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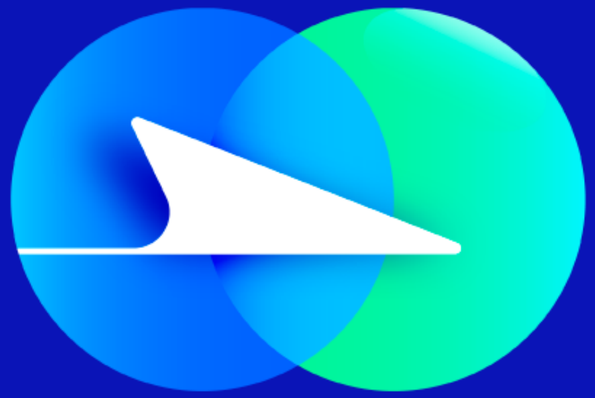

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RefMap Clustering Event 2025

Advancing Sustainable Aviation & Urban Air Mobility

Modeling and Simulation of Drone Traffic Public Acceptance Criteria

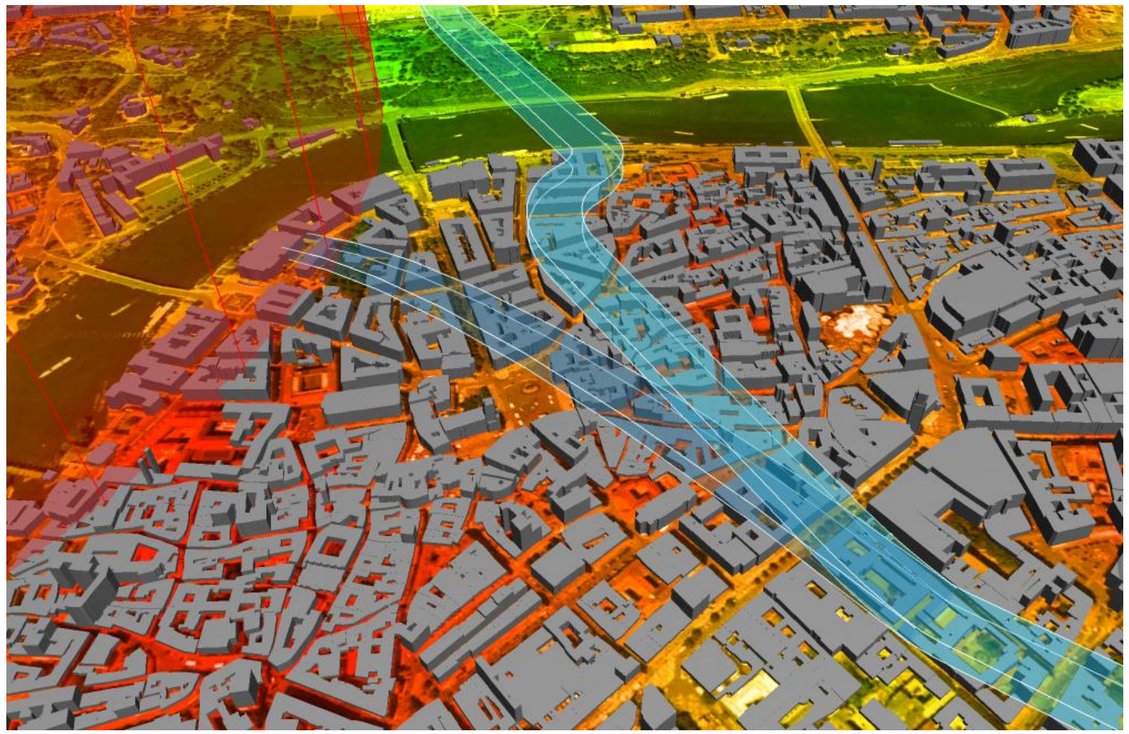
Milan Rollo, AgentFly Technologies

ImAFUSA

29–30 July 2025, Athens, Greece

Outline

- Purpose of the simulation
  - Simulation framework
  - Extensions to evaluate public acceptance
- Environment model
- Metrics and indicators
  - Noise annoyance
  - Visual pollution
  - Safety perception
- Scenario setup
- Outcomes
- Conclusion and future work



Purpose for the Use of the Large-Scale Simulation Framework

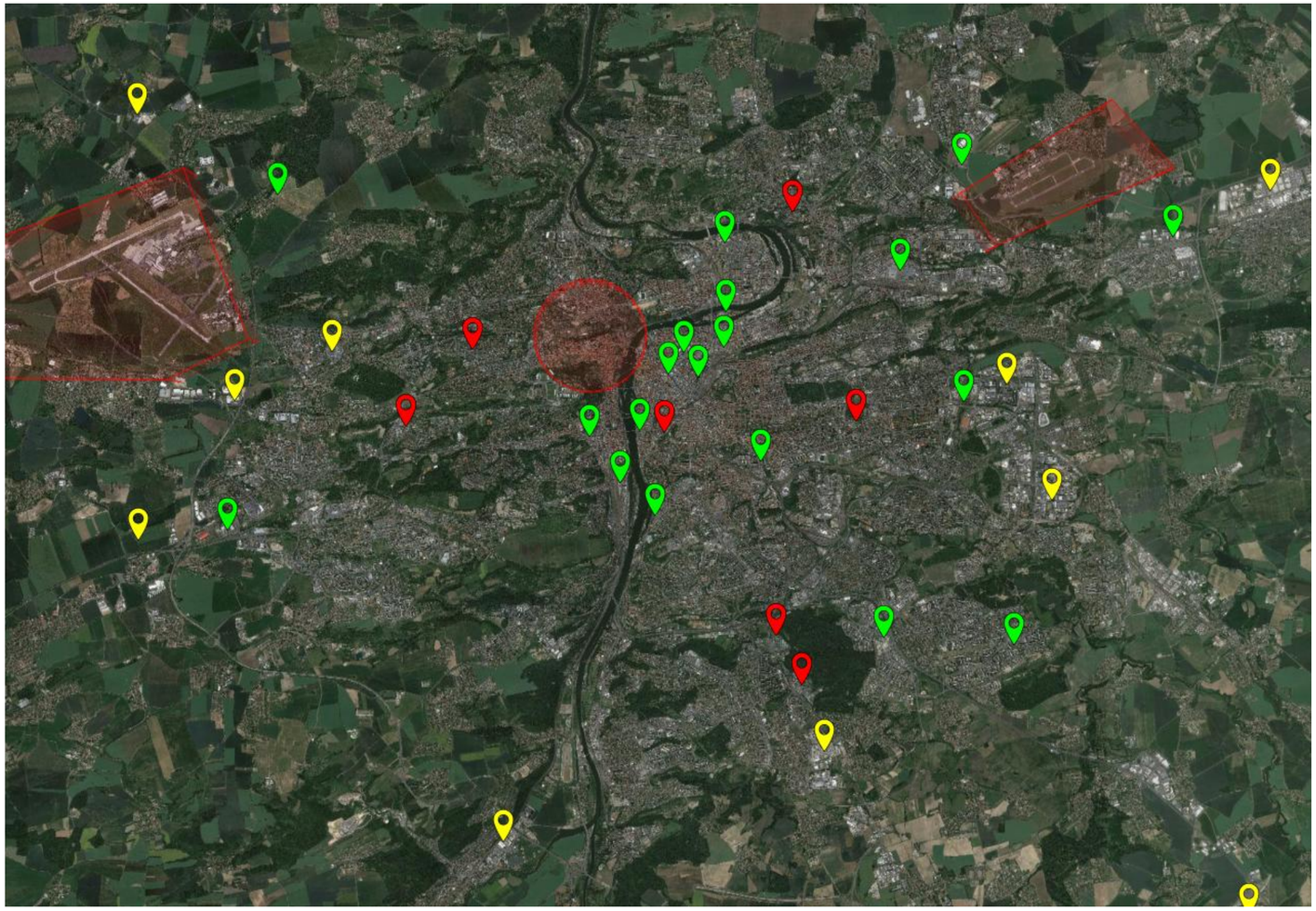
- AgentFly simulation framework
  - Large-scale fast-time agent-based simulation
  - Detailed 3D environment modeling
  - Airspace structure modeling
  - Air traffic generators
  - Logging and data processing tools

