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The Development of Air Traffic Management Information Exchange Interoperability Framework for Civil Aviation Authority of Malaysia

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Abstract

The effective and secure transmission of crucial data within the air traffic management (ATM) ecosystem is one of the significant obstacles in the constantly changing aviation environment. Given the anticipated increase in aviation traffic during the post-pandemic age, the utilisation of automated systems becomes an inevitable necessity. Given the significance of the aviation industry and the current demand, it is imperative for the Civil Aviation Authority of Malaysia (CAAM) to establish the Air Traffic Management Information Exchange Interoperability Framework. This framework will serve as a pioneering guideline to promote the standardisation of efficient data communication and interoperability among various stakeholders within the CAAM's Air Traffic Management Ecosystem. This article presents a succinct summary of the framework's development process, with a focus on its development methodology, essential components, and its alignment with the System Wide Information Management (SWIM) guideline established by the International Civil Aviation Organisation (ICAO). The development process utilises action research methodology and the Soft System Methodology (SSM) framework to initially identify the requirements of stakeholders through brainstorming sessions. It also highlights the significance of data standardisation, emphasising the benefits of adopting common data formats and structures to enhance the efficiency of the exchange process. Subsequently, the procedure entails the conversion of the accumulated requirements into a structured framework, which is subsequently provided to the relevant stakeholders for the purpose of evaluation and approval.

Keywords: Air Traffic Management, System Wide Information Management, Interoperability, Information Exchange, Information Sharing

Introduction

In the context of the increasing volume of worldwide air traffic, the importance of effective communication, sharing of information, and interoperability of systems is becoming increasingly critical. Meier et al (2018) assert that the growing interconnectedness of air

transport necessitates the imperative for many systems to effectively communicate and operate in a cohesive manner. Effective communication in air traffic management encompasses more than just conveying clear communications; it also entails ensuring that these messages are comprehensible across many platforms and jurisdictions. According to Chen et al (2015), the occurrence of miscommunications or misunderstandings might give rise to significant safety risks, such as near misses or crashes. The capacity to effectively share information plays a crucial role in enabling adaptation to changing flying circumstances, unpredictable weather phenomena, and emergency scenarios. The increasing volume of air traffic has the potential to exacerbate any deficiencies in communication, which may then initiate a cascade of delays and disruptions. The interchange of information plays a vital role in establishing connections among various entities in the aviation industry, including airlines, airports, air traffic control, ground handling teams, meteorological departments, and other relevant stakeholders.

Weigang et al (2020) emphasise the significance of interoperability within this context, as it facilitates the ability of diverse systems to retrieve and comprehend shared information, irrespective of their distinct technological architecture or geographical placement. This process enhances the effectiveness of scheduling, minimises the time required for completion, and allows for prompt reactions to unforeseen interruptions. With the increasing sophistication of communication and information exchange systems, it is also imperative to ensure their security to mitigate any cyber threats that may jeopardise the integrity of the air traffic network. Bicchi et al (2021) emphasise the significant relevance of interoperability within this setting. To achieve complete security coverage, it is imperative to implement and acknowledge security mechanisms such as encryption, authentication, and network designs in a universal manner across all systems. The complex air traffic network relies on efficient communication, robust information exchange, and system interoperability as its fundamental components. Dai et al (2019) mentioned that the increasing volume of air travel will lead to a corresponding increase in demand for interconnected systems.

The continuous progress and development of new technologies are necessary to address the growing requirements of the expanding global air transport industry, while simultaneously ensuring safety, efficiency, and reliability. To tackle the matter of interoperability among systems, this paper proposed the development of an Air Traffic Management Information Exchange Interoperability Framework (ATMIEIF). The proposed framework aims to establish standardised information flows and business processes for CAAM ATM, adhering to the guidelines set forth by the International Civil Aviation Organisation (ICAO) and System Wide Information Management (SWIM).

Analysis on Other Similar Global Initiatives

To better understand the challenges of similar framework development which align towards the ICAO SWIM, the study analyzes improvement initiatives undertaken by countries which include implementation of SWIM as one of their deliverables. The initiatives reviewed are:

- ***United States Federal Aviation Administration Next Generation Air Transportation System (US FAA NextGen)***

  FAA (2016) defines that Next Generation Transportation System (NextGen) is a term for the continuing transformation of the National Airspace System (NAS) of the United States, planned in stages between 2012 and 2025. NextGen consists of five elements namely Automatic dependent surveillance-broadcast (ADS-B), Next Generation Data

Communications, System Wide Information Management (SWIM) and NAS voice switch (NVS).

