VERY LARGE-SCALE DEMONSTRATION

SESAR VLD1-W2 DREAMS Demo Report

Deliverable ID:	D1.4
Dissemination Level:	PU
Project Acronym:	DREAMS
Grant:	874469
Call:	H2020-SESAR-2019-1
Topic:	SESAR-IR-VLD-WAVE2-14-2019 VLD.01 W2 GBAS/SBAS precision approaches including variable approach path
Consortium Coordinator:	INDRA
Edition Date:	29 December 2022
Edition:	00.01.03
Template Edition:	02.00.06

Founding Members

EUROPEAN UNION EUROCONTROL

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HONEYWELL	04/11/2022
INDRA	04/11/2022
NLR	04/11/2022

Rejected By - Representatives of beneficiaries involved in the project

Beneficiary	Date

Document History

Edition	Date	Status	Beneficiary	Justification
00.00.01	30/11/2021	Draft	DBL (ENAV LTP)	Initial Draft
00.00.02	09/05/2022	Draft	DBL (ENAV LTP)	Intermediate Version
00.00.03	09/05/2022	Draft	DBL (ENAV LTP)	Intermediate Version integrating contributions from HON; DAV; NLR; DLR; DFS
00.00.04	14/06/2022	Draft	DBL (ENAV LTP)	Intermediate version internal review comments' integration
00.00.05	19/07/2022	Draft	DBL (ENAV LTP)	Intermediate version Including Honeywell Input to EXE3 Report, EXE4 Report, Appendix E, G and initial draft of section 4, 5 and 6. Integration of previous version SJU comments. Removal of Ciampino questionnaires
00.00.06	02/08/2022	Draft	DBL (ENAV LTP)	D1.4.030 version SJU and internal review comments' integration
00.00.07	19/10/2022	Draft	DBL (ENAV LTP)	Integration of EXE2 report and EXE1 noise results
00.01.00	02/11/2022	Final	DBL (ENAV LTP)	Integration of Project members' comments

				Final Version for formal approval
00.01.01	07/11/2022	Final	DBL (ENAV LTP)	Final Version approved for the submission to SJU
00.01.02	09/12/2022	Final	DBL (ENAV LTP)	Integration of SJU final comments
00.01.03	29/12/2022	Final	DBL (ENAV LTP)	Integration of SJU final comments

DREAMS

VLD1 WAVE 2 DEMONSTRATION OF RUNWAY ENHANCED APPROACHES MADE WITH SATELLITE

This DEMOR Part I is part of a project that has received funding from the SESAR3 Joint Undertaking under grant agreement No 874469 under European Union's Horizon 2020 research and innovation programme.

Abstract

The SESAR 2020 Very Large Demonstrator (VLD) VLD.01-W2 DREAMS (DEMONSTRATION OF RUNWAY ENHANCED APPROACHES MADE WITH SATELLITE) project encompasses three SESAR operational solutions enhancing the approach procedure operations to reduce noise and possibly wake turbulence separations: Increased Second Glide Slope (ISGS), Second Runway Aiming Point (SRAP), Increased Glide Slope to Second Runway Aiming Point (IGS-to-SRAP) supported by ground and space-based augmentation systems (GBAS & SBAS).

This document collects the results and the conclusions of the demonstration exercises at Twente, Frankfurt and Rome Ciampino airports conducted to bring enhanced approach procedure operations to the next maturity stage (V4) through a proof of concept (PoC) with flight trials, tests and preparations for the necessary changes in standardisation and regulations.

Main conclusions of the project are:

- SRAP and IGS-to-SRAP
    - Noise benefits were clearly identified as aiming for a SRAP threshold further down the runway displaces the ground noise impact area towards the airport and away from inhabitants and makes the aircraft noise benefit from the altitude difference. Furthermore IGS-to-SRAP procedure increases the aircraft noise benefit by increasing the altitude difference.
    - (IGS-to-)SRAP approaches can be safely and confidently performed without any difficulties; the procedures are straightforward and well within the capabilities of any current crew, maintaining crew coordination and workload within acceptable limits.
- ISGS

- No differences have been observed between 3.2° ISGS and 3.0° standard approaches.
- Clear noise benefits have been measured for approach angles at 3.9° and 4.5°. The ISGS procedures provide positive relative noise scale results:
  - for the 3.9° approach path : up to 4dBA on the first part of the final approach (depending on the moment where the landing configuration is extended) and 1 dBA when the aircraft is stabilized in the approach configuration
  - for the 4.4° approach path : up to 4dBA on the first part of the final approach and 3dBA when the aircraft is stabilized in the approach configuration
- No degradation of human performance and safety level was observed with workload and situational awareness remaining within acceptable limits.

The SRAP, the IGS to SRAP and ISGS approach procedures are not considered fully matured at TRL7 as no ATC assessments have been conducted in the scope of DREAMS, even if from an airborne point of view they are considered more mature considering the project results.

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1 Executive summary

The SESAR 2020 Very Large Demonstrator (VLD) VLD.01-W2 DREAMS (DEMONSTRATION OF RUNWAY ENHANCED APPROACHES MADE WITH SATELLITE) project encompasses three SESAR operational solutions enhancing the approach procedure operations to reduce noise and possibly wake turbulence separations: Increased Second Glide Slope (ISGS), Second Runway Aiming Point (SRAP), Increased Glide Slope to Second Runway Aiming Point (IGS-to-SRAP) supported by ground and satellite-based augmentation systems (GBAS & SBAS).

This document collects the results and the conclusions of the demonstration exercises conducted to bring enhanced approach procedure operations to the next maturity stage (V4) through a proof of concept (PoC) with flight trials, tests and preparations for the necessary changes in standardisation and regulations.

The demonstration exercise took place at:

- Twente to demonstrate SRAP, IGS to SRAP and ISGS
- Frankfurt to demonstrate ISGS
- Rome Ciampino to demonstrate ISGS

The objectives of the demonstration demonstrated the human performance and safety feasibility from a flight crew perspective and the noise benefits of the enhanced approach procedures above mentioned.

ATC perspective has not been addressed for Twente (SRAP, IGS to SRAP and ISGS) and there are some limitations for ATC assessment of Ciampino demonstrations (ISGS).

Main conclusions of the project are:

- SRAP and IGS-to-SRAP
    - Noise benefits were clearly identified as aiming for a SRAP threshold further down the runway displaces the ground noise impact area towards the airport and away from inhabitants and makes the aircraft noise benefit from the altitude difference. Furthermore IGS-to-SRAP procedure increases the aircraft noise benefit by increasing the altitude difference.
    - (IGS-to-)SRAP approaches can be safely and confidently performed without any difficulties; the procedures are straightforward and well within the capabilities of any current crew, maintaining crew coordination and workload within acceptable limits.
    - (IGS-to-)SRAP runway markings and PAPI are sufficiently distinguishable from existing markings and PAPI, and do not negatively impact approaches to the conventional runway. The steeper the IGS-to-SRAP approach, the better the runways can be distinguished.

  - Inclusion of "first/second runway" in the landing clearance is acceptable, whereas the choice of runway designator remains subject of personal preference: some subjects prefer e.g., "05A/B" over "05/06".

- ISGS

  - No differences have been observed between 3.2° ISGS and 3.0° standard approaches.

  - Clear noise benefits have been measured for approach angles at 3.9° and 4.5°. The ISGS procedures provide positive relative noise scale results:

    - for the 3.9° approach path : up to 4dBA on the first part of the final approach (depending on the moment where the landing configuration is extended) and 1 dBA when the aircraft is stabilized in the approach configuration
    - for the 4.4° approach path : up to 4dBA on the first part of the final approach and 3dBA when the aircraft is stabilized in the approach configuration

  - No degradation of human performance and safety level was observed with workload and situational awareness remaining within acceptable limits.

  - For airborne part, approaches up to 4.49° are already allowed by the current airworthiness regulation and constitute standard operations for some types of aircraft. Therefore, no evolution in the airworthiness regulation is needed (including no energy management assistance or flare assistance are required for ISGS, still bringing the benefits).).

  - For ATC part, it was not possible to assess the ISGS solution with approach angles above 3.2° for the limitations mentioned in section 4.3 (No ATC at Twente and limitations due to local ATC environment for Ciampino airport).

  - Specific attention might be required for Energy Management and Aircraft configuration for big size aircraft, however even bigger aircraft and flight crew are capable to manage the energy during ISGS procedures effectively.

  - No issues were raised in relation to the employed phraseology during the live trials from a flight crew perspective.
  - For energy balance: The evaluation of energy envelopes and the variation of influencing parameters revealed in general a great dependency of the ability of aircraft to fly approaches with increased glideslope angles in an energy-efficient manner. Main influencing parameters are the aircraft gross weight and wind conditions but also the intercept altitude showed a significant influence. It was shown that the maximum glideslope angle, with which energy-efficient approaches are still feasible, differs significantly between aircraft types, depending on the specific flight performance of the respective aircraft type.

Despite the very positive results, some recommendations have been recorded in the context of the demonstration exercises.

- SRAP and IGS to SRAP

- Further demonstration activities are recommended to assess the ATC impact and demonstrate the HP and SAFETY feasibility of the proposed solutions before the deployment
- The light intensity of the transportable SRAP PAPI turned out to be less than the conventional fixed PAPI. The SRAP PAPI became visible at 7-8 Nm out on the straight-in approach (5 Nm for bright sunshine conditions). For testing purposes this is acceptable (i.e., it does not influence the ratings) as observed by NLR test pilots during the check-out flights. However, when implementing such solutions in daily operations, it is highly recommended to have both PAPI's operating at equal brightness.
- In case the (IGS-to-)SRAP procedures are to be performed in worse weather conditions than the VMC encountered during the tests, the use of (some kind of) SRAP approach lights is recommended.
- For approaches to runways with conventional and (IGS-to-)SRAP procedures, it may be good for the mindset to include the runway designation also in the 500 ft call.
- Small changes/additions to the approach briefing and crosschecks to verify the correct runway end will need to be incorporated in the SOPs.
- 4.0 and 4.49 degree IGS-to-SRAP approaches, although within normal approach design criteria for the Citation and demonstrated by the Citation in Exercise 01, may require careful energy management for larger aircraft.
- For a good mental picture, it may be helpful to include "lower/higher glide" in traffic info messages.
- In (IGS-to-)SRAP charts it may be even more clear when using "2nd Threshold" in the header.

- ISGS
  - In follow-up projects on this matter, the additional PAPI should be totally comparable with the existing, fixed PAPI, in terms of intensity and power supply (use of batteries is not recommended).
  - The ISGS procedures with two active PAPI's should also be checked in IMC and poor light/visibility conditions. More specific example for further investigation: becoming visual at low altitude in IMC approach with deviation (above/below) from correct glide path. This may lead to confusion.
  - During ISGS approaches with two active PAPI's, no last-minute changes (e.g., by ATC) should be made.
  - Consider the use of two totally different colours for the ISGS PAPI (e.g., magenta-green) so that it even better shows that the ISGS PAPI is totally different.
  - An awareness call on which PAPI to use during approach may be helpful.
  - Moreover, as the deceleration capability is reduced on a steeper flight path, the risk of an unstable approach increases if the pilot is required to maintain a speed greater than the required landing speed down to a too low height. Therefore, airport speed requirements such as « Maintain 160kt until 4 NM » are not recommended when using an ISGS procedure.

- Specific assessment is recommended on the local test environment before deploying ISGS: a local safety and human performance assessment is recommended to assess possible safety and human performance (airborne and ground) issues dependent on the characteristics of the operational environment.

The SRAP, the IGS to SRAP and ISGS approach procedures are not considered fully matured at TRL7 as no ATC assessments have been conducted in the scope of DREAMS, even if from an airborne point of view they are considered more mature considering the project results.

2 Introduction[1]

2.1 Purpose of the document

This DEMO Report Part I document is part of the DEMO Report for VLD01 project.

DEMO Report Part I provides the demonstration results collected to address the validation objectives and success criteria established by the project. It includes a description of the demonstration approach and context as well as the demonstration scenarios and exercises.

It is complemented by the following documents:

- VLD01-W2 DEMOP Part II Safety Assessment Report
- VLD01-W2 DEMOP Part III Human Performance Assessment Report
- VLD01-W2 DEMOP Part IV Environment Assessment Report
- VLD01-W2 DEMOP Part V Performance Assessment Report

2.2 Scope

This DEMO Report Part I document describes the conducted exercises, providing the detailed demonstration reports and the project collective results, conclusions and recommendations, including:

- VLD1-EXE-001 SRAP & IGS-to-SRAP Twente Demonstration
- VLD1-EXE-002 ISGS Frankfurt Demonstration
- VLD1-EXE-003 ISGS Ciampino Demonstration
- VLD1-EXE-004 ISGS Twente Demonstration

2.3 Intended readership

[1] The opinions expressed herein reflect the author's view only. Under no circumstances shall the SESAR Joint Undertaking be responsible for any use that may be made of the information contained herein

The intended audience for this document is primarily all the partners involved in SESAR 2020 VLD01, but may be of interest as well to the following stakeholders:

- PJ.02-W2-14.2, PJ.02-W2-14.3 and PJ.02-W2-14.5 solutions
- PJ.14-W2-79a solution
- ANS providers
- ATM infrastructure and equipment suppliers
- Airspace users
- Aircraft Manufacturer
- Airport owners/providers
- Affected NSA
- Standardisation and Regulatory Authorities (EASA, Affected NSA…)
- Affected employee unions.

2.4 Background

This document builds on the work performed in SESAR 1 and in SESAR 2020 W1:

- SESAR 1 P06.08.08 – Enhanced Arrival Procedures Enabled by GBAS
    - D07 - Enhanced Arrival Procedures Enabled by GBAS – OSED Consolidation Ed .00.01.01
    - D17 - Enhanced Arrival Procedure Enabled by GBAS – VALR – V2 Last iteration Ed .00.01.01
    - D11 - Enhanced Arrival Procedures Enabled by GBAS - VALR - Last iteration Ed .00.01.01
- SESAR 2020 W1 PJ02-02
    - D2.1.01 - PJ02-02 OSED-SPR-Interop Part I - Ed. 00.01.00
    - D2.1.01 - PJ02-02 TS - Ed. 00.01.00
    - D2.1.04 - SESAR PJ02-02 VALR - Ed. 00.01.00.

The results of VLD01 activities have been used by the solutions PJ.02-W2-14.2, 14.3 and 14.5 to update the OSED-SPR/Interop and TS documents as necessary. .

2.5 Structure of the document

This DEMOR is compose of:

- Part I providing :
    - Project results in section 4, 5 and 6
    - Detailed demonstration reports in Appendix A to D
    - Standardisation and Regulatory evolution needs in Appendix E

- Final HONEYWELL Flight Simulation Session for Energy Management Report in Appendix F
- DFS Fast Time Simulation report on Frankfurt airport in Appendix G

2.6 Glossary of terms

Term	Definition	Source of the definition
ISGS	Increased Second Glide Slope	SESAR PJ.02-W2-14.3 Solution
SRAP	Second Runway Aiming Point	SESAR PJ.02-W2-14.2 Solution
ISG-to-SRAP	Increased Glide Slope to Second Runway Aiming Point	SESAR PJ.02-W2-14.5 Solution

Table 1: Glossary of terms

2.7 List of Acronyms

Acronym	Definition
ATM	**Air Traffic Management**
CONOPS	**Concept of Operations**
CR	**Change Request**
DEMOP	**Demonstration Plan**
DEMOR	**Demonstration Report**
DREAMS	**Demonstration Of Runway Enhanced Approaches Made with Satellite**
EAP	**Enhanced Approach Procedures**
EATMA	**European ATM Architecture**
E-ATMS	**European Air Traffic Management System**
FC	**Flight Crews**
HPAR	**Human Performance Assessment Report**
HUD	**HEAD UP DISPLAY**
GBAS	**Ground Based Augmentation System**

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GAST-C	GBAS (Ground Based Augmentation System) Approach Service Type (aircraft) C
GAST-D	GBAS (Ground Based Augmentation System) Approach Service Type (aircraft) D
IGS-to-SRAP	Increased Glide Slope to a Second Runway Aiming Point
INTEROP	Interoperability Requirements
ISGS	Increased Second Glide Slope
KPA	Key Performance Area
LDA	Landing Distance Available
LG	Landing Gear
Lmax	Maximum A-Weighted Sound Level
MLW	Max Landing Weight
PAPI	Precision Approach Path Indicators
OI	Operational Improvement
OPAR	Operational Performance Assessment Report
OSED	Operational Service and Environment Definition
PAR	Performance Assessment Report
PAPI	Precision Approach Path Indicator
PAQ	Post Approach Questionnaire
PEQ	Post Experiment Questionnaire
PRQ	Post Run Questionnaire
PIRM	Programme Information Reference Model
QoS	Quality of Service
RAIM	Receiver Autonomous Integrity Monitoring
SAC	Safety Criteria
SAR	Safety Assessment Report

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SBAS	**Satellite Based Augmentation System**
SecAR	**Security Assessment Report**
SESAR	**Single European Sky ATM Research Programme**
SF2	**Slats/flaps position 2 on Falcon Aircraft**
SF3	**Slats/flaps position 3 on Falcon Aircraft**
SJU	**SESAR Joint Undertaking**
SOP	**Standard Operating Procedures**
SPR	**Safety and Performance Requirements**
SRAP	**Second Runway Aiming Point**
SWIM	**System Wide Information Model**
TS	**Technical Specification**
VFR	**Visual Flight Rules**
VMC	**Visual Meteorological Conditions**

Table 2: List of acronyms

3 Very Large Demonstration (VLD) Scope

3.1 Very Large Demonstration Purpose

The VLD1-W2 DREAMS project focus on the Enhanced Arrival Procedures (EAP) solutions supported by advanced GNSS navigation technologies (GBAS / SBAS), aiming at progressing solution maturity and demonstrating the feasibility in operational environment.
It cover the following EAP:

- steeper operations on a second glideslope, namely Increased Second Glide Slope (ISGS)
- two threshold operations, namely Second Runway Aiming Point (SRAP)
- mix of ISGS and SRAP, Increased Glide Slope to Second Runway Aiming Point (IGS-to- SRAP).

The objectives of the project are:

- Enabling airborne and ground sub-systems to support the implementation and deployment of EAP
- Enabling and improving GNSS deployment around Europe by the introduction of GBAS CAT II/III implementation
- Demonstrating operational feasibility into real environments (providing interoperability with standard operations) and measuring KPIs
- Disseminating and communicating on results and performance benefits of demonstration exercises.

Validation activities have been conducted on several airports, at different geographical locations. The following table offers a summary of the environmental characteristics.

EAP	Airport	Enabler	Aircraft	Type	Number of approaches
ISGS	Ciampino	SBAS RAIM	ENAV P180 FI DAV Falcon 7/8X HNW Embraer 170-100LR	Flight Inspection pilots Test pilots	~62
ISGS	Frankfurt	GBAS GAST-C	Airbus A320 family Boeing B748 (backup) Boeing B777x (backup)	Commercial pilots	~50

SRAP	Twente	GBAS GAST-D (temporary installation)	NLR - Cessna Citation II	Test pilots	07 experiment approaches in total;
IGS-to-SRAP	Twente	GAST-D (temporary installation)	NLR Cessna Citation II	Test pilots	18 SRAP, 22 IGS-to-SRAP 3.5 deg, 23 IGS-to-SRAP 4.0 deg, 19 IGS-to-SRAP 4.49 deg, 25 conventional
ISGS	Twente	SBAS	NLR Cessna Citation II	Test pilots	~150

Table 3: List of VLD1-W2 Activities

3.2 SESAR Solution(s) addressed by VLD

The following tables gives the solutions addressed in DREAMS demonstration activities, together with the list of enablers associated. The required ones are in bold. The table is consistent with DS 21.

SESAR Solution ID and Title	SESAR Solution Description	OI Steps ref. (coming from the EATMA)
PJ.02-W2-14.2 Enhanced Arrival procedures using Second Runway Aiming Point (SRAP)	Enhanced arrival procedures using a Second Runway Aiming Point (SRAP) will allow inbound aircraft reducing noise footprint impact in the surrounding areas of the airport and possibly runway occupancy time and/or taxi-in time, while also allowing potential increased runway capacity (via optimized wake separations). The SRAP concept is a published approach procedure, enabling aircraft to land on a second further runway aiming point (with associated runway ground markers, lights and visual aids).	AO-0319

	The SRAP procedure is designed with a glide slope parallel to the nominal one operated for the first aiming point.	
PJ.02-W2-14.3 Enhanced Arrival procedures using Increased Second Glide Slope (ISGS	Enhanced arrival procedures using Increased Glide Slope (ISGS) will allow inbound aircraft to reduce noise footprint (environmental benefit). ISGS procedures are published approaches which feature a glide slope between the published one (commonly 3 degrees) and 4.49 degrees (limit above which steep approach concept applies).	AO-0320
PJ.02-W2-14.5 Enhanced Arrival procedures using	The Solution introduces the Increased Glide Slope to a Second Runway Aiming Point (IGS-to-SRAP) as a new concept of enhanced	AO-0331

Increased Glide Slope to Second Runway Aiming Point IGS-to-SRAP	approach operation. The distance between the second threshold and the nominal one is at least of 1100m. IGS-to-SRAP increases runway performance by using two active thresholds on a single runway and an increased glide slope to the second one. By doing so, the environmental impact (e.g., noise, fuel) should be reduced. In addition, runway throughput may be increased (e.g., via optimization of ROT and/or wake turbulence separations).	

Table 4: SESAR Solution(s) under Demonstration

The following table gives the solution relevant enablers from W2.PJ02.14-x.
The table is consistent with DS 21.

SESAR SOL	OI	Description	Enabler	Required (R) Or Optional (O)	Covered
PJ.02-W2-14.2	AO-0319	Enhanced arrival procedures using a second runway aiming point (SRAP)	AERODROME-ATC-25 *(REG-0529)*	Optional	
PJ.02-W2-14.2	AO-0319	Enhanced arrival procedures using a second runway aiming point (SRAP)	AERODROME-ATC-102	Required	
PJ.02-W2-14.2	AO-0319	Enhanced arrival procedures using a second runway aiming point (SRAP)	AIRPORT-56 *(STD-112)*	Required	Yes (Runway marking and PAPI)

PJ.02-W2-14.2	AO-0319	Enhanced arrival procedures using a second runway aiming point (SRAP)	APP ATC 115 *(REG-0529)*	Optional	
PJ.02-W2-14.2	AO-0319	Enhanced arrival procedures using a second runway aiming point (SRAP)	APP ATC 170	Required	No
PJ.02-W2-14.2	AO-0319	Enhanced arrival procedures using a second runway aiming point (SRAP)	REG-0529	Required	
PJ.02-W2-14.2	AO-0319	Enhanced arrival procedures using a second runway aiming point (SRAP)	HUM-023	Required	Yes (Twente)
PJ.02-W2-14.2	AO-0319	Enhanced arrival procedures using a second runway aiming point (SRAP)	HUM-031	Required	
PJ.02-W2-14.2	AO-0319	Enhanced arrival procedures using a second runway aiming point (SRAP)	STD-112	Required	
PJ.02-W2-14.3	AO-0320	Enhanced arrival procedures using an increased second glide slope (ISGS)	A/C-86	Optional	Yes (HNW-Ciampino)
PJ.02-W2-14.3	AO-0320	Enhanced arrival procedures using an increased second glide slope (ISGS)	A/C-87	Optional	Yes (HNW-Ciampino)
PJ.02-W2-14.3	AO-0320	Enhanced arrival procedures using an increased second glide slope (ISGS)	AERODROME-ATC-71 *(REG-0530)*	Optional	
PJ.02-W2-14.3	AO-0320	Enhanced arrival procedures using an increased second glide slope (ISGS)	AERODROME-ATC-102	Required	
PJ.02-W2-14.3	AO-0320	Enhanced arrival procedures using an increased second glide slope (ISGS)	APP ATC 114 *(REG-0530)*	Optional	

PJ.02-W2-14.3	AO-0320	Enhanced arrival procedures using an increased second glide slope (ISGS)	AIRPORT-53 *(STD-113)*	Required	Yes (Twente)
PJ.02-W2-14.3	AO-0320	Enhanced arrival procedures using an increased second glide slope (ISGS)	APP ATC 170	Required	
PJ.02-W2-14.3	AO-0320	Enhanced arrival procedures using an increased second glide slope (ISGS)	REG-0530	Required	
PJ.02-W2-14.3	AO-0320	Enhanced arrival procedures using an increased second glide slope (ISGS)	HUM-022	Required	
PJ.02-W2-14.3	AO-0320	Enhanced arrival procedures using an increased second glide slope (ISGS)	HUM-032	Required	
PJ.02-W2-14.3	AO-0320	Enhanced arrival procedures using an increased second glide slope (ISGS)	STD-113	Required	
PJ.02-W2-14.5	AO-0331	Enhanced arrival procedures using an increased glide slope to a second runway aiming point (IGS-to-SRAP)	A/C-86	Optional	
PJ.02-W2-14.5	AO-0331	Enhanced arrival procedures using an increased glide slope to a second runway aiming point (IGS-to-SRAP)	A/C-87	Optional	
PJ.02-W2-14.5	AO-0331	Enhanced arrival procedures using an increased glide slope to a second runway aiming point (IGS-to-SRAP)	AERODROME-ATC-94 *(REG-0533)*	Optional	
PJ.02-W2-14.5	AO-0331	Enhanced arrival procedures using an increased glide slope to a second runway aiming point (IGS-to-SRAP)	AERODROME-ATC-102	Required	

PJ.02-W2-14.5	AO-0331	Enhanced arrival procedures using an increased glide slope to a second runway aiming point (IGS-to-SRAP)	AIRPORT-56 *(STD-112)*	Required	Yes (Runway marking and PAPI)
PJ.02-W2-14.5	AO-0331	Enhanced arrival procedures using an increased glide slope to a second runway aiming point (IGS-to-SRAP)	APP ATC 163 *(REG-0533)*	Optional	
PJ.02-W2-14.5	AO-0331	Enhanced arrival procedures using an increased glide slope to a second runway aiming point (IGS-to-SRAP)	APP ATC 170	Required	
PJ.02-W2-14.5	AO-0331	Enhanced arrival procedures using an increased glide slope to a second runway aiming point (IGS-to-SRAP)	REG-0533	Required	
PJ.02-W2-14.5	AO-0331	Enhanced arrival procedures using an increased glide slope to a second runway aiming point (IGS-to-SRAP)	HUM-024	Required	Yes (Twente)
PJ.02-W2-14.5	AO-0331	Enhanced arrival procedures using an increased glide slope to a second runway aiming point (IGS-to-SRAP)	HUM-033	Required	
PJ.02-W2-14.5	AO-0331	Enhanced arrival procedures using an increased glide slope to a second runway aiming point (IGS-to-SRAP)	STD-112	Required	

Table 5: Enablers under Demonstration

3.2.1 Deviations with respect to the SESAR Solution(s) definition

Deviations for solutions PJ.02-W2-14.2 SRAP and 14.5 ISG-to-SRAP: For these two solutions where two thresholds are active on one runway, PJ02 W1 requirements identify the need to implement runway marking and lighting for the second threshold. As implementing the lighting would be very complex and expensive in the context of a limited trial, the demonstrations took place without it.

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Also, for similar reasons, no specific ATC system support (HMI) and separation delivery tool were available to support the trial. The participating aircraft were also well separated from other traffic due to local applicable separation or segregated from other traffic and no evaluation of the advantage of the optimised wake turbulence minima was possible in order to ensure an acceptable level of safety for the demonstration trial.

3.3 Summary of Demonstration Plan

3.3.1 Demonstration Plan Purpose

The project supports the industrialisations and (pre)deployment of SRAP, ISGS, IGS-to-SRAP through:

- Live Trials performed by aircraft manufacturers and research institute on flight test aircraft where the developed ATM airborne and/or ground based elements are not certified and restricted to flight test only. AUs can be invited to participate.
- Pre-Operational (Proof of Concept) and Operational Trials performed with certified aircraft with flights approval and approach procedure (for restricted use or not), with either non-revenue or revenue flights.

3.3.2 Operating method description

3.3.2.1 SRAP Approach

The use case takes place in the execution phase. It describes how one flight performing an Enhanced Arrival Procedure (EAP) as a Second Runway Aiming Point (SRAP) approach is integrated in a flow of traffic.

The use case starts when the flight enters the approach control area (taking into account that the Flight Deck has performed a "Prepare & Brief Approach" at the end of cruise), and is initiated following a request from Approach Executive Control and ends when the aircraft has landed.

Pre-conditions:

- The ANSP shall inform Airspace Users (e.g. via AIC) about the availability of SRAP procedure with their differences from the local conventional approaches (including applicable separation minima, location of the second aiming point, landing distance available etc.)The need for displaying to the Controllers the interception points respective for each procedure shall be evaluated as part of the local deployment, such that the visual references are operationally relevant and unambiguously presented without e.g. cluttering on the controller air surveillance display.
- ANSPs shall reinforce through a request to Aircraft Operators the need for Flight Plans to be complete and correctly filled with aircraft navigation capabilities.
- A single SRAP procedure type may be supported by different navigation guidance systems and part of or all the SRAP procedures may be active at the same time.
- The SRAP approach chart shall be specific to one final approach path (i.e., touchdown aiming point) and supporting navigation guidance mean. The position and colour of the associated PAPI shall be indicated on the chart.

