PERFORMANCE COMPARISON OF A320 AND 737NG REGARDING THE VERTICAL AND AND SPEED PROFILES IN ADVANCED RNP TO XLS ARRIVALS

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Abstract

We report on the performance comparison between an Airbus A320 and a Boeing 737NG in vertical path following and speed profile during novel advanced required navigation performance (RNP) procedures which contain a fixed radius turn that delivers the aircraft onto a short ILS precision final. The approaches were flown automatically with guidance and automatic thrust as computed by the flight management system. Main areas of interest of the flight trials were the performance of the vertical path following during the RNP part of the procedure as well as maintaining an optimized speed profile during the continuous descent approaches. Results show that the 737 delivered the same performance at all 5 different coding options following the vertical and lateral path within the prescribed lateral and vertical required navigation performance. On the other hand, the A320 thrust reduction depended greatly on the point at which the IAF was located. The Airbus began to reduce thrust two miles before each the IAF which leaves insufficient time to decelerate in case of three miles track distance between IAF and FAP. While the B737 demonstrated the same behavior in vertical path following at all times, the A320s vertical path following depended on the energy state of the aircraft. In the "hot and high" case with 3 miles track between IAF and FAP, the vertical path was not maintained within the required corridor

1 Introduction

Within the PBN concept, it is possible to incorporate turns with a precise ground track into departure, en-route, arrival and approach procedures called fixed radius transitions or radius-to-fix. They offer the advantage of repeatable ground tracks during the turn and thus more freedom for the procedure designer when route planning in dense traffic, high terrain or obstacle rich environments. Additionally, ARINC 424 allows to specify altitude constraints at waypoints and vertical path angles for each RNP segment terminating at such a waypoint. The vertical path angle feature is currently largely unused and unexplored, except for the final approach segment of an RNP approach. These new options, when properly exercised, would allow any aircraft to benefit from better fuel efficiency during a continuous descent approach and a potentially reduced obstacle clearance due to the fixed vertical RNP profile and RF tracks. Ground tracks are repeatable and could be used for better noise abatement - besides their main purpose, obstruction clearance along the aircraft's path.

In this study, we investigated the use of the ARINC424 coding options "vertical path angle" and "altitude constraints" at path terminators Track-to-Fix and Radius-to-Fix onto the performance of the speed profile for arrival time optimization and the vertical path following. Moreover, we study the influence of splitting the procedure into a standard Terminal arrival route (STAR) and instrument approach procedure (IAP) components of varying lengths as shown in the Figure 1 below. The procedure designed for this experiment delivers the aircraft onto the instrument landing system of Braunschweig-Wolfsburg airport's ILS runway 26. The glide path intercept point or final approach point (FAP) is located 1500ft above aerodrome level. The approach has 5 initial approach fixes (IAF) located 3,4,5,6 and 7 miles uptrack of the FAP. Additionally, 5 separate STARs were coded, all commence at the same point in the terminal area at an altitude of 4000ft MSL and ending at the respective IAF. The ground track for all 4 procedures is identical, only the transition from STAR to IAP is shifted. The descent angle from the beginning of the STAR until the FAP of the approach was designed and coded with 1° downwards. The idea is to test, where an automatic thrust reduction takes place in order to decelerate the aircraft as late as possible

We compare the performance between the two most commonly used passenger transport aircraft, the Airbus A320 and the Boeing 737NG. For the trials, we used DLR's own Advanced Technology Research Aircraft (ATRA), an Airbus A320 MSN659 with flight test instrumentation and a Thales flight management system (FMS) 2 as well as a Boeing 737-800 Simulator located at Lufthansa Flight Training in Berlin. The approaches were entirely flown using the auto flight guidance in managed mode and with automatic thrust activated.

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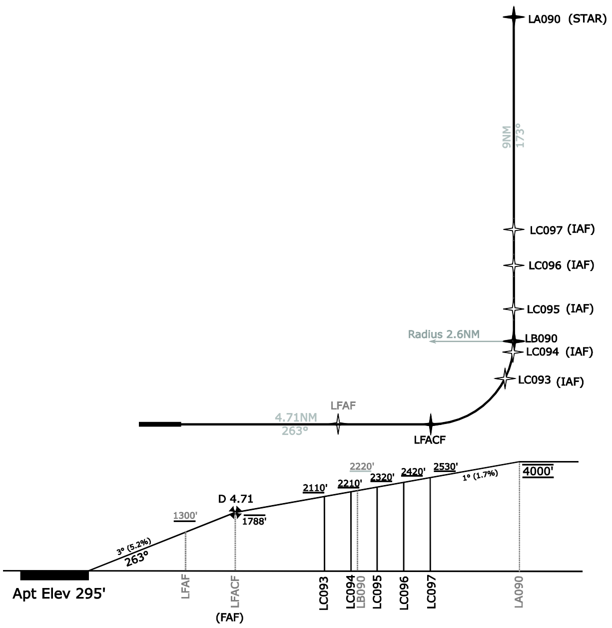

Figure 1 Schematic of the RNP to ILS procedure for Braunschweig-Wolfsburg Airports Runway 26. The procedure is split into arrival and approach parts of varying lengths.

