CEAS-GNC-2024-074

EuroGNC Bristol, UK June 11th-13th 2024

# Operational Permit: Application for a tilt-wing UAV according to the EU-2019-947 regulation in the specific category

**Fabian Baader** R&D Engineer, flyXdrive GmbH, 52074 Aachen, Germany. baader@flyxdrive.com, ORCID: 0000-0002-5653-4496

**Philipp Müller** Research Associate, Institute of Flight System Dynamics at RWTH Aachen University, 52062 Aachen, Germany. philipp.mueller@fsd.rwth-aachen.de

**Ann-Kristin Sturm** Research Associate, Institute of Flight System Dynamics at RWTH Aachen University, 52062 Aachen, Germany. sturm@fsd.rwth-aachen.de

**Johanna Holsten** CEO, flyXdrive GmbH, 52074 Aachen, Germany. holsten@flyxdrive.com

**Dieter Moormann** Professor, Institute of Flight System Dynamics at RWTH Aachen University, 52062 Aachen, Germany. moormann@fsd.rwth-aachen.de

*ABSTRACT*

**Long-range unmanned flights beyond the line of sight in shared airspace require a thorough risk assessment to ensure safe operations. For European countries, the specific category as defined in the EU-2019/947 regulation allows a wide range of mission and UAS characteristics on the basis of a risk analysis. Within this framework, the competent authority permitted operations in an area of approximately 18 000 km$^2$, and flights subsequently took place in July 2023, accumulating a total flight distance of more than 10 000 km.**

**Taking this large-scale low-risk flight campaign in Germany as an example, we provide guidance on the process to identify the respective Specific Assurance and Integrity Level and on additionally mitigating risks to account for the current capabilities of specific vehicles. On this basis, we present a method and tooling concept to establish multiple spacious operational volumes in an automated way that each allows for different flight constraints and enables ad-hoc flight scheduling. The default calculation basis for dimensioning the operational volume and risk buffers is adjusted to better represent the UAV characteristics and to maximize the authorized operations area. Based on the experience gained in the authorization request process and during flight operations, we propose future steps from the operator's point of view. These include refining category specifications, enhancing operational protocols, and implementing advanced safety measures.**

**Keywords:** EU 2019/947; SORA; Flight Permit; UAV; BVLOS; Flight Geography; Automatisation

## 1 Introduction

The complexity of commercial unmanned aerial vehicle (UAV) operations continually increased in recent years, along with the confidence of operators and the systems' capabilities. In Europe, this development was supported by the introduction of the supranational Implementing Regulation (EU)

2019/947 [1]. It practically allows any operation in the specific category (according to Article 12), given that a set of requirements determined by the operational risk are met. This flexibility comes with a downside, though: Operations in the specific category always require an elaborate and extensive analysis of the risks on the ground and in the air according to a standardized process called the Specific Operations Risk Assessment (SORA), which is described in EASA's Easy Access Rules for Unmanned Aircraft Systems (EAR)[2]. The SORA is a methodology that can be used in order to demonstrate compliance with Article 11 of the unmanned aerial system (UAS) Regulation and to evaluate the risks and acceptability of an operation of an UAV within the specific category and safe integration in the airspace.

We employed this methodology to obtain an operating permit from the competent authority[1] enabling long-range beyond visual line of sight (BVLOS) flights throughout the German federal state of Saxony, which allowed the fulfillment of an industrial contract in a multi-week flight campaign in July 2023. Within this campaign, the state of agricultural areas should be documented through aerial photography serving the purpose of satellite image verification. The fact that final target coordinates could only be provided within less than 48 h before the flights required additional tooling for clustering and flight planning. For details on the used operational toolchain, along with a more thorough description of mission objectives and peculiarities, please refer to [3].

While the standard SORA approach follows the path of defining an Operational Volume (OV) for a UAS before assessing the requirements to be fulfilled, we use a reverse approach that starts with a given feature set for a UAS and adjusts the OV according to the acceptable operational risk. The unprecedented size of the OV led to challenges in the process of both, volume definition and volume checking.

Section 2 details the applicable regulatory framework for BVLOS flights in the European Union (EU) and shortly lists additionally relevant aspects of German national law, while the specific application of these rules and processes is described in Sec. 3. It also provides information on the used UAS, which decisively shapes the character of the operations. The required tools and data sources for an automated Operational Volume definition process and the peculiarities of the resulting OV are presented in Sec. 4. Sections 5 and 6 discuss the current process for large-scale operations, identify opportunities for improvement in both processes and safety, and explore potential enhancements that may increase confidence in the results.

# 2 Regulatory Framework

The general process to obtain a flight permit within the specific category comprises the Specific Operations Risk Assessment process based on the EU-2019/947 regulation [1]. It requires detailed knowledge of the flight geography and information on the UAS with all its safety features. In addition to EU-wide regulations, further national law may apply depending on the country in which the operation takes place. This applies in particular to flying in certain geo-zones such as nature conservation areas, or close to industrial facilities or power generation plants.

