The performance of dynamic airspace management

Report Commissioned by the Performance Review Commission

Prepared by Airspace Unlimited Scotland

Background

This report has been commissioned by the Performance Review Commission (PRC).

The PRC was established in 1998 by the Permanent Commission of EUROCONTROL, in accordance with the ECAC Institutional Strategy (1997).

One objective in this Strategy is «*to introduce a strong, transparent and independent performance review and target setting system to facilitate more effective management of the European ATM system, encourage mutual accountability for system performance...*»

The PRC's website address is https://www.eurocontrol.int/air-navigation-services-performance-review

Notice

Airspace Unlimited Scotland has made every effort to ensure that the information and analysis contained in this document are as accurate and complete as possible. Should you find any errors or inconsistencies we would be grateful if you could please bring them to the PRU's attention.

The PRU's e-mail address is pru-support@eurocontrol.int

The performance of dynamic airspace management

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Executive Summary

This is the final report on a study for the EUROCONTROL Performance Review Commission (PRC) to measure the performance of dynamic airspace management.

The study focuses on the systemic issues arising from the interfaces between civil and military stakeholders. The phrase 'dynamic airspace management' was used to broaden the concept of the Flexible Use of Airspace and focus on the dynamic aspects of the overall management.

Stakeholder consultations

The study consulted with military and civil stakeholders in the UK, France, Spain, Italy and Switzerland. The consultations also included a Military Liaison Officer (MILO) from the EUROCONTROL Network Manager, and representatives from CMC and the PRISMIL team. We also held some informal discussions with airlines.

The consultations revealed varied strategies to maximize the efficient use of national airspaces. There is a general willingness to reduce any excessive routing and release airspace into the network as quickly as possible. There is a perception from some actors that the military are not as proactive as they might be in releasing ARES in a timely manner. Conversely there is frustration from the military when they do release airspace only to observe civilian traffic continuing to avoid the area. We have addressed this study from a systems perspective and found that improvements can be made on all sides, including improved integration between Network Manager Operations and LARA. Also noted is the action of pilots and ATCOs who seek better routings during the tactical phase[1].

Systems level perspective - timing of processes across multiple stakeholders

The discussions with stakeholders identified two potential timing gaps in the system, which might be addressed to achieve better performance in terms of how deactivated ARES is used. These gaps are:

- Flight planning gap **-** Military planning is typically done in sufficient time to allow aircraft operators (AOs) to accurately flight plan, although there may be issues for long-haul flights. AOs generally finish flight planning 5-10 hours before operation (H0), resulting in a gap between the opportunities presented by deactivated ARES and the ability of AOs to replan flights.
- Tactical gap **-** A further gap emerges between the ability of ANSPs to offer tactical routings and those flights ready to take them up once a change of airspace status is known and the system can cope with such tactical action at the network level.

Our understanding from airlines is that the high workload from operations staff dictates that once a day's filings are completed the flight dispatchers move on to the next day, with limited resources available to improve routings. It is down to individual airlines to manage their resources in this respect. We also see more opportunities to respond to deactivated ARES if LARA were to be

[1] For example, the difference between KEA and KEP indicators is understood to reflect tactical action by controllers in identifying and providing opportunities for directs, which may be instigated by aircrew.

deployed at the air force squadron level. For tactical rather than flight planning responses to deactivations, LARA integration into ATM Systems could further improve flight routings.

Gaps and bottlenecks

The study has considered where the gaps and bottlenecks may be in the existing system, stemming from the PRC's recent review of coordination and cooperation agreements, which updated the review in 2015. There remain low levels of record keeping since the first survey in 2015, and aligned to this there does not appear to be significant post-operations analysis. States are also not yet routinely publishing performance indicators, although this is starting to happen through States' performance monitoring.

Emerging requirements

The study identifies several influences that will shape the future of dynamic airspace management. In particular:

- **The international and national legal requirements to achieve Net Zero aviation for civil and military by 2050**. Climate change remediations – and the resulting state treaties, EU and national regulations – are driving all sectors of the economy and may also apply to military aviation.
- **The increased military need for airspace**. The military need to transition to accommodate training for fifth-generation fighters, remotely piloted and autonomous systems and new sixth-generation concepts under development. This is in spite of the vast majority of flying training being conducted synthetically, as an element of live training is required to ensure aircrew are fully prepared for the combat environment.

A review of emerging requirements from the SESAR programme identified the following main development directions for dynamic airspace management:

- Increased flexibility in airspace configuration and activation times.
- Modular and variable profile airspace structures, which is already part of the A-FUA concept.
- Real-time information sharing.
- Sharing resources and harmonising processes.

Potential new performance indicators

A key part of the study was to review the existing performance monitoring indicators and consider how the impact of dynamic airspace management could be monitored. The study focused on the monitoring indicators set out in Regulation 2019/317, the Performance and Charging Scheme, and the 2015 EUROCONTROL Civil Military ATM Performance Framework.

The study has identified some promising new metrics that have shown a sizable flight efficiency and environmental benefit is possible, if the performance of dynamic airspace management is improved in the coming years. These metrics are:

Indicator	Type	Description
ARES-MO (ARES Monitoring)	Monitoring	This concerns the probability that a flight partially circumnavigates a non-active ARES and is a 'missed opportunity' for taking a shorter route through it. This indicator may be integrated into HFE-ARES or needs further work to be a stand-alone indicator. E.g., number of missed opportunity flights per ARES.
ARES-HFE (ARES Horizontal Flight Efficiency)	KPI	This indicator extends the analysis of the missed opportunity flights into: (a) an assessment of the probability that a flight's routing really was a missed opportunity for a better route; and (b) the impact in additional flight minutes of the missed opportunity. E.g., Total ARES flight extension per State, in terms of additional flight minutes converted to approximate fuel burn and CO2. Such data could then be developed to support European, State and airline actions to minimise the flight extension. This could cover active and non-active SUAs.
ARES Occupancy	Monitoring	This concerns the number of civil aircraft in an ARES (active or non-active state) at any given time, such as in 15-minute windows. E.g., Total, or average ARES occupancy by civil flights between, e.g., 0900-1700 per State over a year, divided into weekday and weekend flights. This period corresponds with nominally-activated periods but could be more precise if it included actual times for active and non-active ARES.
AUP analysis	Monitoring	This analysis the evolution of AUP bookings over the course of one day's operations. This is not the same as airspace usage but does give insight into the level of airspace need by the military. E.g., Total airspace volume hours per year per State for AUP (and UUP at, e.g., 0900).

Further work is needed to develop the indicators; however, to indicate the scale of benefits, the HFE-ARES metric has been applied to several ARES. As an example, an ARES in southwest France was considered for flights that flew around it, outside of the period when it is normally booked (0700:1600). This amounted to 15 flights on a weekday, generating horizontal flight extensions of between 2% and 4% and a total of 59 minutes for the day. Extrapolating to a year this results in 328 flight hours that might have been avoided, 687 tonnes of fuel burned and 1735t CO_2. Another ARES showed 61 minutes of flight extension on a Sunday. These numbers are tentative prior to further development; however, they indicate the scale of benefit for the actions currently being developed by CMC, the NM and States.

A potential new dynamic airspace management concept

A final aim in the study was to synthesise the various strands, including stakeholder meetings and discussions with the PRU, into a high-level view of a dynamic airspace management concept. The military need for larger airspace volumes and States' commitment to combating climate change led the study to consider if these seemingly opposing contexts could be met through advances in dynamic airspace management, i.e., increased military airspace *and* civil flight efficiency.

What is apparent from this study is that civil-military stakeholders are willing to adopt increasingly flexible approaches. A further observation is that while traffic flows are constrained by ARES, there may be substantial wind effects that take a flight clockwise or counter clockwise around an ARES. Given the effects of wind vectors on routing there is a case for the overall boundaries of ARES to be made larger but more flexible.

Within such an enlarged flexible airspace structure, exercises could potentially be moved according to forecast winds, to avoid impacting civil traffic flows, with a quid quo pro of larger areas for mission training. There are practical limits to doing this without curtailing the military exercises through a lack of fuel, but there could be significant reductions in civil flight fuel consumption and the corresponding emissions. Such an approach would be compatible with existing and future airspace objectives, principally the ‘variable profile area concept’ but also the SESAR R&D reviewed in Section 3.2.2. The VPA concept is likely to be instrumental in meeting both military airspace and Net Zero goals.

Recommendations

Recommendation 1: Dialogues between military and civil stakeholders, facilitated by EUROCONTROL CMC and the Network Management Directorate, could be used to develop and promulgate best practices. We are aware that good efforts are already underway in CMC and the Network Management Directorate.

Recommendation 2: The processes around AUP updates (UUP) and UUP timings are studied in detail to see whether it could be enhanced and made a more routine component of flight re-planning and tactical operations of ANSPs. This would include an assessment of current practices in civil and military ATC operations. It is also recommended that certain system improvements are accelerated. This includes the B2B integration of LARA into Network Manager Operations and the deployment of Digital NOTAMs. Such actions will ensure that the local and network levels will become more integrated and responsive to changes in the tactical activation and deactivation of ARES.

Recommendation 3: We recommend that the practice of offering and accepting tactical directs, aligning with existing practices in some States, could be encouraged among pilots and ATCOs provided the actions are timely and within the network context and operational capabilities of the actors concerned. The Network Manager has a focus on network predictability and is discouraging tactical intervention, but the possibility to have a direct reduction in fuel consumption and related emissions is a high priority in Europe.

Recommendation 4: We recommend that States act quickly to address the issues identified in the EUROCONTROL 2015 and 2022 civil-military coordination and cooperation surveys.

Recommendation 5: Further develop the analytics addressed in the study, so that they are manageable at a large scale (such as 3-12 month data sets), enhancing the algorithms and using higher-power processing. We also recommend using EUROCONTROL database sources for AUP/UUP analyses.

Recommendation 6: As it was not covered in this study, develop a capacity analysis based on airspace occupancy analytics, including comparing Network Manager Operations' sector occupancy data.

Recommendation 7: States review their airspace to consider improvements from the application of the Variable Profile Area concept defined in SESAR Solution #31 and create enlarged but more flexible special use areas, including cross border areas (CBAs) and Cross-Border Operations (CBO) (use of adjacent areas across borders).

1 Introduction

1.1 General

This document is the final report on a study for the EUROCONTROL PRC to measure the performance of dynamic airspace management, carried out under EUROCONTROL contract 220028.

1.2 Study background

The EUROCONTROL Agency is tasked with the permanent monitoring of the performance of the European air navigation system and of the associated civil-military coordination.

The Performance Review Commission has long been involved in civil-military aspects of performance and recently launched this study on the performance of 'Dynamic Airspace Management' to focus on the systemic issues arising from the interfaces between civil and military stakeholders. The phrase 'dynamic airspace management' was used to broaden the concept of the Flexible Use of Airspace and focus on the dynamic aspects of the overall management and not exclusively on the operational activities. In practice, however, the recommendations made in the study are likely to fit within the existing regulatory framework.

The timing of the study is particularly relevant given the increasing demand for airspace from civil and military users, the demands on States in achieving Net Zero, and the higher tempo of military training during the Russian invasion of Ukraine.

1.3 Study objectives

At the interface between civil and military users there are a variety of processes and information exchanges that support military mission effectiveness and civil flight efficiency. The study has reviewed the current situation at the system level and makes proposals for how a more dynamic approach to airspace could be taken, to yield performance benefits for all Stakeholders. A known example is the reaction times of civil actors to early deactivation of special use airspace (ARES). The study has addressed the following:

- In Section 2, a summary of stakeholder views on current airspace management processes and emerging requirements, identifying any bottlenecks in current practices.
- A review of current and emerging requirements for civil and military stakeholders is presented in Section 3.
- Section 4 covers a review of airspace management monitoring measures and recommends potential new indicators to support a transition to dynamic airspace management.
- In Section 5, a proposal for a high-level concept of operations for dynamic airspace management is presented.
- Conclusions and recommendations are presented in Section 6.

The study took a systems-level perspective, with the aim of being a 'no blame' examination of the ability of the system to effectively maximise the benefits of the Flexible Use of Airspace for all airspace users.

We would like to express our great thanks to the military and civil stakeholders who participated in the study.

1.4 Study terminology

Airspace Reservation (ARES)

In this document we refer to flexible use of airspace (FUA) structures generically as Airspace Reservation(s) (ARES) in the plural or singular. This naming covers Temporary Reserved Areas (TRA), Temporary Segregated Areas (TSA), Danger Areas (DA) etc.

We also refer to the state of an ARES as either active or non-active. For example, the military may book and subsequently activate an ARES, then deactivate it (when the booking has ended, or the exercise has finished early and there is no longer need for the active ARES).

Airspace Management (ASM)

Airspace management (ASM) refers to formal processes defined at the levels of strategic (ASM1), pre-tactical (ASM2) and tactical (ASM3).

Dynamic airspace management

We refer to 'dynamic airspace management' in the study to widen the scope beyond the flexible use of airspace and encompass emerging concepts for how airspace could be managed more dynamically.

Civil-military airspace utilisation

We refer to airspace as a shared resource used by civil and military actors, rather than civil or military airspace, in line with the FUA concept that airspace is a continuum.

2 Stakeholder consultations

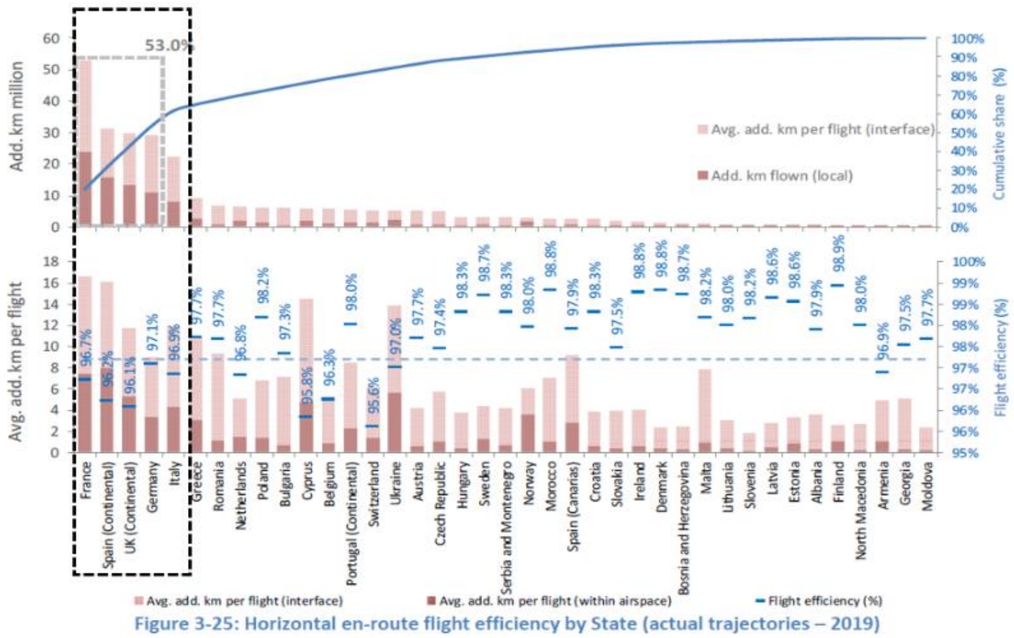
2.1 Introduction

The aim of the consultations was to determine a baseline understanding from which to build potential new monitoring measures.

While it would have been desirable to engage with all EUROCONTROL Member States, time constraints guided us to engage with the core/busiest national players. The States consulted included the United Kingdom, France, Spain and Italy. Unfortunately, Germany was not able to participate at the time.

These States were mostly identified from the scale of their military activity. We also note they have lower horizontal flight efficiency than other States, as shown in Figure 2-1 taken from PRR2019 [1]. In addition, we added Switzerland as it has substantial traffic flows, a significant air force and in combination a challenging airspace to manage. The consultation activity also included a Military Liaison Officer (MILO) from the EUROCONTROL Network Manager and representatives from CMC and the PRISMIL team. We also held some informal discussions with airlines.

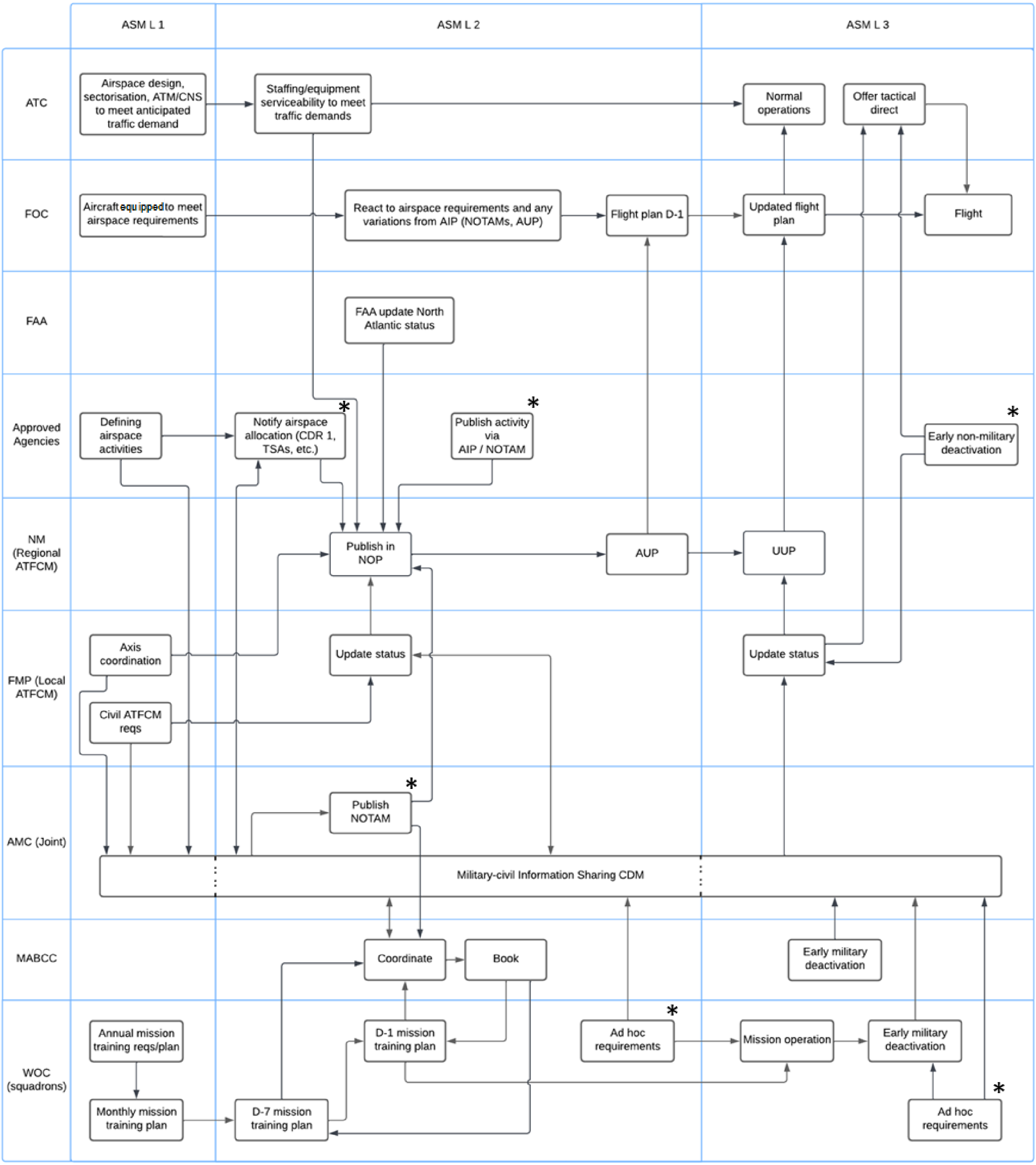
Figure 2-1: Possible correlation between HFE and military activity from PRR2019



2.2 Comparison of States' high-level processes

The study created a 'meta model' to check the similarities and differences between airspace management processes. This is shown in Figure 2-2. On the whole, this model was validated with the Network Manager's procedures [2]. However, the difference between States was found in the details, with different approaches and tools used to reflect national needs and practices. We recommend an exchange between States, which could be coordinated by EUROCONTROL, to develop and share best practices.

