




# Methodology for the performance evaluation of airspace use by military aviation

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## Abstract

This paper aims to present the evolution of methods for measuring and evaluating the effectiveness of flexible use of airspace by military aviation in terms of the air navigation services performance scheme in European Union countries. Airspace management, which is a part of air traffic management, takes into account the operational needs of civil and military aviation without favouring either of them. However, some military aviation operations cannot be safely interconnected with civil aviation operations as they differ in nature and purpose. There is, therefore, a requirement to set aside airspace for exclusive military use to accommodate such operations. Military aviation must also use airspace in the most efficient and effective manner when conducting its operations. The existing situation provides a rationale for improving the methodology for assessing the efficiency of airspace use by military aviation, regardless of the requirements of the performance scheme for air navigation services intended for civil aviation. This article reviews the development of performance assessment methodologies in the field in question. The findings show considerable variation in the methods used, suggesting the need to establish standard procedures for collecting and processing performance data related to airspace used by military aviation.

**Keywords:** aviation safety, civil-military dimension, mission effectiveness, performance indicators, performance targets.

## 1. Introduction

Military aviation, together with civil aviation, is one of the main airspace users. The needs of both civil and military airspace users should be met to the fullest extent possible while respecting State sovereignty, national defence, international security and law enforcement obligations. Balancing the needs of civil aviation with the requirements of military aviation to conduct operations and training (including the necessary exercises) in order to maintain its capability to safeguard essential national security or defence policy interests also serves to improve the performance of the European air traffic management network (Baumgartner & Finger, 2014; Calleja Crespo & Mendes de Leon, 2011; Cook, 2007). Airspace should be used in a safe and efficient manner, taking into account the reduction of aviation's environmental footprint (Motyka & Njoya, 2020; Van Houtte, 2004). Achieving the most efficient use of airspace based on the actual needs of civil and military aircraft operators and, when possible, avoiding permanent airspace segregation are the main goals of airspace management (ASM). According to the principles of the flexible use of airspace (FUA) concept (Eurocontrol, 2009), this process is carried out at three interdependent organizational levels (strategic, pre-tactical, and tactical), based on agreements and procedures of civil-military coordination and cooperation. The primary objective of the FUA concept is to provide military airspace users with access to sufficient airspace, allowing them to accomplish their mission objectives

effectively and with no excessive impact on the safety and efficiency of civil aircraft operations. An important task at ASM levels is continuously monitoring the efficiency application of the FUA procedures.

The purpose of this paper is to present the evolution of methods for measuring and evaluating the effectiveness of flexible use of airspace by military aviation in terms of the air navigation services performance scheme in European Union countries. In relation to the adopted purpose, the following main research problem was formulated: *How do we improve the efficiency of military aviation's use of airspace without adversely affecting civil aircraft operations?* Due to the complexity of the main research problem, the following specific problems were identified:

- 1) *What is the correlation between the air navigation services performance system and military aviation mission effectiveness?*
- 2) *What current methods are used to measure and evaluate the effectiveness of flexible use of airspace?*
- 3) *How can the performance assessment methodologies in civil-military airspace management be improved?*

In view of the defined main research problem, the general hypothesis for the following analysis is that the organization, procedures, and tools of airspace management have the greatest impact on military aviation mission effectiveness. In order to meet the changing requirements of both civil and military aviation while minimizing the constraints imposed on each party, continuous improvement of the ASM process and air navigation service performance evaluation methodology are essential. The study is based on a qualitative analysis of the selected EU regulations as well as ICAO and Eurocontrol documents on the assessment methodology of air navigation services performance.

