A Tour of the AIXM Concepts

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Abstract

The Aeronautical Information Exchange Model (AIXM) and the related Aeronautical Information Conceptual Model (AICM) contain hundreds of entities, data types, and relationships used to represent aeronautical data. AICM and AIXM were originally developed by EUROCONTROL to aid in standardizing data exchange and aeronautical products within the European States. The models are primarily based on ICAO requirements for international aeronautical data exchange (Annex 15 to the ICAO Convention) and on industry standards such as ARINC 424. AICM and AIXM's adoption within the United States government means that aeronautical data providers and consumers are almost certain to encounter AIXM in the near future. This paper provides an overview of the AICM and AIXM structure. AICM and AIXM may be divided into six concepts—Airspace, Services, Fixes, Routes, Aerodromes and Procedures. We highlight the major entities and relationships within these data concept areas and discuss AIXM's geographical model for representing the locations and extents of the aeronautical data entities.

Background

Harmonization of aeronautical data both internationally and within a state's aviation system is an important goal that will significantly improve the safety and accuracy of air traffic. Figure 1 illustrates a typical aeronautical data chain [6] (RTCA [6] terminology for the data chain steps is included parenthetically in the diagram). The data chain diagram describes how aeronautical data moves from its origination to end use. Within the United States Federal Aviation Administration (FAA), aeronautical data is originated, stored, charted, published, integrated and analyzed in many FAA divisions. Historically, each FAA division is responsible for maintaining the currency and accuracy of the division's instance of the aeronautical data. Today the data transmission steps illustrated by the arrows in Figure 1 are fragmented and can involve repeated human data entry and validation steps.

Progress towards the goal of a fully integrated aeronautical information management system requires a consistent mechanism for aeronautical information exchange between data providers, stewards and distributors both within the aviation authority as well as to external aviation data users (such as commercial aviation data consumers and providers).

To address the need for a common understanding of aeronautical data, EUROCONTROL developed the Aeronautical Information Conceptual Model (AICM). AICM describes the entities, attributes, relationships and rules that make up aeronautical information. AICM is based on:

- ICAO (International Civil Aviation Organization) standards and recommended practices (SARPS)
- Data concepts contained in Aeronautical Information Publications (AIPs)
- Industry standards such as ARINC 424 (mainly for encoding instrument approach and departure procedures)

Following AICM, EUROCONTROL developed AIXM, the Aeronautical Information Exchange Model. AIXM is an XML-based instance of the AICM: AIXM includes XML schemas as well as operational rules that define how to exchange aeronautical information as XML documents. The current version 3.3 of AIXM is a mature XML language that is implemented as part of the EUROCONTROL's European AIS (Aeronautical Information Services) Database (EAD) [4].

In 2003 the United States, represented by the FAA and the National Geospatial Intelligence Agency (NGA), adopted AICM/AIXM as a common format for aeronautical data exchange. The United States along with EUROCONTROL and others, are recommending that ICAO adopt AICM and AIXM as the international aeronautical data exchange standard.

As a result of this international standardization effort, the aviation community is certain to encounter AICM and AIXM with increasing frequency. The purpose of this paper is to provide a technical overview of AICM/AIXM and identify resources for additional information. The next three sections cover:

- AICM and AIXM structure
- Introduction to AICM/AIXM data concepts
- AICM/AIXM future

Finally, the references section of this document includes references to additional information on AICM and AIXM.

AICM and AIXM Structure

The conceptual model (AICM) describes entities, attributes and relationships in six aeronautical concept areas:

Concept Area	Description
Aerodromes	Represents a defined area used for takeoff, landing and surface movement operations of aircraft and helicopters. This conceptual area includes runways and equipment used for departure and arrival operations (such as landing lights) as well as information about ground services and facilities.
Airspace	Entities for representing three dimensional regions such as air traffic control sectors, international flight information regions (FIRs), military operating areas (MOAs) and other airspace.
Fixes	Locations within the airspace system which may be defined geographically or in relation to ground based navigational equipment such as a VHF Omni-directional Radio Range beacon (VOR). Fixes are used to describe air traffic routes, approach and departure procedures.
Routes	Represents a path through the en-route airspace using a set of significant points. Within the United States this includes Jet and Victor routes. The concept also includes a model for routing restrictions, such as those contained in letters of agreements between control centers.

Procedures	Terminal routes such as instrument approach procedures, departure procedures and standard terminal arrival routes. The procedures data concept area is based on the ARINC 424 specification and it includes entities for defining flight legs, turns and other entities for directing the flight path into and out of terminal areas.
Services	Generic entities used to represent organizations, units and services within the airspace system. This data concept area is used, for instance, to represent weather briefing services that may be located within an en route control center.

