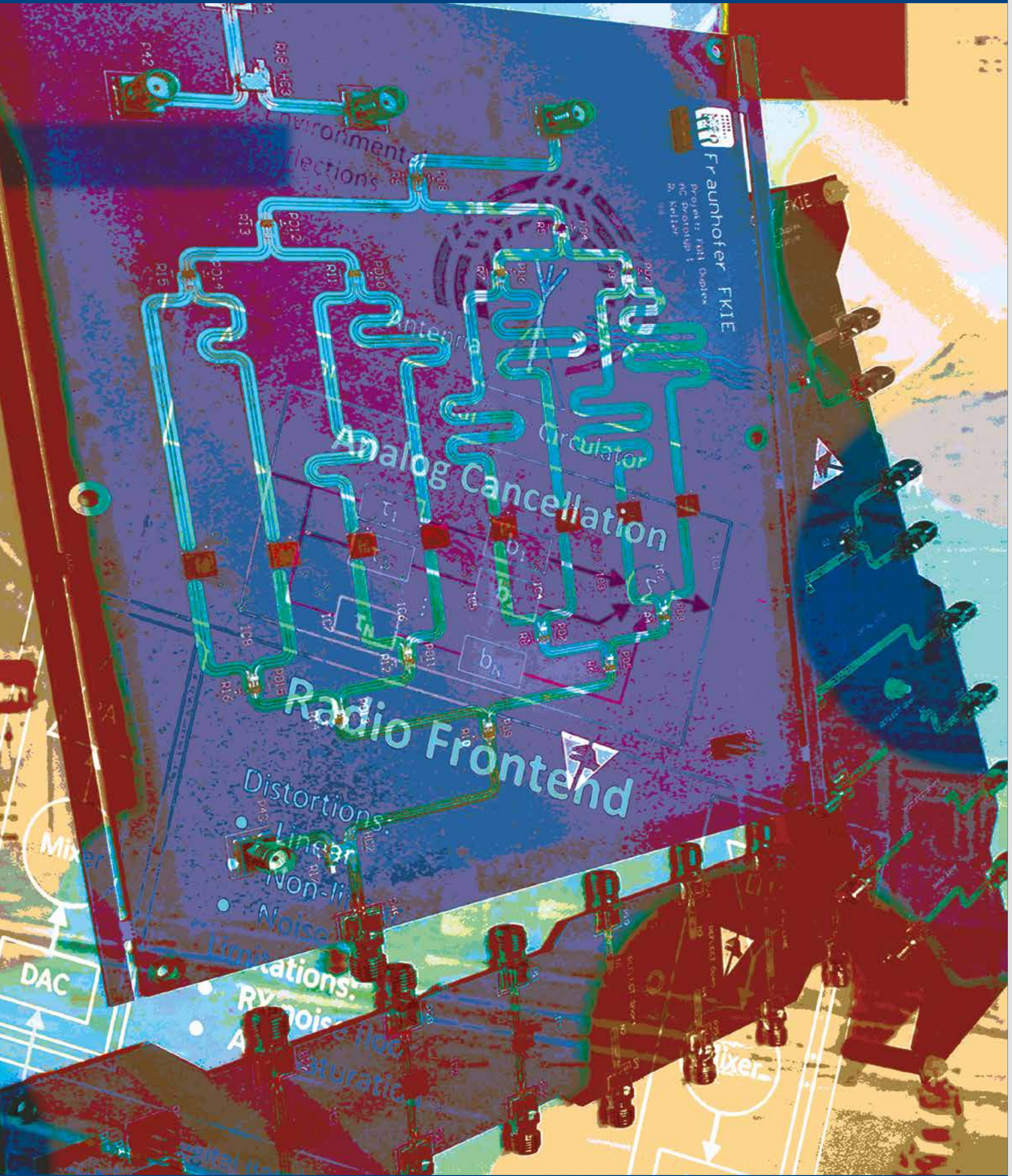


Fig. 4: Trafficability for a tracked vehicle in Mali (Source: BGIC)



5

Cyber and Information Technology Research

Military research in the fields of cyber and information technology takes place as a trade-off between civilian disruptive innovations and military constraints. Cyber and information technologies must be able to function quickly and reliably, even under extreme environmental, operational and combat conditions.

Both the spectrum of operational demands and the requirements regarding interoperability with national and international partners and supranational organisations are challenges for which optimum solutions are continuously sought. For this reason, innovations appearing on the market need to be made available for the information and communication network of the Bundeswehr as quickly as possible.

The fields of research relating to cyber and information technologies touch on individual topics of classical cyber security as well as communication within heterogeneous networks and associated applications. They also address cross-system issues such as digitisation of the battlefield.

Two examples in the following articles provide a closer look at defence research in cyber and information technologies.

TORR Dr.-Ing. Volker Krebs
Bundesamt für Ausrüstung, Informationstechnik und Nutzung
der Bundeswehr (BAAINBw)
Koblenz

BAAINBwPosteingang@bundeswehr.org

Highly autonomous systems and transparent battlefields

Disruptive technological advances are changing lives, and will also have massive implications for future warfare. As always, it is a matter of information superiority, but this time not only for humans. (Fully) automated battlefields are becoming technically feasible.

