Innovative time-based separation procedures for civil RPAS integration

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Abstract

Purpose – This paper aims at suggesting feasible solutions to overcome the problem of unmanned aerial vehicles integration within the existing airspace.

Design/methodology/approach – it envisages innovative time-based separation procedures that will enhance the integration in the future Air Traffic Management (ATM) system of next generation of large remotely piloted aircraft system (RPAS). 4D navigation and Dynamic Mobile Area (DMA) concepts, both proposed in the framework of Single European Sky ATM Research (SESAR) program, are brought together in order to hypothesize innovative time-based separation procedures aiming at promoting integration of RPAS in the future ATM system.

Findings – Benefits of proposed procedures, mainly evaluated in terms of volume reduction of segregated airspace, are quantitatively analysed on the basis of realistic operational scenarios focusing on monitoring activities in both nominal and emergency conditions. Eventually, the major limits of time-based separation for RPAS are investigated.

Practical implications – The implementation of the envisaged procedures will be a key enabler in RPAS integration in future ATM integration.

Originality/value – In the current ATM scenario separation of RPAS from air traffic is ensured by segregating a large amount of airspace areas with fixed dimensions, dramatically limiting the activities of these vehicles.

Keywords Air Traffic Management; Remotely Piloted Aircraft System; Airspace Integration; On-board avionic system; 4D navigation; Dynamic Mobil Area.

Paper type *Research paper*

Introduction

The aim of the paper is to propose and evaluate benefits of time-based separation procedures aimed at contributing to the integration of large Remotely Piloted Aircraft (RPAs) in the future Air Traffic Management (ATM) system. In particular, proposed time-based separation procedures fully exploit and bring together advantages of the 4D Navigation and

Dynamic Mobile Area concepts which have been both under study and development in the frame of Single European Sky ATM Research (SESAR).

The introduction of an increasing number of RPASs, apart from their peculiar roles, will clearly interfere with the existing ATM and even more with the future ATM. Indeed, in the majority of the Nations all around the world, the RPASs can operate in restricted area and this condition implies a reduction of the available airspace for the other users. It is a common idea and will that in order to reach the main goals proposed for SES, the RPASs shall be integrated within the future ATM. In order to allow the integration process, these unmanned aircraft shall comply with a specific set of requirements and constraints

In this context, Section 2 of this paper deals with a general description of the European ATM system and related foreseen developments together with an analysis of European RPAS roadmap. In addition, this section presents a review of available works performed in the field of civil RPAS interoperability. In the third section of this paper time-based separation procedures are discussed by considering the cases where a potential conflict may involve crossing tracks and same tracks between an RPAS and a civil aircraft. Then, a quantitative evaluation of the major benefits of time-based separation in terms of reduction of area to be segregated for ensuring safe RPAS operations is reported and commented in Section 4. Eventually, at the end of the paper, future studies will be briefly presented and in particular, ideas to evaluate the impact of the introduction of these procedures on RPAS avionics.

2. Single European Sky and development of the future Air Traffic Management (ATM)

2.2. 4D trajectory management

The SESAR concept, as in reported in (SESAR JU, 2017a) and in (SESAR JU, 2017b), envisages the existence of a standardized trajectory sharing/revision capability mediated by collaborative processes. In SESAR, both aircraft and ground systems will use shared flight data to get a common understanding of trajectory evolution. However, the ground system will still have specific local trajectories derived from a shared trajectory to support the various ATM tasks required to control aircraft that, for any reasons (capability or failure), cannot share their own trajectories, ensuring the proper management. The Trajectory Management concept implies systematic sharing of aircraft trajectories between various participants in the ATM system (including aircraft) in order to obtain a common view of flights and have access to the most up-to-date data available. As a result, both airborne and ground systems must build and maintain an identical view of the trajectory and its details using the shared net-centric distributed information environment and they must be able to process this shared information.

2.2.1. Initial 4D navigation

In SESAR, the target concept Initial 4D has been the first implementation step of 4D Trajectory Management. The most innovative characteristic of this type of procedures is the introduction of time as an additional variable in the determination process. Time is intended as a new dimension, meaning that ATC shall give time constraints at a given waypoint along with the already existing methods of 3D navigation.

In accordance with literature (Jackson, M.R.C, 2009) (Muresean S., 2008), the 4DTRAD concept is based on the sharing of trajectories from all the participant aircraft in a standardized and unique format and to provide separation from other aircraft by time constraints on given points, via data-link communications. This operation will involve coordination between airspace users, Air Traffic Flow and Capacity Management (ATFCM), ATC and airports authorities. The coordination will start analyzing airspace structures, air traffic demand and ATC capacity while taking into account the airspace users intentions. All shared trajectories data will lead to the elaboration of a plan of operations with the aim to equilibrate the demand and the capacity of airspace. The plan will continue to be redefined during the pre-tactical and tactical phase as the data coming from the airspace users gets updated continuously. The resulting plan is an airspace scenario to be used as the basis for filling-in the flight plans.

2.3. Dynamic Mobile Area (DMA)

Flexible/Special use of airspace (FUA or SUA) is a concept to define an area designated for operations of a nature such that limitations may be imposed on aircraft not participating in those operations. In accordance with Eurocontrol, Advanced Flexible Use of Airspace (AFUA) concept has been developed to provide more flexibility in the use of airspace by the idea of activating and de-activating reserved areas, instead of having them fixed on the Aeronautical Information Publication (AIP). The main purpose is to provide more capacity since the segregated areas will not be permanent.

