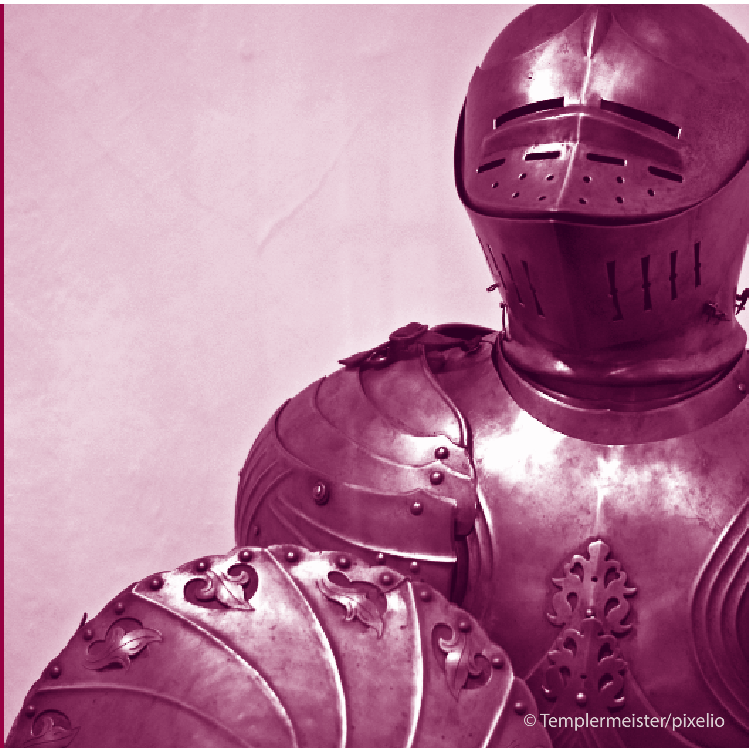
OFFICE OF TECHNOLOGY ASSESSMENT
AT THE GERMAN BUNDESTAG

Thomas Petermann
Reinhard Grünwald

Status quo and perspectives of the military use of unmanned systems

Summary



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SUMMARY

In the first decade of the present century, the number of deployments of unmanned systems (UMS) in armed conflicts such as in Iraq and Afghanistan has increased drastically. Aerial systems have been used hundreds of thousands of hours for reconnaissance purposes and to combat the enemy, robotic remotely controlled ground systems have been used in innumerable missions, particularly for the detection and clearance of explosive ordnance. Due to the stand-off capability of such systems, which often are controlled from a very remote location, the armed forces are given the possibility of carrying out numerous missions with minimum endangering of soldiers, because the soldiers remain outside the operational range of enemy forces. Thus, it is not only possible to improve capabilities such as intelligence and reconnaissance or effective engagement, but also to develop novel options on the battlefield, particularly in high-risk operational environments. Finally, the substitution of unmanned for manned systems is expected to offer substantial cost advantages. However, there are also objections that in a crisis the threshold of conflict might be reduced or the risk of armed conflicts – e.g. as a consequence of an accident or of an inadvertence - might increase due to the option of carrying out operations without any risk for soldiers. Beyond military use, unmanned systems bring up further questions, for example regarding the role of technological progress, the transformation of the armed forces, possible civil applications and their economic potentials. Moreover, unmanned systems coalesce with considerations concerning ethics, international law and arms control policy. Thus, the complex subject area of unmanned systems proves to be a topic of considerable significance with regard to research policy, industrial policy, innovation policy and security policy.

COMMISSIONING

On the initiative of the Committee of Defence, the Office of Technology Assessment at the German Bundestag (TAB) has been commissioned by the Committee on Education, Research and Technology Asessment to make a survey and impact assessment regarding current national and international developments and prospects of unmanned systems. The report shall focus on the following aspects:

> overview of the range of unmanned systems (Germany, USA);
> status and prospects of the relevant key technologies and systems;
> operational concepts and scenarios of the Bundeswehr (German Federal Armed Forces);

> economic aspects and relevance regarding innovation policy;
> assessment with regard to security policy and arms control policy in consideration of proliferation risks and terrorist threat scenarios;
> aspects regarding traffic law as well as humanitarian law.

