Implications and Significance of Technological Developments with Unmanned Systems for the Future Capability Profile of the Luftwaffe

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Germany's comprehensive approach in the field of security policy calls for readiness and capability to credibly guarantee or re-establish security also by use of military means. This requires the protection of Germany and its citizens as well as an appropriate participation in multinational operations in the entire mission spectrum. As to this, new conflict patterns have complemented the classical picture of linear warfare. Already today are the armed forces confronted in complex scenarios with one or several parties in which the adversaries use means and procedures of asymmetric warfare. As a consequence, military operations will in future be governed by complex, interdisciplinary factors and a multifaceted threat spectrum. The spectrum of potential targets and imaginable effect mechanisms is increasing. Instead of unilateralism the armed forces are more and more faced with diffuse and covertly acting enemies. They will possibly use strategic mechanisms, which are incompatible with our moral code and ethical understanding. This challenge must be met by the air forces, too, which have the task of demonstrating and exercising air power. Key features of air power are speed, range, and the three-dimensional characteristic of the area of operations as well as flexible operational possibilities. Depending on the situation this flexibility is expressed in a versatile connectivity of components in the "reconnaissance-command control-effect" combine as well as in the capability to bring about agile and responsive co-acting of all these components, also across and beyond organizational and geographic boundaries.

On the basis of Bundeswehr-joint, interservice thinking and acting the capabilities of the individual Services and organizational areas will no longer figure prominently, but the capabilities of the Bundeswehr as a whole. On the score of the higher principle of Network Enabled Operations (NEO) the armed forces can, for the first time, be effectively employed in a combine on the basis of a joint understanding of the situation. NEO means command and control and employment of armed forces based on an interservice, interoperable information and communication pool overarching all command levels which links all relevant personnel, agencies, units, and installations/facilities as well as sensors and effectors with each other. This new dimension of the combine of reconnaissance, command control, and effect allows the desired military acting in the entire task spectrum to be produced more rapidly, more effectively and more efficiently within the meaning of the mission.

Effectiveness of the Luftwaffe

The effectiveness of the Luftwaffe will not in the first place be judged by the quantity of personnel or weapon systems, but by the capability to reach the effects in a controlled and precise way within a very large – partly not foreseeable – mission spectrum. Precision must, when measured against a previously determined desired effect, be possible to be equally ensured in the dimensions of space, time, and scalability. Moreover, future missions should be possible to be conducted in all regions of the globe and – according to the political objective – also in high-threat operations. Only this will permit the specific control of a military operation and the avoidance of collateral damages or the endangerment of friendly forces. The Luftwaffe is thus confronted with the challenge of adapting it forces and means to the extended tasks. This adaptation process takes place against the background of an extreme dependency on technology of the air forces and the limited availability of investment means.

Aspects of economy and scarce financial resources necessitate the concentration on such fields of technology, which exhibit a special potential for strengthening the specific, inherent capabilities of the Luftwaffe and advancing them in accordance with the requirements. The further development of the Luftwaffe is an extremely complex optimization process within the scope of technically feasible and financially possible projects. Air warfare means are complex systems. A large number of most diverse technologies and their applications are conjointly active in them in a capability-determinant way. Functions and serviceability of modern weapon systems are largely determined by IT systems and their software. This applies to both aircraft and modern "intelligent" weapons. The "performance explosion" with IT systems that occurred in the past years makes applications possible which even recently didn't seem to be realizable. In addition, clearly improved possibilities for data transmission allow building up and using a common information network based on interoperability. As a rule, German air forces are employed in a multinational combine. Resulting from that is the enormous significance of interoperability within the alliance.

Modern micro engineering and nanotechnology allow the miniaturization of mechanical elements and thus form the basis for significant reductions in size and weight. In combination with the IT systems it is thus possible to produce compact modular subsystems. In addition, modern materials make it possible to extend and exploit the maximum potentials of modern systems. Substantial progress was also achieved in the field of automation. Improvements in the field of sensors, particularly in the area of opto-

System Integration of an agile UAV. Grafic: EADS electronics, electronics, and electromagnetism, contribute decisively to filling and using the available information space.

A MQ-9 Reaper UAV of the US armed forces in a landing approach after a mission in Afghanistan as part of Operation Enduring Freedom; the UAV can be equipped with precision bombs and air-to-ground guided missiles.
Picture: Pentagon

UAS – MALE – HALE – UCAS

Unmanned aerial systems (UAS) possess a particular potential to strengthen and extend the specific, inherent capabilities of air warfare means. The unmanned design considerably increases the degrees of freedom for the design engineer, since crew-related systems like cockpit, monitors/indicators and control devices, panoramic view canopy or life support and rescue systems are no longer needed. The gained design possibilities can be used to optimize the technical configuration of the system according to the capability requirements.

