Federal Ministry
of Defence

Military Scientific Research
Annual Report 2015

Defence Research for the German Armed Forces

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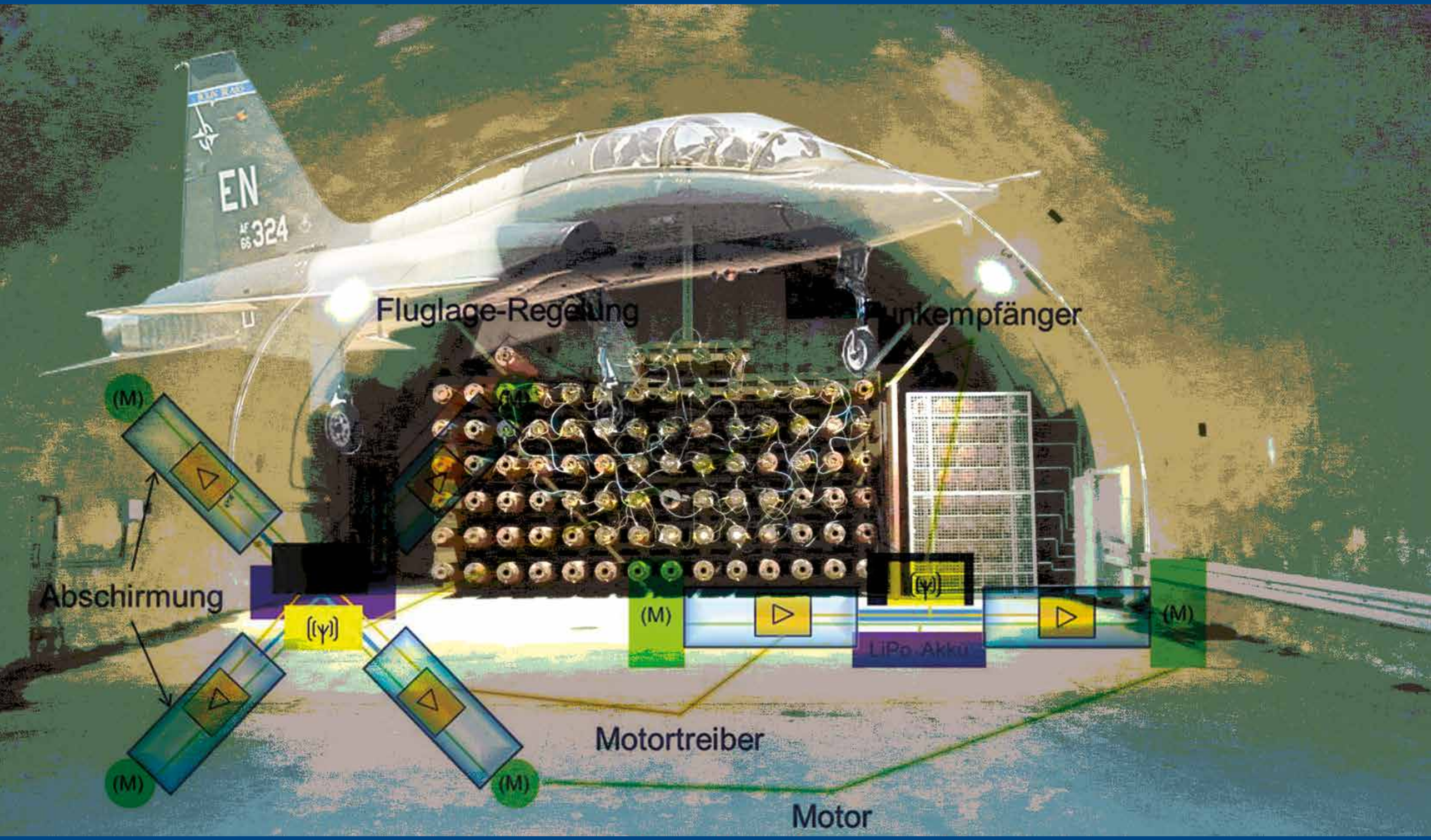
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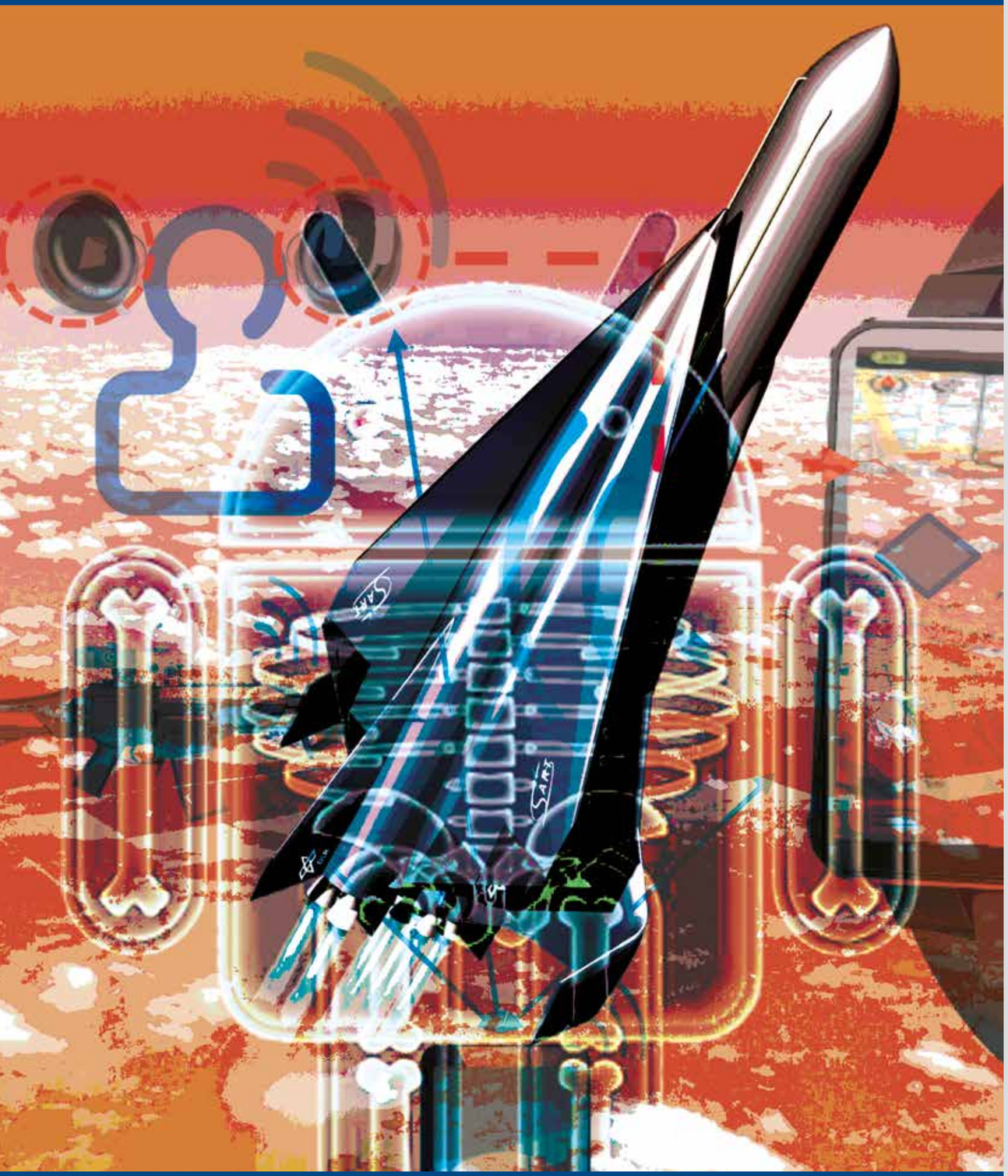

Unterabteilungsleiter AIN II Ressortforschung
Bundesministerium der Verteidigung

Military Scientific Research

10th Annual Report

The German armed forces (Bundeswehr) are an integral part of Germany‘s foreign and security policy. They serve to provide security and protection for its citizens, to preserve the territorial integrity and sovereignty of Germany and its allies, and to help meet international responsibilities. Besides ensuring the capability for territorial and collective defence and for humanitarian assistance, they are required particularly to contribute to the prevention and management of international crises and conflicts. The Bundeswehr must consequently have a broad and flexible spectrum of military capabilities at its disposal. The variety of operational environments means having to plan and provide forces and assets that are flexible, robust, modular, as well as capable of responding to escalating situations. The broad spectrum of capabilities expected of the Bundeswehr calls for defence research as a whole especially to maintain an all-round ability to carry out analyses and assessments across all fields of research relevant to military science and to identify and pursue new defence developments and trends in research projects at an early stage in preparation for ministerial decisions. In this important role, research creates the requisite early basis to meet the military capability needs of the Bundeswehr and, in particular, to close existing capability gaps over the medium and long term. Defence research also ensures Germany’s capability for international cooperation in the defence domain by suitably strengthening bi- and multilateral research collaboration, especially in the European framework of the European Defence Agency (EDA) and in the transatlantic context of the North Atlantic Treaty Organisation (NATO).

A retrospective look at the last ten years reveals more than 40 scientific articles per year in which almost 700 authors have contributed information on current topics. The German and English language versions and their presentation on the website and Intranet platform of the Federal Ministry of Defence have met, and continue to meet, with positive feedback throughout.

The Military Scientific Research Annual Report 2015 illustrates, through selected examples, the varied and successful activities being undertaken in all areas of defence research, including:

- defence technology research,
- military medical and military psychology research,
- social science research,
- military history research, and
- geoscientific research.

In representation
Ministerialrat Gerhard Coors

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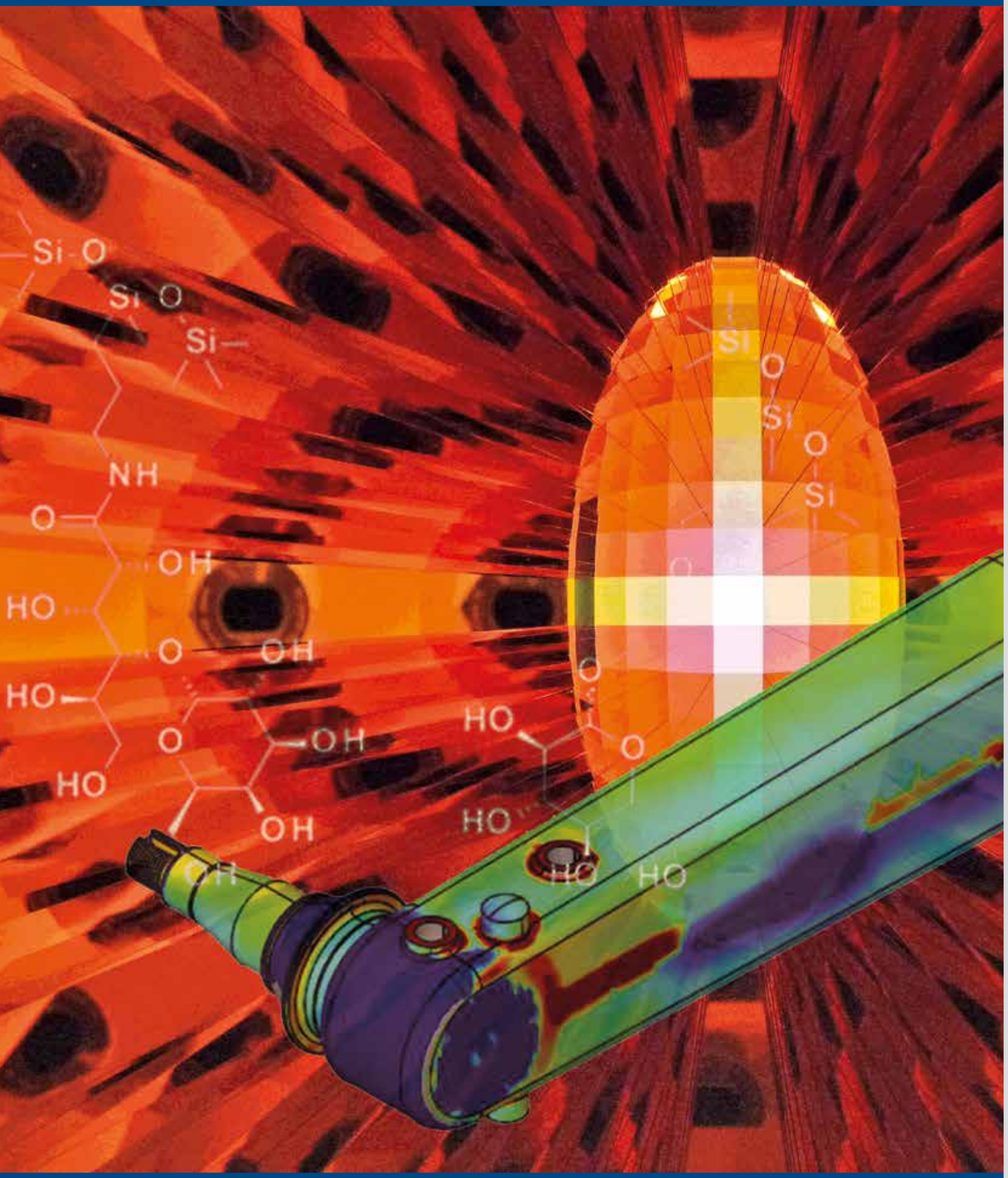

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Defence Technology Research

The broad capability spectrum of the Bundeswehr calls for intensive monitoring and utilisation of all fields of science and engineering relevant to defence applications. Defence research and technology (R&T) activities provide the analysis and assessment capability required for decision-making on equipment; in other words, they serve to analyse technological developments for their future military usefulness or their threat potential; identify new technologies in order to advance existing capabilities of the Bundeswehr; take findings from civilian research into account, and drive relevant emerging technologies forward to the stage of production readiness at the proper time. Defence R&T, then, is the first link in a value chain, at the end of which the Bundeswehr should have the best possible equipment available, on time and in compliance with mission requirements.

In Germany, defence R&T activities are conducted

- at Bundeswehr-own technical centres and research institutes,
- within the scope of shared government funding at the Fraunhofer Society of Advancement of Applied Research (Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V., or FhG), 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
- within the framework of project-funded research through the award of R&T contracts and funding to third parties, i.e. to industry and business, universities and institutes of higher education, and non-university research institutes.

The articles hereinafter present examples of defence R&T activities conducted in 2015 based on these three modes of implementation.

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Soft recovery for the evaluation of complex munitions

The ability to soft-catch projectiles – so-called "soft recovery" – is essential for identifying critical failure modes during the development and qualification of complex modern-day munitions. Currently, a methodology toolbox and a materials database are being developed at the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut EMI that allow faster design of soft-recovery systems for present and future task formulations.

The progressive miniaturisation of electronic and (micro-) mechanical components has made it possible to realise ever more complex functions in modern ammunition. This, however, also leads to new failure modes which have to be found and eliminated. A basic prerequisite in this regard is a system for the soft-catch ("soft recovery") and subsequent evaluation of duds. The challenge is to keep the deceleration forces acting on the projectile so low that no damage occurs which masks the critical failure mode. Traditionally, there is the tendency to resort to natural soft-catch options, such as snowfields or tidal flats, which involves extensive preparation and logistics. Their use, though, is to be reduced for reasons of environmental protection. It is, therefore, necessary to develop more efficient and flexible soft-recovery methods for munitions testing.

Two concepts for soft recovery basically come into consideration (Fig. 1). One possibility is the controlled deceleration of the projectile in a tube of the same calibre that is flange-mounted directly onto the muzzle of the weapon. The disadvantage of this is the calibre-specific design and the ability only to fire single shots. The second method is based on catching the projectile after a defined free-flight distance. This method is generally more flexible, but for specific tasks means weighing up between shooting distance (larger catch area needed) and projectile velocity (greater deceleration forces expected). This can be done reliably only through the use of numerical simulations, measuring and sensor technology and laboratory testing. EMI has, for this reason, started to develop a methodology toolbox for the design of free-flight soft-recovery systems.

The work is being carried out using 30 mm medium-calibre ammunition as an example, which, with its high muzzle velocity and fragile construction, presents a particular challenge for soft recovery. Crucial in terms of the system's design is the material used for soft recovery, whose deceleration properties can vary widely according to the choice of density, hardness and porosity. Measurement of the projectile acceleration inside the material is, therefore, a necessary capability, for which the "g-Rec" data recorder developed at EMI is used. This is integrated into a 30-millimetre measurement projectile that is modelled on the projectile under evaluation (Fig. 2) and records the acceleration acting upon the projectile during the penetration process (sample measurement shown in Fig. 3). With these data it is possible to characterise various materials and examine their suitability for soft recovery.

Figure 4 shows the measured acceleration as a function of the projectile velocity for two configurations of foam glass insulating material. The one is a target constructed of boards which behaves homogeneously and rigidly, and the other is a loosely deposited granulate. The latter has approximately twice the density, from which a greater deceleration effect would be expected. The opposite is the case, however. It is also noteworthy that the deceleration effect of the granulate target is largely constant. Both effects are believed to be due to a displacement process of the grains that occurs at low velocities. The granulate is thus well-suited for soft recovery in cases where projectile velocities are low, i.e.over greater distances.

These initial findings underline how important it is to quantitatively characterise materials experimentally and to generate a materials database in which the deceleration potential is recorded as a function of velocity and projectile shape. Tests are currently being carried out at higher velocities and with other materials. This information, supported by numerical simulations, will enable faster design of suitable soft-recovery systems in future.

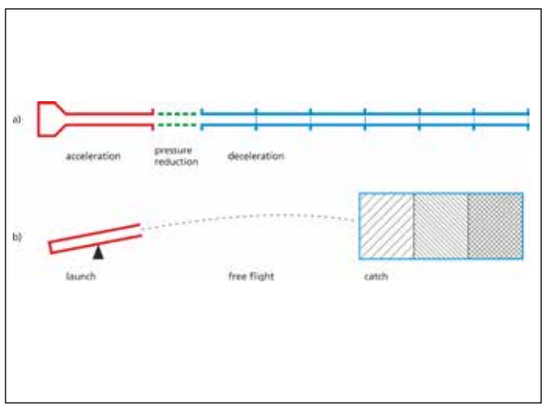

Fig. 1: Schematic of the two most-used soft recovery concepts

Fig. 2: 30 mm measurement projectile (bottom) and data recorder "g-Rec" (top)

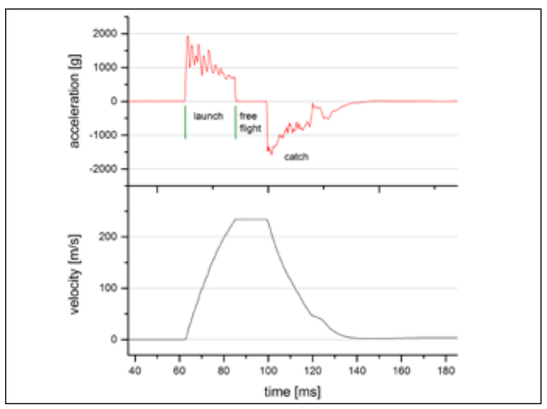

Fig. 3: Sample measurement of the g-Rec shot from a pressurised air gun, and subsequent penetration of a foam glass target

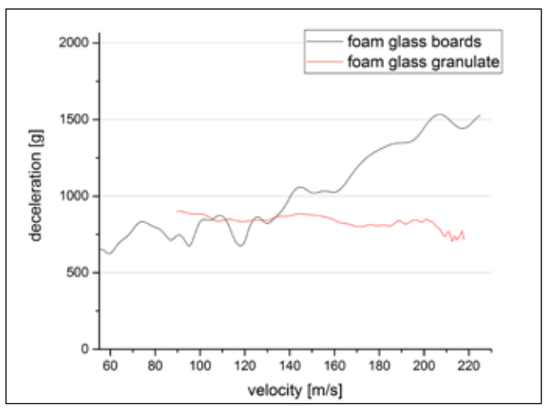

Fig. 4: Deceleration as a function of projectile velocity in two foam glass target configurations

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Sea clutter modelling for multichannel signal processing with maritime radar systems

Maritime radar systems need to be capable of advanced multichannel signal processing in order to detect moving targets. The detection performance of such processing can be calculated only if the multichannel properties of sea clutter are known. Such a model has been developed and validated with the aid of real data at Fraunhofer Institute for High-Frequency Physics and Radar Techniques FHR.

Pirates, smugglers and illegal fishermen pose a threat to general maritime security. They operate mostly in small and agile boats and over large areas, thus requiring suitable means of detection. Such monitoring can take place using airborne platforms. However, because of the geometry that is involved, the target still has to be identified among a strong amount of sea clutter. To make matters more difficult, the described waterborne craft have only a small radar cross-section (RCS), meaning that it is necessary to detect targets with weak signal-to-clutter plus noise ratio (SCNR). This can be accomplished only with the aid of advanced signal processing.

At the Fraunhofer FHR it has been demonstrated that so-called ‘space-time adaptive processing’ (STAP) is needed to detect small boats reliably. STAP exploits the particular relationship between the look direction and the radial velocity of unwanted echoes to estimate an advanced filter for suppressing backscatter. To apply STAP to a given maritime radar system, it is important to know in advance the theoretical detection performance so that the optimum radar parameters can be calculated, for example, and it can be decided if the additional cost of a multichannel system is justified in comparison with a single-channel variant.

To be able to model the detection performance of STAP, it is necessary to know the multichannel properties of unwanted so-called clutter. Even though the multichannel properties of land clutter are known, they cannot be used for maritime radar systems because the echoes received from a land surface differ from those caused by sea scatterers. Sea clutter is generated by a moving surface, with scatterers from breaking waves also having to be taken into consideration.

A model has been developed at Fraunhofer FHR to calculate and simulate the multichannel properties of sea clutter and the associated characteristics that are of importance for STAP. To validate the model, several measurement campaigns were conducted with the PAMIR multifunctional radar system, for which the Transall C-160 carrier platform was flown over the North Sea, as shown in Fig. 1.

To evaluate the detection performance, it is vital to know the STAP filter as, although it eliminates the clutter, it may also attenuate or even suppress the signal from the target. This filter is estimated adaptively from the data set and indicates the power by which a target is attenuated as a function of the directional cosine and radial velocity. Fig. 2 shows the normalised gain of such a filter for real and simulated land data. It can be seen that this filter corresponds to a diagonal line, in other words attenuates the target only for one particular radial velocity for each look direction.

Fig. 3 shows the normalised filter gain for real and simulated sea data. This filter differs clearly from that in Fig. 2 due to its broader and asymmetrical filter notch. The broadening of the filter comes about because of the water’s movement, and the asymmetry is caused by scatterers from breaking waves. With this filter it is more difficult to detect targets with a weak signal, especially where negative radial velocities are concerned. The real filter for the sea data shows that the multichannel land clutter model cannot be used to calculate the detection performance for maritime radar targets because that would lead to incorrect data. The filter gain for the simulated sea data shows that the proposed multichannel sea clutter model reproduces the multichannel properties of real data well and can therefore be used to calculate the detectability of potential maritime targets.

Fig. 1: Experiment over the North Sea

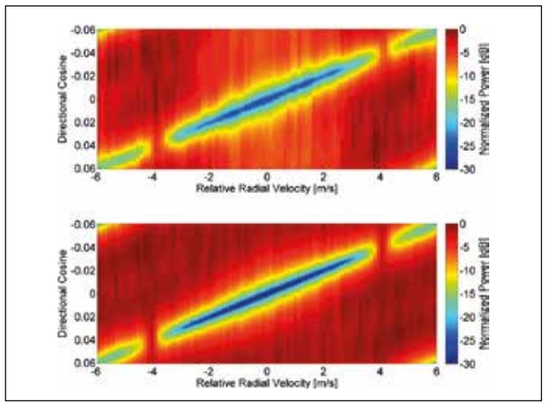

Fig. 2: Normalised STAP filter gain for real (above) and simulated (below) multichannel land data

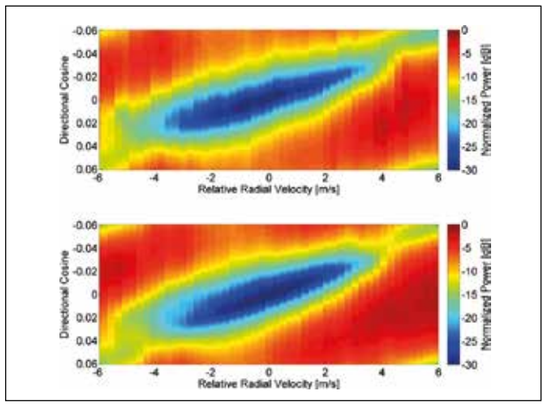

Fig. 3: Normalised STAP filter gain for real (top) and simulated (bottom) multichannel sea data

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A short chirp

Unlike any other sensor, radar offers numerous degrees of freedom, the efficient handling of which greatly depends on the experience and skill of the operator. Cognitive radar control systems can be of assistance in this respect. Machine learning techniques and other methods from the field of computer science allow the partial automation of cognitive abilities and expertise.

Modern times are characterised by complexity and speed, with difficult decisions having to be made in an ever shorter period of time. Situations are becoming less and less straightforward and also tend to change rapidly. The resultant challenges are growing, not only for people and society, but also for the technical systems on which we increasingly rely as the requirements become more complex. Those systems must become more efficient and achieve a higher level of automation so that they can continue to perform their function of supporting us in our daily life or at work.

Modern radar systems are intelligent sensors with a variety of software-defined degrees of freedom. They are increasingly able to carry out a number of things simultaneously and call for a very high level of skill and maximum concentration from their operators. They are, however, not yet capable of self-optimisation based on data derived through measurements.

Cognitive radar control systems can rectify this. They facilitate optimal adaptation of the waveform and of other parameters to the environment. The research field of “cognitive radar” combines methods of computer science, such as machine learning techniques and artificial intelligence methods, with traditional signal processing and electrical engineering approaches. The aim is to create a “smart” sensor system that is capable of adapting the waveform and the operating parameters dynamically to the scenario and mission context. Besides the closed do-loops between the receive (“perceptor”) and transmit (“actuator”) paths, it is necessary to increase the degree of automation based on the human model – but without any elements of fatigue - with a high level of precision and with a continuously high level of performance.

The approach adopted by the Fraunhofer Institute for High-Frequency Physics and Radar Techniques FHR to link these ”cognitive sub-functions” to just such an efficient system is geared to the ”Three-Level Model” of human cognitive performance. This model was published by Jens Rasmussen in 1983 and finds use in cognitive psychology, ergonomics and robotics. It makes a distinction between three behavioural levels which – although vertically structured – are, in principle, all active at the same time. These comprise highly automated control loops, efficient procedural responses, and highly flexible knowledged-based behaviour on a high level of abstraction.

The rapid advances made in electronic components, such as highly dynamic, high-speed sampling A/D converters, arbitrary waveform generators and fast-processing modules (FPGAs, DSPs), have paved the way for the principle of ”software-defined radar”, which is the basic requirement for the desired adaptivity and reconfigurability and is already available to Fraunhofer FHR. Particularly the technical hardware solutions for real-time adaptation of the transmit signal have recently prompted a global increase in research activity in the field of cognitive radar as well as other experimental testing.

The dynamic adaptation of radar parameters to the scenario and mission context realised mainly through software makes it possible to upgrade existing conventional radar systems with “cognitive capabilities” as well as highly flexible radar sensors specially developed with that in mind, for example in the domain of military multi-function radar systems.

The advantages and versatility of adaptive behaviour are also impressively in evidence in nature in the form of echolocation used by bats and dolphins. These, thanks to their highly developed and adapted neuronal circuits, are capable of adapting the pulse repetition rate and length as well as emitted waveform to the distance to their prey (dolphins can emit chirps with a length of just 120 microseconds; bats, on hearing an echo, can distinguish a temporal difference of 10 nanoseconds between both ears). Evolution has thus provided a uniquely efficient and precise combination of sensors and movement trajectory to serve as examples.

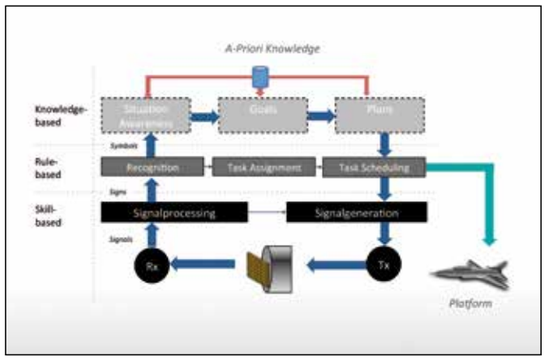

Fig. 1: Cognitive radar architecture at Fraunhofer FHR according to the Rasmussen model. © Fraunhofer FHR

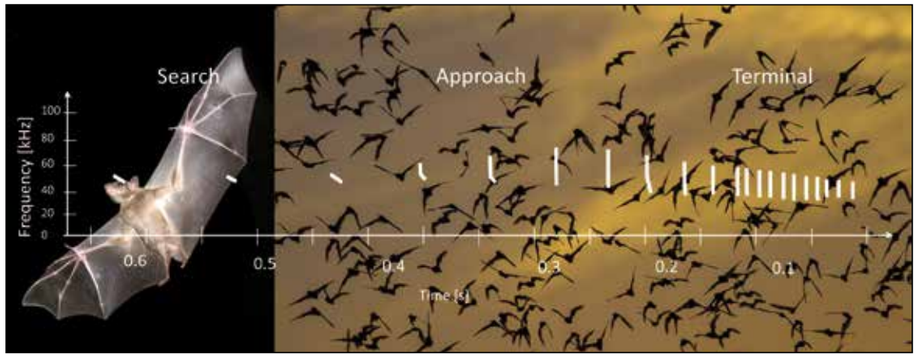

Fig. 2: “Living proof” of cognitive sensors – bats of the genus Tadarius, and waveform sequence for target localisation. © Composition of CC BY 2.5 Wikipedia/Oren Peles; Shutterstock; Haykin, Simon: “Cognitive radar: a way of the future.” Signal Processing Magazine, IEEE 23.1 (2006): 30-40

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CIMIC Information Management Database (CIMD) – Information and process management in Civil-Military Cooperation (CIMIC)

The demands in terms of effective in-theatre Civil-Military Cooperation (CIMIC) during Bundeswehr missions are increasing. Diverse information has to be collected, evaluated and collated to form a Recognised Civil Picture (RCP). This process requires integrated communication between all levels of management. The "CIMIC Information Management Database" ensures a supply of information to meet the needs in hand.

Military actions are reflected in a variety of tasks: identifying information requirements, delegating duties and responsibilities, collecting, collating and evaluating data and, subsequently, making decisions. At the heart of any successful, targeted coordination and cooperation between the forces involved is a common understanding of management processes and suitable implementation of flows of information according to requirements. Undesirable developments in the past have shown that this "dynamic" aspect of management support is more difficult to implement than the "static" aspect, which is confined to the definition of standardised data structures and exchange formats. Having clarity concerning organisational structures, information relationships and clearly defined process steps is absolutely critical, however, for successfully functioning management support. The Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE has, for this reason, been developing database-supported procedures that optimise cooperation between all organisational elements in a directly task-oriented manner.

Methods for clearly setting the procedures to carry out specific tasks had long been lacking in the complex specialist field of Civil-Military Cooperation. In 2014, NATO (ACO) developed the CIMIC Functional Planning Guide (CFPG), which describes the process of CIMIC support for the planning of NATO operations. It comprises six successive phases, from initial situational awareness in a crisis scenario, to strategic and operational analysis, to planning of the actual military mission, to execution and transition (during these phases, CIMIC staff at all levels provide input for one common Theatre Civil Assessment (TCA).

In the autumn of 2014 the Bundeswehr CIMIC Centre conducted the "Joint Cooperation 2014" CIMIC exercise involving extensive multinational participation with the aim of optimising the workflows at the tactical and operational levels. Fraunhofer FKIE supported the headquarters work in this exercise in part with its first version of the "CIMIC Information Management Database" (CIMD). The "Lessons Identified" were described in detail in the after-action report. Identified as "typical" problems were a lack of a common process understanding; imprecise documentation with regard to tasking and reporting formats; format discontinuity, from the gathering of basic information, across all levels of evaluation, to the structure of briefings; and training deficits.

The "Lessons Learned" were taken into account in the autumn of 2015 in the preparations for "Joint Cooperation 2015". The CIMD system was embedded throughout at every level of management. The J9 staff formulated its tasks within the system, which were broken down into subtasks along the chain of command and forwarded as specific operational activities to the CIMIC field teams. The interview and observation results were correlated with the associated activities and reported up the chain of command (CIMIC Support Unit, J9 Division). As required in the CFPG, the CIMD methodology strictly follows PMESII classifications. To allow further delineation, the ASCOPE categories at all levels are added to allow further and more detailed sorting of information (Fig. 3). The CIMD concept thus makes it possible to determine which CIMIC-related factors will impact on a potential engagement, following the sequence "factor – deduction – conclusion". Based on his/her experience, J9 is able to determine if the current situation requires any action (implied/assigned task), if it inherits a critical capability or vulnerability, if the information is incomplete, and if a Request for Information (RFI or TASK) has to be initiated. Evaluation results (Theatre Civil Assessment, TCA) relating to the area of responsibility form the basis for the "Recognised Civil Picture" (RCP), which is incorporated into the Common Operational Picture at the operational level. The result is a Full CIMIC Estimate (FCE), which serves to support the commander's decision on how CIMIC intends to engage in theatre (CIMIC Concept).