“Boots on the ground” – that is the military credo for taking and holding territory sustainably. Are there any smarter solutions? The modern-day battlefield is already becoming more and more lethal for troop concentrations on account of real-time intelligence and accurate weaponry. In open terrain as in arduous urban operations, there is a “golden hour” – explicitly because of a lack of information.

In the same way as humans are already inferior to the artificial intelligence of machines for a wide range of tasks, it is also possible to replace military personnel with machines. The requirement that they should remain “in the loop” where the use of weapons is concerned is due to ethical reasons. Technically, it is not absolutely necessary, and could even be a disadvantage from an operational viewpoint because of the inherent time loss.

All the necessary technical conditions are already in place. Powerful mobile radio devices – decoupled from the civilian network – create a tactile ‘internet of things’, allowing real-time applications in milliseconds.

Fig. 1: Situational awareness through smartphones

Fig. 2: Command and control for unmanned systems

On the sensor side it is possible to identify, merge and process many types of militarily relevant signatures (acoustic detection of shooting sounds, broadband frequency evaluation for the identification of already known radio signals, thermal image evaluation for the detection of people and vehicles) on a friend / foe basis.

Together with known three-dimensional terrain models this creates a transparent battlefield, which can be displayed as a mixed reality, even on ordinary smartphones. New, enhanced operational possibilities, such as displaying three-dimensional fields of fire, can thus be generated.

For mobile applications, these sensors can be adapted to unmanned flying or moving platforms (swarm or, better, multi-robotic deployment: at first centrally, later also decentrally controlled). These are, themselves, provided with so much ‘worldly’ knowledge and equipped with their own additional sensors that they are able to act intelligently, even in the event of GPS signal disruption, for example.

Will there still be voice/radio communication between soldiers at tactical level? Yes, because it is best for humans when under stress and avoids excessive burdens. However, there will be data communication established in parallel to control the unmanned systems (swarm control) and to evaluate the large amount of different sensor data (fusion engine).

The necessary human-machine interaction will be controlled intuitively thanks to AI and to evaluable operational work-up “on the system” (mission command). The future role of military personnel will be not so much the control of individual systems but, instead, high-level command, technical support and, in particular, the manual verification and processing of – automatically generated – tactical situation pictures for higher command and control systems and real-time fire support.

What scenarios are now imaginable? Support for high-intensity combat is currently unrealistic due (still) to the lack of robustness of such systems, to single, system-critical points of failure (centralised network and swarm control), and to the lack of a redundant number of individual unmanned systems.

More realistic applications will initially include camp protection, surveillance of borders, transport routes and overextended battlefields and mine barriers, as well as assistance at checkpoints / in patrol activity and urban operations. A glance at their smartphones will, in future, give soldiers more situational awareness than looking at the terrain.

Fig. 3: Virtual reality battlefield

Fig. 4: Sensors and unmanned systems

TROI Rhega Wenske
Bundesamt für Ausrüstung, Informationstechnik und Nutzung
der Bundeswehr (BAAINBw)
Koblenz

BAAINBwPosteingang@bundeswehr.org

Rapid prototyping for software defined radio technologies

Software defined radio (SDR) technology is set to take on special importance as the radio equipment of the Bundeswehr is modernised. In order to keep pace with the fast innovation cycle, there have been various research initiatives using a rapid SDR prototyping platform to create the conditions needed to implement new technologies and evaluate them operationally and technically.

The variety of tactical radio equipment standards both in the Bundeswehr and implemented by its NATO partners is to be replaced in future by so-called software defined radios (SDR). SDRs are characterised by their modularity of device functionalities and also by their portability and instancing of waveforms. Thanks to the inherent flexibility of SDR capabilities, it is possible to operate several frequency bands, various modes and diverse roles simultaneously.

The interface between a waveform application (WFA) and the hardware platform is defined in the so-called software communications architecture (SCA). At the start of this year, as part of an R&T study entitled “Contributions to the Assessment of Current and Future SCA Versions for SDR (AZuSCA)”, the next consistent step in SDR research was taken by gathering detailed knowledge of SCA 4.1 nationally for the first time. It is conceivable that this will also be of great importance for the Bundeswehr in future procurement and development projects. For example, at the Bundeswehr Technical Centre for Information Technology and Electronics (WTD 81) there is the so-called Bundeswehr SDR Certification Body (SZSBw), which assesses