This work is the continuation of [3], where we tested the RNP2ILS intercept performance using various intercept altitudes and path coding variations.

2 Procedure Design and ARINC424 Coding

The procedures were coded in ARINC 424 in DLR's tailored ARINC 424 [2] FMS database. They consist of a one STAR and one approach each and commence at a common point LA090. A RNP 1 track with a 90° radius to fix (RF) turn delivers the aircraft onto the final approach fix (FAF), where, in a standard atmosphere, it is exactly centered on the localizer and glide path of the ILS. During the RNP part of the procedure, a vertical path angle of 1 degree down is coded in the ARINC424 database and the altitude constraints at waypoints are set accordingly. We chose the FAF altitude at 1500ft above aerodrome level in order to allow sufficient time for establishing stable approach criteria [5] (Section III-4-3-1) at 1000ft AAL.
Now we varied the length of the approach track from the initial approach fix (IAF) to ILS intercept from 7 nautical miles to 3 nautical miles in order to test its effect on deceleration and vertical path following. The IAFs are designated LC09x, with x a discrete variable, indicating the distance between IAF and FAF. The corresponding STARs are called LINAx.

2 737 Simulator and A320 Flight Trials

DLR's experimental Airbus A320 is equipped with the current Thales FMS2 and a basic Flight Test Instrumentation (FTI). The FTI provides ARINC429 data acquisition from the avionics as well as additional sensors such as precise high quality GNSS receivers and data storage as well as real time visualization of this data to the flight test engineer. It consists of 6 CRONOS data acquisition units from IMC, three controlling computers and 7 display screens for two engineer workstations. From the FTI a custom IENA data stream can be provided to further experimental stations if needed. More details can be found in [4]. All data is recorded at a rate of 20Hz.

For the RNP to ILS experiments, we used the FTI to record the relevant ARINC429 data including position, autopilot modes, ILS data, cross track error, altitude and time. The entire experiments were flown using the OEM automatic flight guidance system in managed mode with only gear, flaps and approach mode arming performed by the pilots.
Boeing 737 position data was recorded from a 737-800 flight simulator via proprietary ARINC 429 output channels [1] using an AIM 429/16 PCI recording card. The associated autopilot modes were recorded via video feed from the primary flight display and the multifunction display and later manually tabulated in one second resolution. For the 737 FMS, the DLR ARINC424 database was repacked into the appropriate binary format for the Smiths FMS with the 737 flag set.
Both aircraft we flown in speed managed mode as calculated by the flight guidance computers. While Airbus recommends pilots to fly the aircraft this way, Boeing suggests that the flight crew controls the speed via the mode control panel at all times during approach. For the experiment, we deviated from this philosophy in order to have comparable results

Figure 1 ILS L with 3NM from IAF to FAF. Procedure loaded from database into flight plan.

