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Assessment of the North European free route airspace deployment

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ABSTRACT

Free Route Airspace is an operational concept for the modernization of the airspace, addressed to improving the efficiency of the flights. It also aims at the environmental friendly performance area by reducing the emissions from fuel burnt. But these benefits should not derive in a loss of safety. Several areas are introducing free route as part of the Single European Sky Airspace Research programme (SESAR). This paper assesses the Northern Europe Free Route Airspace deployment, where two SESAR solutions are combined: the Free Route Airspace and the Functional Airspace Blocks. This assessment is produced using fast-time simulations and presented from a safety perspective using two indicator sets: the aircraft loss of separation and the airspace complexity. The number of potential separation losses, together with complexity metrics, such as adjusted density, potential horizontal, vertical and/or speed interactions, are presented for different free route deployment status. Results reflect that from the safety perspective the free route deployment in North Europe did not present notable changes in terms of the selected indicators, despite of the increase of traffic of last years.

1. Introduction

The air traffic forecast indicates an increase of approximately 2.2% per year, reaching a European sky with 11.2 million operations in 2021 (19% more than the 2014) (Eurocontrol, 2015). This is a challenge for the safety and for the en-route sectors capacity. The implementation of two new operational concepts, the Free Route Airspace (FRA) and Functional Airspace Block (FAB), is part of the path to an efficient European airspace. Both can be considered as relevant intermediate steps on the road to the Single European Sky Airspace Research programme (SESAR) to facilitate the implementation of business trajectories and fuel-efficient 4D profiles. The SESAR Joint Undertaking (SJU) is leading the implementation and deployment several FABs in Europe with the aim to improve the air navigation services performance (ACE, 2006), but with unequal results (Button; Neiva, 2013). According to the first an 11% of the en-route flight inefficiency are attributable to the fragmentation of airways between states within each FAB; and an additional 25% are attributable of the fragmentation between FABs.

In coordination with Eurocontrol and the Air Navigation Service Providers (ANSP), the European airspace is, at the same time, moving from the current airspace structure, based in fix navigation points and airways, to a new airspace structure oriented to free route operations. The activation of FRA is established on principles exposed in EC 677/2011 and, at the end of the year 2014, almost half of the European airspace (30 Area Control Centers out the 64) had implemented various steps of free route. The overall benefits of free route operations are distance and flight time savings, deriving in less fuel consumption and a notable reduction of jet engine emissions which benefits the environment (Aneeka and Zhong, 2016). These benefits are important for the society, but very relevant for the airspace users, reaching a cost reduction up to 3.8% if applied to full Europe (Bentrup and Hoffmann, 2016). Specific FRA partial deployments allowed to save around 25,000 NM flight distance per day (between 2 and 3.5% of flight distance) (Nava-Gaxiola and Barrado, 2016).

In a FRA airspace users freely plan a route between the defined Entry and Exit fixes, with the possibility of routing via Intermediate points. A FRA has also Arrival and Departure fixes available, but does not have airways. The free route flights remain subject to air traffic control (ATC) for the separation provision and flight level change authorizations. With the combination of the two concepts (FAB and FRA) the air traffic controllers are assuming important modifications on their day-to-day activity. To assess the new concepts the Air Traffic Management system (ATM), ICAO proposes the use of Performance Indicators. In Europe, the Commission Regulation No 691/2010 defines its own Performance Framework, being the safety performance area of main interest. Safety performance indicators include concepts such as compliance and maturity, but also number of airspace events per flight. In particular, the number of occurrences of Separation Minima

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Infringements at en-route is used with some limitations. Since separation incidents are very infrequent and they can be produced by a number of external factors during the tactical phase, in this paper we propose the use of the potential separation infringements found in the pre-tactical trajectories as a proxy for the airspace safety. Moreover, the complexity of the traffic flows are used as a second safety proxy indicator.

In this paper is assessed one of the largest FRA in Europe, the Northern Europe Free Route Airspace (NEFRA). NEFRA is formed by two FABs: the North European FAB (NEFAB) and Danish-Swedish FAB (DK/SE FAB); and six countries: Norway, Finland, Estonia and Latvia from NEFAB, and Sweden and Denmark from DK/SE FAB (also known as NUAC). The evaluation aims to provide the evolution of safety by determining how complex this airspace evolves while the FAB and the FRA concepts are combined and operating together. As an added value with respect to previous studies, the paper shows for the first time some joined results of the FRA deployment in two interacting FABs.

The structure of the paper is the following: Section 2 exposes the research of the literature related with conflict detection and with complexity. The third section describes the metrics and the traffic data used for the assessment. Then, section 4 presents the simulation results. Finally, in section 5 conclusions and future work are exposed.

