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Geospatial technologies for an automated holistic risk assessment of UAS operations

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Abstract. The rising number of UAS operations in the European airspace poses a safety issue. The key problem is to ensure safe drone traffic management and their integration into the existing air traffic environment. Thus, risk assessment becomes an integral part of every UAS operation and its automation is of great importance when dealing with growing numbers of flights. There exist many attempts to support such risk assessment, but an optimal solution is yet to be found. This paper presents a prototype of a web application, which automates strategic risk assessment of open and specific UAS operations in Austria with the use of open government geodata. Risk assessment results are visualized on a map, showing spatial distribution of classified risks in the operational area. This prototype is the first attempt to combine the functions of a "drone map" representing relevant geodata and a questionnaire usually used to support specific operation risk assessment. There is a potential to turn it into a tool which is used to create a comprehensive pre-flight safety portfolio or to support the automatic risk assessment performed by a UTM before a UAS operation is checked in. Simplifying the creation of safety portfolios and automating UAS operation risk assessment are important factors in promoting a wider and safer use of UAS.

Keywords. UAS, risk assessment, UTM, SORA, U-Space

1 Introduction and problem statement

Unmanned Aerial Systems (UAS), also known as drones, have a wide range of applications: hobby flights, research activities, agriculture, law enforcement, search, rescue and disaster relief, infrastructure inspections, photography and many others (Hassanalian and Abdelkefi, 2017). By 2035, the European Commission expects about 20,000 UAS flights over one city per hour (Ky, 2019). As the number of UAS operations continues to grow, the importance of minimizing associated risks increases. In January 2019, Joint Authorities for Rulemaking for Unmanned Systems (JARUS) have published the second version of guidelines for Specific Operations Risk Assessment – SORA (JARUS, 2019). Later in 2019, a new EU legislation was adopted which formalized the categorization of UAS operations into open, specific and certified based on the risk level (European Commission, 2019). Though no formal decision has been made to adopt SORA as the only suitable risk assessment methodology on the EU level, in many Member States SORA has de facto become the state-of-the-art risk assessment approach for specific UAS operations (Denney et al., 2018), being used in various application domains (Capitan et al., 2019; Cain et al., 2021; Martinez et al., 2021; Janik et al., 2021).

Risk assessment is a key part of a UAS operation life cycle (Appendix A). SAEARP 4754A / ED-79A defines risk as "the combination of the frequency (probability) of an occurrence and its associated level of severity" (Landi and

Nicholson, 2011), whereas the consequence of an occurrence is a harm of some type (JARUS, 2019), including injuries to involved or uninvolved parties on the ground or in the air (e.g. due to collisions with manned aircraft), damage to infrastructure or property, damage to the environment, or to the unmanned aircraft itself. UAS operation risk assessment includes the identification of likely risks in the operational area and the estimation of their severity. It follows the initial planning and may lead to a necessity of plan correction if identified risks are too high. It is crucial for getting an operation approval from a responsible Aviation Authority (AA). Risk assessment represents an integral part of a decision making process, which takes place on the side of an Unmanned Traffic Management System (UTM) when a UAS operation is checked in for UTM support.

Each UAS operation has a key spatial component – a 3D trajectory of the flight. Thus, spatial information plays an important role in UAS operation risk assessment. Such information includes locations of controlled areas and limits of airspaces of different classes, presence and characteristics of obstacles, the classification of ground areas into urban and rural, etc.

In order to assess risks correctly, geodata used to derive the necessary spatial information must have sufficient resolution, be accurate, comprehensive and up-to-date. Further, the derived spatial information must be suitable and sufficient for risk assessment according to the selected methodology, it must be understandable and accessible.

In the recent years, various government institutions and commercial organizations of the EU Member States have developed the so called "drone maps" – map-based representations of spatial information relevant for UAS operation risk assessment. Several examples of such maps are given in Tab. 1. These maps help UAS pilots to analyze which risk factors are present in the intended operational area.

Table 1. Examples of "drone maps".

#	Drone map	Country	Type*
1	https://www.flynex.io/map2fly/	DE	W, S
2	https://www.dronespace.at/	AT	W, S
3	swisstopo-App	CH	S
4	https://dronview.rlp.cz/	CZ	W
5	https://aeret.kaartviewer.nl/index.php?@dpf_basic	NL	W
6	https://airspace.pansa.pl/map	PL	W
7	https://daim.lfv.se/echarts/dronechart/	SE	W

* W = web application; S – smartphone app

At the same time, tools for automation of SORA have been developed (https://www.airhub.app/online-sora-tool, https://www.online-sora.com/). These SORA tools, as the one proposed by Terkildsen and Jensen (2019), represent step-by-step questionnaires (Fig. 1).

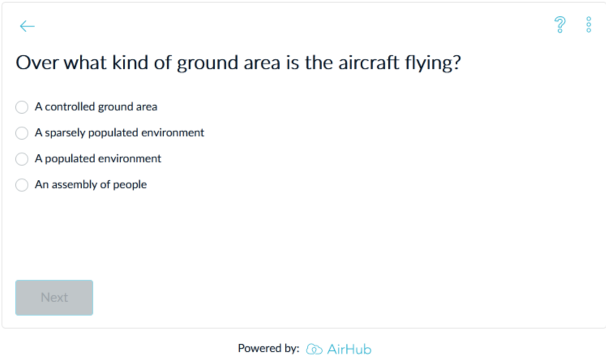


Figure 1. An example of a question in an online SORA tool at https://sora.airhub.app/

If a required input depends on the spatial component of the flight plan, UAS pilots have to consult external sources (e.g. "drone maps"). For example, it is not always obvious to the drone pilot whether the intended operational area is populated or sparsely populated. Currently available SORA tools do not help to answer this question.

