STEEP SEGEMENTED APPROACH AT COLOGNE/ BONN AIRPORT

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ABSTRACT

Increasing the altitude of approaching aircrafts has been considered as a way to reduce perceived aircraft noise, particularly in densely populated areas. At Germany's third largest freight airport a steeper approach profile consisting of two segments will be tested. The first segment is a steeper than normal approach angle (≤4.0°) followed by a second segment which is a conventional 3.0° approach angle to landing.

This paper discusses the results of previous flyability studies using the data of Level-D simulator trials on B767-300W and MD-11. It will as well indicate preliminary estimates of noise and impacts on airspace capacity.

Keywords: Aircraft Noise, Steep Segmented Approach, Noise Abatement Flight Procedure

1. INTRODUCTION

The concept of flying a steeper than normal approach is not new. Several industry groups including aircraft manufacturers, airlines, the Federal Aviation Agency (FAA), National Aeronautics and Space Administration (NASA), Deutsches Zentrum für Luft- und Raumfahrt [German Aerospace Center] (DLR) have studied this issue for many decades. (ZALOVCIK 1967).

The specific concept which is explored in this study and based in research of the DLR Institute of Flight Guidance (MOLLWITZ 2014a, KORN 2015), is a dual segment (angle) approach. The first segment is a steeper than normal approach angle (up to 4.5°) followed by a second segment which is a conventional 3° approach angle to landing.

The rationale behind this concept is the following: the noise received (heard) from a noise source is greatly affected by the distance between the noise emitter and the noise receiver (ISERMANN 2013). It naturally follows that the higher the aircraft is located above the ground, the greater the distance between emitter and receiver, thus the lower is the noise level experienced by the receiver on the ground.

The aim of the test flights which will be conducted at Cologne/ Bonn Airport (EDDK) is to evaluate the specific noise impact of the Steep Segmented while approaching runway 32R. During the test flights advanced noise measurements will be conducted close to the approach path. Together with the data from the flight data recorder (FDR) this precise information will provide a basis for gaining optimum results on the review of the approach.

2. PROCEDURE DESIGN

The approach profile at EDDK was mainly designed by the DLR Institute of Flight Guidance. Using the knowledge gathered on previous tests e.g. at EDDF and EDDV (MOLLWITZ 2014b) as well as the experience from flight simulator trails conducted by TUIfly and UPS Airlines, three vertical profiles were devised.

Figure 1 shows the current instrument approach routes on runway 32R starting either at the Initial Approach Fix (IAF) *Nörvenich* or *Cola* (AIP GERMANY).

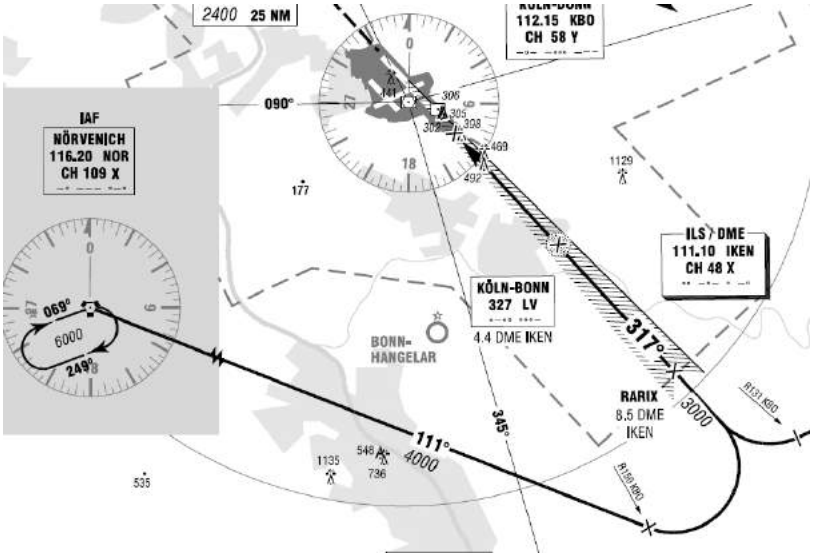


Figure 1: EDDK Instrument Approach Chart RWY 32R (AIP EDDK)

As every approach procedure is designed from the landing threshold backwards, the design will be discussed from end to beginning. The following section will give a summary of the main design elements and their rationale (MOLLWITZ 2014b).