- Framework extensions
  - Calculation and logging of physical variables (speed, distances, visibility, acoustic pressure levels)
  - Integration of metrics calculation algorithms
    - Noise, visual pollution, safety perception
  - Additional data loaders (population density, ambient noise)
  - Capacity assessment measurement extension
  - Data visualization of a form of heatmaps

- Large-scale simulation scenarios
  - City-scale simulation, up to thousands of drones and million+ of people
  - Trade-off evaluation between airspace capacity (# of flights) vs. environmental and social acceptance

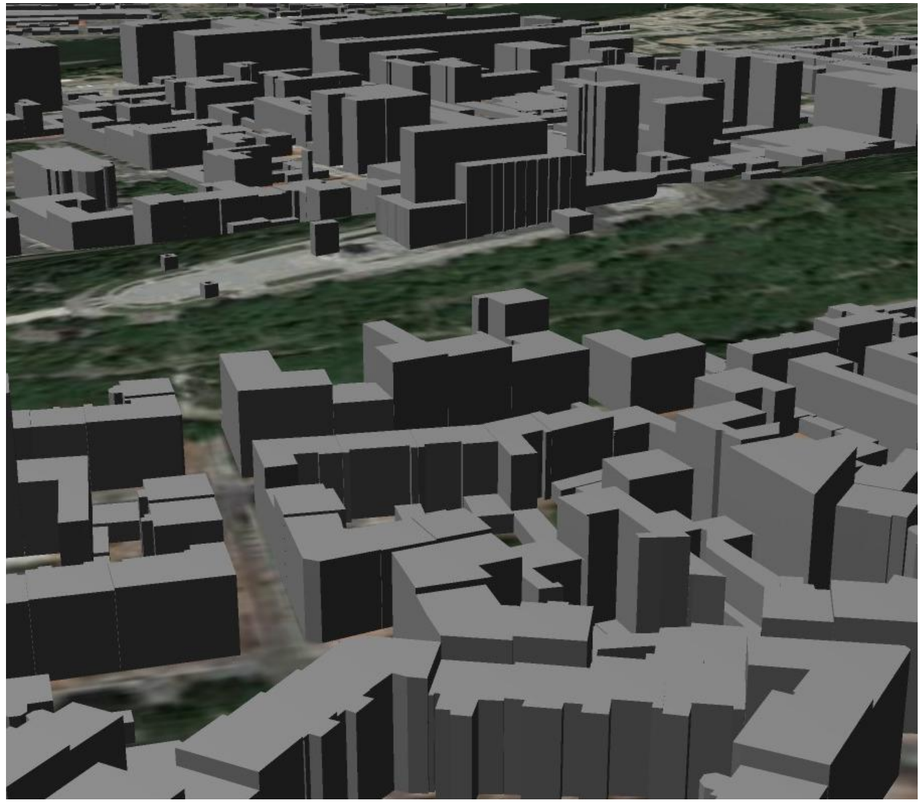
Environment Modeling

- Geospatial data
  - Terrain
  - Buildings/obstacles – OSM
- Airspace structure
  - Zones
- Metrics-related data
  - Population density
  - Urban area classification maps
  - Background noise maps
- Air traffic simulation data
  - Points of interest



Geospatial Models

- Terrain
  - SRTM dataset
- Buildings
  - OpenStreetMap
  - 3DBag (e.g. Delft)
  - Other



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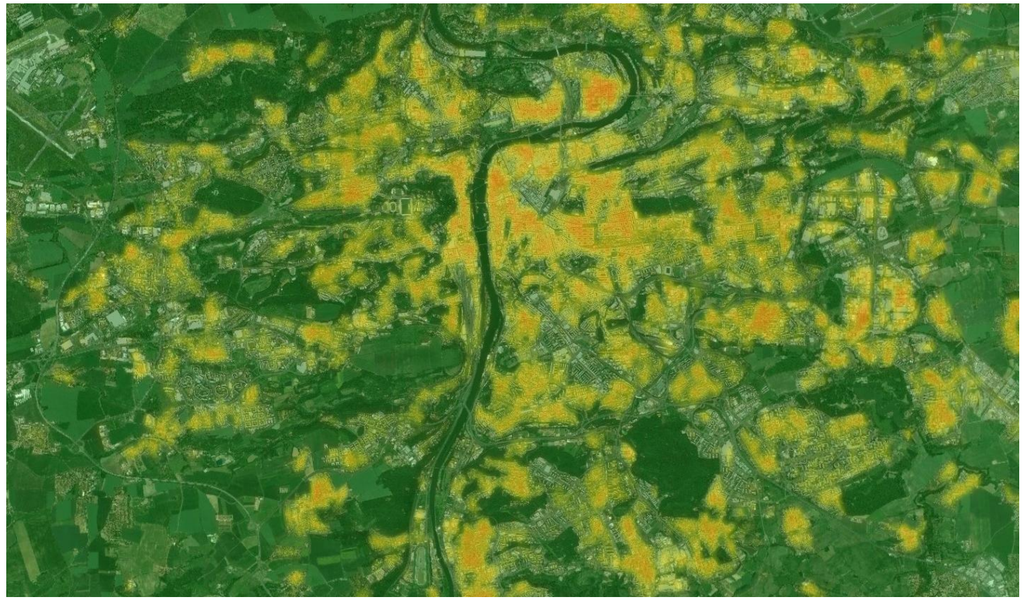
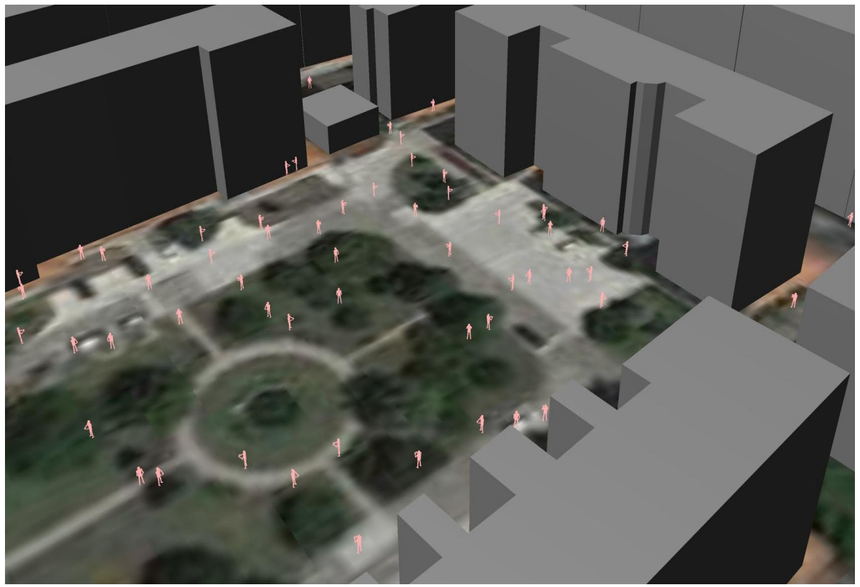
Population Density