AFUA appeared because of the imminent future coexistence of civil air traffic and military air traffic, as many military air operations require segregated areas. The case is extendable to RPAS, which can be military or civil, but their mission profile is more similar to a military aircraft, because of the need of segregated areas for their operations. Apart from improving the coexistence of civil and military traffic, in accordance with Eurocontrol the airspace capacity will also increase as times of segregated areas may decrease compared with current permanent areas, and even more in case operations are done under mission trajectory concept.

In the SESAR environment and from the RPAS point of view, area segregation (ARES) can be a strict segregation from other traffic, but the sizes and position may vary. They can be static in a fixed location with fixed size permanently (generally published in AIP), static with fixed size but on demand by RPAS operators with declared activation time and a deactivation time (the most interesting under the civil RPAS point of view in early phases of SESAR deployment) or areas following the aircraft (DMA). I this case, the presence of a not permanent ARES will be published and will be known by civil air operators so that they can adapt their mission. As will happen with military aviation, ad-hoc developed tools will calculate the required volume of airspace for the given mission depending on the number and type of RPAS involved or other criteria such as environmental limitations, for example. From the point of view of RPAS, it will result into a proposal of airspace which may be:

- A fixed TSA/TRA (fixed dimensions and location),
- A Military Variable Profile Area (MVPA),
- A Variable Geometry Area (VGA),
- A Dynamic Mobile Area (DMA).

For the purpose of this paper, only DMA concept is considered, being the most promising approach for long-term integration of RPAS with civil air traffic. These DMAS, representing temporary areas surrounding the aircraft and moving with it along its mission allows a more efficient exploitation of the airspace with respect to the ARES concept. DMA definition has been formalized by Eurocontrol for military aviation, but it has been considered applicable for civil RPAS operations too. Following the Eurocontrol suggestions, the dynamic geographical position of DMAs ensures that at all times, volumes of segregation are at the best place of constraints sharing. Moreover, the dynamic profile changes ensure that at all time exclusion volumes are as small as possible and that only unavoidable business or mission trajectories are affected in a given period of time

Of course, it is essential that all relevant information about DMAs from the operators of RPAS and also to all the surrounding air traffic operators could be shared among the major players in real-time. In particular, the presence of a DMA has to be included in the shared mission trajectory.

Time-based separation procedures

In the frame of SESAR Time Based Separation (TBS) concept is used for providing a consistent time spacing between aircraft in airports in order to increase runway throughput in accordance with Morris (Morris, 2013). Time-based separation concept is here proposed as a logical way to solve possible conflicts between a RPAS and a civil aircraft with the assignment of a Controlled Time Overfly (CTO) to RPAS. The use of 4D trajectories for conflict resolution has already been examined by Turnbull (Turnbull O., 2013) by focusing on algorithms for optimization of speed advisories for large air traffic volumes rather than single CTO's to RPAS air traffic. The compliance to ATC instructions as primary means for achieving separation from other airspace users by RPAs in controlled airspace is also mentioned by Eurocontrol (Reuber E, 2012), however this does not prevent the presence of an automatic collision avoidance system in the event of failure of traffic avoidance or in case of protection from unknown traffic.

Time-based procedures proposed in this paragraph make use of Initial 4D trajectory concept and Dynamic Mobile Area (DMA). Before starting with the description and the proposal of flight procedures, the hypothesis of simulating scenarios in which all the features of future ATM, as envisaged by SESAR, will be implemented, together with the simplification of straight and not curves trajectories. Moreover, the DMA radius has been defined equal to Actual Navigation Performance (ANP) precision value multiplied for a safety factor. This choice has been led by safety considerations, in order to take into account possible positioning errors.

In Figure 1, the basic idea of the procedure is depicted, where it is possible to appreciate the intersecting tracks of a civil aircraft and a RPAS (with its associated DMA), and the separations to be maintained. As established in the hypotheses, the civil aircraft is not affected by the RPAS operations. The strategy of defining a virtual ARES (grey in the Figure) enhances the safety in the procedure, as more separation, between the civil aircraft and the RPAS, is set. The borders that suppose the minimum separation distance between RPAS1 and civil aircraft will never be tangent, as virtual ARES dimensions guarantee it. The time-based separation is a consequence of the separation distance criteria defined by ICAO (ICAO, 2011b). Since ATC will be able to know the time that the civil aircraft will overfly the intersecting point, then a time-based separation will be able to be applied to the RPAS. Important times are the Estimated Time Overfly (ETO) of the civil aircraft at track intersection and the time at which the virtual ARES is cleared. The CTO assigned by ATC to RPAS will be the time at which the DMA of the RPAS would be able to enter the virtual ARES once this is cleared by civil aircraft. Procedures presented in these sections refer to two horizontal separation conditions: aircraft on same tracks and aircraft on crossing tracks.

