Air Traffic Management (ATM)

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This paper provides a high-level overview of some of the principal challenges facing Air Traffic Management (ATM). It explains that air traffic control is a natural monopoly that nevertheless facilitates competition among the various actors in the air transport industry. ATM provides airspace capacity to meet traffic demand. The paper provides the latest historical and forecast air traffic statistics, confirming that it will take seven years for European air traffic to fully recover from the pandemic.
Airspace capacity must be provided in a safe, secure, cost-efficient, and sustainable manner to meet demand. Doing so is complex and becomes particularly challenging in the face of external events, such as Russia's invasion of Ukraine, whose impact on ATM is described. The long-term challenges of the decarbonization and digitalization of ATM are addressed, as well as the impact of Artificial Intelligence (AI), with some examples provided of how ATM is adapting.

Introduction

The ICAO Chicago Convention requires States to provide Air Traffic Services, and to ensure a safe and expeditious flow of air traffic. The States do this, in principle, through their Air Navigation Service Providers (ANSPs), which are natural monopolies controlling their State sovereign airspace, or, through ATS delegation agreements, airspace over other States. The monopolistic situation arises from the fact that two different ANSPs cannot provide air traffic services in the same volume of airspace. ANSPs must ensure that the ATM system has adequate capacity, at the right place and at the right time, to meet demand. Capacity is a function of the airspace design and structure, operational procedures, number of air traffic controllers, technical system support and other supporting infrastructure. If there is too much demand to fly through a specific volume of airspace (a "sector", under an air traffic controller's direct responsibility), then action needs to be taken before flights depart to protect that sector from "overload", including delaying or re-routeing flights.

Commercial and competitive pressures from the airspace users to meet demand, challenge ATM to grow system capacity while protecting safety levels, prudently managing costs, and ensuring aircraft are flown as efficiently as possible to reduce fuel burn and emissions. As air traffic grows, so does the complexity of these challenges. A more cross-border approach will be required to adapt airspace structures to traffic flows; a more accelerated recruitment of controllers will be needed; the implementation of more advanced operational concepts and technical solutions will be required. Those will come, indeed, with challenges related to ATS delegations, availability of sufficient interested staff, cultural changes to accept more innovative concepts, and, as a result of more digitalization and artificial intelligence, the risk of bringing with them more intelligent cybersecurity attacks that require appropriate responses from the aviation community.

The challenge of demand - European air traffic in 2023

10.2 million flights were controlled in European airspace in 2023, reaching 92% of 2019's 11 million flights (Figure 1)[1]. The maximum number of flights in a 24-hour period was 34,367, compared to the all-time peak of 37,228 flights in 2019.

Air traffic is expected to reach 2019 levels in 2026 (Figure 2), with 11.2 million flights, according to EUROCONTROL's latest 7-year forecast, covering the period 2024-2030[2].

Air traffic growth is driven by society's demand for business and leisure travel (1.19 billion passengers at Europe's top 40 airports in 2023), and by the strong competition among air carriers to each serve as high a proportion of that demand as possible.

Traffic is majority intra-European. Ryanair Group operated 2,813 flights/day on average in 2023, followed by Lufthansa Group (2,583), IAG (2,167), Air France-KLM Group (1,787), easyJet (1,477), and Turkish Airlines (1,443). Mainline carriers grew their market share from 32% to 35%, with low-cost carriers growing by 1 point to 33%.

Our top airports in 2023 were Istanbul IGA (1,365 flights/day), Amsterdam (1,255), London Heathrow (1,251), Paris CDG (1,247), Frankfurt (1,179), and Madrid (1,066). They were the only airports with more than 1,000 flights/day, with the top 10 completed by Barcelona, Munich, Rome Fiumicino, and London Gatwick. Airline and airport rankings are very similar to those of 2019.

[1] https://www.eurocontrol.int/sites/default/files/2024-01/eurocontrol-european-aviation-overview-20240118-2023-review.pdf (The source of the traffic statistics quoted in this paper).