Access to the complex and constantly growing database has been optimised individually for each user so as to create a situational awareness according to requirements. Optimised filters have been included to take account of multidimensionality, permitting precise spatial, time-based and subject-related classification of the information items.

The CIMD concept successfully supports the key CIMIC functions of

- Information gathering
  i.e. information acquisition and validation,
- Information processing
  i.e. correlation of data in a knowledge database,
- Information storage
  i.e. clear data structuring and classification,
- Information provision
  i.e. timely, problem-oriented visualisation.

Fig 1: Civil-Military Cooperation: The key to targeted coordination and cooperation between the forces involved is a common understanding of management processes and suitable implementation of flows of information according to requirements

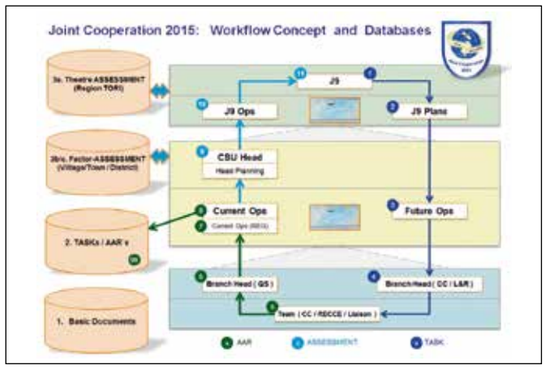

Fig 2: CIMD Process Management: "Knowledge Management" takes account of interdependencies between information technology and organisational strategy, while "Workflow Management" represents the time- and subject-related flow of information based on defined user roles

Fig 3: Context filter: the CIMD concept (screenshot) incorporates powerful, ergonomically optimised selection filters, e.g. PMESII domains (PMESII = political, military, economic, social, information, infrastructure) and ASCOPE categories (ASCOPE = area, structure, capabilities, organisations, persons, events).

Fig 4: Relevance filter: to support multidimensional views of the various data sources, CIMD includes time-based, spatial, and subject-related classification of information items. Role-oriented views enable (semi-)automatic generation of situation pictures (here: combined display of after-action report and associated assessment as a screenshot).

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Cognitive and Cooperative Assistance System (COGAS): an innovative concept to support air target identification onboard ships of the German Navy

Modern combat direction system (CDS) onboard the ships of the German Navy are highly automated, which can lead to problems such as over-reliance on automation or "out-of-the-loop" situations. Cognitive assistance systems offer an innovative technological approach to supporting operators' awareness of current threat situations, depending on their cognitive workload, and thus to optimally carrying out their tasks.

The growing complexity of military human-machine systems requires increasing support from cognitive processes handled by automation systems. Inadequate consideration of human factors in system design, such as intended users' decision-making cycles and mental models, can often lead to ergonomic problems in human-machine interaction which, in complex threat situations, can have fatal consequences. In unpredictable operational scenarios, the highly automated CDS and weapons control systems of the German Navy (Fig. 1) are not always able to act reliably, meaning that qualified and competent human operators will continue to be the primary decision-makers in future. In this regard, effective and efficient integration of the "human factor" into command and control processes and systems is becoming increasingly important when designing and developing complex military human-machine systems.

Against this backdrop, the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE has developed a cognitive and cooperative assistance system (COGAS) for CDS onboard German Navy ships that follows a user-centred approach and supports the decision-making processes of the human operator to ensure effective air target identification. COGAS surveys and analyses the airspace and, on that basis, derives identification indicators with the aid of a priori knowledge. To improve the situational awareness of the human operator, COGAS presents the identification indicators according to the situation at the time and, based on those indicators, recommends possible actions for the operator to take in response within the "Rules of Engagement".

COGAS also supports the operator in carrying out recommended actions. Depending on the operator's behaviour in a threat situation and the complexity of the airspace, COGAS adapts its assistance function to the operator's needs using a flexible automation approach (Fig. 2 and Fig. 3). COGAS determines an individual time interval for every air target so as to initiate necessary measures and a threat priority ranking. It compares these with the operator's inputs and, from that, determines the level of required support as well as the information to be displayed for decision-making purposes. Based on that, the attention of the operator is drawn to the air target that poses the greatest threat, and the decision-relevant indicators are displayed ergonomically on the human-machine interface (HMI) according to the threat situation. In the event of operator overload, COGAS takes over certain aspects of task execution once key points in the designated time interval are exceeded (Fig. 3).

An empirical evaluation involving 17 experienced operators from the German Navy was conducted with the aid of COGAS to compare air target identification flexibility using manual and rigidly automated systems. To provide a realistic test environment, the HMI and the functionality of COGAS were integrated into a prototype of the new CDS of the German F125 frigate class (Fig. 4). During the evaluation the performance, situational awareness and task load of the operators were assessed in three different identification scenarios (Fig. 5). Significant improvements became evident in regard to the number of correct decisions and the processing time required for identification tasks. Furthermore, situational awareness on the part of the operators using COGAS increased considerably in comparison with the two alternative systems. The subjective assessment revealed a slight reduction in stress levels when carrying out air target identification, in addition to improved performance and greater situational awareness.

Fig. 1: Modern CCI and weapons control systems of the German Navy (Source: Bundeswehr Media Centre.)

Fig. 3: Transitions between the different levels of automation. Based on those levels of automation, COGAS configures the HMI and the CDS

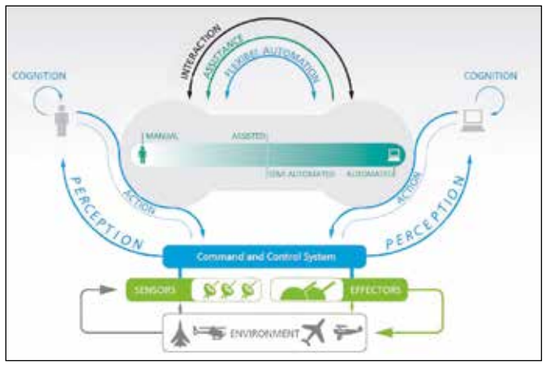

Fig. 2: Support concept of COGAS utilising flexible automation

Fig. 4: CDS prototype for the F125: enhanced with COGAS functionality (screenshot)

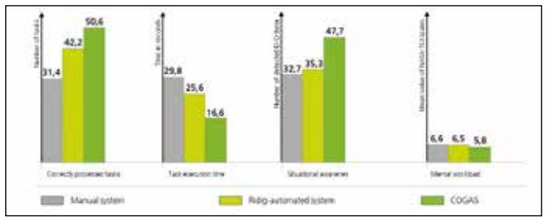

Fig. 5: Overview of the evaluation results

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Satellite-based missile early warning

Detecting ballistic missiles during launch, or after cloud-break, using satellite-based electro-optical sensors is a promising means for pre-instructing fire control radars precisely and thus of being able to initiate countermeasure in good time. A design concept for such a satellite-based early warning sensor has been developed at Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB in cooperation with the German defence industry.

A list recently published by NATO identifies 30 countries that will be capable of producing their own ballistic missiles within the next few decades. The majority of these countries are located in the Middle East – and most European states lie within range of being attacked. The deployment of a satellite-based early warning system would increase the advance warning of any attack with ballistic missiles considerably, thereby gaining valuable time to initiate countermeasures. To ensure timely identification of the danger, electro-optical (EO) systems are employed which are able to detect the infrared (IR) signal emitted by the missile plume.

Reliable early warning and target tracking are possible only if the ratio between ballistic missile signal and observed background (terrestrial and atmospheric) exceeds a certain threshold. To achieve a sufficiently high value, it is very important to select a suitable detection spectral band as this can minimise the subsequent computing time needed to apply target tracking algorithms. Test sequences need to be made as realistic as possible in order to evaluate the performance of those algorithms. Since both background and missile signature are influenced by environmental conditions, it is necessary to

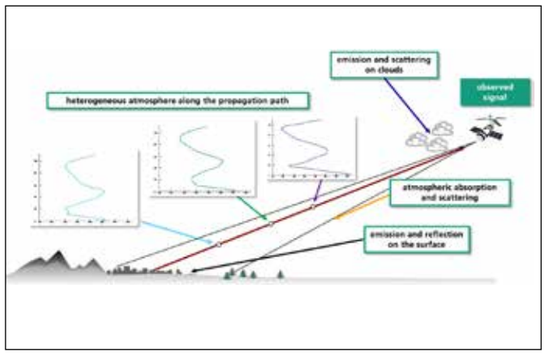

Fig. 1: Overview of the atmospheric effects on the background signal observed from a satellite-based sensor. According to Labarre, Luc et al. (2011): “MATISSE 2.0: new functionalities and comparison with MODIS satellite images”, SPIE Defense and Security Symposium, Orlando

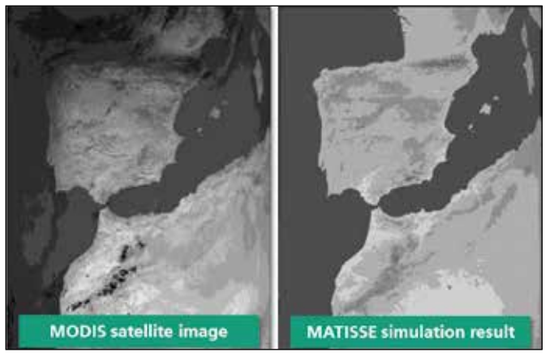

Fig. 2: Comparison of a MODIS (Moderate Resolution Imaging Spectro-radiometer) sensor satellite image with the MATISSE simulation result in thermal infrared

have detailed knowledge of the meteorology and climatology factors involved. Although measurement trials for characterising these influences serve as a reliable basis, they only reflect the conditions at the time of recording. Representing the entire variation of the meteorological and climatological conditions thus requires the use of simulation tools. Radiative transfer models are suitable for evaluating sensor performance and tracking algorithms. To model the field of view as observed from a satellite-based sensor, use is made of MATISSE, a software developed by ONERA (France), which is currently being refined and upgraded by Fraunhofer IOSB in cooperation with ONERA. Before any simulation model is applied, it needs to undergo an extensive validation process. Fraunhofer IOSB, drawing upon its many years of experience in measuring, characterising and modelling atmospheric and meteorological influences, has critically tested and successfully validated MATISSE. During the process, different spectral ranges were considered and the modelling of seasonal, diurnal and climatological influences on the background IR signature analysed. As the simulation tools used for modelling the signature of a ballistic missile are also required to undergo validation, Fraunhofer IOSB has already carried out numerous measurement trials and used the signature measurement data to establish a database which will serve to test and evaluate such simulation models.

Realistic test sequences are being created and subsequently evaluated by means of detection and tracking algorithms in order to test the performance of a particular EO sensor design for its use in space. Modelled in these sequences are not only the entire observation geometry including detector and sensor, but also the atmospheric influence on the detection range of such an EO system. The presence of clouds, different earth surfaces and the prevailing meteorological conditions form part of the overall signature of the observed background. To complete the image sequences, the background image is overlaid with the time- and altitude-dependent signature of a ballistic missile along the coordinates of its trajectory.

It will be possible to develop a suitable sensor concept only after consideration of all the influences that the environmental conditions can have on the performance capability of a satellite-based missile early warning system. Fraunhofer IOSB has teamed up with several German defence enterprises with the aim of developing and building a technology demonstrator for future satellite-based missile early warning systems under the guidance of Bundeswehr Technical Centre (Wehrtechnische Dienststelle) WTD 81.

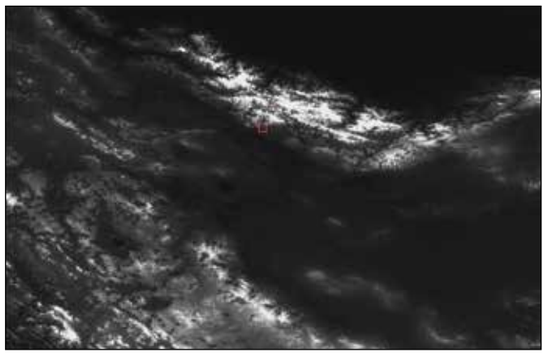

Fig 3: Simulation of the field of view of a satellite-based early warning sensor. The red rectangle indicates that the ballistic missile has been detected successfully in the test sequence

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Resource management in joint ISR

To maximise the benefits offered by today's ISR (Intelligence, Surveillance and Reconnaissance) systems, it is essential to improve the planning of data collection. With this in mind, a two-step method for resource-optimal sensor scheduling has been developed in cooperation with military ISR experts as a basis for a computer-aided assistance system for ISR management personnel.

Decision-makers need improved situational awareness to be able to cope properly with the increasing complexity of modern-day threats. Adequate and timely information form the basis for this. Meeting the demand for this information requires effective and efficient deployment of available ISR systems. The efficiency and effectiveness of using ISR systems can be enhanced through improved operations planning in the field of joint ISR, in particular through adequate support for ISR managers in charge of ISR resource deployment scheduling.

The Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB has developed a method for resource-optimal sensor deployment scheduling as part of a research project designated "Effizienter Einsatz optronischer Ressourcen für die Analyse komplexer Situationen" (Efficient use of optronic resources for the analysis of complex situations), funded by the Bundeswehr Technical Centre for Information Technology and Electronics (WTD 81) .

An analysis of relevant operational processes as well as feedback from ISR experts have revealed the necessity for a computer-aided assistance system as support for ISR managers in

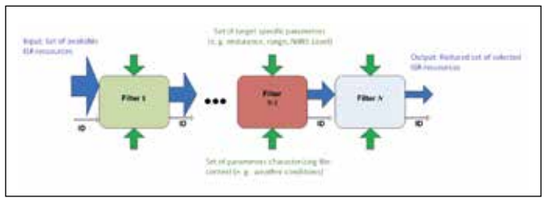

Fig. 1: Schematic of a filter chain. Each filter can be applied individually to the target currently under consideration and correspondingly parameterised

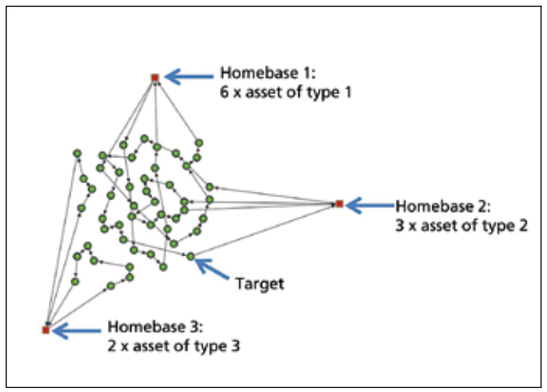

Fig. 2: Schematic illustration of the results (routes) of the automatic scheduling and optimisation process for sensors, sensor platforms and targets in Step 2 of resource-optimal assignment

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matching resources to surveillance and reconnaissance targets. This support has to be designed so that the processes of ISR resource selection, assignment to targets and scheduling are as automated as possible yet still transparent to the ISR manager at all times as the ultimate decision-making authority. Taking into account the inherently high computational complexity because of the underlying combinational problems regarding the selection, assignment and optimised scheduling of ISR resources, a two-step approach to computer-aided sensor platform scheduling has been elaborated.

Step 1 comprises the interactive pre-selection and suitability testing of ISR resources for target reconnaissance. Pre-selection is based on the capabilities offered by those resources, such as endurance, range, stand-off capability, supported IMINT disciplines, and availability of the resources in terms of time, and is realised as a chain of filters (Fig. 1 and Fig. 3) within which the individual filters work independently of one another on the set of available ISR resources. Each filter implements specific selection criteria with regard to the target under consideration. The individual filters can be flexibly concatenated according to mission needs. The output of Step 1 is a list of suitable ISR resources for each target. That list also constitutes a preliminary assignment of resources to the targets under consideration and serves as the input for Step 2.

Step 2 encompasses the automatic assignment of ISR resources to targets and the scheduling of data collection to be performed by the resources (Fig. 2 and Fig. 4). It also takes account of specific constraints such as time windows, priority targets, resource capabilities required with regard to individual targets, etc. It additionally optimises cost factors, such as minimisation of the potential waiting time for all resources on target arrival, minimisation of the overall operating time of all the ISR resources in use, and maximisation of the number of targets under surveillance.

The described two-step approach has been implemented as a laboratory demonstrator and is undergoing evaluation in workshops with the aid of ISR experts.

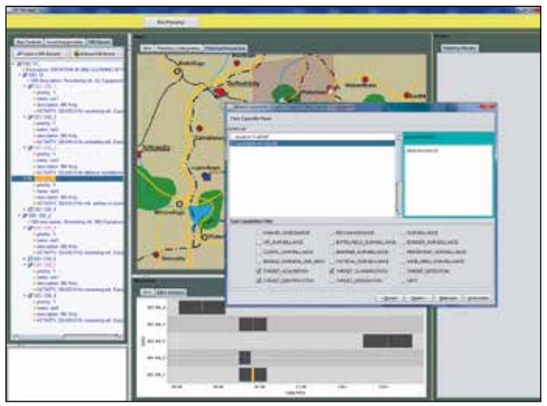

Fig. 3: Screenshot of the laboratory demonstrator for the computer-aided resource-optimal assignment of sensors and their platforms to reconnaissance targets. Shown is Step 1 of the two-step approach

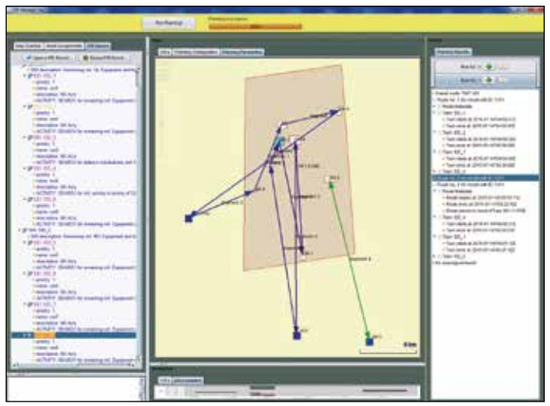

Fig. 4: Screenshot of the laboratory demonstrator for the computer-aided resource-optimal assignment of sensors and sensor platforms to reconnaissance targets. Shown is the outcome of Step 2

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Compact capabilities for high-power microwave generation

The article describes advances in compact microwave power generation for military applications. The recent evolution of gallium nitride semiconductor technology allows the realisation of extremely compact high-frequency amplifiers with high absolute power levels suitable for radar systems and jammers. Such components are meanwhile industrially available in Europe for the armed forces.

The generation of high output power levels at microwave frequencies using compact components is of fundamental importance for the capabilities and the protection of our armed forces on operations abroad. The electromagnetic spectrum of frequencies between 10 MHz and at least 6 GHz constitutes the mainstay of civil and military radio applications, i.e. the range for relevant radar and communication bands. Various military applications such as jamming transmitters to counter RCIED (radio-controlled improvised explosive devices), as well as (secondary) radar applications, require the generation and amplification of several hundreds of watts in output power, in very compact modules, up to at least 6 GHz. The conversion efficiency of the available primary energy into microwaves is a major concern, as any cooling that is required is always a nuisance in terms of volume and weight and is a potential source of system failure.

Thanks to recent advances in research it is meanwhile possible to efficiently generate very high power levels using gallium nitride (GaN) transistors. Industrial availability in Europe has been established through cooperation between Bundeswehr Technical Centre WTD 81 and the Fraunhofer Institute for Applied Solid State Physics IAF, supported by Airbus Defense and Space in Ulm, Germany, and the commercial source for GaN components, United Monolithic Semiconductors, also in Ulm.

Secondary radar applications for friend or foe identification systems require high power levels, preferably from a compact single package, because of their necessary range. Fig. 1 shows a so-called GaN power bar, which is able to generate some 150 W - 300 W of power per bar at frequencies between 0.5 GHz and 3 GHz. Compared with silicon-based technologies, this development represents an improvement in power density per unit area by a factor of 6-7. These power bars can be combined as well as scaled in size so that one single power bar can produce more than 300 W of output power at efficiency levels as high as 80 %, as recently demonstrated at Fraunhofer IAF. When connected in parallel (for example, four bars combined in a single package), these power bars achieve levels approaching the kilowatt range. An amplifier and GaN power bar combination capable of this is shown in Fig. 2.

Jamming radio-controlled improvised explosive devices (RCIED) is a key capability for ensuring the safety of armed forces when they are on the move. The constant advances in mobile communication standards call, in the long term, for flexible protective measures for the armed forces that keep pace with the evolution of cell phones. The current 4G (LTE) cell phone standard and, from 2020 onward, the new 5G standard, in addition to the older technologies such as GSM, need to be taken into account in order to counter potential threats reliably.

Fig. 1: Gallium nitride transistor power bar, fabricated at Fraunhofer IAF, as the core element of RF power generation, including bond wires

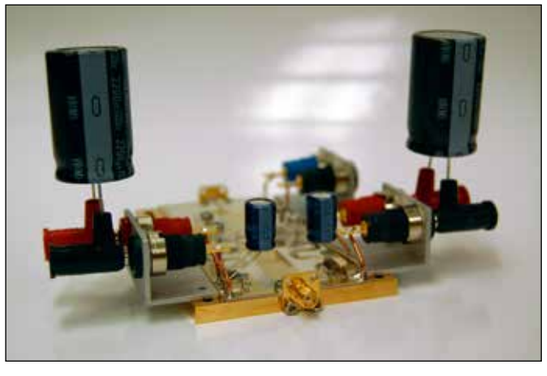

Fig. 2: Compact high-frequency amplifier capable of generating power levels in the kW range for friend/foe identification. The size is dictated mainly by the power supply components such as capacitors and connectors

Fig. 3: Very flexible broadband amplifier demonstrator incorporating gallium nitride transistors for jamming applications and already geared to foreseeable mobile communication developments, for the protection of our armed forces on future missions

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New powerful gun propellants based on thermoplastic elastomers

The deployments undertaken by the Bundeswehr around the globe have led to increased demands on military materials in terms of their performance, reliability and safety. Particular attention, therefore, is being paid at the Fraunhofer Institute for Chemical Technology ICT to the components selected in the development of future propellants in order to take account of the new requirements that munitions will have to meet.

Modern gun propellants have to fulfil a number of different requirements nowadays. Besides long-term availability of the raw materials and their compliance with the REACH regulation, the munitions must be safe and reliable to handle in different climatic zones throughout their service life. In tropical and subtropical regions they have to withstand extreme temperature variations, which lead to accelerated aging of the propellant material in nearly all fielded munitions types and to a reduction of their functional lifespan. The new service scenarios also include a strongly increased threat situation, making low sensitivity of the gun propellants very important in case of external attacks. Conventional single- and multi-base gun propellants have natural limitations in this regard.

All gun propellants currently in use are based on the nitrocellulose binder discovered in 1846, which is synthesised from cellulose by means of a multi-stage process. Naturally occurring raw materials such as cellulose have properties that change, depending on the climatic conditions where they are cultivated. Synthetic binders, in contrast, offer the advantage that they have a constant property spectrum.

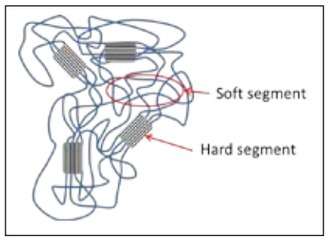

Fig. 1: Schematic view of a thermoplastic elastomer consisting of hard and soft segments

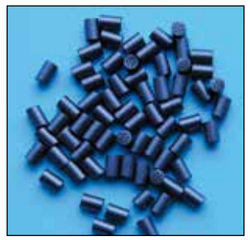

Fig. 2: Gun propellant based on an energetic thermoplastic elastomer in a seven-hole geometry

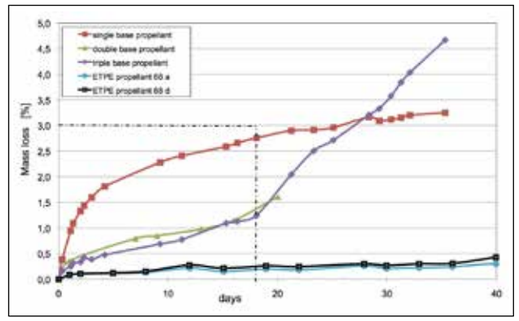

Fig. 3: Mass loss of different gun propellants (single-, double- and triple-base gun propellants, NC-based) and of two ETPE gun propellants, as a function of storage time at 90°C

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A promising approach in the development of new, powerful gun propellants with a low sensitivity is the use of thermoplastic elastomers (TPEs) as binders. These materials consist of a thermoplastic hard phase and an elastomeric soft phase. The combination of hard and soft segments in the matrix gives these polymers special properties. When exposed to external stress, the materials respond with deformation and then return to their original form once that stress is no longer present. This implies insensitive material behaviour in the event of impact stress, for example.

The Fraunhofer ICT has all-round expertise essential for the development of a new generation of plastic-bonded propellants. This includes the synthesis of suitable thermoplastic elastomers with energetic functional groups (ETPEs), combination with different plasticiser systems, formulation with energetic fillers, and the manufacture and subsequent characterisation of the new gun propellants. Software-based analysis and design tools are also being developed with the aim of optimising new gun propellant formulations with respect to performance, erosion and environmental impact. The resultant data will make it possible to compare the performance capability of different propellant formulations in a given gun / ammunition combination on a theoretical basis.

The energy density of the new plastic-bonded gun propellant formulations can be adjusted by changing the content of the energetic components, allowing these materials to be used in a wide range of calibres. The new gun propellants, moreover, display a flame temperature some 600 K lower in comparison with conventional formulations that deliver the same performance, thus permitting expectations of significantly reduced gun barrel erosion. The ignition temperatures are around 200° C and, hence, significantly higher than those of conventional propellants. Besides these advantages the ETPE gun propellants display very good long-term stability, which predestines them for use in tropical climate zones.

The work carried out at Fraunhofer ICT to date has demonstrated the potential of the new generation of gun propellants based on energetic thermoplastic elastomers. Future activities in this field will concentrate on developing ETPE gun propellants ready for practical application.

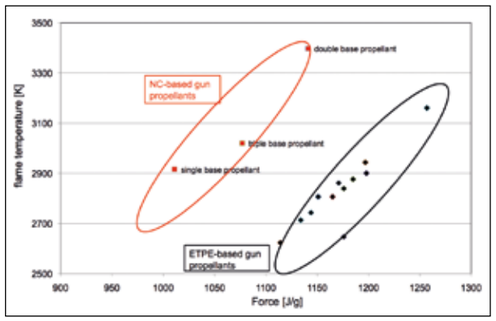

Fig. 4: Flame temperature as a function of force for conventional NC- and ETPE-based gun propellant formulations, calculated using the ICT Thermodynamic Code

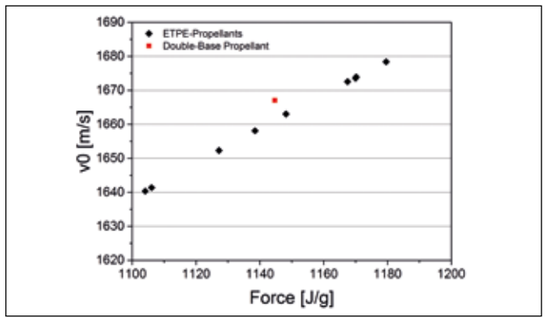

Fig. 5: Muzzle velocity as a function of force for different gun propellant formulations and identical weapon parameters in a thermodynamic simulation with a constant breech pressure; selected was a 120 mm smoothbore tank cannon

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Satellite navigation: new Galileo PRS receiver technology – analysis to address specific capability needs in the German armed forces

A Galileo Public Regulated Service (PRS) prototype receiver designated "PROOF" has been developed, taking as a basis a concept demonstrator hardened against "Navigation Warfare" jammers as well as alternative system concepts featuring cryptographic processing ("APPROVE") remote from the PRS receiver. It is being used to analyse and evaluate the new Galileo PRS service and address capabilities needed within the Bundeswehr (German armed forces).

Galileo PRS is a special, cryptographically protected satellite navigation service intended for governmental/ governmentally authorised as well as military users. The strong cryptography it employs prevents spoofing attacks on the receiver's time and position information. Thanks to its signal design and its dual-band service, Galileo PRS also offers higher robustness and availability than the open Galileo and GPS signals, as well as access control mechanisms. Many safety-critical and complex applications can be thus realised which are not possible using other Galileo services or conventional GPS. Galileo PRS is currently in its deployment phase and will be operationally available within the next 2 to 3 years. Within the framework of R&T studies concerning specific technologies and concepts, it has already been evaluated where capabilities need to be augmented for the Bundeswehr. Serving as the basis for the evaluation is, among others, a developed prototype of a hardened national Galileo PRS receiver (Fig. 1). Different techniques to harden the prototype receiver against jamming and interference (Navigation Warfare, or NAVWAR) have been implemented in order to ensure reliable position and time information in a NAVWAR environment as well as to detect such attacks and be able to evaluate the demands involved. A combination of different algorithmic measures and sensors with PRS are recommended as part of the hardening process. These may, for instance, take the form of mitigation methods in the time and frequency domain, adaptive filters, fusion with inertial sensors, as well as a combination of Galileo and GPS.

Beside NAVWAR hardening techniques, there has been an evaluation of token concepts which outsource specific security functions to an external, interchangeable security module token (SM token, Fig. 2). Such an architectural approach allows not only the realisation of smaller receiver sizes, but also new application scenarios. An authorised user with an SM token can, for example, temporarily upgrade a suitably prepared standard receiver to a PRS receiver. The SM token itself can be personalised to a specific user instead of to a specific receiver hardware (as in a conventional PRS receiver). This allows the short-term activation of SM tokens for a specific user as well as simple, physically secure deposition when not in use. Since security-related functions are realised on the SM token, the actual standard receiver itself requires only elementary physical protection.

Two technology concepts for realising miniaturised and low-cost receivers ("Sample and processing" and "Broadcasting of PRS Replicas") have additionally been analysed, in which regard the complex cryptographic processing and large parts of the PRS signal processing are outsourced to a secure server environment (Fig. 3 and Fig. 4).

Three typical navigation applications – "Infantryman of the Future", "UAVs" and "Military Observers" – have been considered in closer detail and assessed in this context.

With the "Sample and Processing" technique, an inexpensive and miniaturised end user device records solely raw data and forwards them to a secure PRS server environment for the PRS evaluation. The PRS server then decides what is to be done with the PRS position and time information obtained from the raw data, i.e. whether to return that information to the end user device or to use it otherwise, such as for verification management.

Where the "Broadcasting of PRS Replicas" technique is concerned, a central secure PRS server broadcasts snippets of PRS replicas to inexpensive and miniaturised end user devices at configurable intervals. The end user devices use these snippets for a PRS correlation with which they are able to calculate the same secure and non-spoofable PRS time and position information as a conventional PRS receiver. They do not, however, require any dedicated security module.

Fig. 1: A NAVWAR-hardened Galileo PRS navigation receiver prototype, width 125 mm x height 142 mm x depth 225 mm

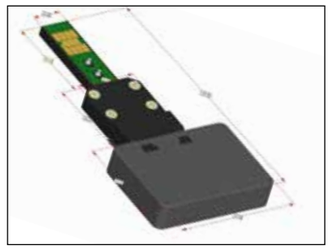

Fig. 2: Design of the SM token containing the PRS security module (the token itself can be removed from the navigation receiver for security reasons, for example); its dimensions are approx. 110 mm in length and 53 mm in width

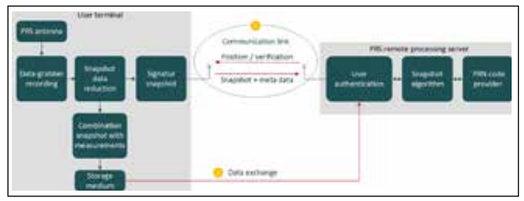

Fig. 3: Concept for a miniaturised, low-cost PRS receiver (user end device) with an external crypto server and bidirectional communication interface: ("Sample and Processing" technique)

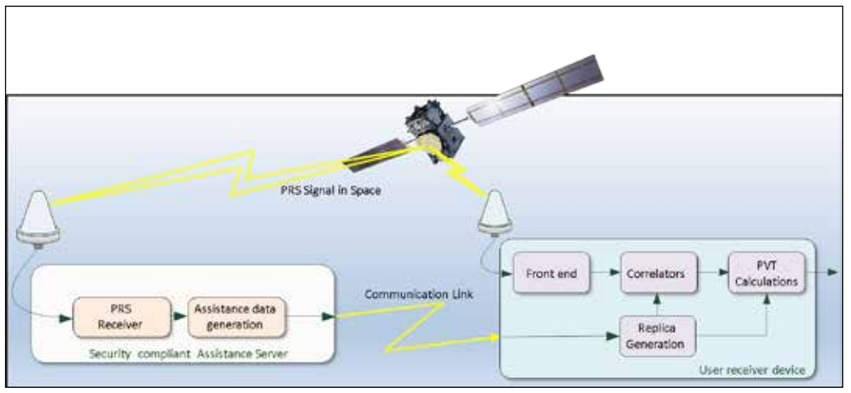

Fig. 4: Concept for a miniaturised, low-cost PRS receiver with an external crypto server and broadcast communication of PRS replicas to one or more PRS navigation receivers ("end user device)

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Standoff detection and online classification of bioorganic materials

In the context of defence and security, detecting and identifying hazardous chemical, biological and explosive materials from a safe distance is an essentiality . With this in mind, the Institute of Technical Physics of the German Aerospace Center (DLR) is developing a standoff detection demonstrator system for the online classification and monitoring of bioorganic substances under real atmospheric conditions.