The SORA process can be approached from two distinct perspectives. Within the framework of the Easy Access Rules for Unmanned Aircraft Systems [2], the process commences with the definition of the intended flight area, from which specific requirements for the flight system are derived eventually. This general approach is briefly explained in 2.1, but we refer the reader to the official document [2] for a detailed description of the procedure. Conversely, our approach starts with a detailed assessment of our flight system, wherein we carefully discern its safety attributes and flight capabilities. From this

[1] In Germany, this is the respective federate state's aviation authority based on the operator's location. Some states, as in this case North-Rhine Westphalia, forwarded their responsibility to the federal aviation office Luftfahrt-Bundesamt (LBA) which then acts as the competent authority.

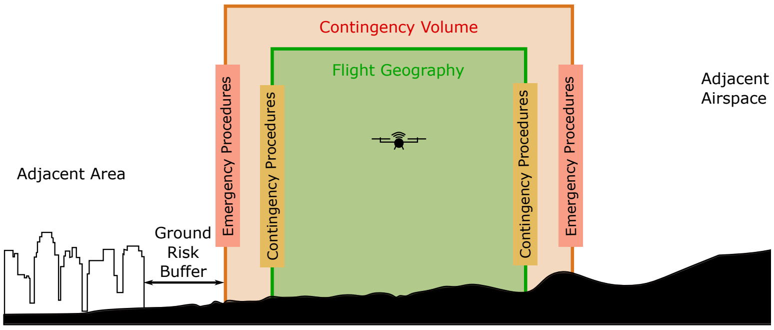



**Fig. 1 Operational Volume (according to [2])**

**Table 1 SAIL determination resulting from Ground Risk Class and Air Risk Class (according to [2])**

| **SAIL** | **Residual ARC** | | | |
|---|---|---|---|---|
| **Final GRC** | a | b | c | d |
| $\leq 2$ | I | II | IV | VI |
| 3 | II | II | IV | VI |
| 4 | III | III | IV | VI |
| 5 | IV | IV | IV | VI |
| 6 | V | V | V | VI |
| 7 | VI | VI | VI | VI |
| $> 7$ | Category C Operation | | | |

evaluation, we delineate a specific operational area wherein the utilization of our flight system is deemed safe and compliant with regulations.

## 2.1 Specific Operational Risk Assessment

Within the SORA, the risk posed by the operation to third parties on the ground and in the used airspace is estimated. The method culminates in a single operational risk classification called the Specific Assurance and Integrity Level (SAIL). It determines a required level of safety that must be reached by the flight system and the operations, which is defined by a list of operational safety objectives (OSOs). Each operation must take place in a pre-defined Operational Volume. This volume comprises the Flight Geography (FG), which covers the intended area of operations and the FG surrounding Contingency Volume (CV) providing a safety zone in case of malfunctions. An additional Ground Risk Buffer (GRB) can be added to the Operational Volume to reduce the operational ground risk. In case the UAS leaves the Flight Geography into the Contingency Volume, contingency measures must be triggered that are appropriate for an immediate return to the FG. When leaving the CV, the flight must be terminated. Contingency and termination procedures are pre-defined in the operations manual.

The SAIL results from the final Ground Risk Class (GRC) and the residual Air Risk Class (ARC), in accordance with table 1. In turn, GRC and ARC are determined in separate processes and based on different reference areas. The underlying philosophies and influencing factors for both are described separately below.

### *2.1.1 Ground Risk Analysis*

The ground risk class quantifies the potential risk and consequences of a person being hit by the UAS within the operational volume and an additional GRB. For this purpose, the affected ground area is characterized with respect to the density of uninvolved people per area as a first parameter. If the operation takes place BVLOS, the risk level for each population density level increases compared to a Visual Line of Sight (VLOS) operation. As a second parameter, the potential severity of injuries caused by a crashing UAS is mapped to the dimensions and typical kinetic energy of the used vehicle. The resulting initial GRC can be reduced in a further step by applying certain mitigations that add additional safety precautions or allow a more realistic description of the operation. These are grouped into three classes, namely strategic mitigations for ground risk (M1, e.g. by a further reduction of the number of people at risk), reduction of ground impact consequences (M2, e.g. using a parachute system), and the implementation of an Emergency Response Plan (ERP).

### 2.1.2 *Air Risk Analysis*

The Air Risk Class represents a qualitative categorization of collision risk for UASs operating within a designated airspace volume. If no initial ARC is pre-defined by a competent authority, it must be determined by estimating the frequency of encounters with manned aviation in the operational volume. Decisive factors in the SORA are, in particular, the flight altitude and airspace class in which the operation takes place, as well as the proximity to airports or heliports. A differentiation is also made between traffic above rural and urban areas. The operator can reduce the initial ARC by effectively arguing that the actual encounter rate is lower than assumed in the previous step.

The residual ARC determines if Tactical Mitigation Performance Requirements (TMPRs) must be implemented that demand for increasing levels of Detect And Avoid (DAA) capabilities in ARC-b/c/d. It is considered safe to fly without TMPR in ARC-a since the encounter rate is expected to be close to zero anyways.

The operational scenario results from the flight area in which the operation is supposed to take place. This total area consists of the in 2.1 mentioned areas (refer to figure 1).