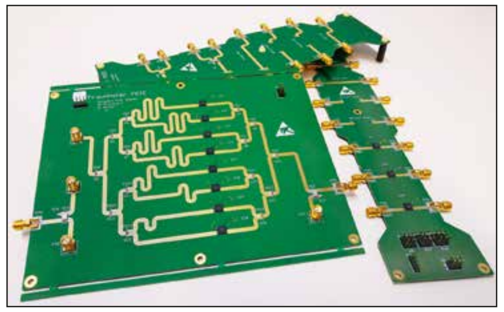


Fig. 1: Analog circuit components for self-interference suppression

Fig. 2: Laboratory setup for the FLIP waveform

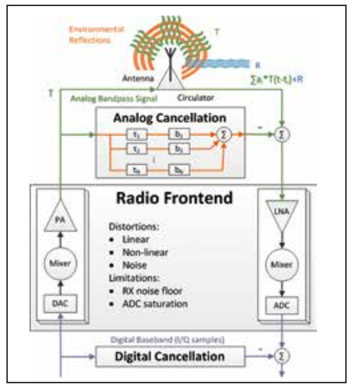


Fig. 3: Block diagram for full-duplex-capable transmission systems

and certifies the operating environments both of SDRs and WFAs with regard to their SCA conformity.

In a research project entitled Flexible IP Waveforms (FLIP), Fraunhofer FKIE and Fraunhofer IIS are investigating the possibility of rapid prototyping with flexible, IP-capable waveforms (FLIP-WF). This involves not only identifying new algorithms, protocols and technologies, but also being able to extensively test and evaluate them on real hardware. FLIP-WF will form a prototype of a flexible IP waveform that serves as a technology demonstrator and is fit for the future thanks to a modular, scalable and reconfigurable design with cross-layer interfaces. The results obtained so far in rapid prototyping with flexible, IP-capable waveforms were presented within the scope of NATO’s Coalition Warrior Interoperability eXploration, eXperimentation, eXamination, eXercise (CWIX) 2017.

To complement the research topics already mentioned, there has also been increased investment as of this year to develop SDR hardware components further. Transceiver modules are relatively expensive for research purposes and only partially suitable for laboratory use. However, various recent research activities have led to the development of an SDR rapid prototyping platform together with analogue transceiver modules that can also emulate the baseband functionality of an SDR for reference purposes. In another R&T study, functionalities of the transceiver module have been expanded further, based on the hardware requirements expected for future WFAs. In particular, the possibility of using a multi-antenna system (MIMO) has been implemented with a view to designing tactical radios as well as waveforms to be much more robust, less detectable and more frequency-efficient.

To date, it had also been considered technically impossible to realise radio frontends that can transmit and receive simultaneously on the same frequency channel. This is due especially to so-called self-interference, i.e. to a disruptive feedover of the transmission signal onto the reception path. The core objective of this study is to implement (and evaluate) the analog and digital components necessary to suppress self-interference for a single-antenna in-band full-duplex transceiver.

It can be stated in summary that all of the mentioned research activities are proving to be valuable contributions in the modernisation of tactical communications and future viability of the Bundeswehr in the cyber and information space.

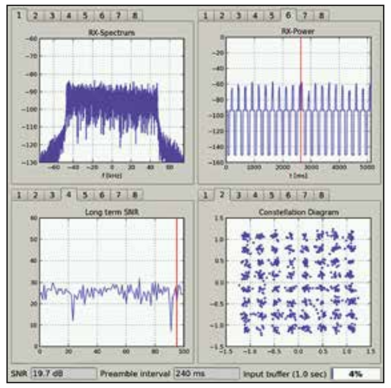


Fig. 4: Signal evaluation of a FLIP WF transmission

Fig. 5: Fast-prototyping SDR transceiver module (RF frontend)

