Introducing Data Model Standards for Data Comm Information Exchange over SWIM
ABSTRACT

ATC services use datalink communication systems such as FANS/ACARS, FAA DCIS, and EUROCONTROL DLS/Link2000+ using dedicated Communication Service Provider (CSP) networks such as Rockwell Collins (ARINC) and SITA. A need has been identified in the broader aviation community for sharing up-to-date status information of ATC instructions and clearances with stakeholders. In order to efficiently disseminate this information, SWIM can be utilized to publish an XML-based data format and leverage existing publish/subscribe schemes. SWIM architecture can support the dissemination of the data and handle governance of the information to authorized users. However, a standard data model for this information is not yet specified. Introducing new “XM”, called Datalink Messaging Exchange Model (DMXM), for datalink information sharing can ensure alignment with current international SWIM development efforts at the ICAO level.

DMXM can enable the use of a common reference data model for datalink information globally through SWIM by integrating it with the ICAO ATM Information Reference Model (AIRM). Aviation industry data exchange standards (e.g. ACRIS) can also benefit from the use of this information. Targeted users of applications for DMXM include airline dispatchers, pilots, airport operation control centers, and fixed-based operators such as ground handlers.

DMXM can provide the aviation community with a standard data model enabling ATC consumer applications through the use of interoperable semantics, thus achieving a higher productivity rate at a lower cost and a shorter time to deployment. Applications may support common situational awareness for controlled flights and enable collaborative decision making among stakeholders.

ATC ADVISORY SERVICES FOR DATALINK PROVIDE A MEANS FOR ADDITIONAL EFFICIENCY

ATM communications systems are currently segregated in two domains: safety and non-safety. The safety domain involves the exchange of command and control information and any data which supports safety of life and regularity of flight, whereas the non-safety domain involves the exchange of advisory information which supports operational efficiency but does not involve aircraft control. This segregation is applied to the ATSU, certain AOC service providers, and to the aircraft systems by means of physical separation of the Aircraft Control Domain and Aircraft Information System Domain.

Data link services are an integral part of safety-driven aviation implementations which use proprietary network services provided by communications service
providers. The first implementations were ACARS-based FANS while, more recently, ATN is being used as the ICAO compliant standard to support ATC services. These data link services implement point-to-point dialogues over dedicated networks and interfaces managed by communication service providers using application-specific packet formats and protocols. On the other hand, SWIM is intended to provide advisory information (i.e. excluding any command or control exchange) and is based on service oriented architectures, standard messaging exchange patterns, and IP-based public/private networks.

Advisory information from SWIM can be greatly enhanced by correlating safety operations information. If data elements such as flight clearances, trajectory negotiations, avionics-sourced position reports, and in-flight weather reports are published to SWIM, then advisory information can be enriched with this data. Data link information distributed via net-centric information sharing using SWIM interfaces can improve collaborative decision making, situation awareness, and operations planning by ATM stakeholders. Users of the ground ATM network such as airports and AOC/FOC centers are the first to benefit from the continuous availability of ATC communications in order to support their own operations planning and execution.

**ATM DATA STANDARDS LOWER COSTS THROUGH RE-USE**

The standardization and adoption of new ATM data models is improving the way in which producers and consumers are sharing ATM information. Using XML, the producers of data are able to exchange information using SWIM which is rapidly decreasing the amount of time required to connect and acquire relevant data. Currently, SWIM is categorized as an efficiency-critical system, in contrast to safety-critical systems such as ERAM. This means SWIM systems and data can be used as a means of improving system efficiency of the ATM network and additionally for advisory information. While Data Comm information is considered safety-critical, the information produced by Data Comm Network Services can be published to SWIM for external consumption by airline operations such as dispatch and flight planning. However, publishing data in legacy formats causes challenges in consuming the data such as use of hexadecimal encoding and legacy nomenclature for point-to-point transport.

ATM data formats are defined in order to standardize the way in which ATM data producers and consumers exchange information. Adopting standards provided by OMG, ISO, and OGC can reduce the costs of implementation for SWIM technical services such as data validation and improve workflows, ensure data quality, and increase safety. The ICAO Information Management Panel (IMP) has introduced the concept of an ATM Information Reference Model (AIRM) for data
standards over SWIM. However, the scope of Data Link information is unclear and does not currently fit in the AIRM. Therefore, defining a data model standard for this type of information in line with the others (AIXM, WXXM, and FIXM) should be considered if it is published to SWIM.