## 2.2 Reversing the SORA process for short-notice operations

In large-scale short-notice[2] operations, key aspects of operational capabilities and UAS performance are often pre-determined by the available hardware and organizational structures. This was also the case with our flight campaign in Saxony, where an existing unmanned tilt-wing aircraft system was used as the best available solution within the available time frame and for the given objectives.

Therefore, in this case, typical for a commercial application, it makes sense to reverse the SORA method and to start with an analysis of the available safety and reliability features of the UAS based on the Easy Access Rules [2]. This analysis reveals the achievable level for each OSO that can be fulfilled by the UAS and its operators. In the next step, the results for the individual OSOs must be mapped to an achievable SAIL by identifying the highest level for which the required OSO levels can be met. To give an example for illustration, a typical result of this analysis could be that the operation accomplishes the requirements of a SAIL II rating, which is considered a low-risk operation. The matrix of table 1 then informs about the highest acceptable ground and air risk categories, which in this case are GRC 3 and ARC-b. Note that at this point the determined Air Risk Class must be cross-checked with the respective TMPR that is required for the ARC.

Assuming all TMPR are met and flight operations take place below FL600, ARC-b directly translates to an OV only covering uncontrolled airspace over rural areas and with a maximum altitude (including the CV) of less than 500 ft AGL.

To determine the ground area that is acceptable to be covered by the OV, the analysis must also include UAS characteristics, as the risk analysis method is decisively linked to the UAS dimensions and impact energy in case of a malfunction. Subsequently, the application of mitigations as described in section 2.1.1 allows for raising the risk scenario to higher risk areas. For example, by implementing measures to further reduce the risk to persons on the ground (mitigation M1 according to [2]) on a low level and by introducing an emergency response plan, BVLOS flights over sparsely populated areas become acceptable in SAIL II operations (instead of SAIL I without mitigations).

## 2.3 National Rules

In addition to the regulations in accordance with EU-2019/947, it is imperative to consider and adhere to additional national regulations. In Germany, the Air Traffic Regulation (LuftVO – *Luftverkehrsor-*

[2]Please note that if no operational permit for the intended complex operation is in place yet, the term *short-notice* typically refers to lead times of several months required for the preparatory work, rather than days or weeks.

*dnung*) provides a comprehensive framework both for manned and unmanned air traffic. Particularly important for UAS operations is § 21 h of LuftVO, which defines restrictions for UAS flights inside certain geographical zones. The regulation covers a multitude of different categories, including ones with a footprint that is typically small (such as authority buildings or hospitals), but also extensive areas such as nature reserves, industrial complexes, highways, and waterways. In principle, exceptions are permissible under certain conditions and can be authorized by the responsible operator of the geographical zone (e.g. nature conservation areas).

# 3 Mapping the Rules on Operations

The realization of the flight campaign was characterized by conflicting aspects: On the one hand, the target locations were only communicated less than 24 hours before the scheduled start of flight operations, meaning that the specific flight routes could not be planned in advance. On the other hand, the preparation of the documents required for BVLOS operations in the EU-2019/947 specific category and the subsequent approval process takes several months. Therefore, a flexible authorization was intended in advance to open up as many options as possible for the subsequent operation. The most straightforward approach is to generate a flight geography that covers an area that includes all potential target locations (i.e. the entire federal state of Saxony), plus parts of the neighboring federal states, to enable more efficient routes in border regions. At the same time, the flight geography must comply with SAIL II regulations. Below we outline the boundary conditions on which the dimensioning of the flight area is based

## 3.1 UAS Capabilities and Technical Specifications

A tilt-wing flight system was used in the flight campaign, as this UAV type combines the flexibility of vertical take-off and landing with the superior velocity and long-range efficiency of fixed-wing aircraft. The UAS called TW-Neo was developed by flyXdrive GmbH and uses an advanced custom flight computer from the Institute of Flight System Dynamics at RWTH Aachen University. The characteristic dimension (wing span) of the UAS is 1.85 m, and its maximum take-off weight of 8 kg allows for payloads of about 1 kg. The electric propulsion system consists of three motors in total, one of which is installed on the tiltable horizontal stabilizer and two motors installed on the left and right part of the tiltable wing, respectively. The in-flight transition from hover flight to fixed-wing flight (and reverse, illustrated in figure 2) is performed automatically at a certain velocity threshold. In fixed-wing flight mode, only the tail motor remains active, while the wing-mounted motors are disabled and their propeller blades fold backward to minimize noise emissions, reduce aerodynamic drag, and improve efficiency. The typical cruise speed is about $25\,\mathrm{m\,s^{-1}}$ and the maximum aerodynamic velocity is $33\,\mathrm{m\,s^{-1}}$, but the tilt-wing characteristics also allow arbitrary lower speeds and even hovering. Aerodynamic velocities below $15\,\mathrm{m\,s^{-1}}$ lead to a significant increase in energy consumption, and consequently result in less flight time and range.

