Technische Universität Braunschweig

NFL

Drones in everyday life

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Authors: Lothar Bertsch, Ulf Bestmann, Johann Dauer, Jörg Dittrich, Thomas Feuerle, Dagi Geister, Peter Hecker, Christoph Keßler, Bernd Korn, Astrid Lampert, Maria Stolz, Gordon Strickert

Editors: Kai Höfner, Christoph Keßler, Astrid Lampert, Rolf Radespiel, Lorenz Tichy

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Preface

The Aeronautics Research Centre Niedersachsen (NFL) is the forum of Technische Universität Braunschweig for fundamental aerospace research. Numerous scientists from the German Aerospace Center in Braunschweig and Göttingen, Leibniz Universität Hannover, the Fraunhofer Gesellschaft and the Physikalisch-Technische Bundesanstalt are involved in this centre. The Aeronautics Research Centre Niedersachsen (NFL) initiates and coordinates basic research and establishes connection to government agencies and relevant industry. Furthermore, the centre publishes research results and takes public positions on current aerospace issues. This paper deals with the use of unmanned aerial vehicles, so-called drones, for civilian application.

Currently, they are mainly used in the leisure sector, while the use for governmental, commercial and public service tasks is still limited in scope. However, considerable growth is expected in the future. This position paper therefore offers an insight into various aspects of research, development and application about the topic of drones. It is aimed at employees in administrations, people in politics, journalists and, of course, interested citizens who would like to inform themselves about this topic.

Drones in everyday life

1. Introduction

Drones are increasingly becoming an indispensable tool in the service of people, the environment and society. In the last decade, a dynamic innovation process has unfolded in the development of drone systems and their operation, opening up a multitude of new fields of application. Hardly any other sector in aviation has developed in a comparable way: Considerable funds have been spent on research and development - both public and private. This initiated a surge of innovation in fundamental research, applied research and industrial development. This is supported by an above-average number of start-ups in this sector. As a result, within a few years unmanned aerial systems have evolved from a niche product for mainly military applications to an increasingly socially accepted aid in many areas of daily life.

Nevertheless, the development of drone systems represents an immense technical and operational challenge: Unmanned aerial systems are subject to the same physical laws as general or commercial aviation aircraft. In addition, they share airspace with conventional aircraft and must meet the highest standards of safety, environmental compatibility and economic efficiency. Consequently, all areas of conventional flight science are indispensable for the development of drones, such as flight mechanics and aerodynamics, aircraft construction and propulsion systems. In addition, there are special challenges resulting from the necessary miniaturisation in terms of weight, size and energy consumption. Furthermore, in contrast to manned flight systems, drones must enable largely automatic flight operations. Both together provide research and development in the field of drone systems with special challenges.

In order to cope with these new technical, societal and scientific challenges in the field of unmanned aerial systems, the Aeronautics Research Center Niedersachsen (NFL) has developed its research portfolio in the past years, starting from the flight sciences of conventional aircraft. Its members have made intensive research efforts to turn drones into the "tool in the service of people, the environment and society" described at the beginning of this article. In order to outline the general challenges in this field as well as current research work at Braunschweig Research Airport as the location of the Aeronautics Research Centre Niedersachsen (NFL), this position paper provides a summary of issues relating to the technology, operation and utilisation of drones, addresses their social acceptance and outlines possible perspectives in research, development and operation of drones.

2. Vehicles

Unmanned aerial vehicles, or drones, are often equated in everyday life with so-called multicopters. These have helped unmanned aerial photography and video recording in particular to achieve a breakthrough with relatively little effort and cost. They are used thousands of times by private individuals, film and television, building surveying, industry and also the police and fire brigade. However, such aircrafts are only suitable to a limited extent for high flight speeds, ranges or flight times.

The need for further applications has led to a large variety of shapes. In addition to aircraft-like systems, hybrid systems are also currently coming onto the market in order to be able to realise the demands for long distance and hovering capability at the same time. Another distinguishing feature of today's unmanned aerial vehicles is their propulsion or their primary energy source. While electric engines are a key to realising quiet, CO2-neutral aircraft and therefore are particularly suitable for urban areas or even interiors internal combustion and hybrid engines still have their legitimacy in the air transport of heavy goods or for flying long distances.

Despite all the differences in configuration and propulsion, the control technology, sensors and actuators (servomotors) of the unmanned aircraft are very similar. The whole of the electrical and electronic equipment on board of an aircraft, the avionics, is of great importance for unmanned aerial vehicles: it serves to replace the pilot who is not on board or at least to shift his function as a navigator from the distance to the ground.