In the field of intelligence the unmanned MALE (Medium Altitude Long Endurance) and HALE (High Altitude Long Endurance) reconnaissance platforms with long times on task in the area of operations have already been providing impressive proof of their potential in current missions. Here it suggests itself to weaponize MALE platforms within the scope of the "reconnaissance-command control-effect" combine with the objectives "protection of own forces" and "time-critical target engagement" in order to be able to engage a target detected by means of their sensors in near real time. The principle "reconnaissance, command and control, and effect" thus finds an immediate combine.

In scenarios with high threats from the ground or from the air the risk of a loss of this weaponized MALE platforms is very high, though, since they are, because of their purpose and end use, optimized for range and time on task in the area of operations. Therefore, concepts for optimized UCAS (Unmanned Combat Aerial Systems) are developed all over the world, the design of which exploits all degrees of freedom in the construction of unmanned aerial vehicles and increases decisively their robustness and survivability.

Among others, the following system-determinant capability requirements for UCAS are derivable from the operational parameters:

- Survivability under threat conditions
- Range
- Time on task (loiter time)
- Adapted, precise target effect
- Mission accomplishment without cooperating systems.

The required technical system capabilities and the technologies necessary for that can be derived from these general capability requirements.

The most significant distinguishing feature between a UCAS and a weaponized MALE is its survivability and robustness under threat conditions. The air forces apply active measures (e.g. extreme low level flight with high speeds to circumvent and underfly enemy radars, use of chaff, infrared (IR) decoys and electronic countermeasures to deceive enemy sensors) to increase the survivability and sustainability under highly intensive threats. Modern integrated air defence and the development of intelligent seeker-heads considerably limit the possibilities and effect of these conventional means, however.

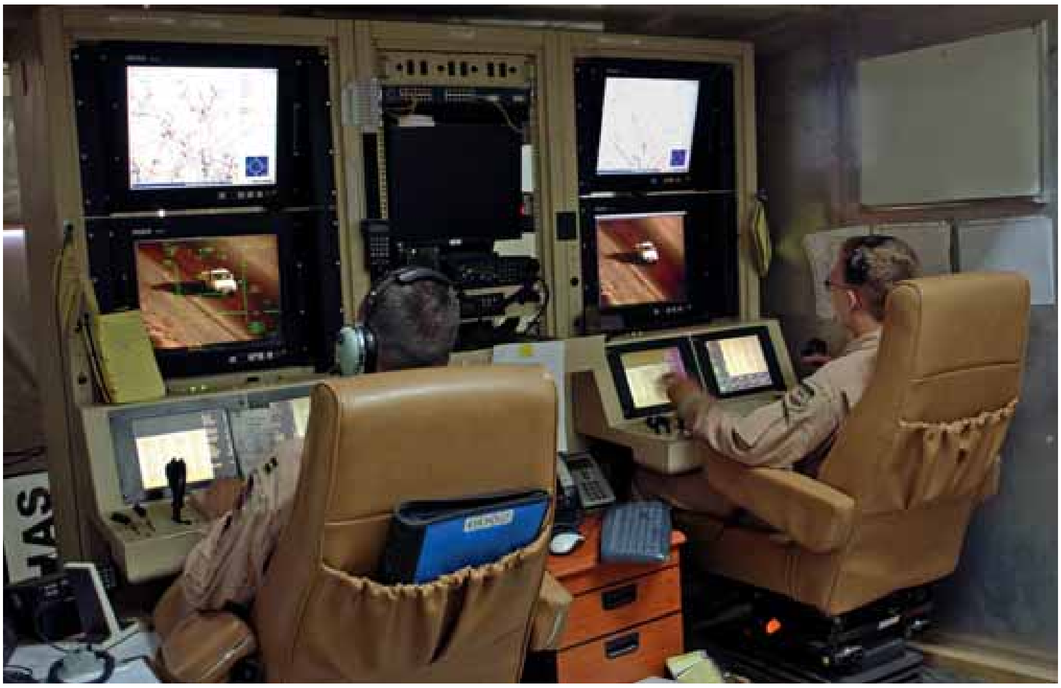
Aside from that, interrelations with other capability requirements such as long range, long times on task, and requirements regarding the efficiency of sensors additionally limit the tactical possibilities for self-protection. The rapidly advancing laser technology will open up new possibilities to counter IR-guided missiles. With the aid of so-called "missile approach warning devices" it is possible today already to identify approaching IR missiles and to blind and/or destroy their IR seeker-heads by means of a laser.