When it comes to defence and security, detecting bio-organic materials with a high degree of sensitivity as well as rapidly identifying hazards with low false alarm rates are vital, especially to ensure the best possible protection for the public and first responders. There is currently no single existing method suitable for meeting these requirements. Particle samplers collect particles in situ which can then be grown on various culture media for identification afterwards by biochemical methods. This is a time-consuming process in the laboratory. As an alternative, particle collectors are often equipped with substance-specific receptors. In either case, however, there is the problem that the particle collectors have to be positioned initially at an unknown, potentially hazardous location (neither method being very suitable for scanning and monitoring larger areas or moving aerosol clouds). Standoff detection based on laser-induced fluorescence (LIF) is capable of directly detecting and tracking bio-organically contaminated material from a safe distance and of classifying those hazardous substances. The LIF method provides very fast information concerning the type of hazard and the optimum positioning of the particle collectors. If the concentration of the hazardous emission is sufficiently high, even identification of the hazardous substance by means of laser-based standoff detection is possible. Combining both methods - particle sampling and LIF - by all means offers a very promising approach to resolving the problem.

When it is a matter of standoff detection over distances of many metres or even kilometres, particularly laser-based techniques are well-suited because, being active techniques, they are comparatively independent of the environmental conditions. The work ongoing at the Institute of Technical Physics is focused on the use of LIF technology. Although the fluorescence data do not yield spectra with sharp, characteristic lines like the Raman technique, for example, they do however provide additional information for distinguishing between different detected substances. Some of the information is gained by comparing fluorescence spectra for multiple excitation wavelengths or by measuring fluorescence lifetimes.

A standoff LIF detection system is being developed on the outdoor laser transmission range at the German Aerospace Center in Lampoldshausen where it is being used to detect bio-organic and chemical substances under real atmospheric conditions at distances from 20 to 135 m with UV laser radiation at wavelengths of 280 nm and 355 nm. A well-directed expanded laser beam and ultraviolet excitation wavelengths allow reliable compliance with eye safety requirements. The substance samples can be irradiated either in a UV glass cell (cuvette) or – where admissible – as aerosols. The ensuing fluorescence is recorded and analysed with an ICCD spectrometer system by means of spectral and time-resolved composition. After preparation, the data are processed automatically with the aid of online classification software. The software has been trained and tested beforehand using separate data sets. The current demonstrator and detection process can be controlled remotely from portable devices, such as an IPad. The result of the measurement is available a few seconds after the start of the measurement process, with the software displaying the class identified by the classification algorithm as well as the probability of assignment to that class.

The demonstrator works faultlessly in cases where the classification software has been trained for medium to high substance concentrations. When used to detect very low concentrations of bio-organic substances, sporadic deviations may occur in terms of class assignment probabilities .

To demonstrate the concept and functionality of the detection system with regard to online capability and correct classification, the classifier software has been designed initially to work with four predefined classes (bacteria/funghi, plants, chemicals, oils). Recent and ongoing LIF work has also proven successful in discriminating between different bacterial strains and in distinguishing between living and inactive biological material.

Fig. 1: Laser test range

Fig. 2: CBE detection system

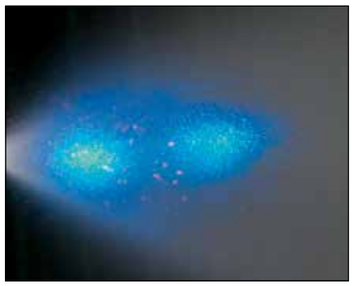

Fig. 3: Fluorescence of different aerosol mixtures excited by UV laser radiation with a wavelength of 355 nm at 135 m distance

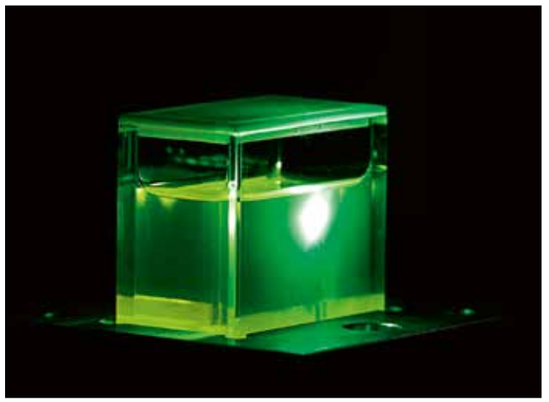

Fig. 4: Fluorescence of liquid in a cuvette excited by UV laser radiation

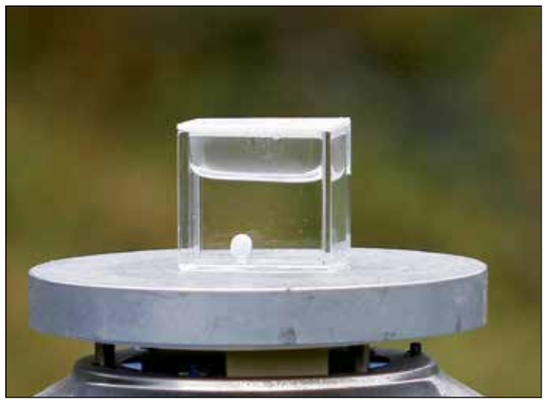

Fig. 5: Bacteria suspension in a cuvette at the laser test range

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Combustion processes of gelled rocket propellants

Propulsion systems based on gelled propellants combine important benefits offered by liquid-fuel systems, such as thrust variation on demand, shut-off and re-ignition, with the easy handling and storage characteristics of solid propellants. The gelled propellants developed in Germany also present several advantages from the viewpoints of safety and the environment.

For some years, gelled propellants and their specific properties have been a subject of research for both rocket and ramjet applications because of the simplicity of implementing thrust control and also because of improved operational safety. A gelling agent produces a 3D net-like structure in which a base liquid – either monopropellant, fuel or oxidizer – is embedded. The gelled fluid behaves like a solid when at rest, but its structure is liquefied once the 3D mesh of the gel is destroyed by sufficiently high shear stress. At very high shear rates therefore, typically reached during the propellant injection processes, the properties of the gelled liquid become similar to those of the base liquid itself, making it possible to combine the advantages of liquid and solid propellants.

At the Institute of Space Propulsion of the German Aerospace Center (DLR), research is being conducted on the topic of gels that are environmentally acceptable and simple to produce and have good combustion and performance characteristics. The goal is to develop a deeper understanding of the processes that take place within the combustion chamber, injector and feed lines, so as to enable reliable design of gel rocket motors with high power densities and stable operating envelopes in future.

Under investigation at present is the influence of the combustion chamber geometry on the combustor performance. These investigations are also part of a government-funded DLR project concerning “Innovative Technologies and Methods for Missiles” (ITEM-FK) and are embedded in the German Gel Propulsion Technology Programme.

Numerous hot fire tests have been conducted, involving a gelled monopropellant in a model combustion chamber with an inner diameter of nearly 21 mm (BK21). In seeking the optimum ratio of combustion chamber volume to nozzle throat area, or so-called characteristic length L* of the combustor, the combustion chamber length has been systematically reduced from 400 mm to 80 mm, which is equivalent to an L* between 7 m and 1 m, taking into account the different nozzle configurations tested. It has been possible to demonstrate self-sustaining combustion for the initial test configuration at L*=7 m and a combustion chamber pressure of approx. 30 bar as well as for very small characteristic lengths of around 1.3 m when operated at a minimum pressure of about 40 bar. The maximum combustion efficiency for BK21 has been achieved for a chamber length of between 150 mm and 180 mm, which is equivalent to a characteristic length L* of around 1.5 m to 2 m. Comparative hot fire tests involving a larger combustion chamber with an inner diameter of 50 mm (BK50) have revealed a generally somewhat lower combustion efficiency with an optimum characteristic length of around 7.5 m, but the latter configuration had a more extensive operational pressure range. The enhanced efficiency of the small-diameter combustion chamber is attributed to a beneficial spray-wall interaction that increases the heat exchange and, as a consequence, leads to more “concentrated” combustion. This opens up the possibility of designing either compact high-performance combustors or motors with superior controllability and a broad operational envelope, depending on the application.

Preliminary tests have already demonstrated the potential of optically examining the gel injection and combustion processes. From early 2016 onward, for the first time, detailed analysis and observation of the chamber processes will be possible for the gelled propellants under consideration using a new model rocket combustor that offers optical access.

Fig. 1: Overview of different gelled propellant laboratory samples

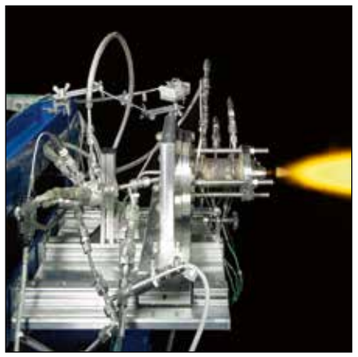

Fig. 2: Gel rocket combustion chamber BK50 installed at test facility M11.4

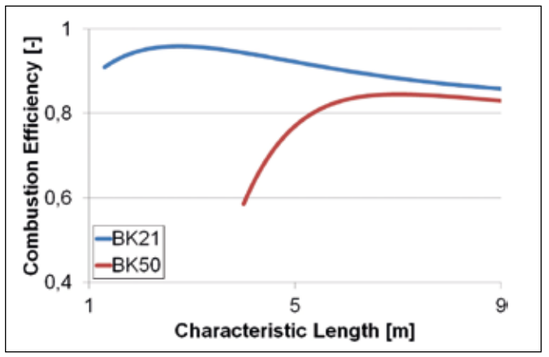

Fig. 3: Comparison of the combustion efficiency of small-diameter combustion chamber BK21 and large-diameter chamber BK50 (schematic)

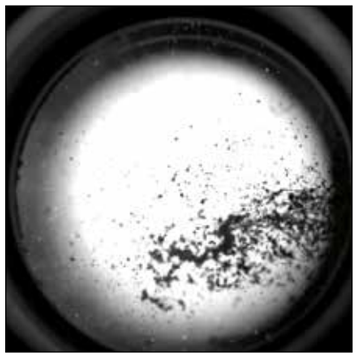

Fig. 4: Preliminary test for optically examining gel injection in a combustion chamber

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Ground-based high-resolution radar sensor for stand-off detection of buried objects

Ground-penetrating radar (GPR) is a suitable tool for detecting landmines, unexploded ordnance or other threats. Most GPRs, however, operate in very close proximity to the ground and tend to scan areas point by point. The method used by Synthetic Aperture Radar (SAR), in contrast, allows fast and laminar stand-off examination of large areas.

Many countries face the problem of having land areas which are infested with land mines and unexploded ordnance (UXO) legacies and present a significant risk to the population. Detecting and subsequently clearing these hazardous explosive objects is, therefore, extremely important and necessary. In the military domain the constraints and objectives with respect to clearance efficiency (e.g. time requirement, areas to be cleared, methodology, degree of decontamination) are frequently somewhat different from those of humanitarian operations, yet in terms of the main basic elements are identical for both activities. Within the framework of an EU project designated TIRAMISU (Toolbox Implementation for Removal of Anti-personnel Mines, Sub-munitions and UXO), the Microwaves and Radar Institute of the German Aerospace Center (DLR) is developing and constructing a ground-based, multi-element broadband radar system for the large-scale detection of hidden objects (first preliminary research was presented in "Military Scientific Research Annual Report 2013")

In comparison with a classical downward-looking, close-range GPR whose sensor is generally 10 to 100 cm from the ground, it is highly desirable to be able to detect mines and UXO from a safe stand-off distance (ideally several metres). By using the SAR method it is possible to investigate larger areas in a reasonable time and from a greater distance. To do this, the radar system is designed to work with a side-looking geometry (see Fig. 1) so that it has a medium operational detection range of several metres average distance (> 6 m) to the target area. Use of such a synthetic aperture produces a high spatial resolution of around 5-10 cm in along-track (azimuth) direction. The scene length in that direction can, theoretically, be selected arbitrarily but is, typically, some 15-20 m. Using a system bandwidth of around 3 GHz achieves a similar spatial range resolution of 5-10 cm in across-track (ground range) direction. Depending on the antenna's beam width, a scene size of about 4-5 m can generally be realised in that direction. The radar consists of two independent transmit channels with almost random signal shaping, and of four independent receive channels, the latter being sampled at a data rate of 8 GS/s per channel, which allows the entire operational bandwidth (300 MHz up to 3 GHz) to be acquired at once (see Fig. 2). The demonstrated operational range encompasses an area of about 100 m², which can be scanned in roughly 3 minutes. A multitude of optimisation and validation experiments have been carried out successfully with this system at DLR facilities in Oberpfaffenhofen, Germany, and at test fields of SEDEE (Service d'enlèvement et de destruction d'engins explosifs) in Leuven, Belgium. With these measurement data serving as a basis, it has been possible to develop several advanced processing tools that focus on the ground and localise objects buried, typically, as deep as around 20 cm.

The transmit and receive antennas are mounted on a flexible boom, allowing use of mono-static and bi-static radar cross-section (RCS) imagery in combination with different polarisations. Such a multi-static view of the targeted scene makes it possible to suppress undesirable ground return signals. The system is, additionally, capable of evaluating different wave polarisations, thus leading to a greatly increased detection probability (see Fig. 3).

The multi-static antenna configuration is useful for collecting additional imagery information in the third spatial dimension, such that depth information can be shown when a threat is detected. Used in combination with classical localisation methods such as GPS, it is possible for scanned areas to be included in an absolute world coordinate system and for detected objects to be marked three-dimensionally for reference by operational demining teams (see Fig. 4).

Fig. 1: Multichannel radar system for detecting buried objects, mounted on a "Unimog" truck as a mobile platform

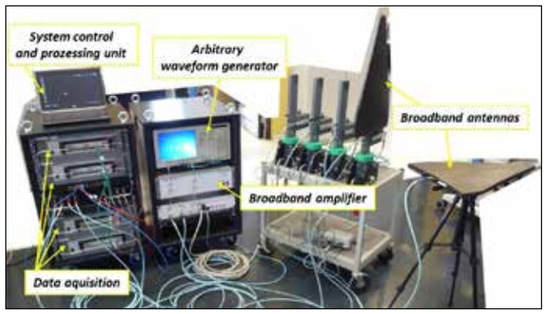

Fig. 2: Radar electronics and broadband antennas in use, including cabling

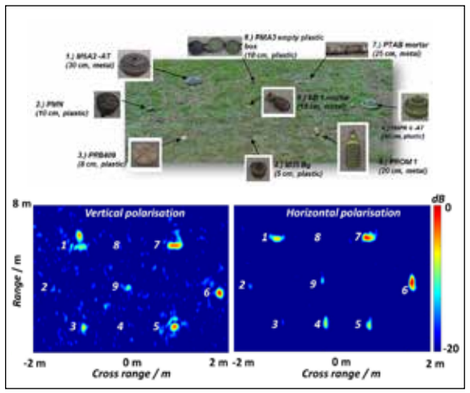

Fig. 3: Photo of test scenario (left), and measurement data after background suppression (centre and right)

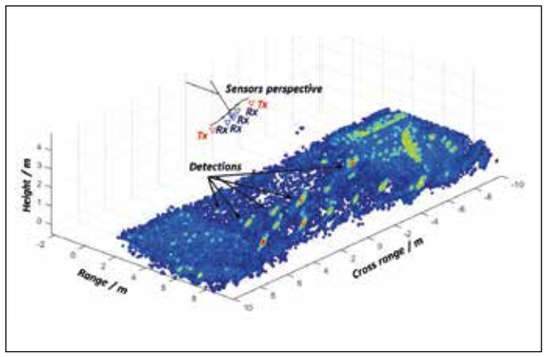

Fig. 4: Three-dimensional imaging result for a scanned ground area in relation to the antenna group. In this view it is possible to mark detections with values of the world coordinate system, thus giving the absolute position of individual detections.

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Low-noise flight procedures for helicopters

So that helicopters cannot be so easily detected in future because of their high noise emissions, the German Aerospace Center (DLR) is developing a simulation and optimisation tool to minimise the noise signature during flight procedures. The noise reduction is validated by means of flight tests with the EC135-ACT/FHS research helicopter operated by DLR.

Helicopters have proven to be versatile aircraft for the Bundeswehr because of their unique capability to hover and land on unprepared terrain. One problem in threat scenarios, however, is helicopters' high noise emissions, leading to their early acoustic detection. The noise signature allows determination of the helicopter type and, through a visual search of the airspace in the direction of the noise source, the helicopter can be fully identified. A low-noise approach has the potential to reduce the risk of detection and thus increase helicopter flight safety and mission success. Outside of threat scenarios, low-noise flight procedures during helicopter training would reduce noise nuisance for the population.

Helicopter noise levels and the directivity of the emitted sound depend strongly on the helicopter's flight condition. Particularly high noise levels occur, for example, during high-speed forward flight and typical landing approach flights. The pilot can reduce the noise emitted by the helicopter by avoiding especially noisy flight conditions. He can also fly around noise-sensitive areas, for which suitable flight paths have to be specified to the pilot. This noise abatement approach is realisable for all existing helicopter types with a small amount of additional effort and is, therefore, also being applied in the research activity presented here by DLR. The alternative possibility of reducing helicopter noise emissions through technological advancements of the main and tail rotors, on the other hand, remains confined to new acquisitions or costly upgrade programmes.

The first step in designing low-noise flight procedures is to characterise the noise emitted by the helicopter as a function of the flight regime. This requires the conduct of flight tests with systematic variations of the flight path parameters. The overflight noise is measured with the aid of a large number of microphones distributed over an extensive ground area in order to determine the noise emissions in all directions. The processed noise data are stored in a database.

The database can then be used to compute the noise emitted for any given flight trajectory. This is done by using a helicopter simulation tool to predict the exact flight condition of the helicopter for each segment along the trajectory. The appropriate noise data are then selected from the database and used to compute the noise emission on the ground as a function of the helicopter's altitude and atmospheric parameters (Fig. 1). By coupling the flight noise prediction with a numerical optimiser, it is possible to derive a flight trajectory for which the noise emission on the ground in a certain area, or also as a whole, will be minimal. This requires consideration of criteria such as critical flight states, pilot workload, and operational constraints. The wind direction also has an important impact on the resulting noise footprint (Fig. 2).

Acoustic flight experiments involving the EC135-ACT/FHS research helicopter operated by DLR are being conducted to validate the numerically derived low-noise flight procedures. During the test campaigns a pilot display mounted on the control panel or a helmet-mounted display can be used to guide the pilot along the flight trajectory (Fig. 3). A comparison between a measured noise footprint and the numerical prediction is shown in Fig. 4, demonstrating excellent concurrence.

The described methodology can be applied to any type of helicopter. Future research will focus on numerically predicting helicopter noise emissions, as a result of which required flight testing will be reduced significantly and noise prediction will become possible for helicopters under development, even before their first flight.

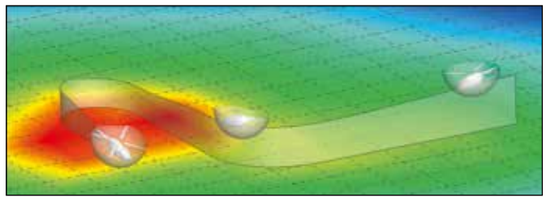

Fig. 1: Computed noise footprint of a helicopter. The noise data, which are strongly dependent on noise directivity, are stored so as to model a hemisphere around the helicopter

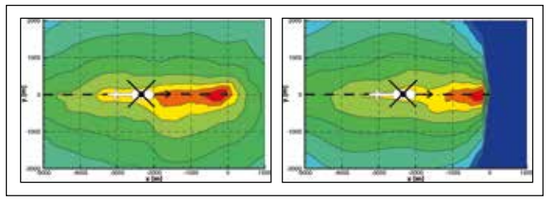

Fig. 2: Helicopter noise footprint during approach and landing from left to right (red: noisy, blue: quiet) left: no wind, right: under headwind conditions, little noise is observed upstream of the landing point

Fig. 3: Flight test with the EC135-ACT/FHS research helicopter operated by DLR. The pilot display used to guide the pilot along the noise-optimised flight path can be seen on the right

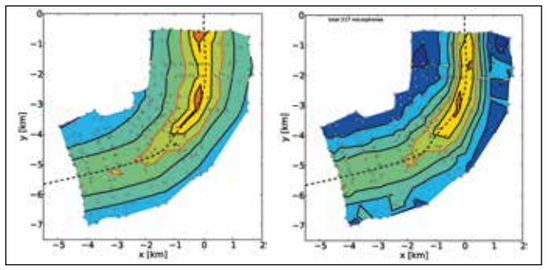

Fig. 4: Minimal-noise flight procedure (dashed line) including landing point at the top of the figure. Comparison of numerically predicted noise footprint (left) with measurement conducted during flight test (right)

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The SESAR revolution and new types of airspace users

New types of aircraft including unmanned vehicles and those operating as far up as space will have to be included in future civil and military airspace. The Single European Sky (SES) currently harmonises the European air traffic management system for civil and military users. Research is ongoing at DLR with a view to integrating these new aircraft into the SES worldwide as well as to analysing possible new security threats.

Our vision for 2020: the pilot of a remotely piloted aircraft system (RPAS) will use a special intranet forming part of the air traffic management (ATM) system and, in doing so, have a smart mobile human-machine interface (HMI) at his/her disposal for flight and mission preparation, briefings, operation, command and control, surveillance, and post-operational analysis of the aircraft. This “miracle” aviation intranet service is referred to as System Wide Information Management (SWIM), which also integrates Controller-Pilot Data Link Communication (CPDLC) and other communication systems.

The flight plan preparation and digital briefing will be done by Digital Briefing Service Orchestration, using services such as flight plan preparation and validation, a weather data exchange service, a flight data exchange service to receive information on the present and future traffic situation, and a service that provides mission-related data. After preparation of the flight and mission, the RPAS pilot will file his/her flight plan via the flight plan service with the SWIM system. All relevant mission data will be transmitted in parallel to the RPAS via a suitable air-ground SWIM communication service. At the

Fig. 1: SWIM Human-Machine Interface for flight planning for an unmanned aircraft system (RPAS) (Source: DLR)

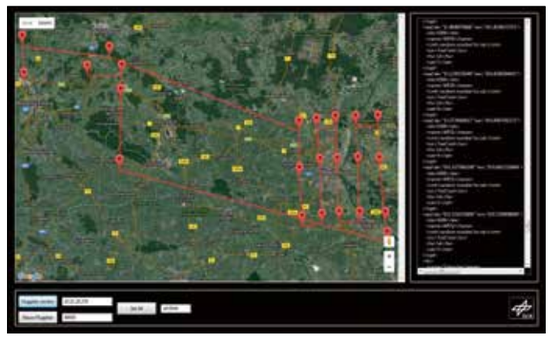

Fig. 2: SWIM-based surveillance mission of an RPAS (screenshot) (Source: DLR)

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time of departure, the onboard avionics will retrieve the SWIM information. The aircraft will then be able to taxi automatically to the runway and take off for its mission. All relevant status information exchanged between the RPAS, pilot and air traffic control will be shared via the SWIM system. Integration into airspace will no longer be managed by complex ground stations but by smart HMI with a high level of overall system automation using artificial intelligence. Additional C2 messages for accomplishing mission objectives will be exchanged via a secure air-ground service.

SWIM is one of the key concepts of the Single European Sky ATM Research programme (SESAR). It will constitute the intranet for future ATM and, especially, military RPAS integration and enable seamless information interchange. SWIM will make information consistently available to different users that support active decision-making, namely pilots, airport operations centres, airlines, air navigation service providers, meteorology service providers, and military operations centres. It will, therefore, also revolutionise future military air(-borne) operations.

New airspace users in the very near future will include so-called spaceplanes – craft which will fly at hypersonic speed into space and return in glide mode. This new mode of transport will affect civil and military air traffic. The technology itself can also be used militarily, however, and therefore has to be regarded as a future additional threat. One type of threat may be the disintegration of a glider at high altitude due to an accident or even malicious intent which, in turn, would endanger civil or military air traffic. What a fatal break-up event (at an altitude of around 231,000 ft. and speed > Mach 20) can entail was demonstrated by the Columbia space shuttle accident in 2003 as debris rained down on air traffic and onto the ground, covering a footprint of around 300 km by 30 km. It was a stroke of luck that the Columbia accident did not lead to any other collisions with air traffic. The casualty probability for air passengers as a result of this event was around 0.3.

DLR is working on the development of SESAR SWIM intranet services capable of taking relevant global risks into account which expected space traffic will pose to nations‘ security.

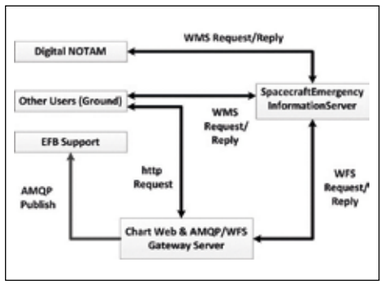

Fig. 3: SWIM emergency server for a suborbital vehicle/spaceplane (Source: DLR)

Fig. 4: World-wide integration of a Spacecraft Reentry Hazard Service (Source: DLR)

Fig. 5: The DLR Spaceliner concept will connect continents point-to-point on suborbital trajectories (Source: DLR SART)

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Research into scalable high-power lasers with enhanced “eye safety” for future weapon systems

The possible use of lasers as weapons is increasing in attraction for the Bundeswehr. Besides generating high laser power and good beam quality, however, there are important safety aspects to consider, such as eye hazards. ISL is addressing this in its MELIAS (medium energy laser in the “eye-safe” spectral domain) project and has developed currently the most powerful solid-state laser in the “eye-safe” wavelength range.

Recent progress in the field of solid-state lasers and related technologies will make the realisation and use of laser weapon systems possible in principle in the foreseeable future. Important in this context are not only technological aspects, such as the generation of high laser power and good beam quality for optimum laser beam focusing over long distances. The operational scenarios in which the Bundeswehr might be engaged, and where civilians are often present, require the consideration of safety aspects associated with the use of laser weapons, with particular importance being attached to ”eye safety”.

Understood by “eye safety” is inability of light at wavelengths of > 1.4 µm to penetrate the eye and thus focus on the retina. According to work safety regulations, the maximum permissible eye exposure to light in this wavelength range can in some cases be orders of magnitude higher than in the so-called ”non-eye-safe” wavelength range, where even very low power levels can lead to permanent eye damage. An additional aspect to be taken into account is that a laser beam with a low, yet already dangerous, level of power in the invisible wavelength range will not produce any natural defensive reaction (palpebral reflex) in people. The safe distances for the important wavelengths of 1.03 µm and 1.6 µm differ by a factor of six in this regard. The requisite protection measures and the risk of collateral damage are, therefore, greatly reduced when using lasers at a wavelength of 1.6 µm.

All of the solid-state lasers hitherto realised or considered in the range from 10 kW to over 100 kW emit at a wavelength of 1.03 µm to 1.07 µm. For this reason the research being conducted at ISL within the MELIAS project is focusing on an alternative with a wavelength of around 1.6 µm that holds many operational advantages in prospect. Basically, the laser source needs to be scalable in power to well beyond 100 kW without any significant deterioration in beam quality. The laser system has, in consequence, to supply the power by using only one laser source (i.e. without combining several beams).

ISL has explored a very promising laser technology within the scope of the MELIAS project, namely the erbium heat-capacity laser. This type of laser is characterised by a compact design, a simple and robust technology, and a scaling law which, in principle, is capable of laser power levels well into the megawatt range for its small volume. The special quality of the laser lies in its operating mode: a laser medium (crystal or ceramic) is used for one shot (lasting about 3 to 5 seconds) without any cooling and is then replaced by a cold medium. Up to 40 laser pulses can thus be generated at 100 kW, without any cooling, using the revolver system designed at ISL. Alternatively, by adding a suitable cooling system, it is possible for the laser to operate in a continuous repetitive mode. The cooling requirements and hence the weight and volume can be optimised according to the mission scenario.

ISL’s MELIAS II laser (Fig. 2) holds the world record (at 4.6 kW) for a directly diode-pumped solid-state laser with enhanced eye safety. Several new technologies (such as for beam guidance or for supplying power to the laser diodes) have also been explored in the project which have been key to the laser’s realisation (Figs. 2 and 3).

In the course of the next three years the intention is to advance to a further level (MELIAS II+) with an envisaged laser source of 25 to 30 kW. This will also involve later integration into containers for field trials. Fig. 4 shows the planned system concept including core components such as energy supply, laser unit, cooling system and command unit.

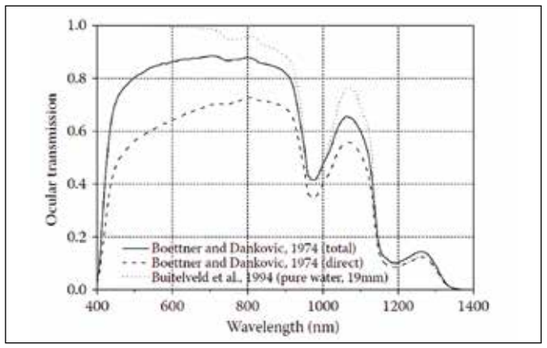

Fig. 1: Transmission of optical radiation in an eye and in water as a function of wavelength (from: Modeling of Laser-Induced Thermal Damage to the Retina and the Cornea, by Mathieu Jean and Karl Schulmeister)

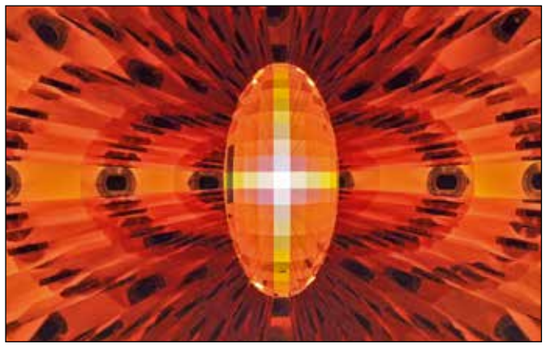

Fig. 2: View inside a pump light compressor designed in the MELIAS project. Such devices are used to homogenise the pump radiation and display efficiencies as high as 98%

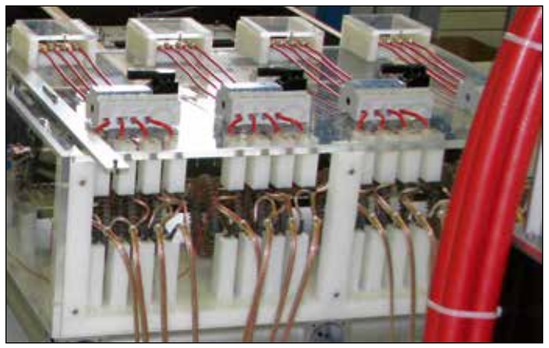

Fig. 3: A special current pulse generator gives the MELIAS II laser an immediate firing capability. The laser switches directly from stand-by to emitting mode in just ~ 5 ms

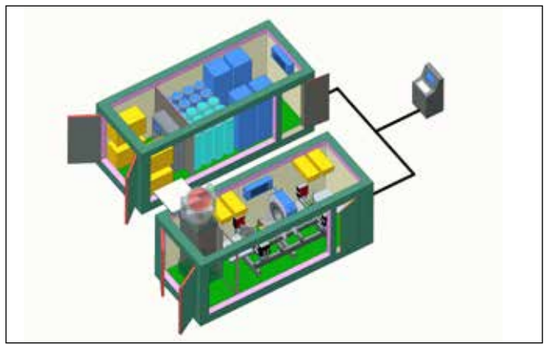

Fig. 4: The future 30 kW MELIAS II+ laser in two containers: one for the laser unit, and one for the energy supply and cooling systems

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Threat detection behind obstacles

Laser gated viewing coupled with computer-based analysis of scattered photons' round-trip times and angular distribution can provide a computer-generated view around obstructions obstacles into areas lying beyond the direct line-of-sight, with the purpose of better detecting optically obscured dangers and of improving friendly forces' situational awareness and, hence, safety.

During military operations in densely populated or urban environments or in fissured mountainous terrain, obstructions such as solid house walls or large rocks offer potential hiding places which hostile forces can exploit for an ambush or for offensive action. ISL is exploring an optical approach to providing a full situational picture in such situations. The technology is based on the computer-based analysis of scattered protons and is expected to provide the possibility to detect masked objects beyond the line-of-sight or behind obstructions, thus significantly improving soldiers' situational awareness.

The method uses a gated viewing system to analyse scattered photons. A short laser pulse illuminates a wall or a randomly shaped surface behind or close to the obstruction. From that surface the light is scattered over the surrounding space. Objects and surfaces behind the obstacle are illuminated and reflect the light back to the first scattering surface. From there the light is directed back to a sensitive detector unit.

