How to guarantee IFP data integrity from procedure design to FIS in IFP flight validation activities

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ABSTRACT

Validation is the final quality assurance step in the procedure design process for instrument flight procedures (IFP). According with the ICAO doc 9906,*[1]* if a flight validation is needed, flight track flown must be compared to the IFP desired track. Starting from proposed IFP chart, and its tabular description, two data set need to be produced: one for FMS of flight validation aircraft, generated by FMS commercial database suppliers using Aeronautical Service Provider data, and one for FIS, usually defined inserting manually data into FIS database increasing risk of data corruptions due to human errors. To guarantee IFP data integrity avoiding human errors, an ARINC 424 *[2]* based decoder was developed, allowing a coded export of proposed IFP data directly from designer software suite and a relative decoding and import in FIS software. This process of automatic encoding paired with an advanced FIS software capabilities allows to control the IFP-related data quality and integrity ensuring that the data into the FIS' flight validation database exactly match with the data used in the IFP design. The scope of this Paper is to explain how this software tools can help in the process of flight validation providing guarantee of data integrity.

INTRODUCTION

ENAV Flight Inspection and Validation department mission is to guarantee quality and efficiency of Navaids and instrumental flight procedures in Italy and in other countries where ENAV operates according with ICAO regulations. ENAV FIV operates by means of 4 Piaggio P180 avanti II aircrafts equipped with 3 Norwegian Special mission UNIFIS 3000 Flight inspection System. ENAV also performs rotorcraft IFP validation (PinS and Low Level Route) through RIFIS system (Repositionable IFP Flight Inspection System). All the activities are performed by highly skilled team including pilots, flight inspection operators and ground staff engineers. All ENAV FIV pilots are trained to perform all activities, on ground and in flight, related to validation of instrumental flight procedure*[3].* ENAV is also a Flight Procedure Designer Operator (FPDO) thus is capable of conducting the entire IFP Validation process, starting from IFP designing using Flight Procedure Design and Airspace Management software (FPDAM an IDS Airnav - ENAV group - property software), going to final IFP publication process, to guarantee and control quality and safety of all processes.

This paper is related to the IFP Validation process whose purpose is, in accordance with ICAO doc 9906, to verify the quality and flyability of designed procedures and, at the same time, to verify the integrity of the IFP associated data. Data integrity is critical during IFP creation and validation because such data packs are generated, transferred and converted several times. Data conversion and transfer could affect integrity of final package provided for preflight and flight validation processes. For this reason, it is essential to study how to improve the whole process passing by the enhancing of all single steps composing the validation process.

In this work one possible implementation of data transfer between the IFP designer operator and ENAV flight inspection and validation department is described. The authors focused in particular on data transfer process related to the creation of Flight Inspection System database used on board of ENAV aircrafts during flight validation activities. The solution proposed in this paper was made possible by collaboration and synergy between ENAV flight inspection department, IDS Airnav, as FPDAM software suite owner and developer, and Norwegian Special mission, as provider of flight inspection system UNIFIS 3000 currently used by ENAV.

DESCRIPTION OF IFP CREATION AND VALIDATION CHAIN

In the following an extract of the ICAO doc 8697 *[4]* Aeronautical Chart Manual is reported, showing the creation flux of an aeronautical chart, also including the process of IFP design. In the following image is shown the upstream data used to create and design the procedure, and the downstream data section which relates to sector end users and commercial providers.

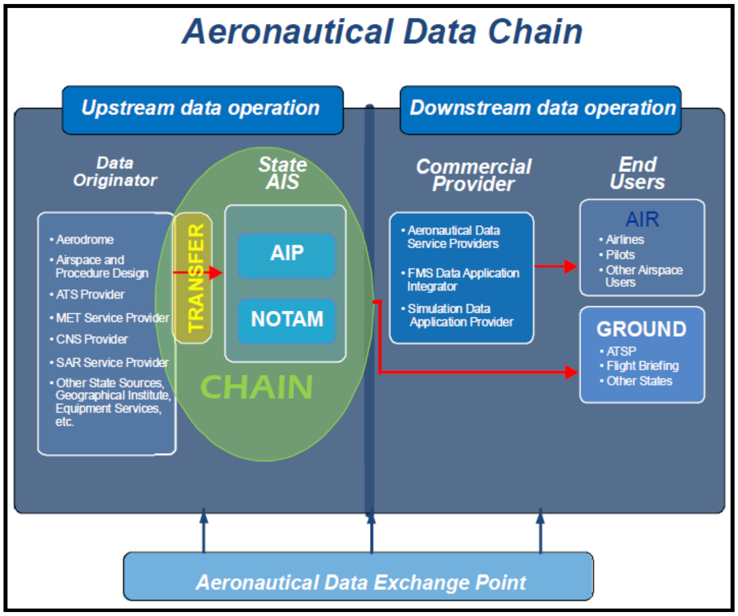


Figure 1 - Doc ICAO 8697 extract

Starting from the above diagram the process related to the FPDO, as owner of IFP definition and data upstream phase, and the role of ENAV flight inspection department in the specific case of IFP validation process, will be described focusing on integrity in data transfer.

