

SYSTEM WIDE INFORMATION MANAGEMENT (SWIM)



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ACKNOWLEDGEMENTS

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1. INTRODUCTION

1.1 GENERAL DESCRIPTION

System wide information management (SWIM) means different things to different people across the CANSO membership and the world of aviation. This is despite many documents, ICAO guidance¹, programmes of work, and engagement over the years. This means that more work is needed to gain a common understanding, including the consideration of a simplified minimum viable approach.

SWIM adoption by air navigation service providers (ANSPs) and other aviation stakeholders has not been as accelerated as was initially anticipated in the ICAO Global Air Navigation Plan (GANP) Doc 9750. After initially being identified as a Block 1 initiative in the fourth and fifth editions of the GANP, the current sixth edition reflects the movement of SWIM to Blocks 2 and 3, putting timeframes at 2025 and beyond.

SWIM is vital for the exchange of information between ANSPs and aviation stakeholders and is a fundamental enabler for the creation of applications and services, enabling global interoperability. Functional services in the GANP cannot be implemented without SWIM. Despite this, there continues to be misunderstandings as to what SWIM is, and a lack of prioritisation.

This white paper:

- Describes the latest research and development at a high level
- Covers SWIM implementation examples from the United States, Europe, Middle East, Asia Pacific, and Latin America and Caribbean regions
- Aggregates the benefits, challenges and feedback from the examples
- Offers practical recommendations for accelerating SWIM implementation

The objective of this paper is to examine regional progress and the lessons that have emerged, and to present recommendations based on the lessons that ANSPs may find useful when analysing the tangible return on a project that needs SWIM to succeed.

Issues around wider data access, data ownership, intellectual property protection, and procurement continue to be complications for achieving meaningful progress on SWIM but are not addressed within this paper. Such topics are being examined by the newly formed CANSO SWIM Workgroup.

¹ ICAO Doc 10039, Manual on System Wide Information Management (SWIM) Concept

1.2 BACKGROUND INFORMATION

ICAO's Global Air Navigation Plan (GANP) identifies the fact that the achievement of sustainable growth within the international air transport system strongly relies on a high-performing and seamless global air navigation system.



*"Ideally, the air navigation system should never impose any restriction on individual flight operations. In practice, this is rarely feasible because of external constraints (beyond the control of air navigation services) or the conflicting needs of airspace users, among other reasons. In such cases, the overall ambition is to seek an optimum combination of trade-offs that maximizes the collective performance of all members (i.e. network optimization), while respecting predefined requirements for safety, security, the environment, access and equity. This will be achieved through collaborative decision-making involving all members on multiple planning horizons."*²

SWIM is considered as a key technical enabler to achieve such level of ambition.

Based on the [ICAO Manual on System Wide Information Management Concept \(Doc 10039\)](#), the definition statement of SWIM is as follows: "SWIM consists of standards, infrastructure and governance enabling the management of ATM-related information and its exchange between qualified parties via interoperable services."

The concept of SWIM has been used in various contexts over the years – unfortunately terms such as 'ATM cloud', 'SWIM box', 'SWIM infrastructure', 'aviation intranet' and other shorthand have not been helpful in supporting a broad understanding. The SWIM definition needs to be clarified to ensure the meaning is not lost in its general use by aviation stakeholders.

For the purposes of this paper, SWIM consists of necessary individual elements that need to be present to become sufficiently defined to be of practical use. The most common characteristics of existing or projected SWIM realisations are³:

1. The service payload follows the industry domain information models (e.g., AIXM, FIXM, IWXXM, AMXM), including any potential extensions, or are mappable to the industry reference model (i.e. AIRM) to preserve consistent concepts and semantics.
2. The message exchange pattern(s) are based on using best practice standard design patterns and practices (e.g. request/reply or publish/subscribe).
3. The message protocol(s) use common lightweight approaches including open standards and loose coupling (e.g., REST API or AMQP).
4. The message transports are secure and encrypted (e.g. HTTPS).
5. The message exchange uses common distributed identity and authentication of users (e.g. PKI/OAUTH).
6. The mechanism that provides capabilities to a service consumer to obtain information about available services operates via a formal registration process for storing, cataloguing, and managing services meta-information (e.g., Service Registry/SWIM Discovery Service).
7. There is a documented SWIM Technical Infrastructure Profile that represents consensus amongst the stakeholders for the SWIM capabilities.
8. SWIM governance - consisting of bodies, standards, policies and processes, is deployed in order to facilitate implementation, help build and maintain trust between stakeholders and support interoperability. Such governance is consistently applied throughout local or regional initiatives, to the identification, design, implementation and operations of SWIM services.

² ICAO Global Air Navigation Plan 6th Edition, Strategy

³ Adapted and extended from https://www.icao.int/APAC/Meetings/2020%20SWIM%20TF4/IP04_AUS%20AI.7%20Australian%20Report-V02.pdf

Within this SWIM definition there has been a great deal of research and development undertaken in the last 20 years. In 2003, the vision of an interconnected ATM system started to take form within the EUROCONTROL Network Manager (NM) team. Service Oriented Architecture was implemented in several iterations from 2004, access management infrastructure in 2008, the NM B2B Services – the SWIM product of NM, went into operations in 2009.

Since 2008, early test beds, funded largely by the FAA within the Open Geospatial Consortium explored the use of AIXM and complex temporality combined with ISO standards for geospatial information within Web Feature Services. Many interoperability test beds and projects covering FIXM, IWXXM and other AIRM derived payloads have also taken place; large scale applied research and development within the Single European Sky ATM Research (SESAR) and NextGen programmes also pushed the boundaries of SWIM, exploring the operational and organisational opportunities presented therein towards goals such as Full FF/ICE and interoperable systems and data.

The drivers for modernisation and SWIM adoption have varied but have included legislative, regional ATM community stakeholder user driven network effects, safety, operational efficiency and cost reduction for legacy and new systems. From these drivers we have seen pockets of mature SWIM implementations deployed operationally, including those run by the FAA, European ANSPs, EUROCONTROL NM and the General Civil Aviation Authority in the UAE.

More recently, European regulation IR 2021/116 also called Common Project 1 (CPI) is mandating the use of SWIM by 31st of December 2025 for Aeronautical, Meteorological, Cooperative network, flight and AMAN-E-AMAN information exchanges by all European relevant stakeholders.

In the current context, despite the many years of global effort, those old and new to SWIM implementations have still experienced significant challenges. In some cases, the guidance is too high-level to be practical. In others, the governance is perceived as too onerous. For some ANSPs the calculated return does not justify the cost, and there is a perception that there is little appetite for experimentation or feedback to improve specifications or use modern software development techniques such as Agile.

The ICAO GANP itself offers flexibility and recognises the challenge of implementation across the different capability areas:



“The expectation of the GANP, which follows the underlying philosophy of “think global, act local”, is not for everyone to implement everything, everywhere. Rather, the expectation is that a seamless quality of air navigation services should be delivered worldwide through regional and national performance objectives for meeting the performance ambitions. To achieve seamlessness while ensuring optimum use and allocation of resources, efforts should be made in each State and region to analyse the operating environment and to make consistent choices for increased modernization.”

