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Operation of drones in German airspace:

transport policy challenges and the conflicting demands of innovation, safety, security and privacy

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Report by the Board of Academic Advisers to the Federal Minister of Transport and Digital Infrastructure

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1 Introduction and intention of this opinion

Under section 1(1) of the Civil Aviation Act, drones are formally classified as aircraft and are "remotely piloted aircraft systems" (RPAS) or "unmanned aerial vehicles" (UAVs). In this document, the term 'drone' is used to cover both types of aircraft. In this context, unmanned therefore refers to the flight operation functions and thus also includes the carriage of persons by drone. Currently, with the onward march of the digital revolution in society and the opportunities it presents for low-cost and increasingly high-capacity data collection and transmission capabilities, drones are experiencing explosive growth, resulting in a similar growth in air traffic. Spatially, these activities have so far been concentrated on very low-level airspace (VLL – <150 m) and low ranges of action (<20 km) of the individual drones. The reason for this is that the monitoring technology used is in the VHF/UHF frequency band and that so far most drones have been flown in visual line-of-sight (VLOS) operation. In Germany, VLL airspace is – except at aerodromes – uncontrolled (airspace class G) and thus self-organizing to a very large extent and managed without VFR (visual flight rules) air traffic control.

Forecasts by the SESAR (Single European Sky Air Traffic Management Research) Drone Outlook[1] state that, by 2050, there are expected to be some 7 million consumer leisure drones (toys) operating across Europe, with a further 400,000 being used for commercial purposes, including:

- around 100,000 in the agriculture sector to enable precision agriculture to help drive increased levels of productivity;
- around 10,000 in the energy sector to limit the risks involved in performing hazardous monitoring and maintenance on complex technical systems;
- around 100,000 in the logistics (urgent services) sector for the provision of vital deliveries and as a premium delivery service for very high-value commodities;
- around 50,000 for police and fire force functions (civil protection).

[1] See https://www.sesarju.eu/sites/default/files/documents/reports/European_Drones_Outlook_Study_2016.pdf

The result would be a significant increase in the density of aircraft in the airspace. In commercial use alone, the increase would be more than 10-fold compared with today's approximately 20,000 conventionally controlled certificated aircraft (business aircraft and helicopters). Over the same period, the number of these conventional aircraft will, according to the SESAR ATM Masterplan Forecast, rise to around 45,000 worldwide – a figure that appears modest in comparison[2]. This is driven by the wide range of emerging new business models based on drones which, according to estimates by PWC and Goldmann Sachs, could achieve an annual worldwide turnover of over 100 billion deals by 2020 alone.[3] [4] Blyenburgh expected similarly progressive trends, with a tripling of the numbers of movements by drone by the end of 2018 alone.[5] These estimates give an idea of the potential, but the actual spread of drones will also depend very heavily on the regulatory environment.

In addition, it has to be assumed that, in the near future, numerous new types of drone will be deployed that can rise to significantly higher altitudes and can even enter the controlled airspace (> 2,500 ft or just over 750 m above ground) where, in a visionary manner, for instance as an air taxi, they can cross long distances without encountering obstacles or congestion and without having to take a detour. In the long term, there are also likely to be increasingly large drones, both in the form of present-day commercial fixed-wing aircraft and rotorcraft in the cargo sector and later also in the movement of persons. SESAR expects remotely piloted/autonomous flights to account for 20 % of air traffic in the aforementioned controlled airspace by 2050[6].

Although the current development of drones offers a wide range of opportunities, there are also various possible undesirable effects (negative externalities). These include accidents involving personal injury or damage to property on the ground, on buildings and other fixed

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[2] (Un)certain skies? Drones in the world of tomorrow – © OECD/ITF 2018, https://www.itf-oecd.org/sites/default/files/docs/uncertain-skies-drones_0.pdf
[3] PwC (2016), Clarity from above: PwC global report on the commercial applications of drone technology, PricewaterhouseCoopers, Warsaw.
[4] Goldman Sachs (2016), “Drones: Reporting for Work”, www.goldmansachs.com/our-thinking/technologydriving-innovation/drones/ .
[5] Blyenburgh (2018), Drone Operations: Today & Tomorrow, Blyenburgh & Co, Paris
[6] PwC (2016), Clarity from above: PwC global report on the commercial applications of drone technology, PricewaterhouseCoopers, Warsaw.

installations; accidents in the air involving aircraft, cable cars or other drones; criminal or terrorist threats posed by devices equipped with firing systems, explosives or chemicals; invasion of privacy through the recording of images or sounds or through the unlawful introduction of sensors into other people's privacy; drones being used to steal objects; noise pollution; disturbing the optical or acoustic environment of people (even still below prescribed noise thresholds); alarming or scaring people with regard to the aforementioned threats or as a result of natural reflexes; having an adverse impact on the natural habitats of animals. These problem areas have been the subject of discussions at national, European and international level for some time now and are currently resulting in initial but not yet comprehensive regulatory steps. National regulations have to date displayed a wide range of administrative, operational and airspace management rules, which also vary significantly depending on the category of drones (OECD/ITF 2018 pp. 15 ff).

It is thus obvious that solutions for addressing the very dynamic development in the VLL airspace, which has so far been predominantly used, will have to be found via more precise regulation in an airspace that will be used to a significantly higher extent in the future. On the other hand, possibilities for fundamentally enlarging the area of operation are to be created in order enable the many and varied business models that involve beyond visual line of sight operations (BVLOS). Germany, as an attractive location for innovative drone manufacturers, needs a framework that allows new business models and transport technologies while simultaneously meeting stringent requirements regarding safety, security, privacy, capacity and efficiency in their integration into the airspace.

Since this framework is established in interaction between national and international bodies, it is imperative, and in our own interests, that we demonstrate national commitment to fleshing it out. In June 2018, the European Commission, the Council of Ministers and the European Parliament agreed on uniform rules for the marking and operation of civilian drones, and thus in particular those weighing less than 150 kg. These rules will enter into force in the near future, and Member States will have to ensure that manufacturers of affected unmanned aerial vehicles meet dedicated requirements. Within the EU, drones that could be dangerous for persons, the privacy of third parties or aviation, are then to be marked for individual identification. In addition, drone manufacturers will, in the future, have to follow rules (not yet completely established), specifically in the construction of heavy drones. These rules will cover requirements for maximum altitudes, ranges, data protection and automatic emergency landing capabilities. The Commission now has to flesh out the details of the new directives. By way of contribution to this process, the following opinion sets out recommendations regarding national involvement in their fleshing-out. The aim is, by means of standardization, to impose as few constraints as possible on innovation by establishing a framework that can be easily grasped.

Accordingly, the present opinion addresses the challenges and opportunities induced by the growth in drones in the mobility sector. It concludes by providing the Federal Minister with recommendations for action to the effect that measures should be consolidated to provide targeted support to the regulatory and standardization processes ongoing in the context of the new EU Basic Regulation from 2018. This is the only way to provide the numerous development and procedural processes that are starting, in Germany and in other countries, with a compatible framework for certification at a later date. Specifically, reference is made here to drone testing centres as a component of *Smart Cities*, the number of which has been growing in Germany as well since 2018, encouraged by the EU's Urban Air Mobility (UAM) initiative[7]. This promises the applicant towns and cities relevant funding for the trialling of 3D mobility in conurbations. 26 towns and cities are currently members of the UAM initiative, e.g. Hamburg, Dresden, Leipzig, Munich, Ingolstadt. The recommendations made in this opinion are designed to support a structured approach in these projects as they pass through the subsequent certification and licensing process.

[7] EIP-SCC - European Innovation Partnership on Smart Cities and Communities, https://eu-smartcities.eu

2 Categorization and operational scenarios of drones

2.1 Categorization, operation categories and drone classes

In accordance with EU Basic Regulation 216/2008 (no longer in force), certification requirements have so far applied only to drones with a maximum take-off mass of more than 150 kg. Light drones were thus governed by the heterogeneous legislation at national level. To achieve harmonization in Europe, the EU Basic Regulation was recast for all weight categories. This instrument was adopted by the Council and Parliament on 4 July 2018 and entered into force on 11 September 2018.[8] To address the different kinds of potential risk inherent in the very specific types of operation, drones have been classified by the European Aviation Safety Agency (EASA) since 2008 into the following three categories – *open*, *specific*, and *certified*.

2.1.1 *'Open'* category

EASA's *open* category focuses on light drones where the risk posed to third parties on the ground or in the air is considered to be comparatively low. The operation of drones in this category is not to be subject to authorization by the aviation authorities. This also includes drones used for recreational or sporting purposes. Another principle is that a pilot may only control one drone at any given time and only within the visual line of sight (VLOS).

Operation categories and drone classes

To ensure safety, the primary subdivision is into operation categories and drone classes. The three operation categories A1 to A3 stipulate the distance from people on the ground at which drones may be operated and are supplemented by restrictions on the permitted altitude. The five *open* drone classes (subcategories) C0 to C4 regulate what drones may operate in the respective operation categories (see also Figure 1). A sixth drone class

[8] See https://www.easa.europa.eu/document-library/regulations/regulation-eu-20181139 or https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32018R1139

additionally takes into account private self-constructed aerial vehicles (model aircraft) as frequently encountered in model aircraft flying clubs. The classification is based on the maximum take-off mass (MTOM) or the kinetic energy of the drone as a measurement of the potential risk posed to people on the ground.

Kinetic energy as a basis of classification

In connection with the kinetic energy, it is possible to determine whether a drone colliding with a person will have fatal consequences. This topic has been the subject of numerous studies in recent years. Dalamagkidis et al. (2008) and Skobir und Magister (2011), for instance, studied the kinetic energy of drones with reference to their velocities. The studies by Monash University (2013) and Arterburn et al. (2017) deepen the studies by including different injury models relating to the region of the body hit and by taking into account the varying degrees of injury by different components of the drone. Shelley (2016) also calculates the "social" costs that accidents involving drones and persons can entail. To determine a kinetic energy threshold as of which a collision is assumed to be fatal, EASA refers to the 1949 Gurdjian Experiment. This experiment demonstrated that, in the event of a collision with blunt objects, the human skull possesses the capability to absorb energies up to 80 J without suffering a fracture. In addition, EASA assumes that, in the event of a mulitícopter crash, an average of only 46.5 % of the actually occurring kinetic energy impacts on the head of a person. This average value produces two scenarios, which analyse different types of hit. In conjunction with the aforementioned threshold of 80 J, the result is an accepted actually occurring kinetic energy of 172 J.

These assumptions are relevant especially because they determine the maximum weight limit of class C1 drones permitted in operation category A1. In this category, drones may be operated over people but not over gatherings of people. EASA assumed a linear connection of 48 J of kinetic energy per 250 g of take-off mass. This results in a maximum take-off mass (MTOM) of 900 g as a ceiling for drone class C1. Because of the great relevance of this weight restriction, given by the permitted operation over people, the correlation established here between the MTOM and kinetic energy in the event of a collision of a drone with a person is definitely worth reviewing and the existing class model is to be verified.

Maximum take-off mass as a basis of classification

The EASA documents do not provide any detailed justification for the weight restrictions of the drone classes permitted in A2 and A3. It thus has to be assumed that the MTOM thresholds have evolved historically or have emerged as a result of market analyses. Thus, for instance, Class C2, which is approved in operation category A2, allows drones with a take-off mass of up to 4 kg. According to an EASA study, this segment comprises 92 % of the drones currently being operated on the European market. These are mostly equipped with navigation and automation systems, can carry payload and pose a heightened risk to third parties. The maximum take-off mass of drone classes C3 and C4, which may only be flown far from people (operation category A3), is 25 kg. Thus, the MTOM of this class is equivalent to the currently prevailing weight limitation for drones on the national levels of the EASA Member States. Operation category A3 reflects not only commercial operations with sophisticated camera systems but also the large number of model aircraft that are traditionally flown in model aircraft flying clubs. It is obvious that higher MTOMs of drones entail a greater operational risk. The reason for this is the positive correlation – described above – between the maximum take-off mass and the kinetic energy that becomes effective in the event of a collision with persons. In order to reduce the risk to third parties on the ground, there is a subdivision into operation categories which, in accordance with the MTOM, permit operations over , at a defined distance from or at a subjectively suitable distance from people. To continue to reduce the risk to third parties in the air, a maximum permissible altitude above ground level (AGL) of 120 m applies to drones, which is thus 30 m below the minimum flight altitude for manned visual flight rules (VFR) aviation (150 m AGL) under the Rules of the Air Regulations. In addition, only visual line of sight (VLOS) flights are permissible in the entire EASA *open* category. The following Figure 1 illustrates once again the links between the operation categories and drone classes (UAS).These links are described in greater detail further below.