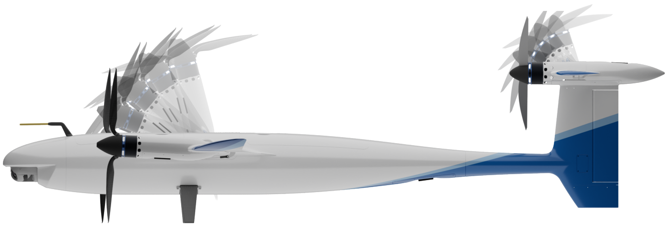


**Fig. 2 Side-View of the TW-Neo UAS, illustrating the tilt movement of the wing and horizontal stabilizer that enables vertical take-off and landing.**

The TW-Neo operates fully automatically on pre-defined routes and is supervised by a human remote pilot. Flight data is transmitted via two independent mobile cellular network modems and a satellite link as a fallback option. Hence, the remote pilot location is independent from the flight location, as long as a reliable internet connection is available. To detect other airspace users nearby, the TW-Neo carries ADS-B ("in") and FLARM ("in" and "out") and publishes its location to the Unmanned aircraft system traffic management (UTM) system of Droniq GmbH. The remote pilot additionally uses publicly available air traffic tracking websites for optimal coverage. Avoidance maneuvers are not carried out autonomously but must be triggered by the remote pilot.

## 3.2 Adapting Safety Margins According to UAS Characteristics and Mission Objectives

The dimensions of CV and GRB (as they were defined in figure 1) must represent the UAV-specific characteristics in order to ensure effective protection of ground areas or airspace outside of the OV. The German Federal Aviation Office (LBA) published guidelines [4] for common configurations (Multicopter and Fixed-Wing UAV) describing procedures that are acceptable to the authority and which are therefore highly recommended as a baseline.

Nevertheless, it makes sense to adapt the provided equations if some of the assumed constraints are not met by the affected UAV for two reasons: The distances required to carry out a Contingency Maneuver (CM) must be greater than assumed in the guidelines to ensure safe operation. In this case, an adaption is mandatory. In the second case, a contingency maneuver is achievable in a smaller volume than proposed by the guidelines. Thus it is in the operator's interest to adapt the method in order to achieve a larger flight geography.

Using the TW-Neo as an example, it makes sense to adjust three implicit assumptions that are used in the guideline's equations, namely the maximum roll angle ($\Phi_{\text{max}} = 30°$, which is 40° for the TW-Neo), the angle of maximum climb rate ($\gamma_{\text{opt}} = 45°$, which is actually 32°) and the Thrust to Weight Ratio (TWR) (guidelines assume TWR= 2, real TWR is approximately 1.5). These parameters are predefined by the flight controller and the propulsion system configuration, respectively.

These changes have implications on the calculation equations for lateral and vertical dimensions of the CV, which must be re-formulated to accept $\Phi_{\text{max}}$, $\gamma_{\text{opt}}$ and TWR as parameters. The lateral extent of the contingency maneuver $S_{\text{CM}}$ for multi-rotor UAV[3] is then calculated by

$$S_{\text{CM}} = \frac{3v_0^2}{\text{TWR} \cdot g \tan \Phi_{\text{max}}}\,, \tag{1}$$

where $v_0$ is the horizontal velocity relative to the ground when leaving the FG, $\Phi_{\text{max}}$ the maximum possible roll angle, and $g$ the gravitational constant. The equation for fixed-wing flight remains unchanged. The vertical CV dimensions $H_{\text{CV}}$ are affected in terms of the vertical reaction distance $H_{\text{RZ}}$ and the fixed-wing contingency maneuver[4] height $H_{\text{CM}}$, while the equation calculating $H_{\text{CM}}$ for multi-rotor configurations remains unchanged. With respect to the angle of optimal climb rate $\gamma_{\text{opt}}$, the vertical reaction distance calculates as

$$H_{\text{RZ}} = v_0 \cdot 1\,\text{s} \cdot \sin \gamma_{\text{opt}}\,. \tag{2}$$

[3]The described contingency maneuver assumes immediate braking until stopping when leaving the Flight Geography laterally. [4]

[4]This maneuver is achieved by exiting the Flight Geography upwards at an angle of optimal climb, then flying on a circular path of constant radius until level flight is achieved. [4]

The vertical contingency maneuver distance with respect to the angle of maximum climb rate is determined by

$$H_{\mathrm{CM}} = \frac{v_0^2(1 - \cos\gamma_{\mathrm{opt}})}{g}\,. \tag{3}$$

As the TW-Neo operates in both, multicopter and fixed-wing configurations, the relevant calculation method is always the one that results in the largest separations. Therefore, in this case, the larger separations associated with fixed-wing flight are decisive in OVs that allow both configurations.

Given the objective to make the largest possible number of destinations accessible to the UAS, we leverage the tilt-wing characteristics and define three overlapping OVs (Volumes A, B and C) with different boundary conditions. The purpose of Volume A is to provide space for efficient cross-country flight at high speed and with a permitted altitude range as large as possible. Therefore, it was designed with a velocity relative to the ground level of $25\,\mathrm{m\,s^{-1}}$ and a maximum FG altitude of 110 m. This results in a total lateral clearance between the FG border and populated areas of any kind $S_{\mathrm{lat}}$ of about 320 m. Moreover, Volumes B and C increase the area covered by operations through the reduction of the maximum flight altitude to 60 m and by limiting the ground speed at the cost of efficiency. In Volume B with $S_{\mathrm{lat}} \approx 160\,\mathrm{m}$, the lift configuration can be both, thrust-borne and wing-borne, and depends on the current wind speed and direction. It is therefore a compromise between area coverage and energy consumption. Instead, the velocity limit in Volume C with $S_{\mathrm{lat}} \approx 80\,\mathrm{m}$ only allows thrust-born flight in multicopter configuration and the volume layout clearly focuses on maximizing area coverage. Mission segments in Volume C therefore reduce the achievable total mission range substantially.