Figure 2-2: Flexible Use of Airspace processes (meta model)



2.3 Timing of processes across multiple stakeholders

A main objective of the consultations was to understand the relative timing of events across the various stakeholder processes. This focused on the development and use of the Airspace Use Plan (AUP) and subsequent updates are known as Updated airspace Use Plans (UUPs).

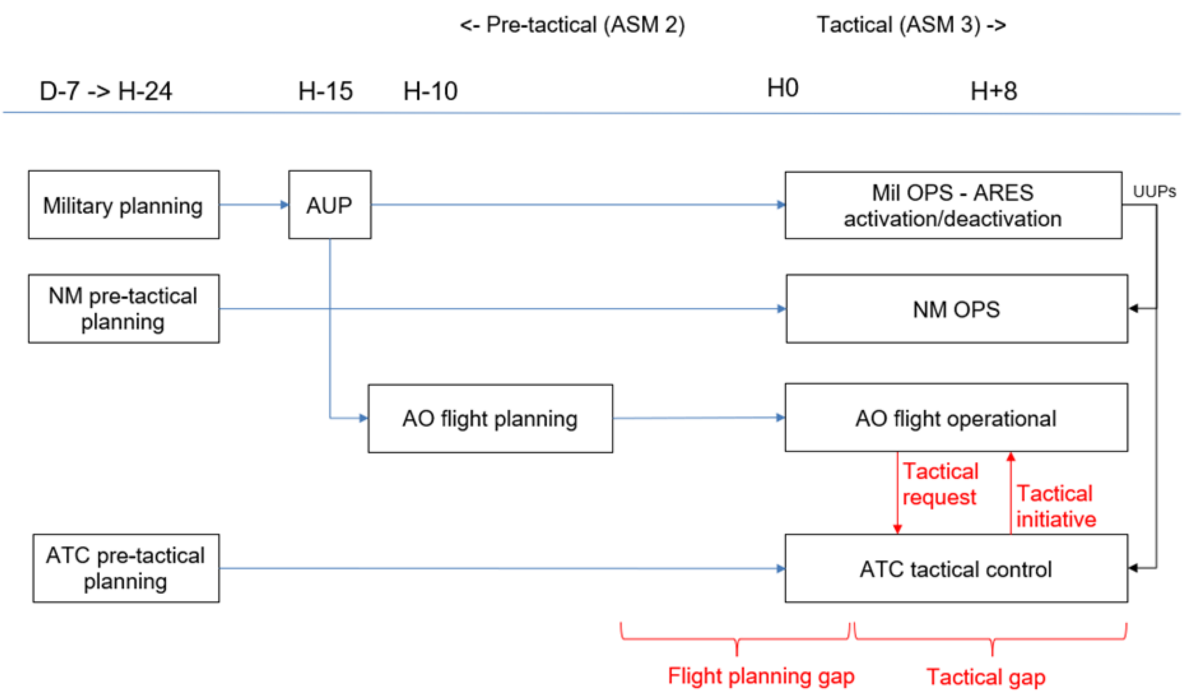
Each State publishes the times of activation and deactivation for Airspace Reservation (ARES) over the course of a day. States' Airspace Management Cells (AMCs) are responsible for promulgating their airspace use plan by 15:00 UTC (at 'D-1'), which is 15 hours (H-15) before the start of the next day's operations (on day 'D', assumed to start at 0600). UUPs are published between 1700 and 2000 UTC on D-1 and then from 0600-2000 UTC on the day of operations, D.

The findings from the discussions with stakeholders are summarised in Figure 2-3. Essentially, the discussions identified two potential gaps in the system, which might be addressed to achieve better performance in terms of how deactivated ARES is used. These gaps are:

Flight planning gap - Military planning is typically done in sufficient time to allow aircraft operators (AOs) to accurately flight plan, although there may be issues for long-haul flights. AOs generally finish flight planning 5-10 hours before operation (H0), resulting in a gap between the opportunities presented by deactivated ARES and the ability of AOs to replan flights.

Tactical gap - A further gap emerges between the ability of ANSPs to offer tactical routings and those flights ready to take them up once a change of airspace status is known.

Figure 2-3: Timings of civil-military stakeholder processes



There is also a lag between submission of airspace activity changes and the publishing of the next UUP, timed every 30 minutes. Often activation changes that would occur with less than 3 hours' notice are not published; the resultant change in availability would then be handled tactically. Hence on the day of operations, stakeholders saw the UUP as less useful than might otherwise be expected and proceeded to handle traffic tactically, through coordination between the relevant military and civil positions, without updating the UUP. Changes to activations of an ARES are currently not communicated from LARA into the NM Operations. Integrating LARA into NM OPS should create a link between the local and regional level. The deployment of Digital NOTAMs may also improve the situation between local and network level [3].

An issue arises for airlines who might be planning a flight and working off an outdated airspace use plan. We expect this to have a small impact, as most airlines flight plan more than three hours ahead, the minimum required being three hours. However, if an ARES is deactivated less than three hours ahead[2], creating an opportunity for a flight to gain a better route, airlines may not re-file as they would then be classified as a late filer and could be penalised in the slot allocation process [4] – i.e., within three hours of estimated off-block time (EOBT) the flight is 'at the back of the queue for flow regulations'.

Our understanding from airlines is that the high workload from operations staff dictates that once a day's filings are completed the flight dispatchers move on to the next day, with limited resources available to improve routings. It is down to individual airlines to manage their resources in this respect. We also see more opportunities to respond to deactivated ARES if LARA were to be deployed at the air force squadron level. For tactical rather than flight planning responses to deactivations, LARA integration into ATM Systems could further improve flight routings, as in Spain through a recently deployed interface between ENAIRE's SACTA ATS system and LARA [5].

2.4 CDM process

While CDM processes are active in each of the States we consulted with, there was a general sense that the military requirement ultimately trumps civil requirements. When asked, "*Who has the final say on airspace issues when there is a conflict of requirements?*" The common answer was that this is resolved through negotiation, with escalation up to ASM level 1, but there was no clear final decision maker. This means that military interests, e.g., for large exercises, are largely met by applying mitigations to limit the impact on civil traffic flows. It was, however, recognised as a 'two-way street', with civil traffic flows being accommodated for special events.

Large military exercises are known and planned for well in advance, giving time to develop mitigations. As reported in the 2022/23 update of the PRC Survey [6], there is a lack of impact assessments for restricted or segregated airspaces and the affect they have on GAT. Hence for larger scale exercises the negotiations appear not to be based on any quantitative objectives of impact.

2.5 Notification of airspace

Generally, States use the daily issued Airspace Use Plan (AUP) to notify airspace activation times. Once the AUP is first published, any subsequent alterations to the availability are communicated

[2] More realistically four hours would be needed to identify the opportunity and file before the Network Manager minimum three hours window.

through the Updated Use Plan (UUP). The dissemination of information relating to airspace activity via the AUP/UUP is the responsibility of the EUROCONTROL Network Manager (NM).

States may also reference activation times in their Aeronautical Information Publication (AIP), such as H24 or 07:00-18:00 M-F.

Information published by AUP/UUP is also notified . If the airspace is no longer required, a NOTAM will be issued advising of airspace availability, but not necessarily the UUP, which is important in providing a single source of up-to-date information that can be read digitally. There would be a distinct advantage to transitioning to Digital NOTAM.

2.6 LARA

The LARA ASM Support System[3], developed and deployed by EUROCONTROL to Member States, is widely utilised to support States in their national ASM process (in pre-tactical and tactical levels) including interfaces with the Network Manager for publication purposes. LARA does not directly update the Network Manager (NM) of airspace activation and deactivation.

The level of integration into national airspace management systems is varied. Apart from in Spain, the use of the LARA tool appears to be at AMC level only, with limited onward availability at a station or squadron level within the various military agencies consulted.

Although some States do not have LARA deployed throughout the military to squadron level, others have internal systems of notification linked in some way into the LARA network, such as France's DIANE system. This system gathers military requirements and supports a CDM process within the military, prior to CDM processes between civil and military.

2.7 Advanced Flexible Use of Airspace

Many jurisdictions have adopted some manner of subdividing larger ARES, and only utilising a selection of segments reflecting the mission's operational requirements. This approach can be effective in allowing more tactical interventions by ATCOs in offering more efficient routes on an ad hoc basis. Several of those consulted interpreted the segmentation of ARES as being the same as Variable Profile Areas of the Pilot Common Project [7].

The French AMC use a locally-developed priority system to weight the civilian traffic demand against the military mission requirements. Depending upon the number of civilian aircraft requesting a specific route, the ARES will then be allocated for military use attempting to reduce the impact to civilian operations.

The Italian AMC use a number of smaller ARES and limit the hours that these are booked to the minimum. The concept is that if more time is needed for an exercise to complete, then civilian flights

[3] A similar system, STANLY ACOS, is in operation in Germany.

are vectored around the ARES in question. In theory this will minimise the impact on airspace usage and allow more flight planned utilisation of ARES.

2.8 Engagement with Airlines

It was planned to host a face-to-face round table workshop as an element of this deliverable, however, the CMC are planning to organise a similar event in future, and it was deemed counter-productive to hold two. The study team has, however, had informal contacts with airline stakeholders to verify the general timeframes from a flight planning perspective and the current reaction times for re-planning routes.

2.9 Humans in the loop

Stakeholders commented there would be benefit from increased interaction between civil and military counterparts concerning ASM capabilities and constraints. It was stressed that technology cannot solve all problems and the role of the pilots and controllers is pivotal in the performance of dynamic airspace management.

2.10 Summary

An open and frank discussion relating to the concept of dynamic airspace management has revealed varied strategies in how to maximize the efficient use of national airspaces. While there are principles, methodologies and guidance available through EUROCONTROL and ICAO, individual States apply solutions tailored to their operations and systems. There is a general willingness to reduce any excessive routing and release airspace into the network as quickly as possible.

Recommendation 1: Dialogues between military and civil stakeholders, facilitated by EUROCONTROL CMC and the Network Manager, could be used to develop and promulgate best practices. We are aware that good efforts are already underway in CMC and the Network Manager.

The AUP is an effective tool to promulgate the activity of ARES on a daily basis and can be exploited by flight planning systems to enable the best routings. However, the UUP is limited in its use for flight re-planning, and there are insights from the consultation on how to exploit routing opportunities from booked ARES being cancelled or deactivated early. These include real-time updates of deactivations (currently done half-hourly), extending LARA to squadron level, and developing ATC procedures to precipitate opportunities.

Recommendation 2: The processes around AUP updates (UUP) and UUP timings is studied in detail to see whether it could be enhanced and made a more routine component of flight re-planning and tactical operations of ANSPs. This would include an assessment of current practices in civil and military ATC operations. It is also recommended that certain system improvements are accelerated. This includes the B2B integration of LARA into Network Manager Operations and the deployment of Digital NOTAMs. Such actions will ensure that the local and network levels will become more integrated and responsive to changes in the tactical activation and deactivation of ARES.

There is a perception from some actors that the military are not as proactive as they might be in releasing ARES in a timely manner. Conversely there is frustration from the military when they do release airspace only to observe civilian traffic continuing to avoid the area. We have addressed this study from a systems perspective and found that improvements can be made on all sides; including improved integration between Network Manager Operations and LARA, and ANSPs offering more tactical directs based on real-time airspace status.

It is also noted that it is the action of the pilots and ATCOs who seek better routings during the tactical phase that makes the system work as efficiently as possible, by making tactical choices based on the situation as it presents itself at the time[4].

Recommendation 3: We recommend that the practice of offering and accepting tactical directs, aligning with existing practices in some States, could be encouraged among pilots and ATCOs provided the actions are timely and within the network context and operational capabilities of the actors concerned, including the Network Manager. The Network Manager has a focus on network predictability and is discouraging tactical intervention, but the possibility to have a direct reduction in fuel consumption and related emissions is a high priority in Europe.

[4] For example, the difference between KEA and KEP indicators is understood to reflect tactical action by controllers in identifying and providing opportunities for directs, which may be instigated by aircrew.

3 Current and emerging requirements

3.1 Current requirements - gaps and bottlenecks

The study has considered where the gaps and bottlenecks may be in the existing system stemming from the PRCs review of coordination and cooperation agreements.

PRC Review of civil-military coordination and cooperation agreements

Important context to the work has been information from a revamped survey of States' civil-military practices [8].

The revised survey has shown little change in FUA practices since the first survey in 2015 [6]. The 2022/23 review of practices has similarly focused on the existing civil and military coordination and cooperation arrangements in each Member State. All three levels of airspace management (ASM) have been addressed, but the main focus was with Airspace Managers, who are responsible for the day-to-day operations of the Airspace Management Cell (AMC), and working at the pre-tactical level (ASM 2). There has been a slight improvement since the 2015 survey, but some key issues remain:

- A general absence of clear national and regional strategic objectives for both Operational Air Traffic (OAT) and General Air Traffic (GAT) at the strategic level (ASM level 1).
- A lack of impact assessments for restricted or segregated airspaces and the affect they have on GAT in terms of available ATC capacity and route options.
- Haphazard flow of information throughout the ASM process (availability of the right information to the relevant parties at the right time).
- A considerable number of Member States are still using the most restrictive approach to airspace management (ARES booked H24 for 365 days and released by NOTAM or UUP).

There remain low levels of record keeping since the first survey in 2015 and aligned to this there does not appear to be significant post-operations analysis. States are also not yet routinely publishing performance indicators. The PRC's recent review has not found any significant improvement since 2015. States have support available from EUROCONTROL PRISMIL in producing indicators; both the civil-military indicators set out in the Performance and Charging Scheme[5] [9], and the 'Civil-Military Performance Framework' developed by EUROCONTROL CMC, known as the 'Civil Use of Released Airspace (CURA)' indicators [10].

On the whole, while States could well claim to be following the bulk of the Flexible Use of Airspace requirements, they would benefit by establishing clear strategic intent from ASM Level 1 through to ASM Level 3. As we will address in Section 3.2, the emerging requirements for larger areas for new aircraft platforms and Net Zero lead to a more strategic focus being necessary.

Recommendation 4: We recommend that States act quickly to address the issues identified in the EUROCONTROL 2015 and 2022 civil-military coordination and cooperation surveys.

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[5] These are referred to as PI#6, PI#7 and PI#8 in the PRB reports.

It is hoped that the analytical aspects of this study discussed in Section 4 will support further progress in performance assessment and thereby impact assessment by States and at European level.

SES Regulations

The SES regulations apply to civil aviation, as defence policy in the European Union is predominantly a competence of the Member States. Without action at State level, the implementation of the flexible use of airspace depends on what can be agreed by States' high-level policy bodies. In effect, both civil and military aviation are responsible for the success of the flexible use of airspace, but only civil aviation is directly accountable via the regulations.

3.2 Emerging requirements

3.2.1 Drivers for new airspace requirements

There are several influences that will shape the future of dynamic airspace management, in this study we have focused on the following two:

- **The international and national legal requirements to achieve Net Zero aviation for civil and military by 2050**. Climate change remediations – and the resulting state treaties, EU and national regulations – are driving all sectors of the economy. The EU's 'Fit for 55' programme may strongly impact aviation, although a substantive part of the action may need to be in off-setting [11] to meet 2030 targets.[6] Such offsetting buys time for new technologies, such as Sustainable Aviation Fuel (SAF), which may also apply to military aviation prior to new technologies being scaled, such as Carbon Dioxide Removal (CDR).
- **The increased need for military airspace**. The military need to transition to accommodate training for fifth-generation fighters, remotely piloted and autonomous systems and new sixth-generation concepts being developed under the multilateral Future Combat Air System (FCAS) [12] and similar programmes. In the UK, a recent airspace change proposal [13] remarked that "*Changing external circumstances make current solutions untenable to deliver the required needs of Defence*". This is in spite of the vast majority of flying training being conducted synthetically, as an element of live training is required to ensure aircrew are fully prepared for the combat environment.

Other influences that have not been covered, but are of growing importance, are:

- **New types of airspace user**, which are expected to scale rapidly: high altitude, space launch, UAVs, eVTOL and airships.

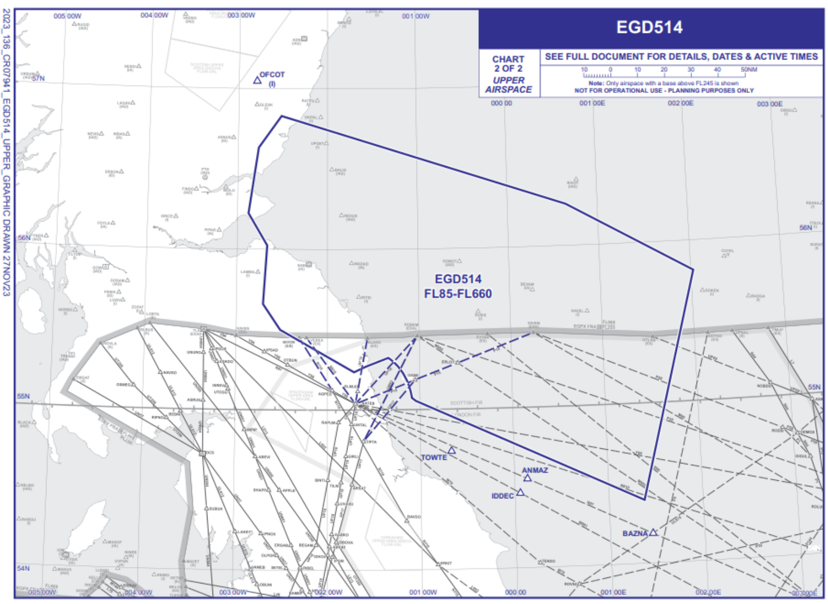
[6] The EUROCONTROL Objective Sky Green report attributes 75.9% - 86.6% of emissions by 2030 to be achieved by Market Based Measures (MBMs). These MBMs effectively comprise ETS and CORSIA and are essentially carbon offsets.