Figure 2 illustrates the entity-relationship diagram that is used to specify AICM by showing a subset of the aerodrome data concept area. Entities like AD_HP and RWY are used to represent major aeronautical features. Here, AD_HP represents an airport and/or heliport and RWY is the airport runway. Each entity includes attributes, which are data that describes the entities. In Figure 2 code_Type is one attribute under the AD_HP entity. The code_Type attribute specifies whether the AD_HP entity is an airport, heliport or combined airport/heliport.

In the entity-relationship diagram, relationships are indicated by lines connecting entities. Solid lines represent mandatory relationships and dashed line are optional. Relationship multiplicity is shown using standard symbology at the end point of the relationships. In Figure 2 the relationship between the AD_HP and RWY entities is as follows:

- An AD_HP entity may optionally have one or more runways associated with it.
- A RWY entity must be associated with a single airport AD_HP.

In addition to the entity-relationship diagram, AICM describes data value domains and data validation rules. Data value domains specify permissible values for the attributes. For example, AD_HP code_Type must be AD', 'AH' or 'HP', which translate to aerodrome only, aerodrome/heliport and heliport only, respectively. Data validation rules provide constraints on relationships and attributes. For example, RWY cannot be associated with an AD_HP of code_Type = AH (translated, this rule specifies that heliports don't have runways).

AIXM is an instance of the AICM, codified as a set of related XML Schemas. As shown in Figure 3, AIXM includes the AICM data values, features or entities as well as AIXM messages within the schema set. Because of limitations in the XML Schema (xsd) language, most of the business rules governing relationships and attributes are not coded into the XML Schemas[1].

The AIXM feature is the basic unit of information in AIXM. AIXM features are derived from the AICM entities. Features include airports, runways, and navigational aids. Features contain attributes and relationships. Within AIXM several conventions are used to define and describe features, attributes and relationships:

[1] This is situation is expected to improve in future releases, through the use of complementary schema languages, such as Schematron (http://www.schematron.com)

AIXM Convention	Description	Examples
Feature Names	Features are named using three-character abbreviations based on ICAO abbreviations.	Runway: <Rwy> VOR: <Vor>
Feature attributes	Attributes names include their data type in the name and the value domains and types are defined in the AIXM data types subschema.	Runway length: <valLen>5000 </valLen>

Feature identification	Features are identified using natural keys. Natural keys were chosen for feature identification because AIXM is designed to be used for aeronautical data exchange between loosely coupled systems. Feature unique IDs also include an optional computer identification number. The feature ID is represented using a XSD complex type whose name includes the "Uid" suffix.	Runway ID:
		<RwyUid>
		  <AhpUid>
		    <codeID>
		    IAH</codeID>
		  </AhpUid>
		  <txtDesig>
		  22L</txtDesig>
		</RwyUid>

Feature relationships	Relationships are created by including a feature's natural key into the related feature.	In the <RwyUid> example above the runway is related to the airport by including the <AhpUid> in the runway natural key.

In AIXM, aeronautical information is exchanged using AIXM messages. Currently, AIXM supports two types of messages:

- **<AIXM-update>** for transmitting aeronautical data changes used to update previously exchanged data.
- **<AIXM-snapshot>** for transmitting a version of aeronautical data that is valid at a specified date.

The <AIXM-update> message structure is shown in Figure 4. Elements in the update structure are defined in the table below:

<AIXM-update> sub-element	Definition
Group	Optionally used to organize aeronautical data updates into updates related to a common effective date and cause. The <Group> element includes optional attributes for specifying a 'Name' and a 'subName.' An AIXM update may contain one or more Group elements. A Group element contains

	zero or more sets of New, Changed or Withdrawn aeronautical features.
New	Contains data for a new aeronautical feature such as a new runway at an airport.
Changed	Contains data about a change to an aeronautical feature. This includes changes in the feature attributes as well as changes in the feature's natural key. Examples include a new frequency at an airport or a change in the location of a VOR. When a feature is changed, the rule is that all attributes of the feature must be included in the Changed message. The changed feature attributes can be optionally tagged by specifying the 'chg' xml attribute.
Withdrawn	Contains data on aeronautical features that are deleted from the data set. For example an obstruction that no longer exists.

In addition to these rules, AIXM includes special rules covering the order and interpretation of multiple New, Changes and Withdrawn messages on the same aeronautical data features. Details of these rules can be found in the AIXM Primer reference given in the references section [3].

The <AIXM-snapshot> message contains a dump of aeronautical data valid at a particular time. Attributes in the <AIXM-snapshot> element are used to record creation date, effective date, origination and version.

