Efficient Calibration of Instrument Flight Procedures

Volker Logemann
Senior Software Engineer
Aerodata AG
Hermann-Blenk-Straße 36
D-38108 Braunschweig, Germany
Internet: http://www.aerodata.de
Email: logemann@aerodata.de

ABSTRACT

In Doc 8071 Rev. 4 ICAO published new requirements to flight check Instrument Flight Procedures such as airways, instrument departure procedures, arrival routes, procedures based upon the use of Flight Management Systems (FMS) and Global Navigation Satellite System (GNSS) operations.

Compared to the well-known inspection of individual navigational aids, these requirements add new tasks to the Flight Inspection crews.
They have to inspect, if the procedure is flyable and safe. They must verify that the navigational aids – on which the procedure is based – are supporting it with sufficient accuracy.

Nowadays with an increasing demand to keep the cost-factor small and at the same time having to flight check complex procedures, it is necessary to employ tools, which enable Flight Inspection crews to make most efficient use of flight hours. When the Pilots test the procedure for flyability, it is the Flight Inspector's task to make an informed judgment about the navigational aids employed in the procedure. This paper explains the inspection of an Instrument Flight Procedure employing a modern Flight Inspection system.

The Flight Inspection software allows programming a complete Flight Inspection program in advance. Similar to a primary Flight Management System, the Flight Inspector sets up for each leg of the procedure courses, waypoints and tuning information. The information is contained in a dedicated ‚Flight List'.

Navigating with Differential-GPS the system plots the flight track and a vertical profile in real-time. Performance plots of the navigational aids are produced simultaneously. As waypoint based approaches (R-NAV) are becoming increasingly important, a brief outlook is given on the Flight Inspection of these procedures.

BACKGROUND

In recent Flight Inspection requirements, ICAO includes the need to flight check Instrument Flight Procedures. These checks are in addition to the flight check activity of the navigational aids themselves. To check an Instrument Flight Procedure is a major task. It involves both the Flight Inspector, who operates measurement equipment, and the Pilots of the flight check aircraft actually flying the procedure.

In the following is described how modern Flight Inspection software can support the Flight Inspector in procedure assessment.

A distinction is made between a 'Flight Inspector' or 'Flight Inspection Engineer', who has an engineering background and assesses the performance of a navigational aid through data recordings, and the 'Flight Crew' or 'Pilots' who actually fly the procedure. A flyability judgment will be made by the Pilots, assuming that the Flight Inspector operates a console in the cabin of the aircraft and therefore has a 'limited view to the outside world'. It is believed that the person judging the procedure for flyability must be an experienced aviator with a thorough aviation background.

It is necessary that Pilots and Flight Inspector interact closely. Their combined judgment will clear the procedure for operational use.

ICAO REQUIREMENTS

ICAO Doc 8071 [1] states in 8.1.1: „Instrument Flight Procedures depict standard routings, manoeuvring areas, flight altitudes, and approach minima for instrument flight rules (IFR) flight activities." It goes on to describe the range of procedures comprised under the term ‚Instrument Flight Procedure': "These procedures include airways, off-airway routes, instrument approach procedures (IAPs), instrument departure procedures, terminal arrival routes, procedures predicated upon the use of flight management systems (FMS) and Global Navigation Satellite Systems (GNSS)."

Before an Instrument Flight Procedure can be cleared for operational use it has to be subject to verification. There will always be an initial flight check, to prove that the procedure is flyable and safe. It will then be subject of periodical checks. ICAO Doc 8071 [1] says in paragraph 8.1.2 of chapter 8: "Instrument flight procedures should be a part

of the flight inspection process for initial certification and a part of the periodic quality assurance program as established by the individual states."

The checks to be carried out are manifold. The objective of the flight check evaluation of the instrument flight procedure is according to [1] 8.3.1: "... to assure that the navigation source supports the procedure, ensures obstacle clearance and checks the flyability of the design".