DEFINITION

In most cases, unmanned systems are reusable powered devices which do not carry a human operator and which conduct missions autonomously or remotely controlled. It is not possible to classify unmanned systems unambiguously by means of technical or operative criteria compared to other systems like cruise missiles and torpedoes. On the one hand, the generic term of unmanned systems might include ground, air, water and underwater systems. On the other hand, it subsumes the different components of unmanned systems: Besides the actual vehicle, an unmanned system includes other components such as a (manned) control station, take-off or launching equipment, a communication link, a landing or recovery system, a repair unit as well as various auxiliary devices.

Currently, the size spectrum of unmanned aerial systems ranges from dragonfly-sized micro aerial vehicles used for reconnaissance purposes to unmanned strategic reconnaissance aerial systems with the dimensions of a commercial aircraft. In the field of medium-sized to large categories, armed systems are realized in addition to reconnaissance systems. Unmanned ground vehicles which are already used include man-portable devices, but also systems with the dimensions of a battle tank. Their main application purpose is the clearance of explosive ordnance. The range of sizes and applications of unmanned maritime vehicles still is very limited. Systems operating on the water have a length of up to 11 m and so far are only designed for coastal applications. Underwater vehicles are mainly used for mine action.

Unmanned Systems used by the Bundeswehr: Concepts, Capabilities, Transformation

As an expeditionary force, the Bundeswehr has become an actor of international conflict prevention and crisis management including the fight against international terrorism. In order to be able to master the resulting challenges (e.g. combat missions), substantially improved capabilities are considered to be essential. For this reason, the objective is to make progress with regard to the capability categories of command and control, intelligence and reconnaissance, mobility, effective engagement, support and sustainability, survivability and protection.

For the future, the Bundeswehr intends to use unmanned systems far more than they have so far. This prospect is based on the expectation that these systems mainly contribute to an improved intelligence and reconnaissance as well as to an increased protection of the forces. In the medium term, however, the intended objective is the capability of using weapons. Particularly in considerations of the German Air Force, the objective is to continuously extend the capabilities of unmanned aerial systems including e.g. airlift, air loading and air combat. The discussion regarding operational concepts, capability requirements of the services of the Armed Forces, requirements for systems and step-by-step integration in the Armed Forces is going on. Corresponding operational concepts and precise descriptions for operational backgrounds and scenarios are developed by the Armed Forces Staff. A further increased use of unmanned systems by the Bundeswehr in the future has to be discussed also against the background of the politically defined objectives of the Armed Forces and the extended capability profile of unmanned systems striven for by the Armed Forces. Here, the objective should be to increasingly pursue and – if necessary - to newly develop current considerations and approaches which aim at joint concepts in international missions. Both the technical dimensions as well as the reasons for and definition of deployment scenarios and capability requirements with regard to multinational operations should be considered. Moreover, a more open discussion regarding trends of increasing autonomy as well as of the intended use of unmanned systems as weapon carriers seems to be indispensable.

TECHNOLOGIES AND SYSTEMS

The development of unmanned systems so far mainly presents two characteristics. On the one hand, parameters such as speed, range, endurance, agility or the payload carried are enhanced continuously. On the other hand, an ever increasing mission autonomy is achieved. Thus, today’s unmanned systems are available with a wide range of sizes for a variety of tasks – from reconnaissance and surveillance to combat missions. Particularly unmanned aerial vehicles have established as weapon platform in so-called hunter-killer missions beyond their function as reconnaissance systems. A comparable variety of functions has not yet been realized for unmanned ground and water vehicles. So far, unmanned ground systems are used almost exclusively as remotely piloted systems for explosive ordnance clearance. Currently, unmanned surface and underwater systems show the least advanced technological development status. For a long time, particularly unmanned surface vehicles have not been focused on by the naval forces. Worldwide, only vehicles of smaller categories are regularly used so far. Here, the focus is on mine action.

Just like it has been so far, also the future development of highly efficient systems used to accomplish complex and often long-lasting missions will depend on the progress made in relevant key technologies. Fields of technology such as drives and energy supply, guidance and control systems, navigation, planning systems, data transmission and communication, sensor payload and autonomy are of particular significance. Moreover, interdisciplinary technologies such as information technology or biotechnology also increase the efficiency of unmanned systems.