Introduction of UAV. Grafic: ES-Archive

Special Technological Features

In spite of these technological developments, the countermeasures also involve risks, as the measures taken here are generally extremely time-critical reactive actions. It is therefore essential to prevent as long as possible the employment possibilities of enemy air defence means. By an effective reduction of the radar, IR, acoustic and optical signature it is possible to decisively delay detection by enemy sensors and a lock-on of enemy air defence systems; an engagement can thus be distinctly obstructed. A comprehensive multi-spectral minimizing of signatures is therefore a prerequisite for employing flying weapon systems under threat conditions in all required altitude ranges and consequently for achieving optimal sensor results and/or maximum weapon effects. This optimized signature reduction can only be achieved by the co-acting of several technologies. Decisive for the reduction of the radar signature are a signature-optimized shaping on the one hand and the use of radar-absorbing materials on the other hand. The aim is to reflect by way of an optimized design as little signal energy as possible to the radar transmitter.

Certain nonmetallic composite materials are "invisible" for radars, whereas metals reflect radar rays directly to the transmitter, if the surface is right-angled to the radar angle of incidence. It is therefore essential to avoid metallic materials with respective angle constellations as much as possible. By integration of



A control unit at the American Ground Control Station (GCS) for monitoring the UAVs. Picture: Pentagon

carbon fiber reinforced plastic structures and use of radar-absorbing coatings for necessary metallic elements it is possible to optimize this design.

All-wing configurations are particularly suitable for this purpose, since they fly completely without a fin assembly (and thus without a large radar cross section). Sensors and antennas are integrated into the surface structure in conformity with the structure/texture. Effectors are carried in an internal bay. Added to this is camouflaged engine integration, which is determinant for the design of the intake and jet nozzle. For camouflaging the intake and the jet nozzle it is necessary to obstruct the direct line-of-sight to the compressor and/or turbine. The absence of a fin assembly in an all-wing configuration can be compensated by a yaw thrust vector control. The aerodynamic compromises in favor of the signature minimization can only be compensated by means of high-performance computers for the flight control. As for the design of the propulsion there will be certain constraints regarding the reduction of IR and acoustic signature. But shaping and design of the propulsion are not only decisive for a unitary multi-spectral minimization of the signature. A continuous omnidirectional emission of radio signals is contradictory to this. Therefore, directional data links on the one hand and a high degree of autonomy of the systems on the other hand will be the main focus in future in order to either fully dispense with data transmissions in certain mission phases or to be able to reduce them to a minimum.

HERON is a very quiet, high-altitude, all weather-capable reconnaissance drone of the Israeli Air Force. It was developed by Israel Aircraft Industries (IAI) and is officially in service since early 2007. Its navigation is effected by an integrate GPS system. Launch, employment and landing happen fully automatically. HERON TP – also designated HERON 2 – is an advanced version of HERON 1. The PT6 turboprop engine provides HERON TP with a longer range, longer time on task, higher altitude and a four times heavier useful load. Picture. IAI

Another big technical challenge is the establishing and maintaining of a comprehensive situational awareness by both the operator and the system itself. This is an important factor in order to allow the UAS controller at the ground control station to act in a situation-related and secure way and/or to guarantee that the platform will have a high degree of autonomy in case of a temporary loss of data link transmission.

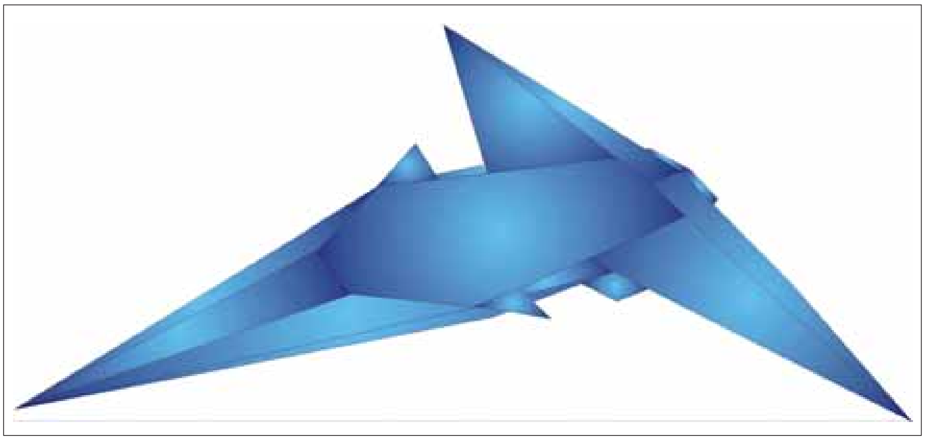
The tremendously fast advancing performance improvement of the information and communications technology allows to establish efficient, interference-resistant, and redundant data links in the line of sight (LOS) and beyond the line of sight (BLOS) which, as a result, will also be of overarching benefit for all capability categories. Flight control and sensor data can be reliably transmitted over great distances via narrow band and/or broadband data links in near real time and will thus be available for processing in due time. Depending on the situation, it is thinkable that, aside from satellites, unmanned aerial vehicles be also used as relay stations for data transmission. Stratosphere airships seem to be particularly suited for that purpose.

