SESAR 2020 VLD - AAL2 Demonstration Report – Appendix A

Deliverable ID:	D2.1
Dissemination Level:	PU
Project Acronym:	AAL2
Grant:	783112
Call:	H2020-SESAR-2016-2
Topic:	SESAR-VLD1-06-2016
Consortium Coordinator:	HON
Edition Date:	10 July 2020
Edition:	01.00.00
Template Edition:	02.00.01

Founding Members
EUROPEAN UNION
EUROCONTROL
SESAR JOINT UNDERTAKING

Authoring & Approval

Authors of the document

Name/Beneficiary	Position/Title	Date
Samuel Merlet/Airbus	Project Contributor	8th July 2020
Guillaume Dageville/ATR	Project Contributor	8th July 2020
Alexander Vanwelsenaere/skeyes	Project Contributor	8th July 2020
Catherine Champagne/DAV	Project Contributor	8th July 2020
Olivier Baudson/DAV	Project Contributor	8th July 2020
Richard Esnon/DAV	Project Contributor	8th July 2020
Thierry Descamps/DAV	Project Contributor	8th July 2020
Olaf Weber/DFS	Project Contributor	8th July 2020
Fethi Abdelmoula/DLR	Project Contributor	8th July 2020
Thomas Dautermann/DLR	Project Contributor	8th July 2020
Sophie Baranes/DSNA	Project Contributor	8th July 2020
Enis Aksu/DLH	Project Contributor	8th July 2020
Vanessa Rullier/EBAA	Project Contributor	8th July 2020
Jiri Ilcik/HON	Consortium Coordinator	8th July 2020
Matej Kucera/HON	Project Contributor	8th July 2020
Martin Walczysko/HON	Project Contributor	8th July 2020
Pavel Ptacek/HON	Project Contributor	8th July 2020
Liam Riordan/Ryanair	Project Contributor	8th July 2020
Shane McKeon/Ryanair	Project Contributor	8th July 2020
Thomas Buchanan/skyguide	Project Contributor	8th July 2020

Reviewers internal to the project

Name/Beneficiary	Position/Title	Date
Samuel Merlet/Airbus	Project Contributor	9th July 2020
Veronique Travers-Sutter/Airbus	Project Contributor	9th July 2020
Antonio Sperandio/ATR	Project Contributor	9th July 2020
Guillaume Dageville/ATR	Project Contributor	9th July 2020
Alexander Vanwelsenaere/skeyes	Project Contributor	9th July 2020
Catherine Champagne/DAV	Project Contributor	9th July 2020
Olivier Baudson/DAV	WP Manager	9th July 2020

Olaf Weber/DFS	Project Contributor	9th July 2020
Fethi Abdelmoula/DLR	Project Contributor	9th July 2020
Thomas Dautermann/DLR	Project Contributor	9th July 2020
Sophie Baranes/DSNA	Project Contributor	9th July 2020
Enis Aksu/DLH	Project Contributor	9th July 2020
Vanessa Rullier/EBAA	Project Contributor	9th July 2020
Jiri Ilcik/HON	Consortium Coordinator	9th July 2020
Matej Kucera/HON	Project Contributor	9th July 2020
Martin Walczysko/HON	WP Manager	9th July 2020
Pavel Ptacek/HON	Project Contributor	9th July 2020
Shane McKeon/Ryanair	Project Contributor	9th July 2020
Thomas Buchanan/skyguide	Project Contributor	9th July 2020
Andreas Lipp/Eurocontrol	Project Reviewer	9th July 2020

Approved for submission to the SJU By - Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date
Veronique Travers-Sutter/Airbus	Project Contributor	9th July 2020
Antonio Sperandio/ATR	Project Contributor	9th July 2020
Tom Snyers/skeyes	Project Contributor	9th July 2020
Catherine Champagne/DAV	Project Contributor	9th July 2020
Olivier Baudson/DAV	WP Manager	9th July 2020
Oliver Reitenbach/DFS	Project Contributor	9th July 2020
Thomas Dautermann/DLR	Project Contributor	9th July 2020
Michael Hopp/DLH	Project Contributor	9th July 2020
Sophie Baranes/DSNA	Project Contributor	9th July 2020
Vanessa Rullier/EBAA	Project Contributor	9th July 2020
Jiri Ilcik/HON	Consortium Coordinator	9th July 2020
Tereza Spalenkova/HON	Project Contributor	9th July 2020
Shane McKeon/Ryanair	Project Contributor	9th July 2020
Thomas Buchanan/skyguide	Project Contributor	9th July 2020

Rejected By - Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date

Document History

Edition	Date	Status	Author	Justification
00.00.01	30/06/2020	First Draft	Honeywell	First draft provided to SJU
01.00.00	10/07/2020	Final	Honeywell	Approved document and handed over to SJU

Copyright Statement

Table of Contents

List of Tables

List of Figures

Appendix A Demonstration Exercise EXE-VLD-V4-100 Report

This is an Appendix A to the SESAR 2020 AAL2 Demonstration Report for Augmented Approaches to Land 2 project. This Appendix presents the detailed analysis and assessments on the objectives from EXE_VLD-V4-100. The section is structured as follows:

- Demonstration Exercise Plan (Section A.1)
- Deviation from the Planned Activities (Section A.2)
- Demonstration Exercise Results (Section A.3)
- Conclusion (Section A.4)
- Recommendations (Section A.5)

A.1 Summary of the Demonstration Exercise EXE-VLD-V4-100 Plan

A.1.1 Exercise description and scope

This section includes EXE-VLD-V4-100 planning, demonstration platforms, ground/airborne preparation activities and flight demonstration description.

1. Demonstration Exercise Platforms, Data Collection and Methods

GBAS CAT II operation on CAT I equipment demonstration exercise was supported on the ground side by Honeywell GBAS ground station SLS 4000. Block II with SBAS receiver upgrade in Bremen was available but not in service. On airborne side, the exercise was be supported by Ryanair (Boeing 737NG) and Lufthansa (Boeing 747-8 and A320 family) revenue flight fleet equipped with current GLS avionics. Aircraft platforms contains flight data monitoring system, Electronic Flight Bag Aircraft Data Recorder (EFB-ADR) on Lufthansa aircraft will allow to gather flight data. Lufthansa and Airbus aircraft simulators (B747-8 and A320 fam) were used to support safety case preparation flight demonstrations.

Demonstration Exercise Technique

Exercise EXE-VLD-V4-100 utilize demonstration flight, data collection and analysis techniques to perform exercise and achieve demonstration objectives.

Data collection methods

Lufthansa and Ryanair collected internal aircraft data, as well as questionnaires with pilots to evaluate human performance and safety KPAs. DLR cooperated with Lufthansa to collect data for fuel/environment efficiency and group as far as possible all approaches regarding used landing system, manual/automatic flight, landing flaps configuration and weather conditions. Data collection is described below with respect to demonstration objectives.

Feasibility of RNP to GLS approaches

In order to evaluate the feasibility of demonstrated approaches, pilots were asked to fill in a questionnaire.

[qualitative]

Feasibility of practice GLS CAT II Autoland approaches GBAS CAT I airborne and ground equipment

In order to evaluate the feasibility of demonstrated approaches, pilots were asked to fill in a questionnaire.

[qualitative]

Horizontal and vertical path accuracy of RNP to GLS approaches

In order to measure the aircraft position Ryanair and Lufthansa collected internal aircraft data to evaluate safety KPA.

[quantitative]

Horizontal and vertical path accuracy of practice GLS CAT II Autoland approaches

In order to measure the aircraft position Ryanair and Lufthansa collected internal aircraft data to evaluate safety KPA.

[quantitative]

Fuel efficiency benefits of GLS approaches compared to legacy ILS

Benefit of the GBAS`s more stable signals compared to ILS in respect to fuel/environmental efficiency, savings on fuel will be evaluated using relevant flight data and recording tools.

[quantitative]

Environment benefits of GLS approach compared to legacy ILS

Based on the fuel burned during approach the CO_2 emission can be estimated.

[quantitative]

To estimate cost efficiency of GLS CAT II approaches on GBAS CAT I equipment

Costs effectiveness of GLS CAT II operation on CAT I equipment will be evaluated through the flight demonstrations and qualitative analysis.

[qualitative]

Measured Parameter	Tool	Data Format	DFS	Lufthansa	Ryanair
Number of demonstration approaches	Flight log, electronic log	Paper, binary	☑	☑	☑
Weather conditions	SW tool	numeric	N/A	☑	☑

GBAS VDB data	Telerad on ground	numeric (binary)	☑	N/A	N/A
GBAS Ground Station Data	Recording tool	numeric (binary)	☑	N/A	N/A
Aircraft parameters (internal bus)	Flight data recorder and currently installed	numeric (binary)	N/A	☑	☑
Pilot qualitative evaluation	Questionnaire	-	N/A	☑	☑

Table 1: Collected data for EXE-VLD-V4-100

2. Ground System Preparation

Ground part involved Bremen Airport – Germany where the Ground System included the conversion of the Honeywell SLS-4000 Block 2 (GAST C) station to SLS-4000 Block 2S (GAST C) that allows GLS CAT II approaches, with approval from appropriate country regulatory body (BAF). Ground system preparation was divided into multiple parallel efforts that consisted of CONOPS creation, GBAS station upgrade, German Type approval receipt, GLS CAT II approach plates publication, flight check and validation of new procedures and upgrade station at Bremen airport.

DFS modified the existing GBAS Concept of Operations (CONOPS) for GBAS CAT II operations addressing all ATC relevant aspects including operation procedures and training. This led to the modification of ATS maintenance interface and training for ATCO. In addition, existing GLS procedures were revised by DFS with CAT II minima and new GLS procedures with feeding RNP including RF legs were designed and published in Bremen in July 2019 AIRAC. New GBAS Final Approach Segment Data Blocks (FAS DB) for GLS CAT II approaches were prepared. Published GLS procedure is a predecessor to GLS CAT II procedure and is using CAT I minima of 200ft before CAT II could be officially published and fly on certified GBAS ground station.

Honeywell provided the needed GBAS Station upgrade from SLS-4000 Block 2 to Block 2S as an in-kind contribution to the project. The US SDA approval of the SLS-4000 Block II with SBAS receiver (Block 2S) was used as a baseline. The conformance reports supported both the safety case and configuration data to update the system to use the EGNOS (EU SBAS) in lieu of the approved WAAS (US SBAS). DFS integrated the required EGNOS SBAS receiver, re-configured the station with configuration files prepared by Honeywell and conducted ground measurements according to ICAO Doc 8071 (Manual on Testing of Radio Navigation Aids). Ground and flight testing of GBAS SLS-4000 Block 2 at Bremen airport were completed as a necessary predecessor for final Block 2S update.

Honeywell created ground station safety case focused on safety assurance activities mainly related to the incorporation of EGNOS into the SLS-4000 Block 2 with SBAS the details are described in section C.1.2. GBAS Ground Station Safety Assessment. Independent audit report was generated for German National Supervisory Authority (Bundesaufsichtamt für Flugsicherung, BAF) to grant the approval. However, due to still ongoing process with BAF on certification of GAST-C Block IIS for operations with EGNOS, certification could not be achieved within AAL2 timeline. Honeywell plans to keep seeking a System Design Approval from BAF for the SLS-4000 Block II GBAS utilizing EGNOS after AAL2 project.

3. Airborne Preparation

The airborne preparation consisted in series of activities to prepare for AAL2 demonstrations and acquire respective operational approvals for GLS CAT II Autoland operations from national regulators namely LBA (Germany) and IAA (Ireland) in Europe and with FAA (US) to show interoperability of the system cross different SBAS systems.

Lufthansa worked with national regulator, LBA, to obtain trial and operational approvals for GLS CAT II approaches on CAT I equipment with support of Airbus for A319, A320, A321, including needed airborne analysis and worked with the necessary regulatory bodies (EASA, FAA) to obtain a GBAS CAT II airworthiness approval of A320 family existing avionics. Operational Risk Evaluation (ORE) was prepared in the frame of safety activities for GBAS Autoland approaches. Demonstration flights campaign was preceded by pilots in the loop simulations on GLS Autoland.

A formal request of the trial approval was thus submitted to LBA for A320fam and B747-8. Due to COVID-19 outbreak, simulator session which was the last element to obtain approval from LBA by DLH for B747-8, could not take place. Operational approval for A320 family is waiting Airbus to finish airworthiness approval process. In the parallel effort Lufthansa submitted a formal request for the trial approval for Newark, US (FAA).

Ryanair worked with their national regulator, IAA, to obtain approvals for GLS CAT II approaches on CAT I equipment with support of Boeing for B737-800 (NG). Considering Ryanair GLS approval status at the beginning of the project, Ryanair completed more than 300 GLS CAT I manual approaches on B737-800 in Frankfurt and Bremen and Malaga during AAL2 project in the frame of preparation on GLS CAT I/II Autoland demonstration approval by IAA approval. Due to delay in obtaining fleet GLS OPS approval Ryanair decided to ask IAA to extend GLS CAT I manual trial approval for GLS CAT I Autoland that would support practice GLS CAT II evaluation instead of waiting for fleet GLS CAT I manual OPS approval and then asking for full GLS. However, revenue practice GLS CAT II approaches could not be performed as approval was finally not obtained in AAL2 timeframe and Ryanair fleet was unexpectedly grounded due to COVID-19 outbreak. Ryanair will seek the approval towards GLS CAT II outside AAL2 starting with GLS Autoland.

Due to delays in certification of Honeywell ground station upgrade from national regulator and OPS approval for airlines, practice GLS CAT II approaches were finally prepared for flight accuracy and pilot feasibility demonstration objective assessment as introduced in Chapter 3.4.2.1.1 and 3.5.1.

Airbus worked on operational approval for A319, A320, A321, including necessary airborne analysis and work with EASA to obtain a GBAS CAT II airworthiness approval of A320 family existing avionics. Further on Airbus completed the Safety Impact analysis and held simulation session with Lufthansa. Airbus is preparing detailed presentation of Simulator Failure Test Program to EASA that will however take place outside AAL2. Results are available, A320 meets CAT II requirements. The delay accommodated during EASA regulatory process in obtaining A320 family GLS CAT II airworthiness approval caused that approval process was not finished before end of AAL2 to allow Lufthansa to obtain GLS CAT II operational approval for A320 family. Airbus intends to continue GLS CAT II certification outside AAL2.

4. Flight Demonstrations

During trial execution, project demonstrated in total 76 demonstration flights. Majority of EXE-VLD-V4-100 demonstration flights were performed as practice GLS CAT II Autoland approach. Due to nature of applied pilot operating method, operational experience with such operation when pilot is practicing GLS CAT II on revenue flight allowed to fill operationally get experience the allows to fill the gap between current GLS CAT I manual approach operation and full GLS CAT II Autoland operation in LVC, especially from onboard perspective, while leveraging GBAS CAT I equipment, current GLS approaches and ATC procedures for non-LVC conditions.

Lufthansa performed 43 practice GLS CAT II Autoland demonstrations in high complexity environment of Frankfurt airport airspace and medium complexity environment of Bremen airport airspace with A320 family. As the baseline GLS CAT I Autoland and published GLS CAT I procedure were used. At the same time of A320 family demonstration flights, the practice GLS CAT II Autoland approaches were flown with B747-8 with 14 approaches finished in the AAL2 timeframe. Compared to GLS CAT I Autoland, the key difference of practice GLS CAT II compared to GLS CAT I was onboard the aircraft and applied pilot operating method as described in Chapter 3.4.2.1.1. This approach allowed to get significant operational experience to demonstrate OPS regulators readiness for full GLS CAT II. Lufthansa also performed 12 RNP to GLS approaches on A320 fam focusing on flight accuracy and pilot feasibility.

To test practice GLS CAT II, Ryanair pilots flew 1 practice GLS CAT II Autoland approach using Ryanair practice CAT II procedures in the USA at Grant county international Airport (KMWH) during aircraft acceptance flight, i.e. non-revenue flight on B737-800 aircraft that was not yet registered on Ryanair. Ryanair flew as well 6 RNP to GLS approaches focusing on flight accuracy and pilot feasibility.

Lufthansa supported also fuel and CO2 evaluation study of GLS vs ILS approach by flight data collection on revenue GLS and ILS approaches to Frankfurt on B747-8 and A320fam. In cooperation with Lufthansa, DLR installed the EFB data recorder on the aircraft, set up an automated process for data in the frame of data collection in Frankfurt for GLS and ILS fuel and CO2 efficiency comparison study. DLR study included simulation on different parameters impacting evaluated CTQs. Then real flight data from Lufthansa data collection for approaches with Boeing 747-8 on runway 25L and 07R in Frankfurt/Main (EDDF) were analysed. In total, 574 approaches of different Boeing 747-8 aircraft conducted between July and December 2018 on runway 25L and runway 07R were selected for the analysis. About one half of the approaches (235 approaches) were conducted using GLS and the remaining approaches (291 approaches) were conducted using ILS. Noise measurements from ground stations were analysed as well. On A320 family, almost 400 GLS and ILS approaches of A319 aircraft were selected for final fuel benefits assessment.

A.1.2 Summary of Demonstration Exercise EXE-VLD-V4-100 Demonstration Objectives and success criteria

Summary of ESE-VLD-V4-100 demonstration objectives and success criteria are provided in the table below.

Demonstration Objective	Demonstration Success criteria	Demonstration Exercise Objectives	Demonstration Exercise Success criteria
OBJ-VLD-V4-011	CRT-VLD-V4-011-001	EX1-OBJ- VLD-V4-011 To demonstrate feasibility of RNP to GLS CAT II approaches with GBAS CAT I airborne and ground equipment	EX1- CRT-VLD-V4-011-001 RNP to GLS CAT II approaches are perceived feasible by pilot at 95% of successful approaches
OBJ-VLD-V4-012	CRT-VLD-V4-012-001	EX1-OBJ- VLD-V4-012 To demonstrate feasibility of GLS CAT II approaches with GBAS CAT I airborne and ground equipment	EX1- CRT-VLD-V4-012-001 GLS CAT II approaches are perceived feasible by pilot at 95% of successful approaches
OBJ-VLD-V4-014	CRT-VLD-V4-012-001	EX1-OBJ- VLD-V4-014 To demonstrate feasibility of practice GLS CAT II Autoland approaches with CAT I airborne and ground equipment	EX1- CRT-VLD-V4-014-001 Practice GLS CAT II Autoland approaches are perceived feasible by pilot at 95% of successful approaches
OBJ-VLD-V4-021	CRT-VLD-V4-021-001	EX1-OBJ- VLD-V4-021 To demonstrate horizontal and vertical path accuracy of RNP to GLS approaches	EX1- CRT-VLD-V4-021-001 Horizontal FTE of GLS approaches is within 0.5 NM
	CRT-VLD-V4-021-002		EX1- CRT-VLD-V4-021-002 Vertical path of GLS approaches does not breach FAP constraint minus 100 ft limit considering temperature compensation

OBJ-VLD-V4-028	CRT-VLD-V4-028-001	EX1-OBJ- VLD-V4-028 To demonstrate lateral and vertical path accuracy of practice GLS CAT II Autoland approach	EX1- CRT-VLD-V4-028-001 Lateral FTE of GLS approach is within 1 dot
	CRT-VLD-V4-028-002		EX1- CRT-VLD-V4-028-002 Vertical FTE of GLS approach is within 1 dot
OBJ-VLD-V4-022	CRT-VLD-V4-022-001	EX1-OBJ- VLD-V4-022 To demonstrate fuel efficiency benefits of GLS approach compared to legacy ILS	EX1- CRT-VLD-V4-022-001 Fuel burnt on GLS approach is decreased compared to legacy ILS by at least 3%
OBJ-VLD-V4-023	CRT-VLD-V4-023-001	EX1-OBJ- VLD-V4-023 To demonstrate environment benefits of GLS approach compared to legacy ILS	EX1- CRT-VLD-V4-023-001 CO2 emissions on GLS approach are decreased compared to legacy ILS by at least 3%
OBJ-VLD-V4-031	CRT-VLD-V4-031-001	EX1-OBJ- VLD-V4-031 To estimate cost efficiency of GLS CAT II approaches on GBAS CAT I equipment	EX1- CRT-VLD-V4-031-001 Costs effectiveness of GBAS CAT II operation on CAT I equipment is proved through flight demonstration and qualitative analysis

Table 2: EXE-VLD-V4-100 demonstration objectives and success criteria overview

A.1.3 Summary of Validation Exercise EXE-VLD-V4-100 Demonstration scenarios

1. Reference scenario

The reference scenario for this project is given by the today's situation regarding operational environment and approach procedures implemented at the Bremen and Frankfurt airport, vectored to CAT I precision approach manually flown by flight crews.

2. Solution scenario

The solution scenario consisted in the demonstration of the practice GLS CAT II Autoland approaches using ground GBAS GAST-C (CAT I equivalent) equipment, airborne GBAS CAT I equipment, ATC and published GLS approach procedures at Bremen and Frankfurt as baseline. For Bremen airport, solution scenario was extended with RNP to GLS approaches with RF legs with Autoland and also manual landings. Demonstrations were conducted in actual traffic and airport environment.

While ground station and ATC CONOPS modification were performed to support full GLS CAT II including ATC interface, they could not be finally demonstrated as approval process was delayed and yet not finished.

A.1.4 Summary of Demonstration Exercise EXE-VLD-V4-100 Demonstration Assumptions

Identifier	Title	Type of Assumption	Description	Justification	Flight Phase	KPA Impacted	Source	Value(s)	Owner	Impact on Assessment
ASS-AAL2-EXE100-1	GBAS CAT II Type Approval	Regulation	The exercise will be conducted assuming that the German regulator will provide Type Approval for GBAS station (GAST C) allowing GLS CAT II operations.	The CAT II operations require unique approval different from current CAT I approval.	Approach	safety, human performance	Type Approval Requirements	N/A	AAL2	High
ASS-AAL2-EXE100-2	Number of ILS and GLS approaches for	Approach number	Over 100 ILS and 100 GLS valid approaches needs to	DLR expects 100 valid approaches per approach	Approach	fuel and environment efficiency	Expert opinion	200	AAL2	Low

	comparison study		be flown on Lufthansa A320 family aircraft to evaluate fuel and environment efficiency	type as sufficient for evaluation						
ASS-AAL2-EXE100-3	Using current airborne GBAS equipment	Regulation	GLS CAT II operation will be demonstrated using currently available GBAS airborne equipment	Demonstration will show GLS CAT II on current fleet revenue flights	Approach	safety, human performance	Validation objective	N/A	AAL2	High
ASS-AAL2-EXE100-4	ATC CONOPS	ATC Procedures	The exercise will be conducted assuming ATC CONOPS will be updated	ATC CONOPS needs to be updated to cover GLS CAT II approach operation	Approach	safety, human performance	Regulation	N/A	AAL2	High
ASS-AAL2-EXE100-5	Approach procedures	Regulation	The exercise will be conducted assuming approach procedures will be published or updated till demonstration flight timeframe	New RNP to GLS procedures (Bremen) and GBAS procedures with CAT II minima (Bremen, Newark) need to be available	Approach	safety, human performance	Type of validation	N/A	AAL2	Medium
ASS-AAL2-EXE100-6	Airline aircraft base	Airline operations	Aircraft base in Bremen is considered to fly high number of GLS CAT II Autoland	Number GLS CAT II approaches depends on number of Ryanair aircraft	Approach	safety, human performance	Airline	N/A	AAL2	Medium

				operated to Bremen						
ASS-AAL2-EXE100-7	OPS approval	Regulation	The exercise will be conducted assuming OPS approval will be obtained by Lufthansa from LBA and by Ryanair from IAA	OPS approval needed to fly GLS CAT II approaches	Approach	safety, human performance	German and Irish Regulator	N/A	AAL2	High
ASS-AAL2-EXE100-8	OP-SPEC approval	Regulation	The exercise will be conducted assuming OP-SPEC approval was obtained by Lufthansa	Approval needed for Lufthansa fly to Newark airport	Approach	safety, human performance	U.S. regulator	N/A	AAL2	Medium
ASS-AAL2-EXE100-9	Airworthiness approval	Regulation	Airworthiness approval will be obtained by Airbus from EASA for A320 family	Need of airworthiness approval for A320 family expected	Approach	safety, human performance	European regulator	N/A	AAL2	Medium
ASS-AAL2-EXE100-10	Airline operational evaluation	Airline rule	Airline internal operational evaluation will allow to fly demonstration flights	Before introduction of new operation, airline conducts internal operational evaluation	Approach	safety, human performance	Airline	N/A	AAL2	Medium
ASS-AAL2-EXE100-11	ANSP FTS	Traffic	ANSP FTS assumed 100% aircraft GBAS equipped for the	Comparison of 100% ILS CAT II traffic scenario with GLS CAT II traffic	Approach	Cost efficiency	Fast Time Simulations	100 %	AAL2	Medium

			RWY 25R in EEDF	scenario in LVC						

Table 3: EXE-VLD-V4-100 demonstration assumptions overview

A.2 Deviation from the planned activities

Significant progress was made in WP2 on both ground and airborne safety case preparation to support GLS CAT II proof of concept flights demonstrations. However, due to delay in certification of Honeywell GBAS Block IIS upgrade, Lufthansa and Ryanair operation approvals and Airbus A320 family airworthiness approval, full GLS CAT II approach demo could not be performed before the end of the AAL2 project and thus pilot feasibility OBJ-VLD-V4-012 was not evaluated.

In support of GLS CAT II Autoland demonstrations with current GBAS CAT I systems, on the way forward project identified and focused on the means to bridge the gap between currently flown GLS CAT I manual approaches and full GLS CAT II deployment, through demonstration of practice GLS CAT II approaches. As practice GLS CAT II approaches build on GLS CAT I Autoland baseline, this approach allowed airlines to get operational experience to obtain operation approval for full GLS CAT II operation as GLS CAT I Autoland operations are not standardly used due to piloting experience and landing currency needs. This approach enabled AAL2 project to get pilot operational experience of new operation by leveraging current ground and airborne GBAS Autoland capabilities on revenue flights. These demonstrations had thus delivered extensive GLS Autoland experience that can be utilized globally during certification of operation targeting GLS Autoland operation down to both 200ft and 100ft DH. Demonstrations thus helps activities related to GBAS Autoland operation in US towards GLS CAT II OpSpec that is supported by the International GBAS Working Group – CAT II Sub-group.

For this reason, EXE-VLD-V4-100 demonstrations were focusing on practice GLS CAT II approaches described in Chapter 3.4.2.1. of DEMR. Thus, as building on GBAS CAT I and focusing on GLS Autoland approach demonstration, project added two demonstration objectives. First was a safety related parameter of Autopiloted GLS approach of flight path accuracy specified in OBJ-VLD-V4-028, where CTQ value of 1 dot was determined following Lufthansa and Ryanair operating procedures. Second was a pilot feasibility assessment specified in OBJ-VLD-V4-14.