Energy and Propulsion System

Energy storage devices and energy converters are key technologies for unmanned systems, because progress in these technologies might induce leaps in quality regarding the capabilities of unmanned systems – e.g. duration of use and speed, but also payload capacity – and thus can increase the diversity of missions. In recent years, there has been a clear trend towards electric drives. Meanwhile, these drives are widely used particularly with small and medium-sized UMS. For large systems, hybrid drives (internal combustion engines or turbines combined with electrical components) are used increasingly.

A possibility for energy supply of mobile systems, which might become more significant in the medium or long term, is obtaining electric energy by means of energy harvesting. As a matter of principle, many different natural energy carriers (e.g. solar radiation, wind, currents and wave movements in the water, electromagnetic waves, sound) can be used for UMS as well. Further progress is to be expected for batteries and storage batteries with regard to energy density, as this segment is of high commercial interest. Improvement is also indicated for fuel cells so that they can be expected to be used in larger systems.

Information Technologies (Navigation, Guidance and Control Systems, Planning Systems)

Navigation, guidance and control systems as well as planning systems benefit from performance increases of electronic components and from progress regarding research on artificial intelligence. Improved sensors enable a self-localization which is independent of external signals mainly due to optical detection of landmarks (»scene matching«), of the altitude profile under the flight path or of the depth profile under water (»terrain contour matching«) and due to the detection of the Earth's magnetic field. Particularly for unmanned ground vehicles, another main task is to detect obstacles and to avoid them. Guidance and control systems already realize a robust obstacle avoidance to a large extent. Autonomously traversing difficult terrain currently is tried and tested in practice. Advanced planning systems allow driving defined routes autonomously and returning automatically to the starting point of a mission. The long-term and fundamental objective of this development is to give individual systems the capability of an autonomous instinct of self-preservation. In the long term, innovative planning systems are to be expected which will join several robots with possibly different structures and various capabilities in a team or in a swarm. Such developments might considerably improve the capability of unmanned systems to act (semi) autonomously even in difficult and unknown terrain.

Data Transmission/Communication

For reconnaissance and surveillance missions, particularly by means of unmanned aerial systems, a variety of image and radar sensors are used due to which enormous amounts of data might incur. For data transmission to the operations center as well as for communication among each other, both wired and wireless methods are available. Wireless systems require a corresponding infrastructure (satellites, wireless networks). Though cables are less easy to use, they offer clear advantages with regard to transmission bandwidth and latency. They are still indispensable for underwater communication. Particularly for reconnaissance missions, high transmission bandwidths are essential. The currently available bandwidths have reached their limits for multispectral images with a large field of view and high resolution or for the transmission of the full radar phase response.

Currently, the technical progress of communication systems is mainly pushed by innovative civil applications. With regard to wired systems, progress is observed mainly in the field of fibre optics technology and due to miniaturization and improved performance of laser systems. In the field of wireless communication, new technologies and standards will considerably increase the speed of data transmission in fourth-generation networks in the medium term. Significantly increased data rates are expected in the field of underwater communication as well.

One of the biggest challenges is the integration of the many different information processing systems which have evolved over time into a functioning entity. In order to ensure interoperability of the systems, extensive work has to be done with regard to norms and standards. Significant effort is put into information security where civil protocols generally serve as a basis.

Sensor Payload

Many of the sensor types and technologies for the detection of acoustic, electromagnetic and optical signals that can be used in military applications are not specific to unmanned systems. It is often possible to make use of technology that is already available. General development goals for sensors of unmanned systems are reductions in size, weight and energy consumption. In the long term, sensor systems shall search and detect relevant objects autonomously and support navigation in the swarm. A long-term objective is to approximate human-like perceptive capabilities for the analysis and evaluation of the information gathered – so-called »cognitive sensors«. In the long term, it could be possible to develop real »cognitive sensors« which not only collect data, but even »understand« their environment by means of a semantic analysis of the parameters measured.

Cross-cutting Technologies

Progress in interdisciplinary technologies often is a key to a breakthrough in other fields of technology. First and foremost, computer and information science and technology, materials science and materials engineering as well as life sciences and biological engineering have to be mentioned here. Nanotechnology and microsystems technology, for example, play an important role for ever increasing performance and miniaturization of components. New materials involve lighter and more resistant systems, a reduced radar signature or increased efficiency for storage batteries.