2.1 Drone Variants

Drones are best classified by their configuration, i.e., the arrangement and number of lift-generating elements for propulsion and control. Vertical take-off and landing or hover-capable aircraft (VTOL, vertical take off and landing) predominantly use rotorcraft, with large rotors and/or propellers providing thrust to compensate for weight and propulsion. In contrast, fixed-wing aircraft realise a separation of lift and propulsion by wings and e.g. propeller propulsion, which makes them particularly efficient or powerful, but they need a runway.

Combining wings with rotary blades to produce lift generation you have drones that allow certain specifications in terms of flight performance and flight characteristics. Drones based on static lift (balloon, airship) or combinations of dynamic and static lift generation have a niche existence. The following are the main configurations for drones with their advantages and disadvantages or main fields of application.

Multicopters

Multicopters are probably the best-known and most widespread drone configuration in public (Fig. 1). Four rotors ("quadrocopters") are often used, driven by electric, speed-controlled motors. Non-standard designs realise configurations with up to 18 rotors to increase safety and load-bearing capacity. Smooth-running, counter-rotating drives and relatively small propellers, combined with low flying speeds, result in low-vibration aircraft that are particularly suitable for taking aerial photographs and videos, making maps and for other measuring purposes. The rotors can be well shielded by cages for safe handling. The noise emission is low, so that multicopters can also be used in places where aircraft with higher noise emission would be disturbing.

Helicopters

Helicopters combine a vertical take-off and landing capability with very good hovering efficiency, while at the same time having a greater range and flight speed than multicopters (Fig. 2). Additionally, they can carry large loads. Recently, even formerly manned helicopters are being converted into drones. Piston engines or turbines are used for propulsion - except in the case of very small helicopter drones. In contrast to the small propellers of multicopters, they use one or two large rotors. However, in order to take advantage of the considerable increase in flight performance due to the increased energy content of the combustion fuels, more complex control must be provided. Increased performance therefore means increased system complexity, higher maintenance costs and greater operational risks.

Fig. 1: DLR-Octocopter shortly after take-off

Fig. 2: DLR-Helicopter superARTIS

Fixed-Wing Aircraft

Fixed-wing aircraft are aircraft whose wings generate lift through freestream airflow through forward speed. In the conventional aircraft with main wing and tail fins, one speaks of the kite configuration (pic. 3). But also the so-called flying wing aircraft belong to the category of fixed-wing aircraft. Such aircraft, whether

Fig. 3: Fixed-wing aircraft ALADINA of Technische Universität Braunschweig in Spitzbergen

manned or unmanned, have significant efficiency advantages over vertical take-off and landing rotary-wing aircraft. The reduced need for propulsion power can be used for higher ranges and flight speeds. Through extreme lightweight construction, which is used for example in solar-powered aircraft, a particularly high flight altitude and flight duration are achievable. In civilian applications, fixed-wing drones have so far been rare due to their requirements for suitable take-off and landing areas. For research and surveillance, however, there are a number of systems, some of which have ranges of several thousand kilometres or possible flight times of 40 hours or more.

Hybrid aircraft

The hybrid aircraft combines the configuration of a fixed-wing aircraft with that of a multicopter by means of fixed or swivelling propellers, so that both hovering flight and fast forward flight can be realised by changing the configuration from multicopter to fixed-wing aircraft and vice versa. This increases the system complexity, but results in a drone with high flight performance that nevertheless does not require any special infrastructure (runway). This makes the hybrid aircraft particularly suitable for short-term missions, such as those frequently encountered in medical applications, emergency aid, etc. Electronic flight control systems play a major role in the manageability of the complex transition between the opposing configurations (more on this in the chapter "Avionics"). Although multicopters are basically equipped with electronic control systems anyway, the flight characteristics change significantly in the transition phase.

2.2 Propulsion

Different configurations, missions and environmental conditions also require different propulsion types and concepts. The drive is divided into the aerodynamically effective part (e.g. propeller), the motor and the energy storage (e.g. battery). These components can be combined into complete propulsion systems to meet requirements for high flight speed, long flight duration, high transport performance or simple mechanical design with low maintenance requirements. The most important propulsion combinations for drones and unmanned aerial vehicles are briefly described below.

Elektric Propeller Propulsion

Electrically driven propellers are used in multicopters as well as in hybrid and fixed-wing configurations (Fig. 4). Energy sources are mostly lithium-based batteries, predominantly rigid, non-adjustable propellers are used. Advantages are the simple mechanical design, good controllability of the propulsion via electronic speed controllers for propeller thrust variation, high performance and a low noise and vibration level. The main disadvantage is the limited capacity of the accumulators, which means that range and payload are currently still severely limited. This disadvantage can be countered by using fuel cells with hydrogen tanks instead of batteries. These tanks can be refuelled as quickly as conventional fuel tanks, but instead of mechanical energy they supply electrical energy, which is very useful in drones.