## 2.Characteristics of the performance scheme for air navigation services

The performance scheme outlined in the EU aims to contribute to the sustainable development of the air transport system by improving the overall performance of air navigation services in key performance areas such as safety, environment, capacity and cost-efficiency. Regulation (EC) No 549/2004 of the European Parliament and of the Council required the European Commission to assess the performance of air navigation services in the EU Member States (Regulation EC, 2004), but implementing acts were not issued for the next five years. Because of their non-appearance and the real impact of the SES legislation on improving the operational and economic efficiency of air navigation services, the European Parliament and the Council adopted Regulation (EC) No 1070/2009 (the second package of reforms concerning the SES) in 2009, which established, inter alia, a performance scheme (Regulation EC, 2009). On its basis, the Commission issued Regulation (EC) No 691/2010, which specified the principles of the functioning of this system (Commission Regulation (EU), 2010) during the so-called first reference period (RP1), which covered the years 2012-2014. For the second reference period (2015-2019), the provisions of the subsequent Regulation (EC) No 390/2013 were applied (Commission Implementing Regulation, 2013). Currently, in its third performance scheme reference period (2020-2024), Commission Regulation (EU) 2019/317 sets out the detailed rules and procedures for introducing the performance and charging scheme. They take into account the performance of air navigation services and network functions as well as the determination, imposition and enforcement of air navigation charges to airspace users (Commission Implementing Regulation, 2019).

The purpose of the SES performance scheme is to improve the overall performance of air navigation services and network functions for general air traffic. The system includes:

- EU-wide and relevant local performance targets relating to the key areas (KPAs) such as safety, environment, capacity and cost-efficiency;
- national or functional airspace block plans containing performance targets consistent with the relevant European Union-wide and local performance targets;
- periodic assessment, monitoring and benchmarking of air navigation and network services performance.

Performance management is a systematic and iterative approach to improving an organization's performance that involves defining and executing a strategy by using its resources and behaviours to attain the desired high performance of an Air Navigation Service Provider (ANSP) over a specified period. The process of managing the performance of an ANSP from the perspective of operational and technical aspects may consist of several stages:

- identifying key performance areas;
- setting performance targets in consultation with users and other stakeholders;
- selecting performance indicators (and additional metrics);
- developing and implementing a plan in cooperation with the other users in the aviation community;
- considering and, when necessary, providing incentives for performance;
- periodically evaluating performance results through reliable benchmarking;
- publishing reports on the achieved results.

The starting point for developing a performance management process is to identify key performance areas (KPAs). Key performance areas are a way of classifying performance areas related to the high-level expectations of the aviation community as well as the strategic ambitions of the air navigation service provider. Within each KPA, there may be several focus areas (FAs)



where performance improvement should occur or is expected to appear. Overall performance objectives represent the desired trend in developing the current level of performance in a qualitative and focused manner (for example, reducing the total number of accidents). These objectives should be measurable but not yet quantified (quantifying objectives is done as part of setting performance targets).