- ***Civil Aviation Bureau of Japan Collaborative Actions for Renovation of Air Traffic Systems (JCAB CARATS)***
  Japanese Civil Aviation Bureau (JCAB, 2016) through its research and development arm Electronic Navigation Research Institute (ENRI) has established a long-term plan for Japanese air traffic systems named Collaborative Actions for Renovation of Air Traffic Systems (CARATS). CARATS outlined the roadmap of Japanese system renovation until the year 2025. It is consistent with ICAO Aviation System Block Upgrade (ASBU) roadmap since CARATS mapped its planning in accordance with ASBU block upgrade modules ensuring the near and longer-term global interoperability of their air navigation solutions. Among the goal of CARATS includes realization of Trajectory Based Operation (TBO), improvement of predictability and ensuring information sharing for collaborative decision-making via SWIM.

- ***Eurocontrol Single European Sky Air Traffic Management (ATM) Research (Eurocontrol SESAR)***
  European Commission (EC, 2004) came forward with ambitious project to reform the architecture of European ATM, namely, the Single European Sky (SES) initiative. This project proposes a legislative approach to meet the future capacity and safety needs at a European rather than a local level. The main objectives of SES are to enhance current air traffic safety, to contribute to the sustainable development of the air transport system, and to improve the overall performance of ATM and air navigation services, thereby meeting the requirements of all airspace users. To fulfil these objectives, the European Commission set high-level goals for the SES initiative, to be met by 2020 and beyond (SESAR, 2014). SESAR program implementation is divided into three concept steps, each of which brings the ATM system closer to achieving the above-mentioned objectives and goals.

This study is focuses on the creation of the ATMIEIF, with a particular emphasis on aligning the framework with the International Civil Aviation Organisation (ICAO) System-Wide Information Management (SWIM). The objective is to ensure that the developed framework can be effectively implemented throughout the civil aviation community and in-line with international standard practices. The alignment of SWIM in this new framework is very much supports the aviation industry's ongoing efforts to enhance operational efficiency, security, and sustainability where the primary objective of SWIM is to optimise information management processes, encompassing a diverse array of data kinds that are essential for the smooth functioning of aviation operations which encompasses flight plans, meteorological data, aeronautical information, and updates pertaining to air traffic management.

Development of ATM Information Exchange Interoperability Framework (ATMIEIF)

Action research method with pragmatism as research paradigm will be the philosophy in developing the ATMIEIF. Johannesson et al (2014) described that action research is a systematic study and creation of artefacts in the context of process improvement and use by organization member and with the goal of solving practical problems. The Soft Systems Methodology (SSM) as defined by Checkland et al (2001) was chosen as the research design

framework. SSM fits well with the study method and it is a structured and useful way to deal with what are seen as social problems. Table 1 shows the steps that were taken to do this research. For this paper, the focus is up to Step 4.

Table 1
Framework Development Process

Step	Phase Name	Description	Outcome Expected
1	Problem situation unstructured	• Problem is formally captured through literature review and brainstorming activities. • Establishment of Focus Group consists of Subject Matter Expert (SME).	• Literature list, identified SME, brainstorming plan & analysis structure • Stakeholder's Wishlist Document (SWD)
2	Problem situation expressed	• Analysis of the SWD • Development of the Stakeholder's Requirement Specification (SRS) which contains function list, current business flow and improvement requirement	• Stakeholder's Requirement Specification (SRS) Document
3	Definition of relevant system actors	• Analysis of the SRS • Identification of System Actors based on CATWOE elements	• CATWOE Table
4	Development of conceptual models/framework	• Development of conceptual framework based on SRS and CATWOE which include framework components, business process flow & implementation plan	• Conceptual Framework Document
5	Conceptual framework evaluation in real world	• Evaluation of the framework through Critical Design Review (CDR) sessions • Verify the proposed conceptual framework against the finalized SRS document as well as the current practices in the CAAM eco-system	• Stakeholders Verification Checklist • Functional Requirement Verification Checklist
6	Define changes to be made	• Upon completion of two (2) iterations of Step 5, the finalized list of comments shall be recorded and changes to the framework shall be finalized.	• Change request list

7	Action to solve or improve problem	• The finalized framework shall be presented to all stakeholders • Upon agreement, recommendation report to use the framework in CAAM shall be drafted	• Finalized framework document • Recommendation report

Highlight of Activities from Step 1 – Problem Situation Unstructured

Activities in Step 1 involves brainstorming sessions with all the subject matter experts shall be conducted to get first-hand information from the main user of these information in the industry. The selected experts are mainly licensed air traffic controllers and systems experts with at least 5 years of experience in air traffic management and controls. Outcome of each session shall be documented by using mind map diagram and analyses with thematic analysis. The question structured for each Focus Group (FG) are as follows:

FG 1 – Operational

a. What kind of information is shared between stakeholders in air traffic management?
b. How does effective information sharing benefit coordination activities and efficiency of ATM?
c. What are the challenges of information availability in air traffic management operations?