The last part of the approach towards the landing runway is flown at the same descent angle as today's approaches, typically 3°, and crosses the runway threshold at 50 ft height. This way, the final approach and especially the landing do not differ from today's procedures and thus make the most critical phase of any flight – the landing – as safe as today. Most airlines follow an internal policy to have the aircraft stabilized at 1,000 ft above the runway. This means that no more changes to flight path, configuration and speed can be made below this height unless the approach has to be aborted. In order to provide enough time before the strict criteria at 1,000 ft apply, the change from the steeper segment to the final 3° segment takes place at approximately 1,700 ft (2,000 ft MSL) above threshold.

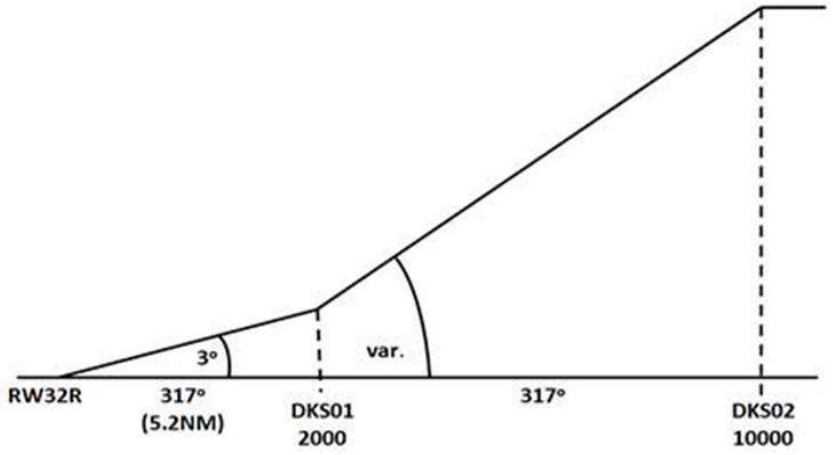


Figure 2: General Layout (DLR Institute of Flight Guidance)

For the steep segment, five different descent angles from 3.5° to 4.5° have been chosen. The start of the procedure has been set at 10,000 ft MSL. The three waypoints in Figure 2 (DKS02, DKS01, RWY32R) were used to define the angular path and segments to EDDK runway 32R.

Depending on the specific descent angle, the initial (steep) segment begins at waypoint DKS02 which varies within a bandwidth of distances to DKS01.at 2,000 ft MSL. Table 1 provides an overview of the applied angles and their respective distances to DKS01 and RWY32R.

Table 1: FMC waypoints (UPS Airlines)

Angle [°]	*Altitude at DKS02 [ft MSL]*	*Dist. to DKS01 [NM]*	*Dist. to RWY32R [NM]*
3.50	10,000	21.5	26.7
3.75		20.1	25.3
4.00		18.8	24.0
4.25		17.7	22.9
4.50		16.7	21.9

3. FLYABILITY STUDY

In collaboration with the DLR, Boing's Airport Noise Analysis & Flight Procedures Branch and the FAA's Environment and Energy section (AEE-400) together with the UPS Europe Chief Pilot Group has undertaken a feasibility study concerning steep segment approaches as a potential means for aircraft noise mitigation. The tests and analysis were conducted at the UPS Flight Training Center in Louisville, Kentucky USA in January 2016 utilizing UPS Full Flight, Level D Simulators.

3.1. Flight Simulator Testing Methodology

The aircraft simulators used for testing were B767-300W and MD-11 Freighter. The tests were designed to explore a range of aircraft and meteorological variables using initial approach angles of 3.50 to 4.50 degrees. The variables used in the flight simulator trails included aircraft landing weight [heavy to light weight], wind [zero wind to 25 knot tailwind] temperature [varied from ISA to ISA+10] as well as aircraft center of gravity (CG). The 'worst case scenario' affecting descent performance was defined to include:

- Heavy landing weight (close to maximum landing weight)
- Higher than standard temperature (ISA+10)
- Tailwinds throughout descent and landing.

The approaches were flown with the autopilot and auto throttles engaged in the VNAV PATH pitch mode and LNAV roll mode. The ILS LOC and GS mode were armed and captured as early as possible to investigate the transition from the steep angle to the ILS final approach.

The factor determining the success of the approach is the ability to safely fly the approach what means the approaches must be stabilized by 1000 ft HAT. An approach is considered stable when the following conditions are met:

- Aircraft in landing configuration and Landing Checklist completed
- Airspeed within +10 or -5 knots of target speed
- Sink rate is less than or equal to 1000 feet per minute
- Engine thrust is stabilized at level when maintains target speed.

An additional desire was to fly the approaches using a configuration and profile which would not require the use of speedbrakes, if possible.

3.2. Conclusions

In total more than 60 approaches were flown by the UPS Europe Chief Pilot Group. The following three sections outline specific conclusions on B767 and MD-11on the Steep Segmented Approach as well as general conclusions.