### 3.3 Unregulated Airspace Users

UAS flights close to airports, heliports, and airfields are regulated both in the Easy Access Rules [2] (effecting the resulting operational risk level) and in the German national LuftVO §21h (by defining mandatory safety clearances for geographical zones). However, other airspace users are not completely covered by these rules, such as paragliders, hang-gliders, and traffic at model aerodromes. As activities of those groups often accumulate in the lower uncontrolled airspace that is also predestined for low-risk UAS operation, it is nevertheless advisable to consider them in operational planning.

Typical take-off locations for paragliders and hang-gliders can often be provided by the respective national associations. The same is true for the locations of official model aerodromes. This information should then be taken into account in the route planning, yet it makes the process more difficult to automate. Although collision warning devices such as FLARM are widespread among airspace users in this category, it must be assumed that some remain invisible to UAS. Consequently, it makes sense for the UAS industry to raise awareness and proactively enter a dialogue with the affected groups.

## 4 Creating a 18000 km$^2$ Operational Volume

The extent of regulatory requirements described in the previous sections already suggests that for an economical industrial application, the generation of large flight areas requires a very high degree of automation. While we focus on the Operational Volume here, there are accompanying publications with respect to our flight campaign addressing the automated mission generation and scheduling[5], as well as trajectory generation[6]. To generate the respective FGs, CVs and GRBs, we relied heavily on custom software utilizing the libraries Geopandas [7] and Shapely [8] for Python. The open-source geographic information system QGIS [9] was used as the major tool to illustrate OVs, geographic zones, obstacles, and other geospatial data.

In the process, two versions of each OV were generated, one as the basis for the authorization process and one for internal use with respect to clustering and detailed route planning. Starting out from the pre-defined outer boundary of the flight geography, geospatial data of a) no-fly zones with respect to the aspired SAIL and b) national geozones to be considered are required to generate the OV for the authorization process. The result is an OV that is valid for the respective SAIL according to the SORA, that can be approved by the competent authority. Figure 3 illustrates the three resulting FGs and gives an impression of the differences in area coverage around no-fly zones.

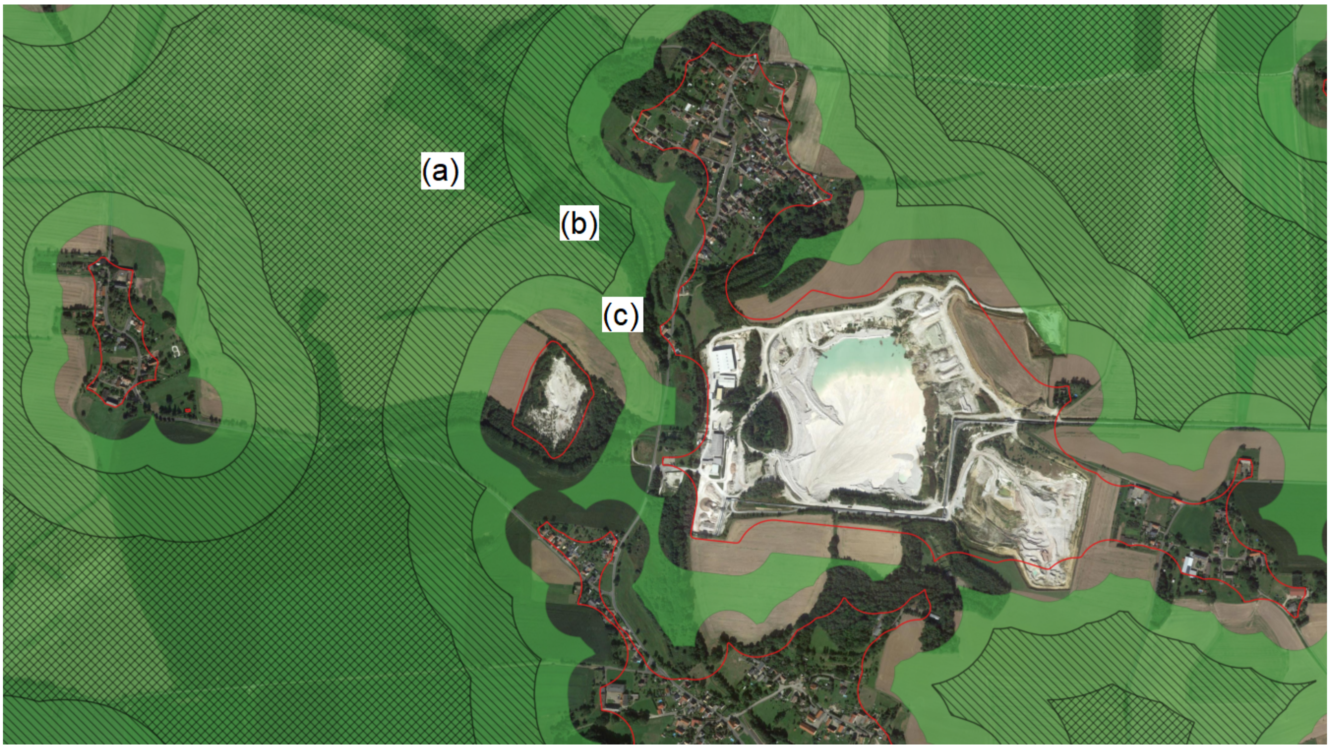
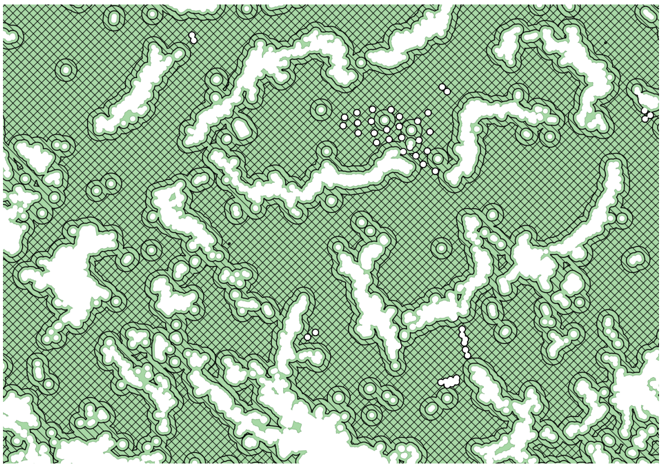