Betriebs-kategorie	UAS Klasse	MTOM/ Joule	Entfernung zu unbeteiligten Menschen	max. Flughöhe	Piloten-kompetenz	Mindest-alter	technische Anforderungen	Regist-rierung	e-ID/ Geofencing
A1	Eigen-bau	< 0,25 kg	Flüge über unbeteiligten Menschen erlaubt (keine Menschenansammlungen)	< 50 m	Broschüre	nein	nein	nein	nein
	C0						Spielzeug-Richtlinie 2009/48/EG, keine scharfen Kanten		
	C1	< 0,9 kg oder 80 J		< 120 m	Broschüre und Online-schulung mit Test	14 Jahre oder mit Aufsichts-person	mechanische Festigkeit, keine scharfen Kanten, einstellbare Flughöhen-begrenzung	Betreiber	e-ID bei Kamera > 5 MP oder bei Audiosensor; e-ID und GF, wenn durch Betriebsbereich vorausgesetzt
A2	C2	< 4 kg	Flüge mit Sicherheitsabstand erlaubt (Drehflügler-UAS > 20 m, Flächenflieger-UAS > 50 m)	< 120 m	Broschüre und Zertifikat über Kompetenz plus Prüfung bei anerkannter Stelle	16 Jahre oder mit Aufsichts-person	mechanische Festigkeit, Loss of Link Management, einstellbare Flughöhen-begrenzung	Betreiber und UAS	ja
A3	C3	< 25 kg	Flüge in Bereichen, wo keine unbeteiligten Menschen zu erwarten sind	< 120 m	Broschüre und Online-schulung mit Test	16 Jahre oder mit Aufsichts-person	Loss of Link Management, einstellbare Flughöhen-begrenzung	Betreiber und UAS	Ja, wenn durch Betriebsbereich vorausgesetzt
	C4		Zusätzlich zu C3 nur Flüge außerhalb von Ortschaften, Siedlungen und Flughafenbereichen				Betriebsanleitung		
	Eigen-bau						nein		

Figure 1 Operation categories and drone classes for the EASA open category [EASA (A) NPA 2017]

Supplementing these requirements are further requirements to be met by pilot competence and the technical equipment for *open* category drones:

- Pilot competence: The remote pilots (RPs) have to be trained. The higher the potential risk (mass, velocity), the more extensive the training of the RP must be, to be demonstrated in online tests or tests at recognized bodies. The form of these competence tests is directly coupled to the drone classification scheme, which means that it should likewise be verified and, if necessary, further fleshed out.
- Product requirements: EASA makes no provision for certification in the *open* category. It does, however, refer to existing rules governing projects under Regulation (EC) No 765/2008. Accordingly, drones are to be inspected by accredited bodies (e.g. TÜV). Manufacturers can find out what requirements have to be taken into account for a product by consulting the harmonized EU standards. If they ascertain that their product is in conformity with these requirements, it will receive the CE marking. In the case of drones, the product will receive an additional marking indicating the drone class whose requirements it meets. So far, however, only few standards have been applicable to drones, and so EASA will establish requirements

specific to each class. As far as safety is concerned, the main aspects to be emphasized here are loss of link management and mechanical strength. One example of loss of link management that can already be found in some drone applications is the return-to-home function. In the event of the loss of the data link, this failsafe functionality ensures that a drone does not continue its mission in an uncontrolled manner but autonomously returns to a pre-programmed location and lands there. This function can also take effect if the state of charge of the battery is too low.

- Type of power: The product requirements also state that all Class C0, C1, C2 and C3 drones must be electrically powered. Only Class C4 self-constructed drones may use other types of propulsion, such as internal combustion engines.
- Geofencing: Geofencing refers to a function that does not allow drones to enter a pre-defined (restricted) area, such as a major airport within the meaning of section 21b of the Rules of the Air Regulations or an urban area. Here, a distinction has to be made between no-drone zones and limited-drone zones. In the former, the operation of drones is categorically prohibited, whereas in the latter it is permissible only for certain drone classes. The result is that as a first step, the EASA Member States are to determine prohibited and restricted areas in their own airspace and indicate them via web-based platforms or apps. In order to prevent drones automatically penetrating these areas, including altitude restrictions, it is necessary to create uniform standards, chart systems and databases so that manufacturers can implement the geofences in the drones' flight controllers. The European Organization for Civil Aviation Equipment (EUROCAE) has been tasked with creating these standards.
- Electronic identification system (e-ID): To make it possible to reproduce infringements, an electronic identification system (e-ID) is a further product requirement to be met by *open* category drones. This means the capability to identify a flying drone without physical access (operator, drone class, position, altitude). One of the data bases for e-ID is the envisaged registration requirement for operators and drones with a take-off mass of 250 g or more. The electronic identification system can then be used for the criminal prosecution of persons who deliberately misuse drones.

2.1.2 *'Specific'* category

The EASA *specific* category covers the operation of drones that do not comply with the aforementioned provisions of the *open* category and thus pose a comparatively higher risk. This concerns, for instance, beyond visual line of sight operations (BVLOS), operation over gatherings of people involving drones whose characteristics do not comply with Class C1 or at altitudes over 120 m above ground level (AGL). This necessitates an authorization granted by the competent aviation authority that includes adapted operating limits in line with the mission-specific risk. This is to be identified in accordance with the specific operations risk assessment (SORA) (see section 5.1 for more details). If the mission-specific risk can be reduced to an acceptable risk by the operator taking appropriate risk mitigation measures, operational authorization will be granted. At this point, however, it should be mentioned that SORA only addresses safety risks. The aspects of security and privacy have not yet been addressed by SORA – a shortcoming that should be remedied by means of an appropriate widening of the risk analysis. The primary requirement for e-ID is that infringements can be reproduced in the same way as in the EASA *open* category. In addition, it is likely that the majority of operations in the *specific* category will be of a commercial nature (the fees for an operating authorization are significantly higher than €200.) The professionalism and competence of the operators involved with this means that the risk of deliberate misuse of drones tends to be low, but it cannot be ruled out. The remaining recreational operations are accounted for primarily by the model aircraft flying clubs. On the clubs' grounds, however, aircraft are also flown at altitudes over 120 m AGL. In addition, model aircraft with an MTOM of more than 25 kg are used. In both cases, the clubs have to obtain an operational authorization. Since, however, the operations are restricted to the grounds of any given club, it can also be assumed here that any risk regarding security or privacy tends to be insignificant. It is possible to additionally reduce the privacy risk by checking whether the organization of the operator is suitable for specific missions. Regardless of the fact that these risk aspects may be of a limited nature, they are to be included in SORA.

2.1.3 *'Certified'* category

Operations in the EASA *certified* category, which involve drones with an MTOM of > 150 kg, are subject to similar rules to those with which we are already familiar from manned aviation. Here, it is not only a specific mission that is authorized. Rather, there is a (costly) certification of the drone, as a result of which, however, it can be used for large number of missions. In the future, the airworthiness of the drone will be tested on the basis of conformity by means of EASA directives (certification specifications – CS). At present, EASA has not issued any CS for drones[9]. Accordingly, for airworthiness certification, a development company must apply the procedure set out in EASA Policy Statement E-Y013-01 or the certification specifications published by JARUS: CS Light Unmanned Rotorcraft Systems (CS-LURS) for rotary-wing aircraft or CS Light Unmanned Aeroplane Systems (CS-LUAS) for aircraft with an MTOM of 750 kg The formulation of a CS for drones in the near future is advisable in order to establish clarity concerning the effort involved for the development company in obtaining certification, ideally through the provision of joint testing and certification grounds by the authorities.

2.1.4 Conclusion

The information provided above illustrates the heterogeneity of drones, identifies the need for action and also demonstrates considerable differences in the current depth of regulation and thus also in terms of standardization. In the *open* category, regulation is already at a very advanced stage today, whereas there are only basic rules governing the *specific* and *certified* categories:

- *Open*: Drones of this category are currently the most common models from the spheres of gaming and surveying/photography. They must not exceed a maximum take-off mass (MTOM) of 25 kg including payload and must exhibit a maximum altitude of between 50 m and 120 m. The do not normally require explicit authorization before use or any further certification of the pilot. Nevertheless, German legislation distinguishes various

[9]Since 1 February 2019, JARUS has had a draft version of a CS-UAS.

sub-categories that require proof of competence as of 2 kg MTOM and a licence as of 5 kg. This also applies as of an altitude of 100 m, irrespective of the mass.

- *Specific*: Drones of this category do not completely meet the requirements of the *open* category (negative definition), have to be precisely explained with regard to their intended use and be issued certification by the competent authority (in Germany the aviation authority of the federal state in question) for this specific scenario. For the scenario, a specific operations risk assessment (SORA) has to be performed as part of the authorization process. Any risk mitigation requirements identified in this process have to be met as a condition for issuing the aforementioned certification.
- *Certified*: These drones with an MTOM > 150 kg do not completely meet the requirements of the *open* or *specific* categories (negative definition) and require individual certification because of the heightened potential of risk, a licensed remote pilot (RP) and an operator certified by a Light or Certified UA Operator Certificate (LUC/CUC) issued by the competent authority.

In Germany, these categories have, since 2017, been formalized by the Federal Ministry of Transport and Digital Infrastructure' national Drone Regulations (see note in the *open* category. However, as a result of the new EU Basic Regulation dating from 2018, it has to be assumed that the national regulations will, in the medium term, by replaced by explicit rules developed by EASA.

2.2 Operating scenarios

The civil drones on which the present opinion focuses are already in use today in the transport sector for measuring instruments, freight and in some cases even persons. A wide range of future specific areas of application is envisaged, and visionary conceptual studies for air taxis for the carriage of passengers have been published (Audi, Airbus, Lillium). Some of the envisaged operating scenarios are only made possible by the "4th Industrial Revolution", because they presuppose a close fusion of physical, digital and human systems. However, business models that have so far been impossible or least not commercially viable using manned aircraft (such as the use of present-day helicopters) are today already developing at a furious pace and with a rapidly growing degree of maturity.

In this context, drones are always a carrier medium. They can transport people, goods, measuring equipment or devices that perform activities themselves, for instance repairs or the fertilization of fields. Among the numerous types of drone, the most common is the multicopter configuration (rotary blade), followed by the fixed-wing configuration. Table1 below shows the current shares and the shares forecast by EASA. Most of these drones are electrically powered; 92 % of all *open* category and *specific* category drones with an MTOM not exceeding 25 kg used for civil purposes effectively weigh less than 4 kg.

Type	2014	2015	2016	2017	2018	2019	2020	CAGR (2015-2020)
Fixed Wing	9,826	17,698	26,700	34,630	40,577	44,943	48,365	22.27%
Rotary Blade	460,351	887,755	1,442,558	2,029,252	2,600,367	3,181,745	3,830,073	33.96%
Nano	-	8,110	14,849	23,268	32,902	44,080	57,721	40.41%
Hybrid	-	2,771	9,198	19,624	33,820	52,124	75,837	69.45%
Total	470,176	916,333	1,493,306	2,106,775	2,707,666	3,322,892	4,011,995	34.36%

Table 1 Global share of drones by design configuration [EASA] [10]

Another characteristic of drones revealed by the EASA study is the expected lifetime of only 30 months, which reflects the currently massive rhythm of innovation.

With the high level of innovative intensity, the heterogeneity of the drones and their areas of application also increases. The first question that arises is: which of the existing areas of application and which of the areas of application conceivable in the future for drones will develop and how? This is the only way to later derive recommendations for action by transport policymakers when addressing the issue of drones. Of course, the following is confined to a selection of operating scenarios.

Drones as a means of transport for measuring equipment

Today, drones are already fitted with a wide range of equipment for data collection and transmission. The main types of equipment transported are cameras (e.g. daylight, thermal imaging, corona, pmd[11]) and detectors (e.g. lasers, radar, ultrasound, temperature,

[10] Cf. EASA [A-NPA (B), 2017], p.10 ff.; CAGR = Compound Annual Growth Rate
[11] Photonic mixer device – an optical sensor whose operating principle is based on the time-of-flight process.

humidity). This sector is currently developing at a very dynamic pace with a wide range of possible areas of application, for instance in agriculture (e.g. monitoring of growth processes, tree populations, infestation with pests, damage, maturity for harvesting), maintenance (e.g. inspection of difficult-to-access or hazardous facilities such as aircraft surfaces, offshore wind turbines, transmitter masts), disaster control (e.g. finding of earthquake victims, landmines or leaks by the German Disaster Relief Agency), industrial espionage, recording of accidents by the police, border protection, capturing of damage by the fire brigade, construction industry (monitoring the progress of construction work and protection against unauthorized access and theft), surveying, taking of aerial photographs, spatial data. In all these sectors, standardization is still low and the market is dominated by special solutions. This state of affairs will in the short term allow noticeably simplified market access, but will in the long term place a constraint on the connectivity and combination of various systems and providers. Requirements in the sphere of privacy rights and, continuing along this path, data protection and safety are easier to meet if the areas overflown are in private ownership (e.g. applications in agriculture or on building sites), which makes these applications more dynamic, especially in these sectors.