Thus there exists a gap between the needs of UAS pilots and the available tools for risk assessment of drone operations. Furthermore, an automated geodata-based UAS operations risk assessment is essential for dealing with a large number of simultaneous UAS operations within a framework of UTM system. Therefore, in order to support ambitious plans for the growth of the UAS market, better tools for automation of UAS operation risk assessment must be developed.

2 Proposed approach

Addressing the need to create a spatially aware UAS operation risk assessment tool, we developed Drone Risk Austria, a prototype of a responsive web application which facilitates risk assessment for open and specific UAS operations in Austria, freely available under (http://www.droneriskaustria.at:8080/). Spatial information integrated into Drone Risk Austria is based on open government geodata.

2.1 Use cases

Drone Risk Austria supports four use cases of UAS operation risk assessment. The first use case is operation categorization. It is useful in situations when a drone pilot wants to find out to which category the intended operation belongs. The categorization is done in a form of a questionnaire. To answer the questions of this survey, no spatial information is needed.

The second use case is a visual analysis of the intended area of operation using a map-based representation of spatial information relevant for UAS operation risk assessment. It is similar to other "drone maps".

The third use case is an open operation feasibility check. While SORA applicable to specific UAS operations considers the associated risks and requires to develop suitable mitigation measures, the result of an open operation feasibility check is the map of operational area divided into subareas: red, where this open UAS operation is forbidden; green, where no limitations have been identified; and yellow, where available information indicates some uncertainty.

The final use case is the automation of the initial SORA. This module of Drone Risk Austria performs an automatic geodata-based calculation of the intrinsic Ground Risk in the operational area and the initial Air Risk in the operational volume. Then, it allows to select ground risk mitigation measures and to calculate the initial Specific Assurance and Integrity Levels (SAIL) value. It does not support the generation of a comprehensive safety portfolio yet but rather provides users with a map-based representation of highly granular risk distribution in the operational area.

2.2 Weather Risk

In addition to the commonly considered Ground Risk and Air Risk, Drone Risk Austria facilitates the assessment of the Weather Risk at the time of the intended UAS operation. A multicomponent weather forecast prepared by an international meteorological service UBIMET is available for any location of the 9500 km^2 big test area in Austria. An hourly weather forecast can be retrieved when risk assessment is performed on the same day as the intended UAS operation. Less detailed weather forecast is available for risk assessment up to six days in advance. An aggregated Weather Risk value is calculated for the whole operational area: green (no risk), yellow (medium risk) or red (high risk). The default limits of individual weather parameters used for Weather Risk calculation can be manually adjusted by users in correspondence with the operational limitations of their UAS.

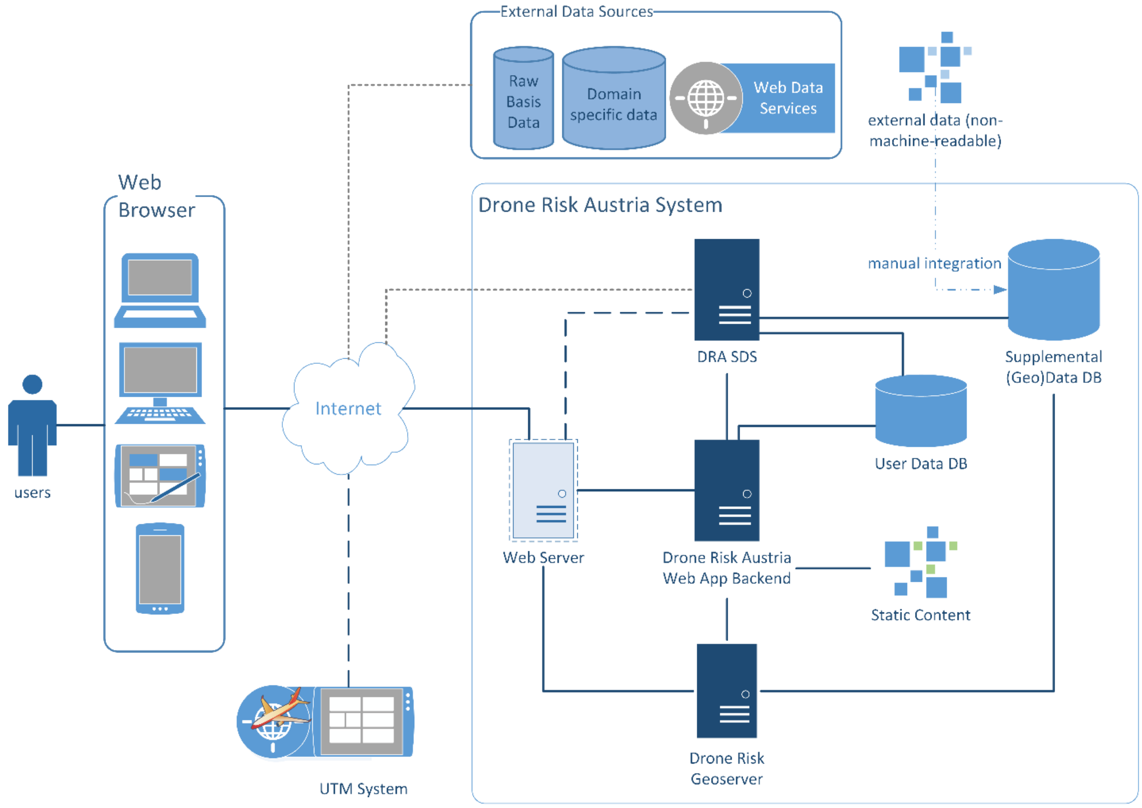


Figure 2. The architecture of the Drone Risk Austria prototype. SDS = Supplemental Data Service, DB = database, UTM = Unmanned Traffic Management.

