HEER

ARTIFICIAL INTELLIGENCE IN LAND FORCES

A position paper developed by the
German Army Concepts and Capabilities Development Centre

BUNDESWEHR

The position paper at hand refers to a study conducted by the German Army Concepts and Capabilities Development Centre, an agency subordinate to the German Army Headquarters. It neither reflects the position of the Federal Ministry of Defence, nor does it prejudice any decisions by the German Chief of Defence regarding his overall planning responsibility for capability development in the Bundeswehr.

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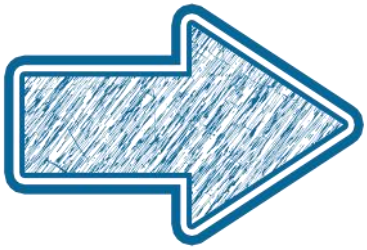

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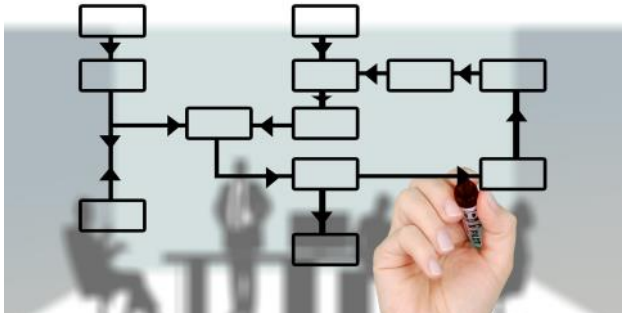
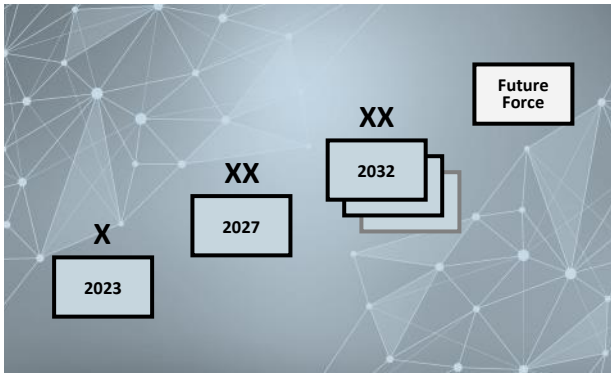




Fellow soldiers and civilian staff,
ladies and gentlemen,

In July 2019 the German Army Concepts and Capabilities Development Centre issued the position paper “Artificial Intelligence (AI) in Land Forces” which forms the starting point and basis for this fledgling technology to be advanced in military research, development and usage. Against the backdrop of our considerations on the battlefield of the future we are going to explore, in the months and years to come, how to promote and enhance the automation of systems of today and of tomorrow.

It is in pursuit of this goal that the German Army Concepts and Capabilities Development Centre has launched the Technology meets Capabilities 2.0 format. Under this approach it is intended to discuss and move forward, in close cooperation with the research sector and industry, a variety of topics for the purpose of targeted innovation management. In 2018/2019 our efforts have focused on artificial intelligence, the results of which are presented in this position paper. In 2019/2020, by contrast, we are going to concentrate on the subject of Robotics and Autonomous Systems, whose findings will be summarised in another position paper.

Owing to the great demand, we are releasing a second edition of the current position paper .

Brigadier General Bernhard Liechtenauer

Commander Army Concepts and Capabilities Development Centre

THE TACTICAL UAS BATTALION — A SCENARIO

Lieutenant Colonel Fuchs and her battalion have been deployed in theatre for days, protecting an important transformer station. The protection of critical infrastructure has become a key task - both on deployment and at home. Fuchs is very experienced, and her servicemen and women are well-prepared. But the situation itself is extremely fraught. For days, organic cyber forces have been fighting off hostile hacker attacks. Now, Fuchs is also being confronted with hostile attacks. For the time being, it has been possible to successfully repel hostile drone attacks by using the battalion's own laser and air defence weapons. Nevertheless, Fuchs has had to watch her own forces become increasingly tied down in the ongoing defensive battle.

Brigade headquarters has therefore decided to support her defensive activities with forces from the TaUAS (Tactical Unmanned Aerial System) battalion. Soon thereafter, Major Wolf, commander of 2nd Company, arrives at the command post of the brigade's UAS battalion. Under his command are a total of four platoons, each comprising 5,000 TaUAS - the largest with a span of more than one metre, and the smallest less than a tennis ball in size. The TaUAS company is quickly ready to move. Its mission is to support the battalion of Lieutenant Colonel Fuchs.

Having arrived in situ, the first UAS platoon takes up position inside two old, abandoned industrial buildings. The hatches of the transport vehicles open, releasing 5,000 UAS, which form into different swarms. One swarm consisting of several hundred sensor UAS even extends over two kilometres in diameter and is equipped with high-resolution cameras. Some swarms have the job of jamming hostile drones or serve as relays for communication among friendly UAS. Others are fitted with micro munitions to attack hostile sensor systems and to mark or track targets, and are also capable of forming a deployable UAS barrier. A counter-UAS swarm is trained to intercept and destroy hostile UAS. Within minutes, all 5,000 systems have left the transport vehicles and are no longer visible to the naked eye. Only the distant and softly humming background noise provides a clue as to what is currently going on in low-level airspace.

Major Wolf has meanwhile made contact with Lieutenant Colonel Fuchs. The available sensor data fusion enables both to access a common operational picture in their battle management systems. The sensor UAS from the combat vehicles of Fuchs' battalion have integrated themselves into the swarms operated by the TaUAS platoon and additionally complement the operational picture with information in real time. Once detected and identified, hostile forces are classified in a highly automated process and assessed in regard to their tactical formation. The presumed intent of the hostile forces is continuously updated. Fuchs now, additionally, has the possibility to use

swarms operated by the UAS platoon, and she decides to employ elements of a munitions-carrying swarm to form a UAS barrier. She also deploys several counter-UAS swarms to protect her own vehicles as well as critical infrastructure. Meanwhile, Major Wolf moves the remaining TaUAS platoons into position and draws up plans for their use. After only a short while, their actions seemingly show first signs of success. The hostile UAS attacks are either being disrupted or successfully repelled by friendly counter-UAS. The hostile forces have advanced in several combat vehicles further and further into the weapon-system barrier. Within seconds, several hundred UAS deploy to destroy specifically the sensors of the hostile forces and to mark the combat vehicles for the friendly forces' own engagement network, so as to collect information on further hostile intentions and bring targeted effects to bear at any time. New UAS barriers are quickly formed with support from the second and third platoons.

This fictitious scenario depicts how combat operations might be conducted in the future. Artificial intelligence, automation and autonomy will have a profound impact, which is why they have become a focal point of land forces' further development.

CONTEXT AND FRAMEWORK

The position paper on Artificial Intelligence (AI) in Land Forces emphasises, to begin with, the importance of AI for the future conduct of combat operations. It also highlights goals, driving forces and fields of action for adopting AI in land forces. With regard to an organisational structure, it defines procedural arrangements and makes recommendations for organisatioal measures. All the measures necessary to achieve early materialisation are described in five different lines of action, which are attached as an annex.

The present document is the first of a total of three position papers that are to be drawn up within the German Army, a major organisational element. To follow are position papers on "Robotics and Autonomous Systems (RAS) in Land Forces" and "Digitisation in Land Forces". The latter-mentioned paper will define goals and focal points for the digitisation of land-based operations (D-LBO). A starting point common to all three position papers is the concept for land forces of the future, which is also being drawn up at present. All of the papers intermesh and are mutually dependent. Robotics and autonomous systems (RAS) are not possible without AI, and D-LBO will be unable to attain their goals without AI and RAS.

Conduct of Future Combat Operations

A central element of conducting future combat operations will be combining classic combat management with waves of cyberattacks and attacks by large swarms of automated and autonomously controlled systems. This approach is currently being discussed within NATO under the term "hyperwar". In that context, AI is an enabler both for the use of automated and autonomously controlled systems and for accelerating the decision-making process through the selective use of AI-driven decision support systems. Although this will not fundamentally change the structure of combat, it will however lead to a completely different dynamic, as there will be the capability and also the need to act faster and over wider areas.

Decisions which can currently take hours as part of the military decision-making process will in future have to be made in just minutes, or even seconds. In specialist military literature this development is referred to as "fighting at machine speed". Numerous automated and autonomous

systems can also be deployed at high speed - for example, by means of rockets - thus creating the capability to "deploy at machine speed".