ICAO GANP Edition 6 – Global Strategy

Although ICAO continue to champion SWIM implementation, and its vital nature for aviation data exchange using modern open standards, fully coherent and consistent availability of SWIM and its related capability definitions and documents continue to be pushed into the future. In the GANP 6th Edition, SWIM capabilities are described in ASBU Block 2 (ready for implementation by 2025) and they include information service provision, information service consumption, SWIM registry, A/G SWIM for non-safety-critical information, and Global SWIM processes. ASBU Block 3 (ready for implementation 2031) includes A/G SWIM for safety-critical information.

Based on the feedback from European and Asia Pacific ANSPs in the drafting of this paper, success stories around SWIM and applications built on top of SWIM have tended to focus on an operational change and/or business value with a narrow scope such as explicit operationally derived exchange needs, disaster coordination, extended arrival management, or a long-haul inter-regional ground delay program. A relatively recent survey conducted in 2019 in Asia Pacific showed that there are many SWIM projects under way by both large and small ANSPs ⁴.

Integrated ATFM/A-CDM is a process that requires comprehensive information exchange across systems and with many stakeholders, and SWIM is the most viable enabler [CANSO Guide on ATFM/A-CDM Integration, October 2020.](#)

⁴ https://www.icao.int/APAC/Meetings/2019SWIMTF3/WP18_AI5-%20Result%20of%20SWIM_survey_HKC_v3.pdf

With new entrants to the aviation community such as remotely piloted aviation systems (RPAS) with unmanned traffic management (UTM) stakeholders, and those operating above FL600+, barriers preventing SWIM adoption must be overcome. SWIM must adapt and enable problem-solving at a pace faster than has been seen thus far lest the picture become more confusing and incoherent. The risk is that SWIM becomes decoupled from new entrants and airspace users who develop independent community standards, that in the medium term, delay a vision for global, fully integrated traffic management.

Information exchanges in other industries, most notably in capital markets, have existed for decades and gone through multiple generations that have fine-tuned the information exchange concept and implementation. This and other perspectives will be explored and leveraged in CANSO Operations Standing Committee (OSC) SWIM Workgroup efforts going forward.

2. MATURITY LEVEL

2.1 R&D INITIATIVES

SWIM or its constituent parts have been part of aviation R&D for 20 years, therefore the challenge for implementers more recently has been the maturation of standards and the adoption of new technologies over time. Service Oriented Architecture and XML have been in part adopted and updated over the years with the implementation of microservices and, in some cases, more lightweight technologies and design patterns. The use of standards profiles that update over time, along with technology-independent information models such as the ATM Information Reference Model (AIRM), has meant that both R&D and operational systems have moved with the times to some extent. Widely adopted in other industries, XML, JSON, GeoJSON, RESTful interfaces and modern Publish and Subscribe protocols have all been exploited successfully in SWIM projects.

2.1.1 SESAR and NextGen

Well-funded research and delivery projects (NextGen, SESAR) have demonstrated mature information flows; they have shown that SWIM based exchanges between ANSPs enable the creation of applications addressing complex concepts that support increased capacity and efficiency. Both NextGen and SESAR have long since moved to deployment phases and operational systems.

2.1.2 ASEAN Trial

The recently completed SWIM trial by the Association of South-East Asian

Nations (ASEAN) focused on SWIM interoperability that enabled information exchange for an operational benefit. Whether complex ATFM and A-CDM interoperability or simply re-routing, managing capacity, or enabling all ASEAN stakeholders to have the consistent and coherent view of the same uniquely identified Flight Object, the approach of streamlining SWIM to enable the operationally benefit-driven exchange is a powerful and pragmatic one. The trial also presented proposals for different architectures based on how an ANSP can utilise both the Common aeronautical Virtual (CRV) private network and other networks such as the public internet for inter-ANSP communication.

2.1.3 SWIM in Japan

The Collaborative Actions for Renovation of Air Traffic Systems (CARATS) is the Japanese National Air Navigation Plan (ANP) and SWIM is one of the main initiatives. The Japan Civil Aviation Bureau (JCAB) plans to implement SWIM in 2024 while collaborating with movements in the APAC region. The main purpose of JCAB implementing SWIM is to replace existing many system point-to-point connections using outdated technologies. This replacement will make it possible to build a platform that can withstand new operations to realise the Global Air Traffic Management Operational Concept (GATMOC). It is necessary to encourage stakeholders to mentally prepare for the next-generation ATM operation and deepen the understanding of SWIM. The goal of JCAB is to provide data services and web services that facilitate the use of aeronautical information and flight information to aviation stakeholders.

2.2 INDUSTRIAL PRODUCT DEVELOPMENT

There are multiple options for SWIM implementation in safety-critical operational and non-safety-critical business environments, although off-the-shelf functional coverage for all use cases in ATM is not complete. A subset of core safety critical operational use cases also do not lend themselves to a direct and feasible SWIM implementation – as per GANP Block 3 with implementation ready by 2031. There is cross industry implementation support for information consumers and publishers with mature products for open standards based messaging and routing. Industry support for the specific SWIM standards is comprehensive and an ANSP may run competitive tender processes for the procurement of tools, software and systems that support SWIM. However, there is room for improvement and some of the examples in this paper describe how the options for ANSPs with constrained budgets could deliver more with a reduced cost. The use of open standards, microservices, low-cost web technologies, off-the-shelf tools and commercial competition should make SWIM more accessible than the previous model of complex systems based on aviation specific technologies.

2.3 IMPLEMENTATION

2.3.1 Americas

2.3.1.1 FAA

In 2007, the Federal Aviation Administration (FAA) established a SWIM programme to allow members of the aviation community to access information needed to facilitate an innovative and effectively run National Airspace System (NAS).

The FAA identified a need to reduce the interdependence among systems by moving away from point-to-point application interfaces to implementing an information-sharing platform that offers a single point of access for aviation data. The intent is that producers of data publish it once and users access the information they need through a single connection, reducing development and integration costs through reuse and commonality.

The FAA SWIM programme is being implemented in segments, starting by making flight, weather, and aeronautical information available for consumption. Figure 1 depicts how the information needed by consumers at various flight stages is mapped to and delivered by SWIM services.