2.3 System architecture

The architecture of the Drone Risk Austria prototype is given in Fig. 2. A responsive design of the frontend allows using the web application on any standard end-user device. System components of Drone Risk Austria – a web server (Ngnix), frontend (React) and backend (python Tornado) application components, a Geoserver installation and a database (PostGIS) run in Docker containers on a CentOs 8 server. Generation of spatial information updates is performed in a semiautomatic mode.

2.4 Geodata integration and derivatives

To derive spatial information necessary for UAS operation risk assessment, Drone Risk Austria uses open government data sources – either in a form of web services, or available as downloadable datasets through INSPIRE (https://inspire-geoportal.ec.europa.eu/) or Copernicus (https://www.copernicus.eu/en) websites. For example, airspace data published by the AA are used to derive information on spatial limits of controlled airspaces. Census data and points representing the locations of buildings are used to differentiate between populated and sparsely populated areas. Classified remote sensing data constitute the basis for differentiation between urban and rural areas, etc. Algorithms of geodata integration and approaches to deriving the necessary spatial information are currently country-specific and based on the availability of reliable open data.

2.5 Aggregation of geospatial information

Spatial information used for risk assessment is often characterized by complex geometries. Calculation of geometry overlaps for multiple information layers is computationally intensive and time consuming. In order to speed up risk analysis and to simplify the interpretation of risk assessment results, all spatial information layers required for the risk assessment are aggregated onto the same hexagonal grid. This grid covers the whole area of Austria with no gaps (Fig. 3).

Though square raster grids are used for data aggregation more widely, a hexagonal grid has an advantage of more accurately reflecting natural borders (e.g. nature protection areas). Further, equal distances between the centers of all adjacent cells (unlike in a square grid) allow to perform data aggregation more precisely. Additionally, hexagonal grids compared to other grids are more visually appealing.

As a result of the aggregation of various information layers onto the same grid, the only spatial operation performed at the time of risk assessment is an identification of grid cells belonging to the intended operational area. Then, for each grid cell, its attributes are analyzed according to standard risk assessment algorithms identified in SORA (JARUS, 2019). This approach is computationally efficient and allows to assess risks in operational areas comprising up to 10,000 grid cells within a few seconds.

Figure 3. An example of a hexagonal grid used for the aggregation of spatial information

3 Drone Risk Austria: examples or risk assessment

3.1 Open operation feasibility check

To analyze the feasibility of an open UAS operation, a user must upload the flight geometry and provide some auxiliary information, such as characteristics of the UAS and operation time span. Fig. 4 illustrates the results of an open operation feasibility check. Flight geometry is represented by a rectangle, which defines the limits of the intended operational area. A maximum flight altitude of 110 m above ground level (AGL) and a safety buffer of 120 m are provided by the user as input parameters. The results of risk assessment show that there is an uncertainty present in the area of the intended UAS operation since it partially falls into the limits of a nearby hang- and paragliding area.

The layer selection menu on the right-hand side of the map allows to visualize the spatial information used for risk assessment (Fig. 5). Thus, it is easy to find out which portion of the grid cell is influenced by a risk factor that determines the identified risk class. For example, Fig. 5 shows that only a minor part of the operation geometry falls into the hang- and paragliding area. Most of the uncertainty is associated with the safety buffer and will not influence the UAS flight in normal circumstances. Only in case of emergency, when safety buffer is used, this risk factor will be of relevance.