FG 2 – Governance/Policy

a. What are the governing policy with regards to information exchange interoperability in CAAM?
b. What external agencies/parties (outside of CAAM) that are interested in ATM information generated by CAAM ATM operations?
c. What is the current measures in term of controlling shared information with external parties?

FG 3 – System Provider

a. What is the most used platform for information exchange interoperability in CAAM ATM?
b. What is the limitation of this platform/protocol?
c. How can the limitation be improved in term of system interoperability?

Highlight of Activities from Step 2 – Problem Situation Expressed

Focus Group 1 (FG1) – Theme for FG1 is on operational related issues with emphasize on information exchanges. Table 2 summarizes findings from FG1 brainstorming session.

Table 2
Summary Responses for FG 1 – Operational

No	Feedback
1	Majority of information involves coordination such as flight plan, notice to airmen and estimates of traffic flow. Operational requirement Information such as weather is also shared. The stakeholders include ATC officers, pilot, military, and airline operator.
2	Type of information exchanged are Flight Plan, NOTAM, Weather Advisory, CTOT and AIDC communication messages for coordination. Information exchange usually transpired between ATC officers, pilots, airport operators and other stakeholders in ATM ecosystem.
3	Information exchanged by stakeholders are flight plans, coordination messages, weather, NOTAM and other advisory. However, information exchange between other FIR (e.g. Singapore FIR) only available through AFTN/AMHS messages and email.

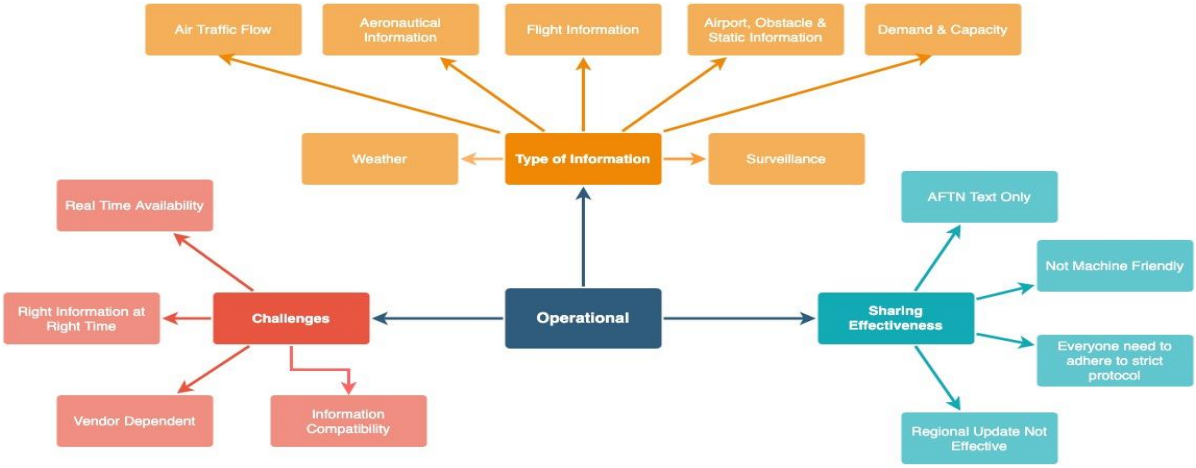

Figure 1. FG 1-Mind Map

Findings from FG1 can be summarize as all respondents agrees that a controlled and safe air travel relies on different types of information required by any of the involved stakeholders namely Aeronautical Information, Flight Information, Airport Information, Weather Information, Surveillance Information, Air Traffic Flow Information and Capacity and Demand Information. Many of these exchanges are not available in real time and the format used are based on AMHS/AFTN format specified in the ICAO Doc 4444.

Focus Group 2 (FG2) – Theme for FG2 is governance and policy with regards to information exchange. Table 3 summarizes findings from FG2 brainstorming session**.**

Table 3
Summary Responses for FG 2 – Governance and Policy

No	Feedback
1	Effective information sharing is crucial in traffic flow planning and air space management. Information such as arrival estimates is one of example of information that can benefit activities and efficiency of ATM
2	Real-time effective information sharing can ensure better traffic flow management and planning. This will help in term of efficiency and flight safety.
3	In theory, effective information sharing is very good for ATM system efficiency. However, this is easier said than done. ATM system is a complex system, and the vendor usually tries to put in proprietary parameters to protect their business thus hampering the effort of achieving effective information sharing.