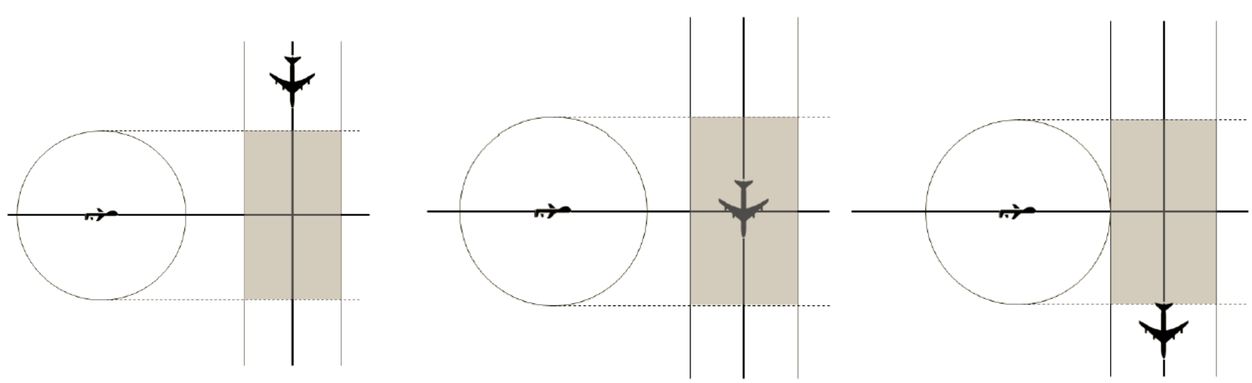


Fig. 1. Use of Dynamic Mobile Area for time-based separation

3.1. ***Time-based procedures with DMA for aircraft on crossing tracks***

In accordance with ICAO (ICAO, 2011b), a longitudinal separation with aircraft on crossing track happen when the angular difference θ between the tracks is between 45° and 135° or between 225° and 315°.

In this paper, the actors considered are a civil RPAS (RPAS1), a manned civil aircraft (AC1), a virtual ARES (ARES) and the pertinent ATC of the scenario airspace. In Figure 2, the dimensions are of ARES1 are “a” and “b” NM, where “a” depends on the dimensions of the DMA associated to RPAS1 and “b” depends on the lateral separation to be applied at AC1. Note that “a” is twice the radius of the DMA. "E1" is the entry point. where the RPAS is supposed to enter the virtual segregated area, "P1" is the intersection point between the flight paths of the aircraft and the RPAS.

The dimensions of ARES1 depends on the flight conditions of AC1 in terms of lateral separation that will determine the value of “b”. In this example it is considered that AC1 flies using RNAV with RNP "X”. RNAV condition is chosen as reference parameter for further evaluations, in compliance with the hypothesis that these aircraft will perform their activities within the future SES. Indeed, as it has been highlighted by SESAR projects, most of the aircraft should be equipped with an avionic system to allow RNAV. The value “X” that characterizes the RNP means that the navigation accuracy has to guarantee the 95% of the time that the aircraft is no further than ±”X” NM. For lateral separation purposes, the corridor width of the track of AC1 is set twice “X” per side (i.e. safety factor 2).

As it is depicted in Fig. 2, this parameter can be evaluated through geometrical considerations. Eq. (1) and (2) allow the definition of this parameters.

$$b = 2 \cdot (\gamma + \beta); \qquad (1)$$

$$b = 2 \cdot \left(\frac{a/2}{\tan\theta} + \frac{SF \cdot X}{\sin\theta}\right) \qquad (2)$$

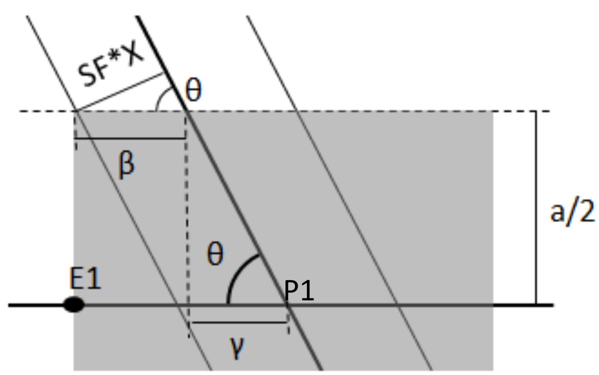


Fig. 2. Geometrical parameters of virtual segregated area

In the previous reported equations, SF is the safety factor to be applied. As it can be noticed and proved, the previous equations are also valid for the particular case in which the angle between the two tracks is 90°. In this case, simplified equation can be used, as suggested in Eq. (3).

$$\mathbf{b = 4\,X} \qquad (3)$$

The value of "a" is directly correlated to the diameter of the DMA associated to RPAS1. The DMA is also related to the RNP value for RPAS1 (RNP "Y"). "r DMA" is the radius of the DMA and it is twice "Y"; the safety factor of 2 is used again for the same safety reason as with AC1. Eq. (4) and (5) give details on "a" and "rDMA" calculations, then:

$$\mathbf{r_{DMA}} = \mathbf{2} \cdot \mathbf{Y} \qquad (4)$$

$$\mathbf{a} = \mathbf{2} \cdot \mathbf{r_{DMA}} = \mathbf{4} \cdot \mathbf{Y} \qquad (5)$$

The under investigation case is developed under complying with all the hypotheses defined previously, and, in addition, it is fair to consider two more hypotheses:

AC1 is the first aircraft to overfly P1, and later RPAS1 overflies P1

The ground speed of AC1 is considerably higher than the ground speed of RPAS1 (at least more than 135 kt to be conservative)

