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Air Risk Assessment Methodology

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Model to harmonize Air Risk calculations for urban operations with UAS until a Detect & Avoid System has been selected and established in lower airspace operations

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1 Challenge

Current SORA air risk assessments for operations below 400 ft AGL in urban areas are frequently based on generic assumptions regarding manned traffic density. In practice, the legal framework under SERA.5005(f)[1] and § 37 LuftVO[2] significantly limits regular manned VFR operations below 400 ft over populated areas. As a result, actual traffic exposure in many German cities outside commercial airport control zones is substantially lower than commonly assumed. The absence of transparent, data-driven and reproducible methodologies creates uncertainty for operators and authorities and may lead to unnecessarily conservative ARC classifications, increased operational restrictions and reduced scalability of commercial BVLOS operations.

2 Problem

Current approaches often lack a harmonized quantitative methodology for estimating low altitude manned traffic exposure below 400 ft AGL. Existing assessments frequently do not sufficiently distinguish between regular air traffic and the limited categories legally authorized to operate below minimum altitude, such as HEMS, police helicopters, military flights and specific permit operations.

This results in several challenges:

- inconsistent risk assessments between authorities and operators
- reduced predictability of SORA approval processes
- excessive dependence on qualitative assumptions
- limited transparency regarding the derivation of ARC classifications
- insufficient consideration of actual operational data and legal airspace structures
- barriers to scalable BVLOS operations in urban and suburban environments
- extra bureaucracy and cost because of missing harmonization in cross-border operations

In addition, the lack of a quantitative framework limits the ability to objectively evaluate the benefits of Detect-and-Avoid systems and electronic conspicuity solutions within the SORA process.

3 Solution

The proposed methodology establishes a transparent and reproducible model for estimating manned flight encounter rates below 400 ft AGL based on actual operational data, legal constraints, and publicly available statistics.

The methodology is fully transparent. All parameters, assumptions, and calculation steps are explicitly documented and can be independently reviewed, challenged or adapted by authorities and experts.

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[1] SERA.5005 Visual flight rules source: https://eur-lex.europa.eu/eli/reg_impl/2012/923/2024-05-01/eng

[2] LuftVO: German Luftverkehrs-Ordnung (Air Traffic Regulation), setting national rules for participation in air traffic in Germany, supplementary to applicable EU rules such as SERA.

The approach also reflects the actual legal framework governing low altitude operations in Germany and demonstrates that sub 400 ft manned traffic in many urban environments is primarily limited to rotary wing operations.

3.1 Scope

The concept includes initially German cities and municipalities only. It is adaptable to other EU Member States. ARC is assigned per SORA 2.5 Annex C (JAR_Doc_28) Table 1[3], which uses a qualitative density rating scale (1–5).

WCV/FLH, derived from JAR_Doc_32 and "Likelihood of Unmitigated Collision Risks for UAS in Defined Airspace Volumes, 2020", is provided as a supplementary quantitative metric to support ARC reduction arguments; it does not replace the Annex C normative classification.

3.2 Daily Rate Manned Aircraft Movements Model

This model provides the exposure input for a UAS operational risk assessment as per JARUS SORA methodology. It estimates the parameter $\lambda_{traffic}$ defined as the daily rate of manned aircraft movements below 400 ft AGL over a given city — and converts that rate to a Well-Clear Violation rate (WCV/FLH) as per the JARUS Explanatory Note JAR_Doc_32.

The model:

- estimates annual HEMS mission rates proportionally to city population and additionally HEMS is assumed to be non-cooperative to derive the risk of a Well-Clear Violation.
- integrates police and special permit traffic contribution
- converts daily traffic movements into WCV/FLH metrics in accordance with JARUS SORA explanatory material
- applies explicit assumptions and conservative safety factors
- enables evaluation of Detect-and-Avoid effectiveness through a configurable WCV avoidance factor
- provides supplementary quantitative evidence to support ARC reduction arguments under SORA 2.5

This methodology serves to lower the initial Air Risk Class assumption instead of mitigating the risk any time later; the TMPR requirements of the Air Risk Class calculated herein shall be applicable.

3.2.1 Legal basis for VLL airspace below 400 ft

Under SERA.5005(f) in conjunction with § 37 LuftVO, the general safety minimum altitude over populated areas is 1,000 ft (300 m) above the highest obstacle within a 600 m radius. Regular VFR powered flight thus does not contribute to the sub-400 ft baseline.