- Demographic data
  - Facebook Data for Good
  - Other geo-referenced open datasets

- Individual observer placement
  - Total population (Prague - 1 324 607)
  - Placement inside buildings

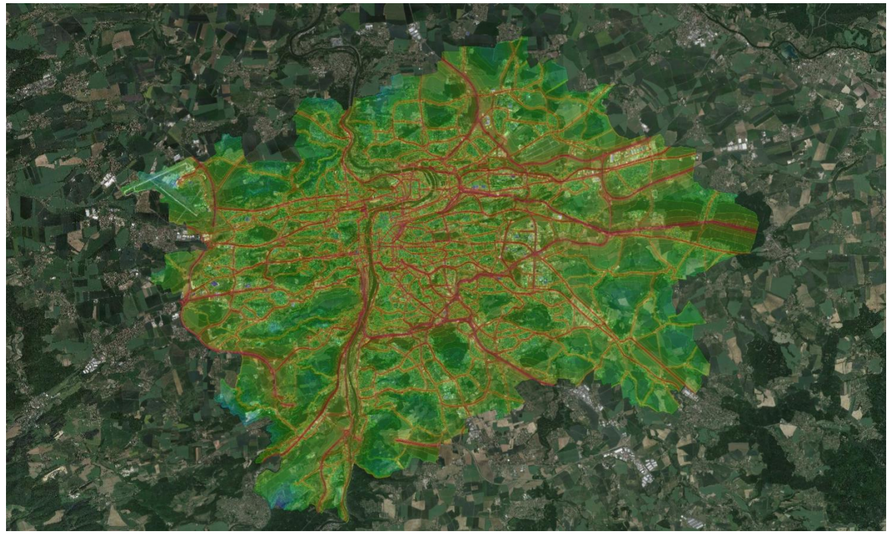


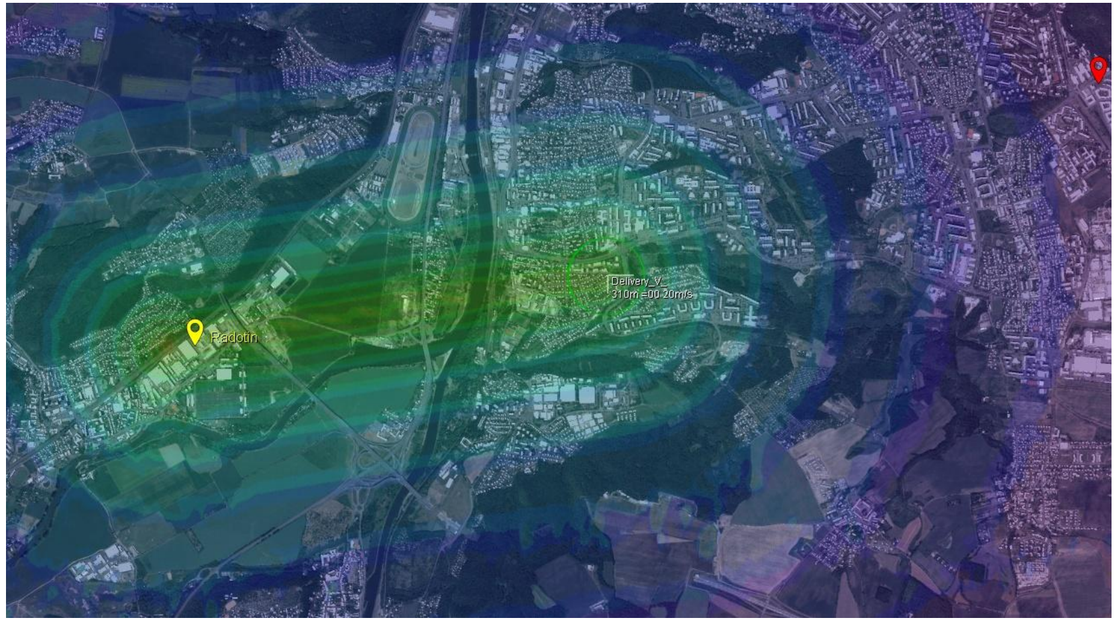


Noise Modeling

- Ambient noise maps
  - Prague city open data portal
  - Daytime and nighttime maps

