Flight Validation between Procedure Development and database integrity issues: challenges of finding the right balance in the Flight Validation domain

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0. ABSTRACT

Flight validation of instrument flight procedures is for many years now an established method to verify the quality of the procedure design process along the integrity path from initial design via charting, database coding and database packing. The following paper describes challenges that were identified in this field over the years. One challenge is a blurring of lines between flight validation and flight inspection: the advent of RNP procedures being based on DME/DME as the prime navigation source requires a closer look on the actual signal in space of these navigation sources, requiring a set of capabilities in the flight validation aircraft used going beyond the minimum set of parameters set in ICAO Doc 9906 Vol V. In a challenging terrain environment, like mountains, the actual performance of the navigation systems can only be simulated beforehand to a limited degree, turning the flight validation mission rather into a development effort vs. the required integrity check.

Both ICAO requirements as well as ever increasing cost pressure have led to a renewed look into using simulators for flight validation purposes. This paper addresses the issues and pitfalls an unreflected use of simulation might have on the outcome of the Flight Validation of a new Instrument Flight Procedure.

The paper closes in appealing to all stakeholders involved to address quality issues identified in the procedure design process and notably, its underlying fundamentally important databases, reassigning resources freed by the outphasing of legacy navaids to procedure design and database integrity.

1. GROUNDWORK: ICAO DOC 9906 VOL.V AND WHAT IT SAYS

The founding ICAO document for Flight Validation Doc 9906 Vol. V gives a clear differentiation between the task of Flight Validation of new Instrument Flight Procedures (IFP) and Flight Inspection of navigation aids [1].

In detail, it says:

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[1] ICAO Doc 9906, Vol V. page (xv) "Foreword"

a) *Flight validation is concerned with factors other than the performance of the navigation aid or system that may affect the suitability of the procedure for publication, as detailed in PANS OPS, Volume II, Part I, Section 2, Chapter 4, Quality Assurance.*

b) *Flight inspection is conducted with the purpose of confirming the ability of the navigation aids/system upon which the procedure is based to support the procedure, in accordance with the Standards in Annex 10 and the guidance in Doc 8071. Personnel performing flight inspection duties should be qualified and certified in accordance with Doc 8071, Volume I.* [2]

Doc 9906 Vol.V continues to stipulate minimum recording requirements for the aircraft on a Flight Validation mission; this pertains mostly to GNSS-based procedures and results in a technical requirement for a relatively simple data logging device. [3]. In essence, Flight Validation can be accomplished with a non-FIS-equipped aircraft, which indeed is done in a number of countries.

As cost-efficient as this approach may be, it clearly hits limits once Flight Inspection aspects are touched upon as well. Notably in the context of PBN / RNP procedures being based on navigational aids other than GNSS, i.e. DME/DME : reliable analysis of this navigation infrastructure requires Flight Validation being done by a suitably equipped Flight Inspection aircraft and qualified crew.

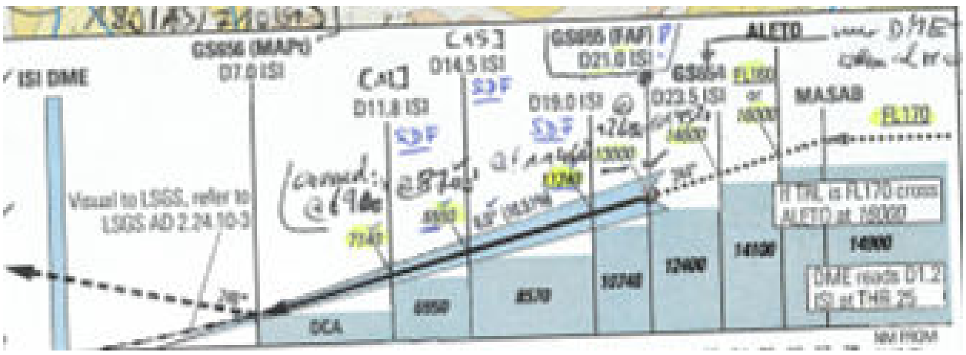
GNSS-based RNP procedures to be backed-up by conventional navigation aids is a standing requirement, i.e. as per ICAO PBN Manual Doc 9613[4] or EASA PBN Implementing Regulation EU 2018/1048[5]. New impetus to these legal requirements came in the wake of the geopolitical environment as of late, which demonstrated the vulnerability of GNSS, a fact well known for 25 years, to a profound scale.