- **New types of propulsion** – In response to Net Zero, new aircraft are under development which may have different flight characteristics and fly at different speeds and altitudes, such as hybrid electric and all-electric aircraft.

Noting that Net Zero applies to the military, there are growing efforts in defence sustainability, where air forces may be the largest contributor to current carbon footprints. For example, the UK RAF is targeting Net Zero by 2040, with work to date is focused on Power to Liquid (PtL)[7]. In France, the 2019 Airspace Modernisation and ATM Strategy [14] references the need for a greater dynamism in the booking and use of 'flexible airspace structures', and that new military aircraft (both manned and unmanned) often require larger volumes of segregated airspace in which to train and maintain operational readiness.

The war in Ukraine is likely to increase NATO activity across Europe, with greater presence of the USAFE, including multiple squadrons of F-35As and additional joint force exercises. The following figure shows a recent UK airspace change request to accommodate such large joint force exercises. The area for this change request is shown in Figure 3-1 and would involve participants from RAF Lossiemouth, Coningsby, Marham and Lakenheath bases [13].

Figure 3-1: Area of recent UK airspace change proposal, now EGD514



The above issues are driving new ways of thinking about airspace and will drive new concepts and requirements. Change in any one driver cannot be divorced from the others, and until aviation becomes sustainable there will likely be increasing prioritisation of flight efficiency as a driver of the system. We will return to this point later in the next section as it appears possible to achieve military and civil needs in a complementary way.

[7] A synthetic Sustainable Aviation Fuel (SAF) based on carbon capture, electrolysis of water to create hydrogen and a chemical process to combine these elements to create jet fuel.

3.2.2 SESAR emerging requirements

A review of emerging requirements from the SESAR programme[8] was undertaken to understand the adequacy of the existing arrangements in dynamic airspace management and the future potential for improved performance.

3.2.2.1 Advanced Flexible Use of Airspace (A-FUA) concept

A key achievement of SESAR in respect of dynamic airspace management was the development of the Advanced Flexible Use of Airspace (A-FUA) concept. This was initially developed under Solution #31 of the SESAR 1 programme, and further developed by EUROCONTROL [15]. The aim of A-FUA is to further integrate FUA into the wider European network management system, covering ASM, ATFCM and ATC at the pre-tactical, tactical and post operational evaluation and performance monitoring levels.

The concept of operations was mandated as part of the 'pilot common project' regulation [7], combining Airspace Management (ASM) and the Advanced Flexible Use of Airspace (A-FUA). Together these concepts address the possibility of managing ARES more flexibly in response to airspace user requirements. The regulation requires changes in airspace status to be shared with all airspace users.[9]

3.2.2.2 A-FUA R&D developments

We have reviewed the implementation objectives that have been determined as part of the European ATM Master Plan 2020 and are described in the eATM Portal [16]. These implementation objectives are under development through R&D in the SESAR programme. We have extracted brief descriptions in Appendix A and summarise them overall as follows:

Summary of emerging requirements from current R&D

- **Increased flexibility in airspace configuration and activation time**
  - *Increased flexibility of airspace spatial configurations.* What is important is not the ability to book a pre-defined exercise area but the right shape of exercise area for the mission training at the same time as minimising the impact on civil flights. This encompasses concepts such as the design and activation of variable profile areas and dynamic mobile areas.

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[8] "SESAR is the technological pillar of the EU's Single European Sky policy and a key enabler of the European Commission's Sustainable and Smart Mobility Strategy. SESAR defines, develops and deploys technologies to transform air traffic management in Europe." Source: https://www.sesarju.eu/discover-sesar

[9] Network Manager, air navigation service providers and airspace users: Flight Operations Centre and Wing Operations Centre.

- *Increased flexibility in time by adapting plans during the execution phase*. Flexibility in time is important to the military, who may have a pressing training need at short notice or need to adapt to inclement weather. This places a need for civil flights to respond through re-filing or even re-routing. We estimate that this will be an occasional rather than regular requirement. It does, however, lie outside of the timescale that civil airspace users would have filed a flight plan and would require late filing without penalisation, most likely through direct NM involvement or specialised processes.

- **Modular and variable profile airspace structures**
  - This is a significant change to existing airspace designs and is already part of the A-FUA concept and PCP regulation [7]. While the SES regulations may be seen as non-binding on the military, there may be both military (airspace volume) and State (net zero) benefits that drive this concept.

- **Real-time information sharing.** Wider sharing of information between FUA actors in the ASM 3 execution phase will likely lead to short-window opportunities being taken. Sharing the data directly with aircraft may enhance this and support greater overall flexibility.

- **Sharing resources and harmonising processes**
  - *European wide harmonisation of ASM3 processes*. This is already occurring at ASM1-2.
  - *European wide sharing of ARES between militaries*. Initially cross-border (as currently practiced), but potentially other areas. A possible precedent for this is the NATO practice of joint force exercises.

- **Automated support**. Already a general trend used to support scaling of FUA processes.

4 Review of airspace monitoring measures and recommendations

4.1 Introduction

In this section we present a review of existing indicators before presenting potential new indicators that have been identified in the study. These potential new indicators are intended to be complementary to existing indicators, with the aim of improving understanding of the impact of the dynamic management of airspace.

The review of indicators has focused on the CMIC [10] and EC [9] performance indicators and the insight provided by the stakeholder consultations.

4.2 EC performance indicators

Performance indicators for the flexible use of airspace are included in the revised performance and charging scheme, Regulation EU 2019/317 [9]. Under this regulation, Key Performance Indicators (KPIs) are nominally used for target setting and Performance Indicators (PIs) for monitoring, and which may lead to future KPIs. Regulation 2019/317 sets out a set of environment indicators to be monitored. Three of these (c, d, and e) are related to civil-military airspace usage at regional level for monitoring purposes only:

- (c) The effective use of reserved or segregated airspace
- (d) The rate of planning via available airspace structures
- (e) The rate of using available airspace structures

These indicators are set at regional rather than local (national) level for monitoring only, and not for target setting as mentioned above. Our assessment of these indicators are as follows:

(c) Ratio of initial requested allocated time for reservation or segregation and the final allocated time used

This is a measure of how good the military are at planning their needs and then releasing un-needed airspace. For clarity, the indicator is interpreted by the PRB as the inverse of the definition in the regulations [17]. For example, if an ARES is booked for 0900 – 1700, and used for 0900-1500, the indicator gives a ratio of 6/8 = 0.75.

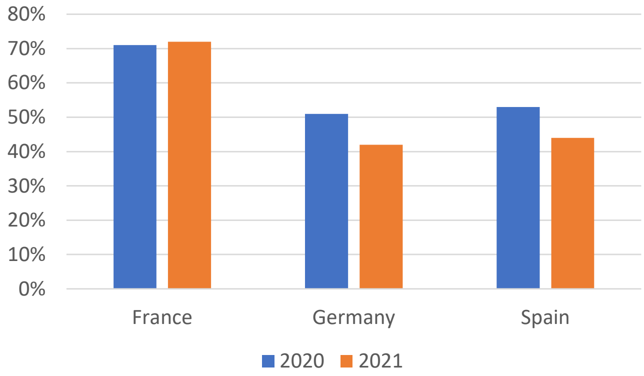
This does not quite measure the effective use of airspace by civil or General Air Traffic (GAT), which would require a measurement of GAT usage only, even if non-usage was caused by civil.

Reporting of this indicator is limited, but there is some data from the PRB's report on Regulatory Period 3 (RP3) [17], as shown in Table 4-1 and Figure 4-1.

Table 4-1: Effective use of reserved or segregated airspace (PI#6)

	France	Germany	Spain
2020	71%	51%	53%
2021	72%	42%	44%

Figure 4-1: Effective use of reserved or segregated airspace (PI#6)



The above data shows that approximately 30-50% of the time that airspace is booked it is not used by the military. There are operational reasons for this, including weather and aircraft technical problems, but nevertheless this is potentially a significant area for improvement; it also requires civil ATC and airspace users to respond in time to realise the benefit.

Recommendation: As per Recommendation 1, EUROCONTROL facilitates and exchange between States on best practices and approaches to airspace bookings to increase their utilisation of special use airspace and develop specific performance plans to address this area.

(d) Ratio of flights filing via airspace structures and the number that could have done so

This compares the number of flight plans intending to use an available airspace structure divided by number that could have done so. For example, 80% of flights plan file a direct through a non-active ARES, its non-active status being informed by the Airspace Use Plan (AUP).

This is a measure of flight planning capability, i.e., whether airline flight planning takes account of available airspace through the AUP.

This performance indicator requires a comparison flight plan to be computed with the AUP data taken into account.

(e) As (d) but ratio of aircraft flying via such airspace structures

This compares the actual rather than planned route with a comparison flight plan. For example, 90% of flights that fly directly through a non-active ARES; based on its published availability through: (a) the Airspace Use Plan (AUP), (b) changes to the AUP promulgated through the Updated Use Plan (UUP) and/or (c) via other means such as direct communications between Military and Civil ATC.

This is also a measure of flight planning capability combined with the ability to accept tactical route changes provided by civil and/or military ATC, i.e., requesting and granting 'directs'.

This indicator also requires that a comparison flight plan be computed with the AUP data be taken into account.

EUROCONTROL Re-routing Tool (RRT)

A comment on indicators (d) and (e) is that the Network Manager already has tools to provide alternative trajectories to airlines through its 're-routing tool'. Whether this can be effectively applied to increase performance depends on the interfaces between LARA and the Network Manager and the time/resources available within airline flight dispatch.

4.2.1 CMIC performance indicators

A further set of indicators has been developed by the 'Civil-Military Interface Standing Committee' [10]. These are being refreshed due to changing sources of data, but we show the current set in Table 4-1 alongside the related EU indicators. As the CMIC indicators are quite technical, they are expanded on in Appendix B. We have organised the indicators in Table 4-1 under the following classifications:

- Military mission planning, making the best use of equipment and airspace resources.
- Military mission costs, minimising the costs of training exercises.
- Civil flight planning performance, e.g., making use of the best information pre-tactically.
- Network performance, making the best of changes in the network.

In Table 4-2 we also show the airspace management (ASM) time horizon.

Table 4-2: CMIC and EU civil-military indicators[10]

Ref[†]	Performance indicator	Benefit*	Benefits direction	Data originator	ASM Level
Military mission planning					
	EU SES indicator (c)	Civil HFE		Military	2
1	ARES time requested (SCr)	Mil. RE	↑ benefits military, ↓ benefits civil	Military	2
4	Allocated ARES dimensions vs optimum ARES dimensions (AvsO)	Mil. RE	↑ benefits military, ↓ benefits civil	Military	2
6	AUP allocation efficiency (AAE)	Mil. RE	↓ benefits civil	Military	2
7	Use of allocated ARES (UoA)	Civil HFE	↑ benefits military and civil	Military	3
11	ARES allocation at short notice (SASn)	Civil HFE	↑ benefits military, ↓ benefits civil	Military	3
12	ARES released to GAT prior to scheduled start (tGAT)	Civil HFE	↑ benefits civil	Military	3
Military mission costs					
2	Transit Cost (CoTT)	Mil. HFE	↓ benefits military	Military	3
3	Average cost of transit (ACoT)	Mil. HFE	↓ benefits military	Military	3
5	Average transit time (AvT)	Mil. HFE	↓ benefits military	Military	3
Civil flight planning					
8	Time planned vs. time used by GAT in available ARES (tPvtU)	Civil HFE	↓ benefits civil	Civil**	2
	EU SES indicator (d)	Civil HFE		Civil (NM)	2
Network					
9	Released ARES time used by GAT (rStU)	Civil HFE	↑ benefits civil	Military + Civil	3
	EU SES indicator (e)	Civil HFE		Civil (NM / ADS-B)	3

† = Reference for Figure 4-2.

*HFE = Horizontal Flight Efficiency, RE = Resource Efficiency

**Noting that military initiate AUP, civil include it in their flight planning.

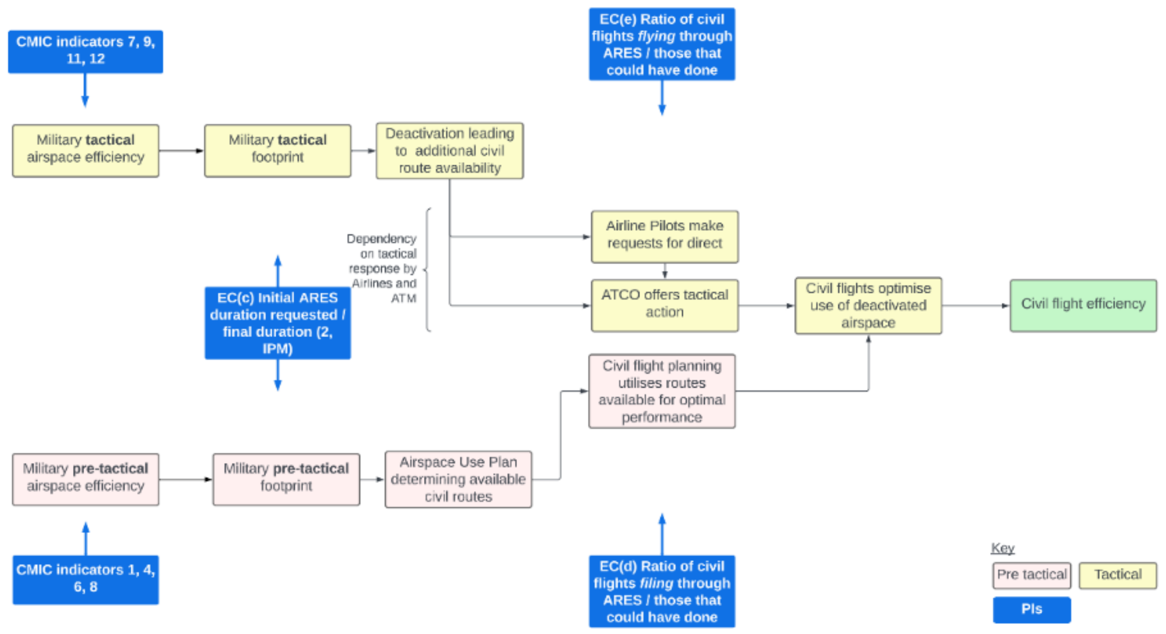
[10] For simplicity we have excluded the PI: 'Proportion of SUAs to which ASM Level X applies (ASMx)'.

4.2.2 Relation of civil-military indicators to expected operations

In Figure 4-2 we relate the performance indicators discussed to how we expect civil-military operations to function. In this figure we have identified the CMIC performance indicators, which affect either the military's pre-tactical or tactical 'footprint'. The footprints are as follows:

- The pre-tactical footprint is the airspace volume booked for a number of hours. Later on, we introduce a measure for this as 'airspace volume-hours'. The important point about this pre-tactical footprint is that it is visible to airline planning through the Airspace Use Plan (AUP).
- While changes to the AUP happen on the day of operations through the Updated Use Plan (UUP), there are system-level challenges for airlines to change flight plans in time. We therefore distinguished a military tactical footprint which can be responded to operationally by pilots and ATC, in an effort to take advantage of early deactivations.

Figure 4-2: Relation of civil-military indicators to expected operations



Overlaid on the above figure are the CMIC performance indicators, which influence the size of the pre-tactical and tactical footprints. The more efficient that airspace management by the military is, the smaller the footprint to civil traffic.

4.3 Analytical development

4.3.1 Introduction

There were four analyses developed in the study, with one as a potential future KPI and the other three as potential monitoring indicators as shown in Table 4-3.

Table 4-3: Potential new indicators

Indicator	Type	Description
ARES-MO	Monitoring	This concerns the probability that a flight partially circumnavigates a non-active ARES and is a missed opportunity for taking a shorter route through it. This indicator may be integrated into HFE-ARES or needs further work to be a stand-alone indicator. E.g., number of missed opportunity flights per ARES.
HFE-ARES	KPI	This indicator extends the analysis of the missed opportunity flights into: (a) an assessment of the probability that a flight's routing really was a missed opportunity for a better route; and (b) the impact in additional flight minutes of the missed opportunity. E.g., Total ARES flight extension per State, in terms of additional flight minutes converted to approximate fuel burn and CO2. Such data could then be developed to support European, State and airline actions to minimise the flight extension. This could cover active and non-active ARES.
ARES Occupancy	Monitoring	This concerns the number of civil aircraft in an ARES (active or non-active state) at any given time, such as in 15-minute windows. E.g., Total or average ARES occupancy by civil flights between, e.g., 0900-1700 per State over a year, divided into weekday and weekend flights. This time period corresponds with nominally-activated periods but could be made more precise to include actual times for active and non-active ARES.
AUP analysis	Monitoring	This analyses the evolution of AUP bookings over the course of one day's operations. This is not the same as airspace usage but does give insight into the level of airspace need by the military. E.g., Total airspace volume hours per year per State for AUP and UUP at, e.g., 0900.

These indicators are described in more detail below.