- Drone noise model
  - 1/3 octave band drone noise spectrum propagation





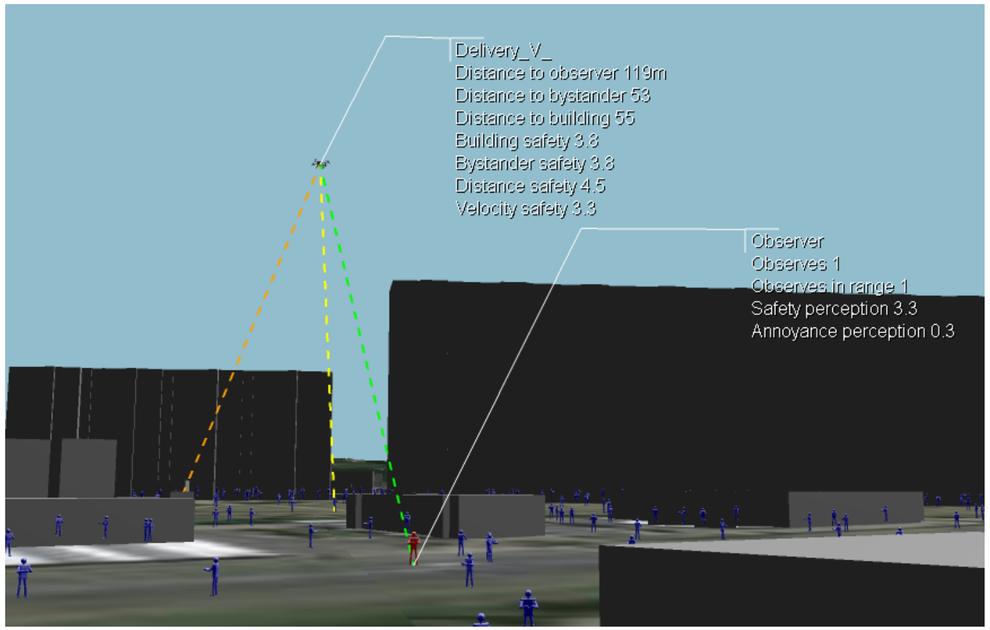
Visual Perception

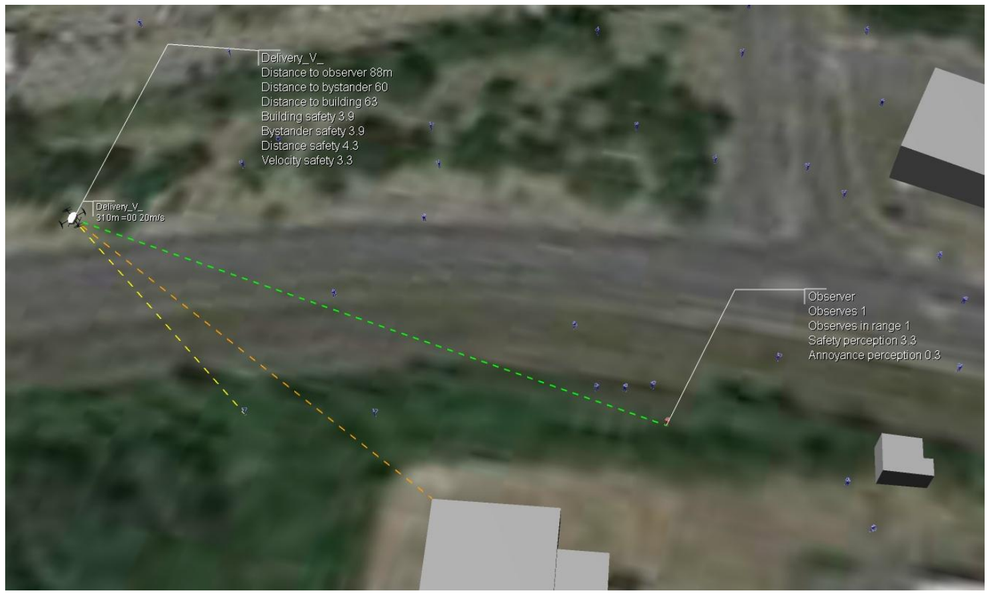
- Observer modeling in a simulation environment

- Metrics calculated for each drone visible by the individual observer
  - Distance of the drone from the observer
  - Relative size of the drone in the observer's field of view
  - Distance of the drone from the closest bystander
  - Distance of the drone from the closest building
  - Distance of the drone from the closest drone
  - Relative perception of drone speed and heading to the observer
  - Relative perception of drone speed and heading to other drones