2. WHEN FLIGHT VALIDATION TURNS INTO PROCEDURE DEVELOPMENT WORK

When a conventional navigational aid, i.e. DME/DME, is the back-up solution for a RNP procedures, the validity and integrity of the respective signal coverage along the trajectory of the IFP has to be verified.

Unfortunately, the performance, accuracy and integrity of the underlying navaids can only be simulated upfront to a certain degree. This is even more pronounced in challenging terrain conditions, i.e. the Alps in Switzerland or Austria.

Due to its stakeholder customers Skyguide of Switzerland and Austrocontrol of Austria, FCS is confronted with these challenges on a regular basis. A fitting example can be found in Sion LSGS, Switzerland (see Attachment A.): the challenging terrain / obstacle situation requires a number of approaches at various heights / altitudes to verify the final procedure outlay, as can be seen in the excerpt of the vertical profile below:



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[2] ICAO Doc 9906, Vol V. page (xv) “Foreword”

[3] ICAO Doc 9906, Vol V., 2.4.7 Record flight validation

[4] ICAO Doc 9613 Performance-based Navigation Manual Volume I, Part A, Chapter 2

[5] (EU) 2018/1048 Annex AUR.PBN.2005 (b) (2)

Another fitting example is Geneva LSGG in Switzerland, where both RNP STARs, SIDs and transitions to ILS are supposed to be backed by a complex DME/DME infrastructure, see Figure 1:

Complex in so far, as terrain interferes with expected signal propagation, as could be proven over the course of the various Flight Validation missions. This was in part surprising as the signal propagation simulation run prior finalizing the concept did not hint at any major problems, see Figure2:

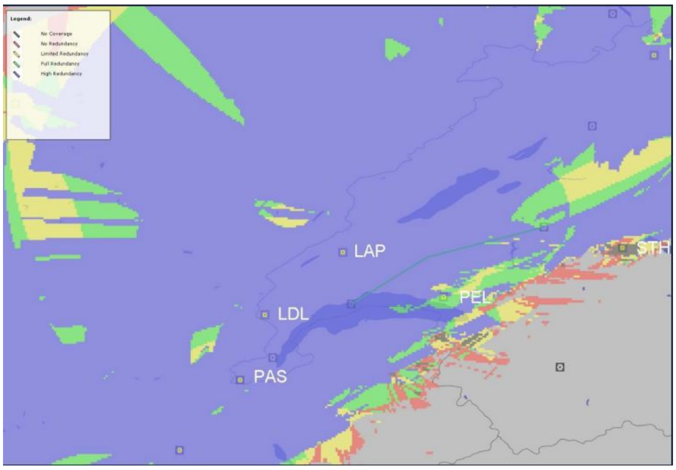

Figure 2: DME performance simulation Geneva Source: Skyguide

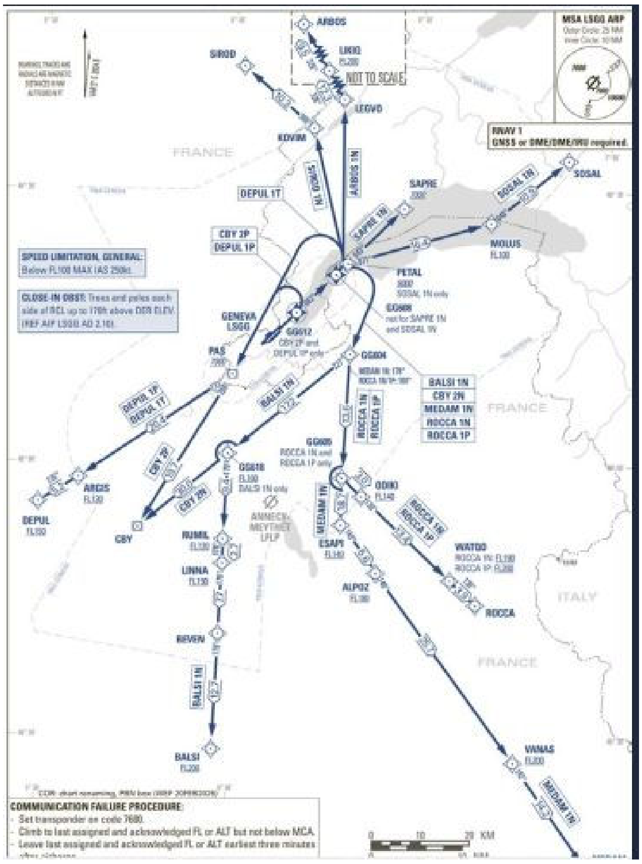

Figure 1: DME system set-up Geneva Source: Skyguide

As a result, the ANSP, together with FCS as the Flight Validation service provider, had to come up with comprehensive and detailed work packages for the upcoming Flight Validation trials, addressing various aspects of the intended flight profile (various altitudes, nav aids to be tuned, etc.). As a sample, the resulting work instruction or mission card would look like in Figure 3:

Here, the same procedure is flown in various avionics modes (AUTO-tune vs. Manual tune) and altitudes (7.000 vs. 6.700 ft).

One of the surprising outcomes of the Geneva project was the fact that the result in part depended on the actual aircraft used, as the 2 aircraft of FCS feature a different avionics suite in the cockpit (ProLine 21 vs. ProLine Fusion). Although both suites being from the same manufacturer Collins, they showed some in part significant different behavior in accepting and thus, tuning various DMEs.. This goes to show the challenges and the complexity of considerations that have to be taken into account when due to terrain and / or obstacle considerations designing procedures at the outer fringes of what is possible as per ICAO PANS OPS criteria. The resulting Flight Validation mission is not necessarily a mission in the strict sense of Dc 9906 Vol.V, where the emphasis is

Flight Calibration Services

Procedure and Enroute Calibration Briefing Sheet

Note:
Groundspeed for Airway and SID Calibration: 180kts or less / Approaches: 160kts or less.
Climb Gradient for SID: 200ft/NM, for Missed Approach Procedures: 168ft/NM (if not otherwise published).
On item no. listed as "ferry", vectors or holdings may be assigned by the controller.

Airport: LSGG	Runway: 22/04	Callsign: FCK1FT	Date:

Nr.	Procedure	From WP Altitude	To WP Altitude	Remarks
1	FRI 1R	FRI 7000	SPR 7000	AUTO-tune; SPR/FRI/GVA included! (Mode "A")
2	FRI 1R	FRI 7000	SPR 7000	AUTO-tune; SPR/FRI/GVA excluded! (Mode "B")
3	FRI 1R + ILS22 incl. MAP	FRI 7000	SPR 7000	AUTO-tune; Decission after Nr. 1 or 2 (Mode A/B?)
4	Options: FRI 1R + ILS22 incl. MAP	FRI 7000	SPR 7000	Manual-tune; SPR/FRI/GVA excluded!
5	FRI 1R @ MOCA	FRI 6700	SPR 4700	AUTO-tune; SPR/FRI/GVA included! (Mode "A")
6	FRI 1R @ MOCA	FRI 6700	SPR 4700	AUTO-tune; SPR/FRI/GVA excluded! (Mode "B")
7				
8	- RWY04 -			
9	FRI 1P	FRI 7000	GG512 7000	AUTO-tune;SPR/FRI/GVA included! (Mode "A")
10	FRI 1P	FRI 7000	GG512 7000	AUTO-tune;SPR/FRI/GVA excluded! (Mode "B")
11	FRI 1P + ILS04 incl. MAP	FRI 7000	SPR 7000	AUTO-tune; Decission after Nr. 9 or 10 (Mode A/B?)
12	Options: FRI 1P + ILS04 incl. MAP	FRI 7000	SPR 7000	Manual-tune; SPR/FRI/GVA excluded!
13	FRI 1P	FRI 6700	INDIS or GG512 tbd	AUTO-tune;SPR/FRI/GVA included! (Mode "A")
14	FRI 1P	FRI 6700	INDIS or GG512 tbd	AUTO-tune;SPR/FRI/GVA excluded! (Mode "B")
15				