Drones as a means of transport for active equipment and machines

There is great potential inherent in drones for carrying out work requiring a high degree of precision at difficult-to-access and/or hazardous locations. Areas of application so far have been primarily agriculture (e.g. targeted fertilization or pest control), maintenance (e.g. repair of difficult-to-access facilities such as power lines, gas and oil pipes, wind turbines), special effects at major events, personal flying assistant (indicates the way to preset destinations, e.g. for people with dementia) and applications in the private sphere.

Drones as a means of transport for goods

Drones can also carry goods as a fast and reliable alternative to land-based transport. Numerous companies in the logistics and, more specifically, CEP (courier, express and parcel) sectors as well as Google and Amazon are currently testing the use of drones for the delivery of parcels. Initially, the focus was on time-critical deliveries and deliveries in difficult-to-access regions. Currently, tests are also being carried out with deliveries to sparsely populated regions. The first delivery operations over urban areas were carried out by the drone manufacturer Matternet in cooperation with Mercedes-Benz and the Swiss online marketplace Siroop. In a three-week project, drones transported parcels weighing up to 2 kg from the dealer to one of four defined "rendezvous" points in the city of Zurich, where they landed on a designated Mercedes-Benz van. The supplier delivers the parcels to the end customer. The project was authorized on case-by-case basis based on SORA. The increasing volume of consignments in the CEP sector in combination with reduced barriers to trade make the need for innovative solutions in the delivery of parcels obvious.

Compared with land-based transport, drones make more direct routes possible by navigating in three-dimensional space. In total, however, they exhibit less favourable energy consumption and emissions because these are significantly higher per flight route than movement on the earth's surface. Modern, electric multicopter drones in the open category have a specific power requirement of over 100 W/kg. Compared with this, an e-Golf requires less [12] [13] than 10 W/kg. One of the strengths of drones is the (easier) access to difficult-to-reach destinations (e.g. large high-rise buildings, oil platforms, islands, mountainous regions, primeval forests/jungle regions, disaster zones, contaminated/irradiated areas) and the very precise (in terms of time and space) delivery to almost any location (e.g. to passenger cars, parcel boxes). Nevertheless, it will not be possible to fully leverage the potential commercial benefits inherent in drones because there are likely to be legal constraints on their usability and because of the costs of safety and security, which are addressed below.

The challenges include the hitherto very short ranges of drones in VLOS operations, the potential risk posed by collisions and crashes, especially in BVLOS operations, the limited load (max. 25 kg heavy drone including payload for the *open* category) and the high costs because of the absence of consolidation effects (maximum of one parcel per drone). In the future, too, drones will continue to be suitable primarily for very urgent deliveries or

[12] See https://www.drohnen.de/19418/dji-phantom-4-pro-v2-0-test/ , https://www.dji.com/de/phantom-4-pro-v2/info#specs (battery power for 30 min. flying time with 1.4 kg)
[13] Calculated from a consumption of approx. 14 kWh/100 km and a mass of approx. 1,800 kg on the basis of the mean speed of the NEDC of 34 km/h (7.8 W/kg).

deliveries to difficult-to-reach areas, where the costs are of less importance than in the case of standard deliveries.

The especially suitable application areas include time-critical deliveries (e.g. spare parts) that are imperative in order to maintain the production line (e.g. in the event of failure of critical machines) or to complete a product plus deliveries that are essential for survival such as organ transport, the movement of medicines or banked blood in competition with the present-day more cost-intensive use of helicopters.

Drones as a means of transport for persons

Numerous companies are currently working on "air taxis", i.e. drones in the *certified* category (see also Chapter 2.1.3). In some cases, modular designs are being developed where the cab of a ground-based vehicle is combined with the propulsion technology of an aircraft and can thus also fly. The technological developments in this sphere are dynamic but still at a very early test phase in the investigation of feasibilities. Appreciable use of air taxis is only likely if, in comparison with present-day manned helicopters, there is a significant reduction in costs and very good connectivity with the ground-based transport systems. This is addressed in more detail in Chapter 6.

In summary, it can be said that the diversity of applications is increasing but there are hardly any resilient figures on market trends, which are considered to be very dynamic. The challenge is thus to examine regulatory approaches to date in the light of risk limitation on the one hand and market growth on the other hand.

3 Regulatory challenges and prospects

3.1 Requirements for action in the context of regulation so far

By 2012 at the latest, the competent aviation authorities of the countries of Europe and thus also the EU, or more specifically the European Aviation Safety Agency (EASA) tasked by it, has recognized a urgent need for the regulation of construction rules and the certification of drones in the "common" airspace (i.e. airspace that has hitherto also been used by conventional aviation) because of the market trends described above and the fundamental need for regulation of all matters concerning the Single European Sky in accordance with Regulation (EU) 216/2008, which was repealed in June 2018. This Regulation called on EASA to draft a uniform European regulatory framework for construction rules and the certification (certification specifications – CS) of drones such as those that already exist for conventional aerial vehicles. The development company is responsible for furnishing proof that the design meets EASA's CSs. Table 2 contains a list of the CSs currently existing for similar aerial vehicles[14]:

Certification specification	Title/subject
CS-22	Sailplanes and Powered Sailplanes
CS-23	Normal, Utility, Aerobatic and Commuter Aeroplanes
CS-25	Large Aeroplanes
CS-27	Small Rotorcraft
CS-29	Large Rotorcraft

[14] See https://www.easa.europa.eu/document-library/certification-specifications

CS-34	Aircraft Engine Emissions and Fuel Venting
CS-36	Aircraft Noise
CS-APU	Auxiliary Power Units
CS-AWO	All Weather Operations
CS-E	Engines
CS-ETSO	European Technical Standard Orders
CS-P	Propellers
CS-VLA	Very Light Aeroplanes
CS-VLR	Very Light Rotorcraft

Table 2 Currently existing EASA Certification Specifications for drone-like aerial vehicles

The intention was to provide the companies developing drones with information as to the conditions under which new products could be operated and how they could be operated, thereby creating a sound planning basis for new business models. The specifications were also designed to address the issues of aviation safety and aviation security. In 2015, EASA published an Advanced Notice of Proposed Amendment (A-NPA 2015-10). Later that year, it added a Technical Opinion in which it called on the industry and the general public to submit comments and proposals for potential adaptations. After reviewing the feedback, EASA then published a 'Prototype' Commission Regulation on Unmanned Aircraft Operations in Europe with 33 proposals in 2016[15]. This version already focused on both industrially developed and self-developed drones, since both variants could ultimately be used for both commercial and non-commercial purposes. From this, it derived that both should also be subject to the same rules. Another significant feature of the recommended regulatory framework was an implicit

[15] See https://www.easa.europa.eu/sites/default/files/dfu/UAS%20Prototype%20Regulation%20final.pdf

questioning of the current Basic Regulation (216/2008) with its 150 kg mass threshold or the competence of EASA for certifying drones and thus with certification requirements uniform throughout Europe. EASA subsequently drafted, especially for "small drones", the technical opinions presented in Chapter 2 above on the introduction of three drone categories, supposedly corresponding to the potential risk in any given case, but also with regard to the intended operating area (for instance use over urban areas versus over water). To this end, the risk-based *open*, *specific* und *certified* categories were introduced across the entire weight range.

The legal foundations for the development and operation of drones must cover aspects of safety, security and privacy. In aviation, safety and security are, as it were, two sides of the same coin. On the one hand there is the safety of operations within the system of aviation, whereas on the other hand there is security, which refers to protection against external threats that may impact on the system of aviation.

As far as security is concerned new types of rules and regulations have to be developed. There are usually no persons on board who could suffer harm if the system were to be intentionally misused or unlawfully interfered with. The rules for safeguarding manned aviation against acts of unlawful interference are set out In ICAO Annex 17. They include, for instance, the security screening of passengers and their baggage, the screening of cargo and the background checking of staff. In the EASA *open* and *specific* categories, they are either not necessary (e.g. passenger screening) or only applicable to specific missions (e.g. cargo screening in commercial operations involving the delivery of parcels) or, in certain cases, only feasible with a great deal of effort and expense (e.g. background checks on pilots of hobby drones in the *open* category).

At present, light drones and their components, especially in the EASA *open* category, are accessible to anyone without appreciable barriers because they can be purchased. This is in stark contrast to manned aviation with its stringent checks. Thus, if drones of this category continue to be available openly and without a requirement for ID to be shown, the security focus may shift from safeguarding against acts of unlawful interference with light drones to preventing the deliberate misuse of light drones. For the EASA *open* category, security focuses on reducing the risk of deliberate misuse, whereas safety addresses this issue from the point of view of ensuring proper operations. For missions in the EASA *specific* category that entail an unacceptable safety or security risk, risk mitigation measures can be defined by the specific operations risk assessment (SORA) they require (see also Chapter 5.1).

In addition to safety and security, the issue of privacy must continue to be addressed. Privacy is relevant in the use of drones because they are frequently fitted with a camera or other sensor technology. This means that personal data can be recorded at places that were previously inaccessible to the public (e.g. private property). On top of this, the parties affected by the recording may not be aware if drones are flying at higher altitudes. This gives rise to the risk of interference with the privacy of third parties and failure to observe the protection of personal data if the data recorded are published or forwarded. It is true that the limits regarding an invasion or privacy are frequently subjective. However, privacy and data protection are deemed to be a basic right, not least following the recent entry into force of the General Data Protection Regulation (GDPR) in Europe and the related renewal of the national Federal Data Protection Act, and must therefore be taken into consideration in the new rules and regulations.

3.2 Challenges concerning the regulation of drones

The trends described above confront the present-day air transport systems with unique challenges in the following spheres:

- maintenance of aviation safety
    - These include firstly challenges resulting from the joint use of the controlled airspace by drones and conventional, commercially used aerial vehicles (using instrument flight rules, IFR) and from the possible risk posed to persons and objects on the ground by the operation of drones. It is to be examined whether, and if so to what extent, present-day air navigation service providers (such as DFS) are able to simply control drones alongside other air traffic. There is much that militates in favour of an enlarged, presumably centralized service.
    - Second, there are unresolved issues regarding the joint use of very low level (VLL) airspace by the open and specific categories with present-day visual flight rules

traffic, which is predominantly not commercially oriented and takes place on a decentralized and, as it were, unplanned basis.

- In light of the ultimately chosen monitoring philosophy for drones, it will then be necessary to consider whether the division into upper, lower and very low level (VLL) airspace on the one hand and controlled and uncontrolled airspace on the one hand should be maintained.
- maintenance of security as the prevention of sabotage or terrorist attacks;
- data security (including cyber security), e.g. in data transmission (robustness of the C2 or C3 data link between remote pilot and drone);
- ensuring privacy and data protection when drones are flown over densely populated, i.e. normally urban, areas;
- ensuring sufficient capacity as the maximum achievable safe air traffic throughput taking into account the various airspace classes (C – G) and types of aerial vehicle (multicopter, fixed wing, tilt-rotor hybrid);
- minimization of further, yet to be identified negative effects of drone operation (e.g. nuisance to humans and nature caused by flying vehicles that are audible);
- ensuring that this new transport system is integrated in a manner compatible with urban planning.

Figure 2 below shows – by way of example for the sphere of safety – trends in the frequency of occurrences involving conflicts between drones and conventional aerial vehicles. What is conspicuous is the high number of sightings at altitudes of more than 150 m (500 ft)[16], which is actually not permissible for the *open* category. Safeguarding today's high level in aviation safety is thus quite obviously a key requirement to be met by the activities to shape the operational framework for drones, and this requirement has not so far been met. An analysis by the European Central Repository[17] (ECR/ECCAIRS) revealed 2,141 drone-related occurrences for the period from 2010 to 2016. These occurrences are subdivided into accidents and incidents. A recent occurrence with huge consequences was the unlawful

[16] Cf. EASA [A-NPA (B), 2017], p. 55 ff.
[17] Evaluated from https://ec.europa.eu/jrc/en/scientific-tool/eccairs-european-central-repository-aviation-accident-and-incident-reports

approach of drones into the no-drone zone at the UK's second largest airport, Gatwick, in December 2018, which resulted in the cancellation of all commercial flight operations at the airport for 36 hours. Most of the occurrences registered were thus incidents in which a drone approaching a manned aircraft was reported. Figure 2 below shows not only the frequency of such incidents but also the distance between the aircraft and the drone at the time of discovery as a measure of the criticality of the situation.

