Update of ICAO Document 8071 Volume I

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ABSTRACT

The ICAO Navigation Systems Panel (NSP) has finalized the update of Doc 8071, Manual on Testing of Radio Navigation Aids, Vol 1 (Testing of Ground-Based Radio Navigation Systems), 4th Edition incl. Amendment 1, October 2002 [1]. The update brings Doc 8071 Vol 1 in line with numerous updates in Annex 10, and removes all material on flight validation, which is contained in ICAO Doc 9906, Quality Assurance Manual for Flight Procedure Design, Volume 5 [2]. The update to the general chapter includes new guidance on inspection periodicity, and brings it in line with current practice. The following chapters were also extensively reviewed. The paper will summarize those changes and associated rationales especially on VOR, DME and ILS. Examples are the recommendation of a new assessment methodology for VOR and updated guidance on ILS displacement sensitivity. The paper also summarizes the ongoing work on the update of Volume 2 on GNSS.

INTRODUCTION

The need to update Doc 8071 was primarily motivated by amendment 84 [3] to Annex 10 [4]. The amendment was published in 2008 and became applicable in 2009. The amendment implemented the results of the NSP review of the ILS, VOR, NDB, DME and MLS standards, recommended practices and associated guidance material. The aim was mainly to amend obsolete and ambiguous provisions, in line with normal standards maintenance practice. Only a small part of amendment 84, relating to ILS critical and sensitive areas, was rejected by States. In the meantime, updated ILS critical and sensitive area guidance material was accepted [5]. The corresponding amendment 91 of Annex 10 will become applicable by 8 November 2018. This amendment has no impact on the update of Doc 8071.

Another aspect that led to some restructuring of Doc 8071 was the removal of material related to flight validation. Since flight validation using a typical flight inspection aircraft is only one method of performing flight validation and only part of an overall instrument flight procedure design validation effort, it was considered better to refer this material to Doc 9906, under the responsibility of the Instrument Flight Procedures Panel (IFPP). This way it could be ensured that flight inspection organizations would have a more complete picture of the overall effort in which they engage in. Much of the flight validation material was contained in Doc 8071 Volume 2 on Testing of Satellite-Based Radio Navigation Systems, thus the impact on Volume 1 was limited. However, it illustrates that the previous notion of Doc 8071 providing a complete “one stop shop” for anything related to ground and flight testing of radio navigation aids is no longer appropriate. However, the removal of flight validation material from Doc 8071 does not preclude that the same organization which conducts flight inspection may also conduct flight validation.

The update of Doc 8071 Volume 1 was completed by the Conventional Navigation Aids and Testing Working Group (CNT WG) at the 4th panel meeting in October 2017, followed by a correspondence review by the full panel. This was done because a line by line review in session at the NSP plenary would have taken too much time. The correspondence review was completed on 5 March 2018 and the document handed over to the ICAO secretariat. Unlike Annexes to the Chicago Convention [6], which undergo a State Letter approval process, regular guidance documents are published by ICAO directly under the authority of the Secretary General. While ICAO could not commit to a publication date, it is expected that at least an advance online edition will be made available in summer 2018.

DOCUMENT STRUCTURE, VOL 2 OUTLOOK AND ODDITIES

New Volume 1 Structure

Chapter 1 on general matters underwent an overall review, keeping the main structure intact, including the attachments on the flight inspection aircraft, documentation and interference. Similarly, the chapters on VOR, DME, ILS, NDB, Markers and PAR remained, undergoing significant revision. Chapter 8, currently titled "flight inspection of instrument flight procedures" (which should have been called flight validation, but the title comes from before the time when a clear distinction was made between the two) was deleted and replaced with a new chapter on PBN. Previously, Doc 8071 contained some text on DME/DME RNAV in the DME chapter. While the text is being referenced in Annex 10 it still had limited visibility. Meanwhile, the PBN Manual (Doc 9613 [7]) specifically identifies the activity of flight inspection of PBN procedures (as in, verification of the signal in space). Therefore, the content on DME/DME RNAV was moved to the new chapter 8 and revised to give more context and make an easier link to the PBN Manual.