- SRAP procedures shall be published approach procedures flown based on ILS or GLS or RNP APCH with vertical guidance.
- The SRAP approach chart shall include altitude/distance information for the applicable runway aiming point to facilitate Flight Crew procedure check during the approach.
- When designing the SRAP local procedure and the location of the second threshold and aiming point, the current and future taxiway layout of the aerodrome shall be taken into consideration for facilitating runway vacation.
- When designing the SRAP local procedure, the location of the second runway aiming point shall provide sufficient landing distance available for all eligible aircraft at that specific airport.
- Contingency procedures shall be revised as appropriate to accommodate non-nominal modes or degraded modes of operations like the navigation guidance supporting an active procedure is no longer serviceable or the ATC separation support function is no longer serviceable (e.g., loss of separation distance indicator).
- Approach Supervision shall decide when a published SRAP becomes active/inactive for operations, considering the conditions for application are and remain met:
    1. No operational ATC & weather limitations
    2. Necessary navigation guidance means are serviceable.
- Approach / Tower Supervision shall inform the Approach / Tower Control about the list of active approach procedures.
- Information about a published SRAP being active to a given runway QFU shall be available to Flight deck in order to prepare expected approach briefing (e.g., via ATIS).
- SRAP Approach separation minima shall be specified for each combination of published approach procedure with different glideslopes, taking into account the associated navigation means and corresponding vertical accuracy around the published profile, for
    - Leader and follower on same glideslope
    - Leader upper glide - follower lower glide
    - Leader lower glide - follower upper glide.
- If the Runway Occupancy Time (ROT) is affected by landing on an active further runway aiming point, this ROT spacing shall be taken into account in the runway separation management (ROT might become the most constraining factor due to changes in separation minima).
- For high density operations supported by Separation Delivery Function with TDIs, when SRAP are flown based on RNP APCH navigation, there is a need for flexibility in final approach axis interception (e.g., using vectoring). In such cases, the ANSP shall request on the charts Flight Crew to inform Approach Controller when aircraft is unable to use FMS guidance for final approach axis interception.
- When the second runway threshold is not active (i.e., operating only the conventional threshold), the lightings of the secondary runway threshold and aiming point shall be switched off such as to avoid confusing Flight Deck.

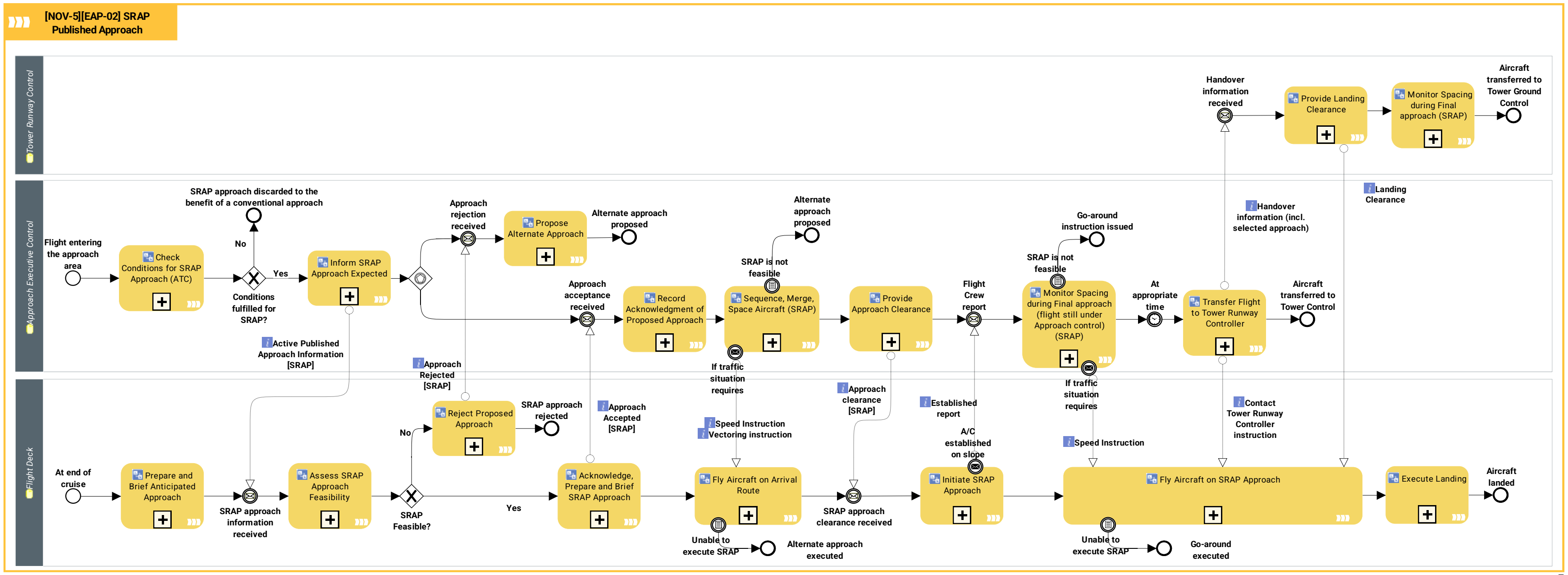

Figure 1: SRAP NOV-5 diagram

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3.3.2.2 ISGS Approach

The use case takes place in the execution phase. It describes how one flight performing a published experimental Enhanced Arrival Procedure (EAP) as an Increased Second Glide Slope (ISGS) approach is integrated in a flow of traffic.

The use case starts when the flight enters the approach control area (taking into account that the Flight Deck has performed a "Prepare & Brief Approach" at the end of cruise), and is initiated following a request from Approach Executive Control and ends when the aircraft has landed.

Pre-conditions:

- The ANSP shall inform Airspace Users (e.g., via AIC) about the availability of IGS procedure with their differences from the local conventional approaches (including applicable separation minima, location of the second aiming point, landing distance available etc.)
- The need for displaying to the Controllers the interception points respective for each procedure shall be evaluated as part of the local deployment, such that the visual references are operationally relevant and unambiguously presented without e.g., cluttering on the controller air surveillance display.
- ANSPs shall reinforce through a request to Aircraft Operators the need for Flight Plans to be complete and correctly filled with aircraft navigation capabilities.
- A single IGS procedure type may be supported by different navigation guidance systems and the same IGS procedure type with different guidance means may be active at the same time.
- The IGS approach chart shall be specific to one final approach path (i.e., angle) and supporting navigation guidance mean, and shall highlight the glide path angle in case it is significantly increased (e.g., more than 3.5°). The position and colour of the associated PAPI shall be indicated on the chart.
- Flight Crew shall be informed about discrepancies from visual aid references when not specifically adapted to increased glideslope procedures.
- IGS shall be published approach procedures flown based on ILS or GLS or RNP APCH with vertical guidance.
- The design of the GLS or RNP (LPV, LNAV-VNAV) procedures supporting IGS shall be compliant with ICAO Doc 8168 and shall be validated in accordance with the Instrument Flight Procedure process specified in ICAO Doc 9906
- Procedure design for IGS operation shall use a glide path angle limited to 4.49°.
- Contingency procedures shall be revised as appropriate to accommodate non-nominal modes or degraded modes of operations like the navigation guidance supporting an active procedure is no longer serviceable or the ATC separation support function is no longer serviceable (e.g., loss of separation distance indicator).

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- Approach Supervision shall decide when a published IGS becomes active/inactive for operations, considering the conditions for application are and remain met:
  1. No operational ATC & weather limitations
  2. Necessary navigation guidance means are serviceable.
- Approach / Tower Supervision shall inform the Approach / Tower Controllers about the list of active approach procedures.
- Information about a published IGS being active to a given runway QFU shall be available to the Flight Deck in order to prepare expected approach briefing (e.g., via ATIS).
- IGS Approach separation minima shall be specified for each combination of published approach procedure with different glideslopes, taking into account the associated navigation means and corresponding vertical accuracy around the published profile, for
  - Leader and follower on same glideslope
  - Leader upper glide - follower lower glide
  - Leader lower glide - follower upper glide

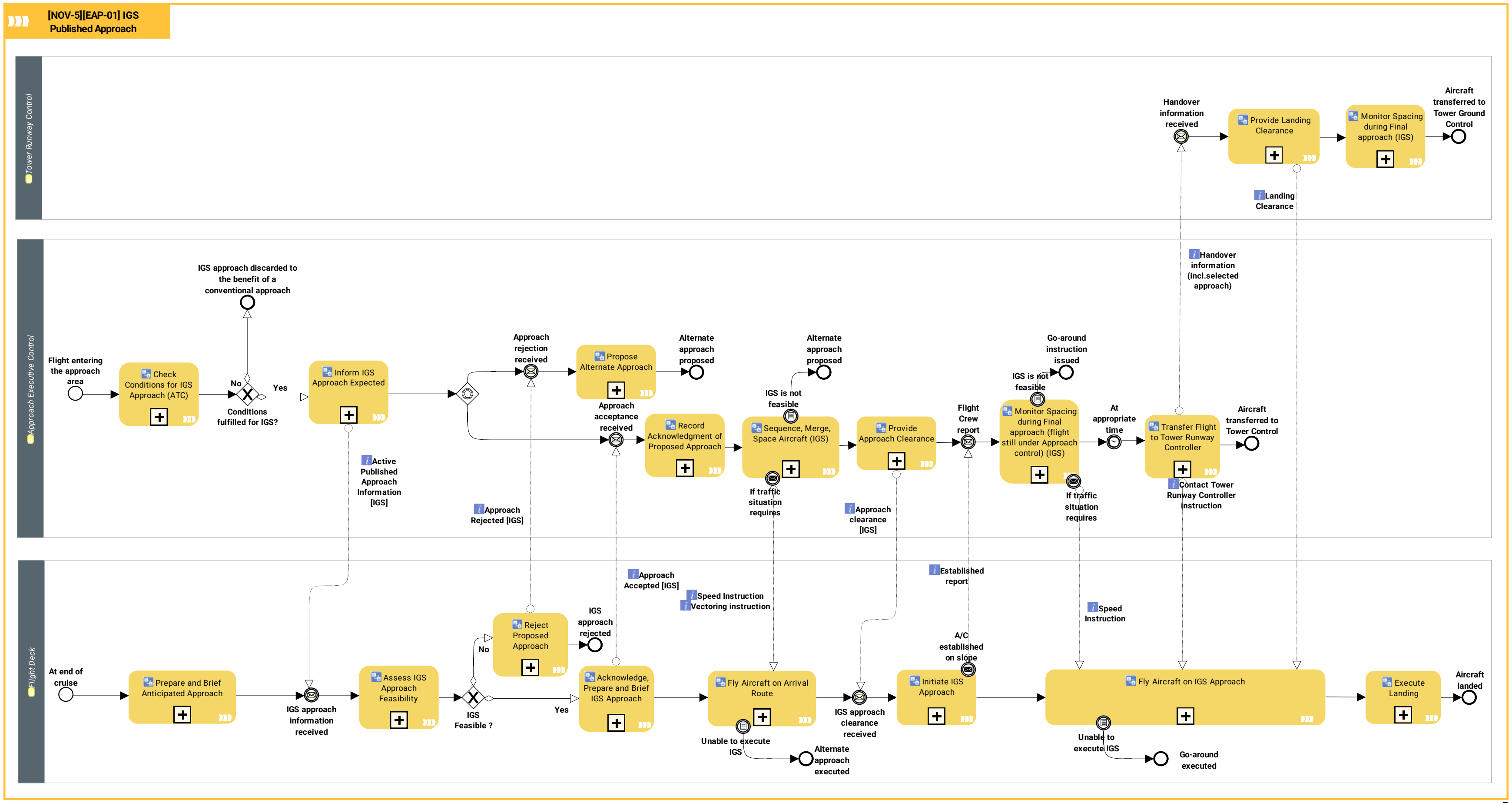

Figure 2: ISGS NOV-5 diagram

Activity	Description
Acknowledge, Prepare and Brief IGS Approach	Upon proposal of an IGS procedure by Approach Executive Control, the Flight Deck acknowledges it and immediately initiates the corresponding briefing to prepare the aircraft to fly the IGS approach procedure, if not anticipated during approach preparation and briefing at the end of cruise.
Assess IGS Approach Feasibility	The Flight Deck assesses the feasibility of the IGS proposed by ATC, i.e.: 1. Aircraft equipment that is necessary for this procedure is available, 2. The proposed published procedure is already available on board, 3. The Flight Deck is able to fly such approach 4. Meteorological conditions do not prevent the execution of such a procedure The feasibility assessment is considered when receiving the expected approach information and then until the final approach is being flown.
Check Conditions for IGS Approach (ATC)	Approach Executive Control determines whether a flight can be given an active IGS published procedure based on: - aircraft declared navigation capabilities (assuming flight crew ability), - relevance of such a procedure for this flight in current traffic context (density, spacing management, etc.)
Execute Landing	The Flight Deck flies the visual segment after DH (if any) and safely executes landing on the runway.
Fly Aircraft on Arrival Route	The Flight Deck follows arrival procedure or ATC instructions towards the final approach.
Fly Aircraft on IGS Approach	The Flight Deck flies and monitors the lateral and vertical approach trajectory until reaching the decision height (DH). If distance/altitude information is provided on the chart, it can be used to perform distance/altitude checks. The Flight Deck continues managing aircraft energy and configuration following SOP to prepare aircraft for landing, while respecting potential ATC speed instructions as long as they are compatible with stabilization criteria. Meanwhile, the Flight Deck contacts Tower Runway Control when instructed to do so in order to receive landing clearance. When visual contact is established with the runway (at or before DH), the Flight Deck needs to properly identify visual references.
Inform IGS Approach Expected	Approach Executive Control initiates the IGS procedure informing the Flight Deck of the expected enhanced arrival approach.
Initiate IGS Approach	Once the IGS approach clearance has been received, the Flight Deck manages aircraft navigation as appropriate to capture the final approach lateral and vertical path.

	The Flight Deck also manages aircraft energy and configuration following SOP, while respecting procedure altitude and speed constraints, or ATC speed instructions if any. Once the aircraft is established on the final approach lateral and vertical path, the Flight Deck reports to ATC.
Monitor Spacing during Final approach (flight still under Approach control) (IGS)	Approach Executive Control monitors the final approach (i.e., aircraft established on the glide slope), especially: 1. the spacing with aircraft ahead, providing speed instructions if traffic situation requires, 2. the adherence to the approach altitude scheme, and 3. compliance to the assigned published final approach profile (i.e., interception of the correct glide and adherence to the glide path). A go-around procedure may be initiated if the conditions for a safe landing are not fulfilled.
Monitor Spacing during Final approach (IGS)	Tower Runway Control monitors the final approach, especially: 1. the spacing with aircraft ahead, and 2. the adherence to the final approach altitude scheme. A go-around procedure may be initiated if the conditions for a safe landing are not fulfilled. Once the aircraft has landed and vacated the runway, Tower Runway Control transfers the flight to Tower Ground Control.
Prepare and Brief Anticipated Approach	The Flight Deck performs the following sub-tasks: 1. obtain weather and landing information for destination and alternate airports 2. check current aircraft approach and landing capabilities against available airport means and weather conditions 3. insert anticipated arrival and approach procedures into the flight plan and check them against published charts 4. insert relevant performance parameters for approach 5. insert landing minimum 6. check/edit relevant performance parameters for go-around 7. check/perform tuning of relevant NAVAIDs 8. perform approach briefing If the airport operates an EAP approach, the Flight Deck also briefs the most likely EAP procedure.
Propose Alternate Approach	After the Flight Deck has rejected the proposed active EAP, Approach Executive Control takes this refusal into account and clears the arrival flight for another active approach.
Provide Approach Clearance	Approach Executive Control issues, at the appropriate time, and records the approach clearance corresponding to the published chart.
Provide Landing Clearance	At the appropriate time, the tower controller provides the landing clearance as well as the wind information.

Record Acknowledgment of Proposed Approach	Once the Flight Deck has accepted the proposed approach, Approach Executive Control records the corresponding arrival approach for this particular flight.
Reject Proposed Approach	Once the proposed approach has been assessed as "not feasible", the Flight Deck rejects it (possibly providing the reason why).
Sequence, Merge, Space Aircraft (IGS)	Approach Executive Control sequences and merges the arrival traffic while respecting all separation and spacing criteria for IGS procedure using speed and vectoring (altitude and heading) instructions whenever needed.
Transfer Flight to Tower Runway Controller	At the appropriate time, Approach Executive Control: 1. hands over and transfers the control of the flight to Tower Runway Control, mentioning the followed published approach chart, and 2. instructs the Flight Deck to contact Tower Runway Control.

3.3.2.3 IGS-to-SRAP Approach

The use case for IGS-to-SRAP combines the two previous uses from ISGS and SRAP.

3.3.3 Summary of Demonstration Objectives and success criteria

The following table summarise the demonstration objectives

Validation Identifier	Name	Primary Text	Category	Success Criterion 1	Success Criterion 2	Success Criterion 3
OBJ-02.02-V3-VALP-SRAP.0401	Reduction of the noise impact around the airports due to SRAP implementation	To confirm that the SRAP concept reduces the noise impact in the airports' surroundings	Performance	Relative noise scale results positive with SRAP use	Noise contours location is shifted to airport area	Average noise value is not increased
OBJ-02.02-V3-VALP-SRAP.0201	SRAP impact on crew task performance	To confirm that the pilot task performance when flying a SRAP approach is not negatively impacted	Human Performance	Pilot succeeds to accomplish a SRAP operation without any difficulty	Impact on crew cooperation and crew workload remains with acceptable limit	
OBJ-14.2-V3-VALP-0301	SRAP impact on phraseology	To confirm that the phraseology used by ATCO and Flight Crew for SRAP is clearly understandable	Human Performance	Controllers accept and judge the proposed phraseology as being appropriate for all encountered operating conditions	Proposed phraseology does not lead to errors related to perception & interpretation of auditory information.	Pilots accept and judge the proposed phraseology as being appropriate for all encountered operating conditions
OBJ-14.2-V3-VALP-0203	SRAP impact on safety crew perspective	To confirm that SRAP does not negatively affect safety from the perspective of the crew	Safety	There is evidence that the level of operational safety is maintained and not negatively impacted under SRAP procedures compared to the reference scenario, from the perspective of the crew	There is evidence that there is no negative impact of SRAP when flying to the conventional / first threshold	

OBJ-14.2-V3-VALP-0204	SRAP operational feasibility from crew perspective	To confirm that the Second Runway Aiming Point (SRAP) is operationally feasible from crew perspective	Operational Feasibility	Pilot succeeds to manage SRAP operation by applying existing SOPs	Pilots are confident when flying a SRAP operation	
OBJ-02.02-V3-VALP-SRAP.0205	SRAP impact on SOPs	To confirm that there is no negative impact of SRAP on existing SOPs	Operational Feasibility	Pilot actions in approach allow to successfully stabilize the aircraft before landing (manage energy,..)	Impact of SRAP approach, existing SOPs are easily manageable by pilots (no impact on task performance)	
OBJ-02.02-V3-VALP-IGS.0401	Reduction of the noise impact around the airports due to IGS implementation	To confirm that the ISGS concept reduces the noise impact in the airport surroundings	Performance	Relative noise scale results positive with ISGS use	Size of noise contours is reduced with ISGS concept	Average noise value is not increased
OBJ-02.02-V3-VALP-IGS.0201	IGS impact on crew task performance	To confirm that the pilot task performance when flying an ISGS approach is not negatively impacted	Human Performance	Pilot succeeds to accomplish an ISGS operation without any difficulty	Impact on crew cooperation and crew workload remains with acceptable limit	
OBJ-02.02-V3-VALP-IGS.0202	ISGS impact on cockpit HMI	To confirm that cockpit HMI is usable and acceptable for ISGS operation	Operational Feasibility	HMI is usable by flight crew	HMI is useful to flight crew	HMI supports the application of the procedure
OBJ-14.3-V3-VALP-ISGS.0203	ISGS impact on safety crew perspective	To confirm ISGS does not negatively affect safety from the perspective of the crew	Safety	There is evidence that the level of operational safety is maintained and not negatively impacted under ISGS procedures compared to the reference scenario from the perspective of the crew	Flight crew initiates the flare at the right moment during ISGS operation in order to prevent hard landing	Stabilization criteria are reached when pilot apply current SOPs

OBJ-14.3-V3-VALP-0204	ISGS operational feasibility from crew perspective	To confirm that the ISGS is operationally feasible from crew perspective	Operational Feasibility	Pilot succeeds to manage ISGS operation by applying existing SOPs	Pilots are confident when flying a ISGS operation	
OBJ-02.02-V3-VALP-IGS.0205	ISGS impact on SOPs	To confirm that there is no negative impact of ISGS on existing SOPs	Operational Feasibility	Pilot actions in approach allow to successfully stabilize the aircraft before landing (manage energy,..)	Impact of ISGS approach, existing SOPs are easily manageable by pilots (no impact on task performance)	
OBJ-02.02-V3-VALP-ITSR.0201	IGS-to-SRAP impact on crew task performance	To confirm that the pilot task performance when flying an IGS-to-SRAP approach is not negatively impacted	Human Performance	Pilot succeeds to accomplish an IGS-to-SRAP operation without any difficulty	Impact on crew cooperation and crew workload remains with acceptable limit	
OBJ-14.5-V3-VALP-0301	IGS-to-SRAP impact on phraseology	To confirm that the phraseology used by ATCO and Flight Crew for IGS-to-SRAP is clearly understandable.	Human Performance	Controllers accept and judge the proposed phraseology as being appropriate for all encountered operating conditions	Proposed phraseology does not lead to errors related to perception & interpretation of auditory information.	Pilots accept and judge the proposed phraseology as being appropriate for all encountered operating conditions
OBJ-14.5-V3-VALP-0203	IGS-to-SRAP impact on safety crew perspective	To confirm that IGS-to-SRAP do not negatively affect safety from the perspective of the crew	Safety	There is evidence that the level of operational safety is maintained and not negatively impacted under IGS-to-SRAP procedures compared to the reference scenario from the perspective of the crew	There is evidence that there is no negative impact of IGS-to-SRAP when flying to the conventional / first threshold	
OBJ-14.5-V3-VALP-0204	IGS-to-SRAP operational feasibility from crew perspective	To confirm that the IGS-to-SRAP is operationally feasible from crew perspective	Operational Feasibility	Pilot succeeds to manage IGS-to-SRAP operation by applying existing SOPs	Pilots are confident when flying an IGS-to-SRAP operation	

OBJ-02.02-V3-VALP-ITSR.0205	IGS-to-SRAP impact on SOPs	To confirm that there is no negative impact of IGS-to-SRAP on existing SOPs	Operational Feasibility	Pilot actions in approach allow to successfully stabilize the aircraft before landing (manage energy,..)	Impact of IGS-to-SRAP approach, existing SOPs are easily manageable by pilots (no impact on task performance)	
OBJ-02.02-V3-VALP-ITSR.0401	To confirm that the IGS-to-SRAP concept reduces the noise impact in the airport surroundings	To confirm that the IGS-to-SRAP concept reduces the noise impact in the airport surroundings	Performance	Relative noise scale results positive with IGS-to-SRAP use	Noise contours location is shifted to airport area	Size of noise contours is reduced with IGS-to-SRAP concept

3.3.4 Demonstration Assumptions

3.3.4 Demonstration Assumptions

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
A1	Subject pilots	OPS	Guest pilots flying in right hand seat in NLR's flight test aircraft most probably have not a Cessna Citation II type rating (from operational point of view this is not required).	Guest pilots fly other type of aircraft on a daily basis	Negligible, as: 1. Pre-flight briefing 2. Familiarization approach(es) 3. Solution scenario ratings is compared to reference scenario ratings

Table 6: Demonstration Assumptions

Refer to Appendixes for the detailed assumptions.

3.3.5 Demonstration Exercises List

[EXE]

Twente

Identifier	EXE-VLD-01-001
Title	Demonstration of pilot acceptability of SRAP and IGS-to-SRAP enhanced approach procedures using GBAS

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Description	Flight tests was executed at Twente Airport (EHTW) in the Netherlands. Enhanced Approach Procedures (EAP) was defined for the single runway at EHTW for SRAP and IGS-to-SRAP operations. Additional, temporal, experimental markings were applied onto the runway to serve as outside visual references to the pilots when flying the EAP. In this context, an additional, temporal, portable PAPI unit was installed at the second aiming point as well. A transportable GBAS ground station from Indra Navia was set up at the airport's premises and was used as source of navigation for the flight tests. The test aircraft was equipped with an Aerodata GBAS receiver as well as with an MMR from Eurocontrol. Latter was not integrated with the aircraft systems and was only used for data acquisition.
Demonstration Technique	Live Trial
KPA/TA Addressed	Safety
Number of approaches	Around 150
Start Date	Sep 29, 2021
End Date	Oct 8, 2021
Demonstration Coordinator	NLR
Demonstration Platform	Twente
Demonstration Location	Twente
Status	<Completed>
Dependencies	No dependencies identified

[EXE Trace]

Linked Element Type	EXE-VLD-01-001
<SESAR Solution>	PJ.02-W2-14.2, PJ.02-W2-14.5

Frankfurt

Identifier	EXE-VLD-01-002
Title	Demonstration of GBAS CAT II approach procedures with IGS feasibility and benefits
Description	Flight demonstration of GBAS CAT II approaches with ISGS using CAT I equipment

Demonstration Technique	Flight Trial
KPA/TA Addressed	Environment – Noise; Human Performance
Number of flights	45
Start Date	Dec 1, 2021
End Date	Sep 30, 2022
Demonstration Coordinator	DFS
Demonstration Platform	Frankfurt
Demonstration Location	Frankfurt
Status	<Completed>
Dependencies	No dependencies identified

[EXE Trace]

Linked Element Type	EXE-VLD-01-002
<SESAR Solution>	PJ.02-W2-14.3

Ciampino

Identifier	EXE-VLD-01-003
Title	ISGS demonstration at Ciampino
Description	This exercise is a Live Flight Trial placed at V4-V5 maturity level. It demonstrated in the real operating environment the potential benefits deriving by the ISGS (Increased Second Glide Slope) concept implementation. The proposed demo configuration for runway 33 is the following one: • LPV approach with GA 3.5° Reference Scenario (single PAPI configuration) • ISGS 3.9° with single PAPI (3 white lamps and 1 red lamp) • ISGS 4.4° without PAPI
Demonstration Technique	Live Trial
KPA/TA Addressed	Noise, Safety, Human Performance

Number of approaches	Around 50
Start Date	Nov 1, 2021
End Date	Mar 31, 2022
Demonstration Coordinator	ENAV
Demonstration Platform	Ciampino
Demonstration Location	Roma Ciampino
Status	<Completed>
Dependencies	No dependencies identified

[EXE Trace]

Linked Element Type	EXE-VLD-01-003
<SESAR Solution>	PJ.02-W2-14.3

Twente

Identifier	EXE-VLD-01-004
Title	ISGS demonstration at Twente
Description	This exercise is a Live Flight Trial placed at V4-V5. It demonstrated in the real operating environment the operational feasibility of ISGS (Increased Second Glide Slope) concept with dual PAPI system. The proposed demo configuration for runway 05 is the following one: • 3.0°deg (SBAS) reference scenario • ISGS 3.5deg (SBAS) (full PAPI configuration) • ISGS 4.0deg (SBAS) (full PAPI configuration) • ISGS 4.49deg° (SBAS) (full PAPI configuration)
At	Live Trial
KPA/TA Addressed	Safety
Number of approaches	Around 100
Start Date	Feb 14, 2022

End Date	Jun 28, 2022
Demonstration Coordinator	NLR
Demonstration Platform	Twente
Demonstration Location	Twente
Status	<Completed>
Dependencies	No dependencies identified

[EXE Trace]

Linked Element Type	EXE-VLD-01-004
<SESAR Solution>	PJ.02-W2-14.3

Table 7: Demonstration Exercise layout

3.4 Deviations

3.4.1 Deviations with respect to the SJU Project Handbook

No deviations

3.4.2 Deviations with respect to the Demonstration Plan

One main positive deviation is the extension of the scope of the DEMOR to include the work conducted by DLR for the energy balance (see Appendix H and Section 5.2) and by HONEYWELL (see Appendix F) to further mature and possibly close the open issue in relation to energy management encountered in Ciampino Flight trial for ISGS procedure and reported in Appendix C.

Detailed deviations for the different demonstration exercises are reported in the detailed demonstration report of each exercise (Appendix A, B, C D).

4 Demonstration Results

4.1 Summary of Demonstration Results

4.1.1 Summary of Demonstration Results – SRAP

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-02.02-V3-VALP-SRAP.0401	Reduction of the noise impact around the airports due to SRAP implementation	CRT-02.02-V3-VALP-SRAP.0401-001	Relative noise scale results positive with SRAP use	Airport - Other	Up to 4dBA under-track LAmax reduction compared to the reference run	OK
		CRT-02.02-V3-VALP-SRAP.0401-002	Noise contours location is shifted to airport area	Airport - Other	Visible acoustic footprint shift towards the airport area and away from inhabitants	OK
		CRT-02.02-V3-VALP-SRAP.0401-003	Average noise value is not increased	Airport - Other	Test run shows a positive under-track noise reduction compared to the reference run	OK

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OBJ-02.02-V3-VALP-SRAP.0201	Impact on crew task performance	CRT-02.02-V3-VALP-SRAP.0201-001	Pilot succeeds to accomplish a SRAP operation without any difficulty under VMC	Airport - Other	See section A.3.2 /1	OK
		CRT-02.02-V3-VALP-SRAP.0201-002	Impact on crew cooperation and crew workload remains within acceptable limit	Airport - Other	See section A.3.2 /1	OK
EX3-OBJ-VLD-01-0203-001	SRAP additional runway markings impact under VMC on SRAP safety from crew perspective	EX3-CRT-VLD-01-0203-001	There is evidence that the additional SRAP runway markings are sufficient to not negatively impact SRAP procedures under VMC compared to the reference scenario, from the perspective of the crew	Airport - Other	See section A.3.2/2	OK
EX3-OBJ-VLD-01-0203-002	SRAP additional PAPI impact under VMC on SRAP safety from crew perspective	EX3-CRT-VLD-01-0203-002	There is evidence that the additional SRAP PAPI is sufficient to not negatively impact SRAP procedures compared to the reference scenario, from the perspective of the crew	Airport - Other	See section A.3.2 /3	OK
EX3-OBJ-VLD-01-0203-003	SRAP additional runway markings impact under VMC on nominal threshold	EX3-CRT-VLD-01-0203-003	There is evidence that the additional SRAP runway markings do not negatively impact	Airport - Other	See section A.3.2 /4	OK

	approach safety from crew perspective		normal approach procedures to nominal threshold compared to the reference scenario, from the perspective of the crew			
EX3-OBJ-VLD-01-0203-004	SRAP additional PAPI impact under VMC on nominal threshold approach safety from crew perspective	EX3-CRT-VLD-01-0203-004	There is evidence that the additional SRAP PAPI does not negatively impact normal approach procedures to nominal threshold compared to the reference scenario, from the perspective of the crew	Airport - Other	See section A.3.2 /5	OK
EX1-OBJ-VLD-01-0203-005	Nominal runway markings and nominal PAPI impact under VMC on SRAP safety from crew perspective	EX3-CRT-VLD-01-0203-005	There is evidence that the nominal runway markings and nominal PAPI are sufficiently distinguishable from SRAP markings and PAPI in order not to result in unacceptable safety from the perspective of the crew	Airport - Other	See section A.3.2/6	OK
OBJ-02.02-V3-VALP-SRAP.0204		CRT-02.02-V3-VALP-SRAP.0204-001	Pilot succeeds to manage SRAP	Airport - Other	See section A.3.2/7	OK

	SRAP operational feasibility under VMC from crew perspective		operation by applying existing SOPs			
		CRT-02.02-V3-VALP-SRAP.0204-002	Pilots are confident when flying a SRAP operation	Airport - Other	See section A.3.2/7	OK
OBJ-02.02-V3-VALP-SRAP.0205	SRAP impact on SOPs	CRT-02.02-V3-VALP-SRAP.0205-001	Pilot actions in SRAP approach allow to successfully stabilize the aircraft before landing (manage energy,..)	Airport - Other	See section A.3.2 /8	OK
		CRT-02.02-V3-VALP-SRAP.0205-002	Impact of SRAP approach, existing SOPs are easily manageable by pilots (no impact on task performance)	Airport - Other	See section A.3.2 /8	OK
OBJ-02.02-V3-VALP-SRAP.0301	SRAP impact on phraseology	CRT-02.02-V3-VALP-SRAP.0301-001	Proposed phraseology does not lead to errors related to perception & interpretation of auditory information	Airport - Other	See section A.3.2 /9- No ATC Assessment, however test subjects are OK (although minor doubt exist on what SRAP runway designator to use)	NOK (no ATC involved at Twente Airport)

		CRT-02.02-V3-VALP-SRAP.0301-002	Pilots accept and judge the proposed phraseology as being appropriate for all encountered operating conditions	Airport - Other	See section A.3.2 /9 ATC communications exchange not assessed; however, test subjects are OK (although minor doubt exist on what SRAP runway designator to use)	NOK (no ATC involved at Twente Airport)

Table 8: SRAP - Summary of Demonstration Exercises Results

4.1.2 Summary of Demonstration Results - ISGS

The following table summarises the results and the status of the validation objectives. For more details, please look at Appendix C and D.