Also, as initial targeted Newark airport for GLS CAT II demonstration didn't provide any commitment to publish relevant approach procedure during the project timeline, it was decided during the project to select Frankfurt airport as alternative representation of large hub airport operating GBAS, that would allow to conduct demonstration of both initially targeted Lufthansa B747-8 and extend them with A320 family demonstration and thus allow to gather more flights. On Ryanair side, although progress was made from very introduction of GBAS operation at the early part of the project and over 300 GLS CAT I manual approaches finished over the course of AAL2 project on Irish regulator approved GLS approach trials, and safety analysis was finished, due to significant delay in process of obtaining operational approval Ryanair and fleet grounding due to COVID-19 outbreak, Ryanair had made use of only possibility to fly a non-revenue practice GLS CAT II approach during acceptance flight of new B737 in US to be introduce in Ryanair fleet.

With respect to RNP to GLS approaches, no approach category was specified in objectives as it does not have effect on RNP to GLS transition phase neither in level of feasibility, nor flight accuracy during RNP part of approach including transition. As neither of airlines aircraft taking part in EXE-VLD-V4-100 flight demonstrations are equipped with the receiver to determine TSE, FTE parameter was used with tighter CTQ value of 0.5 NM for RNP to GLS approaches to Bremen as designed as RNP 1 and project follow ICAO Doc 9613 (PBN Manual) [8] which require to satisfy the accuracy requirement that the 95 percent FTE should not exceed 0.5 NM.

For GLS CAT II cost efficiency evaluation, historical data record with good statistics, fast time simulation and operational experience were used to extend the coverage of sources for the qualitative study that initially targeted evaluation based on flight data collection only.

A.3 Demonstration Exercise EXE-VLD-V4-100 Results

A.3.1 Summary of Demonstration Exercise EXE-VLD-V4-100 Demonstration Results

Summary of summary of Demonstration Exercise EXE-VLD-V4-100 Demonstration Results is provided in table below.

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Resu
OBJ-VLD-V4-011	Feasibility of RNP to GLS approaches	CRT-VLD-V4-011-001	RNP to GLS approaches are perceived feasible by pilot at 95% of successful approaches	APT - Small	RNP to GLS approaches were p by both Lufthansa and Ry operational, safety, workloa methods focus areas. Altho observation made by Lufthans not related to procedures, Approach procedures were a designed and pilot friendly by
OBJ-VLD-V4-012	Feasibility of GLS CAT II approaches	CRT-VLD-V4-012-001	GLS CAT II approaches are perceived feasible by pilot at 95% of successful approaches	APT - Small	Not assessed
OBJ-VLD-V4-014	Feasibility of GLS CAT II Autoland approaches	CRT-VLD-V4-014-001	Practice GLS CAT II Autoland approaches are perceived feasible by pilot at 95% of successful approaches	APT - Very large, Small	Practice GLS CAT II Autoland a perceived feasible by all p approaches except one.
OBJ-VLD-V4-021	Accuracy of RNP to GLS approaches	CRT-VLD-V4-021-001	Horizontal FTE of GLS approaches is within 0.5NM	APT – Small	All the approaches were succe vertical FTE performance of al approaches to Bremen airport the CTQ limit and approa captured when coming directions.
		CRT-VLD-V4-021-002	Vertical path does not breach FAP constraint minus 100 ft limit		
OBJ-VLD-V4-028	Accuracy of practice GLS CAT II Autoland approach	CRT-VLD-V4-028-001	Lateral FTE of GLS approach is within 1 dot	APT - Very large, Small	During all practice GLS C approaches, FTE was well wit non-standard observation in t as visible from the figures, whi GLS CAT I/II Autoland read deployment.
		CRT-VLD-V4-028-002	Vertical FTE of GLS approach is within 1 dot		
OBJ-VLD-V4-022	Fuel efficiency of GLS approach	CRT-VLD-V4-022-001	Fuel burnt on GLS approach is decreased	APT - Very large	Although there were fou between GLS and ILS approach these were found not to be d approach type, therefore any

	compared to legacy ILS		compared to legacy ILS by at least 3%		cannot be attributed to GLS ba data. Criterion is therefore not is expected that if larger amo available, positive influence c type due to better stability thar (ILS beam bends) for heavier a A320, A321) for specific ILS ins analysed EDDF RWY25R would
OBJ-VLD-V4-023	Environment efficiency of GLS approach compared to legacy ILS	CRT-VLD-V4-023-001	CO2 emissions on GBAS approach are decreased compared to legacy ILS by at least 3%	APT - Very large	With constant factor consumption and CO2 em changes in fuel consumption ca as relative changes in CO2 differences between CO2 emis ILS approaches can be observ sufficient evidence to claim th attributed to approach type. expected that if larger amou available, positive influence c type due to better stability thar (ILS beam bends) for heavier a A320, A321) for specific ILS ins analysed EDDF RWY25R would
OBJ-VLD-V4-031	Cost efficiency of GLS CAT II approaches using GBAS CAT I equipment	CRT-VLD-V4-031-001	Costs efficiency of GBAS CAT II operation on CAT I equipment demonstrated by flight demonstration and qualitative analysis	APT - Very large, Medium, Small	Study provided evidence base airspace users that GBAS is e establish new operation with (airlines) and capacity (ANSP/ for operations down to CAT II using GAST C/CAT I equipment

Table 4: Exercise EXE-VLD-V4-100 Demonstration Results

1. Results per KPA

Demonstration Exercise EXE-VLD-V4-100 results are provided per Key Performance Areas addressed in table below.

KPA	KPI	CTQ definition	Where	CTQ value	Exercise Results
Safety	Horizontal flight accuracy (RNP to GLS)	Horizontal FTE of GLS approaches is within CTQ limit.	Bremen	0.5NM	All the approaches were s of flight path accuracy wa performance of all the Bremen airport was w approaches were well different directions.
	Vertical flight accuracy (RNP to GLS)	Vertical FTE of GLS approaches is within CTQ limit.		No descend below FAP constraint -100 ft	All the approaches were s of flight path accuracy v Vertical path performa approaches to Bremen a limit and approaches we from different directions
	Lateral flight path accuracy of practice GLS CAT II Autoland during final approach	Lateral FTE of GLS approaches is within CTQ limit	Bremen, Frankfurt	1 dot	Accuracy evaluation shov CAT II Autoland approacl CTQ without non-standa visible from the figures, v Autoland readiness for w
	Vertical flight accuracy of practice GLS CAT II Autoland during final approach	Vertical FTE of GLS approaches is within CTQ limit	Bremen, Frankfurt	1 dot	Vertical accuracy evalu practice GLS CAT II Autola well within CTQ without r data as visible from the fi CAT I/II Autoland readine
Fuel/ Environment Efficiency	Average fuel burned per approach set (GBAS compared to ILS)	Decreased fuel consumption for GBAS approaches compared to legacy ILS thanks to more stable signal.	Frankfurt – revenue flights	By at least 3%	Although there were four ILS approaches in fuel bu directly related to ap decrease in fuel cannot available data. Criterion it is expected that if available, positive influer better stability than on for heavier aircraft types installations such as ana observed.

	CO2 emission per approach (GBAS compared to ILS)	Decreased CO2 emissions for GBAS approach compared to legacy ILS thanks to more stable signal.		By at least 3%	With constant factor be CO2 emission, relative ch be considered as relati While differences betwe ILS approaches can be o evidence to claim that approach type. Howeve amount flight data is ava approach type due to approach (ILS beam ber (e.g. A320, A321) for sp analysed EDDF RWY25R v
Human Performance	Perceived level of feasibility – pilots (RNP to GLS)	RNP to GLS approaches are feasible based on feedback form pilots	Bremen - pilot questionnaires (revenue flights)	YES,	RNP to GLS approaches v Lufthansa and Ryanair workload and working r there was observation r was not related to proc procedures were assess friendly by Ryanair.
	Perceived level of feasibility - pilots (GBAS CAT II Autoland)	GLS CAT II Autoland approaches are feasible based on feedback form pilots	Bremen - pilot questionnaires (revenue flights)	>95% appr. successful	All practice GLS CAT I perceived feasible by al except one.
Cost efficiency	Cost efficiency of GBAS CAT II approaches on CAT I equipment	Cost efficiency of GBAS CAT II approaches on CAT I equipment	Study	YES, Qualitative outputs	Study provided evidence GBAS airspace users tha establish new airspace (airlines) and capacity operations down to CAT C/CAT I equipment.

Table 5: Exercise EXE-VLD-V4-100 Demonstration Results

A.3.2 Analysis of Exercises Results per Demonstration objective

1. EX1-OBJ-VLD-V4-011 Results

Human factor is an essential element considered in the demonstration. Therefore, record of pilots' view was provided in post-flight filled questionnaires. This allowed to analyse the flight and provide information about the new GLS CAT II on GAST C equipment solution such as information on success of the flight, reason for unsatisfactory trial and necessary information to be collected from flight crew.

Feasibility of new designed and published RNP to GLS approaches with RF legs to EDDW from both approach directions were demonstrated by Lufthansa on A320 family and by Ryanair on B737-800 aircraft in total on 13 revenue flights. Lufthansa crews were briefed with handout and/or CBT. Ryanair crews undertook an e-learning course and each crew were briefed about the approach by RYR GLS coordinator and asked to fill out a questionnaire via EFB email.

Lufthansa flight Crews (CPT/SFO/FO) allocated to AAL2 were briefed (F2F and Handout) by the AAL2 Team together with the respective fleet management. All crew members had the required information package supplied via e-mail and hardcopy in their crew mailboxes. This package contained the Handout and the crew feedback form (see Appendix F). The filled-out forms were returned via Company Mail to the AAL2 team where they have been analysed and kept for further clarification with the crew that have been necessary. In such cases the Demo team contacted the crews and the F2F Feedback also found its way into the HF POV

Post demonstration pilot assessment was based on pilot questionnaires that were divided into 5 key areas: Operational side, Safety, Workload, Working methods and other comments from pilot used in the final assessment and conclusions. In case of Lufthansa, some crews flew approach several times, during Ryanair demonstrations, each crew was different, and no pilot flew the approach twice. The RNP to GLS CAT I approaches in Bremen and the GLS CAT I approaches in Frankfurt were published in the AIP.

The Lufthansa has flown 11 RNP to GLS Revenue Flights at Bremen airport with Airbus A320 family aircraft. The RNP Transition is designed with Altitude Constraints (Max and Min altitude windows) which allows aircrafts to fly continuous descent profiles.

From operational point of view, there were some changes required in cooperation with ATC as the descent was initiated at a pilots desired Top of Descent, but this was not an issue as the traffic volume in this specific sector remains usually quite low. From monitoring the fully managed descent profile, there was some additional workload experienced when flying the transition for the first time, but that decreased as pilots flew the transition multiple times. This had no impact on flight safety as the workload always remained at a very acceptable level. In general, the transition can be well managed with the knowledge of Constant Descent Operations that has been in place at FRA and MUC for many years now. There is no change in working methods required. The outcome of Lufthansa overall assessment was that new RNP to GLS approaches in Bremen were feasible at 95% of successful approaches.

It must be noted that all of Lufthansa flight crews experienced low performance of the A320 autoflight system when flying the RNP transition in Bremen. The autoflight system commanded level offs and ineffective speed controls in Managed mode which makes it impossible to fly the optimum descent path. Some of DLH flight crews needed to correct the flight path by using speed brakes or changing the autoflight system from managed to selected mode. However, analysis of Airbus showed that the FMS software which is installed in the Lufthansa A320 Fleet is not designed for Continuous Descent Approach (CDA), which was important parameter of the DFS design of new RNP to GLS procedures to Bremen. More analysis is needed to find out if there could be an improvement by changing the way how the procedures are coded in the Navigation Data Base of the FMS.

The Ryanair has flown 6 RNP to GLS Revenue Flights at Bremen airport with Boeing 737-800 aircraft flown via different RNP to GLS approach procedure (EMIV, PIXUR, VERED) to Bremen and to different runway 09/27. Some approaches were affected by ATC constrains. From operational point of view, the RNP approach to BRE was considered very efficient in comparison to other RNP approaches. This efficiency leads directly to fuel and time savings. No adverse safety concerns were noted in terms of safety and workload. Workload was exactly the same as other RNP approaches and no differences to normal Ryanair standard operating procedures. The RNP to GLS approach to EDDW was having the same behaviour as RNP to ILS approach from pilot point of view. Ryanair found the shortened RNP approach efficient and time saving, well-constructed approach and very pilot friendly. All of flown RNP to GLS approaches were assessed by pilots as feasible and the criterion of feasibility at 95% of successful approaches was reached based on overall Ryanair assessment.

2. EX1-OBJ-VLD-V4-012 Results

Objective not addressed by flight demonstrations.

3. EX1-OBJ-VLD-V4-014 Results

The core objective from the human factors perspective evaluation of practice GLS CAT II Autoland approach was to collect subjective data on pilot and system performance as well as the perception of the practice GLS CAT II Autoland approaches in support of the evaluation of pilot feasibility with a different kind of aircraft (long and short haul) and at different airports onto varying runways.

The approaches performed on Lufthansa revenue flights were flown by following GLS equipped aircraft:

- Airbus A319
- Airbus A320
- Airbus A321
- Boeing 747-8.

All flights were performed with dedicated crews (mainly training Captains or other management pilots) that were briefed with handout and/or CBT either. Approaches with A320 family were flown to both Frankfurt (EDDF) and Bremen (EDDW) airport, approaches with B747-8 were flown to Frankfurt (EDDF).

The flight Crews (CPT/SFO/FO) were allocated and briefed (F2F and Handout) by the AAL2 Team together with the respective fleet management (B748 and A320). All crew members had the required information package supplied via e-mail and hardcopy in their crew mailboxes. This package contained the Handout and the crew feedback form (see Appendix F). The filled-out forms were returned via Company Mail to the AAL2 team where they have been analysed and kept for further clarification with the crew that have been necessary. In such cases the Demo team contacted the crews and the F2F Feedback also found its way into the HF.

The questionnaire used was divided into 4 main sections:

- Operational
- Safety
- Workload
- Working Methods.

In total, 43 practice GLS CAT II Autoland approaches were performed by Lufthansa with A320 Family and 14 with B747-8 on revenue flights.

To fly the practice GLS CAT II approach in Autoland Mode, a DH of 100ft was inserted into the FMS. All flights were cleared for a GLS CAT I Approach by ATC and weather conditions were better than for CAT I conditions (according to Operational Risk Evaluation). Pilot operating method is described in 3.4.2.1.1.

All Boeing 747-8 flight crews reported a smooth and good performance of the Autoflight function during the Autoland Approach. There were no anomalies reported and no difference to an ILS based Autoland was experienced. All A320 flight Crews reported safe landings in Autoland mode but made some observations which is under investigation by Lufthansa and Airbus. First analysis showed that the performance of the Autoflight system is the same that flight crews experienced when flying an ILS Autoland. The crew workload when flying the GLS CAT I Autoland remained low as the procedure was almost identical to the conventional ILS CAT II/III Autoland procedure at DLH. The only visible difference for pilots on A320 family was the Mode designator in the FMA (Autoland vs. CAT III Dual). System behaviour did not change and when flying the approach several times, the workload remained at this level. Autoland approaches were within the required limits and out of 58 practice GLS CAT II Autoland approaches, only once pilot felt that approach may be too long and landed manually. Therefore, it can be concluded that practice GLS CAT II approaches were perceived feasible by pilots during more than 95% of successful approaches required by criterion set up for OBJ-VLD-V4-014 demonstration objective.

One Lufthansa approach flown to Bremen airport was autopiloted in RNP segment and followed practice GLS CAT II Autoland, which demonstrated the autopiloted advanced procedures, RNP and GLS Autoland. No non-standard deviations were observed by pilots.

Ryanair pilots flown 1 practice GLS CAT II Autoland approach using Ryanair practice CAT II procedures in the USA at Grant county international Airport (KMWH) during aircraft acceptance flight, i.e. non-revenue flight on B737-800 aircraft that was not yet registered on Ryanair. Ryanair pilots flown 1 practice GLS CAT II Autoland approach using Ryanair practice CAT II procedures in the USA at Grant county international Airport (KMWH) during aircraft acceptance flight, i.e. non-revenue flight on B737-800 aircraft that was not yet registered on Ryanair. Therefore, flight data were not recorded for AAL2 and are not included in flight accuracy demonstration objective evaluation. Based on feedback from flight crew no non-standard behaviour was experienced and approach was found feasible following evaluation of pilot questionnaires focus areas (operational, safety, pilot workload and working methods).

4. EX1-OBJ-VLD-V4-021 Results

The following sections describe the demonstration flights results of results of exercise objective EX1-OBJ-VLD-V4-028 separately for airports involved in this demonstration exercise – Bremen and Frankfurt. Demonstration flights includes practice GLS CAT II Autoland and RNP to GLS approaches, all on revenue flights with passengers. For all these demonstration flights the horizontal and vertical Flight Technical Errors (FTE) were evaluated.

The Lufthansa gathered data for 9 flights out of 12 flown with Airbus A320 at Bremen. The Ryanair gathered data for 4 RNP to GLS flights out of 6 flown with Boeing 737-800 at Bremen. The overall summary of number of flights per aircraft and airline is provided in table below. The analysis results of demonstration flights are show separately for each flown procedure, airport, mainline aircraft type and its airline operator for revenue flights.

Operator	Aircraft type	EDDW		
		Total	GLS part	
			Manual	Autoland
DLH flown	A320fam	12	11	1
DLH analyzed		9	8	1
RYR flown	B737-800	6	6	0
RYR analyzed		4	4	0
Total flown		**18**	**17**	**1**
Total analyzed		**13**	**12**	**1**

Table 6: Total number of RNP to GLS demonstration flights

Based on ICAO Doc 9613 (PBN Manual) [8], routes designed as RNP 1, to satisfy the accuracy requirement, the 95 per cent FTE should not exceed 0.5 NM on the initial and intermediate segments. This limit is used for procedure design and infrastructure evaluation and all demonstration flights thus need to comply with this 0.5 NM requirement. The new RNP to GLS procedures in Bremen were used during trials.

The data always starts at the point when the A/C was closer than 0.3 NM to the intended published flight path. It is to be noted that 'spikes' in the horizontal FTE graphs are caused by the way of sampling and the data export process.

Operator/AC type	RWY	RNP Procedure	Procedure	Number of flights	Figures
DLH A320	09	PIXUR	G09Y	1	Figure 1 and

DLH A320	27	VERED	G27Y	8	Figure 3 and Figure 4
RYR B737	09	EMBIV	G09A	1	Figure 5 and Figure 6
RYR B737	09	PIXUR	G09A	1	Figure 7 and Figure 8
RYR B737	27	VERED	G27B	1	Figure 9 and Figure 10
RYR B737	27	PIXUR	G27Y	1	Figure 11 and Figure 12

Table 7: Summary of RNP to GLS flights to Bremen

a. Bremen Airport (EDDW): RNP to GLS Approaches

i. Lufthansa A320 family

The Lufthansa flown 12 RNP to GLS revenue flights at Bremen airport with Airbus A320 family aircraft for which flight data from 9 approaches were gathered for analysis. Out of 9 approaches, 8 were flown on RWY 27 via point VERED and 1 approach was flown to RWY 09 via point PIXUR. Access to flight data of the latest approaches was limited due to COVID-19 outbreak. The overview of all performed flights in Bremen is provided in Table 7 per runway and flown procedure. The FTE performance results are then showed in Figure 1 - Figure 4 for lateral and vertical domain.

All the approaches were successful. Lateral and vertical FTE performance of all the RNP to GLS approaches to Bremen airport was well within the CTQ limit indicated by the red line in the plots. Approaches were well captured when coming from different directions with horizontal FTE well within defined CTQ (±0.5 NM) indicated by red lines on the top and the bottom of the graphs. The CTQ 'No descend below FAP constraint – 100ft' was met as well for all flights. All the approaches were performed with revenue flights during normal operating hours and some flights were vectored to different waypoints.

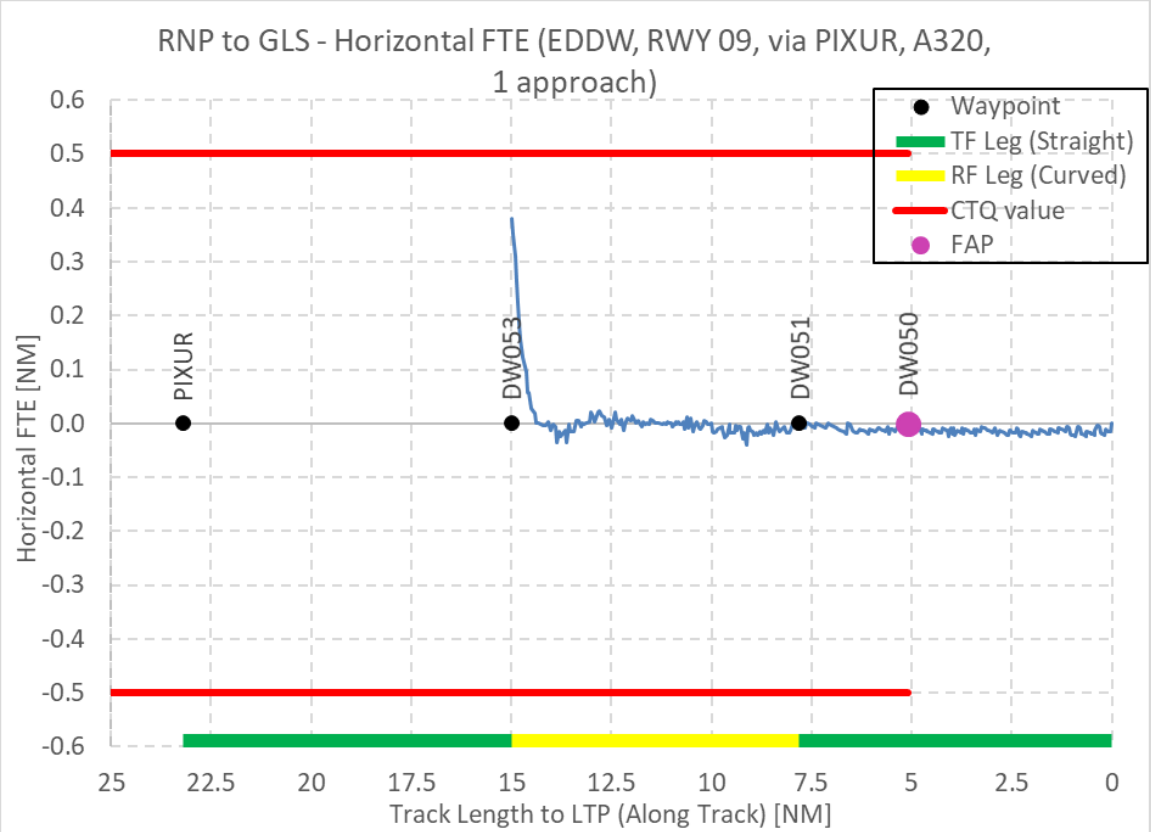

Figure 1: RNP to GLS (DLH) – Horizontal FTE (EDDW, G09Y RWY 09 via PIXUR, A320)

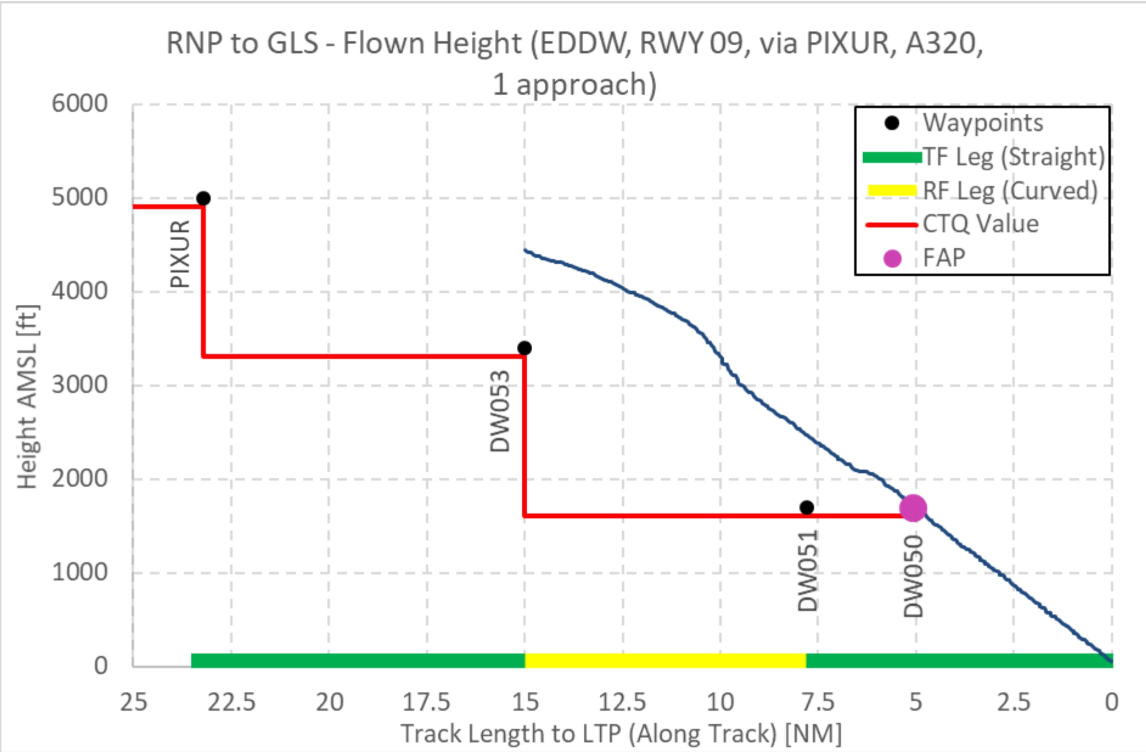

Figure 2: RNP to GLS (DLH) – Vertical Path (EDDW, G09Y RWY 09 via PIXUR, A320)