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[3] SORA 2.5 Annex C (JAR_Doc_28) Table 1 http://jarus-rpas.org/wp-content/uploads/2024/06/SORA-Annex-C-v1.0.pdf

The following categories are authorized to operate below 400 ft:

- Emergency Medical Service helicopters (HEMS)
- Police and government helicopters
- Military aircraft (Bundeswehr)
- Special permits issued by state aviation authorities
- Gliders, hang-gliders and free balloons

3.3 Model structure

The model has three sequential steps:

1. estimate annual HEMS missions attributable to the city,
2. add police and permit contributions and calculate parameter λ traffic,
3. convert to WCV/FLH.

Step (1) – HEMS mission rate

HEMS mission count is allocated in strict proportion to city population, using a nationally calibrated base rate:

$$\boldsymbol{HEMS_{missions,city} = EW_{city} * BASE\_RATE}$$

$$\boldsymbol{EW_{city} = city\ population}$$[4]

$$\boldsymbol{BASE\_RATE_{calibration} - national\ station\ dataset\ (n = 25\ stations, 2024)}$$

$$\boldsymbol{BASE\_RATE = 0.0025\ missions\ per\ inhabitant\ per\ year.}$$

To estimate the base rate of HEMS movements per inhabitant per year, explicit data from 2024 of 25 HEMS stations were analysed across Germany, covering 36.47 million inhabitants.
The annual movements per inhabitant ranged from 0.0003 (C2 Frankfurt am Main) to 0.0034 (C39 Perleberg). The median value is 0.00133.
For this example, the base rate of 0.0025 missions per inhabitant per year was chosen, which is higher than 23 out of the 25 HEMS stations and therefore considered conservative.

Step (2) – Total movements and daily rate

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[4] Ref. : Destatis 2022

$$HEMS_{movements} = HEMS_{missions,city} * 2$$ [5]

$$\mathrm{Police}_{\mathrm{movements}} = \frac{\mathrm{EW}_{\mathrm{city}}}{100\,000 \times 30}$$

$$\mathrm{Permit}_{\mathrm{movements}} = \max(2, \frac{\mathrm{EW}}{100\,000 \times 2})$$ [6]

$$\lambda_{\mathrm{traffic}} = \frac{(\mathrm{HEMS}_{\mathrm{movements}} + \mathrm{Police}_{\mathrm{movements}} + \mathrm{Permit}_{\mathrm{movements}})}{365}$$

Step (3) – WCV/FLH

Per JARUS JAR_Doc_32, ARC is measured as WCV/FLH where WCV is defined as the Well-Clear-Volume and FLH as UAS flight hours. The well-clear volume is a cylinder of radius 2,000 ft and height ±250 ft centered on the manned aircraft.

The derivation (conservative assumption):

- A manned aircraft transiting at 200 km/h across a 5 km urban diameter spends approximately 1.5 min = 0.025 h in the well-clear cylinder per movement.
- A daily movement rate of λ movements/day corresponds to λ/14 movements per operating hour, assuming daytime operations (07:00–21:00, 14 hours);
- The expected number of WCV events per UAS flight hour equals (λ/14) × 0.025.

$$\frac{WCV}{FLH_{intrinsic}} = \lambda_{traffic} \times (\frac{0.025}{14}) = \lambda_{traffic} \times 0.001786$$

$$\lambda_{traffic} = daily\ movements\ (movements/day)$$

$$0.025 = transit\ time\ per\ movement\ (h)\ at\ 200\ km/h\ across\ 5\ km$$

$$Result = expected\ WCV\ events\ per\ UAS\ flight\ hour\ in\ this\ airspace$$

[5] Röper, Krohn, Fleßa & Thies (2020), Health Economics Review, doi:10.1186/s13561-020-00287-8, PMID 33030618

[6] LBA Statistics 2022: 1 247 total special permits; ~10 % relevant to sub-400 ft urban operations; < 3 % of total

Assumption: manned traffic is uniformly distributed over daytime hours. In practice, HEMS dispatch peaks during morning and evening – meaning the per-flight-hour rate may be somewhat higher during peak periods. This is compensated in the calculation as all traffic occurring during nighttime is being uniformly distributed throughout the daytime operations, providing a conservative approach. The daytime assumption is used throughout this document as the conservative baseline.

