Noise certification and regulation for eVTOL operation

Public Workshop: Novel Tools for Novel Aircraft

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eVTOL mUlti-fideliTy hybrid desIgn and Optimization for low Noise and high aerodynamic performance - Grant Agreement 101138209

Noise certification and regulation for eVTOL operation

- Work Package 3 provides a comprehensive summary of proposed noise regulations and recommendations applicable to the intended eVTOL vehicle and its mission profile.
  - continuously reviews emerging regulations and how they affect design objectives and constraints.
- Noise regulations typically fall under two categories:
  - **Noise Regulations (Legislative)**: Issued by authorities (local, regional, national) to limit community exposure.
  - **Certification Requirements (Aviation Authorities)**: Ensuring aircraft meet certain noise performance specifications.
- **International Regulations (ICAO)**
  - The International Civil Aviation Organization (ICAO) establishes **Standards and Recommended Practices (SARPs)** to harmonize regulations worldwide.
  - **ICAO Annex 16 Volume I** deals specifically with aircraft noise across different categories.
  - **Chapter 13 of Annex 16** addresses tilt-rotor aircraft noise.
- **European Certification Framework (EASA)**
  - In July 2024, EASA published **Environmental Protection Technical Specifications (EPTS)** for VTOL-capable aircraft with tilting rotors.
  - These requirements draw from:
    - **ICAO Annex 16 Volume I, Chapter 13** and its Appendix 2 "Evaluation Method."
    - Guidance Material from ICAO's **Environmental Technical Manual (ETM)**.
  - EASA's certification governs **single-event noise** of a design. Setting **local noise limits** (often considering repeated or cumulative noise events) remains the prerogative of National Aviation Authorities (NAAs) or municipal governments, respecting the subsidiarity principle.

EASA regulations

- **Noise Evaluation Metrics (NVTOL-TILT.1100)**
  - **Take-off, Overflight, and Approach**: Noise is evaluated using the **Effective Perceived Noise Level (EPNL)** measured in **EPNdB**, as specified in *"NVTOL-TILT.1105 – Calculation of Effective Perceived Noise Level."*
  - **Hover**: Noise is evaluated using the **A-weighted equivalent continuous sound pressure level (L_{Aeq})** as specified in *"NVTOL-TILT.1110 – Calculation of A-weighted equivalent continuous sound pressure level."*
- **Reference Procedures (NVTOL-TILT.1205)**
  - Defines how to perform the **take-off, overflight, and approach** reference procedures for noise testing.
  - The **maximum acceptable noise limits** for each procedure depend on the **Maximum Take-Off Mass (MTOW)** (see Table below).
- **Maximum Noise Limits**
  - The table shows allowable noise levels (in EPNdB) for take-off, overflight, and approach, calculated via formulas depending on aircraft MTOW (in 1000 kg, "M").
  - Illustrative Limits from the Table

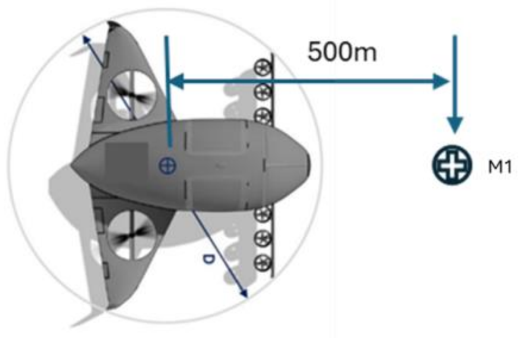
M from/to:	0	0.788	80
Take-off noise level (EPNdB)	86	$87.0314 + 9.9673 \log_{10} M$	106
Overflight noise level (EPNdB)	84	$85.0314 + 9.9673 \log_{10} M$	104
Approach noise level (EPNdB)	89	$90.0314 + 9.9673 \log_{10} M$	109

EASA reference eVTOL flight procedures

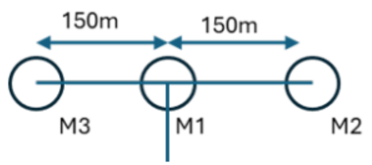
- For reference noise measurement points, four different reference procedures have been discussed in detail in these regulations which are:
  - Take-off, Overflight, Approach and Hover