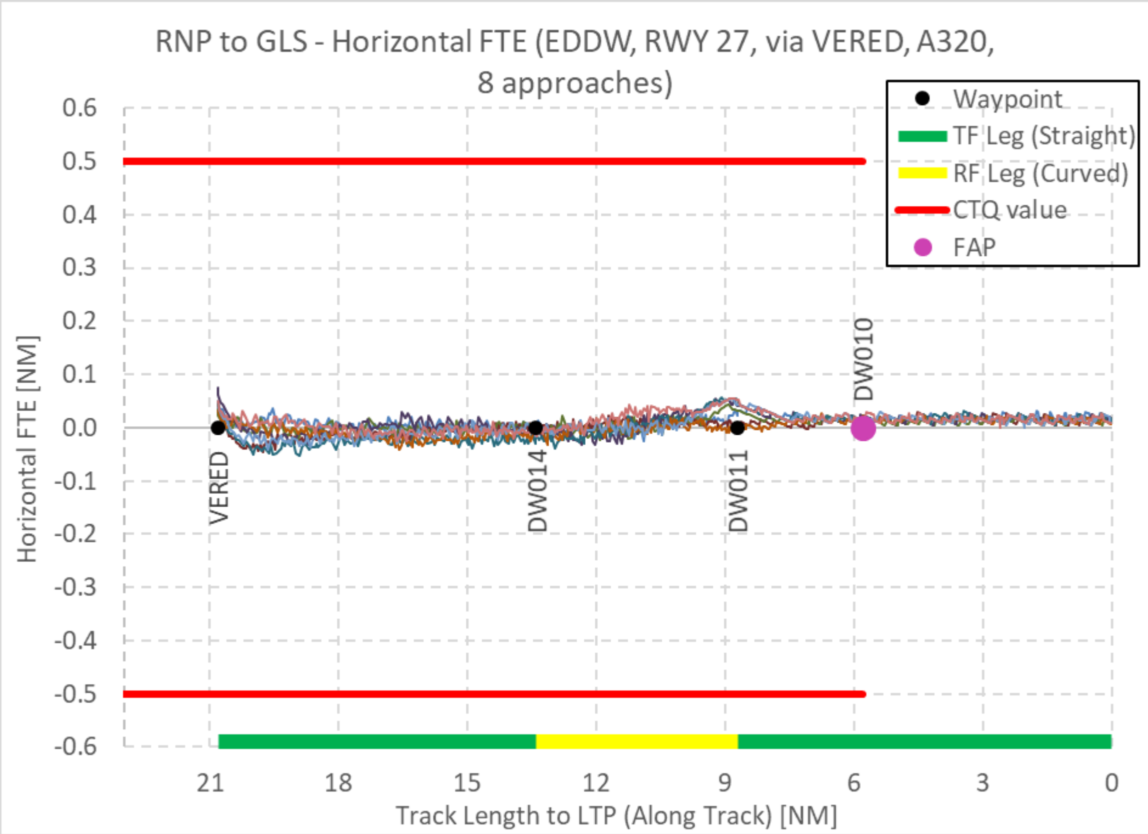

Figure 3: RNP to GLS (DLH) – Horizontal FTE (EDDW, G27Y RWY 27 via VERED, A320)

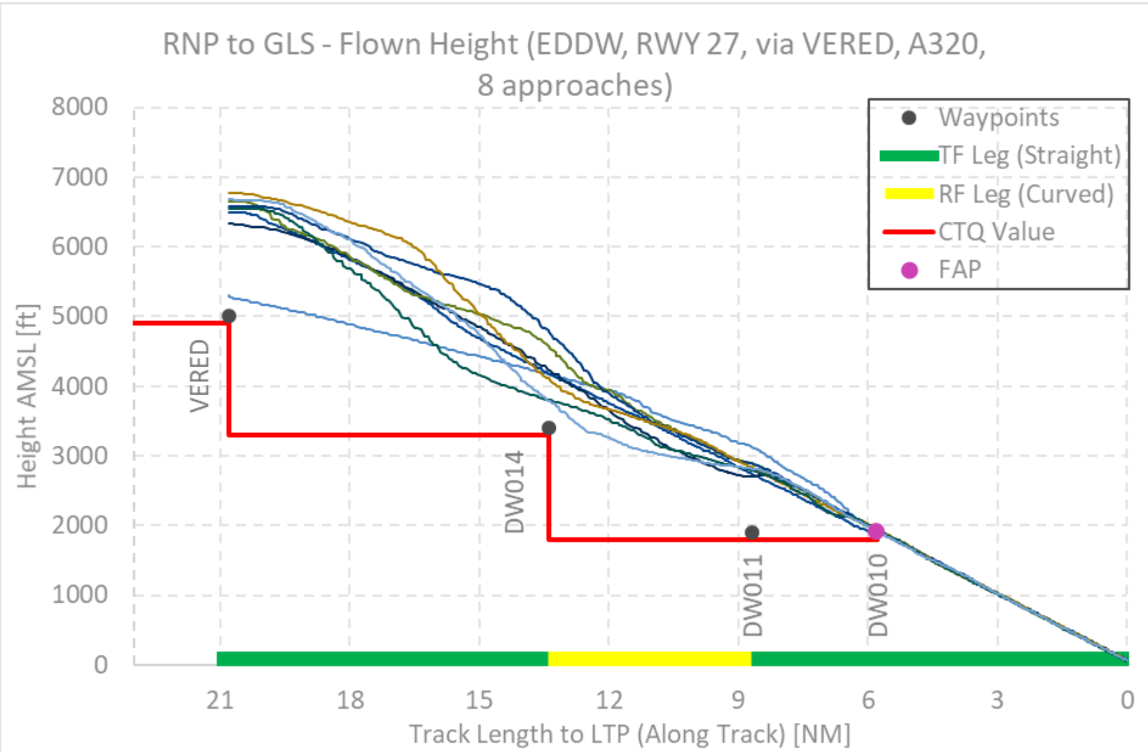

Figure 4: RNP to GLS (DLH) – Vertical Path (EDDW, G27Y RWY 27 via VERED, A320)

ii. Ryanair: B737

In total, 6 RNP to GLS revenue flights with B737-800 at Bremen airport were evaluated, where all 4 approaches were flown via different approach procedure to either RWY 09 or RWY 27. The overview of all performed RYR flights in Bremen is provided in Table 7 per runway and flown procedure. The FTE performance results are then showed in Figure 5 – Figure 12 for lateral and vertical domain.

All the approaches were successful. Lateral and vertical FTE performance of all the RNP to GLS approaches to Bremen airport was well within the CTQ limit indicated by the red line in the plots. Approaches were well captured when coming from different directions and after the stabilization phase the horizontal FTE was well within defined CTQ (±0.5NM) indicated by red lines on the top and the bottom of the graphs. In addition, you will find charts showing the vertical performance (flown height) for all procedures. The CTQ 'No descend below FAP constraint – 100ft' was met as well. Two approaches were affected by ATC constrains, one approach planned via EMBIV to RWY 09 and second via PIXUR to RWY 09. Therefore, FTE was evaluated only for available part of approach path.

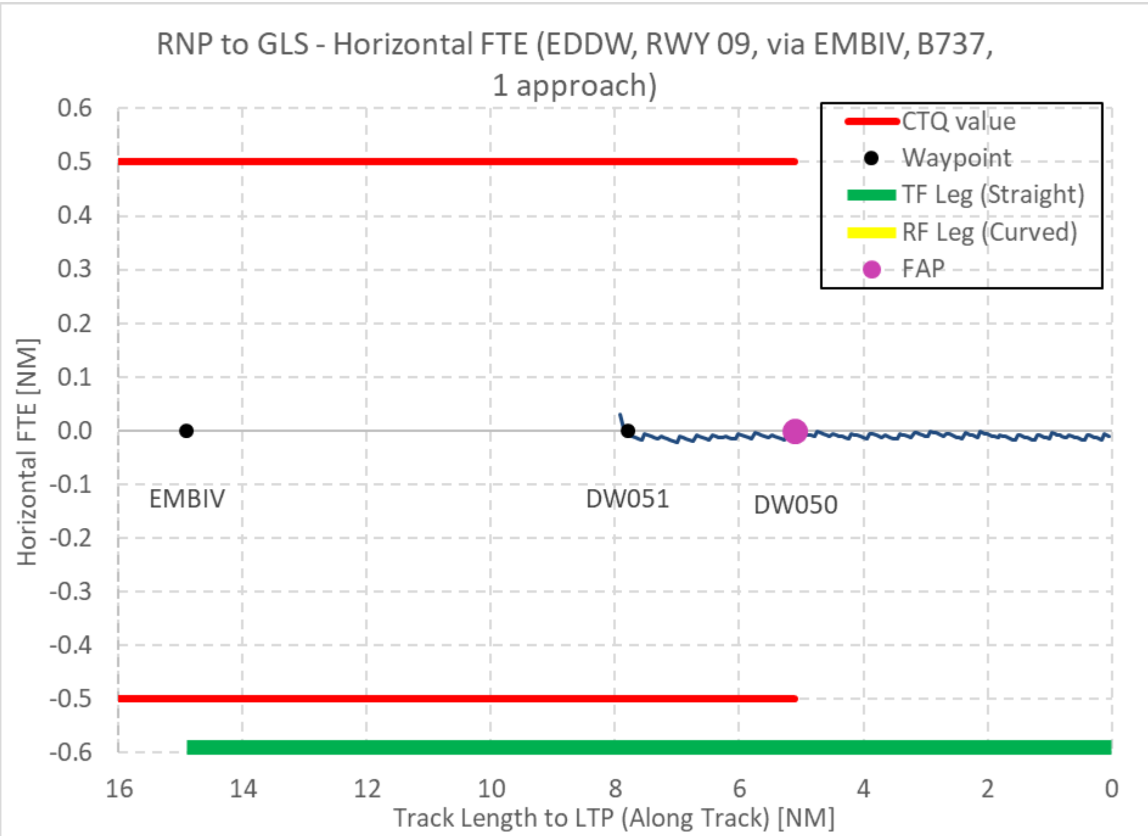

Figure 5: RNP to GLS (RYR) – Horizontal FTE (EDDW, G09A RWY 09 via EMBIV, B737)

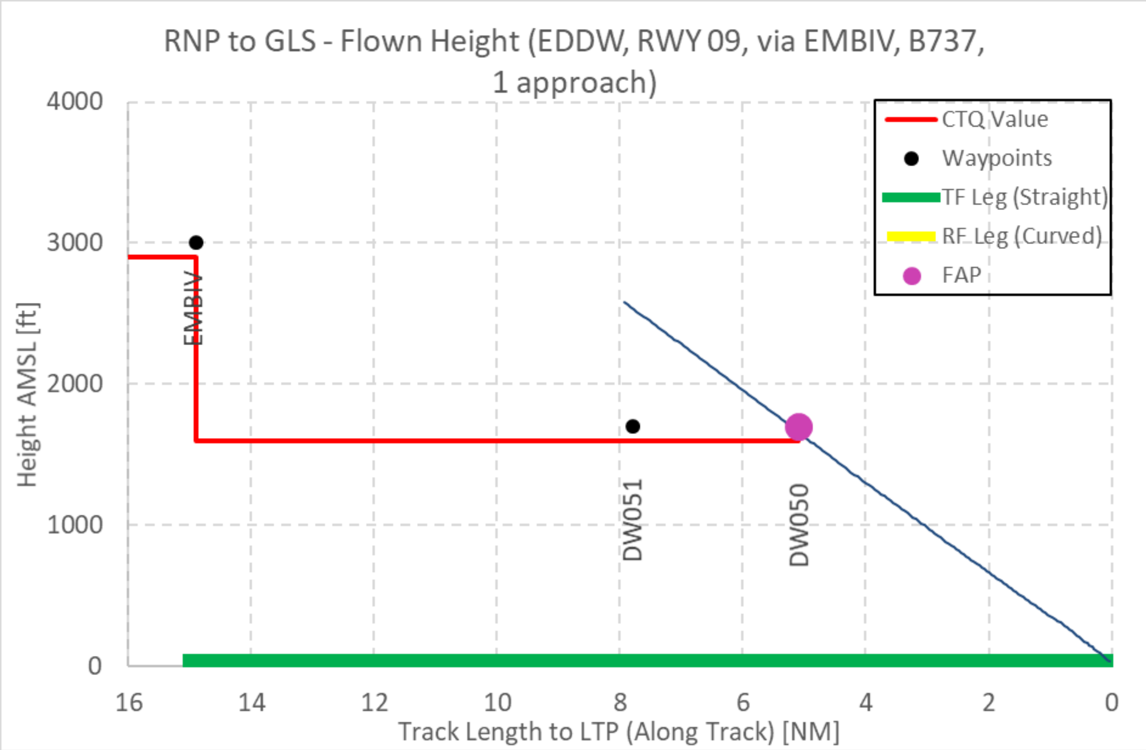

Figure 6: RNP to GLS (RYR) – Vertical Path (EDDW, G09A RWY 09 via EMBIV, B737)

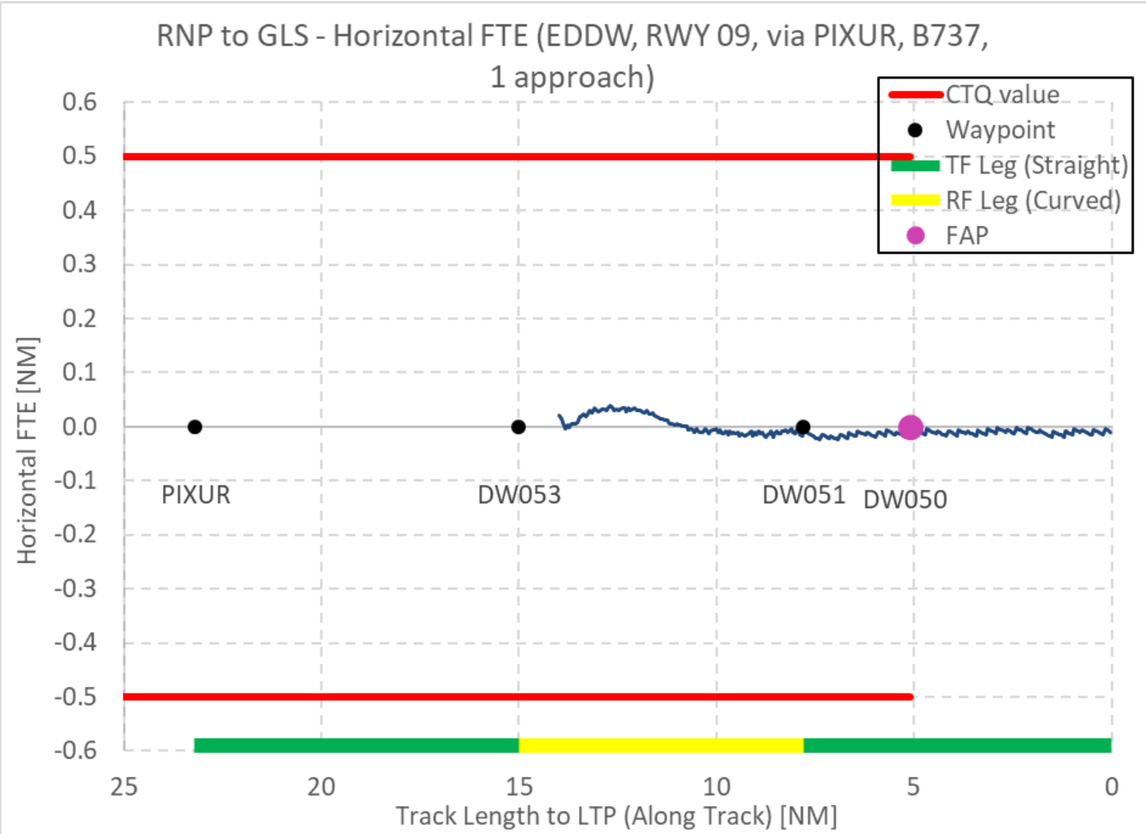

Figure 7: RNP to GLS (RYR) – Horizontal FTE (EDDW, G09A RWY 09 via PIXUR, B737)

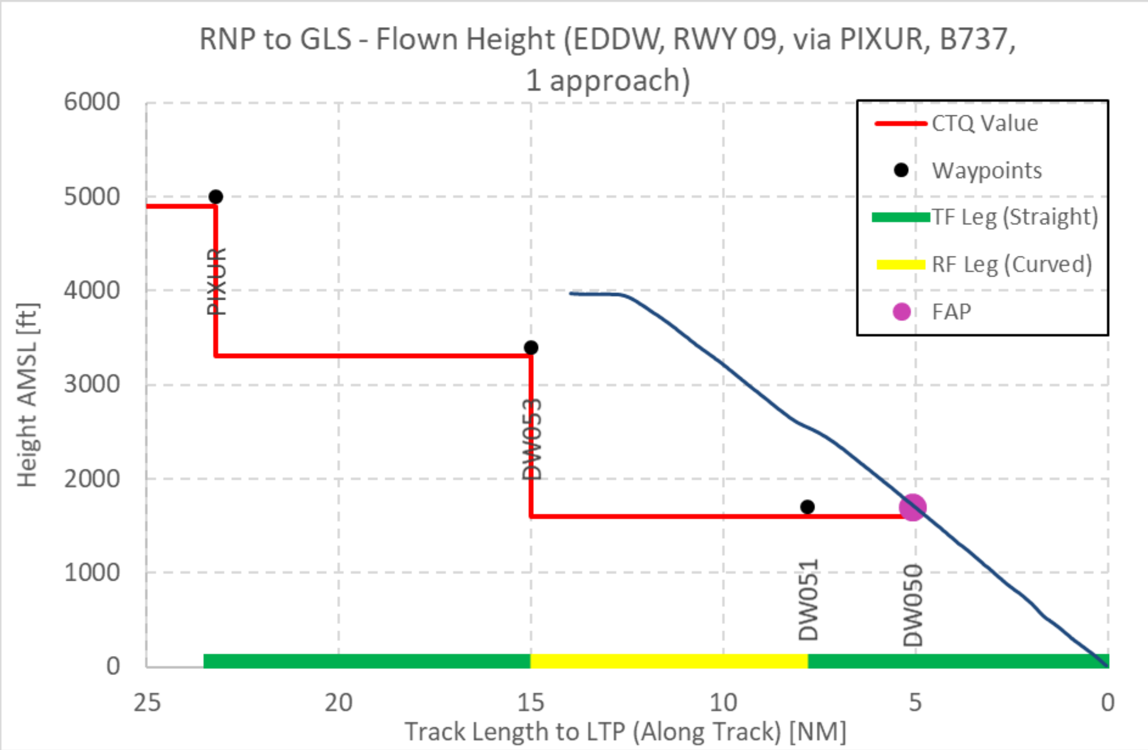

Figure 8: RNP to GLS (RYR) – Vertical Path (EDDW, G09A RWY 09 via PIXUR, B737)

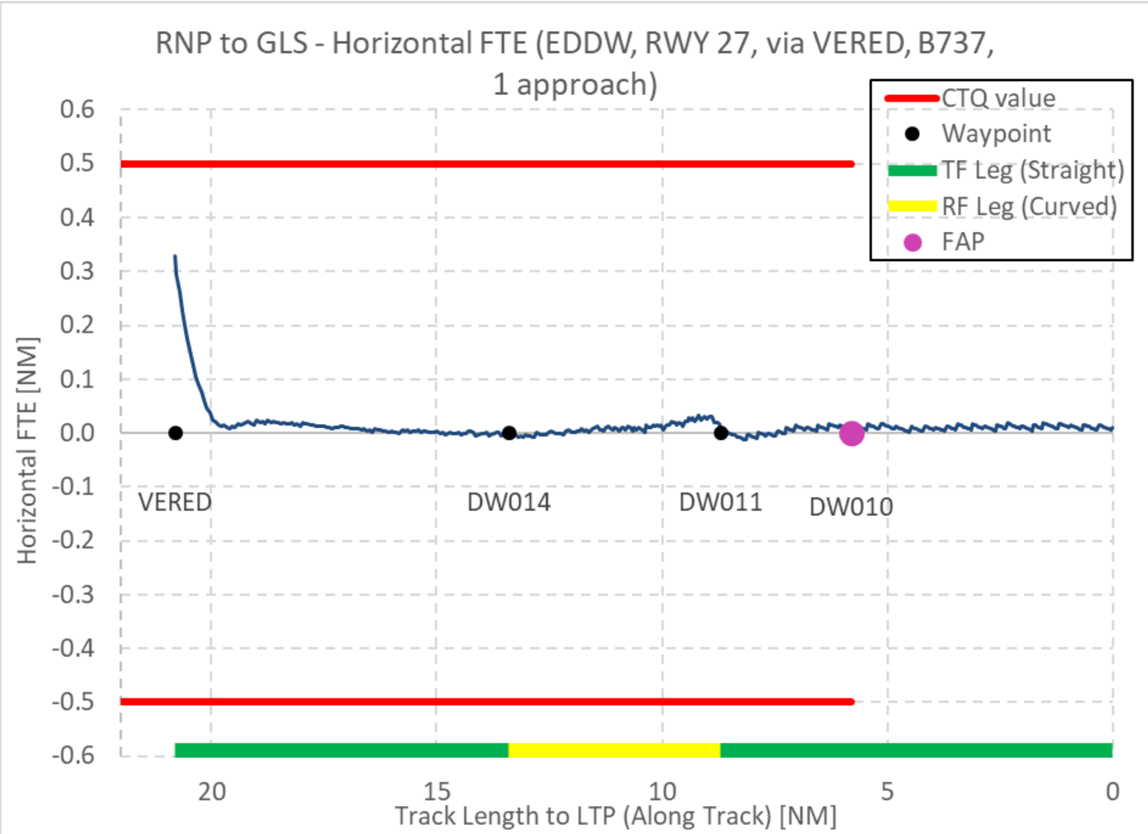

Figure 9: RNP to GLS (RYR) – Horizontal FTE (EDDW, G27B RWY 27 via VERED, B737)

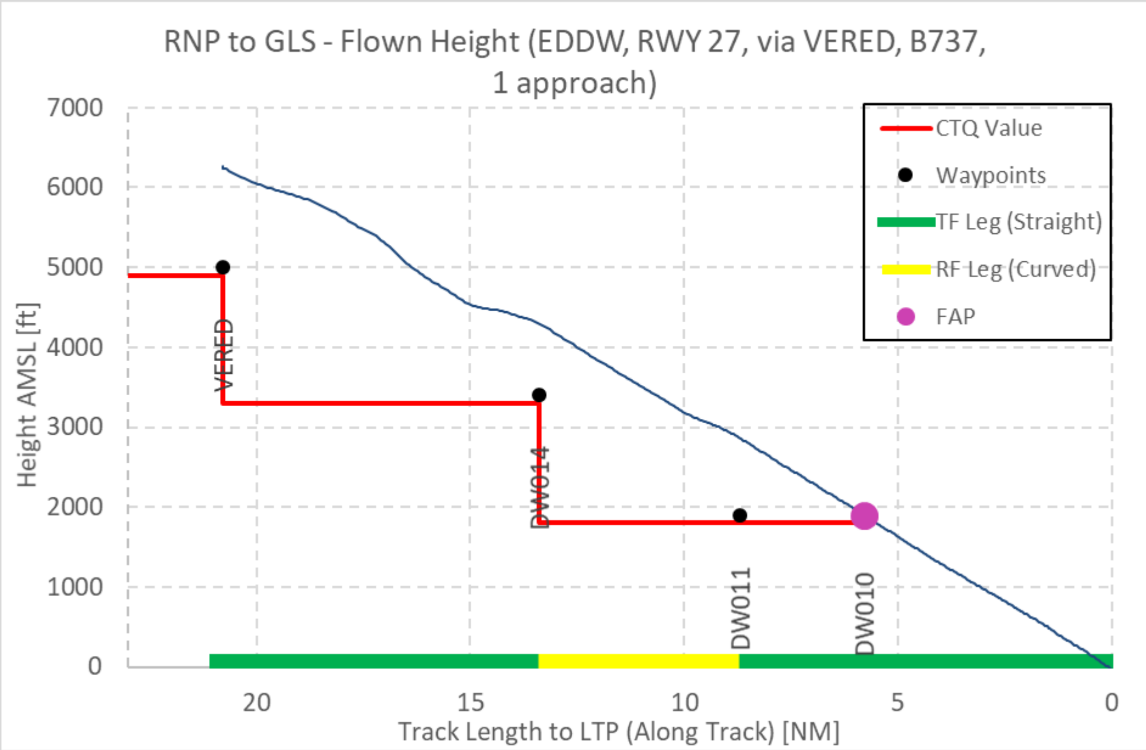

Figure 10: RNP to GLS (RYR) – Vertical Path (EDDW, G27B RWY 27 via VERED, B737)

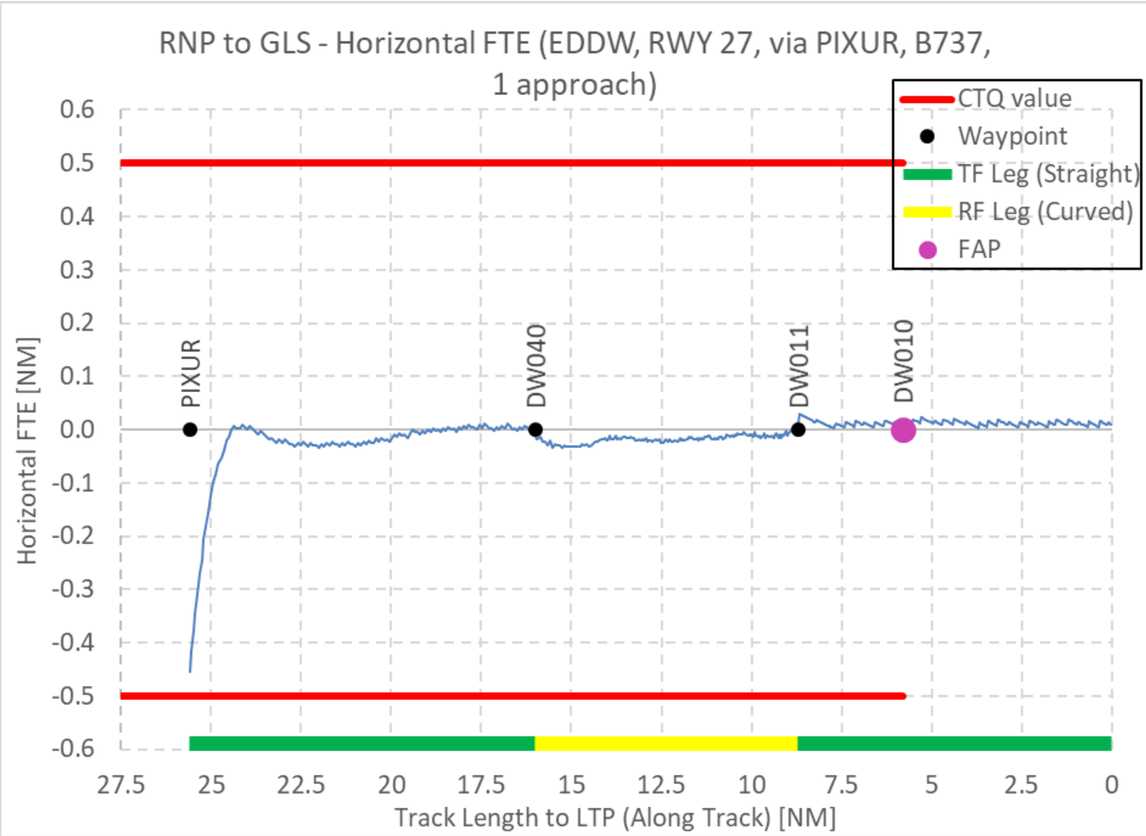

Figure 11: RNP to GLS (RYR) – Horizontal FTE (EDDW, G27Y RWY 27 via PIXUR, B737)

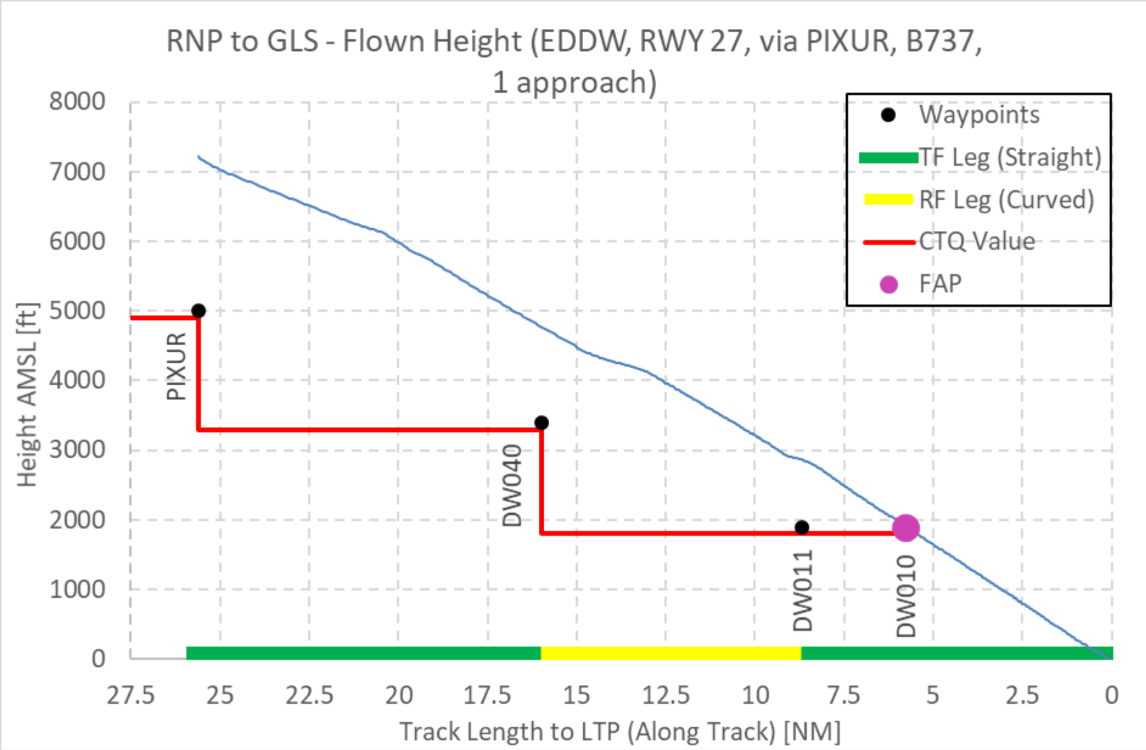

Figure 12: RNP to GLS (RYR) – Vertical Path (EDDW, G27Y RWY 27 via PIXUR, B737)

b. Conclusion on RNP to GLS Accuracy Assessment

This section aims to summarize the accuracy results for revenue demonstration flights with mainline aircraft for all RNP to GLS procedures. Published GBAS approach procedures in Bremen were used. The objective EX1-OBJ-VLD-V4-021 evaluation results with respect to CTQ compliance down to FAP (Final Approach Point) can be found in Table 8.