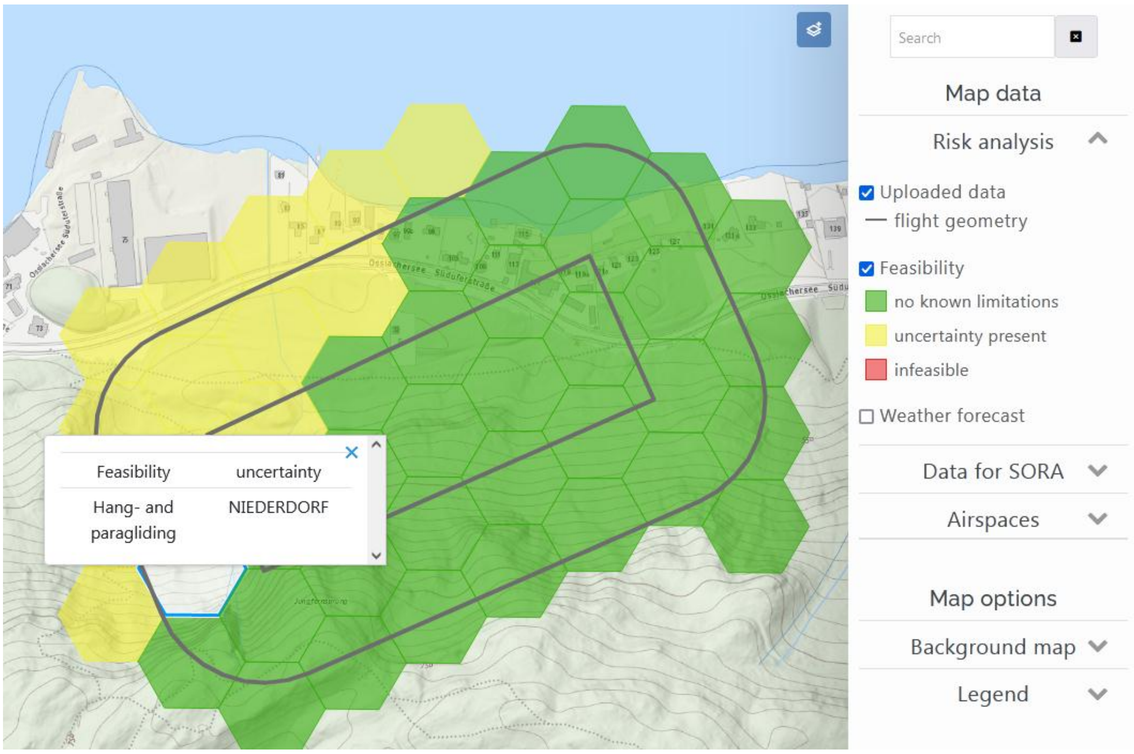


Figure 4. Results of an open operation feasibility check

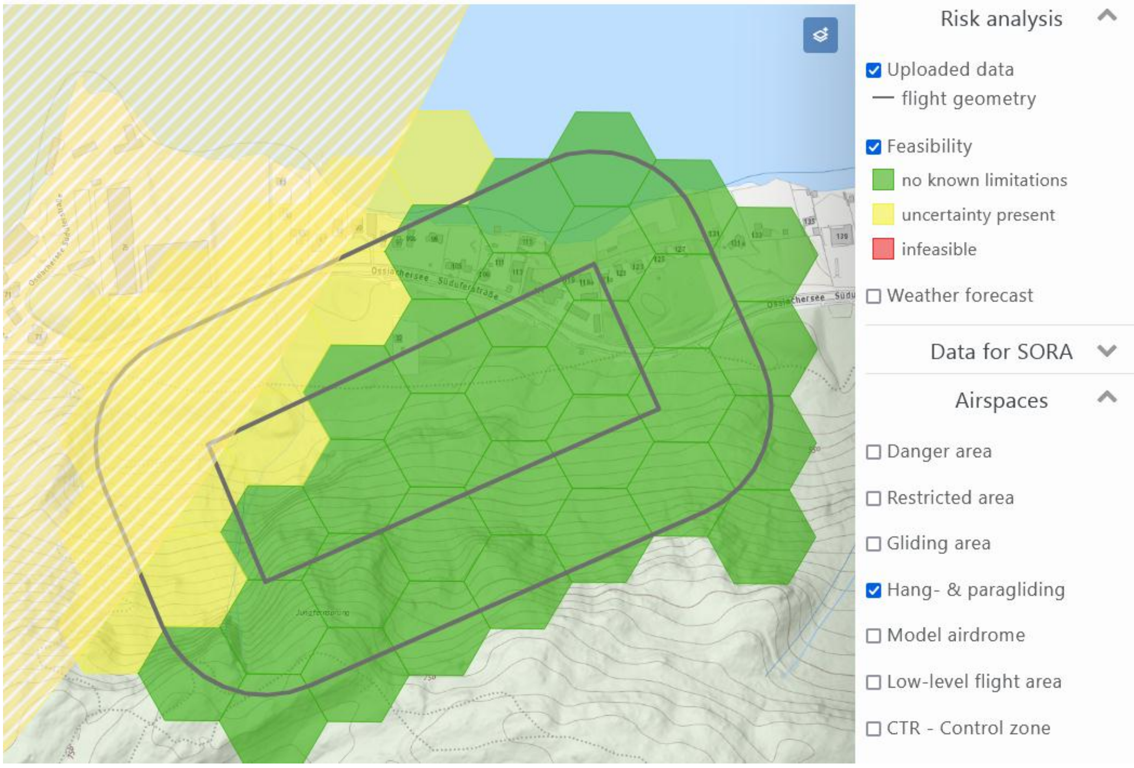


Figure 5. The limits of a hang- and paragliding area intersecting with the area of the intended UAS operation

3.2 Initial SORA and weather risk assessment

The category of a UAS operation depends on the combination of its parameters. Thus, if the same operational area as considered in the previous example is overflown at a maximum altitude of 300 m AGL, this operation is considered specific and its risk assessment should be performed with the use of the SORA approach.

Risk assessment results acquired with the use of SORA are represented by a spatial distribution of SAIL, as well as Ground Risk Class (GRC) and Air Risk Class (ARC). This helps the UAS operator to understand, which mitigation measures must be developed in order to perform a safe UAS operation in the intended operational area and to assess whether these measures are attainable. In a case when there is no possibility to mitigate risks associated with the intended UAS operation, its parameters must be changed in order to reduce the associated risks.

An example of initial SORA results with a GRC layer visible and other layers turned off is given in Fig. 6. An example of all initial SORA results for a BVLOS UAS operation with a 3D line flight geometry and a 150 m wide safety buffer is given in Appendix B.

Appendix C contains a visualization of Weather Risk assessment results for the same UAS operation. In addition to the calculated Weather Risk Class in the operational area, details of the underlying weather parameters (air temperature, wind speed and direction, precipitation probability, etc.) are provided as well.