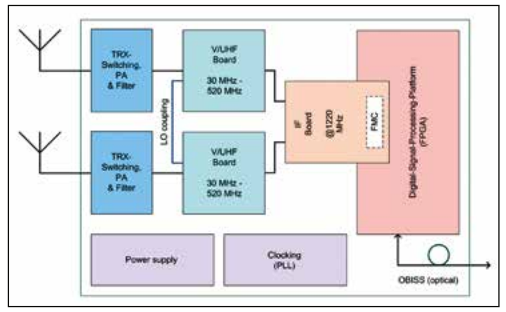
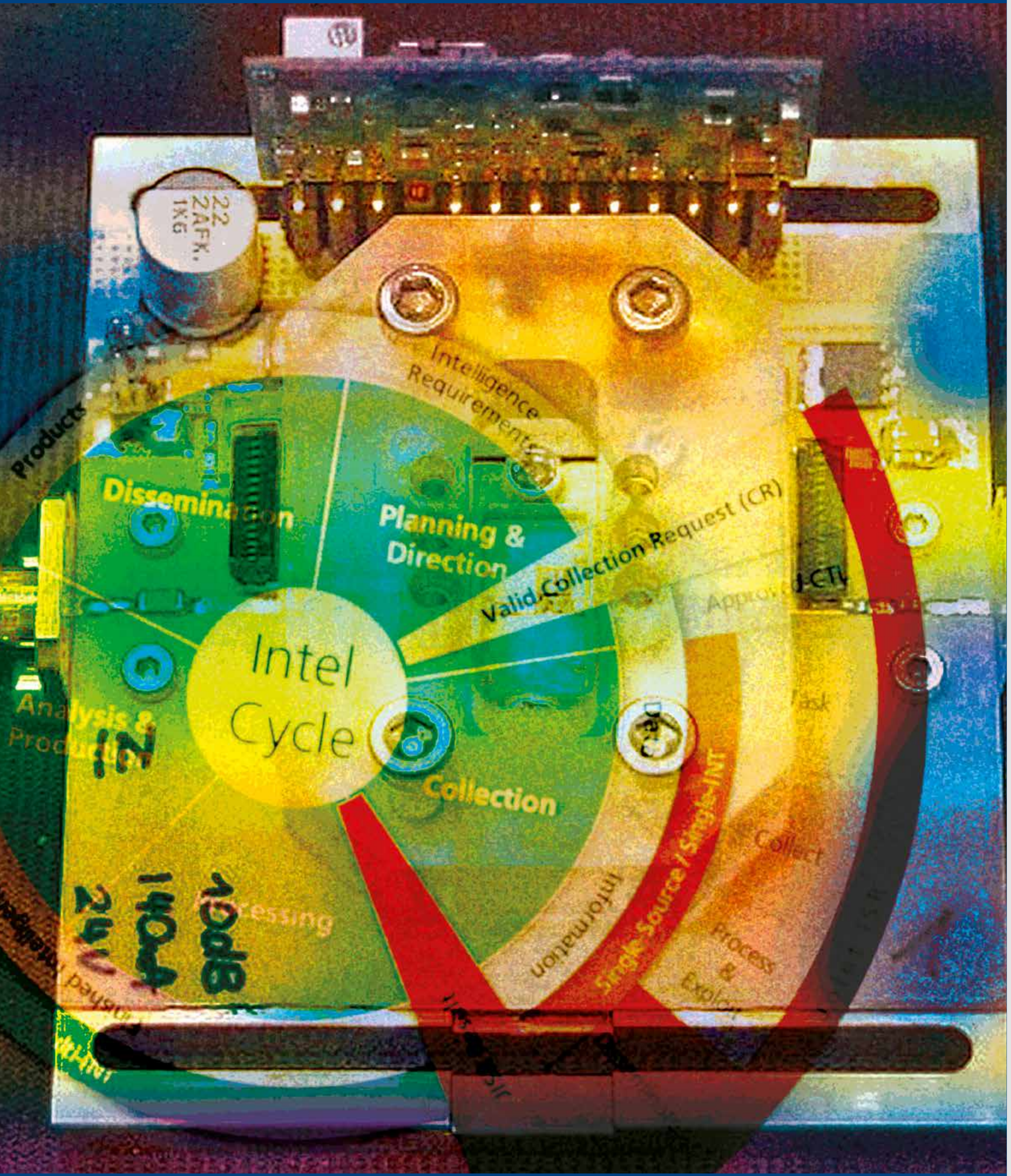


Fig. 6: Block diagram of the MIMO implementation


Intelligence
Requirements
Products
Planning &
Direction
Valid Collection Request (CR)
Intel
Cycle
Collection
Information

6

Appendix

Bundesministerium der Verteidigung

Bundesministerium
der Verteidigung
Postfach 13 28
53003 Bonn
Internet: www.bmvg.de

Abteilung Ausrüstung - A II 5
phone: +49 (0) 228 / 99 24 - 1 41 66
fax: +49 (0) 228 / 99 24 - 35 94
email: BMVgAII5@bmvg.bund.de

Abteilung Ausrüstung - A II 6
phone: +49 (0) 228 / 99 24 - 1 41 80
fax: +49 (0) 228 / 99 24 - 4 41 89
email: BMVgAII6@bmvg.bund.de

Abteilung Cyber / Informationstechnik
- CIT I 2
phone: +49 (0) 228 / 99 24 - 2 61 22
fax: +49 (0) 228 / 99 24 - 3 35 61 21
email: BMVgCITI2@bmvg.bund.de

Abteilung Führung Streitkräfte - FüSK III 3
phone: +49 (0) 30 / 2004 - 2 48 38
fax: +49 (0) 30 / 2004 - 18 03 68 13
email: BMVgFueSKIII3@bmvg.bund.de

Abteilung Führung Streitkräfte – FüSK III 5
phone: +49 (0) 30 / 20 04 - 2 48 54
fax: +49 (0) 30 / 20 04 - 8 97 00
email: BMVgFueSKIII5@bmvg.bund.de

Abteilung Personal - P I 5
phone: +49 (0) 30 / 18 24 - 2 31 57
fax: +49 (0) 30 / 18 24 - 8 95 40
email: BMVgPI5@bmvg.bund.de

Abteilung Personal - P III 5
phone: +49 (0) 228 / 99 24 - 1 33 51
fax: +49 (0) 228 / 99 24 - 4 35 30
email: BMVgPIII5@bmvg.bund.de

Bundesamt für Ausrüstung, Informations-
technik und Nutzung der Bundeswehr
(BAAINBw)
Ferdinand-Sauerbruch-Straße 1
56073 Koblenz
phone: +49 (0) 261 / 400 - 0
fax: +49 (0) 261 / 400 - 3866
email:
BAAINBwPosteingang@bundeswehr.org
Internet: www.baainbw.de

