From Signal Inspection to Data Validation: Safeguarding IFP Data Integrity for PBN Flight Validation with ARINC 424

Sigurd A. Bjelkarøy
CTO
Norwegian Special Mission
Gardermoen, Norway
E-mail: sab@nsm.aero

ABSTRACT

Validation is the final quality assurance step in the Instrument Flight Procedure (IFP) design process, where the flight track flown is compared to the desired track as prescribed in ICAO Doc 9906. With the transition to Performance-Based Navigation (PBN), validation depend on accurate, traceable data. In conventional aviation, Flight Inspection focuses on the quality of the signal-in-space while in the PBN environment, the focus shifts to Data Validation.

Ensuring correct ARINC 424 waypoints and path terminator coding (e.g., TF, RF, CF legs) is essential, as even a minor error can cause significant deviations. The validation process must maintain data integrity from procedure design to the aircraft's Flight Management System (FMS) and to the flight inspection system.

This paper introduces a data-centric workflow using ARINC 424 to move procedures directly from the design suite to the Flight Inspection System (FIS) database. This eliminates manual data entry errors, guarantees the validation dataset matches the original design, and enables automated comparison against high-accuracy facility databases (e.g., threshold positions/heights), and flags where ARINC 424 resolution or WGS-84 conversions warrant special attention.

INTRODUCTION

Digital aviation navigation data are normally stored and shared in either AIXM or ARINC 424 format. The two formats have slightly different purpose.

To understand the difference between AIXM (Aeronautical Information Exchange Model) and ARINC 424, it is best to view them as two different stages of a single lifecycle: one manages the "world," while the other manages the "machine."

AIXM: The Global Database

AIXM is an object-oriented, XML-based data standard designed to capture the entire aeronautical environment. It acts as the "Source of Truth" for digital aviation.

- Primary Use: It is used by civil aviation authorities and designers to manage and exchange a massive variety of data, including airport infrastructure (runways, taxiways), airspace boundaries, obstacles (towers, cranes), and temporary changes like Digital NOTAMs.
- The Advantage: Because it is object-oriented, AIXM understands relationships. If a runway is closed, AIXM can automatically link that closure to every associated approach procedure and departure route. It is highly detailed and allows for real-time updates.

ARINC 424: The Flight Instruction

ARINC 424 is a legacy, column-based ASCII format that has been the industry standard since the 1970s. It was specifically designed to be read by Flight Management Systems (FMS) with limited processing power and memory.

- Primary Use: Its sole purpose is to provide the "Path and Termination" logic required to fly an aircraft. It translates geographic coordinates into specific "leg types" (such as a straight track to a fix or a curved radius turn) that an autopilot can follow.

- The Constraint: It is a "flat file," meaning it is rigid and limited in the amount of extra information it can carry. It follows a strict 28-day update cycle (the AIRAC cycle) and cannot easily handle real-time dynamic changes.

THE OPERATIONAL FLOW

The transition of aeronautical information from a state authority to an aircraft's Flight Management System (FMS) follows a strictly regulated "Chain of Custody."

This process ensures that complex environmental data is distilled into executable machine instructions while maintaining absolute data integrity.

Upstream Data Modeling (AIXM)

The process begins at the Upstream level, where State Authorities and procedure designers utilize the AIXM data. At this stage, the data exists as a "digital twin" of the global airspace. Unlike static formats, AIXM is an object-oriented structure that captures rich metadata, including 3D obstacle geometry, airport infrastructure details, and dynamic temporal changes (Digital NOTAMs).

Navigation data providers use these AIXM feeds to serve as the foundational source for both terrestrial aeronautical charts and digital navigation products.

Downstream Standardization (ARINC 424)

The navigation data provided convert the received data into a Master ARINC 424 dataset. This stage converts the complex relationships found in AIXM into the standardized, column-based ASCII format required for global interoperability.

This master dataset serves as the central repository from which all subsequent navigation data is derived.

Tailoring and Sub-setting

Because aircraft hardware is subject to finite memory constraints and varying operational requirements, the master dataset undergoes a sub-setting process. The navigation data provider extracts applicable data based on:

Geographic Scope: Regional tiles (e.g., North America, Europe) or specific airline route structures.

Operational Suitability: Filtering based on aircraft type (e.g., excluding helicopter-only procedures for fixed-wing operators).

Regulatory Compliance: Ensuring the data meets specific State or operator-mandated safety criteria.

The resulting tailored **ARINC 424** files are then transmitted to the data packaging house (the avionics manufacturer).

Packaging and Final Integration

The final phase involves the **FMS Data Packer**, which performs a dual-function transformation:

Logical Filtering: The data is scrubbed against the specific capabilities of the target FMS software version. Any "Path and Termination" leg types (such as RF legs) that the specific hardware cannot process are removed or flagged to prevent system errors.