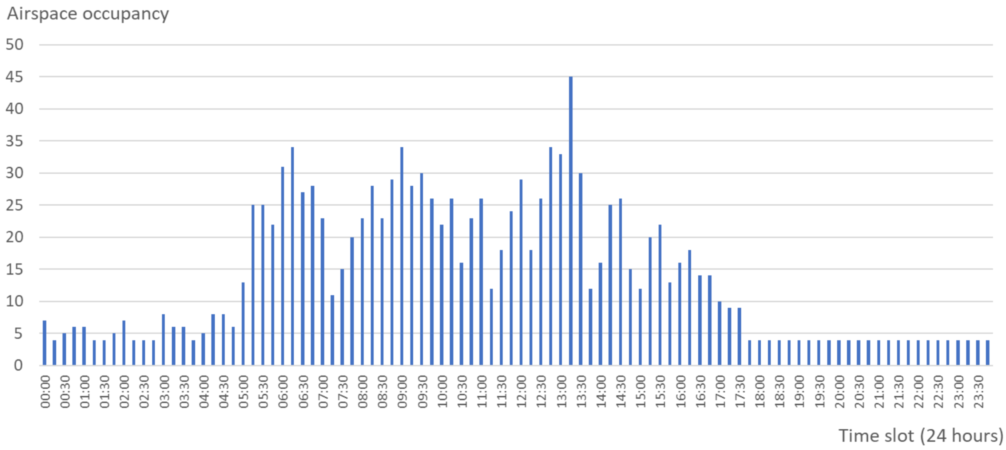
4.3.1.1 ARES occupancy

An example of the airspace occupancy analysis is shown in Figure 4-3. It shows the occupancy of the ZRTORION 1-4 ARES in France, which have a combined area of 6924 NM^2. Data is from 1/5/2019. The idea behind the analysis was to show the times of day that the airspace concerned was used by civil traffic and to look for signs of tactical airspace management processes where an ARES may be booked but civil and military controllers facilitate tactical directs through the ARES concerned. This indicator is different to sector occupancy as the volumes are different although they will overlap. However, there were some issues which prevented a meaningful analysis, and the work was paused pending the approach described for the HFE-ARES indicator. These issues were:

- Some duplication in the count per time slot as the analytics did not filter out flights that had been through two or more ARES.
- Some military flights included in the count, which require filtering out.
- No AUP data for the period in question, and there appeared to be limited military activity.

While this analysis was paused in the study, there remains potential with some further work to correct and validate it based on the above points.

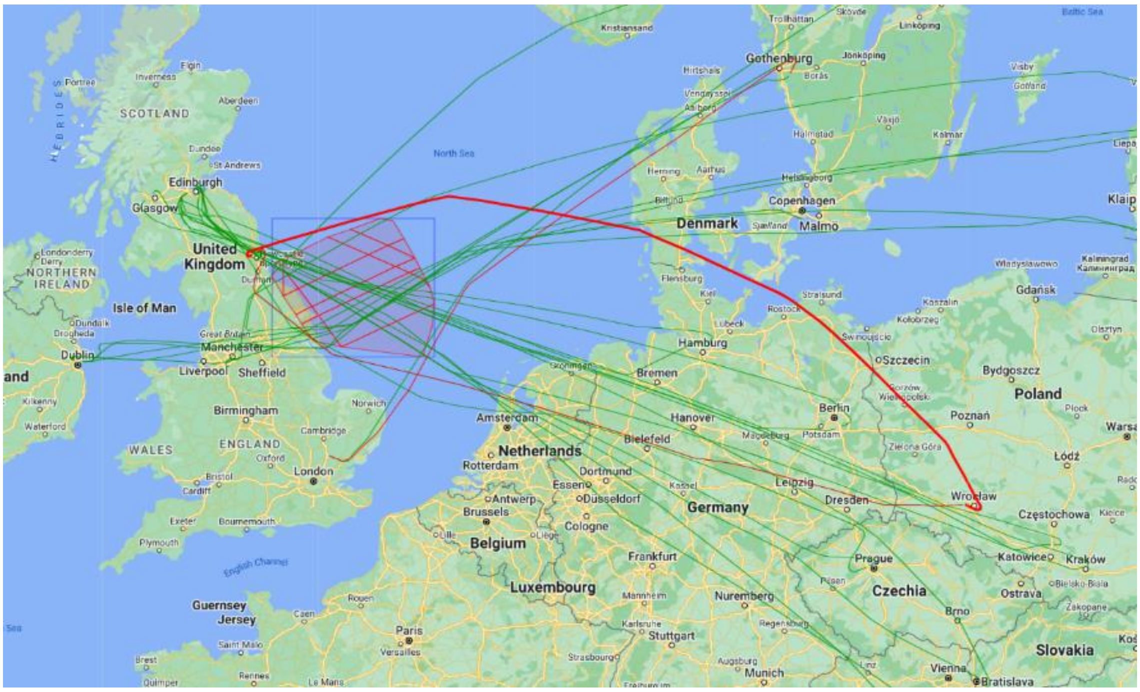
Figure 4-3: Occupancy of France's Orion ARES ZRTORION 1-4



4.3.2 Non-active ARES - potential 'missed opportunity' flights

Figure 4-4 shows two potential missed opportunity flights. The NCL-WRO flight takes a northerly route around the D323 exercise area and the return flight a southerly direction. At the time of these flights the D323 was not activated, and the flights flew within 10Nm of its boundary. The great circle route is also shown on the figure, indicating that in distance terms these were longer flights.

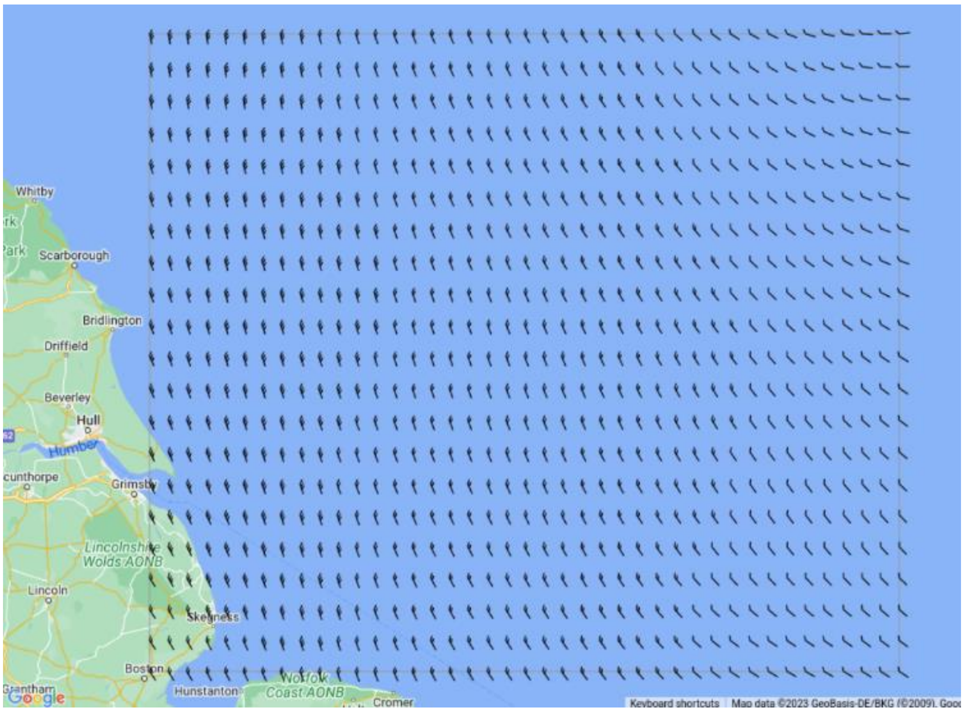
Figure 4-4: Potential missed opportunity flight, NCL-WRO / WRO-NCL Sunday 5 May 2019



What cannot be discounted is that the winds at the time may have strongly influenced the routing. From a manual analysis of the winds, shown in Figure 4-5 (for 2 May 2019 due to limited wind data), there were strong northerly to north-westerly winds, up to 30kts, which would present a healthy tail-wind component for NCL-WRO and a head wind component on the return. Given this, it is not clear why the routings were as they were, and indeed the NCL-WRO route might have been shorter if it had taken the southerly route shown in **Figure 4-4**.

This is a first comparison of winds and the data needs further checking in case of any errors in reading the wind data. However, this does demonstrate that a more sophisticated analysis including wind vectors would be beneficial and our recommendation is to develop a wind component to the analyses to better understand the potential for performance improvement.

Figure 4-5: Wind vectors for the D323 complex on 2 May 2019 (not 5 May as per Figure 5-2)



4.3.3 AUP analysis

The AUP analysis is based on published information from the NOP website[11]. Each State publishes the times of activation and deactivation for each ARES over the course of a day. The information first published is known as the Airspace Use Plan (AUP) and subsequent updates are known as Updated airspace Use Plans (UUPs).

[11] European AUP/UUP, available from https://www.public.nm.EUROCONTROL.int/PUBPORTAL/gateway/spec/

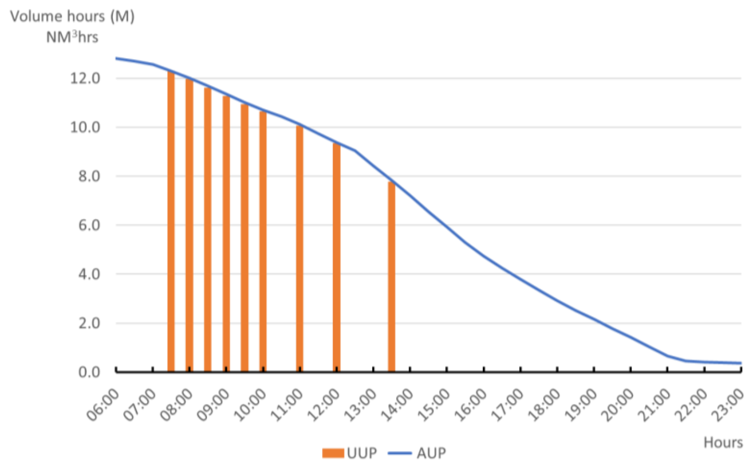
States' Airspace Management Cells (AMCs) are responsible for promulgating their airspace use plan by 15:00 UTC (at 'D-1') before the start of the next day's operations (on day 'D'). UUPs are published between 1700 and 2000 UTC on D-1 and then from 0600-2000 UTC on the day of operations, D.

The purpose of the following analyses was to explore the scale and changes to airspace bookings over the course of a day.

To analyse the AUP and its evolution through the UUP, we examined the changes in the 'airspace volume hours' booked and remaining to be used throughout the day, using data from two weeks in 2021 (17-23 May and 19-25 July 2021). We took the measurement of volume as NM^3, which has been used by CMC, converting flight levels (FL) to NM. We then calculated the volume hours booked from the AUP/UUP data.

Figure 4-6 shows the evolution of airspace volume hours for the five main States considered in this study for 19 May 2021. At the start of the day (0600), there are about 13M NM^3hrs booked in ARES, of which about 0.5M have expired by 0700. We do not know whether the airspace is used in this time from the AUP data alone; this is a matter for the military performance indicators discussed in sSection 4.1.2. In the consultations we discovered that there can be an initial drop off in the early morning due to aircraft with technical problems or poor weather for the planned exercises. Throughout the remainder of the day there is a decrease in airspace volume hours as exercise bookings expire.

Figure 4-6: Airspace volume-hours evolution over a day, five States 19 May 2021



UUPs are used to update changes in exercise plans, but these seem to be discontinued in the early afternoon, in spite of continued exercises. The figure shows that airspace booking does not decrease to zero overnight, as there are a few areas that are booked H24. The day shown is 19 May 2021, and this was a day of more significant military activity than other days sampled.

By comparison we show data for the 20 and 21 of July 2021 in Figure 4-7 and Figure 4-8. In these figures we also show the percentage change in airspace volume hours of each UUP to the AUP. If these values are 100% then there has been no change, if <100% then the volume hours have decreased, which could be an exercise that finished early, or a cancellation of an exercise. Where there has been an increase in airspace volume hours this could represent an exercise that has been delayed and extended, effectively a cancellation and rebooking at a later time. It is not possible to study this further without a comparison to military data on airspace usage for the same period.

Figure 4-7: Airspace volume-hours evolution over a day, five States 20 July 2021

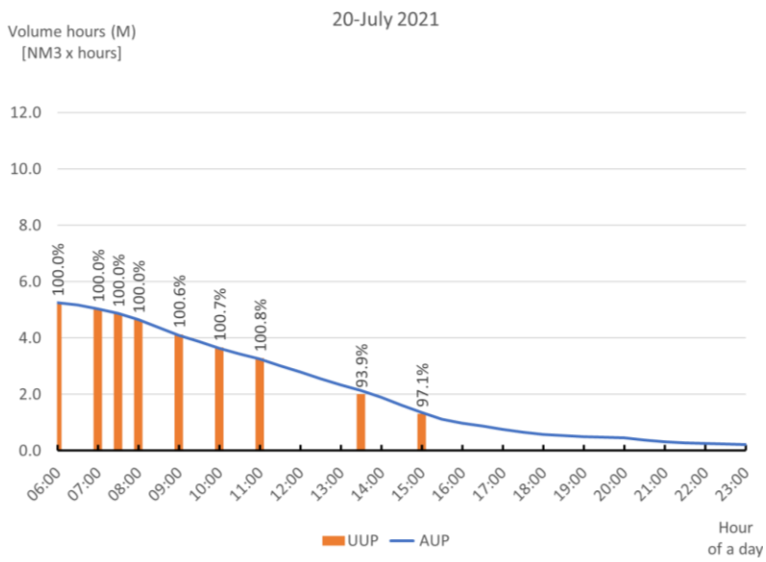
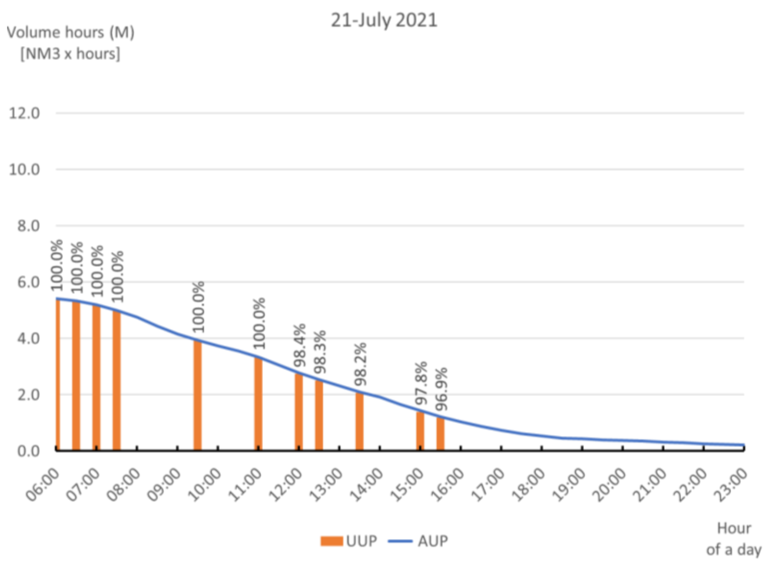


Figure 4-8: Airspace volume-hours evolution over a day, five States 21 July 2021



4.3.3.1 Day-to-day airspace volume hours booked

From the preceding graphs we have the following sample observations on airspace volume hours booked, shown in Table 4-4.

Table 4-4: Sample of airspace volume hours booked for the five key States

Sample day	AUP volume hours (Nm^3 hrs)
Weekdays	
Tue 18 May 2021	6.2M
Wed 19 May 2021	12.8M
Tue 20 July 2021	5.2M
Wed 21 July 2021	5.4M
Weekends	
Sat 22 May 2021	3.1M
Sun 23 May 2021	3.0M
Sat 24 July 2021	0.3M
Sun 25 July 2021	0.4M

From the above table, we can see some overall differences in the scale of military exercises during weekdays, and that there remain bookings during the weekends. In May 2019 there was one large NATO exercise (Formidable Shield) and additional air policing exercises.

4.3.3.2 ARES booking statistics

In Appendix C we show, for a variety of ARES, the booking statistics for weekdays, Saturdays and Sundays. Example data is shown in Table 4-5.

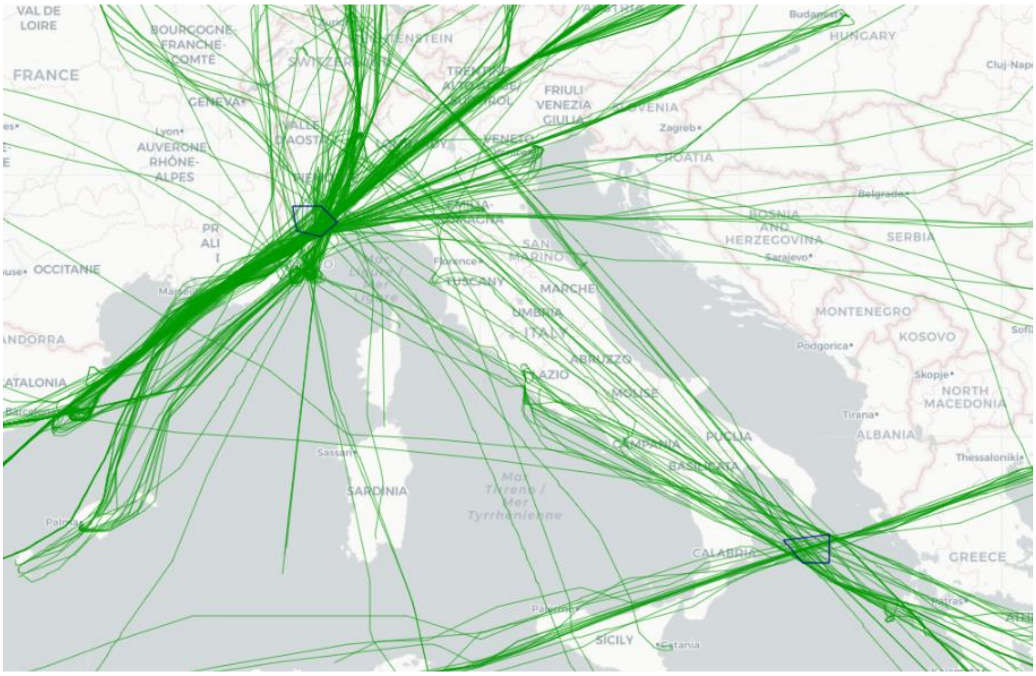
Table 4-5: Example ARES booking data for Saturdays (only showing ARES where bookings were made)

Hour of day (0600- 1800)

ARES	6	7	8	9	10	11	12	13	14	15	16	17	18
EDD100Z													
EDR136AZ	100%	50%	50%	50%	50%	50%	83%	50%	50%	67%	67%	67%	50%
LED122	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%
LER63	33%	50%	67%	67%	67%	67%	67%	17%					
LFR175BZ1	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%
LID409B	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
LIR50	83%	83%	83%	83%	83%	83%	83%	17%					
LIR64	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Of particular interest to the study were weekend and H24 bookings. In Figure 4-9 we show two Italian reservations that are typically booked all day on Saturdays and Sundays (LIR64 and LID409B), which also show heavy use by civil traffic. A State-level view of ARES bookings is discussed in Section 4.4.

Figure 4-9: Example ARES with traffic overlay (Saturday 4 May 2019)



4.3.4 ARES flight extension analysis

In this analysis we have estimated the amount of deviation for a flight flying around an ARES. This is done by comparing flight tracks around an ARES with historic tracks through it, for example when the ARES was non-active (or active and taking advantage of a tactical direct).