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-02.02-V3-VALP-ISGS.0401	Reduction of the noise impact around the airports due to ISGS implementation	**CRT-02.02-V3-VALP-ISGS.0401-001**	Relative noise scale results positive with ISGS use	High complexity TMA/ Medium and large airports	The ISGS procedures provide positive relative noise scale results: ▪ For 3.2°: up to 4dBA LAmax reduction under-track, but not directly linked to 3.2° glide slope ▪ for the 3.9° approach path : up to 4dBA on the first part of the final approach (depending on the moment where the landing configuration is extended) and 1 dBA when the aircraft is stabilized in the approach configuration ▪ for the 4.4° approach path : up to 4dBA on the first part of the final approach and 3dBA when the aircraft is stabilized in the approach configuration See section Appendix B & C for more details.	Partially OK

		CRT-02.02-V3-VALP-ISGS.0401-002	Size of noise contours is reduced with ISGS concept	High complexity TMA/ Medium and large airports	▪ Below or at 3.2°: Areas inside LAmax contours are similar between 3° and 3.2° ▪ Above 3.2°: The 65 dBA (LA,MAX) noise contour for the reference approach runs (RNAV Z in orange) and the ISGS runs (RNAV Y in blue and RNAV X in green) is considered as representative metric. The size of the noise contour is reduced in average for the flights by 27% for the 3.9° approach and by 44% for the 4.4° approach. See section Appendix C for more details.	Partially OK
		CRT-02.02-V3-VALP-ISGS.0401-003	Average noise value is not increased	High complexity TMA/ Medium and large airports	For 3.2° Under-track LAmax averages for all A319 flights are slightly quieter. See above criteria **CRT-02.02-V3-VALP-ISGS.0401-002 & CRT-02.02-V3-VALP-ISGS.0401-001**	OK
OBJ-02.02-V3-VALP-ISGS.0201	ISGS impact on crew task performance	**CRT-02.02-V3-VALP-ISGS.0201-001**	Pilot succeeds to accomplish an ISGS operation without any difficulty	High complexity TMA/ Medium and large airports	Pilot succeeded to accomplish an ISGS operation without any difficulty as recorded in the demonstration exercises by means of questionnaires and debriefing (See Appendix B, C & D for more details)	OK

		CRT-02.02-V3-VALP-ISGS.0201-002	Impact on crew cooperation and crew workload remains with acceptable limit	High complexity TMA/ Medium and large airports	Impact on crew cooperation and crew workload remained within acceptable limit as recorded in the demonstration exercises by means of questionnaires and debriefing (See Appendix B, C & D for more details)	OK
OBJ-02.02-V3-VALP-ISGS.0202	ISGS impact on cockpit HMI	**CRT-02.02-V3-VALP-ISGS.0202-001**	HMI is usable by flight crew	High complexity TMA/ Medium and large airports	Ciampino demo showed that implementation of Energy Management (EM) tool had usability limits with impact on easy-to-use aspects. Collected flight demo data were used for EM improvements and were further flight-tested within Honeywell final flight test in November. (See appendix C & F for more details)	POK
		CRT-02.02-V3-VALP-ISGS.0202-002	HMI is useful to flight crew	High complexity TMA/ Medium and large airports	Energy Management is useful according to the collected results (see appendix C & F for more details)	OK
		CRT-02.02-V3-VALP-ISGS.0202-003	HMI supports the application of the procedure	High complexity TMA/ Medium and large airports	The effectiveness of the HMI for the ISGS procedure was improved (see appendix F for more details). Modified algorithm and HMI on displays improved the crew awareness about timing of configuration changes when performing ISGS procedures	OK

OBJ-14.3-V3-VALP-ISGS.0203	ISGS impact on safety crew perspective	**CRT-14.3-V3-VALP-ISGS.0203-001**	There is evidence that the level of operational safety is maintained and not negatively impacted under ISGS procedures compared to the reference scenario from the perspective of the crew	High complexity TMA/ Medium and large airports	Subjective and positive feedback about the level of safety for ISGS procedures that was not degraded were collected. (See Appendix B, C & D for more details)	OK
		CRT-14.3-V3-VALP-ISGS.0203-002	Flight crew initiates the flare at the right moment during ISGS operation in order to prevent hard landing	High complexity TMA/ Medium and large airports	Pilot succeeded to manage ISGS operation by applying existing SOPs (See Appendix B, C & D for more details) based on CRT-14.3-V3-VALP-ISGS.0203-001, CRT-14.3-V3-VALP-ISGS.0204-001, CRT-02.02-V3-VALP-ISGS.0201-001 & OBJ-14.3-V3-VALP-ISGS.0204	Ok

		CRT-14.3-V3-VALP-ISGS.0203-003	Stabilization criteria are reached when pilot apply current SOPs	High complexity TMA/ Medium and large airports	Pilot succeeded to manage ISGS operation by applying existing SOPs (See Appendix B, C & D for more details) based on CRT-14.3-V3-VALP-ISGS.0203-001, CRT-14.3-V3-VALP-ISGS.0204-001, CRT-02.02-V3-VALP-ISGS.0201-001 & OBJ-14.3-V3-VALP-ISGS.0204	Ok
OBJ-14.3-V3-VALP-ISGS.0204	ISGS operational feasibility from crew perspective	**CRT-14.3-V3-VALP-ISGS.0204-001**	Pilot succeeds to manage ISGS operation by applying existing SOPs	High complexity TMA/ Medium and large airports	Pilot succeeded to manage ISGS operation by applying existing SOPs (See Appendix B, C & D for more details). There is no need of updating current SOPs, only 1 comment was that the SOP may/should be slightly amended by inclusion of mandatory briefing item.	OK
		CRT-14.3-V3-VALP-ISGS.0204-002	Pilots are confident when flying a ISGS operation	High complexity TMA/ Medium and large airports	Pilots were confident when flying a ISGS operation (See Appendix B, C & D for more details)	OK
OBJ-02.02-V3-VALP-ISGS.0205	ISGS impact on SOPs	**CRT-02.02-V3-VALP-ISGS.0205-001**	Pilot actions in approach allow to successfully stabilize the aircraft before landing (manage energy,..)	High complexity TMA/ Medium and large airports	Pilot succeeded to manage ISGS operation by applying existing SOPs (See Appendix B, C & D for more details) based on CRT-14.3-V3-VALP-ISGS.0204-001	Ok

		CRT-02.02-V3-VALP-ISGS.0205-002	Impact of ISGS approach, existing SOPs are easily manageable by pilots (no impact on task performance)	High complexity TMA/ Medium and large airports	No impact on existing SOPs Pilot succeeded to manage ISGS operation by applying existing SOPs (See Appendix B, C & D for more details) based on CRT-14.3-V3-VALP-ISGS.0204-001. Only 1 comment was that the SOP may/should be slightly amended by inclusion of mandatory briefing item.	Ok

Table 8: ISGS Summary of Demonstration Exercises Results

4.1.3 Summary of Demonstration Results – IGS to SRAP

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-02.02-V3-VALP-ITSR.0401	To confirm that the IGS-to-SRAP concept reduces the noise impact in the airport surroundings	CRT-02.02-V3-VALP-ITSR.0401-001	Relative noise scale results positive with IGS-to-SRAP use	Airport - Other	Up to 5dBA under-track LAmax reduction compared to the reference run	OK
		CRT-02.02-V3-VALP-ITSR.0401-002	Noise contours location is shifted to airport area	Airport - Other	Visible acoustic footprint shift towards the airport area and away from inhabitants	OK
		CRT-02.02-V3-VALP-ITSR.0401-003	Size of noise contours is reduced with IGS-to-SRAP concept	Airport - Other	Reduction of 29% for 70dBA LAmax and 72% for 75dBA LAmax iso-noise contour	OK
		CRT-02.02-V3-VALP-	Average noise value is not increased	Airport - Other	Test run shows a positive under-track noise	OK

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		ITSR.0401-004			reduction and footprint reduction compared to the reference run	
EX3-OBJ-VLD-01-0201-001	3.5 deg IGS-to-SRAP impact under VMC on crew task performance	EX3-CRT-VLD-01-0201-001-01	Pilot succeeds to accomplish a 3.5 deg IGS-to-SRAP operation without any difficulty	Airport - Other	See section See section A.3.2 /10	OK
		EX3-CRT-VLD-01-0201-001-02	Impact on crew cooperation and crew workload for 3.5 deg IGS-to-SRAP operation remains within acceptable limit	Airport - Other	See section A.3.2/10	OK
EX3-OBJ-VLD-01-0201-002	4.0 deg IGS-to-SRAP impact under VMC on crew task performance	EX3-CRT-VLD-01-0201-002-01	Pilot succeeds to accomplish a 4.0 deg IGS-to-SRAP operation without any difficulty	Airport - Other	See section A.3.2 /11	OK
		EX3-CRT-VLD-01-0201-002-02	Impact on crew cooperation and crew workload for 4.0 deg IGS-to-SRAP operation remains within acceptable limit	Airport - Other	See section A.3.2 /11	OK
EX3-OBJ-VLD-01-0201-003	4.49 deg IGS-to-SRAP impact under VMC on crew task performance	EX3-CRT-VLD-01-0201-003-01	Pilot succeeds to accomplish a 4.49 deg IGS-to-SRAP operation without any difficulty	Airport - Other	See section A.3.2/12	OK
		EX3-CRT-VLD-01-0201-003-02	Impact on crew cooperation and crew workload for 4.49 deg IGS-to-SRAP operation remains within acceptable limit	Airport - Other	See section A.3.2/12	OK
EX3-OBJ-VLD-01-0203-001	SRAP additional runway markings impact under VMC on	EX3-CRT-VLD-01-0203-001	There is evidence that the additional SRAP runway markings are sufficient to not	Airport - Other	See section A.3.2/13	OK

	IGS-to-SRAP safety from crew perspective		negatively impact IGS-to-SRAP procedures compared to the reference scenario, from the perspective of the crew			
EX3-OBJ-VLD-01-0203-002	IGS-to-SRAP additional PAPI impact under VMC on IGS-to-SRAP safety from crew perspective	EX3-CRT-VLD-01-0203-002	There is evidence that the additional IGS-to-SRAP PAPI is sufficient to not negatively impact IGS-to-SRAP procedures compared to the reference scenario, from the perspective of the crew	Airport - Other	See section A.3.2/14	OK
EX3-OBJ-VLD-01-0203-003	Nominal runway markings and nominal PAPI impact under VMC on IGS-to-SRAP safety from crew perspective	EX3-CRT-VLD-01-0203-003	There is evidence that the nominal runway markings and nominal PAPI are sufficiently distinguishable from SRAP markings and PAPI in order not to result in unacceptable safety from the perspective of the crew	Airport - Other	See section A.3.2/15	OK
OBJ-02.02-V3-VALP-ITSR.0204	IGS-to-SRAP operational feasibility under VMC from crew	CRT-02.02-V3-VALP-ITSR.0204-001	Pilot succeeds to manage IGS-to-SRAP operation by applying existing SOPs	Airport - Other	See section A.3.2/16	OK
		CRT-02.02-V3-VALP-ITSR.0204-002	Pilots are confident when flying an IGS-to-SRAP operation	Airport - Other	See section A.3.2/16	OK
OBJ-02.02-V3-VALP-ITSR.0205	IGS-to-SRAP impact under VMC on SOPs	CRT-02.02-V3-VALP-ITSR.0205-001	Pilot actions in IGS-to-SRAP approach allow to successfully stabilize the aircraft before landing (manage energy,..)	Airport - Other	See section A.3.2/17	OK

		CRT-02.02-V3-VALP-ITSR.0205-002	Impact of IGS-to-SRAP approach, existing SOPs are easily manageable by pilots (no impact on task performance)	Airport - Other	See section A.3.2/17	OK
OBJ-02.02-V3-VALP-ITSR.0301	IGS-to-SRAP impact on phraseology	CRT-02.02-V3-VALP-ITSR.0301-001	Proposed phraseology does not lead to errors related to perception & interpretation of auditory information	Airport - Other	See section A.3.2/18 ATC not assessed; however, test subjects are OK (although minor doubt exist on what SRAP runway designator to use)	NOK (no ATC involved at Twente Airport)
		CRT-02.02-V3-VALP-ITSR.0301-002	Pilots accept and judge the proposed phraseology as being appropriate for all encountered operating conditions	Airport - Other	See section A.3.2/18 ATC communications exchange not assessed; however, test subjects are OK (although minor doubt exist on what SRAP runway designator to use)	NOK (no ATC involved at Twente Airport)

Table 9: IGS to SRAP Summary of Demonstration Exercises Results

4.2 Detailed analysis of Demonstration Results per Demonstration objective

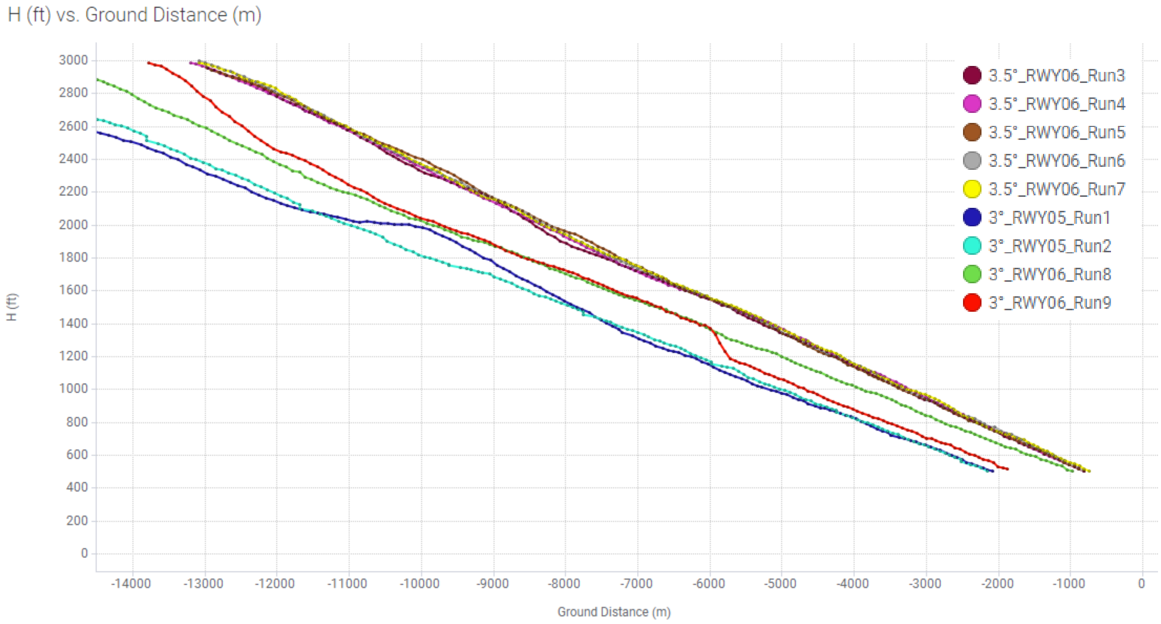
4.2.1 Detailed analysis of Demonstration Results per Demonstration objective – SRAP

Results provided in the following sections apart for the noise results, are based on PRQ and PEQ indicated in section A.3.2.1.

4.2.1.1 OBJ-02.02-V3-VALP-SRAP.0401

The objective of demonstrating the SRAP interest for noise reduction has been addressed through under-track and noise contour analysis of recorded flight data from the trials performed on 6th October 2021 by Lufthansa and coordinated by NLR on Twente airport (EHTW).

During the flight tests, for each landing, the aircraft did not arrive at touchdown and the pilots performed a go-around to follow the 9 landing procedures in a row. Thus, to focus on the landing procedure only, recorded data has been truncated up to the start of the descent and down to 500ft of altitude for each run.



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CRT-02.02-V3-VALP-SRAP.0401-001 : Relative noise scale results positive with SRAP use.

Run2 (3°; RWY 05; Reference) and Run8 (3°; RWY 06) are considered for SRAP noise impact assessment.

Run8 represents the SRAP approach with a glide slope of 3° onto Runway 06, while Run2 represents the reference approach with a glide slope of 3° onto Runway 05.

Noise scale results are positive :

The SRAP landing induces a noise reduction under-track all along the trajectory, up to 4dBA.

Criterion CRT-02.02-V3-VALP-SRAP.0401-001 is reached.

CRT-02.02-V3-VALP-SRAP.0401-002 : Noise contours location is shifted to airport area.

The 70dBA LAmax and 75dBA LAmax iso-contours are both shifted towards the airport area and away from the inhabited neighbourhoods compared to the reference iso-contours. Twente Airport is mostly surrounded by forests, which might not best underline the SRAP advantage but the method can be extrapolated to any other airport which may be situated closer to populated neighbourhoods.

A population count could illustrate better the advantage obtained thanks to the SRAP method.

Criterion CRT-02.02-V3-VALP-SRAP.0401-002 is reached.

CRT-02.02-V3-VALP-SRAP.0401-003 : Average noise value is not increased.

The number of flights was not sufficient to perform a statistical analysis and conclude on an average noise gain. However, this criterion can be addressed through contour and under-track noise level analysis.

Objectively, the SRAP method mainly brings the advantage of displacing the noise impact area rather than reducing it.

Nonetheless, the under-track LAmax simulations allow us to determine that the SRAP fulfils the objective, as the noise reduction is positive for the whole track, because of the induced displacement.

Criterion CRT-02.02-V3-VALP-SRAP.0401-003 is reached.

4.2.1.2 OBJ-02.02-V3-VALP-SRAP.0201 Results

This objective concerns the impact on crew task performance. Two criteria have been defined:

- Criteria 1 - CRT-02.02-V3-VALP-SRAP.0201-001
  Pilot succeeds to accomplish a SRAP operation without any difficulty under VMC

PRQ results for FLT 1 / RUN 3, 5, 6, 8					
Test Subject	Q1 (PAPI) Average	Q2 (markings) Average	Q3 (safety) Average	Q4 (workload) Average	Q5 (confusion) Average
A	4.3	6.0	6.0	5.8	5.8
B	4.5	4.8	4.8	4.3	4.3

C	5.5	6.0	6.0	6.0	6.0
E	6.0	5.5	6.0	6.0	6.0
F	6.0	6.0	6.0	6.0	6.0
G	6.0	5.0	5.0	5.5	6.0
Overall average	5.4	5.5	5.6	5.6	5.7

PEQ results						
Test Subject	Q3	Q7	Q8	Q20	Q21	Q22
A	5	6	6	5	5	6
B	4	4	5	3	3	3
C	6	6	6	3	6	6
E	5	6	5	5	6	4
F	6	6	6	6	6	6
G	5	5	5	6	6	--
Average	5.2	5.5	5.5	4.7	5.3	5.0

Criteria 1 is passed as the average scores for all questions are well above 3.5.

- Criteria 2 - CRT-02.02-V3-VALP-SRAP.0201-002
  Impact on crew cooperation and crew workload remains within acceptable limit

PRQ results for FLT 1 / RUN 3, 5, 6, 8	
Test Subject	Q4 (workload) Average
A	5.8
B	4.3
C	6.0
E	6.0

F	6.0
G	5.5
Overall average	5.6

Criteria 2 is passed as the average scores for all questions are well above 3.5.

4.2.1.3 EX3-OBJ-VLD-01-0203-001 Results

This objective concerns the impact of SRAP additional runway markings under VMC on SRAP safety from crew perspective. One criteria has been defined:

Criteria 3 - EX3-CRT-VLD-01-0203-001
There is evidence that the additional SRAP runway markings are sufficient to not negatively impact SRAP procedures under VMC compared to the reference scenario, from the perspective of the crew.

PRQ results for FLT 1 / RUN 3, 5, 6, 8			vs.	PRQ results for FLT1 / RUN 2	
Test Subject	Q2 (markings) Average	Q5 (confusion) Average		Q2 (markings)	Q5 (confusion)
A	6.0	5.8		5	6
B	4.8	4.3		4	4
C	6.0	6.0		6	6
E	5.5	6.0		6	6
F	6.0	6.0		6	6
G	5.0	6.0		--	--
Overall average	5.5	5.7		5.4	5.6

PEQ results		
Test Subject	Q2	Q22
A	5	6
B	5	3
C	6	6
E	5	4
F	6	6
G	5	--
Average	5.3	5.0

Criteria 3 is passed as the average scores for all questions are well above 3.5.

4.2.1.4 EX3-OBJ-VLD-01-0203-002 Results

This objective concerns the impact of SRAP additional PAPI under VMC on SRAP safety from crew perspective. One criteria has been defined:

Criteria 4 - EX3-CRT-VLD-01-0203-002
There is evidence that the additional SRAP PAPI is sufficient to not negatively impact SRAP procedures compared to the reference scenario, from the perspective of the crew.

PRQ results for FLT 1 / RUN 3, 5, 6, 8			vs.	PRQ results for FLT1 / RUN 2	
Test Subject	Q1 (PAPI) Average	Q5 (confusion) Average		Q1 (PAPI)	Q5 (confusion)
A	4.3	5.8		6	6
B	4.5	4.3		5	4
C	5.5	6.0		5	6
E	6.0	6.0		6	6
F	6.0	6.0		6	6
G	6.0	6.0		--	--
Overall average	5.4	5.7		5.6	5.6

PEQ results	
Test Subject	Q6
A	6
B	5
C	6
E	6
F	6
G	5
Average	5.7

Criteria 4 is passed as the average scores for all questions are well above 3.5.

4.2.1.5 EX3-OBJ-VLD-01-0203-003 Results

This objective concerns the impact of SRAP additional runway markings under VMC on nominal threshold approach safety from crew perspective. One criteria has been defined:

Criteria 5 - EX3-CRT-VLD-01-0203-003
There is evidence that the additional SRAP runway markings do not negatively impact normal approach procedures to nominal threshold compared to the reference scenario, from the perspective of the crew.

PRQ results for FLT 1 / RUN 4, 7				vs.	PRQ results for FLT1 / RUN 2		
Test Subject	Q2 (markings) Average	Q4 (workload) Average	Q5 (confusion) Average		Q2 (markings)	Q4 (workload)	Q5 (confusion)
A	6.0	6.0	6.0		5	5	6
B	5.0	4.5	5.0		4	5	4
C	6.0	6.0	6.0		6	6	6
E	--	--	--		6	6	6
F	--	--	--		6	6	6
G	--	--	--		6	6	6
Overall average	5.7	5.5	5.7		5.5	5.7	5.7

PEQ results	
Test Subject	Q4
A	6
B	6
C	6
E	6
F	6
G	6
Average	6.0

Criteria 5 is passed as the average scores for all questions are well above 3.5.

4.2.1.6 EX3-OBJ-VLD-01-0203-004 Results

This objective concerns the impact of SRAP additional PAPI under VMC on nominal threshold approach safety from crew perspective. One criteria has been defined:

Criteria 6 - EX3-CRT-VLD-01-0203-004
There is evidence that the additional SRAP PAPI does not negatively impact normal approach procedures to nominal threshold compared to the reference scenario, from the perspective of the crew.

PRQ results for FLT 1 / RUN 4, 7				vs.	PRQ results for FLT1 / RUN 2		
Test Subject	Q1 (PAPI) Average	Q4 (workload) Average	Q5 (confusion) Average		Q1 (PAPI)	Q4 (workload)	Q5 (confusion)
A	6.0	6.0	6.0		6	5	6
B	5.0	4.5	5.0		5	5	4
C	5.5	6.0	6.0		5	6	6
E	--	--	--		6	6	6
F	--	--	--		6	6	6
G	6.0	--	--		--	6	6
Overall average	5.6	5.5	5.7		5.6	5.7	5.7

PEQ results	
Test Subject	Q5
A	5
B	5
C	6
E	6
F	6
G	6
Average	5.7

Criteria 6 is passed as the average scores for all questions are well above 3.5.

4.2.1.7 EX1-OBJ-VLD-01-0203-005 Results

This objective concerns the impact on SRAP safety from crew perspective. One criteria has been defined:

Criteria 7 - EX3-CRT-VLD-01-0203-005
There is evidence that the nominal runway markings and nominal PAPI are sufficiently distinguishable from SRAP markings and PAPI in order not to result in unacceptable safety from the perspective of the crew.

PRQ results for FLT 1 / RUN 2 thr. 8				
Test Subject	Q1 (PAPI) Average	Q2 (markings) Average	Q3 (safety) Average	Q5 (confusion) Average
A	5.0	5.9	6.0	5.9
B	4.7	4.7	4.9	4.4
C	5.4	6.0	6.0	6.0
E	6.0	5.7	6.0	6.0
F	6.0	6.0	6.0	6.0
G	6.0	5.3	5.0	6.0
Overall average	5.5	5.6	5.6	5.7

PEQ results		
Test Subject	Q1	Q22
A	5	6
B	5	3
C	6	6
E	5	4
F	6	6
G	6	--
Average	5.5	5.0

Criteria 7 is passed as the average scores for all questions are well above 3.5.

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4.2.1.8 OBJ-02.02-V3-VALP-SRAP.0204 Results

This objective concerns the SRAP operational feasibility under VMC from crew perspective. Two criteria have been defined:

- Criteria 8 - CRT-02.02-V3-VALP-SRAP.0204-001
  Pilot succeeds to manage SRAP operation by applying existing SOPs.

PEQ results	
Test Subject	Q9
A	5
B	4
C	6
E	5
F	6
G	5
Average	5.2

Criteria 8 is passed as the average scores for all questions are well above 3.5.

- Criteria 9 - CRT-02.02-V3-VALP-SRAP.0204-002
  Pilots are confident when flying a SRAP operation.

PRQ results for FLT 1 / RUN 3, 5, 6, 8					
Test Subject	Q1 (PAPI) Average	Q2 (markings) Average	Q3 (safety) Average	Q4 (workload) Average	Q5 (confusion) Average
A	4.3	6.0	6.0	5.8	5.8
B	4.5	4.8	4.8	4.3	4.3
C	5.5	6.0	6.0	6.0	6.0
E	6.0	5.5	6.0	6.0	6.0
F	6.0	6.0	6.0	6.0	6.0
G	6.0	5.0	5.0	5.5	6.0
Overall average	5.4	5.5	5.6	5.6	5.7

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PEQ results	
Test Subject	Q10
A	6
B	4
C	6
E	6
F	6
G	6
Average	5.7

Criteria 9 is passed as the average scores for all questions are well above 3.5.

4.2.1.9 OBJ-02.02-V3-VALP-SRAP.0205 Results

This objective concerns the SRAP impact on SOPs. Two criteria have been defined:

- Criteria 10 - CRT-02.02-V3-VALP-SRAP.0205-001
  Pilot actions in SRAP approach allow to successfully stabilize the aircraft before landing (manage energy,..).

PRQ results for FLT 1 / RUN 3, 5, 6, 8		
Test Subject	Q3 (safety) Average	Q4 (workload) Average
A	6.0	5.8
B	4.8	4.3
C	6.0	6.0
E	6.0	6.0
F	6.0	6.0
G	5.0	5.5
Overall average	5.6	5.6

  Criteria 10 is passed as the average scores for all questions are well above 3.5.

- Criteria 11 - CRT-02.02-V3-VALP-SRAP.0205-002
  Impact of SRAP approach, existing SOPs are easily manageable by pilots (no impact on task performance).

PRQ results for FLT 1 / RUN 3, 5, 6, 8	
Test Subject	Q4 (workload) Average
A	5.8
B	4.3
C	6.0
E	6.0
F	6.0
G	5.5

Overall average	5.6

PEQ results	
Test Subject	Q9
A	5
B	4
C	6
E	5
F	6
G	5
Average	5.2

Criteria 11 is passed as the average scores for all questions are well above 3.5.