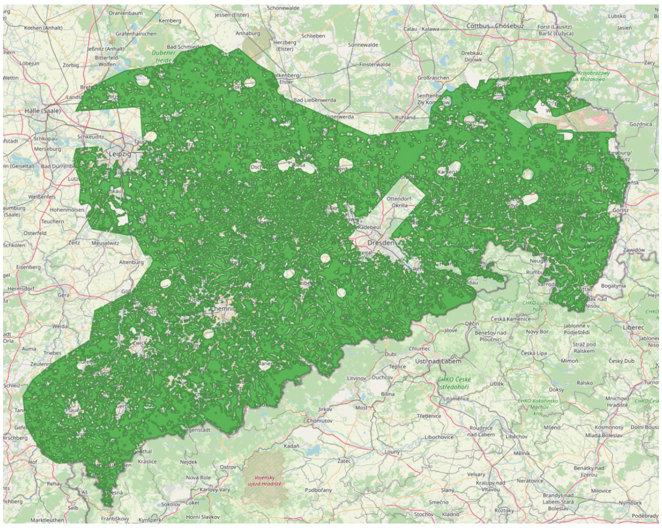

**Fig. 3 Excerpt of the resulting overlapping flight geographies calculated based on Sec. 3.2. The FG designed for efficient cross-country flight is marked with (a), the intermediate one that is characterized by increased energy consumption and reduced flight altitude is marked with (b), and the hover-only FG with (c). The red line represents a single Ground Risk Buffer that is common to all OVs. The respective CVs were omitted here to improve readability. (Background Satellite Images ©2023 CNES/Airbus, GeoBasis-DE/BKG, GeoContent, Maxar Technologies)**

Taking this OV as a basis, additional geographic zones, as well as data including obstacles and unregulated air traffic hot spots (as described in section 3.3), were taken into account to generate geodata suitable for effective clustering and flight route preparation. Obstacles include locations of wind turbines, radio and transmission towers, restricted airspace, and others, each adopted with an appropriate safety margin per category. In addition, nature conservation areas must be observed for which there are special regulations according to § 21 h LuftVO. Consequently, the operational area used for the actual flight planning is more restricted than the originally authorized OV because the originally operational area does not consider geozones like masts or wind turbines which we take into consideration and avoid during our flights. The outer boundary of the flight geography ultimately encompassed an area of more than 18 000 $km^2$.

Experiences show that efficient and scalable OV generation benefits both from a consequent focus on multi-threaded code during software development and from powerful computation hardware. Note that the former is also a prerequisite for efficiently utilizing the latter, though. Obtaining reliable data sources in machine-readable form remained a challenge throughout the preparations for the flight campaign. In Germany in particular, responsibilities are divided between the federal state and its 16 constituent states, so that it can be required to use separate sources for individual data categories when operating across



**(a) Detailled view on the final FGs using the same color and shading as in Fig. 3. As a reference, the diagonal of this figure equals about 12 km.**



**(b) Total extent of the three overlapping FGs (Background map is based on OpenStreetMap: `openstreetmap.org/copyright`).**

**Fig. 4 Final Flight Geography that was used in automatic flight planning algorithm.**

several federal states. Consequently, we relied on a multitude of different data sources from national and federal state ministries, but also from the OpenStreetMap project[10].