Successful command and decision-making is based primarily on correctly deploying a sufficient amount of the right resources at the right time, those resources having to be deployed effectively at a distance, or in force-on-force situations. This principle will also apply in future combat operations and any hyperwar. The underlying decision-making process however will have to be adapted to the new circumstances. In a hyperwar scenario, therefore, commanders will have to make skillful use of situations described hereinafter.

It will be important to seize every opportunity to communicate more quickly and more effectively, so as to achieve and/or maintain command and control superiority. Cyberattacks, enhanced AI-enabled electronic warfare, and selective jamming of communications by TaUAS will lead, almost invariably and with a high probability, to communications being disrupted in critical phases. Command and control superiority hinges on instantly using the few and possibly short phases of connectivity as efficiently as possible across all channels, so as to achieve an optimum distribution of information. Information, in addition to ammunition, energy or fuel, is set to become the third important "expendable" on the battlefield. In critical situations, however, this resource will almost always be in short supply.

The high dynamic, as well as full-coverage ISR, will lead to classic, static command posts no longer having a future. High-value targets such as C2 structures will have to be continuously on the move on the battlefield to increase their sustainability. They will also, wherever possible, need back-up structures. Only thus will it be possible, over the long term, to maintain command and control superiority in a protracted hyperwar situation.

With communications being restricted and time being of the essence when fighting at machine speed, it will mean having to make decisions faster and farther forward. Commanders will have to reach decisions very quickly, often within a few seconds. In classic warfare it was possible to prepare for and make those decisions from a command post with a much longer lead time. Rear command posts, for reasons of time and the restricted situational information available, will be able to conduct combat operations only by way of extended mission command. They will also require suitable protection.

Command responsibility will remain as it is, but the rules will change. Hyperwar will use AI to deploy a high number of weapon systems collectively. In fractions of a second, it will be decided which combination of systems will engage which targets. In such very high-intensity phases of combat, humans can no longer effectively allocate the weapon systems at their disposal and assign individual targets. Defensive actions must, consequently, also be controlled by AI. Force commanders will, as before, be required to release such systems for use. But they will no longer select individual targets; instead, they will approve weapon system assets for a particular space-time window.

Mirroring developments in the civilian sector, digitisation in the armed forces is pursuing the automation of processes on the battlefield. Tomorrow's weapon systems, especially under the sensor-to-shooter concept, will have to come with a very high degree of automation. But it will not be possible to attain the necessary degree of automation without drawing, militarily, on the new capabilities emerging in the field of AI. A good example of this is image analysis, which is needed for target acquisition and identification. A number of further applications are listed and described in the annex.

Artificial Intelligence

The Artificial Intelligence Strategy of the Federal Government clearly differentiates between the vision of a superintelligence - referred to in the document as "strong" AI - and narrow application-specific problems being resolved through mathematical and computer science methods - termed in the document as "weak" AI. Not least because this is where technological breakthrough is perceived, the Federal Government and hence also the Bundeswehr and this position paper have focused solely on the positions of "weak" AI. Any association with natural, biological intelligence (like that of human beings) is to be avoided as this does not reflect the current state of the art.

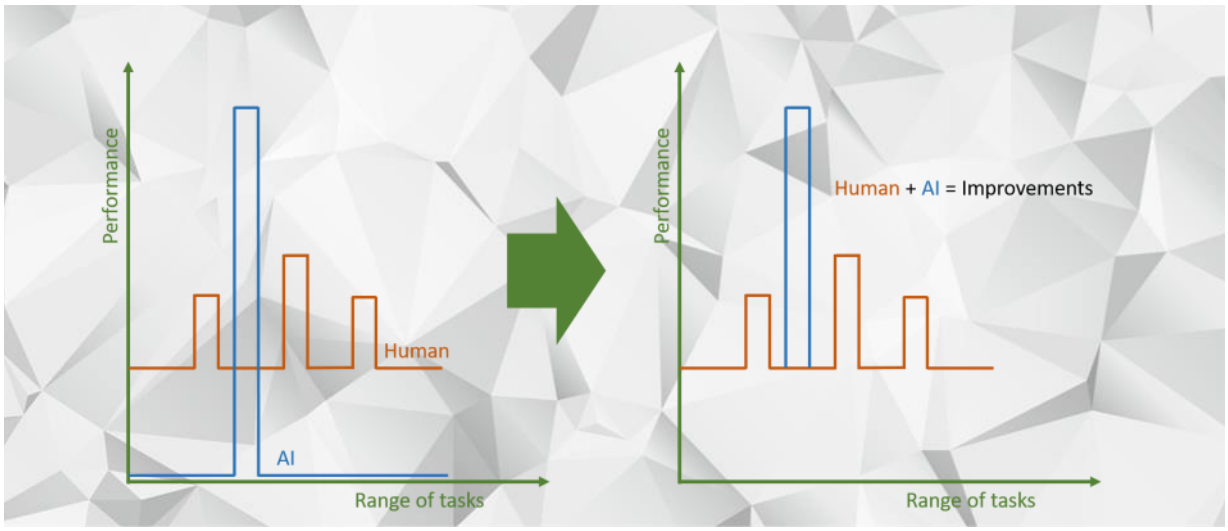
Generally, when reference is made nowadays to achievements in AI, it is often the application of artificial neural networks (ANNs), as used in a (deep) learning system, that is meant. This approach is extremely effective in narrow and clearly defined fields of application - for example, in image, voice or video recognition. But the scientific domain of AI encompasses even more methods which are necessary for the development of applications. An AI system must also store and sort the acquired knowledge efficiently and make it retrievable. When human skills are complemented by those of specifically trained AI systems, far better results can be expected, at least for some tasks. Humans will retain responsibility and make decisi-

ons themselves, but when doing so will, wherever possible, be optimally supported by an AI system. AI systems will be able, and also be required, to replace the functions of individuals in processes entirely as, ultimately, the requirement of accelerating the decision-making process can only thus be achieved. Possibly required monitoring and control functions will then have to be carried out from another location.

A valid assessment of the opportunities and risks offered or posed by AI components calls for rational (demystified) consideration of the subject area of AI as well as a saturated understanding of the methods involved. From a military perspective, AI components are mainly computing methods that enhance the automation of processes and procedures in capability domains, in training, and in routine duty.

The decision-making process will remain basically as it is in terms of its structure, but will need to be adapted to the high dynamic on future battlefields. This applies in particular to the operational level. The more extensive the amount of data to be managed, the greater the need for AI -based support systems. Headquarters, however well-trained, will not be remotely able, without AI support, to deal with and evaluate the flood of information generated. Big data-based techniques for condensing information, and AI methods for recognising particularly critical or relevant patterns, are imperative for headquarters to work soundly and with sufficient speed. Especially in the phases of assessing a situation, of decision-making and of issuing orders, effectiveness and efficiency will need to be significantly increased through suitable AI methods. Only thus can information superiority be translated into command and control superiority and, ultimately, also into effects superiority.

In highly automated and autonomous systems, superiority is essentially defined through the quality of the algorithms, the computing capacity, and the degree of miniaturisation. A new generation of IT hardware or AI can frequently boost effectiveness by a factor of two. As these components are based more or less completely on dual-use technology, the pace of the developments in the civilian sector will also determine the pace of the arms race internationally. Upgrade cycles, or at least important upgrades, occur at a two- to three-year interval, comparable to the pace of smartphone, hardware or AI developments in the civilian sector. The dynamic observable in civilian IT and AI developments clearly indicates that current upgrade process cycles take too long to be able to prevail on the battlefield of tomorrow with competitive products. Systems that are consistently modular in design could, particularly in combination with a dual-use approach and regular upgrades, lead to an improvement in this regard.



As and where necessary, the upgrade process will have to be adapted to the new circumstances. The chapter on “Fields of Action for the Organisational Structure” contains pertinent recommendations on the setting-up a national defence agency.

Political and Legal Framework

The opportunities and risks offered or posed by the digitisation of battlefield processes call for their extensive consideration in any decision-making. Humans must always retain authority over life and death decisions. The principle of effective human control applies.

The development of digital technologies and AI in combination with weapon systems should enable humans to concentrate more greatly on those functionalities in which human decision-making is essential, and to exercise control. Such control encompasses especially the critical functions of a weapon system and its entire life cycle.