IFP Design and Validation process

The following figure shows the details of the IFP-related workflow between the FPDO IFP definition and the IFP final publication in AIP. This is a high level block diagram showing all key players involved and their related actions in the IFP Validation process without detailing all possible options foreseen by regulation, but generally applicable to any FPDO and Flight Validation provider ICAO compliant *[5]*.

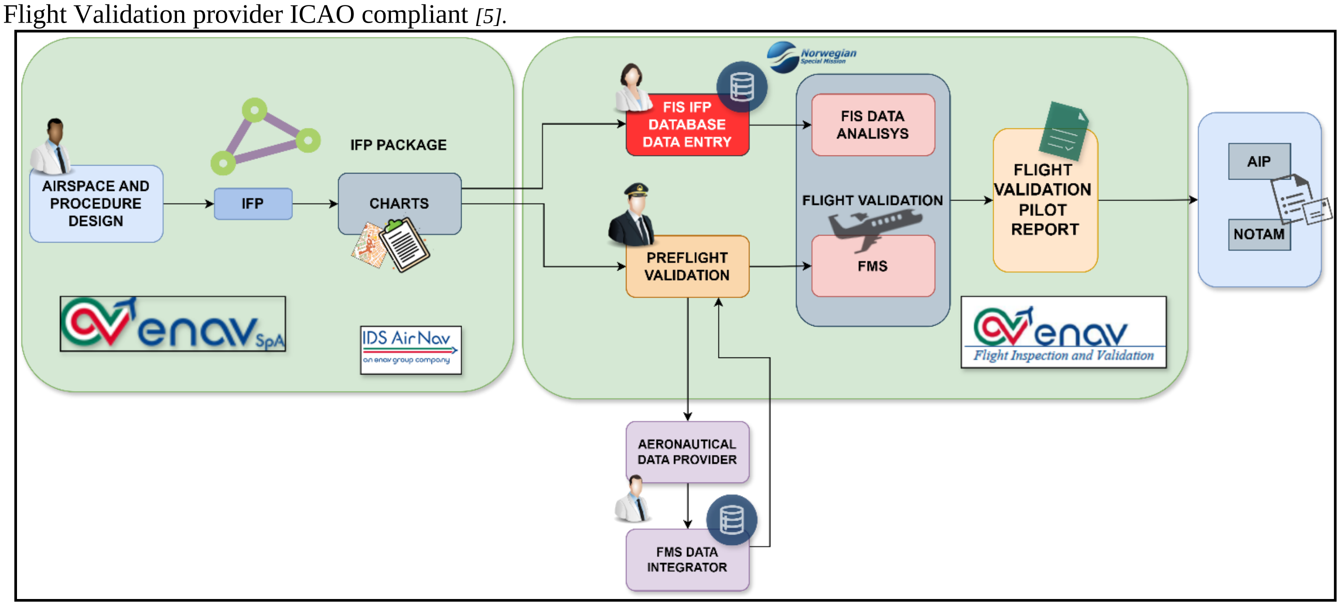


Figure 2 - Process of IFP creation and validation in ENAV

Starting from the Procedure Designer, the IFP is created and the IFP package is released. This package, composed of IFP charts and its tabular description, is then provided to Flight Inspection and Validation department before the preflight validation. A flight validation pilot is in charge performing the on ground preflight validation including checking data consistence, data quality and the IFP flight profile. After preflight validation, IFP package goes through the Aeronautical data provider and FMS data integrator encoding. In this step a new embedded and property database is built. FMS custom database is strictly dependent on FMS hardware and software specifics thus means that same IFP data will be encoded in different way depending on FMS specifics. This implicates a fundamental role of CRC algorithms during the entire process to ensure that data in the charts are consistent with data used to validate the procedure *[1]*. After FMS customer database has been created, it is checked by validator pilot and then uploaded to FMS for the flight validation step.

A parallel stream of data, starting from IFP package, is needed to provide IFP data to Flight Inspection System allowing analysis of all navigation errors subcomponents and related signal-in-space parameters at a suitable sampling rate during flight validation. The IFP FIS customized database is usually created by a manual data entry, starting from tabular description and IFP specifics into UNIFIS3000 FIS *[1]*. Flight activities of IFP validation are then performed, but after the described double encoding process starting from the same IFP package, one regarding the FMS, and one regarding the FIS.

As specified in ICAO doc 9906 the process of data quality and consistency control is performed by different actors, starting from FPDO, passing through validator pilot, aeronautical data provider, FMS integrator and FIS engineer. As known the data integrity level of the whole chain is as strong as the weakest part of it. In this case the weakest part of the process is surely the manually data entry activities. If safety is directly connected to the robustness and reliability of data encoding and decoding processes, data integrity and consistency control is also an important topic of the chain of IFP validation. This data integrity and consistency control is facilitated if all data are in a digital format, reducing the possibility of data manipulating and allowing the possibility to implement the efficiency of control algorithms.

<u>Requirements and proposal solution</u>

The proposal solution, aimed to mitigate errors in creating the FIS database due to manually data enter during the process of data conversion, is to automatically encode the IFP package in a known data format that can be then transferred to the FIS database. Particularly, two types of IFP FIS database format will be provided together with IFP packages: ARINC 424 and .kmz.