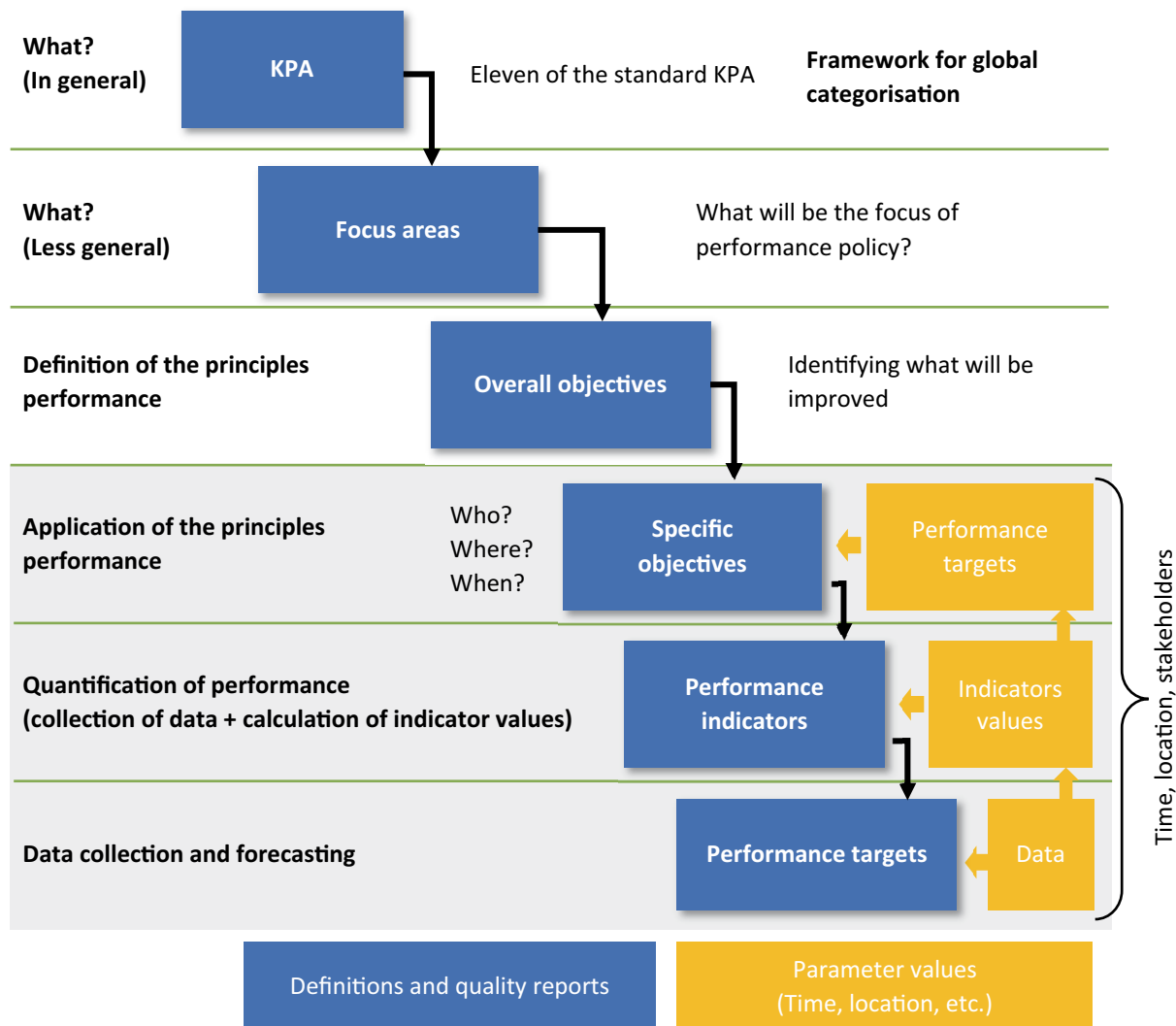
Key performance indicators (KPIs), which are used to set performance targets, are another issue of concern. They should be specific (addressing the objects and events related to air traffic and its environment) and measurable (associated with one or more well-defined performance indicators) in order to assign responsibility for achieving the performance targets. In addition, performance indicators (PIs) are used to determine the extent to which performance targets are achieved. They are used to monitor, compare and verify the performance of air navigation services and network functions. Performance indicators are a tool to quantitatively measure past, present and expected future performance as well as the degree to which overall performance targets should be met.

Indicators should correctly reflect the essence of effectiveness objectives and therefore should not be developed without specific aims in mind. The number of performance indicators within each overall performance objective should be limited to ease the burden of monitoring (collecting and processing statistical data), but it should be appropriate and sufficient for a comprehensive performance assessment. Each performance indicator should have a value for a unique performance target that must be met or overrun within a specified time in order to determine whether the overall performance objective has been achieved.

Performance target is the last term used in the SES performance scheme. It relates to a binding performance parameter adopted by the Member States as part of a performance plan and included in an incentive scheme or corrective action plan. Performance targets should be achievable, realistic and time-bound. The desired performance target may be established as a function of time (i.e. the required speed to achieve the target) and at different levels of aggregation (i.e., local, regional or even global). Realistic and achievable action performance targets should be developed in consultation with airspace users and other stakeholders. The taxonomy of performance measurement is shown in Figure 1. A prerequisite for setting performance targets is determining the level of the initial performance. To help achieve these targets, incentives can be used in the performance management process. Performance management should be a part of the ANSP business plan.