HELMUT SCHMIDT UNIVERSITÄT

Helmut-Schmidt-Universität /
Universität der Bundeswehr Hamburg
Postfach 70 08 22
22008 Hamburg
phone: +49 (0) 40 / 65 41 - 1
fax: +49 (0) 40 / 65 41 - 28 69
email: forschung@hsu-hh.de
Internet: www.hsu-hh.de

Universität München

Universität der Bundeswehr München
Werner-Heisenberg-Weg 39
85579 Neubiberg
phone: +49 (0) 89 / 60 04 - 0
fax: +49 (0) 89 / 60 04 - 35 60
email: info@unibw.de
Internet: www.unibw.de

Wehrtechnische Dienststelle für landgebundene
Fahrzeugsysteme, Pionier- und Truppentechnik
(WTD 41)
Kolonnenweg
54296 Trier - Grüneberg
phone: +49 (0) 651 / 91 29 - 0
fax: +49 (0) 651 / 91 29 - 26 00
email: WTD41posteingang@bundeswehr.org
Internet: www.baainbw.de/wtd41

Wehrtechnische Dienststelle
für Schutz- und Sondertechnik
(WTD 52)
Oberjettenberg
83458 Schneizlreuth
phone: +49 (0) 86 51 / 76 82 - 10 01
fax: +49 (0) 86 51 / 16 00
email: WTD52posteingang@bundeswehr.org
Internet: www.baainbw.de/wtd52

Wehrtechnische Dienststelle
für Luftfahrzeuge – Musterprüfwesen
für Luftfahrtgerät der Bundeswehr
(WTD 61)
Flugplatz
85077 Manching
phone: +49 (0) 84 59 / 80 - 1
fax: +49 (0) 84 59 / 80 - 20 22
email: WTD61posteingang@bundeswehr.org
Internet: www.baainbw.de/wtd61

Wehrtechnische Dienststelle
für Schiffe und Marinewaffen,
Maritime Technologie und Forschung
(WTD 71)
Berliner Straße 115
24340 Eckernförde
phone: +49 (0) 43 51 / 467 - 0
fax: +49 (0) 43 51 / 467 - 120
email WTD71posteingang@bundeswehr.org
Internet: www.baainbw.de/wtd71

Wehrtechnische Dienststelle
für Informationstechnologie und Elektronik
(WTD 81)
Bergstraße 18
91171 Greding
phone: +49 (0) 84 63 / 652 - 0
fax: +49 (0) 84 63 / 652 - 607
email: WTD81posteingang@bundeswehr.org
Internet: www.baainbw.de/wtd81

Wehrtechnische Dienststelle
für Waffen und Munition
(WTD 91)
Am Schießplatz
49716 Meppen
phone: +49 (0) 59 31 / 43 - 0
fax: +49 (0) 59 31 / 43 - 20 91
email:
WTD91posteingang@bundeswehr.org
Internet: www.baainbw.de/wtd91

Wehrwissenschaftliches Institut
für Schutztechnologien – ABC-Schutz
(WIS)
Humboldtstraße 100
29633 Munster
phone: +49 (0) 51 92 / 136 - 201
fax: +49 (0) 51 92 / 136 - 355
email: WISPosteingang@bundeswehr.org
Internet: www.baainbw.de/wis

Wehrwissenschaftliches Institut
für Werk- und Betriebsstoffe
(WIWeB)
Institutsweg 1
85435 Erding
phone: +49 (0) 81 22 / 95 90 - 0
fax: +49 (0) 81 22 / 95 90 - 39 02
email: WIWeB@bundeswehr.org
Internet: www.baainbw.de/wiweb

Zentrum für Geoinformationswesen
der Bundeswehr
Frauenberger Straße 250
53879 Euskirchen
phone: +49 (0) 22 51 / 953 - 0
fax: +49 (0) 22 51 / 953 - 50 55
email:
ZGeoBwEingang@bundeswehr.org

Zentrum für Militärgeschichte und Sozialwissen-
schaften der Bundeswehr
Zeppelinstraße 127/128
14471 Potsdam
phone: +49 (0) 331 / 97 14 - 501
fax: +49 (0) 331 / 97 14 - 507
email: ZMSBWEingang@bundeswehr.org
Internet: www.zmsbw.de

Institut für Mikrobiologie der Bundeswehr
Neuherbergstraße 11
80937 München
phone: +49 (0) 89 / 99 26 92 - 39 82
fax: +49 (0) 89 / 99 26 92 - 39 83
email:
InstitutfuerMikrobiologie@bundeswehr.org

Institut für Pharmakologie und Toxikologie
der Bundeswehr
Neuherbergstraße 11
80937 München
phone: +49 (0) 89 / 99 26 92 - 29 26
fax: +49 (0) 89 / 99 26 92 - 23 33
email:
InstitutfuerPharmakologieundToxikologie
@bundeswehr.org