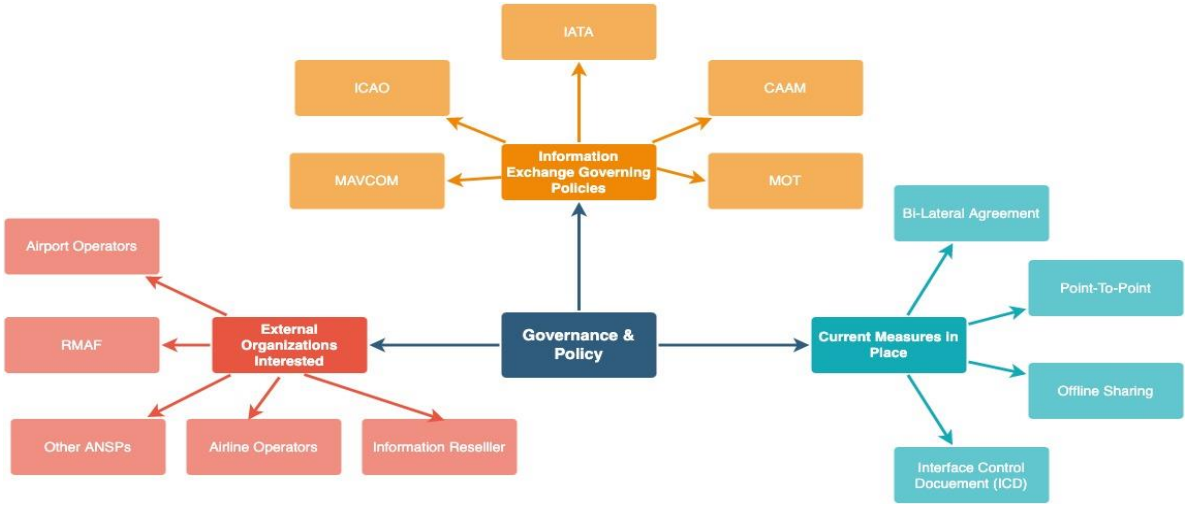

Figure 2. FG2-Mind Map

Findings from FG2 can be summarize that the respondent agrees that the key to keep up with the increased air traffic movements, is the availability of an agile and scalable solution for information sharing. Traditional information exchanges within ATM are built around dedicated point-to-point information systems, often developed individually and specific to the needs of the information sharing partners. As the volume and complexity of the global air traffic system increases, so does the complexity of the point-to-point infrastructure, with the need for multiplication of interfaces and agreements between an ever-increasing pool of stakeholders. With an agile information exchange, a much more efficient coordination can be achieved. This will lead to a much safer and efficient allocation of airspace and demand capacity planning.

Focus Group 3 (FG3) – Theme for FG3 is system provider with regards to system interoperability and integration. Table 4 summarizes findings from FG3 brainstorming session**.**

Table 4
Summary Responses for FG 3 – System Provider

No	Feedback
1	ATC usually faced with information overload if the information is not properly managed during system design stage. Cybersecurity is also an issue that need to be addressed early in setting up the system.
2	There is no structured flow in sharing some of the information. Especially information from adjacent FIRs. The use of email to share tactical estimates for arriving flights can lead to mistakes in estimates and traffic flow planning.
3	Without the right information at the right time, mistakes in coordination and planning are unavoidable. If not addressed, it is a disaster waiting to happen. ATM systems need to be designed to include all the right ingredient to achieve efficient information exchange.

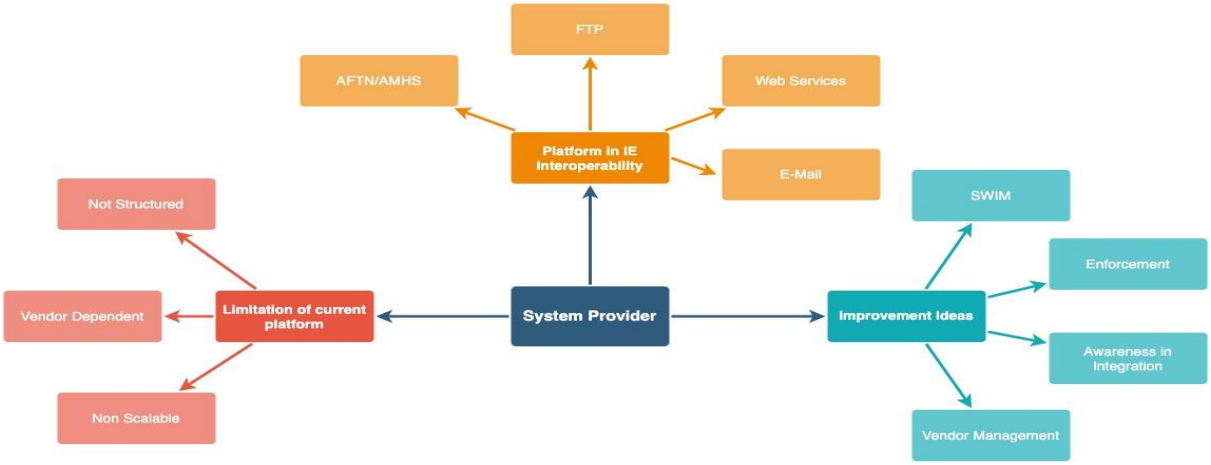

Figure 3. FG3-Mind Map

From the above responses and FG3, the requirements that can be established from the analysis can be further grouped into Interoperability, Reliable On-Time Information, Cybersecurity, and Information Governance Policy**.**