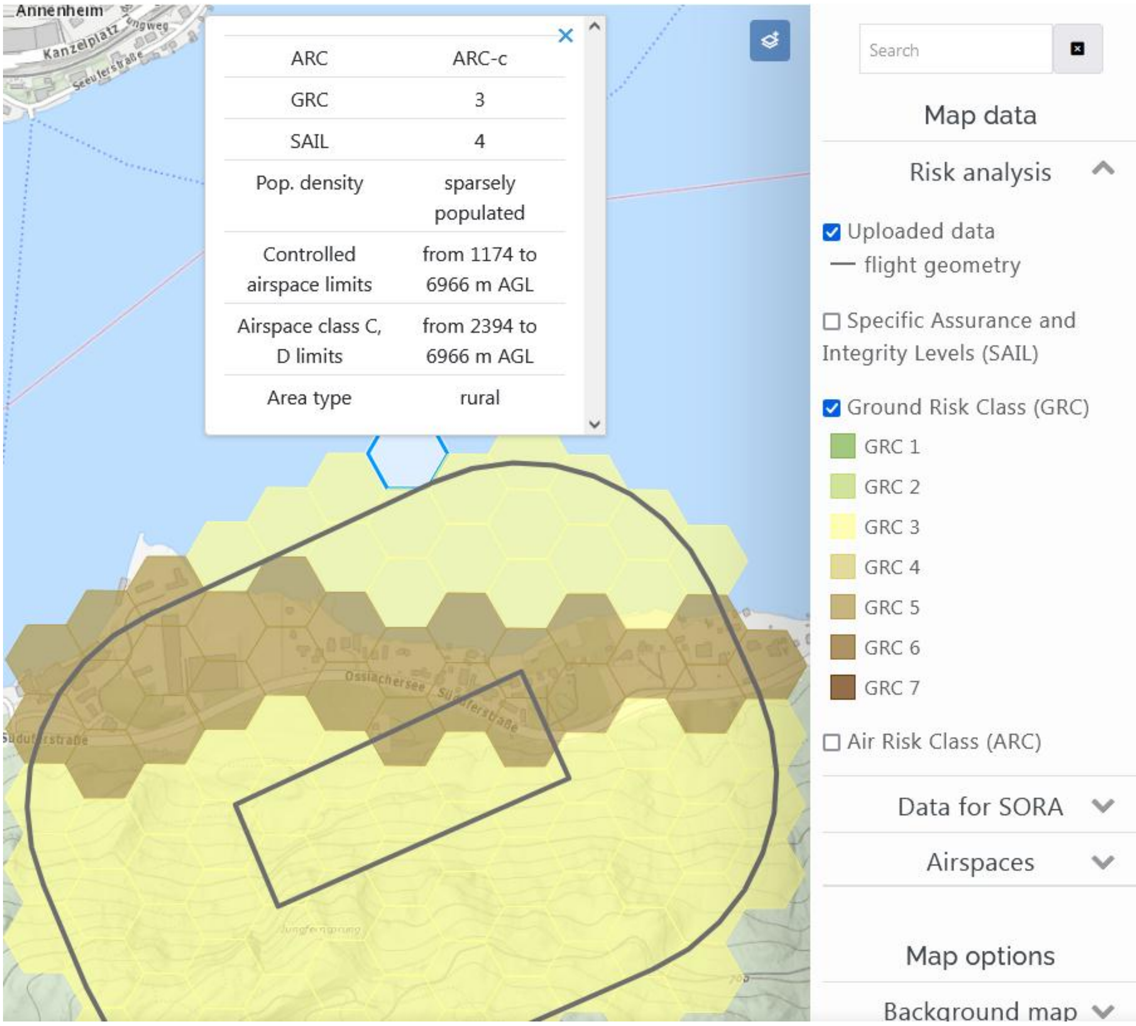


Figure 6. Ground risk distribution in the operational area

4 Open issues

Currently, UAS operation risk assessment is mostly performed in a non-scalable manner. Drone Risk Austria prototype is an attempt to automate a geodata-based pre-flight risk assessment of UAS operations. It does not intend to support tactical risk assessment and risk mitigation during the flight. Such functionality lies within the scope of other U-Space services (CORUS, 2019) which are yet to be developed.

Aggregation of spatial information on a grid cell has an advantage of more efficient risk calculation. As any aggregation, however, this approach leads to a distortion of underlying spatial information, e.g. change of the original airspace borders. The use of smaller grid cells minimizes information distortion but increases the computational intensity of both risk assessment and results visualization.

There exists no standard hexagonal grid for the EU. Currently, pan-European square grids with a spatial resolution starting with 100 m based on the ETRS-LAEA projection in line with the EU's INSPIRE directive are used for regional statistics. Hexagonal geometry of grid cells used in Drone Risk Austria allows to more accurately reflect natural borders (e.g. of an environment protection area) and is optically significantly more appealing. On the other hand, using a standard square grids for derived spatial information can minimize information loss when the original geodata is aggregated onto the same standard grid.

A term “UAS geographical zone” has been introduced in legislation to enable a standard approach to establishment of areas where UAS operations are facilitated, restricted or excluded. However, the understanding of what should be included into these geographical zones and how they should influence risk assessment has not yet been formed. Thus, the potential of geographical zones remains unused.

Many of the Drone Risk Austria algorithms used for deriving spatial information required for SORA cannot be directly reused by other Member States. This is due to the differences in the formats, resolution and contents of underlying geodata. The potential of INSPIRE infrastructure could be utilized in order to unify the required geodata for standard UAS operation risk assessment on the whole territory of the EU (Paulus et al., 2018).

5 Conclusions and outlook

Today, maintaining the safety of the airspace is a primary concern preventing a wider application of UAS. When dealing with large numbers of UAS operations, an automation of risk assessment is of key importance. Drone Risk Austria prototype demonstrates that it is possible to automate a geodata-based pre-flight UAS operation risk assessment. Further development can transform it into a tool for creation of a comprehensive safety portfolio and/or a supplemental data service performing preliminary risk assessment within the framework of a national UTM or the EU wide U-Space.

References

Cain, S., Torens, C., Volkert, A., Juchmann, P., Tomasello, F., Natale, M., Vreeken, J., Birgelen, T. v., Ribeiro, M., Ellerbroek, J., Taurino, D., and Ducci, M.: Standards for UAS - Acceptable Means of Compliance for Low Risk SORA Operations, in: AIAA Scitech 2021 Forum, Virtual Event, 1177, 2021.

Capitan, C., Capitan, J., Castano, A. R., and Ollero, A.: Risk Assessment based on SORA Methodology for a UAS Media Production Application, in: 2019 International Conference on Unmanned Aircraft Systems (ICUAS), Atlanta, GA, USA, 451–459, 2019.

CORUS: U-space Concept of Operations, 2019.

Denney, E., Pai, G., and Johnson, M.: Towards a Rigorous Basis for Specific Operations Risk Assessment of UAS, in: 37th DASC - Digital Avionics Systems Conference: London, England, UK, September 23-27, 2018 2018 conference proceedings, London, 1–10, 2018.

European Commission: Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft: REG EU 2019/947, L 152, 2019.

Hassanalian, M. and Abdelkefi, A.: Classifications, applications, and design challenges of drones: A review, Progress in Aerospace Sciences, 91, 99–131, https://doi.org/10.1016/j.paerosci.2017.04.003, 2017.