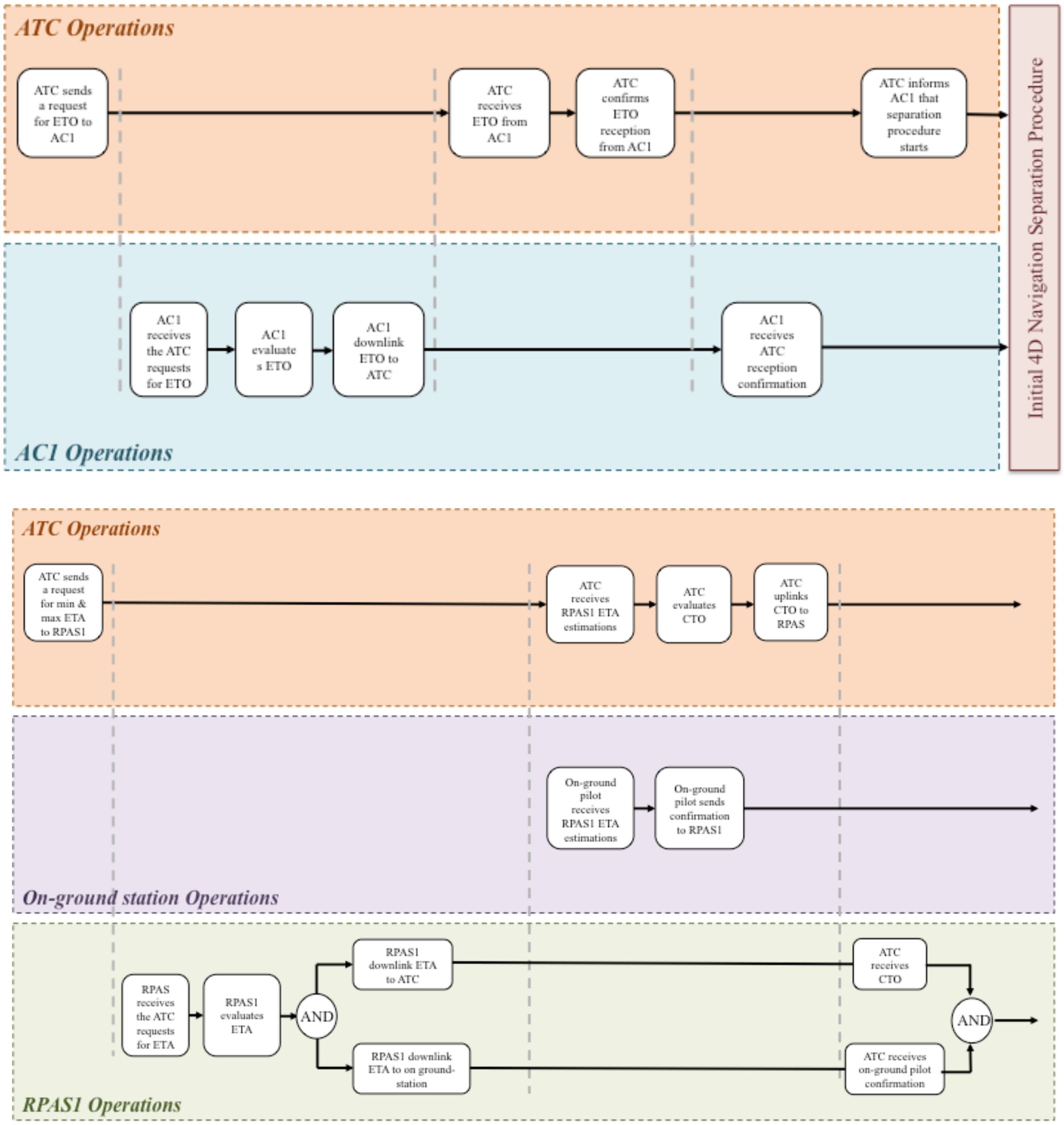
The procedure (Fig.3) starts with the identification by the ATC of the potential risk situation in the intersection of the routes of RPAS1 and AC1, where separation regulations may be applied. In accordance with above discussed 4D navigation concept, the ATC will know in advance the shared trajectories of both RPAS1 and AC1. This means that the ATC is responsible for the decision to proceed with the procedure is in the tactical phase.

ADS-C Extended Project Profile (EPP) request is then sent by ATC to AC1 and RPAS1, by elaborating received EPP data the ATC is aware of the Estimated Time Overfly (ETO) of AC1 on P1. The ATC, then sends a request for minimum and maximum Estimated Time Overfly (ETO) to RPAS1 at E1, via ADS-C. The point E1 is given by latitude, longitude and altitude because, as it can happen for P1, this is a point could not be defined in the Aeronautical Information Publication (AIP). The Mission Computer of RPAS calculates the maximum and minimum ETO at E1 and they are sent via ADS-C to both the ATC and the RPAS ground station. After receiving the data, the ATC determines a specified time (CTO) for RPAS1 to overfly E1. CTO shall be determined by the ATC so that DMA intersect virtual ARES only when this latter has been cleared by AC1. A key point of this procedure is the calculation of the CTO, it depends on the ETO of AC1 at P1, the time that takes to AC1 to clear ARES1, and the time that takes RPAS1 to travel the radius of the DMA (rDMA). For this general case of crossing tracks, the CTO can be geometrically estimated, as it is clearly shown in Eq. (6).

$$CTO = ETO_{AC1,P1} + \frac{a/2}{\sin\theta \cdot GS_{AC1}} + \frac{r_{DMA}}{GS_{RPAS1}} \qquad (6)$$

It has to be noticed that calculation of CTO implies an estimation by ATC there of the ground speed (GS) of RPAS1, which could be variable. This speed should be estimated as an average cruise speed so that RPAS1 is able to reach E1 at the agreed time. However, considering the typically reduced speed envelopes of RPAS an error in estimating its ground speed is negligible considering also the application of a safety factor for calculation of virtual ARES sizes.

From Fig. 4 it can be imagined the moment when the DMA of RPAS1 enters virtual ARES, just after AC1 has cleared, and when the RPAS enters the virtual ARES at the CTO. The time distance of these two moments is minimum when the angle θ is 90° so when the two trajectories of RPAS1 and AC1 are orthogonal.