- Used for visual pollution and safety perception calculation

- Calculated for 1 s intervals

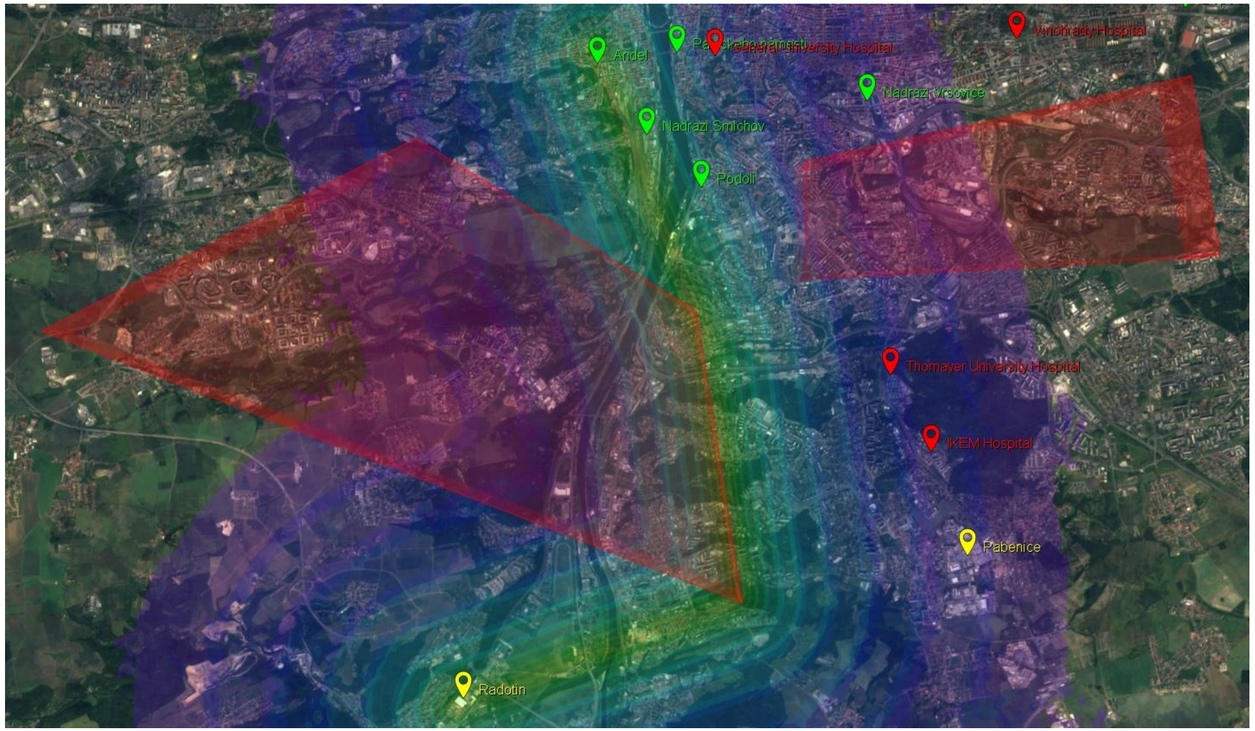




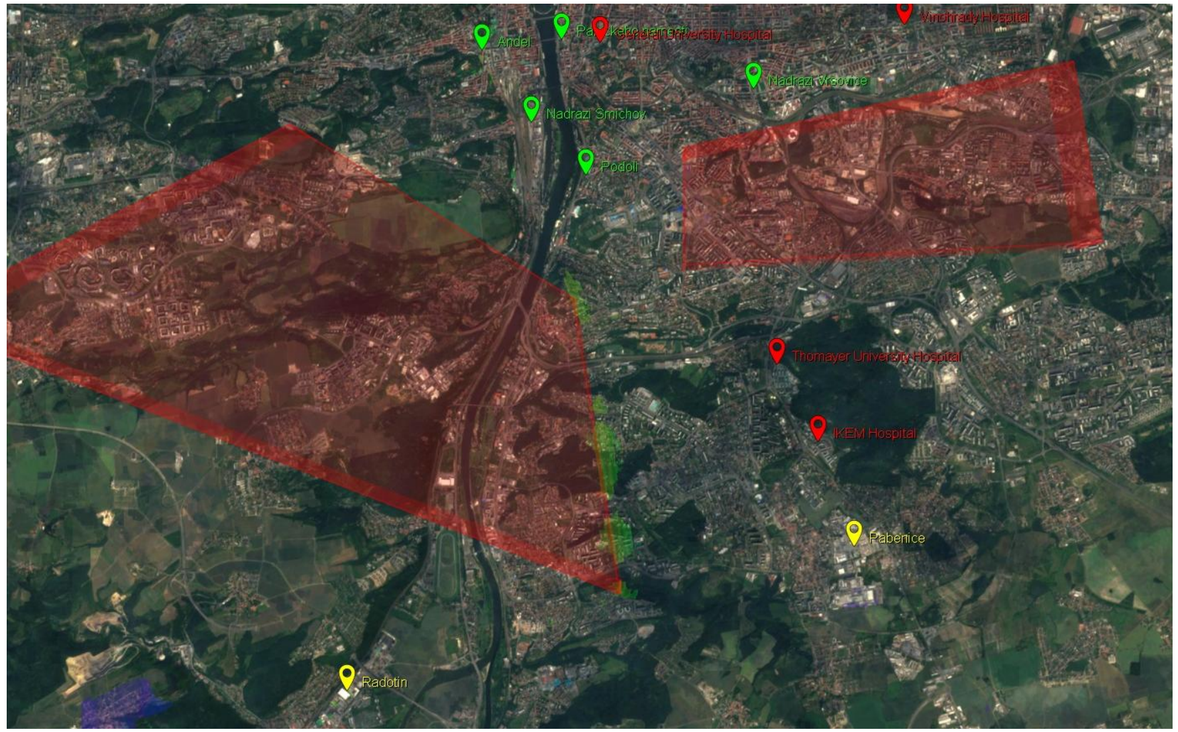
Green line - drone ↔ observer visibility line
Orange line - drone ↔ closest building
Yellow line - drone ↔ closest bystander to drone

Noise – Single Flight Scenario Example

Noise L_{Amax} from the single flight

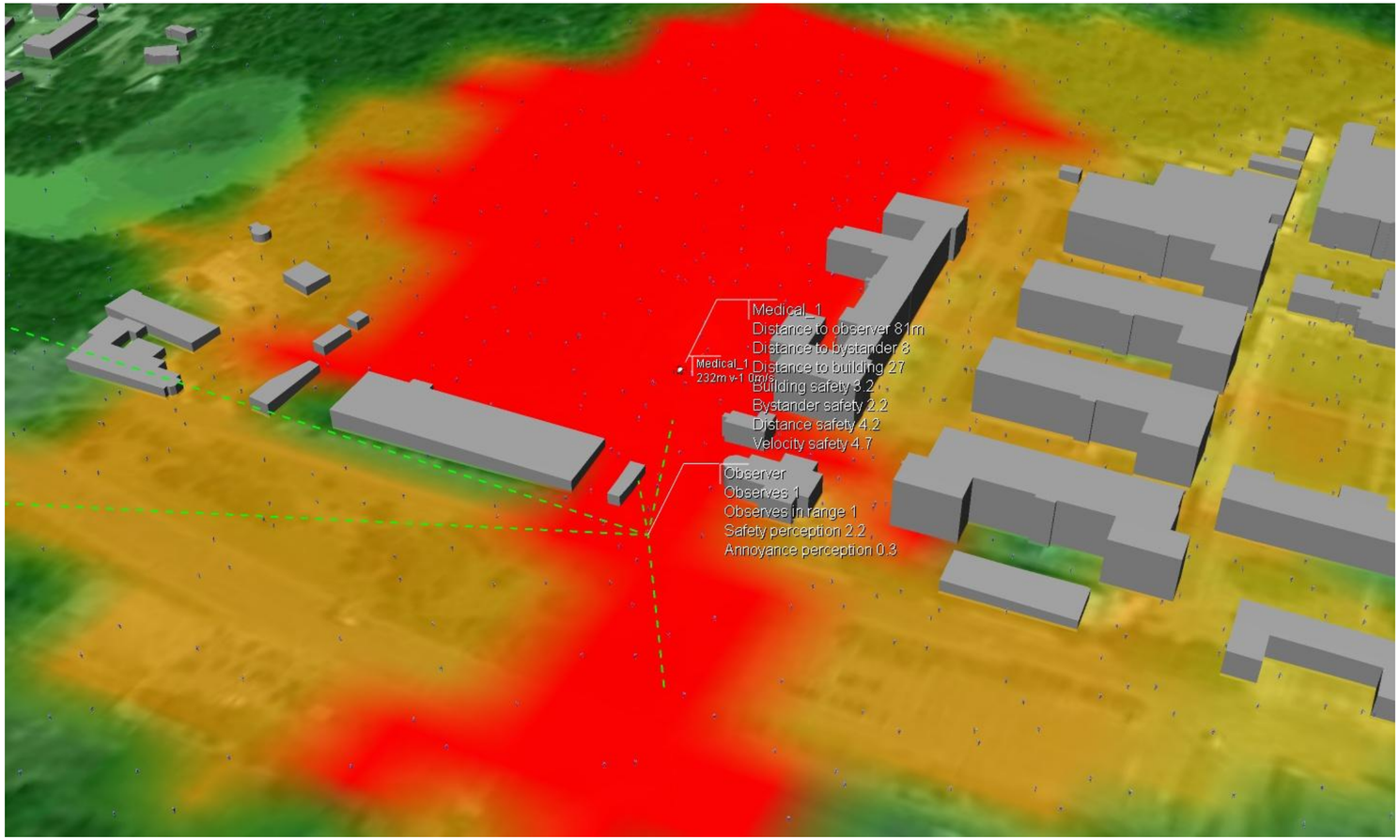


Noise L_{Amax} from the single flight, where it is higher than ambient noise levels



Safety Perception – Single Flight Scenario Example

- View obstruction of the drone safety perception, the most prominent is the distance from the bystander; observers behind buildings can not see the drone landing