The proposed data model, called the Datalink Messaging Exchange Model (DMXM), is intended to provide information traditionally contained in legacy data link formats such as ACARS (ARINC 620 & ARINC 622) and FANS CPDLC (DO258A). DMXM needs also be designed in view of future support of ATN applications. Information published using DMXM benefits the airspace user community such as dispatch centers while providing additional information to enhance the SWIM data feeds for post-operations such as metrics calculations for improved operational efficiency.

**DATALINK MESSAGING TYPOLOGY IS FRAGMENTED**

Current datalink communications are driven by standards that mandate specific application functions over specific packet formats and message interfaces in order to be certified for operation in safety-domain networks. The phraseology for permitted ATS services is described in the PANS ATM Manual (ICAO, 2007), and communication and networking protocols must be compliant with ARINC, RTCA, and EUROCAE standards. These define different communication stacks per application type, which results in the fragmentation of datalink standards. The following existing standards are currently in use:

**Aircraft Communications Addressing and Reporting System (ACARS)** is a character-based messaging protocol for air-to-ground services using specific Communication Service Providers (CSP). ACARS core messaging is defined in ARINC 620 (ARINC, 2014), together with the conversion rules between air/ground, CSP, and ground segments.

ARINC 623 (ARINC, 2005) specifies character-oriented ATS messages (also called pre-FANS) that support D-ATIS, Departure Clearance (DCL) and Oceanic Clearance (OCL) applications. Although quickly superseded by FANS, character-oriented applications have been widely implemented by making use of the ACARS network for AOC services.

**Future Air Navigation System (FANS) 1/A+** services standardized by ARINC 622-4 (ARINC, 2001) also use ARINC 620 core messaging, but support bit-oriented ATS applications, introducing error detection and addressing the interoperability among regional implementations as compared to ACARS.

RTCA DO-258A (RTCA/EUROCAE, 2005) specifies three defined ATS FANS applications: ATS Facilities Notification (AFN), controller to Pilot Data Link Communications (CPDLC), and Automatic Dependent Surveillance (ADS). FANS
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covers oceanic routes globally as the communication performance adequate for Oceanic and Remote use. In addition, the FAA Data Comm program has chosen FANS 1/A+ for use in domestic operations, including the introduction of Departure Clearance (DCL) in 2015, and plans to extend CPDLC services for enroute operations in 2019.

**Aeronautical Telecommunication Network (ATN),** also called FANS 2/B+, is a communication architecture developed by ICAO to provide a global air-ground and ground-ground data link applications and a communications standard for ATS. ICAO Doc 9880 (ICAO, 2014) defines the ATN air-ground applications as CPDLC, CM, ADS-C and FIS.

The main difference in ATN compared to FANS is the existence of a Dialogue Service (DS), which allows end points to communicate in a standard way, agnostic to the application, and supports either connectionless or connection-oriented communication services underneath.

The first implementation stage of ATN is called ATN Baseline 1 (B1) services (RTCA/EUROCAE, 2007) (RTCA/EUROCAE, 2012) which include CM and CPDLC, currently deployed in Europe following the Data Link Services Implementing Rule (DLS-IR) over VDL Mode 2. Future ATN Baseline 2 (B2) [9, 10, 11], includes additional applications supporting the all of the ICAO ATN applications that enable 4D trajectory based operations.

This fragmentation of datalink network and application specifications makes it challenging for the aviation community to access to ATC data communications in a re-usable, cost-effective way. By making it available via SWIM in a standardized format, Data Comm operational information can be decoupled from the message phraseology and typology and simplify processes using a common data model.