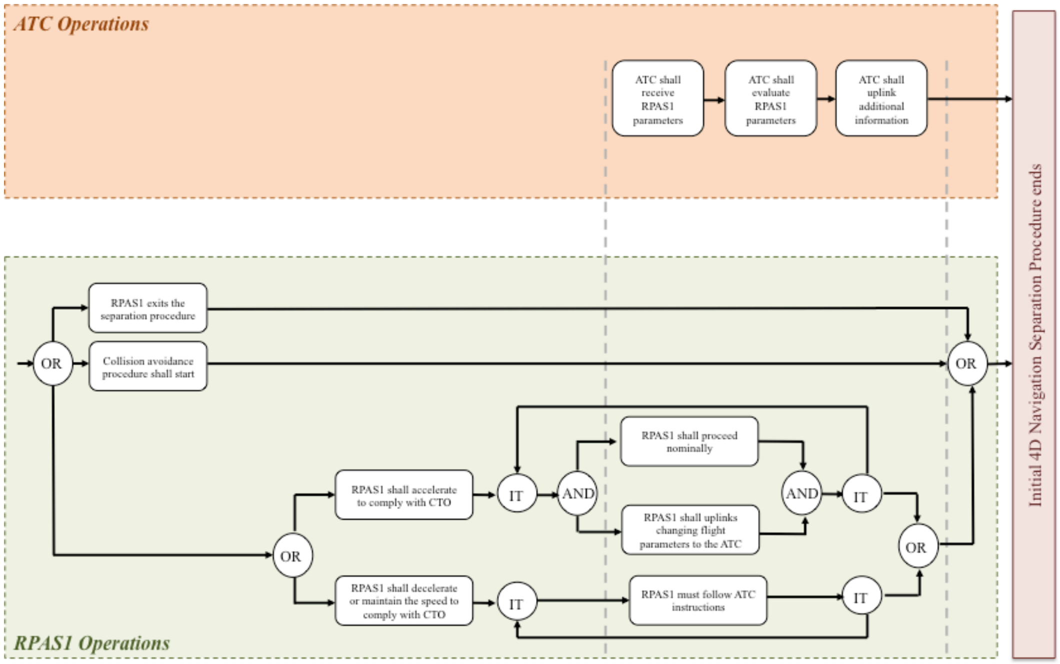


Fig. 3 Time-based separation procedure summarized by a functional block diagram

In accordance with ICAO (ICAO, 2011b), a longitudinal separation with aircraft on same track applies when the angular difference θ between the tracks is less than 45º or between 315° and 360°. A first consideration to be done is that, the generation of a virtual ARES for ensuring separation is less efficient in this case. The reason of it can be better understood by analyzing Eq. (2) where it is evident that "b" dimension of virtual ARES diverges to infinite for small angles tending to zero, as a consequence advantages of the above mentioned procedure in terms of reduction of airspace reservation are limited in this case. In addition, analyzing Eq. (6), it is possible noticing that the CTO of RPAS also tends to infinite for small angles tending to zero, this is correlated to the time needed by the civil aircraft to clear the virtual ARES which also tend to infinite with "b" dimension of virtual ARES.

Furthermore, considering the small difference of track angles for aircraft on same track, lateral separation has also to be ensured and considered in the definition of procedures (see Fig. 4 and Fig.5).

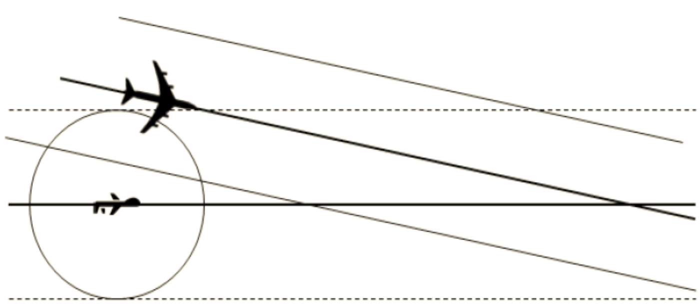


Fig. 4 Lateral separation violation for aircraft on same tracks

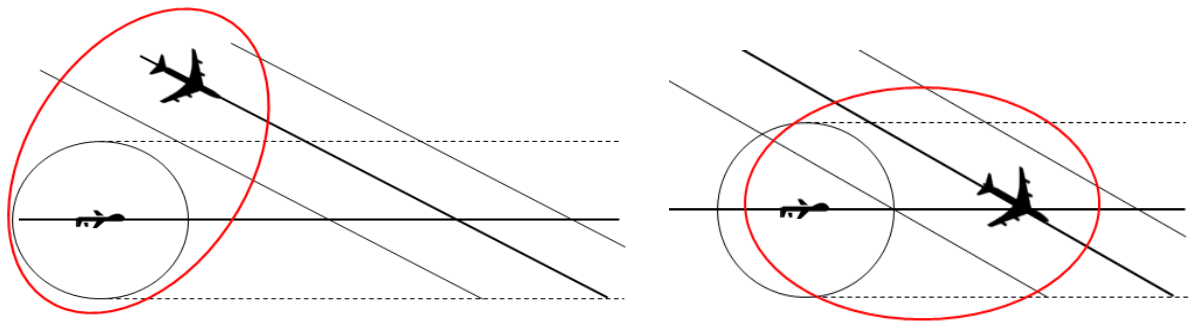


Fig. 5: Time-based separation with aircraft on same tracks: area where lateral separation applies (left) and area where longitudinal separation applies (right)

Time-based separation procedure with DMA maintains advantages in terms of efficiency on the use of airspace without sacrificing safety and the hypothesis that the RPAS always yields to civil aircraft is applied; the most critical point is where lateral separation is applied. Figure 6 shows the most important elements and parameters that are present in the time-based separation for same track case, which differ from the ones for crossing tracks. Indeed, virtual ARES disappears and time constraint for RPAS is applied at the point here called Never Exceed Point (NEP), corresponding to the point where RPAS has to be for making the DMA tangent to RNP corridor of civil aircraft.