Janik, P., Zawistowski, M., Fellner, R., and Zawistowski, G.: Unmanned Aircraft Systems Risk Assessment Based on SORA for First Responders and Disaster Management, Applied Sciences, 11, 5364, https://doi.org/10.3390/app11125364, 2021.

JARUS: JARUS guidelines on Specific Operations Risk Assessment, 2019.

Ky, P.: U-space Regulatory Framework, in: U-space workshop, 14-15 May, 2019.

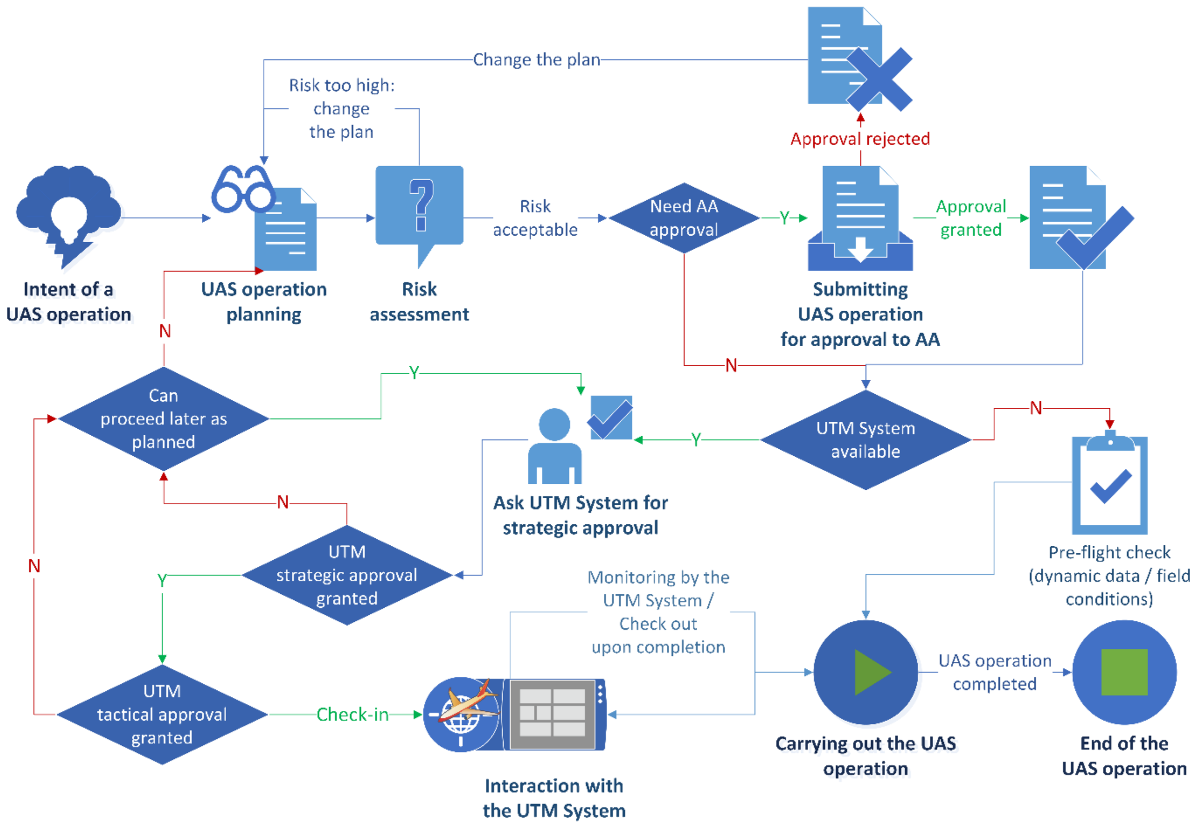
Landi, A. and Nicholson, M.: ARP4754A/ ED-79A - Guidelines for Development of Civil Aircraft and Systems - Enhancements, Novelties and Key Topics, SAE Int. J. Aerosp., 4, 871–879, https://doi.org/10.4271/2011-01-2564, 2011.

Martinez, C., Sanchez-Cuevas, P. J., Gerasimou, S., Bera, A., and Olivares-Mendez, M. A.: SORA Methodology for Multi-UAS Airframe Inspections in an Airport, Drones, 5, 141, https://doi.org/10.3390/drones5040141, 2021.

Paulus, G., Strelnikova, D., Anders, K.-H., Preduschnig, T., and Wagner, K.: The Need of a High Resolution European Spatial Data Infrastructure for Unmanned Aerial System Mission Planning & Risk Assessment, in: Proceedings AGILE 2018, Lund, Sweden, 13-15 June, 2018.

Terkildsen, K. H. and Jensen, K.: Towards a Tool for Assessing UAS Compliance with the JARUS SORA Guidelines, in: 2019 International Conference on Unmanned Aircraft Systems (ICUAS), Atlanta, GA, USA, 460–466, 2019.