Fig. 4: Electrically driven propeller of the DLR Explorer

Propeller Drive with Piston Engine

If aircraft propellers are driven by piston engines (Fig. 5), significantly higher flight times can be achieved with the same flight performance compared to electric propulsion systems. However, operation is becoming more complex, noise emissions and mechanical stress are increasing. Flight concepts such as multicopters cannot be safely realised with this propulsion system due to the distributed drives and poor controllability of the drive system.

Fig. 5: Boxer engine of the DLR-aircraft Prometheus

Turbine Propulsion for Rotors

When maximum performance with minimum weight is required, turbine engines are used, as in manned helicopters (Fig. 6). In combination with a large rotor, which is coupled to a shaft turbine via a gearbox in order to reduce the very high speed of the turbine to the required, lower speed of the rotor, one obtains high-performance vertical take-off and landing (VTOL) aircraft. Their particularly good ratio of payload to total mass is mainly used by professional users. The propulsion and control systems are complex and maintenance-intensive.

Fig. 6: Shaft turbine of the DLR superARTIS

Hybrid Propulsion

The propulsion systems mentioned can also be hybridised, i.e. combined with alternative energy sources or engines. A common approach is to combine electric propulsion systems with all their advantages with combustion engines or fuel cells, in particular to increase range and flight time. Combustion engines are then used together with electric generators to relieve or charge the additional batteries. In solar flight configurations, accumulators are combined with solar cells to provide sufficient energy for flight and payload both during day and night.

2.3 Avionics

It is electronic equipment that makes it possible to guide the systems remotely or to technically replace the pilot skills normally found on board. This equipment is known collectively as avionics. Avionics includes components for:

- Navigation (e.g. satellite navigation such as GPS, Global Positioning System),
- Remote guidance and monitoring,
- Airspace integration (Transmission of the own position),
- Measurement data acquisiton (Sensorics, metrology),
- Control engineering (mostly computer-based),
- Influencing the flight attitude (Actuators, Servomotors) and
- Measurement data recording (Flight recorder, „Blackbox“).

Global Navigation Satellite Systems (GNSS), together with attitude sensing systems, usually form the basis for determining the position, speed and attitude of an aircraft and thus for its automatic operation. Due to the availability of various GNSS (GPS, GALILEO, Glonass and Beidou) and other systems, there are considerably more available satellite signal sources for this task these days than there were just a few years ago. At the same time, however, the threat to these signals from intentional or unintentional interference has increased significantly. It is therefore necessary to use further technologies.

The interaction of navigation with autopilots available today will enable the reliable and accurate execution of missions along predefined coordinates, which has already been demonstrated in diverse automated applications ranging from surveillance and inspection to air cargo applications. Take-off and landing are also reliably programmable by autopilots. The human pilot‘s function on the ground is mostly reduced to monitoring the performance of the pre-programmed flight.
Artificial intelligence (AI) offers new ways of using sensors and potential applications for drones in aviation, e.g. in agriculture, construction, surveillance, photogrammetry (image measurement), mapping and surveying of terrain, infrastructure and entire cities. Optical sensors in particular can be used for navigation and can also serve as an intelligent payload for measurements and aerial surveillance. In emergency scenarios, drones are used for rapid situational awareness in areas that are difficult to access.

2.4 Autonomy

A differentiation is often made between degrees of autonomy and degrees of automation. Assisted, automatic, fully automated or autonomous are terms that are used to differentiate. Essential here is how much an operator or pilot is involved in the operation or how independently a technical system is allowed to act. Technical systems can perform some tasks better than a human pilot and thus enable new applications. For example, "unflyable" systems become "flyable" and several aircraft can be controlled simultaneously by one pilot.
AI techniques are pacesetters of automation for improved situational awareness, object recognition, dealing with changing or unknown flight behaviours, etc. In comparable technical and safety-relevant environments such as autonomous driving, AI makes it possible to condense the experience of millions of test kilometres into one vehicle. However, caution is required when implementing them in unmanned aircraft, as the conditions under which these procedures can be used in aviation are only just being worked out so as not to endanger flight safety. For individual applications such as image processing for landing site evaluation, realisation is already foreseeable. The use of AI for decision-making is particularly challenging in terms of reliability, transparency and explainability. In manned aviation, proving the functionality of complex software under all

conceivable conditions is a standard process in safety testing. The development processes of manned aviation are not directly transferable to drones. While in manned aviation an aircraft must always be safe, i.e. there must be no catastrophic system failures, this is not necessarily the case with a drone. Technical errors or unforeseen behaviour can be accepted as long as no one is harmed or the environment is endangered. Novel methods are emerging here to safeguard such requirements.