In time-based procedures for same track, RPAS should stay at NEP1 when AC1 is at P1 so the CTO constraint given at NEP1 for RPAS1 will be the same value of the ETO at P1 for AC1. As a consequence, the ATC shall estimate the position of NEP1, which it is calculated in a very similar way to the width of the virtual ARES for crossing tracks (plus a safety DMA radius) (Fig.6)..

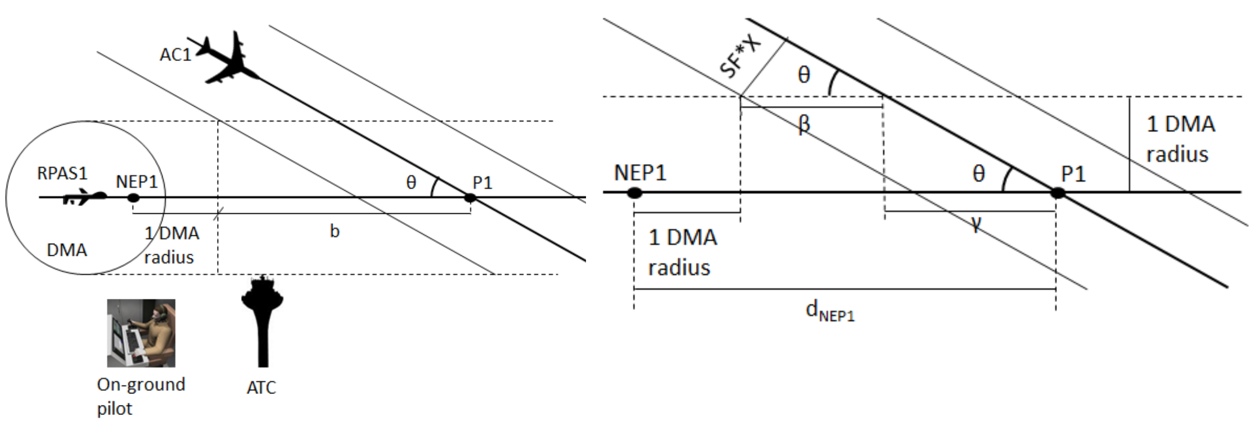


Fig. 6: Time -based separation for aircraft on same tracks

$$d_{NEP1} = \gamma + \beta + r_{DMA}; \qquad (7)$$

$$d_{NEP1} = \frac{r_{DMA}}{\tan\theta} + \frac{SF \cdot X}{\sin\theta} + r_{DMA} \quad (8)$$

The procedure for time-based separation starts also in this case with the identification by the ATC of a potential conflict at the intersection of the routes of RPAS1 and AC1, and the procedure is very similar to the one described above, but in this case, the estimated times of arrival have to be calculated at the point NEP1. As already said, the calculus of the position of NEP1 is responsibility of the ATC. After the ATC receives and analyzes the min/max ETO at NEP1, the ATC sends a CTO for RPAS1 at NEP1 which correspond to the time ETO estimated by AC1 in the first steps of the procedure. Minimum and Maximum ETO at NEP1 allow the ATC to understand if the CTO constraint could be feasible for RPAS1. The calculus of the position of NEP1 is responsibility of the ATC. In case where estimated CTO is out of min/max ETO interval, analysis done in previous paragraph applies.

After the ATC receives and analyzes the min/max ETA at NEP1, the ATC sends a CTO for RPAS1 at NEP1. The negotiation between RPAS1 and ATC proceeds as defined before, with the same data-flow and sequence of messages. Once the CTO has been accepted by pilot of RPAS1 via CPDLC message, the automatic speed adjustment of RPAS1 is activated and it will overfly NEP1 at CTO if no further instructions are given.

Note that in this case when the angle of intersection between tracks tends to 0º, the distances between NEP1 and P1 tend to infinite asymptotically, meaning that in case of small θ angle, the ATC is requested to predict and identify the conflict in a large time horizon. This limitation of time-based separation procedures is mitigated by Medium Term Conflict Detection (MTCD) tools which are currently under-development, that will represent powerful tools for enlarging time horizon of confliction detection in accordance with (SESAR, 2017a). Nevertheless, in case where a conflict between a RPAS and civil aircraft is detected when RPAS has already passed NEP a separation can also applied. The vertical separation is not affected by the use of DMA or 4D navigation.

4. Benefits of DMA procedures

Benefits of the envisaged procedures have been evaluated through their application to a specific case study where a fleet of RPAS has been envisaged for advanced monitoring purposes, in both nominal and emergency conditions. For any additional details on the selected reference case study, the reader can refer to (Chiesa S., 2014a), (Chiesa S., 2014b), (Fusaro R., 2015a), (Fusaro R., 2015b). For the purposes of this work, flood scenario, coastal water pollution scenario and regional monitoring scenario have been selected.

The RNP value taken for both the civil aircraft and the RPAS is RNP5, which means that the aircraft is within 5 NM (laterals) from the track in a > 95% of the time. In addition, a safety factor of 2 has been considered, so the width of the corridor for both aircraft is 10 NM.

Two other parameters should be hypothesized: the ground speed of the civil aircraft and the ground speed of the RPAS. The civil aircraft is supposed to have a speed of 700 km/h; while the RPAS is supposed to have a speed of 150 km/h. The value chosen for the civil aircraft is a guide value between the usual cruise speed of turbofan aircraft and the usual cruise speed of a turboprop aircraft. The value chosen for the RPAS represents an average cruise speed for a MALE RPAS.