The first approaches for the ***B767-300W*** were flown with a 3.50° initial approach angle starting at DKS02. Even under worst case scenario conditions, (ISA+10, 25 kt tailwind, heavy aircraft) the stabilized approach criteria were met at 1,800 ft AFE. During the course of test flights, the following configuration and profile appeared to be most suitable for B767 steeper approaches:

- Flaps 15 or 20 and speed 190 KIAS prior to starting descent from DKS02.
- Arm and capture ILS localizer and glideslope (from above) as soon as practical.
- Maintenance of approximately 190 KIAS until 8-10 NM from runway and begin of decelerating toward 160 KIAS for final gear and flap configuration.
- Extension of the landing gear at 2,000 to 2,500 ft AFE depending on gross weight and wind conditions.

Using this configuration and profile the B767-300W was found to be able to perform the steep segment descent under worst case scenario conditions up to angles of 4.00°. Provided Flaps 15 or 20 are used with speedbrakes, as required. Test flights above angles of 4.00° with heavy weights and winds during descent indicated that stabilized approach criteria may not be attained for every approach. Setting the recommended angle of 4.00° as the maximum angle was found to provide adequate margin for error.

The approaches using the **MD-11** followed the same method as tests with the B767. All MD-11 approaches on the 3.50° angle were assessed as uncritical. However, particular attention needed to be paid on the flap setting on heavy weight and/ or tailwind conditions to prevent exceeding speed limits, e.g. 210 KIAS for flaps 28. Extending the landing gear for decelerating be avoided for noise abatement reasons. Beside the tradeoff on flap settings, the 3.50° approaches met the

stabilized approach criteria even under worst case scenario conditions at 1,500 ft AFE. During the course of test flights the following configuration and profile was found most suitable for MD-11 steeper approaches:

- Flaps 15 and speed 190 KIAS prior to starting descent from DKS02. Set speed to 170 KIAS, or less, after starting descent. Select Flaps 28 as required to control airspeed – no later than 205 knots.
- Arm and capture ILS localizer and glideslope (from above) as soon as practical.
- Maintenance of approximately 170 - 190 KIAS until 8-10 NM from runway.
- Extension of the landing gear at 2,000 ft AFE.

Using this configuration and profile the MD-11 can perform the steep segment descent under worst case scenario conditions up to angles of 4.00°. Test flights above angles of 4.00° with heavy weights and tailwinds during descent indicated that it's questionable if stabilized approach criteria can be attained for every approach. The recommended angle of 4.00° as the maximum angle provides adequate margin for error.

As a **general conclusion** the approaches both for the B767-300W and MD-11 are flown differently than the standard 3.00° approach. The pilot situational awareness and workload management is thus negatively affected the first time a pilot is exposed to the steeper approach. Some amount of pilot training will be required in order to conduct steep segment approaches in line operations. Furthermore additional and reliable information is needed to evaluate the actual noise comparison of different aircraft drag configurations. For example, for specific aircraft types it is not clear whether extending the landing gear produces more noise than using increase speedbrakes.

4. NOISE IMPACT

Simulations with the Integrated Noise Model (INM) were performed in order to estimate aircraft noise impacts around the airport of EDDK. The INM is computer software based on algorithms using noise-power-distance data (FAA 2016). In order to increase the accuracy of the distance measured between aircraft and source-receiver geometry, relief maps were recorded within the INM.

All simulations were done for the MD-11 with PW4460 engines. An aircraft landing weight of 460,000 lbs. (heavy) was used, as well as ISA weather conditions (no wind, 15°C). Simulations were conducted for the three different angles 3.00°, 3.50° and 4.00°. In contrast to the full flight simulator trails the noise simulations started at 7,000 ft MSL. This difference occurs due to the additional time that is given to the pilots to prepare the approach, as approaches on a trial basis were found to negatively affect the pilots' workload management (see 3.2). However, the noise simulation does not require the inclusion of this factor, as the outcome on ground noise above the altitude of 7,000 ft can be disregarded.

Table 2: Changes in affected area (reference 3.00°)

Noise Level LA_{max} [dB]	***3.50°approach [%]***	***4.00° approach [%]***
60	-14.6	- 24.8
65	-15.2	- 25.4
70	- 8.9	- 6.6
75	- 0.8	- 1.0
80	- 0.3	- 0.2
85	- 0.5	- 0.4
90	+0.3	+ 0.6

Table 2 shows the mean change in noise levels retrieved from the simulation with different approach angles. Using alternative angles, the greatest impact appears to be achieved for the lowest reference noise levels (from 60 to 70 dB). The affected area on a noise level of 60 and 65 dB can be reduced by roughly one quarter using a 4.00° approach segment compared to a conventional 3.00° approach. For noise levels above 70 dB the INM did not show significant changes in the affected area, using any of the alternative angles. A possible explanation for this can be derived from Figure 3 and the knowledge of the vertical profiles of the investigated approaches.