Take-Off

- **Measurement Point Layout**
  - **Central Reference Point (M1)**
    - Placed on the ground, directly below the prescribed flight path (per “NVTOL-TILT.1205 – Reference procedures”).
    - Positioned **500 m horizontally** in the direction of flight from the point where the aircraft transitions to climbing flight.
  - **Two Lateral Points (M2, M3)**
    - Located on the ground, **150 m to the left and right** of the flight path.
    - Aligned with M1 on a straight line.
- **Take-off Reference Procedure**
  - **Flat Terrain**: The flight path is defined assuming flat terrain under the entire take-off trajectory.
  - **Stabilized Power**: The aircraft must be at **maximum climb power** in the **reference atmospheric conditions** (“NVTOL-TILT.1210”).
    - The path starts **500 m before** the central microphone point (M1) at an **altitude of 20 m** above ground.
  - **MTOW**: Use the **maximum take-off mass** for which certification is sought.



Take-Off measurement - top view

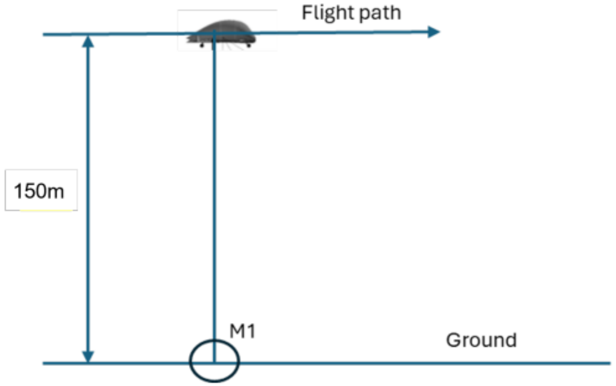


Take-Off measurement distance from Microphone M2 and M3

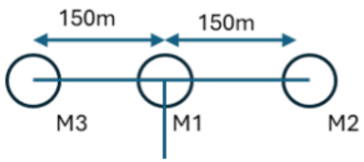
EASA reference eVTOL flight procedures

Overflight

- Measurement Points
  - **Central Reference Point (M1)**
  - Located on the ground, directly **150 m below** the aircraft's overflight path as specified in "NVTOL-TILT.1205 – Reference procedures."
- **General Conditions** (Apply to Both VTOL/Conversion Mode and Aeroplane Mode)
  - Flight is defined over **flat terrain** for the entire path.
  - The aircraft maintains **level flight** directly above M1 at **150 m altitude**.
  - The aircraft's **mass** is at **maximum take-off mass** (MTOW) for certification.
- **VTOL/Conversion Mode Procedure**
  - The **nacelle angle** is set to the **lowest angle** approved for zero airspeed.
  - The aircraft flies at **0.9 × VCON** (where *VCON* is the conversion mode reference speed).
- **Aeroplane Mode Procedure**
  - The **nacelle angle** is near **0°**, aligned with the aircraft's longitudinal axis.
  - The aircraft flies at **0.9 × VMCP** or **0.9 × VMO**, whichever is **less** (where *VMCP* is the maximum continuous power speed and *VMO* is the maximum operating speed in aeroplane mode).



