DACUS

UAV collision risk as part of U-space Demand and Capacity Balancing

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Introduction

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The DACUS project

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Continuous Demand and Capacity Balancing process for U-space

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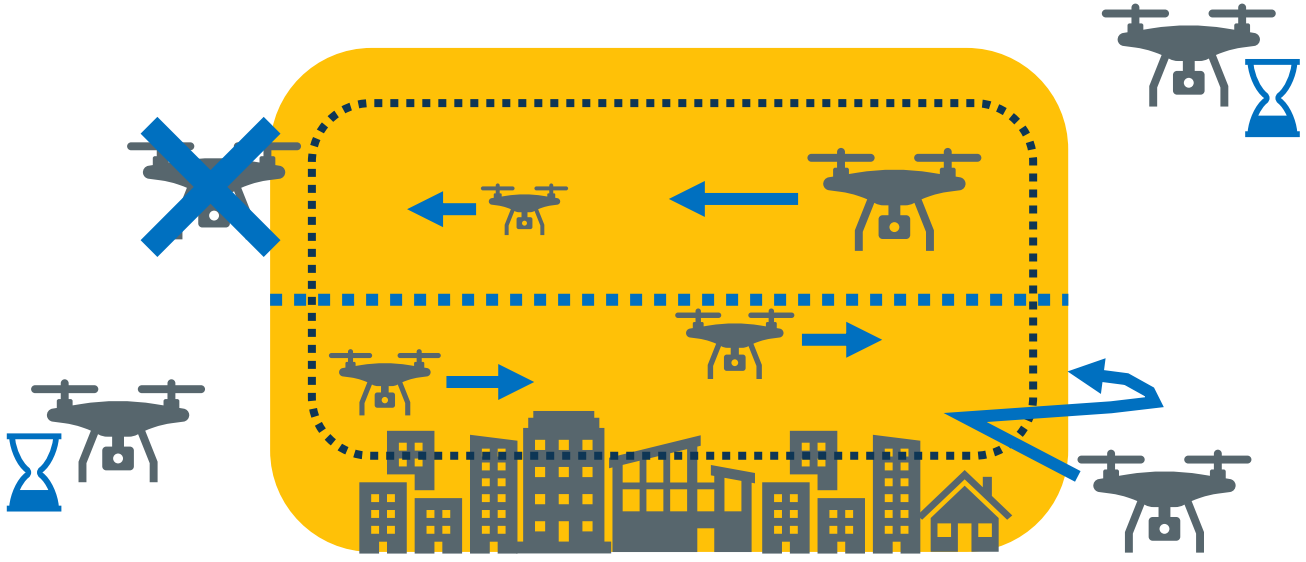
U-space DCB concept