Simulation Scenario Definition

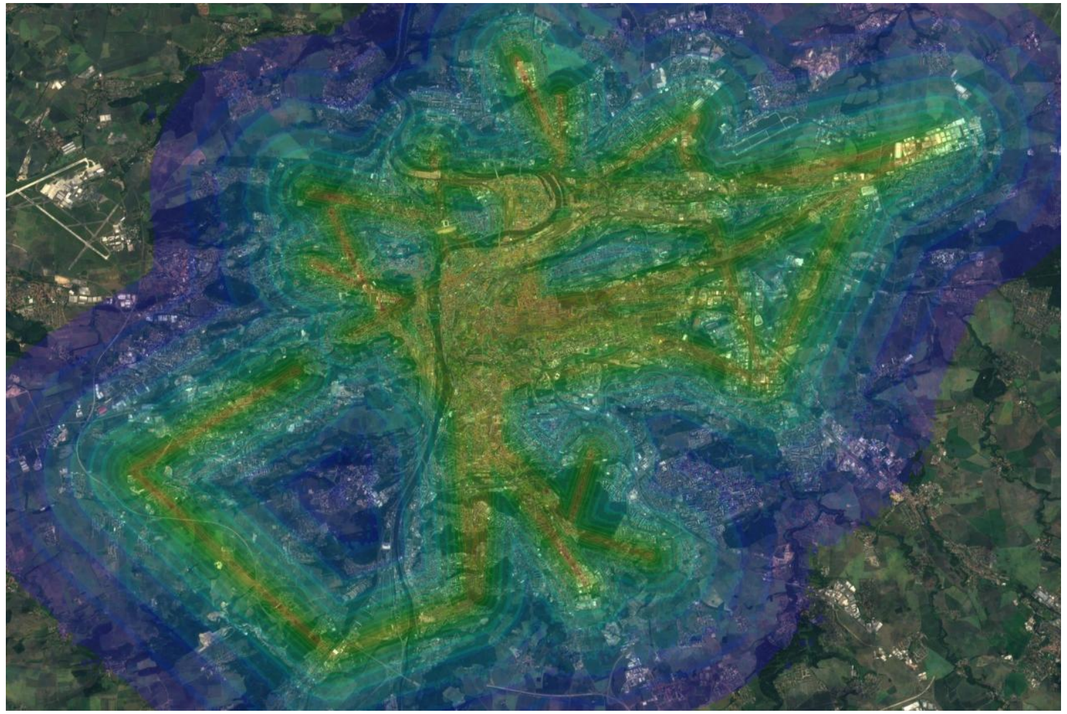
- Environment
  - 3D terrain taken from the open SRTM elevation dataset;
  - 3D modeled buildings based on OpenStreetMap data
  - Ambient noise data for daytime;
  - Population density and number of citizens (1 324 607);
  - Artificially created no-flight zones simulating regulations of UAM traffic;
  - Points of interest (POI) in the form of important traffic nodes, hospitals, and warehouses.

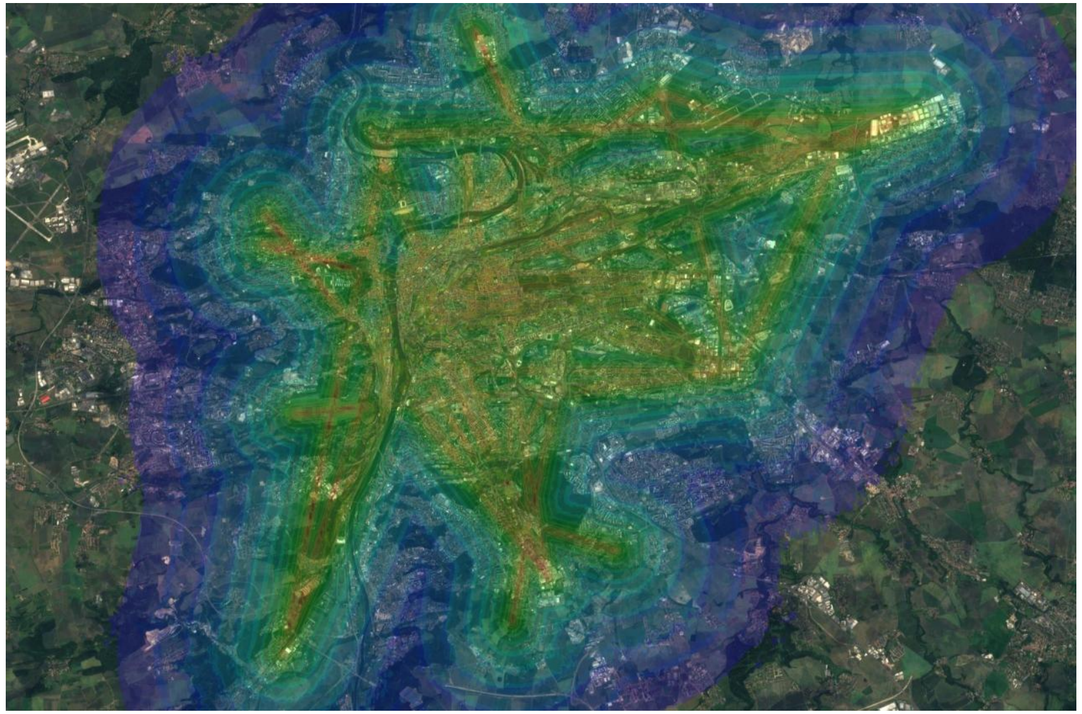
- Traffic generator [- baseline 80 drones/hour
  - Deliveries from warehouses to vertiports at a rate of 10 drones/hour
  - Medical deliveries between hospitals with a rate of 15 drones/hour
  - Cargo flights between vertiports with a rate of 15 drones/hour
  - Deliveries from warehouses to random locations at a rate of 30 drones/h
  - AED drone flights from hospitals to random locations with a rate of 10 drones/hour

- Safety range between drones 80 m, constant cruise speed 15 m/s
- One-layer traffic flying at 310 m AMSL

Simulation Outcomes

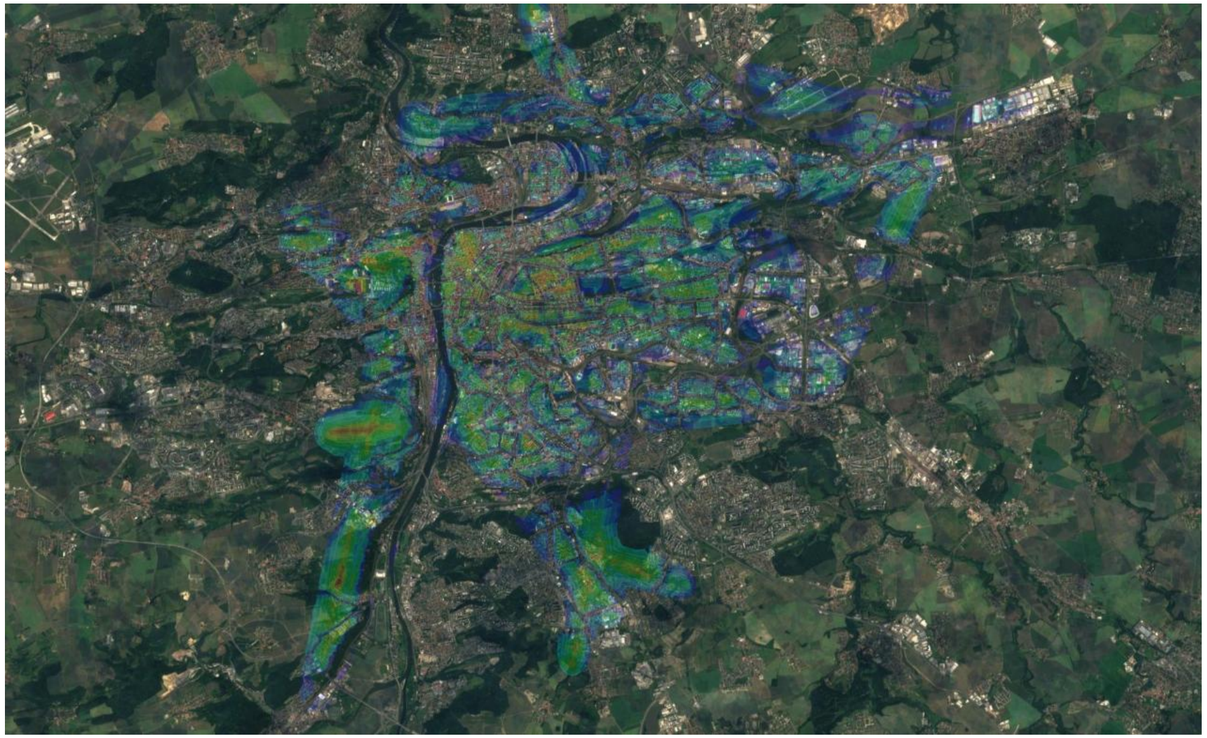
Noise L_{Amax} heatmap, scenario with no-flight zones vs scenario without no-flight zones, 80 drones