Although direct imaging information about the masked space is lost due to multiple scattering processes, the recorded signals nevertheless contain information about the round-trip times and reception angles of the scattered photons. From that information it is possible to draw conclusions about the positions of scattering surfaces. The computer-aided analysis is based on several algorithms similar to those used in 3D microscopy or X-ray computer tomography (CT) scanners.

ISL uses a laser gated viewing system for illumination and data recording which, in comparison with other approaches, delivers high-resolution, two-dimensional images. The temporal sampling is achieved through systematic variation of the temporal delay between the laser pulse emission and its reception by the sensor gate, thereby offering the possibility to record both the direct signal from the first scattering surface and the indirect signal from objects behind the obstruction. The first signal is used to calculate a 3D model of the scattering surface, while the second signal can serve to derive the position of objects in the masked space.

Through back-projection of the data measured for the scattered photons it is possible to plot a 3D map of the masked area containing the distribution of the most probable positions of scattering surfaces. Use of signal enhancement and feature selection algorithms allows delimitation of areas of possible interest and facilitates reconstruction of the masked area.

ISL has carried out first-time measurements for viewing behind obstructions using a laser gated viewing system. The experimental setup has not been limited to the use of an optical bench and, with a photon round-trip path of more than 10 m, has offered the possibility to test the method under near-operational conditions. It has shown itself capable of detecting multiple targets and of analysing complex scenarios. Viewing behind obstructions is limited to the computer-aided reconstruction of surface contours. Because of the multiple scatter, complex image information such as local intensity contrasts is lost. It is, therefore, possible to detect and reconstruct object shapes, but not to identify detailed textures (e.g. writing).

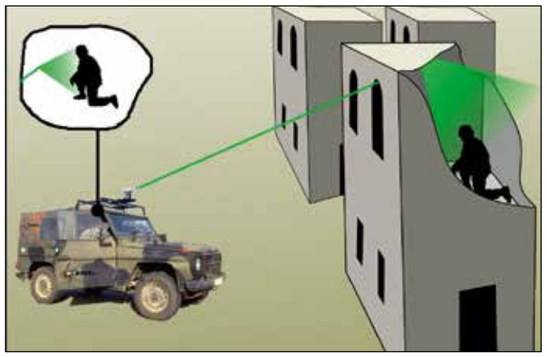

Fig. 1: Scattered photons are sensed and analysed to detect objects in a masked space

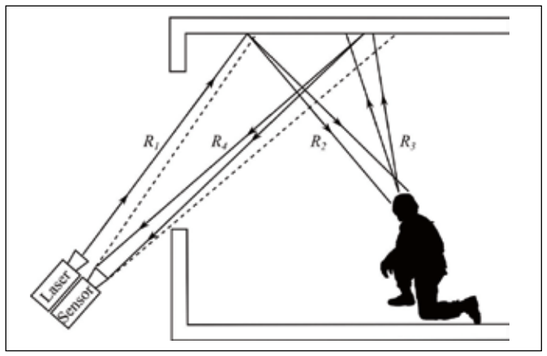

Fig. 2: The reflection of a laser pulse is used to gain information about a masked space

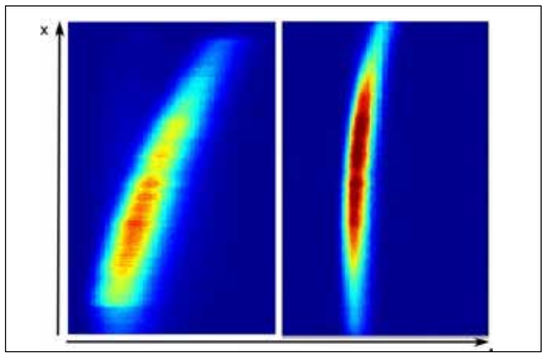

Fig. 3: Signals from direct reflection from a wall (left) and from indirect reflection of scattered photons from a masked object (right)

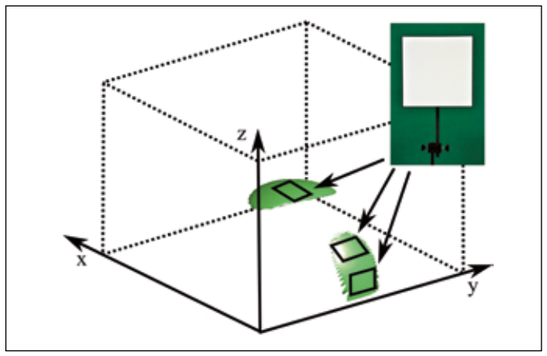

Fig. 4: Reconstruction of multiple targets placed in a masked space

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Impact analysis and early crisis detection in the information environment: SPIDER – an indicator model

Information and communication are two key terms that, not only for the Bundeswehr, are taking on an ever more central role in this highly networked world. SPIDER is an indicator model which quantitatively displays relevant system elements in the complex information environment and will help to create a better understanding of the effect of information.

The conflicts that the Bundeswehr has to expect nowadays are of a complex nature. Failing states, asymmetrical threats, state and non-state actors, as well as the growth of global networking have an impact on the security situation. The information environment in which people absorb, share and use information as the basis for their actions is a factor that is shifting more and more into the spotlight. For the Bundeswehr as an actor in the information environment it is therefore crucial to understand that every word and every action has an effect in that environment which can help it to achieve its own goals or play a part in their failure. To gain an understanding of how information works, it is important to systematically reduce and, where necessary, recondition the relations in their complexity within the information environment. Pure facts are not enough, however. They have to be put into context with soft, socio-dynamic factors.

A change in the behaviour of the population in a theatre of operation can have countless reasons and cannot be portrayed in simple shares or ratios. That behaviour depends on, among other things, the perception and attitude of the population. To assess the impacts of information, it is necessary to measure any changes in the information environment, because a central goal of any civil-military activity is to bring about a change in the way actors behave in theatre.

An indicator model called SPIDER (Social Perception and Intercultural Dynamic Evaluation Reference system) is currently undergoing development as part of a military/academic cooperation arrangement between the Bundeswehr Operational Communication Centre (ZOpKomBw) and the Bundeswehr University, Munich (UniBW) to evolve the operational communication capabilities of the Bundeswehr, the aim being to holistically consider all the elements of modern conflict scenarios and thus create a better understanding of (cor-)relations in the information environment.

Multiple social indicators are defined and brought together in order to systematically gather and analyse the situation in the information environment. The focus along the impact chain (input-output-outcome-impact) is on the impact caused by a civil-military operation and the individual actions it involves. SPIDER has additional options to offer beside a summative (ex-post) evaluation or impact analysis, For stabilisation operations undertaken over an extended period, it offers the possibility of a formative (accompanying) evaluation of the operation and can indicate if there is any need for action. It can also support operational planning by enabling better identification of critical developments in the information environment. SPIDER is divided into five hierarchical levels: topic areas, topics, clusters, factors and measurable variables. The uppermost level encompasses the topic areas of local security, social relations, governance and landscape. Socio-dynamic indicators that are scalable and can thus be aggregated, and structural indicators whose characteristics are not ratable yet serve to provide a better categorisation and interpretation of the collected data are both used.

This use of socio-dynamic and structural information collected by different methods (e.g. open source intelligence, surveys and observations) as well as quantitative and qualitative analyses enables SPIDER to reduce the complexity of the information environment and to process the information according to requirements. Consideration of the data on the status quo ante and its changes over time allows SPIDER to offer a resilient impact analysis of already realised activities and also to deliver information on risks and opportunities for crisis early detection.

Fig. 1: The entire information environment is acquired

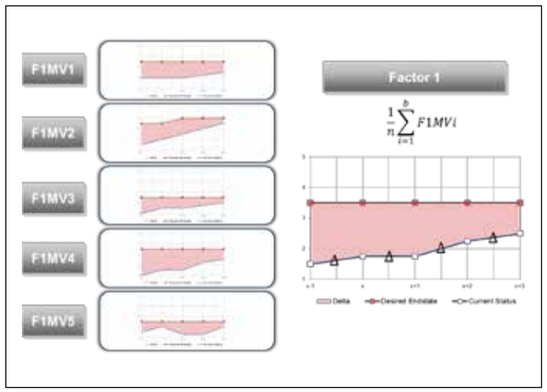

Fig. 2: Statistical methods of aggregation

Fig. 3: Impact analysis through civil and military expertise

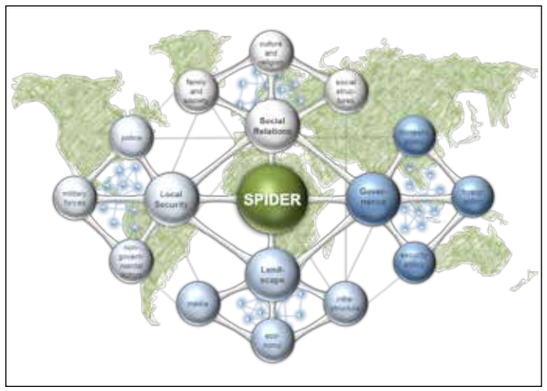

Fig. 4: Multiple indicators in a complex operating environment

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Development of a platform to support medical intelligence in NATO

To prepare and carry out missions abroad, it is essential to have efficient information management in the medical intelligence field. The quality and speed of best-practice processes can be improved through the use of mobile devices. The latest data are fed instantly into a central situation report which also serves as an early warning system for identifying disease outbreaks.

In cooperation with the Bundeswehr Medical Service Headquarters (KdoSanDst), a central platform for information management designed to meet a variety of requirements has been created to provide medical intelligence (MedInt) support. Every day there are new disease outbreaks as well as other medically relevant news to be recorded. These data are augmented with geographic information so that they can be cross-referenced with current as well as planned operations. In addition to open-source intelligence, there is the need to be able to incorporate information from in-situ forces into the system.

A prototype that addresses these requirements has been developed as part of the RAAPIT (Routine Analysis, Assessment and Publishing Medical Intelligence Tool) research project at the Cyber Defence Research Centre (CODE) of the Bundeswehr University, Munich. The platform is being evaluated by KdoSanDst with regard to its practical suitability and to identify supporting functional enhancements. One such enhancement is a mobile application called EMILIA (Electronical Medical Intelligence Lightweight Internationalised Application) which, on the one hand, makes information from the central in-theatre database available in offline mode and, on the other hand, offers various ways to record and report new intelligence. Information is presented on a map, while local institutions and contact persons are available at all times along with details such as equipment, contact information etc. The prototype has been implemented both with various mobile operating systems (iOS and Android) and with different device types. It has already been possible on several occasions to demonstrate EMILIA to a broader range of users during regular meetings of the NATO COMEDS Medical Intelligence Expert Panel and to have it tested by the representatives of different nations.

Allied armed forces have similar requirements in the MedInt field, collect similar information and evaluate it according to international standards. The cross-linking of allied nations' MedInt departments can hence increase the efficiency of this process significantly. As part of the recently launched RAAPIT-Plus project the existing prototype is to be enhanced with functions for international cooperation. Automated monitoring of Internet content will additionally offer the opportunity to feed information from social online networks, etc. into the RAAPIT database.

The EMILIA client is undergoing further development in a separate, dedicated project. Beyond the collection of, and access to, relevant local information, there will also be mobile end-user devices to record observed illness symptoms. An early warning system for outbreaks of infectious diseases is being created by connecting EMILIA to an existing NATO system. The recording of symptoms by community health workers – lay health advisors in current theatres of operation – is to be explored in the project and its effect on the speed and quality of outbreak detection evaluated.

Thanks to excellent networking with industry, government and academia as well as with projects such as fit4sec, new technology trends are being identified and explored in research projects such as EMILIA and RAAPIT-Plus at the CODE Research Centre. The interdisciplinary set-up of this research centre allows the latest research findings to feed directly into the development of prototypes including instant evaluation of their suitability for practical use.

Fig. 1: Screenshot of the RAAPIT prototype

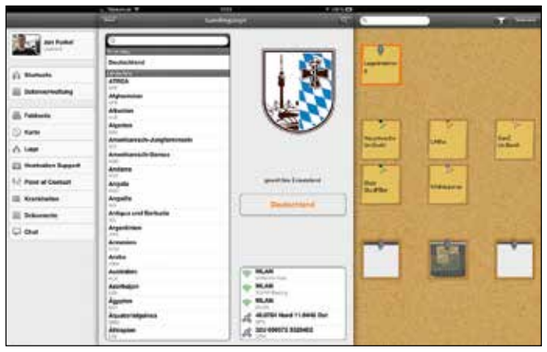

Fig. 2: Exploded view of the EMILIA app

Fig. 3: Details of medical equipment available on site

Fig. 4: Display of information including geographical reference on a map

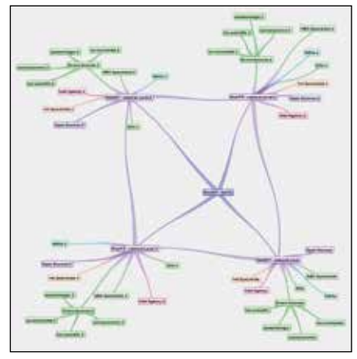

Fig. 5: Networking of internationally cooperating MedInt departments

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Use of steel fibre-reinforced concrete as protection against weapons effects

Protecting personnel and operationally relevant materiel represents a major challenge against the backdrop of the growing threat that terrorist attacks pose to military infrastructure of the Bundeswehr. An important element of any holistic security concept is structural protective measures. Steel fibre-reinforced concrete is a construction material well-suited for this purpose.

The design of protective structures must ensure that, in the aftermath of weapons effects, local damage remains limited and the global structural conditions are preserved. The protective function of infrastructure can become necessary when there is exposure to air blasts, contact explosions, fragmentation effects, projectile impact, or a combination thereof, as a result of weapons effects. Damage can be limited locally through adequate component thickness, the attachment of additional protective elements such as steel plates, or by modifying the building materials.

Providing structural protection for out-of-area deployments constitutes a particular challenge when predominantly local resources (building materials, personnel, equipment) are to be used and the manufacture of high-strength concrete is not always possible. To be able to provide technically and cost-effectively optimised solutions, Bundeswehr Technical Centre (WTD 52) and the Bundeswehr University, Munich (UniBwM), are, on behalf of the Federal Office of Bundeswehr Infrastructure, Environmental Protection and Services (BAIUD), developing and testing steel fibre-reinforced concrete mixtures suitable for out-of-area deployments (it is expected that the amount of steel fibres will be around 1 vol.-%, with the

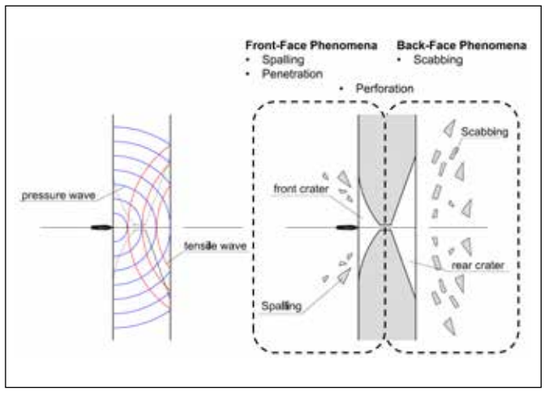

Fig. 1: Wave propagation and damage

Fig. 2: Full penetration, AP 7.62 mm x 51

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concrete admixtures being brought from Germany and all other constituents (99 vol.-%) being provided as local resources).

An overview of the state of research into protective structures built of steel fibre-reinforced concrete has been compiled in a preliminary study. The content of the study focuses on the load-bearing characteristics of steel fibre-reinforced concrete, on testing to determine its dynamic (mechanical) properties, and on structural components when exposed to weapons effects. Suitable concrete mixtures and manufacturing methods are also disclosed.

Given the complex state of stress induced in structural components by wave propagation and reflection when exposed to blast and impact, a distinction is made between two types of concrete failure: spalling comes about on the exposed side of the protective component as a result of the high compressive and shear stresses that occur, while scabbing is caused on the protected side by tensile stresses that occur due to the wave reflected on the free surface. The accompanying secondary debris poses an additional threat to personnel and equipment.

Although using steel fibre-reinforced concrete for protective structures has only a small influence on the penetration depth of projectiles, it does however reduce the visible cratering on both the exposed (front) and protected (rear) side. The cracking behaviour of the concrete is improved, and the velocity and mass of secondary debris are reduced. The protective performance and blocking effectiveness can thus be maintained longer, even in pre-damaged areas, compared with plain concrete. With the right combination of steel fibres and reinforcement with rebar steel it is possible to increase the ductility of structural components and activate additional reserve bearing capacity. Steel fibre-reinforced concrete can be used to fabricate vehicle barriers, protective shields for containers and modular infrastructure, as well as to reinforce existing structures with fibre shotcrete.

Based on the findings of the preliminary study, an extensive test programme has been drawn up which WTD 52 and the Institute of Structural Engineering at the UniBwM will conduct as part of a study lasting several years. Slabs with and without reinforcing fibres will be subjected to AP projectile impact and contact detonation. The proof-shooting and penetration trials will be carried out at the weapons technology and materials science laboratory of the Department of Mechanical Engineering at the UniBwM, and the contact detonation tests at the test site of WTD 52 in Oberjettenberg. The focus will be on normal-strength concrete that can be made primarily using local resources available in theatre during out-of-area deployments of the Bundeswehr.

Fig. 3: Contact detonation, crater on slab rear side, 850 PETN

Fig. 4: Cross-section of slabs after contact detonation

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Development of Bundeswehr-specific sofware for bridge classification and load-bearing capacity assessment

Quick assessment of bridges' load-bearing capacity is essential to ensure the mobility of friendly forces during operations. Continual advancements in computing power have led to the use of mobile devices in a wide range of applications nowadays. These technologies offer new perspectives for Germany's armed forces who can benefit particularly from their quick-handling characteristics.

Because of the rapid advances being made with smartphones and tablets in today's society, we are only just beginning to develop new areas of implementation for computer programmes. The general acceptance and use of these mobile devices also presents new opportunities for their integration into the Bundeswehr. Commercial programmes are only moderately suitable for this as they are capable either of too much or too little in regard to Bundeswehr-specific matters. In addition, the use of open-source software creates the risk of weak points developing where data security and defence against external exploitation are concerned. For this reason there is the need for software development that is geared specifically to military applications and criteria.

Particular requirements stipulated by the Bundeswehr concerning software development include, among other things, the highest possible robustness of the programme against misuse, a very structured and straightforward interface, a visual display of inputs, and a clear interpretation of results. For in-service use there is also the need to optimise the

Fig. 1: Mobile devices for software use in any situations

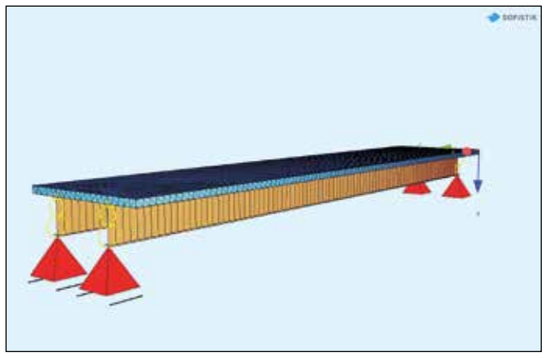

Fig. 2: Three-dimensional numerical model of a composite slab and girder bridge

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amount and accuracy of the input parameters as well as the computing time. The ongoing development of a computer programme to classify bridges merits mention as an example of the functionality that is needed.

The commercial market offers a wide range of programmes for the calculation of load-bearing structures and the creation of numerical models. The performance capability of these products often ranges from a simple two-dimensional calculation to a numerical calculation of complex three-dimensional models. Considered structures vary from simple warehouses to complex civil engineering works. Such a variety of applications is sought-after and required on the commercial market, while a fraction of the covered spectrum suffices for the problems encountered with regard to the Bundeswehr. The great number of calculation and visualisation possibilities requires a high computing power which, at present, can be attained only by computers and laptops. The development of a platform-independent software could hence facilitate its use on mobile devices as well as reduce the input data and application possibilities to what is actually needed.

In the case described here – that of classifying bridges quickly – the modelling can be accelerated by using predefined sub-cross-sections which make up the bridge's total cross-section. By following this approach it is possible to largely automate the generation of the numerical model, with only the variable parameters such as the dimensions of the cross-section and the segment lengths being needed as input values. Once these values have been entered into the programme, the cross-section and structural system are visualised to enable the operator to examine his/her input. The calculation is then carried out and the safe load-bearing capacity (MLC = military load class) displayed.

This is just one example of how the use of special software can benefit the armed forces when on operations. Constant dialogue with the end-user can lead to the creation of an efficient computer programme which covers the bridge types and geometries most frequently encountered on military operations. New scenarios can also be easily integrated into the software as the Bundeswehr continues to develop.

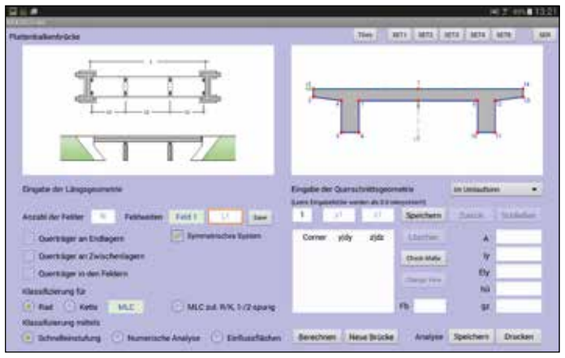

Fig. 3: User interface of the BRASSCO-NG bridge assessment programme

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LTE over Satellite system study

The missions which the Bundeswehr undertakes around the globe require the development of highly mobile and tactical communication networks with very short preperation times in many cases. These networks can seamlessly be integrated into long-haul communication links by using Bundeswehr-owned satellites. The "LTE over Satellite" system study, led by the Bundeswehr University, Munich, addresses possible solution approaches.

A core requirement underlying the modern-day operational principles of the Bundeswehr is the provisioning of broadband voice and data communication between the operations support coordination centre and forces on out-of-area deployment. Air-dropped and mobile forces operate on foot or in vehicles, and they need flexible and dynamically reconfigurable communication solutions that also incorporate long-haul satellite links with SATCOM on-the-Move (SOTM) terminals.

The latest mobile commercial communication standard, i.e. Long Term Evolution (LTE) fulfills many of the defined requirements. Based on Internet Protocol (IP), LTE offers comparatively high and scalable data transmission rates from the fixed base station to the mobile users as well as standardised IP interfaces within the core network.

The mobile command vehicle would incorporate a complete LTE network and an SOTM terminal for the long-haul connection to the mission network. In such a scenario the terrestrial communication network should remain independently operational even if the satellite link is disrupted. A further requirement of the Bundeswehr is to centrally integrate the security related

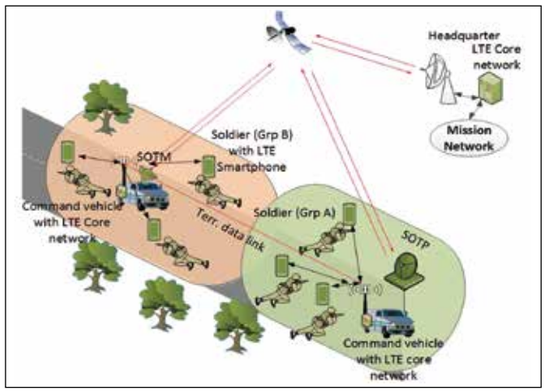

Fig. 1: Complex communication scenario comprising LTE subscribers and mobile LTE core networks connected via satellite and mobile as well as transportable SATCOM terminals to long-haul communication links

Fig. 2: Receive Broadcast Management (RBM) satellite terminals with transportable 1.20m dishes that will be used for the "LTE over Satellite" demonstration

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LTE core network components, such as the Home Subscriber Server (HSS) in the secure operations support cordination centre. In the event of the command vehicle being compromised, important information or even control of the LTE network might otherwise fall completely into enemy hands.

Therefore, the distributed LTE core network components have to cope with the typically long delays of geostationary satellite links and much lower data rates in comparison with the terrestrial links. The possibilities and constraints regarding the implementation of an end-to-end quality-of-service (QoS) concept also presents a major challenge. Hence, there is a need to harmonise the QoS models of the satellite, LTE and terrestrial network. With this in mind, the Institute for Information Technology of the Bundeswehr University, Munich (UniBwM), is conducting the "LTE over Satellite" system study on behalf of the Federal Office of Bundeswehr's equipment, information technology and in-service support. The UniBwM heads a consortium that includes the institute of integrated circuits of the Fraunhofer Society (FhG-IIS) and a small enterprise called INRADIOS GmbH. The project team is also supported by the Bundeswehr Communication and Information Systems School in Feldafing.

It is for the first time in a R&D that a holistic approach is being taken in the design of hybrid satellite and terrestrial networks, based on the results of the SOTM system performance analysis.

Once the system design phase has been completed, a practical demonstration on the feasibility of the developed solution approaches will follow in the second half of 2016 at the UniBwM. A communication scenario will be demonstrated in which a mobile and a stationary LTE network are interconnected via a satellite link, enabling the IP-based data traffic between the command vehicles, a drone and the dismounted soldiers carrying LTE equipment.

First laboratory trials involving the Bundeswehr's Wideband Broadcast Access (WBA) SATCOM network have yielded promising results. Altogether, the "LTE over Satellite" system study will demonstrate essential aspects of a comprehensive mobile tactical communication solution approach and thus provide decision-makers in the Bundeswehr with information that is useful for the current procurement initiatives.

Fig. 3: Example of a low-profile SATCOM on-the-move (SOTM) terminal mounted on the roof of a vehicle

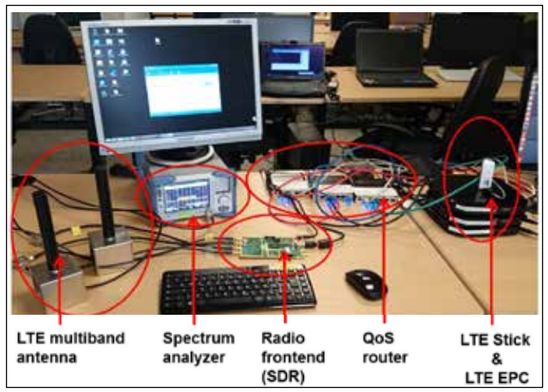

Fig. 4: Evaluation of a first system prototype of the LTE network during the laboratory trial phase

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New siloxane surfactants for highly effective environmentally friendly firefighting foams

The armed forces, when performing their tasks, can be at high risk from pool fires. The best extinguishing agents for fighting such fires are Aqueous Film Forming Foams (AFFF). However, AFFF have a major drawback in that they contain mandatorily persistent compounds. The Bundeswehr Research Institute for Protective Technologies and CBRN Protection is working within the scope of a research project to replace those compounds with more environmentally friendly surfactants.

AFFF constitute the most effective agent for fighting extensive pool fires. They surpass all other firefighting foams in their extinguishing performance. Their excellent extinguishing efficiency and high resistance to residual flames derive from the eponymous water film. This water film not only cools the fuel's surface, it also acts as a vapour barrier between the foam and fuel, facilitates the spread of the foam, and closes breaches in the foam blanket autonomously.

Because of their superior performance profile, AFFF are used anywhere there is a high risk of extensive fluid fires. This can be the case, for example, at facilities used for the storage, transportation and processing of petrochemical products, or at airports. Like civil airports, the military airfields of the Bundeswehr are dependent on the performance capability of AFFF due to their particular hazard situation.

In addition to the described advantages, however, today's AFFF have a serious drawback: they use mandatorily persistent, environmentally harmful polyfluorinated compounds (PFC) to form the water film. These compounds are environmentally non-degradable and can be bio-accumulative as well as toxic. Given these extremely negative characteristics, they are viewed critically nowadays and are increasingly subject to legal restrictions. This also has a strong impact on the use of AFFF.

The Bundeswehr Research Institute for Protective Technologies and CBRN Protection is carrying out research involving a PFC-free AFFF with the aim of making the valued AFFF extinguishing agent more environmentally friendly and of safeguarding its continued availability for the firefighting forces of the Bundeswehr. As a first step, using theoretical work as a basis, silicon-based surfactants - so-called siloxane surfactants - have been identified as possible film formers for a PFC-free AFFF. Literature research and study of the market, however, have shown that suitable compounds are neither commercially available nor known in literature as yet. For that reason it has been necessary initially to conduct an intensive screening programme for suitable siloxane surfactants during which more than 250 compounds have been synthesised and tested as film formers for AFFF. Of this great number of new siloxanes, however, only a few compounds have, after intensive research, been found to fulfil all the requirements as a film-forming agent for a PFC-free AFFF. Only one of these compounds has ultimately proven simple enough to synthesise, to be able to test its extinguishing effectiveness in medium- and large-scale experiments. It has been found that siloxane-based surfactant solutions greatly surpass the extinguishing performance of PFC-free firefighting foams hitherto available on the market and achieve the performance level of AFFF. Building on these findings, we have been able to produce experimental foam concentrates, which have been subjected to extinguishing trials using NATO standard F-34 fuel over areas of 4.5 m² and 100 m². In these trials, the new firefighting foams met the requirements laid down in German military specifications for PFC-containing AFFF. In addition to testing the extinguishing performance, the foaming behaviour and other physical parameters, we have had selected sample concentrates, and the siloxane surfactant serving as the basis, examined for their environmental behaviour. The experimental PFC-free foam concentrates have yielded surprisingly good results in these tests. Even at this early stage of research, their environmental performance has already been better than that of many commercially available PFC-free extinguishing foams.

To complete the picture, further trials to test the application of the experimental siloxane-based foam concentrates are to be carried out in future. Once this basic work has been completed, it will be possible to take the step of realising a demonstrator for an environmentally friendly PFC-free AFFF.

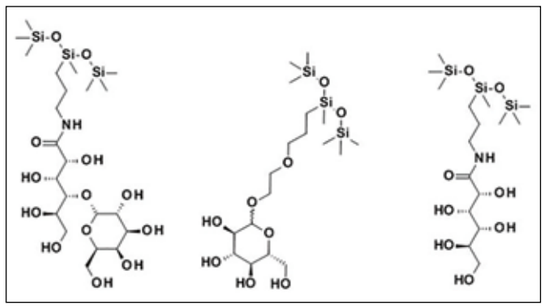

Fig. 1: Examples of siloxane surfactants synthesised and tested for AFFF suitability

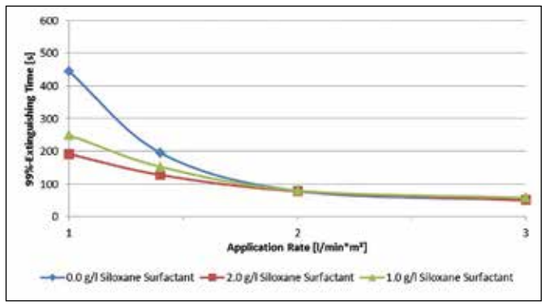

Fig. 2: 99% extinguishing times in small-scale trials as a function of foam application rate and siloxane surfactant concentration

Fig. 3: 100 m² extinguishing trial involving F-34 fuel shortly after start of foam application

Fig. 4: 100 m² fire suppressed successfully with a PFC-free, aqueous film-forming foam

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High-Power Electromagnetics (HPEM) as an alternative effector for counter-UAS applications

The use of Unmanned aerial systems (UAS) by hostile forces, possibly as a platform to deliver IEDs or CBRN agents, poses a threat to the safety and security of people, individually and collectively. Whereas the employment of jammers suppresses the functional capability of UAS only while the jammer is operating, the exposure of UAS to HPEM leads to their sustained malfunction.

The rapid development of microelectronics over the past few years has led to a use of nano, micro and mini UAS that is no longer limited to the military domain. These systems are finding ever greater use in civilian applications, both professionally (e.g. police, fire service) and recreationally. The capabilities of commercially available UAS are reaching a level of sophistication that, in the past, only military systems could offer. One example of this is autonomous navigation via predefined waypoints. In combination with a payload weighing as much as several kilogrammes, these systems become an ideal platform for carrying a variety of reconnaissance sensors as well as weapons such as explosives or CBRN agents, thus posing a threat to security and safety.

The design of such systems is comparatively simple. Beside its mechanical supporting structure, a typical UAS consists of different electronic components such as a radio receiver and antenna, a circuit board for attitude control, motors and drivers, and the battery for the energy supply. As most of these parts are manufactured for civilian use, their electronics are designed to function faultlessly solely in the civilian environment and meet only basic electromagnetic compatibility (EMC) requirements. Countermeasures designed to interfere with the electronics' operability thus represent an interesting alternative when it comes to engaging UAS. While there is already widespread use of jamming systems in the military domain, the employment of HPEM effector systems additionally opens up new possibilities.

The acronym HPEM denotes the formation of high-power electromagnetic fields exceeding a field strength of 1 kV/m at the target, generated either by a nuclear electromagnetic pulse (NEMP) or by a non-nuclear pulse source. The most common types to have established themselves in this respect are ultra-wideband (UWB), damped sinusoidal (DS), and high-power microwave (HPM) waveforms. All of these are comparatively easy to generate nowadays, with some of the generators already commercially available. The advantage of HPEM over classic jamming lies not only in the increased range of effectiveness in some cases but also in its efficiency (it can affect even autonomously operating UAS), and in the fact that it allows permanent suppression. Jamming is effective only as long as the jammer is active, after which the UAS is fully functional again. Electronic malfunctions induced by HPEM invariably cause UAS to crash and be destroyed as a result of their ensuing flight attitude, which is inherently unstable.