[2] https://www.eurocontrol.int/publication/eurocontrol-forecast-2024-2030

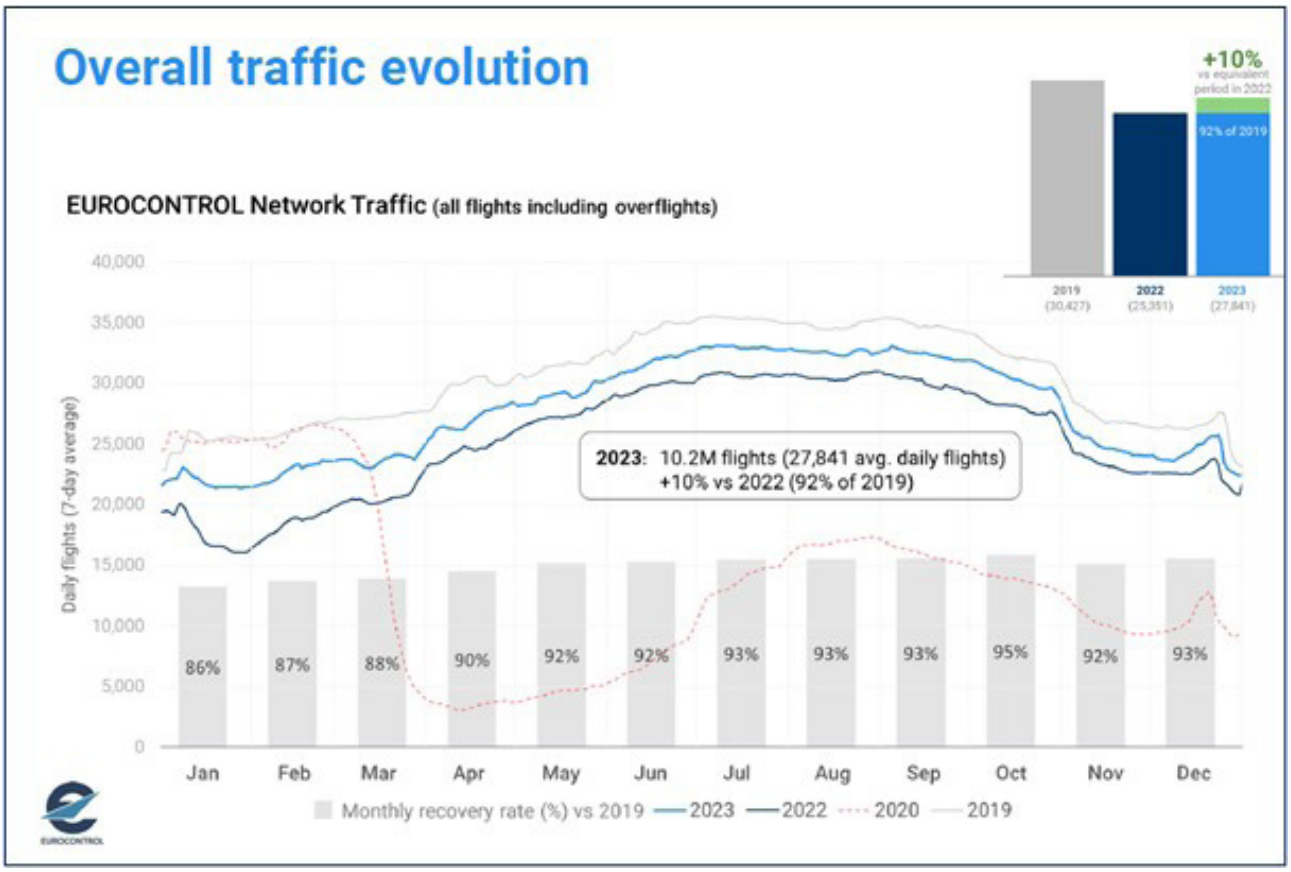

Figure 1: Evolution of European Air Traffic 2019-2023

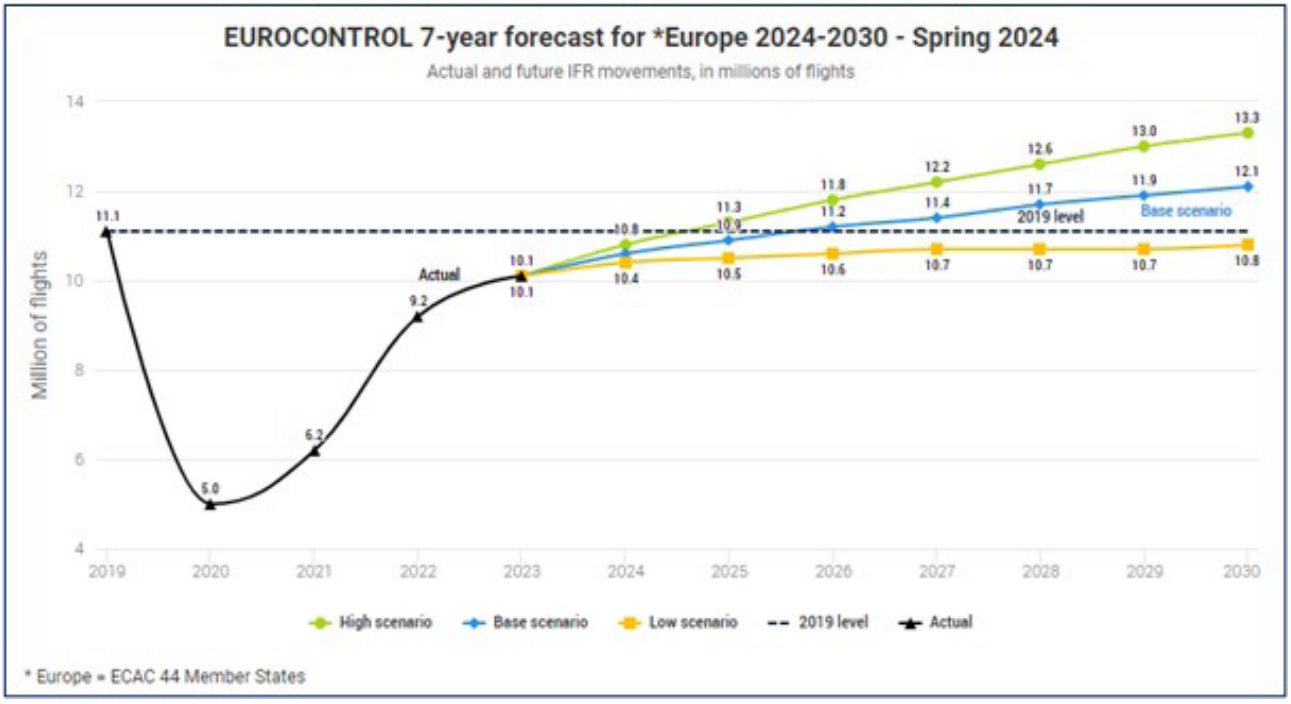

Figure 2: EUROCONTROL 7-year traffic forecast for 44 ECAC Member States 2024-2030

This is reflected in country-by-country statistics, with the UK, Spain, and Germany each handling more than 4,500 departures and arrivals daily. Türkiye posted the highest increase (+16%) as part of the dynamic South-East axis flows, owing to tourist flights, the continuing expansion of Istanbul IGA Airport and the shift of some flights from Russian to Türkish airspace. Indeed, the Europe-Middle East traffic flow is now greater than the North Atlantic flow (1,401 *vs* 1,227 flights/day) The Europe-North Africa traffic flow is the only other with over 1,000 flights/day, with these three accounting for 2/3 of the traffic to/from Europe.

THE CHALLENGE OF WAR – RUSSIA'S INVASION OF UKRAINE

European ATM is coping with a geographic reconfiguration of traffic as a result of Russia's unprovoked invasion of Ukraine. For Ukrainian aviation, it has been disastrous with the closure of its airspace to civil air traffic (Figure 3).

Approximately 20% of Europe's airspace is not available to civilian air traffic due to the war. Although overall traffic is 8-9% below what it was in 2019, it is now consistently above 2019 numbers in South-West, South-East, and Central Europe. This concentration of traffic means that the skies are more congested than before, potentially leading to an increase in departure and arrival delays.