Institut für Radiobiologie der Bundeswehr
in Verbindung mit der Universität Ulm
Neuherbergstraße 11
80937 München
phone: +49 (0) 89 / 99 26 92 - 22 51
fax: +49 (0) 89 / 99 26 92 - 22 55
email:
InstitutfuerRadiobiologie@bundeswehr.org

Zentrum für Luft- und Raumfahrtmedizin
der Luftwaffe
Flughafenstraße 1
51147 Köln
phone: +49 (0) 22 03 / 9 08 - 16 10
fax: +49 (0) 22 03 / 9 08 - 16 14
email:
zentrlurmedlwpresseoea@bundeswehr.org

Schifffahrtmedizinisches Institut
der Marine
Kopperpahler Allee 120
24119 Kronshagen
phone: +49 (0) 431 / 54 09 - 17 00
fax: +49 (0) 431 / 54 09 - 17 78
email: SchiffMedInstM@bundeswehr.org
Internet: www.marine.de

Institut für Präventivmedizin
der Bundeswehr, Abteilung A
Aktienstraße 87
56626 Andernach
Dienstort:
Andernacher Straße 100
56070 Koblenz
phone: +49 (0) 261 / 896 - 7 74 04
fax: +49 (0) 261 / 896 - 7 74 09
email:
InstPraevMedBwA@bundeswehr.org
Internet:
www.sanitaetsdienst-bundeswehr.de

Deutsch-Französisches
Forschungsinstitut Saint-Louis

Postfach 1260
79547 Weil am Rhein

5, rue du Général Cassagnou
F-68300 Saint-Louis
phone: +33 (0) 389 / 69 50 - 00
fax: +33 (0) 389 / 69 50 - 02

email: isl@isl.eu
Internet: www.isl.eu

Streitkräfteamt
Pascalstraße 10s
53123 Bonn
phone: +49 (0) 228 / 12 - 43 83
fax: +49 (0) 228 / 12 - 33 41
email: SKALdP@bundeswehr.org
Internet:
www.streitkraefteamt.bundeswehr.de

Bundeswehrkrankenhaus Ulm
Oberer Eselsberg 40
89081 Ulm
phone: +49 (0) 731 / 17 10 - 0
fax: +49 (0) 731 / 17 10 - 23 08
email: BwKrhsUlm@bundeswehr.org
Internet: www.ulm.bwkrankenhaus.de

Psychotraumazentrum der Bundeswehr
Im Bundeswehrkrankenhaus Berlin
Scharnhorststraße 13
10115 Berlin
phone: +49 (0) 30 / 28 41 - 22 89
fax: +49 (0) 30 / 28 41 - 10 43
email: BwKrhsBerlin@bundeswehr.org
Internet: www.berlin.bwkrankenhaus.de

Fraunhofer VVS

Fraunhofer-Verbund
Verteidigungs- und
Sicherheitsforschung VVS
Fraunhoferstraße 1
76131 Karlsruhe
phone: +49 (0) 721 / 60 91 - 210
fax: +49 (0) 721 / 60 91 - 413
email: info@iosb.fraunhofer.de
Internet: www.vvs.fraunhofer.de

Fraunhofer EMI

Fraunhofer-Institut für
Kurzzeitdynamik,
Ernst-Mach-Institut EMI
Eckerstraße 4
79104 Freiburg
phone: +49 (0) 761 / 27 14 - 101
fax: +49 (0) 761 / 27 14 - 316
email: info@emi.fraunhofer.de
Internet: www.emi.fraunhofer.de

Fraunhofer FHR

Fraunhofer-Institut für
Hochfrequenzphysik und
Radartechnik FHR
Fraunhoferstraße 20
53343 Wachtberg
phone: +49 (0) 228 / 94 35 - 227
fax: +49 (0) 228 / 94 35 - 627
email: info@fhr.fraunhofer.de
Internet: www.fhr.fraunhofer.de

Fraunhofer FKIE

Fraunhofer-Institut für
Kommunikation, Informations-
verarbeitung und Ergonomie
FKIE
Fraunhoferstraße 20
53343 Wachtberg
phone: +49 (0) 228 / 94 35 - 103
fax: +49 (0) 228 / 94 35 - 685
email: info@fkie.fraunhofer.de
Internet: www.fkie.fraunhofer.de

Fraunhofer IAF

Fraunhofer-Institut für
Angewandte Festkörperphysik
IAF
Tullastraße 72
79108 Freiburg
phone: +49 (0) 761 / 51 59 - 458
fax: +49 (0) 761 / 51 59 - 714 58
email: info@iaf.fraunhofer.de
Internet: www.iaf.fraunhofer.de

Fraunhofer ICT

Fraunhofer-Institut für
Chemische Technologie ICT
Joseph-von-Fraunhofer-Straße 7
76327 Pfinztal
phone: +49 (0) 721 / 46 40 - 123
fax: +49 (0) 721 / 46 40 - 442
email: info@ict.fraunhofer.de
Internet: www.ict.fraunhofer.de

