Rule-based Separation for Dynamic Airspace Management

A study on separation and traffic organisation to support drone demand and capacity optimisation in U-space

White Paper| July 2021

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DACUS

SESAR JOINT UNDERTAKING

The following White Paper is based on the results of a Master's Thesis with the title "Development and Evaluation of a Concept for Rule-based Airspace Management in Low-level Airspace" by Ramón Meyer auf der Heide conducted at Technical University Darmstadt 2020/2021. The thesis work is based on the research performed by DACUS, a U-space exploratory research project.

Motivation

In 2020, there was hardly any commercial UAV traffic above cities, most of it being proof of concepts. However, by 2050 about 400,000 (BMVI 2019) commercial drones are expected. To handle the high number of expected drones, a flexible and resilient airspace management has to be developed. Specifically, in DACUS, new mechanisms that can enable the future balancing of demand and capacity are analyzed, through efficient and safe management of drone traffic and low-level airspace (DACUS Project 2021). The aim of the Master's thesis is to evaluate solutions for the traffic organisation of drones in support of dynamic airspace management in order to reduce the number of conflicts through focused strategic separation. Considering related research activities and recognizing the ongoing regulatory development, multiple separation rules have been developed and compared. Finally, the implications of implementing these rules are discussed.

State of the Art

To handle the amount of expected traffic, research has been conducted on current research projects on drone separation. A current research project is the bubbles project that develops separation minima and conflict resolution algorithm (Bubbles Project 2021). However, this research has concentrated on separation rules one step before this, meaning to develop an airspace management system that will lead to less conflicts that need to be resolved. Comparable research was conducted by the Altiscope Project (Altiscope 2018) and Metropolis Project (METROPOLIS Project 2015). At the same time the regulatory process is ongoing to create the regulations as a basis for drone operations above cities. At the basis of the Final Model UAS of the ICAO, the European Commission has implemented the Open, Specific and Certified Class. However, only the Open and Specific Class are regulated yet. The certified class will follow in the future. At the time this research was conducted, no regulation regarding the U-Space was published, only a draft from the EASA existed (EASA 2020). As a result, this draft was considered as a regulatory basis regarding U-Space operations. However, in the meantime the corresponding implementing regulations were published.

Methodology

The separation rules were developed to accommodate the high number of expected drones and these shall adhere to a defined airspace structure. Prior research showed, that a horizontal separation, like it could be done with airways, is not suitable (METROPOLIS Consortium 2015). Separating aircraft in a timely manner (like assigning time windows) could pose a great challenge for certain mission types in the strategic phase when the operators are required to define their flight plans with a high level of certainty. With this considerations in mind, only a strategic separation of the aircraft in the scope of a traffic organisation using vertical layers was further considered.

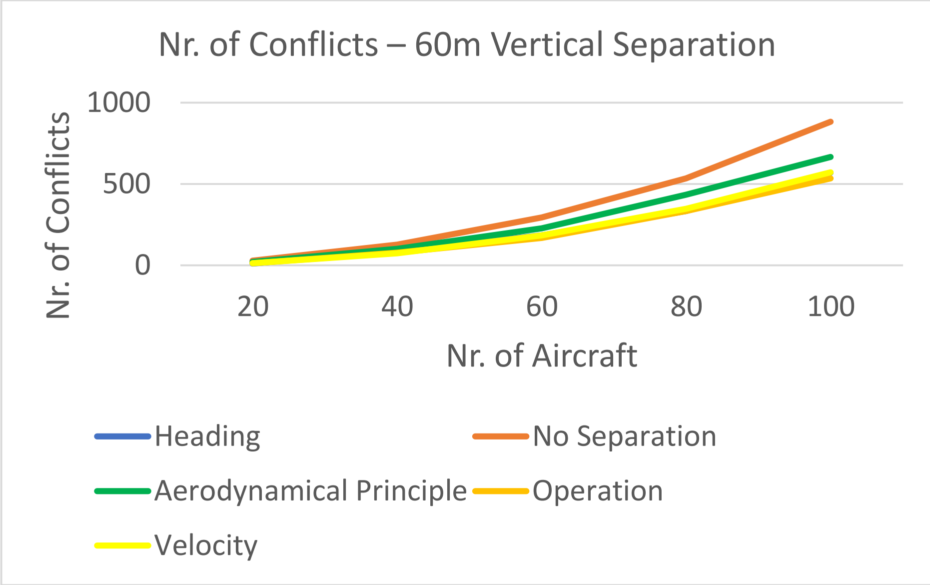
The parameter that serves as a separation criterion is either flight parameters or the priority of operation, that was introduced in the draft of the U-Space regulation. Afterwards these separation rules were investigated by the means of a dedicated simulation model, where different numbers of aircraft were placed randomly in the model volume and flew their assigned flight path. As a metric served the number of conflicts and for the ease of conflict resolution the number of aircraft near a conflict. Flight durations of 30 minutes were considered. Afterwards a refined simulation model was developed that took also take-off and landing as well as fixed routes into consideration. The separation rules were compared with a benchmark without any separation regime.