System Trends

Much of the described progress in the relevant fields of technology allows an increasingly autonomous mission accomplishment. Autonomy is a key capability of unmanned systems that enables increasingly complex missions also within a team of other manned and unmanned units. For this reason, it is a declared objective to replace human operators as far as possible with autonomous technical systems in the future. However, taking into consideration technological and financial aspects, a high level of autonomy must not necessarily be desirable without any restrictions. Thus, with autonomy increasing, the complexity of the systems considerably increases as well which might involve negative impacts on their life cycle costs, robustness and reliability.

For unmanned *aerial system*s, efforts in the higher size categories concentrate on approximating the range of capabilities to that of manned systems e.g. by improving camouflage and by increasing payloads (weapons and sensors) and range. In the long term, the development of unmanned systems for combating even long-distance strategic targets and for air combat is to be expected. In the field of small and medium-sized aerial systems, the focus is likely to be on improving weaponization. One option is to use unmanned systems as weapon platforms for close range (e.g. in urban terrain) in order to allow action against enemy targets even without direct line of sight.

For unmanned *ground systems*, the focus is on a diversification of missions and on an increase of autonomy. Here, transport and convoy missions as well as surveillance and protection tasks will remain central objectives. Particularly in the United States, there are also intentions regarding the realization of systems with lower requirements concerning navigation, mobility and survivability. Envisaged tasks are, for example, repair, maintenance, refueling and ammunition supply of different platforms.

Based on a comparably low technological development status of unmanned *maritime systems*, development programs are aiming at extending the range of sizes. It has to be assumed that after having completed corresponding tests successfully, larger systems are likely to be procured and used during the next years. Furthermore, it is intended to develop further functions. Besides mine action, tasks in the field of reconnaissance just to large-scale ocean surveillance as well as the use as communication nodes in a network-centric warfare scenario for networked operations are of great military interest. Overall, a trend towards an increase of system autonomy can be finally stated.

MARKET AND MARKET STRUCTURES

Due to the unreliable nature and lacking transparency of data regarding the economic significance of unmanned systems, statements related to this topic have to be made with caution. However, it can be said that the market for unmanned systems is dominated by military aerial systems and that it has grown continuously during the past decade. To date, the civil share of the overall sector still remains only marginal. In the considerably smaller overall market for unmanned ground systems, civil applications account for almost one quarter of the share of sales, e.g. with vehicles used to defuse bombs and used in the event of disasters. In this respect, the maritime domain – which represents the smallest submarket – is an exception. The sales volume reached with systems used for civil applications is considerably higher than that of systems used for military applications and can be estimated to approximately three quarters. Particularly the extractive, oil and gas industries are important consumers. In all submarkets, research and development are contributing considerably to the generation of sales. However, expenditures for procurement are increasing as well.

The global market for unmanned aerial systems is dominated by companies from the United States. Israeli companies are playing an outstanding role as well. There is only little reliable information regarding the substantially smaller markets for unmanned maritime and ground vehicles. However, it is plausible to assume that companies from the United States are showing the largest sales volume here as well.

The volume of international trade in large UAVs currently is rather low compared to trade in manned aircrafts. From 2000 to 2009, for example, approximately 580 systems were transferred (compared to approximately 10,550 manned aerial vehicles). Considering the mere number of units, the Israeli industry is dominating with 230 units whereas the United States delivered 84 units and France 79 units. With approximately 90 systems (80 of which have been produced under license), the United Arab Emirates are heading the list of a total of 39 recipient countries, followed by India with 68, Romania with 65 and Pakistan with 55 units.

According to estimates from industry and from consultancy companies using industry data, increases for the individual submarkets can be expected for the future as well. With regard to unmanned aerial systems, a significantly increasing demand for complete systems (aircraft, ground station, payload) as well as for research and development projects is expected for the next few years. Regarding the market structure, companies from the United States will maintain their strong position and civil market shares will grow only slowly at least in the next ten years. For unmanned ground vehicles, increases are assumed to occur both in the market of civil security and in the military sector. The global market for unmanned maritime systems might grow within the next few years due to the increasing exploration of natural resources on the bottom of the sea as well as due to the construction, maintenance and surveillance of supply and drain lines. At the same time, there will be a successive conversion from remotely controlled systems to autonomous systems.