Overflight measurement distance from microphone M1

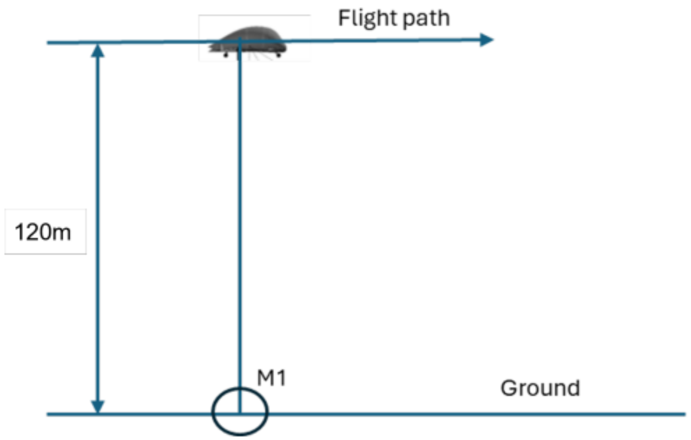


Overflight measurement distance from Microphone M2 and M3

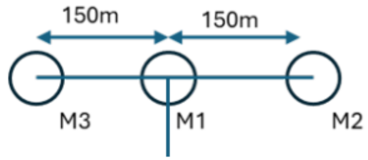
EASA reference eVTOL flight procedures

Approach

- **Measurement Points**
- **Central Reference Point (M1)**
  - Located on the ground, **120 m** below the aircraft's approach path (per "NVTOL-TILT.1205 – Reference procedures").
- **Lateral Reference Points (M2, M3)**
  - Positioned on the ground, **150 m to the left and right** of the approach flight path.
  - All three microphones (M1, M2, M3) lie on the same straight line.
- **Approach Reference Procedure**
  - **Flat Terrain**: The approach profile is flown over **flat terrain**.
  - **6.0° Approach Path**: The aircraft passes above M1 at **120 m** altitude while maintaining a **6.0° descent angle**.
  - **Stabilized Airspeed & Power**:
    - Fly at **best rate-of-climb speed** (based on nacelle angle) or the **lowest approved approach speed**—whichever is **greater**.
    - Maintain **stabilized power** throughout the approach.
  - **Maximum Landing Mass**: The aircraft's **landing mass** for the procedure is the **maximum landing mass** intended for certification.



Approach measurement distance from microphone M1

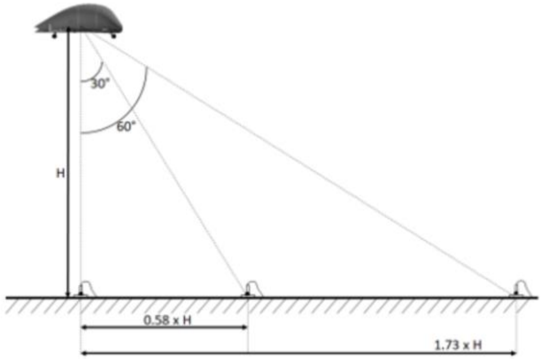


Approach measurement distance from Microphone M2 and M3

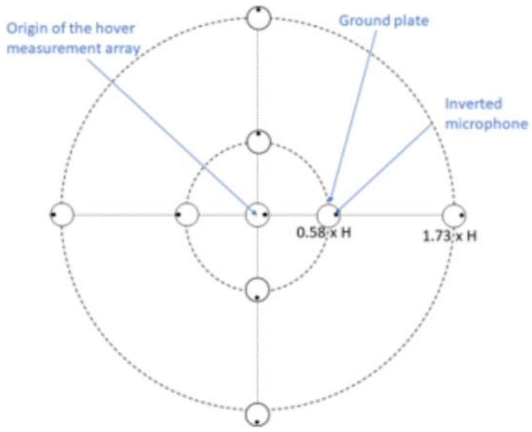
EASA reference eVTOL flight procedures

Hover

- **Microphone Placement**
- **Central Reference Point**
  - One microphone at the **origin** of the measurement array, located on the ground and directly beneath the hover positic specified in “NVTOL-TILT.1205 – Reference procedures.”
- **First Pair of Lateral Microphones**
  - Placed on the ground along a straight line from the origin at distances of **0.58 × H** and **1.73 × H**, where **H = 25 m**.
- **Additional Microphone Sets**
  - Three more **pairs** of microphones are placed by **rotating** this first pair by **90°**, **180°**, and **270°** around the origin (Figure 24).
  - This creates a full **360° array** around the central microphone.
- **Hover Reference Procedure**
  - **Hover Position**
    - The aircraft remains **stationary** in flight directly above the origin of the measurement array at a **reference height of 25 m**.
  - **Aircraft Mass**
    - The aircraft is set to its **maximum take-off mass (MTOM)** during the measurement.