3. Airspace Integration and Air Traffic Management

A major challenge for future air traffic is to safely and efficiently integrate new air traffic participants with different flight performance, capabilities and mission profiles, such as those arising from the drone applications described in Chapter 5 or for air taxis, high-flying solar platforms, see Chapter 7, into the airspace. There is currently neither a complete legal framework nor an established traffic management infrastructure to enable and safely manage the use of general airspace for these new participants. This requires, in particular, a reorganisation of airspace, an adaptation of flight rules, the definition of standards and common interfaces between manned and unmanned air traffic, as well as the establishment of a traffic management system that can react dynamically to changes and facilitate a high number of aircraft movements safely and efficiently.

In Europe, the term "U-Space" has become established for the new traffic management of drones. In American usage, the term Unmanned Traffic Management (UTM) is used instead. U-Space is divided into four phases and envisages a gradual integration of drone traffic. Different services are to be offered in the individual phases. This starts with a registration obligation for the electronic identification of drones, through monitoring and tracking services to airspace capacity management, conflict detection and conflict avoidance.

For the joint use of airspace by drones and manned air traffic, many requirements arise for the operation of drones. The previous subdivision of airspace is therefore extended by a corresponding subdivision in U-Space. Depending on the type of drone mission, the airspace flown through in each case must be taken into account. Missions within the pilot's visual range (typically up to 500 metres around the pilot and up to 120 metres in altitude) have a relatively low risk and can largely be carried out without special permission. Missions that go beyond the pilot's field of view take place in a different category of airspace. These impose a number of requirements on drone operations:

- Identification: The drone must transmit its identification in order to be uniquely identified by air traffic controllers, for example.
- Respect of restricted areas (geo-fences): It must be ensured that the drone cannot enter critical areas, e.g. control zones of airfields, even in the event of system malfunctions.
- Position transmission: The drone must be able to transmit its position (coordninate and altitude) together with the current time. The accuracy of the position data must meet the requirements of the airspace
- Collision Avoiding (Detect&Avoid): Requirements for the behaviour of drones to actively avoid collisions with other aircraft are currently being coordinated.
- Strategic conflict avoidance: The drone operator must be able to submit a timed flight plan before the flight, receive corrections and react accordingly.
- Tactical conflict avoidance: The drone must be able to receive and execute tactical conflict avoidance instructions from air traffic control via the operator.

- Emercency management: The drone operator must report technical emergencies and react to possible nearby drone accidents.
- Entry into controlled airspace: This requires the operator to communicate with air traffic controllers. Air traffic controllers can allow, divert or prohibit the entry of the drone.

In current projects, the U-Space concept is being investigated for drone operations in cities, for example (Fig. 7). In addition to operating procedures and requirements for drone operation, this is particularly about safety, efficiency and social acceptance. Central components of the study are also the development and analysis of scenarios for potential market penetration by drones by 2050. Resulting economic aspects such as vehicle utilisation and cost-benefit potential are evaluated by researchers.

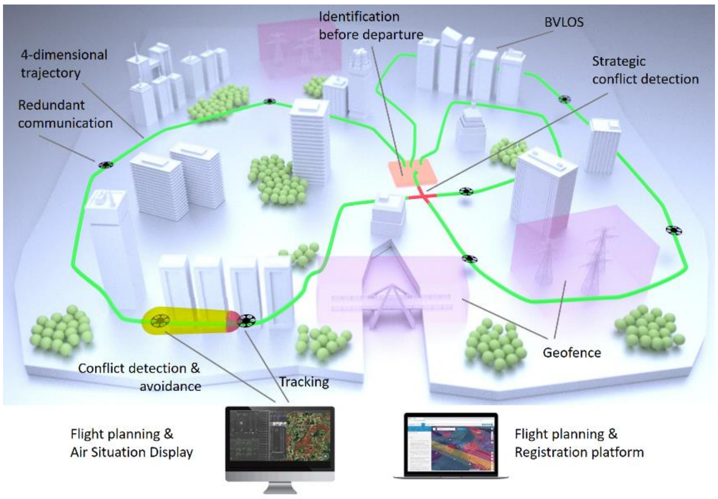

Fig. 7: Exemplary implementation of an U-Space in the DLR project City-ATM

New air traffic entrants are expected not only in urban or low level airspace, but also in significant numbers in upper airspace above 20 kilometres altitude. So-called HAPS ("High Altitude Pseudo Satellites") are high-flying platforms with a very high endurance. Due to their high operating altitudes and the resulting area coverage, it is planned to use these systems for telecommunications as well as surveillance applications. HAPS are currently operated infrequently and only under special conditions. For each HAPS flight mission, sufficient separation from other air traffic must be ensured. This reserves large airspace regions for a single flight event, which would severely affect the overall performance and capacity of the air transport system if the number of HAPS flight movements increases significantly. The U-Space concept must also be adaptable to such missions, e.g. in the form of dynamic special airspaces.

