Helicopter IFR Steep and Curved Approaches Using SBAS Guidance

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Abstract:

The European project OPTIMAL (Optimised Procedures and Techniques for IMprovement of Approach and Landing) is aiming to define and validate innovative procedures for the approach and landing phases of aircraft and rotorcraft in a pre-operational environment. In particular, Simultaneous Non Interfering (SNI) procedures(4) are considered for rotorcraft which will allow fully independent aircraft/rotorcraft traffics. Increasing the ATM capacity while maintaining or even improving safety is one goal of this project. Those achievements will be enabled by new technologies such as SBAS and/or GBAS as well as available precision approach landing aids (ILS, MLS).

One of the objectives of the Institute of Flight Guidance of the German Aerospace Center in Braunschweig within the EU project OPTIMAL is to demonstrate the rotorcraft system's 4D flight guidance capabilities. In the framework of the flight trials the practical flyability of the helicopter-specific steep and curved time referenced IFR approach procedure will be confirmed.

NOMENCLATURE

AGL	Above ground level
APV	Instrument Approach with Vertical Guidance
ATM	Air Traffic Management
DLR	Deutsches Zentrum für Luft- und Raumfahrt
EP	Evaluation Pilot
FAF	Final Approach Fix
FHS	Flying Helicopter Simulator
FMS	Flight Management System
FTE	Flight Technical Error
GBAS	Ground Based Augmentation System
IAF/IF	Initial Approach Fix / Initial Fix
ILS	Instrument Landing System
MLS	Microwave Landing System
PAVE	Pilot Assistant in the Vicinity of Helipads
SBAS	Satellite Based Augmentation System
SNI	Simultaneous Non Interfering
SP	Safety Pilot
TDZE	touchdown zone

INTRODUCTION

Modern GNSS-based guidance, particularly with augmentation such as GBAS and SBAS (EGNOS), allows the design of special IFR approach procedures for rotorcraft. Moreover, they can be adapted to take full benefit of unique rotorcraft manoeuvring capabilities, e.g. IFR approach paths as steep as 10° compared to the standard ILS slope of only 3°. A steep rotorcraft approach allows a relatively high altitude to be maintained when flying over populated areas in the vicinity of an airport (a 10° approach slope reaches 2000 ft agl as close as 3400 m from the landing point). Also the noise emitted by the rotors is known to decrease significantly when the descent slope is increased beyond 6°. The combination of these two effects is expected to largely eliminate noise nuisance outside of the airport boundaries.

To increase passenger capacity at busy airports, these specific approach procedures can also be designed to allow Simultaneous Non Interfering (SNI) rotorcraft / aircraft operations. Indeed, the development of SNI procedures opens the way for new concepts of operations in which rotorcraft are expected to replace turboprop airplanes for short distance flights, thus leaving more takeoff and landing slots available for long and medium haul transport airplanes with large capacities.

Moreover, rotorcraft specific IFR procedures will allow the installation of scheduled air connections between small cities without airports, thus reducing the need to use private transport to reach the nearest airport. It has to be remembered that today a significant number of passengers drive as far as 100 km to reach the nearest airport or high speed train station.

The increased transportation freedoms opened up by more flexible rotorcraft SNI operations need to be developed with a deeper understanding of the special rotorcraft flight dynamics issues associated with flight during steep descent profiles and in the vicinity of the wake vortices from fixed wing aircraft.

Concerning rotorcraft, there are no specific instrument procedures in Europe. Today, under IFR conditions, rotorcraft have to follow the same procedures as airplanes which are very penalising from an operational standpoint. Typically, ILS approaches have been optimised for airplanes and are not adapted to the unique manoeuvring capabilities of rotorcraft that are capable of flying much shorter and steeper approach paths at lower flight speeds. This is one of the reasons why almost all helicopter passenger transport operations are still performed under VFR rules today, although modern helicopters are full IFR capable, including flight in icing conditions.

In the United States, the FAA has already approved 220 helicopter specific Non Precision Approaches (NPA) relying on GPS guidance. Criteria for helicopter GNSS-based Point in Space approaches have been established by the ICAO Obstacle Clearance Panel (OCP) and the development of helicopter specific approaches in Europe is just starting.