Figure 4-10 and Figure 4-11 show some examples of this analysis. We have identified flights that route close to an ARES of interest, and then analysed them in more detail to determine if they were likely to have been influenced by the ARES in their routing. The first example in Figure 4-10 shows three flights and the estimated flight extension caused by the ARES LER86B. From our analysis of AUP data for this date, Sunday 5 May 2019, we have high confidence that the airspace was not in use by the military at the time, but the flights appear to route around the ARES boundaries. The flight extensions were between 2.3 and 3%. While the LER86B ARES was the focus of this analysis, we also show other ARES which were close to the flight paths.

Figure 4-11 focusses on the German ARES EDD100. Also shown in grey are other ARES along the route for the flight. As this data was for a Sunday, it is very unlikely that any of these ARES were activated. It can be seen that some non-active ARES are flown through whilst others look to be avoided. There are multiple influences in obtaining the optimum routing, including route availability and winds.

Figure 4-10: Example of flight extension from ARES LER86B

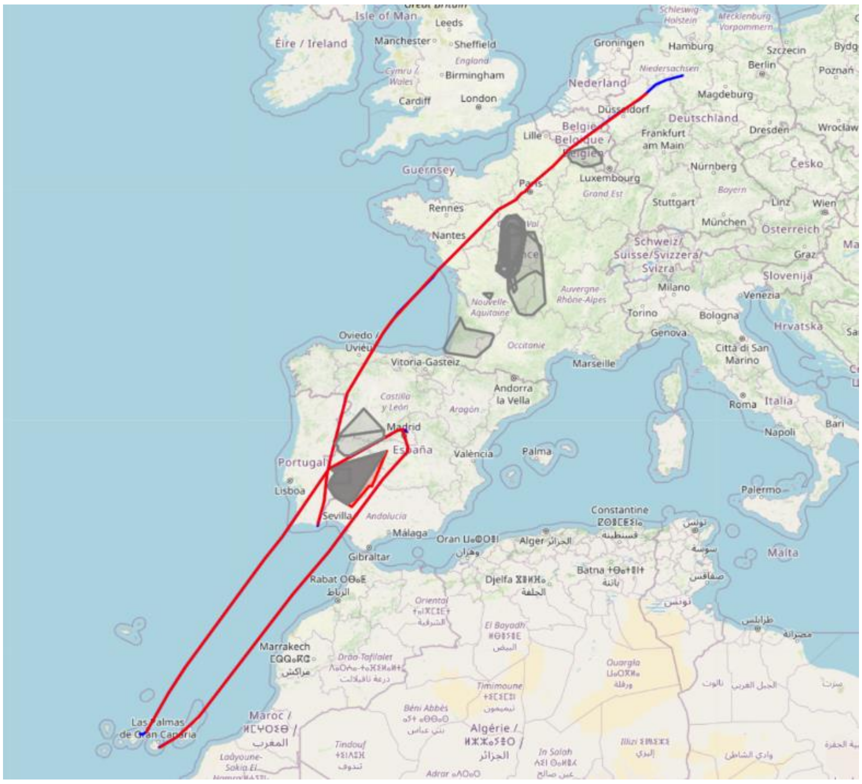
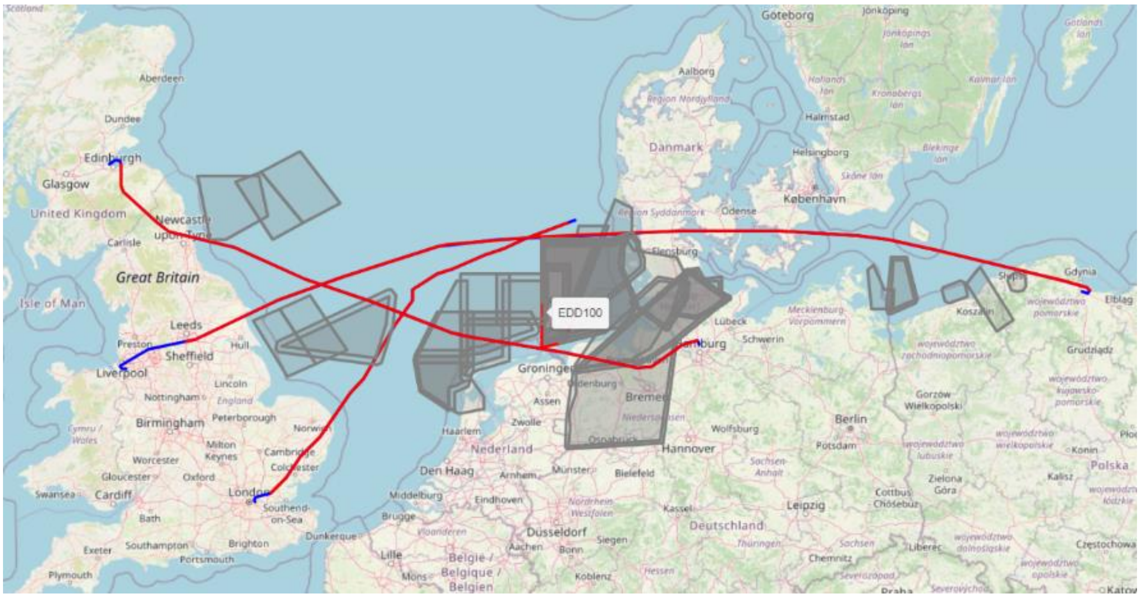


Figure 4-11: Example of flight extension from ARES EDD100Z



4.3.4.1 Quantifying impacts

To quantify the impact, we studied various ARES. As an example, an ARES in southwest France, LFR108HW, was considered for flights that flew around it, outside of the period when it is normally booked (0700:1600). This amounted to 15 flights on a weekday, generating horizontal flight extensions of between 2% and 4% and a total of 59 minutes for the day.

Extrapolating to a year this results in 328 flight hours that might have been avoided, 687 tonnes of fuel burned (at a nominal 35L per minute), and 1735t CO_2 produced (assuming CO_2 = 3.15 x fuel (kg) and 1L fuel ~ 0.8Kg).

Another ARES showed 61 minutes of flight extension on a Sunday, similarly to LFR108HW. These numbers are tentative pending further development; however, the analysis indicates the scale of benefit for the actions currently being developed by CMC, the NM and States.

4.4 State level analyses of the use of ARES in flight planning and operation

4.4.1 Introduction

The PRISMIL team of the CMC Division of EUROCONTROL supported further analyses of the interaction between ARES and flights using the PRISMIL database and we are very grateful for their support.

In this section we cover:

- A comparison between times that an ARES is booked for and the flights that planned and/or went through the ARES.
- The 'ARES status' information flows from flight planning to operation.
- An analysis of the use of ARES by flights.

4.4.2 Comparison of ARES booking and flights through the ARES

A typical PRISMIL analyses is shown in Figure 4-13. The ARES and States have been de-identified, as this study is concerned with general insight rather than specific State performance. The PRISMIL database combines data from various Network Manager sources including LARA, the Flight Tactical Flow Model, State AIPs. Of particular use, it allows a comparison between the AUP, flight plans and the shortest constrained routes (SCRs).

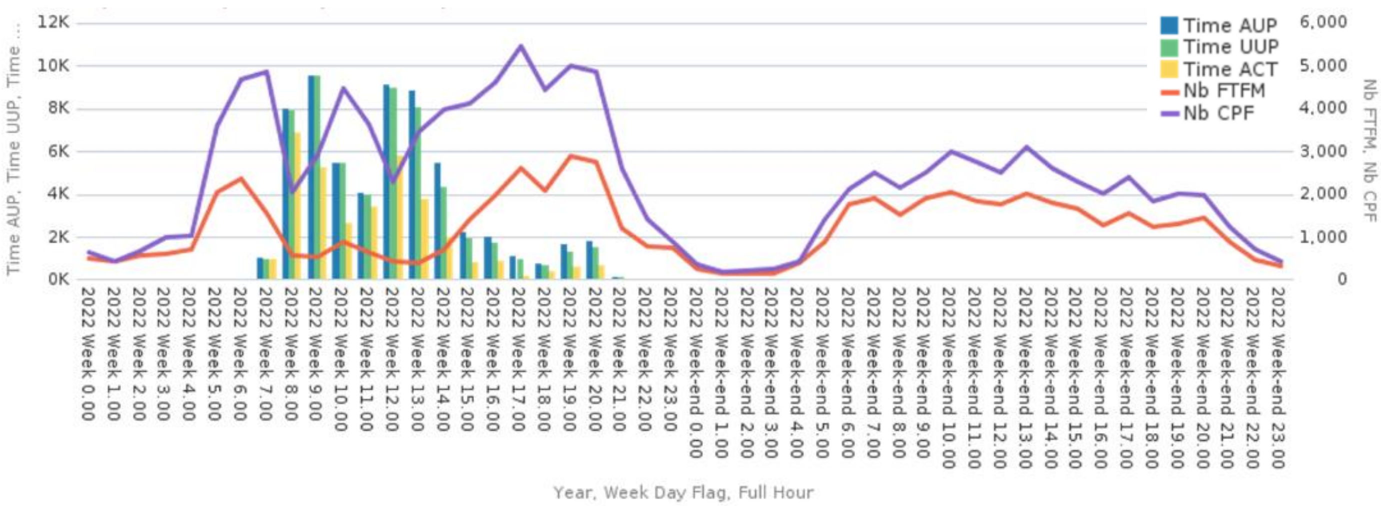
The data in Figure 4-13 are summed over 23 weeks. Weekdays and weekends are shown sequentially on the horizontal axis.

The left vertical axis shows the sum of minutes for the data in columns: as promulgated in the AIP (Time AIP); as booked in the AUP (Time AUP); as updated in the UUP (Time UUP); and the actual time the ARES is activated for (difference between activation time and deactivation time, which is not the same as the duration of the actual airspace usage).

The right vertical axis refers to the data represented in lines:

- Nb FTFM: the number of flights than planned to go through the ARES (number of FTFM), referring to the Flight Tactical Flow Model data;
- Nb CTF: the actual flights that went through (number of CPF), referring to correlated position reports (CPF);

Figure 4-12: PRISMIL example analysis (ARES 1) over 2022 (weekdays and weekends shown separately)



To give an example of the data, between 0800 and 0900 there were, totalled over 23 weeks, approximately:

AUP

- 8,000 minutes booked for the ARES through the AUP and UUP
- 7,000 minutes that the ARES was actually activated.

Flights

- 500 flights planned through the ARES (from FTFM data)
- 2,000 flights that passed through the ARES according to CPF data.

Our interpretation of the difference between the planned and actual flights passing through the ARES is that this is caused by tactical directs coordinated between military and civil controllers, some of which may also be at the request of flight crew. An uncertainty in this is whether an active airspace is temporarily deactivated without notifying or an active airspace is crossed by civil flights.

Considering the difference between weekday and weekend flights we make the following observations:

- While there are no bookings at the weekend (measured by AUP, UUP or Actual), the number of flights passing through the ARES is around 1500 planned and 2500 actual.
- There remains a difference between planned flights and actual flights through the ARES.

There are larger differences between planned and actual flights through the ARES (CPF-FTFM) during weekdays than at the weekends:

- ~2k flights difference (CPF – FTFM) during weekdays;
- ~1k flights difference during the weekend.

These differences raise some issues:

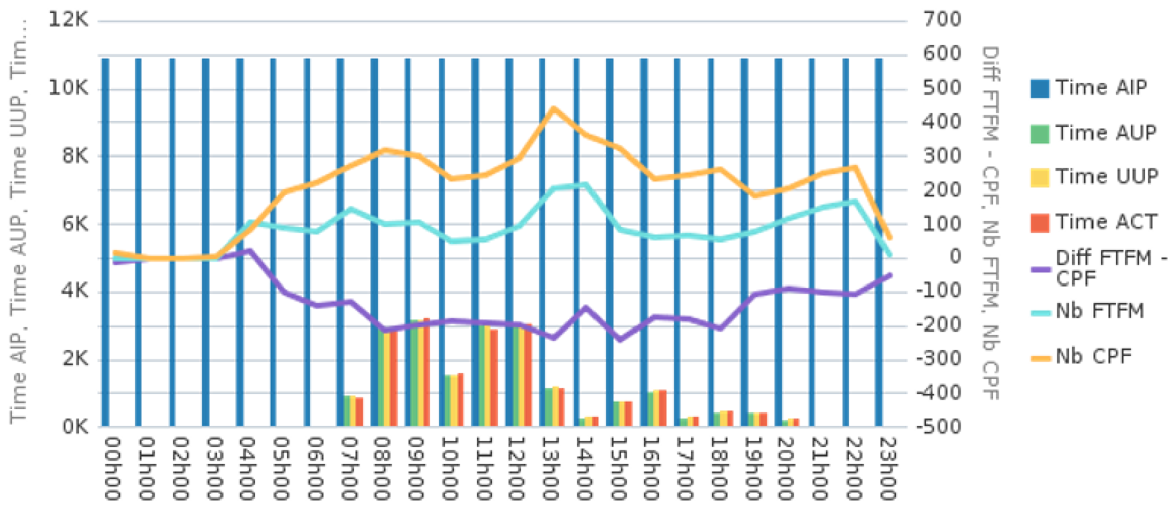
- Because ARES are generally not booked at the weekends, why are there not more civil flights using them?
- Why is there still a difference between CPF and FTFM counts at the weekends?

Previous analyses[12] have suggested that some flights are not being planning according to the AUP, which is published on D-1. The following may also be influences:

- While the traffic may be lower at the weekends, the workload on ATCOs may be adjusted to the lower level of weekend flights. This means that there will not necessarily be any more opportunity for controllers to identify and offer directs.
- Cancellation of an airspace booking is a positive indication that airspace is available. When an ARES is not booked and therefore does not change status, it may be less obvious to ATCOs that there is an opportunity for a direct. At some point civil controllers will notice some flights passing through ARES whereas others go around it, giving them an opportunity to offer tactical directs. This interpretation may be supported by the CPF and FTFM data having very similar shapes (peaks and troughs); i.e. controllers may identify flights that have planned through a reservation as a model for flights that have not planned to do so, or pilots request directs based on their tacit knowledge.

In Figure 4-13 we show a similar figure to Figure 4-12, but with the difference between planned flights and actual flights through a different ARES shown by 'Diff (FTFM-CPF)'.

Figure 4-13: PRISMIL example analysis over 2022



What is not known from the data in the above figures is the following:

- While the civil flight occupancy shows good use of the reservation for the flights depicted, it does not shown flights that may have flown around the ARES when it was deactivated (overnight and at weekends).

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12 EUROCONTRROL. Aircraft operator uptake on available and released airspace reservations (CURA barriers). 2023.

- While 'Time ACT' represents the hours that the ARES was reported as being activated, there is some uncertainty as to how long the airspace was used for and any delays in reporting deactivated status. This data is a matter for the military to report and there may be some security restraints in not reporting these details.

4.4.2.1 ARES notified as H24

An initial analysis using the PRISMIL database has been done on ARES published in the State Aeronautical Information Publication (AIP) as being permanently in use, known as 'H24'. This is a first pass analysis and there is a need to filter out ARES that are 'not plannable', for example, where they may be small areas around restricted sites such as nuclear power plants.

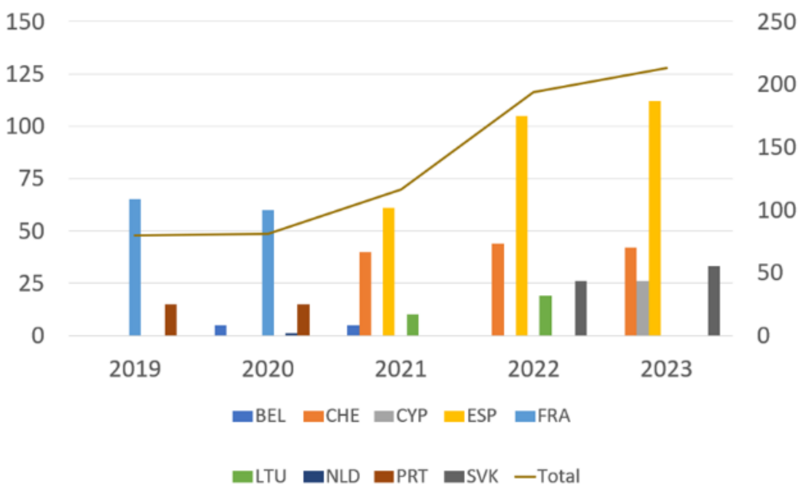
The graph in Figure 4-14, plots a count of ARES that were booked H24 over the last five years. It shows that the use of H24 activations has been on a mostly upward trend, driven by increasing use in Spain. However, other States have been using H24 less over time. An additional factor is that some States do not publish any times for their ARES but default to the minimum, but default to the legal requirement of using NOTAMs.

The concern with ARES being notified as H24 in the AIP are:

- it is never available for civil use; or
- there are some airlines who may do their flight planning with reference to the AIP, rather than the daily AUP.

We cover flight planning through ARES in Sections 4.4.3 and 0 and show there are a minority of airlines who do not appear to flight plan through un-booked ARES, even though they are available for routing. As mentioned, further work on this analysis is needed, to filter flight plannable H24 areas and we also propose to correlate the analysis of ARES usage to H24 areas.