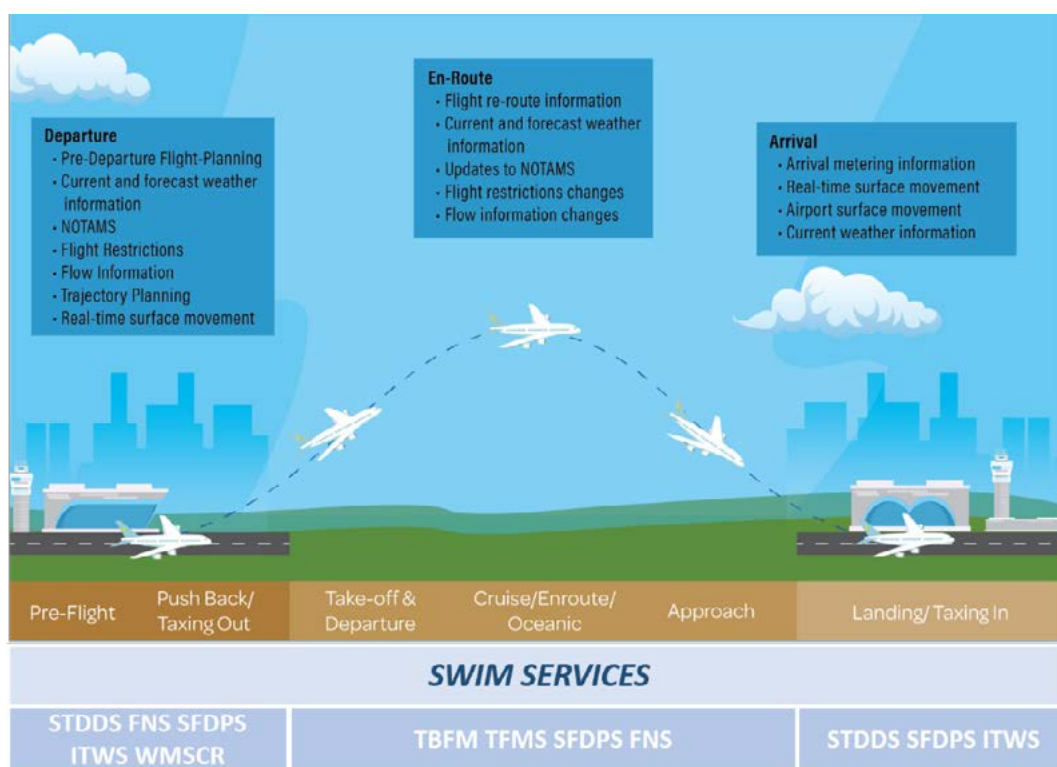


Figure 1 Information made available by the FAA SWIM implementation covers all phases of flight.

Segment 1 also focused on the cultural shift required for implementing service-oriented architecture (SOA) by establishing enterprise wide governance rules for stakeholders and services/applications and ensuring the use of common standards, protocols, interfaces, and shared data models. Segment 1 established the NAS Service Registry and Repository (NSRR) for making information about services visible and discoverable.

The NAS Enterprise Management System (NEMS) nodes were deployed at Air Route Traffic Control Centres (ARTCCs) and additional gateway locations such as Atlanta (ATL) and the William J. Hughes Technical Center (WJHTC) near Atlantic City (ACY). Subsequently, SWIM provisioned message brokers based on producer and consumer profiles, including publications for producers and subscriptions for consumers. Additional FAA programmes were added as producers, and the number of services offered for consumption was increased. The number of SWIM publications in various topic areas such as traffic flow and flight information, aeronautical information management, and weather information gained increasing popularity among FAA partners, e.g., airlines.

The SWIM Cloud Distribution Service (SCDS) was then introduced to address the increasing external demand for SWIM data from adjacent industries and new entrants. SCDS will reduce the bandwidth needed for the NAS Enterprise Service Gateway (NESG), lower the cost for service delivery through automation, and improve the user experience. SCDS is a publicly accessible cloud-based infrastructure dedicated to providing near real-time SWIM data to SWIM consumers via JMS-based messaging.

2.3.1.2 CADENA

The CANSO ATFM Data Exchange Network for the Americas (CADENA) is an initiative established in 2016 to promote and facilitate the safe and efficient movement of air traffic in the Latin America and Caribbean regions through effective implementation of air traffic flow management (ATFM) and collaborative decision-making (CDM). ATFM balances air traffic demand with the declared capacity of airports and airspaces. Having an accurate forecast of demand is a key component of the ATFM, however, obtaining such data is a challenge in the region where multiple ANSPs are delicately intermingled.

To obtain the demand forecast data, ANSPs in the region need to exchange the planned and active flight data and fuse them. The original vision of the CADENA Regional Implementation Group (RIG) was to implement the regional SWIM and traffic flow management system (TFMS) to share the forecasts of demand from the current time to several hours ahead. This vision was short-lived when the RIG realised the cost of development and maintenance of CADENA regional SWIM and TFMS were out of reach. Benefits of better ATFM services do not come back equally to ANSPs and all other stakeholders; the airspace and airport users also realise the benefits. This made the justification of return on investment difficult for the ANSPs.

The CADENA RIG determined to take a different approach and would take advantage of the FAA's operational SWIM and TFMS and its generous data sharing policy. CADENA ANSPs became FAA's SWIM data provider and data consumer. As a data provider, the CADENA ANSPs will send International Data Provider (IDP) messages such as Flight Plan Information, Flight Plan Amendments, Arrival Information, Departure Information, Flight Plan Cancellations, Flight Delay Information, Track Information, and Oceanic Reports, to TFMS via SWIM. As a data consumer, CADENA ANSPs will consume TFMS flight data via SWIM.

As an example of a SWIM governance “opt-in” by a state, external FAA SWIM service users are expected to follow the policies, standards, and specifications for governance, network security, and data exchange set forth by the FAA. SWIM Governance Policy, FAA Telecommunications Infrastructure (FTI) National Air Space (NAS) Boundary Protection System (NBPS) User's Guide for External Users, and Enterprise Security Gateway Virtual Private Network (VPN) Requirements documents must be followed. Flight Information Exchange Model (FIXM) is used for all flight data exchange.

Trinidad & Tobago Civil Aviation Authority (TTCAA) signed the TFM Data Exchange agreement with the FAA in September 2017 and successfully on-ramped in October 2017. COCESNA signed the agreement in May 2019 and the on-ramp test was successfully completed in December 2020. The operational cut-over will take place when the COVID-19 related restriction is lifted at the FAA facility.

Thus far, only one ANSP has successfully on-ramped on SWIM and only one other ANSP is in the implementation process. One lesson identified was that the implementation of flight data exchange via SWIM has been slow even with this simplified approach. It is still costly for the resource-restricted ANSPs and investment justification for implementation of SWIM is difficult. However, it is evident that the CADENA RIG improved ATFM operations in the region rapidly and greatly by exchanging a lot of information and working collaboratively – although in some cases not using SWIM. As the ATFM operations in the region further mature, the needs of forecasted flight demand data will increase. States in CADENA region may still find that the return does not justify the cost of a full SWIM implementation across all required data exchanges. The CADENA consensus is that taking advantage of the FAA's SWIM and TFMS via the usage of FIXM is a sensible approach for the time being.