The first certification for the operation of drones in civil airspace has been issued in Israel. The certification is for a surveillance drone (Hermes StarLiner), an aircraft with a maximum take-off weight of approximately 1.6 tonnes and a wingspan of 17 metres. The certification enables the drone to be operated in civil, non-segregated airspace for the first time.

In Switzerland, the company Meteomatics regularly carries out drone measurements up to an altitude of six kilometres with the approval of the Federal Office of Civil Aviation in order to obtain data for improved weather forecasting.

4. Operating

EU-Law and Framework

In recent years, there have been very major regulatory shifts in the field of aviation law for drones, which are expected to lead to market growth in unmanned aerial vehicle systems. In the past, the use of civilian drones with a maximum take-off mass of less than 150 kilograms was regulated individually and extremely heterogeneously by the individual EU member states. Due to this different treatment, only simple, mostly privately used drone systems have prevailed, which are operated in the visual flight range of the controller.

The obstacles for more complex applications (longer flight distances, autonomous operation, cargo transport) have so far mainly consisted in the fact that it has not been worthwhile for manufacturers to develop safe, operational drone systems due to the various and complicated European and also global exemption rules. Thus, developments so far have mainly been demonstrator prototypes.

To address this conflict of objectives, the European Commission has created the regulatory basis for drone operations in three categories with the publication of the "Implementing Regulation (EU) 2019/947":

- The licence-free "open" category applies to most drone activities by hobby pilots and low-risk commercial activities. It refers to a take-off weight of less than 25 kilograms, operating primarily within visual range and at a safe distance from people.
- In addition, there is a "special" category requiring approval, which will be applied in the 27 EU states and some other European countries from 31.12.2020 and will be relevant for most commercial drone applications. An operation in this class requires a risk assessment to determine the requirements for safe operation.
- The third category is the "certification-required" category. It is currently still being developed by EASA (European Union Aviation Safety Agency) and the European Commission. This will include the operation of air taxis, which are intended to fly autonomously in the long term, but also the transport of dangerous goods and similar types of operating with a high basic operational risk.

The existence of this Europe-wide framework now creates the necessary investment security that will enable the development of new standard drone operations for the first time. At the same time, the responsibility for drone operations of all system dimensions is raised to a European level.

Risk-Based Operating Licence

The major innovation introduced into aviation by the "special" category is the analysis of operational risk as an essential part of a licence for drone operators. Since the risk to uninvolved persons does not only depend on the size of a drone, but is primarily determined by the place of operation (population density on the ground and density of airspace to be flown), certification is reorganised in contrast to manned aviation: During an approval process for the operation of an unmanned aerial vehicle, the risk for each type of operation and each operating location is determined individually. Based on this, a portfolio of equally individual certification and qualification requirements for the technology of the drone, the organisation of the owner and for the training of the operating personnel is identified and prescribed.

This new way of thinking means that drones with lower certification standards compared to manned aviation may be used for regular commercial operations if the remaining risk of operation to uninvolved persons is considered to be equally low. This will enable the widespread use of drones for the first time to fly beyond the sight of a "pilot" on the ground. Through these rules, the European Commission also allows for the first time the regular autonomous flight of drones, without the constant supervision of a remote pilot, provided that the risk of the mission is considered very low through appropriate safety precautions.

In order for the mentioned risk assessments of operators to produce equivalent results, Europe focuses on the international standard of the "Specific Operation Risk Assessment" (SORA), which effectively introduces six risk classes for drone operations. In this way, manufacturers of drones, drone companies, maintenance and training companies have the opportunity to specialise in the requirements of one or more risk classes and can offer their products and services throughout Europe in the future. In the future, new, specialised service companies will emerge that are not covered by the classic maintenance, manufacturing and training companies of manned aviation.

However, the application of this risk-based operating licence requires protected areas in which the necessary procedures and technologies for risk reduction can be developed and tested. For this purpose, DLR is establishing the National Test Centre for Unmanned Aerial Systems at Cochstedt Airport, where large and heavy drones can also be tested in a safe environment in the future.

5. Applications

5.1 Urban Air Mobility

The aim of Urban Air Mobility is to transport passengers on short and medium distances between the most important transport hubs of a city (airport, city centre, railway station) with the help of electrically powered aircraft. While this will initially be done with a pilot on board, in the long term the pilot will be replaced by autonomously acting systems.
Urban airspace is particularly challenging because dense development presents

obstacles to the aircraft and it offers few landing sites outside of specially established landing points that can be approached in an emergency. This places particularly high demands on the flight safety of the aircraft. In addition, the air taxis must be particularly quiet to avoid disturbing residents living near air taxi sites. Airspaces of large cities are already highly frequented by air traffic arriving at and departing from airports close to the city. Special solutions must therefore be found to efficiently connect urban areas to airports. The first applications are expected in the coming years.