Binary Conversion: The ASCII-based ARINC 424 code is compiled into a proprietary **binary format**. This compact, machine-readable executable is optimized for the flight computer's processor.

Once loaded into the aircraft's Flight Management System, this binary data provides the definitive steering commands and path-steering logic necessary to guide the aircraft along its intended trajectory.

ICAO RECOMMENDATIONS

Validation is the final quality assurance step in the procedure design process for instrument flight procedures (IFP) and is essential before the procedure design documentation is issued as part of the integrated aeronautical information package. Ref. ICAO DOC 9906 Vol V [1].

The flight validation is performed to:

- Verify data
- Verify chart depictions and details
- Assess obstacle infrastructure
- Assess airport infrastructure
- Assess flyability and Human Factors
- Conduct associated validation tasks
- Record flight validation

In order to be sure that the procedure is validated as designed and coded, both the FMS and flight inspection system should have the actual procedure loaded.

FLIGHT VALIDATION

Flight validation organizations typically secure access to unpublished instrument flight procedures through agreements with navigation data providers and packaging houses.

Because ARINC 424 data are used to program the FMS navigation database, using identical input on the flight inspection system guarantees that the procedure performed by the FMS matches exactly with what is validated on the flight inspection system, eliminating the possibility of human errors from manual entry.

ARINC 424 data for import into the flight inspection system can be obtained both directly from the procedure designer tool and form the navigation data provider.

THE BENEFIT OF IMPORTING ARINC 424 DATA INTO THE FLIGHT INSPECTION SYSTEM

By importing ARINC 424 data into a flight inspection system, the system can benefit from having access to accurate and up-to-date information about the airspace and the environment in which it operates.

Importing ARINC 424 coded Instrument Flight Procedures (IFP) into the flight inspection system will improve IFP validations accuracy and efficiency.

It eliminates manual typing of data and lets the flight inspection system use all the relevant navigation data to inspect the airspace more effectively.

The ARINC 424 data is generated directly by the procedure design tool, and when imported to the flight inspection system the procedure shown is exactly as originally designed.

Another benefit of importing ARINC 424 data into a flight inspection system is that it can enhance the system's ability to detect and diagnose issues. With detailed information about the airspace, the flight inspection system can more easily identify anomalies or discrepancies and can provide more accurate and detailed reports to help maintenance teams address any issues that are found.

During import the flight inspection system can check if any of the data found in the ARINC 424 file which are relevant for the imported contents already exist in the flight inspection database, and a comparison report can be generated to show these differences. This is useful to make the inspector aware of differences found in threshold heights, positions etc, and since the flight inspection facility database normally consists of highly accurately surveyed position data, this automatic comparison will flag potential errors in the ARINC 424 data at an early stage with no additional effort required.

A ARINC 424 file can contain information of a single IFP procedure, a single facility, all facilities and procedures in a whole country or all facilities and procedures for a whole continent and anything in between. All entries are defined with country codes and with links to relevant facilities which makes the ARINC 424 data very useful for the flight inspection system.

Since the ARINC 424 data can represent a complete navigation database the ARINC 424 import is also a very powerful tool for flight inspection organizations that want to add new NAVAIDS into the flight inspection system database.

The ARINC 424 import can easily filter out NAVAIDS added in a specific nav database cycle or all NAVAIDS of a certain type for a specified country and all relevant links between each facility is added automatically. As a default, facilities existing in the flight inspection system database will not be overwritten unless specified by the operator.

As an example, if an Instrument Flight Procedure is imported and the associated airport is not already in the flight inspection system database, the import can also add the airport data, the data for all runways and all facilities associated with that airport. If the airport the imported IFP is associated to already exist in flight inspection facility database, the procedure will be linked to existing data and only new data are added.

Position format

In ARINC 424 the standard position format is Latitude, Longitude, Elevation where Latitude and Longitude are presented in Degrees, Minutes and Seconds with a resolution of a hundred of an arc second. This is equal to a resolution of approximately 30cm which is sufficient accuracy for most NAVAIDS except ILS and runway data where higher accuracy is required.

Still, having the capability to import all facilities on an airport or all VORDME stations for a whole country correctly linked is a huge timesaver where only the ILS coordinates need to be updated with higher accuracy data.

ARINC 424 imported ILS data are be marked to make it clear for the flight inspector that the accuracy of imported position is limited by the ARINC 424 data set.

Elevations in ARINC 424 are generally related to Mean Sea Level and provided in feet. The conversion from MSL elevation to WGS-84 ellipsoid height will induce some inaccuracies but it would only be significant for glideslope.

For FAS data and runway threshold data ARINC 424 do support specific fields for WGS-84 ellipsoid heights.