2.3.2 Asia Pacific

The ICAO Asia and Pacific (APAC) region established the SWIM Task Force (SWIM TF) in 2017 and has been making an effort to introduce SWIM in the region while maintaining harmony between the ICAO GANP and the APAC Regional Air Navigation Plan (ANP). The SWIM TF members engaged ATM stakeholders⁵ to help share knowledge and understanding of SWIM. The SWIM TF also demonstrated operational scenarios via the ASEAN SWIM Demonstration to make steady progress towards SWIM implementation.

Although progress has been made, there continue to be differences in the way of thinking about SWIM across the region. The region includes many ANSPs and a complex arrangement of FIRs without a network coordinator such as can be found in Europe. Thus, each country is required to take a more active role to investigate and subsequently realise regional benefits that could be enabled via the use of SWIM⁶.

Therefore, in the region, considering interoperability between SWIM and legacy AFTN/AMHS systems, and cooperation between the CRV and SWIM service providers is required to satisfy the current and future needs of the stakeholders. To ensure the performance of CRV for conventional AFTN/AMHS applications and improve the flexibility required for regional SWIM implementation, the SWIM TF in the region has recommended that the CRV communication and SWIM communication be divided into different layers. The Task force has also recognised that a limited number of legacy systems may never transit to SWIM because of a very low number of air traffic or information consumers. This has significant legacy maintenance implications for stakeholders that interact with “non-SWIM enabled” ANSPs.

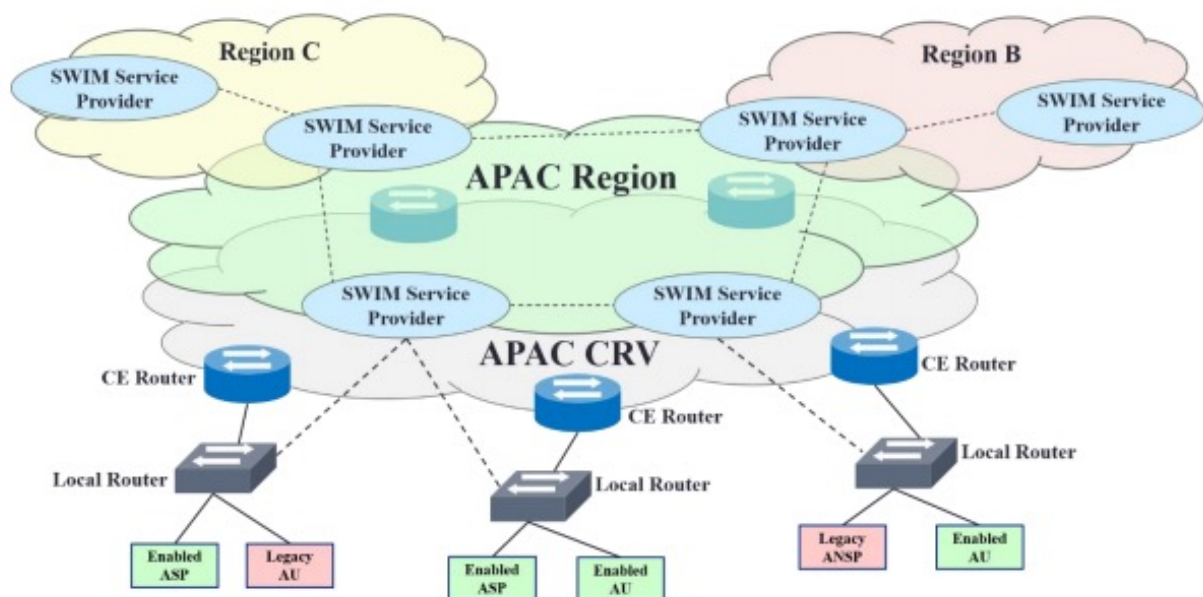


Figure 2 Interoperable Architecture

5 https://www.icao.int/APAC/Meetings/2019SWIMTF3/WP18_AI5-%20Result%20of%20SWIM_survey_HKC_v3.pdf

6 https://www.icao.int/APAC/Meetings/2019SWIMTF3/WP06_JPN%20and%20HKG%20AI3-SWIM-TF-Task-1-8-WP-ver2.0.pdf

For the consideration of SWIM infrastructure in APAC⁷, the draft *ICAO SWIM Manual* was considered as implementation guidance. This, in combination with lessons from the ASEAN SWIM Demonstration, lead to the selection of Global Enterprise Messaging Services (GEMS) as an option in the region. That said, the CRV will be one potential network in which data (not just SWIM data) in the region will be exchanged between ANSPs – similar to NewPENS in Europe. Therefore, for some exchanges, the ANSP will need to join the CRV before those aspects of inter-ANSP SWIM exchange can begin. Other SWIM-based exchanges to and from airlines, UTM, airports and new entrants could occur securely over non-CRV open internet networks.

The CRV also provides states with an on-premise option to build their own SWIM services. It will also provide a “SWIM as a service” option for states who don’t want to invest in their own service or a hybrid service. In these scenarios it is anticipated that ANSPs will act as the gateway between their own national and international stakeholders.

Outside the scope of the CRV, the *Airservices Australia (ASA) Data Interoperability Plan* incorporates SWIM as a means to enable exchange between ATM and UTM and other stakeholders, with governance-supporting business and operational services. ASA has also developed a SWIM Technical Infrastructure Profile (the “GOLD” Profile). The objective here is to document the necessary requirements and supporting capabilities for the SWIM services offered by ASA to the wider community. This is similar to the EUROCONTROL Yellow Profile, with ASA adopting a narrower selection of technologies to support capabilities for message exchange patterns, protocols, and security.

The Australian Bureau of Meteorology (BOM) recently started generating METAR, SPECI, TAF, SIGMET, AIRMET, Volcanic Ash Advisories, Tropical Cyclone Advisories and Space Weather Advisories in IWXXM version 3 format. The BOM has plans to generate the IWXXM from the source systems, however some IWXXM data are generated by translating their traditional alphanumeric code (TAC i.e. text) form to IWXXM. The BOM has a project to distribute the IWXXM via AMQP and this capability is expected to be operational in mid-2021. The BOM is also formulating plans to make additional meteorological datasets, such as satellite imagery, thunderstorm objects, probabilistic gridded information (including volcanic ash) available through SWIM services.

In summary, the driver for SWIM in the region is the operational need to improve safety and efficiency by implementing multi-nodal ATFM (and ATFM/A-CDM exchange) or as a means to engage and enable interoperability with wider stakeholders such as UTM and Defence. CAAS, HKCAD, Airservices and AEROTHAI are actively building in this area with maturing SWIM implementations.

Stakeholders such as the BOM, HKO (Hong Kong Observatory) and Korea Airports Corporation (KAC) are implementing MET applications over SWIM. AOT (Airports of Thailand) will also establish interfaces with AEROTHAI’s SWIM system. For the smaller ANSPs in the region, Laos and Nepal are prioritising an AIXM 4.5/5.1 database for AIM, eAIP, DNOTAM. Fiji is prioritising SWIM at their airports.