5.2 Unmanned Cargo Transport

Cargo transport ranges from small, light loads to large, heavy loads. This concerns small delivery drones or even large cargo aircraft. In the first case, applications are conceivable for supplying poorly connected areas with urgently needed goods, such as medicines or catastrophe relief equipment. A further step is the extensive exchange of urgently needed production parts between industrial locations. Parcel delivery from the air is a future topic with broad application potential. In the second case, we are investigating how air freight can increasingly be handled globally by unmanned transporters in order to reduce costs. The path from today's two-man cockpit to autonomously operating cargo aircraft leads via the intermediate stages of one-man cockpit, cockpit manned as needed and remote-controlled cargo aircraft. In parallel to these plannable, regularly scheduled medium- and long-haul cargo flights, drones are already being developed for supplying areas with poor infrastructure and urgent immediate needs.

5.3 Crisis Management and Humanitarian Aid

In the event of a disaster, humanitarian aid workers need to know as quickly as possible - preferably in real time - the extent of the damage to the infrastructure in the affected region and which transport routes can be used to reach the site of the disaster. Humanitarian aid must be brought quickly and effectively to inaccessible regions. In this area, drones are already a frequently used means of operation (Fig. 8). Fire brigades, police and aid organisations use small multicopters with thermal imaging cameras to detect hot spots and search for missing persons. Airborne sensors help forces improve situational awareness and can also operate in physically, biologically or chemically harmful environments. In the case of large-scale damage situations such as floods or earthquakes, aerial photographs can support the creation of situation maps.
Drone operations are particularly flexible: existing facilities for take-off are not necessarily required, non-existent or destroyed traffic infrastructure on the ground is no longer an obstacle. Drones also allow the transport of relief supplies to areas whose security situation does not permit manned flights. In the coming years, the use of drones will increasingly become a matter of course at all levels of civil protection - in some cases it is already a matter of course today.

Fig. 8: Humanitarian aid flights with the DLR-superARTIS.

5.4 Medical Drone Flights

In the future, drones will also be used for medical flights. Various projects are currently underway in numerous cities. For example, the three locations of the Braunschweig Municipal Hospital are up to twelve kilometres apart. Medical drones can help to bridge such distances and transport important aids quickly to the site. One possible application is the rapid transport of tissue samples, so-called frozen sections, between operating theatres and pathology during ongoing operations. For frozen sections, several samples are usually taken from different locations and taken to the pathology department for examination. This is the only way to determine whether all diseased tissue has been removed during the operation. The use of drones is intended to shorten transport times and thus reduce the risk for seriously ill patients during an operation.
Medical drone missions do not only relate to urban areas, but provide for the transport of medical supplies such as blood reserves, rare medicines or defibrillators to rural areas.

5.5 Athmospheric Research

In the field of atmospheric research, drones fill a gap: measurement with high spacial resolution on small scales of typically a few kilometres horizontally and up to one kilometre vertically. This is not possible with previous measurement methods. This can be used to describe the highly dynamic development of the lower air layers of the atmosphere, in which interaction processes between the ground and the atmosphere take place. The spectrum of applications in atmospheric research ranges from the regular measurement of meteorological parameters such as temperature, humidity, wind direction and wind speed, to the measurement of air pollutants, aerosol particles and gases, to the collection of air samples for further analysis in the laboratory (Fig. 9). A special capability of the systems is the measurement of small-scale distribution and variability, i.e. also the verification of how representative other measurements are for a location.

Fig. 9: Quadrocopter MesSBAR of the TU Braunschweig for pollutant measurement

5.6 Inspection flights

Infrastructure is exposed to heavy loads in many areas. This applies to roads, rails, cranes, bridges, high-voltage power lines and many other structural facilities. Only when it is ensured that their condition is within certain tolerances smooth functioning is guaranteed. Regular inspection is necessary for this, but often involves tiring or dangerous working conditions for people. In addition, conventional inspections often require the interruption of ongoing operations, for example through route closures or shutdowns. Drones are an ideal tool here: Their view from the air enables perspectives that people themselves cannot reach at all or only with a lot of effort and risk (industrial climbers). By using drones with optical sensors, entire plants can be reconstructed three-dimensionally with millimetre accuracy, in some cases even without disrupting operations (Fig. 10). This allows reliable regular inspection, which can thus also make subtle changes visible.

Fig. 10: Drone inspecting an elevated bridge, DLR

5.7 Agriculture

Agriculture offers a wide range of potential uses for drones, from searching for fawns and other creatures in fields to be mown, to monitoring the growth of crops, to the targeted application of fertilisers. Investigations and use of drone use in agriculture began relatively early, as the risk to humans, animals and the drone can usually be classified as very low here. However, there are still decisive steps to be taken before the potential of drones can be fully utilised in other agricultural applications.