4.2.1.10 OBJ-02.02-V3-VALP-SRAP.0301 Results

This objective concerns the SRAP impact on phraseology. Two criteria have been defined:

- Criteria 12 - CRT-02.02-V3-VALP-SRAP.0301-001
  Proposed phraseology does not lead to errors related to perception & interpretation of auditory information.

PEQ results	
Test Subject	Q20
A	5
B	3
C	3
E	5
F	6
G	6
Average	4.7

  Criteria 12 is passed as the average scores for all questions are well above 3.5. . Test subjects B and C have some doubts about using "06" as the SRAP runway designator, which is reflected in their scores.

- Criteria 13 - CRT-02.02-V3-VALP-SRAP.0301-002
  Pilots accept and judge the proposed phraseology as being appropriate for all encountered operating conditions.

PEQ results	
Test Subject	Q20
A	5
B	3
C	3
E	5
F	6

G	6
Average	4.7

Criteria 13 is passed as the average scores for all questions are well above 3.5. Test subjects B and C have some doubts about using “06” as the SRAP runway designator, which is reflected in their scores.

4.2.2 Detailed analysis of Demonstration Results per Demonstration objective – ISGS

4.2.2.1 OBJ-02.02-V3-VALP-ISGS.0401 "Reduction of the noise impact around the airports due to ISGS implementation" Results

The objective has been evaluated through the DASSAULT EXE3 live trials. The evaluation of the noise benefits principle linked to overall geometrical effects, enabled by ISGS, are reported in Part IV ENVAR.

Further details can be found in Appendix C.

- CRT-02.02-V3-VALP-ISGS.0401-001 Relative noise scale results positive with ISGS use
    - Dassault flights

The IGS procedure's effectiveness was assessed by comparing the noise levels generated during a IGS run (3.9° or 4.4° approach angle) to the noise levels generated during the reference run (3.5° approach angle) under the final approach.

Whatever the scenario, the ISGS procedures provide positive relative noise scale results:

- for the 3.9° approach path : up to 4dBA on the first part of the final approach (depending on the moment where the landing configuration is extended) and 1 dBA when the aircraft is stabilized in the approach configuration
- for the 4.4° approach path : up to 4dBA on the first part of the final approach and 3dBA when the aircraft is stabilized in the approach configuration

- CRT-02.02-V3-VALP-ISGS.0401-002 Size of noise contours is reduced with ISGS concept
- The size of the noise contour is reduced in average for the flights by 27% for the 3.9° approach and by 44% for the 4.4° approach (Analysing the 65 dBA ($L_{A,MAX}$) noise contour for the reference approach runs and the ISGS runs)
- CRT-02.02-V3-VALP-ISGS.0401-003 Average noise value is not increased

See above criteria CRT-02.02-V3-VALP-ISGS.0401-002 & CRT-02.02-V3-VALP-ISGS.0401-001

4.2.2.2 OBJ-02.02-V3-VALP-ISGS.0201 "ISGS impact on crew task performance" Results

• CRT-02.02-V3-VALP-ISGS.0201-001 Pilot succeeds to accomplish an ISGS operation without any difficulty

The criteria have been addressed through post experiment/post approach questions and debriefing involving EXE2, EXE3 and EXE4 flight crew.

Pilots indicate they can fly ISGS approaches without any difficulty.

Acceptance, usability and level of confidence have positive results.

- See Appendix B, C, D & F for further details CRT-02.02-V3-VALP-ISGS.0201-002 Impact on crew cooperation and crew workload remains with acceptable limit

The criteria have been addressed through post experiment/post approach questions and debriefing involving EXE2, EXE3 and EXE4 flight crew. Pilots indicate they can fly ISGS approaches without any difficulty.

Pilots indicate that crew coordination and work load remain within acceptable limits; the experimented ISGS operations have not introduced any issue or differences on the crew cooperation respect to the reference scenario, neither to the daily pilot experience.

Teamwork was at acceptable level and not affected at all by ISGS.

See Appendix B, C, D & F for further details

4.2.2.3 OBJ-02.02-V3-VALP-ISGS.0202 "ISGS impact on cockpit HMI" Results

The objective has been evaluated through the HONEYWELL EXE3 EU live trials and later within HONEYWELL separate US flight test further described in Appendix F. During the EU flight trials, Honeywell evaluated two systems, which could improve the flight crew performance during the ISGS procedures. The Energy management system on the approach from Top of Descent to the stabilization gate provides flight crew an awareness on an excessive energy and help them to manage the aircraft to be stable at the gate altitude and the Flare Assistant provides flight crew with cues to initiate flare at an appropriate time.

An Energy management prototype was used by the Pilot Flying during 23 out of 30 flown approaches. 7 approaches were flown without the Energy management tool. Two notes need to be emphasized regarding the Energy management prototype:

- Note 1: the Energy Management Tool was an experimental prototype, and it included few known limitations which negatively affected how the data were presented on the display, resulting in deteriorated perception of the tool by pilots.
- Note 2: specific comments regarding the Energy Management Human-machine interface and suggestions for improvements were collected and will be used to further improve the prototype[2].. These are not disclosed publicly in this document.

The Flare Assistant[3] was tested during 4 approaches, which end up with landing. The HMI was provided on the head-down display, where pilot flying is not looking during flare operation. Therefore, post evaluation review of the recorded screens was conducted with 2 pilots, who participated on trials. Two solutions containing 4.4 degree solution and two with 3.9 degree solution were replayed for pilots, who observed, filled questionnaires and provided aural comments.

Results for both systems are presented for all following objectives:

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[2] Data collected within Ciampino demonstration were further used for EM algorithm, HMI improvements and finally flight tested in US in November 2022. Results are described in Appendix F.

[3] Flare assistant prototype was not further tested in November US flight test.

- CRT-02.02-V3-VALP-ISGS.0202-001 HMI is usable by flight crew

A) Energy Management

Two questions have been answered after each approach. Answers to both indicates that current implementation of Energy Management tool shows usability limits with impact on easy-to-use aspects. Collected data were further used for EM algorithm and HMI improvements. More details in Appendix F.

B) Flare Assistant

After every approach replay, both pilots provided answers to two questions regarding usability. Mostly negative results (fluctuating from “Strongly disagree” to “Somewhat disagree”) suggest that Flare Assistant usability should be improved with respect to the symbology, its visibility and saliency on the display. Some fine-tuning and polishing of the algorithm, which would make the movement of the symbol smoother, were also suggested in comments.

- CRT-02.02-V3-VALP-ISGS.0202-002 HMI is useful to flight crew

A) Energy management

One question regarding the usefulness of the Energy Management system during ISGS procedures, has been asked after every approach. The rating shows, that 17 out of 23 answers tent to agree, that Energy Management is useful. With general comment, that the Energy Management is beneficial in case of steeper approach procedures at unknown airports and in bad weather conditions. 4 answers disagreed with that statement and 2 were “Neither agree nor disagree”.

B) Flare Assistant

Responses to the question regarding potential usefulness of the Flare Assistant for the ISGS procedures were rather positive. 6 out of 8 responses are fluctuating from “Neither agree nor disagree” to “Agree”. Overall, pilots would consider the Flare Assistant as a useful tool for ISGS procedures if the prototype worked correctly and usability limitations were corrected as suggested above.

- CRT-02.02-V3-VALP-ISGS.0202-003 HMI supports the application of the procedure

A) Energy management

One question covered the effectiveness of the Energy Management HMI for the ISGS procedures. The answers are impacted by the poor usability of the current system, which was also described in the above (section CRT-02.02-V3-VALP-ISGS.0202-001). 12 out of 23 answers were rather positive fluctuating between “Somewhat agree” and “Agree”. 10 out of 23 were rather negative and 1 was undecided. After improvements made based on Ciampino collected data, modified algorithm and HMI improved the crew awareness about timing of configuration changes when performing ISGS procedures.

B) Flare Assistant

Pilots feedback suggested the Flare Assistant would be effective tool to manage the ISGS procedures (6 out of 8 responses are fluctuating from “Neither agree nor disagree” to “Agree”), if the usability of the tool were improved, as noted above already. Also, pilots commented, that the primary flight display (head-down diplay) is not the appropriate location, where pilots look during flare operation. The head-up display is the best place to present the flare cue.

4.2.2.4 OBJ-14.3-V3-VALP-ISGS.0203 "ISGS impact on safety crew perspective" Results

- CRT-14.3-V3-VALP-ISGS.0203-001 There is evidence that the level of operational safety is maintained and not negatively impacted under ISGS procedures compared to the reference scenario from the perspective of the crew

The criteria have been addressed through post experiment/post approach questions and debriefing involving EXE2, EXE3 and EXE4 flight crew.

The perceived level of safety was remained within acceptable limit

The situation awareness perceived during the trials was always at acceptable.

PAPI indications did not generate issue in majority of cases of Twente trial conditions with preferences on specific color coding.

For Ciampino exercises, about PAPI set at 3.5° for RWY33, the ENAV and DASSAULT flight crew did not underline any issue for the lack of visual aids for the specific conditions of the trial: at 3.9° descent angle they had the 3 white lamps and 1 red lamp as guidance while at 4.4° descent angle they had no guidance at all. In contrary, Honeywell pilots strongly suggested having PAPI information charted in the navigational approach charts to prevent any confusion for the flight crew.

Indeed, in Ciampino case, while three out of seven pilots found it "acceptable only because it was a trial. In normal operations it MUST be synchronized" or "appropriately charted in navigation approach charts", most pilots stated that this was not disturbing the approach as the flight crew was already informed and briefed about that, especially for the DASSAULT flight crew that reported they usually don't use the PAPI guidance.

Furthermore, it should be considered that ISGS procedure were flown using SBAS that provide precision vertical guidance and can be considered as a fundamental enabler for such kind of approaches.

See Appendix B, C & D for more details.

- CRT-14.3-V3-VALP-ISGS.0203-002 Flight crew initiates the flare at the right moment during ISGS operation in order to prevent hard landing

The criteria have been addressed through post experiment/post approach questions and debriefing involving EXE2, EXE3 and EXE4 flight crew on the basis of CRT-14.3-V3-VALP-ISGS.0203-001, CRT-14.3-V3-VALP-ISGS.0204-001, CRT-02.02-V3-VALP-ISGS.0201-001 & OBJ-14.3-V3-VALP-ISGS.0204:

Pilot succeeded to manage ISGS operation by applying existing SOPs and no specific issues were reported about the flare initiation neither about hard landings during the debriefings.

- CRT-14.3-V3-VALP-ISGS.0203-003 Stabilization criteria are reached when pilot apply current SOPs

The criteria have been addressed through post experiment/post approach questions and debriefing involving EXE2, EXE3 and EXE4 flight crew on the basis of CRT-14.3-V3-VALP-ISGS.0203-001, CRT-14.3-V3-VALP-ISGS.0204-001, CRT-02.02-V3-VALP-ISGS.0201-001 & OBJ-14.3-V3-VALP-ISGS.0204:

Pilot succeeded to manage ISGS operation by applying existing SOPs and no specific issues were raised in relation to stabilization criteria in the context of the executed operational trials.

4.2.2.5 OBJ-14.3-V3-VALP-ISGS.0204 "ISGS operational feasibility from crew perspective" Results

The Objective have been addressed through post experiment/post approach questions and debriefing involving EXE2, EXE3 and EXE4 flight crew.

The results show that the ISGS experimented operations at Ciampino and Twente airports are operationally feasible.

PAPI indications did not generate issue in majority of cases of Ciampino trial conditions.

Energy management without assistance during the flare was acceptable.

See Appendix B, C & D for more details.

- "CRT-14.3-V3-VALP-ISGS.0204-001 Pilot succeeds to manage ISGS operation by applying existing SOPs

There is no need of updating current SOPs, only 1 comment was that the SOP may/should be slightly amended by inclusion of mandatory briefing item.

See Appendix B, C & D for more details.

- CRT-14.3-V3-VALP-ISGS.0204-002 Pilots are confident when flying a ISGS operation

The level of confidence was high.

See Appendix B, C & D for more details.

4.2.2.6 OBJ-02.02-V3-VALP-ISGS.0205 ISGS impact on SOPs

- CRT-02.02-V3-VALP-ISGS.0205-001 Pilot actions in approach allow to successfully stabilize the aircraft before landing (manage energy,..)

The criteria have been addressed through post experiment/post approach questions and debriefing involving EXE2, EXE3 and EXE4 flight crew on the basis of CRT-14.3-V3-VALP-ISGS.0204-001.

Pilot succeeded to manage ISGS operation by applying existing SOPs (See Appendix B, C & D for more details) based on CRT-14.3-V3-VALP-ISGS.0204-001

- CRT-02.02-V3-VALP-ISGS.0205-002 Impact of ISGS approach, existing SOPs are easily manageable by pilots (no impact on task performance)

The criteria have been addressed through post experiment/post approach questions and debriefing involving EXE2, EXE3 and EXE4 flight crew on the basis of CRT-14.3-V3-VALP-ISGS.0204-001.

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No impact on existing SOPs Pilot succeeded to manage ISGS operation by applying existing SOPs (See Appendix B, C & D for more details) based on CRT-14.3-V3-VALP-ISGS.0204-001. Only 1 comment was that the SOP may/should be slightly amended by inclusion of mandatory briefing item.

4.2.3 Detailed analysis of Demonstration Results per Demonstration objective – IGS to SRAP

Results provided in the following sections apart for the noise results, are based on PRQ and PEQ indicated in section A.3.2.1.

4.2.3.1 OBJ-02.02-V3-VALP-ITSR.0401

The objective of demonstrating the interest of IGS-to-SRAP has been addressed through under-track and contour noise analysis of recorded flight data from the same trials at Twente airport (EHTW) as in the previous objective.

CRT-02.02-V3-VALP-ITSR.0401-001 : Relative noise scale results positive with IGS-to-SRAP use.

Run2 (3°; RWY 05; Reference) and Run6 (3.5°; RWY 06) qualify for IGS-to-SRAP noise impact assessment. Run6 represents the IGS-to-SRAP procedure with a glide slope of 3.5° onto Runway 06, while Run2 represents the reference approach with a glide slope of 3° onto Runway 05.

IGS and SRAP procedures combined allow for a positive noise scale reduction, from 0.6 dBA LAmax to 5.2 dBA LAmax. The altitude difference due to the slope angle increase and the SRAP displacement result in a significant noise reduction under-track despite higher CAS. It has to be noticed that part of the acoustic gain between -11km and -13km is also due to a smaller CAS (10kts less).

Criterion CRT-02.02-V3-VALP-ITSR.0401-001 is reached.

CRT-02.02-V3-VALP-ITSR.0401-002 : Noise contours location is shifted to airport area.

The iso-contour areas are shifted towards the runway and away from populated neighbourhoods, compared to the reference run. Similarly, to CRT-02.02-V3-VALP-SRAP.0401-002, a population count comparison could show the advantage brought by the combination of both IGS and SRAP procedures, and could be extrapolated to other airports surrounded by a larger population.

Criterion CRT-02.02-V3-VALP-ITSR.0401-002 is reached.

CRT-02.02-V3-VALP-ITSR.0401-003 : Size of noise contours is reduced with IGS-to-SRAP concept.

With reference to Run2, the Run6 shows a 29% iso-contour area reduction for 70 LAmax dBA, and a 72% iso-contour area reduction for 75 LAmax dBA. The effective noise reduction is positive.

Criterion CRT-02.02-V3-VALP-ITSR.0401-003 is reached.

CRT-02.02-V3-VALP-ITSR.0401-004 : Average noise value is not increased.

The number of runs (9) was not sufficient to perform a statistical analysis and conclude on an average noise gain. Nonetheless, when considering the under-track LAmax(dBA) noise level, one can observe the constant gain from implementing the IGS-to-SRAP procedure. The same observation can be made about the reduced noise iso-contour areas, which are also shifted towards the airport area and away from inhabitants.

Criterion CRT-02.02-V3-VALP-ITSR.0401-004 is reached.

4.2.3.2 EX3-OBJ-VLD-01-0201-001 Results

This objective concerns the 3.5 deg IGS-to-SRAP impact under VMC on crew task performance. Two criteria have been defined:

- Criteria 14 - EX3-CRT-VLD-01-0201-001-01
  Pilot succeeds to accomplish a 3.5 deg IGS-to-SRAP operation without any difficulty.

PRQ results for FLT 2 / RUN 2 thr. 6					
Test Subject	Q1 (PAPI) Average	Q2 (markings) Average	Q3 (safety) Average	Q4 (workload) Average	Q5 (confusion) Average
A	5.8	6.0	6.0	6.0	6.0
B	4.8	4.8	4.4	4.4	4.6
C	6.0	6.0	6.0	6.0	6.0
E	6.0	6.0	6.0	6.0	5.5
F	6.0	6.0	6.0	6.0	6.0
G	6.0	6.0	5.0	5.3	6.0
Overall average	5.8	5.8	5.6	5.6	5.7

PEQ results						
Test Subject	Q3	Q7	Q11	Q20	Q21	Q22
A	5	6	6	5	5	6
B	4	4	5	3	3	3
C	6	6	6	3	6	6
E	5	6	5	5	6	4
F	6	6	6	6	6	6
G	5	5	5	6	6	--

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Average	5.2	5.5	5.5	4.7	5.3	5.0

Criteria 14 is passed as the average scores for all questions are well above 3.5.

- Criteria 15 - EX3-CRT-VLD-01-0201-001-02
  Impact on crew cooperation and crew workload for 3.5 deg IGS-to-SRAP operation remains within acceptable limit.

PRQ results for FLT 2 / RUN 2 thr. 6	
Test Subject	Q4 (workload) Average
A	6.0
B	4.4
C	6.0
E	6.0
F	6.0
G	5.3
Overall average	5.6

Criteria 15 is passed as the average scores for all questions are well above 3.5.

4.2.3.3 EX3-OBJ-VLD-01-0201-002 Results

This objective concerns the 4.0 deg IGS-to-SRAP impact under VMC on crew task performance. Two criteria have been defined:

- Criteria 16 - EX3-CRT-VLD-01-0201-002-01
  Pilot succeeds to accomplish a 4.0 deg IGS-to-SRAP operation without any difficulty.

PRQ results for FLT 3 / RUN 2 thr. 6					
Test Subject	Q1 (PAPI) Average	Q2 (markings) Average	Q3 (safety) Average	Q4 (workload) Average	Q5 (confusion) Average
A	6.0	6.0	6.0	6.0	6.0
B	4.6	5.0	4.5	4.2	4.6
C	5.4	6.0	6.0	6.0	6.0
E	6.0	6.0	5.0	4.5	6.0
F	6.0	6.0	6.0	6.0	6.0
G	6.0	6.0	5.3	5.0	5.7
Overall average	5.7	5.8	5.5	5.3	5.7

PEQ results						
Test Subject	Q3	Q7	Q12	Q20	Q21	Q22
A	5	6	5	5	5	6
B	4	4	5	3	3	3
C	6	6	5	3	6	6
E	5	6	4	5	6	4
F	6	6	6	6	6	6
G	5	5	5	6	6	--
Average	5.2	5.5	5.0	4.7	5.3	5.0

Criteria 16 is passed as the average scores for all questions are well above 3.5.

- Criteria 17 - EX3-CRT-VLD-01-0201-002-02
  Impact on crew cooperation and crew workload for 4.0 deg IGS-to-SRAP operation remains within acceptable limit.

PRQ results for FLT 3 / RUN 2 thr. 6	
Test Subject	Q4 (workload) Average
A	6.0
B	4.2
C	6.0
E	4.5
F	6.0
G	5.0
Overall average	5.3

Criteria 17 is passed as the average scores for all questions are well above 3.5.

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4.2.3.4 EX3-OBJ-VLD-01-0201-003 Results

This objective concerns the 4.49 deg IGS-to-SRAP impact under VMC on crew task performance. Two criteria have been defined:

- Criteria 18 - EX3-CRT-VLD-01-0201-003-01
  Pilot succeeds to accomplish a 4.49 deg IGS-to-SRAP operation without any difficulty.

PRQ results for FLT 4 / RUN 2 thr. 6					
Test Subject	Q1 (PAPI) Average	Q2 (markings) Average	Q3 (safety) Average	Q4 (workload) Average	Q5 (confusion) Average
A	--	6.0	6.0	6.0	6.0
B	5.0	5.0	4.6	4.2	5.0
C	6.0	6.0	6.0	6.0	6.0
E	5.5	6.0	5.0	5.5	6.0
F	6.0	6.0	6.0	6.0	6.0
G	6.0	6.0	5.0	5.0	6.0
Overall average	5.7	5.8	5.4	5.5	5.8

PEQ results						
Test Subject	Q3	Q7	Q13	Q20	Q21	Q22
A	5	6	5	5	5	6
B	4	4	4	3	3	3
C	6	6	5	3	6	6
E	5	6	3	5	6	4
F	6	6	6	6	6	6
G	5	5	4	6	6	--
Average	5.2	5.5	4.5	4.7	5.3	5.0

Criteria 18 is passed as the average scores for all questions are well above 3.5.

- Criteria 19 - EX3-CRT-VLD-01-0201-003-02
  Impact on crew cooperation and crew workload for 4.49 deg IGS-to-SRAP operation remains within acceptable limit.

PRQ results for FLT 4 / RUN 2 thr. 6	
Test Subject	Q4 (workload) Average
A	6.0
B	4.2
C	6.0
E	5.5
F	6.0
G	5.0
Overall average	5.5

Criteria 19 is passed as the average scores for all questions are well above 3.5.

4.2.3.5 EX3-OBJ-VLD-01-0203-001 Results

This objective concerns the impact on SRAP additional runway markings under VMC on IGS-to-SRAP safety from crew perspective. One criteria has been defined:

Criteria 20 - EX3-CRT-VLD-01-0203-001
There is evidence that the additional SRAP runway markings are sufficient to not negatively impact IGS-to-SRAP procedures compared to the reference scenario, from the perspective of the crew.

PRQ results for FLT 2, 3, 4 / RUN 2 thr 6			vs.	PRQ results for FLT1 / RUN 2	
Test Subject	Q2 (markings) Average	Q5 (confusion) Average		Q2 (markings)	Q5 (confusion)
A	6.0	6.0		5	6
B	4.9	4.7		4	4
C	6.0	6.0		6	6
E	6.0	5.8		6	6
F	6.0	6.0		6	6
G	6.0	5.9		--	--
Overall average	5.8	5.7		5.4	5.6

PEQ results		
Test Subject	Q14	Q22
A	6	6
B	5	3
C	6	6
E	6	4
F	6	6
G	6	--
Average	5.8	5.0

Criteria 20 is passed as the average scores for all questions are well above 3.5.

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4.2.3.6 EX3-OBJ-VLD-01-0203-002 Results

This objective concerns the impact on IGS-to-SRAP additional PAPI under VMC on IGS-to-SRAP safety from crew perspective. One criteria has been defined:

Criteria 21 - EX3-CRT-VLD-01-0203-002
There is evidence that the additional IGS-to-SRAP PAPI is sufficient to not negatively impact IGS-to-SRAP procedures compared to the reference scenario, from the perspective of the crew.

PRQ results for FLT 2, 3, 4 / RUN 2 thr 6			vs.	PRQ results for FLT1 / RUN 2	
Test Subject	Q1 (PAPI) Average	Q5 (confusion) Average		Q1 (PAPI)	Q5 (confusion)
A	5.9	6.0		6	6
B	4.8	4.7		5	4
C	5.8	6.0		5	6
E	5.8	5.8		6	6
F	6.0	6.0		6	6
G	6.0	5.9		--	--
Overall average	5.7	5.7		5.6	5.6

PEQ results	
Test Subject	Q15
A	6
B	5
C	6
E	6
F	6
G	6
Average	5.8

Criteria 21 is passed as the average scores for all questions are well above 3.5.

4.2.3.7 EX3-OBJ-VLD-01-0203-003 Results

This objective concerns the impact on IGS-to-SRAP safety from crew perspective. One criteria has been defined:

Criteria 22 - EX3-CRT-VLD-01-0203-003
There is evidence that the nominal runway markings and nominal PAPI are sufficiently distinguishable from SRAP markings and PAPI in order not to result in unacceptable safety from the perspective of the crew.

PRQ results for FLT 2, 3, 4 / RUN 2 thr. 6				
Test Subject	Q1 (PAPI) Average	Q2 (markings) Average	Q3 (safety) Average	Q5 (confusion) Average
A	5.9	6.0	6.0	6.0
B	4.8	4.9	4.5	4.7
C	5.8	6.0	6.0	6.0
E	5.8	6.0	5.3	5.8
F	6.0	6.0	6.0	6.0
G	6.0	6.0	5.1	5.9
Overall average	5.7	5.8	5.5	5.7

PEQ results		
Test Subject	Q1	Q22
A	5	6
B	5	3
C	6	6
E	5	4
F	6	6
G	6	--
Average	5.5	5.0

Criteria 22 is passed as the average scores for all questions are well above 3.5.

4.2.3.8 OBJ-02.02-V3-VALP-ITSR.0204 Results

This objective concerns the IGS-to-SRAP operational feasibility under VMC from crew perspective. Two criteria have been defined:

- Criteria 23 - CRT-02.02-V3-VALP-ITSR.0204-001
  Pilot succeeds to manage IGS-to-SRAP operation by applying existing SOPs.

PEQ results	
Test Subject	Q16
A	5
B	4
C	6
E	5
F	6
G	5
Average	5.2

  Criteria 23 is passed as the average scores for all questions are well above 3.5.

- Criteria 24 - CRT-02.02-V3-VALP-ITSR.0204-002
  Pilots are confident when flying an IGS-to-SRAP operation.

PRQ results for FLT 2, 3, 4 / RUN 2 thr. 6					
Test Subject	Q1 (PAPI) Average	Q2 (markings) Average	Q3 (safety) Average	Q4 (workload) Average	Q5 (confusion) Average
A	5.9	6.0	6.0	6.0	6.0
B	4.8	4.9	4.5	4.3	4.7
C	5.8	6.0	6.0	6.0	6.0
E	5.8	6.0	5.3	5.3	5.8
F	6.0	6.0	6.0	6.0	6.0
G	6.0	6.0	5.1	5.1	5.9
Overall average	5.7	5.8	5.5	5.5	5.7

PEQ results	
Test Subject	Q17
A	6
B	5
C	6
E	5
F	6
G	5
Average	5.5

Criteria 24 is passed as the average scores for all questions are well above 3.5.

4.2.3.9 OBJ-02.02-V3-VALP-ITSR.0205 Results

This objective concerns the IGS-to-SRAP impact on SOPs. Two criteria have been defined:

- Criteria 25 - CRT-02.02-V3-VALP-ITSR.0205-001
  Pilot actions in IGS-to-SRAP approach allow to successfully stabilize the aircraft before landing (manage energy,..).

PRQ results for FLT 2, 3, 4 / RUN 2 thr. 6		
Test Subject	Q3 (safety) Average	Q4 (workload) Average
A	6.0	6.0
B	4.5	4.3
C	6.0	6.0
E	5.3	5.3
F	6.0	6.0
G	5.1	5.1
Overall average	5.5	5.5

  Criteria 25 is passed as the average scores for all questions are well above 3.5.

- Criteria 26 - CRT-02.02-V3-VALP-ITSR.0205-002
  Impact of IGS-to-SRAP approach, existing SOPs are easily manageable by pilots (no impact on task performance).

PRQ results for FLT 2, 3, 4 / RUN 2 thr. 6	
Test Subject	Q4 (workload) Average
A	6.0
B	4.3
C	6.0
E	5.3
F	6.0
G	5.1

Overall average	5.5

PEQ results	
Test Subject	Q16
A	5
B	4
C	6
E	5
F	6
G	5
Average	5.2

Criteria 26 is passed as the average scores for all questions are well above 3.5.

4.2.3.10 OBJ-02.02-V3-VALP-ITSR.0301 Results

This objective concerns the IGS-to-SRAP impact on phraseology. Two criteria have been defined:

- Criteria 27 - CRT-02.02-V3-VALP-ITSR.0301-001
  Proposed phraseology does not lead to errors related to perception & interpretation of auditory information.

PEQ results	
Test Subject	Q20
A	5
B	3
C	3
E	5
F	6
G	6
Average	4.7

Criteria 27 is passed as the average scores for all questions are well above 3.5. Test subjects B and C have some doubts about using “06” as the SRAP runway designator, which is reflected in their scores.

- Criteria 28 - CRT-02.02-V3-VALP-ITSR.0301-002
  Pilots accept and judge the proposed phraseology as being appropriate for all encountered operating conditions.

PEQ results	
Test Subject	Q20
A	5
B	3
C	3
E	5
F	6

G	6
Average	4.7

Criteria 28 is passed as the average scores for all questions are well above 3.5. Test subjects B and C have some doubts about using "06" as the SRAP runway designator, which is reflected in their scores.

4.3 Confidence in Results of Demonstration Exercises

4.3.1 Confidence in Results of Demonstration Exercises SRAP and IGS to SRAP

4.3.1.1 Limitations and impact on the level of Significance

ATC impact has not been validated for SRAP and IGS to SRAP.

The extend of the applicability of the Exercise 01 results depends on the way this exercise has been defined (see also DEMOP section 5.1) and performed. Especially the following items are of interest:

1. *VFR/VMC*
   The test flights have all been executed under VFR/VMC.

2. *PAPI*
   A transportable SRAP PAPI has been used for the approaches (together with the existing PAPI). Light intensity of this transportable SRAP PAPI was slightly less than the existing PAPI, but was acceptable for the tests (see also section A.5.1).

3. *Runway markings*
   The SRAP markings at Twente Airport are consistent with ICAO Annex 14 guidelines (see DEMOP section 5.1.4.2). The markings are applicable to the local situation. This situation is characterised by an LDA of 2406 m for RWY 05 and an LDA of 1386 m for RWY 06. The SRAP touchdown zone markings would have more elements on longer runways such as found at major international airports.
   In the sense that Twente Airport has a somewhat shorter runway than most major international airports, Twente Airport can be viewed as a worst case scenario for SRAP operations, as the LDA for the SRAP runway is simply smaller. The LDA for the SRAP runway at Twente Airport is sufficient for NLR's test aircraft (a business jet), relatively short for medium-haul commercial airliners such as single-aisle Airbus of Boeing commercial airliners like the aircraft from TUI FLY and LUFTHANSA as used in this exercise, and too short to land for twin-aisle commercial (long haul) airliners. However, aircraft (just) not able to land at Twente Airport SRAP 06, may (in future) well be able to land on SRAP approaches on long(er) runways at major international airports.