Pursuant to Article 9 of Regulation 390/2013, we can distinguish one key performance indicator (KPI) and several performance indicators (PIs) corresponding to each key performance area (KPA), which are presented in the Annex to the Regulation. The performance of air navigation services is assessed based on the degree of achievement of binding targets for each key performance indicator. Because of the adopted regulations, a performance-based approach (PBA) has become mandatory for EU Member States.

An analysis of the SES regulations governing the performance scheme shows that they neither define indicators to measure the performance of military missions nor performance targets for civil-military cooperation and coordination in air traffic management. This situation is due to the lack of competence of the EU to decide on a type, scope or implementation of military operations and training. Nevertheless, the adopted regulations underline the importance of civil-military coordination and cooperation to achieve the objectives of the performance scheme (Commission Regulation (EU), 2010; Commission Implementing Regulation (EU), 2013) as well as the need to comply with requirements to ensure the protection of essential security interests and defence policy (Commission Regulation (EU), 2010; Commission Implementing Regulation (EU), 2013; Regulation (EC), 2004). The most important issue concerning the use of airspace by military aviation is the inclusion of a description of the civil-military dimension in the performance plan as one of the mandatory elements. It should show the effectiveness of the application of the FUA concept to increase capacity with due regard to military mission effectiveness and, if necessary, relevant performance indicators and targets consistent with other indicators and targets of the performance plan (Commission Implementing Regulation (EU), 2013).



**Figure 1.** Taxonomy of performance measurement

Source: own elaboration based on *Manual on Global Performance of the Air Navigation System*, ICAO Doc 9883.

### 3. Background and evolution of methods in assessing flexible use of airspace effectiveness

Research on the implementation status of the FUA concept was initiated by the Eurocontrol Agency in the second half of 2000 at the request of the Provisional Council functioning within this organization. The aim of the study was to identify best practices for civil-military integration of air traffic services in the Eurocontrol Member States and to develop a set of proposals for the ASM process optimization and civil-military coordination in air traffic management. In the first phase of the project, it was found that there are as many as four different organizational and functional solutions in airspace management (Eurocontrol, 2001), hindering international coordination in the field of uniform application of the FUA concept. One of the tasks of the subsequently initiated pilot project was to establish a common methodology for measuring the actual use of airspace structures by military aviation in order to assess its impact on civil air traffic and military operations. The work resulted in submitting a final report that contained an analysis and assessment of the potential for applying key performance indicators in a military context (ICAO, 2009). This paper was published in 2004.

In 2005, the Commission adopted Regulation (EC) 2150/2005, which obliges Member States to monitor the effectiveness of the application of the FUA concept at the strategic level of airspace management. An established set of military key performance indicators (KPIs) was agreed upon among the pilot countries and endorsed by the Military Team in 2006. These indicators were then tested in a database with manual data entry, and a manual for their use was developed (Eurocontrol, 2009a). As the data for determining the indicators were scattered in different data systems, documents, and locations, their collection, processing, and



sharing required considerable effort, especially at the international level. In this situation, a program called PRISMIL was initiated to establish a European civil-military performance monitoring system. In early 2008, Eurocontrol's Directorate of Civil-Military ATM Coordination presented a draft document defining military key performance areas and indicators (KPAs/KPIs) to the CMIC and the Military Harmonization Group. Both reviewing bodies concluded that the proposed concepts take into account the military specifics of airspace use, but they should be aligned with civilian counterparts and recommended further work in this area.