For Accuracy Assessment, the horizontal and vertical flight path accuracy was evaluated for the procedures. Flight path in the lateral direction on the TF and RF leg is precisely provided and therefore the Flight Technical Error (FTE) can be computed and compared to CTQ derived according ICAO Doc 9613 (PBN Manual) [8], i.e. for the horizontal FTE the limit was set to 0.5 NM as indicated on all figures down to the FAP with the FTE compliance is clearly demonstrated. All the approaches were successful. Lateral and vertical FTE performance of all the RNP to GLS approaches to Bremen airport was well within the CTQ limit indicated by the red line in the plots. Approaches were well captured when coming from different directions and after the stabilization phase the horizontal FTE was well within defined CTQ (±0.5NM) indicated by red lines on the top and the bottom of the graphs. The CTQ 'No descend below FAP constraint – 100ft' was met as well. Two approaches were affected by ATC constrains, one approach planned via EMBIV to RWY 09 and second via PIXUR to RWY 09. Therefore, FTE was evaluated only for available part of approach path. Some minor increases of FTE occurred around the transition points from RNP to GLS and in the RF leg, but still well within the limit and shows a "well natured" auto-flight behaviour (not shown in the graphs, but all flights flown with smooth bank angles). At some horizontal FTE plots (Figure 3 and Figure 9) a small increase of FTE value during the transition from RF to TF leg can be observed that may be caused by the small vertical deviation during RF leg from the optimal descent path.

FTE within CTQ / AC type	EDDW	
	Lateral	Vertical
DLH A320	OK	OK
RYR B737	OK	OK

Table 8: EX1-OBJ-VLD-V4-021 Accuracy Assessment

Table 9 and Table 10 contain an overview of measured performance in terms of mean and standard deviation of horizontal FTE for RNP to GLS approaches in Bremen for both Lufthansa A320 aircraft family and Ryanair Boeing 737 aircraft.

Operator/AC Type	Number of flights	Horizontal FTE	
		Mean [NM]	STD [NM]
DLH A320	9	-0.009 - 0.014	0.012-0.023

Table 9: Performance statistics per airport for DLH RNP to GLS approaches

Operator/AC Type	Number of flights	Horizontal FTE	
		Mean [NM]	STD [NM]
RYR B737	4	-0.010 - 0.008	0.005-0.017

Table 10: Performance statistics per airport for Ryanair RPN to GLS approaches

Summary of Environmental Conditions

In order to provide more details for the assessment of RNP to GLS approaches to Bremen the environmental aspects in terms of air temperature, wind direction and wind speed (experienced during the flights) were investigated for the revenue flights performed by Lufthansa and Ryanair.

Statistics (mean, std, min and max) are summarized in the Table 11 for wind speed, Table 12 for wind direction (only the mean and std) and Table 13 for air temperature. In general, the environmental conditions (wind, temperature) were mostly nominal (not extreme) during the all of the approaches but they were quite different for each approach as each flight was performed in different time of the year. Only a few flights were flown during the strong wind conditions (at the upper parts of final approach) with magnitude of 40 to 50 knots.

While processing the RNP to GLS flights data, the impact of weather conditions on FTE was checked for each flight. Results confirms that the wind influences the FTE - mainly in lateral direction with effect noticeable in cases when the wind was changing the direction, the strength (speed and/or gusting) during the approach or both. Although the weather conditions varied across approaches as visible from wind speed, direction and temperature tables, it had a small impact on the flight accuracy without any major deviations from desired flight path.

Wind Speed [kts]	Mean	Std	Min	Max
Bremen				
DLH A320	11.6 - 42.4	2.7 - 8.9	1.5	52.1
RYR B737	13.6 - 42.6	2.4 - 8.7	6.0	54.5

Table 11: Summary of wind speed conditions during RNP to GLS flights

Wind Direction [°]	Mean	Std
Bremen		
DLH A320	55.7 - 325.6	8.7 - 30.3
RYR B737	147.3 - 290.0	9.3 - 34.3

Table 12: Summary of wind direction conditions during RNP to GLS flights

Air Temperature [°C]	Mean	Std	Min	Max
Bremen				
DLH A320	-3.2 - 7.8	2.2 - 5.4	-11.3	15.3
RYR B737	-16.5 - 10.8	0.9 - 5.9	-27.3	15.0

Table 13: Summary of air temperature conditions during RNP to GLS flights

5. EX1-OBJ-VLD-V4-028 Results

In this section current results of exercise EX1-OBJ-VLD-V4-028 for accuracy evaluation of practice GLS CAT II Autoland approaches is presented. The Lufthansa performed together 43 revenue flights with Airbus A320 and 14 with the Boeing 747-8 at Bremen and Frankfurt. Out of total 57 practice GLS CAT II Autoland approaches, the flight data for 32 approaches were available for accuracy assessment for the Demonstration Report because of the of limited data access due to COVID-19 outbreak. The overall summary of number of flights per airport and airline operator is provided in Table 14: Total number of practice GLS CAT II Autoland demonstration flights.

Ryanair pilots flew 1 Practice GLS CAT II Autoland approach using Ryanair practice Cat II procedures in the USA at Grant county international Airport MWH during aircraft acceptance flight, i.e. non-revenue flight and aircraft, while aircraft was not yet registered on Ryanair. Therefore, flight data were not recorded for AAL2 and are not included in flight accuracy demonstration objective evaluation and not done on a Ryanair registered aircraft at Grant county international Airport (KMWH).

Operator	EDDF		EDDW		Other	Total
	A320 fam	B747-8	A320 fam	B737-800	B737-800	
DLH flown	31	14	12	N/A	0	**57**
DLH analyzed	24	0	8	N/A	0	**32**
RYR flown	N/A	N/A	N/A	0	1	**1**
RYR analyzed	N/A	N/A	N/A	0	0	**0**
Total flown	**45**		**12**		**1**	**58**
Total analyzed	**24**		**8**		**0**	**32**

Table 14: Total number of practice GLS CAT II Autoland demonstration flights

The demonstration objective criterion (CTQ value) for lateral and vertical FTE is 1 dot (i.e. FTE should be within ±1 dot). The evaluation of FTE was performed on the glidepath segment starting at the point when the A/C got stabilized on the glidepath (assumed being 0.3 dot from the glidepath) as the A/C was capturing the glidepath from different directions (left/right, above/below) and ending at DH.

Approaches start at different distance to the runway threshold as the capture was done from different directions and distances and on different airports. Data end at the touchdown (0 ft above runway threshold). It can be concluded that observed performance was well within the CTQ value. The deviation for the lateral direction was practically always within ±0.1 dot; and for the vertical direction within usually within ±0.3 dot and absolute maximum within ±0.4 dot.

Flights overview	Number of flights in evaluation
Bremen	
DLH A320	8
Frankfurt	
DLH A320	24
Total evaluated	**32**

Table 15: Summary of Practice GLS CAT II Autoland demonstration flights

One Lufthansa approach flown to Bremen airport was autopiloted in RNP segment and followed practice GLS CAT II Autoland, which demonstrated synergies of autopiloted advanced procedures and opportunity of deploying environmentally friendly procedures with optimal CDO operation followed by GBAS based low visibility landings using autopilot. No non-standard deviations were observed during the flight and in the analyzed data.

a. Bremen Airport (EDDW): Practice GLS CAT II Autoland Revenue Flights

i. Lufthansa A320 family

The Lufthansa has flown 8 practice GLS CAT II Autoland Revenue Flights at Bremen airport with Airbus A320 family aircraft, 5 approaches to RWY 09 by procedure GLSW and 3 other approaches to RWY 27 via different procedures. The overview of all performed flights in Bremen is provided in Table 16 per runway and flown procedure. The FTE performance results are then showed in Figure 13 – Figure 20 for lateral and vertical domain.

Lateral and vertical FTE performance of all the Practice GLS CAT II Autoland approaches to Bremen airport was well within the CTQ limit indicated by the red line in the plots.

RWY	Procedure	Route indicator	Number of flights	Figures
09	GLS Z	GLSW	5	Figure 13 and Figure 14
27	GLS Z	GBAE	1	Figure 15 and Figure 16
27	GLS Z	G27B	1	Figure 17 and Figure 18
27	GLS Y	G27E	1	Figure 19 and Figure 20

Table 16: Summary of practice GLS CAT II Autoland flights to Bremen

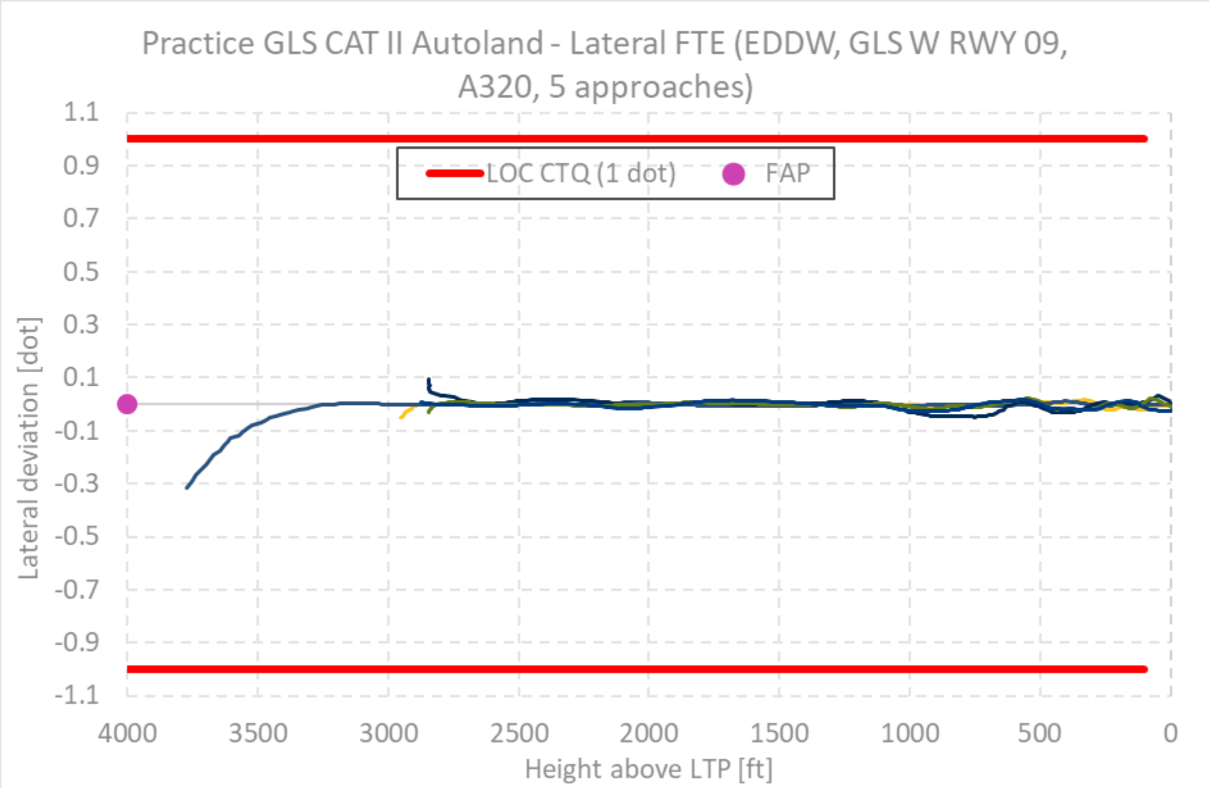

Figure 13: Practice GLS CAT II Autoland (DLH) – Lateral FTE (EDDW, GLS W RWY09, A320)

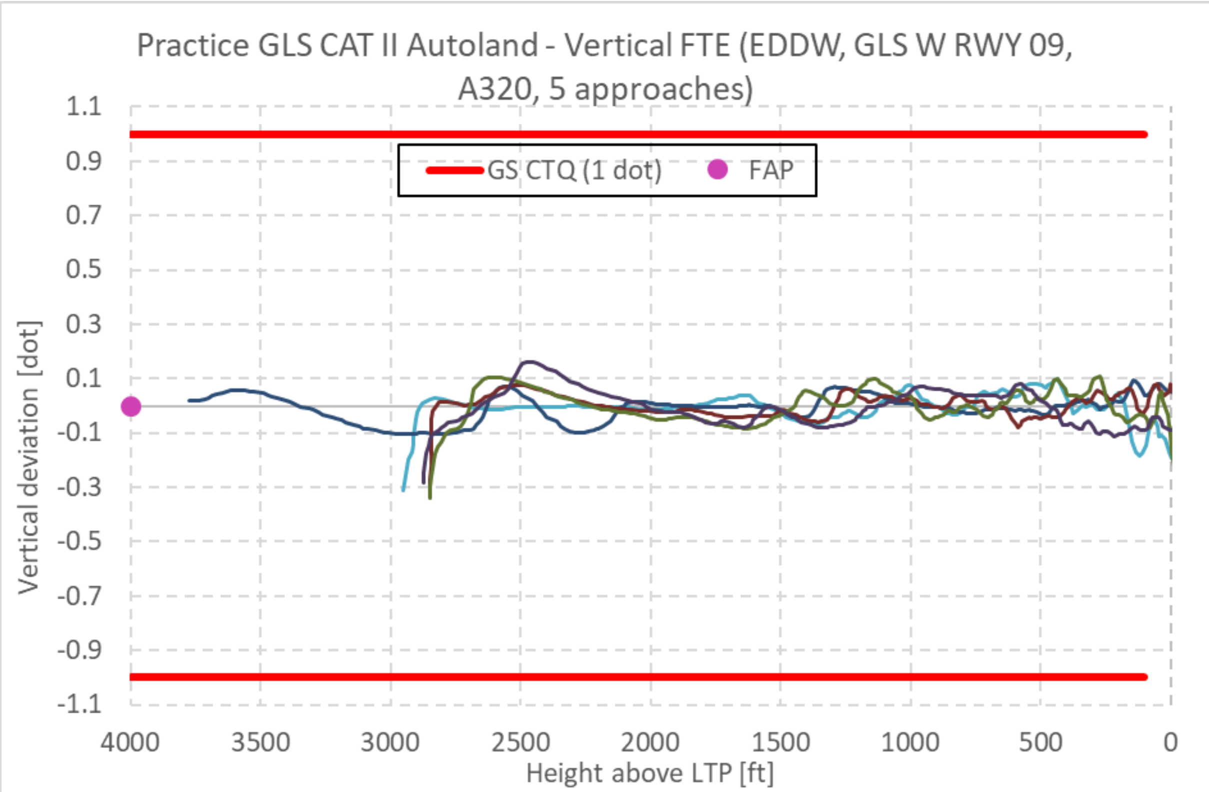

Figure 14: Practice GLS CAT II Autoland (DLH) – Vertical FTE (EDDW, GLS W, RWY 09, A320)

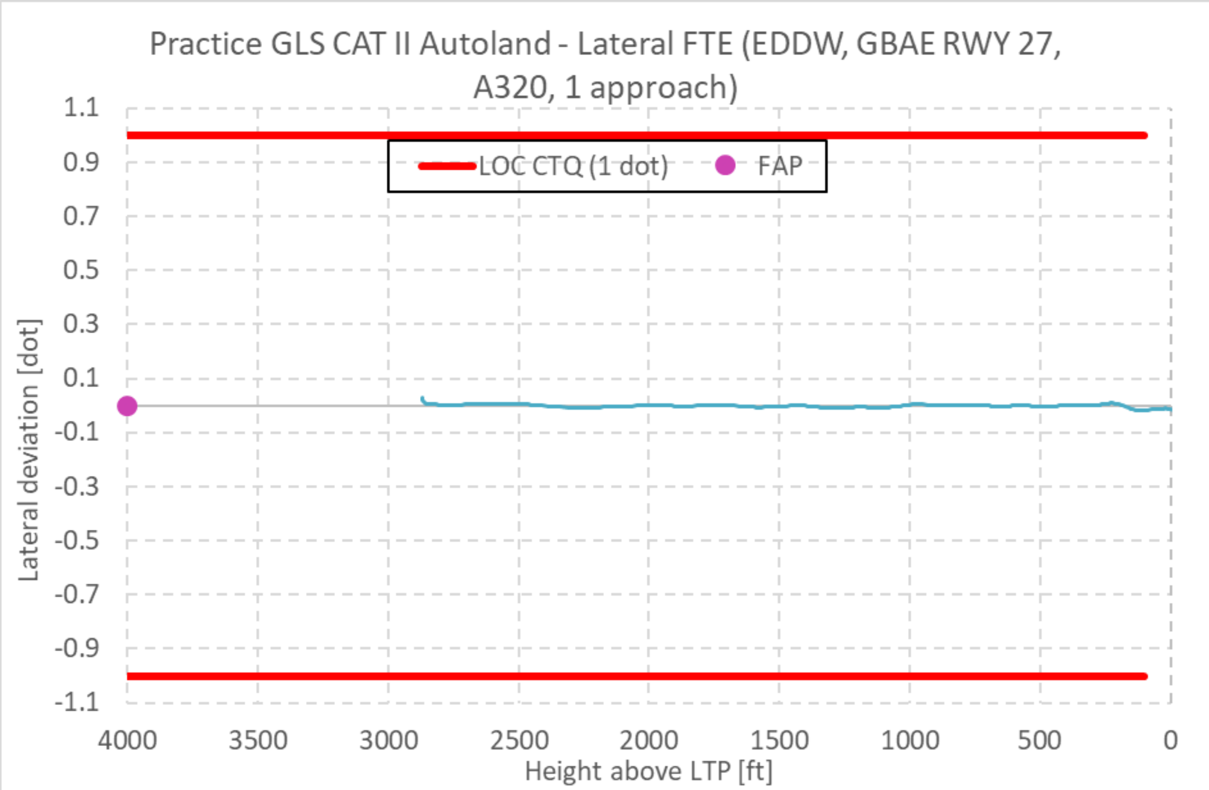

Figure 15: Practice GLS CAT II Autoland (DLH) – Lateral FTE (EDDW, GBAE RWY 27, A320)

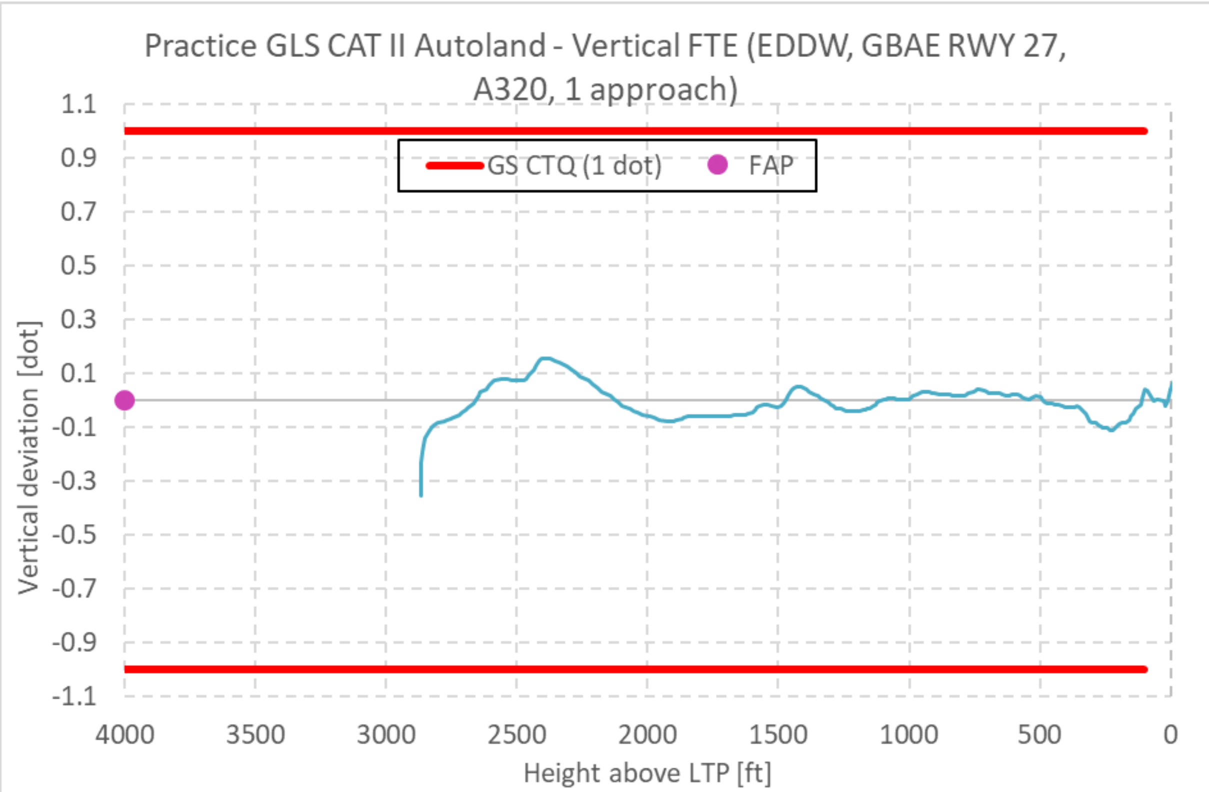

Figure 16: Practice GLS CAT II Autoland (DLH) – Vertical FTE (EDDW, GBAE RWY 27, A320)

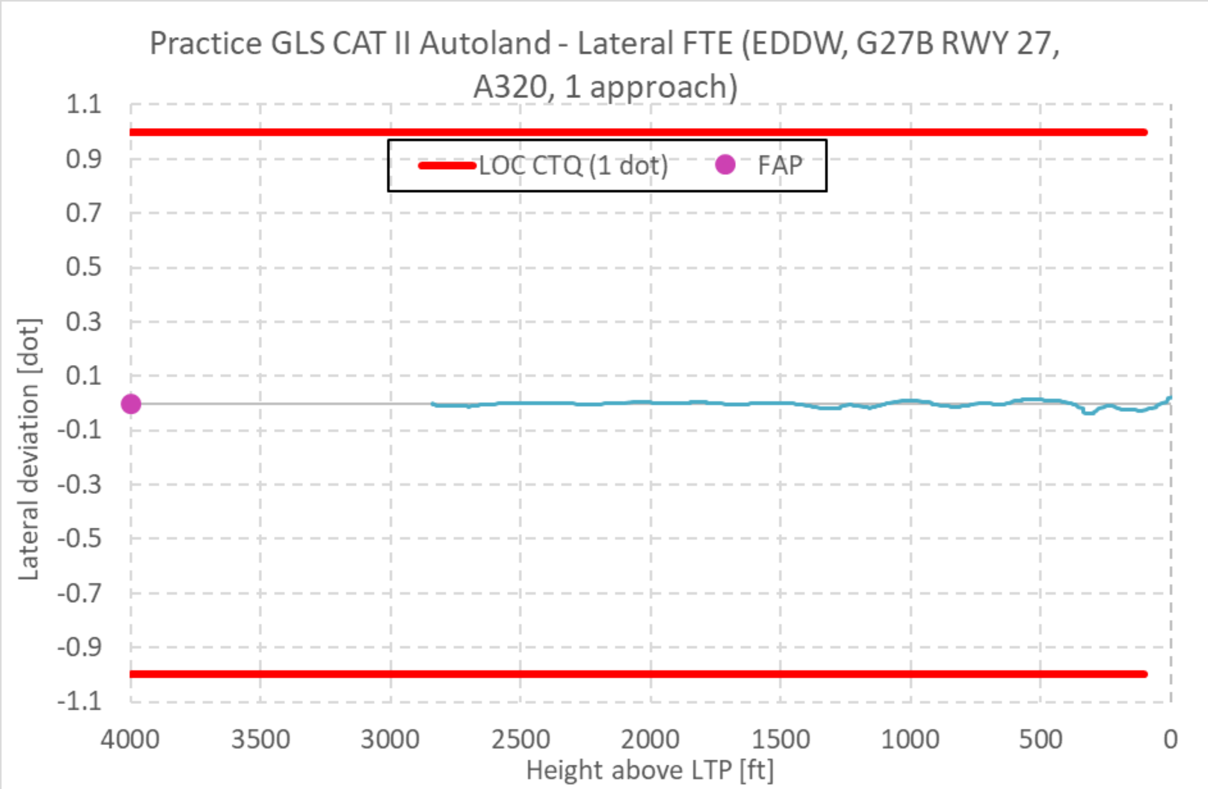

Figure 17: Practice GLS CAT II Autoland (DLH) – Lateral FTE (EDDW, G27B, RWY 27, A320)