Hover measurement - side view



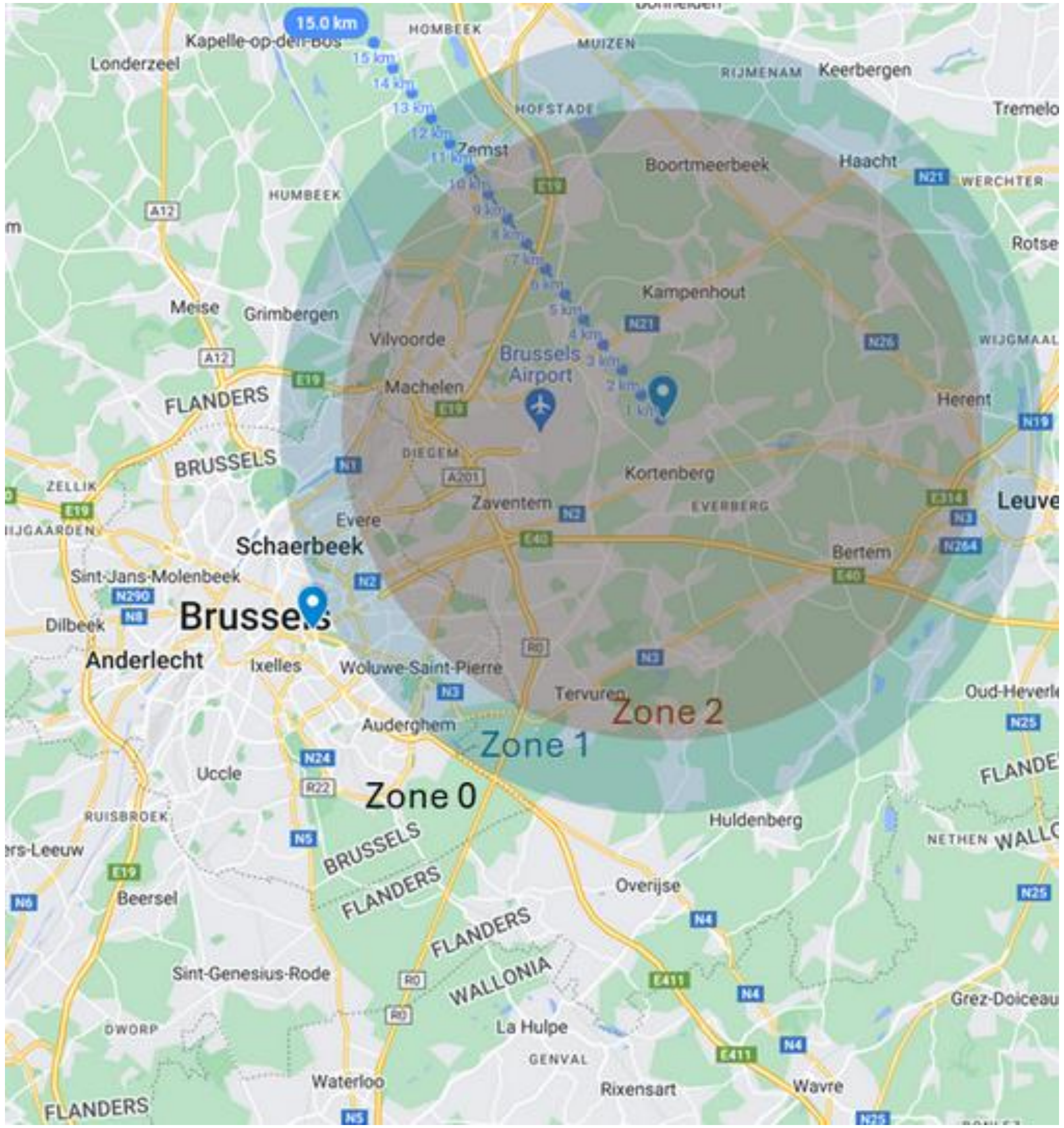
Hover measurement - top view

Local Noise Regulations

- Local authorities set their own noise limits → Brussels: ”Decree of the Brussels Capital Government regarding the combating of noise pollution caused by air traffic”
- Brussels divided into zones
- Metrics for average noise (L_{sp}) and single events (L_{evt}) for zone and day/night:

	L_{evt}, dB		L_{sp}, dB	
	Day	Night	Day	Night
Zone 2	90	80	60	50
Zone 1	85	75	55	45
Zone 0	75	70	55	45

*Lsp: Noise of the aircraft distinct from ambient noise for a given observation period
*Levt: Sound exposure level calculated for a given event