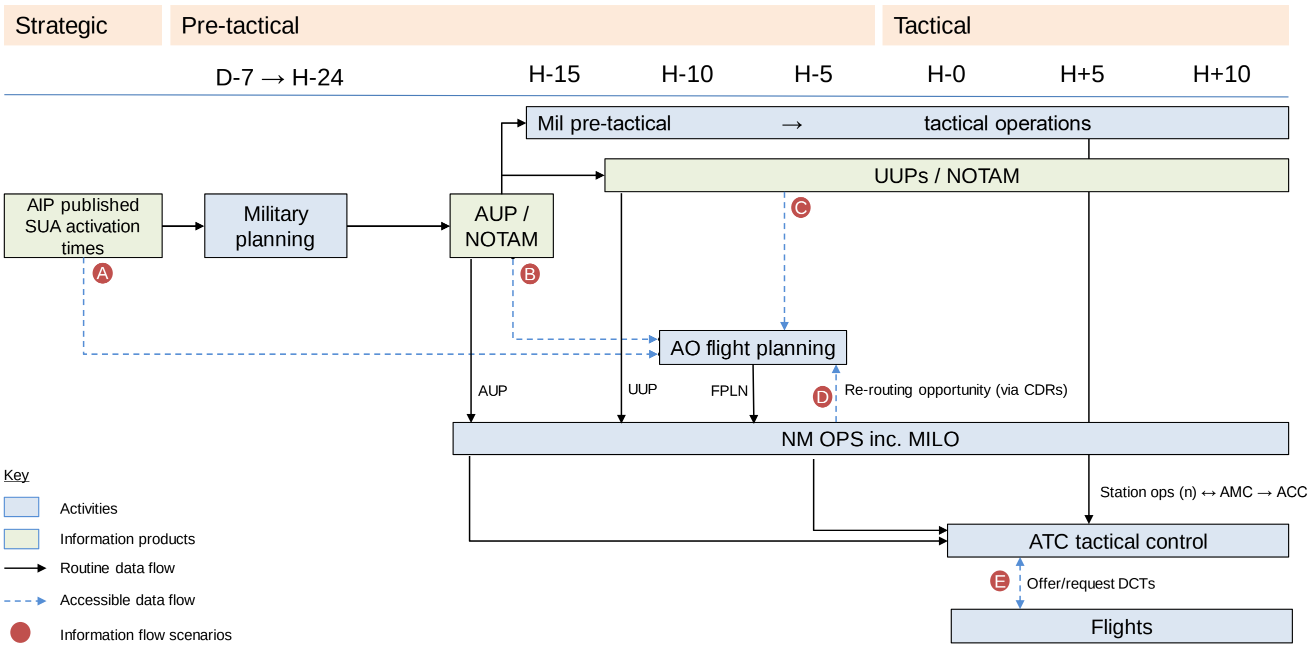
Figure 4-14: Count of ARES that are booked H24 for different States



4.4.3 ARES status information flows

In Figure 4-15 we show the ARES status information flows that influence flight routing in the context of the flexible use of airspace (FUA).

Figure 4-15: ARES status information flows



In Figure 4-15 we have labelled various branches of the information flows as scenarios A-E for further analysis:

(A) At the strategic level, States promulgate ARES details in their Aeronautical Information Publication (AIP), which may include the hours that they are booked, H24 or as notified by NOTAM.
(B) Military planners work within the AIP parameters to develop their airspace usage plan (AUP), and these are consolidated by the Network Manager into a network level AUP. The AUP is available as an input to airline flight planning. Airspace is activated by military users and notified by NOTAM and LARA where implemented, which may be integrated into ACC operations rooms. This process was discussed in Section 2. Once an ARES is booked at D-1, airlines are able to flight plan with this information and take advantage of more direct routes where ARES enroute are not booked at the time of any particular flight.
(C) On the day of operations there may be changes to the AUP, which are promulgated through the Updated AUP or UUP. There may be an opportunity for airlines to re-plan on the basis of UUP data, but they may also not be able to respond in time.
(D) Another possibility to update a flight plan is that the Network Manager Military Liaison Officers (MILOs) identify a re-routing opportunity and coordinate with flight dispatchers.
(E) Once flight planning opportunities are exhausted, there are tactical mechanisms that may secure a more direct route: either pilots making a request for a direct to ATC, or by ATC offering directs. Directs are provided by ATCOs and we note that there is concern from the Network Manager that directs can reduce network predictability and create demand capacity imbalances.

Each ARES status scenario has an impact on flight routing, which is summarised in Table 4-6. In the next section we present our work to evidence these scenarios, focusing on A and B.

Table 4-6: Impact on flight routing of the ARES status scenarios

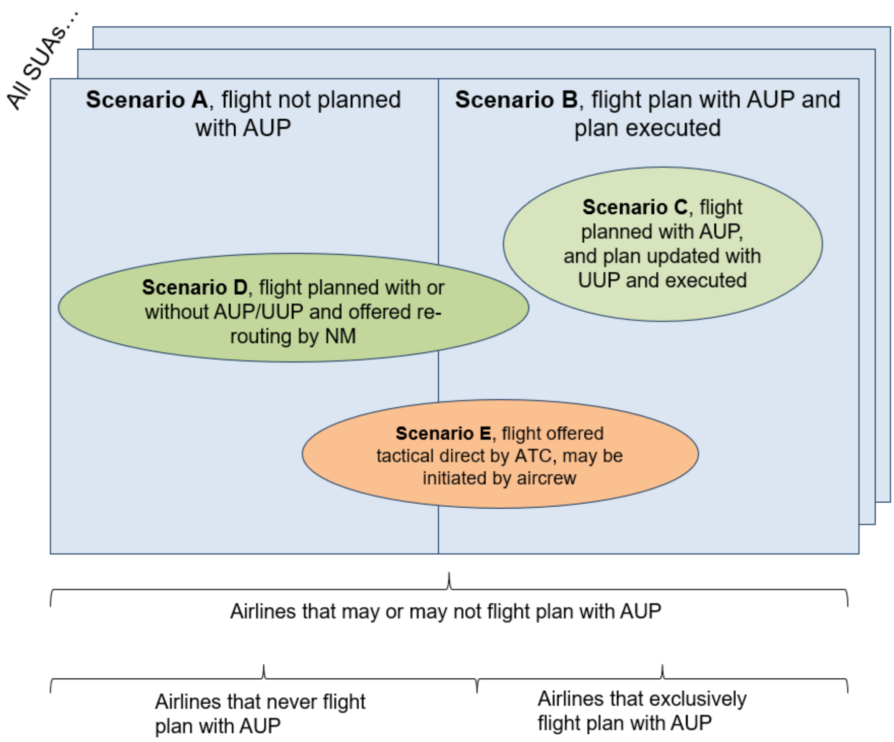
Info. Flow	ARES status (booked or not) known by civil	Flight routing based on	Effect of routing	Flight efficiency	Dependencies
Pre-tactical phase					
A	Unknown by AOC	AIP ARES activation times	Route around deactivated ARES	↓	
B	Known as booked or not by AOC	AUP & NOTAM	Route through deactivated ARES	↑	Capability of CFSP system (Computerised Flight Plan Service Providers)
C	Booking updated and update known by AOC	UUP (updated before flight) or NOTAM.	(a) Reduced airspace volume booked => more accurate flight plan, shorter route (b) Additional airspace volume booked => more accurate Flight Plan, less ATC tactical intervention	(a) ↑ (b) ↓	Military station ops workload / automation support + Flight Dispatch processes and resources
D	Known as not booked after FPLN submitted	NM OPS enables a re-route with RRT	NM proposes shorter routing	↑	Flight dispatch processes and resources
Tactical phase					
E	Known as not booked, e.g. early deactivation	ATC (C or M) offers a direct and flight crew accept or flight crew request DCT and ATC (C or M) confirms.	Route through deactivated ARES	↑	ATCO resources (FMP, tactical and planner controllers) and flight crew resources.

4.4.4 Analysis of the use of ARES by flights

In this section we report on an analysis of how the status of ARES was used to support flight routings. We used 2023 data from one week for different States, working with the PRISMIL team. The aim was to develop a methodology and understand the 'benefits pool' and so the States are not identified.

To frame the analysis, we defined the scenarios into different sets where Scenario A and B are a subset of total flights and C, D and E are subsets of these. The focus of this work has been on distinguishing Scenarios A and B.

Figure 4-16: Illustration of the analysis framework, with scenarios as sets of data



4.4.4.1 State A

Scenario A flights

Scenario A flights are those that appear to have no knowledge of the status of an ARES when they were flight planning, and consequently have not flown a shortest constrained route through an ARES.

Figure 4-17 shows the set of flights in this category that did not flight plan through any ARES in the State and did not subsequently go through an ARES by a tactical direct. These flights have been identified by filtering flights where:

- Their flight plan showed that they would not go through any ARES.
- AUP and UUP times showed the availability of ARES.

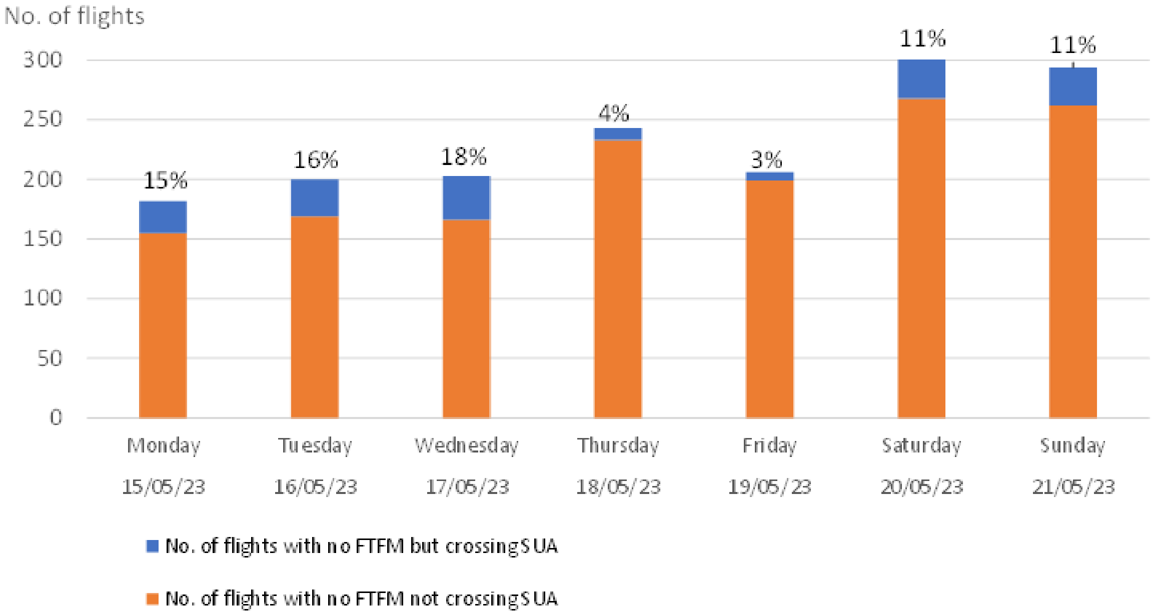
- A shortest constrained route through an ARES existed.

The above conditions imply that there was an opportunity to use a deactivated ARES for a shorter route. There are two groups within this set of flights:

Group 1: Flights that did not cross any ARES.

Group 2: Flights that crossed an ARES through a tactical direct.

Figure 4-17: Flights not flight planning through an ARES



For Group 1, the number of flights shown in the figure varies from 155 on Monday 15 May 2023 to 268 on Saturday 20 May 2023, a total of 1452 for the week. There were 23,801 total flights for the week[13], so the proportion of flights in Scenario A Group 1 is 6%. Furthermore, there were 178 flights in Group 2, or 0.7% of the total. Combing Groups 1 and 2 gives 1630 flights that did not flight plan through any ARES, and of this number 11% managed to obtain a direct through at least one ARES.

In summary, it appears that ~7% of flights in the week did not use the Airspace Use Plan (AUP) in their flight planning to obtain a better routing. Of these 7% of flights, 11% managed to take a more direct route during the flight through controller action.

Scenario B flights

Figure 4-18 shows the set of flights that flight planned through an ARES in the State.

These flights have been identified by filtering flights where:

[13] Source: PRISMIL

- Their flight plan showed that they would go through one or more ARES.
- AUP and UUP times showed the availability of ARES.
- A shortest constrained route through an ARES existed.

There are three groups of flights within this set according to whether the flight crossed one, all or none of the ARES that they planned to fly through:

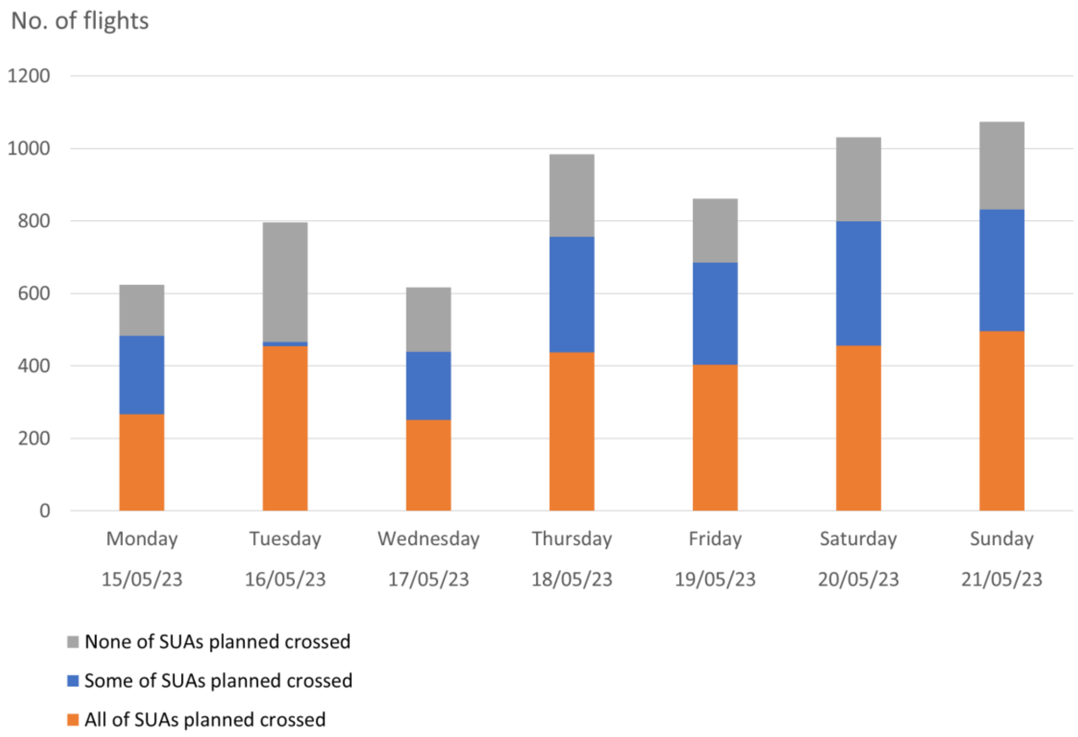
Group 1: Flights that crossed *all* ARES that they planned.

Group 2: Flights that crossed *some* ARES that they planned.

Group 3: Flights that did not cross any ARES that they planned.

The flights are shown in Figure 4-18 according to the Groups 1-3 defined above. There were 5986 flights in Scenario B out of 23,801 total flights for the week, so the proportion of flights in Scenario B is 25%.

Figure 4-18: Flights which planned to cross the ARES



Summary of flights in Scenarios A and B

Summarising the above, at the State level, ~7% of flights did not flight plan through an ARES and 25% did. The remainder 68% of the flights through the airspace are assumed to have not needed to use an ARES for their routing. Of these flights, there are interactions outside of the State that may have influenced their routing, including upstream and downstream ARES, which has not been covered in the study.

4.4.4.2 State B

Scenario A flights

Scenario A flights are those that appear to have no knowledge of the status of an ARES when they were flight planning, and consequently have not flown a shortest constrained route through an ARES.

Figure 4-19 shows the set of flights in this category that did not flight plan through any ARES in the State and did not subsequently go through an ARES by a tactical direct. These flights have been identified by filtering flights where:

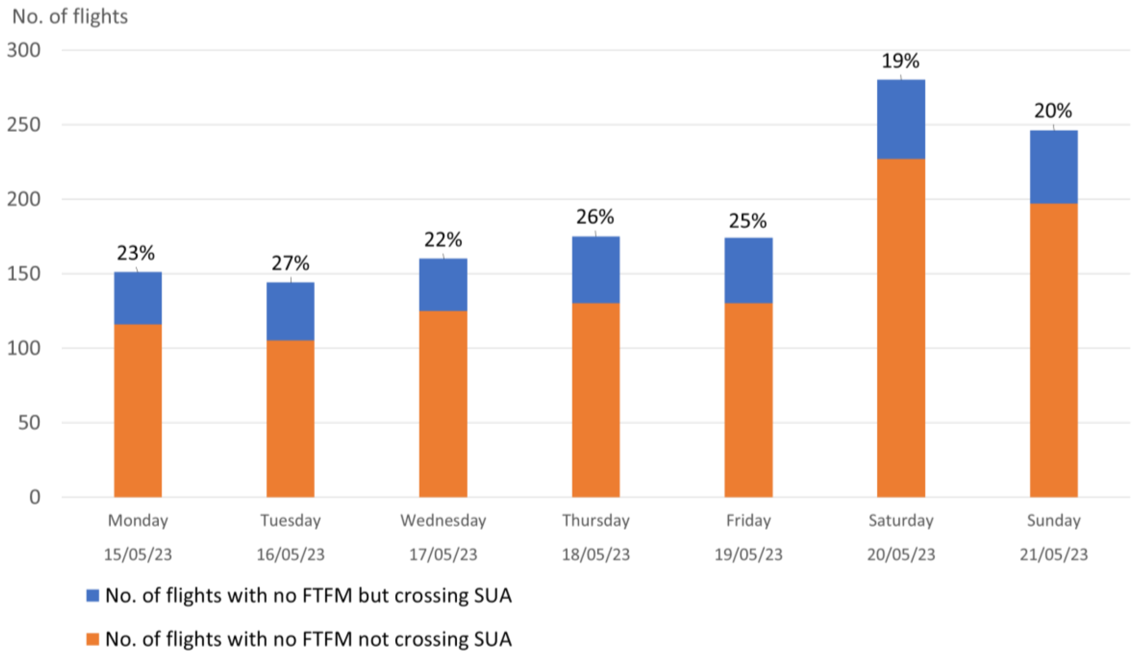
- AUP and UUP times showed the availability of ARES.
- A shortest constrained route through an ARES existed.

The above conditions imply that there was an opportunity to use a deactivated ARES for a shorter route. There are two groups within this set of flights:

Group 1: Flights that did not cross any ARES.

Group 2: Flights that crossed an ARES through a tactical direct.

Figure 4-19: Flights not flight planning through an ARES



For Group 1, the number of flights shown in the figure varies from 105 on Tuesday 16 May 2023 to 227 on Saturday 20 May 2023, a total of 1030 for the week. There were 34,576 total flights for the week[14], so the proportion of flights in Scenario A Group 1 is 3.1%. Furthermore, there were 300

[14] Source: https://www.EUROCONTROL.int/Economics/DailyTrafficVariation-States.html

flights in Group 2, or 0.9% of the total. Combing Groups 1 and 2 gives 1385 flights that did not flight plan through any ARES, and of this number 22% managed to obtain a direct through at least one ARES.

Scenario B flights

Figure 4-20 shows the set of flights that flight planned through an ARES in the State.

These flights have been identified by filtering flights where:

- Their flight plan showed that they would go through one or more ARES.
- AUP and UUP times showed the availability of ARES.
- A shortest constrained route through an ARES existed.