Flows between the EUROCONTROL area and other parts of the ICAO EUR Region including Russia are down by 68% in comparison with 2019 (Figure 4). Russian airspace is closed to most European long-haul airlines heavily impacting carriers, such as Finnair that operated through the Russian airspace to reach the Far East. Russia's invasion means that aircraft will fly greater distances, take longer to reach their destinations, burn more fuel, and release more greenhouse gases.

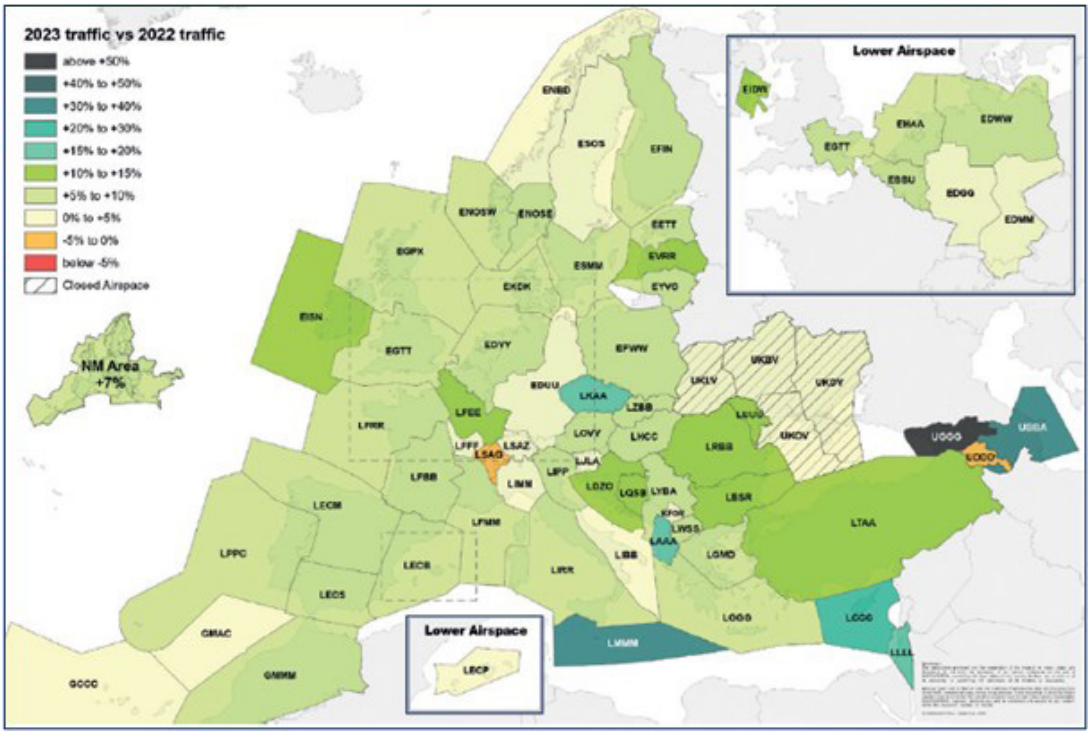

Figure 3: Increase/decrease in traffic for European flight information regions 2022-2023.

Region	Average daily flights	% 2022	% 2019
Intra-Europe	21,660	+8%	-6%
Europe ↔ Middle-East	1,401	+17%	-1%
Europe ↔ North Atlantic	1,227	+14%	+4%
Europe ↔ North-Africa	1,098	+28%	+7%
Europe ↔ Asia/Pacific	712	+33%	-10%
Europe ↔ Other Europe	332	+8%	-68%
Europe ↔ Southern Africa	297	+9%	-5%
Europe ↔ Mid-Atlantic	175	+1%	+1%
Europe ↔ South-Atlantic	172	+18%	-7%
Non Intra-Europe	5,414	+18%	-12%

Figure 4: Average daily departure/arrival flights between regions 2023.

THE CHALLENGE OF CLIMATE CHANGE – DECARBONIZING ATM

Improving flight efficiency remains ATM's main contribution to the European "Green Deal", reducing fuel burn and its associated greenhouse gas emissions. In April 2022, EUROCONTROL published a major study[3] which analyzed long-term air traffic and emissions forecasts, to outline how our industry might achieve net zero CO_2 emissions by 2050.