It is the Flight Inspector's responsibility, to ensure that the navigational aids are accurate enough to support the procedure. It is believed that all single navigational aids were subject of a previous flight check. Now they are tested in conjunction and for correlation.

The measurement instruments of the Flight Inspector will in most case be more accurate as the primary instruments on the flight deck. The Flight Inspector can therefore support and provide accurate readings for the debriefing of the flight. In a modern Flight Inspection aircraft the output of Flight Inspection receivers can be switched to the primary displays enabling the Pilots to follow ‚raw' guidance signals. This eliminates an error source caused by possibly different behavior of primary and Flight Inspection receivers.

Further checks such as identifying obstacles, flyability judgment or approach lighting checks, may be carried out by the flight crew.

FLIGHT CHECKING A NEW PROCEDURE – THE REQUIREMENTS

In the following the flight check of an Instrument Approach Procedure shall be discussed based on the ILS/DME/VOR instrument approach chart of runway 09, Kirkwall airport in the United Kingdom. The recent installation of ILS resulted in the need for new procedures. The example chart is not yet officially published and is undergoing flight tests.

The ILS/DME/VOR instrument approach to runway 09 described in words:

1. Fly holding pattern based on VOR/DME KWL or NDB KW. The outbound leg is on a magnetic heading of 273. The inbound leg is magnetic heading 093 towards NDB KW or inbound radial 273 KWL VOR.

2. Category C aircraft: Fly on radial 248 until 10 NM KWL DME (or 9.5 NM I-ORK ILS/DME) is reached. Begin descend from 2600ft overhead the KWL beacon to 2400ft. Category A and B aircraft fly radial 260 from the KWL beacon.

3. Make right-hand turn to intercept the I-ORK localizer. The localizer beam is aligned with the 273 radial of KWL VOR (inbound track 093)

4. At 6.8 NM KWL DME (or 6.3 NM I-ORK ILS/DME) start descending on the glide path. The DME distances mark the Final Approach Fix (FAP).

5. Missed Approach Procedure: Climb straight ahead on runway heading to 1500' or 3 NM of I-ORK ILS/DME whichever is later. Then make climbing turn left to return to VOR KWL.

There is an alternate routing making use of the VOR/DME KWL, which shall not be discussed here.

The NDB may be used in lieu of VOR KWL. Instead of the VOR the NDB can be used to establish on the outbound track.

The procedure requires the aircraft to fly at a certain speed and be at a certain altitude/height at certain distances from ILS/DME I-ORK.

As the inbound turns are defined through DME distance, the procedure is not available without DME.

Sufficient ground clearance is important. There is high ground to the West and to the North of the procedure, plus a number of obstacles close to the runway.

The following discussion is written from the Flight Inspector's point of view. It is assumed that performance of the different navigational aids on which the procedure is based has been verified. The flight check activity now concentrates on how the navigational aids act together.

The Flight Inspector must monitor a number of navigational aids simultaneously. The Flight Inspection system must therefore allow a 'multiple facility inspection'.

Data should be presented in a form that shows errors versus the time or distance traveled on the procedure.

Azimuth and range errors must be correlated to true distances from a reference point and they must be seen in conjunction. The following readings are required for the example procedure of Kirkwall's runway 09:

- VOR KWL radial accuracy (248, 260 for outbound tracks; 273 for inbound track) versus the distance from a reference point
- Correlation of DME information I-ORK and KWL; range accuracy of both DMEs throughout the procedure
- NDB oscillations throughout the procedure and during the missed approach; NDB needle reversing when flying over it
- Localizer and Glide Path Capture
- Presence of ident tones of VOR, DME, NDB and ILS throughout the procedure

Field Strength and Modulations shall be monitored but shall not be the primary focus. They are subject to separate flight checks.

In addition to the above the following parameters need to be recorded:

- Barometric altitude
- Radio Altitude
- Position

The position reference must be sufficiently accurate. GPS in an integrated navigation solution, combined with wide area or local area corrections, provides the required reference system accuracy.