Figure 3 Source: FCS

on verifying the integrity of the Procedure Design – to – Database Path. It is rather a research and development effort, requiring additional Flight Validation missions once all parameters are identified, verified and agreed upon by all relevant stakeholders. To that end it should be regarded as an additional effort to be undertaken in the wake of the Flight Operational Review (FOR) as per the pending Second Edition of Doc 9906 Vol.V,

Needless to say that this approach involves considerably more resources in terms of manpower, time and money, which must be taken into considerations when setting up a IFP project in this challenging environment.

3. THE USE OF FULL FLIGHT SIMULATORS IN THE FLIGHT VALIDATION DOMAIN

Not least the cost implications as per above have led to a growing desire of using Full Flight Simulators (FFS) in the Flight Validation domain.

ICAO Doc 9906 Vol.V encourages the use of an FFS [6]. In Required Navigation Performance – Authorization Required (RNP – AR) IFPs the use of FFS is mandatory as per ICAO [7]. Here the main rationale is to minimize the risk to the Flight Validation mission (aircraft / crew) in the light of a potentially challenging operational environment due to obstacles / terrain.

Further reasons and benefits for using a FFS is the repeatability of the profile flown and a positively controlled environment in terms of wind, weather, speeds, aircraft configuration and weight. Furthermore, Flight Validation in FFS has no impact on actual traffic, and thus no impact of at times limited capacity, notably at major airports.

On top, using FFS in Flight Validation might help to minimize the environmental impact of the Flight Validation mission (noise, fuel = CO2).

The downside: FFS only give a first indication of the suitability of a proposed IFP, as the integrity of notably the terrain and obstacle databases unfortunately is not guaranteed. The terrain and obstacle databases for simulators are not subject to the strict regulatory and certification environment as the databases for a Flight Management System (FMS) and thus, are not subject to a strict update cycle according to i.e. AIRAC cycle timeframe. In fact, in most cases updates to the terrain and obstacle database of a simulator, with an update of its visual system that goes along with it, is done on a rather irregular interval. Apart from question marks this fact raises with regard to the integrity of terrain and obstacle data, modern Enhanced Ground Proximity Warning System (EGPWS) or Terrain Awareness and Warning Systems (TAWS) inevitably cannot be trusted on new IFPs in the simulator.

Furthermore, the correct propagation and reception functions of navigational aids cannot be predicated / simulated in a FFS reliably. This applies to both legacy / conventional navaids like VOR or DME as well as GNSS.

The connectivity to and suitability of a new IFP in a given airspace structure cannot be validated reliably in FFS either – as this might be a vital aspect of any IFP design, especially in complex and busy airspace, the lack to validate that aspect will have a limiting effect on the meaningfulness of a Flight Validation in a FFS only.

In essence, a certain amount of actual Flight Validation will be indispensable even after prolonged FFS trials. For RNP AR ICAO is straight forward in requiring both (see above), for all other IFPs it would be up to the ANSP and its respective Regulator to agree on a scheme that maximizes the benefits of using a FFS and still covers all aspects of the Flight Validation requirements as described above.

One example for that scheme might be flying a SID in the actual aircraft only until above MSA, with all other aspects, like database coding, waypoint sequencing, etc., having been validated in the simulator.