ARINC 424 is a file conforming to ARINC version 19 standards, a widely used aviation industry standard that specifies the format for aeronautical data, including information about airports, navigation aids, waypoints, airways, FAS Data Block and more. This data format is used in case of fixed-wing IFP flight validation activities performed with ENAV P180 fleet. The .kmz format data package, includes IFP data and the underlying ATS reference geography, is compatible with free web tool, returns IFP graphical view, and it is also used in Rotorcraft IFP validation activities for both PinS (Point in Space) and Low-Levels Routes (LLR) procedures to represent IFP desired flight path in case of RIFIS FIS. Both cases, and relative IFP FIS file format, are shown in the following figures.

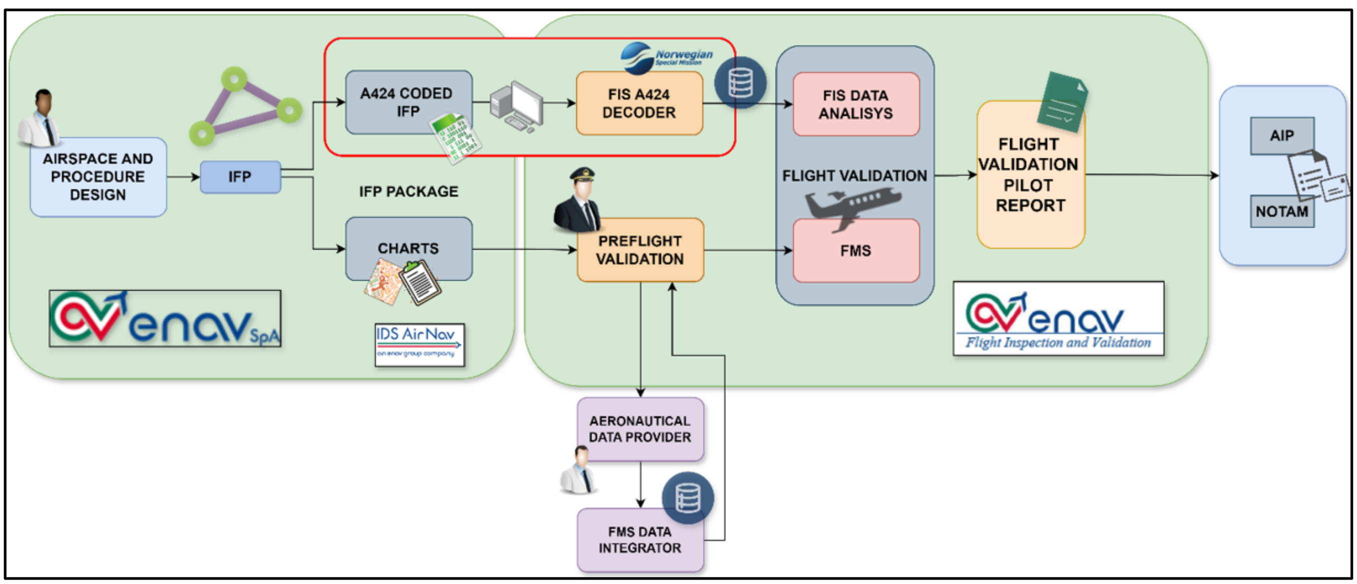


Figure 3 - Process of fixed-wing IFP creation and validation in ENAV, ARINC 424 format IFP coded

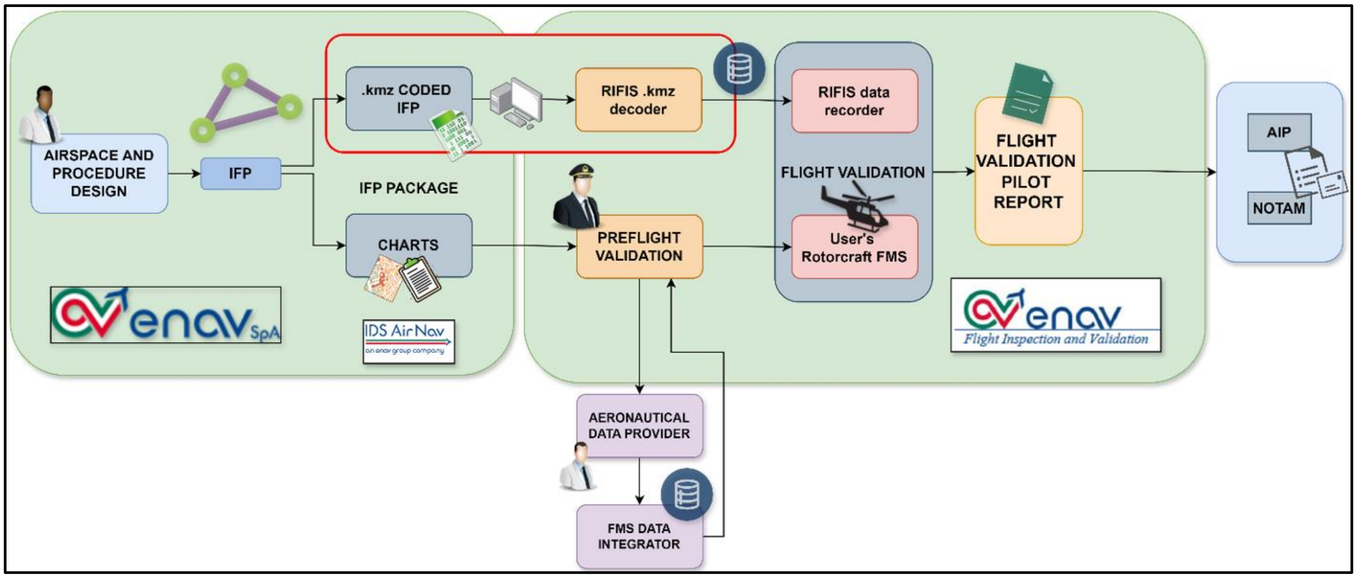


Figure 4 - Process of rotorcraft IFP creation and validation in ENAV, .kmz format IFP coded