The above information can be used to plot a flight track or a height profile. Combined with the original chart, this helps to assess the flyability of the procedure. The radar altimeter readings show a height profile of the area over which the aircraft flew.

FLIGHT CHECKING A NEW PROCEDURE – THE OPERATION

As the procedure makes use of a number of navigational aids, a sufficient number of compatible receivers are needed in the Flight Inspection system.

A NAV, DME and an ADF receiver are the minimum requirement. A second NAV receiver helps to monitor ILS and VOR at the same time. A second DME receiver allows monitoring the KWL and the I-ORK DME simultaneously. A reasonable approach is therefore to double the NAV and DME capability in the system. Less receivers means that more runs have to be flown.

Tuning of the receivers for the different stages of the procedure should be easy. If the system helps the Flight Inspector to automatically tune the receivers for the next leg, this will reduce the workload and help him concentrate on the data.

As mentioned above, the system must be able to handle multiple facilities.

All frequencies are best read from a common database containing all sorts of navigational aids, Enroute and approach aids.

When VOR tracks are concerned, two radials have to be programmed (i.e. the outbound leg, and the inbound leg towards KWL). This could be done manually during the flight, but would take up valuable time. All flight profiles are better set-up beforehand and then loaded into the system.

But the system must not be too stringent. It must allow the Flight Inspector the flexibility to decide. As flight checks are often subject to short-notice changes of plan (e.g. ATC requests) repeats of a run should not be a problem. The Flight Inspection system should support where possible but must allow flexibility.

Before the actual flight the following steps should be undertaken:

1. Preparation of flight based on the procedure chart and maybe in cooperation with the procedure designer
2. Route planning and programming of profiles, tuning plan.
3. Flight Briefing including the Flight Inspector and the flight crew

A 'FLIGHT LIST' IMPLEMENTATION

The following describes an FMS-like set-up tool for Flight Inspection runs, which shall be used to program the Instrument Flight Procedure.

Once the procedure definition dialogue has been initiated, two different input windows are available: One is designated to define Flight Inspection runs for approach aids, one is for Enroute navigational aids. The software automatically decides which input dialogue is opened based on the Flight Inspector's input of the three/two letter ident code for Enroute beacons or the four letter ICAO ident code of airports.