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4. *Lighting*
   No Approach Lighting System (ALS) for the RWY06 and SRAP was implemented (in accordance with DEMOP), preventing to evaluate the solution in IMC down to CAT I minima.

5. *ATC*
   Twente Airport is an uncontrolled airfield with no ATC. Therefore, no ATC service could be provided, preventing to assess the required ATC system support (HMI) and wake minima separation management support. The specific ATC phraseology for dual threshold operations (SRAP and IGS-to-SRAP) was however simulated within the cockpit.
   The participating aircraft was segregated from other traffic and no evaluation of the advantage of the optimised wake turbulence minima applicable to dual threshold / SRAP operations was possible (in accordance with DEMOP).

6. *Wind*
   Due to operational implications (vicinity of German airspace), the SRAP runway was chosen (in the DEMOP) to be 06 (second threshold from 05), even when prevailing wind directions are from the south-west. During the test flights considerable tail wind conditions existed.

7. *Test subjects*
   Test subjects have been chosen such that a wide range of pilots were represented (see Table 14). Test subject ages ranged from in-the-20 to in-the-50 with ages in-between also covered. The flight experience of the test subjects ranged from little experienced (200 hrs) up to well experienced (>14000 hrs). Most test subjects are flying air transport type aircraft, but also test subjects flying small aircraft were included. Finally, the test subjects included both test- and regular pilots.

8. *Aircraft*
   Test flights were performed with NLR's Cessna Citation II research aircraft with the test subjects in the right hand seat. Although all test subjects are pilots, not all of them have a type rating on this aircraft. The ferry flights to Twente Airport and some first approaches (as well as thorough briefing material) were used to familiarize the test subjects with the aircraft and with (IGS-to-)SRAP operations. The questionnaire ratings are well comparable to air transport category aircraft, as the Lufthansa (A319) and TUI (B737 Max 8) flights have shown comparable ratings.

Summarizing the above, it can be concluded that the level of significance is high and that the outcomes are very useful for future implementations of the (IGS-to-)SRAP procedures, either in daily regular operations or in further testing/demonstration activities (e.g. including lighting solutions).

The extent of the applicability of the results of this demonstration exercise is affected by the following items.

For EXE-001 SRAP and IGS-to-SRAP at Twente airport:

- *Aircraft*: the tested aircraft is an Airbus A319-112 equipped with CFM56-5B6/3 engines owned and operated by Lufthansa. Different aircraft types might perform the studied procedures differently in terms of aircraft speed, engine regime or use of airbrakes, parameters that significantly affect noise.

- *Glide slope*: 3.5° in the case of IGS-to-SRAP. Different slopes might produce different results because their effect on aircraft speed, engine regime or use of airbrakes are not evaluated in this study.
- *Go-arounds*: the use of go-around instead of complete landing procedures limits the analysis to the section of the trajectory where the aircraft is over a certain height. Confidence is high from a certain distance of the airport, excluding only the zone that is very close.
- *Number of test runs*: the number of test runs is relatively small for providing a statistical analysis.
- *Absence of noise recordings*: Twente airport is not equipped to monitor noise. Noise recordings can be used not only to confirm the conclusions of the study but also to improve the quality of aircraft noise models in the application condition, which may be different to the model generation conditions.
- *Noise prediction:* noise results are based on Airbus in-house models that are calibrated on different noise measurements performed during the development of the aircraft, including flight tests, wind-tunnel tests and engine static tests.

4.3.1.1.1 Quality of Demonstration Exercises Results

Questionnaires have been used to collect ratings from the test subjects on the different aspects of the (IGS-to-)SRAP procedures (see section A.3.2). The rating scale ranged from “completely disagree” (rated 1) to “Completely agree” (rated 6). The ratings have been processed in accordance with Table 17 (pg. 135) (and as described in further detail in the DEMOP) and include averaging to arrive at the (un)acceptability of the particular questionnaire item. Averages higher than 3.5 are thereby interpreted as “acceptable” or “met”, whereas averages below 3.5 are interpreted as “unacceptable” or “failed”. Most of the average scores are well above 5.5 (especially for the Post Run Questionnaires) with the lowest average scores at 4.5 (Post Experiment Questionnaire). Given that these average scores are well above 3.5, the ‘accuracy’ of the ratings is no factor and the interpretation as “acceptable/met” is justified.

Complementary to the DEMOP description of the evaluation process and handling of the test results, it is also important to look at individual scores below 3.5 (i.e. scores in the range of slightly, mostly or completely unacceptable). A few individual ratings in the Post Run Questionnaire scored as low as 3 (slightly unacceptable) – being the lowest individual score. None of these scores related to PRQ Question 3 on safety, but on PRQ Question 1 on PAPI. These “slightly unacceptable”-scores were however all rated by the least experienced pilot, test subject B (see Table 18). This test subject only has roughly 200 hrs experience on SEP/MEP aircraft and was invited based on the test subject’s experience in automated approach guidance based on outside visual reference by cameras. The test matrix provided for repetition of runs and it is interesting to see that test subject B rated repeated runs as acceptable.

Another few individual ratings in the Post Experiment Questionnaire scored also 3 – also being the lowest score. Most of these scores concerned again test subject B, but also C and E had these scores.

These scores mainly relate to the phraseology, charts and runway designation, all of which depend on personal preferences.

Aircraft noise is sensitive to many physical variables and the error in their recording or modelling contributes to an uncertainty in the noise prediction methodology. In order to draw conclusions about the objective, the results of the study must be compared to the error of their methodology.

Most of the criteria, including the results of exercise EXE-001, presented a noise impact large enough to provide significant conclusions with a high level of confidence.

4.3.1.1.2 Significance of Demonstration Exercises Results

Statistical significance

Given the uncontrolled nature of the total set-up of the experiment – e.g. wind-, cloud-, precipitation- light- and visibility conditions were different for each flight/approach –, together with the relatively small amount of test subjects, the experiment data have not been subjected to statistical analyses other than simple comparison of average pilot ratings to critical acceptability values or reference scenario results (in accordance with DEMOP).

For EXE-001 SRAP and IGS-to-SRAP at Twente airport, one test run is used to represent each procedure for each objective, therefore no statistical analysis has been performed. All test runs were performed on the same day, aircraft and runway, which reduced the variability in the parameters that affect noise: temperature, humidity, aircraft weight.

Operational significance

See heading 1 in section above.

For EXE-001 SRAP and IGS-to-SRAP at Twente airport, all runs correspond to one dedicated flight test, therefore the operational significance of these results is limited.

4.3.2 Confidence in Results of Demonstration Exercises IGS

4.3.2.1 Limitations and impact on the level of Significance

The flight test aircrafts used to comply with demonstration activities are representative of commercial/production aircraft cockpit.

In addition, they are equipped with specific and peculiar instrumentation (SBAS capable), needed to perform the relative flight experimental activities.

No ATC objective has been addressed in the scope of the executed trials.

For EXE-002 ISGS at Frankfurt airport:

- *Aircraft*: all flights analysed correspond to different Airbus A319-112 equipped with CFM56-5B6/3 engines and operated by Lufthansa. Different aircraft types might perform the studied procedures differently in terms of aircraft speed, engine regime or use of airbrakes, parameters that significantly affect noise.
- *Glide slope*: 3.2° for ISGS. Different slopes might produce different results because their effect on aircraft speed, engine regime or use of airbrakes are not evaluated in this study.
- *Commercial flights:* there was a large diversity in the test population, which encompassed different runways, weather conditions, aircraft weights… and a large variability in the aircraft performance parameters that affect noise.
- *Mix of visibility conditions*: flights in CAT I conditions are compared to CAT II, which has an influence on the operation of the aircraft.
- *Mix of standard procedures with procedural trials*: in this exercise, a different use of engine power between both types of procedures was observed, which could be caused by different pilot behaviour due to the fact that procedure trials were compared to typical operations.
- *Number of test runs*: the number of test runs was relatively large but not large enough to remove some parameters as variables of the analysis, such as runway or visibility conditions.
- *Absence of noise recordings*: although Frankfurt airport is equipped with noise monitoring stations, noise recordings were not available for their use in this study.

The absence of noise recordings reduced the precision of noise predictions, but in the majority of the results, a large noise reduction was conclusive. The mix of flights where the pilots performed standard procedures versus procedure trials raised questions during the analysis that affected the results and were proposed for further investigation.

See appendix B, C & D for more details.

4.3.2.1.1 Quality of Demonstration Exercises Results

The collected data and the analyzed results are based on the subjective experience and perception of the participating test pilots in the specific context of the demonstration exercise. The results and the data have been collected in an accurate manner and there is a high confidence on the provided feedback, but of course the results are strictly dependent on the experimented condition and context.

Aircraft noise is sensitive to many physical variables and the error in their recording or modelling contributes to an uncertainty in the noise prediction methodology. In order to draw conclusions about the objective, the results of the study must be compared to the error of their methodology.

Some of the results of exercise EXE-002 have been inconclusive because the noise impact was small in comparison with the error in the methodology. This is probably related to the smaller difference in glide slope angle. However, a calibration with noise measurements performed during the trials, with few microphones located under the ground track, could have decreased the noise source model uncertainties. Unfortunately, the noise data recorded by Frankfurt stations have not been available for this study.

See appendix B, C & D for more details.

4.3.2.1.2 Significance of Demonstration Exercises Results

The demonstration exercises have been conducted on operational airports in part hosting conventional traffic at the same time of the testing aircraft with testing aircraft proving an operational significance equivalent to the daily operations.

A significant number of total runs have been conducted considering the EXE3 and EXE4

Considering the demonstration technique (flight trials) and the executed numbers of runs it is judged the results have a high level of significance.

For EXE-002 ISGS at Frankfurt airport, the number of test subjects is of a medium size but of a large operational diversity: different runways, days (weather), routes (weight), visibility conditions. It was found that there were not enough flights to reduce the number of variables and present a statistical analysis. Both an analysis one-to-one and a statistical analysis are proposed, depending on the success criterion that was evaluated.

For EXE-002 ISGS at Frankfurt airport, commercial flights were analysed, therefore the operational significance is very high. There was a large diversity in the test population, which encompassed different runways, weather conditions, aircraft weights, etc.

See appendix B, C & D for more details.

5 Conclusions and recommendations

5.1 SRAP and IGS to SRAP

As indicated in section 4.3.1.1, no ATC impact has been evaluated in the context of the conducted demonstration exercises.

5.1.1 Conclusions

5.1.1.1 Noise

The EXE-001 demonstration exercise concludes with noise reduction due to SRAP and IGS-to-SRAP with 3.5° glide slope. Aiming for a SRAP threshold further down the runway displaces the ground noise impact area towards the airport and away from inhabitants and makes the aircraft noise benefit from the altitude difference. The IGS-to-SRAP procedure with 3.5° glide slope makes the aircraft noise benefit by increasing the altitude difference. For both SRAP and IGS-to-SRAP procedures, noise reduction is visible when looking at the LAmax levels under-track, and area shift is visible when reviewing noise contours.

All EXE-001 objectives are validated as each associated criteria has been assessed.

5.1.1.2 Human Performance and Safety

NLR's Cessna Citation has performed the GBAS-based (IGS-to-)SRAP flight tests in Exercise 01 at Twente Airport in the period from 28 September through 8 October 2021. In this period the experiment set-up has been checked successfully (see AN D5.1) and the test subjects have been exposed to the EAP's. The check-out consisted of multiple flight inspections to demonstrate correct set-up of the GBAS ground system (INDRA NAVIA), transportable PAPI system and additional runway markings, as well as the onboard GBAS system and MMR (EUROCONTROL). Subsequently, 6 subject pilots have flown the (IGS-to-)SRAP approaches. Based on the ratings provided by the test subjects in the questionnaire forms, it follows that all demonstration objectives have been met. This generally implies that under VMC/VFR:

1. (IGS-to-)SRAP approaches can be safely and confidently performed without any difficulties; the procedures are straightforward and well within the capabilities of any current crew. (4.0 and 4.49 deg IGS-to-SRAP approaches, although within normal approach design criteria for the Citation and demonstrated by the Citation in Exercise 01, may require careful energy management for larger aircraft.)

2. Impact on crew coordination and work load remains within acceptable limits.

3. (IGS-to-)SRAP runway markings and PAPI are sufficiently distinguishable from existing markings and PAPI, and do not negatively impact approaches to the conventional runway. The steeper the IGS-to-SRAP approach, the better the runways can be distinguished.

4. Inclusion of "first/second runway" in the landing clearance is acceptable, whereas the choice of runway designator remains subject of personal preference: some subjects prefer e.g. "05A/B" over "05/06".

The environmental conditions encountered during the flight tests included bright sun shine from back to side, as well as patchy sun shine conditions on the runway markings of both conventional and SRAP runways. The tests also contained overcast situations. Furthermore, flight tests included runs with considerable tail wind components and moderate turbulence.

Twente Airport does not provide an ATC environment. Nevertheless, the specific ATC phraseology for dual threshold operations (SRAP and IGS-to-SRAP) was simulated within the cockpit during most runs or otherwise judged by the test subjects from paper and imagination. The phraseology was in this respect found good, i.e. most test subjects agreed on the related questions/statements on the questionnaires. Although some test subjects had some minor doubts on what runway designator to use. The choice of runway designator remains subject to personal preference: some subjects prefer e.g. “05A/B” over “05/06”. The mentioning of the first/second threshold is the most important part. There is no difficulty to associate lower glide slope (traffic information) with first threshold (landing clearance) or upper with second. “Lower/upper” vs. “first/second” allow crew to clearly distinguish between a traffic information and a landing clearance. All in all, it should be reminded that Twente Airport is an airport without ATC and therefore the demonstration objectives related to phraseology could not be assessed in a strict sense (and for that matter could not be included in the DEMOP).

Although all demonstration objectives have been well met based on the questionnaire scores, the subject pilots have also provided comments (in Post Experiment Questionnaire and/or briefings) that are input to a number of recommendations as well, which are covered in the next section.

5.1.2 Recommendations

5.1.2.1 Recommendations for industrialization and deployment

Standardization and regulation needs are detailed in Appendix E.

5.1.2.1.1 Noise

SRAP and IGS to SRAP procedures showed clear noise reduction. From the noise perspective it can be recommended to deploy this kind of operations for the slopes flown during the exercise.

It is important to state that depending on the A/C type, further increasing the slopes may have a negative impact on noise as it could be challenging for Energy Management leading to the crew to deploy configurations, speed breaks and landing gear prematurely to reach stabilisation.

5.1.2.1.2 Human Performance and Safety

Following recommendations are based on subject pilot notes/remarks:

1. Further demonstration activities are recommended to assess the ATC impact and demonstrate the HP and SAFETY feasibility of the proposed solutions before the deployment
2. The light intensity of the transportable SRAP PAPI turned out to be less than the conventional fixed PAPI. The SRAP PAPI became visible at 7-8 Nm out on the straight-in approach (5 Nm for bright sunshine conditions). For testing purposes this is acceptable (i.e. it does not influence the ratings) as observed by NLR test pilots during the check-out flights. However when

implementing such solutions in daily operations, it is highly recommended to have both PAPI's operating at equal brightness.

3. In case the (IGS-to-)SRAP procedures are to be performed in worse weather conditions than the VMC encountered during the tests, the use of (some kind of) SRAP approach lights is recommended.
4. For approaches to runways with conventional and (IGS-to-)SRAP procedures, it may be good for the mindset to include the runway designation also in the 500 ft call.
5. Small changes/additions to the approach briefing and crosschecks to verify the correct runway end will need to be incorporated in the SOPs.
6. 4.0 and 4.49 deg IGS-to-SRAP approaches, although within normal approach design criteria for the Citation and demonstrated by the Citation in Exercise 01, may require careful energy management for larger aircraft.
7. For a good mental picture it may be helpful to include "lower/higher glide" in traffic info messages.
8. In (IGS-to-)SRAP charts it may be even more clear when using "2nd Threshold" in the header.
9. If PAPIs are on opposite sides of the runway for first and second threshold (as was the case for EXE01), it could be possible and considered to add that information to the phraseology as an additional distinguishing factor.
10. Application of runway designation like used at Twente Airport (next lower or higher runway designation number for the SRAP runway when compared to conventional runway) can be recommended based on the fact that most of the test subjects were totally comfortable with it. Nevertheless, as some test subjects preferred other designations (e.g. conventional runway designation followed by A or B), it could also be recommended to consider further assessment of which runway designation system is best to be used. Fact is however that first mentioned runway designation system has been demonstrated under real flight conditions.

5.1.2.2 Recommendations on regulation and standardisation initiatives

See Appendix E.

5.1.2.3 Recommendations for updating ATM Master Plan Level 2

No recommendations.

5.2 ISGS

5.2.1 Conclusions

No differences have been observed between 3.2° ISGS and 3.0° standard approaches.

VLD has demonstrated that ISGS concept above of operation can be beneficial for resident, air operator and aerodromes (noise) even if for approaches up to 3.2° no clear differences have been observed respect to standard 3.0° approaches.

For airborne part, approaches up to 4.49° are already allowed by the current airworthiness regulation and constitute standard operations for some types of aircraft. Therefore, no evolution in the airworthiness regulation is needed (including no energy management assistance or flare assistance are required).

For ATC part, it was not possible to assess the ISGS solution with approach angles above 3.2° for the limitations mentioned in section 4.3 (No ATC at Twente and limitations due to local ATC environment for Ciampino airport).

Through the application of Expanded Service Volume (ESV) it was demonstrated that low intermediate altitude with long low-level flights can be avoided during parallel operations on downwind in high density traffic. Implementation requires new operational procedures in the air traffic control environment to exploit the benefits of ESV. Further trial are needed to develop and introduce these procedures.

No further issue has been highlighted.

Conclusion on applicable standards and regulations is given in Appendix E.

The following sections details the conclusions for the different areas of the conducted assessment.

5.2.1.1 Noise

For 3.2° approaches no clear benefits are observed respect to 3.0° approaches (EXE2).

The EXE-002 demonstration exercise doesn't conclude with an evident noise reduction due to ISGS with 3.2° glide slope. Theoretically, between two landings with similar performance, the aircraft altitude difference (150-200ft) should bring a noise impact at ground. However, the analysis of flights performed in operational conditions shows a large dispersion in speed and engine power management, which are major contributors to noise. When comparing pairs of flights, ISGS introduces noise reduction under-trace of up to 4 dBA, but this is not consistent over all the trajectory nor all cases, and engine power management differences are suspected to influence the result. Comparing the size noise contours did not show a consistent improvement. Only average noise under-track is consistently reduced, although this reduction is very small (< 1 dBA).

Further investigation should be done in order to determine if the different engine power and speed management are introducing a bias in the glide slope noise impact assessment.

Clear noise benefits have been measured from the EXE03 Dassault live trial at Ciampino. The ISGS procedures provide positive relative noise scale results:

- for the 3.9° approach path : up to 4dBA on the first part of the final approach (depending on the moment where the landing configuration is extended) and 1 dBA when the aircraft is stabilized in the approach configuration
- for the 4.4° approach path : up to 4dBA on the first part of the final approach and 3dBA when the aircraft is stabilized in the approach configuration

The 65 dBA (LA,MAX) noise contour for the reference approach runs and the ISGS runs is considered as representative metric. The size of the noise contour is reduced in average for the flights by 27% for the 3.9° approach and by 44% for the 4.4° approach.

5.2.1.2 Human Performance and Safety

No differences have been observed between 3.2° ISGS and 3.0° standard approaches (Frankfurt trial).

- No degradation of human performance and safety level was observed in Ciampino and Twente trials.

- Current Standard Operations Procedures (including energy management during approach) of the participating aircraft to Ciampino trials are acceptable to conduct ISGS operations
- ISGS PAPI
    - ISGS LPV approach flown in Ciampino have confirmed that PAPI guidance is not essential from pilot perspective considering the specific set-up of the demonstration and that the approach is a 3D approach with vertical LPV guidance (same on ILS).
        - Despite this result seems to contradict PJ02 outcomes concerning the mandatory requirement of a second PAPI, the result must be read considering the content of the Ciampino trial, where the pilots experimenting the ISGS procedures were fully briefed on the PAPI difference, while the PJ02 requirements are based on flight simulations which were flown by Airline Pilots who are used to have PAPI guidance available, as required in ICAO (Annex 14) /EASA for runways where turbojets are operated.
        - Anyway, if PAPI were installed for both approach slopes, they should be coherent of the slope flown to avoid misleading. These conclusions are only relevant for the context of the EXE003.These conclusions are only relevant for the context of the EXE003.
    - In the case of Twente trial, the ISGS PAPI was not always as good as the existing PAPI. This was caused by lighting conditions (clear skies with full sun shine)and the contrast with the surrounding terrain (mostly grass), which at some runs caused the ISGS PAPI to be visible/usable from 2 Nm onwards. Also battery performance was suspected to influence the brightness (best on first flights of test subjects), as was lamp 3 (for white/red colour-coding), which seemed to have less red in it (and for that reason was placed in position 1, i.e. outer position, which normally shows white when on glide path). With fully charged batteries and overcast weather, the ISGS PAPI was demonstrated during the shakedown period to be only marginally less bright than the existing PAPI.
    - In general, the ISGS approaches with a second active PAPI (on the opposite side of the existing PAPI) were acceptable and could be flown without any difficulty in VMC/daylight conditions. The test subjects indicated that they were confident in flying the ISGS operations. That means it could be flown safely and within acceptable crew cooperation and work load boundaries. The existing SOP’s could be used, however, a crew briefing item on which PAPI to use, should be added and trained.
    - Not a strong and clear indication was recorded about the colour coding of the second PAPI.
- Specific attention might be required for Energy Management and Aircraft configuration for big size aircraft, however even bigger aircraft and flight crew are capable to manage the energy during ISGS procedures effectively.
- Phraseology:
    - No issues were raised in relation to the employed phraseology during the live trials from a flight crew perspective.

5.2.1.3 Cockpit Assistance

- An Energy Management

An Energy Management system has been tested by the Honeywell flight crew during 23 approaches (plus final Honeywell flight testing of improved EM prototype was done in US based on results from Ciampino demo). It needs to be noted, that it is an experimental prototype with known limitation, which needs to be considered during the result interpretation. The Energy Management system seems to be useful during ISGS procedure, especially during the approach to an unfamiliar airport in bad weather. With modified EM prototype it was observed improved crew awareness about timing of configuration changes when performing ISGS procedures. Nevertheless, prototype needs further improvement to increase level of usability and effectiveness, how it supports the crew during ISGS procedures. More specifically and based on final EM flight test results conducted in November 2022 in US following needs for improvements were identified:

- Improve drag component of the performance model
- Harmonize further FMS & Displays messages – timing and content of the messages

Maturity status for A/C-86 (On-board assistance to aircraft energy management):

- EM on Embraer 170 reached TRL5 and is close to TRL6 (NASA TRL process). After improvements identified in last flight demonstrations, plan is to have it available on NG FMS core with entry to service from 2025-2026.
- It is expected further expansion to more NG FMS equipped platforms under Honeywell Primus® Epic (exact aircraft type is not specified yet, however full list of Primus® Epic equipped aircraft can be found here).
- EM on Airbus, if agreed with Airbus and after dedicated re-design per Airbus requirements as well as adaptation of the Airbus FMS platform, development phase and testing, the EM function could target an FMS update by ~2030.
- Boeing – plans still to be defined.

- Flare Assistant

The Flare Assistant was implemented on the Honeywell primary flight display (E170 used within Ciampino demo was not equipped with HUD). Due to safety reasons, pilots did not look at the primary flight display during the flare phase of flight. Therefore, the post evaluation video review was conducted with 2 pilots. Pilots were asked to observe 4 recorded ISGS approaches captured during the Rome trials, where primary display with the Flare Assistant is visible. Pilots feedback suggests that the Flare Assistant could be useful and could effectively support pilot during ISGS procedures, if usability of the system were improved and especially, if flare related cues were provided on the head-up instead of the head-down display.

Maturity status for A/C-87 (On-board assistance to flare):

- Based on the results, head-down display (HDD) solution is not preferred. Flare assistant shall be integrated on head-up display (HUD).
- Next steps with respect to HUD implementation and entry to service still to be defined.

5.2.1.4 Energy Balance

For the general investigation of the flight physics related to aircraft operations with increased glideslope angles so-called energy envelopes have been developed and assessed. Further information on this is given in Appendix H.

The evaluation of energy envelopes and the variation of influencing parameters revealed in general a great dependency of the ability of aircraft to fly approaches with increased glideslope angles in an energy-efficient manner. Main influencing parameters are the aircraft gross weight and wind conditions but also the intercept altitude showed a significant influence.

It was shown that the maximum glideslope angle, with which energy-efficient approaches are still feasible, differs significantly between aircraft types, depending on the specific flight performance of the respective aircraft type.

5.2.2 Recommendations

5.2.2.1 Recommendations for industrialization and deployment

Standardization and regulation needs are detailed in Appendix E.

The introduction of GBAS to low visibility operations (LVO) can be considered as a relevant milestone. The results of fast time simulations (Appendix G) indicate promising benefits in terms of traffic throughput and airport capacity during LVO compared to existing ILS procedures. At airports where weather conditions do not force CAT III guidance, GLS CAT II is meaningful to be deployed as the number of capable aircraft is increasing with the renewal of fleets in the coming years.

GLS CAT II on GAST C including ISGS can be seen as step towards GAST D, enabling LVO with very oversee able effort on the airborne side for a great number of mainline aircraft, provides environmental benefits (noise, gas emissions), and potentially increases arrival capacity at congested airports.

Based upon the input from the test subjects, the following recommendations are given:

- In follow-up projects on this matter, the additional PAPI should be totally comparable with the existing, fixed PAPI, in terms of intensity and power supply (use of batteries is not recommended).
- The ISGS procedures with two active PAPI’s should also be checked in IMC and poor light/visibility conditions. More specific example for further investigation: becoming visual at low altitude in IMC approach with deviation (above/below) from correct glide path. This may lead to confusion.
- During ISGS approaches with two active PAPI’s, no last minute changes (e.g. by ATC) should be made.
- Consider the use of two totally different colours for the ISGS PAPI (e.g. magenta-green) so that it even better shows that the ISGS PAPI is totally different.
- An awareness call on which PAPI to use during approach may be helpful.

It is expected that with higher amount of ISGS procedures provided to the equipped aircraft in the future, in would also rise rate of non-stabilized approaches. Cockpit Energy Management function is not required to fly ISGS operations, however it might help to reduce number of non-stabilized approaches to acceptable level.

In sense of cockpit Energy Management assistant system deployment process, the following steps were identified towards productization:

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- Finish up design improvements for the EM function in accordance with findings identified within E170 flight tests and demos, repeat testing. Improvements includes drag component of performance model, harmonization of certain aspect of HMI. Then the certification for E170 aircraft can be done.
- Based on the discussions with OEMs and further business decisions, it is expected to expand the Energy Management function to wider portfolio of the aircraft types and cockpit suites:
    - More NG FMS equipped platforms under Honeywell Primus® Epic (exact aircraft type is not specified yet, however full list of Primus® Epic equipped aircraft can be found here),
    - Honeywell cannot speak for OEMs; however it is expected to develop Energy Management assistant for Airbus cockpit in coming years.

In sense of Flare Assistant system, next steps are to integrate system to HUD and finish prototype validation and certification for use on NG FMS cockpit.

Further demonstration activities are recommended to evaluate the benefits stemming from GBAS ESV and to achieve a quantitative assessment.

5.2.2.2 Noise

Regarding the demonstrated noise benefits that helps to comply with the green deal objectives, it is recommended to implement ISGS operations simultaneously to the deployment of RNP approaches at all instrument runway ends as required by PBN-IR, in complement to nominal conventional slope approaches.

5.2.2.3 Human Performance and Safety

- Should a second PAPI be required, following recommendations should apply:
    - One recommendation relates to the PAPI information, which needs to be addressed and charted properly in the navigation approach charts so that flight crew can be briefed ahead of the approach and have a correct expectation what kind of visual information they see out-the window during steeper approach. The PAPI out-the window needs to be aligned with charts. It must be adjustable on the ground to reflect steeper approaches, or it needs to be clearly stated that pilots will experience inconsistency during steeper glide slope. These recommendations are relevant for the specific set-up of the demonstration EXE003
    - In follow-up projects on this matter, the additional PAPI should be totally comparable with the existing, fixed PAPI, in terms of intensity and power supply (use of batteries is not recommended).
    - The ISGS procedures with two active PAPI's should also be checked in IMC and poor light/visibility conditions. More specific example for further investigation: becoming visual at low altitude in IMC approach with deviation (above/below) from correct glide path. This may lead to confusion.
    - During ISGS approaches with two active PAPI's, no last minute changes (e.g. by ATC) should be made.
    - Consider the use of two totally different colours for the ISGS PAPI (e.g. magenta-green) so that it even better shows that the ISGS PAPI is totally different.

    - An awareness call on which PAPI to use during approach may be helpful.

- Moreover, as the deceleration capability is reduced on a steeper flight path, the risk of an unstable approach increases if the pilot is required to maintain a speed greater than the required landing speed down to a too low height. Therefore, airport speed requirements such as « Maintain 160kt until 4 NM » are not recommended when using an ISGS procedure.
- Specific assessment is recommended on the local test environment before deploying ISGS: a local safety and human performance assessment is recommended to assess possible safety and human performance (airborne and ground) issues dependent on the characteristics of the operational environment.
- Energy Management current prototype needs to be refined to improve the level of usability and effectiveness, how it supports the crew during ISGS procedures.
- Flare Assistant usability of the system should be improved .

5.2.2.4 Recommendations on regulation and standardisation initiatives

See Appendix E.

5.2.2.5 Recommendations for updating ATM Master Plan Level 2

None recorded.