In the ensuing years, DCMAC, in close coordination with the Performance Review Unit, developed performance indicators for civil-military cooperation in air traffic management for the SES performance scheme. Special emphasis was placed on ensuring military mission effectiveness and civil use of released airspace, drawing on lessons learned from the ongoing initiatives and programs. The result of these endeavours was a document published in early 2015 entitled *Civil-Military ATM Performance Framework* (Eurocontrol, 2015). According to Eurocontrol's recommendations in regard to the flexible use of the airspace (Eurocontrol, 2009), the national strategic airspace management body should implement, where possible, three key performance areas/indicators: airspace efficiency, mission effectiveness and flexibility. Airspace efficiency consists of an effective reservation system, application of FUA procedures, adherence to optimal airspace dimensions, and airspace utilization. The area of mission effectiveness assesses the economic impact of flying through temporary segregated areas (TSAs) and temporary reserved areas (TRAs) and the impact of the location of airspace structures on training. The level of flexibility is determined by factors such as the provision of flight training in non-segregated areas, the release of airspace for civil use, or the consideration of civil and military needs at short notice. To meet the above requirements, the national strategic airspace management authority should:

- periodically (at least once a year) assess the airspace and procedural efficiency at all three levels of the ASM;
- monitor the performance of ATM against the needs of civil and military airspace users at national and European ATM network level using the key performance areas (KPAs) and key performance indicators (KPIs) defined for this purpose;
- assess the effectiveness of FUA procedures through KPIs, taking into account its impact on civil and military airspace users, provision of ATM services, and civil-military coordination;
- use safety, capacity, cost-effectiveness, and environmental KPAs to review procedures and operations in terms of efficient and flexible use of airspace.

#### 4. Eurocontrol concept for measurement and performance assessment in civil-military airspace management

Requirements concerning performance assessment and effectiveness of civil-military airspace management cooperation at the level of Member States and FABs are considerably greater than those established by Regulation (EC) 390/2013. In addition, as already mentioned, the SES performance scheme does not specify how to assess and monitor the effectiveness of military missions. In order to fill this gap, Eurocontrol has prepared a framework document providing guidance for civil and military actors that work towards a civil-military performance-based partnership in the creation of the SES. The mentioned paper defines new performance indicators (PIs) in relation to the previously used key performance areas (KPAs), as well as other areas (ICAO, 2009) where civil-military coordination and cooperation in air traffic management take place. Compared to the SES performance scheme, this document also includes more comprehensive methods for aspects such as monitoring, measuring and evaluating civil-military performance in ATM.

The guidelines developed are intended to support a more harmonized and unified approach towards performance monitoring and evaluation for civil-military coordination and cooperation in airspace management at the national and international levels (FAB, EU or ECAC). It was assumed that consistency in performance description would further facilitate comparative analysis and a better understanding of the levels concerning performance achieved by stakeholders in different countries. Eurocontrol's methodology for performance assessment studies is modelled on the ICAO scheme and is based on the decomposition of key performance areas (KPAs) into focus areas (FAs) and the definition of relevant performance indicators (PIs). In the first edition of the document, it was proposed to use four KPAs where civil-military coordination and cooperation in ATM take place, or where the military side defines performance requirements for air navigation services to fulfil its tasks, and where proven performance indicators already exist. These KPAs are capacity, cost-effectiveness, efficiency, and flexibility. It is planned that the next edition of the document will also address additional key performance areas such as equitable access (to airspace and ATM resources), interoperability and security.

##### Capacity

The capacity KPA refers to the ability of the ATM system to meet the demand for air traffic (in terms of size and distribution in time and airspace) (ICAO, 2009). However, due to the complex nature of different military operations, the ATM system should meet specific military requirements. It is therefore recommended that performance management should be established for SUA capacity as a civil-military focus area (FA) requires the reservation or restriction of airspace at a specified time interval. Currently, fielded combat-ready fifth-generation fighters and the increasing number and variety of unmanned aircraft systems (UAS) require different



and often greater portions of airspace for flight training purposes. Adequate level concerning special use airspace (SUA) is the basic military requirement to enable uninterrupted planning and conduct of training and operations. Since military aviation training programmes are, in most cases, approved annually, SUA capacity should also be determined yearly, relying on the actual training programme for the specific type of training. The demand for SUA capacity should not exceed the designed SUA capacity. In addition to the training duration, the designed SUA capacity must consider ATM inefficiencies, scheduling inefficiencies and the impact of weather conditions on training and operations. The designed SUA capacity will be assessed for a reference airbase.