[6] ICAO Doc 9906, Vol V. Chapter 2.3 and on
[7] ICAO Doc 9906, Vol V. Chapter 2.3.1.4

4. THE CHALLENGE TO MAINTAIN DATABASE OVERSIGHT

Databases for Flight Management Systems (FMS) are at the core of PBN / RNP procedures. In turn, validating the integrity of the path from initial procedure design and charting to coding to packing of the final FMS database is the main objective of any Flight Validation. The challenge here is the huge variety of FMS and their combination with the respective avionics suites across the aviation fleet of today, caused in part by the long production run of individual types, like the Airbus A320 or the Boeing B737, which are in production of close to 40 years and 60 years, respectively. Ensuing obsolescence issues, together with specific market requirements, led to an almost indefinite number of permutations of FMS and avionics, which in turn lead to an astonishing high amount of individual database types that have to be maintained by both the FMS as well as aircraft manufacturers, or more precisely, aircraft integrators. As an example, Airbus alone is distributing more than 600 (!)[8] individual database types every AIRAC cycle (28 days), to cover the variety of its aircraft fleet.

This begs the question what to do with feedback received from the Flight Validation as well as the regular user community as to the quality / identified errors of FMS databases. Not least in the light of the sheer overwhelming amount of databases to be maintained, as per the experience of the author over the last couple of years the current stance of ANSPs or even Regulators is to turn a blind eye. The reasoning behind that stance is the fact that legally the scope of responsibility and accountability ends at the point the respective IFP design organization issues its final product (chart, textual & tabular description, including suggested coding as per ARINC 424). It is then up to the internal quality assurance procedures / mechanisms of the operator to catch any potential errors in the data chain.

Strictly legally speaking that stance does carry some merit, as EASA, for instance, is adamant that the responsibility for maintaining the accuracy of data in operational, flight management, and navigational systems ultimately lies with the aircraft operator [9]

In reality this stance is delusional to a certain degree, as only big air carriers on scheduled air travel have the resources and the benefit of time to apply that regulation to a meaningful extent. All other stakeholders in the aviation community, like smaller operators, or the Business or Special Operations community, with a considerable amount of their work being ad-hoc, simply lack the time for that in-depth database integrity check. A classic example being air ambulance operations, where time is of the essence.

Thus this legally conforming approach runs the grave danger of serious errors in the data chain being overlooked and / or not being addressed properly, which in the domain of PBN / RNP is no longer acceptable, as a "safety net" in the shape of legacy navaids in these types of procedures does not exist anymore. Additionally, ICAO is still quite clearly adamant that the State remains ultimately responsible for its IFPs. [10] With databases being a systemic, integral part of any PBN / RNP IFP, in a technical sense, States do not have the option to shy away from the task of oversight over the complete Procedure Design-to-Database Integrity.

It is therefore strongly recommended that the State – or the ANSP tasked with caretaking of the IFP domain of the State – should re-direct some funding freed-up by phasing out legacy navaids towards a clearing entity within its organization to act as the focal / clearing point for all matters IFP and databases, to liaise and exercise oversight of the various stakeholders involved (Data houses, avionics manufacturers, aircraft manufacturers/integrators). Admittingly, this is a daunting task, but in the light of the ongoing concentration process of the aviation industry, with just a handful of first tier airframe as well as avionics manufacturers remaining, and effectively 3 big data houses providing all required databases, this task seems to be manageable and should be taken on.