6 Summary of Communications and Dissemination activities

6.1 Summary of communications and dissemination activities

The communication channels and actions that have been carried out are defined in the Communication and Dissemination Plan in the DEMOP and some of the activities reported have emerged during the project through different channels and types of communication:

- **Press releases:** 3 press releases.
    - A press release introducing the flight trials at Twente written by EUROCONTROL and NLR with the contribution of the project coordinator and SJU. https://www.sesarju.eu/index.php/news/sesar-ju-members-trial-solutions-reduce-noise-arrival-aircraft-and-support-more-efficient-use
    - A press release written by ENAV as EXE Coordinator and reviewed with the main WP3 partners (Dassault Aviation and Honeywell) and SJU, introducing the flight trials session 1 in Rome-Ciampino. https://www.sesarju.eu/news/european-demonstrations-offer-new-angle-reducing-noise-arrival-aircraft
    - A press release written and published by DFS about the use of the GBAS precision landing system for poor weather conditions at Frankfurt Airport. The first system of its kind in the world. https://www.dfs.de/homepage/en/media/press/2022/18-07-2022-world-premiere-at-frankfurt-airport-satellite-based-precision-landings-possible-even-in-bad-weather/
- **Social Media:** https://www.linkedin.com/company/vld1-dreams-sesar/. A dedicated LinkedIn page: between 2 and 3 weekly posts are published on this platform, which are previously planned in an editorial calendar of content that is shared with the partners each month. Website content is also shared on the LinkedIn profile.

  The content shared on LinkedIn about the demonstrations has been provided by the partners in charge of them, who have reported on the progress and provided pictures to support the information.
- **Website:** https://www.vld1dreams.com/. The DREAMS website is updated with any new communication activity in the shape of a news item. Contains all important information for all relevant audiences of the project like objectives, impacts, the description of each enhanced arrival procedure, partners… All information and documents shared in the downloadable section called documents. Public interest material will continue to be uploaded until the end of the project. There are 8 news published with the information provided by the exercise leaders, and 4 downloadable presentations.
- **Events:** 6 carried out.

- The participation at the **EUROCONTROL LATO-36 (Landing and Take-Off) Stakeholder's meeting.**
- The participation at the **SESAR Joint Undertaking Digital Academy Webinar about smarter, safer and more efficient arrivals** by EUROCONTROL.
- The presentation of **Twente demo at "ICAO EUR PBNC TF/5 - EUROCONTROL NSG/32"**
- The participation at **AEOLUS meeting** about topics related to deployment of European GNSS applications for aviation.
- The participation at **33rd ICAS** (Congress of the International Council of the Aeronautical Sciences) – Stockholm about **"energy balance":** Assessment of energy-efficient approaches with increased glideslope angles.

The participation at **21st I-GWG meeting** with a presentation about **GLS CAT III with ISGS at Frankfurt.** The following table includes all the communication and dissemination activities carried out until October 2022 with the links to the publications and a brief description of each one. These are available in STELLAR.

C&D activities	Type of activity	Date	Description
Participation at EUROCONTROL LATO-36 2020	Event	08/09/2021	Presentation about ISGS, A-IGS, SRAP, IGStoSRAP with PJ02 by Frédéric Rooseleer.
Launch of LinkedIn page	Social Media	04/10/2021	Currently more than 80 posts. https://www.linkedin.com/company/vld1-dreams-sesar/
Twente Flight Trials	Social Media	06/10/2021	LinkedIn posts about Twente SRAP and IGStoSRAP flight trials: https://bit.ly/3nZZWBM https://www.vld1dreams.com/news-events
SESAR webinar "Smarter safer and more efficient arrivals - Part 2"	Event	25/10/2021	https://www.youtube.com/watch?v=2LPMr9beYNI In this webinar Frédéric Rooseleer presented the important facts about the two operational solutions that will be implemented in the project. Dissemination of the webinar through LinkedIn and DREAMS website.
Project Kick-Off Meeting	Publication	27/10/2021	https://www.sesarju.eu/news/sesar-ju-members-trial-solutions-reduce-noise-arrival-aircraft-and-support-more-efficient-use https://www.vld1dreams.com/news-events

			Press release about SRAP and IGStoSRAP flight Trials in Twente with PJ.02
Launch of DREAMS website	Other media	15/12/2021	https://www.vld1dreams.com/ Currently with 8 news.
Presentation of Twente demo at "ICAO EUR PBNC TF/5 - EUROCONTROL NSG/32" meeting	Event	15/12/2021	Presentation of Twente demo at "ICAO EUR PBNC TF/5 - EUROCONTROL NSG/32" meeting: sharing content about Twente Flight Trials.
Rome-Ciampino Experimental Flight Session 1	Publication	12/01/2022	Press release about the progress during the flight trials in Ciampino airport: SESAR Joint Undertaking | European demonstrations offer new "angle" to reducing noise of arrival aircraft (sesarju.eu) https://www.vld1dreams.com/news-events
Twente Flight Trials Results	Other Media	18/03/2022	https://www.youtube.com/watch?v=SO2C5Qtz8x0&t=116s Present the VLD1 DREAMS Twente trial & results at IGSG. EUROCONTROL is preparing another video to be released soon.
Rome-Ciampino Experimental Flight Session 2	Social Media	26/04/2022 - 04/05/2022	We would like to inform you that yesterday Honeywell had the first - VLD1 DREAMS SESAR on LinkedIn https://bit.ly/3o6QHzI
AEOLUS meeting	Event	12/05/2022	AEOLUS is the EUSPA (European Union Agency for the Space Programme) panel of ANSPs for EGNSS. The meeting deal with topics related to deployment of European GNSS applications for aviation. Speaker from DREAMS: Patrizio Vanni.
SRAP and IGS to SRAP solution promotion	Social Media	01/02/2021 - 30/09/2022	Promote the SESAR solutions, benefits and VLD. The solutions are mentioned and explained at each event in which DREAMS participates and shared on the DREAMS website and LinkedIn.

			https://www.vld1dreams.com/about#solutions https://www.linkedin.com/feed/update/urn:li:activity:6874704283552628736 https://www.linkedin.com/feed/update/urn:li:activity:6863437396340555776 https://www.linkedin.com/feed/update/urn:li:activity:6876534416563429376
Frankfurt Flight Trials	Social Media	20/07/2022	https://www.linkedin.com/feed/update/urn:li:activity:6955515992051449856 And press release published by DFS: https://www.dfs.de/homepage/en/media/press/2022/18-07-2022-world-premiere-at-frankfurt-airport-satellite-based-precision-landings-possible-even-in-bad-weather/
"Energy balance" presentation at ICAS – Stockholm	Event	08/09/2022	"Energy balance" presentation at 33rd ICAS (Congress of the International Council of the Aeronautical Sciences) – Stockholm by Dennis Vechtel from DLR: Assessment of energy-efficient approaches with increased glideslope angles. Presentation available for download in DREAMS website: https://www.vld1dreams.com/about#documents
Participation at 21st I-GWG meeting	Event	08/09/2022	Presentation about GLS CAT III with ISGS at Frankfurt by Olaf Weber (DFS) in the 21st International GBAS Working Group (I-GWG) meeting in EUROCONTROL's Brussels Headquarters on 8 September 2022 Presentation available for download in DREAMS website: https://www.vld1dreams.com/about#documents

IGS Ciampino video	Other media	26/10/2022	Video of flight tests at Ciampino. The video will be released to the public on the day of the final results dissemination event.

Table 10: Communication and Dissemination activities completed

The following table shows the final dissemination results event that will be carried out in the next month. It is worth emphasizing that the final results dissemination event will be held before the Maturity Gate on the 17th of November 2022.

C&D activities for coming period	Type of activity	Date	Description
DREAMS final results dissemination event	Event	17/11/2022	Hybrid event: online and on-site in Madrid.

Table 11: Next Communication and Dissemination activities planned

6.2 Target Audience Identification

- **Interested general public:** informing of the benefits that society can obtain thanks to these procedures, such as the reduction of noise near airports or the reduction of flight delays due to weather conditions. Raise awareness of the sector's concern for the environment and the operations that will be carried out to help protect it. Definitions of the procedures and the GBAS have also been provided at a high-level and at a deeper level to engage the project audience and ensure that they would be able to understand more technical concepts.

- **Industry partners:** during the project, there has been information published about all partners and LTPs through LinkedIn and the DREAMS website for the knowledge of the audience, and we also collaborated by sharing information about projects such as PJ02.

- **Research Organisations and Universities**: generate knowledge about the new use of SRAP, IGS-to-SRAP and A-IGS and the benefits it offers to different communities as in the **SESAR Joint Undertaking Digital Academy Webinar.**

- **Organizational bodies:** including ICAO, EASA, EUROCONTROL, CE, EUROCAE and EBAA. National and international standardization bodies will be reached with specific strategies and operations. They can be the main users of the improvement procedures designed by DREAMS to proceed with the standardisation of these EAPs that guarantee benefits to society, the environment, runway performance and the ATM community. An example of this is the participation of DREAMS in events such as the “ICAO EUR PBNC TF/5 - EUROCONTROL NSG/32” meeting or the EUROCONTROL LATO-36 meeting.

- **ATM community** (airspace users, ATCOs, ANSP, airport operators, industry associations, aircraft manufactures, avionic and ATC systems): these stakeholders will be aware of the benefits to air traffic of these improvement procedures after having been provided with full information on the necessary enablers and recommended methodology after having successfully carried out operations of the project. We report on the application of new technologies to improve safety, sustainability and airport capacity towards greener aviation.

- **European and national aviation authorities:** they will be able to develop new regulations. The authorities will be able to use the results of the project as input for the development of new regulations and some aspects of the current regulations will be tested during the project, providing valuable feedback for the authorities.

- **SESAR staff:** highlight SESAR's support during the whole project by mentioning it in every communication and dissemination activity with the use of relevant keywords and hashtags related to DREAMS, SESAR3 JU and H2020.

6.3 Project High Level Messages

Key messages are a crucial mean to provide meaningful impacts and expected outputs to the audience. Hence, some high-level key messages have been developed for initial graphical material whereas additional messages targeting specific audiences have been developed during the C&D activities.

For this reason, all key messages defined in the DEMO plan have been respected and applied in all channels.

Key message 1: DREAMS project aims to develop and validate so-called Enhanced Arrival Procedures (EAP) through advanced GNSS navigation technologies to ensure sustainability and the increase of air traffic. SRAP and IGS-to-SRAP will provide environmental benefits and track performance benefits.

Key message 2: DREAMS project will ensure that the implementation of the new approach procedures will avoid delays caused by bad weather conditions, limit noise disturbances near airports, increase airport capacity and contribute to the environment by optimising fuel and reducing emissions.

Key message 3: DREAMS project will facilitate and enhance the deployment of GNSS across Europe through the introduction of GBAS CAT II/III by demonstrating the operational feasibility in real-world environments and the performance benefits that will be reflected in demonstration exercises.

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7 References

Content Development

[1] SESAR PJ02-02 D2.1.01 PJ02-02 OSED-SPR-Interop Part I, II, III, IV, V, Edition 00.01.00

Performance Management

[2] SESAR Performance Framework ed. 01.00.01 - 2019 (1.0)

Validation

[3] SESAR D4.2.004 - PJ.02-W2-14.2 VALP V3 Final

[4] SESAR D4.3.004 - PJ.02-W2-14.3 VALP Final

[5] SESAR D4.5.004 - PJ.02-W2-14.5 VALP Final

[6] SESAR D1.3 DEMO Plan Part I v 00.01.00

Safety

[7] SESAR Safety - Guidance to Execute Proof of Concept - VLD 00.04.00

Human Performance

[8] SESAR Human Performance Assessment Process V1 to V3 v 00.03.02

Environment Assessment

[9] SESAR ENV - Guidance Reference Material 00.04.00

Programme management

For what concerns the general collaboration between all the members of the programme:

[10]SESAR 2020 Membership Agreement

[11]SESAR 2020 Programme Management Plan

For what concerns the definition of the solutions being addressed by the project, their initial maturity levels and the target maturity dates aimed for:

[12]ATM Master Plan

[13]SESAR Maturity Report

[14]SESAR Release Strategy

For what concerns the specific scope of work covered by this project and the general way of working expected from all projects in the SESAR 2020 programme:

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[15]874469 DREAMS Grant Agreement

[16]SESAR 2020 Project Handbook W2

7.1 Reference Documents

[17]ED-78A GUIDELINES FOR APPROVAL OF THE PROVISION AND USE OF AIR TRAFFIC SERVICES SUPPORTED BY DATA COMMUNICATIONS.4

[18]SESAR Solution #55 (GAST-D) Data Pack

[19]SESAR Solution #119 (GLS CAT II operations using GBAS GAST-C) Data Pack

[20]SESAR Solution #55 (GAST-D) Data Pack

[21]SESAR Solution #119 (GLS CAT II operations using GBAS GAST-C) Data Pack

[22]SESAR D4.1 - Solution PJ.02-14.2 V3 Data Pack

[23]SESAR D4.2 - Solution PJ.02-14.3 V3 Data Pack

[24]SESAR D4.3- Solution PJ.02-14.5 V3 Data Pack

4

Appendix A Exercise VLD1-01 Report - SRAP & IGS-to-SRAP Twente Demonstration

A.1 Summary of the Demonstration Exercise VLD1-01 Plan

A.1.1 Exercise description and scope

The Exercise 01 scope can be found in the DREAMS DEMOP (intermediate version 00_00_05) section 5.1.1. In the remainder of this appendix, the designation "DEMOP" is used exclusively to refer to this particular intermediate version. This intermediate version was the one active at the time of performing Exercise 01.

A.1.2 Summary of Demonstration Exercise VLD1-01 Demonstration Objectives and success criteria

The Exercise 01 scope can be found in the DREAMS DEMOP section 5.1.3.

A.1.3 Summary of Validation Exercise VLD1-01 Demonstration scenarios

he Exercise 01 scope can be found in the DREAMS DEMOP section 5.1.4.

A.1.4 Summary of Demonstration Exercise VLD1-01 Demonstration Assumptions

The Exercise 01 scope can be found in the DREAMS DEMOP section 5.1.5.

A.1.4.1 Demonstration Assumptions

A.1.4.2 Aircraft configuration

The aircraft tested was MSN05284, an Airbus A319-112 equipped with CFM56-5B6/3 engines, registration D-AIBI, owned and operated by Lufthansa.

A.1.4.3 Test matrix

During the flight tests, for each landing, the aircraft did not arrive at touchdown and pilots performed a go-around to follow the 9 landing procedures in a row. Thus, to focus on the landing procedure only, recorded data has been truncated up to the start of the descent and down to 500ft of altitude for each run. Every run starts to descend around the same altitude of about 3000ft, after a plateau which allows the aircraft to place itself on the right track in the right direction. The lowest threshold of 500ft represents the minimum altitude where every run is still performing the landing procedure before the aircraft starts the next go-around procedure.

Recorded flights are marked using two runway designations: the RWY 06 threshold corresponds to the SRAP and it is located 1020m further away from the RWY 05 threshold on the same runway. Note that the RWY 05 Aiming Point (AP) is located at 386m from the RWY 05 threshold and the RWY 06 AP (SRAP) is located at 260m from the RWY 06 threshold. Therefore the two aiming points (for RWY 05 and for RWY 06) will be separated by 894m.

The input data is split into 9 approach runs, designated Run1 to Run9. Run characteristics are displayed in the following table:

Run	Landing weight (t)	Glide Slope (°)	Runway	Final conf Slat/Flap	Landing gear extension (Km from the runway threshold)	Auto-Pilot
3°_RWY05_Run1	50.2t	3°	05	3	7.7	AP ON
3°_RWY05_Run2	49.9t	3°	05	3	10.0	AP ON
3.5°_RWY06_Run3	49.4t	3.5°	06	Full	10.2	AP ON
3.5°_RWY06_Run4	49.2t	3.5°	06	3	9.5	AP ON
3.5°_RWY06_Run5	48.8t	3.5°	06	Full	10.1	AP OFF
3.5°_RWY06_Run6	48.4t	3.5°	06	3	10.3	AP OFF
3.5°_RWY06_Run7	48t	3.5°	06	Full	11.2	AP OFF
3°_RWY06_Run8	47.7t	3°	06	3	10.9	AP ON
3°_RWY06_Run9	47.4t	3°	06	Full	11.1	AP OFF

Test matrix

Flights ruled out of the simulations are presented below :

Run	Landing weight (t)	Glide Slope (°)	Runway	Final conf Slat/Flap	Reason for ruling out
3°_RWY05_Run1	49.9t	3°	05	3	S/F timings differ from other runs and trajectory aiming point was overshot
3.5°_RWY06_Run4	47.7t	3°	06	3	S/F and LG timings differ from other runs, as well as engine usage

3°_RWY06_Run9	47.4t	3°	06	Full	Bird avoidance trajectory modification

The datasets with similar Slat/Flap final configuration selected to evaluate each criterion are specified in the following subsets tables :

OBJ-02.02-V3-VALP-SRAP.0401 :

Run	Landing weight (t)	Glide Slope (°)	Runway	Final conf Slat/Flap	Landing gear extension (Km from the runway threshold)	Auto-Pilot
3°_RWY05_Run2	49.9t	3°	05	3	10.0	AP ON
3°_RWY06_Run8	47.7t	3°	06	3	10.9	AP ON

SRAP subset test matrix

OBJ-02.02-V3-VALP-ITSR.0401 :

Run	Landing weight (t)	Glide Slope (°)	Runway	Final conf Slat/Flap	Landing gear extension (Km from the runway threshold)	Auto-Pilot
3°_RWY05_Run2	49.9t	3°	05	3	10.0	AP ON
3.5°_RWY06_Run6	48.4t	3.5°	06	3	10.4	AP OFF

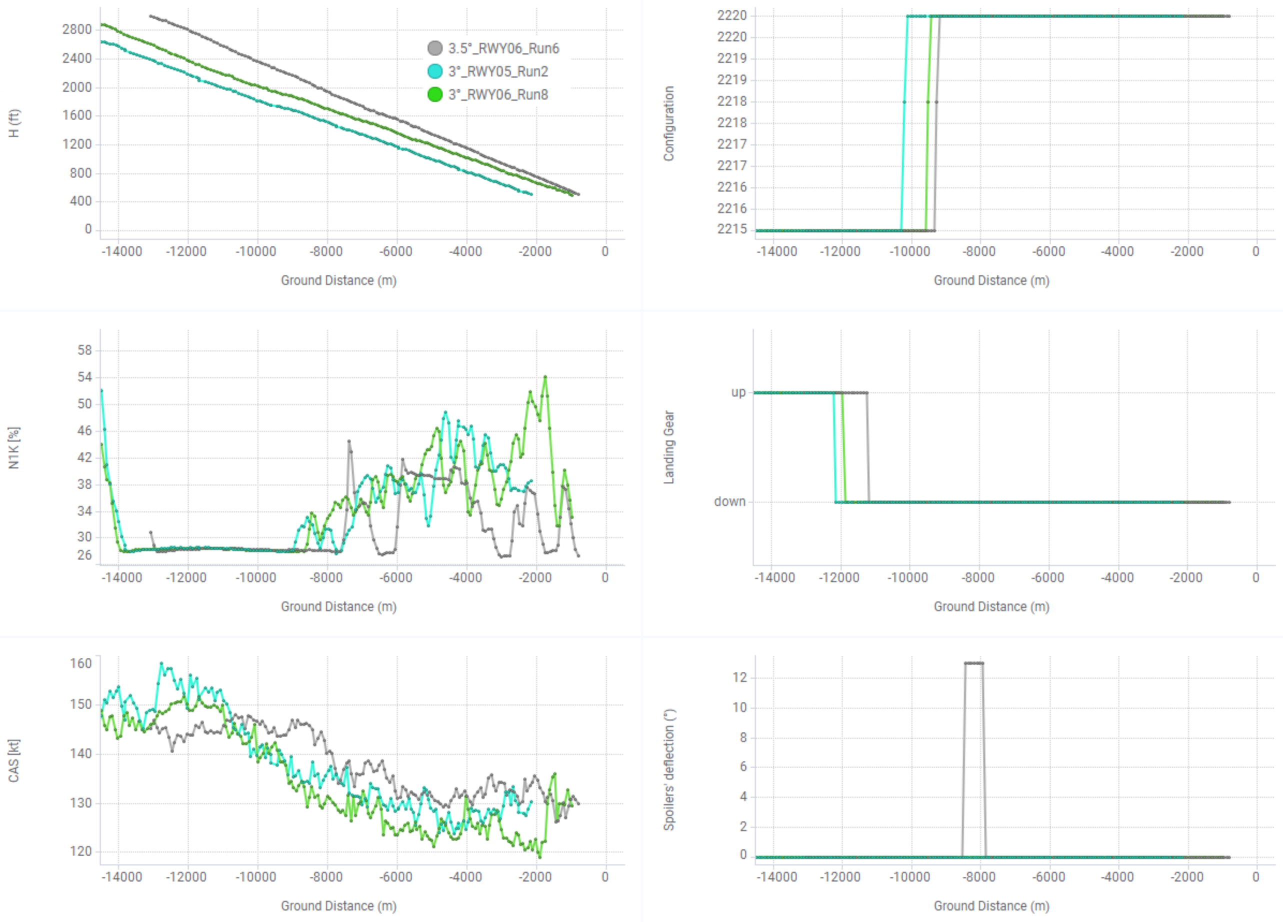
ITSR subset test matrix

A.1.4.4 Flight configuration

All the performance charts present the here-under parameters relative to the ground distance (in meter):

- Aircraft height in ft (H),
- Engine power in % (N1K),
- Calibrated air speed in kts (CAS),
- Slat/flap deflection in degrees (Configuration),

- Landing gear extension (Landing gear),
- Airbrakes extension (Spoilers deflection).

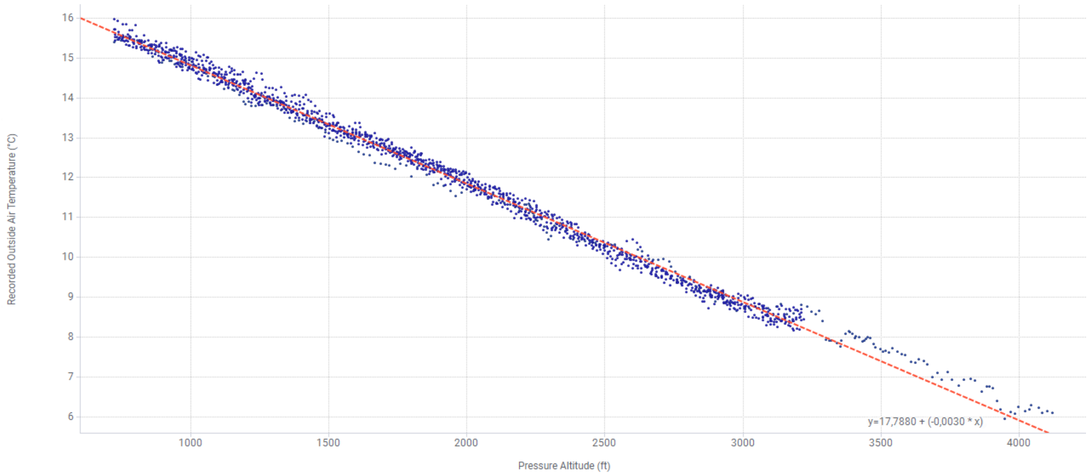


Run's performance in terms of ground distance in meters.

A.1.4.5 Weather

The flight test was performed on the 6th of October of 2021, between 11h30 and 13h29 local time.

Outside air temperature measurement at the aircraft is available in the flight data recording. The following figure presents air temperature against pressure altitude. With all the recorded data, a linear regression is used to generate a common temperature profile, which will have an effect in the atmospheric propagation of noise predictions.



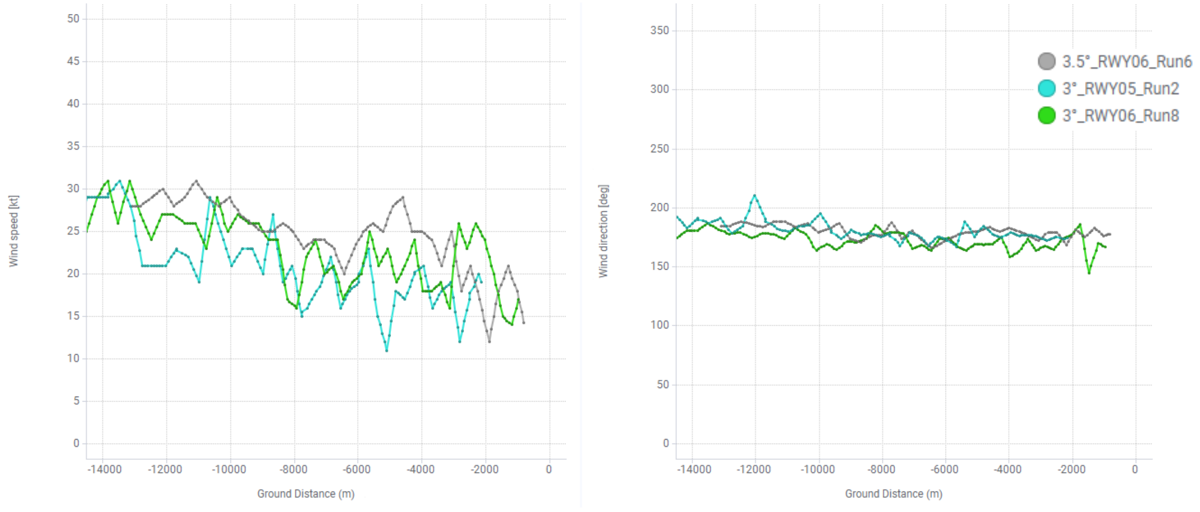
Outside Air Temperature (in blue) of all recorded runs in terms of pressure altitude in feet, with a linear regression.

In order to estimate geometric height from pressure altitude, altimeter setting QNH is set at 1004 hPa following on-site recordings included in the crew feedback.

Relative humidity in acoustic prediction is set at a value of 94%. This is an average of a nearby weather station measurements during the time of the tests. Measurements are obtained from Weather Underground (ref. X) which is a community of people sharing Personal Weather Station data.

Noise predictions take into account temperature and humidity profiles for calculating atmospheric absorption coefficient (SAE ARP5534 method) and for predicting noise sources (such jet noise).

Wind speed and direction is included in the measured data for each run.



Wind speed (kt) and direction (deg) of selected runs in terms of ground distance in meters.

Wind effect is not taken into account for noise calculations. It is presented in order to understand flight performance profiles.

A.1.4.6 Noise prediction

Noise impact has been evaluated with Airbus in-house tool, performing noise predictions based on a separate noise sources model. These models are calibrated on different noise measurements performed during the development of the aircraft, including flight tests, wind-tunnel tests and engine static tests. This tool is used along the available flight data and weather conditions to predict noise contours for each landing procedure run, as well as under-track noise.

The Airbus A319-112 aircraft possesses 8 different spoilers, 4 on each wing, numbered 1 to 4 from closest to farthest from the fuselage. Each pair follows a similar behaviour. During some runs (including Run6), the pilots deployed the spoilers either fully or at half the maximum angle.

The atmospheric absorption used is SAE ARP5534 and lateral attenuation is SAE AIR5662. Microphone elevation is set to 1.2m. For noise contours, the microphone zone grid is set up with a 100m delta in both X and Y directions. Under-track calculations are also set up with a 100m distance between microphones.

A.2 Deviation from the planned activities

Deviations concerning the test matrix (DEMOP section 5.1.8.2)

The run numbers used in the test matrix for flight 1 (of each flying day) were slightly different than published in the DEMOP. For flights 2 through 4 (of each flying day), only one run for the conventional runway 05 was included in the matrix. For reasons of clarity, the test matrix as used during the exercise is given in the following tables in accordance to the respective glide path angles for runway 06: 3.0, 3.5, 4.0 and 4.49 deg.

RUN	FAS	RPID	Channel	HEX	DESCRIPTION	PAPI 05	PAPI 06
1	FAS1	A530	20691	9434D0	RWY05, 3.00°	ON	OFF
2	FAS1	A530	20691	9434D0	RWY05, 3.00°	ON	OFF
3	FAS6	A630	24801	183850	RWY06, 3.00°	ON	ON
4	FAS1	A530	20691	9434D0	RWY05, 3.00°	ON	ON
5	FAS6	A630	24801	183850	RWY06, 3.00°	ON	ON
6	FAS6	A630	24801	183850	RWY06, 3.00°	ON	ON
7	FAS1	A530	20691	9434D0	RWY05, 3.00°	ON	ON
8	FAS6	A630	24801	183850	RWY06, 3.00°	ON	ON

Table 12: Test matrix for flight 1/part 1

RUN	FAS	RPID	Channel	HEX	DESCRIPTION	PAPI 05	PAPI 06
1	FAS1	A530	20691	9434D0	RWY05, 3.00°	ON	OFF
2	FAS8	A635	25623	9905D0	RWY06, 3.50°	ON	ON
3	FAS8	A635	25623	9905D0	RWY06, 3.50°	ON	ON
4	FAS8	A635	25623	9905D0	RWY06, 3.50°	ON	ON
5	FAS8	A635	25623	9905D0	RWY06, 3.50°	ON	ON
6	FAS8	A635	25623	9905D0	RWY06, 3.50°	ON	ON

Table 13: Test matrix for flight 2/part 2

RUN	FAS	RPID	Channel	HEX	DESCRIPTION	PAPI 05	PAPI 06
1	FAS1	A530	20691	9434D0	RWY05, 3.00°	ON	OFF
2	FAS9	A640	26034	196C90	RWY06, 4.00°	ON	ON
3	FAS9	A640	26034	196C90	RWY06, 4.00°	ON	ON
4	FAS9	A640	26034	196C90	RWY06, 4.00°	ON	ON
5	FAS9	A640	26034	196C90	RWY06, 4.00°	ON	ON
6	FAS9	A640	26034	196C90	RWY06, 4.00°	ON	ON

Table 14: Test matrix for flight 3/part 3

RUN	FAS	RPID	Channel	HEX	DESCRIPTION	PAPI 05	PAPI 06
1	FAS1	A530	20691	9434D0	RWY05, 3.00°	ON	OFF
2	FAS10	A645	26445	99D350	RWY06, 4.50°	ON	ON
3	FAS10	A645	26445	99D350	RWY06, 4.50°	ON	ON
4	FAS10	A645	26445	99D350	RWY06, 4.50°	ON	ON
5	FAS10	A645	26445	99D350	RWY06, 4.50°	ON	ON
6	FAS10	A645	26445	99D350	RWY06, 4.50°	ON	ON

Table 15: Test matrix for flight 4/part 4

For the exercise, six flying days (excluding the flights required for the check-out of the GBAS, the transportable PAPI and runway markings for runway 06) were planned with in total six test subjects and four flights per day.

