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ATM Systems Interoperability

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SUMMARY

TOC and PLC were tasked to study the issues of interoperability between ATM systems, especially how they affect the workload of ATCOs, but also the impact of interoperability in various aspects of ATS provision such as capacity, quality of service, information and data availability. This paper aims to comprehend the challenges and solutions of system harmonisation at a global level.

1. INTRODUCTION

1.1. Aviation is one of the most global and cross-border industries, with Air Traffic Services (ATS) at its core, managing flights worldwide. The objective is to ensure a consistent level of ATS throughout flights across the globe.

1.2. While the quality of services provided and increased capacity are important objectives, safety will always take precedence in Air Traffic Management (ATM). This also applies to the availability of information and data exchange.

1.3. Every piece of information entering an ATM system must be as reliable, verified, and securely delivered as possible.

2. DISCUSSION

How ATM systems work with each other

2.1. Effective ATM relies on a robust exchange of data between various Air Navigation Service Providers (ANSPs). The complexity and safety-critical nature of air traffic control (ATC) necessitate that this data be both accurate and timely, ensuring seamless coordination between different airspace sectors, ANSPs, and/or states.

2.2. This chapter examines the types of data required by ANSP operating systems, the critical data essential for ATM, and the methods by which this data is exchanged, integrating global standards and local examples—regardless of a system's level of technological advancement. Types of data can be broadly categorised into several key areas:

- Flight (Plan) data: central to ATM, flight data includes all relevant information regarding an aircraft's flight plan. This encompasses departure and arrival times, route information, altitude, and speed. Accurate flight data is essential in combination with surveillance data for tracking aircraft movements, predicting potential conflicts, and ensuring that flights follow their planned routes through various controlled airspaces (ICAO, 2016a).

- Surveillance data: this includes real-time information on aircraft positions, obtained from surveillance systems. Surveillance data provides ATCOs with up-to-date information about the location, speed, and altitude of each aircraft, allowing them to maintain safe separation and manage air traffic flow effectively.
- Communication data: communication data refers to all exchanges between aircraft and ATS (air-ground communication), as well as between different ATS units (ATSUs) (ground-ground communication). Effective communication is critical for coordinating flight movements, especially during handovers between different ATSUs (ICAO, 2007).
- Weather data: weather conditions can significantly impact flight safety and efficiency. ATM systems integrate meteorological data, such as wind speeds, temperature, and turbulence forecasts, to help ATCOs make informed decisions about flight paths and altitudes (ICAO, 2021).
- Aeronautical information: this category includes data on the physical characteristics of airports, airways, and airspace, such as Notices to Airmen (NOTAMs) and airspace restrictions. This information ensures that all stakeholders are aware of current conditions that might affect flight operations.

2.3. Efficient and automated data exchange is absolutely critical for managing the complex and dynamic air traffic environment, reducing air traffic controllers' workload, and enhancing safety. The exchange of data must occur in real time or, at the very least, as soon as possible, eliminating any noticeable delay for ATCOs unless such a delay is intentionally required. This ensures that ATCOs experience no unnecessary delay, allowing them to focus solely on managing traffic and maintaining safe separation between aircraft.

2.4. The entire infrastructure—from the Human-Machine Interface (HMI) that ATCOs interact with, down to the electrical signals transmitted through network cables—is meticulously managed by Communication, Navigation, and Surveillance (CNS) specialists. These experts ensure that all support systems operate seamlessly, without any interruptions or delays. The goal is for ATCOs to be solely focused on the HMI, free from any concerns about the underlying systems, again allowing them to concentrate fully on traffic management and maintaining appropriate separation.

2.5. Furthermore, as ATCOs rely on automatic message transfers to handle the coordination of flights entering or exiting the airspace, this reduces the workload, minimises the risk of errors, and ensures that ATCOs can operate the highest capacities of air traffic with the utmost safety levels.

2.6. Automated data exchange systems are integral to the effective management of air traffic, ensuring that data is efficiently and accurately transmitted between various ANSPs. The process of data exchange in ATM is structured across multiple interconnected levels (EUROCONTROL, 2008a; ICAO, 2016b; Indra Avitech, 2025; FAA & Eaves, 2020):

I. HMI: starting at the operational level, the HMI acts as the front-end software, allowing ATCOs to interact with and manage real-time data.