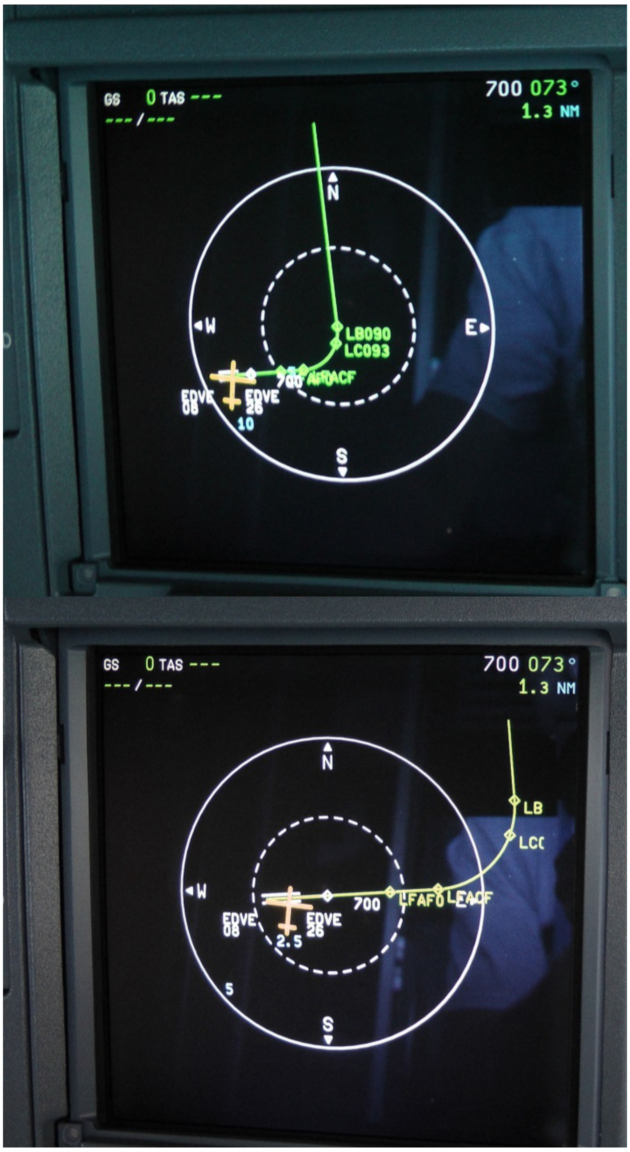

Figure 2 ILS L with 3NM from IAF to FAF

3 Results

Figure 3 shows the extracted flight technical error, airspeed and autopilot modes of both 737 and A320. We can see that the A320 prefers the dive and drive and descends below the profile. shortly before LC094. There, the autopilot is holding the altitude constraint till the next waypoint is overflown. The Boeing 737 follows the vertical track during the entire approach in VNAV Path mode and the vertical flight technical error is much smaller. Laterally however, the Airbus neatly delivers the aircraft onto the localizer centerline subsequently follows it to the runway with little flight technical error. The 737 captures the localizer early, doglegs and slowly brings the aircraft back to center of the runway. However, this effect is very small, only with a maximum error of about 100m.

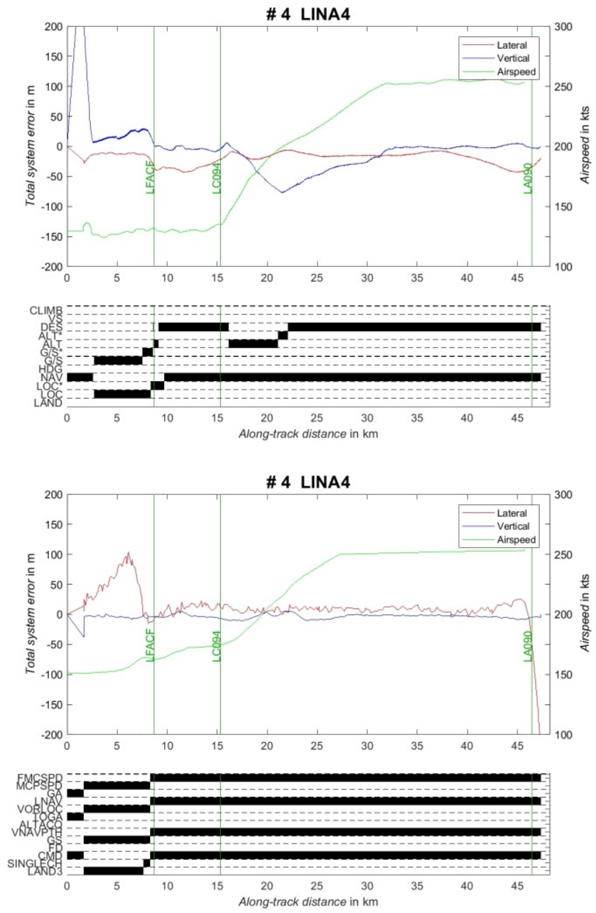

Figure 3 (top) Flight technical error, speed and autopilot modes of the Airbus A320. The aircraft performs an intermediate level of before continuing on the approach, leading to an undershoot of the profile (bottom) Flight technical error, speed and autopilot modes of the 737 for approach LINA4

At this point, it is not quite clear if this is actually happens due to a misaligned localizer in the 737 simulator environment or an actual feature of the aircraft. At the distance of LFCAF from the localizer, a lateral displacement of the localizer of 100 meters is equivalent to 0.5 degrees angular. The 737 begins the start of the deceleration later while the A320 begins early and reaches its approach spread already at LFCAF. Since the A320 pilots only selected the next flap setting at VFE_{next} according to the aircrafts deceleration commanded by the auto thrust this is also a design feature of the FMS /FMGC control logic.

4. Conclusions

Both aircraft types performed the approaches within the limits of their respective design. While the 737s VNAV path function tracks the vertical track as it should, the A320s design philosophy is centered on fuel savings and passenger comfort. Therefore, the A320 prefers idle descents to the next constraint altitude to following the calculated vertical trajectory. The A320s ILS lateral intercept performance is softer than the one of the 737, which immediately switches from RNP to ILS guidance when tracking the localizer inbound. The Airbus transitions from RNP into ILS guidance via the “LOC*” mode, which softens the mode switching.

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