Fraunhofer IIS

Fraunhofer-Institut für
Integrierte Schaltungen IIS
Am Wolfsmantel 33
91058 Erlangen
phone: +49 (0) 91 31 / 776 - 0
fax: +49 (0) 91 31 / 776 - 20 19
email: info@iis.fraunhofer.de
Internet: www.iis.fraunhofer.de

Fraunhofer INT

Fraunhofer-Institut für
Naturwissenschaftlich-
Technische Trendanalysen INT
Postfach 14 91
53864 Euskirchen
phone: +49 (0) 22 51 / 18 - 0
fax: +49 (0) 22 51 / 18 - 277
email: info@int.fraunhofer.de
Internet: www.int.fraunhofer.de

Fraunhofer IOSB

Fraunhofer-Institut für
Optronik, Systemtechnik und
Bildauswertung IOSB

Standort Karlsruhe
Fraunhoferstraße 1
76131 Karlsruhe
phone: +49 (0) 721 / 60 91 - 210
fax: +49 (0) 721 / 60 91 - 413

Standort Ettlingen
Gutleuthausstraße 1
76275 Ettlingen
phone: +49 (0) 7243 / 992 - 131
fax: +49 (0) 7243 / 992 - 299

email: info@iosb.fraunhofer.de
Internet: www.iosb.fraunhofer.de

Deutsches Zentrum für Luft- und Raumfahrt
Programmkoordination Sicherheitsforschung (PK-S)
Linder Höhe
51147 Köln
phone: +49 (0) 2203 / 601 - 40 31
fax: +49 (0) 2203 / 673 - 40 33
email: info-pks@dlr.de
Internet: www.dlr.de/sicherheit

Deutsches Zentrum für Luft- und Raumfahrt
Institut für Aerolastik DLR AE
Bunsenstraße 10
37073 Göttingen
phone: +49 (0) 551 / 709 - 23 41
fax: +49 (0) 551 / 709 - 28 62
email: info-pks@dlr.de
Internet: www.dlr.de/ae

Deutsches Zentrum für Luft- und Raumfahrt
Institut für Aerodynamik und Strömungstechnik DLR AS
Braunschweig:
Lilienthalplatz 7
38108 Braunschweig
phone: +49 (0) 531 / 295 - 24 00
fax: +49 (0) 531 / 295 - 23 20
Göttingen:
Bunsenstr. 10
37073 Göttingen
phone: +49 (0) 551 / 709 - 21 77
fax: +49 (0) 551 / 709 - 28 89
email: info-pks@dlr.de
Internet: www.dlr.de/as

Deutsches Zentrum für Luft- und Raumfahrt
Institut für Antriebstechnik DLR AT
Linder Höhe
51147 Köln
phone: +49 (0) 2203 / 601 - 21 44
fax: +49 (0) 2203 / 673 - 10
email: info-pks@dlr.de
Internet: www.dlr.de/at

Deutsches Zentrum für Luft- und Raumfahrt
Institut für Bauweisen und Strukturtechnologie DLR BT
Pfaffenwaldring 38-40
70569 Stuttgart
phone: +49 (0) 711 / 6862 - 81 82
fax: +49 (0) 711 / 6862 - 227
email: info-pks@dlr.de
Internet: www.dlr.de/bt

Deutsches Zentrum für Luft- und Raumfahrt
Institut für Faserverbundleichtbau und Adaptronik DLR FA
Lilienthalplatz 7
38108 Braunschweig
phone: +49 (0) 531 / 295 - 23 01
fax: +49 (0) 531 / 295 - 28 75
email: info-pks@dlr.de
Internet: www.dlr.de/fa

Deutsches Zentrum für Luft- und Raumfahrt
Institut für Flugführung DLR FL
Lilienthalplatz 7
38108 Braunschweig
phone: +49 (0) 531 / 295 - 25 00
fax: +49 (0) 531 / 295 - 25 50
email: info-pks@dlr.de
Internet: www.dlr.de/fl

Deutsches Zentrum für Luft- und Raumfahrt
Institut für Flugsystemtechnik DLR FT
Lilienthalplatz 7
38108 Braunschweig
phone: +49 (0) 531 / 295 - 26 00
fax: +49 (0) 531 / 295 - 28 64
email: info-pks@dlr.de
Internet: www.dlr.de/ft

Deutsches Zentrum für Luft- und Raumfahrt
Institut für Hochfrequenztechnik und Radarsysteme DLR HR
Oberpfaffenhofen
82234 Weßling
phone: +49 (0) 81 53 / 28 23 05
fax: +49 (0) 81 53 / 28 11 35
email: info-pks@dlr.de
Internet: www.dlr.de/hr

Deutsches Zentrum für Luft- und Raumfahrt
Institut für Luft- und Raumfahrtmedizin DLR ME
Linder Höhe
51147 Köln
phone: +49 (0) 22 03 / 601 - 35 24
fax: +49 (0) 22 03 / 69 62 12
email: info-pks@dlr.de
Internet: www.dlr.de/me