Given its many years of research work in the field of HPEM interaction, the Bundeswehr Research Institute for Protective Technologies and CBRN Protection has access to an extensive set of source systems to emulate all kinds of HPEM threats. In the course of an in-house R&T programme to establish susceptibility thresholds against different HPEM threats, some 25 micro and mini UAS have been procured since 2013. The UAS capabilities that have been examined range from simple recreational drones to professional systems including well-known representatives such as the Parrot Drone and DJI Phantom. The research has shown all tested systems to be vulnerable to HPEM. The measured susceptibility thresholds, i.e. the electrical field strengths to induce the system to crash, have varied however as a function of both the UAV model and the employed HPEM waveform. Systematic test series involving varying pulse forms have revealed a greatly reduced susceptibility threshold for HPM compared with UWB and DS (by as much as a factor of 50) and, therefore, a potentially higher range of effectiveness for the same power output. As HPEM sources are often used with a high repetition rate, it is possible to vary both the exposure time and the repetition rate. Test results in this regard have indicated the possibility of reducing susceptibility thresholds further by increasing the repetition rates and exposure times.

Fig.1: Examples of considered micro and mini UAS

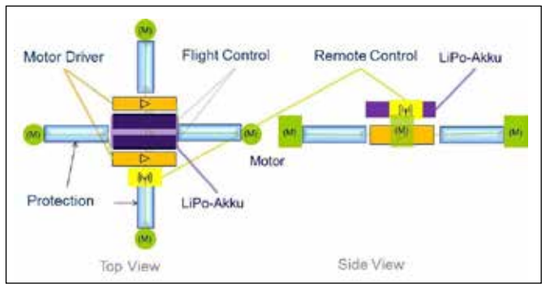

Fig.2: Micro and mini UAS consist of a simple design and few components (LiPo-Akku = Lithium Polymer Battery)

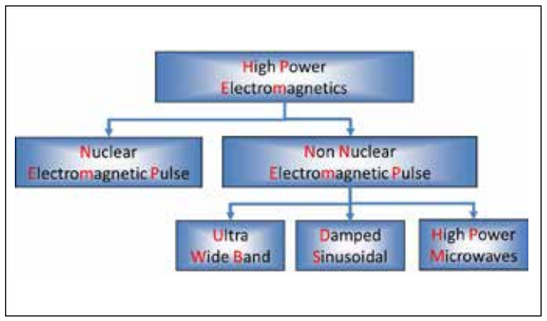

Fig.3: Taxonomy of HPEM threats

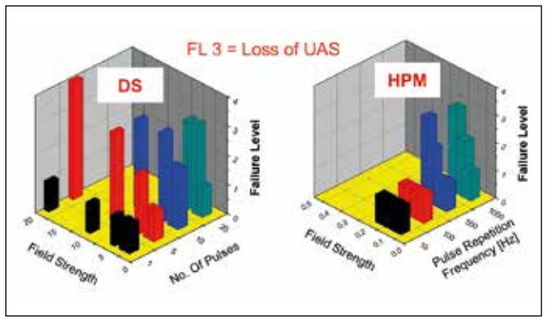

Fig.4: Susceptibility thresholds for different pulse forms

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Additive manufacturing – benefits for the Bundeswehr

By setting up a "Centre for 3D Printing in the Bundeswehr" and establishing a working group for "Additive Manufacturing in the Bundeswehr", the Bundeswehr Research Institute for Materials, Fuels and Lubricants is laying the foundations to research important defence-related aspects of this technology together with partners from the Bundeswehr, industry and research institutions.

Additive manufacturing processes have become familiar in the field of polymers under the headings "3D printers" and "rapid prototyping". These have meanwhile progressed in their development to the point where it is possible to manufacture high-quality components from many different materials. Additive manufacturing has advanced beyond the prototyping stage to become a process suitable for use in many fields, offering the potential to manufacture components in almost any, hitherto impracticable, geometry. Such processes will find use in many areas in future. Although the technology is undergoing advancement mainly in the civil sector, it will be of great importance in many different ways for Germany's armed forces due to its wide field of application. For that reason the Bundeswehr needs to examine at an early stage if, and how, the findings from civil research and use can be applied to meet military requirements. The Bundeswehr Research Institute for Materials, Fuels and Lubricants (WIWeB) has, for some years now as an organisational unit in the Bundeswehr, been exploring the practical uses of additive manufacturing processes for Germany's armed forces.

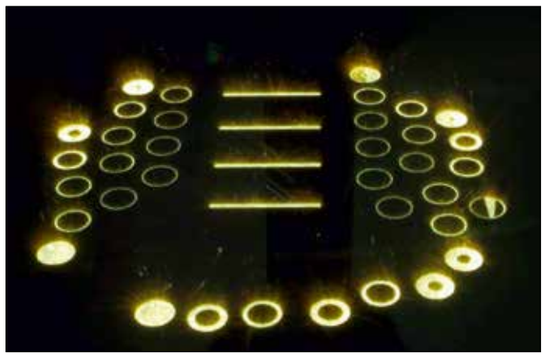

Fig. 1: Selective laser sintering – layer-by-layer buildup of specimens by melting powder particles with a laser

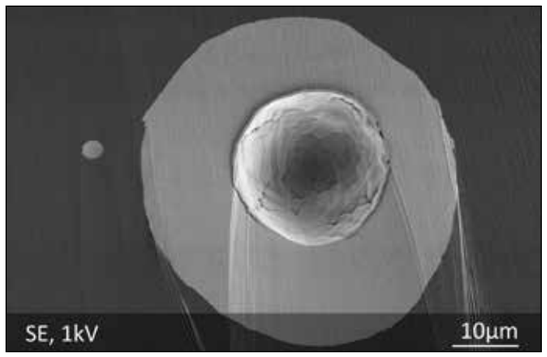

Fig. 2: Scanning electron microscope image of a powder particle with a pore (cross-section)

WIWeB initially looked into the material-related aspects of additive manufacturing in order to understand the process in detail and to ensure the necessary ability to assess this technology within the Bundeswehr. An exchange of information through continuous discussions with experts and participation in symposia and working groups is also essential so as to develop a common analysis and assessment capability with appropriate partners from industry and research institutions in defence-relevant areas. In this connection, the Bundeswehr's first symposium on this topic took place at WIWeB this year and met with great approval both within the Bundeswehr and among representatives from industry and the research community.

Actual components for particular weapon systems are being constructed and tested, militarily relevant materials and designs explored, and the behaviour of additively manufactured components examined under service conditions, in cooperation with partners, with a view to making this technology available for the Bundeswehr as soon as possible.

In addition to the above-described use of this technology, the goal of the research activities at WIWeB is to create, together with industry and external institutes, the foundations for employing additive manufacturing for spare parts replication and / or repairs in the field. For this purpose a "Centre for 3D Printing in the Bundeswehr" has been set up at WIWeB where the entire process chain, ranging from data acquisition and processing, to 3D printing of polymers and metals, to the final-machining of components, will be available. There members of the Bundeswehr and cooperation partners will be able to work on specific problems in future with the support of WIWeB staff. The "Centre for 3D Printing in the Bundeswehr" will thus offer the possibility to explore this topic holistically, in other words while taking account of all the process steps involved in the manufacture of a ready-to-use component.

A working group for "Additive Manufacturing in the Bundeswehr", headed by WIWeB and including participants from almost every area of the Bundeswehr – both military and civilian – has been established with the aim of coordinating and promoting work on this topic within the Bundeswehr. Besides cultivating cooperation and creating synergies in the Bundeswehr, the intention is to identify future work priorities in regard to this technology by integrating external experts from industry and research institutes.

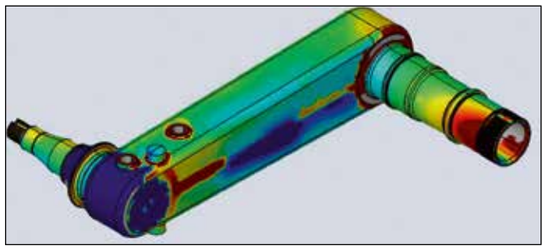

Fig. 3: Geometry model of a suspension arm – generated with a 3D laser scanner (Source: TU Kaiserslautern)

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Reducing the vulnerability of lightweight UAV structures

Within the scope of an EDA Cat B project, battle damage-tolerant UAV designs have been assessed with a view to reducing their vulnerability. Two design solutions for a wing and fuselage structure have been realised and successfully tested. Besides the improvements in regard to vulnerability, the assessment has given consideration to the impact on cost, weight and aerodynamics at the overall platform level.

An EDA Cat B project aimed at reducing the vulnerability of unmanned aerial systems (Battle Damage Tolerance for Lightweight Unmanned Aerial Vehicle (UAV) Structures, or BaToLUS) has led to the successful development of new and rapid prototype modelling strategies and simulation methods. Among those involved in the project are major European aviation industry entites, European research institutes as well as small European enterprises. This has led to an effective scientific dialogue and enabled the participating nations to benefit industrially from the collectively achieved synergies.

Extremely lightweight structures show different distributions of strength and stiffness compared with more conventional combat aircraft designs. Cost-efficient alternatives to a well-defined baseline configuration of a UAV system have been developed within the project which, while meeting the original requirements, reduce vulnerability without negatively affecting aerodynamics, weight or cost. This has involved the development of new, rapid prototype modelling methods and their successful implementation in a generic

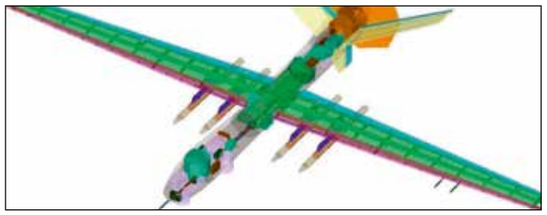

Fig. 1: Generic model of a lightweight structure for an unmanned aerial vehicle (Source: Airbus Defence & Space)

Fig. 2: Wing structure demonstrator before ballistic testing (Source: Airbus Defence & Space)

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design process that includes various vulnerability load cases and the demonstration of novel simulation methods. A large number of structural concepts designed to reduce UAS vulnerability have been identified, assessed and, where two selected concepts are concerned, implemented and tested as demonstrators, focusing on the wing and centre fuselage. To do this, material coupons and small substructures have been tested quasi-statically, using dynamic as well as low-speed impact and ballistic set-ups, and their behaviour has been simulated by means of numerical modeling. In Germany a fully instrumented wing demonstrator has been fabricated, taking into consideration typical loads as well as vulnerability load cases. The ballistic vulnerability performance of this structure has been simulated, predicted and subsequently tested using the newly developed tools, including the hydrodynamic RAM mechanism from the impact scenarios planned for the tests. Ballistic testing on a partly liquid-filled structure has been successfully carried out, and the Bundeswehr Research Institute for Materials, Fuels and Lubricants has assessed the induced damage using modern non-destructive test procedures such as microfocus computed tomography. The level of agreement between the damage prediction and the actual test results has been good. In an evaluation of the overall platform, the structural behaviour revealed by the vulnerability analyses and the aerodynamic damage, has been assessed and the design appraised with respect to cost, weight and performance capability. The main objectives of the project – to define a new UAV design and development process that takes account of vulnerability as an integral aspect, to demonstrate an improvement in current UAV modelling, simulation and design capabilities and to provide a guideline for designing less vulnerable, lightweight UAV structures – have been achieved.

The BaToLUS project has been funded by Germany, France, Sweden and the UK and carried out by Airbus Defence & Space Germany, the Fraunhofer Institute for High-Speed Dynamics – Ernst-Mach-Institut EMI, Industrieanlagen-Betriebsgesellschaft mbH (IABG), the Bundeswehr Research Institute for Materials, Fuels and Lubricants, Airbus Group Innovations France, ONERA – The French Aerospace Lab, DGA Aeronautical Systems, CEA Gramat, Dynamec Research AB,SAAB Aerosystems, Defence Science and Technology Laboratory (DSTL), and BAE Systems.

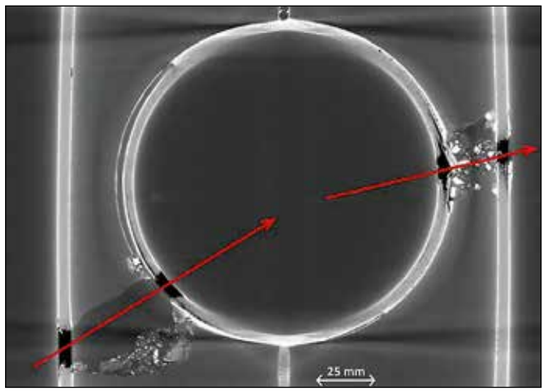

Fig. 3: Microfocus computer tomography image of a section of the wing demonstrator structure after ballistic testing

Fig. 4: Participants in the BaToLUS project

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Lightweight road wheels in a hybrid carbon fibre/metal design for light tracked vehicles

The Bundeswehr Technical Centre for Automotive and Armoured Vehicles (WTD 41) has, under the lead management of Department 220, in cooperation with the Bundeswehr Research Institute for Materials, Fuels and Lubricants (WIWeB) in Erding and manufacturing partner Capricorn Composite GmbH, developed the first lightweight road wheel in a hybrid carbon fibre/metal design for light tracked vehicles. In comparison with conventional road wheels the weight of the new design is now reduced by as much as 55% to 5.35kg.

Department 220 of WTD 41 is currently working on several individual projects devoted to the topic of lightweight manufacture that also include a lightweight road wheel described hereinafter. The reason for these projects is developments in the course of current missions which have led to a conflict of interests in the strategic transport of air-transportable combat vehicles. Although there is the call for an improvement in the level of ballistic and mine protection, the resulting increase in vehicle weight is irreconcilable with aircraft performance capability in terms of range and maximum payload. A reduction in vehicle weight is by all means desirable, however, in regard to off-road mobility and vehicle agility.

A more detailed look at the design of light tracked vehicles reveals that, on aggregate, the road wheels, return rollers and track support rollers account for the second largest share of the running gear weight after the track. Based on work that has already proven successful in regard to reducing weight through material substitution (e.g. wheel rims in motorsports), activities have been undertaken to apply this technology to road wheels for tracked vehicles. It is not, however, possible to apply the design on a 1:1 basis because the requirements are basically different. Although the absence of drive and brake torques is conducive to the design, the necessity to maintain guidance of the track centre guide and to periodically replace the road wheel tyres raises challenges which composite carbon fibre material does not cope with well. Any drift of the centre guide due to twisting of the track can cause irreparable impact damage to the carbon fibre structure, while the continual rubbing of the centre guide against the road wheel leads automatically to the erosive removal of carbon fibres, thus eventually resulting in the wheels' destruction. To strengthen the critical areas, they are reinforced by adding metal inserts, in which respect either hardened heat-treated steel or a particularly lightweight titanium alloy can be used as a wear ring.

For maximum weight reduction, the layer build-up sequence has been optimised in an iterative process consisting of a variation of the build-up sequence, alignment of the fibres, and different fibre types, in combination with a subsequent verification by means of finite element analysis. Found to be specially suited for this application is a UHT (ultra-high tensile) fibre which, besides having a high tensile strength, is characterised by high breaking elongation and thus offers significant advantages in comparison with HM (high-modulus) fibres, particularly when subjected to impact loads. The fibre has been combined with an epoxy resin-based thermosetting matrix, which represents the best compromise between impact toughness, stability, breaking elongation, hydroscopicity and glass transition temperature. The latter nevertheless lies below the process temperature for rubber-based elastomer vulcanisation, which is why only a polyurethane-based material is considered for the tread.

After the design freeze, the CAD data were converted with the aid of a CAD-CAM network into an NC programme, making it possible to mill the multi-part aluminium mould on a 5-axis milling machine. In a pre-preg process the carbon fibre was then cured at temperature and under pressure in an autoclave.

As a last step the carbon fibre road wheel was tested under continuous load on a test bench (1*10^5 load cycles) as well as in driving trials on a WIESEL DIOK running gear demonstrator vehicle (200km). In either case a computer tomography analysis showed the inner structure afterwards to be damage-free.

Fig. 1: Road wheel on a test rig

Fig. 2: Carbon fibre road wheel mounted on the WIESEL DIOK running gear demonstrator vehicle

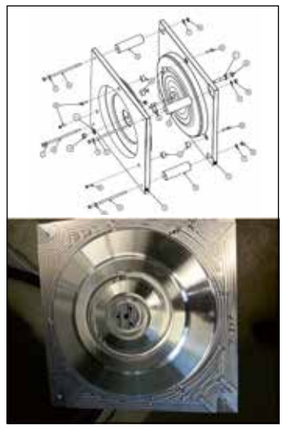

Fig. 3: 5-axis milled aluminium negative mould – WIWeB Erding

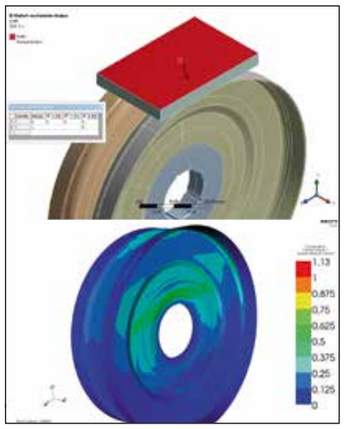

Fig. 4: FEM analysis, load application (screenshot)

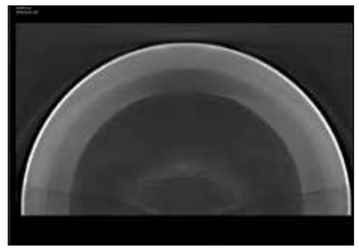

Fig. 5: Computer tomography of carbon fibre road wheel – WIWeB Erding (screenshot)

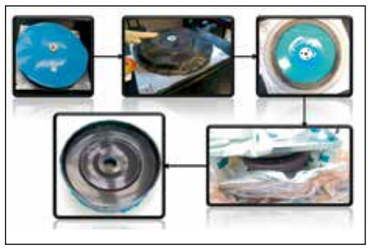

Fig. 6: Carbon fibre road wheel manufacturing process – Capricorn Composite GmbH

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Intelligent damper systems for light tracked vehicles improve target accuracy in firing mode

A new WIESEL eDK2 running gear demonstrator vehicle (electric damper control) based on a WIESEL MK 1 has been realised in a multidisciplinary project conducted by Departments 220 (lead management), 320 and 130 of the Bundeswehr Technical Centre for Automotive and Armoured Vehicles (WTD 41). Extensive modifications to the vehicle at the locations where the running gear is adjoined to the hull allow the testing and comparison of various intelligent damper system types on one single vehicle.

Through numerous activities in the past, Department 220 (Running Gear & Associated Components) of WTD 41 in Trier has many years of experience in the field of semi-active and active damper systems for wheeled and tracked vehicles. Coordinating conventional passive damper types always represents a compromise between driving safety, which requires a high damping-force characteristic line, and driving comfort, which in contrast calls for a softer set-up. Intelligent damper systems are able to overcome these seemingly irreconcilable requirements and allow adjustment of the characteristic line according to the driving situation. Modifications to the running gear can help to optimise dynamic driving performance, such as pitching and rolling, and also to prestabilise the integrated weapon system, thereby enhancing accuracy of fire on target.

In this special case a WIESEL MK 1 weapons carrier has been converted into a demonstrator vehicle whose hull modifications and reconfiguration of the track support roller and damper mountings at the forward road wheel positions now permit the integration of dampers of a larger diameter as well as of dampers fitted with additional electric actuators. The short length of track on the ground in combination with the low weight of the WIESEL 1 is not particularly conducive to making significant damper adjustments and, indeed, is more of a challenge in that respect. But for future driving and firing trials it will now be possible to undertake comparisons between standard passive dampers and semi-active dampers as well as frequency-selective dampers. The latter-mentioned dampers are available in a purely passive version with one FSD valve in rebound (extension) direction, and in a second ver-sion which is fitted with an additional FSD valve in bump (compression) direction as well as two electric actuators (D-FSD with e-lockout). It is even conceivable to do a comparison with lightweight hydro struts, which are being developed in a further project for the WIESEL MK 1. FSD dampers generate a damper force which is dependent on the excitation frequency. As a rule, the higher the frequency, the lower the damper force, and vice-versa. This makes itself noticeable during vehicle operation through greater driving comfort yet undiminished driving safety. Moreover, the integrated electric actuators allow complete locking of the extension and compression stages, making it possible to reduce vehicle body movement significantly when in firing mode. Past testing of the semi-active damper's predecessor version has already shown that a higher damper characteristic line reduces vehicle body movement and target deviation.

The results of the firing trials that have been conducted at WTD 91 in Meppen clearly vindicate the initial assumption. Both the photogrammetry analysis of the weapon and vehicle movement and the acoustic hit recordings show the reduction in barrel deflection to be greater than 80% over wide areas in Y-direction for a burst of 7 shots and turret position of 0° in active damper lockout mode. Also worthy of mention is that the D-FSD damper in non-active mode reduces deviation by more than 70% in comparison with the standard passive dampers. Slight target deviation is also discernible in active mode, while in X-direction the improvements tend to be marginal. These effects are attributable to weapon movements, something which has been verified through detailed analyses of the relative movement of the weapon barrel assembly and vehicle body.

Firing and driving trials involving the other damper systems are planned for the future with a view to comparing data afterwards and being able to arrive at an informative damper recommendation.

Fig. 1: WIESEL eDK2 running gear demonstrator vehicle – detailed view of the running gear

Fig. 2: WIESEL eDK2 and WIESEL DIOK running gear demonstrator vehicles – WTD 41 testing ground

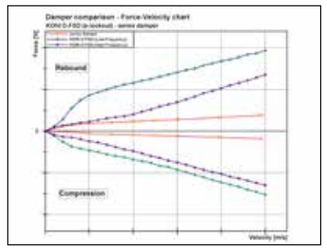

Fig. 3: Comparison of damper characteristic lines: passive damper & D-FSD damper

Fig. 4: Firing test measurement setup at WTD 91 in Meppen

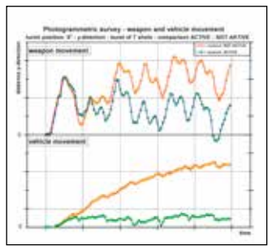

Fig. 5: Comparison of weapon and vehicle body movement in Y-direction

Fig. 6: Comparison of target deviation – damper mode lockout function ON & OFF

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Experiments to determine the protective properties of gabion systems when exposed to blasts

Heavy protective walls are typically the first and most important structural measure for protecting field facilities against the threat posed by car bombs. Experiments have been conducted at the Bundeswehr Technical Centre for Protective and Special Technologies (WTD 52) with the aim of enhancing numerical models designed to simulate the reaction of protective walls to blast detonation.

Heavily constructed walls represent a practical and effective method for protecting camps against direct and indirect ballistic attack on operations abroad. They are also a proven means of mitigating the effects of large explosive charges, especially in the form of VBIEDs (Vehicle Borne Improvised Explosive Devices). This class of reinforced protective walls includes barriers based on flexible honeycomb systems and chain-linked concertainers (gabions). The protection is provided essentially by the large amount of fill material. The dimensions of the gabions and the type of filling material can vary according to the required level of protection.

A software-based tool is to be developed so as to make the planning of protection for in-theatre accommodation easier in future. By using this software tool it should then be possible to exactly simulate the extent of damage caused to protective walls and barriers after exposure to weapons effects. It should additionally be possible to simulate collateral hazards such as secondary fragments.

Fig. 1: Large Blast Simulator (LBS) with pressurised bottles

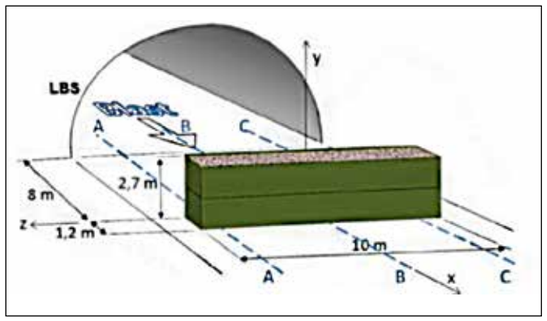

Fig. 2: Experiment set-up

To do this it is necessary to gain precise knowledge about the deformation behaviour of these protective walls. Many factors, such as type of filling material, geometry and friction, have an influence on the deformation behaviour. The exact correlations need to be explored experimentally for the purpose of generating the numerical simulations.

Experiments have been performed in the Large Blast Simulator (LBS) at the Bundeswehr Technical Centre for Protective and Special Technologies (WTD 52) in Oberjettenberg. Technically the LBS (Fig. 1) is a shock tube and is driven by pressurised air (filled in bottles). The sudden pressure surge (blast) comes about through the abrupt expansion of compressed air, which rapidly flows into a tube (within a tunnel inside a mountain). There a blast wave is formed by the very quick release of pressurised air from several compressed-air bottles whose closure mechanisms are opened through the detonation of high explosives.

The chain-linked concertainer and the flexible honeycomb structure systems (Fig. 3) were used for the series of experiments (Fig. 2). A wall size of 10.0 m x 1.2 m x 2.7 m (W x D x H) was selected for both types so that test results would be comparable. The wall position and configuration of the bottles (number, pressure etc.) were chosen in order to reproduce the blast loading of the corresponding far field scenario.

Each protective wall system was exposed to two different blast loads. Since each experiment was repeated at least once, nine in total were conducted. During the test series, pressure gauges and accelerometers, in addition to high-speed and HD video cameras, were used to evaluate the response. Photogrammetry was also performed before and after each experiment in order to graphically visualise the deformation of the wall in terms of 3-D point clouds. The transient displacement of the walls was determined by analysing high-speed video recordings. A research institute also identified important sand properties.

Based on the results of the experiments, and as part of a close collaboration between WTD 52 and the Defence Science and Technology Laboratory (Dstl) in Great Britain, it has already been possible to develop a preliminary approach for the development of a software tool (Fig. 4) to simulate the structural behaviour of protective walls. With the knowledge and information that has been gained from the experiments, there is now also the opportunity to validate, further develop and enhance the numerical models.

Fig. 3: Chain-linked concertainer and flexible honeycomb structure systems of bulk material-filled concertainers

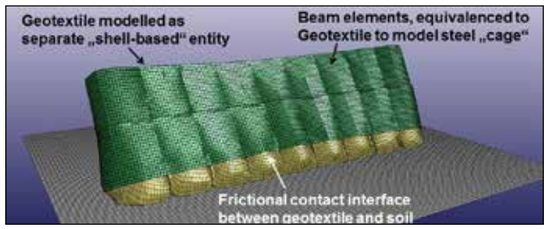

Fig. 4: Example of the numerical simulation model

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Underwater gliders – a trend-setting measuring platform for operational oceanography

The high variability of oceanic processes affects the performance of maritime detection and defence systems. Knowing the mechanisms and relationships involved will determine the success of naval and civilian operations. Autonomously operating underwater gliders record tactically relevant information concerning the stratification and current conditions with a high temporal and spatial resolution.

The demands facing operational oceanography in the 21st century are complex and very often characterised by naval missions worldwide. Up-to-date and useful environmental information within tactically relevant time frames is essential for reliable predictions of acoustic detection ranges in operating areas so as to gain an information edge and tactical advantage over possible adversaries.

The most recent knowledge possible about the local stratification of salinity and temperature is important particularly for predicting underwater sound propagation, to be able to calculate the depth-dependent sound speed profiles and the depth and characteristics of the sound channel. The sound channel is of profound interest in this regard as it is conducive to the propagation of sound energy over large distances, its location and properties being shaped by ocean dynamics in the form of oceanic fronts and eddies. Numerical regional prediction model systems - similar to those used in numerical weather prediction – are employed to predict mesoscale structures extending between 10 km and 200 km.

Fig. 1: Glider deployment

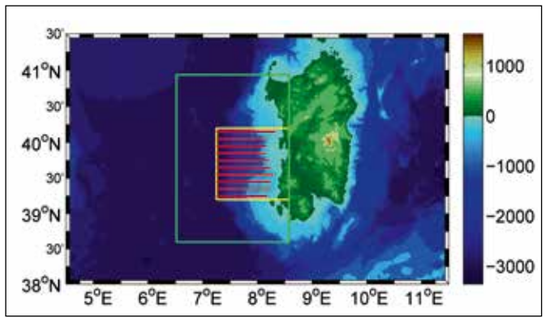

Fig. 2: Experiment to forecast ocean currents and stratification west of Sardinia in June 2014: observational area (yellow box), modelling region (green box), and sections to be measured by the gliders (red lines). Coloured contours depict heights and bathymetry in metres

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Nowadays, autonomous measuring platforms, referred to as underwater gliders (Fig. 1), ideally supplement the cost- and personnel-intensive use of survey vessels stationed in operating areas. These independently operating underwater robots record vertical temperature and salinity profiles down to a depth of 1000 m, the data being required as input for model calculations and for assessing the prediction quality. They resurface at predetermined times or waypoints and transmit their data in near-real time via satellite phone to the operations centre or, as appropriate, receive the coordinates of new waypoints. Gliders operate energy-efficiently, are quiet, and their mission duration may be as long as several months. Given their short presence on the sea surface during communication with satellites and the near-invisibility of their antenna, they can operate more or less covertly. Compared with a research vessel, however, they are too slow to be able to prevail against a strong current.

In June 2014, the Centre for Maritime Research and Experimentation (CMRE) and the Bundeswehr Technical Centre for Ships and Naval Weapons, Naval Technology and Research (WTD 71) conducted a joint sea trial west of Sardinia to demonstrate the capabilities and operational benefits of concentrated glider deployment. In close collaboration with 18 partners from six NATO nations, the German research vessel RV Planet and NATO research vessel NRV Alliance surveyed a sea area measuring 10,000 square kilometres during a three-week period using various platforms and instruments (Fig. 2). An important contribution was made by the fleet of eleven gliders which, during that period, acquired a total of more than 4,500 data profiles along a track of more than 3,000 km. Fig. 3 shows the vertical sound speed distribution along a section at 39°21'N.

Compared with the classic possibilities offered by a research vessel and mooring, gliders offer an initial high-resolution situation picture spatially and temporally, as well as a higher measuring performance, irrespective of the sea state and meteorological situation, and lighten the work burden of research vessels.

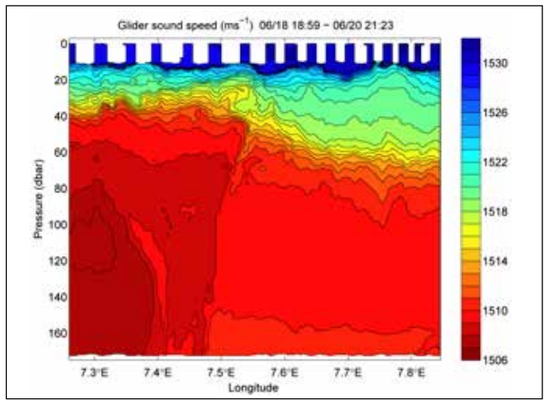

Fig. 3: Sound speed section west of Sardinia along 39°21'N, measured by a glider

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Android app validation

Accessing information from mobile devices is becoming increasingly commonplace. The use of applications (apps) for mobile end-user devices, especially those that are Android-based, will become increasingly relevant in the Bundeswehr in future. To satisfy the requirements of such a security-critical environment, these apps have to be tested and validated in terms of IT security.

Through the widespread use of mobile applications and the development of ever more efficient hardware as well as a wide variety of sensors, these apps not only offer increasing possibilities but also pose higher risks as a result.

Research in the field of security-related app validation is still in its relatively early stages. The Android operating system has been on the market since 2009. In terms of market share, it outweighs other mobile operating systems such as iOS, Blackberry OS and Windows Phone by far at more than 80%.

In a study of the 10,000 most popular Android apps from the official Google Play Store conducted in the first quarter of 2014, the Fraunhofer Institute for Applied and Integrated Security AISEC found that many apps can be ranked as critical with regard to IT security. For example, 69% of those apps used unencrypted communication, and 49% identified the location of the user, while 448 apps transmitted the device's unique identifier code (IMEI) as soon as the app was started.

It is very difficult for the end user to differentiate between legitimate and malicious apps. Although it is possible to check the permissions for an app before installing it, there are however ways and means for an app to evade certain permissions and to embed malicious content in an existing app (also referred to as 'repackaging'). Besides this, there is malicious software (malware) which can exploit certain gaps within the Android operating system to perform random actions on smartphones beyond the control of the security system.

In this connection the need to set up an innovative test environment for the identification and assessment of vulnerabilities in Android apps has been pinpointed. It has been possible to win the support of Fraunhofer AISEC for the R&T "validation of apps" study conducted within the framework of the Military Mobile Computing (MMC) project. Fraunhofer AISEC has developed a testing process and integrated test workstations into the test environment of Branch 210 ("IT Security") at the Bundeswehr Technical Centre for Information Technology and Electronics (WTD 81).