Parameter	**Heading**	**Velocity**	**Operation**	**Aerodynamical Principle**
Separation Rule	Height assignment to a layer according to the flown heading	Height assignment to a layer according to the flown velocity	Height assignment according to the priority of operation	Separate rotorcraft and fixed wing aircraft to different height bands
Airspace Structure Principle	Layering Principle	Layering Principle	Layering Principle	Choice of height within a band

Separation Regimes

As a first parameter to assign the height, the heading was chosen, as the approach speed between two aircraft becomes smaller the smaller the angular difference is. With small angular difference between the aircrafts, only small changes in the heading is needed to avoid a conflict. The next parameter is the flown velocity. Aircraft that fly at a slower velocity have a smaller safety volume demand as approaching speeds are smaller and conflicts can therefor be anticipated better. This results in the possibility to pack slower aircraft denser in the assigned layer.

In contradiction aircraft have a higher safety volume demand if flying at higher velocities and can therefore not be packed at the same density. The next examined separation parameter is the aerodynamical principle as fixed wing aircraft have a minimum velocity whereas rotorcraft aircraft do not have a minimum velocity and also a higher manoeuvrability. Therefore other conflict resolution mechanics can be implemented for rotorcraft aircraft as for fixed wing aircraft. The last separation parameter is the conducted operation. The U-Space draft of the EASA has prioritized different types of operations. With this separation rule the higher prioritized aircraft have layers that are reserved for them and the lower prioritized aircraft do not have to change their flight plans this often as they operate within their own layer.

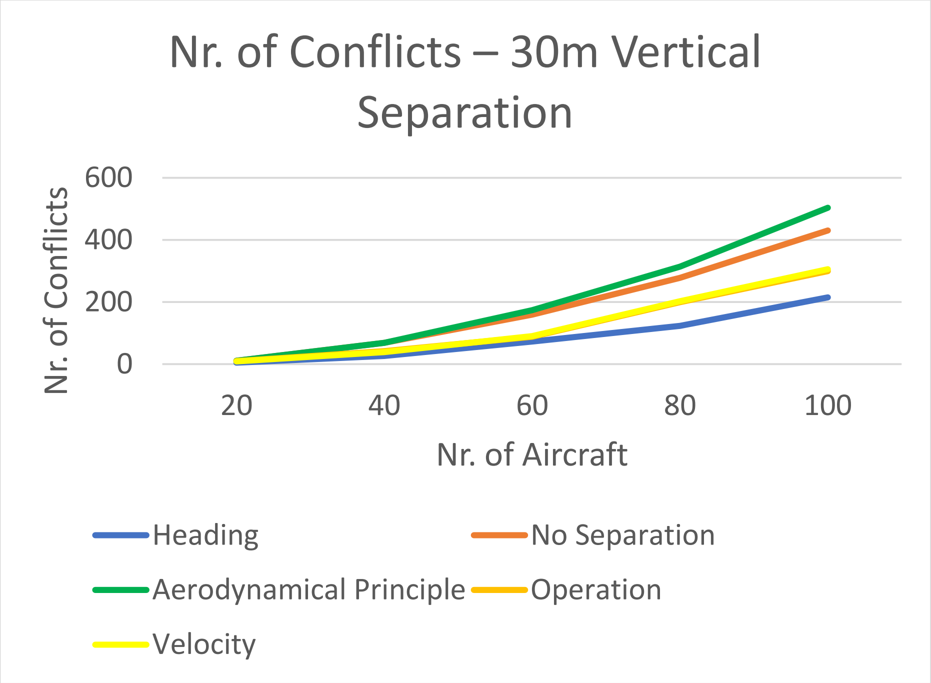


First Simulation

Initially, the number of conflicts were analysed with the help of the simulation model that will result in applying each separation rule. Within this model all aircraft were placed randomly and a randomly heading was assigned to each aircraft. It was assumed, that all operators are able to keep their flight plans as accurate as 120s.