'As-Is' Flow of ATM Information

The brainstorming sessions also mapped out the current business process of Malaysian ATM Information Exchange. Figure 5 below shows the current context diagram and information flow of CAAM ATM eco-system.

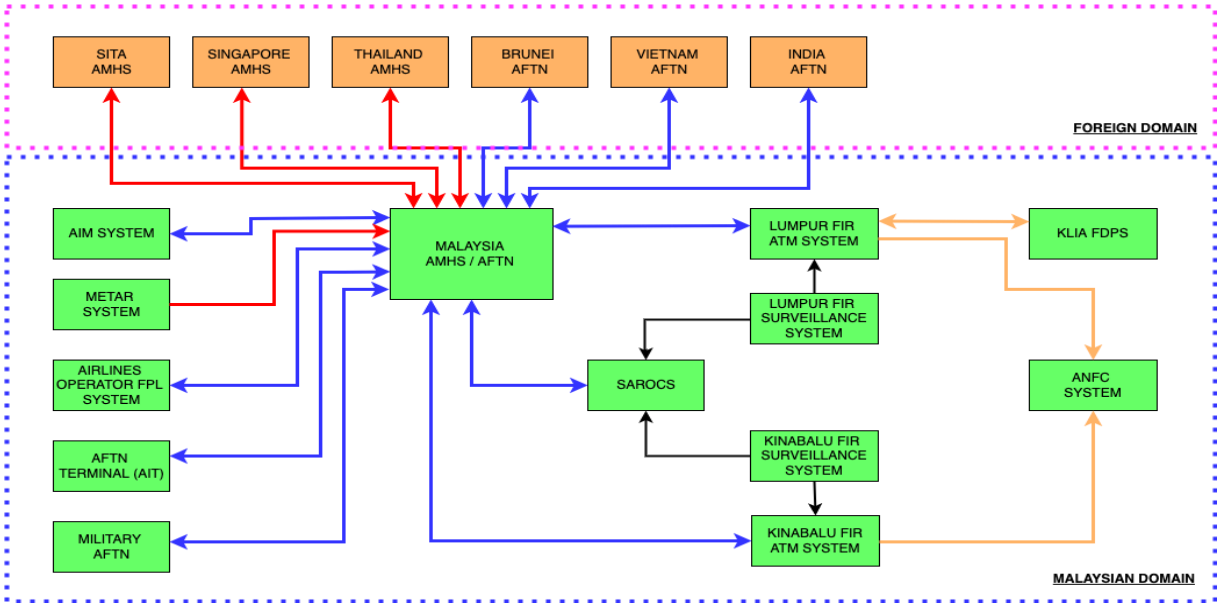

Figure 4. CAAM's ATM Eco-System 'As Is' Context Diagram & Information Flow

Table 5
Context Diagram Entity and Information Flow Description

No	Entity Name	Info In-Flow	Info Out-Flow	Format
1	Malaysia AMHS/AFTN	FPL, ATS, NOTAM, METAR, AIDC, CPDLC, ATFM, SVC	FPL, ATS, NOTAM, METAR, AIDC, CPDLC, ATFM, SVC	IA-5, X.400, IWXXM
2	AIM System	FPL, NOTAM	NOTAM, NOTAM	IA-5
3	METAR System	N/A	METAR	X.400
4	Airlines Operator FPL System	FPL	FPL	IA-5
5	AFTN Terminal	FPL, ATS, NOTAM, SVC	FPL, ATS, NOTAM, SVC	IA-5
6	Military AMSS/AFTN	FPL, ATS, NOTAM, METAR, SVC	FPL, ATS, NOTAM, METAR, SVC	IA-5
7	SAROCS	FPL, ATS, SIT185, SURV	N/A	IA-5, ASTERIX
8	Lumpur FIR ATM System	FPL, ATS, NOTAM, METAR, AIDC, CPDLC, ATFM, SVC, SURV	FPL, ATS, NOTAM, METAR, AIDC, CPDLC, ATFM, SVC, SURV	IA-5, ASTERIX
9	Lumpur FIR Surveillance	N/A	SURV	ASTERIX