Further useful and important applications of unmanned aerial vehicles can be found in the BMVI publication "Unmanned Flying in the Service of People, Nature and Society", May 2019, Berlin. The document is available under the link provided:

https://www.bmwi.de/Redaktion/DE/Publikationen/Technologie/drohnen-unbemanntes-fliegen.pdf?__blob=publicationFile&v=6

6. Social Acceptance

6.1 Attitude towards drones

In 2018, a representative survey conducted by DLR with 832 participants revealed that various concerns exist in society with regard to drones (Fig. 11). For example, a large part of the population fears that drones could be misused for criminal purposes, that privacy could be violated or that damage could be caused by accidents and crashes. In addition, the study showed that the acceptance of drones strongly depends on the purpose for which they are used. Drones used for rescue mobility or research are more popular than those used for transporting parcels or people. Therefore, it is important to research more closely why these tasks have not been accepted very much so far. Furthermore, it is important to investigate which measures could contribute to a greater acceptance and willingness to use them.

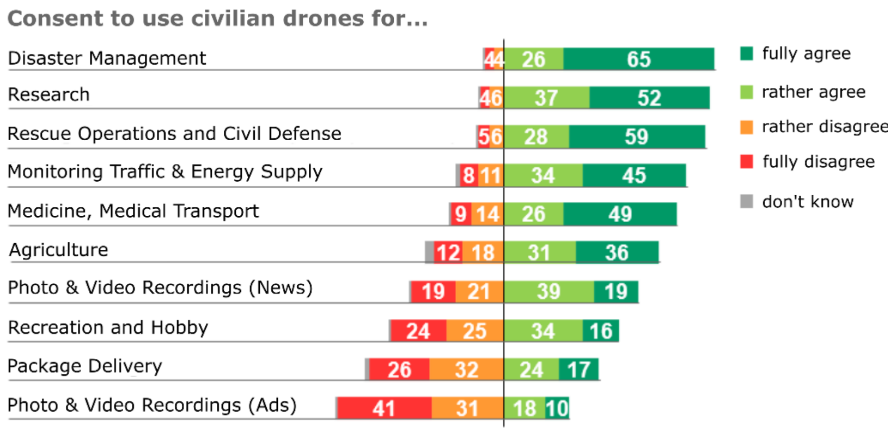

Fig. 11: Result of a telephone survey conducted by DLR in 2018 on the approval of the population for various uses of drones. Figures in percent. Figures for "refused / don't know" are hidden.

6.2 Acoustic annoyance

One major factor that has an influence on social acceptance is aircraft noise. In a telephone survey conducted by DLR in 2018, 52 per cent of people questioned said they were concerned about the noise generated by aircraft. Psychoacoustic studies are necessary to determine the exact noise impact of drones on the population. These could, for example, look at how aircraft noise is perceived in rural and urban areas and how it interacts with other environmental sounds. Since there are more acoustic irritations in cities than in rural areas, the question also arises as to whether the aircraft noise from drones is drowned out in larger cities due to a different background noise (e.g. car traffic) and is therefore less noticeable, or whether this leads to a further increase in acoustic pollution for the inhabitants.

6.3 Visual pollution

Flying drones in cities generate not only acoustic but also visual stimuli that have an impact on social acceptance. There is a fear that drones could make the sky too crowded (Fig. 12). This raises the question of the number of drones above which the sky is experienced as overcrowded and, as a result, acceptance among the population decreases. More detailed investigations are necessary for this. In a virtual reality simulation, test persons were shown an urban scenario in which the number of flying drones was varied. The effect of this was recorded on the subjective feeling of well-being. There was a certain correlation in that a higher number of drones was perceived as more disturbing.

The research results described show how important it is to involve the population from the very beginning - both in the process of integrating drones into air traffic and in the development of U-Space concepts. On the one hand, the findings of previous studies should be taken into account in the conception and various acceptance factors such as visual and acoustic exposure to drones should be researched in more detail. On the other hand, early and comprehensive information of society about new development steps in the field of drone utilization should be ensured.

Fig. 12: Virtual-Reality-Study of the DLR in the projekt City-ATM

7. Research Projects in Braunschweig

5G real lab for future mobile radio standards

The 5G Real Lab pursues the research and lively presentation of the practical needs and possible applications of the 5G mobile communications standard as a key technology in the context of a Smart Region/Smart City. DLR and other research institutions are being funded to set up an open 5G real laboratory in the Braunschweig-Wolfsburg region. The DLR Institutes of Flight Guidance, Traffic Systems and Flight Systems are working together on the integration of drones into future mobile radio systems. Rescue drones will then be able to be remotely and safely controlled over a wide area via 5G or interact with their environment. Accident sites can consequently be secured and the expansion of the networked road system promoted.