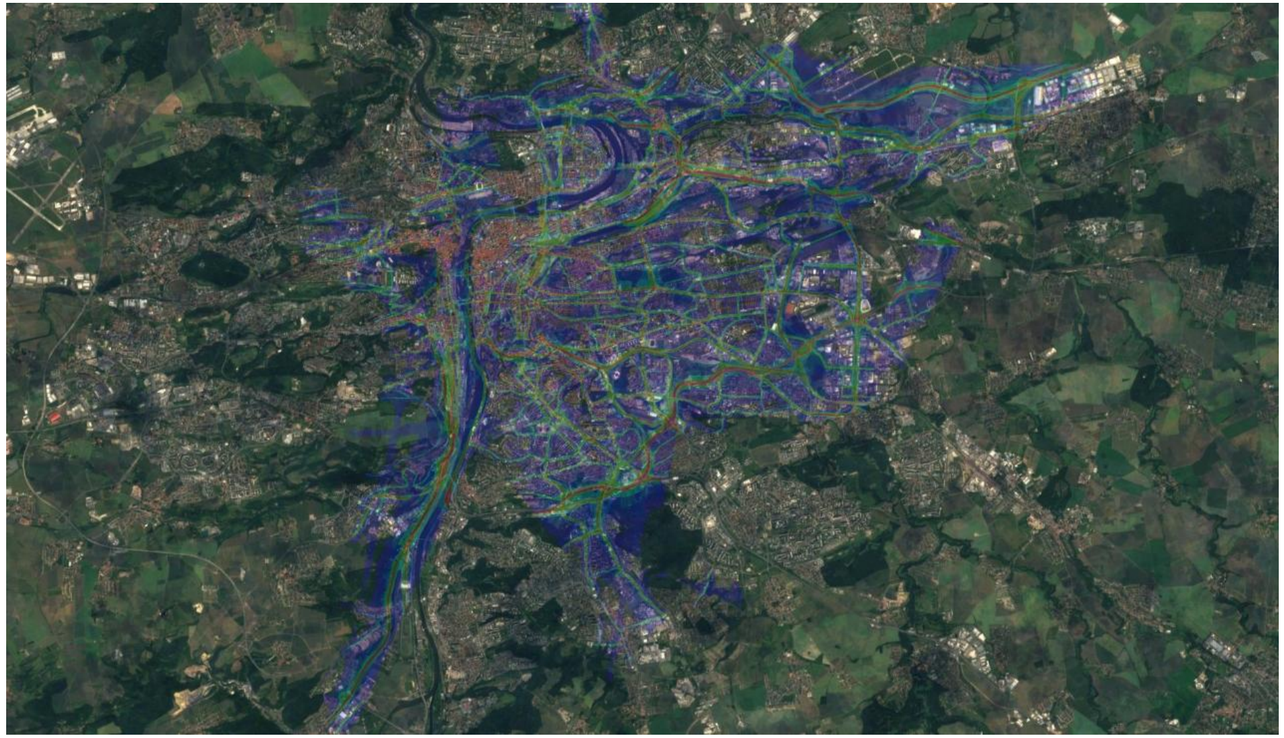


Simulation Outcomes

Mean change in annoyance $\mathbf{\Delta A}$ caused by drone noise, scenario without no-flight zones