There are three groups of flights within this set according to whether the flight crossed one, all or none of the ARES that they planned to fly through:

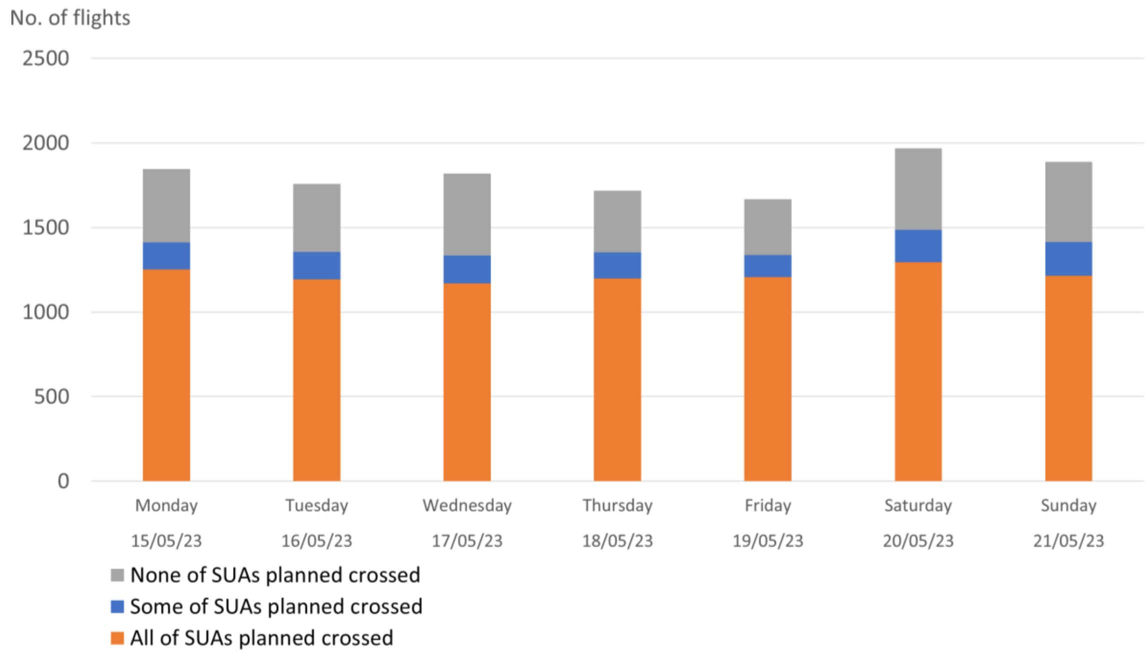
Group 1: Flights that crossed *all* ARES that they planned.

Group 2: Flights that crossed *some* ARES that they planned.

Group 3: Flights that did not cross any ARES that they planned.

The flights are shown in Figure 4-18 according to the Groups 1-3 defined above. There were 12660 flights in Scenario B out of 34,576 total flights for the week, so the proportion of flights in Scenario B is 37%.

Figure 4-20: Flights which planned to cross the ARES



Summary of flights in Scenarios A and B

Summarising the above, at the State level, ~4% of flights did not flight plan through an ARES while 37% did. The remainder 59% of the flights through the airspace are assumed to have not needed to use an ARES for their routes. As for State A, of these flights, there are interactions outside of the State that may have influenced their routing, including upstream and downstream ARES, which has not been covered in the study.

4.4.5 Summary of the analysis

The above analyses are summarised in Table 4-7 for State A and Table 4-8 for State B .

What we can conclude with this analysis of two States is that there are between ~4 and 7% of flights that do not refer to the AUP in their flight planning. An initial analysis of air operators has shown no clear pattern of flight planning from particular airlines; this will be investigated further in the study. It is possible that not including ARES in the flight planning is due to local rather than carrier-level flight dispatch resources.

We have not estimated the impact of these flights from the extra route length incurred. However, as an illustration, 1452 flights per week adding an extra minute of flight time equates to ~76k minutes of flight. Monetising this at €69 per minute gives €5.2M per year total cost. Assuming an average fuel consumption of 45kg per minute[15], this is ~3400 tonnes of fuel and ~11,000 tCO_2 per year for flights over State A. For State B, these sums amount to 55k minutes of additional flight time, €3.7M in costs, ~2400 tonnes of fuel and ~8,000 tCO_2 per year.

Further analysis is needed to expand these figures to the European level, but a rough estimate would be a benefits pool of 35,000 - 70,000 tonnes of fuel and 0.1-0.2M tCO_2 might be saved per year through an improved use of the AUP in airline flight planning.

Table 4-7: State A: Summary of analysis of ARES use in flight planning and operation

State A	Identified flights	Total number of flights	Percentage
Group 1	1452	23801	6%
Group 2	178	"	0.7%
Total in scenario A	1630	"	6.8%
Total in scenario B	5986	23801	25%

Table 4-8: State B: Summary of analysis of ARES use in flight planning and operation

State B	Identified flights	Total number of flights	Percentage

[15] Weighted average from EUROCONTROL Standard Inputs (original source was BADA) modified by a 1.5% per year average efficiency improvement over six years.

Group 1	1030	34576	3%
Group 2	300	"	0.9%
Total in Scenario A	1330	"	3.8%
Total in Scenario B	12660	34576	37%

4.5 Further development of indicators

Following on from the initial development described above, the study has considered the challenges in scaling the indicators to European level. The main challenge lies with the ARES flight extension analysis (HFE-ARES), as the other indicators already scale to European level.

HFE-ARES indicator

The HFE-ARES indicator takes a single ARES at a time, filters the missed opportunity flights and then calculates the likely deviation made by the flight routing around a specific ARES. The main development issues are: (a) to speed up the computation and (b) to introduce a wind component into the analysis. To initially improve processing speed, higher processing power is recommended and some algorithm improvements.

Concerning wind, the current horizontal flight efficiency approach is to measure flight efficiency against great circle routing, see Box 2-1 for further details. Wind vectors could be used to replace the great circle comparison.

An alternative approach to consider is to re-route the suspected missed opportunity flights for the whole of their routes. This would be similar to the EC environmental monitoring indicator '(e) The rate of using available airspace structures'[16] [9]. The disadvantage of this approach is that it could be second-guessing airline flight planning systems choice of the whole route, whereas the underlying issue may only be the exploitation of the airspace use plan (AUP) and updated use plan (UUP).

[16] "The rate of using available airspace structures, including reserved or segregated airspace, conditional routes, by general air traffic calculated as the ratio of aircraft flying via such airspace structures and the number of aircraft that could have planned through these airspace structures."

Box 4-1: The growing importance of wind-vector based analysis

> The current horizontal flight efficiency approach is to measure flight efficiency against great circle routing. When this was first introduced by the PRC it was acknowledged that this was an imperfect method, as it does not include wind vectors, but at the time there were significant gains to be made in route development without considering the wind component. Introducing wind vectors was also computationally highly demanding 20 years ago for European-level flight analysis. In the network today, KEA indictors are converging towards 2-3% inefficiency and the gains to be made may seem to be becoming exhausted. However, within this 2-3% range there is now uncertainty of whether the inefficiencies are really inefficiencies or just different routing strategies to take account of headwind and tailwind components along different parts of a flight. This issue has been recognised by the EASA-EUROCONTROL ATM/ANS Environmental Transparency Working Group and A4E has recently (2022) voiced the need to develop wind-based indicators.

AUP and UUP indicator

For the AUP-UUP indicator, a practical issue in scaling is the availability of the AUP and UUP data from which potential missed opportunity routings may be identified. This data is available from the NOP portal and was used in spreadsheet form in this study[17]. Using internal EUROCONTROL sources in future work is therefore recommended and for long-term utility, making access available through a NOP API. We did not consult with the NM during this study and there may be initiatives already in progress in this area.

4.6 Summary of analytical development

In this section we have described a set of analyses that have the potential to become monitoring or key performance indicators for the performance of dynamic airspace management.

A comment on the work is that the timescales for the study necessitated the study team to use a limited set of data that had been previously collected. The 2019 data supports analysis of the last busy year for civil flights, and the 2021-2022 data supports analysis where there has been continued busy military training, with 2022 likely to have increased in tempo. We conclude that the data set was not perfect, but is unlikely to have skewed the results. This said, the focus has been more on the methodological development than a fully-fledged annual analysis.

The work has identified some promising new metrics that have established a sizable flight efficiency and environmental benefit if performance is improved in the coming years. Further work to develop the indicators and improvements should develop with pace given the environmental impact. This is also important as States are seeking to expand their training areas, to provide for fifth-generation aircraft, with airspace designs emerging such as the North Sea Airspace Initiative. Civil-military

[17] European AUP/UUP, available from https://www.public.nm.EUROCONTROL.int/PUBPORTAL/gateway/spec/.

performance monitoring will help States integrate this growing demand while achieving an overall optimum in terms of flight efficiency, sustainable aviation and capacity for civil and military operators.

Our recommendation for the analytics addressed in the study is:

Recommendation 5: Develop the analytics addressed in the study further, to be manageable at a large scale (such as 3-12 month data sets), enhancing the algorithms and using higher-power processing. We also recommend further use of the EUROCONTROL CMC PRISMIL database for combined AUP/UUP and flight analysis.

5 High-level concept of operation for dynamic airspace management

A final aim in the study was to synthesise the various strands, including stakeholder meetings and discussions with the PRU, into a high-level view of a dynamic airspace management concept.

As mentioned earlier, there are two important contexts to the future concept of operations:

1. The military need for larger airspace volumes for fifth-generation weapons platforms and fighters such as the F35, which is increasingly apparent as air forces deploy in the face of continued Russian aggression, the invasion of Ukraine in particular.
2. Climate change, with mitigating actions most recently framed by the European Union's 'Fit for 55' package of measures.

Both points are recognised by the stakeholders consulted. There is also a general industry view that aviation will continue to grow without restriction, and indeed there are only limited calls for demand capping. This places continued emphasis on airspace capacity and flight efficiency. In this study we have not addressed the capacity KPA, however we recommend further exploration of how dynamic airspace management relieves capacity constraints:

Recommendation 6: To further explore how dynamic airspace management relieves capacity constraints.

Concerning flight efficiency, the question to be asked of dynamic airspace management is if, and how, the above contexts can be jointly met – increased military airspace *and* civil flight efficiency.

What is apparent from this study is that there are a number of best practices emerging in how airspace is managed pre-tactically (ASM 2) and tactically (ASM 3). For example, some Italian ARES are constrained in booking time at ASM 2 and managed tactically in ASM 3. This maximises the potential for airlines to account for booked ARES in their flight planning. This practice can be optimised over time to achieve a balance of the planned crossing of an ARES versus tactical re-routing around it. In turn this could lead to optimised fuel consumption and emissions. While this particular issue would benefit from deeper analysis, it signals a willingness from civil-military stakeholders to adopt increasingly flexible approaches.

A further observation from the study is that while traffic flows are constrained by ARES, there may be substantial wind effects that take a flight clockwise or counter clockwise around an ARES. Given the effects of wind vectors on routing there is a case for the overall boundaries of ARES to be made larger but more flexible. Within such an enlarged flexible airspace structure, exercises could potentially be moved according to forecast winds, to avoid impacting civil traffic flows, with a quid quo pro of larger areas for mission training. There are practical limits to doing this without curtailing the military exercises through a lack of fuel, but there could be significant reductions in civil flight fuel consumption and the corresponding emissions.

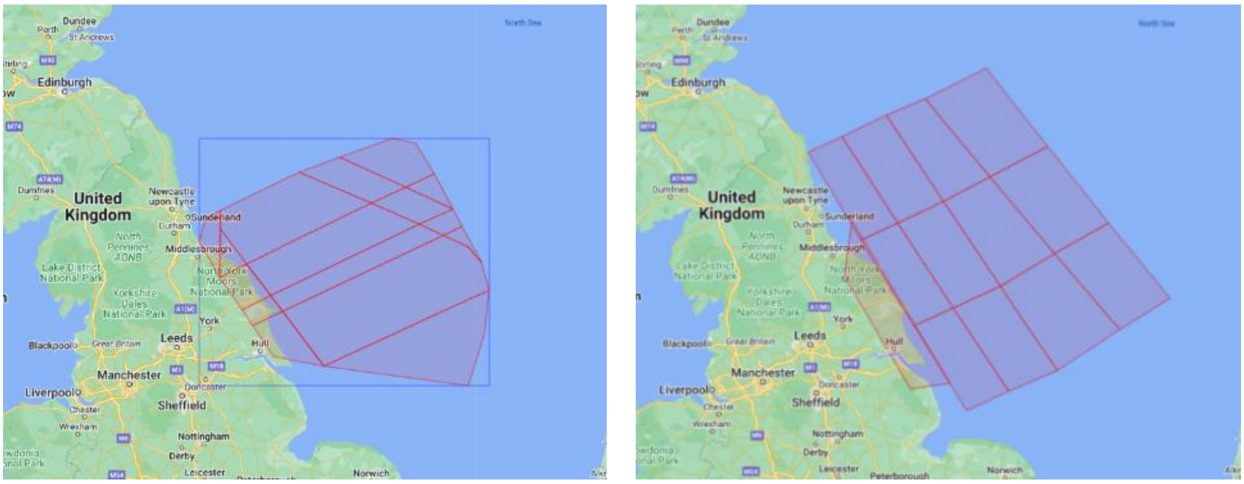
Such an approach would be compatible with existing and future airspace objectives, principally the 'variable profile area concept' but also the SESAR R&D reviewed in Section 3.2.2. The VPA concept is likely to be instrumental in meeting both military airspace and Net Zero goals.

In Figure 5-1 we show an early draft of a potential new concept for dynamic airspace management. In this we postulate that the existing UK D323 ARES, which influences civil traffic flows to and from the North Atlantic, could be made larger and more flexible at the same time. In the figure we postulate an enlarged D323 ARES which could provide an additional 2-3 larger airspace segments for airspace for mission training at the same time as being flexible to accommodate civil traffic flows closer to land. There are several key considerations in such a concept, such as not overly extending military transit times and responding to mission needs, and this could be developed through further study.

Figure 5-1: Potential concept for enlarging and reconfiguring ARES to meet civil and military needs

Existing EGD323 ARES

Postulated D323 with increased area but the same or less impact on civil traffic



The above high-level concept is an initial attempt to bring together what may at first sight appear to be conflicting demands of civil and military airspace users. Permanent airspace changes can be time consuming and, as identified elsewhere in this report, there are improvements to be gained from current processes. However, we recommend that States consider the possibilities from new concepts of more flexible airspace and engage more deeply with the concept of VPAs and consider the fast tracking of SESAR Solution 31 [18].

Recommendation 7: States review their airspace to consider improvements from the application of the Variable Profile Area concept defined in SESAR Solution #31 and create enlarged but more flexible military areas including cross-border areas (CBAs).

6 Conclusions and recommendations

6.1 Summary

The study has developed a set of analyses to explore the performance of dynamic airspace management in support of the PRC's 2021 commitment to provide additional analyses of the potential efficiency and capacity gains from Civil-Military coordination under the Flexible Use of Airspace (FUA) concept. The analyses have been informed by stakeholder consultations and we are extremely grateful for their time and insights.

Due to a lack of relevant data in the study timeframe, this work has focused on the impacts of civil-military coordination and cooperation on flight efficiency, and it is anticipated that the impact on capacity can be addressed through further work.

The work has identified some promising new metrics that have established a sizable flight efficiency and environmental benefit if performance is improved in the coming years.

For example, an ARES was analysed for flights that flew around it, outside of the period when it is normally booked (0700:1600). This amounted to 15 flights on a weekday, generating horizontal flight extensions of between 2% and 4% and a total of 59 minutes for the day. A similar amount of extension was found on a Sunday where it is rare that ARES are active. Extrapolating to a year this results in 328 flight hours that might have been avoided, 687 tonnes of fuel burned (at a nominal 35L per minute), and 1735t CO_2 produced (assuming CO_2 = 3.15 x fuel (kg) and 1L fuel ~ 0.8Kg). Further work is needed to validate these results, but the level of impact points towards significant benefits in flight efficiency and for the environment.

The PRISMIL team of the CMC Division of EUROCONTROL supported further analyses of the interaction between ARES and flights using the PRISMIL database. From this we concluded from an analysis of two States that there were between ~4% and 7% of flights that did not refer to the AUP in their flight planning. An initial analysis of air operators has shown no clear pattern of flight planning from particular airlines and this will be investigated further in the study. It is possible that not including ARES in the flight planning is due to local rather than carrier-level flight dispatch resources.

- The study has not estimated the impact of these flights from the extra route length incurred. However, as an illustration, 1452 flights per week adding an extra minute of flight time equates to ~76k minutes of flight. Monetising this at €69 per minute gives €5.2M per year total cost. Assuming an average fuel consumption of 45kg per minute[18], this is ~3400 tonnes of fuel and ~11,000 tCO_2 per year for flights over State A. For State B, these sums amount to 55k minutes of additional flight time, €3.7M in costs, ~2400 tonnes of fuel and ~8,000 tCO_2 per year.

[18] Weighted average from EUROCONTROL Standard Inputs (original source was BADA) modified by a 1.5% per year average efficiency improvement over 6 years.

- Further analysis is needed to expand these figures to the European level, but a rough estimate would be a benefits pool of 35,000 - 70,000 tonnes of fuel and 0.1-0.2M tCO_2 might be saved per year through an improved use of the AUP in airline flight planning.

The development of the indicators and improvements should develop with pace given the environmental impact. This is also important as States are seeking to expand their training areas, to provide for fifth-generation aircraft, with airspace designs emerging such as the North Sea Airspace Initiative. Civil-military performance monitoring well help States integrate this growing demand while achieving an overall optimum in terms of flight efficiency, sustainable aviation and capacity for civil and military operators.

6.2 Recommendations

Our key recommendations are:

Recommendation 1: Dialogues between military and civil stakeholders, facilitated by EUROCONTROL CMC and the Network Management Directorate, could be used to develop and promulgate best practices. We are aware that good efforts are already underway in CMC and the Network Management Directorate.

Recommendation 2: The processes around AUP updates (UUP) and UUP timings are studied in detail to see whether they could be enhanced and made a more routine component of flight re-planning and tactical operations of ANSPs. This would include an assessment of current practices in civil and military ATC operations. It is also recommended that certain system improvements are accelerated. This includes the B2B integration of LARA into Network Manager Operations and the deployment of Digital NOTAMs. Such actions will ensure that the local and network levels will become more integrated and responsive to changes in the tactical activation and deactivation of ARES.

Recommendation 3: We recommend that the practice of offering and accepting tactical directs, aligning with existing practices in some States, could be encouraged among pilots and ATCOs, provided the actions are timely and within the operational capabilities of the actors concerned, including the Network Manager. The Network Manager has a focus on network predictability and is discouraging tactical intervention, but the possibility to have a direct reduction in fuel consumption and related emissions is a high priority in Europe.