2.3.4 Europe

Europe has pockets of advanced SWIM implementation, with inter-ANSP exchanges being developed with a separation between administrative pre-flight information for business process automation and timely operational data for coordination. In contrast to the North American and Asia Pacific regions, the institutional landscape in the western part of Europe is more complex. Air navigation is organised such that certain planning and coordinating responsibilities are performed by a central network entity, operated by EUROCONTROL with States and individual ANSPs keeping control over local matters and the provision of air traffic services. To support the safe and efficient provision of air navigation services in an environment of shared responsibilities, ANSPs are striving for a level playing field of an information architecture which is based good standards, infrastructure and governance enabling the management of ATM-related information and its exchange between qualified parties via interoperable services. This necessitates a different and occasionally complex approach to SWIM governance and coordination. Two SWIM related examples have been selected from the many European projects to highlight where, despite a successful project, some challenges remain.

⁷ https://www.icao.int/APAC/Meetings/2020%20SWIM%20TF4/WP05_JPN%20AI.6%20-%20SWIM%20IN%20APAC%20REGION.pdf

2.3.4.1 EUROCONTROL Network Manager (NM) B2B

The NM B2B supports business process automation of the network functions for the exchange of aeronautical, flight and flow information. AIXM 5.1 is used for the publication of airspace structure and in support of the flexible use of airspace. The flight services are offered in two flavours: one supporting the ICAO 2012 concepts and, lately, a first implementation of FF-ICE/R1 based on FIXM 4.2 became available for operational validations. The flight services support the airport-CDM and target times concepts, allowing the integration of the airports in the network, as well as the publication of flight updates reflecting the progress of the flight execution. The flow services support the exchange of data with the ANSPs in support of demand and capacity balancing in the European network.



Violeta Bulc @Bulc_EU · 21 Dec 2018

#Europe & #Brazil are now exchanging #flight data! This will improve predictability of traffic flows & enhance capacity. Updated trajectory info will benefit air traffic control centres & airports directly, & ensure efficiency & safety for #Passengers.

The NM B2B Services, the SWIM product of NM, went into operation in 2009. It was an early success, with users accessing the services just one month after the start of operations. Over the years many new services have been added to the capability, which now covers all phases of flight and more besides. Now, practically all NM data and services are available through the NM B2B Services, engaging users from all segments, with a much higher uptake by airspace users and industry. The engagement with ANSPs started later and has been growing steadily in recent years. A few ANSPs are very heavy users (e.g., MUAC, DSNA, ENAIRE, Skyguide, Czech Republic), others are currently implementing (e.g., skeyes, Bulatsa, LVNL). The recent availability of the NM B2B Services over the NewPENS network is expected to bring in more ANSPs, especially the ones that do not allow the use of internet.

Airports were also early adopters, especially small airports, allowing them to have access to arrival traffic, *without needing to have AFTN connectivity – directly reducing cost*. In recent years the Airport-CDM is being migrated to SWIM with five airports (Amsterdam, Lisbon, Copenhagen, Nice, Warsaw) currently integrating A-CDM via the NM B2B.

Currently NM is working to achieve compliance of the NM B2B with the three EUROCONTROL SWIM specifications. The main gaps that are being addressed relate to the mapping between the NM model and the AIRM model, and some documentation requirements.

Compliance with the technical specification (SWIM TI Yellow Profile) was achieved.

The NM B2B Services are used worldwide. Bilateral agreements are in place between EUROCONTROL and other countries, of which the General Civil Aviation Authority (GCAA) in the UAE is an example. The publish/subscribe technologies of the SWIM Yellow Profile (AMQP) are the preferred means for the exchange of flight data between NM and other regions, used for instance in the exchange with the FAA and Brazil.

Tweet of the Commissioner Violeta Bulc when the exchange with Brazil started:

2.3.4.2 Coflight

An example of a complex capability built on top of SWIM, designed and developed by a Franco-Italian ANSP cooperation (DSNA-ENAV & Thales-Selex ES), Coflight is a Flight Data Processing System (FDPS). Coflight is also proposed "as a service", building on top of SWIM and cloud-computing systems. The "Coflight as a Service" feasibility study was launched in March 2014 during the World ATM Congress (WAC) by DSNA, ENAV, MATS and Skyguide CEO's. The four ANSPs decided to partner in order to study the feasibility to remotely provide flight data processing and related services based on Coflight-EFDP, to other ANSPs.

After the first steps for delivering the cooperation agreements between ANSPs and the program management plan, the whole feasibility study and the trials to demonstrate the services were delivered in 2015 and 2016. This concept is based on the more global concept of "Virtual Center" that has been implemented in SESAR1 and two consecutive projects in SESAR2020. The so-called "Virtual Centre" concept refers to the virtualisation ambition captured within the European ATM Master Plan.

This concept focuses primarily on the geographical decoupling of the Air Traffic Service Units (ATSUs) with the controller working position (CWP), viewed as the client; and the ATM Data Service Providers (ADSPs), that provide remotely ATM data and technical services, such as flight data distribution and management, and surveillance data through open and standardised service interfaces, published in the European SWIM registry.

In 2017 the four ANSPs (DSNA, ENAV, Skyguide and MATS) launched the first implementation phase of the CCS program that aims at developing the CCS "Technical Integration Service" (e.g. Test Mission). In 2019 a live demonstration of CCS showed a sample of almost 100 flights involving interoperable systems simultaneously. The CCS data centre was connected to 3 HMI located in different places over Europe and from 3 different suppliers.

SWIM is a key enabler for CCS, at a technical infrastructure level, CCS implements the SWIM TI Yellow Profile specifications and meets the requirements for system interfaces (e.g. protocols) and for IT infrastructure capabilities required to enable a reliable, secure and efficient exchange of information.

2.3.4.3 SWIM User Group

After the closure of the European SWIM Governance Implementation Project in July 2020, activities related to the establishment of a European Governance for SWIM were continued in order to support and foster the implementation on SWIM across Europe.

This ultimately led to the establishment of the European SWIM User Group, a coordinated initiative supported by EUROCONTROL Network Manager, the SESAR Deployment Manager and the A6 Alliance, acting as an interim solution until the final European SWIM Governance is established as part of the Single European Sky Digital Backbone.

The SWIM User Group is an expert forum for discussion on SWIM implementation aspects (e.g. implementation strengths, API specifications and test implementations). The objective is to have a group that allows for the transparent exchange of views on implementation tips, bottlenecks or shortcomings.

Currently the deployment of SWIM in Europe is mainly driven by the NM and ANSPs. However, this group will also be open to other stakeholders be involved in SWIM deployment such as airspace users, airport operators, MET providers and militaries.