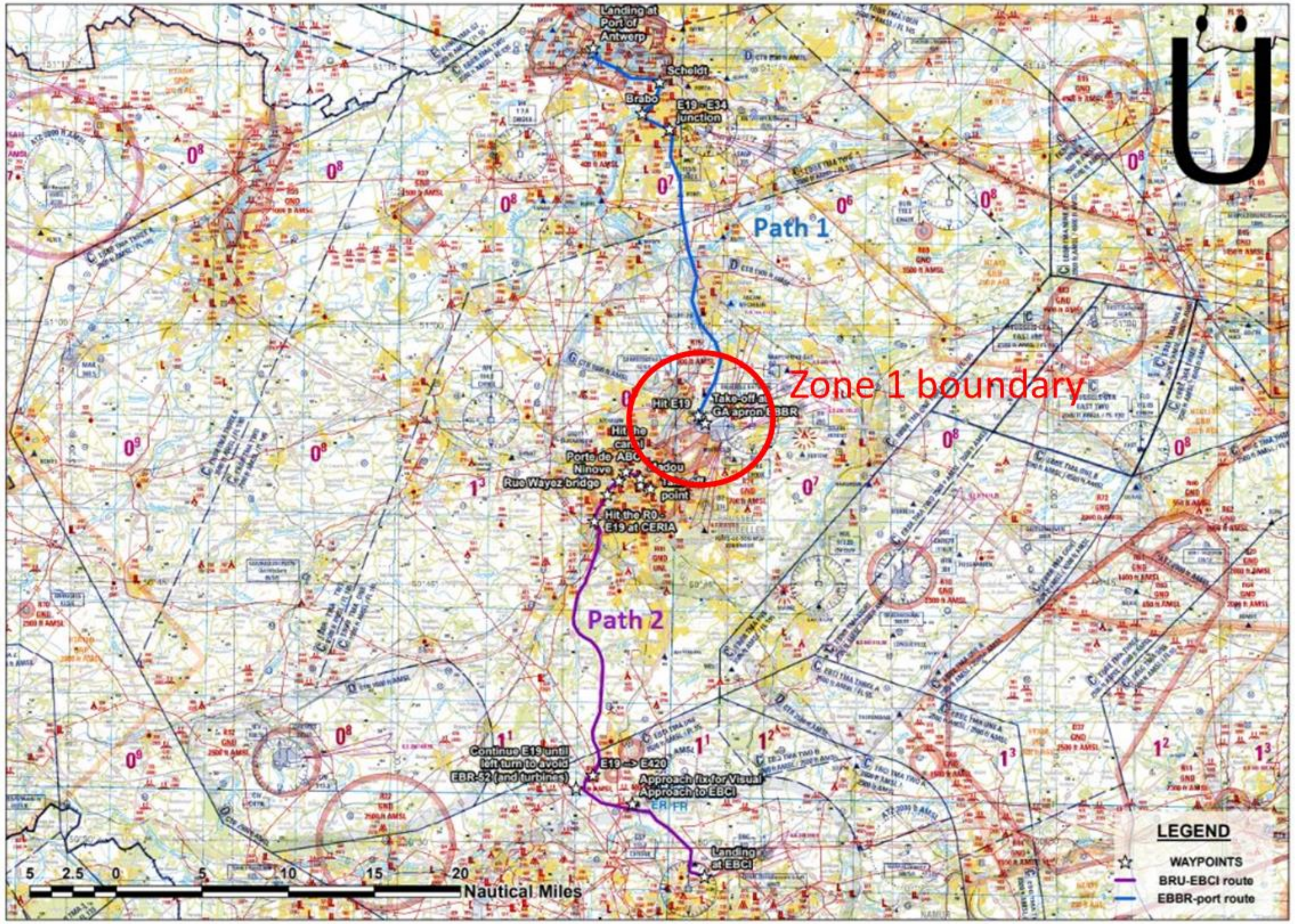


eVTOLUTION Flight Paths

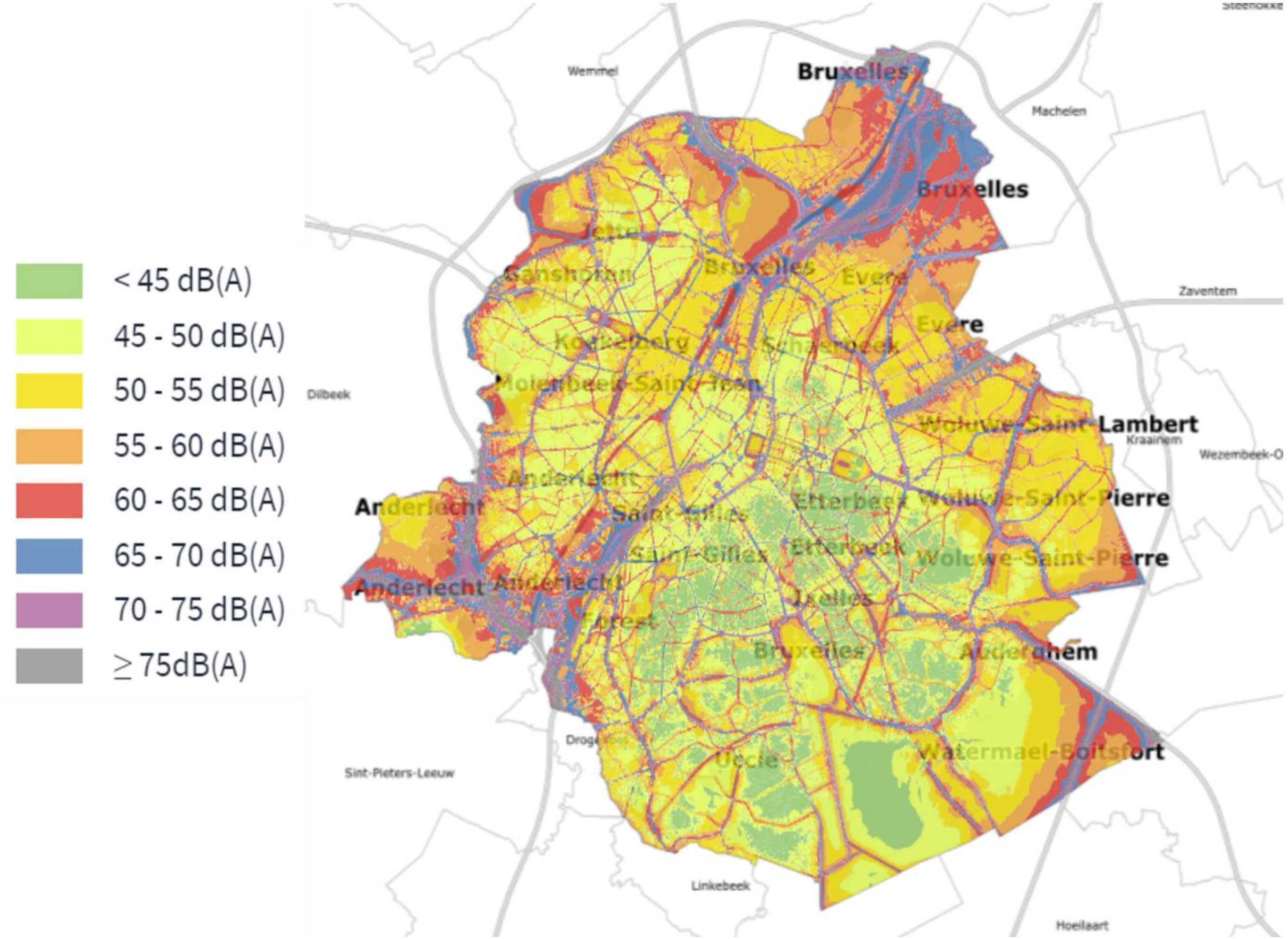
- Path 1: Brussels Airport (EBBR) - Port of Antwerp
- Path 2: Berlaimont building -South Charleroi airport (EBCI)
- Zone 0 restrictions apply