Recommendation 4: We recommend that States act quickly to address the issues identified in the EUROCONTROL 2015 and 2022 civil-military coordination and cooperation surveys.

Recommendation 5: Develop the analytics addressed in the study further, to be manageable at a large scale (such as 3-12 month data sets), enhancing the algorithms and using higher-power processing. We also recommend further use of the EUROCONTROL CMC PRISMIL database for combined AUP/UUP and flight analysis.

Recommendation 6: As it was not covered in this study, to develop a capacity analysis based on the airspace occupancy analytics and comparing Network Manager Operations' sector occupancy data.

Recommendation 7: States review their airspace to consider improvements from the application of the Variable Profile Area concept defined in SESAR Solution #31 and create enlarged but more flexible special use areas, including Cross-Border areas (CBAs) and Cross-Border Operations (CBO) (use of adjacent areas across borders).

7 References

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A SESAR A-FUA implementation objectives

In the following paragraphs we summarise the implementation objectives which are driving current R&D in SESAR in the area of A-FUA. Note that SESAR uses the term 'ARES' for 'airspace reservation', for which we have substituted ARES which has active and non-active states.

AOM-0201 — Moving airspace management into day of operation

This operational improvement aims to extend the FUA process to short-notice military airspace requirements up to three hours before operations, or very short term changes to accommodate bad weather. The emphasis is on increased flexibility in processes and better notification and use of CDR-2[19] routes.

AOM-0202 — Enhanced real-time civil-military coordination of airspace utilisation

This objective enhances the real-time coordination by adding 'what-if' functions and automated support to airspace booking and airspace management. It is intended to create an integrated toolset for Airspace Management Cells (AMCs) to "design, allocate, open and close military airspace structures on the day of operations". In particular, this set of functions will support more dynamic use of airspace.

AOM-0202-A — Automated support for strategic, pre-tactical and tactical civil-military coordination in ASM

This implementation objective is intended to enhance civil-military coordination across all ASM phases through direct B2B services connecting civil and military airspace users, ATFCM (Local, Sub Regional and Regional) and ATC. Information shared will include static airspace data from ASM1, AUP/UUP in ASM2, where UUP is seen as a rolling update to the AUP, and real-time ARES activation status in ASM 1. The automated support is intended to trigger additional CDM processes: to increase flight efficiency by coordinating use of deactivated ARES; and support ATFCM processes to optimise traffic flows (demand – capacity balancing).

AOM-0203 — Cross-border operations facilitated through collaborative airspace planning with neighbours

This objective is to harmonise collaborative civil-military airspace planning process across State borders, including the ASM rules and procedures for the establishment, allocation and use of airspace structures. This is for bilateral or FAB level collaboration and may lead to pre-tactical airspace allocations on a sub-regional rather than a national basis. It applies where there are already ARES at State boundaries.

[19] CDR-2 routes have opening periods negotiated in the pre-tactical phase. CDR-1 routes have fixed times of opening and CDR-3 is made available in real-time only.

AOM-0204 — Europe-wide shared use of military training areas

This objective is for Europe-wide sharing of airspace and is primarily subject to political agreement. Contributory factors are an expected harmonisation of airspace design and use at European level, and military-military cooperation.

AOM-0205 — Modular temporary airspace structures and reserved areas

Reference [9] defines this objective as introducing a modular design for new airspace requirements that enables sub-divisions, new areas or revised airspace requirements closer to air bases. This is also defined as a military variable profile area in Reference [13]. The aim is to provide flexibility to accommodate military requirements by extension or sub-division of military training areas (TSA/TRA/CBA) adjusted to match the military training and operational requirements for each type of mission.

AOM-0206-A — Flexible and modular ARES in accordance with the VPA design principle

Noting that AOM-205 addresses the design of modular temporary airspace, this implementation objective appears to address the design principles of ARES using a Variable Profile Area (VPA) to be introduced on a harmonised European level.

The VPA design principle aims to allow higher flexibility and increased airspace volume to the surrounding (civil) traffic improving the DCB process. ARES designed according to VPA may also be activated as combinations of modules, including as ad hoc configurations within predefined structures at short notice – to respond to short-term airspace users' requirements.

The objective is to better respond to military airspace requirements, ATM and/or meteorological constraints while giving more freedom to GAT flights to select the preferred route trajectories and to achieve more flexibility from both civil and military partners.

AOM-0206-B — Sharing real-time airspace information with the aircraft

This operational improvement continues the previous one, AOM-206A by extending the ASM shared situational awareness to include civil and military aircrews. It achieves this by an uplink of activation status and ARES coordinates if not already present on board.

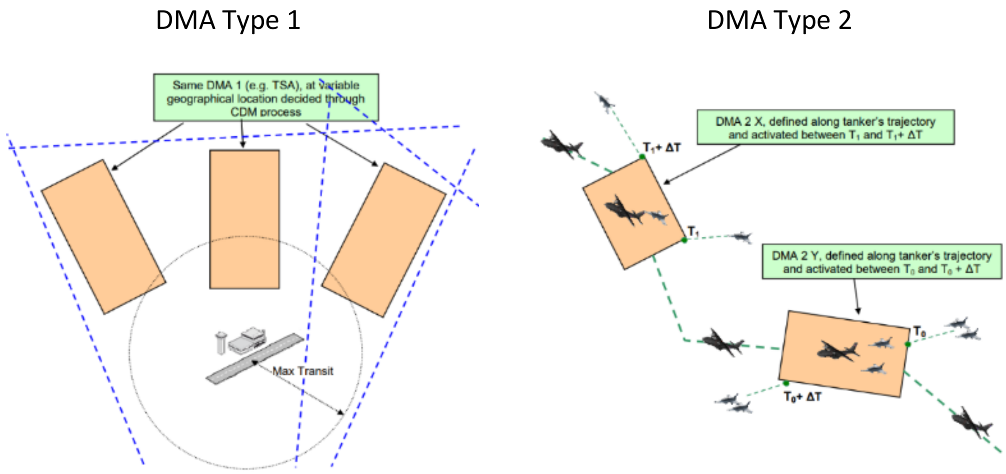
AOM-0208-B and AOM-0208-C: Dynamic mobile areas

AOM-0208-B — Dynamic mobile areas (DMA) of types 1 and 2

The dynamic mobile area aims to position ARES in different positions as part of a CDM process to minimise impacts on civil flights. There are 3 types of DMA, this operational implementation objective covers Types 1 and 2.

DMA Type 1 is a volume of airspace that may be placed in different locations from a reference point, such as an aerodrome and in doing so minimises the impact on other traffic. DMA Type 2 enables smaller ARES spaced along a longer trajectory. See Figure 8-1.

Figure 8-1: DMA Types 1 and 2 [20]

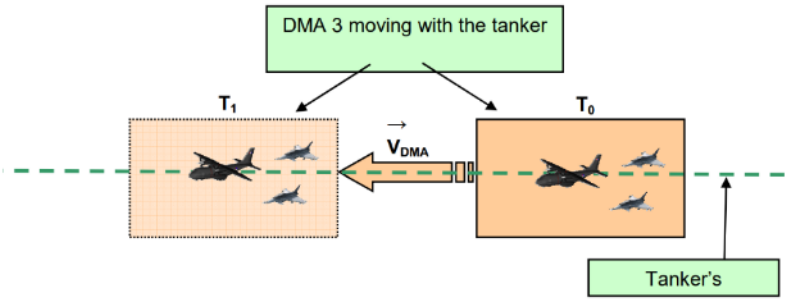


AOM-0208-C — Dynamic mobile areas (DMA) of Type 3

DMA Type 3 is a volume of airspace designed around moving aircraft (an aircraft centric bubble) requiring specific separation criteria based on aircraft configuration (e.g., Fighter, Tanker, Formation). See Figure 8-2.

The use of areas moving with the aircraft allows to keep the size and duration of the volume of segregated airspace to the absolute minimum required. It can also be beneficial to the military airspace user, by increasing flexibility. It allows the same tanker to move to different locations to refuel several aircraft, thus removing the need for several tankers located in fixed ARES. It can also increase safety by defining a volume of protection around a suspicious aircraft to be intercepted.

Figure 8-2: DMA Type 3



AOM-0805 — Collaborative airspace configuration

The operational implementation objective is to improve the use of airspace capacity for both civil and military users by increasing the granularity and the flexibility of airspace configuration and management within and across ANSPs' areas of responsibilities.

This will result in the integration of concepts and procedures to allow flexible sectors that can be dynamically modified according to demand. This includes potential implications for ATCO licences, international boundaries, and potentially interoperability and air-ground multi-datalink communication capabilities.

B CMIC performance indicators

This appendix summarises the CMIC performance indicators developed in 2015 and some of these are currently being redeveloped. We have grouped the indicators into the following categories:

- Capacity - of ARES for military mission training.
- Cost effectiveness - concerning the transit *costs* of military flights between the originating air base and the ARES training area.
- Efficiency – concerning the efficient use of ARES in time and airspace volume. This category also includes a transit-time measurement.
- Flexibility – concerning the flexibility of rules applied and lead times for actions.

Note that these indicators are currently being updated due to changing data sources.

CMIC PIs with comments

Ref	Indicator definition	Simplified definition	Comments
Capacity			
1	ARES time requested (SCr) = ARES time requested / time available where: - ARES requested time for training - ARES time available for a planning	(Military) ARES duration available ÷ ARES duration requested	E.g., ARES available for 6 hours, requested for 8 hours, SCr = 0.75. The optimum value for military users is 1, whereas civil users benefit from values greater than 1. An occupancy measure, used capacity vs designed capacity can inform future airspace design, VPA in particular. ↑ benefits military, ↓ benefits civil
Cost effectiveness			
2	Transit Cost (CoTT) = Transit time * cost where: - transit time is the total transit time (in minutes) for all aircraft participating in missions, and - cost is the cost per flying hour, defined by each State, for the aircraft involved in the missions	CoTT = (Military) Total transit time x Total transit cost (€)	E.g., the cost of a 20-min transit time from aerodrome to exercise area. ↓ benefits military
3	Average cost of transit (ACoT) = CoTT/number of aircraft where: - CoTT is computed as per the above section, and - number of aircraft is all aircraft participating in missions	= CoTT ÷ number of military aircraft (€)	This could also allow for aircraft type banding for different CoTT. ↓ benefits military
Efficiency			
4	Allocated ARES dimensions vs optimum ARES dimensions (AvsO) = the mean over all missions of: AvsO= {min (A1/Ao, 1) * min (FL1/FLo, 1)} where:	AvsO = mean allocated ARES volume ÷ optimal ARES volume	Volume could be adapted to units of NM^3 but this will not affect the indicator. Indicator will inform future airspace design especially variable profile area (VPA).

Ref	Indicator definition	Simplified definition	Comments
	- A1 is the ARES surface area (in nm2) used in the mission, - Ao is the optimum ARES surface area (in nm^2) for the mission, - FL1 is the allocated flight-level range, - FLo is the optimum flight-level range for the mission	Where ARES area is in NM^2 and height in FL.	↑ benefits military, ↓ benefits civil
5	Performance Indicator: Average transit time (AvT) = Transit time/number of aircraft where: - transit time is the total transit time of all aircraft participating in missions, and - the number of aircraft is the total number of aircraft which participated in completed missions	= Total transit time ÷ number of aircraft (min)	↓ benefits military
6	AUP allocation efficiency (AAE) = AUP allocated time / Allocated time where: - AUP allocated time is a total ARES allocated time by AUP - Allocated time is sum of ARES allocated time by all means	AAE = total time allocated by AUP ÷ time allocated by all means	All means could be NOTAM or direct communications between military and civil actors. ↓ benefits civil
7	Use of allocated ARES (UoA) = Time used / Time allocated where: - time used is the time used for training event in ARES, and - time allocated is the time allocated for training in ARES	UoA = time ARES is used ÷ time allocated	This appears the inverse of EC(c) (booked / used). E.g., used for 6 hours, allocated for 8, UoA = 6/8 = 0.75. ↑ benefits military and civil
8	Time planned vs. time used by GAT in available ARES (tPvtU) = Available ARES time planned by GAT / Available ARES time used by GAT where: - Available ARES time planned by GAT is the amount of time during which available ARES was planned for use by GAT. - Available ARES time used by GAT is amount of time during which available ARES was actually used by GAT.	tPvtU = (civil) time planned in ARES ÷ time used	This seems to tie into SES indicator (d), comparing what GAT planned given the AUP with the time that it was actually used. Differences in the two could presumably be due to downstream changes in flight plans or tactical instructions from ATC. that could have done as ARES was available. ↓ benefits civil
9	Released ARES time used by GAT (rStU) = Released ARES time used by GAT / Released ARES time where: - Released ARES time used by GAT is the time during which released ARES was actually used by GAT. - ARES Released time is the total time for which ARES was released for GAT use. RStU	rStU = where ARES is released, the time used by GAT ÷ the total time released	Where an ARES booking is deactivated, it creates a tactical opportunity to be used by flights under ATC. E.g., deactivated early for 1 hour and ATC direct two flights through for 15 mins each. Usage could be 15 + 15 or 15 mins. So, ratio is 2 or 4. ↑ benefits civil

Ref	Indicator definition	Simplified definition	Comments
Flexibility			
10	Proportion of ARES to which ASM Level X applies (ASMx) = ARES surface area to which ASM Level X applies / ARES surface area where X = 1,2 or 3 where: - ARES surface area to which ASM Level X applies is the total published ARES surface area (in nm2) to which ASM level 1,2 or 3 applies, - ARES surface area is the total published ARES surface area (in nm2) subject to FUA.		*It is not clear why ASM would not apply to all levels and this indicator may need updating.*
11	ARES allocation at short notice (SASn) = Number of ARES allocated / Number of ARES requested where: - Number of ARES allocated is the sum of ARES allocations upon request at short notice - Number of ARES requested is the sum of ARES allocation requests at short notice	SASn = (military) number of ARES allocated at short notice ÷ no requested	An increase in this indicator shows flexibility in the system to respond to short notice military requests, but may also indicate increased vectoring of flights to avoid ARES activated at short notice. ↑ benefits military, ↓ benefits civil
12	ARES released to GAT prior to scheduled start (tGAT) = Time released before scheduled start / Time cancelled where: - Time released before scheduled start is the total amount of allocated ARES time given back to GAT prior to its scheduled start time of activation upon cancellation of a mission. - Time cancelled is the total amount of allocated ARES Time for all cancelled missions	tGAT = where ARES is deactivated early, the total time released back to GAT prior to SOBT ÷ total of ARES time cancelled. ARES released before GAT flight SOBT	As it stands, this indicator identifies the time of release, but not whether this time is useable by civil airspace users. We have suggested here that the scheduled start is the SOBT. If A-CDM processes were brought into the equation, this could be TOBT with a link between ARES, A-CDM and Enroute ATC to maximise the outcome. ↑ benefits civil

C Utilisation of ARES bookings per hour

The following tables show, for a series of the larger ARES in each of the five States, the booking times for weekdays, Saturdays and Sundays. The data set is the following weeks:

- 11-17 Jan 2021
- 12-18 April 2021
- 17-23 May 2021
- 19-25 July 2021
- 18-24 October 2021
- 20-26 December 2021

C.1 Probability that ARES is booked on weekdays by hour (0600 – 1800)

Hour of day (0600- 1800)

ARES	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
EDD100Z	47%	93%	97%	67%	37%	57%	70%	93%	57%	40%	3%	3%	
EDR136AZ	100%	83%	83%	83%	83%	83%	83%	83%	83%	100%	100%	90%	83%
EDR201EZ	10%	57%	90%	90%	40%	37%	80%	87%	73%	33%	13%		23%
EDR305Z		37%	57%	60%	60%	53%	57%	67%	70%	50%	30%	13%	13%
EDR407CZ		53%	77%	77%	77%	33%	50%	73%	73%	30%	30%	13%	13%
EGD323A	17%	37%	67%	100%	100%	87%	87%	93%	77%	83%	40%	17%	10%
EGD323B	17%	37%	63%	100%	100%	87%	83%	90%	73%	80%	37%	17%	10%
EGD323C	17%	40%	63%	100%	100%	100%	90%	100%	77%	100%	47%	27%	10%
EGD323D	17%	40%	63%	100%	100%	100%	100%	100%	77%	100%	47%	27%	10%
EGD323E	17%	40%	63%	100%	100%	100%	93%	100%	77%	100%	47%	27%	10%
LED104		33%	53%	37%	50%	53%	37%	13%	3%	3%		10%	13%
LED122	70%	67%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
LED169		23%	50%	50%	23%	40%	40%	27%	7%	83%	83%	83%	83%
LER63	90%	73%	73%	73%	73%	73%	73%	87%	87%	87%	37%		
LER86B	67%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
LFD12GA			23%	23%	27%	7%	10%	30%	30%	3%			10%
LFD300A		7%	20%	13%									
LFD54BNZ		13%	13%	13%	10%	3%	17%	17%	17%	10%			
LFR108HS		30%	33%	33%	37%	43%	43%	17%	20%	13%	13%		
LFR175BZ1													
LID409B	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
LID67	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	33%		
LIR50	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
LIR54	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
LIR64	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

C.2 Probability that ARES is booked on Saturdays by hour (0600 – 1800)

Hour of day (0600- 1800)

ARES	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
EDD100Z													
EDR136AZ	100%	50%	50%	50%	50%	50%	83%	50%	50%	67%	67%	67%	50%
EDR201EZ													
EDR305Z													
EDR407CZ													
EGD323A													
EGD323B													
EGD323C													
EGD323D													
EGD323E													
LED104													
LED122	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%
LED169													
LER63	33%	50%	67%	67%	67%	67%	67%	17%					
LER86B													
LFD12GB													
LFD300A													
LFD54BNZ													
LFR108HS													
LFR175BZ1	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%
LID409B	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
LID67													
LIR50	83%	83%	83%	83%	83%	83%	83%	17%					
LIR54													
LIR64	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

C.3 Probability that ARES is booked on Sundays by hour (0600 – 1800)

Hour of day (0600- 1800)

ARES	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
EDD100Z													
EDR136AZ	100%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
EDR201EZ													
EDR305Z													
EDR407CZ													
EGD323A													
EGD323B													
EGD323C													
EGD323D													
EGD323E													
LED104													
LED122													
LED169													
LER63	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
LER86B													
LFD12GB													
LFD300A													
LFD54BNZ												17%	17%
LFR108HS													
LFR175BZ1	17%	17%	17%	17%	17%	17%							
LID409B	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
LID67	67%	67%	67%	67%	67%	67%	67%	67%	67%	67%	67%	67%	67%
LIR50	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
LIR54	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
LIR64	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

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