City-ATM (Air traffic control in an urban environment)

In the City-ATM project, a concept für the integration of new airspace participants such as unmannes aerial vehicles or air taxis into uncontrolled airspace is being developed. Various technical and operational aspects are to be considered and analysed and evaluated with regard to their risk. At the end, the concept will be demonstrated with flight tests (Fig. 13).

Fig. 13: Drone formation in front of the Cochstedt airport building, DLR

ALAADy – Automated Low Altitude Air Delivery

Using unmanned aerial vehicle systems for transport is already a reality. Systems with payloads of a few kilograms are commercially available. A few operators have already completed several thousand flight hours with such systems. There is as yet no experience in civil aviation in Europe for the use of heavy drones weighing several 100 kilograms. DLR is therefore investigating cargo drones with a payload of one tonne in the ALAADy project (Fig. 14). The requirements of SORA as a verification method for safe operation are being investigated. A variety of perspectives are being explored in ALAADy - from economic viability to technical implementation. Questions of airspace integration, data links and aircraft configuration play just the same important role as technologies for safe autonomy. In recent years, a 450 kilogram gyrocopter was converted into a transport drone as a technology demonstrator and automated (Fig. 14). This concept is currently being expanded for out-of-sight operation

Abb. 14: ALAADy demonstrator in flight, DLR

HAP - High-flying unmanned platform

With the HAP (High Altitude Platform) project launched in 2018, DLR aims to build up and provide comprehensive know-how for the realisation of high-performance, high-flying solar aircraft (Fig. 15). For this purpose, the platform itself as well as the necessary ground station and payloads weighing up to five kilograms are being developed for Earth observation. In particular, the long-term stationing of the platform at an altitude of 20 kilometres poses a significant challenge. Solar cells and batteries must be combined with extremely lightweight construction and sophisticated thermal management. Only in this way an overnight flight is possible at very low air density and in a wide temperature range between up to +40 Celsius in intense sunlight to -80° Celsius at night at high altitude.

Fig. 15: Presentation of the DLR-HAP

AeroInspekt – Inspection of rail facilities in ports

In the AeroInspekt research project, Technische Universität Braunschweig has developed a drone-based automatic measuring system with which even the smallest deformations of an industrial rail system can be inspected and measured (Fig. 16). Highly overlapping aerial images are taken from aboard a drone with the help of a high-resolution camera, from which the three-dimensional rail structure is subsequently reconstructed with millimetre accuracy. The measurement can be carried out during operation, as the flight planning reacts directly to the movement of the cranes.

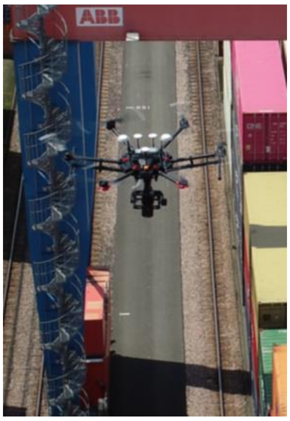

Fig. 16: Hexacopter of the TU Braunschweig surveying rails

Summary

This position paper deals with the subject of unmanned flying in aviation. Drones have already been used in research for decades in individual cases. At the same time, miniaturisation and automation in the field of electronics and sensor technology have made them popular as hobby flying machines. Overall, drones are already in use across a very broad spectrum today. It is already impossible to imagine aviation without them. Drones long ago outgrew the status of a hobby or as a subject of mere scientific inquiry. Their operational use, on the other hand, is just beginning. In the future, drones will increasingly become an indispensable tool for numerous applications.

The market for drone applications and development holds enormous potential. Estimates range from a value of 80 billion euros in sales over the next ten years to the sum of 1.3 trillion euros by 2040[1]. Therefore, an extremely dynamic innovation process has unfolded in the development of drones and the systems surrounding their operation in recent decades, which in turn has resulted in a multitude of new fields of application.

This leads to a particularly innovation-promoting mix of young and enthusiastic as well as very experienced specialists in engineering, computer science, etc., which has a particularly innovation-promoting effect. Another positive effect is that drones can be purchased and operated very cheaply compared to manned aircraft. Disciplines that previously had little contact with aviation are now dealing with drones. As an example, artificial intelligence plays an essential role in automating the operation of drones. So far, it has played no role in the development of manned aircraft. In the future, however, it is conceivable that the results achieved with drones could be transferred to conventional aviation.

[1]… mit Drohnen - Unbemanntes Fliegen im Dienst von Mensch, Natur und Gesellschaft. Publisher: Federal Ministry for Economic Affairs and Energy (BMWi), as of May 2019.