The use and development of weapons, means and methods of warfare must always be in compliance with international law, in particular international humanitarian law. The latter applies universally to all weapon systems and must be heeded especially where the development of digital technologies and AI is concerned.

Whenever new weapons, means or methods of warfare are reviewed, developed, acquired and introduced into service, the Federal Ministry of Defence is required, under international law, to carry out an assessment. This ensures that the Bundeswehr introduces into service and employs only weapons, means and methods of warfare that are in conformity with international law.

The development of new technologies can help to improve the enforcement of international humanitarian law - particularly the protection of civilian populations in armed conflicts - through enhanced precision and scalability of weapon effects, more extensive ISR of areas including data analysis, as well as improved response capability and control of weapons, for instance.

A weapon system is military equipment designed or suited to kill or injure people or to eliminate or degrade their offensive or defensive capabilities, and/or to destroy or damage objects (definition as per Type A General Publication “Prüfung neuer Waffen, Mittel und Methoden der Kriegführung” [Verification of new weapons, means and methods of warfare], A-2146/1). In this respect a distinction is made between automated and autonomous as well as lethal and non-lethal systems.

Automated weapon systems carry out particular actions in a largely predictable and rules-based manner according to commands programmed by humans as “if-then operations”. Examples of this include the Phalanx, Mantis and sea mines weapon systems. Autonomous weapon systems, by comparison, carry out complex actions without any human intervention, are completely independent, self-learning or capable of formulating new rules, and are thus unpredictable. There are no examples of such systems in the Bundeswehr.

A lethal autonomous weapon system (LAWS) is one which is intended primarily to bring lethal force to bear against people only and which, without any human intervention and control, is aware of its environment and its internal state, assesses the situation, makes decisions, takes action, evaluates, and learns accordingly. The LAWS definition, in particular, does not apply to:

- Weapon systems that merely adhere to defined stimulus-response patterns or automated programme steps yet are unable to make any situational assessment without human intervention, take decisions, act rationally, evaluate, and learn.
- (Weapon) systems that are not primarily intended to apply lethal force against people.
- Weapon systems that are primarily intended for use against objects such as missiles, aircraft, tanks or ships.
- Weapon systems that are remote-controlled by humans.
- Weapon systems whose human operators can, at any time, override decisions or actions taken by the system, or abort their mission .

Aside from the political and legal aspects, the employment of LAWS is an undesirable and unintended option also from a military viewpoint. It must however be assumed that potential adversaries will develop weapon systems which do not adhere to the afore-mentioned criteria. To be able to respond to such situations, it will be necessary to research, develop and procure suitable defence capabilities.

GOALS

The use of AI will serve to increase effectiveness and efficiency, this applying to all areas of the Army. This will include weapon systems, command and control systems, and personnel and material management systems, among others. The use of AI can be successful only if the following requirements are met:

- The technology to which AI is applied is sufficiently developed and also fit for service use when controlled by AI.
- The functionality of the AI is sufficient to deliver the required performance. The complexity of the AI and IT systems is manageable.
- The AI-based component contributes an increase in value also as part of an integrated system network incorporating other relevant capabilities. This applies, in particular, to human-machine and manned-unmanned teaming (MUM-T).

All three aspects need to be substantiated by means of suitable studies, testing and trials before initiating any procurement measures. This is the case especially in view of the fact that the effectiveness of AI methods is often unpredictable and has to be verified experimentally.

Goal 1: Increasing efficiency in routine duty

Against the backdrop of an increasingly globalised and digitised world, a great number of operational tasks will in future be supported from home bases and also, therefore, as part of routine duty. Every army on operations will thus require a strong basic organisation from which to routinely function. Routine duty will need to be automated further and its efficiency enhanced through the selective use of AI.

Goal 2: Improving capabilities on operations

When on operations it is essential to have competitive resources available across all capability domains (command and control, JISR, effects, and support). Improvements may be of a qualitative (closing of gaps, achieving superiority) or quantitative (greater effect or longer sustainability at the same cost) nature. The information superiority thereby achieved will lead to command and control superiority and, consequently, effects superiority.

Goal 3: Addressing potential capability gaps

Based on current observations, a large number of nations are forging intensively ahead with the use of AI in military applications. It is to be expected that also potential adversaries will have such systems at their disposal at some point. This will also, inevitably, mean a changed force structure. Potential new capability gaps will therefore need to be addressed quickly and effectively.

DRIVING FORCES (DF)

The position paper “AI in Land Forces” delivers responses to the driving forces described hereinafter. These driving forces can neither be influenced nor avoided.

DF1: AI capabilities of potential adversaries

AI-based components employed by adversaries may lead to capability gaps for the German Army. It needs to preclude this by having its own AI-based components with passive and offensive characteristics.

DF2: Increasing dynamics of combat operations

The developments emerging with regard to the future conduct of combat operations (Land Forces of the Future) will lead to an increase in effective ranges, to shorter force-on-force engagements, to better reconnaissance coverage, and to correspondingly more dynamic command, control and logistic structures. In combat engagements with increased dynamics, AI will help to command, control and act faster, more purposefully and more effectively.

DF3: Fewer qualified personnel available

It is difficult to meet the demand for qualified personnel. This problem could get even worse in the future. Through targeted use of AI, it may be possible to further automate complex tasks and simplify them for humans. Use of AI may thus provide a positive counterbalance to this human resources problem.

DF4: Declining relative purchasing power and shortage of resources

AI offers an opportunity to cut costs by simplifying systems and processes. There is, additionally, the possibility to act with a variety of small, cost-effective components. AI supports effective use of limited resources, such as radio frequencies, making it possible to achieve a greater overall effect for the same cost.

DF5: Increasing quantity and density of information

Modern systems deliver a growing amount of information (big data). Dynamic combat operations call for a faster military decision-making process. AI permits the most effective and efficient use of information possible and thus ensures information superiority as well as command and control superiority when dealing with a high volume of data under tight time constraints.

DF6: Increasing dynamics in the development of IT and AI

Large IT enterprises are investing a very high amount of human and financial resources in future IT and AI systems. As economic activity gathers pace, it can be expected that this development will intensify. It can also be observed that defence suppliers to potential adversaries are working on the development of AI-based weapon systems. The first systems have already appeared on the market. The resulting erosion of [our] own capabilities will, over time, lead to a significantly increased threat.

FIELDS OF ACTION FOR ARMY DEVELOPMENT

AI can be put to practical use in various areas, this applying both to routine duty and to operational deployments. Where operational deployments are concerned, systems in service use need to be developed further, as well as systems upgraded with new characteristics. In regard to routine duty, particularly the fields of personnel and materiel management, and training, offer potential for the use of AI.

In a series of workshops as part of the "Technology meets Capabilities" (TmC) format at the Army Concepts and Capabilities Development Centre, AI applications in land forces have been identified across all capability domains, arms and services and categorised by lines of action, based on the NATO Comprehensive Operations Planning Directive (COPD). The fields of action (FoA) described hereinafter generally reflect this categorisation. A detailed list of the lines of action is attached as an annex to this position paper.

FoA1: Further development of existing systems

(Weapon) systems in service use will be upgraded and modernised significantly with the aid of AI-based components. New, improved versions of these assets will be developed. This will include, for example, activities to upgrade existing platforms by means of AI-based object and image recognition systems, so as to improve ISR and force-on-force capability. Any required modifications can be incorporated as a product improvement along the lines of Customer Product Management (CPM).

FoA2: New weapon systems and weapons armament

This field of action will ensure that the Army keeps pace with ongoing developments where military equipment with largely new characteristics is concerned. This will include, for example, activities relating to smaller tactical UAS (TaUAS) for ISR and barrier purposes. This field of action often has a strong exploratory character. For the development of countermeasures, it may also be necessary to analyse systems the Army is not to be equipped with. Where activities whose implementation can be considered feasible are concerned, the 'initiative' tool will be employed. In cases involving extensive exploration, the tools of research and technology and of non-technical scientific support will be used.

FoA3: Use of AI capabilities in personnel and materiel management

Almost all AI methods and procedures require a very high volume of training data. The more extensive and detailed the available data, the more efficient the trained AI system. AI systems should, consequently, be used in areas in which extensive data resources are available. In the context of routine duty, this applies particularly to personnel and materiel management. In personnel administration, for example, AI systems could submit proposals for the staffing of key posts. In materiel management, a good example of the use of AI would be predictive maintenance.