Regarding precision approaches, specific helicopter procedures have not been developed until now because of the lack of adapted guidance means. Now this becomes possible thanks to SBAS and GBAS technologies. The target time frame for the operational implementation of OPTIMAL proposed procedures is 2010 and beyond, consequently it is expected that OPTIMAL will pave the way, in conjunction with other European projects, towards a significant evolution of the operational concept for pilots and controllers.

FLIGHT TRIALS AT BREMEN AIRPORT (EDDW)

Within the scope of the OPTIMAL project one goal for the Institute of Flight Guidance was to demonstrate the rotorcraft system's 3D flight guidance capabilities and to confirm the practical flyability of the helicopter-specific steep and curved IFR approach procedure initially developed for Bremen airport[(3)] (EDDW, Figure 2). Due to the unique layout and geometry of Bremen airport and its environment, the procedure will not only be time-referenced but will also contain steep segments as well as a curved final approach. Figure 1 shows DLR's EC 135 FHS test helicopter which was equipped with additional precision navigation equipment (SBAS receiver) and a special 4D-capable experimental rotorcraft flight management system developed by an internal DLR project called PAVE[(1),(2)].

Figure 1: DLR's EC 135 FHS experimental research helicopter

The FHS (Flying Helicopter Simulator) research rotorcraft is based upon a highly modified Eurocopter EC 135 T1 helicopter. The helicopter has a hybrid Cockpit architecture make up of:

- On left, safety pilot (SP) side: a conventional copilot instrument panel (EC135T instrument panel)
- On right, experimental pilot (EP) side: an experimental pilot instrument panel (flexible display and test panels)