FPDAM IFP FIS database encoding

The entire process of conversion has been created implementing an IFP encoder directly in FPDAM software. FPDAM, whose owner is IDS AirNav (an ENAV group company), offers an interactive three-dimensional environment allowing designer to create, visualize, verify, and maintain Instrument Flight Procedures in accordance with international standards, including ICAO Doc. 8168, ICAO Doc. 9905, and Canadian TP308, up to the latest amendment / change. It fully supports all types of instrument flight procedures including SID/departures, STARs/arrivals, and approaches for conventional, RNAV/PBN, RNP AR, APV/LPV, GLS, Baro-VNAV, guidance systems. Interoperability with other systems is facilitated through the import and export of aeronautical data using standard AIXM 4.5, AIXM 5.1, and ARINC 424 file formats. FPDAM features a dedicated graphical user interface that allows procedure designers to input or modify instrument flight procedure data, and the reference aeronautical data. This interface provides a comprehensive view of IFP data, divided into transitions and segments/legs. The 'Coded View' offers a representation of the procedure elements (transitions and legs) that closely aligns with the extended AIXM 5.1 FPDAM data model.

During the design process, the system performs automatic checks to ensure compliance with design standards (e.g., PANS-OPS, ARINC 424). For instance, the system can evaluate whether the sequence of Path and Terminator used in the procedure coding is permissible. Additionally, the system provides a tabular data view in a format ARINC lookalike, allowing the user to verify the procedure coding during the design process.

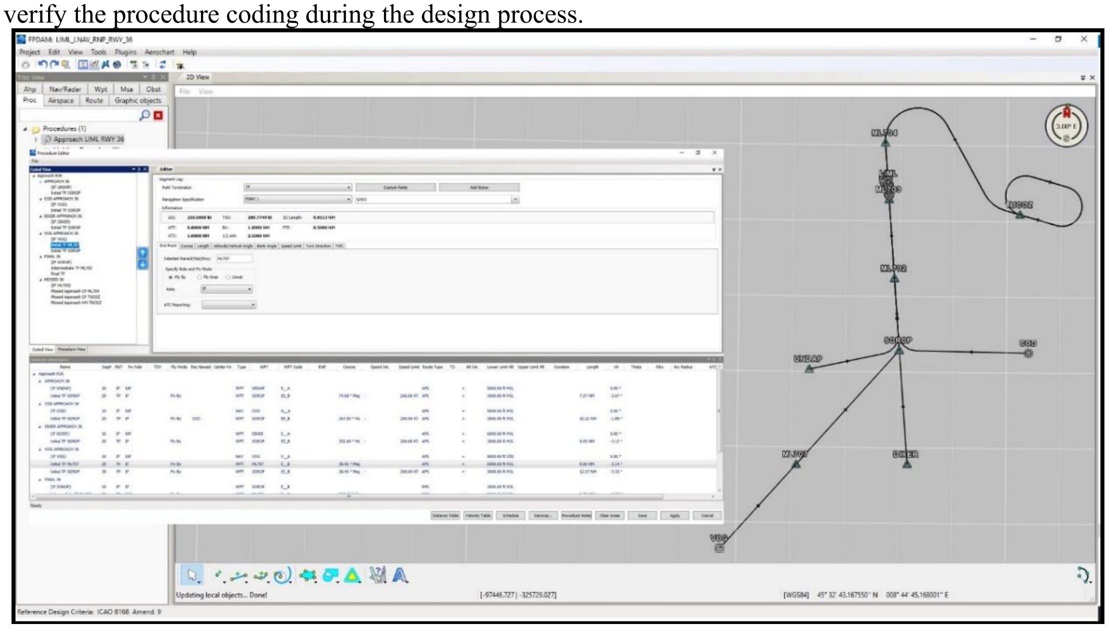


Figure 5 – IFP FPDAM design process

Once the design of an instrument flight procedure is completed, the designer can export a data package, that can be uploaded directly into the FIS systems, into two mentioned formats: ARINC 424 and .kmz.