2. Related work

The research in air traffic metrics has been historically done in two main areas: safety and capacity, both very interrelated. In the safety area, the main indicators are the number of occurrences, this is, violations of aircraft separation, collision avoidance alerts and incidents. All of them are a posteriori indicators which can rarely be anticipated, and usually involve abnormal situations such as human errors, aircraft contingencies, strong weather conditions or ATM system failures (Vogel et al., 2013). As a priori safety measure the capacity is used in Europe as part of the safety net applied. Despite the upgrades in the onboard systems, humans still constitute the core of the ATM system. Thus, the capacity is mainly determined by the controllers' workload (Majumdar et al., 2005). But ATC's workload is a subjective value and can be measured only during the ATC activity. Simulations are a very frequent tool to assess the limits of the workload. And finally experience is used to fix a capacity to each sector. Admitting a number of aircraft in a sector higher than its capacity is considered as not safe, and delays or re-routings are applied to avoid it. In a posteriori assessment, indicators on capacity compare the aircraft entry counts with the capacity. It is considered as convenient an entry count at the 80% of the capacity. Higher values can compromise safety if prolonged too long, while lower values are considered as inefficiency of the ATM resources.

A large number of research works in the area of conflict detection exist (De Prins et al., 2008). They model the aircraft trajectory using 4D vector geometry, and determine the closest point of approach between two linear segments and the time remaining until the protection separation standard is violated. If the closest point of approach is less the minimum distance and the time remaining for the separation loss is within a look ahead window, then a conflict is declared. Conflict detection methods are embedded in current short-term collision avoidance tools. This tools can help the ATC in anticipating conflicting situations, but they are rarely used to evaluate a priori situations, because of the lack of predictability at the tactical level.

Many studies focus in the structured airspace, where conflicts are normally found in known merge navigation fixes or in airways crossing points. Air traffic controllers solve potential loss of separations with vectorizations, altitude or speed changes or re-routing to alternate network fixes. In FRA the separation losses between aircraft can emerge in any point of the airspace. The ELSA project (Gurtner et al., 2017) built an agent based air traffic simulator to evaluate new air traffic operational concepts. Using simple software agents ELSA simulated mechanistic controllers. The project conducted several runs with close to 2 thousand synthetic trajectories derived from historical planned flights of the area of central Italy. Strategical and tactical levels of deconflicting were examined. The results were given by counting the actions required by the ATC agent. This number was defined as a new complexity indicator, and was compared with another 20 metrics from literature. They found that, in free routing, the air traffic controllers perform less operations, but these actions are more disperse over a large portion of the airspace. This disperse factor can potentially increase the complexity of the air traffic controllers' work, and thus their workload. Results also showed the existence of a quadratic relation between this complexity indicator and the density. Using regression and principal component analysis techniques authors also show that the four metrics from (Chatterji and Sridhar, 2001) were directly related with the number of ATC agent actions, validating in this way the ELSA proposal.

Given that the number of conflicts do not completely figure the workload of the air traffic controller, aviation communities have been very interested in developing new quantifiable metrics using the term complexity (Kopardekar et al., 2009) (Vogel et al., 2013). The air traffic complexity aims at being '*a measure of the difficulty that a particular traffic situation will present to an air traffic controller*' (Schäfer and Modin, 2003), but is implemented with a large number of metrics: in (Gurtner et al., 2017) is "the number of controller's actions" used for separating the traffic by a simulated ATC agent, while in (Flenera et al., 2007) it is determined by the numbers of flights within a managed sector, near its border, and on non-level segments.

(Toy, 2015) proposes two types of complexity that are related with airspace and ATC systems: inherent and apparent. The inherent complexity is related with affecting factors such as weather, terrain, airspace restrictions, traffic density, traffic flows, aircraft performance characteristics, abnormal events, etc. Inherent complexity is limited to the characteristics of the traffic situation itself, and it is thus considered as a factor causing workload. Future refinements of the complexity calculation will depend very much on the availability of more accurate data. For that reason some new approaches consider 4D trajectories instead of linear vectors. The Trajectory-Based complexity (TBX) metrics is a modified aircraft counter. The main advantage of the TBX is that it can be computed easily and thus communicated in real-time. This fact makes TBX very appropriate to predict sector complexity under the business trajectory SESAR concept.

The Eurocontrol's working group on complexity defined a new indicator, the complexity score (ACE, 2006). Two main metrics define the complexity score: the adjusted density and the structural index. The adjusted density evaluates the potential interactions resulting from density, including uncertainty in the trajectories and time, while the structural index balances the density metrics according to the interaction geometry and aircraft performance differences. The metrics used reflect the difficulty to manage the presence of several aircraft in the same area at the same time, particularly if those aircraft are in different flight phases, have different performances, and/or have different headings.

3. Northen Europe free route airspace deployment

The NEFRA programme was established on 11th March 2013. Six states of two Functional Airspace Blocks, the Denmark-Sweden (DK/SE FAB), and the Norway, Finland, Estonia and Latvia (NEFAB), signed a declaration of commitment in airspace development. They committed themselves to undertake necessary actions to ensure implementation of the FRA concept above FL 285 in the joined airspace, named as NEFRA. In the Norway airspace, BODO oceanic will be considered apart, within the ICAO NAT region. In (Holstila and Andersson, 2015) we can see details of the work done for the design and implementation of NEFRA, after a consultation process involving 18 stakeholders.

Over 2500 flights are crossing NEFRA every day. Due to geographical location (see Fig. 1) NEFRA is used as a bridge to the East for flights between Europe and Asia, and to the West to connect North