Finally, the appendices providing a copy of the ITU recommendations relating to FM immunity were deleted. These are easily available from ITU today and are of limited use without additional test procedures, which is an unpublished document that can be obtained on request from the ICAO secretariat. Deleting the ITU documents themselves (but not the references) eliminates configuration control problems when the ICAO-external documents are updated.

Shrinking Volume 2

With the removal of flight validation material, volume 2 on GNSS will become quite thin. The NSP debated if, after just splitting into two volumes in the last update in 2000, Doc 8071 should not recombine volumes 1 and 2. Since NSP is aware that in many States, Doc 8071 is used in contract specifications, often translated into a specific national language, this was rejected. The aim was to keep the document structure as constant as possible in order not to create a lot of subsequent administrative effort in States. Especially since many people may actually appreciate when a document is thin.

The main chapter changes, according to the current ICAO NSP Doc 8071 Vol. II work plan, can be summarized as follows:

- Chapter 1 (General) will be shortened to contain only GNSS-specific aspects, and not repeat things already contained in chapter 1 of volume 1;
- Chapter 2 on ABAS supporting Non Precision Approaches will become a more general chapter on GNSS core constellations and RAIM, and make a link to the new material in Doc 9849, GNSS Manual [8], on performance monitoring;
- Chapter 3 on SBAS will be significantly shortened, but may (subject to discussion) be updated to contain more material relevant to how the SBAS provider demonstrates compliance to Annex 10 requirements (thus not really for a flight inspection audience);
- Chapter 4 on GBAS will be updated based on operational implementation experience and to support the new GAST D standards (supporting Cat III operations). The GBAS chapter will be the most significant part of volume 2;
- Chapter 5, previously on Flight Validation, will be entirely removed and replaced with a chapter that will discuss RFI measurement techniques, building on attachment 3 to chapter 1.

While it is hoped that the work can be completed in 2019, this is mainly dependent on how much work is required to update the GBAS chapter.

The Third Volume

Officially, Doc 8071 contains three volumes. The third volume covers the testing of surveillance radar systems. The rationale for covering surveillance systems in a document titled radio navigation aids can be speculated on:

- Navigation and surveillance services are related in terms of ITU designations (radio-navigation is a subset of radio-determination and closely related to radio-location)
- Some navigation systems use radar techniques, which are commonly associated with surveillance systems (Precision Approach Radar, PAR, and radio altimeters, for example)

However, no formal explanation exists for why this was done by ICAO other than for the simplification of its publication processes. In terms of flight inspection practice, it does make some sense to group these activities in one document. While volume 3 is under responsibility of the ICAO Surveillance Panel, they have struggled to maintain volume 3, which discusses traditional radar systems. The focus of the Surveillance Panel activities was on new surveillance technologies such as ADS-B and Multilateration. While they are in the process of completing a minor, minimum change update of volume 3 (mainly to remove dramatically obsolete text), Doc 9924, Aeronautical Surveillance Manual [9], contains up to date guidance on testing of modern surveillance

systems. A reference to this document will be included in Doc 8071.

Unofficially, an alternate "third" volume exists on the Microwave Landing System, MLS. The document remains available from the ICAO NSP secretariat on request. However, given the low level of implementation of MLS, no effort will be made to integrate it into the formal Doc 8071 document structure.

STATUS OF ICAO DOC 8071

Only "shall" statements in SARPS (Standards and Recommended Practices) and PANS (Procedures for Air Navigation Services) represent binding requirements in the ICAO framework. Doc 8071 is a non-binding, voluntary guidance document. Its reason for existence however, is linked to a standard:

> 2.2.1 Radio navigation aids of the types covered by the specifications in Chapter 3 and available for use by aircraft engaged in international air navigation *shall* be the subject of periodic ground and flight tests.
> (Chapter 2.2, Ground and flight testing, of Annex 10 Vol 1)

The way the Annex 10 requirement is phrased (*periodic tests*) makes it clear that the purpose of Doc 8071 is to ensure the quality and safety of in-service performance of navigation facilities. Even if Doc 8071 contains commissioning and site proving tests, the aim is to ensure that standards continue to be met in the installed environment, and NOT to demonstrate compliance with Annex 10 requirements in the sense of a design approval. Any navigation aid that is installed to support international air navigation must first go through a design acceptance test to ensure that performance requirements are satisfied. In many cases, additional industry standards are available to support such design approvals (such as EUROCAE ED-57 for DME transponders). Simply demonstrating that a facility can meet Doc 8071 test procedures is clearly not enough to ensure that, for example, an ILS is providing the integrity required by Annex 10.