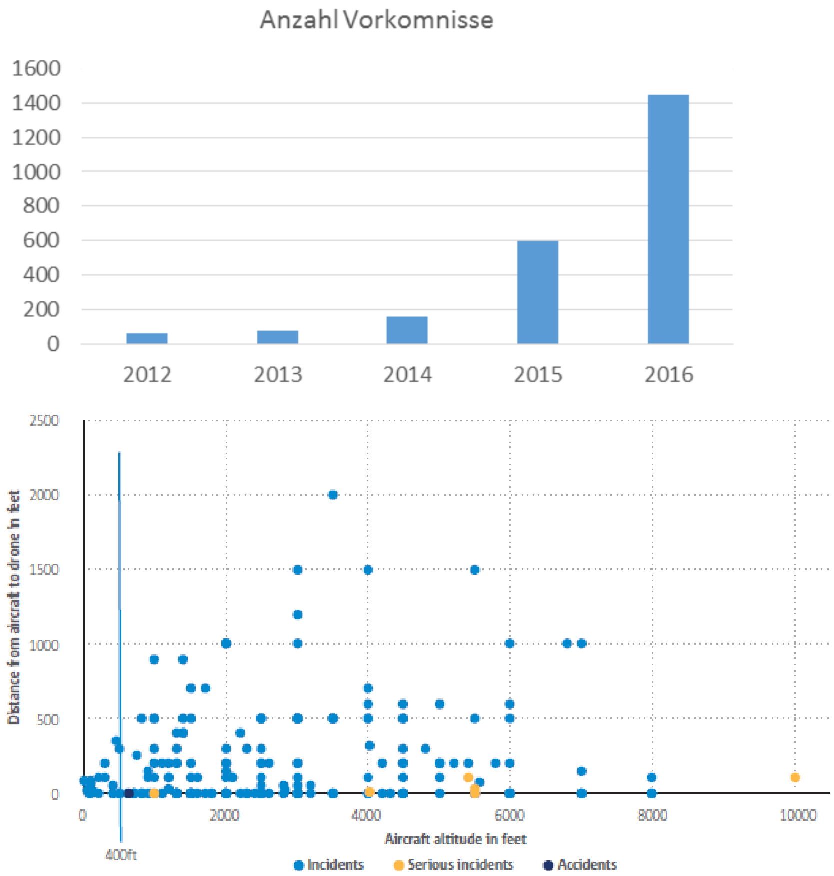

Figure 2 Reported drone incidents, 2012-2016 (top) with distance at time of discovery, 2010-2016 (bottom) [EASA]

A look at EASA's UAS Safety Risk Portfolio[18] for the reported occurrences involving drones in the period between 2012 and 2016 provides further insight: in addition to a large number of incidents, there were also 33 accidents with no fatalities. The greatest safety problems are of an operational nature, followed by those of a terrorist and human nature. The aforementioned UAS Safety Risk Portfolio identifies three components as sources of the

[18] See https://www.easa.europa.eu/sites/default/files/dfu/UAS%20Safety%20Analysis.pdf

technical safety issues: *guidance and control system* (flight controller), *propulsion* and *power supply*.

3.3 Consequences for the evolution of the regulatory framework

Because of the especially dynamic market trends, the *open* and *specific* categories were given priority for the development of the aforementioned regulatory framework. This process is now getting underway for the *certified* category. In 2017, EASA published NPA 2017-05 (B)[19] – revised on the basis of 3,700 (!) comments from around 250 institutions and interested users – as a regulatory framework for both of the first-mentioned drone categories. This large participation illustrates just how much importance is obviously attached to the regulation of drone operations by the users. In NPA 2017-05 (B), the suggestion is made that the EU Basic Regulation be updated to the effect that, in the future, all drones, regardless of their mass (MTOM), in other words also those below 150 kg, are to be considered in a harmonized manner throughout the EU. The Basic Regulation was then adopted by the European Parliament on 22 December 2017 and transposed by the EU in line with this suggestion. To be able to interpret the Basic Regulation in as purposeful a manner as possible, EASA prepared a further Technical Opinion (01/2018[20]), published on 6 February 2018, for the *open* und *specific* drone categories. In this opinion, EASA again makes it clear that the operation of drones continues to need a regulatory framework harmonized throughout Europe in order to guarantee a maximum level of aviation safety, privacy and data protection. Thus, taking into account developments at ICAO, the *Joint Authorities for Rulemaking on Unmanned Systems* (JARUS) and the US Federal Aviation Administration (FAA), EASA has already prepared a draft[21] of such a regulatory framework. The main recommendations contained in the draft are as follows:

- Risk mitigation for the operation of drones in the *open* category is to be achieved through a combination of operational restrictions, rules, requirements concerning the

[19] https://www.easa.europa.eu/sites/default/files/dfu/NPA%202017-05%20%28B%29.pdf
[20] https://www.easa.europa.eu/sites/default/files/dfu/Opinion%20No%2001-2018.pdf
[21] https://www.easa.europa.eu/sites/default/files/dfu/Draft%20AMC%20%20GM%20to%20draft%20Regulation%20.-.%20and%20to%20the%20draft%20Annex%20%28Part-U.pdf

qualifications of the remote pilot and technical requirements (CE label) to be met by the drone. This is to be done in such a way that operation is "safe" without prior authorization by the supervisory authority (Federal Aviation Office/German Air Navigation Services in Germany).

- Risk mitigation for the operation of drones in the *specific* category is to be achieved by making it mandatory for the operator to conduct a specific operations risk assessment (SORA) before putting the drone into service or before the start of the mission in the case of specific mission conditions. Alternatively, the operator can obtain a certificate that authorizes him to conduct clearly defined operations.
  For Member States, i.e. also for Germany, there remains a relevant scope for decision-making:
- for determining the use of airspace, including specifically its "non-use" by drones of all categories; and
- for implementing the construction and certification specifications for all drone categories, including specifically the *certified* category, which are now being fleshed out by EASA.

Thus, prohibited zones, restricted zones and – vice versa – special zones for drone operations are to be defined nationally (EU Basic Regulation, Article 12 *Airspace areas or special zones for UA operations*). As a first step, the Federal Ministry of Transport and Digital Infrastructure's 2017 Drone Regulations implemented this at a very general level.

Further requirements for action can be derived from the draft as follows:

- In areas in which drones are allowed to operate, it must be ensured that intervention (safe failure) is possible if the remote pilot loses control of the drone.
- For operations involving the transport of dangerous substances, which have so far not been allowed to be transported or only allowed to a limited extent, control/inspection procedures are to be established along the lines of ICAO's recommendations in Doc 9284 'Technical Instructions for the Safe Transport of Dangerous Goods by Air'.
- To enforce compulsory registration, a 10-digit numerical code for the clear identification of the drone keeper is recommended. Because of the very dynamic market, the requirements derived from this alone that are to be met by the digital database

management system are very demanding if this system is to have real-time capability and be able to withstand legal scrutiny.

- The competent authority (Federal Supervisory Authority for Air Navigation Services/Federal Aviation Office) is to establish permanent practices for risk-based oversight (RBO) that will ensure that the drone operators actually meet the requirements, in particular reporting, training of inspectors, conduct of audits.
- The Aeronautical Information Service (AIS), with the airspace adjustments implemented for the operation of drones, is to be adapted geometrically, geographically (3D) and procedurally (rules governing entry, exit, distance from objects, etc.).
- The publication information in the Aeronautical Information Publication Germany (AIP) has to be enlarged.
- Reports of accidents/incidents caused by drones are to be included in the litigation procedures of the Federal Aviation Office and the Federal Agency for Air Accident Investigation.

These fundamental requirements (SESAR also refers to the requirements in the last bullet points as *U-space services* – see below) make it clear that the requirements relating to drone operations in areas of dense ground infrastructure or densely populated areas, especially around safety-critical installations (such as airports), have to be very detailed if safe air traffic is to continue to be ensured. For instance, Munich Airport has already had security analyses conducted in order to determine the likelihood of drones unlawfully entering the airport grounds. It will then draw up risk mitigation measures that can be used to respond immediately and efficiently to such occurrences[22].

This requirement obviously has objectives that conflict with the needs for the flexible use of airspace, promoted by a dynamic market and the resultant increasing scarcity of airspace, which in the past has always seemed to be unlimited. The challenge is thus to give concrete shape to the rules governing the use of airspace by drones and to shape, in terms of space and content, construction and certification specifications (CS, GM (guidance material and

[22]Project by Flughafen München GmbH with DLR GfR mbH in 2017/2018.

AMC (acceptable means of compliance)) shoulder-by shoulder with EASA, which, in the opinion of the Board, should be attended to by the Federal Minister.

4 Planning certainty through specific drone airspace management

The lack of rules, or the existence of unclear rules, governing the use of airspace by drones entail some uncertainty for both manufacturers and users, which can result in a reluctance to innovate. Thus, regulation that is more foreseeable can help to enhance planning certainty for the stakeholders, thereby boosting innovations. With this in mind, several categories of airspace management for drones are addressed.

4.1 Drone categorization

The introduction of the three risk-based drone categories and the additional classes in the *open* category has obviously not yet created a sufficiently accurate degree of separation with regard to the specific operational framework for flight planning within an operational areas to be determined with maximum range and integration into the UAS traffic management system (UTM) for an individual drone design (construction and certification). This requires the establishment of a further framework, the reasons for which are given below.

So far, drones in the *open* and *specific* categories have been assessed and certified at national level, because EASA had no competency before the recast of the EU Basic Regulation. In the wider context of the application of SORA for *specific* drones, developers of these drones focused primarily on specific missions. Thus, for instance, some drones that are used for reconnaissance missions have significantly longer flying times but hardly any additional payload because of the heavier batteries they need to reach higher altitudes. This has resulted in significant heterogeneity of the drones available on the market.

The following examples of drones are designed to illustrate this situation, singling out in each case one representative of the various configurations. So far, there have been very few fixed wing drones in the category up to 25 kg. They are, however, an important element of many urban air mobility schemes, because they reach a higher flying speed and range than propeller-based designs, although this is at the expense of reduced controllability (manoeuvrability) in dense urban areas. This approach is thus also listed in the following Table 3.

	Flettner-type helicopter drone	Single rotor drone	Hexacopter drone	Airship drone	Fixed wing drone
Rotor diameter (RD)	2.8 m	2 m			
Length			< 1 m	10 m	
Width			< 1 m	3.34 m	
Height			< 0.5 m	3.77 m	
Wingspan					3.2 m
MTOM	85 kg	14 kg	5 kg	15 kg	25 kg
Horizontal flying speed	20 m/s	15 m/s	15 m/s	10 m/s	40 m/s
Rate of climb	2 m/s	5 m/s	2 m/s	3 m/s	5 m/s
Maximum flying time	50 min	20 min	18 min	120 min	30 min
Payload	30 kg	6 kg	1 kg		6 kg

Table 3 Examples of different types of drone

When considering these values, however, their high dependency on the useful load must not be overlooked. It is therefore advisable to further differentiate these values for later regulation. Notwithstanding this, these different operational parameters result in significantly divergent flight profiles, mission planning activities and potential risks which should be reflected in the UTM blueprint in the form of different flight performance categories (along the same lines as ICAO 's conventional aircraft performance categories as a function of the approach speed). Such rules could be possibly incorporated into updated Drone Regulations at national level, but above all into EASA rules, including the envisaged CS for drones in the *certified* category. For drones in the *open* and *specific* categories, the aforementioned Certification Specification for Light Unmanned Rotorcraft Systems (CS-LURS) published by the legally non-binding JARUS group could serve as a model for this.