Introduction to AICM/AIXM data concepts

In this section we summarize the six data conceptual areas by presenting an example of the data concept in each area and discussing the major AICM and AIXM features represented in the illustration.

Airspace concept

According to the AICM Manual [1], "Airspace is a generic entity representing variously 'regions' (ICAO and otherwise), 'areas', 'zones', 'sectors' (elementary and/or consolidated)…" Basically, the airspace concept can be used to represent any three dimensional geographic space. Within the context of the FAA, we might use airspace to represent an air traffic control sector, an en route control center boundary, a military operating area or a temporary flight restriction.

Figure 5 illustrates a complex airspace made of two parts. The part on the left is semicircular while the piece on the right is shaped like the state of Utah. Together these two airspace parts make up a single more complex airspace. Within AIXM and AICM any 3D airspace definition is modeled as an AIRSPACE feature. The AIRSPACE feature can define a simple airspace polygon made from an altitude range and a horizontal airspace border or the airspace might be a complex combination of more primitive airspace definitions.

In this example the two airspace parts are primitive AIRSPACE objects with altitude limits and an AIRSPACE BORDER. The AIRSPACE BORDER object is made from a sequence of AIRSPACE VERTEX objects. Each AIRSPACE VERTEX object defines a geographical point and a path towards the next AIRSPACE vertex. It can also reference a GEOGRAPHICAL BORDER object. The paths between AIRSPACE VERTEX objects can be great circle (straight lines), arcs or rhumblines.

A GEOGRAPHIC BORDER object is used to define a known geographical/political border like a state boundary or a river course.

Finally, all airspaces have an AIRSPACE TIMESHEET associated with them. The timesheet gives the operating hours for the airspace.

Fix concept

The fix conceptual area defines points in space used for navigational and air traffic control purposes. An abstract concept called “Significant Point” is defined by ICAO as a “specified geographical location used to define an ATS route, the flight path of an aircraft or for other navigation/ATS purposes.” [1] Within the abstract concept of Significant Points are those points marked by a radio navigation aid and those points that are not marked by a navigational aid. In this document, the general term NAVAID is used to represent points marked by the site of a navigation aid. NAVAIDS include VOR, DME, TACANs and others. The phrase “Designated Points” is used to represent locations that are not sited at a NAVAID.

Figure 6 illustrates a NAVAID called BVT which happens to be a TACAN collocated with a VOR (in FAA terminology this would be called a VORTAC). The BVT NAVAID has specific performance limitations outlined by the orange and yellow volumes. Within 5 nm of BVT there is full coverage from 0 to FL300, but from 5 to 15 nm from BVT there is a gap in coverage between the 355 and 25 degree radials. The coverage definition is termed a LIMITATION.

NAVAID TIMESHEETS are used to model the working hours for the BVT NAVAID - from 8:00 AM to 5:00 PM on weekdays.

In addition, this diagram shows a point in space called BVT075015, this is a DESIGNATED_POINT. A DESIGNATED_POINT represents a waypoint and is a specialization of the SIGNIFICANT_POINT. In the example, the designated point can be defined as an angular reference (called ANGLE_INDICATION) from the VORTAC and a distance (called DISTANCE_INDICATION) from the co-located TACAN.

Airport concept

The Aerodrome and Heliport data concept area is a complex area describing the makeup of airports and heliports. Within this concept area are definitions of airports, runways, final approach and takeoff areas, aprons, taxiways and lighting systems. Figure 7 highlights some of the major features of the Aerodrome domain. This illustration is by no means exhaustive.

The example illustrates the Beaumont-Port Arthur (BPT) airport located in southeastern Texas. The overall airport is represented with a AD_HP feature that captures information on the airport name, type and location. The AD_HP has relationships to the major components of the airport. The airport includes RUNWAYS and each runway has two RUNWAY DIRECTIONS. The runways are connected to each other and the other airport facilities via TAXIWAYS. The APRON defines areas of the airport where passengers enter and exit the aircraft. Significant vertical obstructions are identified by the OBSTACLE feature and these can be linked to the airport in general or associated with a specific takeoff/landing direction on a runway or final approach/takeoff areas (FATO). Finally the airport has associated operating hours. In this case, BPT airport operates continuously (encoded as ‘H24’ in AIXM).

Services concept

The services data concept area is used to describe organizations, divisions, units and the services that they provide. Services can be explicitly connected to other aeronautical element such as airspace, airports, procedures and routes. Figure 8 shows a model of an air traffic control service located at a Federal Aviation Administration en route facility. The FAA is the parent ORGANIZATION for the En Route Control Center UNIT. Both UNITS and ORGANIZATIONS can have addresses and associations. A sample association is shown for the En Route Control Center where the Flight Service UNIT may be a child of the en route UNIT. The En Route Control Center will have many SERVICES, one of which is air traffic control services. These services may include FREQUENCIES and operating hours.