In the course of two workshops, up to four staff members of Branch 210 have received training from AISEC experts on app fundamentals, the Android security model, threats and attacks, how to perform app analyses, use of the Android app analysis tool "App-Ray", and the evaluation of security-critical data. App-Ray can be used for a fully automatic analysis of Android apps as well as various security problems, data leaks and programming errors. In addition to a metadata scan which includes the files contained in the .apk-package and the AndroidManifest.xml, a static and dynamic analysis is carried out.

In the static analysis the bytecode contained in the app is disassembled and analysed for code structure, data streams, contained strings and invoked API functions. The major advantage of static analysis is that the entire contained code is analysed irrespective of the time of execution. In the dynamic analysis the app is run in a virtual analysis environment where its behaviour is monitored. Interaction with the app while it is running is also possible. It offers the advantage that dynamically reloaded code and any communication with external servers can also be monitored.

In summary, it can be said that security-critical problems exist in many Android apps, especially where not enough importance has been attached to security-specific aspects during the apps' development. Identification of these risks as early as an app's development phase is thus highly desirable as, at that stage, it is still possible to correct identified problems cost-effectively before the apps are used in a military environment.

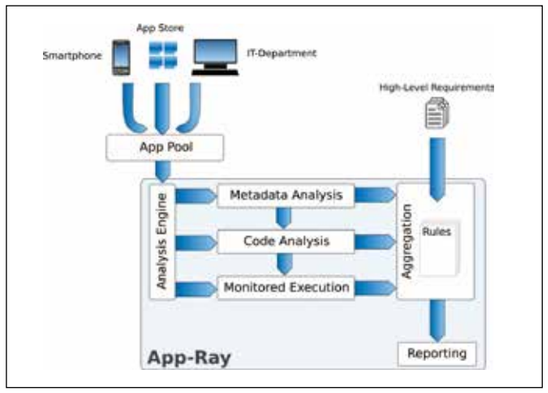

Fig. 1: AppRay architecture

Fig. 2: AppRay Logo

Fig. 3: Connections

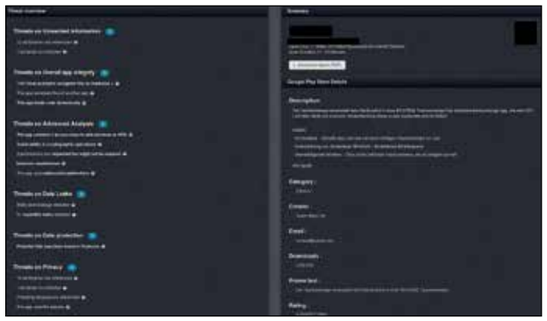

Fig. 4: AppRay results overview (screenshot)

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Research on precision-enhanced ammunition for machine guns with automatic aiming correction

Automatic aiming correction in combination with automatic weapons is being explored with a view to increasing the density of hits on target during burst fire. Such a system would detect any deviations in the munition's detonation point relative to the aiming point and automatically correct the weapon's aim for the next shot

To achieve a high density of hits with burst fire from a machine cannon and thus a high probability of hitting a target, it is neces-sary to minimise the overall system deviation of the weapon and its ammunition.

With the current state of the art, established automatic weapons and their ammunition are designed in such a way that, through systemic inaccuracies and external influences such as side winds, they do not automatically impact directly on target but achieve a statistical spread within a larger dispersion circle. This inaccuracy has, as a result, to be compensated for through a higher number of shots.

The probability of destroying smaller targets with short fire bursts (2-3 shots) thus diminishes. Such effective use of ammunition would nevertheless be desirable in view of the limited weight-carrying capacity that vehicles have.

The approach pursued with the automatic aiming correction technique can help the gunner in that it uses a modified electro-optical aiming sight to automatically register the target

Fig. 1: Principle of automatic aiming correction, first shot (Source: DBD)

Fig. 2: Principle of automatic aiming correction, corrected second shot (Source: DBD)

Fig. 3: Sensor platform for the detection of detonation flash (Source: DBD)

dispersion of each individual shot from a fire burst, based on its detonation blast in the target area. The telescope units of modern remote-controlled weapon systems can be set up for suitable image processing whereby the detonation signature of the last shot is registered and, from that, a better aiming point for the next shot is calculated. A sighting correction is then made for the new aiming point and the weapon is automatically redirected for the next shot. This makes it possible to compensate for an entire sequence of variables, ranging from aiming errors to external influences, for each following shot (until a new target is acquired).

Such a system has to meet two requirements: reliable detection of the detonation flash of its own ammunition, and a high intrinsic precision of the ammunition and weapon. Reliable detection, however, requires the projectile to by all means detonate in the target area and the timing of the detonation to be known. This is the case for modern time-fuzed HE ammunition. It has been possible to demonstrate within the scope of the conducted studies that shot detonations are reliably detected in a very tight time window.

Good intrinsic precision of the ammunition and weapon is necessary in order to have as little statistical target dispersion as possible. The following steps were explored in 2015:

- greater intrinsic precision of conventional full-calibre (HE) ammunition
- detection of the detonation point

Using an ammunition concept for the 27 mm calibre, it has been possible with multiple single shots to realise a dispersion smaller than 0.5' (evaluated with the D90 method). A very effective, lightweight barrel vibration damping device has additionally been developed as a measure to help reduce the jump of the weapon.

Automatic aiming correction has the potential to significantly reduce the number of shots required for the precise neutralisation of small-area targets. The diagram in Fig. 5 shows important elements of automatic aiming correction. Current research at WTD 91 is focusing on the need to increase the inherent precision of time-fuzed HE ammunition, the requisite design work for which has been conducted at Diehl BGT Defence (DBD) in 27 mm calibre and is later to be validated in 50 mm calibre.

WTD 91plans to carry out the following next steps to demonstrate the automatic aiming correction system as a whole technologically: proof-shooting with the selected ammunition concept; verification of the required fragmentation efficiency; and integration of image analysis electronics and tracing software into an existing electro-optical sighting system.

Fig. 4: Precision ammunition, 27 mm cal. (Source: DBD)

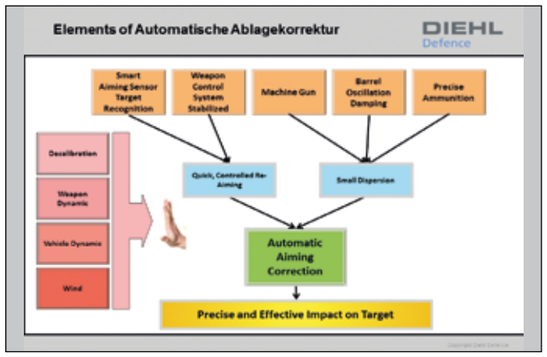

Fig. 5: Elements of the automatic aiming correction system (Source: DBD)

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Biometrics

A request to record, process and transmit biometric data in the Bundeswehr has been expressed for the first time as a system capability requirement relating to the field of intelligence, leading to a study in which commercially available technical solutions permitting mobile biometric data acquisition have been examined and assessed for their suitability for military scenarios. Capabilities for face recognition and for identification at a distance of several metres have also been developed.

Within the framework of a study entitled “Biometrics”, overseen by the Bundeswehr Technical Centre for Weapons and Ammunition (WTD 91), the Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB and enterprises Videmo, Diehl BGT Defence and Airbus Industries have been contracted to carry out the accompanying scientific work.

Scenarios have been derived from a system capability requirement relating to the field of intelligence. A first scenario concerns the acquisition of biometric data from persons who behave cooperatively. Mobile, hand-held devices are able to record and process a very broad variety of biometric data without any time constraints.

In a second scenario a person under investigation is described as behaving non-cooperatively. The military user is supported in identifying and recognising persons in complex situations – several of whom at a distance, largely by means of automated procedures.

Fig. 1: Selected components – Crossmatch: SEEK II and Avanger, RED: Dragon (from left to right)

The large variety of possible biometric attributes such as finger prints, iris, hand veins, ear shape, voice, facial image and body motion have been examined to see to what extent the biometric techniques in use can extract attributes that, although present in all humans, are nevertheless different for every person yet are constant over time.

The first phase of the study has been about whether, and to what extent, compact hand-held devices available on the market are suitable for acquiring and processing biometric data for use in military environments. Based on the biometric algorithms and devices that have already been under development for years for the security forces, such as the police, border control (Federal Police) and customs authorities etc., it has been possible to identify and explore several avenues. One device has stood out as it embodies a multitude of the required features and is also MIL-STD 810-certified.

The second study phase has involved examining and further developing possibilities for automated observation of limited open spaces over lengthy time periods. Detecting, recognising and identifying a person under varying ambient conditions has proven to be a particular challenge as the aim has been to extract biometric data in scenarios where non-cooperative people move about in a crowd.

The demands on the sensors used for such purposes are high as a minimum of 70 pixels per pupil distance is required to be able to extract biometric attributes. The sensors must have a very high resolution while being very photosensitive and capable of operating in a high dynamic range.

The study has focused on the visual spectral range so as to keep the technical outlay within limits. Factors influencing single-sensor facial recognition and identification, such as resolution, blurring, compression artifacts, illumination, noise, non-frontal aspects, occlusion and mimic, have been explored and solutions realised for identifying biometric facial features at a distance. Combining individual sensors and handling the huge amounts of data involved have represented a further focal point of the research study.

The results of these developments have been successfully demonstrated in several live scenarios at WTD 91. Potential military users have been invited to these demonstrations to inform them about the state of the study work. The study group has also benefited from the direct response of users, enabling it to adjust the study foci according to actual requirements. The now concluded “Biometrics” study provides the baseline for a potential decision on the procurement of hardware for mobile use in military scenarios. Several technical solutions for facial detection and identification at a distance are now available to the Bundeswehr for the visual spectral range.

Fig. 2: Face captured in the visual, near-infrared and mid-infrared range (from left to right) source: Diehl BGT Defence

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Secure mobile devices: sustainability despite fast-paced changes in hardware and software

The special challenges of mobile computing lie in the fast-paced changes in hardware and software. It is not conducive to adopt every small change immediately, but rather to make adjustments in suitable cycles. The life cycles are frequently so short, however, that the latest solutions are already obsolescent by the time the mobile devices are made available to users in-theatre. A study has revealed options for agilely and dynamically updating a mobile ecosystem in terms of functionality and scope.

Daily routine without mobile devices is no longer imaginable, with there also being various ways of using them in military, tactical environments in the meantime. They are thus an integral component of system architectures in the "Letzte Meile (Last Mile)" programme as well as for other users. An unresolved issue in this regard is the fast-paced dynamics of hardware and software development and, consequently, obsolescence.

The study has focused on the updating and design of a mobile ecosystem throughout its life cycle. For the purposes of sustainability, the most up-to-date, sufficiently secure and functional "intermediate solution" possible for the ecosystem needs to be used, while giving due regard to risk reduction, until that solution is updated by the next improved incarnation. The objective is always to have an up-to-date version available and to ensure interoperability through selected standards and apps, and to make adaptations of functionality quickly possible on the basis of app updates. The basic assumption is that all technical challenges resulting from new requirements can be resolved in the course of one life cycle; but that this cannot and need not be done immediately on day one. This has led to the selection of an agile development model (Scrum) for further technical developments and associated individual approvals for operations in co-operation with BSI (German Federal Office for Information Security).

The underlying technology for this is called "trust|me" (trusted mobile equipment), a hardened Android-based operating system developed at Fraunhofer AISEC. The design aim of "trust|me" is to minimise the effort involved in porting to new end-user devices and also to configure necessary modifications on the Android platform in the least invasive way possible, in parallel with implementing a strong isolating mechanism for separating several information spaces and further security functionalities. Because of the resulting compatibility with the open-source Android platform, the "TOP-5 apps" from the Bundeswehr AppStore familiar from the "Letzte Meile" programme can also be used.

Technical advancement is agile and based at all times on current requirements. Enhancements may affect the backend infrastructure or the mobile end-user devices directly. They are implemented in the most modular, isolated and interchangeable manner possible to suit the architecture. Besides enhancement by way of apps, "trust|me" implements operating-system-level virtualisation for this purpose that allows isolated running of "operating system containers". Implemented at the moment, for example, are a "SharedStorage" for maps and charts, the integration of a location service including a military GPS, the connection of specific security tokens, and the realisation of specific VPN configurations.

Further activities, such as security testing, a risk analysis including identification of appropriate risk minimisation measures, and preparation of documentation, are ongoing with the aim of obtaining the required approval. The establishment of an app validation process that is as widely automated as possible is another important component, so as to minimise app updating efforts in this context.

Preparatory measures for the next incarnation, or cycle, are being conducted in parallel, such as porting to new hardware, additional drivers (e.g. radio systems), and more. In the next step there will be joint testing of the platform together with potential users, as well as the preparation of multinational interoperability tests (CWIX), field testing, etc. The activity is due to extend over several years since the objective of the study is to examine sustainability, interoperability, and acceptance on the part of the user. Not until the meanwhile attained intermediate result has been ported several times, approved, upgraded, linked to other systems and used, can successful support of the entire ecosystem's life cycle be assumed and also derived for Customer Project Management projects such as "IT Services for Mobile Bundeswehr Elements" or "Command and Control Support for Small and Miniature Contingents".

Fig. 1: The 3-stage mobile ecosystem allows flexible combination of apps by way of the secure platform, which is based on standardised and transparent IP transportation networks

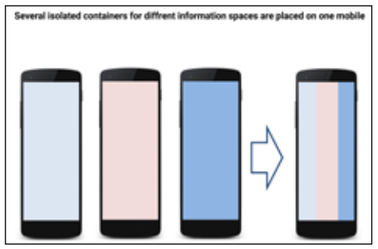

Fig. 2: Multiple isolated areas for various information spaces on one mobile device (here: Nexus 5)

Fig. 3: The TOP-5 apps originate from the "Letzte Meile" programme; as micro apps, they can combine their functionalities and be linked to a back end based on micro-services

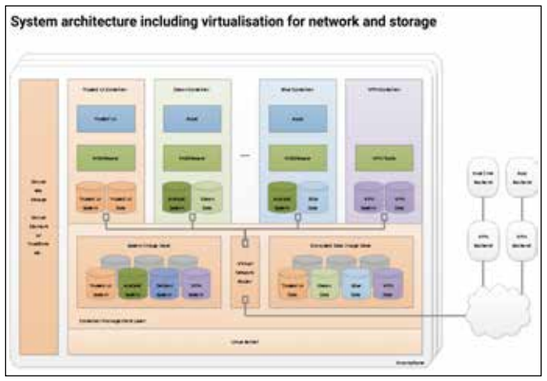

Fig.4: Overview of the trust|me architecture including network and storage virtualisation

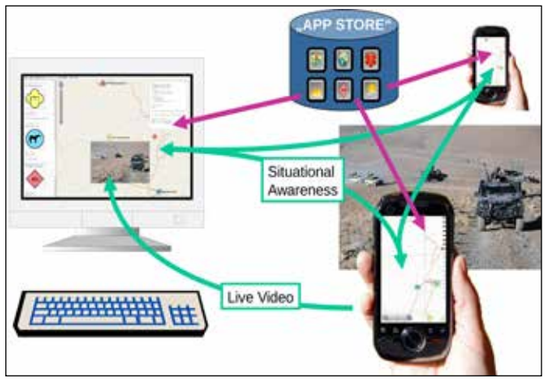

Fig. 5: Mobile computing links combat operations centres to mobile device sensors and creates real operational pictures as well as a common situational awareness

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Wearables offer new perspectives for voice radio links and BlueForceTracking

Military users are, to an increasing extent, adding portable computing devices to their inventory for tactical operations, thereby gaining a potent supply of information in addition to voice communications. The greater sensor and processing capacities created through miniaturisation in the form of "wearable computing" are opening up new avenues in classical fields such as voice radio or situation display.

With mobile computing devices having become a dominant feature in our everyday lives, the march of miniaturisation continues unabated, offering us a new dimension of sensors, processing capabilities and human-machine interfaces in the form of "wearables". A multitude of devices also appear suitable for a wide range of uses in the military tactical environment. The importance of oral command and control assets such as voice radio is repeatedly emphasised in the tactical domain as being a channel for (audio) information that complements the main activities (observation, fighting, etc.). There have been extensive technical innovations in recent times, while the basic user interface of "think - press - speak - listen" has remained almost unchanged for the last 100 years.

New possibilities have been explored with a view to widening the voice radio channel so that information on situation and status is transmitted in addition to language. The aim of such exploration has been to integrate any supplementary information from portable computing devices and wearable sensors into the channel without the need for any additional user interaction and with the subsidiary character (concurrence) of this asset thus being retained. The "3D voice radio" and "BlueForceTracking with supplementary information" applications have been defined as examples.

Fig. 1: Wearables such as headsets or networked sensors on weapons or clothing, for example, ensure the sharing of information and enhance map display or voice radio communications by providing 3D information

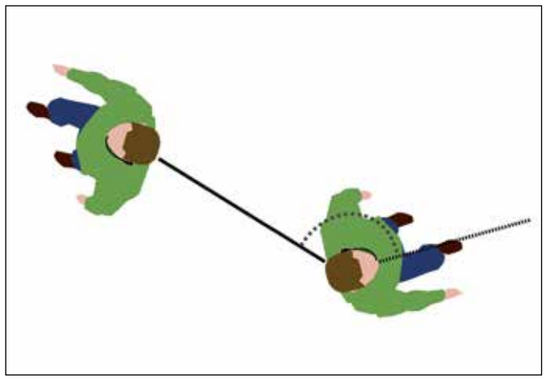

Fig. 2: A highly capable headset sensor and processor unit serves to combine soldiers' orientation in the field with voice intelligence

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Both applications have been considered for the operational scenario of a squad-size reconnaissance team. With 3D voice radio, an enhanced stereo effect provides the listening person with information about the relative position of the speaking person. The information required for this comprises the locations of the speaking person and listening person as well as the viewing direction of the listening person. Sensors in the headsets help to ascertain this (the technology for which is commercially available). The distance between the speaking and the listening person can be additionally indicated via the voice channel in diverse ways, for instance by means of the sound volume or through reverberation effects. Further exploration and practical trials are necessary in this regard in order to identify suitable methods that least affect intelligibility.

The "BlueForceTracking with supplementary information" application communicates additional information besides the locations of individual persons. In the explorative work conducted so far, this has been information in the form of bio-parameters such as pulse rate and body temperature. Communicating such data via the voice channel is not always practical, for which reason other channels are being sought that retain the principle of concurrence (e.g. haptic, by way of vibration). Generally, the aim is to decouple the type of information from the way it is displayed. Procedures for transforming language into text or language synthesis are thus becoming relevant as ways to create a gateway to text-based channels such as the TOP-2 app "WhatsBw" or "JChat".

As, in particular, the issue of user acceptance will have to be considered besides the technological challenges involved, the next planned step is to test a prototype system jointly with potential users and to prepare field trials. The complexity of the technology and the expected variety of possible applications make a longer-term study necessary, since the only way to achieve the desired level of quality is to carry out frequent reviews and tests together with the users in an iterative approach. User acceptance of the current state of voice channel development will be crucial for successful implementation of the selected method as well as for easing the demands on the user.

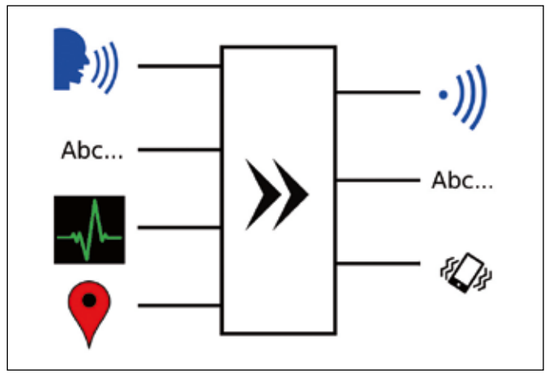

Fig. 3: The networked devices interconnect the sources of information (TOP-2 App, BlueForceTracking, language etc.) via a user-customised matrix to a single voice channel

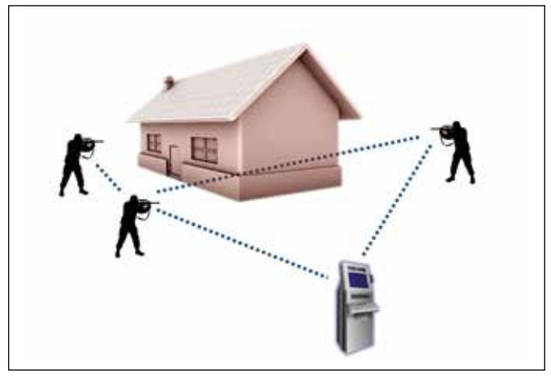

Fig. 4: Application is being explored and tested in training exercises, taking as a basis a recce squad and its information exchange with command posts

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WhatsBw, or: a virtual shared information space clad in a modern app

Social media are part of everyday life for users of mobile computing. Even when on deployment and in peacetime operation, messaging and thus social media can become significant components of official communication. Using a modern web service as a basis, an agile and dynamic social media app has been created so that official information is not openly shared on the internet yet is permanently available and can be used for official purposes.

As mobile devices are introduced into daily military routine, there is also a growing demand for modern information exchange apps. User surveys conducted within the "Letzte Meile" (Last Mile) programme have shown that, besides voice communication, messaging is becoming more and more important as a TOP 2 app.

Use of commercial or public social media products for official purposes is however prohibited, not only for security reasons. Information exchanged via such media may be used sustainably from diverse perspectives and for further analysis as a knowledge base only if the web service is under the complete control of official authorities.

Conceptually, information flows in messaging between individuals and groups constitute interlinked shared information spaces in the manner also understood in Network-Enabled Operations (NEO). In previous studies this understanding has been broadened to include a NEO-capable information management process and demonstrated prototypically with the aid of metadata registries and repositories. The objective of the new study has been to show that the availability of new technologies in the form of graph databases for a simpler display and repository of shared information, in combination with a lean processing layer and a dynamic presentation layer by using HTML5, meets today's requirements for reactive and flexible application development. The messaging application example has been selected so as to demonstrate the technology approach and has been supplemented with specific military features such as formatted messages, evaluations and displays.

A modern architecture that, at its core, shows the information model as a graph forms the basis in this regard. All of the components that build upon this use the same data model, which can easily be extended since it persists in a schema-less graph database. Subordination of the presentation layers under the overarching information model and their close integration simplify the development and adaptation of applications such as REST-API/web service, HTML5 or native apps in their complexity to the configuration of various display modes.

The central rights management system and the integration of business logic into the information model reduce the complexity further in favour of high flexibility. It is thus possible to include interactive elements such as system profiles, and the media-neutral repository permits the output of information in almost any desired new form of aggregation and export format. The standardised component architecture is currently undergoing further development so that services can also run autonomously and in distributed mode in the manner of a microservice environment. Features such as modularity, encryption and open-source standards – requirements that the platform already meets – are important in this respect. The selected combination of a graph database including HTML5 processing and presentation layers has proven to be practical. It allows high flexibility in meeting changing demands during operations, particularly where the fast-paced display of information models and the dynamic build-up of user-driven displays with processing and information integration modules added from the modular system are concerned. Although the web apps can also be provided as a mobile client, the latter has disadvantages with regard to bandwidth and availability compared with native apps. For this reason, and in order to exploit all the functions of mobile devices, the "WhatsBw" Android app is indispensable as a TOP 2 app. Tests involving potential users, as well as interoperability exercises (such as CWIX) and field trials etc. are at the preparation stage. The ecosystem comprising a secure mobile device and the other TOP apps will, in combination with the resultant shared information space, play a central role in the "IT Services for Mobile Bundeswehr Elements" or "Command and Control Support for Small and Miniature Contingents" initiative.

Fig. 1: All users share the information to which they have access in semantic order in accordance with the information requirements of their communities of interest

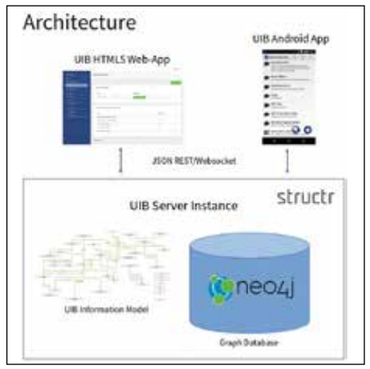


Fig. 2: The basis of the technology is a 3-stage architecture comprising a graph database, a processing layer including REST interface, and a graphic user interface (HTML5)

Fig. 3: The information models can be created and maintained realistically in a graphic schema editor

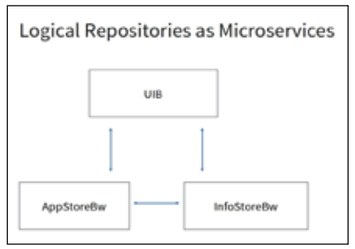
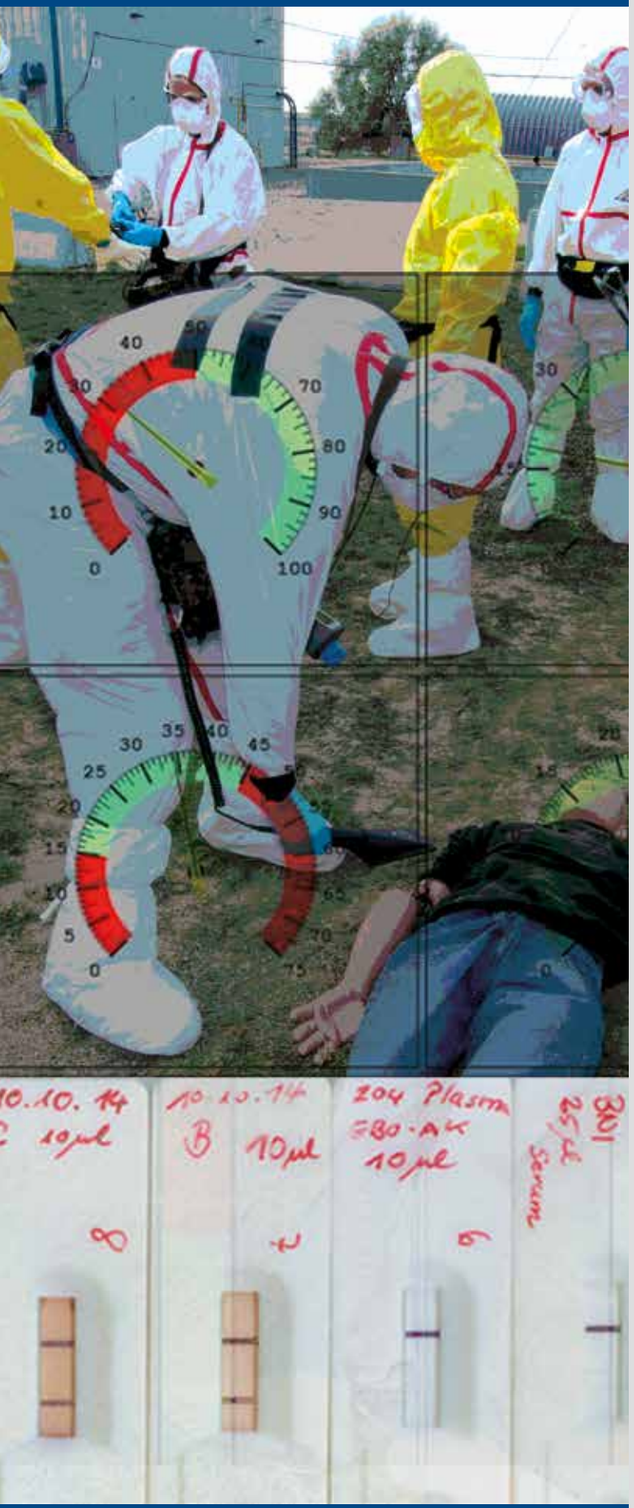


Fig. 4: Various applications (such as WhatsBw, AppStoreBw etc.) are combined as microservices

Fig. 5: For classic IT there is a web app that can be accessed by all common browsers, as well as a native Android app for smart phones

Fig. 6: In mobile communication the Android app enables access to the shared information space anywhere and at any time



2

Military Medical and Military Psychology Research

The paramount priority of the Bundeswehr Medical Service is to preserve and restore the health of the service personnel entrusted to its care. Potential health threats during service in the armed forces are manifold and range from severe physical and mental stress as early as in the course of exercises and routine duty, to the danger of severe wounding on operations, to the risk of exposure to biological and chemical agents or ionising radiation. To make optimum prevention, diagnosis, therapy and aftercare possible in step with changing risks and the state of advancing medical science, the Bundeswehr Medical Service undertakes a variety of research activities at its own departmental research establishments as well as in cooperation with partner universities.

The focus of clinical medicine and CBRN medical defence is on the special aspects of in-theatre medical support. The challenges of Bundeswehr-specific working conditions and associated individual personnel performance requirements are considered from the perspective of military ergonomics and occupational physiology, while the field of preventive medicine and hygiene covers specific aspects of preventive health care. The research institutes of the German Air Force and Navy explore specific issues that arise in aviation, diving and maritime medicine in regard to the particular health burdens which ensue from such assignments.

The articles hereinafter present some examples of the projects being conducted in the field of military medical research.

Some one-and-a-half years ago, the Ebola outbreak in West Africa assumed dramatic proportions and gave rise to the fear of it posing a threat far beyond that region. Containing the outbreak became the aim of an assistance mission in which the involvement and expertise of the Bundeswehr Institute of Microbiology were crucially important. The article contributed by that institute describes the development and optimisation of rapid test procedures for detecting bacterial and viral pathogens which were also used during the mission. The capability to rapidly identify an outbreak is vital for the Institute and for the biological medical defence task force it provides. Another article contributed by the Bundeswehr Institute of Microbiology concerns the genotypic typing of pathogens as part of identifying a glanders outbreak in Bahrain.

Recently, there have been disturbing reports of possible chemical agent attacks carried out by Islamic State terrorist militias. The capability to biomedically verify potential exposure to chemical agents or chemical attacks is increasing in importance again, given the current situation. An article by the Bundeswehr Institute of Pharmacology and Toxicology describes the Institute's role as a partner of the Organisation for the Prohibition of Chemical Weapons in the field of biomedical verification, based on years of intensive research work at the Institute.

The Bundeswehr universities are growing in stature as highly productive partners in military medical research. The RAAPIT medical intelligence software developed at the Bundeswehr University, Munich, greatly improves capabilities in this field and can deliver important information for the management of countermeasures and the protection of German military personnel in the event of natural outbreaks or of a biological attack involving a possibly transmissible pathogen. The Bundeswehr University, Munich, also undertakes military medical research in the field of post-deployment stress disorders and describes in a subsequent article the development of an app as an easily accessible, straightforward means of support for PTSD sufferers.

A closely related topic is military psychology research, as conducted at the Bundeswehr Armed Forces Office whose contribution describes their spectrum of research activities.

An article contributed by the Bundeswehr Medical Service Headquarters reports on the scientific development of a system of performance indicators for occupational health management within the area of responsibility of the Federal Ministry of Defence.

Cognitive processes and performance capability are also the central topic of an article from Department IV of the Central Institute of the Bundeswehr Medical Service, Koblenz. Its authors report on the simulation of screen-based tasks for analysing external and internal influences on job performance.

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Military medical research in the field of psychological trauma sequelae at the CODE Research Centre

The posttraumatic stress disorder (PTSD) is getting into focus of public interest due to deployments abroad. In cooperation with the University Medical Center Dresden and the Bundeswehr Center of Military Mental Health at the Bundeswehr Hospital in Berlin, a mobile application (app) has been developed and adapted at the CODE Research Center at the Bundeswehr University Munich to provide a low-threshold access to information and services for affected persons.

According to a study from 2012 49.2% of the investigated servicemen with deployment abroad reported one and 13.0% more than three traumatic incidents. Half of the PTSD cases remain undetected and untreated (estimated number of unreported cases 45%). Subjective barriers for seeking help are high. E-health techniques obtain to be approved to lower the threshold to seek help in case of psychological trauma sequelae. This is shown by statistics for the app PTSD Coach from the anglophone area. It was downloaded 100.000 times in 78 countries and was awarded (Federal Communication Commission AAA Award (2011)) due to a high consumer satisfaction (iOS: 5/5; Android: 4.5/5).

Through the adaptation of the PTSD Coach app from the anglophone area to the german-speaking area and the enhancement with specific requirements a platform shall be developed as contact point for people seeking information and help.

To meet these requirements in a first step, existing offers were analyzed for available functions with the following results:

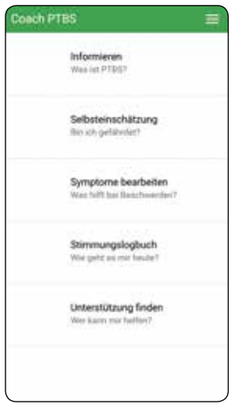

Fig. 1: Main screen of the PTBS-Coach in German language

Fig. 2: Several choices to “get support” can be accessed on this subscreen

Fig. 3: Excerpt from selftest for traumatic symptoms

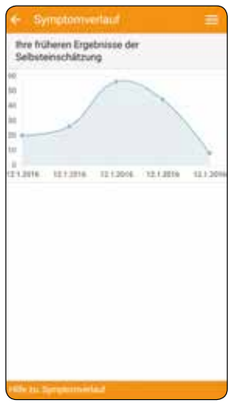

Fig. 4: The personal progress can be monitored by the app

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The mobile application gives priority to four topics: transfer of knowledge on the theme of posttraumatic stress disorder, performing self-assessment of PTSD symptoms, managing symptoms and getting support. The topic transfer of knowledge gives information about the illness of PTSD and frequently asked questions on topics like getting help and therapy options are addressed. In the category self-assessment possible own symptoms are evaluated. Therefore the “PTSD-Checklist” builds a validated measurement tool for the evaluation. The topic manage symptoms presents methods that shall help to deal with acute symptoms. The field getting support offers the choice to access known self-chosen auxiliary systems, such as known contacts, on the one hand and supports the seeking of professional help (e.g. emergency call, crisis line) on the other hand. The application to be developed is designed for affected military and civil persons and relatives.