COSTS

Very often, an argument mentioned in favour of unmanned systems are the lower costs compared to those of manned systems. This applies to some systems and under certain conditions of use. Due to their superior endurance, unmanned systems seem to be more efficient than manned systems particularly for long-lasting missions. There are also cost benefits for dangerous missions, if unmanned systems are able to substitute for complex and hazardous deployments of man and material. Furthermore, costs could be reduced where particularly miniaturized systems can be used with lower logistical effort and reduced risk for man and machine instead of alternatives which are more complex both technically and in terms of personnel. In case of more complex configurations of tasks such as border surveillance, it becomes apparent that cost-effective operational options might include the combination of manned and unmanned systems.

Economic efficiency considerations as they have been carried out so far by means of system comparison seem to be hardly relevant anymore in the military sector given the dynamics of development and the high efficiency of the systems regarding mission accomplishment. As experience in the United States shows, expenditures for research, development and procurement meanwhile entail a considerable financial burden for public budgets. In view of the scarce financial scope of public authorities, this should be taken into account at an early stage.

CIVIL APPLICATIONS

To date, the civil (public and private-sector) use of unmanned aerial systems is limited to niche markets. This includes the surveillance of infrastructures, borders, traffic or sports events in restricted airspaces. Particularly surveillance tasks in the field of border control and police-related activities are likely to become a future market. In the submarket of unmanned ground systems, a limited growth is to be expected in the medium term. Promising fields of application might include the surveillance and reconnaissance of terrain, transmission pipelines, roads and buildings as well as search and rescue missions e.g. after disasters. Besides civil protection and disaster prevention, also tasks of risk prevention and response by the police will be accomplished increasingly by means of unmanned systems. In the long term, goods and passengers might also be transported by means of unmanned vehicles (‘automated highways’). The economic prospects of unmanned maritime vehicles can be considered to be promising. Besides the protection of coasts and coastal infrastructures, the scientific and economic exploration of the bottom of the sea as well as the extraction of natural resources are fields of application of strongly growing interest. These future markets will have to face fierce competition and already now, the course is set by research and development, by public project promotion, by procurement programs and by newly developed business models.

PROSPECTS FOR INNOVATION

In the course of the expected further transformation of the armed forces into high-tech forces qualified for networked operations worldwide, unmanned systems will play a central role. The global markets for military systems will grow correspondingly.

From political economics' point of view, the development and use of military systems turn out to be reference markets which demonstrate the possibilities of autonomous systems, bring about technological progress and cost-cutting effects and support the corresponding industrial basis as well as its R&D capacities. This opens up the perspective of a large-scale civil use of unmanned systems. It will be anticipated and prepared by means of numerous activities such as research, standardization, promotion as well as by business strategies and political concepts.

The technical possibilities and economic perspectives suggest that - in two to three decades – unmanned systems will occupy more than only a few niche markets. Thus, it will be decisive for future innovation and diffusion processes and thus also for the generation of value chains and economies of scale in Germany, whether and to what extent a global market for unmanned systems will be constituted also beyond military preventive security. In many cases, civil security technologies are mentioned to be the driving forces for growth. Moreover, the transformation of traffic systems by integrating remotely controlled and autonomous systems will be unstoppable.

Due to the probably further increasing significance of unmanned systems with regard to industrial policy and political economics, the question arises whether politics should help to shape the innovation process to be expected by creating specific framework requirements. However, due to the expectable significance of unmanned systems for new and expanding markets as well as due to a fundamental transformation of the manufacturing industry (aviation and automotive industry), it should be verified at least whether a more active approach could be beneficial. Initially, an assessment of the development status and of foreseeable prospects as well as of the preconditions given in Germany as a location would be a first step.

Currently, the diffusion of unmanned systems in civil, private-sector applications is still restrained by numerous technical problems as well as by a lack of beneficial social and legal framework conditions. For unmanned *aerial vehicles*, a need for legislation (e.g. European legal framework, certification, approval) and technical security issues (e.g. technologies and standards to avoid collisions in the airspace, emergency procedures e.g. for data link failure) have to be mentioned primarily. Currently, there is also a lack of an internationally binding regulation architecture upon which the worldwide use of unmanned aerial systems in the general airspace could be based as well as of sufficient and secure radio frequencies with the necessary bandwidth. However, numerous activities are going on both nationally and internationally by means of which actors from public authorities and from the private sector want to eliminate the deficiencies mentioned. However, an integration of large unmanned systems into civil airspace in such a way as to ensure the same level of security as for manned aviation still is a distant prospect.