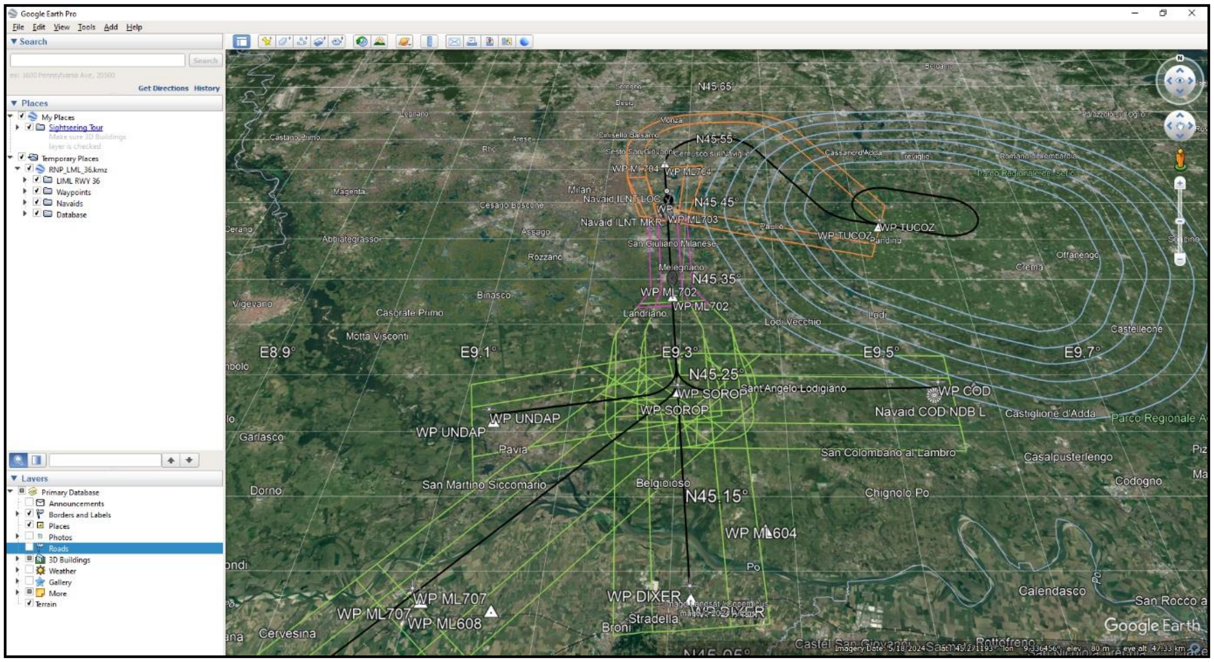
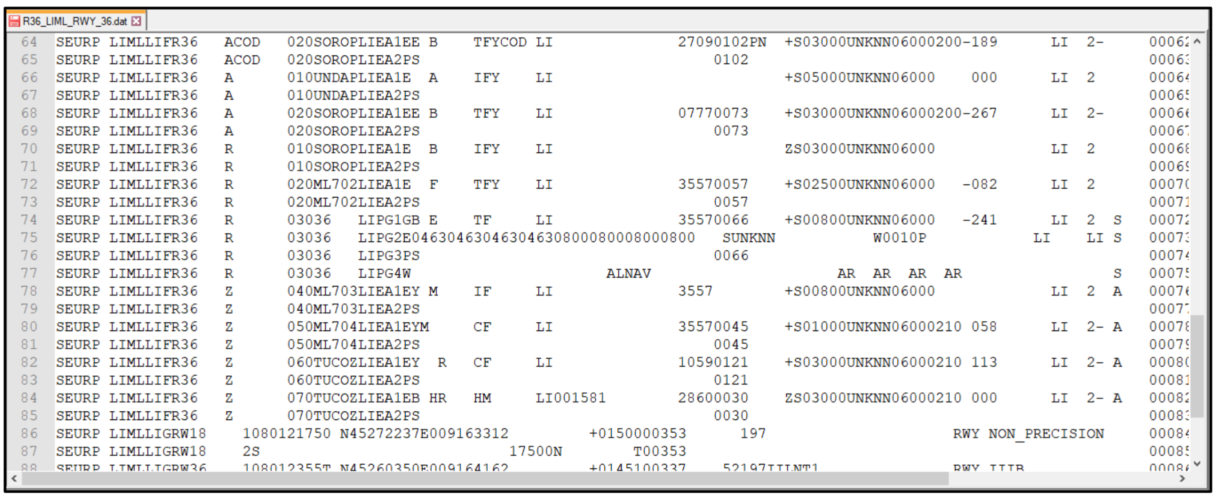