During the self-assessment of PTSD symptoms and in some tools of the part managing symptoms sensitive personal data is collected that has to be protected with special regard to confidentiality, integrity and availability. Therefore cryptographic techniques are analyzed and implemented for its usability. This includes the encryption with the Advanced Encryption Standard (AES) and securing the users chosen password with the Secure Hash Algorithm (SHA). Furthermore a secure communication between the mobile devices and the server has to be guaranteed. For this purpose Secure Sockets Layer (SSL) or Transport Layer Security (TLS) is used.

The implementation of the app is done with a state-of-the-art web framework (Apache Cordova) to ease the transferring to multiple platforms such as Android, iOS or BlackBerry.

Finally a study with PTSD patients and people not concerned is carried out with the purpose to measure the usability and perceived support of the developed application. While development and adaption of the software has been conducted at CODE Research Center in Munich, scientists from the University Medical Center in Dresden and the Bundeswehr Center of Military Mental Health have provided unique insights into this novel intervention strategy and to adapt the product to the specific needs of Bundeswehr soldiers.

Apart from the usual publications on scientific platforms, the results of the research are made available to a wide range of industry, government and military through regularly held events at the CODE Research Center. The interdisciplinary approach, both within the Research Center as well as through networking with partners, synergies will be used in other projects and identify future research questions.

Fig. 5: Audio content to support relaxation exercise

Fig. 6: Access to the app and stored data is password protected

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Development and optimisation of rapid diagnostic tests for the identification of bacterial and viral pathogens

One of the challenges facing medical biodefence is the need to have different diagnostic methods available for the rapid and reliable identification of biological agents under greatly restricted field conditions. In addition to the well-established molecular biological methods, rapid immunological tests such as lateral flow assays offer a promising approach to providing suitable point-of-care detection.

When it comes to identifying biological agents, molecular biological assays continue to represent the gold standard regarding diagnostic sensitivity and specificity, but also involve high demands in terms of logistics, laboratory facilities and staff training. Lateral flow assays (LFA) offer a valuable alternative to the well-established molecular biological field diagnostic methods. The assays do not require any intensive training of the laboratory personnel, are easy to conduct, and deliver results within just a few minutes. They thus permit rapid identification of biological agents under the simplest conditions with a minimum of logistic and personnel resources. Although there is still the need to use molecular biological assays for definitive confirmation, a preliminary diagnosis is extremely valuable, especially in outbreak situations. LFAs are available from a variety of commercial sources, but by far not for all pathogens relevant to medical biodefence. Often, many of the available tests additionally lack the requisite diagnostic sensitivity and/or specificity. A research initiative formed at the Bundeswehr Institute of Microbiology (InstMikroBioBw) aims to close this capability gap and develop rapid methods for the robust, reliable detection of bacterial and viral pathogens under field conditions.

Depending on their design, LFAs are capable of detecting both the antigen (i.e. the infectious biological agent itself) and the immune response of the host (antibodies formed to fight the pathogen) in the sample material requiring analysis. Classic LFAs are based on antibodies as detection molecules, in which respect antibodies are used that, as so-called “catcher molecules”, specifically immobilise the targeted molecule on a nitrocellulose membrane. Once the sample fluid has been applied to the assay system, it first of all migrates to a reaction zone where any target molecules react with a second specific, gold-marked antibody. The thus formed antigen-antibody-gold complexes are then transported laterally by capillary forces through the pad material to an area where they are immobilised by the catcher molecules, thereby forming a positive test line. A control line additionally provides information whether the test can be considered as valid.

Such LFAs have been implemented for the detection of antibodies or antigens of the causative agents of tularemia (Francisella tularensis) and the plague (Yersinia pestis) within the framework of pilot projects at the InstMikroBioBw. Very good results have been achieved in regard to diagnostic sensitivity and specificity: The F1 antigen specific to Yersinia pestis has been detected with a high sensitivity (6ng/ml) in different fluid samples. In the case of the tularemia pathogen, it has been possible to detect antibodies formed by patients against the F. tularensis lipopolysaccharide in blood and serum. (Fig. 1) An LFA specific to the Ebola Zaire virus has been developed as a response to the Ebola outbreak in West Africa, and a prototype finalised. The latter was initially tested in a fixed laboratory environment where it showed very good specificity (Fig. 2). The prototype was then tested further under field conditions by staff of the InstMikroBioBw in a laboratory of the European Mobile Laboratory Project (EMLab) and compared with the established molecular biological Ebola polymerase chain reaction test method (Fig. 3). It was found that, although the diagnostic specificity was very high (i.e. a very low rate of false-positive results), the diagnostic sensitivity was however not yet adequate for any routine testing (too many false-negative results). Work based on these first important results is currently underway at the InstMikroBioBw with the aim of optimising the prototype.

Test format	Cassette
Readout after:	15 - 20 Min.
Sensitivity	90 %
Specifity:	92 %
Negative Control:	
Positive Control:	

Fig. 1: Summary of the LFA data for the detection of Francisella tularensis antibodies in human samples. One test line: control line – test is valid and negative. Two test lines: control line and target line – test is valid und positive

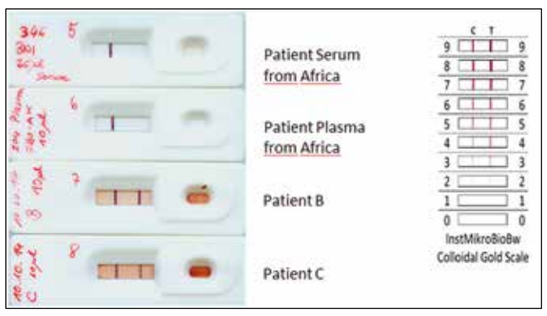

Fig. 2: Detection of Ebola Zaire virus in inactivated human samples under laboratory conditions by LFA. Blood plasma from African patients served as negative control. Interpretation: one test line: control line – test is valid und negative. Two test lines in patient B and C: control line and target line – test is valid and positive. The colour intensity of the colloidal gold test lines was determined by scaling the colour from 0-9.

Fig. 3: Field evaluation of the LFA prototype developed at the InstMikroBioBw for detecting the Ebola Zaire virus. An Institute staff member tests patients’ blood samples in a glovebox of the European Mobile Laboratories in Freetown, Sierra Leone, for the presence of the Ebola Zaire virus

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Genotyping of *Burkholderia mallei* from an outbreak of glanders in Bahrain suggests multiple introduction events

***Burkholderia mallei*, the causative agent of glanders, is a potential biological weapon that can cause severe infection with high therapeutic resistance in humans. Using highly discriminating molecular typing methods, we demonstrate that a recent outbreak of glanders among horses in Bahrain was caused by at least two different *B. mallei* strains, indicating a complex epidemiological background.**

Glanders, caused by the gram-negative bacterium *Burkholderia mallei*, is a highly infectious zoonotic disease that primarily affects solipeds, particularly horses, and through close contact can be transmitted to humans. The clinical symptoms include skin changes ('farcy'; Fig. 1) and infections of the respiratory tract, especially the nasal passages and lungs. Typical in this regard are inflammatory nodules and ulcers that develop in the nasal passages and give rise to a sticky yellow discharge. In the cutaneous form, the lymph vessels are enlarged and nodular abscesses form along their course which then ulcerate and discharge yellow pus. The various clinical symptoms can arise in parallel or may merge, making any strict differentiation very difficult in most cases.

Glanders was still a globally occurring animal disease and zoonosis in the early 20th century. Radical countermeasures such as the strict culling of positively tested animals succeeded in eradicating the disease in Germany and in other western European countries. It is still endemic however particularly in Asian countries such as Turkey, Iran, Iraq, Pakistan, Syria, India, Mongolia and China, as well as Brazil. These areas provide reservoirs for the re-introduction of glanders into countries previously listed as glanders-free. Due to its rareness, little is known about outbreak dynamics of the disease and its epidemiology. The risk of re-introduction also exists in Germany, given the extensive trade in horses.

As a highly infectious agent that can be transmitted by aerosol, causing invasive fatal disease in combination with resistance to multiple antibiotics, *B. mallei* is listed as a category B bio-threat agent by the CDC (www.bt.cdc.gov/agent/agentlist-category.asp). Licensed vaccines against the disease do not exist. Antibiotic treatment is cumbersome and requires the combination of at least two different antibiotics over several weeks.

Officially, Bahrain was free of glanders until an outbreak in the north (Jannusan, Shakhurah and Saar municipalities) that began in April 2010. A total of 126 horses, 4 donkeys and one positively tested camel were euthanised. It was possible to isolate *B. mallei* from nine infected horses and the camel and to analyse it further at the Bundeswehr Institute of Microbiology (InstMikroBioBw). The dataset was compared with data from 42 other B. mallei strains originating from the strain collection of the InstMikroBioBw (samples obtained from an outbreak in the United Arab Emirates in 2004), and with previously published *B. mallei* data, so as to put the new outbreak strains in a broader phylogeographic context. The molecular characterisation of the *B. mallei* was performed using high-resolution genotyping (multiple-locus variable number of tandem repeats, MLVA), comparative full genome sequencing, and Single Nucleotide Polymorphism analysis (SNP).

Fig.1. Different clinical manifestations of glanders, horse. Left: Farcy, Middle: Nose purulent discharge, Right: lung nodules.

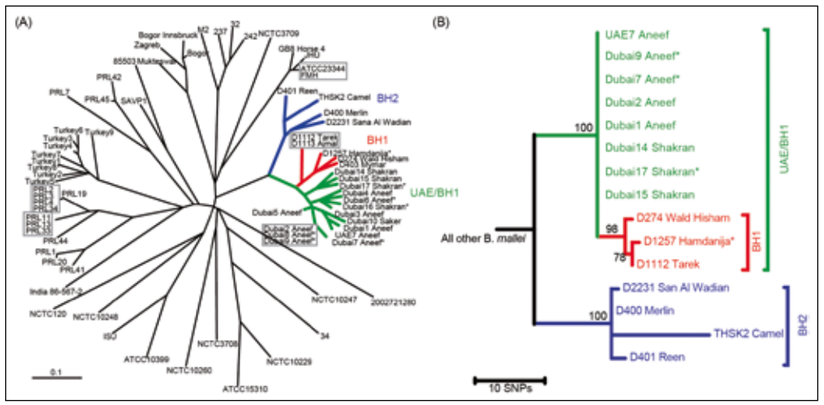

Fig. 2. Phylogenetic reconstruction (maximum parsimony) of *B. mallei* strains based on MLVA-23 (A) and full genome SNP data (B). BH1 and BH2 = clusters of the outbreak in Bahrain, 20110/20111. UAE = United Arab Emirates (Outbreak 2004).

The MLVA-23-based phylogenetic reconstruction of the outbreak in Bahrain shows a clear separation of the 9 *B. mallei* strains into two distinct clusters (BH1 and BH2), comprising 4 and 5 strains respectively (Fig. 2A) The relatively high genetic distance of 8 VNTR markers between BH1 and BH2 suggests a complex epidemiological background and evidence of the involvement of two different *B. mallei* populations. The samples of cluster BH1 from Bahrain were more closely related to the B. mallei isolated from horses in the United Arab Emirates in 2004 than to other *B. mallei* from the same outbreak (BH2 cluster), which indicates repeated importation into the region from similar geographic sources. The full genome sequencing-based SNP analysis also showed this separation (Fig. 2B), such that it can be assumed that the outbreak was caused by two different *B. mallei* strains. The close genetic relationship between the BH1 population and outbreak strains from Dubai/UAE in 2004 is, moreover, indicative of a broader spread of genetically very similar *B. mallei* strains in that region.

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Bundeswehr Institute of Pharmacology and Toxicology: partner of the Organisation for the Prohibition of Chemical Weapons in biomedical verification

From 2009 to 2015 the Organisation for the Prohibition of Chemical Weapons (OPCW) conducted five international exercises for detecting chemical warfare agents in biological samples. The Bundeswehr Institute of Pharmacology and Toxicology played a successful part in them and, in early 2016, looked forward to a first official OPCW round robin test (BioPT) designed to identify designated laboratories.

The Bundeswehr Institute of Pharmacology and Toxicology (InstPharmToxBw) is a federal research institute of the German Ministry of Defence and a centre of scientific excellence in all aspects of medical defence against chemical warfare agents (CWA) and comparable noxious substances. Besides optimising therapeutic intervention and discovering potential new antidotes, its central activities include the unambiguous bioanalytical detection of CWA in biological samples (blood, plasma, urine, tissue) for the purpose of verification. There has thus been close collaboration with the OPCW for many years (Nobel Peace Prize in 2013). The OPCW monitors compliance with the Chemical Weapons Convention and operates a worldwide network of laboratories that, using instrumental analysis and experimentation, are capable of documenting CWA deployment and toxin incorporation with a view to litigation. While there has been a close circle of qualified (designated) laboratories authorised by the OPCW for the verification of environmental samples (soil, water, air) for some decades, the first corresponding seal of quality for biological sample analysis is to be awarded in 2016. In the course of preliminary confidence-building exercises (biomedical exercises, BME) that the OPCW has been organising since 2009, the InstPharmToxBw has already been able to demonstrate its analytical capabilities successfully. For example, the Institute has developed and established modern bioanalytical methods specially for detecting intact nerve (NA) and blister agents (BA) as well as their degradation (hydrolysis) and reaction products (protein adducts) in biological samples.

During the first BME the Institute succeeded in detecting relevant concentrations of hydrolysis products of NA VX, soman and sarin in artificial and native urine samples. These analytes (EMPA, or ethyl-methylphosphonic acid, for VX; PMPA, or pinacolyl-methylphosphonic acid, for soman; and IMPA, or isopropyl-methylphosphonic acid, for sarin) were detected using a validated LC-MS/MS procedure (liquid chromatography tandem mass spectrometry) meanwhile accredited by German accreditation body DAkkS (Deutsche Akkreditierungsstelle) to DIN/EN/ISO 17025.

The year thereafter the OPCW sent plasma for the first time together with urine as a sample matrix to prove the presence of organophosphorus NA by means of fluoride-induced reactivation. In this procedure, protein-bound NA was separated from the protein through an excess of fluoride ions, thereby producing a fluoridated NA variant that was detected by GC-MS (gas chromatography mass spectrometry). By applying this method it was possible to detect sarin in the plasma samples whose presence was additionally confirmed by the detection of IMPA in the plasma. The same hydrolysis product was also to be found in urine alongside additional traces of EMPA and PMPA.

In the 4th BME in 2014, plasma samples were received for analysis of the protein adduct of plasmacholinesterase (BChE) and NA. This involved isolating the modified protein from plasma and then hydrolysing it enzymatically to obtain peptides. One of the peptides was still modified by the NA and could be detected correctly by means of LC-MS/MS as a selective biomarker.

As part of the last exercise in February 2015, plasma samples were to be analysed for the presence of protein adducts of the BA sulphur mustard (HD). Similar to the BChE adduct analysis, HD serum albumin adducts were detected as a modified peptide by means of LC-MS/MS. Accordingly, thiodiglycol (hydrolysis product of HD) was detected by means of GC-MS after alkaline hydrolysis from plasma proteins.

Encouraged by its successful participation in the exercises outlined above, the InstPharmToxBw is looking forward to the first official round robin test of the OPCW (biomedical proficiency test, BioPT) in 2016 and, thereafter, to being awarded the status of a designated laboratory.

Fig. 1: Arrival of samples for the 3rd OPCW biomedical exercise (“confidence-building exercise”) held in 2013

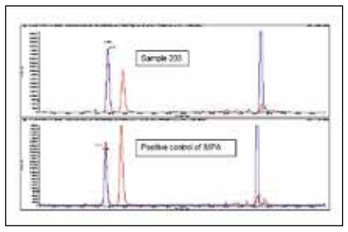

Fig. 2: Example from the 2nd biomedical exercise held in 2012 – Detection of the sarin metabolite IMPA in urine

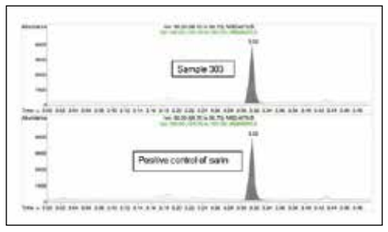

Fig. 3: Example from the 3rd biomedical exercise held in 2013 – Detection of sarin after fluoride-induced reactivation

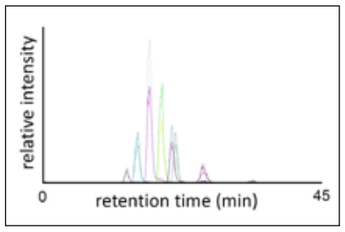

Fig. 4: Example from the 4th biomedical exercise held in 2014 – Detection of nerve agents as protein adducts with plasmacholinesterase after enzymatic proteolysis into phosphylated nonapeptides

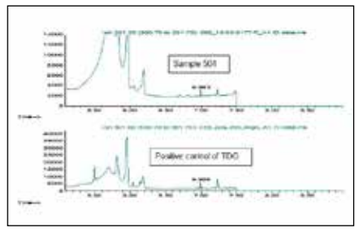

Fig. 5: Example from the 5th biomedical exercise held in 2015 – Detection of thiodiglycol after total hydrolysis of the adduct formed between serum albumin and sulphur mustard

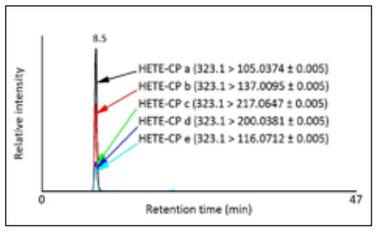

Fig. 6: Example from the 5th biomedical exercise held in 2015 – Detection of sulphur mustard as a protein adduct with albumin after enzymatic proteolysis

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Radiological Nuclear Medical Task Force – PRECISE Care 2015 exercise

During the annual PRECISE Care exercise in Suffield (Canada), the Radiological Nuclear Medical Task Force from the Bundeswehr Institute of Radiobiology had the opportunity to test and improve physical, biological and clinical dosimetry. A particular challenge consisted in dealing with "live agent" sources. The present article describes the exercise and some of the methods applied.

The Radiological Nuclear Medical Task Force (RN Med. TF) from the Bundeswehr Institute of Radiobiology is a unit highly specialised in the examination, diagnosis and treatment of radiologically exposed persons (Fig. 1). Together with other emergency services such as decontamination specialists and rescue teams, it is capable of providing medical support locally, both at national and international level, in response to radiological incidents.

The primary focus of its work is on the early diagnosis of acute radiation injury, the objective being to identify both exposed and non-exposed individuals (so-called. "worried wells"). In addition to this important distinction, affected soldiers are examined for acute radiation injuries, which is followed by a prognosis as well as decisions regarding treatment options and required treatment resources.

The annual PRECISE Care exercise at the "Counterterrorism and Technology Centre" in Suffield / Canada enables the RN Med. TF to train and evaluate its methods under challenging "live agent" conditions. Besides the establishment of well-known algorithms (H-module, see below), the conceptual development of new procedures (comparison of physical dosimetry with clinical signs of acute radiation injury) in an adapted "field research" environment is crucial.

In 9 scenarios involving a total of 29 patients, various new algorithms were established which allowed a first estimation of the radiation injuries expected for individual patients and made a particular therapy recommendation possible. As part of the scenarios, not only civilian accidents such as a critical incident in a nuclear power plant, but also military storylines such as the situation after the explosion of a "dirty bomb" or the emergency treatment of persons irradiated in a "terror lab" were simulated. During the exercise, patients possibly exposed to radiation were evacuated by supporting forces from the hazardous area and brought to the RN Med. TF (Fig. 2).

The RN Med. TF assessed the clinical data (prodromal symptoms; Fig. 3) through individual anamnesis and physical examination. These data then served as the basis for preliminary dose estimation (clinical dosimetry; Fig. 4). The dose corresponds to the absorbed radiation energy, which can cause biological radiation damage. These clinical dose estimations were validated by means of measurements using highly specialised equipment (physical dosimetry).

Blood counts were additionally evaluated with the aid of a custom-made software tool (H-Module). H-Module has been developed in-house by the Bundeswehr Institute of Radiobiology and is a reliable and highly sensitive tool for estimating the radiological damage caused to the hematopoietic system. The module recommends an appropriate treatment facility on the basis of the blood cell profiles and identifies patients with inconspicuous blood cell counts who do not require further clinical surveillance. It also identifies patients with minor hematopoietic injuries who can be monitored at outpatient clinics. Distinguishing in such a way allows sensible and early allocation of available treatment resources.

During the clinical observations RN Med. TF collected additional blood samples for analysis in the highly specialised laboratories of the Bundeswehr Institute of Radiobiology where, using the methodology of biological dosimetry, molecular damage or damage responses caused by radiation within the human cells can be visualised. The occurring changes usually correlate with the absorbed dose.

Where there is any suspicion of incorporation, there is the possibility, through individual risk analysis, of simulating an antidote therapy on site.

The described "Precise Care" exercise has contributed significantly to the maintenance of RN Med. TF competence and to the ongoing enhancement of the aforementioned methods and serves to ensure outstanding expertise in all aspects of medical radio-nuclear protection.

Fig. 1: Members of RN Med TF performing physical measurements for medical risk evaluation during a scenario simulating an underground terror lab

Fig. 2: Members of the RN Med TF performing a medical examination on a patient after an assumed explosion of a dirty bomb

Max Mustermann, born on 9 February 1954

Airway:	stable
Breathing:	normal respiratory
Circulation:	BP=190/100 mmHg; HR= 72 bpm; no pallor
Disability:	GCS = 11
Vomiting (start):	2015/10/17 at 09:30 a.m.
Vomiting (end):	persistent
Stool frequency:	8 times a day
Diarrhea (start):	2015/10/17 at 14:00 p.m.
Diarrhea (end):	2015/10/17 at 22:00 p.m.
Skin affects:	erythema on both hands (fingertips and palm)
Body temperature:	37.3 °C
BB: day 1 p.i.:	
Granulocytes Count:	8/nl
Thrombocytes Count:	300/nl
Lymphocytes Count:	0,5/nl

Fig. 3: As a way of practicing medical diagnostic procedures and therapeutic measures after radiation exposure, medical case histories for a total of 29 irradiated patients were created. Based on these data (see above), the RN Med TF members from the Bundeswehr Institute of Radiobiology were required to make a possible diagnosis and initiate suitable therapeutic steps.

Prodromi after radiation exposure	un-known	< 1 Gy	1-4 Gy	4-6 Gy	6-8 Gy	> 8 Gy
vomiting, onset		> 9 h	2-9 h	1-2 h	≤ 1h	≤ 0.5 h
vomiting, duration		< 24 h	< 24 h	< 24 h	24-48 h	> 48 h
diarrhea, onset				3-8 h	1-3 h	< 1 h
diarrhea, frequency		1-3x	1-3x	3-5x	> 5x	
body temperature, onset		> 3 h	1-3 h	1-3 h	< 1 h	< 1 h
body temperature (axillar), severity			≤ 38-39°C	≤ 39-40°C	≥ 40°C	≥ 40°C
Recommending hospitalization prognosis (rough estimate)		no good	yes fair	yes critical	yes very critical	yes poor

Fig. 4: Dose assessment on the basis of prodromal symptoms (Sandgren et al., Health Physics, 2010 and personal correspondence, modified by Abend et al.)

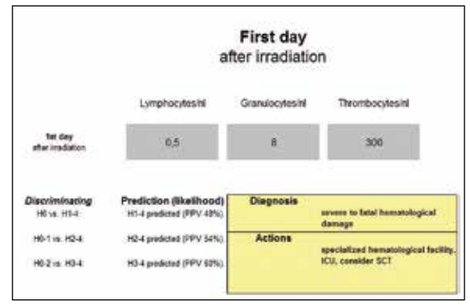

Fig. 5: H-Module evaluation after manual input of the blood count 24 hours post-irradiation. Besides a first risk stratification for the expected radiation damage caused to the hematopoietic system, the module makes preliminary clinical recommendations regarding therapy

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Simulation of screen-based tasks to analyse external and internal influences on job performance

Computer-based multitasking activities that involve several input and output modalities are becoming increasingly common in the military working environment. Analyses of the effects of external stressors and subjective factors require a special set of tools. This has been developed in the form of a generic workplace simulation that replicates cognitive demands independent of specific military tasks.

Increased use of information technology in many military workplaces has frequently given rise to complex screen-based workflows that place increased demands on the cognitive abilities of service personnel. Often, these tasks also involve a high level of responsibility. Depending on the situation and threat level, incorrect or delayed reactions as well as overlooked or misinterpreted information can pose a danger to life and health. Valid data is needed for early detection of changes in performance and to optimize working conditions on deployment as much as possible. Owing to the special nature of the military environment and the exceptional external stressors involved, civilian ergonomic regulations can be applied only to a limited extent. For this reason one of the core tasks of departmental research is the collection and assessment of relevant parameters using standardised procedures.

Against this backdrop, the simulation of a generic workplace with high cognitive demands was developed and tested as part of a joint research project conducted by the Performance Epidemiology Research Group (German Sports University Cologne)

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and Laboratory Department IV of the Central Institute of the Bundeswehr Medical Service Koblenz. The aim was to implement an adequate level of stress in terms of cognitive demands while also ensuring that the tasks involved can be learned easily and quickly. In a different study, construct validity and retest reliability have been analysed.

The generic workplace simulation consists of three subtasks which are designed so that there is as little overlap as possible between perception and reaction modalities.

- Instrument monitoring (Fig. 1): The task involves monitoring 12 analogue instruments on two touch screens. If one of the status indicators drifts into the red zone, it has to be reset by touching the appropriate on-screen instrument.
- Auditory tasks (Fig. 2): Three different types of auditory tasks are introduced via headphones. They involve responding verbally to logic questions and addition problems, as well as repeating sequences of numbers.
- Situation map management (Fig. 3): This task involves transferring text messages from various reconnaissance and surveillance units concerning the position and status of detected units onto a situation map in form of an aerial image.

The effectiveness of this complex and cognitively challenging workplace simulation has been shown with subjective methods (NASA-TLX and scales for mental strain and task difficulty) as well as objective measurements of oculomotor parameters. Further analyses indicate that it is possible to successfully match cognitive processes to the multitasking components. In addition to attention and short-term memory, processing speed and working memory have been identified as important correlates. The temporal stability of the demands has also been demonstrated.

This simulation offers a valid test environment for military-specific work tasks. This approach allows for prevention-oriented analysis of external stressors and subjective factors on work performance in a laboratory setting. The generic workplace simulation differs substantially from the training simulators used in the Bundeswehr both in respect to its task structure and the assessment of psychophysical characteristics.

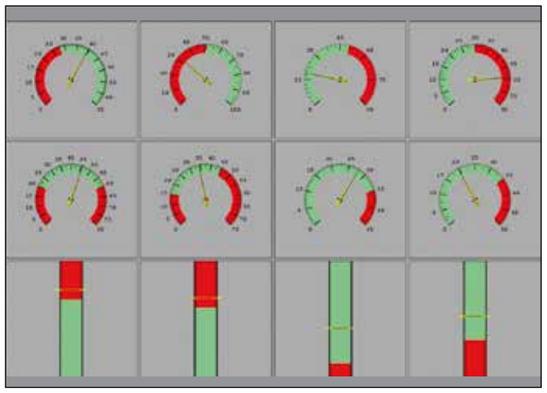

Fig. 1: Subtask: instrument monitoring

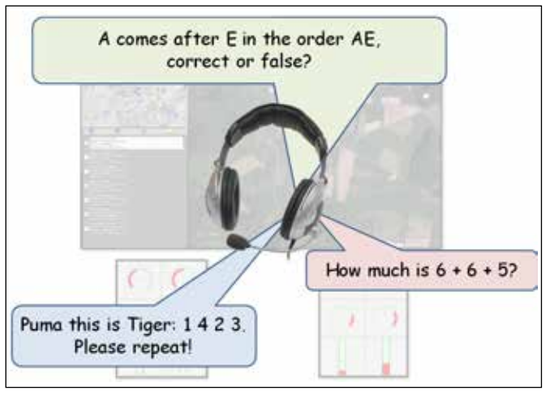

Fig. 2: Examples of auditory task types

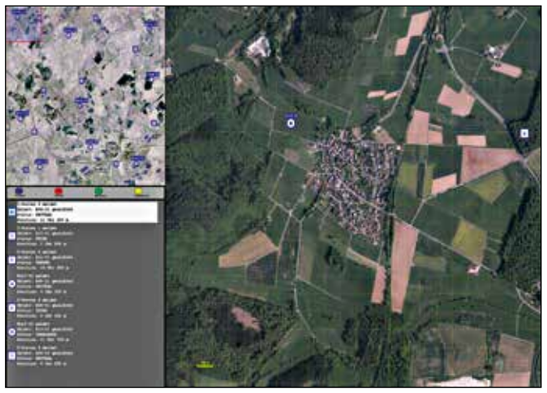

Fig. 3: Subtask: situation map management

Fig. 4: Participant operating the workplace simulation

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Scientific development of an indicator system for workplace health management within the area of responsibility of the German Ministry of Defence

In workplace health management it is necessary to compile valid indicators in order to evaluate the achievement of targets. Indicators help, furthermore, to adjust and improve processes, and need to be established at agency/local level. They serve to develop suitable health management measures and to gauge their effectiveness.

Surveys were conducted among the staff employed at eleven agencies as part of a test phase (in the first half of 2015) in connection with introducing workplace health management in the area of responsibility of the German Ministry of Defence (MoD). Using an online internet platform and, in any cases where internet access was unavailable, a paper-and-pencil questionnaire, the staff were asked questions on various topics and aspects relating to workplace health management.

The aim was to develop an indicator system that uniformly applies to the entire area of responsibility of the MoD, but which also takes into account the special characteristics of the various agencies, particularly with regard to their work and staff composition.

Based on the first part of the survey involving 2,076 participants (from a total of 9,267 staff; participation rate: 22.4%), an indicator system was developed with the focus on leadership behaviour and social aspects of work, work structure, job responsibility, work materials and equipment, ambient conditions, work habits, mental health, stress, health-related behaviour, commitment, diet and exercise/sport.

Besides circumstances which arise directly and indirectly from the working conditions and the leadership behaviour of superiors, there is the need to address consequences in terms of mental health and the experience of stress as subjectively reported by participants, as well as aspects of workplace health promotion measures. The attitude of staff regarding the attractiveness of the Bundeswehr as an employer is an important factor in recruiting and retaining qualified personnel and thus essential for determining indicators. This approach can be compared with other indicator systems only to a certain extent but offers the possibility to reflect the general conditions that are typical of the area of responsibility of the German MoD and fundamentally different in terms of the tasks and compositions encountered in private-sector enterprises. Use of indicators for workplace health management specific to the Bundeswehr and, thus, specific to its target group therefore becomes possible in the long term. What is more, this approach allows the comparison of indicators at agency/local level, among groups of agencies and across the entire area of responsibility.

It involves calculating an indicator for every subject area. That indicator represents the mean value for the percentages of personnel who have responded with answers from negative categories to the individual items of the subject areas. While combining questions under one score reduces the level of detail, it also serves to address various sub-aspects under one indicator. When checked, the calculated indicators have shown good-to-very-good internal consistency (Cronbach's alpha 0.506 – 0.906).

In this test phase, clear and significant differences in the indicators were found between the individual agencies for all the subject areas. Those differences exist essentially between agencies which have dissimilar core tasks and dissimilar staff compositions.

It has thus been shown that use of this method in future will make it possible not only to compare individual agencies in terms of an overall reference value but also to compare them with agencies that have similar core tasks and similar staff compositions for the purposes of agency clustering. Where the individual agencies are concerned, the results of the staff survey can be displayed in a one-page approach as a management support tool.

The next step will consist in weighting the subject area-specific indicators and, consequentially, developing central indicators and indicator-monitorable targets.