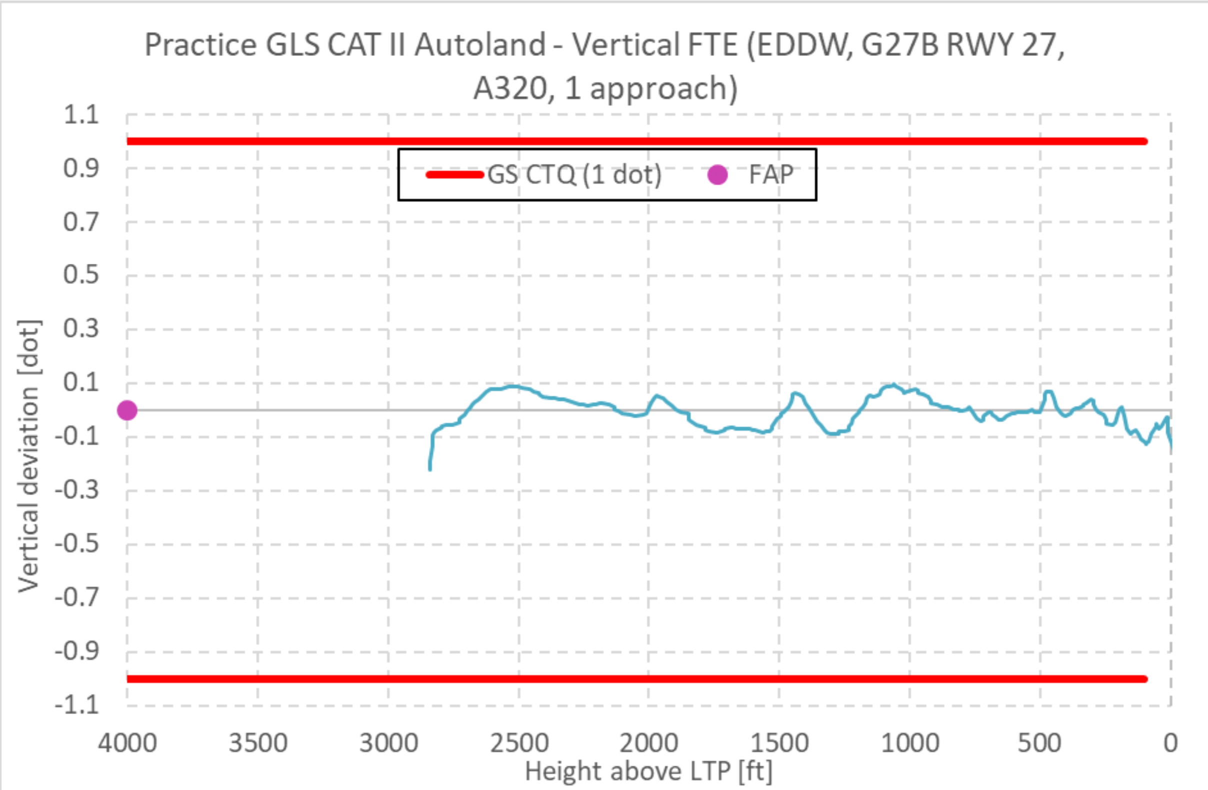

Figure 18: Practice GLS CAT II Autoland (DLH) – Vertical FTE (EDDW, G27B, RWY 27, A320)

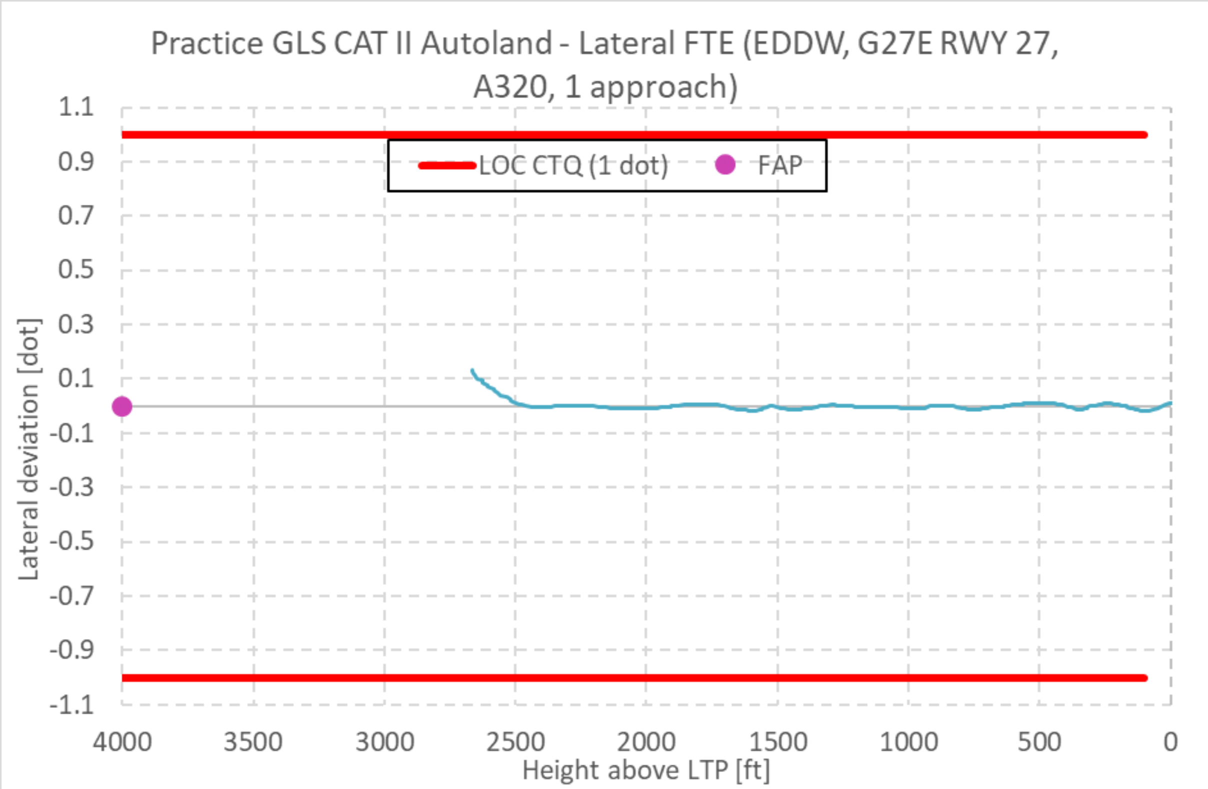

Figure 19: Practice GLS CAT II Autoland (DLH) – Lateral FTE (EDDW, G27E, RWY 27, A320)

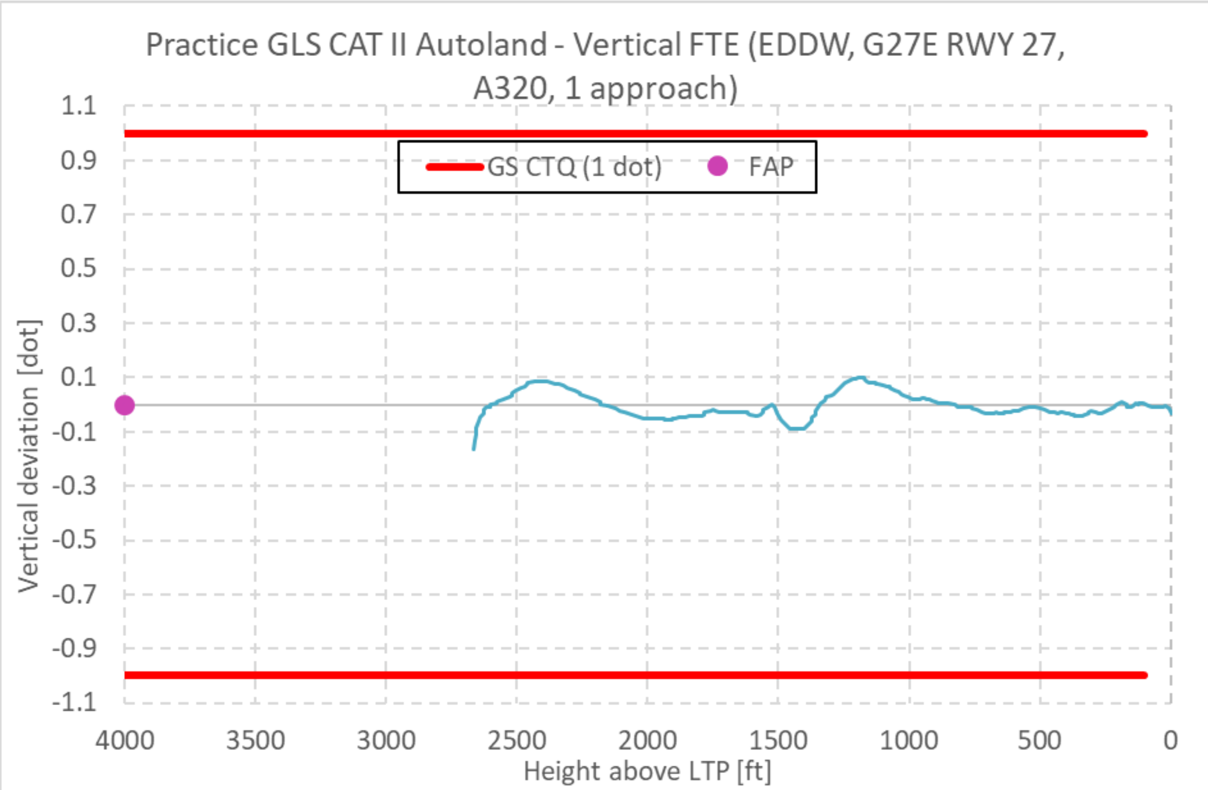

Figure 20: Practice GLS CAT II Autoland (DLH) – Vertical FTE (EDDW, G27E, RWY 27, A320)

b. Frankfurt Airport (EDDF): Practice GLS CAT II Autoland Revenue Flights

i. Lufthansa A320 family

The Lufthansa has flown 24 practice GLS CAT II Autoland Revenue Flights at Frankfurt airport with Airbus A320 family aircraft. The overview of all performed flights at Frankfurt is provided in Table 17 per runway and flown procedure. The FTE performance results are then showed in Figure 21 – Figure 36 for lateral and vertical domain.

All evaluated final approaches were autopiloted since capture through touchdown. For all runways and procedures, the performance showed that FTE was well within the CTQ limit (1 dot) indicated in the figures by red line.

RWY	Procedure	Route indicator	Number of flights	Figures
07L	GLS Y	G07E	2	Figure 21 and Figure 22
07L	GLS Z	G07A	5	Figure 23 and Figure 24
07R	GLS Y	G07F	1	Figure 25 and Figure 26
07R	GLS Z	G07B	2	Figure 27 and Figure 28
25L	GLS Z	G25B	5	Figure 29 and Figure 30
25R	GLS Y	G25B	1	Figure 31 and Figure 32
25R	GLS Z	G25A	7	Figure 33 and Figure 34
07C	GLS Z	G07D	1	Figure 35 and Figure 36

Table 17: Summary of practice GLS CAT II Autoland flights to Frankfurt

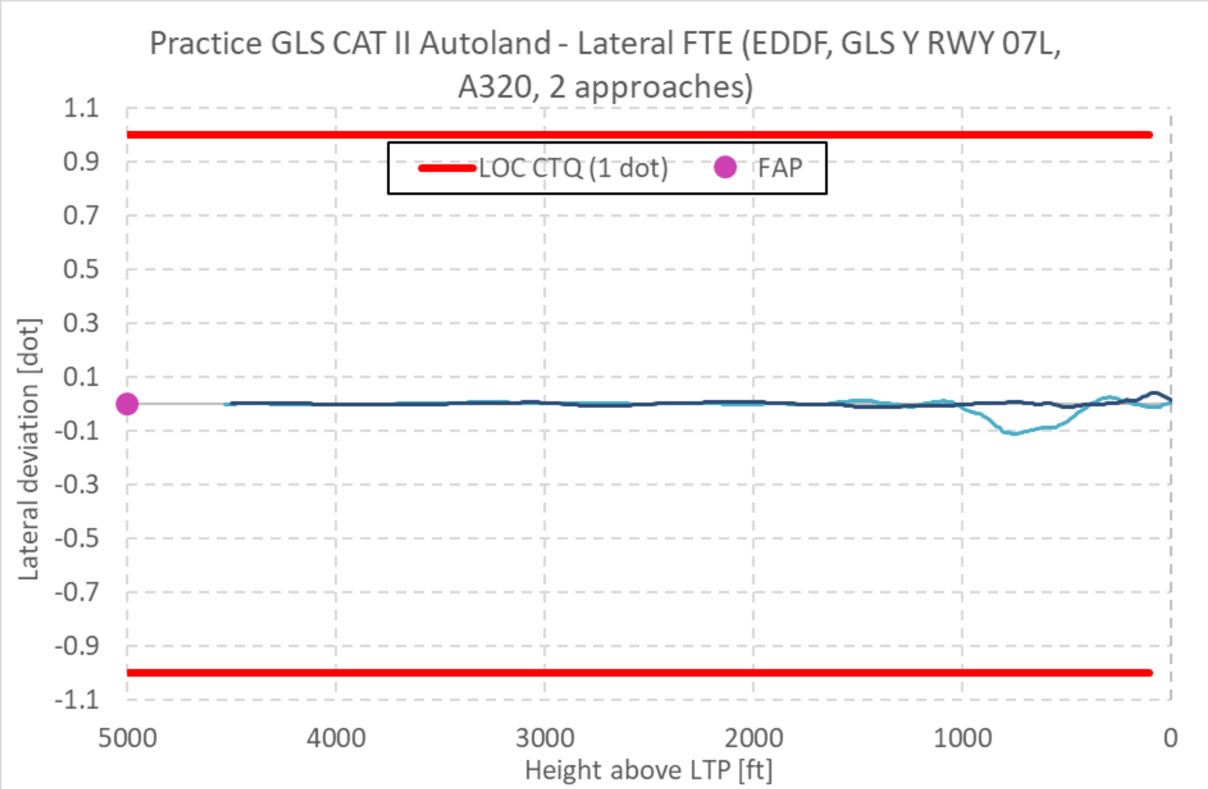

Figure 21: Practice GLS CAT II Autoland (DLH) – Lateral FTE (EDDF, GLS Y RWY 07L, A320)

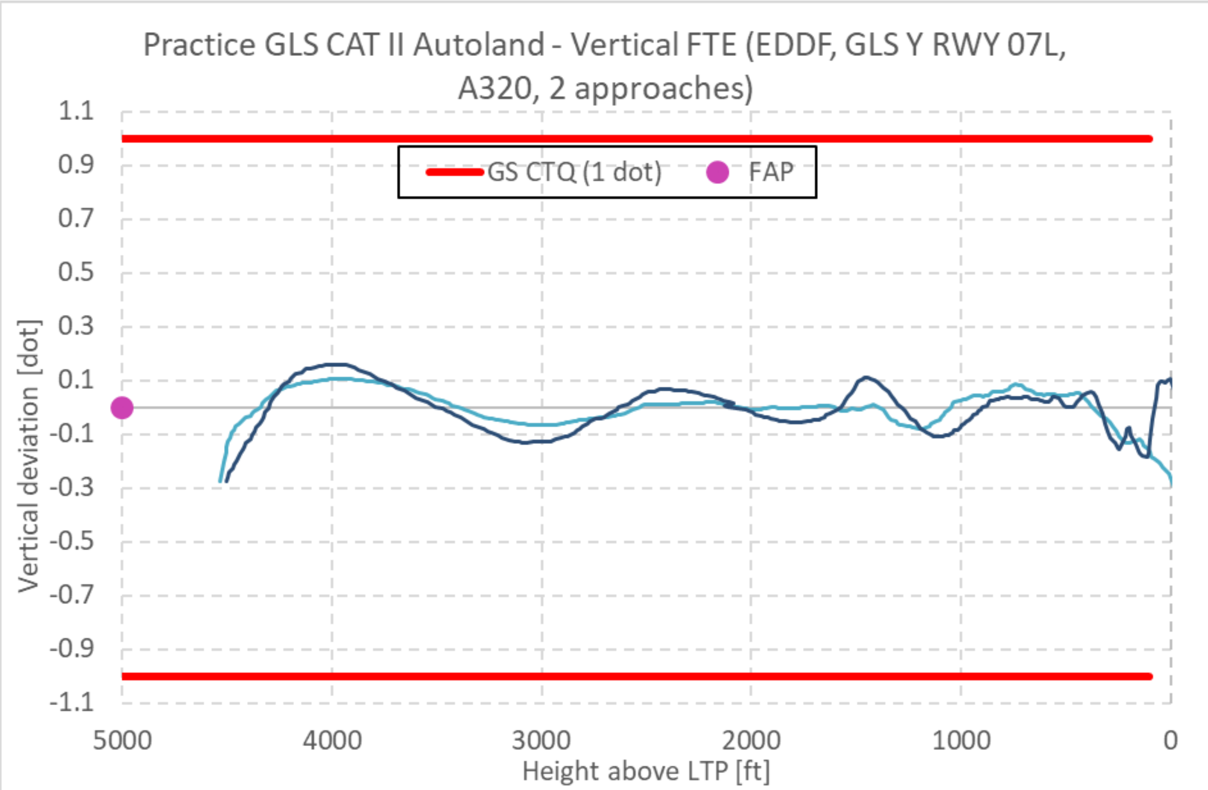

Figure 22: Practice GLS CAT II Autoland (DLH) – Vertical FTE (EDDF, GLS Y RWY 07L, A320)

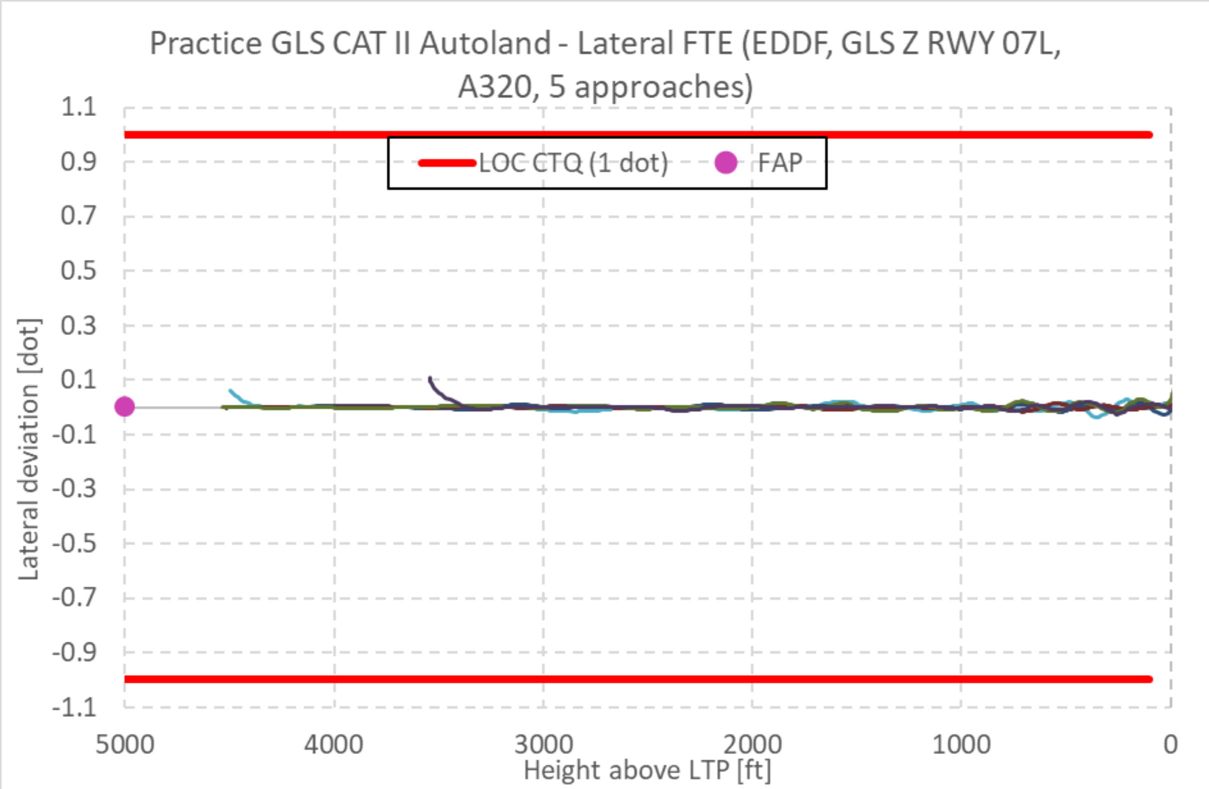

Figure 23: Practice GLS CAT II Autoland (DLH) – Lateral FTE (EDDF, GLS Z RWY 07L, A320)

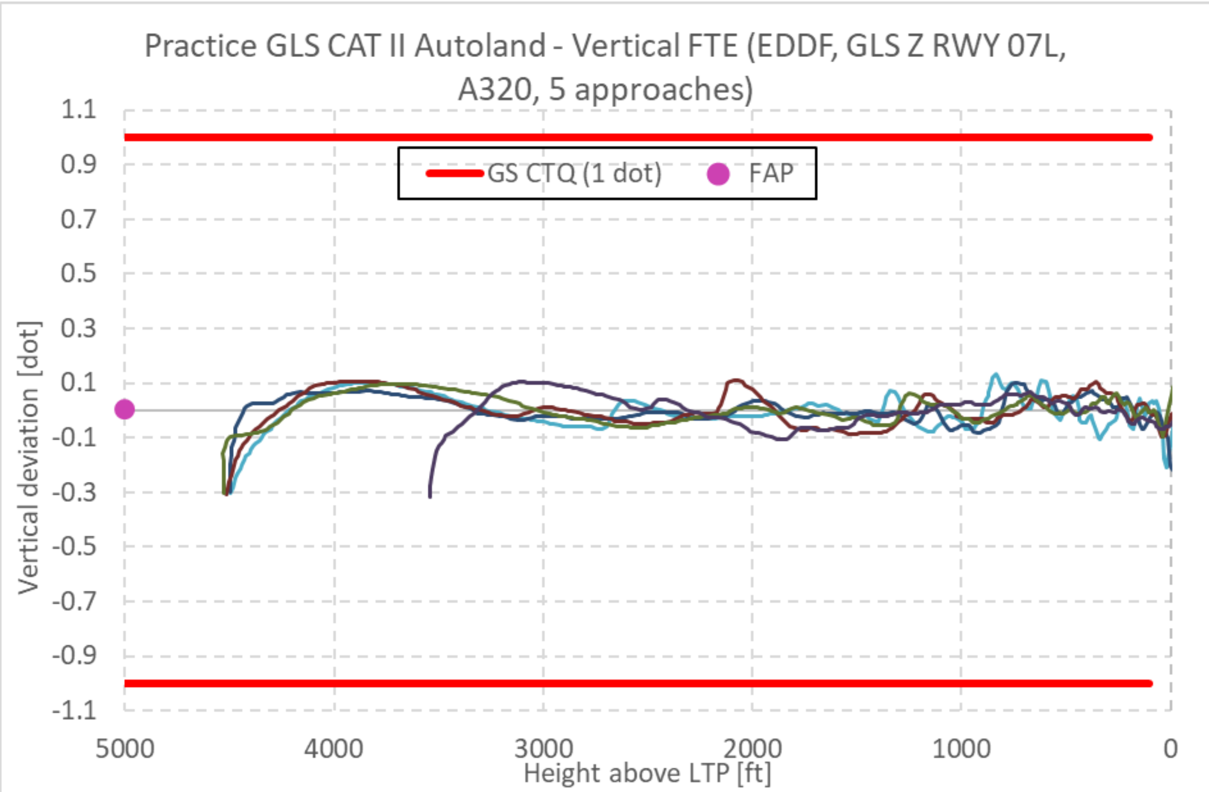

Figure 24: Practice GLS CAT II Autoland (DLH) – Vertical FTE (EDDF, GLS Z RWY 07L, A320)

Founding Members

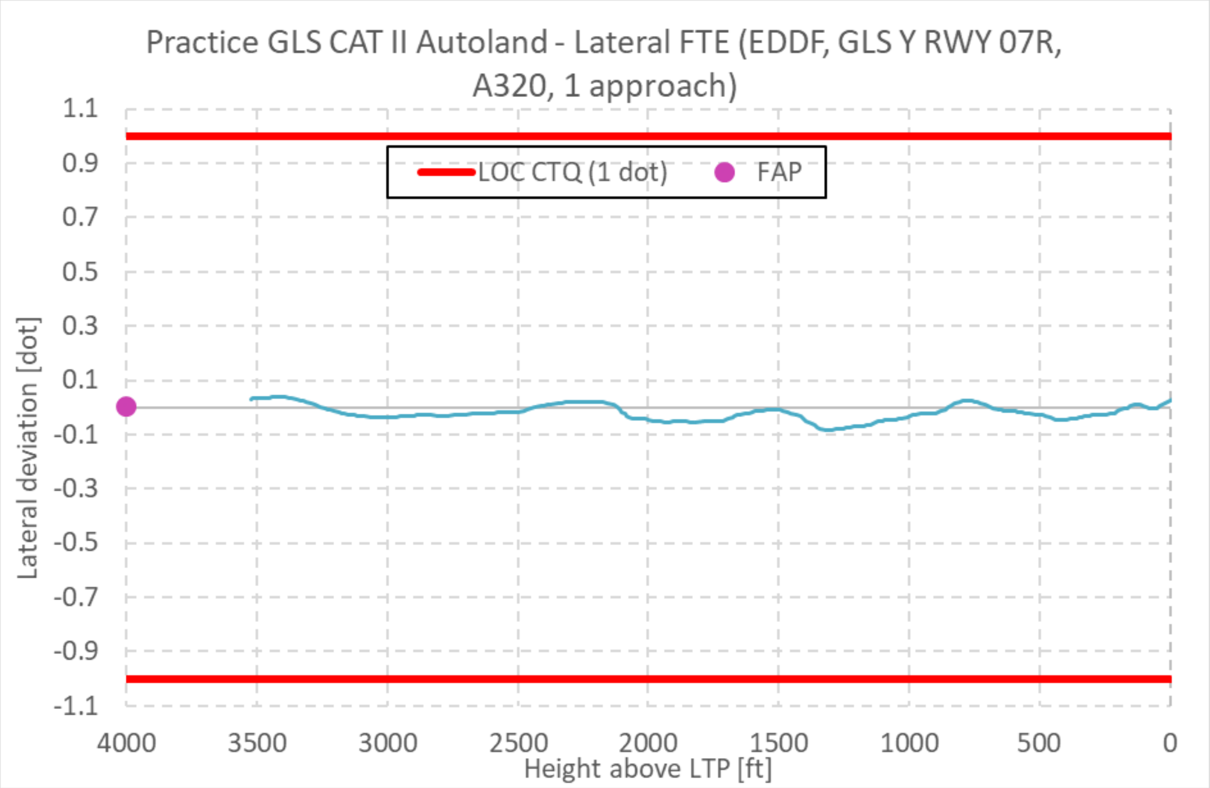

Figure 25: Practice GLS CAT II Autoland (DLH) – Lateral FTE (EDDF, GLS Y RWY 07R, A320)