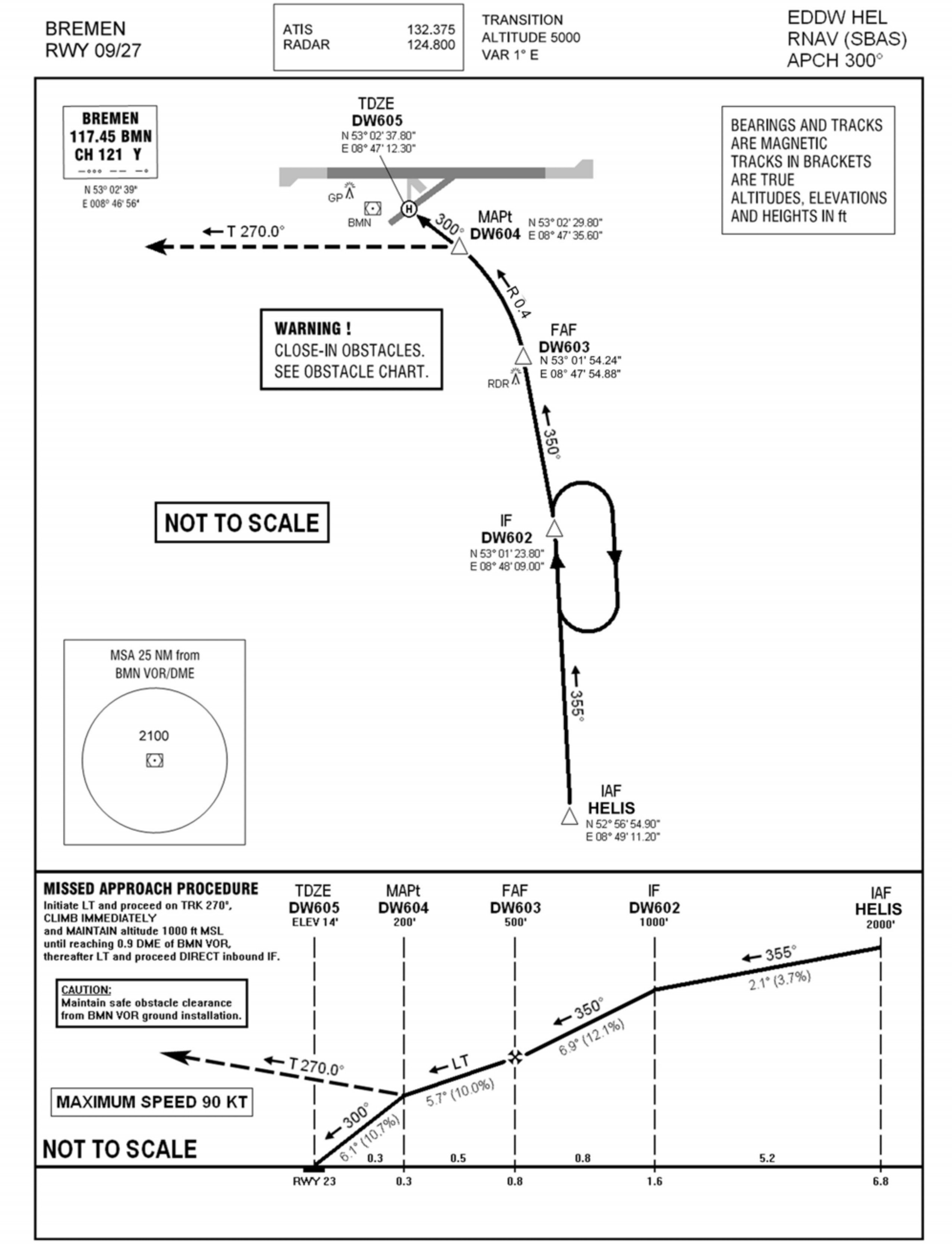

Figure 2: **Helicopter specific steep and curved IFR approach procedure initially developed for Bremen airport (EDDW)**

Both pilots have conventional helicopter controls. In contrast to the standard seating arrangement of five, this helicopter has three seats with the flight test engineer's station being located directly behind the two pilots.

The curved approaches to Bremen were flown manually. Two different guidance concepts have been used: a tunnel display and a Bug-PFD-guidance display. The Bug-PFD-guidance display is based on a standard PFD display which is extended by guidance commands for speed, altitude and heading. The approaches were flown in accordance to Figure 2.

In total four flight days with 49 approaches to Bremen airport have been arranged with both display versions. The tunnel version was more accepted by the pilots and is described in detail in the following.

"Tunnel in the sky"-DISPLAY

The tunnel-in-the-sky display shows the predefined flight route in form of a virtual 3D-tunnel to increase pilot's situation and mission awareness. The tunnel coordinates are based on the time-based trajectory which is generated by the trajectory generator of the FMS taking into account the performance parameters of the helicopter. In essence, in this process some bases are added to the predefined discrete waypoints to describe a continuous sequence of the flight route. The tunnel coordinates are ground referenced in contrast to the heading command which considers the current wind speed and direction.