Finally, with regard to the "risk-based" approach, the question has to be asked, especially for the EASA category *open*, class C1 (operation also permissible over people), whether, given the heterogeneity identified, there can be any risk equivalence at all within one category. The risk is (primarily) determined via the risk of a crashing drone hitting people on the ground. Quantitatively, this risk can be determined via the kinetic energy E 0.5 $m\,v^2$ of the drone at the moment of the hypothetical collision (m = mass of the drone, v = true airspeed of the drone). As already explained in section 4.3.1, EASA provides for an MTOM of 900 g and a maximum impacting kinetic energy of 80 J in this class. In simple terms, the acceptability of this limit can be determined by balancing the vertical forces which, starting from a hovering drone at a height h, result in a corresponding falling velocity at near-ground level. This balance places gravitational force in opposition to resistance. Maximum sped v_E is a result of the balance of these forces ($mg = \frac{1}{2}\,\rho \cdot v_E^2 \cdot A \cdot c_w$) Using this fundamental correlation, it is possible to calculate any speeds that are dependent on the collision height (e.g. 1.80 m above ground level as the average height of a human being). If these calculations are performed for typical present-day multicopters, the results for potential energy and v_E are those shown in the following Table 4. To obtain the average impacting kinetic energy in a collision with a human being (to EASA), this is multiplied by a factor of 0.465 (representation of a partially elastic collision):

ID	**Drones**	**Mass *m* [kg]**	**Diameter *d* [m]**	**Effective reference area *A* [m²]**	**v_E [m/s]**
A	Blade200QX	0.2	0.2	0.009	18.5

B	DJI Spark	0.3	0.17	0.007	27.0
C	DJI Mavic	0.7	0.33	0.026	21.5
D	YUNEEC H520	1.6	0.52	0.064	20.5
E	DJI Inspire	4.0	0.61	0.086	28.0

Table 4 Geometric and operational parameters of various drones in the *open/specific* categories[Bluhm, 2018]

The results are shown in the following Figure 3 taking the maximum permissible altitude into account. It will be seen that multicopters A, B and C are not above the threshold of 80 J even at an altitude of 120 m AGL. On the other hand, and as expected, multicopters D and E exhibit at the maximum permissible altitude a higher impacting kinetic energy than is allowed in operation category A1.

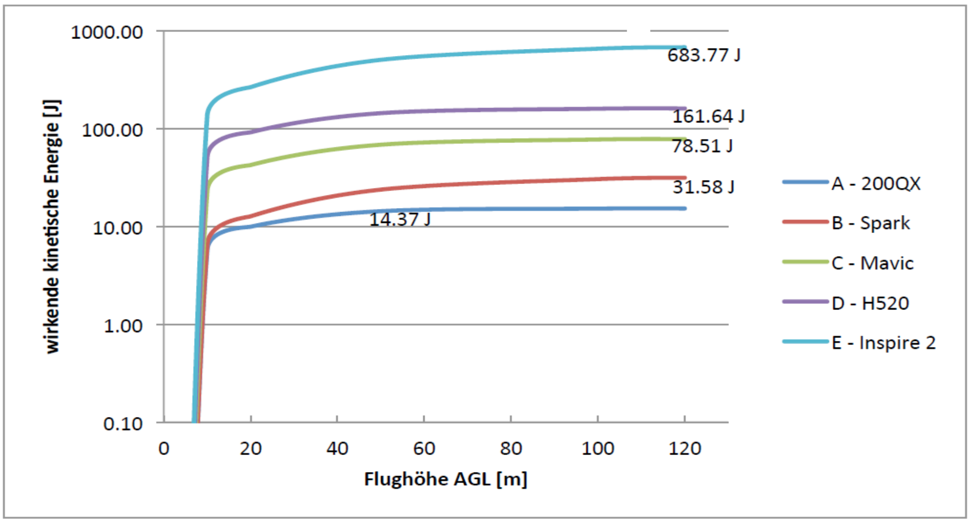

Figure 3 Impacting kinetic energy of the modelled multicopters as a function of altitude [Bluhm, 2018]

With these results, the assumption of a linear connection between the MTOM and the kinetic energy (to EASA) can continue to be examined. To this end, the values of the impacting kinetic energy from the preceding calculations are compared with the expected EASA values.

Drone ID	MTOM [kg]	E_{kin} calculated [J]	E_{kin} EASA [J]	Deviation [%]
A	0.2	14	17	+ 19

B	0.3	31	27	- 15
C	0.7	78	65	- 16
D	1.6	161	146	- 10
E	4.0	684	357	- 48

Table 5 Error analysis of the linearized energy model (to EASA)

Table 5 shows significant deviations in this regard. Moreover, since the threshold of 80 J is based on the Gurdjian experiment with blunt objects, other design-specific and, if appropriate, person-specific factors have to be taken into account. In particular, elements such as sharp edges on the fuselage, propellers, landing skids or payloads (e.g. camera system), which constitute a small contact area in the event of a collision, require further consideration. In summary, it can thus be said that the present risk-based approach cannot yet be classified as finally matured and that the provisions will have to be specified in greater detail in order to objectively reconcile risk and flexibility in construction and operation.

4.2 Taking the weather into account

The weather, especially wind, has a major impact on the controllability of a drone. Accordingly, impacts such as rain, snow or operation in a humid atmosphere (fog) have to be examined by the manufacturer of the drone and operational limitations have to be specified[23]. If, for instance, a reduction in manoeuvrability under certain conditions is identified, this must be observed when planning the flight route. The manufacturer is obliged to state the ambient conditions necessary for any given operation. This includes, among other things, the operating temperature range plus the humidity and wet weather capability. If a drone is unable, according to its operational properties, to be operated reliably under certain environmental conditions such as precipitation, critically low or high temperatures (a typical problem in battery technology), a detect and avoid (DAA) system on the drone must be able to detect this adverse condition and warn the remote pilot (RP) in a

[23] EASA; Technical Opinion, p.98, 2015

timely manner.[24] In conventional aviation, there exist numerous meteorological thresholds, including for the minimum horizontal visibility (flight visibility), ground visibility yes/no (obviously dependent on the height of operation), light (day/night definition), wind speeds and thus side wind components, precipitation (rain, snow, ice) and significant meteorological phenomena (SIGMET) such as icing zones, thunderstorms). From this depend operational procedures and infrastructure use (runway or helipad according to EASA, NOTAM and IR-OPS). Such thresholds are to be reviewed for the UAS Traffic Management System (UTM) and to be specified appropriately.

4.3 Technologies and institutions for UAS traffic management

As already described, drones are very heterogeneous in their technological capabilities. As a result, it is recommended that, for targeted UAS traffic management (UTM), operational areas be formulated in which any given drones are likely to be active and consequently have to be monitored and, if necessary, controlled.

4.3.1 Operating ranges

Restrictions specific to drones, such as maximum range, maximum flying time and the horizontal and vertical speed, must be observed when routing and determining their operational purpose. It remains the fact that a drone is controlled at all times by a remote pilot (RP). This pilot is situated with the visual line of sight (VLOS) of the drone. First, the parameters for a drone with a low useful load are assumed. In addition, it is assumed that at the destination there is a possibility to charge the drone with energy. This term means the complete restoration of the optimum condition of a drone. This includes the replenishing the energy resources, filling up the drone with all substances required for the flight and possible maintenance work. This implies that the full range of the aerial system stands for the flight from an origin to a destination. However, this does not refer to safety allowances for reaching alternative landing sites or to other reserves. Especially in areas close to city centres, which may be characterized by a large number of flight restrictions, instructive results may be created.

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[24] ICAO Manual on Remotely Piloted Aircraft Systems (RPAS) Doc 10019 AN/507

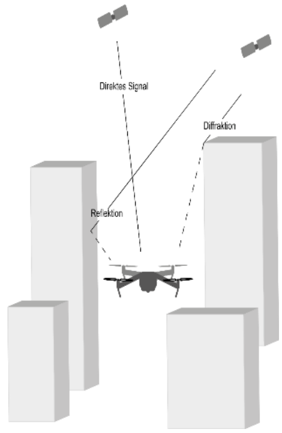
In conventional manned aviation, the limits of the area of operation have to be defined precisely. Within this mission area, it must be possible to demonstrate a safe flight in flawless normal state plus faulty conditions and emergency restoration capabilities. As described above, environmental conditions such as wind speed and light/visibility have to be taken into account when determining this area. In manned aviation, various masses are given for each aircraft type: dry operating mass, zero fuel mass, maximum landing and maximum take-off mass. The "flight envelope" is additionally taken into account with minimum and maximum speeds (failure to comply with which may result in low and high speed buffet (stall) and maximum altitude.

Thus, the operation of drones also requires a definition of areas of operation. Compliance with these operational limitations is imperative, especially in a complex urban operating area. The operation of a drone outside its area of operation should be considered a serious incident within the meaning of the Air Accident Investigation Act and should be described more precisely. On the other hand, normal operation should be defined as the drone being able to autonomously regulate its flight parameters with a sufficiently small statistical error provided that the external influences do not exceed pre-defined limits. This relates to the behaviour of the pitch and roll angle, the flight speed, the course, the course speed and the altitude. An exemplary challenge here is determining the minimum necessary accuracy, and, further on, statistically actual (higher) accuracy in drone routing.

4.3.2 Accuracy in routing

The accuracy achievable in routing is thus obviously dependent on numerous factors (sources of error) and/or the correct determination of the current environmental conditions and those that are likely to be encountered during the operation. These include the response distance due to the time lag in flight control: a control command consists of two sub-processes, namely command and control. First, status information is sent from the drone to the remote pilot (RP) (control). This contains information from the detect and avoid devices, the position and location of the drone and other system-relevant information. With the help of data provided, the RP is able to respond and send a control command to the drone (command). With an operating range of just under 30 km, this results in a time lag of

$2 \cdot 10^{-4}$ s, which may appear minute but nevertheless has to be taken into account when determining the flight expectation area. In addition there are signal processing times in the drone and the response and action time of the RP. These parameters may be relevant especially in the case of a disturbance. If, based on the automotive industry, a response and action time of around 1.5 seconds[25] is estimated and a travel speed of around 12.5 m/s is taken as a basis, this already produces a location error of the drone of around 20 m. In addition, the dimensions of a drone have to be taken into account when calculating permissible flight routes (with the standard assumption of a spherical drone: the sphere is transformed into a point and its radius is added to the obstacle areas and subtracted from the open spaces). Finally, for the dimensioning of safety distances, it is imperative that positioning accuracy be considered. As a rule, the direct positioning of drones to the nearest centimetre is based on an on-board multi-sensor system consisting of an RTK-capable (real-time kinetics) GNSS receiver and additional sensors. In this case, the absolute positioning accuracy depends greatly on the local GNSS measuring conditions. However, especially in urban areas, satellite shadowing, non-line of sight reception, signal diffraction or multipath effects may cause positioning errors that are relevant in this respect. Based on a 3D model of the buildings and vegetation in the operating area, a GNSS geometric chart should thus be prepared and integrated into the flight planning process. This will make it possible to already avoid degraded GNSS environments during the planning process. The challenge is thus to ensure continuously good geo-referencing even though it is likely that only small and lightweight sensors will be used on drones. Additional sensors (e.g. MEMS [micro-electro-mechanical systems] inertial sensors) can be used to reduce positioning errors. However, drift effects result in a deterioration of the positioning accuracy only a few seconds after the loss of GNSS[26]. Even if additional MEMS inertial sensors are used, a GNSS loss of 30 seconds can result in deviations of 10 to 100 m. This could lead to serious complications in urban



[25] Breuer, Bert; H. Bill, Karlheinz, Bremsenhandbuch: Grundlagen, Komponenten, Systeme, Fahrdynamik, p. 61 ff. Springer Verlag, 2017
[26] Mohamed, H. A.; Hansen, J. M.; Elhabiby, M. M.; El-Sheimy, N.; Sesay, A. B., Performance characteristic MEMS-based IMUs for UAVs navigation, pp. 337-343, International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2015

areas. Satellite shadowing is another determining effect that impacts on positioning accuracy.

In addition to GPS-based control, increasing numbers of stationary navigation marks or transmitters (4G/5G transmitter masts) have been installed in recent years, especially in conurbations, which can provide very accurate guidance to drones. Moreover, it is likely that, in the future, drones will be able to communicate with one another, in a similar manner to the present-day Traffic Collision Avoidance System (TCAS), which will greatly enhance air safety as the number of drones increases.

4.4 Need for action

The Board thus sees a need for action in the adaptation of the airspace structure in the VLL airspace, which, over conurbations, has so far been either uncontrolled airspace (type G) or – but usually only very partially – has fallen within a control zone (type D) of an airport near or in a city.

Furthermore, it is obvious that today's self-organized decentralized airspace management in this uncontrolled VLL airspace is not very compatible with the requirements of safe drone management. Here, approaches have to be developed that can resolve the conflict between the objectives of present-day visual flight rules (VFR) operations (often of a recreational nature) and those of drone traffic (likely to be of an increasingly commercial nature) that will then correspond more to planned, present-day instrument flight rules (IFR) operations. Here, the only suitable solution would appear to be a centralized approach to surveillance similar to present-day air traffic control of IFR operations, because this is the only way to appropriately take into account the likely automation of drone operations.