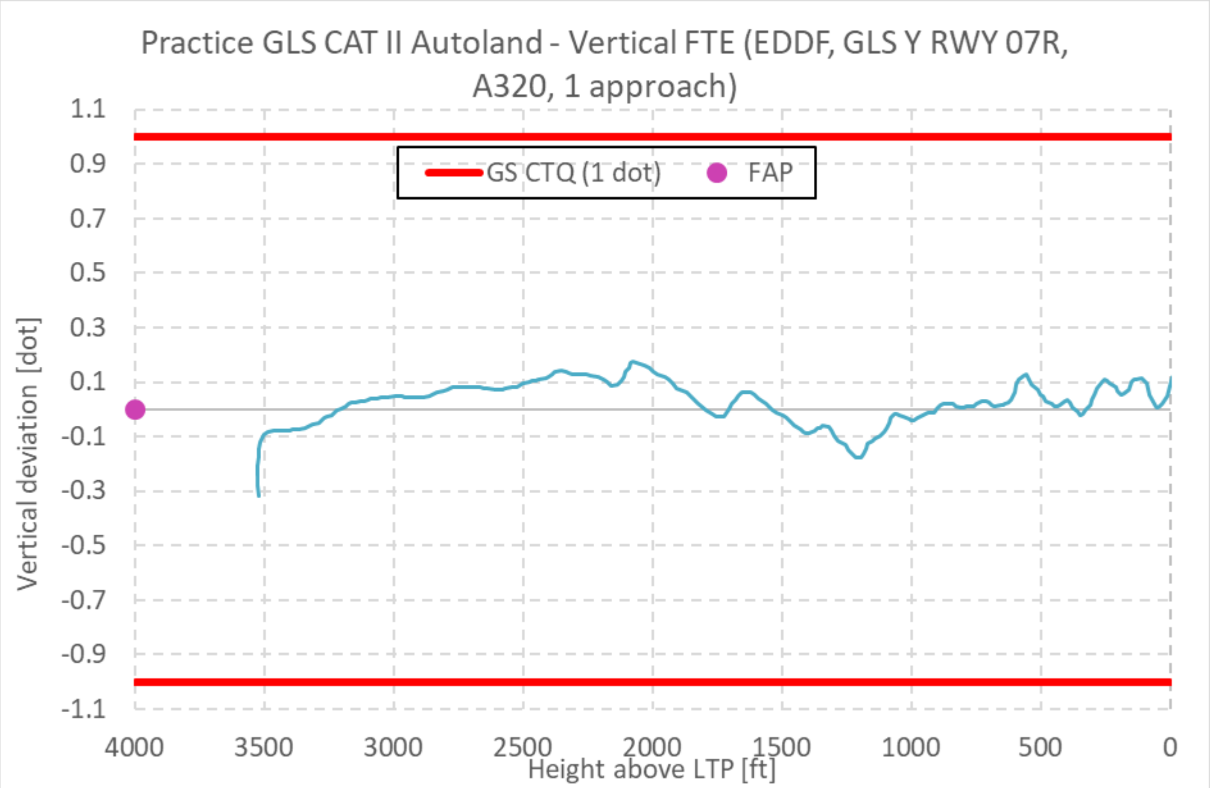

Figure 26: Practice GLS CAT II Autoland (DLH) – Vertical FTE (EDDF, GLS Y RWY 07R, A320)

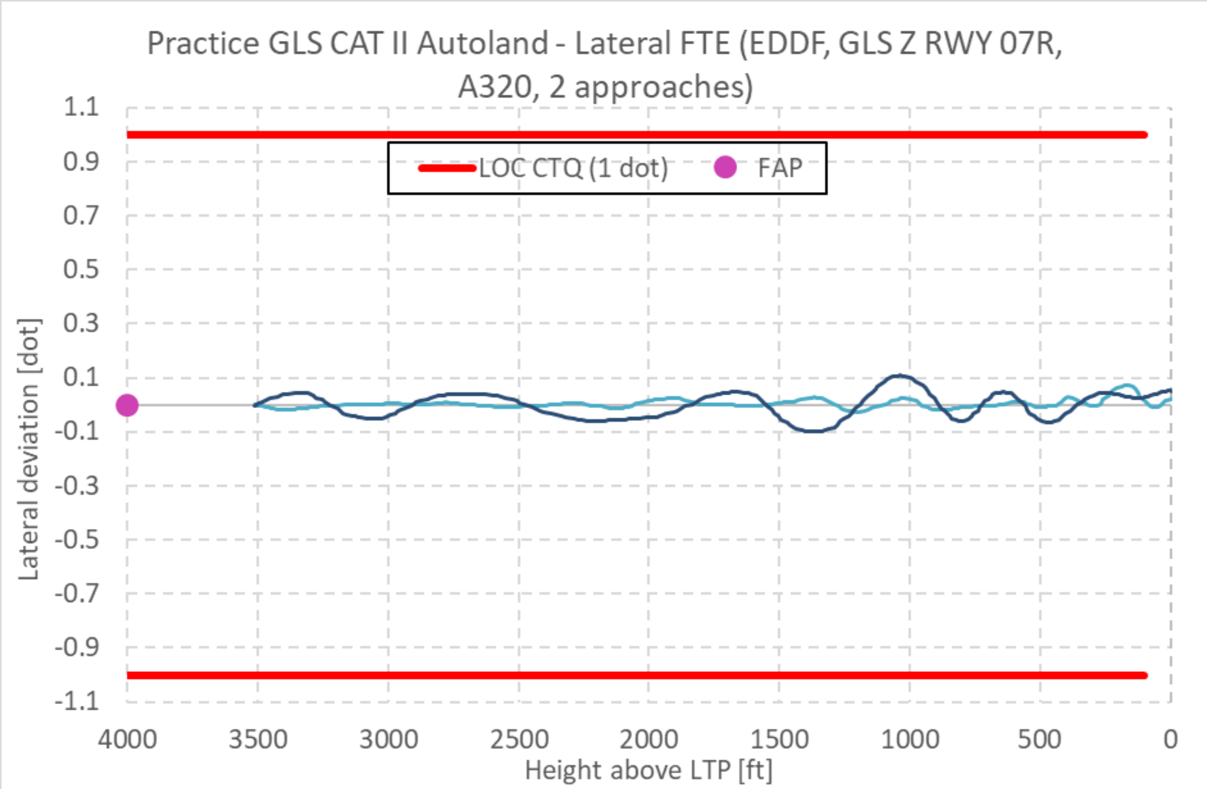

Figure 27: Practice GLS CAT II Autoland (DLH) – Lateral FTE (EDDF, GLS Z RWY 07R, A320)

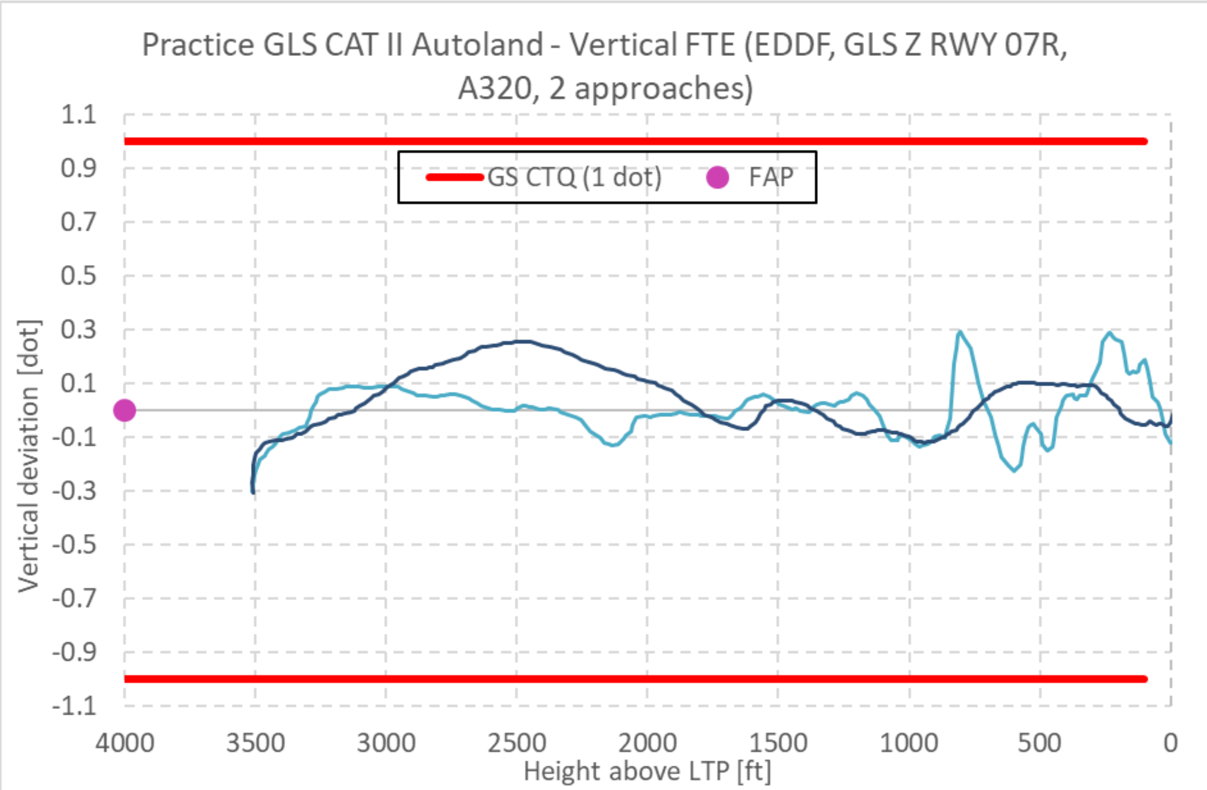

Figure 28: Practice GLS CAT II Autoland (DLH) – Vertical FTE (EDDF, GLS Z RWY 07R, A320)

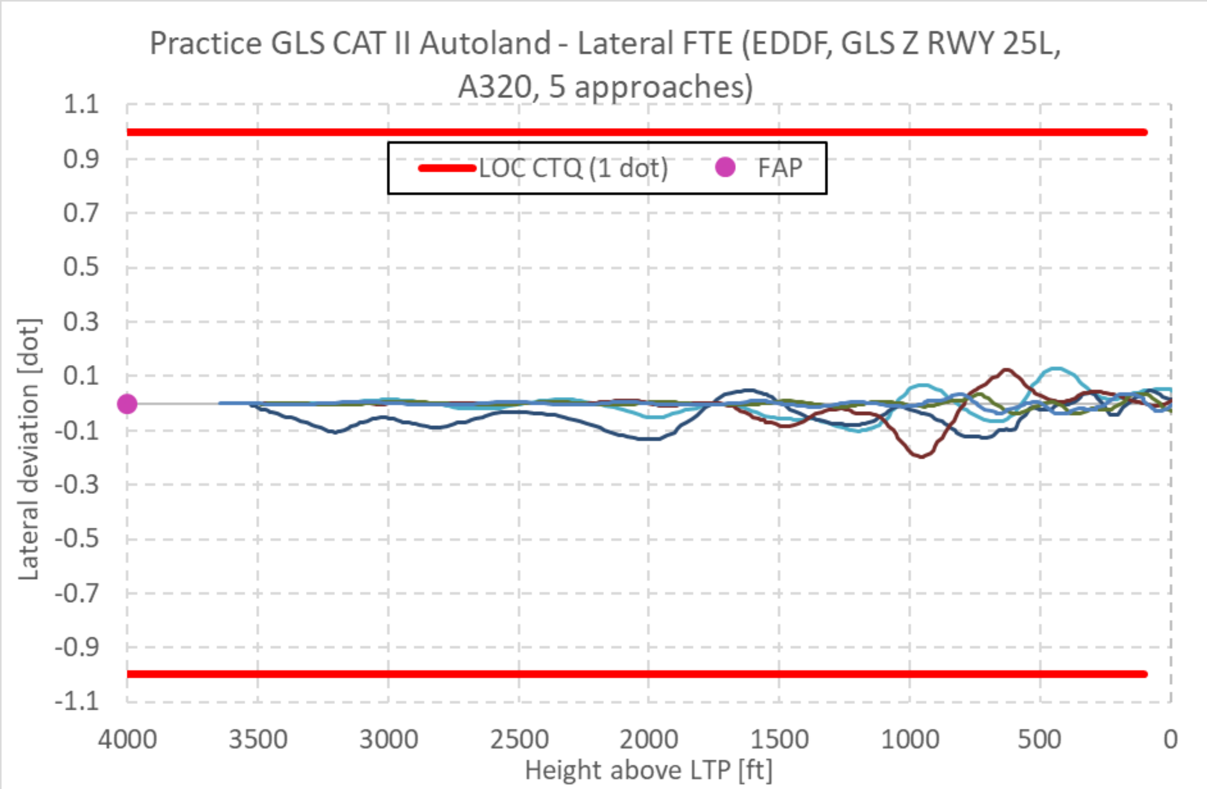

Figure 29: Practice GLS CAT II Autoland (DLH) – Lateral FTE (EDDF, GLS Z RWY 25L, A320)

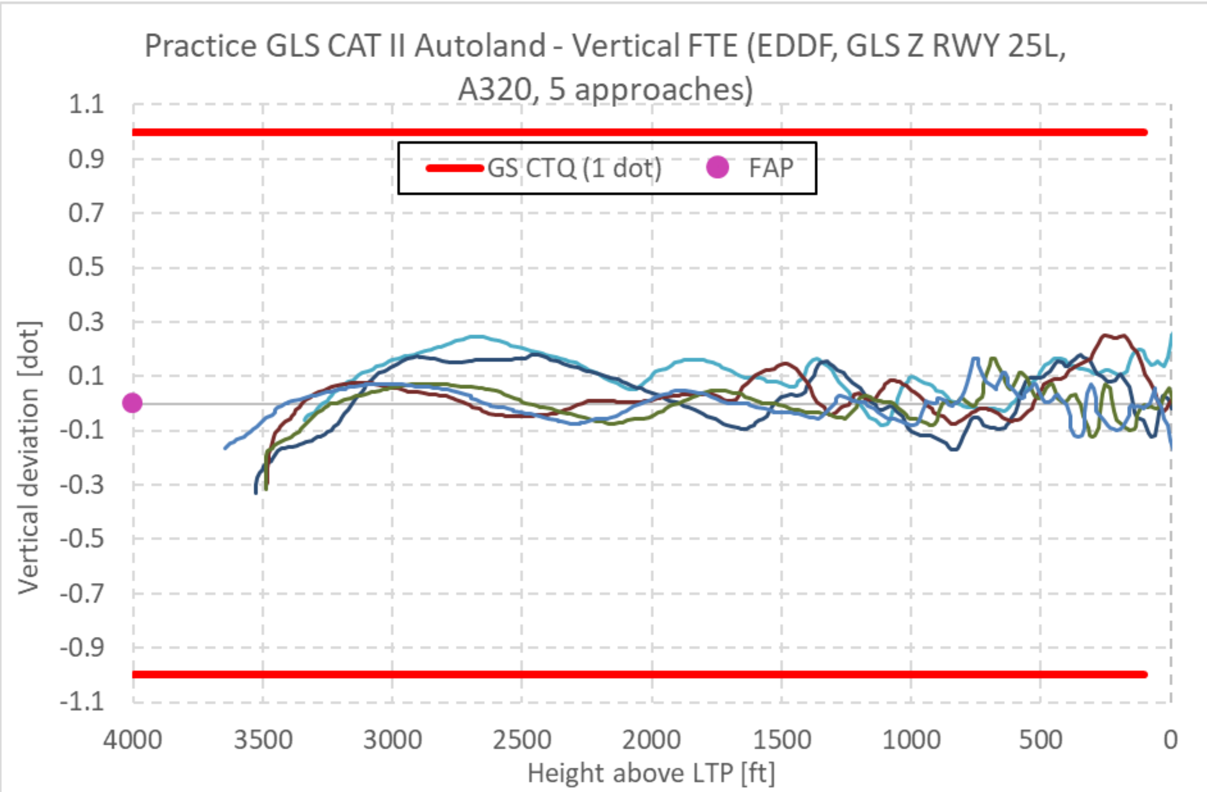

Figure 30: Practice GLS CAT II Autoland (DLH) – Vertical FTE (EDDF, GLS Z RWY 25L, A320)

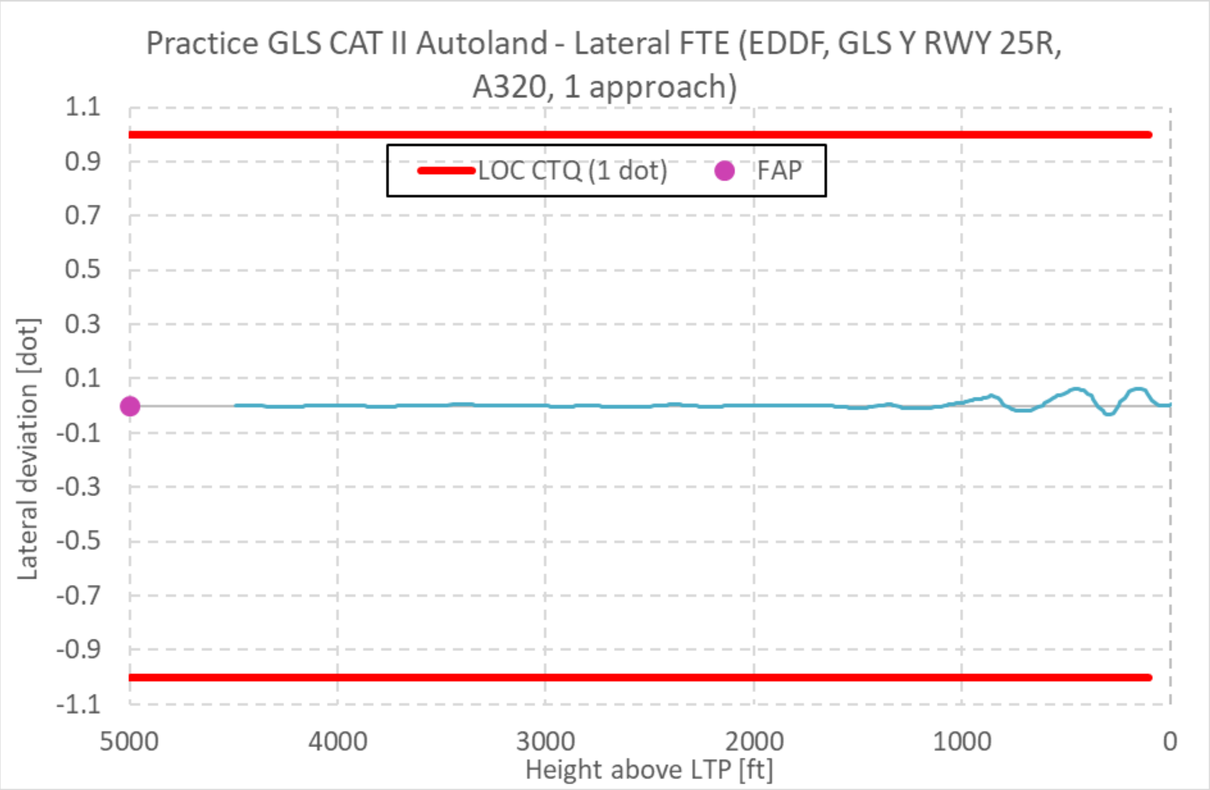

Figure 31: Practice GLS CAT II Autoland (DLH) – Lateral FTE (EDDF, GLS Y RWY 25R, A320)

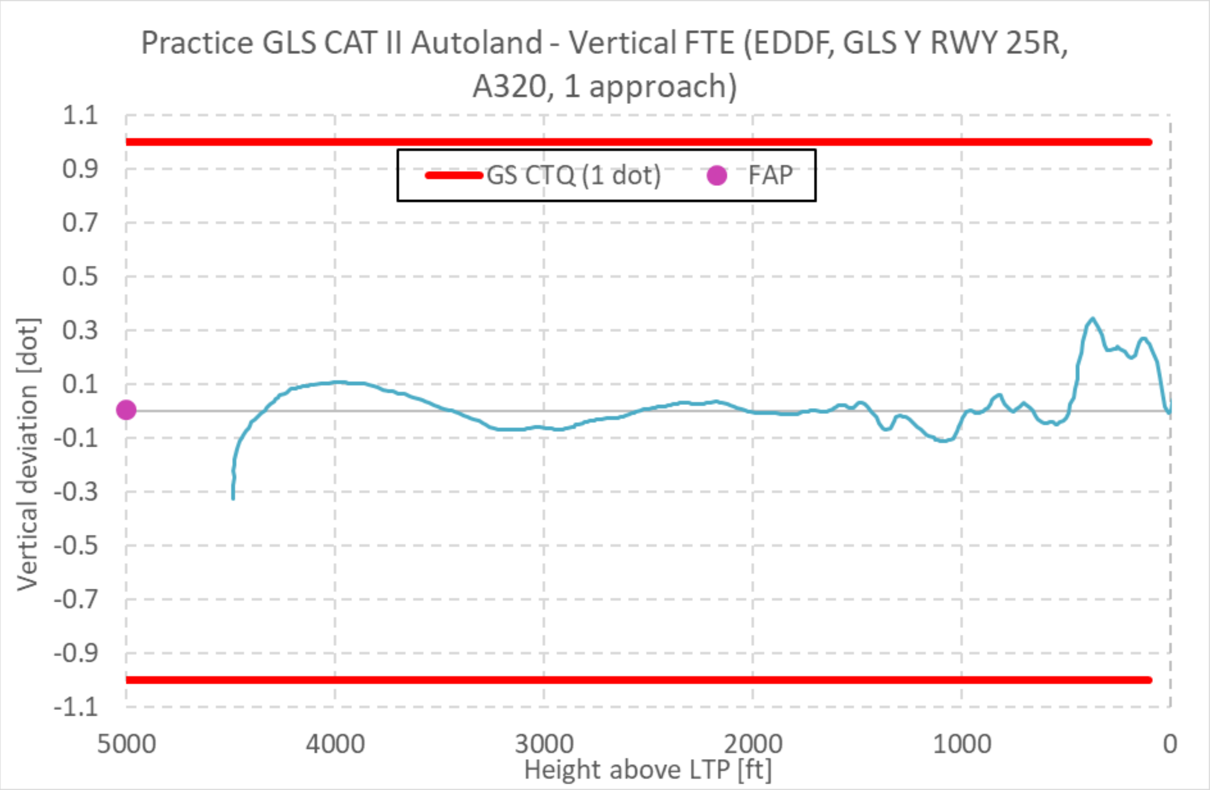

Figure 32: Practice GLS CAT II Autoland (DLH) – Vertical FTE (EDDF, GLS Y RWY 25R, A320)

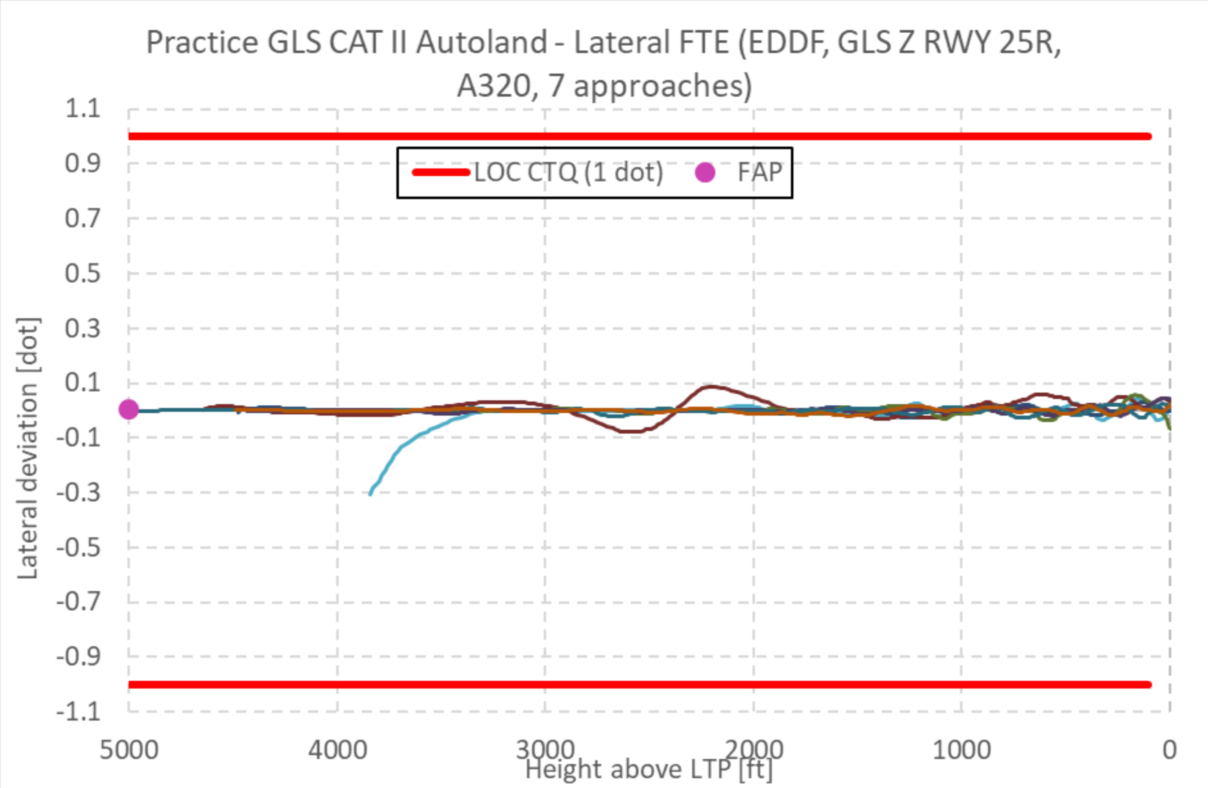

Figure 33: Practice GLS CAT II Autoland (DLH) – Lateral FTE (EDDF, GLS Z RWY 25R, A320)