### Cost-effectiveness

As the Air Navigation Services Charging Scheme mostly does not cover military aircraft flights, the cost-effectiveness of the ATM system in relation to military operations should be adequately addressed. The focus area of performance in terms of mission cost-effectiveness concerns the cost of flight training that is directly attributable to the ATM system. The economic impact of the transit area should be determined as the cost involving the shortest distance with the optimum flight profile from the air base to the training area and back. However, flight time between SUAs is not considered transit time. Cost-effectiveness refers to the actual cost in comparison to the optimal cost. The difference between the actual and optimum costs represents the non-training cost. The calculation of the transit cost should be based on the cost per flight hour. As the methodology for calculating cost per flight hour differs from country to country, it is recommended that transit costs be measured at the national level.

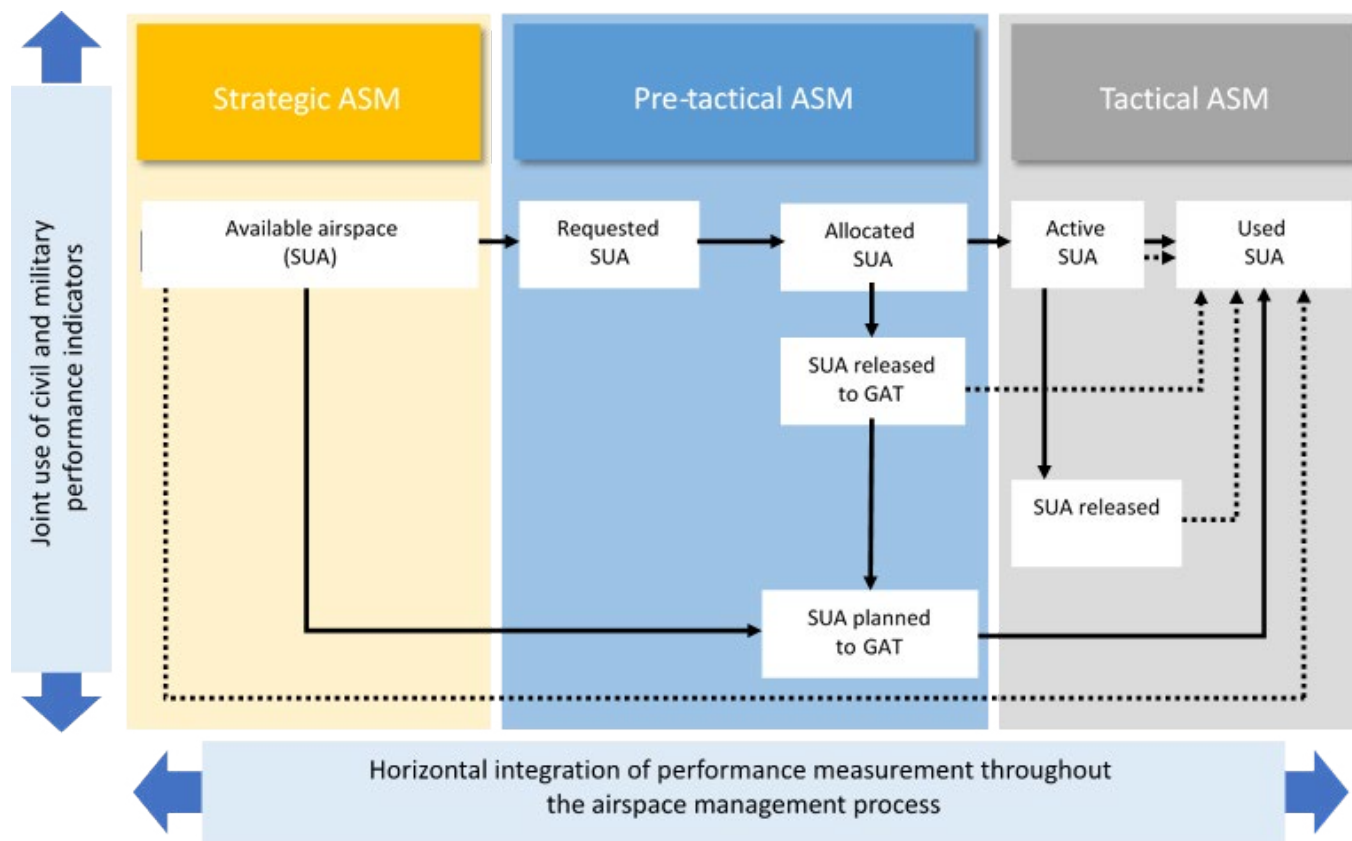
### Efficiency

According to the ICAO, the efficiency KPA refers to the operational and cost-effectiveness of gate-to-gate flight operations from a single flight perspective. Airspace users prefer to depart and arrive at a time of their choice and to fly a trajectory that they consider optimal for all phases of the flight. Unlike civil aviation, GAT IFR operations focusing on flight efficiency, military operations are mission-oriented. Achieving the mission objective is a fundamental requirement for military airspace users. Very often, a single mission (sortie) may consist of more than one aircraft flight involving different aircraft types. Therefore, the assessment of the impact of ATM on military aviation operations and training should focus on how the ATM system can meet military operational and training needs. There are two focus areas distinguished concerning efficiency KPA: mission effectiveness and airspace efficiency. The following two parameters mainly influence military mission effectiveness:

- the dimensions and location of SUAs: defined at the ASM strategic level for a fixed structure to meet operational requirements; and
- SUA availability offered through the FUA and CDM process.