The consequence of this is that the Board believes that UTM surveillance and control should be technologically and procedurally *centralized*. Depending on the degree of automation, it should be based either at an ANSP such as DFS (low level of automation) or at companies such as the DLR GfR or similar, which specialize in the surveillance of highly automated remote objects (here, for instance, GALILEO satellite navigation systems with centralized surveillance). Appropriate extensions and/or adaptations to the certification requirements for ANSPs on the basis of Regulation (EU) 1035/2011 should be developed for this purpose.[27]

Subsequently, a decision would have to be taken on the funding of such a centralized institution. Clearly, the operators of drones will have to pay the costs. In the future, this will in turn raise the question as to the economic regulation of this centralized institution that monitors the type and level of drone charging with the aim of covering the costs of the efficient provision of services to the effect that this institution does not generate any excessive monopoly returns.

[27]Commission Implementing Regulation laying down common requirements for the provision of air navigation services and amending Regulations (EC) No 482/2008 and (EU) No 691/2010

5 Safety, safety acceptance and privacy rights

5.1 Specific operations risk assessment (SORA)

The need for safe drone flight operations has already been frequently addressed. The risk-based approach of all EASA drone categories specifically points in this direction, although there are still shortcomings, examples of which were identified in Chapter 3 (e.g. compliance with 80 J, failure to consider safety, security and privacy risks). SORA provides concrete guidance within the framework of the approval procedure, specifically for the *specific* category, but it does not provide the standards against which residual risks are to be assessed and ultimately tolerated. However, the target levels of safety (TLS), which are to be derived via the residual risks, are instrumental in defining the nature and scope of possible risk mitigation measures within SORA and in this way define the height of the market access barrier (red/green decision in the flow chart in Figure 4).

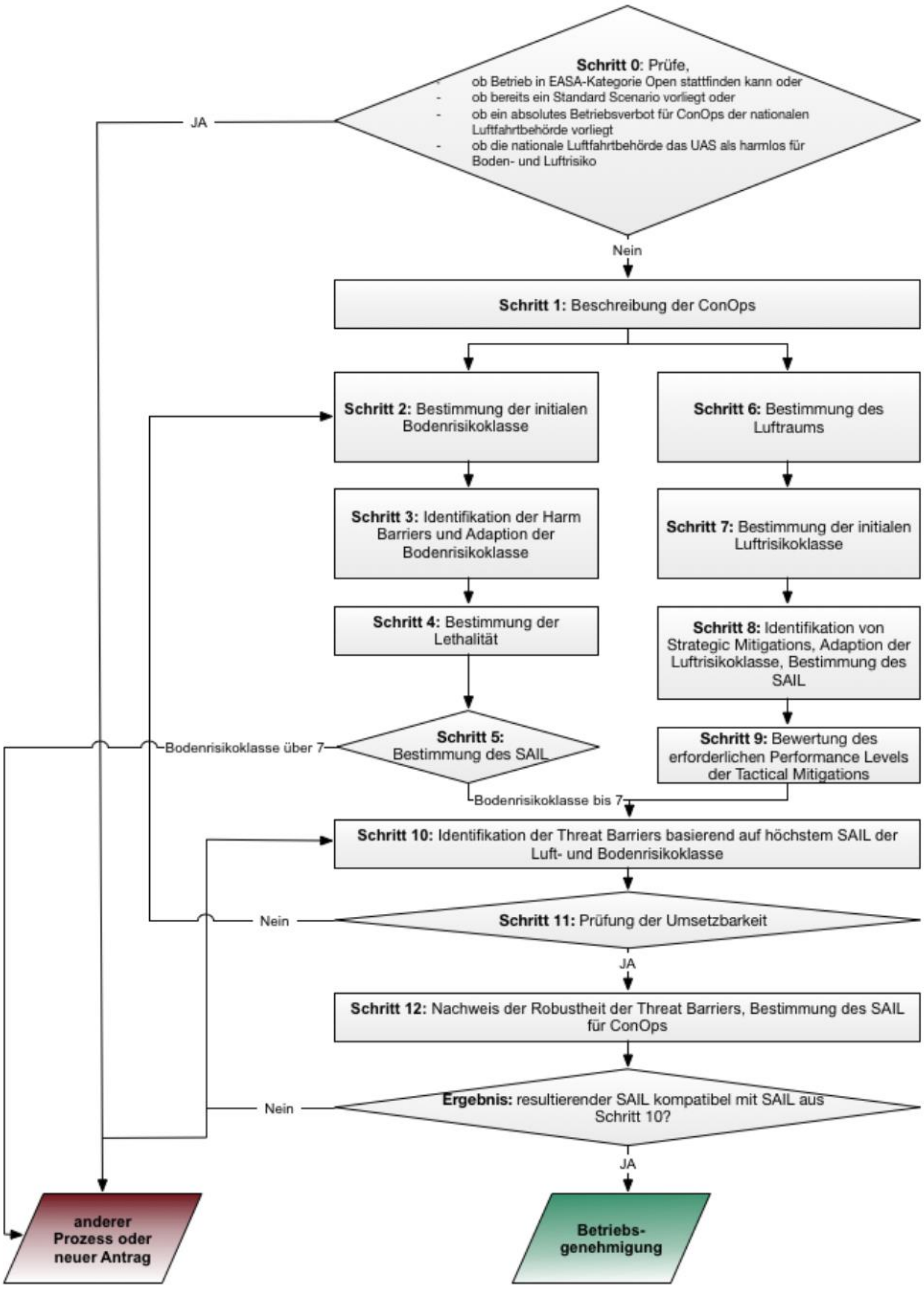


Figure 4 SORA process on the basis of JARUS [Bluhm, 2018]

The key risk, the uncontrolled crash of a drone onto people on the ground, is reflected in three ground risk classes in SORA[28]. Each class stands for a maximum permissible kinetic

[28]The bases for determining the ground risk class (step 2 of the SORA process) are the maximum diameter of the drone and the resultant kinetic energy plus the envisaged operational scenario (e.g. VLOS over a controlled area, located inside a sparsely populated environment).

energy between 700 J and just under 1,100 kJ (i.e. orders of magnitude higher than in the *open* category C1 with 80 J) coupled with one of eight operational scenarios that reflect essentially the dependence on the density of persons overflown and the distance from the drone (VLOS/BVLOS). By taking into account lethality factors (mortality rate) per ground risk class, which can be improved by means of risk mitigation measures (e.g. providing a parachute for the event of motor failure on the drone) and widening the concept of operations to up to 12 airspace classes[29], an air risk class is determined for each ground risk class, which takes account of a collision of the drone with manned aircraft (but not between drones). Air risk classes 1 to 4 are then converted into Specific Assurance and Integrity Levels (SAILs). To mitigate the risk, collision prevention systems can then be retrofitted. SORA is thus not a genuinely transparent, differentiated safety assessment, event though it is heading in the right direction. There is thus a need for evolution of SORA, including in the light of the introduction of possible new drone categories or even classes and evolving airspace classes.

5.2 Privacy and security

Privacy refers in particular to the risk of private individuals or enterprises being deliberately spied on by means of drones fitted with cameras, directional microphones or other sensor technology or wanting to introduce sensors into the private life or corporate sphere of third parties. The last-mentioned aspect overlaps with the sphere of security, i.e. in particular preventing the deliberate misuses of drones. Going further, there is also the possibility of people feeling annoyed by flying devices when on the street or in the countryside (e.g. impairment of their enjoyment of the great outdoors). The adverse external effects are subsumed here under the heading "privacy and security". Similarly, aspects of nature conservation (e.g. interference with animals) should be considered.

[29]The initial assessment of the air risk class is based on a determination of the airspace that the envisaged operation will use. This makes it possible to determine the risk of collision with manned aircraft. The classification into 12 airspace categories in accordance with SORA is thus significantly more granular than differentiation based on ICAO airspace categories A-G.

There has so far not been any specific procedure for taking account of privacy in SORA, even though its inclusion would appear to be basically possible as a further risk category. Taking privacy into account should have no impact on the logic for determining the ground and air risk class, as there is no direct connection with operational safety (of course it is assumed that persons are present in the first place). However, a link can be established with the operational scenarios (density of persons, airspace class).

Consideration should be given to the formulation of separate risk barriers within the framework of SORA with regard to security, too. A frequently mentioned security risk is the unauthorized takeover of the control of a drone. This can happen either by interference with the signals of a GNSS or the command and control (C2) link of the drone or by sensing spoofed signals. In particular, the unencrypted civil signals of the Global Positioning System (GPS) that are used in non-military drones are vulnerable to spoofing, as a result of which the drone gets out of control for as long as the flight controller uses these signals for flight attitude control. As a result, there is a need for methods/algorithms to be developed that reliably prevent interference with the GPS signal by spoofing (cyber security). The actual shape of tolerable residual risks regarding the invasion of privacy and security in an evolved SORA should be fleshed out and implemented.

Once a specific operational scenario has been fixed, it would be basically conceivable to internalize privacy costs for the operation of zones in densely populated areas and at a low altitude by requiring operators to obtain overflight rights. Various procedures for awarding such overflight rights are conceivable, ranging from highly regulated solutions based on current plan approval procedures to solutions close to the market. The former entail the risk of protracted approval processes, but on the other hand also the chance that flight routes will actually be implemented. Solutions close to the market create scope for innovations, but entail the risk of business models and thus specific flight routes being blocked by individual players and thus prevented. Another conceivable option for the latter case would be to widen the Land Register Code (GBO) by including three-dimensional land register entries under section 13 ff, which assign an upper airspace limit to the individual property/plot of land. Overflight rights for "sought-after" (because located between relevant origins and destinations) airspace could be reviewed and, if appropriate, approved by the person in possession of the land, who in the case of residential areas may also be the home owner, in order to internalize negative effects resulting from overflights with transaction costs that are as low as possible. However, such an approach also entails the risk of flight routes not materializing because individual players do not give their consent to an overflight. In the case of rented housing, there is the additional problem that the rights of tenants may be infringed by agreements concluded by the homeowner. What is definitely needed is regulation of the clearance of flight routes, times and altitudes, which would then have to be laid down in the Rules of the Air Regulations (LuftVO, current version from 2015) on the basis of the Regulations Governing the Operation of Unmanned Aircraft (as at 2017).

Another possibility would be to regulate the logic behind the use of airspace over densely populated areas, especially those with a high proportion of tenancies, at the local authority level in the regional development plans. They would codify airspace use rights for drones by various categories (e.g. types of drone and operational purposes, especially no-drone zones. In this case, too, the legal basis would have to be created by the Federal Government in accordance with the EU Regulation. Since many of the aforementioned negative external effects do not become virulent until there is a sizeable number of drones, rules can also aim to restrict access by drones, thereby limiting the number of drone flights over an area in a period of time (in turn, and if appropriate, establishment of capacity benchmarks, such as those established for airports, differentiated by type of drone, operational purpose, etc.). However, it would then be necessary to establish how such "drone slots" (by analogy with the term "existing airport slots") of which a shortage had been created by regulation were to be allocated to the various interested users. Appropriate ways could be price setting or auctions, for which the Federal Government would likewise have to create the legal framework.

Seen as a whole – and taking into account the requirement mentioned in section 4.4 for a centralized control institution and its funding – it is thus quite possible that the drone sector will be the first network sector in which the costs of the control level exceed those of the fixed infrastructure. Because the fixed infrastructure for drones, which will consist merely of landing and unloading sites, will probably involve relatively low costs (especially sunk costs) per device or flight (for instance compared with rail-based transport systems).[30] This fact has an impact on the current need for regulatory action. Because drones can manage without heavy infrastructure investment, the risk of serious inappropriate investment is relative low, especially in the initial stage of the market.[31] This means that it will also be easier to push drones out of certain operational zones by means of later regulatory interventions if the people in these zones perceive them as being a nuisance or a danger. This fundamental technological flexibility will permit evolutionary and flexible access to the regulation of drones. It would thus be premature to enact highly detailed rules governing the operation of drones at the present time. It will not be possible to conduct a meaningful political discussion on the social acceptance until the population have experienced drones themselves. This should be done by monitoring with subsequent evaluations. Thus, the areas of application and number of drones on the one hand and restrictive rules on the other hand will undoubtedly develop in parallel, hand in hand. Because the drone industry is keen to see a good uptake of its products and will therefore not oppose efforts to prevent excrescences and dangers.