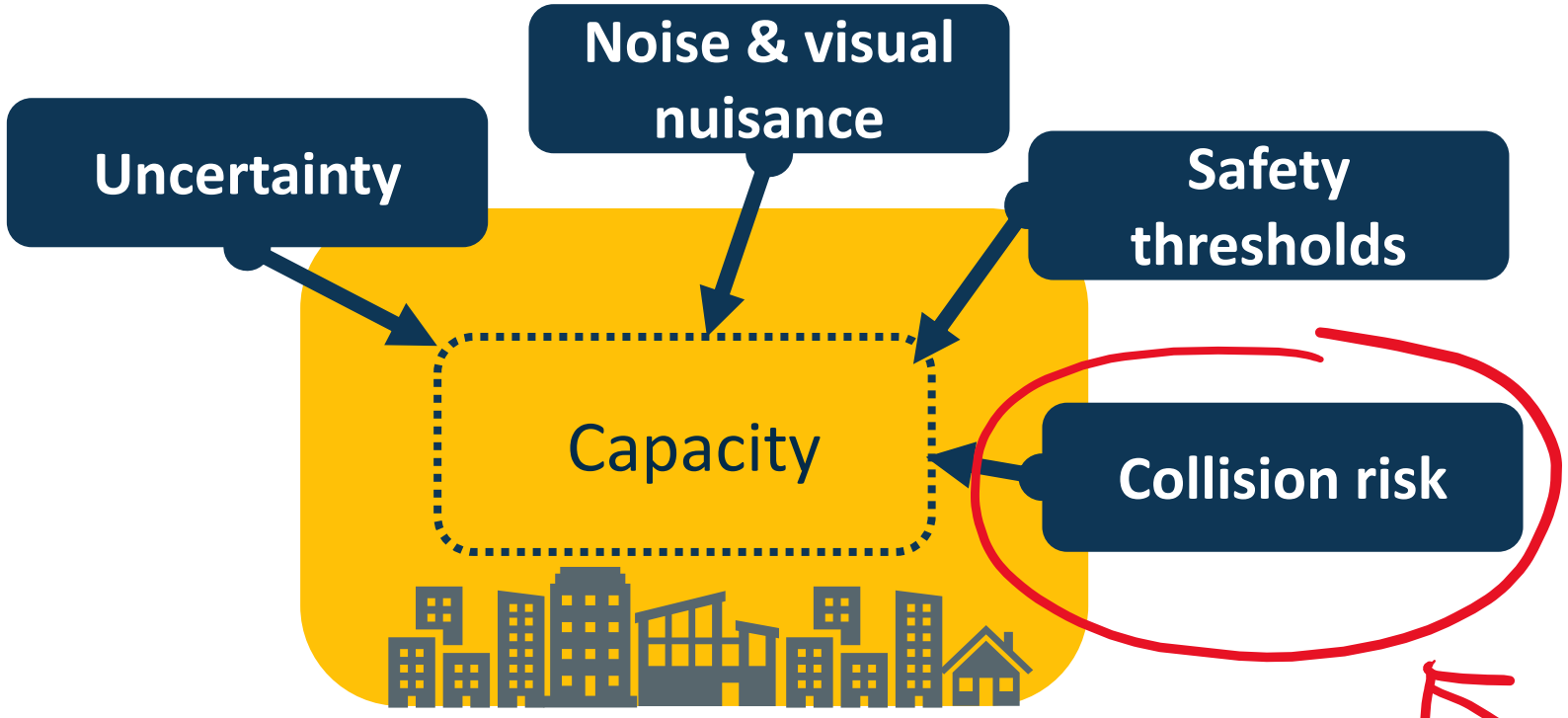


Principles:

- Maintain target level of safety (1E-6 fatalities per flight hour)
- Minimize restrictions
- Prioritize mission objective fulfilment

More info on the DCB concept in the DACUS DCB ConOps:
https://dacus-research.eu/wp-content/uploads/2021/03/DACUS-D1.1-Drone-DCB-concept-and-process_01.00.00.pdf