FoA4: Use of AI in training

The introduction of AI capabilities can also support and improve training. Two fundamentally different fields of application present themselves in this regard. One is the use of AI for digital agents in constructive and virtual training simulation systems. This can significantly reduce the number of operators for hostile as well as friendly forces. Another major area of application is the analysis of teaching and learning data, which is steadily growing in volume as training facilities are digitised. This specific area, referred to as Learning Analytics, is already finding use at many civilian training facilities at all levels. It is possible for the analysis of learning level and progress to be automated. Teaching and learning structures can be suitably adapted to a learner's progress (see also the position paper "Training the Army in 2035 and beyond", of the Army Concepts and Capabilities Development Centre).

FIELDS OF ACTION FOR THE ORGANISATIONAL STRUCTURE

Implementing and using AI in land forces will require adjustments to the organisational structure. This applies both to process-related and structural measures.

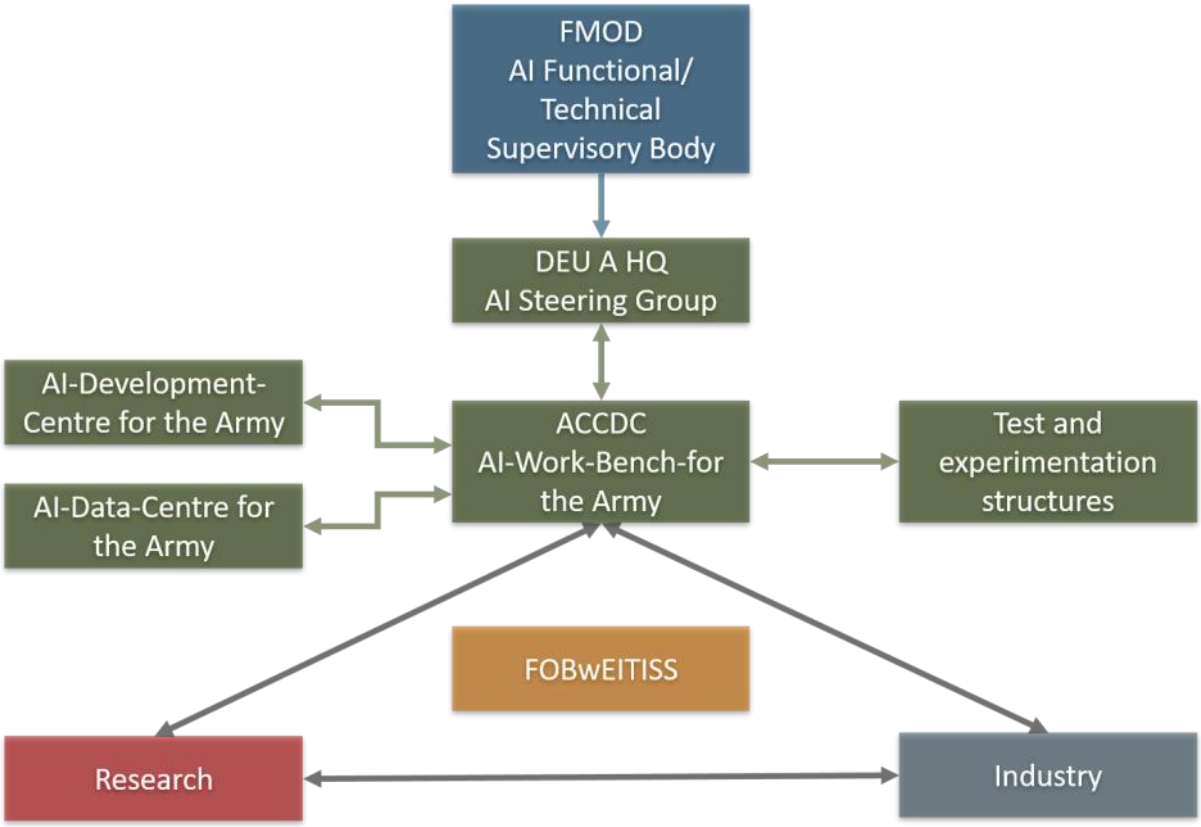
In anticipation of the organisational structure including organisational AI elements still to be decided on in the Bundeswehr, working initially with the structure described below is proposed.

It comprises a variant in which a still-to-be-established "AI Work Bench for the Army" would centrally coordinate all the AI-relevant measures, plans and projects in the Army. This would also include commissioning and properly integrating the test and experimentation structures. An echelon above this AI Work Bench for the Army, at the level of the German Army Headquarters (DEU A HQ), an AI Steering Group and, at the level of the Federal Ministry of Defence (FMOD), an AI functional/technical supervisory body, are to be set up. Besides the still-to-be-established AI Work Bench for the Army, the structure comprises two further new elements: the AI Data Centre for the Army, and the AI Development Centre for the Army. All the elements depicted in the diagram are discussed hereinafter.

Recruitment of AI specialists

To put AI to successful use, specially trained personnel are required. Such personnel are being desperately sought in commerce and industry. In its OR/M&S specialists, the Bundeswehr already has these much-in-demand experts at its disposal. The academic Master's degree in "Operations Research" provides all that is needed to handle AI-related tasks. As the importance of AI methods grows and the number of applications throughout the land forces increases, the demand for these experts is expected to rise rather than stagnate in future.

Reliance solely on the OR/M&S specialists is not expected to suffice in the medium to long term. For this reason, graduates of the MINT programmes at the Bundeswehr universities must be recruited early for long-term and constructive assignments in the AI field.



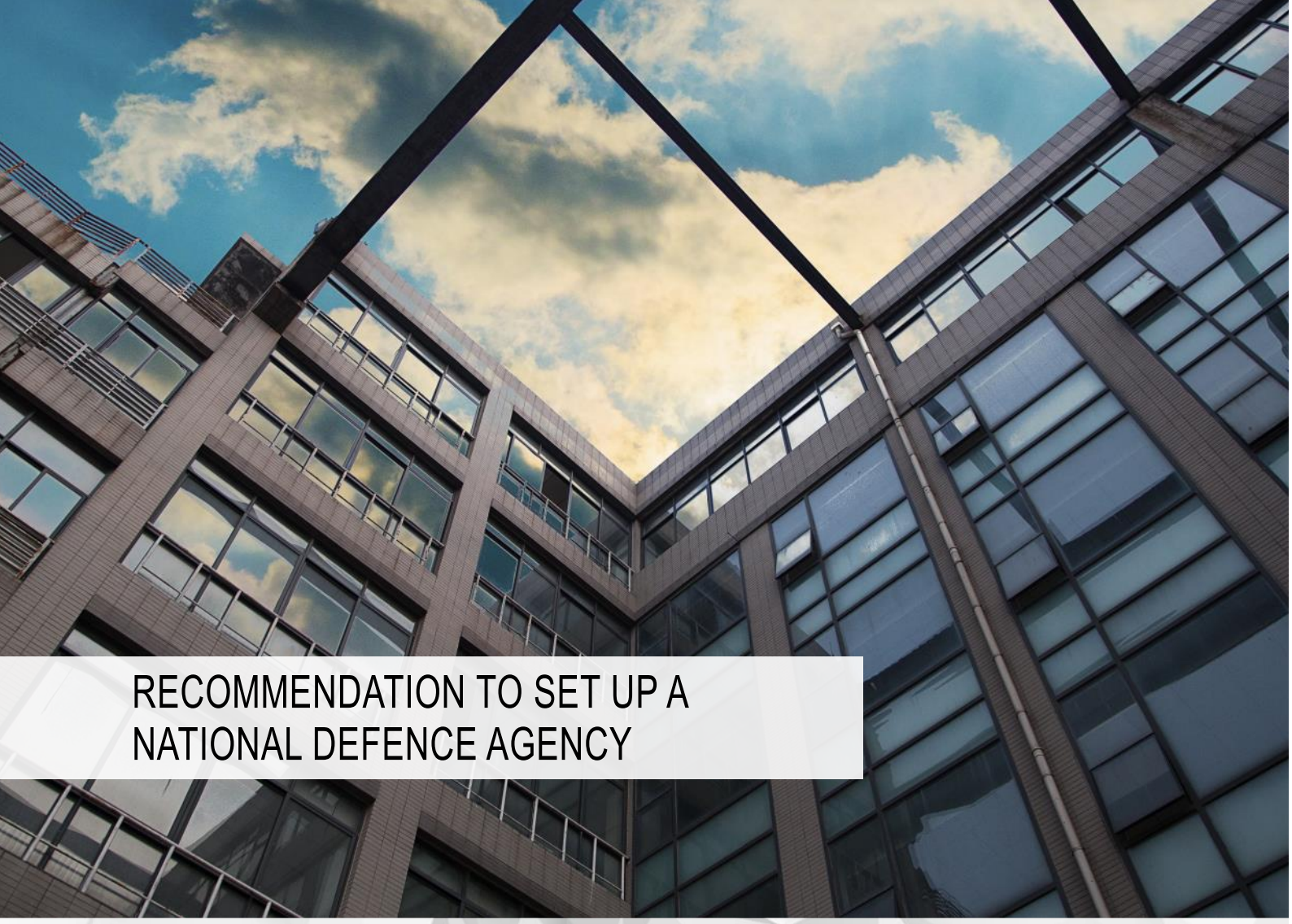
RECOMMENDATION TO SET UP AN AI WORK BENCH