A summary of the actual number of flights per flying day in the exercise is given below as it deviated slightly from the DEMOP:

Flying day 1 – 30 September 2021
At the end of the third flight of the day, the batteries of the transportable PAPI ran low, resulting in white light becoming less and less pronounced while red lights remained unchanged. This became obvious when the crew reported some lights to turn orange and later resulted in four reds irrespective of position above/below glide path. The test subjects' ratings for the last four runs of the third flight of the day were influenced by this PAPI issue. As there was not enough time to charge the

PAPI batteries prior to the fourth flight, it was decided to only fly two runs without making use of the transportable PAPI.

Flying day 2 – 01 October 2021
During the check-out flights prior to the Exercise and during the first flying day, experience has been gained on how to adjust the transportable PAPI system to different glide path angles. This resulted in shorter times required for the adjustments enabling the combination of flights. The test runs comprising the originally planned second and third flights have been combined in one second flight, totalling three flights for the entire day.

Flying day 3 – 04 October 2021
For same reasons as on Flying day 2, the originally planned first and second flights were combined as were the third and fourth flights, resulting in two flights for the entire day.

Flying day 4 – 05 October 2021
The two flights on this day were performed in the context of public relations. One of the NLR pilots however filled out the Post Experiment Questionnaire (PEQ) based on the approaches flown on this and other (as safety pilot) days.

Flying day 5 – 07 October 2021
The weather on 06 October was below VMC for the entire day. All flights had to be cancelled.
The weather on 07 October started below VMC but with a forecasted and noticeable improving trend. When the weather (forecast) was judged to become just right upon arrival in Twente, the take off in Rotterdam (home base of NLR aircraft) was commenced. However, when entering the Twente area, the weather was still below VMC. After a short stay overhead the field while assessing the meteorological situation for a swift improvement, the aircraft had to be returned to Rotterdam as the improvement was developing slower than expected. When the weather finally improved, time had become the limiting factor and only two flights could be performed, the runs in which were a selection from the runs in the originally planned four flights, but covering all (IGS-to-)SRAP angles.

Flying day 6 – 08 October 2021
Given the unfavourable weather forecasts for 11 October and onwards, this flying day was planned as the final day. In order to get a total of six test subjects involved, two test subjects were flying on this sixth flying day, thereby reducing the number of runs (note: some pilots during the exercise remarked, after repeating the approaches twice, that they had seen enough), however, all (IGS-to-) SRAP angles were covered. Three flights took place: two flights with each another test subject and the final flight ferrying back to Rotterdam after refuelling at Twente.

A.3 Demonstration Exercise VLD1-01 Results

A.3.1 Summary of Demonstration Exercise VLD1-01 Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating enviro-ment	Exercise Results	Demonstration Objective Status
OBJ-02.02-V3-VALP-SRAP.0201	Impact on crew task performance	CRT-02.02-V3-VALP-SRAP.0201-001	Pilot succeeds to accomplish a SRAP operation without any difficulty under VMC	Airport - Other	See section A.3.2 /1	OK
		CRT-02.02-V3-VALP-SRAP.0201-002	Impact on crew cooperation and crew workload remains within acceptable limit	Airport - Other	See section A.3.2 /1	OK
EX3-OBJ-VLD-01-0203-001	SRAP additional runway markings impact under VMC on SRAP safety from crew perspective	EX3-CRT-VLD-01-0203-001	There is evidence that the additional SRAP runway markings are sufficient to not negatively impact SRAP procedures under VMC compared to the reference scenario, from the perspective of the crew	Airport – Other	See section A.3.2/2	OK
EX3-OBJ-VLD-01-0203-002	SRAP additional PAPI impact under VMC on SRAP safety from crew perspective	EX3-CRT-VLD-01-0203-002	There is evidence that the additional SRAP PAPI is sufficient to not negatively impact SRAP procedures compared to the reference scenario, from the perspective of the crew	Airport – Other	See section A.3.2 /3	OK

EX3-OBJ-VLD-01-0203-003	SRAP additional runway markings impact under VMC on nominal threshold approach safety from crew perspective	EX3-CRT-VLD-01-0203-003	There is evidence that the additional SRAP runway markings do not negatively impact normal approach procedures to nominal threshold compared to the reference scenario, from the perspective of the crew	Airport - Other	See section A.3.2 /4	OK
EX3-OBJ-VLD-01-0203-004	SRAP additional PAPI impact under VMC on nominal threshold approach safety from crew perspective	EX3-CRT-VLD-01-0203-004	There is evidence that the additional SRAP PAPI does not negatively impact normal approach procedures to nominal threshold compared to the reference scenario, from the perspective of the crew	Airport - Other	See section A.3.2 /5	OK
EX1-OBJ-VLD-01-0203-005	Nominal runway markings and nominal PAPI impact under VMC on SRAP safety from crew perspective	EX3-CRT-VLD-01-0203-005	There is evidence that the nominal runway markings and nominal PAPI are sufficiently distinguishable from SRAP markings and PAPI in order not to result in unacceptable safety from the perspective of the crew	Airport - Other	See section A.3.2/6	OK
OBJ-02.02-V3-VALP-SRAP.0204	SRAP operational feasibility under	CRT-02.02-V3-VALP-SRAP.0204-001	Pilot succeeds to manage SRAP operation by	Airport - Other	See section A.3.2/7	OK

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	VMC from crew perspective		applying existing SOPs			
		CRT-02.02-V3-VALP-SRAP.0204-002	Pilots are confident when flying a SRAP operation	Airport - Other	See section A.3.2/7	OK
OBJ-02.02-V3-VALP-SRAP.0205	SRAP impact on SOPs	CRT-02.02-V3-VALP-SRAP.0205-001	Pilot actions in SRAP approach allow to successfully stabilize the aircraft before landing (manage energy,..)	Airport - Other	See section A.3.2 /8	OK
		CRT-02.02-V3-VALP-SRAP.0205-002	Impact of SRAP approach, existing SOPs are easily manageable by pilots (no impact on task performance)	Airport - Other	See section A.3.2 /8	OK
OBJ-02.02-V3-VALP-SRAP.0301	SRAP impact on phraseology	CRT-02.02-V3-VALP-SRAP.0301-001	Proposed phraseology does not lead to errors related to perception & interpretation of auditory information	Airport - Other	See section A.3.2 /9 ATC Not assessed; however test subjects are OK (although minor doubt exist on what SRAP runway designator to use)	NOK (no ATC involved at Twente Airport)
		CRT-02.02-V3-VALP-SRAP.0301-002	Pilots accept and judge the proposed phraseology as being appropriate for all encountered operating conditions	Airport - Other	See section A.3.2 /9 ATC communication exchange Not assessed; however	NOK (no ATC involved at Twente Airport)

					test subjects are OK (although minor doubt exist on what SRAP runway designator to use)	
EX3-OBJ-VLD-01-0201-001	3.5 deg IGS-to-SRAP impact under VMC on crew task performance	EX3-CRT-VLD-01-0201-001-01	Pilot succeeds to accomplish a 3.5 deg IGS-to-SRAP operation without any difficulty	Airport - Other	See section See section A.3.2 /10	OK
		EX3-CRT-VLD-01-0201-001-02	Impact on crew cooperation and crew workload for 3.5 deg IGS-to-SRAP operation remains within acceptable limit	Airport - Other	See section A.3.2/10	OK
EX3-OBJ-VLD-01-0201-002	4.0 deg IGS-to-SRAP impact under VMC on crew task performance	EX3-CRT-VLD-01-0201-002-01	Pilot succeeds to accomplish a 4.0 deg IGS-to-SRAP operation without any difficulty	Airport - Other	See section A.3.2 /11	OK
		EX3-CRT-VLD-01-0201-002-02	Impact on crew cooperation and crew workload for 4.0 deg IGS-to-SRAP operation remains within acceptable limit	Airport - Other	See section A.3.2 /11	OK
EX3-OBJ-VLD-01-0201-003	4.49 deg IGS-to-SRAP impact under VMC on crew task performance	EX3-CRT-VLD-01-0201-003-01	Pilot succeeds to accomplish a 4.49 deg IGS-to-SRAP operation without any difficulty	Airport - Other	See section A.3.2/12	OK
		EX3-CRT-VLD-01-0201-003-02	Impact on crew cooperation and crew workload for 4.49 deg IGS-to-SRAP	Airport - Other	See section A.3.2/12	OK

			operation remains within acceptable limit			
EX3-OBJ-VLD-01-0203-001	SRAP additional runway markings impact under VMC on IGS-to-SRAP safety from crew perspective	EX3-CRT-VLD-01-0203-001	There is evidence that the additional SRAP runway markings are sufficient to not negatively impact IGS-to-SRAP procedures compared to the reference scenario, from the perspective of the crew	Airport - Other	See section A.3.2/13	OK
EX3-OBJ-VLD-01-0203-002	IGS-to-SRAP additional PAPI impact under VMC on IGS-to-SRAP safety from crew perspective	EX3-CRT-VLD-01-0203-002	There is evidence that the additional IGS-to-SRAP PAPI is sufficient to not negatively impact IGS-to-SRAP procedures compared to the reference scenario, from the perspective of the crew	Airport - Other	See section A.3.2/14	OK
EX3-OBJ-VLD-01-0203-003	Nominal runway markings and nominal PAPI impact under VMC on IGS-to-SRAP safety from crew perspective	EX3-CRT-VLD-01-0203-003	There is evidence that the nominal runway markings and nominal PAPI are sufficiently distinguishable from SRAP markings and PAPI in order not to result in unacceptable safety from the perspective of the crew	Airport - Other	See section A.3.2/15	OK

OBJ-02.02-V3-VALP-ITSR.0204	IGS-to-SRAP operational feasibility under VMC from crew	CRT-02.02-V3-VALP-ITSR.0204-001	Pilot succeeds to manage IGS-to-SRAP operation by applying existing SOPs	Airport - Other	See section A.3.2/16	OK
		CRT-02.02-V3-VALP-ITSR.0204-002	Pilots are confident when flying an IGS-to-SRAP operation	Airport – Other	See section A.3.2/16	OK
OBJ-02.02-V3-VALP-ITSR.0205	IGS-to-SRAP impact under VMC on SOPs	CRT-02.02-V3-VALP-ITSR.0205-001	Pilot actions in IGS-to-SRAP approach allow to successfully stabilize the aircraft before landing (manage energy,..)	Airport – Other	See section A.3.2/17	OK
		CRT-02.02-V3-VALP-ITSR.0205-002	Impact of IGS-to-SRAP approach, existing SOPs are easily manageable by pilots (no impact on task performance)	Airport - Other	See section A.3.2/17	OK
OBJ-02.02-V3-VALP-ITSR.0301	IGS-to-SRAP impact on phraseology	CRT-02.02-V3-VALP-ITSR.0301-001	Proposed phraseology does not lead to errors related to perception & interpretation of auditory information	Airport - Other	See section A.3.2/18 ATC Not assessed, however test subjects are OK (although minor doubt exist on what SRAP runway designator to use)	Partially OK / OK
		CRT-02.02-V3-VALP-ITSR.0301-002	Pilots accept and judge the proposed phraseology as being	Airport - Other	See section A.3.2/18 ATC communic	Partially OK / OK

			appropriate for all encountered operating conditions		ation exchange Not assessed; however test subjects are OK (although minor doubt exist on what SRAP runway designator to use)	
OBJ-02.02-V3-VALP-SRAP.0401	Reduction of the noise impact around the airports due to SRAP implementation	CRT-02.02-V3-VALP-SRAP.0401-001	Relative noise scale results positive with SRAP use	Airport - Other	Up to 4dBA under-track LAmax reduction compared to the reference run	OK
		CRT-02.02-V3-VALP-SRAP.0401-002	Noise contours location is shifted to airport area	Airport - Other	Visible acoustic footprint shift towards the airport area and away from inhabitants	OK
		CRT-02.02-V3-VALP-SRAP.0401-003	Average noise value is not increased	Airport - Other	Test run shows a positive under-track noise reduction compared to the reference run	OK
OBJ-02.02-V3-VALP-ITSR.0401	To confirm that the IGS-to-SRAP concept reduces the noise impact in the airport surroundings	CRT-02.02-V3-VALP-ITSR.0401-001	Relative noise scale results positive with IGS-to-SRAP use	Airport - Other	Up to 5dBA under-track LAmax reduction	OK

					compared to the reference run	
		CRT-02.02-V3-VALP-ITSR.0401-002	Noise contours location is shifted to airport area	Airport - Other	Visible acoustic footprint shift towards the airport area and away from inhabitants	OK
		CRT-02.02-V3-VALP-ITSR.0401-003	Size of noise contours is reduced with IGS-to-SRAP concept	Airport - Other	Reduction of 29% for 70dBA LAmax and 72% for 75dBA LAmax iso-noise contour	OK
		CRT-02.02-V3-VALP-ITSR.0401-004	Average noise value is not increased	Airport - Other	Test run shows a positive under-track noise reduction and footprint reduction compared to the reference run	OK

Table 16: Exercise 1 Demonstration Results

A.3.1.1 Results per KPA

Safety

The (IGS-to-)SRAP approaches have been performed at Twente Airport under VMC and daylight conditions with NLR's Cessna Citation II research aircraft. Twente Airport is an uncontrolled VFR-only airport.

Under above conditions, and judging from the test subjects' questionnaires, the (IGS-to-)SRAP approaches are acceptable. The approaches could be flown safely and without confusion on which approach and PAPI to use. Perceived situational awareness was good. The PAPI indications from the

PAPI that is not used, are not compromising safety. The second (IGS-to-)SRAP PAPI is helpful for outside visual guidance to the second runway threshold. The test subjects were comfortable with flying an approach with two PAPI's active at the same time. The additional runway markings for the SRAP runway could be clearly distinguished from the conventional markings and are required for safe operations to the second threshold. The steeper the IGS-to-SRAP approach, the better the runways can be distinguished. At the same time, the SRAP markings do not bother the test subjects when flying an approach to the conventional first threshold and, vice versa, conventional markings are no factor when flying to the second threshold. Overall, test subjects have indicated that they have flown all approaches to the SRAP configured runway (i.e., both to the first and second threshold while both PAPI's are active) safely and with confidence. The procedures are straightforward and well within the capabilities of any current crew. Note however that for 4.0 and 4.49 deg IGS-to-SRAP approaches, although within normal approach design criteria for the Citation and demonstrated by the Citation in EXE01, may require careful energy management for larger aircraft.

Finally, a subset of the (IGS-to-)SRAP approaches have also been flown by a Boeing 737 Max (TUI) and Airbus A319 CEO (LH) for glide path angles 3.0 and 3.5 deg. Crew's safety perception for these approaches were in line with those stated in above paragraph.

Human Performance

The (IGS-to-)SRAP approaches have been performed at Twente Airport under VMC and daylight conditions with NLR's Cessna Citation II research aircraft. Twente Airport is an uncontrolled VFR-only airport.

Under above conditions, the impact of (IGS-to-)SRAP approaches on crew coordination and work load remained within acceptable limits. SOPs could be used, however, small changes/additions to the approach briefing and crosschecks to verify the correct runway end will need to be incorporated in the SOPs and trained. For approaches to runways with conventional and (IGS-to-)SRAP procedures, it may be good for the mindset to include the runway designation also in the 500 ft call. Twente Airport does not provide an ATC environment. Nevertheless, the specific ATC phraseology for dual threshold operations (SRAP and IGS-to-SRAP) was simulated within the cockpit during most runs or otherwise judged by the test subjects from paper and imagination. The phraseology was in this respect found good, i.e. most test subjects agreed on the related questions/statements on the questionnaires. Although some test subjects had some minor doubts on what runway designator to use. The choice of runway designator remains subject to personal preference: some subjects prefer e.g. "05A/B" over "05/06". The mentioning of the first/second threshold is the most important part. There is no difficulty to associate lower glide slope (traffic information) with first threshold (landing clearance) or upper with second. "Lower/upper" vs. "first/second" allow crew to clearly distinguish between a traffic information and a landing clearance. All in all, it should be reminded that Twente Airport is an airport without ATC and therefore the demonstration objectives related to phraseology could not be assessed in a strict sense and for that matter could not be included in the DEMOP. Furthermore, if PAPIs are on opposite sides of the runway for first and second threshold (as was the case for EXE01), it could be possible and considered to add that information to the phraseology as an additional distinguishing factor.

Finally, a subset of the (IGS-to-)SRAP approaches have also been flown by a Boeing 737 Max (TUI) and Airbus A319 CEO (LH) for glide path angles 3.0 and 3.5 deg. Crew's human performance perception for these approaches were in line with those stated in above paragraph.

Noise

The (IGS-to-)SRAP approaches performed at Twente Airport show a clear noise reduction. SRAP threshold displacement down the runway moves the ground noise contours towards the airport area. The IGS-to-SRAP procedure with 3°5 clearly reduces the ground noise contours with respect to the 3° slope. Both type of approaches (IGS-to-)SRAP provide noise benefits when flying over surrounding neighborhoods by increasing the altitude difference.

A.3.1.2 Results impacting regulation and standardisation initiatives

Results impacting regulation and standardization initiatives for (IGS-to-)SRAP operations can be subdivided into following new features. These features are deemed necessary or supportive to safely fly (IGS-to-)SRAP procedures in general and the EXE01 flight tests in particular and have therefore been applied during the EXE01 flight tests at Twente Airport. All these features were well accepted by the test subjects during EXE01.

Second runway markings

Second runway markings consist of following elements: transverse stripe, threshold ('zebra'), runway designation, touch down zone (length of which depends on the LDA for the second runway) and aiming point. Only deviation from ICAO Annex 14 concerns the transverse stripe, which was chosen to be a dashed instead of a solid line.

Second PAPI

In order to provide the crew with outside visual vertical guidance also when flying an approach to the second threshold, a second PAPI is positioned (in accordance with ICAO Annex 14) next to the aiming point of the second runway.

Approach charts

Approach charts were drafted for the EXE01 approach procedures. These charts include information on the runway layout containing both a conventional and an SRAP threshold, as well as information on the position and indication of both the conventional and SRAP PAPI's. Furthermore, the charts contain a caution box, outlined in red, indicating to the crew that two PAPI's are active. The box also contains information on which PAPI to disregard for the particular approach.

Phraseology

Twente Airport does not provide an ATC environment. Nevertheless, the specific ATC phraseology for dual threshold operations (SRAP and IGS-to-SRAP) was simulated within the cockpit during most runs or otherwise judged by the test subjects from paper and imagination. The phraseology was in this respect found good, i.e. most test subjects agreed on the related questions/statements on the questionnaires. Although some test subjects had some minor doubts on what runway designator to use. The choice of runway designator remains subject to personal preference: some subjects prefer e.g. “05A/B” over “05/06”. The mentioning of the first/second threshold is the most important part. There is no difficulty to associate lower glide slope (traffic information) with first threshold (landing clearance) or upper with second. “Lower/upper” vs. “first/second” allow crew to clearly distinguish between a traffic information and a landing clearance. All in all, it should be reminded that Twente Airport is an airport without ATC and therefore the demonstration objectives related to phraseology could not be assessed in a strict sense and for that matter could not be included in the DEMOP.

See also section Appendix E.

A.3.2 Analysis of Exercises Results per Demonstration objective

As the numbering of the Test Matrix has slightly changed (see Appendix A.2, the table in which the test runs and flight numbers are coupled to the PRQ and PEQ question numbers for each criteria has changed as well. The updated table is given in A.2. The criteria are thus checked against the PRQ/PEQ questions for the given Flights/Run numbers. Per criteria, the results are given in the sections further below. The Flights/Runs in this appendix section concern the flights performed with NLR's Cessna Citation II research aircraft.

For reasons of convenience, the PRQ and PEQ are copied here:

PRQ

1. In your opinion and during the last approach, the PAPI indications were acceptable.
2. In your opinion and during the last approach, the runway markings were acceptable.
3. In your opinion and during the last approach, the level of safety of a landing would have been acceptable.
4. In your opinion and during the last approach, your workload and task performance were acceptable.
5. In your opinion and during the last approach, there was never confusion regarding which runway threshold and aiming point to use.

PEQ

1. In your opinion, the runway markings and PAPI for the (IGS-to-)SRAP approaches to RWY06 are clearly distinguishable from the markings and PAPI for the conventional approaches to RWY05.
2. In your opinion, are SRAP runway markings sufficient to not negatively impact SRAP procedures when compared to normal approaches to the conventional threshold.
3. In your opinion, the simultaneous use of two PAPIs (one for each threshold) is acceptable.
4. In your opinion, final approach, landing and roll out on the conventional RWY05 are or would not have been unacceptably influenced by the additional SRAP runway markings.
5. In your opinion, final approach, landing and roll out on the conventional RWY05 are or would not have been unacceptably influenced by the additional SRAP PAPI indications.
6. In your opinion, the impact of the SRAP PAPI on SRAP approaches is comparable to normal approaches to the conventional threshold/PAPI.
7. In your opinion, not having approach lighting/cross bars for SRAP RWY06 is acceptable under the conditions as present during the approaches.
8. In your opinion, the SRAP approaches are acceptable.
9. In your opinion, SRAP operations can be managed by applying existing SOPs.

10. In your opinion, you were confident in flying SRAP operations.
11. In your opinion, 3.5 deg IGS-to-SRAP approaches are acceptable.
12. In your opinion, 4.0 deg IGS-to-SRAP approaches are acceptable.
13. In your opinion, 4.5 deg IGS-to-SRAP approaches are acceptable.
14. In your opinion, the impact of the SRAP runway markings on (IGS-to-)SRAP approaches is comparable to normal approaches to the conventional threshold/runway markings.
15. In your opinion, the impact of the SRAP PAPI on IGS-to-SRAP approaches is comparable to normal approaches to the conventional threshold/PAPI.
16. In your opinion, IGS-to-SRAP operations can be managed by applying existing SOPs.
17. In your opinion, you were confident in flying IGS-to-SRAP operations.
18. In your opinion, proposed phraseology for SRAP operations do not lead to errors related to perception & interpretation of auditory information.
19. In your opinion, pilots accept and judge the proposed phraseology as being appropriate for all encountered SRAP operating conditions.
20. In your opinion, proposed phraseology for (IGS-to-)SRAP operations is unambiguous and acceptable.
21. In your opinion, the approach charts provided all required information and were acceptable.
22. In your opinion, the (IGS-to-)SRAP RWY designation “05” was acceptable.

Each question of the PRQ and PEQ could be answered by checking one of six boxes:

- 1. Completely disagree
- 2. Mostly disagree
- 3. Slightly disagree
- 4. Slightly agree
- 5. Mostly agree
- 6. Completely agree

For the evaluation of the results, these six answers were given the respective values of 1 (completely disagree) to 6 (completely agree). A particular criteria is therefore considered “passed” when the average values of the particular set of questions (for the particular set of flights/runs – see A.2) all exceed 3.5 and considered “failed” when one or more questions score on average below 3.5.

Before the results are analysed for each demonstration objective in the current chapter, first an overview is given of some general data/information concerning the flight tests:

An overview and some anonymous information of the test subjects that took part in the experiments with the PH-LAB is given in the table in next page.

The questionnaire scores are given per test subject in the tables in next pages for respectively the PRQ and PEQ as indicated in the caption.

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	CRITERIA	RESEARCH QUESTION	PRQ	PEQ	RUN	2	3	4	5	6	7	8	2	3	4	5	6	2	3	4	5	6	2	3	4	5	6
1	CRT-02.02-V3-VALP-SRAP.0201-001	Does the pilot succeed to accomplish a SRAP operation without any difficulty?	1,2,3,4,5	3,7,8,20,21,22			x		x	x		x															
2	CRT-02.02-V3-VALP-SRAP.0201-002	Does impact on crew cooperation and crew workload remain within acceptable limit?	4				x		x	x		x															
3	EX3-CRT-VLD-01-0203-001	Are SRAP runway markings sufficient to not negatively impact SRAP procedures in VMC compared to the reference scenario, from the perspective of the crew?	2,5	2,22		x	x		x	x		x															
4	EX3-CRT-VLD-01-0203-002	Is the SRAP PAPI sufficient to not negatively impact SRAP procedures in VMC compared to the reference scenario, from the perspective of the crew?	1,5	6		x	x		x	x		x															
5	EX3-CRT-VLD-01-0203-003	Do the SRAP runway markings not negatively impact normal approach procedures to nominal threshold compared to the reference scenario in VMC, from the perspective of the crew?	2,4,5	4		x		x			x																
6	EX3-CRT-VLD-01-0203-004	Does the SRAP PAPI not negatively impact normal approach procedures to nominal threshold in VMC compared to the reference scenario, from the perspective of the crew?	1,4,5	5		x		x			x																
7	EX3-CRT-VLD-01-0203-005	Are the nominal runway markings and nominal PAPI sufficiently distinguishable from SRAP markings and PAPI in order not to result in unacceptable safety from the perspective of the crew?	1,2,3,5	1,22		x	x	x	x	x	x	x															
8	CRT-02.02-V3-VALP-SRAP.0204-001	Does pilot succeed to manage SRAP operation by applying existing SOPs?		9			x		x	x		x															
9	CRT-02.02-V3-VALP-SRAP.0204-002	Are pilots confident when flying a SRAP operation?	1,2,3,4,5	10			x		x	x		x															
10	CRT-02.02-V3-VALP-SRAP.0205-001	Do pilot actions in SRAP approach allow to successfully stabilize the aircraft before landing (manage energy,..)?	3,4				x		x	x		x															
11	CRT-02.02-V3-VALP-SRAP.0205-002	Are impact of SRAP approach, existing SOPs easily manageable by pilots (no impact on task performance)?	4	9			x		x	x		x															
12	CRT-02.02-V3-VALP-SRAP.0301-001	Does proposed phraseology not lead to errors related to perception & interpretation of auditory information?		20			x	x	x	x	x	x															
13	CRT-02.02-V3-VALP-SRAP.0301-002	Do pilots accept and judge the proposed phraseology as being appropriate for all encountered operating conditions?		20			x	x	x	x	x	x															
14	EX3-CRT-VLD-01-0201-001-01	Does pilot succeed to accomplish a 3.5 deg IGS-to-SRAP operation without any difficulty?	1,2,3,4,5	3,7,11,20,21,22									x	x	x	x	x										
15	EX3-CRT-VLD-01-0201-001-02	Does impact on crew cooperation and crew workload for 3.5 deg IGS-to-SRAP operation remain within acceptable limit?	4										x	x	x	x	x										
16	EX3-CRT-VLD-01-0201-002-01	Does pilot succeed to accomplish a 4.0 deg IGS-to-SRAP operation without any difficulty?	1,2,3,4,5	3,7,12,20,21,22														x	x	x	x	x					
17	EX3-CRT-VLD-01-0201-002-02	Does impact on crew cooperation and crew workload for 4.0 deg IGS-to-SRAP operation remain within acceptable limit?	4															x	x	x	x	x					
18	EX3-CRT-VLD-01-0201-003-01	Does pilot succeed to accomplish a 4.49 deg IGS-to-SRAP operation without any difficulty?	1,2,3,4,5	3,7,13,20,21,22																			x	x	x	x	x
19	EX3-CRT-VLD-01-0201-003-02	Does impact on crew cooperation and crew workload for 4.49 deg IGS-to-SRAP operation remain within acceptable limit?	4																				x	x	x	x	x
20	EX3-CRT-VLD-01-0203-001	Are the SRAP runway markings sufficient to not negatively impact IGS-to-SRAP procedures compared to the reference scenario, from the perspective of the crew?	2,5	14,22		x							x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
21	EX3-CRT-VLD-01-0203-002	Is the IGS-to-SRAP PAPI sufficient to not negatively impact IGS-to-SRAP procedures compared to the reference scenario, from the perspective of the crew?	1,5	15		x							x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
22	EX3-CRT-VLD-01-0203-003	Are the nominal runway markings and nominal PAPI sufficiently distinguishable from SRAP markings and PAPI in order not to result in unacceptable safety from the perspective of the crew?	1,2,3,5	1,22									x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
23	CRT-02.02-V3-VALP-ITSR.0204-001	Does pilot succeed to manage IGS-to-SRAP operation by applying existing SOPs?		16									x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
24	CRT-02.02-V3-VALP-ITSR.0204-002	Are pilots confident when flying a IGS-to-SRAP operation?	1,2,3,4,5	17									x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
25	CRT-02.02-V3-VALP-ITSR.0205-001	Do pilot actions in IGS-to-SRAP approach allow to successfully stabilize the aircraft before landing (manage energy,..)?	3,4										x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
26	CRT-02.02-V3-VALP-ITSR.0205-002	Are impact of IGS-to-SRAP approach, existing SOPs easily manageable by pilots (no impact on task performance)?	4	16									x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
27	CRT-02.02-V3-VALP-ITSR.0301-001	Does proposed phraseology not lead to errors related to perception & interpretation of auditory information?		20									x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
28	CRT-02.02-V3-VALP-ITSR.0301-002	Do pilots accept and judge the proposed phraseology as being appropriate for all encountered operating conditions?		20									x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 17: Combination of PRQ and PEQ question numbers and Flight/Run numbers to be used as per criteria.