10	Kinabalu FIR ATM System	FPL, ATS, NOTAM, METAR, AIDC, CPDLC, ATFM, SVC, SURV	FPL, ATS, NOTAM, METAR, AIDC, CPDLC, ATFM, SVC, SURV	
11	Kinabalu FIR Surveillance	N/A	SURV	ASTERIX
12	Air Navigation Facility Charges (ANFC) System	T-FPL	N/A	SQL Query/Respond
13	KL International Airport – Flight Data Processing System (KLIA FDPS)	Flight Status, METAR, NOTAM	Flight Status	SQL Query/Respond
14	Foreign AMHS (SITA, Singapore, Thailand)	FPL, ATS, NOTAM, METAR, AIDC, CPDLC, ATFM, SVC	FPL, ATS, NOTAM, METAR, AIDC, CPDLC, ATFM, SVC	X.400
15	Foreign AFTN (Brunei, Vietnam, India)	FPL, ATS, NOTAM, METAR, AIDC, CPDLC, ATFM, SVC	FPL, ATS, NOTAM, METAR, AIDC, CPDLC, ATFM, SVC	IA-5

The central hub for the information flow is currently the Malaysia AMHS/AFTN system which handles majority of the information exchanges. This system operates based on the ICAO Doc 4444 guidelines and employs the International Alphabet No. 5 (IA-5) format as the basis of exchanging information. Other format used in the AMHS/AFTN also includes X.400 format which is specific towards the AMHS system and ASTERIX format for exchanging of surveillance information. The description for each of the information type depicted in the context diagram and the information flow colour code is explained in Table 6 as follows:

Table 6
Information Type Description

No	Type	Description	Format (Flow Colour Code)
1	FPL	Flight Plan	IA-5 & X.400 (Red & Blue)
2	ATS	Air Traffic Service (CHG-Change of FPL, DLY-Delay of FPL, CNL-Cancel of FPL)	IA-5 & X.400 (Red & Blue)
3	NOTAM	Notice to Airmen	IA-5 & X.400 (Red & Blue)
4	METAR	Meteorology Message (SIGMET - Significant MET, TAF-Terminal Area Forecast, TAFOR)	X.400 (Red)
5	AIDC	ATS Interfacility Data Communication	IA-5 (Blue)
6	CPDLC	Controller-Pilot Data Communication	IA-5 (Blue)
7	ATFM	Air Traffic Flow Management	IA-5 (Blue)
8	SVC	Service Message	IA-5 (Blue)
9	SURV	Surveillance data include sources from PSR, SSR, ADS-B & MLAT.	ASTERIX (Black)
10	T-FPL	Terminated FPL.	SQL Query/Respond (Yellow)
11	Flight Status	Inbound/Outbound flight status, METAR information and NOTAM	SQL Query/Respond (Yellow)

Highlight of Activities from Step 3 – Definition of Relevant System Actors

Activities from Step 3 includes the identification and definition of system actors based on CATWOE model in accordance with the SSM methodology. The identified system actors are as per Table 7 as follows:

Table 7
System Actors (CATWOE Table)

Element	Description	Parameter
Customer	Who are the beneficiaries of the process flow and how it affects them?	• ANSP (CAAM), Airlines & Airport Operator • Improve of flight efficiency through effective information sharing
Actors	Who is involved in the situation?	• Air Traffic Control Officer, Pilot, Airlines Operation Manager, Airport Operation Manager
Transformation	What is the transformation that lies at the heart of the system	• Information exchange efficiency through system interoperability
World View	What is the big picture and what are the wider impact of the view?	• Global Interoperability, Flight efficiency • Cost Savings from efficient flight operation
Owner	Who own the process and what role will they play in the solution?	• ANSP owned the process. ATCO from ANSP will be brokering the information exchange

Environmental Constraint	What are the constraints that will impact the solution and its success?	• Attitude toward change, framework understanding & existing legal policy. • Inter ANSP system compatibility.

Highlight of Activities from Step 4 – Development of Conceptual Framework

To add the SWIM part to the current ATM eco-system, two new entities are added to the information flow: the SWIM Gateway and the SWIM National EMS. The SWIM Gateway's job is to turn data from the AMHS/AFTN system and the surveillance system into SWIM format, which is FIXM, AIXM, and IWXXM. After the messages have been changed, they are put in a queue in the National SWIM Enterprise Message Service (EMS) so that SWIM-enabled apps can use them. Figure 6 shows the new context diagram.