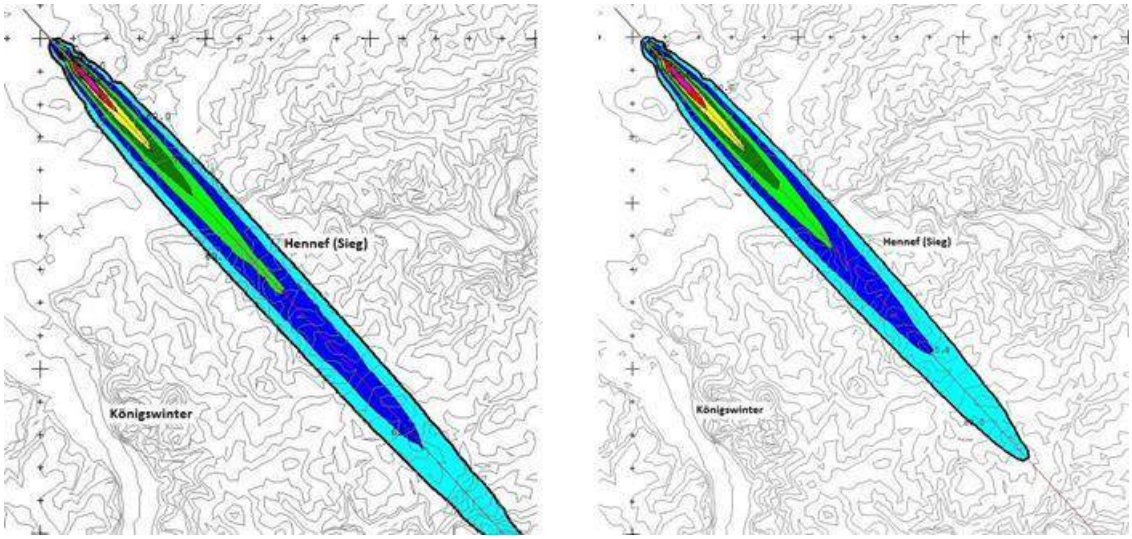


Figure 3: Noise footprint of a 3.00° (left) and 4.00° (right) approach

While greater noise levels naturally occur close to the runway, the influence of a steeper approach angle is declining the closer the approach path runs above the ground. As depicted in Figure 2, both the conventional and the steeper approach follow the same path for the last 5.2 NM disabling varieties on the noise level during the final approach. The colored noise footprints in Figure 3 as well show changes in the contours in more distant regions from the airport.

It should be noted that the simulation conducted with the INM has a number of limitations. Main disadvantages occur in the flaps setting on the MD-11 and in the deployment of the gear. Therefore, more comprehensive simulations and studies beyond that are needed to verify the results of this study. Additionally, more environmental data is needed for comparison and correlation before any conclusions can be drawn.

5. EFFECTS ON AIRSPACE CAPACITY

As the Steep Segmented Approach follows an alternative vertical profile compared to conventional arrival procedures, a negative effect on airspace capacity for mixed operations can be anticipated. Figure 4 reveals the difference in the qualitative characteristics of the vertical profiles for the conventional and steeper approach. Both approaches consist of the same waypoints – route to runway 32R: KOPAG 32 – IAF COLA – FAF RARIX (AIP) – and only differ in the altitude on the equivalent route. As wake vortexes constitute a threat for subsequent aircrafts and ordinarily descent down, default separations can’t be applied for mixed operations, a least for the case of conventional 3° approaches trailing a steeper approach.

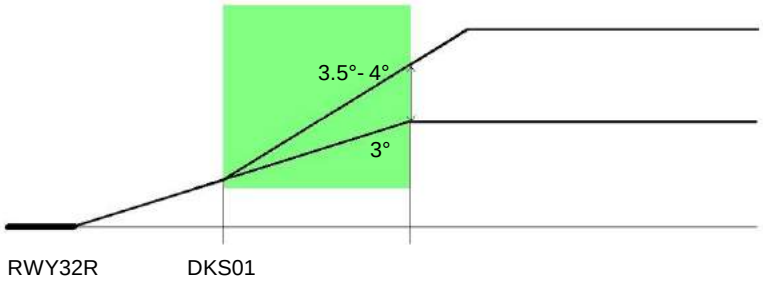


Figure 4: Vertical profiles (qualitative) of a conventional and a steeper approach

For a first assessment of the changes on the airspace capacity, simulations with the Simmod Plus software (version 8.2.1) were undertaken. A wide variety of test series with differing assumptions on the percentage share of Steep Segmented Approaches were used to demonstrate the influence on the capacity. Every single simulation run with a defined percentage share of steeper approaches included 500 landing aircrafts (5% light, 90 % medium, 5 % heavy). No departures have been considered in the simulation.