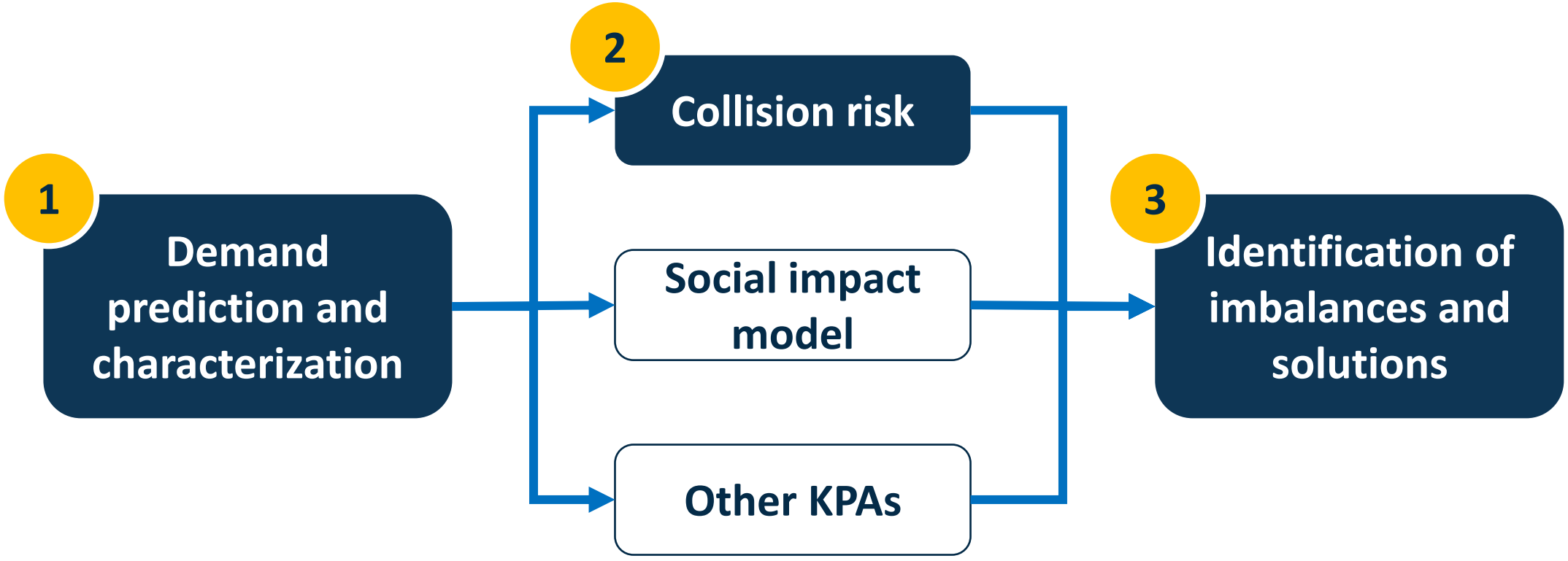
Defining U-space capacity



- DACUS is modelling this process in a series of simulations
- Role of “collision risk” is the emphasis of our paper

More info on the DCB concept in the DACUS DCB ConOps:
https://dacus-research.eu/wp-content/uploads/2021/03/DACUS-D1.1-Drone-DCB-concept-and-process_01.00.00.pdf

Detecting risk-based capacity imbalances

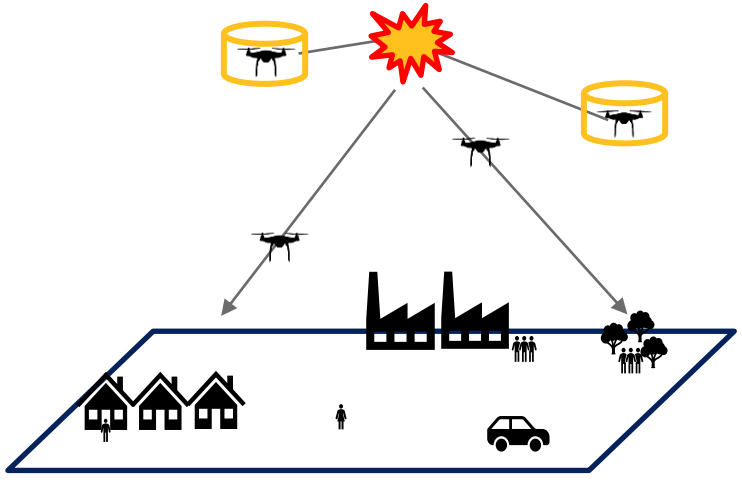


More info on this process is provided in the DACUS Separation Management Process Definition:
https://dacus-research.eu/wp-content/uploads/2021/09/DACUS_D5.2_Separation-Management-Process.pdf

Developing a risk model

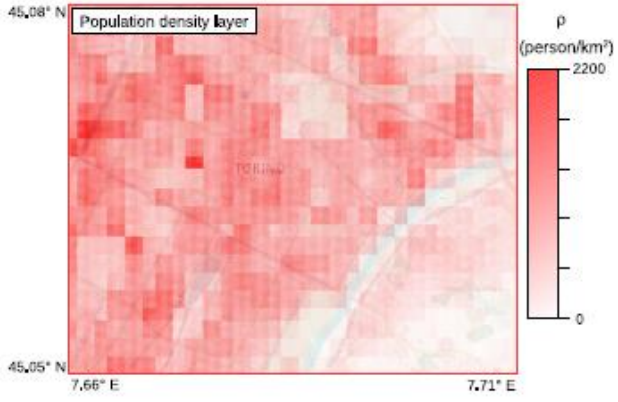
Probability of fatal injuries to third parties on the ground = **Collision + failure risk** × **The probability of injuring person due to a collision** × **The probability of the injury evolving into a fatality**

SORA (JARUS): TLS=1E-6 fat./FH



Based on:

- Population density map
- Sheltering factor
- Kinematic energy
- Failure probability (MTBF)
- Collision risk probability



https://sedac.ciesin.columbia.edu/data/set/gpw-v4-population-density-rev11/data-download

https://land.copernicus.eu/pan-european/corine-land-cover/clc2018

Experiment setup and objectives

The proposed setups combine different factors in order to analyze the impact of each one of them on the overall fatality risk. The objectives of these setups are to evaluate the impact of:

Tactical Conflict Resolution Service (U-Space)	Positioning Update Rate	Navigation Accuracy	Overflown Area
2 setups tested: **Without U-Space**: All potential collisions will occur **With U-Space**: Some of the collisions can be **detected and avoided** It depends on **Positioning update rate and Navigation accuracy**	How often the position of the UAV is reported **3 setups tested:** - Every **1 second** - Every **3 seconds** - Every **5 seconds**	Navigation error in reported position **2 setups tested:** - **GPS L1:** $\sigma_{x,y} = 1.63\ m \mid \sigma_z = 2.55\ m$ - **GPS SBAS:** $\sigma_{x,y} = 1.02 \mid \sigma_z = 1.1\ m$	Population density and shelteting factor of the area **Various setups tested:** **-Big cities** **-Medium cities** **-Small cities** with **low**/**med**/**high** SF

Experiment scenarios – Results

- **Scenario 1**: Collision Risk reduction with U-space Tactical Conflict Resolution service.

RESULTS

Collision Risk [coll/FH] GPS + SBAS for different Update Rates

Update Rate	Without U-space system (Potential collisions)	With U-space (Non-avoidable collisions)
1 s	3.41E-02	2.86E-03
3 s	3.44E-02	4.68E-03
5 s	3.40E-02	7.60E-03

Without U-Space system: No tactical conflict resolution so all the potential collisions will occur

With U-Space system: The higher the update rate, the lower the collision risk

Experiment scenarios – Results

- **Scenario 2**: Impact of Navigation Accuracy on the Conflict Detection Rate and the remaining collision risk.

RESULTS

	Collision risk for 1s update rate [coll/FH]		*% of undetected collisions*		*False conflicts per FH*	
Conflict Margin	GPS L1	GPS+SBAS	GPS L1	GPS+SBAS	GPS L1	GPS+SBAS
3 m	2.33E-02	1.21E-02	63%	24%	0.122	0.107
5 m	1.32E-02	3.78E-03	26%	2%	0.353	0.33
10 m	3.93E-03	3.83E-03	2%	1%	1.465	1.467

Several highlights:

1. Collision Risk decreases with SBAS augmented GPS compared to GPS L1 **but**
2. When Margin of Conflict increases, the improvement introduced by SBAS is attenuated compared to GPS L1
3. The percentage of undetected collisions is drastically reduced when Conflict Margin increases **but**
4. High Conflict Margins imply high rates of False Conflicts

Experiment scenarios – Results

- **Scenario 3:** Fatality risk and maximum capacity in different overflown cities with and without UTM system