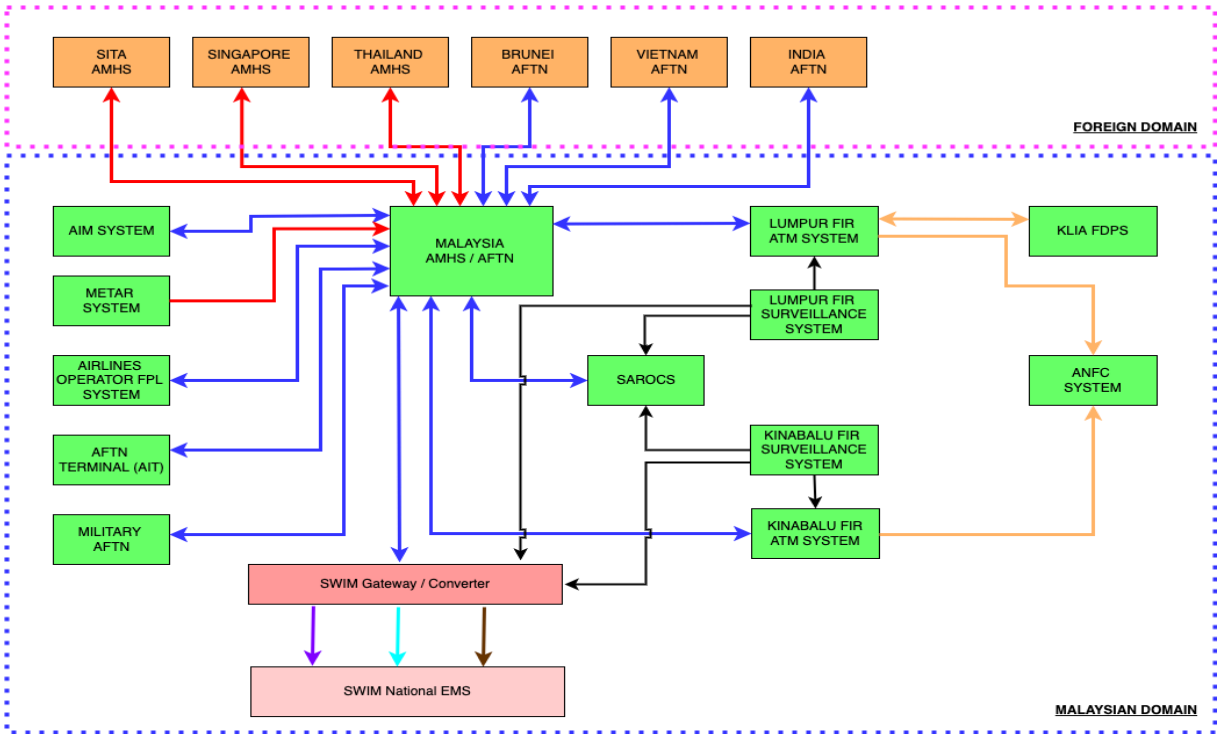

Figure 5. CAAM's ATM Eco-System 'New' Context Diagram & Information Flow

Table 8

Context Diagram New Entity and Information Flow Description

No	Entity Name	Info In-Flow	Info Out-Flow	Format
1	SWIM Gateway / Converter	FPL, ATS, NOTAM, METAR, ATFM, SVC, SURV	Converted SWIM messages	IA-5, ASTERIX, FIXM, AIXM & IWXXM
2	SWIM National EMS	Converted SWIM messages	SWIM Messages	FIXM, AIXM & IWXXM

Description of the information type that has been converted to SWIM format are as per Table 9.

Table 9

Information type available in SWIM format

No	Type	Description	Format (Flow Colour Code)
1	FPL	Flight Plan	FIXM (Purple)
2	ATS	Air Traffic Service (CHG-Change of FPL, DLY-Delay of FPL, CNL-Cancel of FPL)	FIXM (Purple)
3	NOTAM	Notice to Airmen	AIXM (Cyan)
4	METAR	Meteorology Message (SIGMET - Significant MET, TAF-Terminal Area Forecast)	IWXXM (Brown)
5	ATFM	Air Traffic Flow Management	FIXM (Purple)
6	SURV	Surveillance data include sources from PSR, SSR, ADS-B & M-LAT	FIXM (Purple)

With the establishment of the SWIM Converter and SWIM National EMS, the above information is now available in standardize SWIM format. The following Figure 7 describe the conceptual operational workflow of the proposed ATM Information Exchange Interoperability Framework which the stakeholders need to use to subscribe or access to the information.