II. Data Interchange Protocol/Standard: below this, systems like the On-Line Data Interchange (OLDI) in Europe or its equivalent, the North American (NAM) protocol or the Automated Interfacility Data Communication (AIDC) protocol, used in American and Asia-Pacific regions, function similarly to back-end software, handling the processing and exchange of Ground-Ground (G-G) flight data between ATSUs.

III. Data Transfer Protocol: beneath the messaging systems, different data protocols, such as The Flight Message Transfer Protocol (FMTP) in Europe, are responsible for ensuring the secure transmission of this data between different systems. While NAM and AIDC also ensure secure data exchange, they do not have a direct equivalent to FMTP but include integrated data transmission functionalities as part of their broader coordination roles.

IV. Data Transmission: ultimately, the physical transmission of data occurs as electrical signals through wires within the network infrastructure.

2.7. Human-Machine Interface

At the operational level, the HMI is the most critical aspect of the data exchange system for ATCOs. Designed primarily to ensure safety, the HMI provides a user-friendly interface that enables ATCOs to deliver a safe, efficient, and orderly ATC service. It is essential that the HMI is intuitive and responsive, granting ATCOs access to essential tools, safety features, and safety nets in a way that balances minimalism with the need to display all relevant data. This requires a careful trade-off between simplicity and the volume, accuracy, and relevance of the information presented. The HMI must display this data clearly and concisely to support informed, rapid decision-making, ultimately enhancing the safety and efficiency of air traffic management.

The importance of interoperability in ATM systems

2.8. Every ATM system of an ICAO member state must comply with ICAO regulations and requirements (Annexes, Documents, etc.). The entire ATM concept is based on interoperability, as this is the only way to ensure cross-border operations, and aviation is fundamentally about connecting the world.

2.9. What began with the adoption of common units of measurement, weather report encodings (such as METAR and TAF), standard flight plans (FPL), and NOTAMs, which every ATM system had to be capable of processing to facilitate information exchange and manage daily operations, must now evolve further as traffic volumes increase and quality requirements become more demanding.

2.10. ICAO (2008), in their Doc 9882 – Manual on Air Traffic Management System Requirements and Doc 9854 – Global Air Traffic Management System Requirements, state that:

> The global ATM operational concept envisions a system that is service-oriented, performance-driven and predicated on the guiding principles described in this document.
>
> The ATM system will consider the trajectory of a vehicle during all phases of flight and manage the interaction of that trajectory with other trajectories or hazards to achieve the optimum system outcome with the minimal deviation from the user-requested flight trajectory, whenever possible. The ATM system will provide seamless service to the user at all times and will operate on the basis of uniformity throughout all airspace. Uniformity embodies both application of common ATM system rules and procedures across all airspace and use of common core technical functionality in the systems used.
>
> "It is not intended that this will establish an all-embracing requirement for identical equipment or systems, although minimizing system duplication or reducing equipment or <u>systems needed to operate in a global ATM system environment is an obvious goal.</u>
>
> It is intended that agreed required minimum levels of aircraft equipment, performance and ATM system network capabilities will be matched by defined levels of service. It is intended that the ATM system should provide all users, at a minimum, the same level of access to runways and airspace when compared to a regionally agreed baseline year.
>
> (ICAO 2005, ICAO 2008)

2.11. In addition to these general requirements, ICAO Doc 9882 also requires an ATM system to:

- "be designed to accommodate all types of airspace user missions and all types of vehicles and associated characteristics";
- "ensure that the ATM community works collaboratively to plan and implement the capacity needed to cost-effectively meet the forecast demand";
- "be based on global standards and uniform principles, ensure the technical and operational interoperability of ATM systems and facilitate homogeneous and non-discriminatory global and regional traffic flows";
- "establish common operational procedures within similar operational environments".

2.12. A study by Kalvoda and Bauer (2019), although focused on military aviation, highlights that automated data exchange is the most significant factor in reducing the workload of controllers and, consequently, in enhancing air traffic safety. Their findings underscore the importance of automated data exchange systems, not just in reducing manual coordination but in improving overall operational efficiency and safety within ATM systems. This aligns with global efforts to standardise and automate data exchanges across different regions and sectors.