5.3 Safety risks for people on the ground

In addition to the analysis of risks to persons and buildings directly actively involved in the flight operations (of drones), there are also genuine safety risks to third parties on the ground. Especially in the case of autonomous approaches to air transport such as drones, special importance attaches to this aspect, because the only human factor remaining is on the ground. These risks are summarized under the term "societal risks" or "external/third party risks". The current ground risk classes (safety) have, as already described, been defined in very rough manner and only quantitatively with regard to the assumed density of persons. Taking the Federal Immission Control Act as a starting point, which is already to be applied

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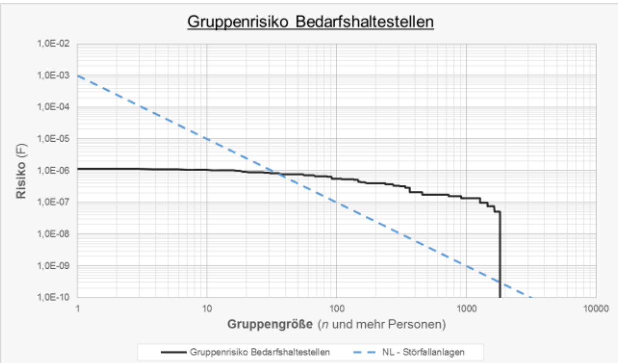
[30]The costs of both the fixed infrastructure and the control systems will depend heavily on the safety and security requirements and the technologies required to meet them.
[31]Nor is it likely in the long run that drones could significantly "cannibalize" demand for other means of transport so that there was the risk of seriously incorrect decisions leading to the dismantling of this infrastructure.

mutatis mutandis today in accordance with the ICAO recommendation (Annex 14) to commercial aviation in the vicinity of installations requiring protection, there are detailed risk models that make it possible to quantitatively identify area-related individual and group risks. It is recommended that such societal risk models also be used for UTM within the scope of safety assessments in order to transparently quantify individual and group risks for people on the ground resulting from drone accidents and to take them into account, for instance within the scope of urban planning. The individual risk provides information about how high the probability is of a person who is permanently in one location (plot of land, grid, see below) dying from the consequences of a flight accident. Group risk is defined as the probability of *n* and more persons (group) dying from the consequences of a flight accident (in this case a drone crash). The group risk, and thus the totality of all possible affected parties, refers to the entire study site, in this case in accordance with the operational scenario. If there is nobody in the area in question, the group risk there is by definition zero, The following Figure 5 shows typical evaluations for individual and group risk (including boundary value information as a dashed line) for manned aviation:



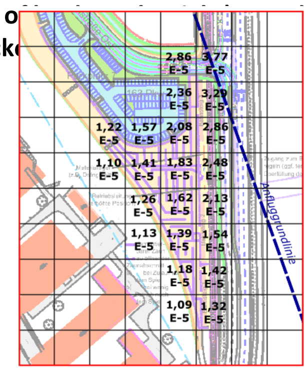


Figure 5 Group (accumulated, on the left) /individual risk (by plot o[illegible] **by flight operations in the area around request stops, City of Freiburg [Fricke**[illegible]

6 Opportunities for and risks posed by drones in passenger transport

From a transport planning perspective, drones that carry passengers or goods are a means of transport. As a traffic route, they use the airspace and require designated landing sites. The benefit of a means of transport is derived primarily from the time required for and the costs of carriage and the fundamental accessibility of the destination. The time required depends on the time required to travel to and from the landing sites, the flight speed and the transfer times at the landing sites. To obtain an initial idea of the journey time advantages offered by an air taxi, a model calculation is performed comparing the journey times and costs of a future air taxi (drone of the *certified* type) with those of the passenger car and public transport. This calculation is performed for passenger transport, but can also be applied to freight transport.

Figure 6 shows estimates of door-to-door journey times in passenger transport for the passenger car (good, fair and poor link quality), public transport (good link quality)[32] and air taxi. In the case of the air taxi, a flight speed of 100 km/h is assumed, which is certainly still optimistic at the present time. The transfer times for check-in and check-out at the two landing sites total 15 minutes (see Figure 7). The journey times of a change in location by air taxi are significantly influenced by the times required to travel to and from the landing sites. In the case of one landing site per 100 km^2, which corresponds roughly to the area of a city, the time required at both ends of the journey is around 15 minutes in each case. This requirement would drop to around 5 minutes if the density of the landing sites were one landing site per square kilometre, which corresponds to the typical density of rapid transit railway stations. In this case, travellers could walk to the landing site. The journey time differences between an air taxi and a passenger car depicted in Figure 7 show that air taxis offer an advantage in regional transport (journey length of 20 to 100 km) only if the density

[32] The journey times for the quality levels are derived from the Guidelines for Integrated Network Design (RIN 2008) published by the Road and Transport Research Association. The RIN contain “levels of service quality” (LSQs) for the direct travel speed of passenger cars and public transport, from which typical journey times for different quality levels can be derived.

is at least one landing site per 10 km^2. For short-distance changes in location, a density of one landing site per 1 km^2 is required.

In Figure 8, the journey time advantages of an air taxi are converted into maximum prices that a journey by air taxi may cost. The maximum price is estimated in a very simplified manner. The price advantage of the value of time assumptions is added to the price of a passenger car journey. In road transport, the value of time is around €5 to 10/h[33]. However, it may be much higher in the case of well-off individuals or business trips. For normal travellers with a value of time of €10/h, an air taxi would be attractive from a price of €0.5/km. For travellers with a value of time of €100/h[34] who use a private car, a fare of around €2.0/km would be competitive. Users of a taxi costing around €2.0/km would also pay a higher fare of around €4.0/km. By way of comparison: a helicopter flight carrying four passengers currently costs around €20/km per person[35]. Over longer distances, the kilometre prices would have to drop or the flight speed of the air taxi would have to increase, because the journey time advantage of an air taxi decreases at 100 km/h.

The estimates show that, in an initial phase, air taxis – like present-day helicopters – would be attractive primarily to travellers who are willing and able to pay higher fares. To this end, the landing sites would have to be in the vicinity of the destinations. In a city with a population of 500,000, and with an air taxi capacity of 5 seats, around 1,000 flights per day with 2,000 take-offs and landing could be expected. With 10 landing sites, this would be around 200 flight movements per landing site and day and up to 20 flight movements per hour. This is of the same order of magnitude as operations at a medium-sized aerodrome.

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[33] Axhausen, Ehreke, Glemser, Hess, Jödden, Nagel, Sauer Weis (2014). *Ermittlung von Bewertungsansätzen für Reisezeiten und Zuverlässigkeit auf der Basis eines Modells für modale Verlagerungen im nicht-gewerblichen und gewerblichen Personenverkehr für die Bundesverkehrswegeplanung.* ETH Zürich.
[34] The value of time at around €100/h can be illustrated using the example of a person travelling from an airport into a city who chooses to take a taxi (around €55, journey time 30 minutes) rather than using public transport around €5, journey time 60 minutes).
[35] See for instance. http://www.helikopterfliegen.de/fliegen/preise.html: Price of a helicopter flight with 4 passengers – €1,200/h.

If fares were lower, there would be a significant increase in demand for air taxis, which means that around 5,000 flights per day in a large city would appear realistic. A city dweller will then always see around 1 to 5 air taxis in the air at the same time.

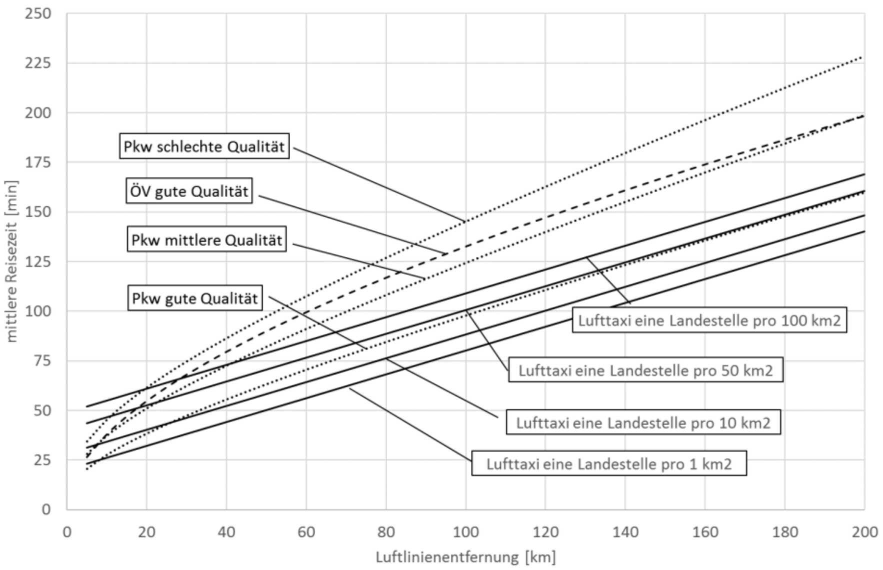

Figure 6 Comparison of door-to-door journey times in passenger transport for the passenger car (good, fair and poor link quality), public transport (good link quality) and air taxis (check-in und check-out-time15 minutes) with different densities of landing sites and flight speeds, assuming constant speed

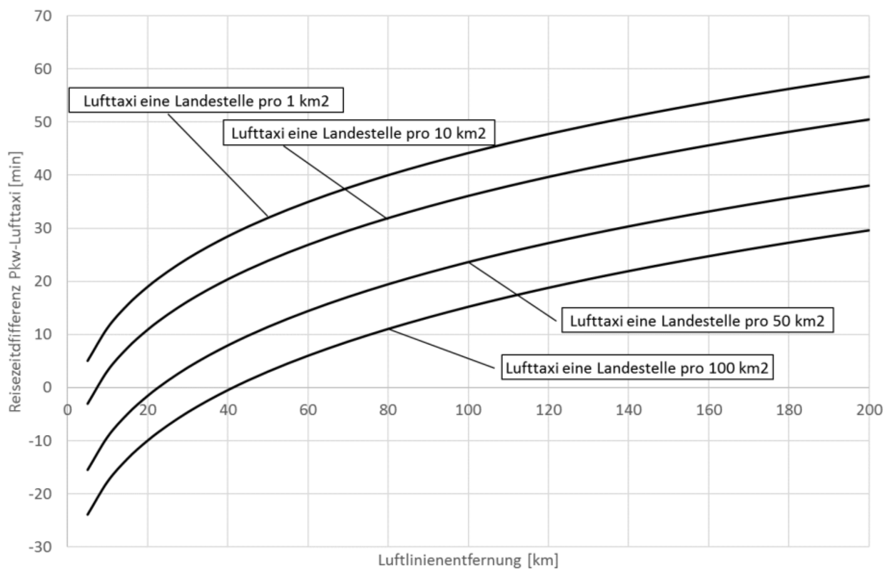

Figure 7 Journey time advantages for an air taxi at a flight speed of 100 km/h with check-in and check-out time of 15 minutes, compared with a passenger car with a fair service quality typical of urban conurbations in peak traffic hours.

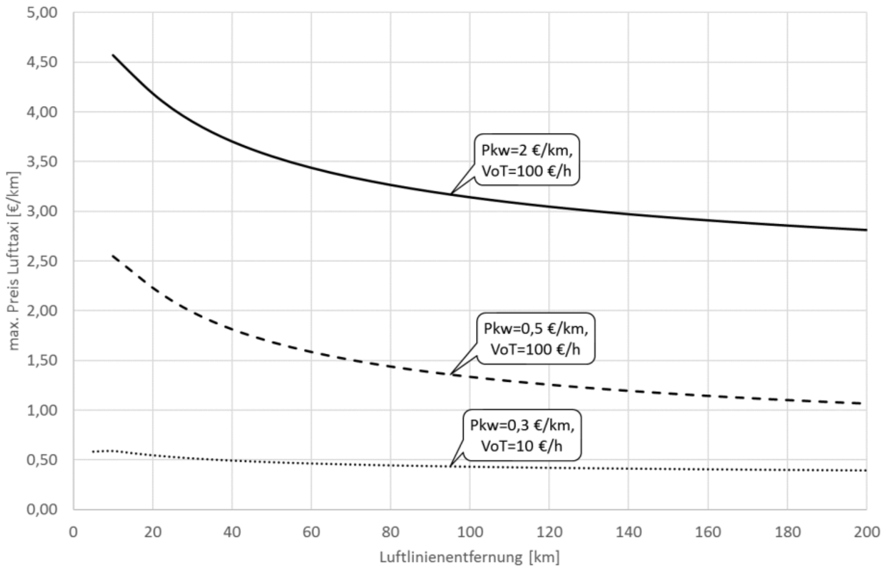

Figure 8 Estimate of maximum acceptable fares per kilometre for an air taxi at a flight speed of 100 km/h. Three cases are shown:

(1) Travellers using a taxi (€2.0/km) and with a very high value of time (€100/h).

(2) Travellers using an executive vehicle (€ 0.5/km) and with a very high value of time (€100/h).

(3) Travellers using a taxi (€ 0.3/km) and with a customary value of time (€ 10/h).

Other assumptions: Journey time difference for the case of fair passenger car quality, check-in and check-out time 15 minutes and one landing site per km^2.