Figure 4a shows a detailed view of the final FGs as they were used as an input to the clustering algorithm (described in detail in [5]). In this processing step, they include obstacles and additional geographical zones that are excluded from the flights. An overview of the full area covered by the FGs is presented in Figure 4b.

# 5 Discussion

Large scale BVLOS operations covering the area of small countries are not yet daily routine in commercial drone operations under the current EU regulation. This became particularly apparent in several aspects during the preparation of our flight campaign in July 2023, some of which address problems specifically in Germany, but are also likely to be relevant for other EU countries:

1) The competent authority handling our operational authorization application was not yet prepared for requests of this scale. Thanks to an early contact to discuss preliminary information months before the actual operation and a communicative working atmosphere on both sides, it was possible to establish a targeted working method along the process.
2) The data sources required to define flight areas are neither officially defined nor uniformly available, although our operation only covered a single country. Currently, it is up to the operator to identify and verify appropriate data sources and due to the federal structure of Germany, these even change with each federal state for many data categories. Although the dipul map service of the German Federal Ministry for Digital and Transport provides a binding reference for geographical zones, the underlying data is (as of July 2023) too incomplete to be used for reliable flight planning. For example, to ensure that buildings are generally excluded from the OV, at some point, it was necessary to work with satellite imagery in order to identify objects that obviously really exist but are not included in official or community-maintained map sources. The recency of the recordings consequently also limits the confidence in the results.
3) The regulation on geographical zones (geo-zones) currently established in Germany as described in Section 2.3 is immature and hinders commercial operation over longer distances. Indeed

the dipul map tool allows to reliably identify overlaps between flight path and geozones, and it also provides machine-readable interfaces that work well for spatially narrowly limited flight operations defined by complex polygons. The process of applying for waivers from the responsible entity poses several problems, though. First, there is often no specific contact point provided for a geo-zone, or, even worse, only the geozone category is shown, but specific information on the geozone owner is missing (e.g., the name of a company in an industrial zone). This makes it difficult to contact the responsible party. Second, geo-zone owners are often inexperienced and unsure of what requirements must be met in order to be able to issue a fly-through permit and whether this can have legal consequences for them. This prolongs the time between contact and permission and makes it hard to perform missions on short notice. Third, we encountered several cases where the geo-zone operator neither knew about geographical zones at all nor that their area was classified as such. Naturally, in these cases, there are no approval processes in place and it takes time for the geo-zone operator to implement internal responsibilities. Additionally, engaging with nature reserves presents a particular challenge. The oversight of nature conservation areas falls under the jurisdiction of various lower nature conservation authorities. Due to the fact, that there are multiple entities involved, establishing contact with them is intricate and time-intensive.

4) The co-existence of low-altitude UAS traffic and non-aircraft recreational airspace users (hang- and paragliders, model aircraft) is currently based on the goodwill of the UAS operators. Although close coordination with affected groups is indisputably in the greatest interest of safe airspace use, the decentralized nature of organization and the small number of public information sources on common take-off fields and activity hot spots make it difficult to obtain the information in the first place. This multi-stakeholder coordination also revealed to be work-intensive.
5) Information campaigns aiming to raise awareness for the still uncommon BVLOS operations in lower airspace are partly positively received, but some airspace users also perceived them as a threat to their (actually unchallenged) right to use the airspace. Authorities could help to improve both, acceptance and safety with professional information campaigns specifically targeting non-commercial aviation.
6) In a hilly or mountainous environment with large elevation gradients, it is challenging to operate in the narrow altitude range above obstacles and below 500 ft AGL (to maintain ARC-b). At high flight speed, the required climb and sink rates become large, which can be problematic with respect to the flight controller and UAV performance. Efficiency also suffers from frequent changes in flight altitude. Preserving the original intention of this altitude limit (which is to maintain a very low encounter rate with manned aviation), one could think of a modified rule based on the smallest clearance to the ground in any direction instead of only considering the clearance vertically downward. This is a reasonable approach since manned aviation is also oriented to the distance to terrain and not necessarily only to the vertically measured flight altitude. They typically avoid flights close to the ground in steep terrain or deep and narrow valleys.

The aforementioned aspects are some of the aspects that currently hinder large-scale long-distance automated flight operations from becoming more common. They are mostly independent of an aspired SAIL, which limits the options to approach them purely by technology on the operator side. Instead, centralized information sources per country, but better EU-wide, providing reliable and binding map services and contact information could significantly reduce the workload required to prepare a large-scale flight campaign. At the same time, it would increase safety, as well as confidence both on the operator's side and the involved authorities' side.