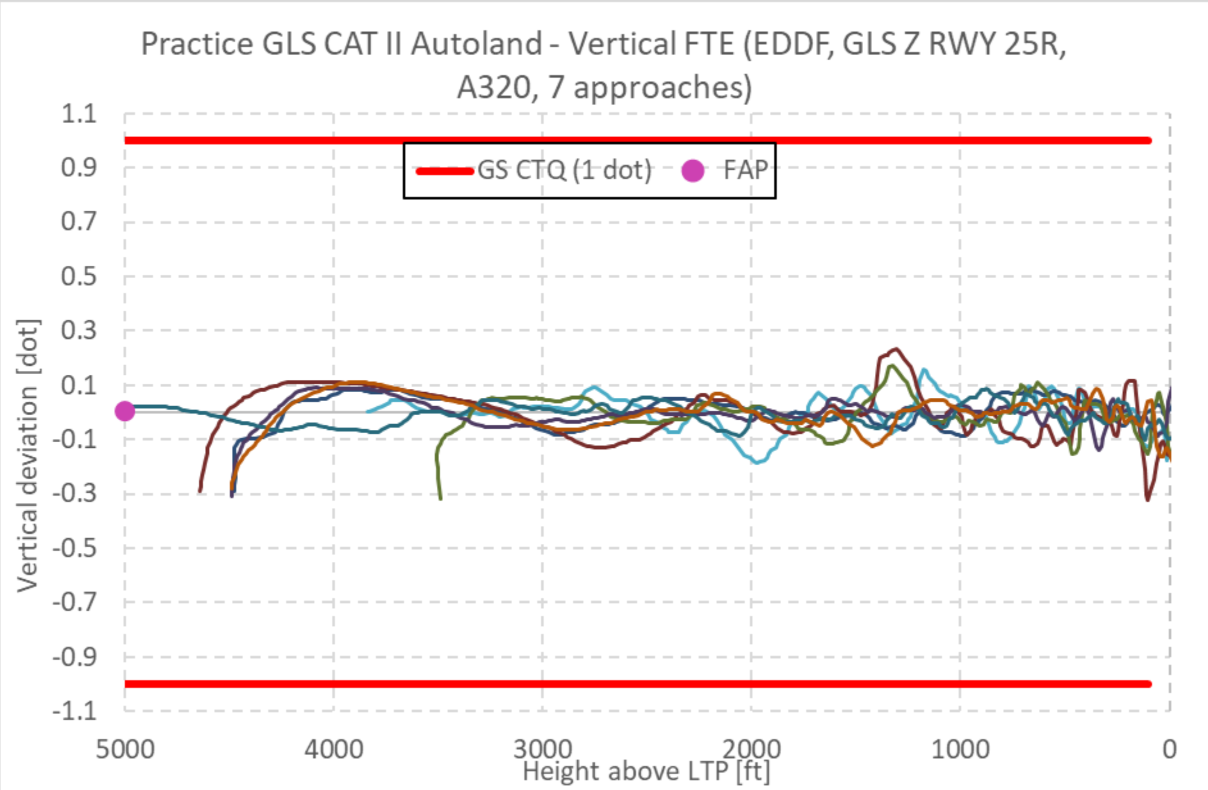

Figure 34: Practice GLS CAT II Autoland (DLH) – Vertical FTE (EDDF, GLS Z RWY 25R, A320)

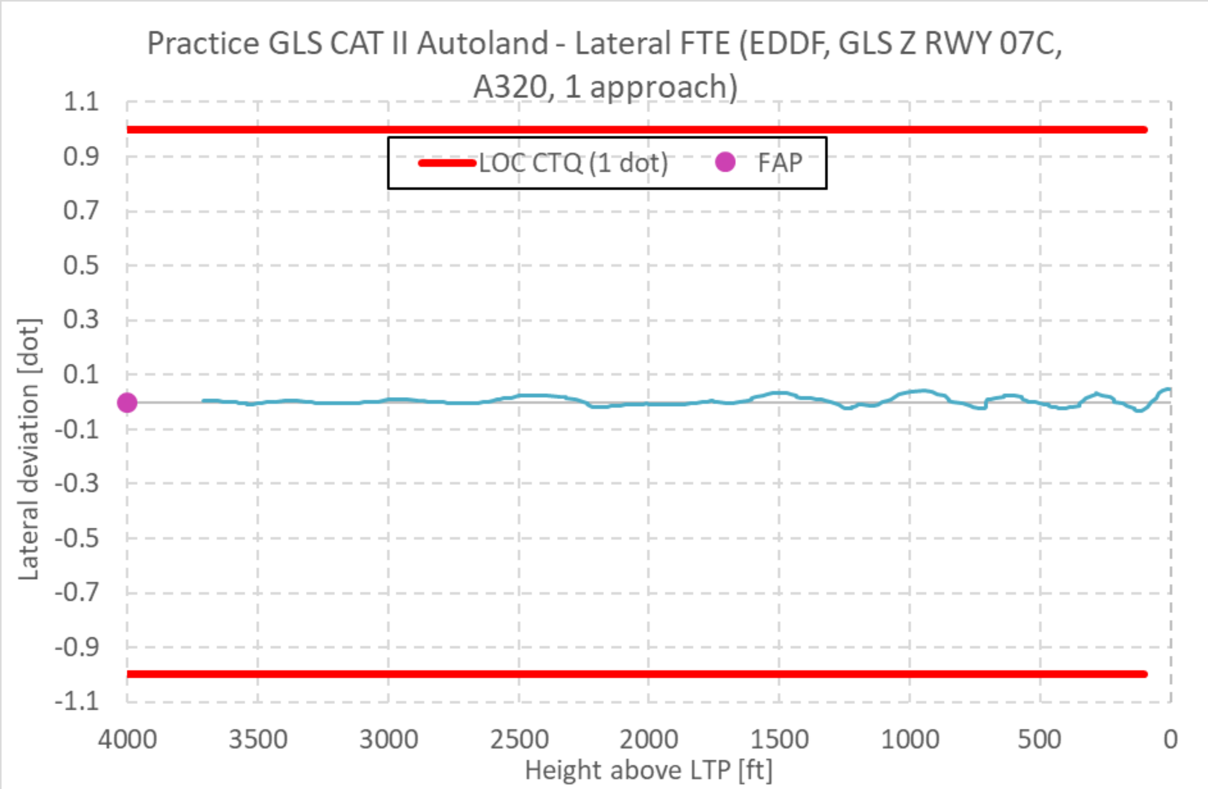

Figure 35: Practice GLS CAT II Autoland (DLH) – Lateral FTE (EDDF, GLS Z RWY 07C, A320)

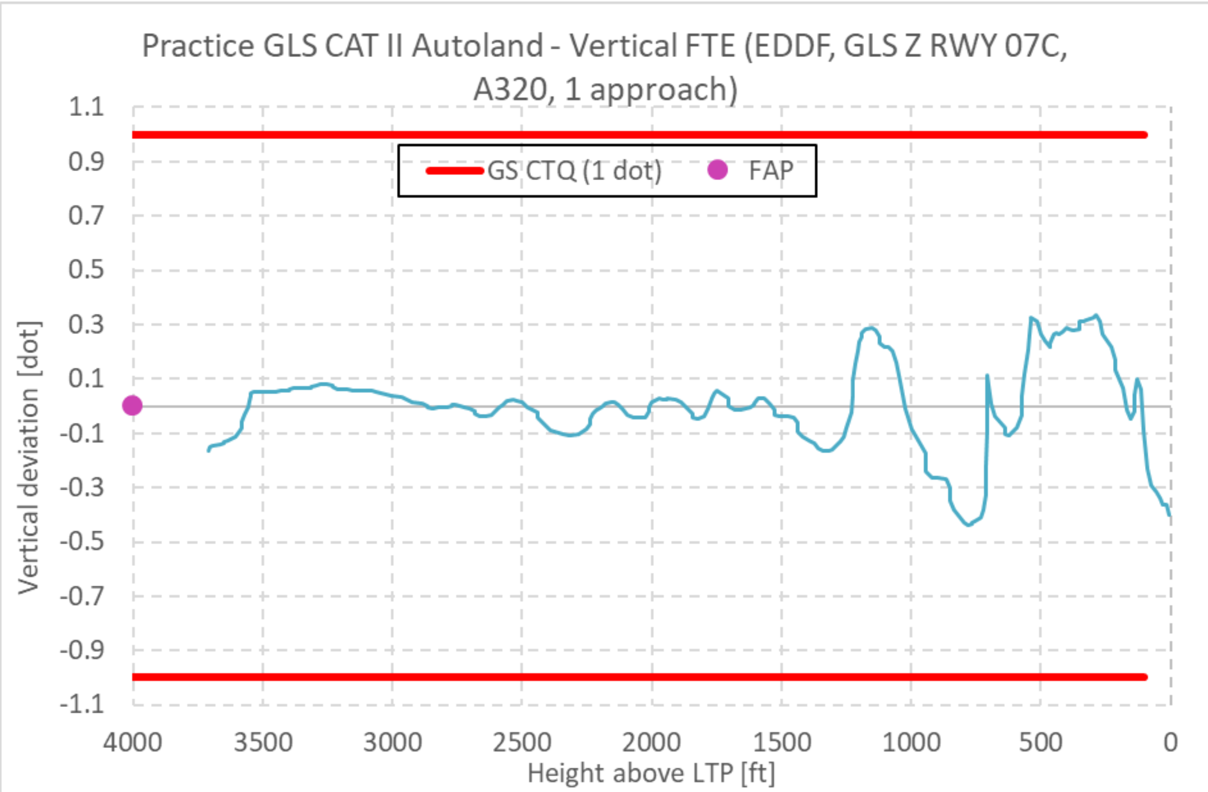

Figure 36: Practice GLS CAT II Autoland (DLH) – Vertical FTE (EDDF, GLS Z RWY 07C, A320)

c. Conclusion on Practice GLS CAT II Autoland accuracy

This section aims to summarize the accuracy results for revenue demonstration flights with mainline aircraft for all Practice GLS CAT II procedures. Published GBAS approach procedures in Frankfurt and Bremen were used. The objective EX1-OBJ-VLD-V4-028 evaluation results with respect to CTQ compliance down to 100 ft can be found in Table 18. During all 32 Practice GLS CAT II Autoland approaches the demonstrated parameter of horizonal and vertical FTE was well within CTQ value from the capturing and stabilizing on approach (bellow 0.3 dot) down to 100 ft. As CTQ limit was applied on all figures down to 100ft, the FTE compliance down to GBAS CAT II DH is clearly demonstrated.

FTE within CTQ / AC type	EDDW		EDDF	
	Lateral	Vertical	Lateral	Vertical
DLH A320	OK	OK	OK	OK

Table 18: EX1-OBJ-VLD-V4-028 Accuracy Assessment

Table 18 contain an overview of measured performance in terms of mean and standard deviation of lateral and vertical FTE in Frankfurt and Bremen.

Airport	Number of flights	Lateral FTE		Vertical FTE	
		Mean [dot]	STD [dot]	Mean [dot]	STD [dot]
EDDW	8	0.005 – 0.018	0.004 – 0.022	0.038 – 0.060	0.028 – 0.049
EDDF	24	0.003 – 0.057	0.003 – 0.045	0.035 – 0.110	0.036 – 0.111

Table 19: Performance statistics per airport for DLH practice GLS CAT II Autoland flights

Ryanair pilots flown 1 practice GLS CAT II Autoland approach using Ryanair practice CAT II procedures in the USA at Grant county international Airport (KMWH) during aircraft acceptance flight, i.e. non-revenue flight on B737-800 aircraft that was not yet registered on Ryanair. Therefore, flight data were not recorded for AAL2 and are not included in flight accuracy demonstration objective evaluation.

Summary of Environmental Conditions

In order to provide more details for the assessment of Practice GLS CAT II Autoland approaches to EDDW and EDDF the environmental aspects in terms of air temperature, wind direction and wind speed (experienced during the flights) were investigated for the revenue flights performed by Lufthansa.

Statistics (mean, std, min and max) are summarized in the Table 20 for wind speed, Table 21 for wind direction (only the mean and std) and Table 22 for air temperature. In general, the environmental conditions (wind, temperature) were mostly nominal (not extreme) during the all of the approaches but they were quite different for each approach. Only a few flights in Frankfurt (DLH A320) were flown during the strong wind conditions (at the upper parts of final approach) with magnitude of 40 to 50 knots.

While processing the Practice GLS CAT II Autoland flights data, the impact of weather conditions on FTE was checked for each flight. It was discovered that the wind influences FTE mainly in lateral direction. The greatest effect was noticeable in cases when the wind was changing the direction, the strength (speed and/or gusting) during the approach or both. The usual case was the wind speed decreasing with lower altitude, but it was observed even the opposite case, when the wind speed was continuously increasing while descending from 3000 ft to approx. 500 ft above the runway and then suddenly dropped. There were multiple scenarios of the wind direction too, multiple flights with stable wind direction (varying from head winds to cross winds) and variable wind directions, when the direction of the wind continuously changed almost about 140 degrees during the final approach.

These described variable environment conditions had a small impact on the flight accuracy without any major deviations from desired flight path.

Wind Speed [kts]	Mean	Std	Min	Max
Bremen				
DLH A320	8.2 – 29.4	2.8 – 7.1	0.3	39.9
Frankfurt				
DLH A320	3.5 – 39.3	1.2 – 10.2	0.2	54.6

Table 20: Summary of wind speed conditions during Practice GLS CAT II Autoland flights

Wind Direction [°]	Mean	Std
Bremen		
DLH A320	90.7 – 283.6	13.1 – 45.0
Frankfurt		
DLH A320	64.6 – 256.1	7.2 – 151.2

Table 21: Summary of wind direction conditions during Practice GLS CAT II Autoland flights

Air Temperature [°C]	Mean	Std	Min	Max
Bremen				
DLH A320	-1.9 – 17.0	0.8 – 2.4	-4.5	20.3
Frankfurt				
DLH A320	-11.7 – 23	0.7 – 9.9	-34.5	30.3

Table 22: Summary of air temperature conditions during Practice GLS CAT II Autoland flights

6. EX1-OBJ-VLD-V4-022 Results

Execution of the fuel and CO2 demonstrations started with a simulation study that was conducted using a six-degrees-of-freedom simulation model of an A320 in order to investigate general effects of final approaches with a GBAS-like, perfectly straight glideslope and bended glideslopes with different amplitudes and frequencies of bending as it might occur with ILS. General effects on fuel burn and airbrake activity due to flightpath bending under consideration of different wind conditions and aircraft gross weights were demonstrated, see first part of Appendix F.

The simulation study revealed a potential of approaches with perfectly straight glideslopes in comparison to approaches with bended glideslopes in terms of a possible reduction of fuel consumption and the use of air brakes. However, the simulation study also showed that the influences of the aircraft weight and especially of the amount of head wind has a much higher influence on the fuel consumption than the effects from glideslope bends.

a. Evaluation of DLH B747-8 GLS and ILS approaches to EDDF

To perform analysis of the real flight data, data collection was conducted first on Lufthansa revenue GLS and ILS approaches to Frankfurt on B747-8 and A320fam. Then an analysis of real flight data has been performed for approaches with Boeing 747-8 on runway 25L and 07R in Frankfurt/Main (EDDF) in order to analyse fuel efficiency benefits of GLS approach compared to legacy ILS. In total, 574 approaches of different Boeing 747-8 aircraft conducted between July and December 2018 on runway 25L and runway 07R were selected for the analysis. About one half of the approaches (235 approaches) were conducted using GLS and the remaining approaches (291 approaches) were conducted using ILS.

The analysis was based on different parameters, namely fuel consumption (also applied as indicator for CO2 emissions), approach duration, approach stability and noise. Figure 37 shows the results in terms of fuel consumption for both landing directions for ILS and GLS approaches. Please note that Figure 37 does not show the current fuel flow at a given distance to the threshold but the total amount of consumed fuel over a given evaluation distance from the threshold. In order to compare the fuel consumption of the full approach the values at an evaluation distance of 12 nm need to be considered.

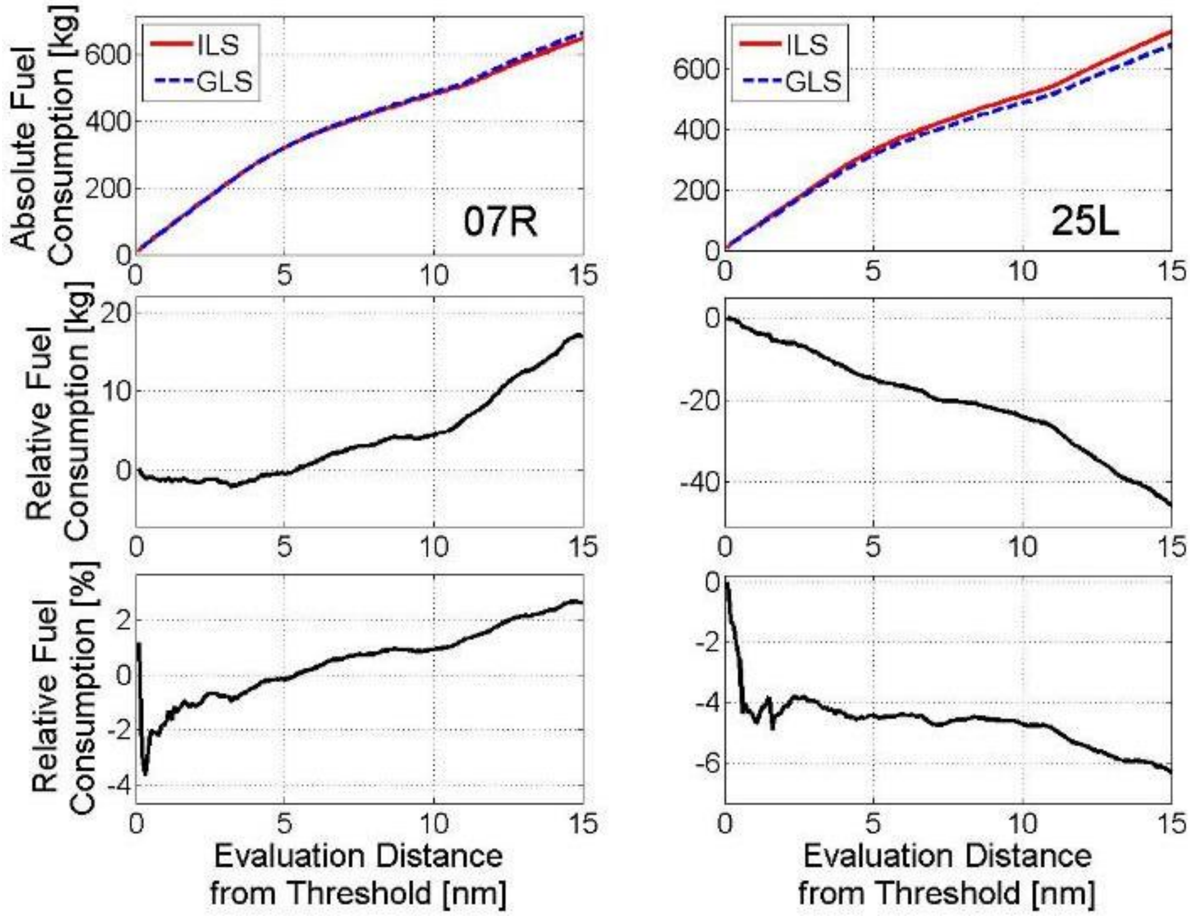

Figure 37: Relative differences in fuel consumption between ILS and GLS for RWY 07R and RWY 25L

The analysis of the flight data shows for the full approach (evaluation distance of 12 nm in Figure 37) an about 5 % lower fuel consumption for GLS approaches in westerly landing direction (25L) and about 2 % more fuel consumption for GLS approaches in easterly landing direction (07R). Westerly landing direction is more frequent for airlines operating to Frankfurt airport due to prevailing wind direction.

The differences in fuel consumption were found not to be directly attributed to the approach type. They can only be explained by a different behaviour of the pilots in terms of flap deflection and landing gear deployment. This different operational behaviour might possibly be attributed to the approach type (amongst other possible causes), but the exact reason for the differences could not be clarified based on the given flight data. For future evaluation it would be useful to have pilot questionnaires explaining the specific causes for decisions, when and how to configure the aircraft during approach. In the analysis of the B747 flight data no general differences in the stability of ILS and GLS approaches could be observed. The amount of flight data was considered statistically significant. The results imply that the differences in the vertical profiles of ILS and GLS approaches on the southern runway in both landing directions are too small to be observed in the flight data. As the deviations from the glideslope have not been recorded but only the absolute flight path in space, the actual profiles of both approach types could not be evaluated. However, measurement data from DFS support the findings that the ILS-glideslopes in both landing directions on runway 25L/07R are relatively straight, hence similar to the GBAS approach path.

As a part of this task, the analysis of the measurement data of all noise monitoring stations was conducted and showed that the determined level differences were not significant. For approaches with B747-8 no noise advantages in the comparison between ILS and GLS were recognizable.

b. Evaluation of DLH A319, A320, A321 GLS and ILS approaches to EDDF

Altogether, 1334 approaches with A319, A320 and A321 on different runways of EDDF were analysed. However, these approaches were split into different amounts of approaches on each runway, approach type and the three aircraft types of the A320 family (A319, A320 and A321). For this reason, not all groups of data (specific aircraft type on specific runway with specific approach type) were useful, as for some the number of approaches was too small to provide reliable statistical results. It must be noted that characteristic differences between ILS and GLS that is runway-related, so analysis for all runways together was not useful. For this reason, the flight data were analysed for each aircraft type and each runway separately. Also, as the range of aircraft mass was very widespread with this whole family of aircraft types, it was not meaningful to analyse the flight data for all aircraft types together. By doing so the aircraft mass was the predominant parameter which drives the results, such as fuel flow. The only identified runway of interest in EDDF from fuel and CO2 savings point of view when comparing GLS and ILS approach was RWY 25R, as only on this runway considerable differences in the glideslopes of ILS and GLS exist, as shown on the flown glide path angle of analysed A320fam flight in Figure 38, Figure 39, and as well as flight inspection figures from DFS included in Appendix F.

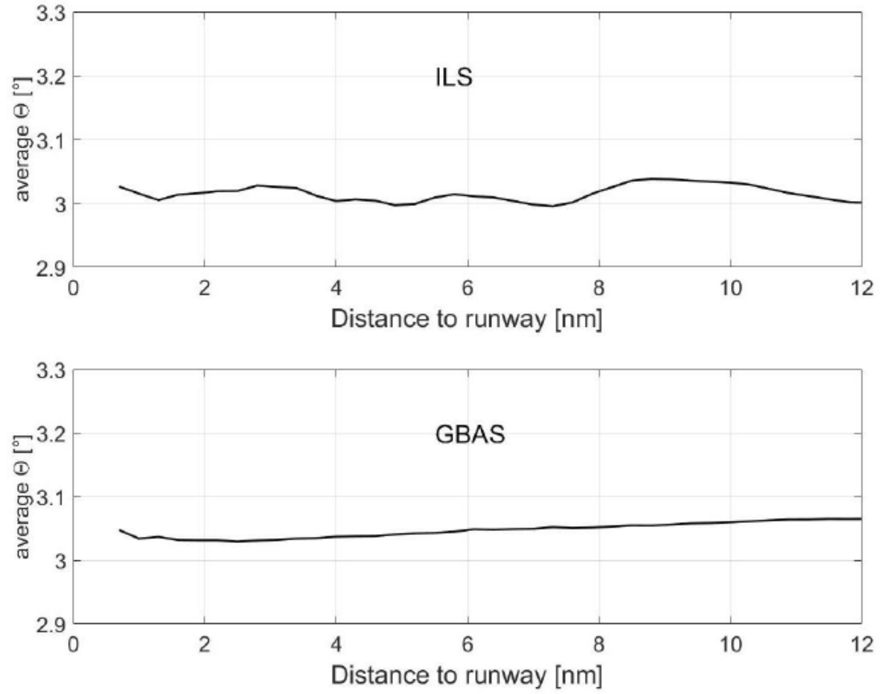

Figure 38: Actual glideslope angle of ILS and GLS for runway 25R 3°

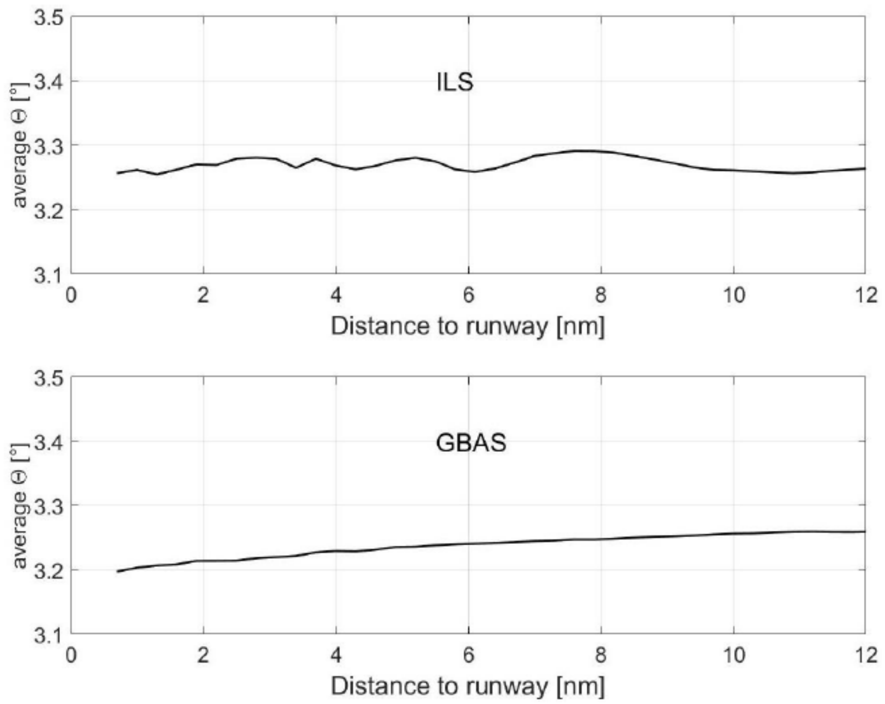

Figure 39: Actual glideslope angle of ILS and GLS for runway 25R 3.2°

For the most interesting runway, landing direction 25R, where glideslope bends with the ILS exist, the 3.0° approaches needed more fuel in average with GLS, whereas the 3.2° approaches needed less fuel in average with GLS. Both relative differences were in the same order of magnitude, slightly below 2% fuel consumption, but with different sign. The same tendency was observed for runway 25L with 3.0°, where the GLS approaches used less fuel in average than the GLS, and 07L with 3.2°, where the GLS approaches used more fuel in average than the ILS. These findings indicated that the reason for the different average fuel consumptions was not the approach type but other causes, e.g. operational issues, such as the configuration of the aircraft or wind.