AI WORK BENCH FOR THE ARMY

The AI Work Bench for the Army is the central coordinating element for all AI-relevant measures in the Army. In order to promote an interdisciplinary exchange of ideas for the purposes of innovation, it is recommended that the Work Bench cover a broad spectrum of expertise.

In addition to the requisite AI expertise, which can mainly be sourced through already available OR/M&S personnel, MINT graduates as well as bionics specialists, sociologists and legal specialists are required, for example. The activities of the AI Work Bench for the Army will include:

- Coordination and cooperation between research and industry in all AI-relevant matters of the Army.
- Innovation management to identify AI-relevant applications in land forces during routine duty and on operational deployment.
- Initiation of research as part of non-technical scientific support, and prototypical implementations by means of R&T projects.



RECOMMENDATION TO SET UP A NATIONAL DEFENCE AGENCY

It is recommended that a national defence agency be set up which, as a non-profit association, would pool the activities of the Bundeswehr, the European defence industry, and of research in order to promote a platform for accelerated development of AI and RAS solutions in addition to existing defence-related processes.

The agency would be funded by industry and by the Bundeswehr. The governing body would be put together from those groups. Industrial enterprises would be paying members, while selected research institutes would be non-paying members.

The agency would be open to all European industrial enterprises, provided they have suitable security clearance. Membership would require a unanimous decision from the governing body.

Upon the decision of the governing body, the agency could initiate activities, the results of which would be freely available to, and could be freely used by, the members participating in the activity. The outlays incurred by the activities would be funded by the agency.

The agency would work closely together with the AI Work Bench and with the test and experimentation structures of the German Army. It would organise periodic conferences to present the current status of developments in relevant areas.

The aim of the agency would be to develop operationally viable basic solutions, through which defence equipment could then be produced with little effort/expense and within a short space of time (using established defence-related processes, with the industrial enterprises in competition with one another).

Cooperation between the military, research, and industry

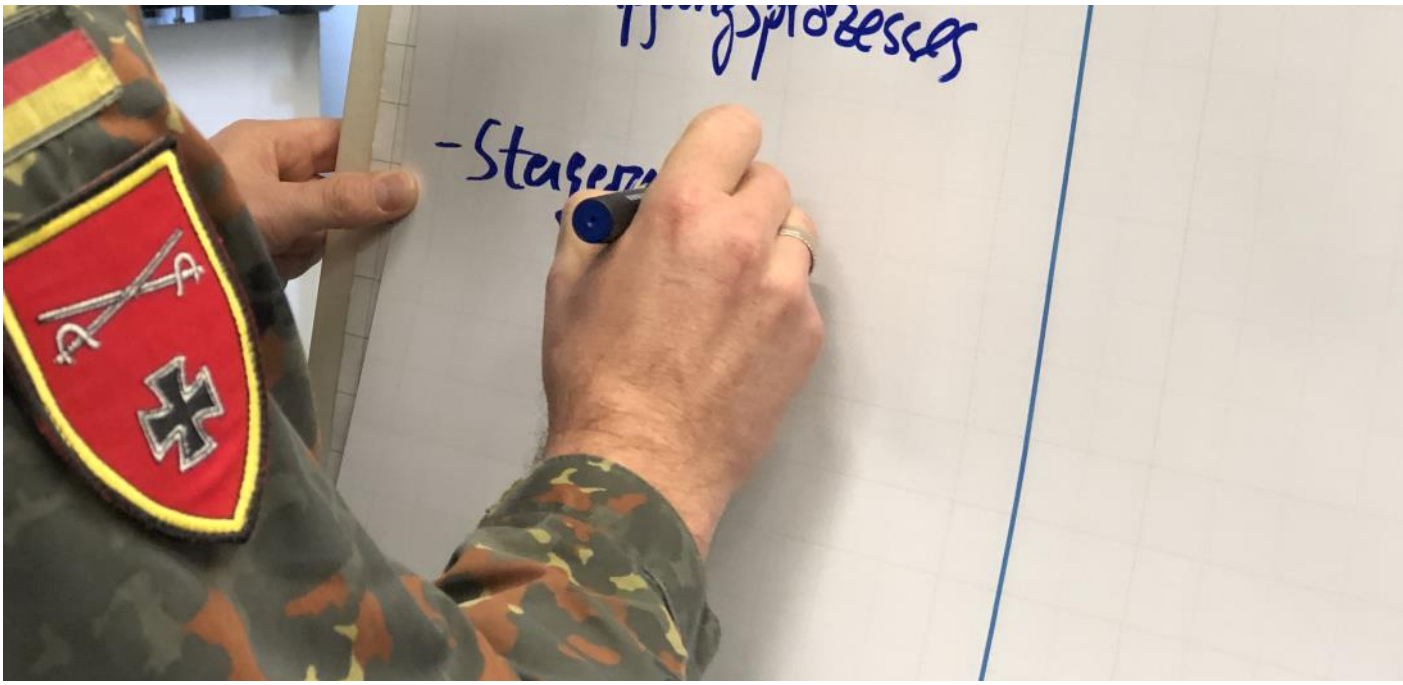
AI is high technology requiring substantial expertise and development effort to arrive at top-performing and operationally viable solutions. Drawing upon dual-use products and applications as well as the latest civilian research findings is key to providing affordable and competitive solutions. It can be regarded as unlikely that the Army, albeit a major organisational element, will be able to manage this completely on its own, and focusing only nationally, in an acceptable timeframe. A way must be sought via which close and early cooperation with European industry and research might take place (while keeping within the legal framework). Cooperation with industry must be supported by regular conferences on clearly outlined individual issues. The TmC format at the Army Concepts and Capabilities Development Centre has delivered the first results in this regard.

TMC

The Technology meets Capabilities (TmC) format was developed at the Army Concepts and Capabilities Development Centre (ACCDC). It serves to coordinate the work between the ACCDC (whose main task is the development of the Army), research, and industry.

In 2018/2019, TmC has been focused on the subject of AI in land forces. The series of events that this has involved, in cooperation with the Fraunhofer Society, has led to the identification of more than 30 possible applications of AI in land forces. The annex to the present position paper contains a summarised extract in this regard.

In 2019/2020, TmC will be continued, with the focus on Robotics and Autonomous Systems (RAS).



International collaboration

The increased use of automated and autonomous systems requires close coordination between allied nations, as it has to be ensured that these systems do not mutually classify each other as hostile. The procedures for employing these systems must also be coordinated so that the greatest possible composite effect is achievable.

For this reason, the Bundeswehr must seek to work as closely as possible with allied nations on the development of concepts and systems and actively participate in joint design, coordination and test/experimentation activities. The aim is to initiate at least one joint project with interested allies from the European security environment.

Use of test and experimentation structures

Setting up test and experimentation structures is a focal aspect of the Army's digitisation activities. They are an essential element of the digitisation of land-based operations, to introduce digital technologies into service and make them available sooner to field units. AI-relevant plans and projects fit in seamlessly in this respect. A good example of this is the prototypical realisation and testing of an AI-controlled reconnaissance flight (UAS) at tactical level.

AI data infrastructure and organisation

The application of AI requires extensive databases. Machine learning methods, in particular, are reliant on a large amount of training data, whose order of magnitude in terms of data sets is at least in the six-digit range. Generally, it is necessary to tailor the available database to the AI method that is to be used. This ties up materiel and personnel resources.