7 Conclusions and recommendations

There is indisputably an enormous innovation portal in drones for the transport and logistics sector as well as the leisure sector. Within the years ahead, the business ideas in the aforementioned sectors will multiply with significant economic output. From this are derived socially comprehensive regulatory tasks on the issues of *safety* (and thus also *capacity*), security and privacy, because on the one hand the number of aerial vehicles will grow enormously and on the other hand numerous third parties may consider themselves disturbed (in some cases massively) or their rights to be infringed by these vehicles. Thus, the recast by the EU of the Basic Regulation on the certification of drones was a step in the right direction. All drones, irrespective of their size and other properties, are now subject to the competence of EASA and this follow a uniform European standard. Notwithstanding this, numerous details regarding the development and operation of drones have yet to be resolved. Resolving them in a targeted manner is essential in order to support the dynamically developing urban air mobility schemes in European cities with various synergies, including for technological development in the sphere of automated driving in land-based transport. The international activities in this sphere should thus be supported by the Federal Minister as follows:

1. What is necessary is targeted, clearly visible commitment by the Federal Ministry of Transport and Digital Infrastructure at the European Aviation Safety Agency (EASA) in the ongoing process of transposing the new EU Basic Regulation. This will make it possible, for "small drones"(*open* and *specific* categories), to provide the right impetus in the advancing fleshing-out of the technical and operational parameters (compliance with safety objectives such as maximum kinetic energy per operation category) and, for "large" drones (*certified* category), to intensively involve the certification process – still at the development stage – (development of a certification specification, CS for Drones) and the implementation of the UAS Traffic Management System (UTM). The way in which this is fleshed out will be instrumental in determining the market launch framework for air taxis, among other things.

2. For small drones in particular, the current classification basis is to be verified with regard to the risk posed to third parties, and current threshold values for maximum take-off mass (MTOM) and operating speed (to derive maximum kinetic energies) plus type of propulsion (electric only) are to be reviewed to determine whether they are appropriate (in both a conservative and optimistic scenario). As yet, there are no socially accepted safety target values for the risk-based certification process proclaimed by EASA (when is objectively safe also subjectively safe?) Sociological studies are required for this. With the adoption of the new EU Basic Regulation, updating the German Drone Regulations that have just entered into force may become obsolete. The advantages and disadvantages of national guidelines should be discussed and weighed against each other.
3. For the foreseeable future, drones will not operate autonomously but will be remotely piloted. This means that pilot competence has an important role to play. The competence requirements and testing system, including auditing (procedures for checking the skills of a pilot, aka refresher/recurrent checks) require clear and precise fleshing-out and verification vis-à-vis the objectives set in safety (flight procedures, operating processes), security (background check) and privacy (respecting provisions governing the protection of privacy and even nature conservation).
4. Drones are primarily small flying objects and thus difficult to locate. In the spheres of security, privacy and the protection of the public realm, this poses an enormous challenge, which has so far mainly been addressed with the help of geofencing of/for drones. Under EU law, the airspaces to be protected must be determined at national level, i.e. In Germany at federal level, and should be published via web-based platforms or apps. In this context, feedback for the certification of drones is an important pillar of the establishment of geofencing systems in order to ensure a reliable upload of the corresponding protected areas (prohibited and restricted areas) in the on-board navigation systems. To this end, it is necessary to create uniform standards, chart systems and databases so that manufacturers can implement the geofences in the drones' flight controllers.
5. To guarantee security and privacy in the operation of drones, the envisaged registration requirement for operators and drones with a take-off mass of currently 250 g or more is

a step in the right direction. To this end, however, it is necessary to implement the electronic identification system (e-ID) in an efficient and fraud-proof manner if it is to be effective in prosecuting cases involving the deliberate misuse of drones.

6. Special importance attaches to the regulation of overflight rights, because it creates planning certainty for the providers of the new business models while at the same time ensuring the protection of the privacy rights of third parties and limiting externalities. Here, the advantages and disadvantages of different options are to be carefully weighed against each other. Highly regulated procedures for the issuing of over-flight rights along the lines off the established plan approval procedures involve the risk of protracted approval processes. On the other hand, they also involve a chance that flight routes will actually be implemented. Solutions close to the market create scope for innovations, but entail the risk of business models and flight routes being blocked by individual players and thus prevented. What is definitely needed is regulation of the clearance of flight routes, times and altitudes, which would then have to be laid down in the Rules of the Air Regulations (LuftVO, current version from 2015).
7. The Specific Operations Risk Assessment (SORA) introduced by EASA is to be evolved by fleshing out the safety target values to be achieved. Major causes of risks are to be parameterized (weather, visibility, humidity, outside temperature, etc.). Here, it must not be forgotten that the present-day ATM system only contains sketchy target levels of safety, which moreover are already so “high” that proving compliance with them requires a lot of effort[36]. It is a question of being actively involved in standardizing ATM security calculations, thereby being able to reliably estimate the risks for users and developers of investing in new business models and drones. Target levels of safety influence what is procedurally feasible in the quality and capacity of a transport system. The safety assessment as such should also differentiate in the light of the planned area of operation, ranging from rural areas through suburban to conurbations/mega airports, with regard to traffic density and heterogeneity and the resultant impact both in the air (other, conventional aircraft) and on the ground in the form of risks posed to third

[36]One example is the permissibly rate of fatal accidents on the final approach of a precision instrument landing approach (1 to 10 million approaches) or that during taxiing on runways and taxiways at highly modern major airports (1 to 100 million operations).

parties (societal risks for local residents). For such external risks, too, it is absolutely essential that there be resilient target values and calculation standards.

8. SORA takes into account neither security nor privacy risks. It is recommended that these aspects be included through an enlarged list of risks, in order to base the potential approval of a specific business case on a holistic assessment pattern.
9. Monitoring of both the approval aspects (mission approval) and the operational implementation of drone monitoring should – along the lines of present-day control of instrument flight rules traffic (IFR) – be conceived and implemented via a central competence with a correspondingly high level of automation. This is the only way in which it will be possible to safely manage the high levels of traffic expected. Alongside the institutions established in Germany, there are also UTM service providers with sufficient experience in remote monitoring. Under the EU Regulation on the provision of air navigation services, the (German) applicants must exhibit European competitiveness. In addition, the centralized airspace management should be based on determined operating areas per drone category (altitude-range graph), which are to be reliably assured by the manufacturers. Compliance with these operational limitations fixed in this manner is imperative, especially in a complex urban operating area. The operation of a drone outside its operating area should be considered a serious incident and thus be reflected accordingly in the legal bases.
10. Especially in urban areas, satellite shadowing, non-line of sight reception, signal diffraction or multipath effects may cause positioning errors that are relevant in positioning. Based on a 3D model of the buildings and vegetation in the operating area, a GNSS geometric chart should thus be prepared and integrated into the flight planning process. This will make it possible to already avoid degraded GNSS environments during the planning process. The challenge is thus to ensure continuously good geo-referencing irrespective of the size of sensor that can be installed.
11. For efficient UAS traffic management (UTM), there is a need for action in the adaptation of the airspace structure in the typical operating area of drones, VLL airspace (< 150 above ground level), which, over conurbations, has so far been either uncontrolled airspace (ICAO type G) or – but usually only very partially – has fallen within a control zone (ICAO type D) of an airport near or in a city.

12. To make the construction and approval processes of drones profitable for businesses and more efficient in terms of time, the establishment of combined test/construction and approval centres, preferably under the responsibility of the Federal Aviation Office (LBA), is recommended. The "drone pole" concept developed in Switzerland, in which these various players can operate "under one roof", could serve as a model for this. This task, which is relevant in particular to the *specific* and *certified* categories, should be a federal responsibility in order to ensure that that it is fleshed out uniformly throughout Germany. These centres should have coordinated certification catalogues for as long as no certification specifications (CS) for drones are available.
13. The regional development planning by the federal states, in consultation with the lower-level planning levels, should adopt a far-sighted approach and consider the establishment of drone take-off/landing sites in order to facilitate business models in the sphere of urban mobility. Appropriately supporting technical planning standards should be developed by the Federal Minister within the scope of panel activities at EASA and ICAO and implemented in the near future (along the lines of EASA CS, ADR-DSN or ICAO Annex 14 on "Heliports").
14. It is recommended that the activities to update the parameters in air and ground transport be dovetailed in order to exhaust the potential for synergies between a higher level of automation in all modes of transport, which also includes the adaptable fleshing out of the 4G/5G networks, and ensure that the industry has a reliable framework for the development of technologies and business models. The Board believes that societal acceptance will follow the current trend in automated driving on the ground. In the next ten years, we will see highly and fully automated driving (SAE Levels 4 and 5), at least sporadically, so that the conditions in principle for the unpiloted flying of cargo using present-day large conventional aerial vehicles could also be met societally. It is absolutely essential that these medium to long-term aspects be taken into account today in the aforementioned CS and the further development of GM (guidance material) and AMC (acceptable means of compliance) to enable the developing companies to reliably estimate approval risks. Here, appropriate commitment in the work of international commissions is imperative.

15. Pilot projects in German towns and cities such as those of the EU UAM initiative should be conducted in the light of the aforementioned recommendations. This comprises the multimodal integration of drones into urban traffic, the creation of appropriate transport, communications and monitoring infrastructure (multimodal capture of objects by every airspace user), addressing overflight rights, etc. Even though the remotely piloted or fully automated transport of persons by air is only likely in the longer term, relevant approval and design features should, for the same reason, be intensively co-developed and supported nationally at EASA. This category of aircraft user will, alongside autonomy in driving, follow the trend of electric mobility in terms of energy as well, at least partially. Thus, the Board advocates the development of supplementary specific requirements for batteries, the type of propulsion plus the vertical and lateral operating areas of air taxis (airspace infrastructure). These requirements are to de differentiated depending on the proof of knowledge furnished by any given user, from the pilot with a reduced field of responsibility to the human monitor of a fully automated flight control system. This is designed to give the European, and specially also the German, developers of flight and business models the possibility of developing and testing their models here in Germany, so that they do not have to rely on outsourcing these developments to countries such as New Zealand or the United Arab Emirates, as can currently be observed. This should involve promoting all operational purposes, including the transport of passengers in the form of air taxis, in order to create maximum scope for innovation at this early stage of the development of drones.

Abbreviations

ACI	Airports Council International
AIP	Aeronautical Information Publication
AIS	Aeronautical Information Service
AMC	Acceptable Means of Compliance (part of the CS)
ANSP	Air Navigation Service Provider
ATM	Air Traffic Management
BAF	Federal Supervisory Authority for Air Navigation Services
BDSG	Federal Data Protection Act
BFU	Federal Bureau of Aircraft Accident Investigation
BImSchG	Federal Immission Control Act
BVLOS	Beyond Visual Line of Sight
CEP	Courier, Express and Parcel Services
CVFR	Controlled Visual Flight Rules
DAA	Detect and Avoid
DFS	German Air Navigation Services
DLR	German Aerospace Centre
Drones	Unmanned Aircraft Systems (UAS)

EASA	European Aviation Safety Agency
ELOS	Equivalent Level of Safety
FAA	Federal Aviation Administration
FlUUG	Air Accident Investigation Act
GBO	Land Register Code
GCS	Ground Control Station
GfR	German Society for Space Applications
GM	Guidance Material (Part of the CS, explanatory document on CS implementation)
GND	Integrated Authority File
GNSS	Global Navigation Satellite Systems (GPS, Galileo, GLONASS, …)
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
LBA	Federal Aviation Office
LEP	Federal Stat Regional Development Plan
LFZ	Aircraft
LOS	Line of sight
LUC/CUC	Light/Certified UA Operator Certificate
LuftVO	Rules of the Air Regulations

MEMS	Micro Electro Mechanical System
MTOM	Maximum Take-Off Mass
NOTAM	Notices to Airmen (reports published by DFS)
NPA	Notice of Proposed Amendment
OEM	Original Equipment Manufacturer
RBO	Risk-based oversight
RMZ	Radio Mandatory Zone
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Aircraft System
RPASP	Remotely Piloted Aircraft Systems Panel
RTK	Real-Time Kinematics
SAIL	Specific Assurance and Integrity Level
SARP	Standards and Recommended Practices
SESAR	Single European Sky ATM Research Programme
SIGMET	Significant Meteorological Phenomena
TCAS	Traffic Collision Avoidance System
TLS	Target Level of Safety
UAV	Unmanned Aerial Vehicle
UHF	Ultra High Frequency (300 MHz to 3 GHz)

UTM	UAS Traffic Management System
VDA	Association of the German Automobile Industry
VFR	Visual Flight Rules
VHF	Very High Frequency
VLL	Very Low Level Airspace, < 150 m

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