ARC classification uses SORA 2.5 Annex C Table 1 (density rating 1–5) as the normative tool. WCV/FLH from JAR_Doc_32 is reported as a supplementary quantitative metric. Order-of-magnitude thresholds are given for orientation only:

ARC	Annex C density rating	WCV/FLH (orientation, non-normative)	Typical context
ARC-a	1	$< 10^{-4}$	Segregated / atypical airspace
ARC-b	1–2	10^{-4} – 10^{-2}	Class G < 500 ft, rural, low traffic
ARC-c	2–3	10^{-2} – 10^{-1}	Class G < 500 ft, urban, moderate traffic
ARC-d	4–5	$\geq 10^{-1}$	Controlled airspace / airport environment

The WCV/FLH thresholds as given above are taken from JARUS guidelines on SORA Explanatory Note for Edition 2.5 (JAR-DEL-SRM-SORA-EN-2.5)[7] and from third-party research.

3.3.1 WCV avoidance factor and residual ARC

The parameter WCV/FLH intrinsic represents the geometric encounter rate with no avoidance capability. The WCV avoidance factor α represents the fraction of WCV events that the operator's Detect-and-Avoid (DAA) system successfully resolves before they develop into a proximate encounter.

[7] Source JARUS guidelines on Specific Operations Risk Assessment (JAR-DEL-SRM-SORA-EN-2.5): http://jarus-rpas.org/wp-content/uploads/2024/06/SORA-v2.5-Main-Body-Release-JAR_doc_25.pdf

$$\frac{WCV}{FLH_{residual}} = \frac{WCV}{FLH_{intrinsic}} \times (1 - \alpha)$$

α = 0 no avoidance capability; residual = intrinsic

α = 0.5 operator declares / demonstrates 50 % of WCV events are resolved

α = 0.9 operator declares / demonstrates 90 % of WCV events are resolved

α is applied consistently to WCV/FLH estimates: WCV_upper = WCV_intrinsic × (1 − α).

For a final SAIL assessment, the α claim must be declared or demonstrated in accordance with CAA requirements.

3.3.2 Uncertainty and error analysis

The model predicts more traffic than it is reflected in the observed data. Additionally and for all representative city calculations in this document, a safety factor of 2 is applied to nominal traffic predictions ($\lambda_{safety} = 2 \times \lambda_{traffic}$), which is deemed sufficient for potential outlier cities.

Model output with data of city Bielefeld to compare with confirmed data:

$$HEMS_{missions} = E\_W \times BASE\_RATE = 335,144 \times 0.0025 = 837.9\ missions\ per\ year$$

$$HEMS_{movements} = HEMS_{missions} \times 2 = 1,675.7\ movements\ per\ year$$

$$Police_{movements} = \frac{335.144}{100.000} * 30 = 100.54\ movements\ per\ year$$

$$Permit_{movements} = \frac{335.144}{100.000} * 2 = 6.70$$

$$\lambda_{traffic,model} = \frac{(1,675.7 + 100.54 + 6.70)}{365} = 4.88\ daily\ movements$$

Actual data:

$$HEMS_{missions}: 597\ missions\ in\ 2024\ (Bielefeld.de)$$

$$HEMS_{movements} = 1{,}194\ movements\ (assumption\ based\ on\ 2\ movements\ per\ mission)$$

$$Police_{movements} = 74\ movements$$
$$(population - based\ estimate\ derived\ from\ LZPD\ NRW\ data\ and\ scaled\ to\ the\ city's\ population)$$

$$Permit_{movements} = 6.70\ (model\ assumption\ since\ no\ actuals\ were\ found)$$

$$\lambda_{traffic,actual} = (1{,}194 + 74 + 6.70) / 365 = \mathbf{3.49\ daily\ movements}$$

$\lambda_{traffic}$ – daily movements derived from the model
λ_{safety} – conservative daily movements used for ARC/WCV evaluation

3.3.3 Sample results – representative cities

The table below shows central-estimate WCV/FLH and ARC for a representative sample of 13 cities, with a safety factor of 2 applied to $\lambda_{traffic}$, at α = 0 (no avoidance) and α = 0.5 (50 % WCV resolution by DAA):