Route concept

The Routes data concept area is used to define an en route route. Within the United States, this includes jetways and victor airways used to traverse the en route airspace structure. Note, approach procedures and departure procedures are modeled separately in the procedures data concept area. The example in Figure 9 shows a part of J101 which is a north-south route in the central United States. The ROUTE is made up of a series of SIGNIFICANT POINTS; for simplicity, only the NAVAIDS that make up the route are shown in this example. Pairs of joined SIGNIFICANT POINTS are called ROUTE SEGMENTS. A ROUTE SEGMENT can include altitude limits and a width. Each segment can have a complex usage of flight level and operating hours. In this case the ROUTE SEGMENT between GRB and BAE has a timesheet indicating that the SEGMENT USAGE is weekdays between 8 and 5 PM.

Not shown in this diagram is the concept of traffic flow restrictions. These restrictions can be tied to route segments and are used to restrict traffic along the route based on complex criteria such as aircraft type or city pair.

Procedures concept

The Procedures data concept area defines instrument approach procedures (IAP), departure procedures (DP) and standard terminal arrive routes (STAR). AIXM uses the ARINC 424 standard as the basis for the data model used to represent procedures in AICM and AIXM.

The example in Figure 10 shows a conventional NAVAID-based procedure (IAP) to runway 34 at the Beaumont-Port Arthur (BPT) airport in southeastern Texas. For this example the procedure is assumed to be active from 8 AM to 5 PM weekdays and this is modeled as a time sheet in the IAP USAGE. The procedure includes 3 PROCEDURE LEGs starting at the SBI NAVAID. For instance the final PROCEDURE LEG goes from BAXTR to the decision altitude (DA) at which point the pilot must determine whether to land or take the missed approach to PEVET. Each PROCEDURE LEG is defined by a leg type, eventually associated with a significant point. Decision altitudes are modeled in the OBSTACLE CLEARANCE ALTITUDE entity.

AICM/AIXM future

Although AICM and AIXM are mature, proven data exchange models, both models continue to evolve in response to changes in aeronautical information system management goals and in response to user needs. Potential AICM and AIXM changes are selected based on general applicability to the international aviation community and adherence to standards. It is recognized that local extensions of AICM and AIXM may be required to meet State or system specific needs.

EUROCONTROL has organized a change control board (ACCB) for proposing, reviewing and implementing AICM and AIXM changes, with international participation. Both State agencies and industry are represented. Currently, the ACCB is compiling a list of targeted enhancements for future AIXM releases. AIXM 4, due out at the end of the third quarter of 2004, is slated to include minor changes, such as:

- Domain values changes and additions
- New <Fix> feature for representing designated points defined only as angular and distance offsets from NAVAIDS.
- Enhance the airspace feature by combining sub-parts of airspace associations into a single feature
- Support airspace buffers and vertices defined using named SIGNIFICANT POINTS.
- Add new business and operational rules

An enhanced obstacle model, taking into consideration new ICAO requirements and user needs, is intended for publication either as part of AIXM 4 or as part of the next intermediate version 4.x.

AIXM version 5 is planned for 2006. The goal of AIXM 5 is to extend the AIXM model to support temporary changes to aeronautical data. Today, temporary aeronautical data changes are managed as Notice to Airmen (NOTAMs). NOTAMS are text based messages that describe changes such as aeronautical system usage, operating hours and condition. The current NOTAM system is based on legacy teletype distribution systems and there is no connection between aeronautical data publications (such as a chart) and the NOTAMS. It is up to the NOTAM recipient to manually combine the permanent aeronautical data with the NOTAM information to obtain a current view of the airspace system. Integrating NOTAMs into AIXM and AICM would improve aeronautical data distribution and accuracy, resulting in a safer aviation system.

Conclusions

Comprehensive aeronautical data models and exchange mechanisms are needed to improve the quality, completeness and timeliness of the international community's aeronautical information systems. EUROCONTROL's AICM and AIXM provide a standards-based approach to modeling and transmitting aeronautical data.

AICM and AIXM are organized into 6 conceptual areas: Aerodromes, Fixes, Airspace, Services, Procedures and Routes. Aeronautical data is represented using entities, attributes and relationships. AIXM defines features and messages for exchanging snapshots and updates of aeronautical data using XML.

Today, EUROCONTROL is using AICM and AIXM as part of the European AIS Database (EAD) system. The United States is developing systems and tools that incorporate AICM and AIXM. AICM and AIXM's growing use internationally, including its recent adoption by the United States, means that data originators and consumers are certain to encounter AIXM in the near future.

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