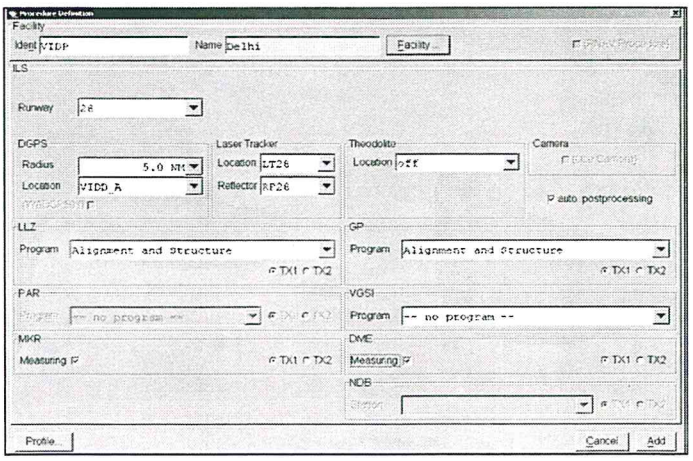

Figure 1: ILS Procedure Definition

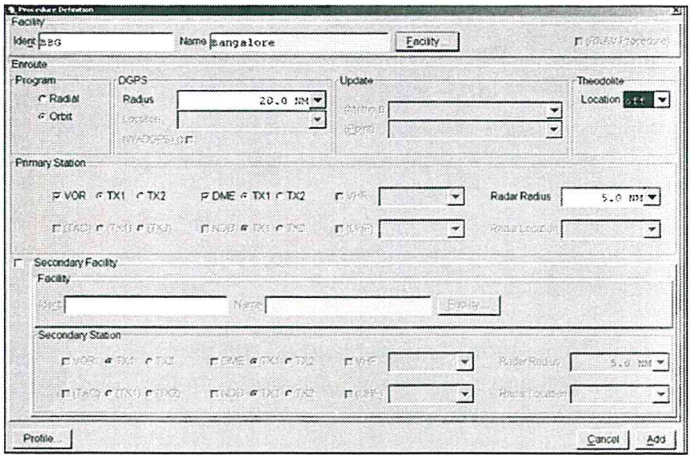

Figure 2: Enroute Procedure Definition

Assuming that a pair of NAV receivers and DME receivers is available, we shall refer to NAV#1 and DME#1 as the master receivers, and to NAV#2 and DME#2 as the secondary receivers. Additionally an ADF receiver is installed to measure the NDB signals.

Both procedure definition dialogues reflect this master and secondary receiver concept. They allow runs to inspect a certain navigational aid while at the same time the supporting aid can be monitored.

An interesting feature of the example approach procedure is that either the ILS/DME or the VOR/DME can be used.

With two to four runs (four, because different tracks are given for category A,B and category C aircraft) Kirkwall's instrument approach procedure to runway 09 can be completely verified. The set-up of the runs would be as follows:

1st run:

Fly outbound on the depicted NDB heading until 9.5 I-ORK DME. Then turn to intercept the ILS. Descend with the ILS. Missed approach on heading 093 until 3 DME I-ORK.

- ADF is tuned to NDB KW
- NAV#1 and NAV#2 are tuned to the ILS
- DME#1 and DME#2 are tuned to I-ORK DME.
- Results of receiver #1 and receiver #2 are averaged

This run will be one entry in the flight list.

2nd run:

Fly outbound on depicted VOR radial until 10 DME KWL, then turn to intercept the ILS. Descend on the glide path. Missed approach on heading 093 until 3 DME KWL. As the ILS is aligned with a VOR radial, the Flight Inspector can program a radial for the inbound track.

- NAV#1 is tuned to VOR KWL
- DME#1 is tuned to DME KWL
- Secondary DME#2 is tuned to I-ORK

The flight list contains two different radials inbound and outbound. Once the first radial is complete, the Flight Inspector needs to stop recording the first and activate the second entry.

Run 1 and 2 need to be repeated for the flight track of the other category of aircraft.

Although it is theoretically possible to combine 1st and 2nd run, it is better practice to fly them separately. Run No.1 concentrates on the ILS, Run No.2 on the VOR and DMEs. Raw signals can be delivered to the flight deck to allow the Pilots to fly Flight Inspection NAV receivers to support the flyability judgment.

The information on top of the flight list window at all times shows the tune status of the receivers, to which station they are looking and which antenna is used. This indicates valuable information for each stage of the flight. The Flight Inspector needs to ‚Instrument Scan' this information regularly, but no further input is required once the runs have been set up.

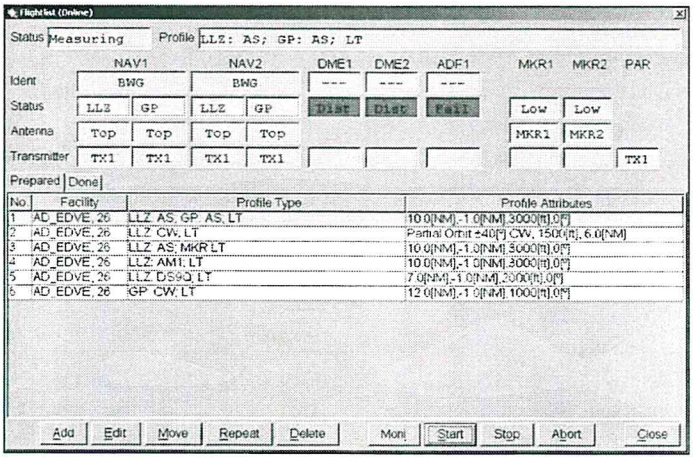

Figure 3: Flight List Window

FLIGHT CHECKING A NEW PROCEDURE – DATA PRESENTATION

The Flight Inspector's (or Flight Inspection Engineer) task is to judge the performance of the navigational aids and if they support the procedure. To do this he needs the following information. A graphical representation of data is desirable.