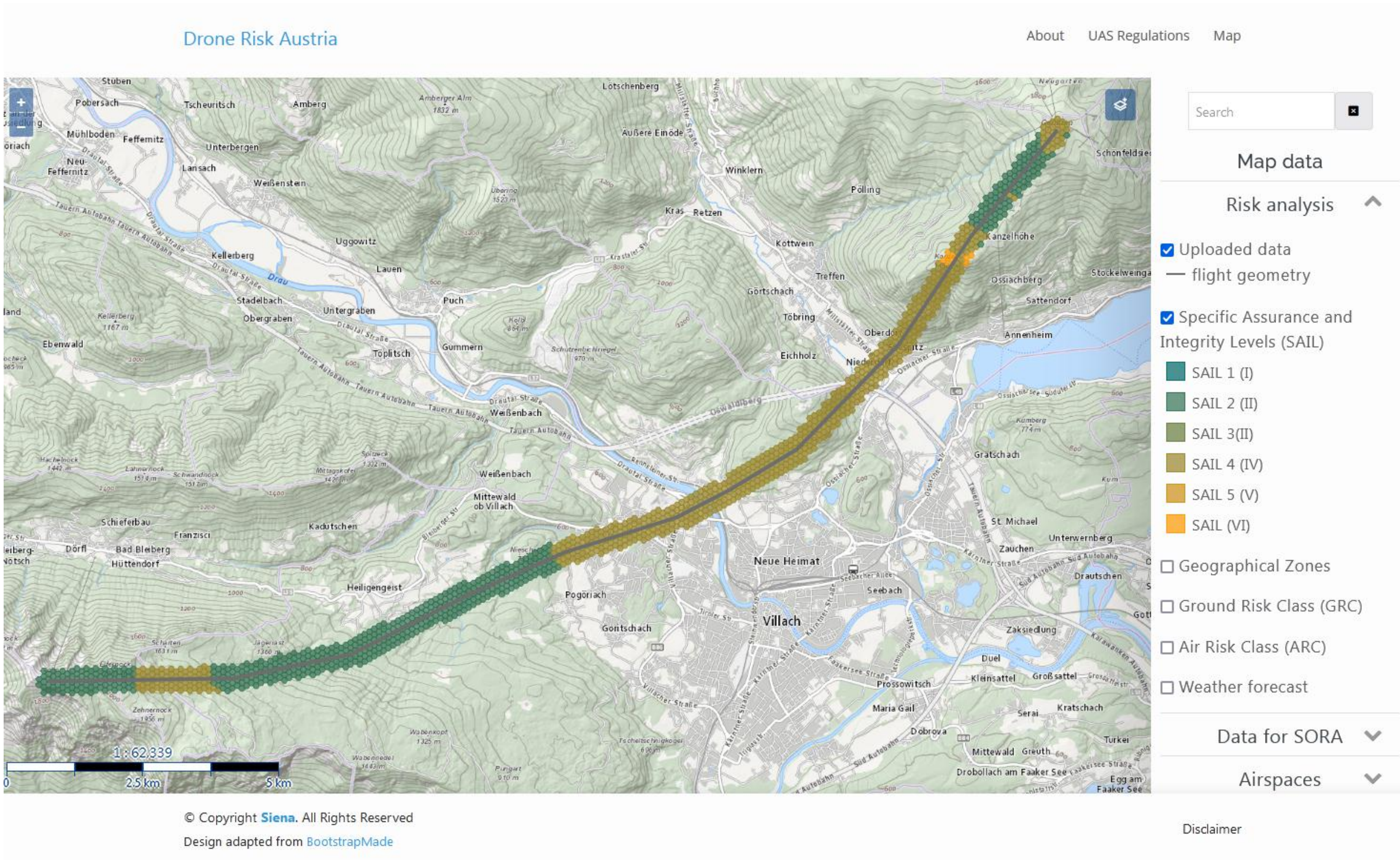
Appendix A



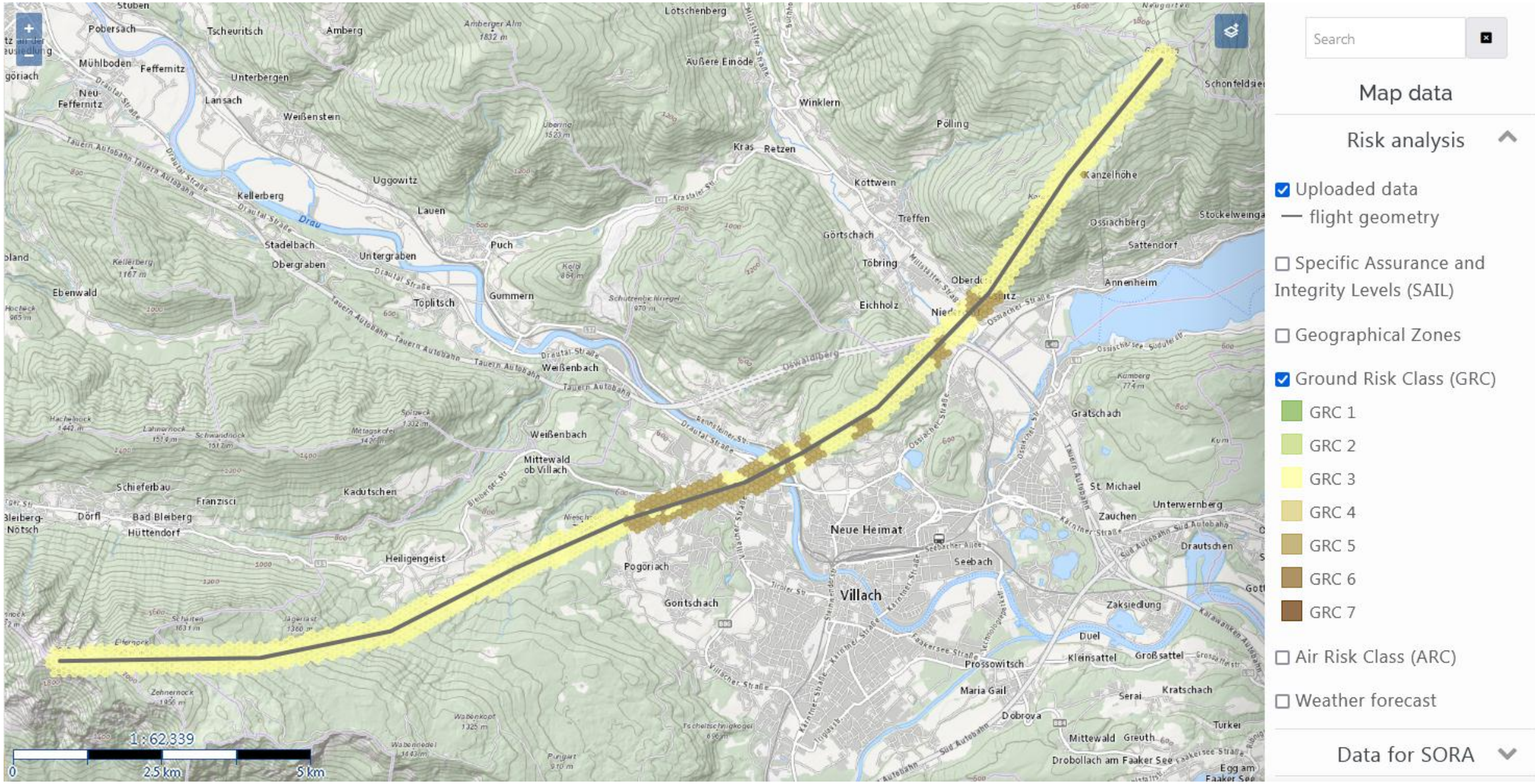
Change the plan
Risk too high: change the plan
Approval rejected
Intent of a UAS operation
UAS operation planning
Risk assessment
Risk acceptable
Need AA approval
Y
Submitting UAS operation for approval to AA
Approval granted
N
Can proceed later as planned
Y
Ask UTM System for strategic approval
Y
UTM System available
N
Pre-flight check (dynamic data / field conditions)
N
UTM strategic approval granted
N
Y
Monitoring by the UTM System / Check out upon completion
UTM tactical approval granted
Check-in
Interaction with the UTM System
Carrying out the UAS operation
UAS operation completed
End of the UAS operation