In Figure 7 and 8, there is the pictorial comparison between the use of fixed ARES and the use of DMA in the flood monitoring scenario. Both considering the Pictures below, as well as the numerical data reported within Table I,itt is easy to notice that, for each case, the restricted airspace saved by using the DMA is considerable. In Table I there are the values of the segregated areas and the comparison with the use of DMA

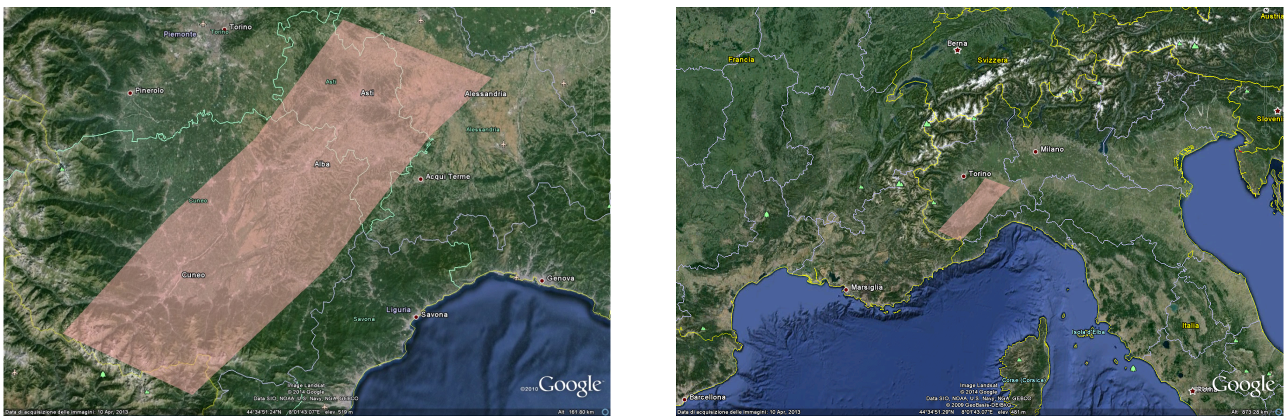


Fig. 7: Simulation of Flood monitoring scenario with ARES procedure

Fig. 8: Simulation of Flood monitoring scenario with DMA procedure

Table I. Results summary.

Scenario	Area covered by the ARES, km^2	Area covered by the DMA, km^2	Airspace segregated by using a DMA in relation to the size of the ARES, %
Flood scenario	**4480**	**1077**	**24**
Coastal water pollution scenario	**18500**	**1077**	**5,8**
Regional monitoring scenario	**9418**	**1077**	**11,4**

The graphs of the same track case are basic to reaffirm the idea that the procedure Initial 4D with DMA for same track is not efficient as for crossing tracks, because if separation is to be applied correctly, the time separation and distances generated in the procedure are completely oversized. By observing the plots in Fig. 9 and 10, it is arguable to state that the procedure is cannot be used for intersection angles of 15º or less, as the values start diverging notably. For same track, the decision to define the procedure without the virtual ARES is analyzed to verify its feasibility and viability. The decision to omit the virtual ARES, at the beginning has been taken intuitively because, if not, the procedure would have taken larger airspace volumes and longer time periods. Figure 10 shows the comparison of the time difference since AC1 overflies P1 until RPAS1 overflies P1, with and without the use of a virtual ARES. Note that the relative difference is more or less constant and the fact of defining the procedure without virtual ARES means a save of 10% of time per all angles. In the graph below, the angles lower than 10deg have not been depicted for graph oversizing reasons.