RECOMMENDATION TO SET UP AN AI DEVELOPMENT CENTRE FOR THE ARMY

AI DEVELOPMENT CENTRE FOR THE ARMY

A particularly promising approach for applying AI components in the context of operations is seen in the training of deep learning models, in which regard the setting-up of an AI Development Centre for the Army is recommended. The work process that this will involve is an indispensable basis for adopting AI capabilities in land forces.

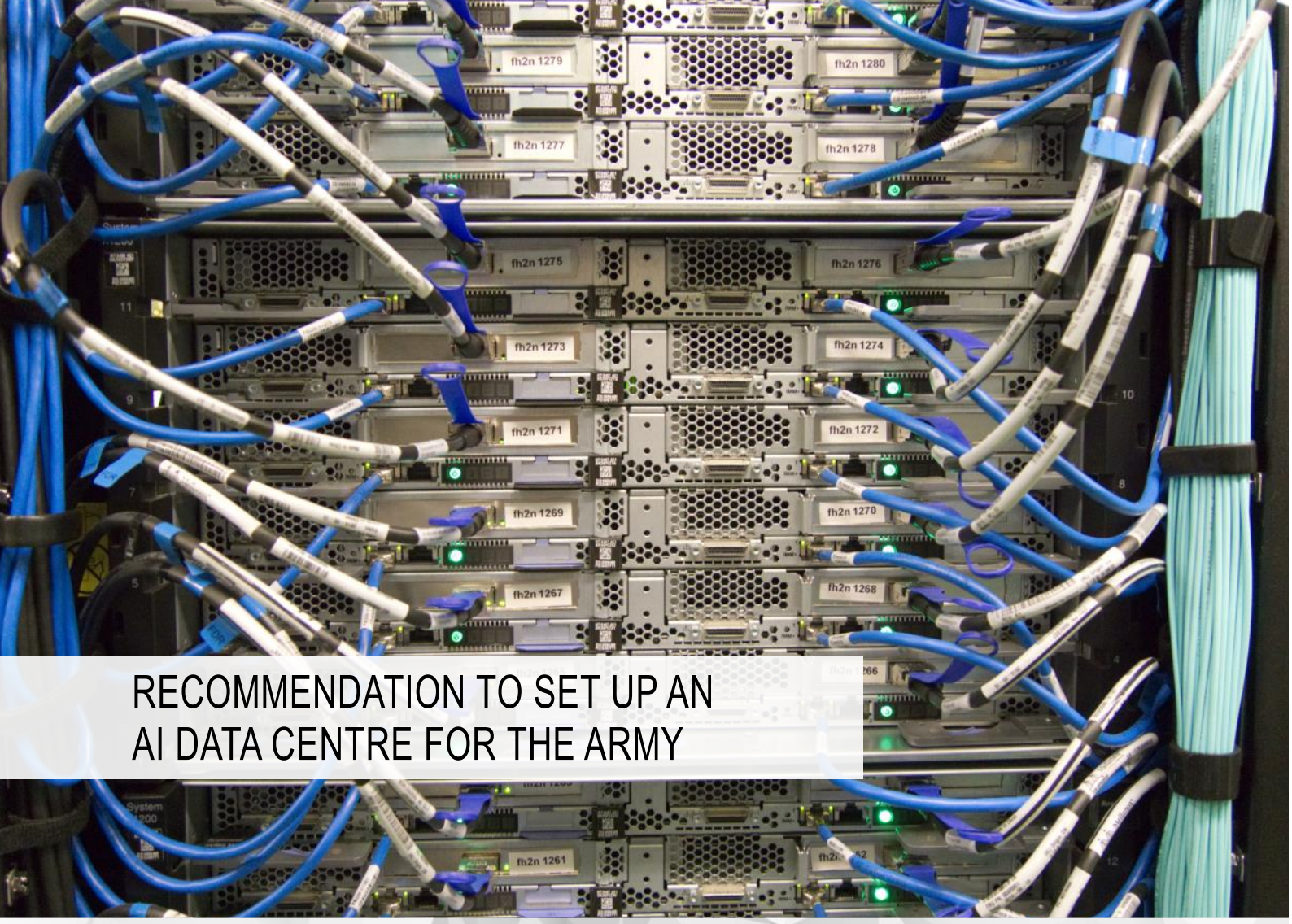
The models for this must be trained for standard operations and standard terrain in a suitable constructive simulation (war game).

Only after in-depth training involving actual terrain and actual operational data will the models achieve their operational readiness and be applicable to real, unmanned systems.

The described procedure requires both extensive military expertise and an effective IT infrastructure in addition to an AI-capable war gaming environment.

Necessary (operational) testing of the trained systems can take place in the test and experimentation structures.

RECOMMENDATION TO SET UP AN AI DATA CENTRE FOR THE ARMY



AI DATA CENTRE FOR THE ARMY

Wide-ranging databases relating both to routine duty and to operational deployments are needed to train AI systems. This includes, for example, sensor data as well as image and video data for a wide variety of spectra. Particularly against the backdrop of a heterogeneous data structure in the Army involving difficult possibilities of access and authorisations needed for every level of classification, it is recommended that an AI Data Centre for the Army be set up as an organisational structure.

Besides being staffed by trained IT experts and data scientists, the centre should have its own legal and data protection expertise. Since it is to be expected that the requisite database will grow strongly in the future, the facility should have appropriate IT infrastructure.

Similar to the wide-ranging AI services on offer in the civilian sector, the centre must also have effective computing capacities at its disposal (e.g. in the form of GPU and TPU clusters), and an efficient AI service environment to be able to perform calculations of artificial neural networks, for instance.

SUMMARY

Numerous fields of action can be identified for the use of AI militarily. Besides consistent further development and AI qualification of the systems in service use, it is particularly future systems with new characteristics that will be able to benefit from the application of artificial intelligence. Routine-duty personnel and materiel management, as well as training, also offer major potential fields of action.

A meticulously defined political and legal framework is imperative, especially for the use of military force. The present and future use of automated and autonomous systems must, therefore, comply with the political and legal requirements of the FMoD. Aside from the political and legal aspects, the employment of LAWS is an undesirable and unintended option also from a military viewpoint.

AI is high technology that calls for considerable expertise and development effort. To achieve this, the Army is seeking close cooperation with European industry and research. The Technology meets Capabilities (TmC) format already established in the context of Army development is being used as a starting point for further activities.

To be able to respond adequately to all AI-relevant challenges in future, the Army must have qualified AI personnel at its disposal. In this respect the Bundeswehr faces strong competition from the civilian sector. To meet the demand over the short term, the Army is relying on existing OR/M&S personnel.

All data currently available indicates that utilisation of AI methods and procedures can increase efficiency and effectiveness in land forces substantially. To be able to respond to upcoming challenges appropriately, measures relating to organisational processes and structures have to be taken. The position paper “AI in Land Forces” therefore recommends setting up an AI Work Bench for the Army, an AI Development Centre for the Army, and an AI Data Centre for the Army. Only thus can innovation in the field of AI, the training of AI systems, and the provision of data be comprehensively covered.

All measures required to make early materialisation possible are described in detail hereinafter in the annex.

ANNEX: MEASURES FOR IMPLEMENTATION IN ARMY CONCEPTS AND CAPABILITIES DEVELOPMENT

In 2018/2019, the "Technology meets Capabilities" format on the topic of artificial intelligence (AI) has been conducted at the Army Concepts and Capabilities Development Centre. In the course of a series of workshops, AI applications in land forces across all capability domains as well as arms and services have been identified and categorised by lines of action, based on the NATO Comprehensive Operations Planning Directive (COPD). Listed in detail in the following are five areas of application, each with different lines of action.

Depending on content and maturity of development, the implementation of the measures and lines of action takes place by means of CD&E and R&T activities, or within the scope of CPM by way of appropriate initiatives. Matching with the Bundeswehr's capability profile is essential. The Army Concepts and Capabilities Development Centre is responsible for implementation.

1. Image analysis

This area pools all the activities in the field of AI-based object recognition and classification systems. The projects are gradually building up a functionality with which to extend, in modular fashion, the Army's various protection and effects components, ranging from ISR to automated effects-based systems. One focus is on utilising existing civil approaches for military purposes.