The security issue is also very significant for *ground-based* unmanned systems, even if the question of integration into the civil traffic is not that urgent yet as it is for unmanned aerial systems. However, civil technologies and applications (e.g. service robots and vehicle control system) are progressing rapidly (from which military use will benefit as well). The performance profile of remotely controlled, but increasingly that of autonomous maritime systems as well seems to be most suited for the future markets of security (protection of port facilities) and marine technology (search for and extraction of natural resources).

For all types of unmanned systems, many necessary framework requirements still have to be adapted or newly developed. This preferably includes an internationally harmonized legislation, internationally applicable technical standards, insurance schemes or sufficient venture capital.

ASPECTS REGARDING TRAFFIC LAW

A future increased use of unmanned systems in civil fields of application raises the question of both their national and international classification regarding traffic law. However, the legal matters related to manned systems are not sufficiently suited to serve as a basis to treat both fields equally.

In a first analysis of the problem, it has become obvious that the overall legal position in the field of *aviation* with regard to a regulation of unmanned systems is fragmented and unclear and – first and foremost – not adequate to the system. On the national and European level, there is a need for (re-)regulation both regarding the definition of unmanned aerial systems and specification of the associated legal consequences as well as regarding the definition of duties and responsibilities of the operating personnel. System-specific traffic and collision rules as well as a compliant and clear regulation regarding the approval of aerial systems and regarding the licensing of the operating personnel would be required. This could also serve as a basis for the rules concerning sovereign use.

In the field of unmanned *ground vehicles*, the legal discussion has hardly developed. A first review of the legal matters, however, shows that an adaptation is necessary. For example, there is a need for regulation with regard to approval. Thus, according to applicable German and European law, fully-automated systems and driver assistance systems that cannot be overridden by the driver are inadmissible for civil use. It should be verified carefully whether the qualification of the operator possibly would have to be regulated specifically. Possible deviations from the law of civil systems for sovereign use are already given. Generally, a considerable need for a jurisprudential analysis can be observed in order to obtain an adequate regulatory approach. In either case, unmanned ground vehicle systems should be integrated into the already highly complex rules and regulations of road traffic law with caution.

At first glance, the national and European legal matters *regarding maritime law* as well as the relevant treaties according to international law seem to be relatively open for an integration of specific provisions regarding unmanned maritime vehicles. Here, the vehicle-related issues of approval are less likely to be focused on. For shipping, mainly the applicable collision rules would have to undergo an accurate analysis in order to identify the need for regulation and to develop system-adequate and implementable regulatory approaches. There is a substantial need for regulation in the fields of the law of the sea and of maritime law. In these fields, there are no specific regulations for unmanned systems. Furthermore, numerous technical details have to be adapted. As far as can be seen, a fundamental debate concerning both regulatory objectives and instruments is still missing also with regard to unmanned maritime vehicle systems. For this purpose, there is a substantial need for research and discussion.

For good reasons, the legislative authority has regulated primarily the private use of vehicles – sovereign use is subject to independent regulations. However, as an increased use of the public space can be assumed for the future, it should be provided that *approval and monitoring rules* for sovereign use in all areas of regulation are as transparent as possible. A high degree of coordination between the requirements regarding private use and those regarding sovereign use is likely not only to create acceptance, but also to ensure a highest possible degree of legal and regulatory coherence.

ARMS CONTROL

Unmanned systems are integrated by an increasing number of nations into their armed forces. The existing arms control treaties do not set effective limits to the development and introduction of conventionally armed unmanned platforms. In view of obvious dynamics in providing the armed forces with unmanned aerial systems as well as of a tendency towards increasingly efficient and armed unmanned systems, some of which can be equipped with weapons of mass destruction, at least a survey would be recommended with regard to arms control and arms exports control.

Some of the existing arms control treaties include unmanned systems. Those treaties include the Chemical Weapons Convention as well as the Biological and Toxin Weapons Convention prohibiting the development, production and stockpiling of weapon delivery systems as far as they are intended for the use of corresponding agents for hostile purposes or in armed conflicts. A similar consideration applies to the Outer Space Treaty which – according to the interpretation of the United States and European countries – does not prohibit the use of specific unmanned systems in outer space for defensive military activities. The categories of weapons of the Treaty on Conventional Armed Forces in Europe (CFE Treaty) are defined in such a way that they include armed unmanned systems. Moreover, the treaty provides mechanisms by means of which it is possible to implement changes regarding the object of the contract – e.g. with regard to smaller ground-based or airborne and armed systems.