1st run

- NDB azimuth and azimuth error correlated with DME readings; this shall be plotted versus the true distance from threshold.
- Graphic to see localizer deviation current decreasing when aircraft closes in to the centerline. Graphic must show that the glide path produces a fly-up indication until the aircraft is fully established on the localizer.
- Graphic to see glide path deviation current correlated with DME readings to verify Final Approach Fix (FAP)

2nd run:

- Azimuth error on outbound track and inbound track plotted versus the true distance from the beacon
- Correlation of azimuth errors and DME readings with the range to the facility
- Correlation between DME readings of I-ORK and KWL
- Proof that aircraft flew depicted track/radial with either a deviation reading or the desired track inserted into the graphic plot.
- Height plotted against the range from the facility.

In addition to these, the following is needed to assist the Flight Inspector in his judging of the procedure:

- Event markers to mark interference sources, pilot calls for threshold, FAP, missed approach point
- Interference sources correlated with the range from the facility and actual position on track. The Spectrum Analyzer readings need to have a time stamp, with which they then can be correlated to DME or true distance readings.
- Radar altimeter profile to show height above ground.
- Ident tones.
- Summary of result data in alphanumerical form.
- The flight track plotted on a map

The data presentation should be in real-time so that immediate judgments can be made.

It shall be mentioned that different reference points are present in the procedure. For the ILS and the ILS-DME it is the threshold point. The NDB, VOR and VOR/DME reference points are the beacons themselves.

This has to be kept in mind when selecting graphic plots, to show the correlation between navigational aids.

COMMONALITIES WITH WAYPOINT-BASED PROCEDURES

This paper describes the inspection of an instrument approach based on conventional navigational aids. But more and more procedures are published based on GPS waypoints. These must also be subject to an initial and to regular flight checks.

A modern Flight Inspection system must be capable to deal with waypoint-based procedures. In many cases these procedures are correlated with conventional facilities. Such correlation must be proven, too.

Aerodata AG in Braunschweig equipped two Bombardier Global Express aircraft with a Flight Inspection system. They were delivered to the Japan Civil Aviation Bureau.

The Flight Inspection software contains a flight list feature as described above. It allows flight checks of GPS waypoint based approach procedures (R-NAV inspection), too. The Flight Inspection system reads waypoint information from the primary FMS. Whilst the Pilots fly the procedure the Flight Inspector can monitor waypoint accuracy, errors and other data he is interested in.

During the extensive test-flight phase in 2002 the R-NAV inspection capability of this new type of Flight Inspection aircraft was successfully proven and demonstrated to the customer.

CONCLUSION

Flight Inspection procedures, which focus on the navigational aids, are very much standard to the Flight Inspection crews. The inspection of complete flight procedures is not as clearly defined. As with other inspections, it is the individual country's aviation authority's responsibility to define guidelines for the inspection of procedures.

Flight Inspection crews will act upon the guidelines. But details and efficiency during completion of the actual task to a great extent depends on their skills. Some thought has to be spared beforehand, to be efficient. A good flight planning and close cooperation between Flight Inspector and Pilots help to greatly increase the performance.
A modern Flight Inspection system offering flexibility and performance can reduce the Flight Inspector's workload. It frees him up to concentrate on the assessment of the procedure and navigational aid's data. The key is to allow the simultaneous inspection of multiple facilities.

The text highlights some issues of the inspection of instrument flight procedures based on an example procedure. The approach offered here is one possible solution. It offers superior flexibility to fulfill all requirements making an effective use of flight time.

REFERENCES

[1] ICAO Doc 8071, VOL I, 4th edition of 2000

[2] UK AIP, AD 2-EGPA-8-1 (10 June 04)
Kirkwall ILS/DME/VOR Rwy 09
(Proc. not published; not for operational use)