Appendix B

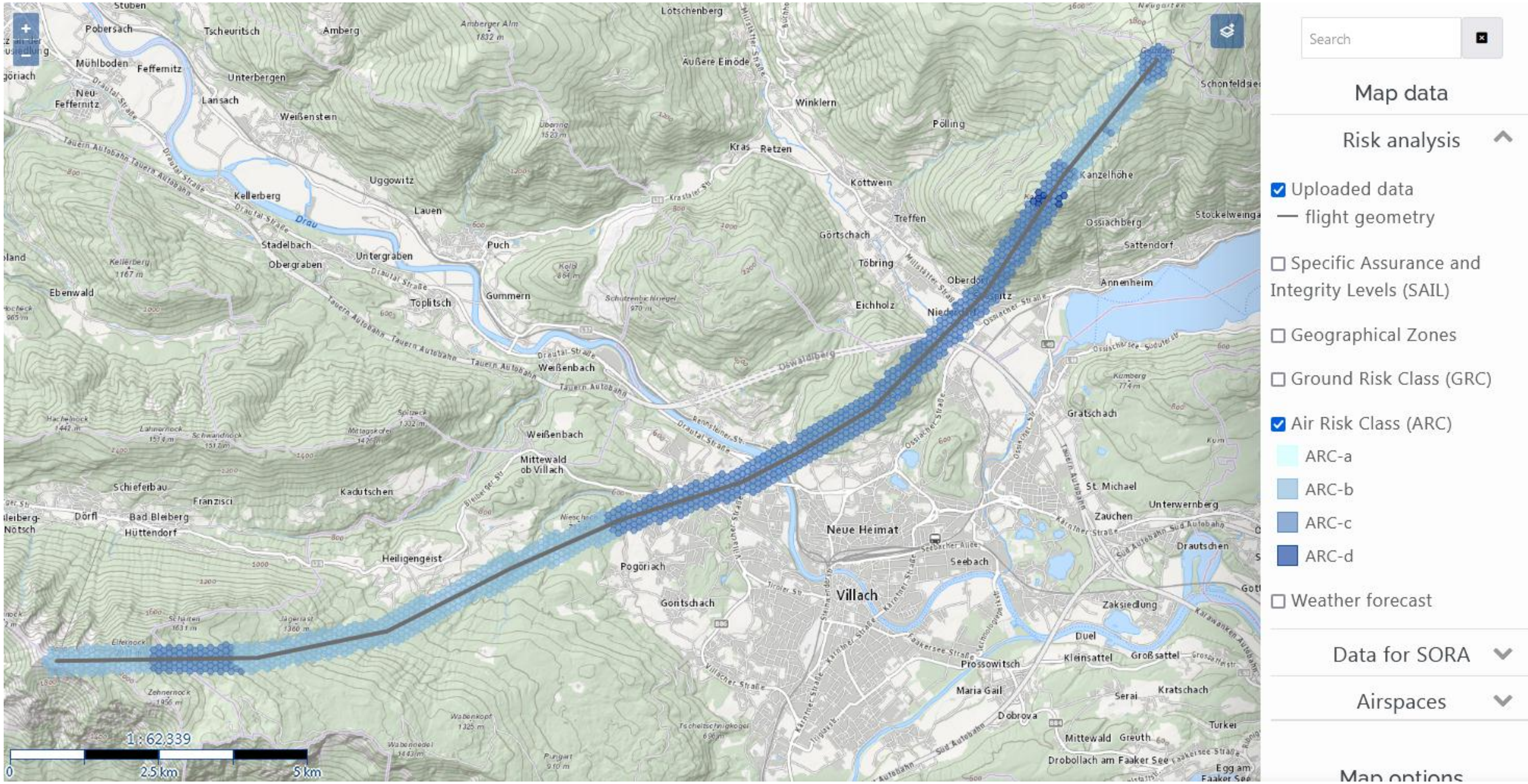
Map B1 – Spatial distribution of SAIL levels in the area of an intended specific UAS operation



Map B2 – Spatial distribution of GRC in the area of an intended specific UAS operation



Map B3 – Spatial distribution of ARC in the area of an intended specific UAS operation



Appendix C

Weather Risk in the area of an intended specific UAS operation