# 6 Conclusion

We illustrated the regulatory framework in the EU that enables unmanned BVLOS operations with efficient automated tilt-wing UAS for agricultural surveys covering a whole German federal state. Acting from the point of view of a drone operator, a reverse approach was demonstrated on how to define an Operational Volume based on a SAIL that is compliable by the operator. The flyXdrive TW-Neo served as an example of how to adopt the safety margin dimension to better fit the characteristics of a specific UAS. In operations of this scale, a high level of automation not only in flight but also during preparation of the OV is key. Therefore, we emphasized the importance of a performant software toolchain. It was used to leverage the hovering capability of the used tilt-wing UAS by defining three overlapping OVs that take advantage of the different rule sets per operating mode. As the operation took place in Germany, the effects of the challenging national regulation for geographical zones were highlighted. After the flight operations were approved according to EU 2019/947, the handling of the geographical zones was responsible for a significant proportion of the total flight preparation workload. We experienced that the co-existence of traditional aviation and UAV in the lower airspace is widely accepted among airspace users, but friction can arise where the parties involved are poorly informed in advance. Yet, there is no obligation on the part of the UAV operator to provide information. Missing information or information that is difficult to obtain, along with uncertainties as to which data sources are recognized as a valid reference, make up for the majority of further reasons that currently hinder operators from efficient large-scale operations in terms of time, workload, and cost. We expect that a number of ambitious authorization applications will motivate the competent authorities to set up scaleable processes in the near- to medium-term.

We conclude that BVLOS operations covering an area equivalent to Slovenia and resulting in thousands of kilometers of distance flown within a few weeks are already possible in Europe. As an operator, we see room for evolution on the regulatory side, especially in clarifying and streamlining processes without reducing the established safety level. On our side, a parachute system will be considered for future operations to decrease the size of no-fly zones in the Flight Geography. However, it must be weighed up on a case-by-case basis whether this advantage outweighs the disadvantages caused by a reduced range and increased lateral margins.

# Acknowledgments

We would like to express our sincere appreciation to the Luftfahrt-Bundesamt (national civil aviation authority of Germany) for their targeted advice and rapid processing of our inquiries during the challenging authorization approval process.

# References

[1] Commission of the European Union. Commission implementing regulation (EU) 2019/947, 2019. https://data.europa.eu/eli/reg_impl/2019/947/oj.

[2] EASA. Easy Access Rules for Unmanned Aircraft Systems: - Revision from September 2022. 2022.

[3] Johanna Holsten, Dagmar Huth, Tobias Islam, Norbert Siepenkötter, and Dieter Moormann. Highly automated bvlos drone operations: A large scale flight campaign for agricultural observation in saxony, germany. In *CEAS Conference on Guidance, Navigation and Control, EuroGNC, 2024-06-11–2024-06-13*, Bristol, UK, June 2024.

[4] Luftfahrt-Bundesamt. Guidance for dimensioning and visualisation of flight geography, contingency volume and ground risk buffer, rev. 1.5. Technical report, Luftfahrt-Bundesamt, Feb. 2023. https://www.lba.de/SharedDocs/Downloads/DE/B/B5_UAS/Leitfaden_FG_CV_GRB_eng.html.

[5] Tobias Islam, Sebastian Seitz, and Dieter Moormann. Automated mission generation and dispatching for bvlos drone operations. In *CEAS Conference on Guidance, Navigation and Control, EuroGNC, 2024-06-11–2024-06-13*, Bristol, UK, June 2024.

[6] Max Hartmann, Nicolai Voget, Sebastian Seitz, and Dieter Moormann. Trajectory planning for efficient bvlos drone flights over agricultural points of interest. In *CEAS Conference on Guidance, Navigation and Control, EuroGNC, 2024-06-11–2024-06-13*, Bristol, UK, June 2024.

[7] Kelsey Jordahl, Joris Van den Bossche, Martin Fleischmann, James McBride, Jacob Wasserman, Matt Richards, Adrian Garcia Badaracco, Alan D. Snow, Jeff Tratner, Jeffrey Gerard, Brendan Ward, Matthew Perry, Carson Farmer, Geir Arne Hjelle, Mike Taves, Ewout ter Hoeven, Micah Cochran, rraymondgh, Sean Gillies, Giacomo Caria, Lucas Culbertson, Matt Bartos, Nick Eubank, Ray Bell, sangarshanan, John Flavin, Sergio Rey, maxalbert, Aleksey Bilogur, and Christopher Ren. geopandas/geopandas: v0.13.0, May 2023. DOI: 10.5281/zenodo.7902652, `https://doi.org/10.5281/zenodo.7902652`.

[8] Sean Gillies, Casper van der Wel, Joris Van den Bossche, Mike W. Taves, Joshua Arnott, Brendan C. Ward, et al. Shapely, Jan. 2023. DOI: 10.5281/zenodo.7583915, `https://doi.org/10.5281/zenodo.7583915`.

[9] Nyall Dawson, Jürgen Fischer, Matthias Kuhn, Alessandro Pasotti, mhugent, Denis Rouzaud, Tim Sutton, Alexander Bruy, Martin Dobias, Mathieu Pellerin, Víctor Olaya, Werner Macho, Paul Blottiere, Radim Blazek, Gary Sherman, Even Rouault, Nathan Woodrow, Harrissou Sant-anna, rldhont, signedav, Loïc Bartoletti, Larry Shaffer, Nedjima Belgacem, Salvatore Larosa, Julien Cabieces, Sandro Mani, Vincent Cloarec, Sandro Santilli, Paolo Cavallini, and Stefanos Natsis. qgis/qgis: 3.28.6, Apr. 2023. DOI: 10.5281/zenodo.7875679, `https://doi.org/10.5281/zenodo.7875679`.

[10] OpenStreetMap contributors. `https://www.openstreetmap.org`, May 2023.