2.3.5 Middle East

The UAE SWIM Gateway entered into operational service in 2018 becoming one of the first SWIM-enabled services in the Middle East. Developed by Cirium, the UAE SWIM Gateway will provide a major step towards a nationwide SWIM architecture. The Gateway harmonises and consolidates real-time data of flight-related information between the existing legacy systems (FDPS, AFTN, AMAN, DMAN, DFLOW, AIM) and those of new SWIM-enabled capabilities. The objective is to enable access to high quality, consistent and consolidated flight-related information to the UAE aviation community. Information is gathered through a data aggregation process and starts with the airline schedules, as well as conventional flight plan messages received from the aeronautical fixed telecommunication networks (AFTN). This flight plan information then generates flight objects which are assigned unique identifiers.

Flight plan information is automatically validated against static airspace data imported into the system using aeronautical information management (AIM) by means of the Aeronautical Information Exchange Model (AIXM). Once generated, flight objects are assigned a Global Unique Flight Identifier (GUFI) using a complex ownership rulebase and are continuously updated with air traffic services (ATS) messages and 4D trajectory information received from multiple data sources, including legacy flight plan data processing (FDPS), arrival manager (AMAN) and the departure flow manager (DFLOW). DFLOW provides functionality to optimise the airspace utilisation by the allocation of assigned calculated take-off times (CTOT) during peak demand.

An additional source of information is the EUROCONTROL Network Manager (NM), which supports the UAE SWIM Gateway by providing updates on all flights within the EUROCONTROL NM area which are of interest to the UAE. The UAE SWIM Gateway in return contributes to the EUROCONTROL NM by providing flight update information for flights bound for the EUROCONTROL NM area. Information from the various data sources is harmonised and consolidated by the UAE SWIM Gateway and represented as aggregated flight objects encoded in flight information exchange model (FIXM) format, mapping all available information to their FIXM elements. Where necessary, available information is added as custom extensions to the FIXM.

By introducing the SWIM Gateway, all access to information by external and new internal systems is channelled through a dedicated platform that maintains accurate copies of flight objects. The service is available within a secured internet protocol (IP) environment as well as through the public internet. The use of the public internet was a specific request by the stakeholders to facilitate simple access without the need for a dedicated communication infrastructure. Access is realised in accordance with the EUROCONTROL specifications for the SWIM TI Yellow Profile and supports request/response services as well as the publish/subscribe pattern. Using the open standards for access and the data presentation encourages stakeholders to support SWIM-enabled applications and harmonisation for the UAE's ATM community. Capability to monitor information is also made available to stakeholders who have not yet invested in SWIM applications by a web server interface to authorised users. Dubai Airports plans to become the first stakeholder to introduce a SWIM-enabled application. All information will become part of the Dubai Airport's operational management systems.

Similarly, Abu Dhabi airport is currently preparing to integrate their Airport Operations Database (AODB) and the Departure Manager (DMAN) within the SWIM gateway. Both airports will not only be data consumers but will become data providers. Emirates Airlines will also pioneer with using an initial SWIM-enabled client application to monitor the movements of their fleet.

2.4 SWIM GOVERNANCE AND REGISTRIES

SWIM Governance is the realisation of the concept of SOA Governance in the context of an ongoing SWIM initiative or program. The major goal is to enable a set of enforceable policies, procedures, processes, tools, and organisational activities to ensure that all of the independent efforts come together to serve the Community of Interest or within enterprise-specific business objectives or policies. There is a key difference between internal SWIM governance that occurs within an ANSP or Enterprise organisation, where policies may be strictly enforced, and the SWIM Governance initiative between a group of ANSPs, Airlines, Airports and UTM in a geographic region.

In the US, the FAA may define Enterprise style policies that must be followed across the country, and as per our example from CADENA a state ANSP may opt-in to the SWIM governance regime. However, in Europe, there is an interplay between EUROCONTROL and state ANSPs, airports and airspace users that necessitates a different collaborative approach, however realistically there is no opting out for European ANSPs. In APAC the state ANSPs may collaborate freely and agree SWIM governance together – but rules and policies are entirely “opt-in” in nature. Therefore the ANSPs in each different region must collaborate to realise SWIM and be able to build trusted applications that realise the benefits.

A Community of Interest (CoI) for the purposes of this paper refers to a regional collection of ANSPs, Airports, Airlines with a common motivation for efficient operations where the SWIM adoption benefits (safety, reduced cost, efficiency and capacity) may be shared. SWIM governance responsibilities include, but are not limited to:

1. Adopting or developing governance standards, policies, and procedural guidelines to support the functional requirements for implementing all aspects of service-oriented development.
2. SWIM Governance is accomplished through a combination of service lifecycle management policies, technical policies, and standards compliance policies that drive the overall behavioural model of the participants (within an enterprise but also within a Community of Interest) and ensures their interoperability.

3. Making all services discoverable, searchable, and retrievable through a formal cataloguing of service metadata. In particular, a Service Registry (SR). The SR can serve as a central point of information about all SWIM services in existence or currently under development within that Col or enterprise and supports governance activities throughout the service lifecycle.

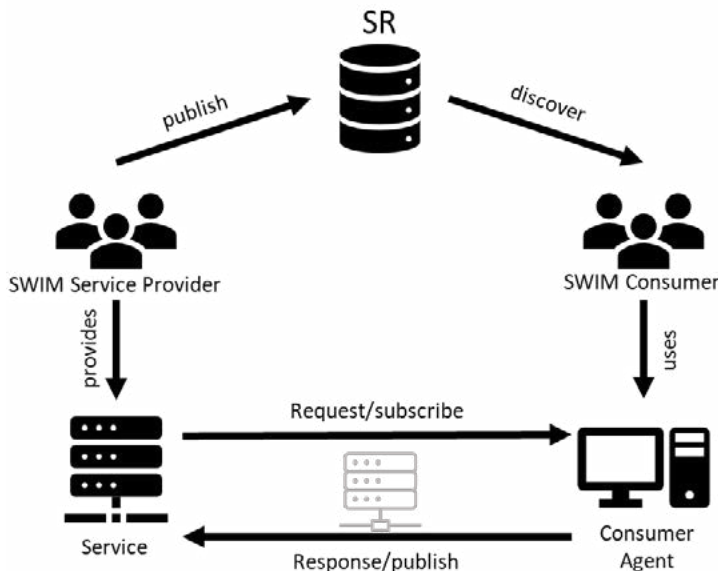


Figure 3 SR in the SWIM context

4. Collaborating with international partners and participating in international organisations to help establish the vision of a “Global” implementation of SWIM and to enable inter-regional interoperability as part of the ICAO GANP.

As far as SWIM registries are concerned, some lessons can already be learned from several initiatives. In Europe, the EUROCONTROL SWIM Registry initiative has been through multiple iterations in coordination with the various ATM Operational Stakeholders and is currently accessible at eur-registry.swim.aero/services, along with sophisticated governance, metadata structures and documentation support. In the USA, the FAA developed the equally advanced NAS Service Registry and Repository, the FAA SWIM Governance team also worked with European partners (e.g. SESAR Deployment Manager, EUROCONTROL) to develop the Service Description Conceptual Model (SDCM) and Registry-Interchange Module (RIM). Further to this, the FAA is working with Korea Airports Corporation (KAC) to develop the SWIM Discovery Service (SDS). In Asia-Pacific the ICAO SWIM Task Force is working on a federated interoperable Registry model between the many ANSPs in the region.