RESULTS

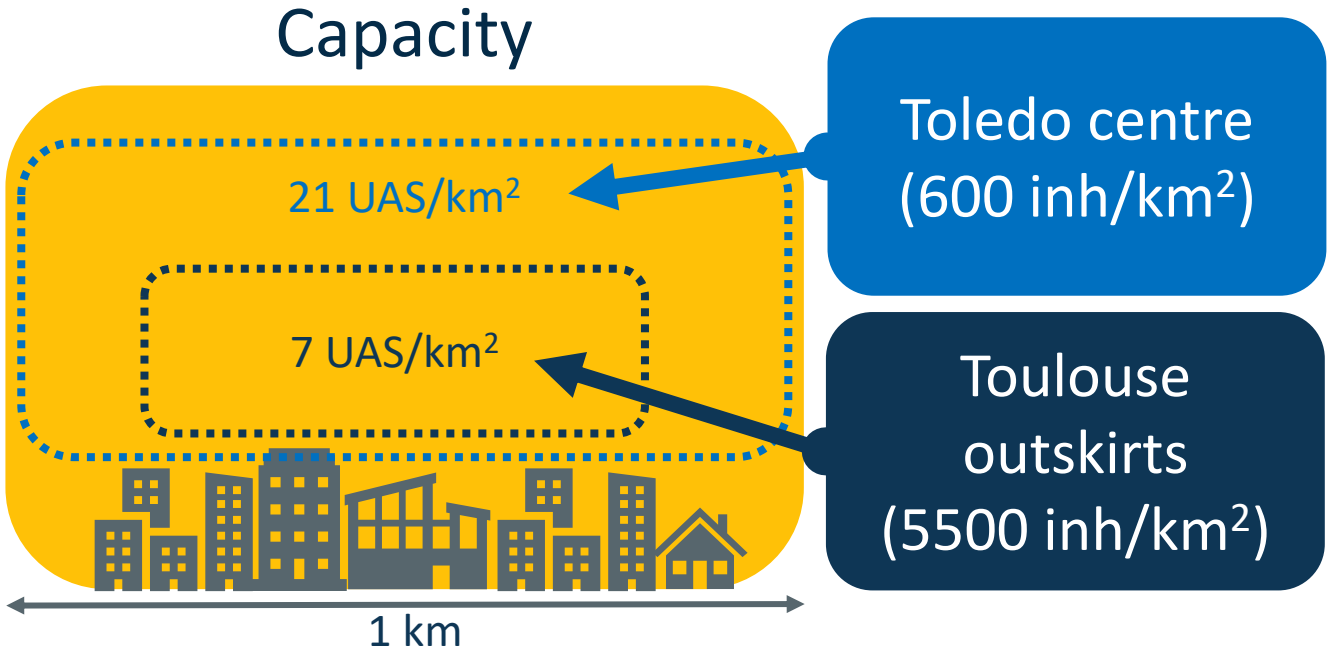
Below TLS (1E-6)

Environment	Without UTM			GPS L1 1s/5m			GPS SBAS 1s/5m		
	7 UAS/km2	14 UAS/km2	21 UAS/km2	7 UAS/km2	14 UAS/km2	21 UAS/km2	7 UAS/km2	14 UAS/km2	21 UAS/km2
Madrid City Centre	2.56E-05	4.6E-05	7.2E-05	5.98E-06	1.50E-05	2.87E-05	2.66E-06	6.98E-06	8.20E-06
Toulouse City Centre	1.14E-05	2.06E-05	3.22E-05	2.68E-06	6.69E-06	1.28E-05	1.19E-06	3.12E-06	3.67E-06
Toulouse Outskirts - Industrial	9.6E-06	1.73E-05	2.7E-05	2.24E-06	5.61E-06	1.08E-05	9.96E-07	2.62E-06	3.08E-06
Toledo Outskirts	3.37E-06	6.06E-06	9.48E-06	7.88E-07	1.97E-06	3.78E-06	3.50E-07	9.19E-07	1.08E-06
Toulouse Outskirts - Residential	1.89E-06	3.39E-06	5.31E-06	4.41E-07	1.10E-06	2.11E-06	1.96E-07	5.14E-07	6.04E-07
Toledo City Centre	1.57E-06	2.82E-06	4.41E-06	3.66E-07	9.16E-07	1.76E-06	1.63E-07	4.27E-07	5.02E-07
Toledo Rural	4.64E-07	8.35E-07	1.31E-06	1.09E-07	2.71E-07	5.21E-07	4.82E-08	1.27E-07	1.49E-07

Global results

- **Providing tactical deconfliction** reduces collision risk substantially
- **1-second update rates** substantially increased conflict prevention
- A **higher position accuracy ($\sigma \approx 1$m)** implied a larger number of potential conflicts detected
- **SBAS augmented GPS** allows for the lowest overall collision risk within the 5 to 10-meter conflict margin range.
- The sweet-spot between UAV position accuracy and false conflict detection is at a **conflict margin of 5 meters**.

Discussion



Limitations:

- Only considers collision risk
- Only considers small UAS
- No DCB processes in place (e.g. strategic de-confliction, airspace structuring)

Verdict: Use these values as a baseline for DCB processes

Outlook

Results can be refined by incorporating:

- On-board collision avoidance schemes
- Strategic deconfliction of trajectories
- Airspace structures
- Multiple UAV types and UAM vehicles
- General aviation
- More refined risk modelling methods
- Varying separation standards
- Wind and precipitation effects
- U-space system performance

Addressed in on-going DACUS experiments

Final results expected by mid 2022

THANK YOU FOR YOUR ATTENTION

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Further information about DACUS: https://dacus-research.eu/