Deutsches Zentrum für Luft- und Raumfahrt
Institut für Methodik der Fernerkundung DLR MF
Oberpfaffenhofen
82234 Weßling
phone: +49 (0) 81 53 / 28 26 68
fax: +49 (0) 81 53 / 28 13 37
email: info-pks@dlr.de
Internet: www.dlr.de/imf

Deutsches Zentrum für Luft- und Raumfahrt
Institut für Robotik und Mechatronik DLR RM
Oberpfaffenhofen
Münchner Straße 20
82234 Weßling
phone: +49 (0) 81 53 / 28 39 76
fax: +49 (0) 81 53 / 28 11 34
email: info-pks@dlr.de
Internet: www.dlr.de/rm

Deutsches Zentrum für Luft- und Raumfahrt
Institut für Technische Physik DLR TP
Pfaffenwaldring 38-40
70569 Stuttgart
phone: +49 (0) 711 / 68 62 - 773
fax: +49 (0) 711 / 68 62 - 788
email: info-pks@dlr.de
Internet: www.dlr.de/tp

Deutsches Zentrum für Luft- und Raumfahrt
Institut für Raumfahrtantriebe DLR RA
Langer Grund
74239 Hardthausen
phone: +49 (0) 62 98 / 28 - 203
fax: +49 (0) 62 98 / 28 - 190
email: info-pks@dlr.de
Internet: www.dlr.de/ra

PUBLISHED BY
Bundesministerium der Verteidigung
Unterabteilung A II
Fontainengraben 150
53123 Bonn

DESIGN AND REALISATION
Konzeptbüro Schneider, Erftstadt

CONTENT SUPPORT
Fraunhofer INT, Euskirchen

PRINTED BY
Warlich Druck Meckenheim GmbH, Meckenheim

AS OF
December 2018

PHOTOS COURTESY OF	Page
© Bundeswehr / Kevin Schrief; Stephan Ink; Jane Schmidt	01
© Bundeswehr / Oliver Pieper	08
© Bundeswehr / David Hecker; Nurgün Ekmekcibasi	09
© Bundeswehr / Jane Schmidt	10
© Bundeswehr / Johannes Heyn; Andrea Bienert	11
https://openclipart.org	26
© Bundeswehr / Neumann; Marc Tessensohn	40
© Bundeswehr / Christian Thiel	41
© DLR / Eppler	45
© Airbus	46
© Bundeswehr / Herr Wurtz (Artescienca)	50
© Deutsche Flugsicherungs GmbH, DFS	82
© Open Database License (ODbL)	83
© Max-Planck-Institut für Bildungsforschung, Berlin	101
© Monika Rausch	102
© Konrad, 2011	102
© Bundeswehr / PIZ Marine	106
© Bundeswehr / Sebastian Wilke	107
© Mees / Vollmuth	111
© Vogel & Leshem (2009)	116
© Bundeswehr / Jane Schmidt 2017; Wilke 2013; Christian Thiel 2017	120
© THW / OV Preetz 2005	120
© Fraunhofer FKIE / Dr. Marc Adrat	126
© Fraunhofer IIS / Robert Koch	127

Bundesamt für Ausrüstung, Informationstechnik und Nutzung der Bundeswehr, Koblenz
Bundesministerium der Verteidigung, Bonn
Bundeswehrkrankenhaus Ulm, Ulm
Deutsch-Französisches Forschungsinstitut, Saint-Louis
DLR, Institut für Aerodynamik und Strömungstechnik, Köln
DLR, Institut für Faserverbundleichtbau und Adaptronik, Braunschweig
DLR, Institut für Luft- und Raumfahrtmedizin, Braunschweig
DLR, Institut für Luft- und Raumfahrtmedizin, Hamburg
DLR, Institut für Technische Physik, Stuttgart
Fraunhofer EMI, Freiburg i. Br.
Fraunhofer FKIE, Wachtberg
Fraunhofer FHR, Wachtberg
Fraunhofer IAF, Freiburg i. Br.
Fraunhofer ICT, Pfinztal
Fraunhofer INT, Euskirchen
Fraunhofer IOSB, Karlsruhe, Ettlingen
Helmut-Schmidt-Universität / Universität der Bundeswehr Hamburg
Hochschule Trier
Institut für Mikrobiologie der Bundeswehr, München
Institut für Pharmakologie und Toxikologie der Bundeswehr, München
Institut für Radiobiologie der Bundeswehr, München
Psychotraumazentrum der Bundeswehr, Berlin
Schifffahrtmedizinisches Institut der Marine, Kronshagen
Streitkräfteamt, Bonn
Universität der Bundeswehr München
Universität Koblenz-Landau, Koblenz
WIS, Munster
WIWeB, Erding
WTD 41, Trier
WTD 52, Oberjettenberg
WTD 61, Manching
WTD 71, Kiel
WTD 81, Greding
WTD 91, Meppen
Zentrum für Geoinformationswesen der Bundeswehr, Euskirchen / Offenbach
Zentrum für Luft- und Raumfahrtmedizin der Luftwaffe, Fürstenfeldbruck
Zentrum für Militärgeschichte und Sozialwissenschaften der Bundeswehr, Potsdam