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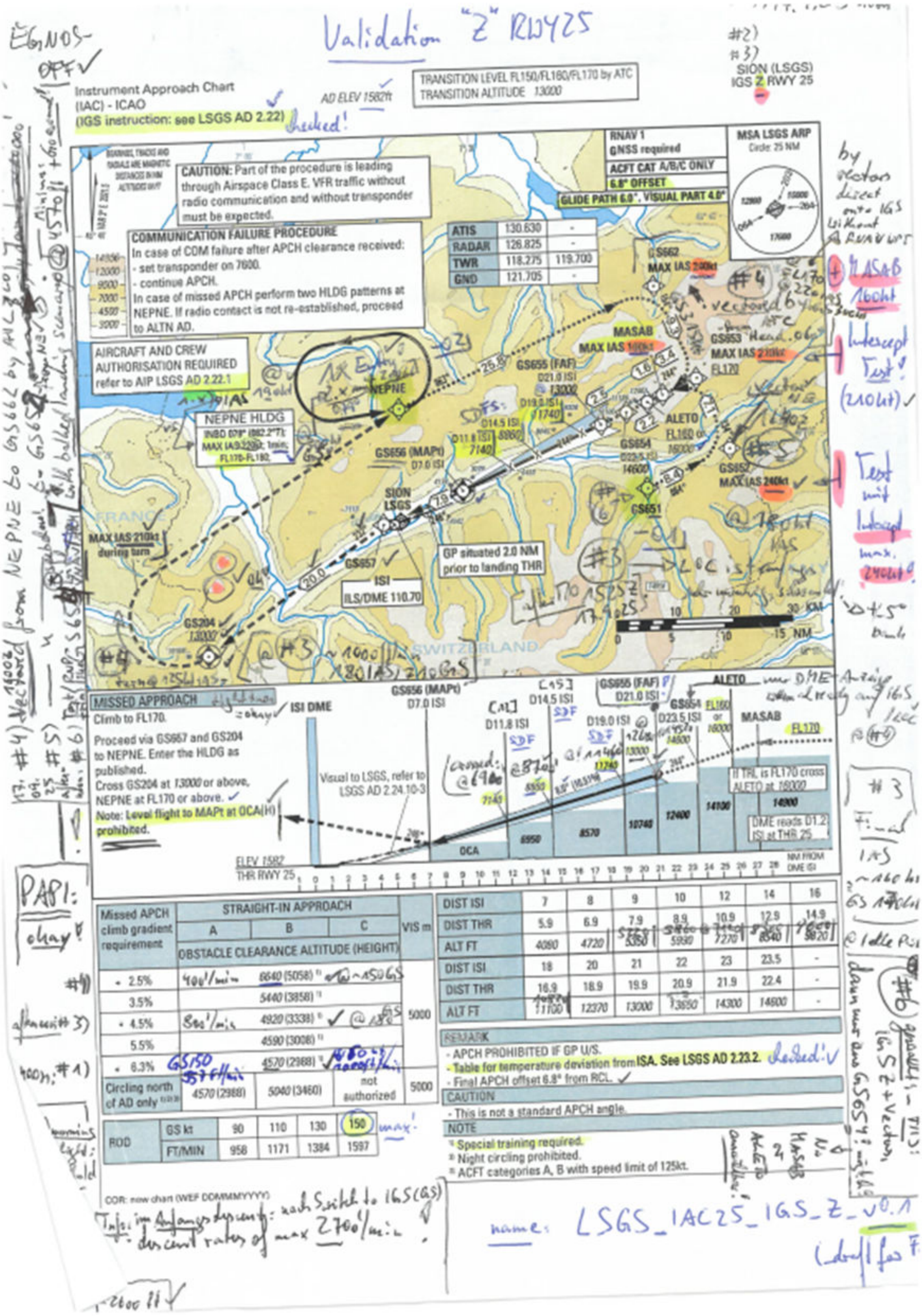
[8] Patrice ROUQUETTE - Mission & Flight Operations Expert Airbus, verbal note, IFPDAVA conference, Oslo, May 2024

[9] Regulation (EU) No 965/2012 on Air Operations (Part-ORO/Part-CAT); ORO.GEN.110 (Operator Responsibilities)

[10] ICAO Doc 9906, Vol V. Page (xv), last paragraph "Foreword"; ICAO Doc 8168 PANS OPS, Volume II, Part 1, Section 2, Chapter 4 "Quality Assurance)

Attachment A. IGS Z RWY 25 Sion LSGS:



Source: Skyguide / FCS O.Schomaker