Airspace efficiency is the second focus area. In terms of airspace utilization, civil-military cooperation contributes to the overall SES performance objective. The performance results concerning civil-military ASM processes at the local level encourage the performance at the network level which directly impacts ATC capacity and opportunities to improve flight efficiency. Civilian and military stakeholders have different but not necessarily conflicting expectations on the part of ASM. Thanks to airspace performance management, both parties can contribute to improvement in flight efficiency and airspace capacity. The most significant positive impact on the network can be achieved by optimizing ASM processes at the strategic and pre-tactical ASM level. Tactical SUA management, affecting ATC capacity and flight efficiency, should be used as a last resort. Monitoring the effectiveness of SUA allocation is done by the AUP that is developed at the pre-tactical ASM level (See: Figure 2).

Efficient use of allocated airspace includes the use of released or available SUA airspace for civil or military purposes, even at short notice. To facilitate required training and military operations, SUA time allocated on D-1 must anticipate ATM and planning inefficiencies, adverse weather effects, as well as other specific factors that may affect mission execution on the day of operation. Therefore, double SUA allocation and/or extended SUA allocation time is very common. However, an ATM system can allocate the appropriate SUAs at short notice on the day of operation, which can significantly reduce the need to overbook SUAs on D-1. In order to improve overall performance at the network level, predictability on D-1 with respect to the day of operation is essential. It should be emphasized that timely activation and processing of airspace reservations are very important for conducting effective military training and operations. Existing discrepancies between planning and actual usage of the available SUAs make it difficult to optimize ATC sector configurations and apply optimal air traffic flow management (ATFM) operations. Therefore, when SUA is released either after mission cancellation or at civilian request, air traffic flow must be restored to ensure that the released airspace is fully utilized by GAT traffic.



**Figure 2.** Monitoring the effectiveness of the ASM process

Source: own elaboration.