However, the A319 is not the best aircraft type for evaluation of differences between ILS and GLS. From the A320 family the A319 is the lightest type, for which reason the aircraft mostly fly in idle during the approach. Heavier aircraft, such as the A321, may fly with a thrust setting above idle for a longer period of time during the approach. For this reason, it can be expected that influences of the approach type on the fuel consumption – if any – are more pronounced with heavier aircraft. Unfortunately, the amount of flight data with the A321 on runway 25R was not enough for a statistical analysis as visible in Table 23. The analysis was mainly performed for A319 on runway 25R with a glideslope of 3.0° and 3.2°. However, as mentions above, this aircraft type is expected not to be the most interesting one for the analysis as it is the lightest one of the three aircraft types.

Number of all gathered approaches per each EDDF RWY, approach type and aircraft can be found in Appendix F.

RWY	Approach angle	Approach type	A319	A320	A321
25R	3.0°	ILS	75	13	44
		GLS	62	9	13
	3.2°	ILS	168	25	66
		GLS	93	14	14

Table 23: Amount of gathered flight data with A320 family type aircraft on EDDF RWY 25R

The analysis of flight data from the A320 family revealed no characteristic differences between approaches with ILS and GLS as A319 is light aircraft and there were not enough A320 and A321 flight data gathered to be statistically significant. The differences found in average fuel consumption (as a measure for CO2 emission) could be attributed to other causes than the approach type. Mainly wind and operational issues such as configuration of the aircraft caused differences between approaches with ILS and GLS. The analysis of the glideslope deviations revealed indeed bends in the glideslope of the ILS of runway 25R (both glideslope angles). Nevertheless, these glideslope bends could not be justified as a cause for differences between fuel results on both approach types.

Concluding, it is expected that a larger amount of flight data on heavier aircraft possibly change these findings and reveal a general difference between ILS and GLS, with fuel benefit on GLS approach. However, given the available amount of data on A320 and A321, no positive influence on fuel that can be attributed to GLS approach type could be found in gathered data in the range of 3% set up by demonstration objective criterion.

7. EX1-OBJ-VLD-V4-023 Results

From the evaluation of fuel demonstration objective EX1-OBJ-VLD-V4-022 of the gathered B747-8 flight data follows that for evaluation distance of 12 nm about 5 % lower fuel consumption for GLS approaches in westerly landing direction (25L) and about 2 % more fuel consumption for GLS approaches in easterly landing direction (07R), CO2 results can be derived as CO2 (as well as other greenhouse gas emissions) correlates with fuel consumption. The fuel demonstration objective evaluation of A319 approaches reveals that both relative differences between ILS and GLS approaches of 3.0° and 3.2° on EDDF runway 25R are in the same order of magnitude, slightly below 2% fuel consumption, but with different sign.

Neither the used simulation model nor the analysed flight data give direct numbers of CO2 emissions. Therefore, SESAR ENV Assessment Process 4 [55] was followed where constant factor between fuel consumption and CO2 emission is assumed, so the relative changes in fuel consumption can be considered as relative changes in CO2 emission. While differences between CO2 emissions on ILS and GLS approaches can be observed, there is not sufficient evidence to claim that these can be attributed to approach type. Therefore, CO2 reduction of 3% criterion due to approach type cannot be claimed based available aircraft data.

8. EX1-OBJ-VLD-V4-031 Results

This demonstration objective focuses on qualitative analysis of GBAS cost efficiency considering CAT II Approach Operation, CAT I equipment, operational experience and needs of ANSP and airlines contributing to WP2. The study is based on historical records, simulation and operational experience of study stakeholders, ANSP (DFS) and airlines (Lufthansa, Ryanair).

From GBAS CAT II operation on CAT I equipment point of view, two categories of benefits can be distinguished in general. First, available GBAS CAT I benefit would now be attainable during LVC/CAT II as well. Second, the GBAS CAT II LVC operation specific benefits that are not available in CAT I conditions.

a. ANSP View

View of ANSP in this study was focused on the case of large hub airport, Frankfurt am Main (EDDW). One of the advantages of GBAS CAT II operation introduction can possibly be an increase of runway capacity during Low Visibility Operations (LVO) that impacts cost efficiency. During LVO the main parameter, limiting the landing capacity of an airport, is the runway occupancy time. This is the time the aircraft needs on the runway to decelerate and to get clear of the runway up to a certain distance. This distance depends on whether the following aircraft is using ILS or GBAS as an approach guidance system. ILS protection zones have been defined, which are not necessary when using GBAS. In simulation, differences between ILS and GLS approaches with respect Obstacle Free Zone (OFZ), Obstacle Free Zone (OFZ), Sensitive Area (SA) /Critical Area (CA) and usage of Landing Clearance Line for GLS CAT II with respect to capacity as a parameter of GLS CAT II operation using CAT I equipment were demonstrated for Frankfurt airport RWY 25R.

In order to evaluate the differences between GBAS and ILS and the potential benefits of GBAS during LVO, Fast Time Simulations have been performed by DFS for a scenario at Frankfurt airport using the AirTOp93 simulator tool. The focus of the simulations was to analyse the consequences of a solely GBAS CAT II operations scenario compared to a solely ILS CAT II operations scenario with respect to the separation on final approach and the capacity of the selected runway 25R. Fast Time Simulations however can only answer these questions when considering certain assumptions. Thus, the results are qualitative tendencies instead of quantitative facts.

The results of the simulations indicate that an increase of capacity runway is most likely when using GLS CAT II approach procedures instead of ILS CAT II as can be seen on figure of capacity vs demand, where GBAS approaches better address airport capacity demand compared to ILS approaches (Appendix G). The reasons for this increase of capacity are the missing protection zones for GBAS and the Landing Clearance Line concept that allows the aircrafts to be clear of the runway at an earlier point of time. The capacity gain depends on the number of aircraft WTC HEAVY that cause most of the restrictions when using ILS. In addition, the taxi speeds of the aircrafts when vacating the runway is relevant for the results.

The simulations have been performed with various assumptions and simplifications. The results have a qualitative character only. One of the major parameters for the simulations is the GBAS equipage rate that was set to 100 percent. Currently the actual GBAS equipage at Frankfurt is around 8 percent and therefore it would not be possible to operate one runway as a GBAS Only runway today. Further investigations and simulations with a more detailed setup should be performed to evaluate the possible benefit e.g. for smaller numbers of equipage rate.

Nevertheless, the presented results of this report demonstrate that there is a positive tendency for greater capacity when using GLS instead ILS in low visibility conditions. With use of GAST C ground station and airborne equipment for GLS CAT II operations, increased capacity would bring ANSPs, Airports and Airlines higher cost efficiency.

b. Airlines view

Both the large HUB airline operator and regional airport operator is captured in the study.

Airline view - large HUB airport

Lufthansa assessed efficiency of GBAS operations for large HUB case as significant Lufthansa operations are done to HUB airports. Therefore, the focus was on identification and analysis of benefits in utilization of GBAS Landing System (GLS) instead of Instrument landing System (ILS) at the specific example of Frankfurt International Airport with high density of traffic, where Lufthansa has aircraft base.

Up to 1400 take-off and landings can be counted at Frankfurt airport per day. The high density of air traffic has implications for the utilization of possible landing systems, landing routes and landing procedures. These varied landing systems, landing routes and landing procedures can cause differences with regard to efficiency and environmental impact (e.g. fuel burn, CO_2 emission, noise level).

Most of the approaches at Frankfurt Airport are currently performed on the base of the Instrument Landing System (ILS). These approaches require a level flight of several nautical miles (NM) before flight crews are allowed to initiate the further descent in an altitude of 5000 or 4000ft. In order to reduce the environmental impact (e.g. CO_2 emission, noise level) and increase flight efficiency (e.g. reduced fuel burn) during an approach a late continuous descent from a high altitude is required.

Instead of an ILS approach, flight crews can also approach with GBAS Landing System (GLS) at Frankfurt Airport if the aircraft is equipped for corresponding GLS approaches and the flight crew receives appropriate clearance from ATC. GLS approaches carry the advantage that GLS Glideslope certification is already available up to 23 nautical miles. As a consequence of this, ATC towers can clear an approach from an altitude up to 7000ft. This is 2000 to 3000ft higher in comparison to the ILS approach.

Simulator and flight data analysis with a Boeing 747-8 has shown fuel savings of approximately 20kg per approach that started from 7000ft (instead of a level flight in 4000ft before commencing the ILS approach). A real Airbus A380 GLS approach from 7000ft to Frankfurt airport confirmed the fuel saving calculation from simulator. Considering SESAR ERM methodology [55] where direct link between fuel burn and the amount of CO_2 produced is provided (i.e. 3.15 times the mass of fuel burnt), fuel savings result in 63 kg savings of CO_2.

A fuel saving analysis for GLS approaches with regard to short-range aircraft (e.g. Airbus A320) could not be accomplished until now. A first estimate (without confirmation) is a fuel saving of approximately 8-10 kg per GLS approach with a short-range aircraft.

The percentage of GLS approaches from 7000ft at Frankfurt airport is limited due to the high density of air traffic and a mixed traffic situation. The DFS expect that currently 10% of Lufthansa approaches at Frankfurt airport with a long-range aircraft can receive a clearance to commence the approach out of 7000ft.

Lufthansa A380 and 747-8 aircraft are equipped for GLS approaches until now. If you calculate 15 to 20 landings per day with above-mentioned Lufthansa aircraft and you consider the 10% DFS clearance, one or two Lufthansa aircraft could perform a GLS approach per day at Frankfurt airport with a fuel saving of app. 40kg per approach. With higher aircraft GLS equipage rate, more clearances could be allowed by DFS which would imply higher fuel and CO_2 savings.

If the GBAS landing system (GLS) would be certified to support CAT II and CAT III operation, these savings could be achieved during Low Visibility Conditions as well. In the case of certified GLS CAT II operation with GAST C equipment, currently available GBAS airborne equipment for CAT I operation would be sufficient to gain these benefits in LVC down to CAT II minimums. Since no protection and safety areas for GLS approaches are required, a higher throughput of two to three aircraft per hour (during LVO) could be achieved. This higher throughput could avoid delays, holdings, diversions and cancellations which would imply lower cost for an airline. Both the fuel savings due to higher altitude of approach start, and reduction of delays, holdings, diversions and cancellations, are achievable with current airborne GBAS CAT I equipment which implies overall good cost efficiency for both non-LVC and LVC conditions.

Airline view - Regional airport

Different aspects of GBAS/CAT II operation cost efficiency from regional airport operator perspective were studied by Ryanair. Provided view on the cost efficiency of the GBAS CAT II solution on CAT I equipment is based on Ryanair extensive experience with flight operation to regional airports, data analysis and specific examples with identified cost efficiency prospects of GBAS CAT II on CAT I equipment solution operational deployment.

GLS CAT II approaches will be available without the cost of extra aircraft equipment. Considering Ryanair fleet, approximately 42 aircraft are equipped with GBAS and all new arriving aircraft will have GBAS fitted with over 100 B737 Max aircraft ordered with options for a significant number more. No retrofit of the existing fleet with GBAS planned at this time. Depending on B737 Max deliveries fleet of approximately 142 GBAS equipped aircraft over the next few years would benefit from GLS CAT II operation introduction without need of any extra equipment to carry out which brings cost benefit.

GLS CAT II approaches will be available without additional training costs. Often when new procedures or new equipment are introduced into the aircraft crews need to first do a training programme in the simulator before they can use the procedure/equipment. In the case of large regional airport operator like Ryanair, 5000 pilots would need to go through a simulator programme. This would include the cost of simulators, training instructors, travel and hotels. There would also be a loss productivity from pilots adding to further cost. GBAS is so similar to ILS that operator can use the same procedures and same SOP call as ILS approaches. This means operator does not need additional training in simulators and the significant cost that entails. Each hour in the simulator costs about 450 euro an hour. A 2-hour training session would cost 900 euros and to train all crews, 2500 sessions in total would be needed at a cost of over 2.25 million euro. Accommodation costs and other training expenses would cost about ¾ million euro so the training costs savings would be 3 million euro. This supports cost efficiency of GLS CAT II operation using current airborne GBAS CAT I equipment from training cost point of view.

GLS CAT II approaches should become available to smaller airports that currently find ILS CAT II approach equipment prohibitively expensive. Operators like Ryanair fly to many smaller regional airports, typically with ILS one side and non-precision approach on the other. GLS CAT II operation gives regional airport operator such as Ryanair the opportunity to operate CAT II approaches to both runways. This has a cost benefit to the airline with far less diversions from regional airports. Diversions can be very expensive; passengers have to be normally bussed to and from the original destination. The aircraft is not doing its planned rotation leading to follow on delays and in the worst-case cancellations. Airline customers are also greatly in inconvenienced and may be slow to travel with the airline again. GBAS CAT II approaches would help mitigate against this.

In this study, Ryanair conducted a detailed analysis of diversions in 2018. In 2018 this year Ryanair had 761 diversions. About 50% were due to the weather being below minima at the destination (Non-precision or CAT 1). GLS CAT II approach would have mostly allowed the aircraft to land. Each diversion costs about 75,000 euro. This includes the cost of EU Regulation 261/2004 (EU law relating to flight delay compensation), handling, coaches, airport charges, fuel etc. This costs about 28 million a year. The cost of having aircraft out of position is difficult to quantify, if a flight is diverted the follow-on flights either need to be completed by a spare aircraft, a different line of flying needs to be disrupted, the flight is delayed and completed by the delayed aircraft or the flight is cancelled. Ryanair estimate the cost to the operation of about 12 million euro a year so the total saving would be in excess of 40 million a year to Ryanair. There are also specificities related to airport location. For example, Ryanair found GLS CAT II being particularly useful in Poland considering character of weather systems and number of flights to Polish regional airports. Due to the nature of fog in Poland affecting large areas of the country the aircraft often need to divert to airports that are a considerable distance away, so diversion cost is higher due to the distances to bus passengers and the time spent waiting for passengers to arrive at the aircraft. In Poland, Ryanair estimates diversion costs closer to 100,000 per flight. These facts thus support cost efficiency of GLS CAT II operation using current airborne GBAS CAT I equipment as well from increased airport accessibility in LVC point of view.

A.3.3 Unexpected Behaviours/Results

Delays accommodated during preparation of GBAS ground station Block II S upgrade certification and airlines ops approval including COVID-19 outbreak ramification forced the project to adapt EXE-VLDV4-100 demonstrations to practice GLS CAT II approach instead of full GLS CAT II. However, finished demonstration allowed to gain significant operational experience on revenue flights that will be used during continuation of the airlines operational approval process.

A.3.4 Confidence in the Demonstration Results

1. Level of significance/limitations of Demonstration Exercise Results

Demonstration preparation activities were conducted in cooperation with regulatory authorities both for ground station, airborne airworthiness and operation approval part. This enables progress towards GLS CAT II, respectively project delivered GBAS Ground Station upgrade capable of GLS CAT II and delivered ground station safety assessment, Airbus A320 safety impact assessment, updated CONOPS for GLS CAT II operation, new RNP to GLS procedures, Lufthansa and Ryanair operational risk evaluation/safety assessment considering GLS Autoland operation down to 100 ft. Practice GLS CAT II operation then allowed further exploit GBAS CAT I systems and clearly demonstrated GBAS readiness for Autoland operation both in flight accuracy and pilot feasibility aspects almost exclusively during revenue flights conducted on three different aircraft types. CAT II operation on CAT I equipment demonstration exercise was supported on the ground side by Honeywell GBAS ground station SLS 4000, by Lufthansa B747-8 and A320family, and Ryanair B737-800.

With respect to fuel and CO2 evaluation which was based on separate data collection campaign from Lufthansa regular flights to Frankfurt, although flight data for over one thousands of GLS/ILS approaches were gathered for A320family to runway with ILS bends, number was not sufficient to get statistically significant results to validated expected fuel/CO savings of gathered flights during flight data collection for fuel and CO2 benefits assessment limit the range.

2. Quality of Demonstration Exercise Results

Demonstrations were performed on revenue flights using various aircraft platforms in various environment including the airports in Europe comprising major hub as well as regional airport (Frankfurt - EDDF, Bremen - EDDW). Flight test data analysis were performed in a very detailed way and enabled to critically assess the analysis results.

Demonstration flights campaign was preceded by pilots in the loop simulations on practice GLS CAT II and was followed by flight demonstration of both practice GLS CAT II and RNP to GLS with human factors assessments on the feasibility of procedures and operations and the assessment of flight accuracy. Simulations and analysis of collected data for the evaluation GLS vs ILS approach environmental benefits (such as fuel consumption and CO2 emission) were complemented.

3. Significance of Demonstration Exercises Results

Demonstration flights were performed in operational environment in the EU ensuring good operational significance. Total number of flight demonstration within EXE-VLD-V4-100 is 76. Table below provides details per aircraft type and flown operation. Amount of trials by different aircraft types, operators at different airports ensures good operation and statistical significance. Demonstration exercise was significant as well from view of cooperation with regulatory stakeholders, both on GBAS ground station part when preparing safety case, airborne side when preparing A320 airworthiness certification and airline operation side, when preparing documentation for operational approval for GLS CAT II operation. RNP to GLS procedures with RF legs designed for Bremen were reviewed by airspace users and CDO capabilities were confirmed by pilots and as such remains published in AIP after AAL2 demonstration.

Operator	Aircraft type	Number practice GLS CAT II approaches	Number of RNP to GLS CAT I approaches
Lufthansa	A320 fam	43	12
	B747-8	14	N/A
Ryanair	B737-800	1	6
Total flown		**58**	**18**

Table 24: Total number of EXE-VLD-V4-100 flight trials

As practice GLS CAT II approaches were demonstrated using GLS CAT I approach and ATC procedures, significance of flight demonstration lies especially on airborne side. It clearly demonstrated pilot feasibility of practice GLS CAT II approach operation and accuracy of GLS CAT I Autoland approach capability with support of current GBAS CAT I equipment as a step towards full GLS CAT II approach. CONOPS extension for GLS CAT II procedure, ATC tools update, GLS CAT II procedures were prepared and GBAS Ground station upgrade with SBAS extension was completed/tested and aircraft safety impact assessment including simulator session was finished. Limitation consists in the fact that full GLS CAT II demonstration could not take place within AAL2 as required approvals were not granted in AAL2 timeframe.

A.4 Conclusions

Project demonstrated the benefits for the aviation community by progressing on GLS CAT II operation on enhanced GBAS CAT I ground station and current GBAS CAT I airborne systems towards deployment of this operations, that focuses on lowering the minimums on GLS precision approaches down to 100ft DH while allowing to bring fuel/CO2 benefits and increasing traffic throughput at airports in LVC.

Large scale demonstration and the participation of all relevant stakeholders enabled AAL2 project to bring a position impact to the speed of deployment of new technologies. By deployment of this new solution market will enjoy much faster the actual realization of GBAS LVC operation and thus support the ultimate goal of efficient and green ATM modernization. Both airborne and ground navigation elements demonstrated GBAS GAST-C technical capability to support GLS CAT I Autoland and GLS CAT

II Autoland approaches at pilot feasibility and approach flight accuracy demonstration level, same as at system safety assessment level.

In support of GLS CAT II demonstration preparation, significant effort was made by WP2 in preparing necessary safety case including assessment of GBAS enhancement with EGNOS data, airborne safety assessment with respect to impact at aircraft level for airworthiness assessment at operational level as a part of operational approval. Individual safety assessment was submitted to regulators CONOPS was updated to allow GBAS operation in LVC. Cockpit and Integration simulator supported safety assessment and operating method. FTS simulations focused on capacity gains due to missing protection zones for GBAS and the Landing Clearance Line concept that allows the aircrafts to be clear of the runway at an earlier point of time, compared to ILS. GLS/ILS study focusing on more stable signal with GLS approaches reveals potential benefits on specific ILS runways, however low number of evaluated flights did not allow to confirm expected level of fuel savings.

With over 70 successful demonstration flights the project has confirmed feasibility and accuracy of practice GLS CAT II operation using GBAS GAST-C/CAT I capability to support Autoland operation, so demonstrating GLS CAT I Autoland capability and aircraft and ground readiness towards full GLS CAT II operation. The approaches demonstrated as well accuracy and feasibility of the new designed RNP to GLS procedures, including RNP to GLS Autoland. The new designed RNP to GLS procedures with RF legs to Bremen under AAL2 will remain in the German AIP after completion of the project. Flight demonstrations were conducted with different aircraft types (A320 family, B747-8, B737-800) on Lufthansa and Ryanair revenue flights in two different environments represented by Bremen and Frankfurt airport. One approach was non-revenue flight. All trials were analysed in detail by the respective partners and data collection as well as feedback from pilots and demonstrated very good accuracy of practice GLS CAT II Autoland that were using deployed GBAS GAST-C/CAT I ground station, approaches as well as the new RNP to GLS approaches. With respect to GLS/ILS comparison, while detailed study was conducted that indicated possible fuel/CO2 benefits, there was not enough flights to support demonstration target.

The exercise EXE-VLD-V4-100 worked on demonstration of enhanced GBAS ground GAST-C system capability and current airborne GAST-C capability to support GLS CAT II operation. As the scope of demonstration was not exactly matching Solution #55, in some instances for example, built on new enhanced capabilities not available in current Solution definition, upon agreement with SJU before DEMR delivery, and by considering criteria to establish new solution and technical achievements of the AAL2 project as well as work done before and outside SESAR project, the EXE-VLD-V4-100 provides new SESAR Solution of Enhanced GBAS GAST-C to support GLS CAT II operation.

A.5 Recommendations

A.5.1 Recommendations for industrialization and deployment

Large number of demonstration approaches was conducted with different aircraft types (A320 family, B747-8, B737-NG), on revenue flights with Lufthansa and Ryanair on practice GLS CAT II approaches and RNP to GLS. All trials were analysed in detail by the respective partners, and data collection as well as feedback from pilots show the practice GLS CAT II as very well feasible with recommendations summarized below. Safety case was prepared both for GBAS ground and airborne part demonstration.

Demonstration showed the technology readiness for broader deployment of GBAS GAST-C solution allowing GLS CAT II approaches.

Recommendations with respect to GLS CAT II approaches using GBAS GAST-C/CAT I equipment:

- Lufthansa crews are familiar with practice GLS CAT II Autoland operation in Frankfurt and Bremen airports, approaches that will support approval process were gathered. Recommendation is to proceed in approval process to allow full GLS CAT II operation in LVC.
- Support of GLS CAT II operation introduction on GBAS GAST-C which doesn't require avionics modification for GAST-D allows to start gaining benefits, both in airport capacity for large hub as indicated by FTS, fuel/CO2 savings and accessibility of regional airports by GLS CAT II approach coverage on all RWY ends, already with current GBAS CAT I avionics.
- From cost efficiency point of view, GBAS GAST C/CAT I that supports operation down to 100ft DH is efficient way of how to address better capacity and accessibility of airports by introduction of GBAS LVC operation, where there are not enough CAT III weather conditions. Also, as leveraging current GBAS technology, this can be intermediate steps towards until GAST-D ground and airborne equipment deployment at sufficient equipage rate is available.
- GBAS airport capacity benefits in LVC down to CAT II are expected to be achieved on hub and large regional airport while on small/regional airports that usually have only ILS CAT I installation on one RWY, benefit comes through availability of GLS CAT II operation on all runway ends with currently available CAT I technology. GBAS can also support approaches from higher altitudes CO2 reductions as already today GBAS glide path can support approaches from 23 NM that would be allowed in LVC as well.
- Procedure design should consider all the required stakeholders: ATC, operators, airframe manufacturers to provide safe and optimal procedures.
- Train and motivate pilots to execute GLS approaches (see benefits in Appendix G).
- Airline GBAS LVC Autoland OPS approval.
- From RNP to GLS point of view, new demonstrated procedures in Bremen demonstrated CDO a-like vertical profile applied in order to reduce noise and fuel consumption, implementation of distance markers to support ATCOs and pilots. Procedures were assessed as well designed by pilots and will remained deployed (published in AIP) after AAL2. Recommendation is that RNP procedures that supports CDO operation should be published and promoted for usage.

Suggestions at consortium level:

- Strive for high GBAS equipage rates of aircraft crucial to realize beneficial effects and to decrease ATC controller's workload (traffic differentiation).
- Support Airlines (Air) and ANSPs/Airports (Ground) to create business cases for investments and align Ground/Air efforts.
- Implement concepts of operations, that deliver benefits to Airlines to push equipage rate (e.g. Best Equipped Best Served concept). It is expected that the methods how to prioritize the flights operated by equipped aircraft in air traffic management will be selected by the Airport/ANSP.

- Contribution of all stakeholders is needed to make decisions aimed at GBAS deployment (Airspace users, Airports, ANSPs, etc). GBAS will be one of the critical components for future airspace development taking the GLS CAT II as first step in transition to replace ILS with GBAS. Operational advantage such as earlier start of approach or reduced delays, diversions and cancellation can bring clear fuel and CO2 benefits if operational advantage of new satellite technologies is leveraged. Airport capacity increase is dependent on GBAS equipage rate. Another means could bring not only capacity increase but environmental impact reduction as well, could be incentive program such as the on at Frankfurt airport that supports the equipage of aircraft with GBAS technology.

A.5.2 Recommendations on regulation and standardisation initiatives

Regarding to operation approval, project recommends staying on track with EASA AWO NPA regulation (NPA 2018-06) timeline and prevent unnecessary delays, so it is ensured that regulatory baseline for GLS AWO operation is fixed for all operators which would helped progress on operation approval side.

With respect to international coordination, **International GBAS Working Group – CAT II Sub-group was created during AAL2.**

At I-GWG/20 it was decided to create a subgroup with the objective to publish the present issue paper, submit it to the relevant authorities with the objective that industry has a need, a plan and the willingness to implement the CAT II operation as there are clear business benefits. It was clarified that while autoland is a prerequisite for CAT II in the current operational concept. I-GWG would try to act as catalyst and a subgroup was formed to progress activities between meetings.

Recommendation for ICAO/Regulators was to deliver appropriate framework to allow quick progress in GLS CAT II operations using GAST-C station.