In Australia, Airservices has implemented a lean proof-of-concept SWIM Registry capability utilising off-the-shelf functions from the 3rd party provider Github. This prototype demo registry is available at airservicesaustralia.github.io/registry.

SWIM Governance aims to establish a collaborative approach, within a regional Community of Interest or within an enterprise, for a controlled evolution of SWIM. It contributes to building and maintaining trust among the SWIM stakeholders, with a focus on the expectations of the consumers of services. It should develop as an enabler and facilitator for SWIM implementation, with a focus on providers of services. In this context the registry is clearly a key asset for discovery, management, and knowledge sharing.

However, the actual engagement of projects, users and services at different stages of maturity with SWIM Registries has been highly variable. While the FAA NAS Service Registry has 2200 users and 96 services, in Europe there are currently few services registered within the SWIM Registry (and all from ANSPs), despite multiple operational systems, development projects, and countless prototypes being created across the aviation industry by airlines, ANSPs, industry, UTM, airports and aircraft OEMs. A couple of years ago EUROCONTROL sought feedback from the community as to why initial adoption of SWIM was not taking place, and the results include mixed opinions from many sources. The views expressed offer some insight into the challenges that existed for the adoption of SWIM and included the perception of:

- an overly complex set of IT standards and technologies
- a possibly costly and intimidating audit against rigid compliance criteria
- in some cases SWIM Registries and strong governance can confuse or intimidate those that wish to implement SWIM
- the lack of an ability to feedback into the process or use of new and better standards
- an old-fashioned approach to software development and validation and verification given the commonplace use of Agile combined with Continuous Integration (CI)/ Continuous Deployment (CD) processes across the industry

It should be noted that a simple managed spreadsheet, Github project, or access-controlled web page can be sufficient to support a governance process, especially when the number of services is low. Implementation of SWIM governance for legacy systems may also be enacted at the external system boundary, between the stakeholders in a regional Col; this approach can yield early SWIM benefits without requiring wholesale replacement of the legacy systems.

In order to address the concerns of the aviation community and in response to the received feedback, activities undertaken by ANSPs have included the creation of supporting material with pragmatic examples, documentation guides, schemas, and tangible feedback loops for improvement triggered by the users.

3. CHALLENGES TO THE WIDER ADOPTION OF SWIM

3.1 CROSS CUTTING CHALLENGES

How can we reap the benefits of SWIM and achieve global interoperability if SWIM implementations vary so much in terms of maturity, or if SWIM compliance is too costly for a global community of CANSO members? Why has the adoption fallen behind original expectations?

There are numerous SWIM success stories, some of which have been shared in this paper, however the challenges to wider adoption articulated below should be considered in the context of smaller budgets, and the need

to avoid operating and maintaining multiple parallel systems. For example, an essential aspect of understanding the success of FAA SWIM is that a significant part of the business case relied on replacing and upgrading costly legacy infrastructure that required myriad point-to-point connectivity. This is not the case for many ANSPs. The challenges for SWIM adoption and suggested mitigations that have been raised by ANSPs both large and small are:

CHALLENGE	RECOMMENDATIONS
The Cost Benefit Analysis does not easily justify the expense of an overly broad general SWIM solution or implementation. The technology alone is not worth the expense. Often this is the case where the SWIM capabilities go beyond the targeted operational efficiency or problem to be solved. This is amplified if only inter-ANSP SWIM exchanges are considered (benefits minimised) and if multiple interfaces (legacy and SWIM) must be maintained subsequently.	The airspace users both traditional and new (UTM/Space) should be included in any business case as the ANSP may not be the only recipient of benefits. There are many SWIM benefits that cannot be fully realised purely with ANSP exchanges. Consideration of the airline and airport consumers and respective benefits, potentially even within a cost benefit sharing mechanism. SWIM is an enabler, and a fair business case considers all applicable and relevant enabled operational improvements.

CHALLENGE	RECOMMENDATIONS
Within the information layer the standards are numerous, detailed and complex, with different approaches to temporality, real world feature version control, and exchange model encoding design patterns (AIXM, IWXXM, FIXM).	Identification and documentation of the relevant standards and models for a streamlined set of information exchange types can help reduce the complexity while still using the required standards. This is a typical SWIM Governance task, that may be carried out regionally - e.g. the “coloured” (Yellow, Blue, Green) Technical Profile in Europe. The use of lightweight protocols along with modern Continuous Integration / Continuous Deployment (CI/CD) software toolchains eases and reduces implementation cost. A combination of small specific open source examples (possibly created by industry and ANSPs) combined with in-house technical expertise, along with industry support can enable cost effective solutions.
Within the infrastructure and network layer, there are private networks such as NewPENS and the CRV, as well as public networks such as the internet. Infrastructure costs may be high and maintaining multiple systems and connections could be cost prohibitive.	ANSPs should utilise both private networks and the public internet in a secure manner. While this risks duplication of exchange, it is necessary to access the benefits and potential additional revenue from new entrants and industry; all infrastructure options should be considered within the SWIM infrastructure and network business case.
SWIM governance, while vital for consistency across a community of stakeholders, can be perceived as formal and constraining, thus contrary to the innovation expected with the application of service orientation.	SWIM governance is an enabler for implementation of SWIM within a community of regional ANSP, airline, airport and industry stakeholders. Governance needs to be adjusted so that it is stringent enough to support interoperability but agile enough to enable innovation. However, governance should not be discounted as something optional. The cost of an ungoverned SWIM, e.g. non-compliance with or lack of standards or consistent processes may lead to needless efforts, disruption or failure of business process, ultimately resulting in more costs.
The use of registries means additional work for service providers, which may not get a direct benefit for their efforts (the benefit does not necessarily occur on the side of the stakeholder investing efforts to register the service). Registries are sometimes perceived as overly difficult to establish and operate.	SWIM governance should help providers to register their services through guidance and support (e.g. automated processes, Q&A, sharing best practices, etc.). Making services discoverable may be achieved through fully-fledged registries, able to host many services from multiple stakeholders, but also through very simple means, such as a website or a spreadsheet when the number of services is low. The principles of consistency, service availability, service performance and coherent metadata can be met with low-cost solutions and should not be interpreted as requiring an expensive project to implement.