City	Population	λ_safety (movements/day, Safety=2)	WCV/FLH (α=0)	ARC (α=0)	WCV/FLH (α=0.5)	ARC (α=0.5)
Heide	22,000	0.65	0.00116	ARC-b	0.00058	ARC-b
Schleswig	23,000	0.68	0.00121	ARC-b	0.00061	ARC-b
Rendsburg	28,000	0.82	0.00147	ARC-b	0.00074	ARC-b
Stralsund	58,000	1.70	0.00303	ARC-b	0.00151	ARC-b
Bayreuth	72,000	2.10	0.00375	ARC-b	0.00188	ARC-b
Siegen	102,000	2.97	0.00531	ARC-b	0.00266	ARC-b
Trier	111,000	3.24	0.00578	ARC-b	0.00289	ARC-b
Göttingen	118,000	3.44	0.00614	ARC-b	0.00307	ARC-b
Kassel	201.000	5.86	0.01046	**ARC-c**	0.00523	**ARC-b**
Kiel	247,000	7.23	0.01291	**ARC-c**	0.00646	**ARC-b**
Augsburg	296,000	8.63	0.01541	**ARC-c**	0.00771	**ARC-b**
Münster	316,000	9.21	0.01645	**ARC-c**	0.00823	**ARC-b**
Bielefeld	335.000	9.76	0.01745	**ARC-c**	0.00873	**ARC-b**

4 Consequences and Impact

The methodology can support a more proportionate and evidence-based application of SORA air risk assessments for commercial UAS operations.
Potential impacts include:

- improved consistency and predictability of approval processes
- reduction of unnecessary operational restrictions
- accelerated deployment of BVLOS operations
- stronger harmonization between operators and competent authorities
- better integration of quantitative evidence into SORA evaluations
- improved scalability of urban drone operations
- enhanced transparency and traceability of ARC determinations
- stronger incentives for Detect-and-Avoid and electronic conspicuity technologies

The methodology may also contribute to broader European discussions regarding quantitative traffic modelling, digital airspace management, and future U-Space implementations.

5 Recommendation for Action

UAV DACH recommends:

- initiating an expert review of the methodology with competent authorities, JARUS experts and industry stakeholders
- evaluating the methodology as supplementary quantitative input within SORA based risk assessments
- further validating the model using additional operational datasets and regional comparisons
- assessing harmonization potential at European level
- considering the methodology within future digital airspace and U-Space frameworks
- encouraging the integration of Detect-and-Avoid performance metrics into operational risk evaluations
- supporting the development of transparent and data-driven approaches for low-altitude air risk classification
- accepting the methodology to adjust the current AMC to SORA 2.5 and harmonize implementation across EU Member States, avoiding the further sustainment of development and additional costs associated with cross-border operations.

The methodology should be understood as a practical contribution to the ongoing evolution of proportionate, scalable and evidence-based risk assessment methodologies for unmanned aviation.

Annex A Primary data sources and references

- DRF Luftrettung GmbH – Annual mission statistics 2024 (C42: 1 527; C.Europa5: 1 312 missions). Presseportal, February 2025.
- ADAC Luftrettung gGmbH – Jahresbilanz 2024 (49 048 total missions across 38 stations). February 2025.
- BBK – Zivilschutz-Hubschrauber Jahresbilanz 2024 (C7 Kassel: 1 156; C13 Bielefeld: 1 109 missions). BBK.bund.de, March 2025.
- bielefeld.de – Jahresbilanz Christoph 13 (2024): district-level breakdown, 597 missions in Kreis Bielefeld. City of Bielefeld press release, 2025.
- Röper J., Krohn M., Fleßa S., Thies K.-C. (2020): "Costing of helicopter emergency services – a strategic simulation based on the example of a German rural region." Health Economics Review 10:34. doi:10.1186/s13561-020-00287-8. PMID 33030618.
- LBA – Statistiken 2022: Sonderflugerlaubnisse. Luftfahrt-Bundesamt, Braunschweig.
- Destatis – Gemeindeverzeichnis: population and area by municipality. Wiesbaden, 2022.
- JARUS SORA v2.5 Main Body (JAR_Doc_25), Annex C (JAR_Doc_28), Explanatory Note (JAR_Doc_32, Doc. Identifier JAR-DEL-SRM-SORA-EN-2.5). June 2024.
- Likelihood of Unmitigated Collision Risks for Uas in Defined Airspace Volumes, 2020" (https://ieeexplore.ieee.org/abstract/document/9222872)
- SERA.5005(f) – Commission Implementing Regulation (EU) No 923/2012.
- LuftVO § 37 – Luftverkehrs-Ordnung, last amended 2023. LuftVG § 30.