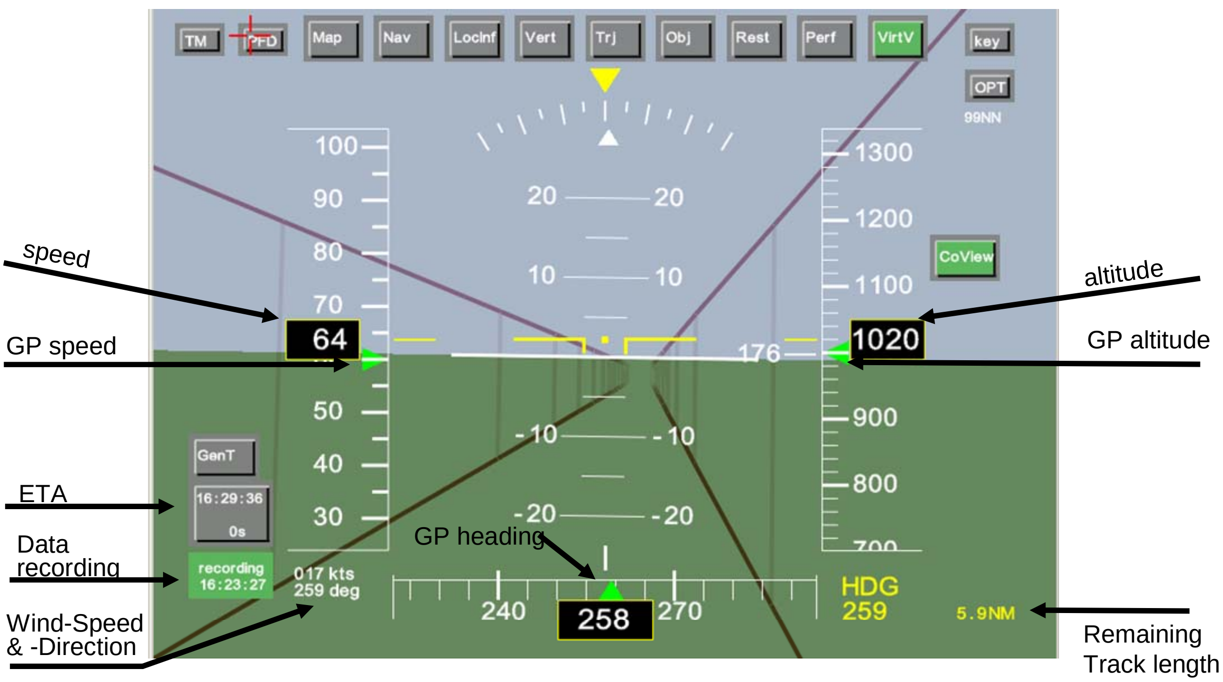

Figure 3: "Tunnel in the sky"-Display

In the scope of the real flight trials the dimension of the 80m x 60m tunnel size was accepted by the pilots. The distance between the tunnel's vertical lines varies in dependency of a straight flight path segment or a radius turn (Figure 4). In addition to the guidance commands, important state vectors of the helicopter are also presented on the tunnel display, e.g. current air speed, altitude, attitude and heading (**Figure 3**). The heading and altitude values are also implied by the tunnel's run. For the pilot the remaining track length and the current wind conditions (speed and direction) are also displayed.

Figure 4: **Enroute flight with tunnel display**

Figure 5: **Approach flight with tunnel display**

Red colored tunnel gates illustrate parts of the tunnel that are below the decision height (typically 200ft AGL) to give the information for flying under visual conditions (Figure 5). Changes of the descent rate between different segments are indicated by the system some seconds before the next segment begins.

LATERAL AND VERTICAL PERFORMANCE

Each segment of the procedure require a reduction of altitude, beginning with a rather shallow descent on the straight initial segment from the IAF (at 2000 ft MSL) to the IF (DW602, at 1000 ft MSL). Due to an initial segment length of 5.2 nautical miles, the resulting slope equals 2.1° (3.7%). This segment will also contain a speed reduction from initially 90 kt (at the IAF) down to 60 kt (at the IF).

From the IF (DW602, 1000 ft MSL), the rotorcraft will continue descending without further speed changes and with a 5° heading change to the left on a straight intermediate segment to the FAF (DW603, ASR, fly-over at 500 ft) on a 6.9° (12.1%) slope.

The curved final approach segment (fixed radius turn, R 0.4nm) from the FAF to the MAPt contains (besides continuous but moderate heading changes to the left) a simultaneous reduction of speed (from 60 kt at turn entry down to 45 kt at turn exit) and altitude (200 ft at MAPt) on a slope of 5.7° (10.0%).

The short straight final segment from the MAPt at 200 ft MSL down to the landing spot (elevation 14 ft MSL) on runway 23 includes a speed decrement from initially 45 kt down to a hover at 0 kt.

The following evaluation of flight test data is based on the results of the second and third day of flight trials at Bremen airport. The wind conditions varied between 2-5 kts from variable direction (third day) to 18 kts from 195° (second day). The SBAS system gave a high precision position and the EGNOS signals were available all the time during operation.

All flight tests have been executed as it had been determined in the pre-flight preparations. A data recording function is part of the FMS to write all relevant state and command vectors to a text file.