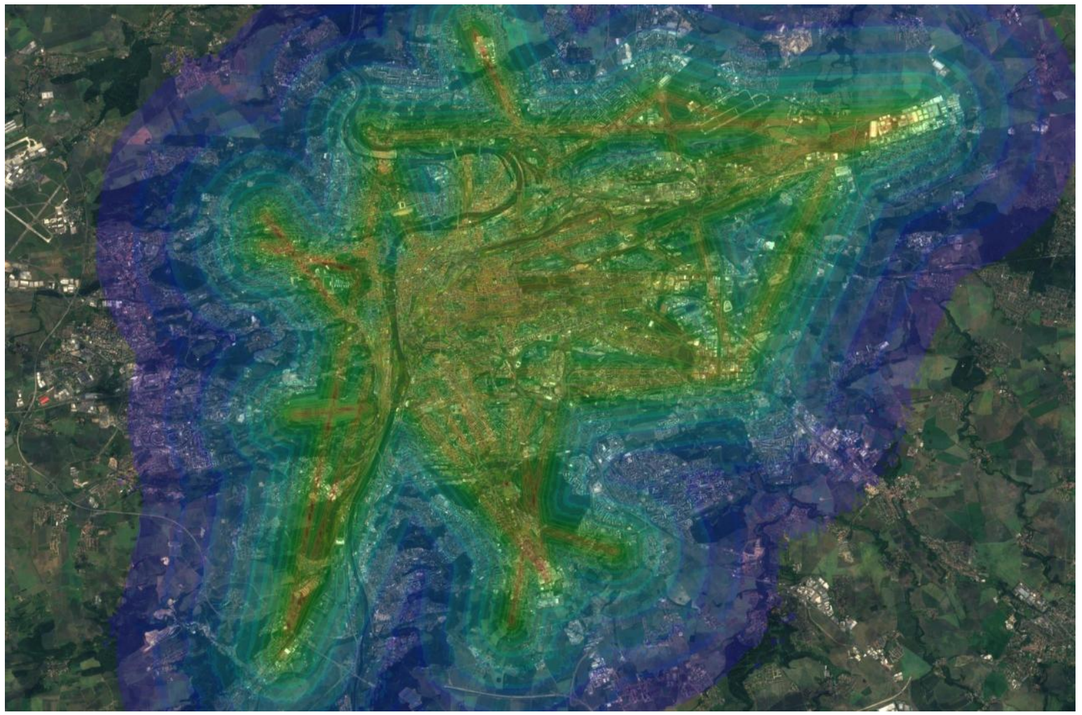


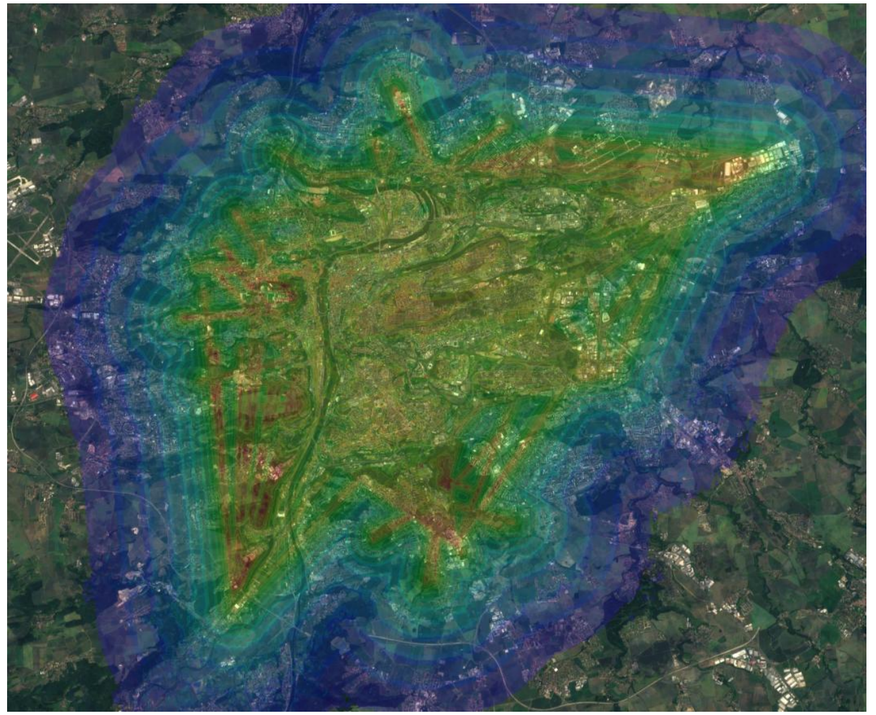
Shift of highly annoyed $\%\mathbf{HA|HAamb}$ caused by drone noise relative to ambient noise, scenario without no-flight zones



Simulation Outcomes

Noise L_{Amax} heatmap, scenario with 80 drones vs 400 drones



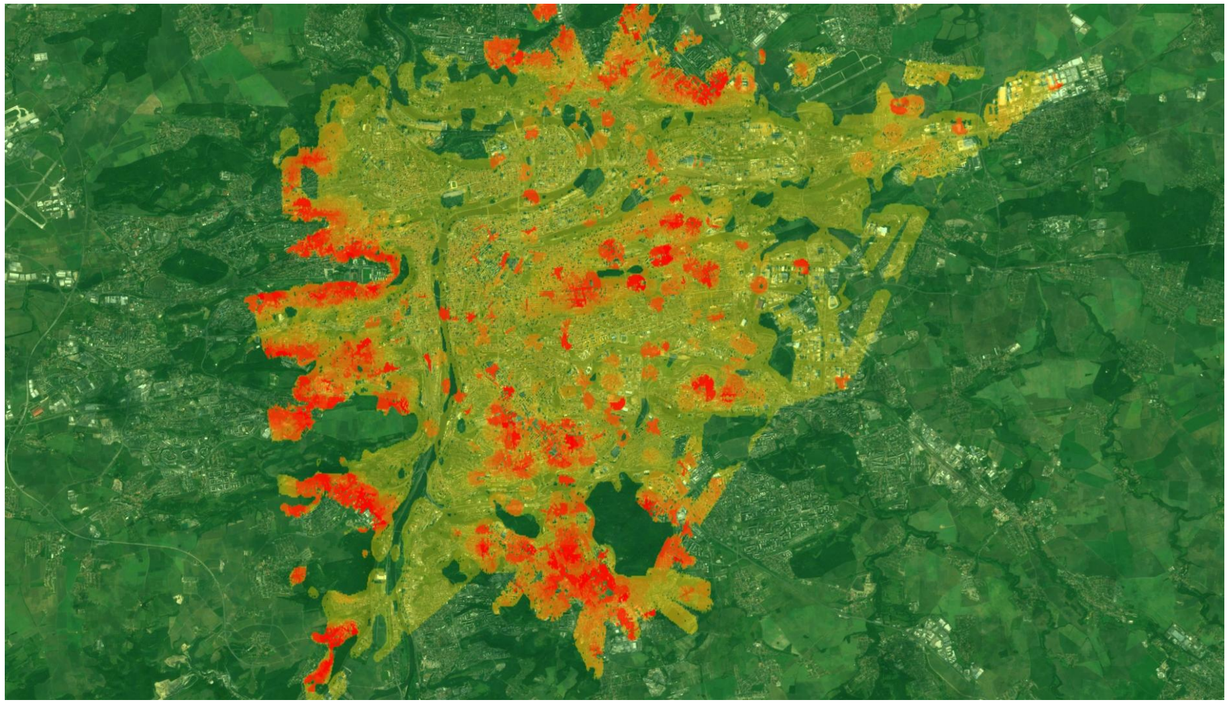


Simulation Outcomes

Visual annoyance heatmap, scenario with 80 flights vs 1600 flights

Simulation Outcomes

Safety perception heatmap, scenario with 80 flights vs 1600 flights



Conclusion and Future Work

- Powerful simulation framework
  - Capability to simulate air traffic and measure various metrics
  - Support for airspace capacity assessment studies – trade-off analysis
  - Data analysis and visualization tools

- Future work
  - Adjustment of indicators for higher traffic volumes (e.g., VR simulations for large-scale traffic)
  - Merging of various metrics and indicators together into a unified parameter (e.g., the aggregation value of all the safety indicators)
  - Aggregation of indicators over the area where multiple observers are located (e.g., one observer with high impact perception vs. multiple observers with medium impact perception)
  - Aggregation of indicators over time (e.g., multiple events with low impact vs. one event with high impact)

  - Additional data sets
    - Drone noise models
    - High-fidelity 3D models
  - Environmental factors modeling
    - Wind, doppler effect

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thank you for your attention!

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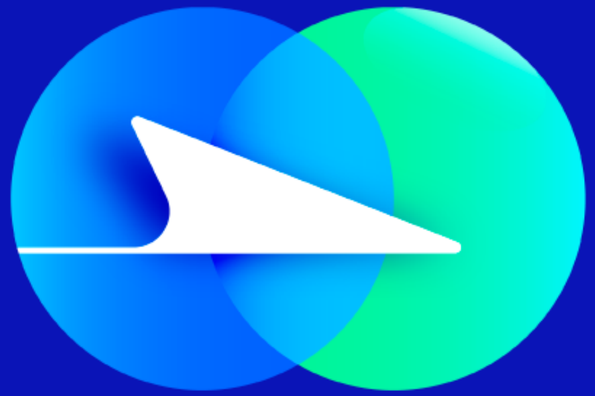

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