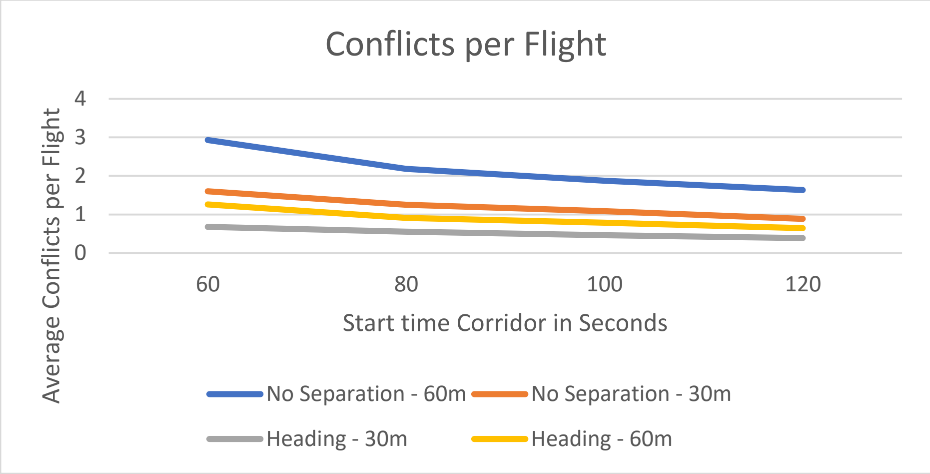
Within this simulation it was shown, that a height assignment using a defined airspace structure (layering principle) lead generally to less conflicts compared to a free choice of height as possible with no separation or the assignment to a height-band. Two different vertical separation requirements were analysed. With a vertical safety demand of 60m it was possible to implement 4 layers and with a vertical safety demand of 30m it was possible to implement up to 8 layers.

It is shown that with eight layers the heading performs better than the other layering principles, as the angular differences between the aircraft within a layer became even smaller.



Refined Simulation

As the layering principle, especially the heading, prove beneficial, this separation rule was analysed in a refined simulation model and compared to the benchmark without separation. In this refined simulation model also the take-off and landing capacities were taken into account. With respect to the number of conflicts the separation according to the heading resulted in less conflicts. However, the take-off capacity was not affected by the separation rule. An important finding is, that with a horizontal separation requirement of 200m, the take-off capacity was reduced significantly above a density of around 2.15 aircraft per square kilometer.



Conclusion

The results show, that a vertical separation according to the layering principle is advantageous with respect to the number of conflicts compared to a free choice in height. If the minimum vertical separation is allowing to implement more than 4 layers then the heading promises the least conflicts and the easiest conflict resolution. However, the departing and landing procedure needs to be refined with considering different performance procedures. Additionally, more possible landing sites could be investigated, as drones could maybe, with higher advanced SAA, land in more places like backyards or public sites. Also, a dynamic safety volume surrounding each drone should be implemented. Additional research has to be conducted regarding the height of the layers. Here the question has to be clarified whether drones shall follow the height of the artificial obstacles and geography or if they shall be installed in a particular height, that is not affected by the ground levels. Maybe different solutions, for different urban areas could be more convenient.

Afterword

The solutions presented in this White Paper have been developed using as starting point the concepts generated by the DACUS research project. The DACUS project addresses, among others, procedural and tactical separation schemes that can be applicable in a future dynamic capacity management process in U-space, serving an overall balancing of the heterogeneous drone traffic demand in urban environments with the capacity of the low-level airspace.

For more information on the DACUS research please contact: info@dacus-research.eu.

Acknowledgement

The underlying Master's thesis of this White Paper has been conducted by Ramón Meyer auf der Heide and was supervised by Michael Büddefeld and Hugo Eduardo at Technical University of Darmstadt, a member of the DACUS Consortium .

DACUS has received funding from the SESAR Joint Undertaking under grant agreement No 893864 under European Union's Horizon 2020 research and innovation programme.

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