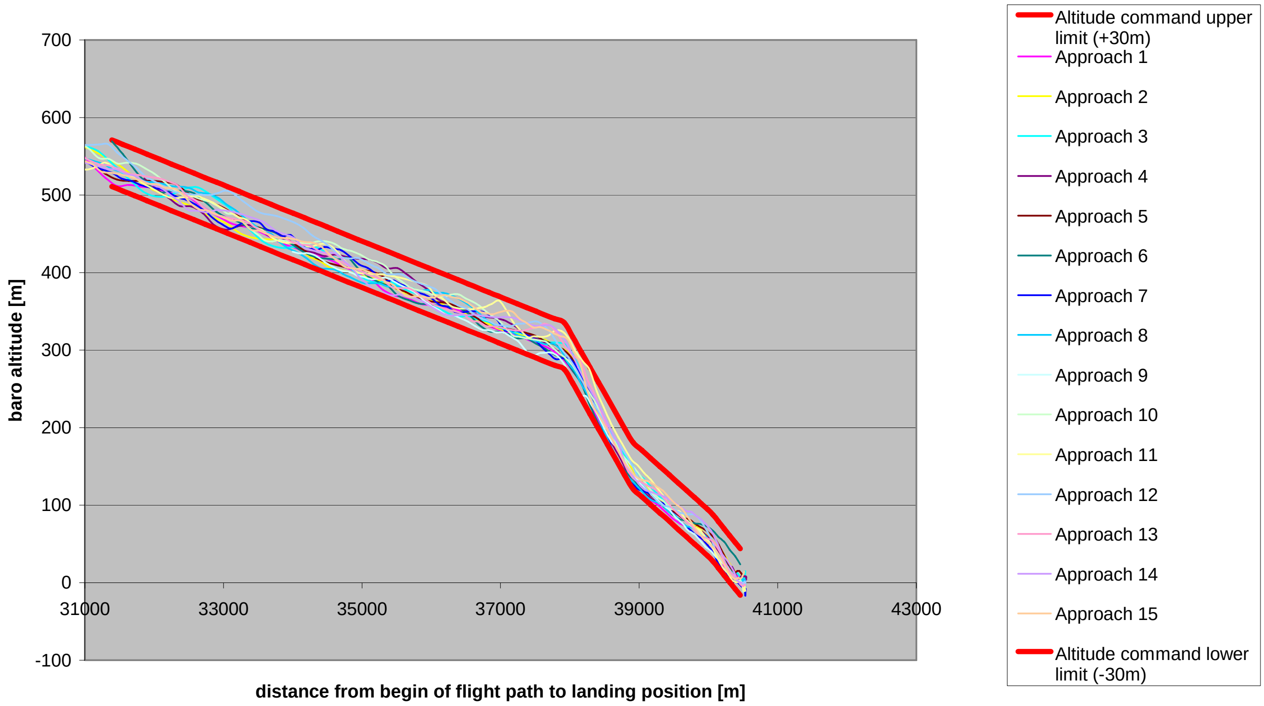

Figure 6: **Comparison between curved approach trajectory and flight paths of 15 approaches with "tunnel in the sky" guidance (altitude)**

Figure 6 shows the deviations of the real and the predefined flight path regarding the commanded altitude constraints for the last 5 NM from the initial approach segment to the touchdown zone TDZE. The two red lines symbolize the upper and lower limits defined by the dimension of the tunnel display. The vertical FTE is about 10m and the lateral FTE is lower than 25m (Figure 7) – this is close to the desired performance.

Figure 6 and Figure 7 only display the results of the “tunnel-in-the-sky” test flights. The flight technical errors with the use of the modified PFD guidance display were much higher, because the pilot has to bring in line the current altitude, speed and heading values with the commanded values. This produces a higher workload. In contrast to the PFD-display the pilot can operate easily inside the area of the tunnel display to feel confident operating inside an obstacle free area.