Sustainable Aviation Fuels (SAFs) have the highest potential to reduce emissions, by over 40%. Nevertheless, improved flight efficiency could deliver 22 million tonnes (8%) of the 279 million tonnes of CO_2 emissions savings required to meet the net zero target. Fuel and emissions savings come from ATM facilitating cross-border free-route operations in the entire airspace of the EUROCONTROL member states, reducing airspace restrictions, supporting airspace users in more efficient flight planning, optimized ascent and descent to/from cruising levels, and more efficient movement of aircraft at airports. Research is also underway into how ATM can facilitate avoidance of contrails, in an initiative to reduce the non-CO_2 impacts of aviation.

ATM is also decarbonizing its ground infrastructure of area control centers, airport towers, offices, and ground equipment for communications, navigation, and surveillance. A 2022 EUROCONTROL Think Paper[4] estimated that European ATM's ground infrastructure consumed approximately 1,140 GWh of electricity in 2020, the generation of which would produce 311,000 tonnes of CO_2 emissions when calculated using carbon intensity of electricity production data. A total decarbonisation of that energy could save over 6 million tonnes of CO_2 by 2050.

ANSPs highlighted some initiatives to "green their infrastructure" at a recent webinar organized by NM. The Croatian, German, and Italian ANSPs, together with NM, shared their experiences, ranging from cloud computing, improved cooling at data centers, renewable energy contracts, and developing local renewable energy solutions (Figure 5) for their facilities (solar power, wind turbines, and even hydrogen fuel cells). Virtualization, embracing cloud-based solutions, is emerging as a key mechanism for conserving energy.

Network Manager's recently opened Network Operations Centre has over 460 solar panels on its roof (Figure 6), generating up to 700kWh of power per day and approximately 137 MWh over the year. It is being certified to the construction industry's BREEAM excellent environmental standard.

ATM, from both the operational and infrastructure perspectives, is innovating to support the European "Green Deal".

[3] Downloadable at https://www.eurocontrol.int/press-release/eurocontrol-2050-air-traffic-forecast-showing-aviation-pathway-net-zero

[4] Downloadable at https://www.eurocontrol.int/publication/eurocontrol-think-paper-13-greening-european-atms-ground-infrastructure

Figure 5: Ground-based navigation facility (DME - Distance Measuring Equipment) on Lošinj Island, Croatia, powered primarily by solar energy (Photo courtesy of Croatia Control).

Figure 6: EUROCONTROL new Network Manager Operations Centre

THE CHALLENGE OF COST EFFICIENCY – PLANNING THE EVOLUTION OF THE GROUND INFRASTRUCTURE

Communications, Navigation and Surveillance (CNS) infrastructure, coupled with the associated avionics on board aircraft, make up ATM's sensory system. Controllers and pilots need to know the speed, height, heading, and position of their aircraft. Without CNS, an air traffic control officer cannot give an instruction to a pilot, nor the pilot acknowledge it.

Over 6,000 European ground-based facilities support CNS, costing approximately €1.3bn annually to run. The advent of space-based CNS systems (*e.g.* Aerion, Galileo, GPS & Iris) has added a new layer of technology, allowing us to reduce some of the layers on the ground, by optimizing the numbers of legacy navigation facilities - Non-Directional Beacons (NDB) and VHF Omnidirectional Range (VOR) in particular. This reduces costs, and also helps to reduce frequency congestion.

For surveillance, we are seeing less and less reliance on what most people think of as the "traditional" radars, and a big increase in the deployment of a mix of facilities all of which have ADS-B (Automatic Dependent Surveillance) at their core.

On the communication front, we know that datalink (think of a tailored SMS between controllers and pilots) improves capacity and safety. But we also know that both ATC and airlines will need more and more data bandwidth in the future, which today's datalink systems may struggle to handle. So, we are working with the SESAR Joint Undertaking (SJU) and SESAR Deployment Manager (SDM) to finalize the business case for future communications infrastructure as the way ahead.

There is much, therefore, to ponder and to plan. To that end, EUROCONTROL has accepted an invitation from the European Commission to include a new "CNS Programme Manager" function within its Network Manager responsibilities[5]. Now operational, the CNS PM will lead the development of a European CNS Evolution Plan that will chart a course for the future of the ground and space infrastructure and associated avionics. It will be compatible with the forthcoming version of the European ATM Master Plan being developed by the SJU.