The challenges to obtain worldwide system interoperability

2.13. The current landscape of global ATM is characterised by significant fragmentation in the operating systems (OS) utilised across different States and regions. Each ANSP often relies on one, more often even multiple distinct operating systems for its operations, which in consequence is an important contributor to reduced efficiency, cost-effectiveness and possibly safety of Air Traffic Management all over the world (EUROCONTROL, 2008b). It is also important to emphasise that this fragmentation is not a reflection of the political boundaries but is a technological and systemic division rooted in the quantitative and qualitative variety of different operating systems being used by different ANSPs.

2.14. The core problem lies in the fact that these disparate operating systems are - to a certain extent, varying between ANSPs - incompatible with one another, creating significant barriers to interoperability. This lack of compatibility means that the systems used by various ANSPs are unable to communicate to the highest possible extent of effectiveness and expedition (Coordination Committee (CCOM) & Deployment Coordination Committee (DCOM) et al., 2018) which are both a fundamental requirement for air traffic management, as defined in ICAO Doc. 4444 (2016a).

2.15. Such inefficiencies are especially visible in very interconnected and politically fragmented regions, such as Europe (Coordination Committee (CCOM) & Deployment Coordination Committee (DCOM) et al., 2018). In regions like Europe, this issue is exacerbated under conditions of high traffic loads, where the lack of interoperability between operating systems becomes even more pronounced - leading to air traffic bottlenecks, leading to capacity regulations, leading to delays and potential safety risks (ATCOs working at or even above published sector capacity levels).

2.16. Moreover, (system) fragmentation is one of the main reasons for the often-cited inefficiency of the European ATM system compared to the one in the United States (European Commission, 2023).

2.17. In Europe, the OLDI standard, with its latest version being OLDI 5.1, could play a critical role in increasing interoperability between systems. OLDI defines specific messages all aimed at reducing the need for verbal coordination and minimising the risk of errors (Eurocontrol, 2023). However, as OLDI standard is not legally enforced by the European Union, this situation somehow exemplifies why the current (European) ATM network is under a significant strain. As a result, not all system manufacturers strictly adhere to the OLDI standard, leading to numerous issues such as inefficiencies due to message inexistence or even errors in automatic message sending and receiving, incorrect encoding, and messages falling into error queues due to improper formatting. Such enforcement would ensure more effective “system communication” necessary for efficient ATM across the region.

2.18. Furthermore, there is inconsistency in the capabilities of different ATC systems; some are able to send more messages while others may only have capabilities for the most basic messages, leading to operational differences depending on the capabilities of their respective systems.

2.19. Globally, similar standards are in place, such as the NAM protocol in North America, which serves a similar role to OLDI. The NAM protocol is used for coordinating flight data exchanges between ATC units across the U.S., Canada, and other regions, supporting functionalities like radar handoffs and communication transfer (FAA & Eaves, 2020). The AIDC protocol is another global standard used widely in regions like Asia-Pacific. AIDC supports extended capabilities in various operational contexts, such as time and distance-based operations (ICAO, 2016b).

2.20. The existence itself, of these multiple standards (Figure 1), vividly illustrates the fragmented nature of global ATM systems. Despite all these protocols aiming to achieve the same goal—facilitating the exchange of flight data between ATSUs—they do so using different messages and formats. This inconsistency adds a paradoxical layer to the global air traffic management landscape: while the goal is seamless communication, the diversity of standards complicates the process, requiring extra effort and resources to ensure interoperability between systems.

Figure SEQ Figure * ARABIC 1: *Comparison of AIDC, NAM and OLDI message sets*

AIDC – NAM – OLDI Message Sets

AIDC	NAM	OLDI
ABI	FPL	ABI
CPL	CPL	ACT
EST	EST	REV
MAC	CNL	PAC
PAC	MOD	MAC
CDN	MIS	SDM
REJ	IRQ	ATC
TRU	IRS	RAP
TOC	TRQ	RRV
AOC	ASM	CDN
EMG	RTI	SBY
ACP	RTU	ACP
LAM	RLA	TIM
LRM	RTA	LAM
ASM	LAM	LRM
FAN	LRM	COF
FCN	CHG	ROF
ADS	ABI	MAS
TDM	AOC	HOP
	TOC	
	POI	
	POA	
	POJ	

Note. From *North American (NAM) Common Coordination Interface Control Document (ICD).* (Slide 16), by FAA, 2020, FAA. Copyright 2020 by FAA.