Figure 6. IFP .kmz format



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R36_LIML_RWY_36.dat
64  SEURP LIMLLIFR36   ACOD   020SOROPLIEA1EE B    TFYCOD LI              27090102PN  +S03000UNKNN06000200-189      LI  2-      00062
65  SEURP LIMLLIFR36   ACOD   020SOROPLIEA2PS                                 0102                                              00063
66  SEURP LIMLLIFR36   A      010UNDAPLIEA1E  A    IFY    LI                          +S05000UNKNN06000    000      LI  2       00064
67  SEURP LIMLLIFR36   A      010UNDAPLIEA2PS                                                                                   00065
68  SEURP LIMLLIFR36   A      020SOROPLIEA1EE B    TFY    LI              07770073    +S03000UNKNN06000200-267      LI  2-      00066
69  SEURP LIMLLIFR36   A      020SOROPLIEA2PS                                 0073                                              00067
70  SEURP LIMLLIFR36   R      010SOROPLIEA1E  B    IFY    LI                          ZS03000UNKNN06000             LI  2       00068
71  SEURP LIMLLIFR36   R      010SOROPLIEA2PS                                                                                   00069
72  SEURP LIMLLIFR36   R      020ML702LIEA1E  F    TFY    LI              35570057    +S02500UNKNN06000   -082      LI  2       00070
73  SEURP LIMLLIFR36   R      020ML702LIEA2PS                                 0057                                              00071
74  SEURP LIMLLIFR36   R      03036   LIPG1GB E    TF     LI              35570066    +S00800UNKNN06000   -241      LI  2  S    00072
75  SEURP LIMLLIFR36   R      03036   LIPG2E04630463046304630800080008000800   SUNKNN         W0010P           LI     LI S    00073
76  SEURP LIMLLIFR36   R      03036   LIPG3PS                                 0066                                              00074
77  SEURP LIMLLIFR36   R      03036   LIPG4W                     ALNAV                      AR  AR  AR  AR             S    00075
78  SEURP LIMLLIFR36   Z      040ML703LIEA1EY M    IF     LI              3557        +S00800UNKNN06000             LI  2  A    00076
79  SEURP LIMLLIFR36   Z      040ML703LIEA2PS                                                                                   00077
80  SEURP LIMLLIFR36   Z      050ML704LIEA1EYM     CF     LI              35570045    +S01000UNKNN06000210 058      LI  2- A    00078
81  SEURP LIMLLIFR36   Z      050ML704LIEA2PS                                 0045                                              00079
82  SEURP LIMLLIFR36   Z      060TUCOZLIEA1EY  R   CF     LI              10590121    +S03000UNKNN06000210 113      LI  2- A    00080
83  SEURP LIMLLIFR36   Z      060TUCOZLIEA2PS                                 0121                                              00081
84  SEURP LIMLLIFR36   Z      070TUCOZLIEA1EB HR   HM     LI001581        28600030    ZS03000UNKNN06000210 000      LI  2- A    00082
85  SEURP LIMLLIFR36   Z      070TUCOZLIEA2PS                                 0030                                              00083
86  SEURP LIMLLIGRW18    1080121750 N45272237E009163312         +0150000353      197                    RWY NON_PRECISION     00084
87  SEURP LIMLLIGRW18    2S                               17500N        T00353                                                  00085
88  SEURP LIMLLIGRW36    108012355T N45260350E009164162         +0145100337    52197IILNT1              RWY IIIB              00086
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Figure 7 - IFP ARINC 424 format

<u>NSM UNIFIS3000 Software developments</u>

As showed in figure 3 (diagram) and figure 10, ARINC 424 IFP data can be imported directly in FIS database reducing the possibility of any data corruption due to manually data entry. This approach ensures an improvement of both FIS database engineer work quality and flight validation process safety. A dedicated software tool, developed by NSM in the context of FIS database software manager, allows an easy and intuitive way to import all IFP procedure starting from ARINC 424 data provided by IFP designer. Such an immediate import process could also improve the FIS database engineer working efficiency, as noisy and repetitive data entry is avoided, and a better quality of IFP procedure data control is ensured. NSM has also developed a graphic map interface that allows FIS engineer to visually check the entire IFP procedure. This consistency control process should also be helpful to validator pilot during ground and preflight validation process to check the consistency between IFP charts, IFP FMS encoding data and all IFP data.

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 data manual typing 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. ICAO suggests flying the procedure on a pre-published navigation database on aircraft FMS. The FMS executes the coded procedures as interpreted by the coding house and FMS manufacturer, while the flight inspector can check if the procedure flown by FMS matches the intended design as received by the procedure designer.

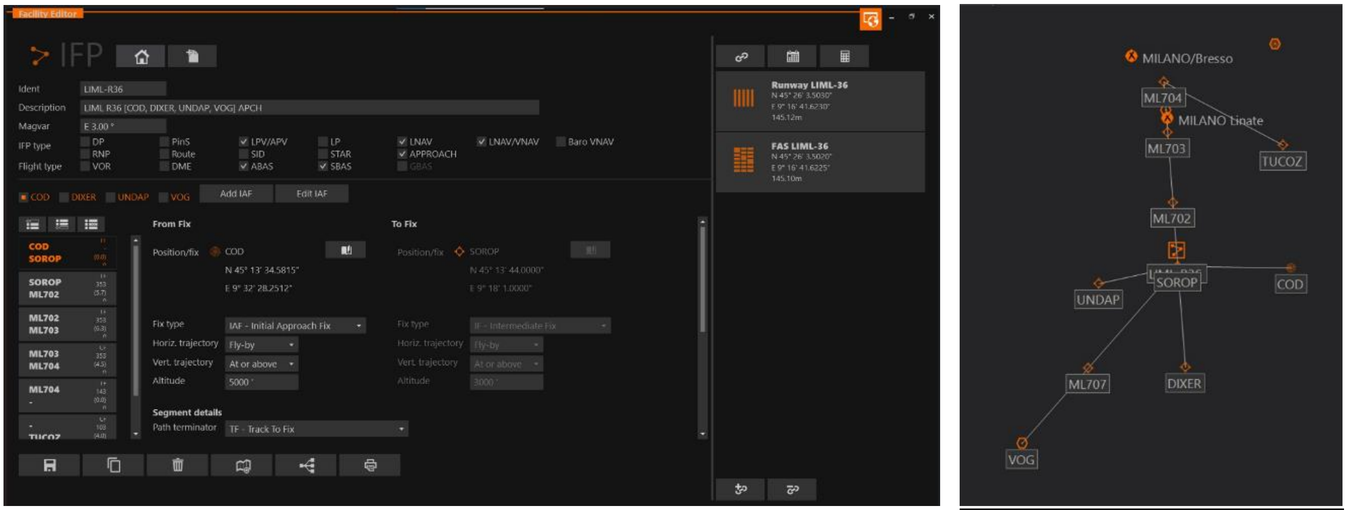

Figure 8 - IFP procedure imported from ARINC 424

Another benefit of importing ARINC 424 data into a flight inspection system is the enhancement of 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 addressing any issue that is found. During data 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.