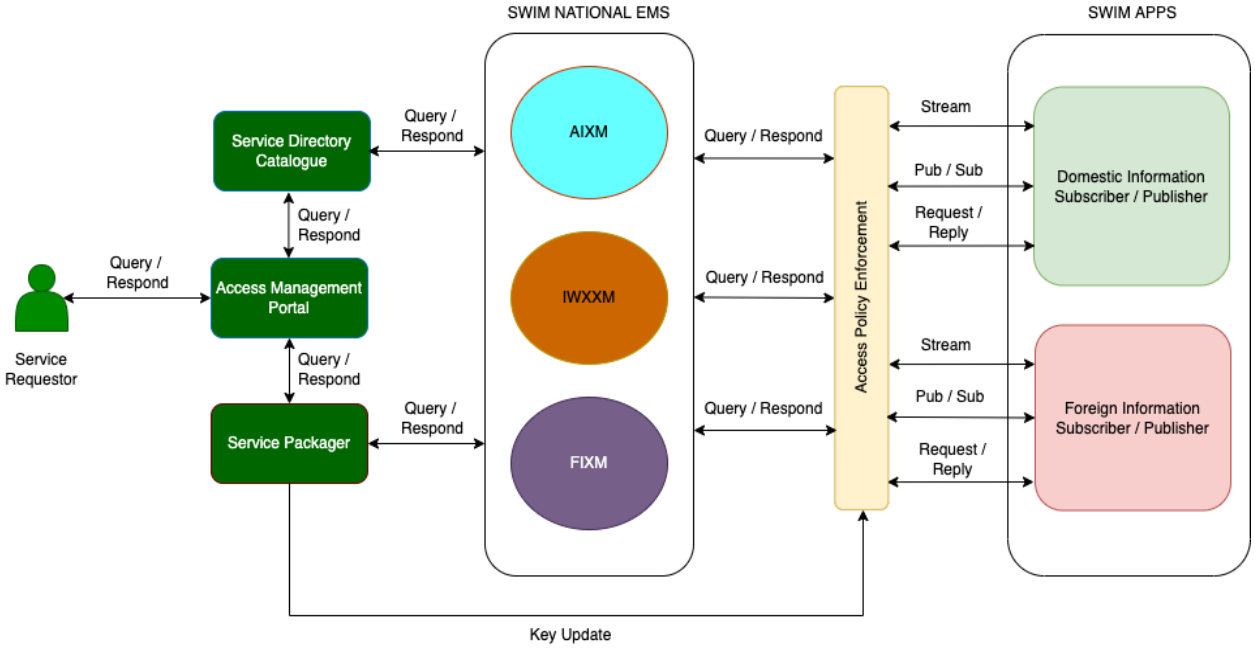

Figure 6. ATM Information Exchange Interoperability Framework

Description for each of the framework components are as follows in Table 10

Table 10

Framework Components Description

No	Components	Functions	Input	Output
1	Service Requestor	Stakeholders that require access to ATM information services.	• Respond from portal	• Query to portal
2	Service Directory Catalogue	Information package catalogue to listing down the information service available in the SWIM EMS	• Query from portal • Respond from SWIM EMS	• Query and Respond to SWIM EMS
3	Access Management Portal	A web-based portal facing the ATM information service requestor	• Query from requestor • Respond from Service Directory Catalogue • Respond from Service packager	• Result to requestor • Query to Service Directory Catalogue • Query to Service Packager
4	Service Packager	A software module that handles information service packaging and manage access key	• Respond from SWIM EMS • Query from portal	• Query to SWIM EMS • Key update to Access Policy Enforcement
5	SWIM National EMS	Enterprise Messaging Service to handle SWIM formatted messages	• Query from Service Directory Catalogue • Query from Service packager • Query from Access Policy Enforcement	• Respond to Service Directory Catalogue • Respond to Service packager. • Respond to Access Policy Enforcement
6	Access Policy Enforcement	A process that handles information access control based on service key	• Key update from Service Packager • Respond from SWIM EMS • Respond from SWIM Apps	• Query to SWIM Apps
7	SWIM Apps	SWIM application that utilizes information in SWIM format	• Respond from SWIM EMS	• Query to SWIM EMS

The SWIM application utilizes the information available in the SWIM EMS securely through the access granted by the Access Policy Enforcement module through a valid key. The process of browsing and selecting the information service is done through the portal. The user is also able to customize the information package required by using the Service Packager

process accessed through the portal. The SWIM apps also will be able to retrieve and submit information through multiple methods namely streaming, publish/subscribe and request/reply in line with SWIM service-oriented architecture (SOA) concept.

Conclusions and Recommendations

The proposed framework is recommended to be presented to the subject matter expert (SME) for validation in the next step of the process where it shall be considered as the first cycle in the SSM process. Upon getting the approval from the SME committee, it is also recommended that a detail Business Process Flow for each of the components to be prepared. This detail process will again go through the SME committee validation and shall be considered as second cycle of the SSM processes. The finalised and approved detail framework will then be documented and presented to the stakeholders and recommended for implementation as part of the intervention effort in-line with the action research methodology.

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