NSP appreciate that many stakeholders take the content of Doc 8071 very serious, especially in States where national aviation legislation elevates ICAO guidance to standards. While the NSP undertakes all reasonable effort to ensure the document is error-free and meeting the objective of ensuring safe in-service performance of navigation aids, it is still a challenge if guidance material is being interpreted too strictly. One specific example to illustrate this are the minimum positioning subsystem accuracy tables in the ILS chapter. A new table was added to complement the existing angular specification (linked to theodolite operations) with linear truth system tolerances. Due to the common application of Differential GPS for such systems, many industry participants expressed a desire for such guidance. However, others continue to feel that both tables are superfluous and that the reference system performance can easily be derived from the actual ILS system and associated testing requirements.

To meet a commonly expressed need, the tables were added to serve those which find such tables useful. Conversely, the derivation of the values does not take into account that at the constraint points close to the facilities, the parameters to be measured are also very noisy, which naturally limits the usefulness of having a highly accurate reference system, since instantaneous measurements may not be repeatable. Some IFIS participants may recall the numerous debates on the ILS Reference Datum Height (RDH) measurements in that context. It would have been excessive for NSP to undertake a detailed analysis of reference system requirements with a view to identify the "truly minimum" accuracy requirements. The values in the table are considered clearly sufficient and practically achievable, but it cannot be excluded that reference systems with slightly worse accuracy performance, when combined with suitable averaging techniques, are not also sufficient to ensure the required facility in-service performance.

Another example that illustrates that readers of Doc 8071 should not expect that everything is spelled out in detail for them in test procedures is the ILS coverage. The coverage flight check requires that: "*Flights at appropriate heights are required for routine and commissioning inspections to ensure the following coverage requirements are satisfied"*. The statement is followed by a verbatim copy of the Annex 10 text, including the more recent option for reduced coverage at the far-out low corners (±35°). Obviously, flying the customary arc at the nominal 17NM threshold distance with varying altitudes in the 15 to 35 degree sectors could be challenging. Doc 8071 expects that Air Navigation Service Providers (ANSP) and flight inspection providers, based on an engineering understanding of the propagation environment and the localizer antenna diagram, can determine a reasonable set of flights to ensure that the signal meets the minimum standards and is operationally suitable.

Doc 8071 should therefore be seen as a "one acceptable means of compliance" which never intends to exclude other means of compliance, as long as the high level Annex 10 requirements are met. It is expected by ICAO and essential that sound engineering judgement continues to be applied to all of Doc 8071 and the associated testing activities.

General Doc 8071 Editorial Principles

A fundamental principle of all ICAO guidance documents is that they may never contradict the standards of an Annex, as SARPS always take precedence. In some cases, guidance has existed that could be seen as telling industry

how to deviate from a standard. These cases are being eliminated. A particular challenge in this context are the testing requirements tables: they provide only limited space to summarize requirements for which a substantial standards document (Annex 10), was written in the first place. The tables can never replace Annex 10. They are provided to give a quick summary of the key numbers, for ease of reference of test personnel. If there is any uncertainty on the meaning of any values which are summarized in the Doc 8071 requirements tables, Annex 10 must be consulted as the ultimate reference. That is the reason for providing table references to the appropriate paragraphs in Annex 10, while ensuring through the table summaries that Doc 8071 is a sufficiently stand-alone document.

A similar issue is the description of test procedures. In many cases, the requirements table entries also summarize the test procedure of a particular parameter. But a table entry can never reproduce the full discussion of a test procedure, which is described in the main body of Doc 8071. Again, the summary tables are there to give a quick memory aid for test personnel in their daily work. If there are any questions on how a measurement is to be made, the guidance text in the main part of the document chapters is to be consulted.