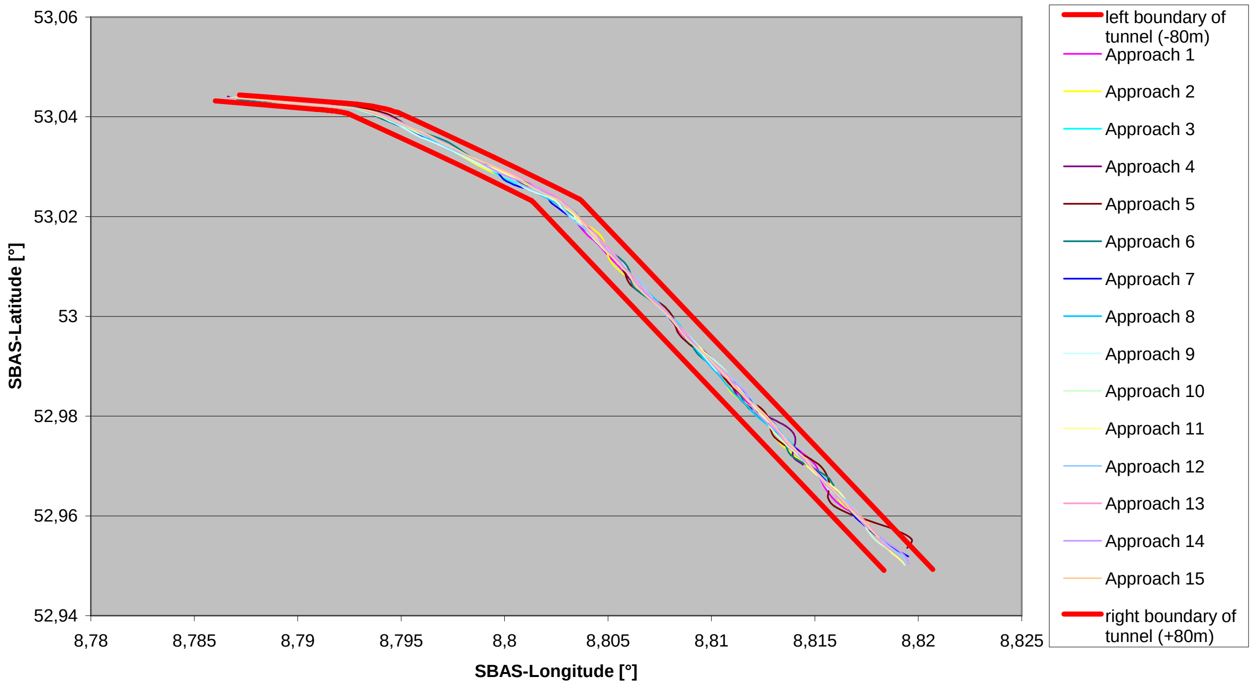

Figure 7: **Comparison between curved approach trajectory and flight paths of 15 approaches with "tunnel in the sky" guidance (lateral)**

RESULTS AND CONCLUSIONS

The technical flights have demonstrated the flyability of the designed helicopter approach procedure under simulated IFR conditions. No problems or complaints related to this subject were reported from any crew member. This had to be expected because the flight crew was also partially involved in the design of the experimental approach procedure.

The GARMIN GNS 480 receiver unit worked as intended and provided the required navigation data to the helicopter's flight management system. The location of the L1 antenna on top of the forward section of the helicopter's vertical stabilizers provided an unobstructed LOS connection to the SBAS navigation satellites with good signal quality. The GARMIN receiver unit is not a stock model. It has been sent to the manufacturer with a request for a special modification. This modification allows it to receive and process EGNOS MT0/2 signals despite the fact that these are not certified for Civil Aviation or other safety critical purposes yet. Therefore, the modified GARMIN 480 unit should be considered an "experimental" status device.

Within the frame of the mission planning, the necessary data were entered into the FMS by the engineering ground team. The FMS was extended by a software component providing a display indication with respect to the required time of arrival (RTA), thus enabling full 4D flight capability.

During earlier (non-OPTIMAL-related) flight tests, a flight with a mission profile containing 15 waypoints over a total distance of 30 nautical miles was conducted

under manual control with a resulting final time error of only 3 seconds delay on arrival at the final destination. This can be considered as quite a success.
The recorded values for the allowed maximum flight technical error were below the defined limits (horizontal error < 25 m, vertical error < 10 m).

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