Desired outcomes regarding interoperability

2.21. The ideal outcome for addressing the fragmentation of ANSPs (and thus systems) worldwide involves harmonised systems being completely interoperable with each other, regardless of the system supplier or its user.

Interoperability would enable an overarching goal to collectively achieve a high level of operational performance.

2.22. ICAO Doc 9882 states that:

> Air traffic management systems and their constituents shall be designed, built, maintained and operated using the appropriate and validated procedures, in such a way as to ensure the seamless operation of the worldwide ATM system at all times and for all phases of flight. Seamless operation can be expressed, in particular, in terms of information-sharing, including the relevant operational status information, common understanding of information, comparable processing performances and the associated procedures enabling common operational performances agreed for the whole or parts of the ATM system.
>
> Flight data processing systems shall be interoperable in terms of the timely sharing of correct and consistent information, and a common operational understanding of that information, in order to ensure a coherent and consistent planning process and resource-efficient tactical coordination throughout the airspace during all phases of flight.
>
> In order to ensure safe, smooth and expeditious processing throughout the airspace, flight data processing performances shall be equivalent and appropriate for a given environment (surface, terminal manoeuvring area (TMA), en-route), with known traffic characteristics and exploited under an agreed and validated operational concept, in particular in terms of accuracy and error tolerance of processing results.
>
> (ICAO 2008)

2.23. ICAO has been a key player in encouraging global standards for data exchange in air traffic management. ICAO's Global Air Navigation Plan (GANP) emphasises the importance of seamless data exchange systems to enhance the efficiency and safety of global airspace (ICAO, 2016b).

2.24. By harmonising systems, ANSPs can significantly reduce the need for manual coordination, streamline the exchange of critical data, and improve overall ATM effectiveness. The automation of data exchanges not only reduces the workload on ATCOs but also enhances the accuracy and timeliness of the information being exchanged, which is crucial for maintaining high standards of safety and efficiency in global airspace management.

Steps taken so far in enhancing interoperability

2.25. ICAO's Global Air Navigation Plan (GANP) is a comprehensive global strategy that, among many other objectives, shifts air navigation development from a technology-driven to a performance-based approach. This shift ensures that, rather than various aviation stakeholders implementing new technologies independently and locally based on their specific needs, a global framework is established to enable the air navigation system to evolve in a strategic and harmonised manner.

2.26. The GANP provides a structured path for the safe, orderly, and efficient evolution of the global air navigation system. Obligations related to the provision of essential air navigation services are incorporated into the Basic Building Block (BBB) framework, ensuring a robust foundation for this evolution. The transformative steps outlined in the conceptual roadmap are further reinforced through the Aviation System Block Upgrades (ASBU) framework, which ensures system interoperability, procedural harmonisation, and a coordinated approach to modernising the global air navigation system. New users, operations, roles, and all stakeholders are integral to this structured transformation.

2.27. ICAO Doc 9750 states that:

> The global air navigation system is becoming more complex as it supports new demand. To manage this complexity, meet the global performance ambitions and realise the GANP vision, the air navigation system must transform and build upon the use of emerging technologies, information and concepts of operations, many of which are not specifically designed for aviation purposes.
>
> (ICAO 2016b)

2.28. GANPs vision is to create one global network connecting operators, aerodromes, ATS providers etc. that will share information in order to optimise flow and capacity for all airspace users. This plan takes the cross-border aviation concept to a whole new level.