The requirements regarding long range and long times on task in the area of operations are linked with each other and dependent on the fuel load and the fuel consumption per unit of range or unit of time. On the one hand, the aim is therefore to reduce the specific consumption of the propulsion by an optimization of the cycle of work parameters "bypass ratio", "overall pressure ratio", and "maximum process temperature" (combustion chamber temperature) as well as the mounting dimension and weight. A revolutionary step in this direction would be a propulsion unit with variable cycle of work. On the other hand it is necessary to achieve a weight reduction of the carrier platform e.g. by an extensive use of integrated carbon fiber reinforced plastic structures and miniaturization of individual components.

A further enhancement of the range and/or period of stay can be attained by the additional capability for in-flight refueling. In the USA it was already demonstrated with respectively modified manned aircraft that automated in-flight refueling is possible without active support by the pilots.

The requirement regarding an adapted, precise terminal ballistic effect depends decisively on the design of the effectors, but also on the design of the platform and the platform-mounted sensors as well as on the synergy of the individual components. By adapting the active mechanisms of the effectors to the respective target type by means of intelligent ignition algorithms it will be possible to achieve doseable effects for an adapted terminal ballistic effect.

The integration of multimodal seeker-heads with miniaturized imaging sensors for terminal phase guidance allow



Grafic of a UAV MFM. Grafic: Author

to a certain extent a precise homing of the target, even if there are no exact target coordinates available or if the target is moving. Here, the development of algorithms for an autonomous "on-board track planning" and for an automatic object identification as well as a sensor data fusion is of paramount importance.

Sensors

In order to be able to effectively conduct a mission in conditions of high threat it is required to control such a mission without directly co-acting, cooperating systems. Particular requirements regarding on-board sensors are possible to be derived from that. They should not only replace the eyes of the pilot for purposes of flight control, obstacle avoidance, and self-protection, but should also serve for local target area reconnaissance and identification and acquisition and/or re-detection of the target.

Multifunctional "sensor suites" are regarded as standard with unmanned reconnaissance aircraft today already; and they continue to be rapidly advanced in respect to their efficiency and performance capacity to meet the special challenges of unmanned flying to the fullest extent.

Due to the specific and limited constructional conditions of a UCAV it is essential to apply new methods for sensors with regard to their installation, energy efficiency, and the heat radiation associated with that as well as the use of the same antennas by different systems (shared aperture). For radar, IFF and emitter localization this means especially the changeover to active, structure-conform and/or structure-integrated antennas on the basis of the energy efficient gallium-nitrite technology. First test models for that are already under study in laboratories.

Exciting and controlling the antenna modules requires specific algorithms which are not only dependent on the shape of the antenna, but also on the mode of operation, i.e. especially the beam shapes to be applied. However, decisive for the efficiency and effectiveness of an UCAS is not the performance of individual system components, but the performance of the overall system. A consistent consideration and integration of all required technologies for all system components is therefore an essential key for the successful development of an UCAS.

Considerable Importance for the Future

Sophisticated technologies expand the application spectrum and enhance the effectiveness of air forces. Civilian technological research and development have become the driving force and pacemaker in many fields, including the military one. But there remain also fields where the specific military requirements represent this pace setter and require research activities financed from the defence budget. The application of modern technology in the Luftwaffe opens up new rationalization potentials and protects lives. Against the background of current and future missions of the Bundeswehr the use of UAVs therefore gains considerably in significance. Technological progress allows a distinct expansion of the military possibilities of using unmanned systems in all capability categories.

In addition to unmanned airborne and space-based reconnaissance systems and communication relay platforms, UCAS can be used autonomously or in combine with manned flying platforms in many scenarios – especially in those with a high threat potential – in the capability category "effectiveness in missions". The inherent capabilities of UAS such as long time on task/mission endurance, long range, and robustness as well as the avoidance of an endangerment of the crews effectively support the operations of the armed forces.

The introduction of UAS into the Luftwaffe will be effected in several phases. The foreseeable start into the capability category "intelligence" will be followed by the application in the category "effectiveness in missions". In a first step, the Luftwaffe follows with particular interest the technological development in context with weaponized UAS to be employed to engage targets on the ground, because, in consideration of the current missions, the biggest added value is seen there for starting the optimization of a reconnaissance, command control, and effect pool. The operational and technological parameters for the employment of UCAS will continue to be studied in subsequent steps in order to support planning and guidance decisions in a way to allow the available means to be employed goal-oriented and as precise as possible to be able to bring necessary technologies to the production stage and thus to realize an overall unmanned combat aerial system in the long term. ■

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Pictures of Predator, Control Unit Heron and X-45 are attached by the Publisher.

A Model of a X-45 UCAV. Grafic: U.S. Air Force