### Flexibility

ICAO KPA flexibility refers to the capability of all airspace users to modify flight trajectories dynamically and to adjust departure and arrival times, thus enabling them to take advantage of emerging operational opportunities. A major concern in the field of civil-military cooperation is the flexible use of shared airspace. This includes the ability of the ATM system to secure the application of the FUA concept and to respond to rapidly changing requests for SUA use by both GAT and OAT. The level of flexibility of the ATM system to address military requests on short notice is commensurate with the efficiency of SUA allocation through the airspace usage plan (AUP) published the day before operations (D-1). Changes after the publication of the AUP in D-1 over three hours prior to mission execution are part of the ASM pre-tactical adaptation process which includes adjusting the ATM system to the anticipated changes. For military operations, the majority of changes are made three hours before the operation (H-3). Changes introduced after H-1 are mainly subject to tactical coordination. When missions are cancelled, assigned SUAs should be restored to civilian use as soon as possible, preferably before the scheduled start time of the airspace assignment. Existing practices indicate that allocated SUAs may be made available again to the GAT upon civil request in certain circumstances, such as ATC capacity constraints.

The key performance areas (KPA) identified in this document outline structured and high-level performance expectations and ambitions where the civilian and military ATM communities interact or where the military identifies specific performance requirements for the ATM system to meet its security and defence aims. Military performance requirements may be represented in all KPAs where civilian and military stakeholders cooperate with each other. In accordance with the Eurocontrol methodology, within each KPA or focus areas there are interest and/or potential to introduce performance management. Focus areas are then cascaded down to lower-level focus areas as appropriate. In order to safeguard the interests of defence and national security policy and to ensure civil-military contributions to the performance scheme, overall performance objectives for civil-military cooperation and coordination within the performance-based approach (PBA) should be agreed upon within each KPA. These objectives should take into account the desired trend in relation to the current performance, focusing on what should be finally achieved. Performance objectives for civil-military cooperation in ATM should be specific, measurable, achievable, relevant and time-bound. The definition of specific performance targets specifying when, where, who and how much is left to Member States.



In order to quantify the extent to which performance objectives are achieved, appropriate performance indicators (PIs) should be defined. Indicators are a way of expressing performance quantitatively as well as showing actual progress towards the performance objectives. Performance indicators should be related to the key processes and focus on what is important and critical to civil-military cooperation. All performance indicators should be measurable as they are used to monitor, benchmark and review performance. In addition, these indicators can be used, among other things, in negotiations between civil and military partners on airspace design and when assessing the impact of ASM on military mission effectiveness. It is recommended that performance indicators for international use should be standardized to ensure consistency in data collection.

## 5. Conclusions

The analysis of EU legislation as well as ICAO and Eurocontrol documents shows that there are currently a number of performance indicators for assessing the efficiency of the use of airspace by military aviation. Under the provisions of the second SES package adopted in 2009, the EU Member States and their air navigation service providers were legally obliged to manage the implementation of the ANS performance scheme at national and functional airspace block level. The SES legislation takes into account a pressing need to protect the operational requirements of military aviation and stresses the importance of civil-military cooperation and coordination in ATM in terms of effectiveness. However, as SES legislation does not apply to the armed forces, the EU performance targets are not binding on the military side. In order to be fully capable of performing tasks arising from national defence strategy priorities and allied commitments, military aviation must be able to conduct training flights based on the highest standards. The need to meet the operational requirements and training instructions of military aviation within the operational air traffic system has a limiting effect on the performance of the air navigation services in the SES. However, the common cooperation objectives between civil and military airspace users and authorities should be defined to increase the efficiency and safety of air operations. The discrepancies in the methods used to measure and evaluate the effectiveness of the use of flexible space structures demonstrated in this article suggest the need to establish standard procedures on the data collection and processing in the field of the effectiveness of the use of airspace by military aviation. Transparent performance assessment of airspace planning and use will increase airspace capacity, ensure a better alignment of diverging interests of the parties involved, and subsequently increase trust between civil and military stakeholders, laying the foundation for a civil-military performance-based partnership.

## Declaration of interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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