However, Russia's invasion of Ukraine and increased disruption of satellite navigation signals near conflict zones probably means that, for security reasons, infrastructure optimization will be more limited, compared to what was being considered.

[5] Article 7 of the Network Functions Implementation Regulation 2019/123 (NFIR 2019/123) within the EU Single European Sky legislation

THE CHALLENGE OF DIGITALIZATION – DATA, ARTIFICIAL INTELLIGENCE AND CYBERSECURITY

ATM is a technology heavy industry, and works on decades-long investment horizons. This is expressed in the European ATM Master Plan, whose ambitious objectives foresee a transition towards the "Digital European Sky" through investing €25-53 billion in the period 2012-2050, of which 80% would be invested by 2035[6].

Digitalization allows observation – that is, monitoring of performance – and then modification by reprogramming digital equipment to improve operational performance. It works best when everything is connected to a network. Digitalization allows for faster reactions and more agility, providing the basis for new digital services.

ATM's digital transition covers the gathering, processing, transporting, sharing, and publication of data, as well as the introduction of new, more efficient ground equipment and software-defined radios on-board aircraft. Digitalization is already happening at pace as the following examples demonstrate.

System-Wide Information Management (SWIM) provides the means to share information and data. At an airport, SWIM allows all relevant actors to know when an aircraft is going to land and arrive at its gate. This allows ATC, the airline, the ground handling agents, and the airport operator to ensure that all relevant services are ready, covering stand allocation, passenger disembarkation, aircraft refuelling, cabin cleaning, catering, customs and passport control, and the introduction of a new crew.

NewPENS – the digital network for the transport of data throughout the ATM system – is an ultra-resilient IP network for exchanging critical and common aeronautical information reliably, securely, and safely in a cost-efficient way. Its architecture guarantees an increased level of end-to-end control and authority, connecting over 100 locations in 47 countries. It operates with 99.999% availability, and includes elaborate cybersecurity precautions. It will evolve to meet business needs, providing the backbone on which more SWIM applications will run. NewPENS is supported by a service desk at EUROCONTROL.

Because SWIM is at the heart of the digitalization of ATM, it needs to be secured against cyberattacks, which are increasing. The purpose of a Public Key Infrastructure (PKI) is to facilitate the secure electronic transfer of information for a range of activities on a network. EUROCONTROL and the SDM have developed a new service to ensure that stakeholders' data and information are transferred securely, in which sending/receiving parties are identified and authenticated using a PKI. It will be used where the identities of counterparties involved must be ensured.

Artificial Intelligence (AI) is developing at pace in all ATM domains, notably since the emergence of large language models, such as ChatGPT. Whilst waiting for regulations addressing aviation safety-related applications, AI is already being used to:

- increase productivity in the Network Operations Centre;
- improve weather predictions and anticipate regulations to reduce impacts at airports;
- introduce speech recognition capability to replace pseudo-pilots in ATC training;
- improve monitoring the performance of European ATM surveillance and navigation services;
- monitor, and classify drone trajectories.

To respond to the recent more intelligent AI-based cyberattacks, EUROCONTROL is developing new AI services to determine the source of cyberattacks.

EUROCONTROL's "integrated Network Management" (iNM) programme will replace our core systems which have successfully ensured the safe and efficient flow of aircraft across the European airspace for over 25 years. It will deliver a range of innovative digital products, enabling EUROCONTROL to maximize the efficiency, safety, and sustainability of the European aviation network through a new generation of cutting-edge, resilient, and scalable operational systems. The incremental renewal of all of NM's main operational systems will be achieved by 2030, resulting in a new digital architecture enabling NM to deliver ever more integrated business services and products to its stakeholders.

CONCLUSION

ATM has been successfully dealing with many different challenges over the decades, and will continue to do so, ensuring that flying remains safe, secure, punctual, cost-efficient, and sustainable through cooperative planning of modernization programmes, and taking advantage of new digital products.

[6] European ATM Master Plan 2020 – Executive View, p118 (downloadable from https://www.sesarju.eu/masterplan2020)