AI-reference

Current AI developments, especially in the field of deep learning, permit fast and capable applications in regard to object recognition and classification. In combination with classic image processing techniques and processes for semantic context-sensitive scene analysis, various effective approach options emerge for automation and MUM-T support.

AI-technology

The systems are able to use multispectral imagery information for object/situation recognition and classification from a position or vehicle. The basic techniques are the same in principle, but individual technological approaches have to be developed for certain operational purposes. These include:

- Fast recognition and classification of disguised/camouflaged objects on the ground.
- Fast recognition of small targets in the air.
- Recognition, from the air, of disguised/camouflaged and strongly concealed targets and their aggregation on the ground.

Line of action 1.1: Image processing reference

Creation of a reference database containing information on the training and testing of adaptive procedures. Development of standard procedures and tools as a reference for further processes and for verification of the reference database. The database and reference methods will be federally owned. The data is categorised 'Unclassified', 'Restricted', or higher. The aim is to provide the database and reference algorithms as support for other projects. This work is a mandatory requirement for all projects involving a machine learning component, as they are essentially reliant on the provision of appropriate training and test data, the aim being to provide a data and reference basis for all projects involving machine learning components relating to image processing.

Line of action 1.2: Target recognition and indentification

Addition of an image processing component possessing remote (retrofittable), fully automatic 360-degree-vision (multispectral) reconnaissance as well as object and target recognition capability to existing weapon systems and protection equipment. The component can, optionally, be integrated into system fire control functions. The aim is to create a ground visibility component which can be suitably adapted for use in different systems.

2. Tactical UAS (TaUAS)

This area pools all the activities relating to small UAS with different geometries. The activities range from reconnaissance, to barriers, to offensive weapon systems. Whatever the activity, the focus is both on defence and on the capability to deploy own TaUAS. An important challenge is, in particular, the creation of TaUAS that are sufficiently hardened and robust to be able to act semi-autonomously, day and night, with very limited communications and without GPS, using passive sensor systems.

AI-reference

Current developments in the field of small aerial vehicles (multicopters or delta-/fixed-wing aircraft) make it possible to construct small, cost-effective and reliable UAS (with a span of up to one metre) capable of performing subtasks autonomously under suitable AI control. AI plays a key role in managing these aerial vehicles over any prolonged

period, and without any remote control, so that military tasks (reconnaissance, barriers, targeted effects) can be reliably accomplished. Since these vehicles are frequently deployed in larger numbers, the AI also has to ensure a swarm capability as well as composite action based on local close-range communication.

AI-Technologies

Reliable, automatic execution of subtasks necessitates AI that safeguards the entire (automated) OODA cycle for managing the UAS including composite action between UAS (swarm) as well as MUM-T. This calls for a cognitive approach which combines different AI techniques to produce a sufficiently effective and sustainable performance. Current developments in the civilian sector (parcel drones, surveillance drones, etc.) demonstrate that such functionalities are feasible in certain cases.

Line of action 2.1: Reconnaissance

Development of a container as a base for around 100 reconnaissance TaUAS, which automatically carry out reconnaissance in an assigned area and send back consolidated situational information. The base station serves to recharge the TaUAS and also as a forward information processing node. The TaUAS can be equipped with various passive/active multispectral sensors. The aim is to demonstrate the feasibility of such systems and to develop parameters for standardised and modular TaUAS.

Line of action 2.2: Barries

Development of automated TaUAS for area denial and for automatic surveillance of barriers. The TaUAS are equipped with munitions capable of engaging combat vehicles or vulnerable components of light armoured vehicles. Swarming is used to compensate for the relatively small payload and high vulnerability of the individual TaUAS through oversaturation attacks. The aim is to estimate the effectiveness of these systems and, in particular, develop protective measures against effectors of this kind.

Line of action 2.3: Effects

Development of automated TaUAS with a range of up to 40 kilometres, capable of systematically engaging single targets. The TaUAS are capable of nap-of-the-earth flying/infiltration and attacking in several waves to systematically and gradually neutralise critical capabilities or to mark hostile forces by multispectral means. The aim is to estimate the effectiveness of such systems and, in particular, to also develop protection and counter-measures against effectors of this kind.

Line of action 2.4: Legal framework

The existing statutory regulations concerning the flying of automatically controlled TaUAS will be adapted so that these can be tested and tried out at suitable Bundeswehr sites (e.g. training areas) in the open and under real conditions. This applies, in particular, to the authorising of any use of TaUAS that are automatically controlled (not remote-controlled by a human). These adaptations are essential, as otherwise TaUAS can neither be developed nor tested.

3. Next Generation Battle Management System (NGBMS)

This area pools all activities focused on command and control. It encompasses both the realisation of single functionalities that, where applicable, can also be retrofitted in already ongoing initiatives, and the conceptualisation of systems and methods for possible use in hyperwar scenarios. There is nothing to indicate any notable dual use. The challenge lies in modelling the relevant parts of the command and control process so as to create hyperwar-viable command and control components. Ideally, parts of the command and control process can be depicted as a game, along games theory lines, so that AI can be used in the sense of an automatic means for decision-making support or command and control. MUM-T is a key challenge in this regard.

AI-reference

Current developments in the context of games (chess, poker, Go, etc.) have shown beyond doubt that AI is vastly superior to humans whenever command and control situations can be formulated as board games with clear rules (chess, Go) or as games with clear alternative courses of action (poker). They are greatly superior in terms of speed as well as potency.

AI-technologies

Many command and control situations can be depicted as games (along games theory lines) if the military commander's alternative courses of action are simplified and formulated as rules. Unless such simplification restricts any options relevant to achieving victory, it can be assumed that AI will potentially lead to command and control superiority. It is, in particular, necessary to examine which aspects of the command and control process can be formalised so as to allow the use of AI.

Line of action 3.1: Decision-making process reference

Creation of a reference database containing information about training and testing of adaptive procedures for command and control in military processes as well as in decision-making support systems. The data is categorised 'Unclassified', 'Restricted', or higher. The aim is to make the database and the reference algorithms available as support in other projects, as well as to provide valid databases for exploring different approaches in regard to automatic means of decision-making support and command and control.

Line of action 3.2: AI-based fire control

Einsatz von Use of AI for fire control and for the relocation of forces in engagements involving a high amount of artillery. In this connection, AI selects the targets, provides the possibility to engage "hostile forces in the process of changing positions", and selects munitions and combination of effectors. AI estimates possible hostile zones of reconnaissance and, on that basis, deploys own artillery and (where practical) also other forces, especially own reconnaissance assets, and leads own/friendly forces in targeted attacks on hostile reconnaissance forces. When doing so, AI considers the current terrain, estimated hostile forces, their equipment and their previous actions in the course of battle. The aim is to assess the feasibility and effectiveness of AI-based fire control.

Line of action 3.3: AI information management

Development of an adaptive system that, as optimally as possible in terms of time, space and content, transfers information between the components of a distributed BMS. When doing so, the system takes account of the infrastructure available, the current situation, the deployment of forces, the mission, and the estimated state of the components (and information) in the cyber and information domain. The system tries to ensure the best possible flow of information even if major parts of the components are disabled by electronic warfare, kinetic effects, or similar, or are unavailable or offer only low-level or close-range communication for reasons of concealment. The system controls and reconfigures the communication network, routes the information flows, and prioritises the transfer of information. The aim is adaptive communication and information management that adjusts dynamically to the ongoing situation and current infrastructure.

Line of action 3.4: Next Generation Battle Management System (NGBMS)

Development of a concept for a Battle Management System (BMS) that takes account of all hyperwar aspects. The system should no longer have any central components. It comprises concepts which, despite heavy and persistent attacks in the cyber and information domain, including EW, maintain the best possible command and control capability. This includes concepts for a rapid and frequent reconfiguration of the system using all currently available components and communication channels.

The system should essentially consist of personalised, mobile and small components. The separation according to command and control information and use of weapons

is set aside. It must support a separation of command and control role, processes and hardware. The aim is to create a concept for a next-generation command and control system.