2.29. The concept of Trajectory-Based Operations (TBO), as defined by ICAO, is fundamentally aligned with the goals outlined in this paper—harmonisation, standardisation, and interoperability. TBO envisions a globally connected ATM environment where flight trajectories are managed collaboratively across different systems and stakeholders, ensuring seamless and efficient operations. Achieving this level of integration requires a structured and standardised approach to information exchange, ensuring that all ATM systems can communicate effectively, process shared data seamlessly, and operate in a harmonised manner. A key enabler of TBO is the implementation of Flight and Flow Information for a Collaborative Environment (FF-ICE) and System Wide Information Management (SWIM). These technologies provide the necessary framework for a unified, data-driven ATM system, where real-time information sharing supports strategic, tactical, and dynamic trajectory management. Given the increasing complexity of airspace operations, regulatory and technical standardisation will be crucial in ensuring the interoperability required to fully implement TBO.

2.30. SWIM, as defined in ICAO Doc 10039 (2024), plays a crucial role in this transformation. While the scope of SWIM extends beyond ATM, it is fundamental to achieving the GANP's objectives. Specifically, Doc 10039 highlights SWIM as an integral component in meeting the goals set out in Doc 9882. By facilitating the seamless exchange of aeronautical, meteorological, and flight data among all relevant stakeholders, SWIM ensures timely access to accurate information, enhancing decision-making, interoperability, and overall airspace efficiency.

How can IFATCA contribute

2.31. To achieve the seamless global Air Navigation System envisioned by ICAO's GANP, collaboration is essential. IFATCA together with CANSO (Civil Air Navigation Services Organisation), and possibly other international organisations in the world of ATM, can pivot the global effort by:

- Converging ideas: IFATCA can bring together ANSPs, industry leaders, and ATM specialists to share knowledge, develop best practices, and shape the future of ATM. By promoting collaboration, IFATCA helps ensure that the development of TBO and related technologies meets the needs of all users, and all stakeholders benefit from the implementation itself.
- Defining user requirements: IFATCA is uniquely positioned to provide common user-defined requirements for the development of TBO technology. By representing the interests of air traffic controllers, IFATCA ensures that new systems are as described in chapter 2.5; user-friendly, reliable, and effective in enhancing safety and efficiency.
- Advocacy and support: IFATCA can advocate for the harmonisation and interoperability of ATM systems on a global scale. This includes pushing for the adoption of global standards like FF-ICE and ensuring that these technologies are implemented in a way that benefits all stakeholders, including controllers, airlines, and passengers.

2.32. The successful increase in system interoperability will bring significant benefits to all stakeholders:

- ATCOs: reduced workload and increased efficiency through automation and real-time data.
- Airlines and passengers: more efficient flight paths, leading to lower operational costs, reduced delays, and lower ticket prices.
- Society and the environment: reduced fuel consumption and emissions due to optimised trajectories, contributing to global sustainability goals.

2.33. IFATCA currently does not have a policy supporting the need for increased interoperability between different ATM systems. Therefore, this paper proposes the addition of such a policy, as outlined in Recommendation 4.1.

3. CONCLUSION

3.1. Seamless air traffic management requires greater interoperability between ATM systems to support cross-border operations, optimise airspace use, and ensure a globally connected aviation network.

3.2. As technology advances and new stakeholders emerge, ATS must maintain a consistent level of safety and quality for all flights. Interoperability enables efficient data exchange, reduces errors, and enhances decision-making.

3.3. With growing traffic numbers and complexity, ATCOs need integrated, interoperable tools to manage workload effectively. Automation and real-time data exchange are essential to maintaining efficiency and safety.

3.4. ATM system upgrades must prioritise interoperability, align with global standards, and prevent unnecessary workload increases for ATCOs by incorporating user-defined operational requirements.

3.5. Ensuring interoperability, harmonisation, and standardisation is key to a globally integrated ATM system. Technologies such as TBO and SWIM support this vision by enabling seamless data exchange. IFATCA must further advocate for these developments to enhance global airspace efficiency and meet operational needs.

4. DRAFT RECOMMENDATIONS

4.1. It is recommended that the following be accepted as policy and inserted into the TPM:

IFATCA TPM (2025), AAS 1.24 – ATM Systems Interoperability
Proposal: Updates, upgrades, design, and development of an ATM system shall: ● endeavour to increase, or at a minimum maintain, interoperability between neighbouring and global ATM systems to support seamless cross-border operations; ● endeavour to reduce, or at a minimum not increase, the workload of air traffic controllers; ● align with global and/or international standards, ensuring interoperability and harmonisation of ATM systems.

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