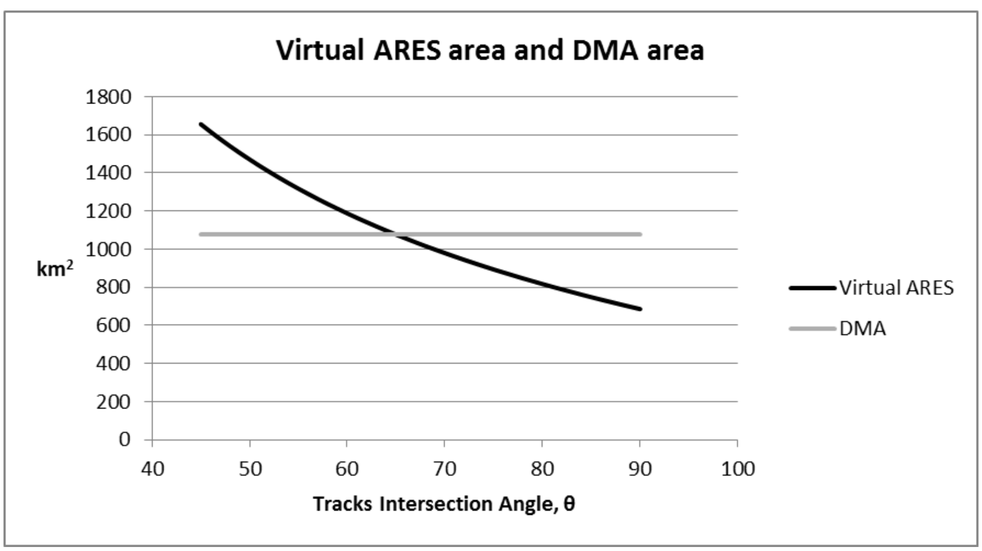


Fig. 9: ARES and DMA variation with intersection angle

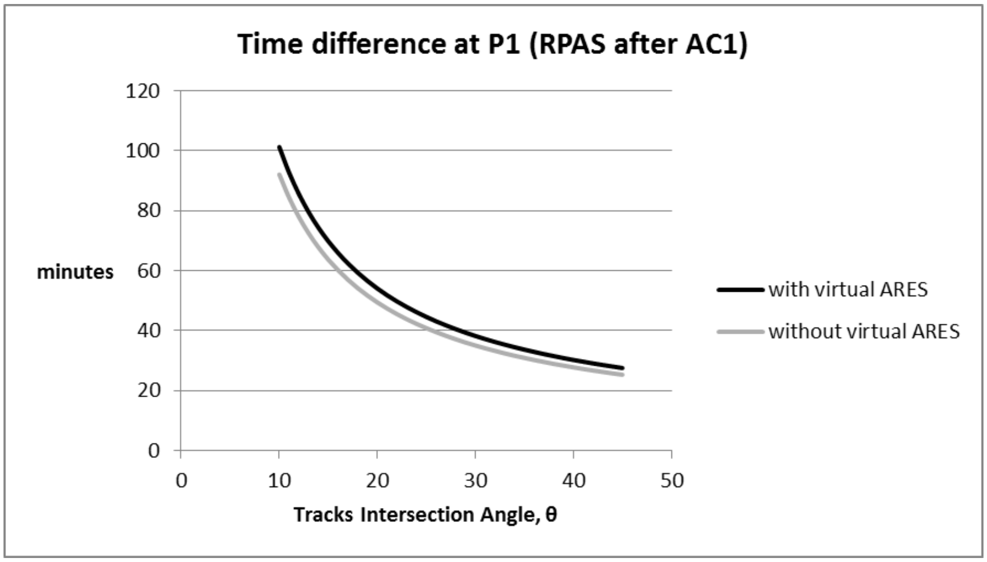


Fig. 10: Time differences with and without virtual ARES

Conclusions and further improvements

The application of the innovative suggested procedures, confirms the extremely usefulness of introducing new Air Traffic Management algorithms to allow RPAS operations in non-segregated airspace. This will pave the way for a massive exploitation of UAVs for a very wide ranges of operative scenarios in both planned or emergency monitoring scenarios.

In future, the procedure will be tested on different and more complex scenarios with the involvement of more than two aircraft at a time. In addition, the impact of the introduction of these procedures on RPAs avionics will be in-depth analyzed.

References

Chiesa, S., Aleina, S.C., Di Meo, G.A., Fusaro, R., Viola, N. (2014a) Autonomous take-off and landing for unmanned aircraft system: Risk and safety analysis (2014) 29th Congress of the International Council of the Aeronautical Sciences, ICAS 2014.

Chiesa, S., Fioriti, M., Fusaro, R. (2014b) UAV based advanced monitoring system: Fleet and logistic system sizing by object based model and Monte-Carlo simulation (2014) 29th Congress of the International Council of the Aeronautical Sciences, ICAS 2014,

International Civil Aviation Organization (ICAO) (2011b) "Procedures for Air Navigation Services - Air Traffic Management", Doc 4444 ATM/501, International Civil Aviation Organization 999 University Street, Montréal, Quebec, Canada H3C 5H7, 2011

Jackson, M.R.C., Gonda J., Mead J. Saccone G. (2009) "The 4D Trajectory Data Link (4DTRAD) Service – Closing the Loop for Air Traffic Control" Integrated Communications, Navigation and Surveillance Conference, Arlington, VA, 2009, pp. 1-10

Fusaro, R., Casti, M., Cresto Aleina, S., Viola, N., Catella, P., Butera, F., Chiarantini, L. (2015a). Hyperspectral sensor for civil applications to Unmanned Aerial Vehicles within a monitoring scenario (2015) 2015 IEEE 1st International Forum on Research and Technologies for Society and Industry, RTSI 2015 - Proceedings, art. no. 7325146, pp. 490-497. DOI: 10.1109/RTSI.2015.7325146

Fusaro, R., Chiesa, S., Aleina, S.C., Fioriti, M. (2015b) Contribution To R.A.M.S estimation in early design phases of unmanned aerial vehicles – UAVs (2015) International Journal of Mechanics and Control, 16 (1), pp. 73-83.

Morris, C., Peters, J., and Choroba, P., (2013) " Validation of the Time Based Separation concept at London Heathrow Airport" Tenth USA/Europe Air Traffic Management Research and Development Seminar, Chicago, Illinois, 2013, pp 1-10

Muresean, S., Tonea, D., Dias, P., (2008) "Initial 4D- 4D Trajectory Data Link (4DTRAD) Concept of Operations", EUROCONTROL Unit DAP/ATS, Rue de la Fusée, 96 B-1130 Bruxelles, Belgium, 2008

Reuber, E., (2012) "Eurocontrol Specifications for The Use of Military Remotely Piloted Aircraft as Operational Air Traffic Outside Segregated Airspace" EUROCONTROL Unit DSS/CM, Rue de la Fusée, 96 B-1130 Bruxelles, Belgium, 2012

SESAR Joint Undertaking (2017a), “The Roadmap for Sustainable Air Traffic Management European ATM Master Plan” European ATM Master Plan Portal [online database], URL: https://www.atmmasterplan.eu/

SESAR Joint Undertaking (2017b),, "D3 – The ATM Target Concept" SESAR Joint Undertaking publication repository [online database] URL: http://www.sesarju.eu/newsroom/brochures-publications/d3-atm-target-concept

Turnbull, O., Richards, A., (2013)"4-D Trajectory Optimizers for Conflict Avoidance Using Speed Advisories" Tenth USA/Europe Air Traffic Management Research and Development Seminar, Chicago, Illinois, 2013, pp 1-10