HIGHLIGHTS OF CHAPTER CHANGES

Chapter 1: General

The majority of restructuring and adding of material took place in the general part. More emphasis has been put on the operational impact of testing the radio navigation aids by means of ground and/or flight measurements. The material on the types of inspection has been extended and made consistent throughout the document. The possibility to conduct several measurements in real-time during combined flight inspections is brought out more prominently. This possibility is provided in modern systems that have improved processing and storage capabilities. Previously, this text was located within the facility-specific sections and did not cover all possible cases of complementary facilities.

Guidance on the organizational aspects, quality control, safety management of the flight inspection unit has been expanded considerably. This concerns amongst others traceability, quality, safety and competence of staff. The information on position reference systems was updated to reflect the evolved means available such as real-time kinematic systems. The material on design qualification of ground equipment was updated, which is linked to integrity references to Annex 10 and the addition of material on safety assessment and hardware/software assurance.

Guidance on modification of flight inspection intervals is now given in more detail with use of more elaborate description of correlation between ground and flight measurements. Material on expiration of nominal intervals for periodic checks is added. While the material applies primarily to ILS, the principles may also be applied to other navigation aids.

A new section discusses the use of Remotely Piloted Aircraft Systems (RPAS) for testing activities. This was done because many questions are being received on the topic. The text basically makes it explicit that nothing in the manual is meant to preclude the use of RPAS as long as correlation with operational utility is established. The text also notes that the use of RPAS can be useful where they enable measurement techniques difficult to achieve with traditional ground and flight inspection methods.

The title of the section on spectrum analysis was changed to signal analysis to emphasize the value of time domain measurements and the fact that modern measurement equipment can nowadays often work quite well in both the time and frequency domain due to digital sampling capabilities.

Chapter 2: VOR

Besides updates of references and improvements of an editorial nature, the main change of VOR material concerns the expansion of the material bends, roughness and scalloping errors in order to better explain the relation between the accuracy examples contained in the Annex 10 Vol.1 Guidance Material and the planning error limits stated in Doc 8071. An alternative method to evaluate the errors based on PFE, PFN and CMN for VOR is given (path following error, path following noise, control motion noise). This method reflects a more aircraft dynamics related approach and aims to create a better consistency and comparability of measurements. In the context of developments such as wind turbines, the lack of clear accuracy performance requirements for VOR in Annex 10 has been the subject of some debate. There are too many legacy concerns to introduce new requirements for VOR into Annex 10, while Doc 8071 is not the right place for such requirements. The updates to the measurement methods is nonetheless trying to make a contribution to reduce debates on the matter.

A small but nonetheless significant change was made by relaxing the flight inspection tolerance for VOR modulation measurements. Both the 30Hz modulation tolerance was relaxed and an overall note was introduced to explain that short duration variations due to flight dynamics are acceptable. This was considered to be more realistic.

In general, it can be observed that some of the most intense debates in flight inspection practice can occur over such tolerance values. If possible, the rule is applied that the measurement capability should be at least a factor

5 better than the Annex 10 tolerance to be measured. However, in some cases this is pushing the state of the art. The goal is to be demanding enough that operational suitability can be assured, while not imposing excessive calibration efforts. Again, the meaning of "excessive" is subject to engineering judgement.

Chapter 3: DME

Besides updates of references and improvements of an editorial nature, the new material in this chapter reflects the possibilities to use more advanced built-in test equipment available in state-of-the-art DMEs. In order to give the current material on the use of DME to support RNAV more visibility, it has been revised and moved to chapter 8.

Similar to the discussion on VOR modulation depth, two key measurement parameters have been made more realistic and achievable. This concerns the range accuracy and the field strength. The range accuracy measurement tolerance is relaxed from 20 to 50m, to be in line with commercially available interrogator output resolution. The field strength measurement uncertainty used to establish coverage is relaxed from 1 to 5dB, while deleting the note about the 1dB being applied to calibration only. While the 5dB value may seem large, the CNT WG felt that this was still challenging in light of the many associated variables, including the installed antenna gain pattern. However, given the continued importance of DME in the context of PBN, it is felt that calibration efforts in this area are worthwhile.