Line of action 3.5: Acceleration of the decision-making process

Development and testing of AI-based methods and tools for accelerating the decision-making process in major headquarters. This encompasses, for instance, big-data-based processes for consolidating information in the situation assessment phase, AI methods for identifying particularly critical or relevant patterns in the planning phase (e.g. the risk of violating decisive conditions or trigger points in operations planning), and the automatic indication and evaluation of possible courses of action in the assessment of situations. The methods should support, not supersede the existing roles of the cells. The system generates an AI contribution on the situation which either can be used in addition to the classic situation or serves to make possible a more or less continuous event-driven situation. The aim is to create methods and tools by which higher headquarters can assess the current situation and, on that basis, exercise command and control as timely and effectively as possible, even in a dynamic hyperwar operation.

4. Material and infrastructure

This area pools all the activities in the fields of logistics, maintenance and IT management. The line of action encompasses various measures which could be implemented relatively quickly and help to better address current challenges in the context of support. Many of the striven-for functionalities are being used or developed in very similar form in the civilian sector.

AI-reference

Modern AI lends itself fully to optimum control of logistic systems, as a great number of applications in the civilian sector demonstrate. Aside from pure planning and scheduling logic, integrating and connecting to users are of major relevance in this regard. Expert systems in the field of maintenance, as well as very flexible personnel management systems (driving services) and material transport (e-commerce), are in the process of revolutionising large parts of civilian business life.

AI-technologies

In modern logistic systems, AI takes on the role of anticipatory scheduling and system configuration, having the capability to resolve combinational tasks where, especially in lengthier, continuous processes, AI is clearly superior to humans.

Line of action 4.1: Initiative: AI-based error analysis

Development of an adaptive AI-based component to analyse errors and support maintenance and repair activities for complex weapon systems (e.g. tanks, combat vehicles, helicopters). The system supports predictive maintenance, the ad hoc analysis of error patterns, the assessment of activities (work schedules), as well as planning for stockpiling and for providing materiel and (maintenance) personnel. The system predicts availability for various service use profiles in terms of space and time. The aim is to substantially accelerate maintenance and repair times for complex weapon systems. This AI-based capability thus supports in-service and supply responsibility for the optimisation of fleet management and, by doing so, helps to increase the availability of operationally ready systems.

Line of action 4.2: Initiative: AI-based configuration

Development of an adaptive AI-based component for the operation-/mission-/situation-specific deployment of configurative components for complex weapon systems and mobile IT components. The system supports the platforms, where possible, immediately before use of the requisite software/hardware. The aim is to shorten and automate deployment and to reduce the rate of missing or misconfigured components.

5. Analysis methods

This area pools various individual solutions in which AI and big data can provide support on classic problems relating to data analysis and optimisation. Digitisation and AI offer the chance of a new quality, as certain problems (recognition, ...) can be solved in real time and up-front (also for vehicles) or in technical devices (e.g. firewall).

AI-reference

AI and big-data methods permit extensive analysis of own, neutral and generic process chains. The techniques required for this are well advanced, as, in the civilian sector, they have a direct effect on economically highly relevant processes relating to distribution.

AI-technologies

AI facilitates the identification of typical patterns in process and behaviour models. In combination with classic image processing techniques, it is possible to compare visual information effectively (for the purposes of a before-and-after comparison). Automatic collection of extensive data using advanced sensors allows the development of large databases for the detection of anomalies and prediction of behaviour.

Line of action 5.1: AI-/big-data-based reconnaissance

This approach applies the civilian idea of pre-crime to military applications. The system rigorously collects all available data concerning the area of operations. This includes both content from the Internet and other public media, and findings from intelligence data collection in the area of operations. Using AI methods, this data is correlated with observed events. The aim is to identify correlations that allow an early indication of dangerous situations in an adversary's preparation phase. This is so that threats to friendly forces, such as a planned IED attack, are already avoided in their early stages.

Line of action 5.2: AI differential scene analysis

The system analyses any changes in scene after the same routes have been travelled several times and, using AI methods, assesses the risk potential posed by such changes. Zones posing a risk are suitably displayed in the driver's and commander' line of sight. The system additionally looks to identify any potentially dangerous configurations when travelling along a route for the first time. The aim is to provide an early indication of any dangers which, in the current situation, will yield information.

GLOSSARY

Automated weapon system

In a largely predictable and rules-based manner, automated weapon systems carry out particular actions on the basis of commands programmed by humans as “if-then operations”. Examples in this regard include the Phalanx, Mantis and sea mines weapon systems.

Autonomous weapon system

Autonomous weapon systems carry out complex actions without any human intervention, are completely independent, self-learning or capable of formulating new rules, and are thus unpredictable. There are no examples in this regard in the Bundeswehr.

Deep Learning

Deep learning is a subdomain of AI and machine learning. It mostly refers to one or several interlinked artificial neural networks with very many layers between the input and output layer.

Artificial intelligence (AI)

AI is a subdomain of computer science, with many approaches and applications from the field of mathematics. AI refers to systems capable of solving problems in a humanlike way. Generally, when reference is made to AI nowadays, it is often the application of artificial neural networks (ANNs) that is meant, as in a (deep) learning system. The greatest successes with the use of these methods have mostly been achieved since 2014.

Artificial intelligence (AI), weak (narrow)

Weak AI refers to AI systems which are focused on a narrow application. Weak AI is based on mathematical and computer science methods. The AI strategy of the German Federal Government, the AI concept of the Bundeswehr, and also the position paper “AI in Land Forces” are based on a weak (or narrow) AI approach.
Examples of weak AI include: image recognition, speech recognition, translation, expert systems.

Artificial intelligence (AI), strong

Strong AI refers to AI systems which have entirely the same intellectual skills and abilities as humans, or even exceed them. Strong AI does not as yet exist. Opinions on possible future implementation vary. Strong AI is not being considered in the AI strategy of the German Federal Government, in the AI concept of the Bundeswehr, or in the position paper “AI in Land Forces”.

Artificial neural networks

Artificial neural networks are a subdomain of computational neuroscience and a subfield of artificial intelligence. Artificial neural networks emulate a biological neural network and comprise an input layer, an output layer, and a varying number of intermediate layers. Artificial neural networks have to be trained before being capable of solving problems.

Lethal autonomous weapon system (LAWS)

An LAWS is intended primarily to bring lethal force to bear against people only and, without any human intervention and control, is aware of its environment and its internal state, assesses the situation, makes decisions, takes action, evaluates, and learns accordingly.
Aside from the political and legal aspects, the employment of LAWS is an undesirable and unintended option also from a military viewpoint.

Machine learning (ML)

ML is a subdomain of computer science and AI and refers to algorithms capable of self-improvement and thus of learning. ML is usually based on artificial neural networks. ML algorithms mostly require a data set to train these artificial neural networks. For certain ML sub-groups, such as reinforcement learning, the artificial neural networks can also be trained without training data.

Weapon system

A weapon system is military equipment designed or suited to kill or injure people or to eliminate or degrade their offensive or defensive capability, and/or to destroy or damage objects. A distinction is made between automated and autonomous as well as lethal and non-lethal systems.

War gaming

War gaming is a procedure in the planning process to find, analyse, evaluate and compare possible courses of action. War gaming is, in the first instance, a thought process in which the possible course of an operation or tactical action is developed and refined step by step in, among others, a role-playing game. It is, though, also possible to support war gaming through the use of computer-assisted simulation, whereby the overall approach or only individual phases/elements from the possible courses of action are tested and assessed and the findings from the simulation integrated into the war-gaming process.

LIST OF ABBREVIATIONS

ACCDC	Army Concepts and Capabilities Development Centre
FOBwEITISS	Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support
BMS	Battle Management System
FMoD	Federal Ministry of Defence
CD&E	Concept Development & Experimentation
CPM	Customer Product Management
COPD	Comprehensive Operations Planning Directive
COTS	Commercial of the Shelf
EW	Elektronic Warfare
R&T	Research & Technology
GPU	Graphical Processing Unit
IED	Improvised Explosive Device
KdB	Konzeption der Bundeswehr (Bundeswehr Concept)
DEU A HQ	German Army Headquarters
AI	Artificial Intelligence
ANN	Artificial neural network
LaSK	Land forces
LAWS	Lethal autonomous weapon system
MINT	Mathematics, Informatics, natural science and technology
ML	Machine Learning
MUM-T	Manned-Unmanned-Teaming
NGMBS	Next Generation Battle Management System
NT	Non-technical
OODA	Observe Orient Decide Act
RAS	Robotics and Autonomous Systems
TaUAS	Tactical Unmanned Aerial System
TmC	Technology meets Capabilities
TPU	Tensorflow Processing Unit
UAS	Unmanned Aerial System

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