CHALLENGE	RECOMMENDATIONS
The ICAO guidance is welcome. However, the volume of information can be overwhelming – there is a perception that a large expensive system is always required, when perhaps a simple solution may have enabled the actual problem to be solved.	The CANSO OSC SWIM Workgroup is looking to provide further detailed support in concert with the SWIM Task Force and other organisations across aviation such as the FAA and EUROCONTROL.
In some cases, the very success of a SWIM project has created some challenges, the growing number of external users putting a strain on the resources which are approaching maximum capacity. Supporting terabytes of data consumed each day necessitates a further implementation to support the wider user base.	Approaches based on cloud or hybrid cloud and on-premise deployment, such as the one adopted by the FAA (SWIM Cloud Distribution Service mentioned earlier) are a possible solution. There is wide industry support for various deployment models including virtualisation and container technologies for secure operational deployment.

This list is not exhaustive, and the newly formed CANSO OSC SWIM Workgroup will produce detailed support material for many of the technical challenges that can be overcome.

4. BENEFITS OF SWIM ADOPTION

Some SWIM successes have tended to focus on an operational and/or business value with a narrow scope (explicit exchange needs driven by solving a problem or enabling a specific use case, disaster coordination, extended arrival management, ground delay program). Where this is not the case, the SWIM success has been a replacement of a large complex legacy estate that results in higher capacity and efficiency but also a reduction in ongoing maintenance cost for the new SWIM implementation. Many of the benefits have been promoted for decades, and so are summarised here.

The FAA and UAE SWIM programs focussed on improving their operations in the following ways:

- Increase efficiency with which the National ANSP shares data and aviation users obtain data
- Reduce implementation and operating costs and increases the ability of the air traffic community to do more with less

- Create collaboration opportunities across international borders and with industry to address some of aviation's most complex problems
- Support development and adoption of a global aviation language
- Provide enterprise-level capabilities and new opportunities for new entrants to operate safely

For Europe, the main benefits directly derived from the use of SWIM are cost and operational efficiency: making interfaces available through SWIM facilitates the exchange of data between European ANSPs and their stakeholders and enables the automation of processes. ATM is moving from a system-centric to an information-centric approach that facilitates better service at lower cost. Furthermore, making data widely available in the aviation community triggers innovation and offers additional non-safety critical revenue opportunities.

SWIM benefits others besides the traditional ATM players to provide safer, cost-efficient and operationally efficient services. It also allows non-traditional players to enter the market contributing to the creation of jobs. Cost-savings and operational efficiency result from elimination or reduction of manual processes, migration to modern and mainstream/low-cost Internet technologies, and timely access to accurate network data.

For example, inter-ANSP exchanges that can reduce workload, and usage of phone/fax/email and potentially eliminate the chance of human error include:

- Exchange of ATC sector configurations and loads
- Sharing of simulation capability to assess flow measures and ATFM regulation impact, with a better traceability for decision making and accountability

- Access to network wide flight object data allows better planning for runway utilisation and better identification of traffic that can be balanced between sectors, maximising available capacity

Many of these benefits are well known, however, the examples in this paper such as CADENA shows that working with just FIXM exchange with a geographically adjacent SWIM partner can yield gains at a lower cost. The same could be said for the SWIM Task Force, Airservices Australia and the ASEAN trial when those systems reach implementation and operational status.

5. CONCLUSIONS AND RECOMMENDATIONS

We have seen SWIM discussed, recommended, built, and used for many years. Digitisation and the automation of some routine human processes enabled by SWIM is essential, however SWIM can be complex and there are many challenges holding back its adoption and delaying the vision of global interoperability for aviation. If SWIM continues to be adopted at this pace, new services such as UTM may become decoupled and disengaged. Unless aviation stakeholders wish to maintain duplicate systems or a multi-tier aviation network – adoption must accelerate.

This whitepaper has attempted to gather feedback from CANSO members borne from the hands-on experience of implementation and business case review. The SWIM success stories described in this paper have made a tangible difference to efficiency, safety and capacity where they have been implemented. However, the challenges for wider adoption are fierce in the current economic climate. The common theme across the feedback received is that often it is perceived that the cost/benefit analysis does not justify the expense of SWIM – and the ANSP itself does not reap enough of the benefits.

The experts and ANSPs that contributed to this paper propose the following guidance as to how this challenge can be overcome:

- Utilise a wider recognition of the SWIM benefits to non-ANSPs and their engagement in the project (and benefits realised)
- Consider the wider aviation market and review potential opportunities for additional revenue that could be derived from data exploitation
- Consider what data could be used to improve service efficiency, bring the wider data publishers and potential data consumers and users together (even non-aviation) using the internet in a secure way as well as private aviation networks
- Create supporting material such as an open source lightweight openAPI package for the SWIM TI Yellow profile and promote it for use by new entrants such as those in UTM via GUTMA and ASTM communities

- Develop and support a regional Community of Interest for the ANSPs, airports, airlines, suppliers and their engineers, data scientists and operational experts, and supporting ground services to reduce the complexity and focus on specific operational efficiency, process digitalisation and automation – to better articulate the problem to be solved and recognise the different SWIM governance approaches to be taken on a region by region basis.
- Develop through this Community of Interest a consistent set of principles, rules, processes and structure that will for a governance framework facilitating SWIM implementation – based on the region within which the ANSP resides.
- Use only the elements of SWIM necessary to solve the operational problem or realise the efficiency gain through process automation – i.e. the minimum viable compliant implementation – that provides an end-to-end solution for common data exchange use cases, and still has a path to a broader implementation in the future
- Collaborate with a regional or industry partner – it may be more effective to reuse and integrate than procure a stand-alone capability. A register of industrial solutions and SWIM compatible implementations may be useful for ANSP discovery and market investigation.
- Consider non-safety-critical use cases first and start small – adopt an agile development approach with small teams to initiate the development.
- Establish an implementation framework, including roles and responsibilities of the various stakeholders, governance bodies, standards, policies and processes that will serve as a common thread for SWIM deployment, and can be subject to adherence checks or enforcement – as deemed appropriate.
- Before identifying data exchange opportunities with other ANSPs or stakeholders, analyse the local system infrastructure and try to identify which parts could be improved by SWIM concepts, i.e. which additional data exchange could improve safety and reduce manual overhead and which existing data exchange would benefit from a SWIM concept driven approach. Run the total cost/benefit analysis on the improvements you can do to your internal network, i.e. move from integrated to interconnected systems.
- Talk to system vendors to find out what additional SWIM services are on the product roadmaps that would enhance your local system infrastructure.
- ANSPs should raise their voice through CANSO workgroup engagement or their regional ICAO office, for the attention of the IMP, and ask for a stricter standardisation of SWIM so that vendors can create systems that are interoperable.

While the above could be considered general guidance borne from the aggregate feedback received, it is also recommended that the CANSO SWIM Workgroup enumerate and categorise a variety of SWIM implementations including the minimum viable that meet the needs of range of users and their respective context. ANSPs may start purely as a consumer of data via SWIM and iterate towards broader adoption.

Finally, it is recommended that the CANSO SWIM Workgroup, ICAO IM Panel and relevant regional bodies and SWIM task forces help States to conduct cost/benefit analysis and return on investment activities to perform realistic cost and both operational and business benefit driven assessments to help justify projects where SWIM enables those benefits.



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