Difference Report

Ident	Type	Imp.Latitude (°)	Imp.Longitude (°)	Imp.Alt (m)	Db.Latitude (°)	Db.Longitude (°)	Db.Alt (m)	Δ Hor (m)	Δ Latitude (m)	Δ Longitude (m)	Δ Alt (m)
LIML	Airport	45.4494444	9.2783333		45.4494463	9.2783013		2.5	-0.2	2.5	
LIML-18	Runway	45.4562139	9.2758667		45.4562153	9.2758669		0.16	-0.15	-0.02	
LIML-36	Runway	45.4343056	9.2782278		45.4343064	9.2782286		0.11	-0.09	-0.06	
ILNT	LLZ	45.4594167	9.2755278		45.45941	9.2755214		0.89	0.74	0.5	
ILNT	GP	45.4368333	9.2759722		45.4368198	9.2759754		1.52	1.5	-0.24	
LIN	VOR	45.46125	9.2752778		45.4612389	9.2752694		1.4	1.23	0.65	
LIN	DME	45.4614444	9.2743889		45.4614514	9.2743861		0.8	-0.77	0.22	
COD	NDB	45.2262778	9.5411944		45.2262726	9.5411809		1.2	0.57	1.06	
VOG	VOR	44.9645833	8.9701944		44.9645953	8.9701844		1.55	-1.33	0.79	
VOG	DME	44.9644722	8.9701944		44.9644823	8.9701833		1.42	-1.12	0.88	

Figure 9 - Comparison report

An ARINC 424 file can contain information about 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 links to relevant facilities, which makes the ARINC 424 data very useful to flight inspection system.

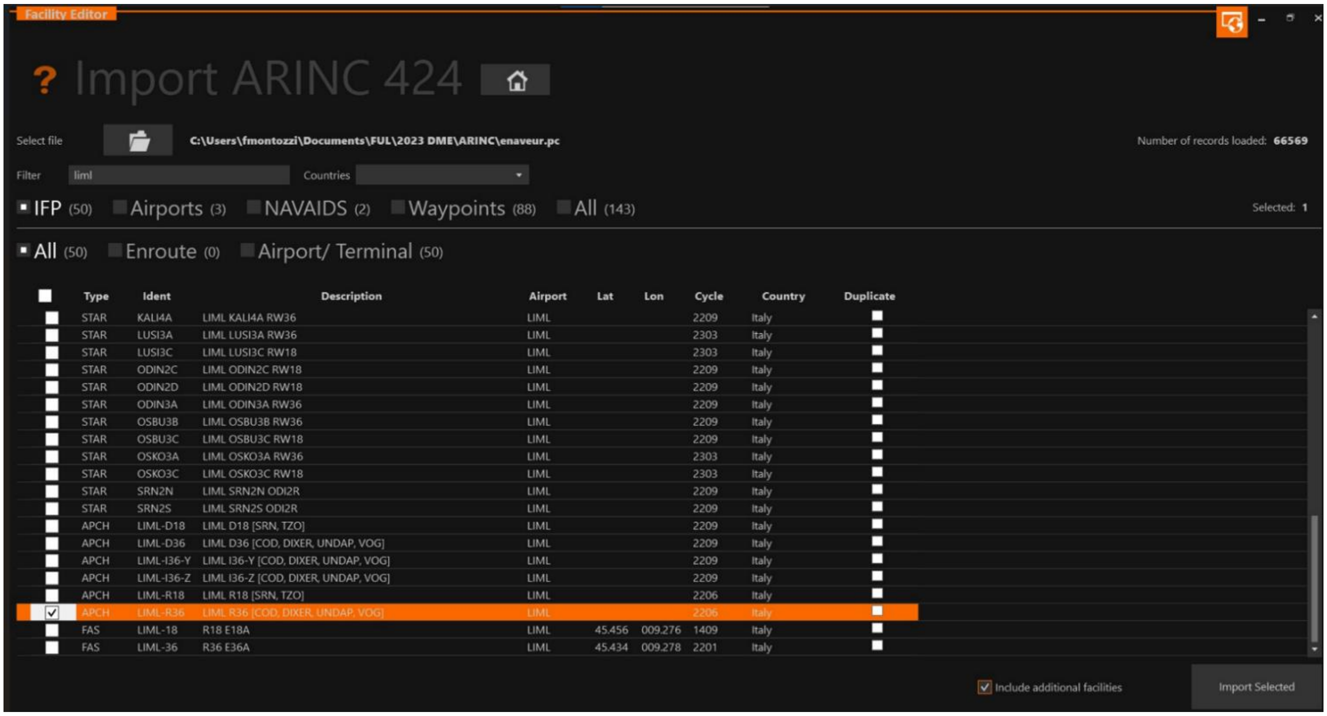

Figure 10 - ARINC 424 import window

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 are added automatically. By 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 exists in flight inspection facility database, the procedure will be linked to existing data and only new data are added.