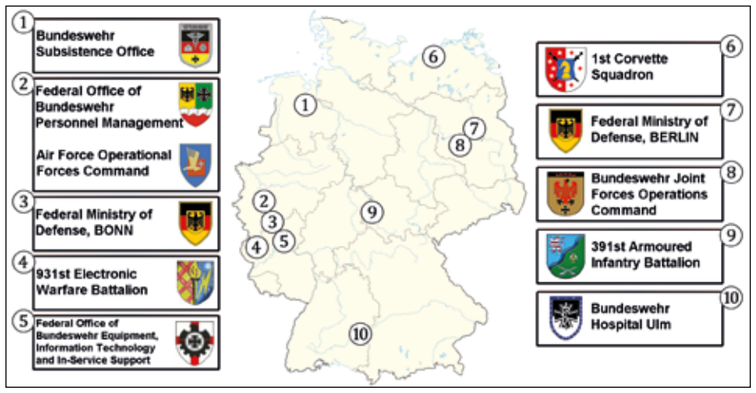

Fig. 1: Agencies included nationwide in the test project

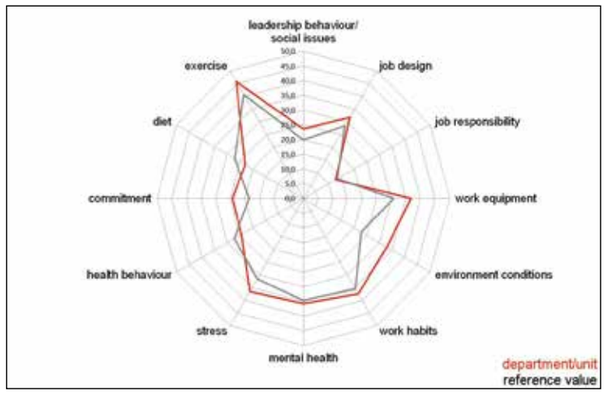

Fig. 2: Indicators for the twelve subject areas; the red line denotes the respective value for the surveyed agency, and the grey line the reference value based on the data from all the surveyed agencies; a higher score is tantamount to a more negative assessment

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A job analysis in German Air Force military training: a comparison of training aircraft

The upgrading of existing aircraft types requires pilots to readapt constantly to their workplace. Because changeovers to new aircraft types in pilot training also call for a high level of adaptability with regard to aircraft control as well as student training, particularly on the part of flight instructors, a regular analysis of requirements is essential.

To be able to analyse and classify workplaces or determine the aptitude of candidates for certain activities, it is necessary first and foremost to describe the characteristics of the workplaces concerned in terms of the individual activities and to define the ensuing requirements that the personnel will have to meet. Work and requirement analyses are the means whereby this information is provided. Since military environments mostly involve very specialised activities for which commercially available analysis instruments have only limited suitability, such tasks require individually designed and customised procedures.

Looked at as an example in this regard is the basic jet aircraft training provided in the German Air Force. In October 2009 the Cessna T-37 Tweet was replaced by the Beechcraft T-6 Texan II within the scope of the Euro NATO Joint Jet Pilot Training (ENJJPT) programme as the aircraft for conducting the basic and advanced training at Sheppard Air Force Base in Texas. This replacement not only meant a changeover of the aircraft propulsion system from jet propulsion to propeller

Fig. 1: Beechcraft T-6 Texan II (Source: www.luftwaffe.de)

Fig. 2: T-38 of the “NATO Joint Jet Pilot Training Programme”, Sheppard Air Force Base (Source: www.luftwaffe.de)

drive, but also led to the discontinuation of the side-by-side concept and the introduction of a modern glass cockpit. These changes resulted in flight improvements, yet also necessitated the adaptation of flight training. With the instruction in tactical procedures being conducted in a follow-on training step in Northrop T-38 C Talon aircraft, this means that an older jet-powered aircraft is available in addition to a modern aircraft with a propeller drive system. This raised the question as to what extent the requirement profiles and the resulting workload and stress for aircrew members (flight instructors and student pilots) differ with respect to the two aircraft types.

A comparative study is expected to provide answers, the data for which will be generated by means of questionnaires in the form of a self-assessment carried out by the subjects, and also by means of an expert rating. Objective physiological data will also be collected using the HealthLab system created by Koralewski, a commercial enterprise. The study subjects will comprise student pilots and flight instructors for the two T-6 and T-38 aircraft types at Sheppard AFB. While the flight instructors will answer the questionnaire in their function as experts for their workplace, the expert rating will be given by two experienced flight instructors, two flight surgeons and an aviation psychologist.

The questionnaire has been developed from a general work analysis questionnaire prepared for the Bundeswehr flight service and consists of a general part (coding, biographical data, and professional experience), a subjective workload and requirements analysis (sensory perception, intake and processing of information, acting on information, and motor skills) as well as an expert rating. The questionnaire datasets from the group of flight instructors and student pilots for both aircraft types will be compared with one another and also with the relevant expert rating data.

In addition to the pure questionnaire data, the HealthLab system will record ECG data, pulse, heart rate and other parameters (e.g. EEG) to determine the physiological stress caused by G forces in the cockpit. The occurring G forces will be recorded by a measuring device installed in the cockpit with a view to comparing the G force stresses to which individual aircraft crews are exposed, as well as their resulting physiological data. The flight manoeuvres will be selected in advance in accordance with the training schedule and then recorded.

Based on the summary of the questionnaire analysis (cross-comparison including self- and external assessment) and a physiological data collection, it should be possible to achieve an objective evaluation of the demands placed on the flight instructors for both aircraft types during daily routine duty.

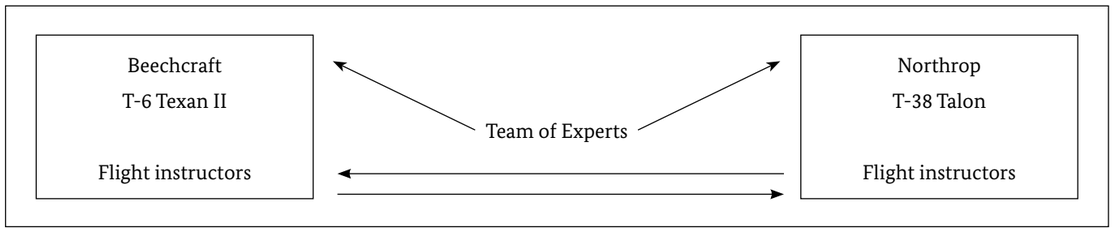

Fig. 3: Trial design of the questionnaire rating

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Military psychology research – scientific expertise and research management

The Military Psychology Research Section of the Armed Forces Office is tasked with gathering scientifically substantiated findings regarding the influences of military stress experienced specifically during routine duty and on operations. It conducts its own as well as externally commissioned studies and evaluates them according to scientific standards. Examples of its activities include Project Charly III and the testing of workplace health promotion measures.

Since January 2015 the newly established Military Psychology Research Section, as part of the Applied Military Psychology and Research Group at the Armed Forces Office, has, on behalf of Branch P III 5 of the German Ministry of Defence (FMoD), been providing scientific services in the field of military psychology research for all organisational areas of the Bundeswehr. Located on the campus of the Helmut Schmidt University (Bundeswehr) in Hamburg, it focuses on three core activities, while benefiting from synergies and close cooperation with the researchers working at the university:

(1) Provision of literature-based expertise in response to issues arising from the practice of military psychology.
(2) Planning and conduct of its own studies and research projects with a view to developing new analysis and intervention methods.
(3) Research management, expert supervision and evaluation of in-house and externally commissioned military psychology projects and preventive measures to influence psychological variables such as cognitive capability, job satisfaction or psychological fitness.

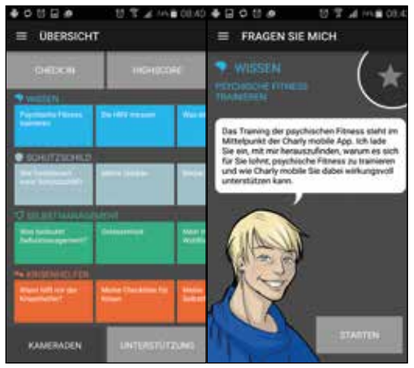

Fig. 1: "Mobile Coach", innovative smartphone app as part of the CHARLY III project

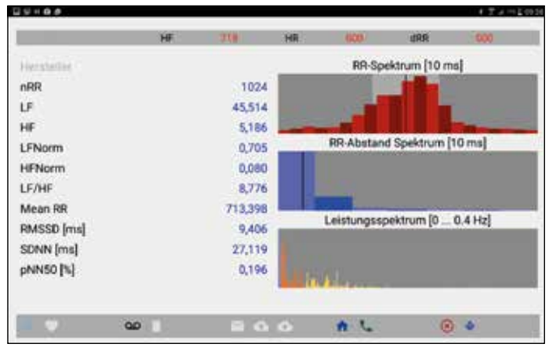

Fig. 2: Heart rate variability analysis display from the CHARLY mobile app (screenshot).

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One example of "research management" as a core activity is the CHARLY III project. In order to provide training in coping with mission-related, specifically military psychological stress, the Bundeswehr tasked enterprise Elektroniksystem- und Logistik-GmbH with developing CHARLY, an interactive multimedia learning and training platform. Military psychologists use this computer-based training system when preparing for operational deployments. Deliberations about intensifying the training while also reducing the organisational and equipment-related effort involved have led to the development of a low-threshold, individually flexible and, thus, also potentially intensively used smartphone app (Fig. 1) called "Mobile Coach" with the following functions: (1) scenario-based 'serious games' for stress management, including mobile biofeedback based on cardiac activity (Fig. 2); (2) feedback on basic psychological fitness through comparison of individual heart rate variability when at rest, with age- and gender-specific standard values; and (3) psycho-education on dealing with exceptional psychological stress, and guidelines for handling excessive stress and persistent stress after-effects.

In cooperation with the Bundeswehr's two universities, the Military Psychology Research Section is also conducting part of the scientific research accompanying the implementation and testing of workplace health promotion measures in eleven pilot agencies within the area of responsibility of the FMoD (Fig. 3). Taking psychological models and factors into consideration, it is already possible to deduce important findings regarding job-related stress and its after-effects in the pilot agencies, the need for workplace health promotion, the effectiveness of the tested measures and factors for success, as well as obstacles to the sustainable implementation of workplace health management.

The factors that influence participation in workplace health promotion measures have been identified, taking as a basis the theories of Planned Behaviour and the Health Action Process Approach (HAPA). It has been found, according to the HAPA model (Fig. 4), that positive outcome expectancy has a much stronger influence than negative outcome expectancy on the factors which precede intention forming and action planning - something that can be used in the design of information and advertising materials for workplace health promotion measures.

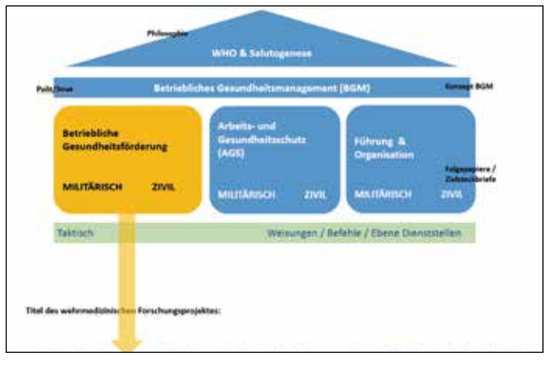

Fig. 3: Overview of workplace health management within the area of responsibility of the FMoD

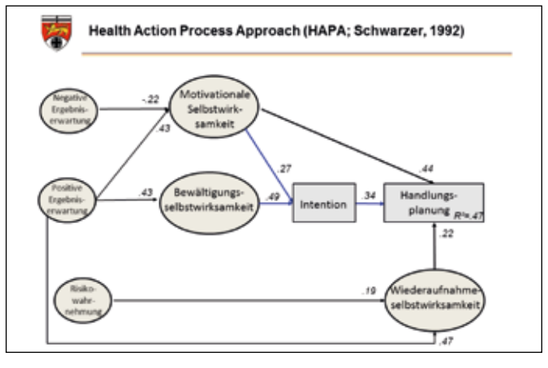

Fig. 4: Outcome of the regression analysis test of the HAPA model

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.

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Military elites in the East and West from 1955 to 1990 – a comparison

The main focus of this research project is on comparing generals of the Bundeswehr and the National People's Army (NVA) during the Cold War era. The project looks at the social backgrounds and career patterns of the two groups and considers them in relation to data concerning German generals who served pre-1945, with the aim of retracing correlations in German 20th century military history from the perspective of a history of ideas.

The present study starts out from questions regarding the backgrounds and careers of the German military elite after 1945. Since, however, the first group of questions is in itself limited in the extent to which it allows any adequate comparison of the Bundeswehr and the National People's Army, two further reference values are needed.

The first is aligned to the call to complement social history with a history of structures. The intention of this is to incorporate the development and change in backgrounds and careers into the structural foundations of a history of organisations. The second touches on the issue of the tertium comparationis, the commonality of a reference value that applies to both sides. This lowest common denominator concerns the overarching issue of continuities in the German military in the 20th century, upon which this study is based. This means that aspects of the backgrounds and careers of the generals who served with the Bundeswehr or the NVA need to be considered in relation to the background and career patterns of the German military before 1945. Only then is it possible to assess the findings expected in the East and West. It is not solely a matter of Americanisation or Sovietisation, that is to say, of an adaptation of German military elites after 1945, but also of aspects of continuity in military history and the history of ideas or of a modernisation of particular German traits which, through the analysis of backgrounds and careers, may help the findings to be put into a historical context.

Relating the backgrounds and careers of West and East German generals post-1945 to those of generals pre-1945 also allows the use of comparison as a method and, at the same time, opens the way for an overarching issue which looks for continuities in the German military of the 20th century. It proceeds on the assumption that the personnel structure can be the immediate product of a certain military idea and thus the expression of a certain military culture of thinking.

Such interest in military history research links topics of social science, the history of structures and the history of ideas together. The commanders of both sets of armed forces constitute, from division level upwards, the selected group of people on which this study focuses. Analysed, where the Bundeswehr is concerned, are the backgrounds and careers of some 260 of the original total of around 1,200 generals and admirals of all ranks. For the NVA, around 200 of the original group of some 300 generals and admirals of all rank categories are studied in closer detail.

A characteristic and innovative feature of the work done as part of the basic research at the Bundeswehr Centre of Military History and Social Sciences to establish a German-German military history after 1945 is its twofold methodical approach, which can be categorised as both historico-critical and statistical-empirical. In a first step that is rather untypical for historians, empirically usable data material is generated from historical sources, in this case officers' service records. The datasets, numbering several tens of thousands, are subsequently evaluated by means of statistical analysis methods. In a further step the thus acquired findings can be critically contrasted with knowledge obtained from historical files and then interpreted.

Ideally, the work will reveal the hoped-for 'bigger picture' of German military history, but even if it fails to do so, it will certainly close a gap in the knowledge about a significant social group in the two German states between 1955 and 1990.

Fig. 1: Publication about the members of the founding generation of the Bundeswehr

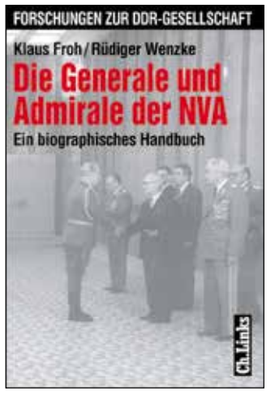

Fig. 2: Biographical compendium on the military elite of the GDR

Fig. 3: A short history of the People's National Army (NVA)

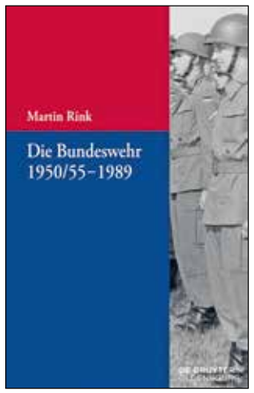

Fig. 4: A short history of the Bundeswehr

4

Geoscientific Research

Since the autumn of 2013 the Bundeswehr Geoinformation Centre, or ZGeoBw, (formerly the Bundeswehr Geoinforma-tion Office, or AGeoBw, from 2003 to 2013) has served as the central agency of the Bundeswehr Geoinformation Service (GeoInfoDBw). Together with its Applied Geosciences Directorate, the BwGIC is the executive body for geoscientific research in the Bundeswehr.

"Geoscientific research" is a sub-process of the Federal Ministry of Defence's (FMoD) "Ensuring Work in the Geospatial Field" performance process. Geoscientific research and development (R&D) activities of the ZGeoBw are geared, on the basis of the FMoD's research agenda, to the immediate needs of the Armed Forces and to the missions they undertake. The global orientation of the Bundeswehr has for years required the GeoInfoDBw to provide comprehensive geospatial support in an interdisciplinary approach, necessitating close cooperation between the 18 geoscientific disciplines represented in the Service. This routinely involves addressing topical and near-term issues as well as handling medium- and long-term tasks.

The goals for the departmental research are derived from the current and evolving mission of the Bundeswehr and GeoInfoDBw. Accordingly, research activities have to be carried out whose results are needed instantaneously to meet the demand for quality-assured geospatial information. There is, on the other hand, the need to keep already employed methods and processes in step with the constantly evolving state of research. Whenever and wherever necessary, it is crucial to be able to identify relevant geospatial factors and environmental influences; to assess their impact on the conduct of operations and on tactics; to provide up-to-date, quality-assured and full-coverage geospatial information worldwide for exercises and for the preparation and conduct of operations; to brief operational forces geoscientifically; and to keep the executive group of the FMoD informed regarding the importance of political processes geospatially.

The resultant data from geoscientific R&D serve to ensure the military core geoinformation support capability, thus enabling the GeoInfoDBw to carry out its mission of providing, at all times, the latest science-based information for all tasks and activities of the FMoD and the Bundeswehr relating to specific geographic areas. The geoscientific R&D data are however also put to use in many other planning and decision-making processes of the FMoD and the Bundeswehr. The ZGeoBw participates and plays an active role both in national and international projects and programmes.

The recommendations from the evaluation made by the "Wissenschaftsrat" (German Council of Science and Humanities) have been gradually implemented with a view to enhancing the R&D performance of the GeoInfoDBw departmental research facility. The FMoD has consequently assigned a Scientific Advisory Board to the ZGeoBw and, in the course of the ZGeoBw's reorganisation that took effect on 1 October 2013, had the departmental R&D work pooled within the Applied Geosciences Directorate, whose director is also the research representative in this regard with responsibility for geoscientific departmental research.

The geoscientific R&D activities build upon the current state of research, with analysis being mission-related and based on pertinent scientific findings and also using the services offered by research institutes of other federal ministries as well as by military and non-military science and research organisations. Geoscientific R&D projects are conducted in cooperation with suitable partners from other departmental research institutes, academic universities, universities of applied sciences, non-university research facilities, or also commercial enterprises. Besides the current focus on steadily improving the geospatial support provided for the Bundeswehr, the geoscientific departmental research is at all times understood as linking science, policy advice and research in areas where, as yet, there is no apparent need for political action or intervention and thus serves to identify and take into account any new developments at an early stage and to ensure that appropriate advice can be given.

The following pages of the "Military Scientific Research Annual Report 2015" feature two examples of geoscientific R&D activities.

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Development of the capability to supply military biometeorological information online

The Bundeswehr Geoinformation Centre is expanding its portfolio of advisory services to include the capability of supplying online analyses and assessments of specific environmental conditions (temperature, air humidity, air pressure, solar radiation) with regard to the thermophysical reactions of the human organism and the degradation of performance to be expected on the part of military personnel.

The capability to analyse and assess any environmental factors globally in any stage of an operation (planning, conduct, and post-operation) has ranked among the core tasks of the Bundeswehr Geoinformation Service ever since the potential deployment area of the Bundeswehr was broadened to include generally all climate zones of the world. The aim is to provide users with environmentally relevant geoinfo products and material so that they have reliable and, where possible, comprehensive decision aids at their disposal at all times. Automated online supply continues to increase proportionally in this context.

Intranet-based applications for the assessment of atmospheric environmental factors are already available. The BIOMET development project initiated at the Bundeswehr Geoinformation Centre (ZGeoBw) early in 2014 expands the range of applications to include the capability to analyse and evaluate specific thermal, hygric, baric and solar environmental conditions with regard to the thermophysical reactions of the human organism and the degradation of performance that military personnel can be expected to experience. Issues relating to application-assisted online supply using modern mobile devices are also being explored for the first time in accordance with the objectives defined for the project.

Following the fielding of the globally applicable BIOMET assessment model, which has been developed at the ZGeoBw on the basis of UTCI (UTCI = Universal Thermal Climate Index, www.utci.org) equivalent temperature for the fully computer-assisted handling of diagnostic issues within the scope of service-incurred disability proceedings, the model has now been gradually adapted to allow the online visualisation of prognostic biometeorological information in an, as yet, low space-time resolution. The results have recently been implemented in a first in-house developed test application that can be used as a universal app with a single code base for the entire family of Windows 10 devices.

The focus of the subsequent exploratory work will now be on clearly improving the space-time resolution of the BIOMET forecast model and, in particular, on calibrating the UTCI equivalent temperature for a collective of military test persons. Serving as a basis for the definition of the UTCI are global response data received within the framework of COST project 730, under the aegis of the International Society of Biometeorology, from a collective of test persons who are representative of the world's civilian population. It will have to be evaluated further, however, whether the physical responses of test persons involved in military activities are sufficiently represented by the above-mentioned compilation of civilian data.

With this in mind, the ZGeoBw is looking to gain access to ongoing departmental research work of the Bundeswehr Medical Service by expanding existing cooperation arrangements. The Bundeswehr Medical Service has, for various exercises held under near-operational conditions, provided military personnel with highly complex, branch-specific sensor vests and continuously recorded relevant physical parameters. The atmospheric environmental factors have been measured at the same time, making it possible to examine the responses of the personnel's thermoregulatory systems to specific weather conditions during particular military activities.

For the military biometeorological calibration of the UTCI equivalent temperature required as the concluding step, the ZGeoBw will be seeking cooperation with the experts who have already parameterised the compilation of civilian data.

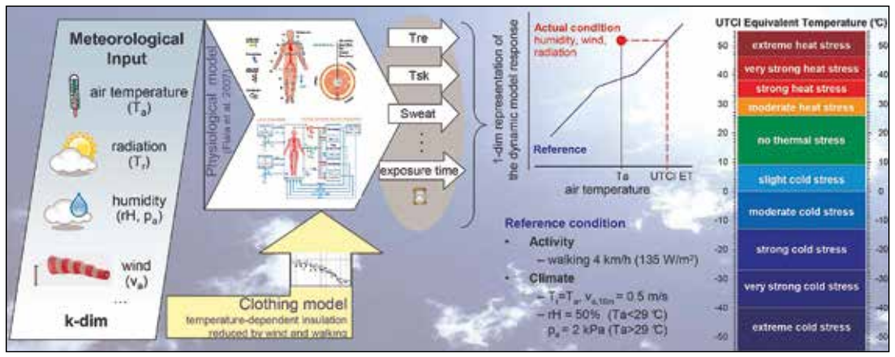

Fig. 1: UTCI – universal physiological equivalent temperature (source: www.utci.org)

Fig. 2: Prototype of a biometeorological Windows universal app: thermophysiological forecast on a Lumia 1520 smartphone (screenshot)

Fig. 3: Prototype of a biometeorological Windows universal app: thermophysiological forecast on a Windows 10 PC (screenshot)

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RegGRAV: a software for generating high-precision regional geoid models for use as vertical control datums in mission areas

When on missions around the world, the Bundeswehr needs vertical control datums at its disposal for precise positioning and navigation. Positioning with a Global Navigation Satellite System (GNSS) yields geometrical heights that use a global ellipsoid of rotation as a reference. To transform these heights into physical heights it is necessary to have high-resolution regional geoid models, which can be generated by means of the newly developed RegGRAV software.

The Bundeswehr, when on missions around the world, needs vertical control datums at its disposal for precise positioning and navigation. Heights nowadays are generally determined with the aid of satellite navigation methods (GPS and other GNSS). These, however, do not directly provide the physical heights, which are sensitive to gravity and are needed for use in (civilian and military) practice. Only physical heights can provide information about the direction of flowing water and are of vital importance, for example, in the construction of pipelines or wells.

GNSS observations yield exclusively geometrical heights that use a global ellipsoid of rotation as a reference. To transform these geometrical heights into physical heights, whose datums are the geoid or quasi-geoid, depending on the preferred height system, it is necessary to have so-called undulations, also known as geoid heights. In large parts of the world, however, especially regions with a highly variable topography, global geoid models such as the EGM96 or EGM2008 (Earth Gravity Model) specified in STANAG 2011 do not provide

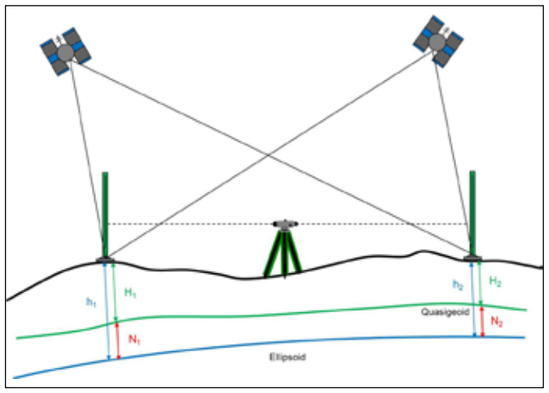


Fig. 1: GNSS levelling with geoid undulations N

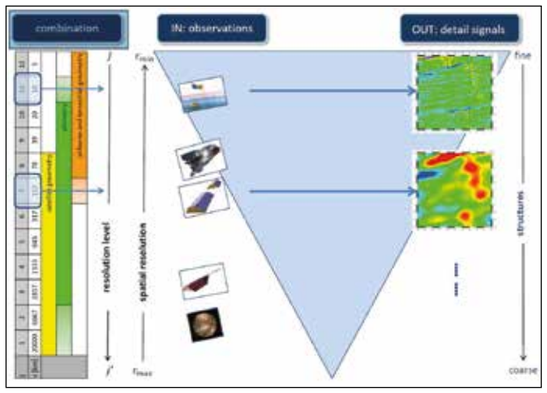


Fig. 2: Multi-scale representation

sufficiently differentiated and precise height information.

Regional geoid models are therefore needed. These are available, if at all, in just a few regions of the world (in Germany, currently the "German Combined QuasiGeoid 2011", GCG2011) or cannot be purchased commercially, or the nations concerned do not grant access to them. The RegGRAV software developed by the Bundeswehr Geoinformation Centre (ZGeoBw) in cooperation with the German Geodetic Research Institute of the Technical University of Munich (DGFI-TUM) fills this capability gap.

Global geoid models are normally based on the spherical harmonic developments of the gravity field, which are always to be applied to the globe as a whole and therefore also require a largely even distribution of the input data all over the world.

In the RegGRAV technical project this traditional representation of the gravity field is replaced by a multi-scale representation that can achieve a considerably higher spatial resolution regionally. The regional densification takes place with the aid of so-called spherical base functions that are assigned to predefined grid points. It is thus possible to close data gaps using the best possible combination of different measuring techniques that complement one another. The long-wave portion of the gravity field (lower-grade gravity field models) is determined by analysing satellite orbits, for which, in the case of RegGRAV, the data from the GRACE (Gravity Recovery and Climate Experiment) and GOCE (Gravity Field and steady-state Ocean Explorer) international satellite missions are used. To determine the short-wave portion of the gravity field, the data are combined in the modelling with other gravity observations, such as altimeter observations, and airborne and terrestrial gravimetry data.

Combining a gravity reference model (e.g. Global Gravity Model GGM or EGM2008) with all the detail signals observed from different gravity measurement techniques ultimately leads to the target product, i.e. a high-precision regional gravitational field model and, hence, a mechanism for the Bundeswehr to compute its own regional geoid models. This will allow considerable improvements in the operational use of height data and thus in the conduct of GNSS levelling, i.e. the direct determination of physical normal heights on the basis of GNSS observations. This is very important, especially for the operational use of height data in mission areas.

The requisite algorithms and associated software have been presented at a number of international symposiums. The technical project was concluded in January 2015, with the software meanwhile being available from Branch V (1) of the ZGeoBw.

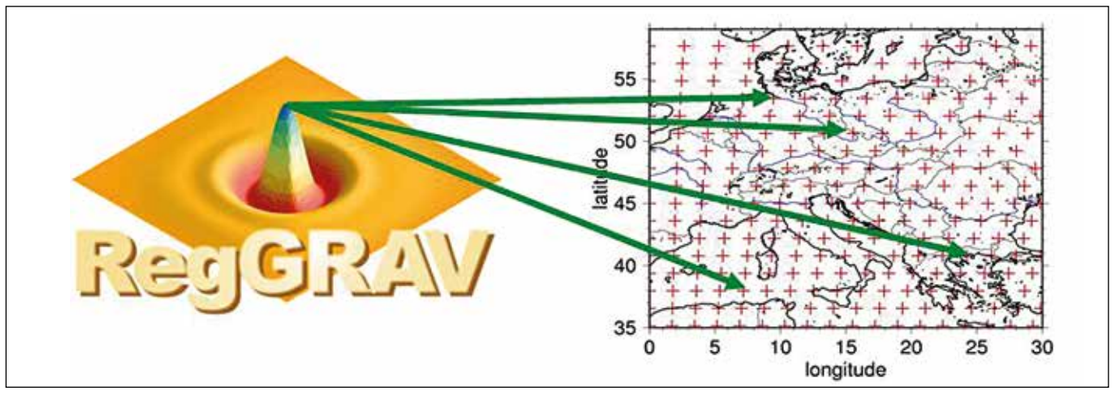
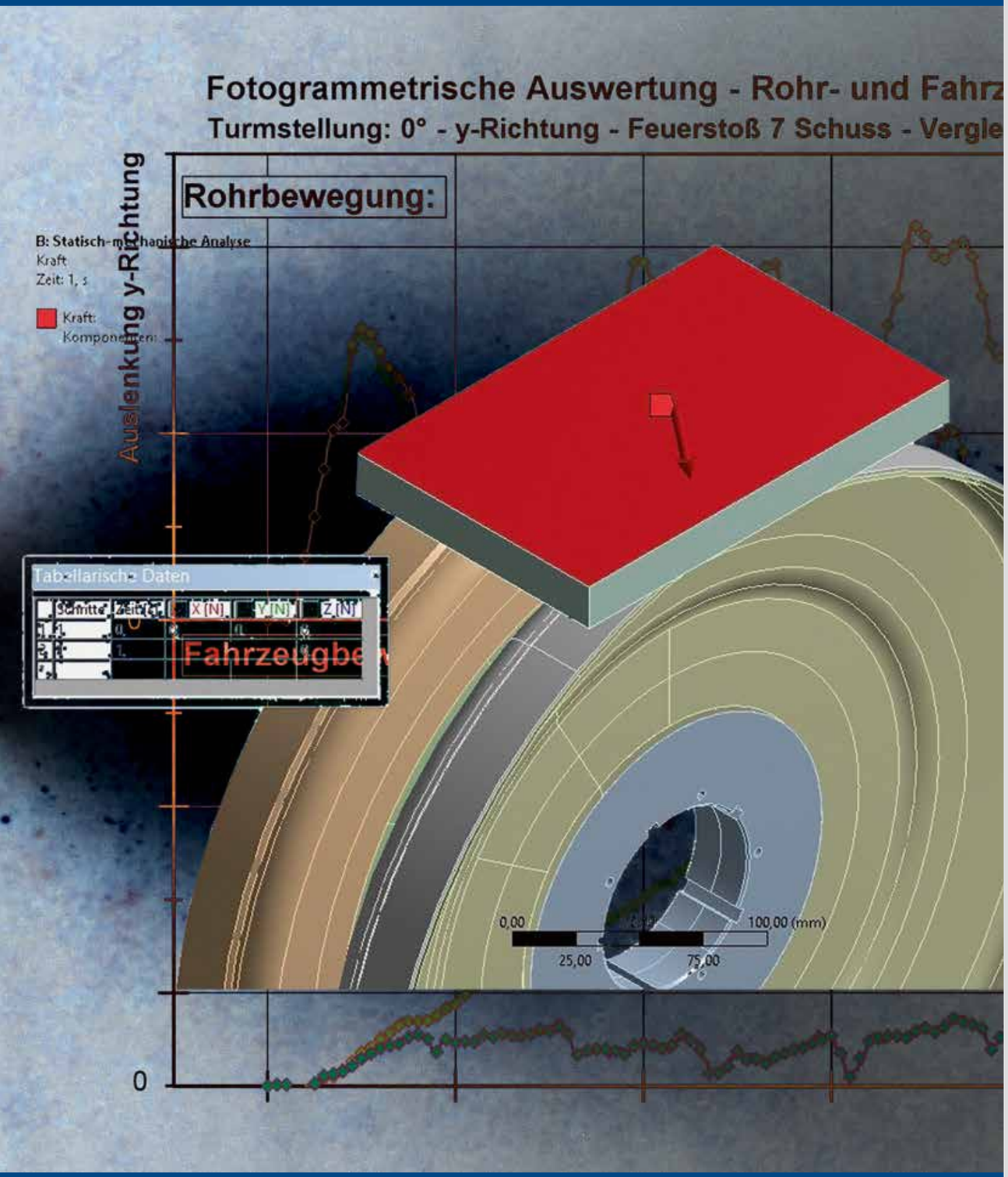


Fig. 3: Spherical base functions assigned to predefined grid points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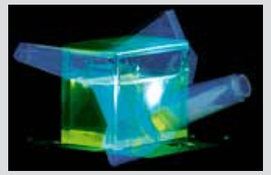

Appendix

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