**DATALINK MESSAGING EXCHANGE MODEL SUPPORTS INTEROPERABLE EXCHANGE FOR FUTURE CDM AND TBO**

As future data link standards evolve, the information becomes more accessible through upgraded ATC systems, especially through the use of SWIM networks to disseminate and exchange information. For example, the FAA DCNS currently aggregates all the data link messages that flow between ATC and aircraft through the Tower Data Link Services (TDLS). This information is decoded and forwarded to the corresponding Rockwell Collins or SITA CSP for processing. Meanwhile, a copy of the message can also be copied and decoded as an XML data message and published on SWIM to be consumed by authorized airspace users. Dispatch offices and Airline Operations Centers (AOC) can use this data to monitor ATC to Pilot communications as well as compute metrics based on ATC-to-Pilot interchange. As this information evolves, the combined information
of flight clearances and trajectory information with flight plans, aeronautical
dcharts and airspace information (NOTAMs and SAAs), and meteorological data
(PIREPS, Altimeter settings, common winds) with SWIM weather products can
help airspace users perform more efficiently through use of SWIM.

The TDLS messages are currently aggregated by SITA using legacy formats and
major airlines are currently paying a fee for use of this bandwidth to consume this
information. The first indication when presented with the concept of a SWIM feed
was overwhelming support from the airline community and dispatch user at large.
Many of the major airlines already have connections into FAA SWIM, and
providing a source of data link messages such as FANS and ACARS information
through already existing channels would be an efficient means of leveraging
existing infrastructure.

One case study is the use of DO-258A as described for FANS messaging. For
example, a complex data element described in DO-258A is the route clearance
element. This element describes a sequence of data structures defined in the
AEEC 702 Characteristic needed to provide a route clearance, and provides
additional data elements in a complex nesting structure. Through the use of an
XML schema, these data structures can be well defined and do not require
human readability to process. The data syntax can be enforced and validated
prior to transmission and upon receipt. Using modern software methods, XML is
easily converted into data objects (e.g. Java JAXB) and loaded into a database
for immediate processing or correlation with other SWIM data elements.

In Figure 1, the Common section of the message contains information on the
SWIM message as produced by the SWIM publication services such as related
metadata such as operator, timestamp, and messageType. The Datalink
Transport section will contain the extracted datalink transport information such as
ACARS, FANS 1/A, and ATN. For example, these elements may include A620
and/or A622 fields from the FANS message. The message payload will contain
the command and control message from ARINC 623, DO-258A, ICAO 9880
formatted sources, for example, an uplink message or downlink message in DO-
258A format transformed to XML.
CURRENT SWIM ARCHITECTURE CAN SUPPORT DMXM

Figure 2 depicts the overall architecture of the datalink message concept in the US National Airspace system (NAS). ATS datalink messages flow between ATSU and aircraft cockpit systems (e.g. FMS) through an ATC gateway operated by the CSP. A copy of the message is created, translated into a DMXM-compliant XML file and published to NEMS using the Java Message Service (JMS). Then this message can be consumed via SWIM by subscribers to the service, whether they are located in a ground network (e.g. airline AOC) or in the aircraft (e.g. EFB). In the latter case, an IP air-ground datalink subnetwork with bandwidth, QoS and security capabilities is required, as described later in this section.
The DMXM must begin with a logical model and consider the current SWIM messaging patterns and standard data models. The future of these standard data models will follow the ICAO AIRM which provides an information model and a logical data model for reference. The FAA NextGen and SESAR have formed the NextGen-SESAR Data Model Coordination Group (NSDMCG) to develop the ICAO AIRM governance considerations [14]. The use of data link and safety-domain information has not yet been considered and will introduce some level of discussion at the ICAO Information Management Panel (IMP). Assuming that DMXM is developed and published for distribution in the future, alignment with the AIRM may be necessary. Therefore, it is important to consider design specifications of the AIRM conceptual model when formulating DMXM constraints and representations. One example is the use of EPSG:4362 Coordinate Reference System (CRS) for representation of position and geospatial references which is used in AIXM, FIXM, and WXXM models.

SWIM provides security control functions such as authorization, authentication, and encryption. For example, the FAA NAS Enterprise Messaging Service (NEMS) acts as a broker between NAS data publishers (such as the publisher of datalink messages) and external consumers of SWIM. Every SWIM consumer must pass a series of stages to “on-ramp” to various NEMS testing environments as a qualification to be approved to connect to the operational environment. First, a user must connect using a secure virtual private network (VPN) connection to the FAA Telecommunications Infrastructure (FTI). Once connected, a user must authenticate using a Java Messaging Service (JMS) client applications. Finally, the user can receive information on their designated JMS queue/topic only.