The provisions of the Vienna Document of the Negotiations on Confidence- and Security-Building Measures can be applied to unmanned systems. With certain restrictions, this also applies to the reporting system for conventional major weapon systems installed with the United Nations' Register of Conventional Arms. As the technical definition of the weapon systems does not differentiate between manned and unmanned units, unmanned systems are also included in the reporting systems as far as they are to be classified as combat aircraft or helicopter, battle tanks or armoured combat vehicles.

Other arms control treaties do not provide for unmanned systems as object of regulation. Thus, corresponding provisions are missing in the INF (Intermediate-Range Nuclear Forces) and »New START« (New Strategic Arms Reduction Treaty) treaties which are relevant to nuclear weapons. Whereas the INF Treaty is to be applied relatively unambiguously to cruise missiles only, the New START treaty between the United States and Russia includes the option to adapt the treaty in case of new weapon platforms being developed.

ARMS EXPORTS CONTROL

To a large extent, unmanned systems as well as their subsystems and technologies are available on the global markets without any regulation. Existing weaknesses of exports monitoring regarding specific dual-use components and the rapid dissemination of technological knowledge give reason to consider the use of unmanned systems by certain state and sub-state actors as well as by terrorist groups to be a serious threat. At the same time, the capability of unmanned aerial systems to carry weapons of mass destruction represents a particular challenge with regard to international exports control and non-proliferation efforts. Remotely piloted aircraft or converted model aircraft are easy to build; radar and air defense systems can be escaped relatively easily by small systems flying at low altitude. The spectrum of possible threats ranges from targeted attacks against important persons by means of smaller aerial systems carrying an explosive payload or piloted directly against a person to systems used as a weapon or as weapon delivery systems to the launch of weapons of mass destruction. Targeted assassinations of leading politicians, attacks against highly symbolic public buildings and critical infrastructures or the launch of toxic agents by means of aerial systems would demonstrate the vulnerability of society and affect the sense of security as well as the public order.

With the Missile Technology Control Regime (MTCR), the Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies and the Hague Code of Conduct against Ballistic Missile Proliferation (HCOC), suitable instruments to control the proliferation of unmanned systems are generally available. However, in view of the technological progress and the ongoing proliferation as well as of the risks involved, the treaties should be further developed and particularly armed unmanned aerial vehicles as well as the corresponding technologies should be included.

INTERNATIONAL HUMANITARIAN LAW

The principles of international humanitarian law are not per se opposed to the use of particularly armed unmanned systems. However, in view of the trend towards a weaponization of unmanned (particularly aerial) systems as well as of the increasing level of autonomy, a national review process based on Article 36 of the Protocol Additional to the Geneva Conventions (Protocol I) might be considered.

As a long-term objective, an explicit settlement under international law (possibly in the form of a manual) might be taken into consideration on the international level. With this in mind, the following aspects would have to be discussed among others:

> obligation of potential conflicting parties to respect the rules of international humanitarian law when using unmanned systems,
> clear separation or distance of a control station from/to civil objects,
> provisions in case of technical failure of a UMS,
> definition of obligations to take action and enabling of interventions by the operator as well as integration of self-destruction mechanisms in case the intervention fails,
> examination of a prohibition against fully autonomous armed systems as far and as long as it is not possible to provide for all requirements regarding target acquisition (»targeting«) and for all necessary precautionary measures to be taken to protect civilians in the same way as it is the case for non-autonomous systems.

With the trends towards depersonalization and automation of the battlefield, urgent ethical questions with regard to technical systems as »morally acting entity« are brought up as well. The question whether and to what extent human decision makers are able to come up to their responsibilities in interaction with technical and increasingly even autonomous systems will not remain restricted to military applications. In fact, it will be necessary to question and – where applicable – to newly define the traditional categories of legal and moral action even in non-military contexts.

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BÜRO FÜR TECHNIKFOLGEN-ABSCHÄTZUNG
BEIM DEUTSCHEN BUNDESTAG

KARLSRUHER INSTITUT FÜR TECHNOLOGIE (KIT)

Neue Schönhauser Straße 10
10178 Berlin

Fon +49 30 28491-0
Fax +49 30 28491-119

buero@tab-beim-bundestag.de
www.tab-beim-bundestag.de