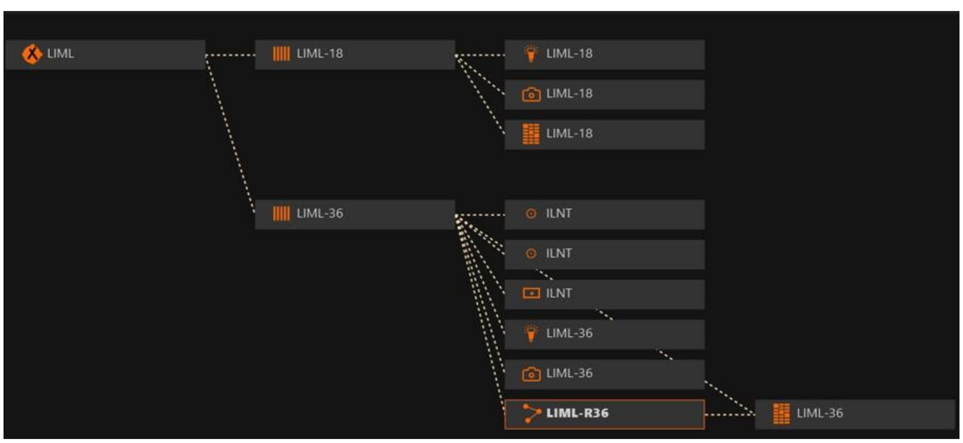

Figure 11 - Added facilities associated to the imported IFP with links.

<u>ARINC 424 DATA POSITION FORMAT AND ACCURACY ASPECTS</u>

As described this new feature add considerable benefits to flight validation activities but, even if ARINC 424 data can represent a complete navigation database, caution should be taken by flight inspection and validation organization using the ARINC 424 data into FIS for flight inspections purposes. There are no clear standards for the accuracy of ARINC 424 navaids position, or any specific rules and checks on how to fill navaids database with data coded in ARINC 424 format. Therefore, any data about navaids for flight inspection purposes should be questioned, examined and, if necessary, verified before doing flight inspection activities. Ignoring this evaluation can lead to inaccurate navaids flight calibration calculation that can cause an air navigation safety issue. 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 30 cm which is sufficient accuracy for most navaids except ILS and runway data, where higher accuracy is required. This means that, if data are proven to be reliable, having the FIS capability to import all facilities on an airport or all VORDME stations for a whole country correctly linked is a huge timesaver, and only the ILS coordinates need to be updated with higher accuracy data. To further highlight this aspect, ARINC 424 imported ILS data will be marked in FIS to make clear to the flight inspector, or to the navaids database manager, that the accuracy of imported position is limited by the ARINC 424 data set.

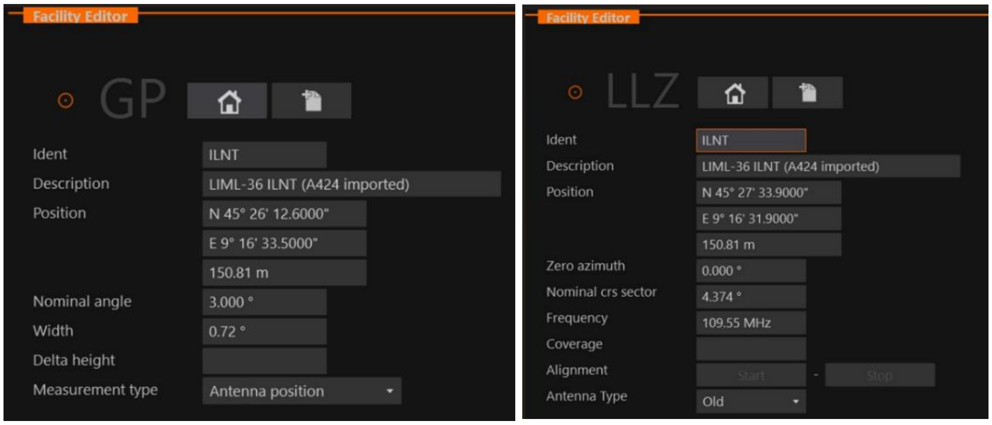

Figure 12 - Imported ILS data

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.

CONCLUSIONS

Since IFP validation is a critical and fundamental process for safety and reliability of the Air Traffic Navigation, it is important to study and continuously improve all the key steps concerning creation and dataset control system used during this process. Developing a tool of auto encoding and decoding of IFP data to a standardized protocol as ARINC 424, allow to enhance a critical step in IFP data set creation and control, improving consistency and quality control of the entire IFP data.
Automation of systems affecting creation and control of aeronautical dataset and database can surely increase the safety of all processes that uses this generated data and, relating Flight validation process, it can significantly optimize flight activities reducing possible mistakes in IFP data, thus, together with a significant safety improvement, can also reduce environment impact.

FUTURE WORK

In a digital and Artificial intelligence-oriented era, in which a lot of AI platforms and software are commonly used in our daily lives, it is possible to think about an AI oriented and user customized software in order to better perform IFP data quality and consistency control especially with machine learning based on user dataset related to stored IFP validation and inspection, thus can consistently improve all Flight inspection and Validation activities.

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