It is necessary to distinguish three scenarios of aircraft separation in this simulation. For two consecutive aircrafts which both are using either a conventional or a steeper approach, standard radar respectively wake turbulence separations as shown in **Erro! Autoreferência de indicador não válida.** can be used. The same applies to two consecutive aircrafts where the leading aircraft is on a conventional and the trailing aircraft on a steeper approach. However, in the reversed case, when the leading aircraft is flying a steeper angle and the trailing aircraft is following the conventional approach path, an increased separation of 10 NM have to be applied.

Table 3: Wake turbulence and radar separation minima

[NM]		*Leading aircraft*		
		Light	***Medium***	***Heavy***
Trailing aircraft	***Light***	4	5	6
	Medium	3	3	5
	Heavy	3	3	4

For the baseline scenario, only conventional 3.00° approaches were considered in the simulation. As a result, an average of 53 landings per hour could be observed on runway 32R. When including steeper approaches in the simulation, the landing rate declined. In a scenario including a 10 % proportion of randomly staggered steeper approaches, only 45 landings per hour could be observed. As shown in Figure 5, a decreasing capacity trend could be seen when the proportion of steeper approaches was increased, up to a minimum of 35 landings per hour based on a share of 50 % steeper approaches. For higher proportions of steeper approaches (> 50 %), the landing capacity increased again with increasing numbers of steeper approaches, reaching 53 landings per hour for exclusively steeper approach operations.

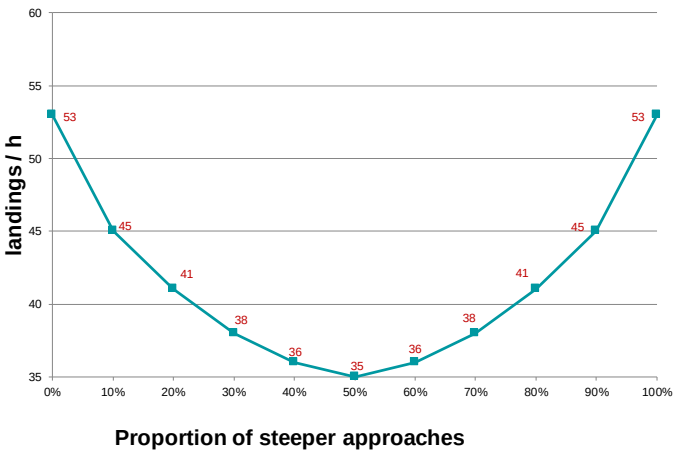


Figure 5: Landing capacity for mixed operations on runway 32R at EDDK (randomly staggered)

A fundamental finding of the simulation is that mixed operations with steeper approaches appear to lower the capacity of the airspace and runway system. This can be explained by substantially differing aircraft separations in consequence of incalculable wake vortex turbulences. As the approaches in the simulation have been randomly staggered, the 10 NM separations occurred frequently and thus significantly lowered the capacity. First analyses in Simmod on approaches in single-variety groups (conventional/ steeper approaches) support the assumption of less declining airspace capacity.

6. DISCUSSION AND OUTLOOK

This paper includes results of a technical evaluation of B767 and MD-11 aircraft capability to fly steep segmented approaches. Within more than 60 approaches flown in a full flight, Level D Simulator, the B767 and MD-11 were found capable of flying dual segment steep approaches up to and including 4.00° angles that account for adequate margins for error.

Furthermore, this paper presents preliminary results on the noise impact of steeper approach paths as well as the effects on the airspace capacity. Simulations with the INM showed remarkable changes in the affected area for noise levels from 60 to 70 dB. However, simulations with the Simmod Plus software implied that mixed operations with steeper approaches might lower the capacity of the airspace. Due to limitations regarding the simulations with the INM more comprehensive simulations are needed to verify the results.

Real test flights will be conducted at the airport of Cologne/ Bonn at the end of 2016. Comprehensive noise measurements and data collected from the FDR during the test flights will help to verify the findings of the various simulations that were examined in this study.

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