Chapter 4: ILS

Besides updates of references and improvements of an editorial nature, the new material in this chapter reflects the extended definition of ILS as contained in Annex 10 Vol. I that concerns the use of markers, DME and alternative means for height checks. Triggered by the compatibility discussions between GBAS and ILS/VOR, a new paragraph has been added on ensuring interference free operations when a runway is equipped with two simultaneously transmitting localizers.

Writing a clear description of the displacement sensitivity requirements has been a painful challenge in the Annex 10 process, and the same appears to apply to the associated measurement techniques. The descriptions have been completely rewritten. Both a commissioning method and a routine method are now given. The description goes into considerable detail to enable selecting the most efficient measurement points, especially for ground measurements.

Another small but important change relates to the localizer course alignment accuracy measurement, where the previous, rather ambiguous statement of "in the vicinity of ILS point B" for Cat I now recommends using at least a 0,5NM long approach segment, in line with best practices in many States.

The current edition already discourages the in-flight measurement of modulation balance for safety reasons, to avoid broadcasting on course signals regardless of aircraft position. However, there was no explicit link made in the description of the measurement and the associated tables. A clarifying statement was added to say that such measurements should be made on special engineering request only.

Various paragraphs concerning the alignment and power monitors have been amended to make them more clear. A completely new example ILS flight inspection report has been incorporated and the outdated example has been deleted. Especially in the ILS chapter, but also in the other chapters, field strength units have been made consistent using dBW/m^2 throughout, accompanied by their µV/m equivalents. The updates to the minimum positioning subsystem accuracy tables to support ILS flight inspection are mentioned earlier in this paper.

Chapter 5: NDB

Besides updates of references and improvements of an editorial nature, the new material in this chapter is limited to some minor additions to the coverage testing part.

Chapter 6: Marker Beacons

Besides updates of references and improvements of an editorial nature, the new material in this chapter incorporates an improvement to the measurement of coverage.

Chapter 7: PAR

The expertise available to the NSP on this topic was limited, given that today PAR is mainly used by the military. Nonetheless, besides updates of references and improvements of an editorial nature, the new material in this chapter reflects the modern types of PAR that use phased arrays and digital displays instead of mechanical scanning antennas and analogue displays. The material on flight inspection methods was amended and improved. While further review to cater for modern systems and methods could have been included, the current version attempts to strike a balance and caters to both modern and older systems.

Chapter 8: Navigation Aids supporting PBN

This is new material not contained in the fourth edition of Doc8071 Vol. I. This chapter deals with the assessment and flight inspection of navigation aids supporting

instrument flight procedures which are not covered by the facility-specific chapters of this document. This more clearly satisfies existing references to Doc 8071 in Doc 9613 (PBN Manual) and concerns mainly the use of DME in supporting PBN. The text also references the new attachment H in Annex 10, "Strategy for rationalization of conventional radio navigation aids and evolution towards supporting performance-based navigation" which is based on work presented to IFIS in [10]. The chapter recognizes the engineering activity of infrastructure assessment and its role in planning and optimizing flight inspection activities associated with PBN.

SUMMARY

This paper gives a comprehensive overview of the multi-year effort by ICAO NSP to update Doc 8071, an essential document for flight inspection and other associated testing activities. It discussed the overall document context (links to other documents), structure, principles and summarized the actual changes in the various chapters. In addition to bringing the document into alignment with recent updates in Annex 10, the goal of NSP was to eliminate mistakes and make the document more consistent and useful. Many IFIS papers have discussed difficult passages in Doc 8071 in the past. Hopefully, this Doc 8071 Volume I update, combined with the additional explanations in this paper, can resolve these issues effectively. The NSP appreciated the engagement from and discussions with ICASC members and hopes that this will continue.

DISCLAIMER

This paper contains no official EUROCONTROL or ICAO position.

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