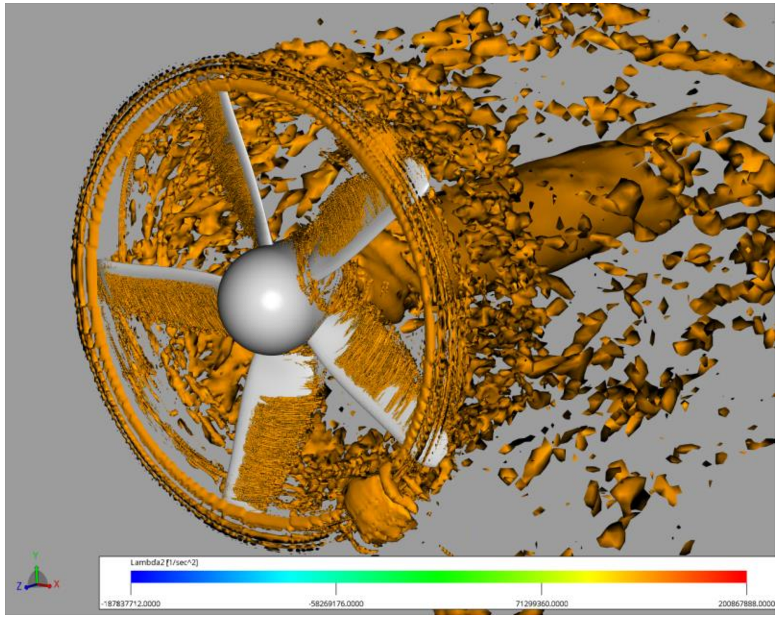
	L_{evt}, dB		L_{sp}, dB	
	Day	Night	Day	Night
Zone 2	90	80	60	50
Zone 1	85	75	55	45
Zone 0	75	70	55	45

- This should be taken into consideration for computing overall noise level of the eVTOL vehicle



eVTOL vs background noise





- EVTOLUTION project intends to compute the eVTOL vehicle noise and compare it with the background noise of the Brussels city and Brussels airport
- This will help to trace the pyscho-acoustics effects of eVTOL operations in urban environments on humans

Local Noise evaluation for eVTOL aircraft – London Airport case study

- As the intended flight paths in the project involve two airports along with the city centre, metrics related to noise regulations should be considered as well

- One of the most well-defined noise regulation method for airports can be seen in the London Airports, which have been monitored strictly based on a Quota Count (QC) system

- The QC are given to the aircraft based on the noise levels they are operating in (their EPNdB)

- This quota count will help to calculate the maximum allowed flights from the airport for a given aircraft type and season type, thus controlling the noise levels in the airport and neighbouring areas

Aircraft type	Quota Count	Noise Classification, EPNdB
a	Exempt aircraft	
b	0	Below 81
c	0.125	81-83.9
d	0.25	84-86.9
e	0.5	87-89.9
f	1	90-92.9
g	2	93-95.9
h	4	96-98.9
i	8	99-101.9
j	16	Greater than 101.9

Airport	Season	Movement limit	Noise quota limit
Heathrow	Winter	2,550	2,415
Heathrow	Summer	3,250	2,735
Gatwick	Winter	3,250	1,785
Gatwick	Summer	11,200	5,150
Stansted	Winter	5,600	3,310
Stansted	Summer	8,100	4,650

Limitations of Noise evaluation for eVTOL aircraft

- EASA EPTS has maximum allowable noise limits for Take-off, Overflight and Approach, but the Hover reference procedure has no such limits
- Local governments have their own noise measurement metrics and procedures
- Moreover, airports have different regulations for noise using Quota count system to control the noise levels in areas neighboring airports
- There are many requirements from different regulations but no clarity on which is the most stringent one and should be followed for eVTOL vehicles
- So, EVTOLUTION project intends to create a framework that will allow comparison of these requirements and make it applicable to the eVTOL vehicle operations in general

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Extra slides

EASA regulations

- **Hover Noise Calculation**
  - For hover, $\mathbf{L_{Aeq}}$ is computed with the formula:
  - t_M =30 seconds (typical reference duration).
  - $SPL_{AS}(l,k)$: The A-frequency-weighted, SLOW-time-weighted sound pressure level in the lth one-third-octave band at the kth instant.
  - Δt: Time increment between samples.
  - Precise **hover noise** must be assessed via measured data during an actual hover operation.

$$L_{Aeq} = 10\log_{10}\left(\frac{1}{t_M}\sum_{k=1}^{N}\sum_{l=1}^{24}10^{0.1\cdot SPL_{AS}(l,k)}\,\Delta t\right)$$