Design of the datalink message publisher must be considered to take full advantage of the NEMS’ brokering capabilities. The NEMS has the capability to route and filter messages based on a series of parameters contained in the JMS properties (often called JMS message headers). These properties may be used along with a NEMS taxonomy to characterize each message to a corresponding consumer desired filter. For example, messages may contain headers such as the airline code, departure airport, arrival airport, message type, flight ID, and so on. A consumer, such as Delta Airlines, may be interested in all messages for flights arriving and departing in Atlanta airport, but the messages they receive will also be filtered to contain only the messages corresponding to Delta Airline’s airline code. A Java Messaging Service Description Document (JMSDD) [15] provides the details of the message headers and taxonomy as it applies to a JMS publisher as well as the requirements related to the service.

A request/response messaging pattern may also be used for on-demand requests for specific data regarding an active flight or airspace boundary. In order to implement such a service, use of web services is required. A web service requirements document (WSRD) [16] describes the characteristics of a web
services designed for the business rules and operations and the requirements of
the services.

In addition, attention should be paid to the infrastructure supporting the message
exchange services described herein. IP-based ground aviation networks (e.g. FTI
in the U.S., PENS in Europe) are the likely candidates. The design of DMXM is
expected to drive requirements on the underlying communication architecture to
transport datalink messages to the authorized users. The following capabilities
should be supported by the network components and hosts to guarantee an
acceptable level of service:

- High capacity and QoS,
- High service and network availability,
- Robust security features: authentication, confidentiality and integrity,
- and Prioritization

**AIRSPACE USERS BENEFIT FROM EFFICIENT RE-USE OF
TOOLS AND APPLICATIONS**

The use of a standard data model for data link information provides a single
mode for transporting all data link information in a standard feed. Airspace users
may use the same software tools to consume FANS data as they do future ATN-
B2 data as long as it retains the same common data elements. Vendor lock-in is
reduced and airspace users (and others, such as airport stakeholders as
described) can invest in augmenting current tools without worrying about
technology refresh due to new data Extract Transform and Load (ETL)
requirements from a new data link technology.

In order to integrate seamlessly IT solutions from airport stakeholders and
airspace users as datalink message service users, the design of DMXM should
consider interoperability with the ACI Airport Community Recommended
Information Services (ACRIS) and the IATA Aviation Information Data Exchange
(AIDX) system. To do this, services incorporating DMXM can define component
identifiers to be instantiated as ACRIS and AIDX-compliant attributes. This will
create uniquely identifiable components for airport stakeholders and airspace
users to facilitate resource reuse in specific business application development.

By using SWIM to transport data to ground networks, dispatch systems can
capture controller-to-pilot communications in real-time and intervene as
necessary to assist pilots. This functionality can be further extended in the future
with the transmission of relevant information directly to the pilots by air-ground
datalink. Electronic Flight Bags (EFB) are already being introduced in the cockpit
to provide pilots with support advisory information, and built-in app clients are
able to consume SWIM information. Visualization tools that consume and
process appropriately filtered ATC information of flights in the vicinity enable a
completely new paradigm of autonomous flight separation and trajectory conflict detection systems. This can also improve collaborative decision making processes and eventually support trajectory based operations once services are hardened per safety requirements.

Post flight analysis on data link information can provide dispatch and flight planning offices at the AOCs to improve flight operations and efficiency. Opportunities exist here to apply big data analytics algorithms on to assess cost impact of ATM over operations, and human factors impact to ATC compliance.

**FUTURE WORK**

Further work must be conducted to translate legacy formats into DMXM and collaboration with industry is of utmost importance. Current development of SWIM services to support data link messages is already underway, and the benefits will be captured by industry and evaluated for improvements.

As new data link standards emerge, a paradigm shift will occur to support trajectory based operations. Uplink and downlink of trajectories for negotiation, uplinking of weather and aeronautical updates, and downlinking of Extended Projected Profiles (EPP) will continue to change the way ATM operates, and sharing of this information with authorized airspace users and dispatch will close the loop on Collaborative Decision Making (CDM). Trajectory Negotiation, Advanced Interval Management, Dynamic RNP, ADS-C Extended Projected Profiles, ATC Winds are some examples of TBO concepts that can benefit from the use of a DMXM data feed. If designed properly, DMXM can support forward compatibility for future datalink services to support 4D trajectory negotiation and execution.
Works Cited


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