Test Subject	Age	Test pilot	Total flt hrs	A/c type	Remarks
A	40-50	yes	4600	B737NG, C550	
B	20-30	no	210	DA42, SE	
C	30-40	no	4000	B737NG, F16	
D	--	--	--	--	Did not fly experiment due to weather
E	50-60	no	1600	SA226/7, C550	
F	40-50	yes	11000	B747-3/400, B737PG+NG	
G	50-60	no	14500	DC10, A310, B767, B737, A330	

Table 18: Overview test subjects on PH-LAB

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Red scores indicate PAPI 06 not aligned with GP

Blue scores indicate PAPI 06 OFF

Test subject									
A	FLT	1							
	RUN	1	2	3	4	5	6	7	8
	Q1	/	6	4	6	5	3	6	5
	Q2	/	5	6	6	6	6	6	6
	Q3	/	6	6	6	6	6	6	6
	Q4	/	5	5	6	6	6	6	6
	Q5	/	6	5	6	6	6	6	6
	FLT	2							
	RUN	1	2	3	4	5	6		
	Q1	x	5	6	6	6	6		
	Q2	x	6	6	6	6	6		
	Q3	x	6	6	6	6	6		
	Q4	x	6	6	6	6	6		
	Q5	x	6	6	6	6	6		
	FLT	3							
	RUN	1	2	3	4	5	6-1	6-2	
	Q1	x	6	6	2	1	1	--	
	Q2	x	6	6	6	6	6	--	
	Q3	x	6	6	3	4	5	--	
	Q4	x	6	6	5	5	5	--	
	Q5	x	6	6	2	2	2	--	
	FLT	4							
	RUN	1	2	3	4	5	6		
	Q1	x	--	--	x	x	x		
	Q2	x	6	6	x	x	x		
	Q3	x	6	6	x	x	x		
	Q4	x	6	6	x	x	x		
	Q5	x	6	6	x	x	x		

Test subject									
B	FLT	1							
	RUN	1	2	3	4	5	6	7	8
	Q1	/	5	5	5	4	5	5	4
	Q2	/	4	4	5	5	5	5	5
	Q3	/	5	5	5	5	5	5	4
	Q4	/	5	4	4	5	4	5	4
	Q5	/	4	4	5	4	5	5	4
	FLT	2							
	RUN	1	2	3	4	5	6		
	Q1	5	5	5	5	5	4		
	Q2	5	5	4	5	5	5		
	Q3	5	4	4	4	5	5		
	Q4	5	4	5	4	4	5		
	Q5	4	5	4	5	5	4		
	FLT	3							
	RUN	1	2	3	4	5	6		
	Q1	3	5	5	5	3	5		
	Q2	5	5	5	5	5	5		
	Q3	5	4	4	--	5	5		
	Q4	4	4	4	4	5	4		
	Q5	4	5	5	4	4	5		
	FLT	4							
	RUN	1	2	3	4	5	6		
	Q1	5	5	5	5	5	5		
	Q2	5	5	5	5	5	5		
	Q3	5	4	4	5	5	5		
	Q4	5	4	4	4	4	5		
	Q5	5	5	5	5	5	5		

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Test subject									
C	FLT	1							
	RUN	1	2	3	4	5	6	7	8
	Q1	3	5	6	5	6	6	6	4
	Q2	6	6	6	6	6	6	6	6
	Q3	6	6	6	6	6	6	6	6
	Q4	6	6	6	6	6	6	6	6
	Q5	6	6	6	6	6	6	6	6
	FLT	2							
	RUN	1	2	3	4	5	6		
	Q1	6	6	6	6	6	6		
	Q2	6	6	6	6	6	6		
	Q3	6	6	6	6	6	6		
	Q4	6	6	6	6	6	6		
	Q5	6	6	6	6	6	6		
	FLT	3							
	RUN	1	2	3	4	5	6		
	Q1	6	5	5	6	6	5		
	Q2	6	6	6	6	6	6		
	Q3	6	6	6	6	6	6		
	Q4	6	6	6	6	6	6		
	Q5	6	6	6	6	6	6		
	FLT	4							
	RUN	1	2	3	4	5	6		
	Q1	6	6	6	6	6	6		
	Q2	6	6	6	6	6	6		
	Q3	6	6	6	6	6	6		
	Q4	6	6	6	6	6	6		
	Q5	6	6	6	6	6	6		

Test subject									
E	FLT	1							
	RUN	1	2	3	4	5	6	7	8
	Q1	6	x	6	x	6	x	x	x
	Q2	6	x	5	x	6	x	x	x
	Q3	6	x	6	x	6	x	x	x
	Q4	6	x	6	x	6	x	x	x
	Q5	6	x	6	x	6	x	x	x
	FLT	2							
	RUN	1	2	3	4	5	6		
	Q1	x	6	6	x	x	x		
	Q2	x	6	6	x	x	x		
	Q3	x	6	6	x	x	x		
	Q4	x	6	6	x	x	x		
	Q5	x	5	6	x	x	x		
	FLT	3							
	RUN	1	2	3	4	5	6		
	Q1	x	6	6	x	x	x		
	Q2	x	6	6	x	x	x		
	Q3	x	5	--	x	x	x		
	Q4	x	5	4	x	x	x		
	Q5	x	6	6	x	x	x		
	FLT	4							
	RUN	1	2	3	4	5	6		
	Q1	x	5	6	x	x	x		
	Q2	x	6	6	x	x	x		
	Q3	x	5	5	x	x	x		
	Q4	x	6	5	x	x	x		
	Q5	x	6	6	x	x	x		

Test subject									
F	FLT	1							
	RUN	1	2	3	4	5	6	7	8
	Q1	x	6	6	x	6	x	x	x
	Q2	x	6	6	x	6	x	x	x
	Q3	x	6	6	x	6	x	x	x
	Q4	x	6	6	x	6	x	x	x
	Q5	x	6	6	x	6	x	x	x
	FLT	2							
	RUN	1	2	3	4	5	6		
	Q1	6	6	6	x	x	x		
	Q2	6	6	6	x	x	x		
	Q3	6	6	6	x	x	x		
	Q4	6	6	6	x	x	x		
	Q5	6	6	6	x	x	x		
	FLT	3							
	RUN	1	2	3	4	5	6		
	Q1	6	6	6	x	x	x		
	Q2	6	6	6	x	x	x		
	Q3	6	6	6	x	x	x		
	Q4	6	6	6	x	x	x		
	Q5	6	6	6	x	x	x		
	FLT	4							
	RUN	1	2	3	4	5	6		
	Q1	x	6	6	x	x	x		
	Q2	x	6	6	x	x	x		
	Q3	x	6	6	x	x	x		
	Q4	x	6	6	x	x	x		
	Q5	x	6	6	x	x	x		

Test subject									
G	FLT	1							
	RUN	1	2	3	4	5	6	7	8
	Q1	x	x	6	6	6	x	x	x
	Q2	x	x	5	6	5	x	x	x
	Q3	x	x	5	5	5	x	x	x
	Q4	x	x	5	6	6	x	x	x
	Q5	x	x	6	6	6	x	x	x
	FLT	2							
	RUN	1	2	3	4	5	6		
	Q1	x	6	6	6	x	x		
	Q2	x	6	6	6	x	x		
	Q3	x	5	5	5	x	x		
	Q4	x	5	5	6	x	x		
	Q5	x	6	6	6	x	x		
	FLT	3							
	RUN	1	2	3	4	5	6		
	Q1	6	6	6	6	x	x		
	Q2	6	6	6	6	x	x		
	Q3	6	5	5	6	x	x		
	Q4	6	5	5	5	x	x		
	Q5	6	6	5	6	x	x		
	FLT	4							
	RUN	1	2	3	4	5	6		
	Q1	6	6	6	6	x	x		
	Q2	6	6	6	6	x	x		
	Q3	6	5	5	5	x	x		
	Q4	6	5	5	5	x	x		
	Q5	6	6	6	6	x	x		

Table 19: Post Run Questionnaire scores per test subject

	A	B	C	D	E	F	G	average
Q1	5	5	6	n/a	5	6	6	5.5
Q2	5	5	6	n/a	5	6	5	5.3
Q3	5	4	6	n/a	5	6	5	5.2
Q4	6	6	6	n/a	6	6	6	6.0
Q5	5	5	6	n/a	6	6	6	5.7
Q6	6	5	6	n/a	6	6	5	5.7
Q7	6	4	6	n/a	6	6	5	5.5
Q8	6	5	6	n/a	5	6	5	5.5
Q9	5	4	6	n/a	5	6	5	5.2
Q10	6	4	6	n/a	6	6	6	5.7
Q11	6	5	6	n/a	5	6	5	5.5
Q12	5	5	5	n/a	4	6	5	5.0
Q13	5	4	5	n/a	3	6	4	4.5
Q14	6	5	6	n/a	6	6	6	5.8
Q15	6	5	6	n/a	6	6	6	5.8
Q16	5	4	6	n/a	5	6	5	5.2
Q17	6	5	6	n/a	5	6	5	5.5
Q18	5	3	3	n/a	4	6	6	4.5
Q19	5	3	3	n/a	4	6	6	4.5
Q20	5	3	3	n/a	5	6	6	4.7
Q21	5	3	6	n/a	6	6	6	5.3
Q22	6	3	6	n/a	4	6	--	5.0

Table 20: Post Experiment Questionnaire scores per test subject

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A.3.2.1 OBJ-02.02-V3-VALP-SRAP.0201 Results

This objective concerns the impact on crew task performance. Two criteria have been defined:

- Criteria 1 - CRT-02.02-V3-VALP-SRAP.0201-001
  Pilot succeeds to accomplish a SRAP operation without any difficulty under VMC

PRQ results for FLT 1 / RUN 3, 5, 6, 8					
Test Subject	Q1 (PAPI) Average	Q2 (markings) Average	Q3 (safety) Average	Q4 (workload) Average	Q5 (confusion) Average
A	4.3	6.0	6.0	5.8	5.8
B	4.5	4.8	4.8	4.3	4.3
C	5.5	6.0	6.0	6.0	6.0
E	6.0	5.5	6.0	6.0	6.0
F	6.0	6.0	6.0	6.0	6.0
G	6.0	5.0	5.0	5.5	6.0
Overall average	5.4	5.5	5.6	5.6	5.7

PEQ results						
Test Subject	Q3	Q7	Q8	Q20	Q21	Q22
A	5	6	6	5	5	6
B	4	4	5	3	3	3
C	6	6	6	3	6	6
E	5	6	5	5	6	4
F	6	6	6	6	6	6
G	5	5	5	6	6	--
Average	5.2	5.5	5.5	4.7	5.3	5.0

Criteria 1 is passed as the average scores for all questions are well above 3.5.

- Criteria 2 - CRT-02.02-V3-VALP-SRAP.0201-002
  Impact on crew cooperation and crew workload remains within acceptable limit

PRQ results for FLT 1 / RUN 3, 5, 6, 8	
Test Subject	Q4 (workload) Average
A	5.8
B	4.3
C	6.0
E	6.0
F	6.0
G	5.5
Overall average	5.6

Criteria 2 is passed as the average scores for all questions are well above 3.5.

A.3.2.2 EX3-OBJ-VLD-01-0203-001 Results

This objective concerns the impact of SRAP additional runway markings under VMC on SRAP safety from crew perspective. One criteria has been defined:

Criteria 3 - EX3-CRT-VLD-01-0203-001
There is evidence that the additional SRAP runway markings are sufficient to not negatively impact SRAP procedures under VMC compared to the reference scenario, from the perspective of the crew.

PRQ results for FLT 1 / RUN 3, 5, 6, 8			vs.	PRQ results for FLT1 / RUN 2	
Test Subject	Q2 (markings) Average	Q5 (confusion) Average		Q2 (markings)	Q5 (confusion)
A	6.0	5.8		5	6
B	4.8	4.3		4	4
C	6.0	6.0		6	6
E	5.5	6.0		6	6
F	6.0	6.0		6	6
G	5.0	6.0		--	--
Overall average	5.5	5.7		5.4	5.6

PEQ results		
Test Subject	Q2	Q22
A	5	6
B	5	3
C	6	6
E	5	4
F	6	6
G	5	--
Average	5.3	5.0

Criteria 3 is passed as the average scores for all questions are well above 3.5.

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A.3.2.3 EX3-OBJ-VLD-01-0203-002 Results

This objective concerns the impact of SRAP additional PAPI under VMC on SRAP safety from crew perspective. One criteria has been defined:

Criteria 4 - EX3-CRT-VLD-01-0203-002
There is evidence that the additional SRAP PAPI is sufficient to not negatively impact SRAP procedures compared to the reference scenario, from the perspective of the crew.

PRQ results for FLT 1 / RUN 3, 5, 6, 8			vs.	PRQ results for FLT1 / RUN 2	
Test Subject	Q1 (PAPI) Average	Q5 (confusion) Average		Q1 (PAPI)	Q5 (confusion)
A	4.3	5.8		6	6
B	4.5	4.3		5	4
C	5.5	6.0		5	6
E	6.0	6.0		6	6
F	6.0	6.0		6	6
G	6.0	6.0		--	--
Overall average	5.4	5.7		5.6	5.6

PEQ results	
Test Subject	Q6
A	6
B	5
C	6
E	6
F	6
G	5
Average	5.7

Criteria 4 is passed as the average scores for all questions are well above 3.5.

A.3.2.4 EX3-OBJ-VLD-01-0203-003 Results

This objective concerns the impact of SRAP additional runway markings under VMC on nominal threshold approach safety from crew perspective. One criteria has been defined:

Criteria 5 - EX3-CRT-VLD-01-0203-003
There is evidence that the additional SRAP runway markings do not negatively impact normal approach procedures to nominal threshold compared to the reference scenario, from the perspective of the crew.

PRQ results for FLT 1 / RUN 4, 7				vs.	PRQ results for FLT1 / RUN 2		
Test Subject	Q2 (markings) Average	Q4 (workload) Average	Q5 (confusion) Average		Q2 (markings)	Q4 (workload)	Q5 (confusion)
A	6.0	6.0	6.0		5	5	6
B	5.0	4.5	5.0		4	5	4
C	6.0	6.0	6.0		6	6	6
E	--	--	--		6	6	6
F	--	--	--		6	6	6
G	--	--	--		6	6	6
Overall average	5.7	5.5	5.7		5.5	5.7	5.7

PEQ results	
Test Subject	Q4
A	6
B	6
C	6
E	6
F	6
G	6
Average	6.0

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Criteria 5 is passed as the average scores for all questions are well above 3.5.

A.3.2.5 EX3-OBJ-VLD-01-0203-004 Results

This objective concerns the impact of SRAP additional PAPI under VMC on nominal threshold approach safety from crew perspective. One criteria has been defined:

Criteria 6 - EX3-CRT-VLD-01-0203-004
There is evidence that the additional SRAP PAPI does not negatively impact normal approach procedures to nominal threshold compared to the reference scenario, from the perspective of the crew.

PRQ results for FLT 1 / RUN 4, 7				vs.	PRQ results for FLT1 / RUN 2		
Test Subject	Q1 (PAPI) Average	Q4 (workload) Average	Q5 (confusion) Average		Q1 (PAPI)	Q4 (workload)	Q5 (confusion)
A	6.0	6.0	6.0		6	5	6
B	5.0	4.5	5.0		5	5	4
C	5.5	6.0	6.0		5	6	6
E	--	--	--		6	6	6
F	--	--	--		6	6	6
G	6.0	--	--		--	6	6
Overall average	5.6	5.5	5.7		5.6	5.7	5.7

PEQ results	
Test Subject	Q5
A	5
B	5
C	6
E	6
F	6
G	6
Average	5.7

Criteria 6 is passed as the average scores for all questions are well above 3.5.

A.3.2.6 EX1-OBJ-VLD-01-0203-005 Results

This objective concerns the impact on SRAP safety from crew perspective. One criteria has been defined:

Criteria 7 - EX3-CRT-VLD-01-0203-005
There is evidence that the nominal runway markings and nominal PAPI are sufficiently distinguishable from SRAP markings and PAPI in order not to result in unacceptable safety from the perspective of the crew.

PRQ results for FLT 1 / RUN 2 thr. 8				
Test Subject	Q1 (PAPI) Average	Q2 (markings) Average	Q3 (safety) Average	Q5 (confusion) Average
A	5.0	5.9	6.0	5.9
B	4.7	4.7	4.9	4.4
C	5.4	6.0	6.0	6.0
E	6.0	5.7	6.0	6.0
F	6.0	6.0	6.0	6.0
G	6.0	5.3	5.0	6.0
Overall average	5.5	5.6	5.6	5.7

PEQ results		
Test Subject	Q1	Q22
A	5	6
B	5	3
C	6	6
E	5	4
F	6	6
G	6	--
Average	5.5	5.0

Criteria 7 is passed as the average scores for all questions are well above 3.5.

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A.3.2.7 OBJ-02.02-V3-VALP-SRAP.0204 Results

This objective concerns the SRAP operational feasibility under VMC from crew perspective. Two criteria have been defined:

- Criteria 8 - CRT-02.02-V3-VALP-SRAP.0204-001
  Pilot succeeds to manage SRAP operation by applying existing SOPs.

PEQ results	
Test Subject	Q9
A	5
B	4
C	6
E	5
F	6
G	5
Average	5.2

Criteria 8 is passed as the average scores for all questions are well above 3.5.

- Criteria 9 - CRT-02.02-V3-VALP-SRAP.0204-002
  Pilots are confident when flying a SRAP operation.

PRQ results for FLT 1 / RUN 3, 5, 6, 8					
Test Subject	Q1 (PAPI) Average	Q2 (markings) Average	Q3 (safety) Average	Q4 (workload) Average	Q5 (confusion) Average
A	4.3	6.0	6.0	5.8	5.8
B	4.5	4.8	4.8	4.3	4.3
C	5.5	6.0	6.0	6.0	6.0
E	6.0	5.5	6.0	6.0	6.0
F	6.0	6.0	6.0	6.0	6.0
G	6.0	5.0	5.0	5.5	6.0
Overall average	5.4	5.5	5.6	5.6	5.7

PEQ results	
Test Subject	Q10
A	6
B	4
C	6
E	6
F	6
G	6
Average	5.7

Criteria 9 is passed as the average scores for all questions are well above 3.5.

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A.3.2.8 OBJ-02.02-V3-VALP-SRAP.0205 Results

This objective concerns the SRAP impact on SOPs. Two criteria have been defined:

- Criteria 10 - CRT-02.02-V3-VALP-SRAP.0205-001
  Pilot actions in SRAP approach allow to successfully stabilize the aircraft before landing (manage energy,..).

PRQ results for FLT 1 / RUN 3, 5, 6, 8		
Test Subject	Q3 (safety) Average	Q4 (workload) Average
A	6.0	5.8
B	4.8	4.3
C	6.0	6.0
E	6.0	6.0
F	6.0	6.0
G	5.0	5.5
Overall average	5.6	5.6

  Criteria 10 is passed as the average scores for all questions are well above 3.5.

- Criteria 11 - CRT-02.02-V3-VALP-SRAP.0205-002
  Impact of SRAP approach, existing SOPs are easily manageable by pilots (no impact on task performance).

PRQ results for FLT 1 / RUN 3, 5, 6, 8	
Test Subject	Q4 (workload) Average
A	5.8
B	4.3
C	6.0
E	6.0
F	6.0
G	5.5

Overall average	5.6

PEQ results	
Test Subject	Q9
A	5
B	4
C	6
E	5
F	6
G	5
Average	5.2

Criteria 11 is passed as the average scores for all questions are well above 3.5.

A.3.2.9 OBJ-02.02-V3-VALP-SRAP.0301 Results

This objective concerns the SRAP impact on phraseology. Two criteria have been defined:

- Criteria 12 - CRT-02.02-V3-VALP-SRAP.0301-001
  Proposed phraseology does not lead to errors related to perception & interpretation of auditory information.

PEQ results	
Test Subject	Q20
A	5
B	3
C	3
E	5
F	6
G	6
Average	4.7

Criteria 12 is passed as the average scores for all questions are well above 3.5. Test subjects B and C have some doubts about using “06” as the SRAP runway designator, which is reflected in their scores.

- Criteria 13 - CRT-02.02-V3-VALP-SRAP.0301-002
  Pilots accept and judge the proposed phraseology as being appropriate for all encountered operating conditions.

PEQ results	
Test Subject	Q20
A	5
B	3
C	3
E	5
F	6

G	6
Average	4.7

Criteria 13 is passed as the average scores for all questions are well above 3.5. . Test subjects B and C have some doubts about using “06” as the SRAP runway designator, which is reflected in their scores.

A.3.2.10 EX3-OBJ-VLD-01-0201-001 Results

This objective concerns the 3.5 deg IGS-to-SRAP impact under VMC on crew task performance. Two criteria have been defined:

- Criteria 14 - EX3-CRT-VLD-01-0201-001-01
  Pilot succeeds to accomplish a 3.5 deg IGS-to-SRAP operation without any difficulty.

PRQ results for FLT 2 / RUN 2 thr. 6					
Test Subject	Q1 (PAPI) Average	Q2 (markings) Average	Q3 (safety) Average	Q4 (workload) Average	Q5 (confusion) Average
A	5.8	6.0	6.0	6.0	6.0
B	4.8	4.8	4.4	4.4	4.6
C	6.0	6.0	6.0	6.0	6.0
E	6.0	6.0	6.0	6.0	5.5
F	6.0	6.0	6.0	6.0	6.0
G	6.0	6.0	5.0	5.3	6.0
Overall average	5.8	5.8	5.6	5.6	5.7

PEQ results						
Test Subject	Q3	Q7	Q11	Q20	Q21	Q22
A	5	6	6	5	5	6
B	4	4	5	3	3	3
C	6	6	6	3	6	6
E	5	6	5	5	6	4
F	6	6	6	6	6	6

G	5	5	5	6	6	--
Average	5.2	5.5	5.5	4.7	5.3	5.0

Criteria 14 is passed as the average scores for all questions are well above 3.5.

- Criteria 15 - EX3-CRT-VLD-01-0201-001-02
  Impact on crew cooperation and crew workload for 3.5 deg IGS-to-SRAP operation remains within acceptable limit.

PRQ results for FLT 2 / RUN 2 thr. 6	
Test Subject	Q4 (workload) Average
A	6.0
B	4.4
C	6.0
E	6.0
F	6.0
G	5.3
Overall average	5.6

Criteria 15 is passed as the average scores for all questions are well above 3.5.

A.3.2.11 EX3-OBJ-VLD-01-0201-002 Results

This objective concerns the 4.0 deg IGS-to-SRAP impact under VMC on crew task performance. Two criteria have been defined:

- Criteria 16 - EX3-CRT-VLD-01-0201-002-01
  Pilot succeeds to accomplish a 4.0 deg IGS-to-SRAP operation without any difficulty.

PRQ results for FLT 3 / RUN 2 thr. 6					
Test Subject	Q1 (PAPI) Average	Q2 (markings) Average	Q3 (safety) Average	Q4 (workload) Average	Q5 (confusion) Average
A	6.0	6.0	6.0	6.0	6.0
B	4.6	5.0	4.5	4.2	4.6
C	5.4	6.0	6.0	6.0	6.0
E	6.0	6.0	5.0	4.5	6.0
F	6.0	6.0	6.0	6.0	6.0
G	6.0	6.0	5.3	5.0	5.7
Overall average	5.7	5.8	5.5	5.3	5.7

PEQ results						
Test Subject	Q3	Q7	Q12	Q20	Q21	Q22
A	5	6	5	5	5	6
B	4	4	5	3	3	3
C	6	6	5	3	6	6
E	5	6	4	5	6	4
F	6	6	6	6	6	6
G	5	5	5	6	6	--
Average	5.2	5.5	5.0	4.7	5.3	5.0

Criteria 16 is passed as the average scores for all questions are well above 3.5.

- Criteria 17 - EX3-CRT-VLD-01-0201-002-02
  Impact on crew cooperation and crew workload for 4.0 deg IGS-to-SRAP operation remains within acceptable limit.

PRQ results for FLT 3 / RUN 2 thr. 6	
Test Subject	Q4 (workload) Average
A	6.0
B	4.2
C	6.0
E	4.5
F	6.0
G	5.0
Overall average	5.3

Criteria 17 is passed as the average scores for all questions are well above 3.5.

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A.3.2.12 EX3-OBJ-VLD-01-0201-003 Results

This objective concerns the 4.49 deg IGS-to-SRAP impact under VMC on crew task performance. Two criteria have been defined:

- Criteria 18 - EX3-CRT-VLD-01-0201-003-01
  Pilot succeeds to accomplish a 4.49 deg IGS-to-SRAP operation without any difficulty.

PRQ results for FLT 4 / RUN 2 thr. 6					
Test Subject	Q1 (PAPI) Average	Q2 (markings) Average	Q3 (safety) Average	Q4 (workload) Average	Q5 (confusion) Average
A	--	6.0	6.0	6.0	6.0
B	5.0	5.0	4.6	4.2	5.0
C	6.0	6.0	6.0	6.0	6.0
E	5.5	6.0	5.0	5.5	6.0
F	6.0	6.0	6.0	6.0	6.0
G	6.0	6.0	5.0	5.0	6.0
Overall average	5.7	5.8	5.4	5.5	5.8

PEQ results						
Test Subject	Q3	Q7	Q13	Q20	Q21	Q22
A	5	6	5	5	5	6
B	4	4	4	3	3	3
C	6	6	5	3	6	6
E	5	6	3	5	6	4
F	6	6	6	6	6	6
G	5	5	4	6	6	--
Average	5.2	5.5	4.5	4.7	5.3	5.0

Criteria 18 is passed as the average scores for all questions are well above 3.5.

- Criteria 19 - EX3-CRT-VLD-01-0201-003-02
  Impact on crew cooperation and crew workload for 4.49 deg IGS-to-SRAP operation remains within acceptable limit.

PRQ results for FLT 4 / RUN 2 thr. 6	
Test Subject	Q4 (workload) Average
A	6.0
B	4.2
C	6.0
E	5.5
F	6.0
G	5.0
Overall average	5.5

Criteria 19 is passed as the average scores for all questions are well above 3.5.

A.3.2.13 EX3-OBJ-VLD-01-0203-001 Results

This objective concerns the impact on SRAP additional runway markings under VMC on IGS-to-SRAP safety from crew perspective. One criteria has been defined:

Criteria 20 - EX3-CRT-VLD-01-0203-001
There is evidence that the additional SRAP runway markings are sufficient to not negatively impact IGS-to-SRAP procedures compared to the reference scenario, from the perspective of the crew.

PRQ results for FLT 2, 3, 4 / RUN 2 thr 6			vs.	PRQ results for FLT1 / RUN 2	
Test Subject	Q2 (markings) Average	Q5 (confusion) Average		Q2 (markings)	Q5 (confusion)
A	6.0	6.0		5	6
B	4.9	4.7		4	4
C	6.0	6.0		6	6
E	6.0	5.8		6	6
F	6.0	6.0		6	6
G	6.0	5.9		--	--
Overall average	5.8	5.7		5.4	5.6

PEQ results		
Test Subject	Q14	Q22
A	6	6
B	5	3
C	6	6
E	6	4
F	6	6
G	6	--
Average	5.8	5.0

Criteria 20 is passed as the average scores for all questions are well above 3.5.

A.3.2.14 EX3-OBJ-VLD-01-0203-002 Results

This objective concerns the impact on IGS-to-SRAP additional PAPI under VMC on IGS-to-SRAP safety from crew perspective. One criteria has been defined:

Criteria 21 - EX3-CRT-VLD-01-0203-002
There is evidence that the additional IGS-to-SRAP PAPI is sufficient to not negatively impact IGS-to-SRAP procedures compared to the reference scenario, from the perspective of the crew.

PRQ results for FLT 2, 3, 4 / RUN 2 thr 6			vs.	PRQ results for FLT1 / RUN 2	
Test Subject	Q1 (PAPI) Average	Q5 (confusion) Average		Q1 (PAPI)	Q5 (confusion)
A	5.9	6.0		6	6
B	4.8	4.7		5	4
C	5.8	6.0		5	6
E	5.8	5.8		6	6
F	6.0	6.0		6	6
G	6.0	5.9		--	--
Overall average	5.7	5.7		5.6	5.6

PEQ results	
Test Subject	Q15
A	6
B	5
C	6
E	6
F	6
G	6
Average	5.8

Criteria 21 is passed as the average scores for all questions are well above 3.5.

A.3.2.15 EX3-OBJ-VLD-01-0203-003 Results

This objective concerns the impact on IGS-to-SRAP safety from crew perspective. One criteria has been defined:

Criteria 22 - EX3-CRT-VLD-01-0203-003
There is evidence that the nominal runway markings and nominal PAPI are sufficiently distinguishable from SRAP markings and PAPI in order not to result in unacceptable safety from the perspective of the crew.

PRQ results for FLT 2, 3, 4 / RUN 2 thr. 6				
Test Subject	Q1 (PAPI) Average	Q2 (markings) Average	Q3 (safety) Average	Q5 (confusion) Average
A	5.9	6.0	6.0	6.0
B	4.8	4.9	4.5	4.7
C	5.8	6.0	6.0	6.0
E	5.8	6.0	5.3	5.8
F	6.0	6.0	6.0	6.0
G	6.0	6.0	5.1	5.9
Overall average	5.7	5.8	5.5	5.7

PEQ results		
Test Subject	Q1	Q22
A	5	6
B	5	3
C	6	6
E	5	4
F	6	6
G	6	--
Average	5.5	5.0

Criteria 22 is passed as the average scores for all questions are well above 3.5.

A.3.2.16 OBJ-02.02-V3-VALP-ITSR.0204 Results

This objective concerns the IGS-to-SRAP operational feasibility under VMC from crew perspective. Two criteria have been defined:

- Criteria 23 - CRT-02.02-V3-VALP-ITSR.0204-001
  Pilot succeeds to manage IGS-to-SRAP operation by applying existing SOPs.

PEQ results	
Test Subject	Q16
A	5
B	4
C	6
E	5
F	6
G	5
Average	5.2

Criteria 23 is passed as the average scores for all questions are well above 3.5.

- Criteria 24 - CRT-02.02-V3-VALP-ITSR.0204-002
  Pilots are confident when flying an IGS-to-SRAP operation.

PRQ results for FLT 2, 3, 4 / RUN 2 thr. 6					
Test Subject	Q1 (PAPI) Average	Q2 (markings) Average	Q3 (safety) Average	Q4 (workload) Average	Q5 (confusion) Average
A	5.9	6.0	6.0	6.0	6.0
B	4.8	4.9	4.5	4.3	4.7
C	5.8	6.0	6.0	6.0	6.0
E	5.8	6.0	5.3	5.3	5.8
F	6.0	6.0	6.0	6.0	6.0
G	6.0	6.0	5.1	5.1	5.9
Overall average	5.7	5.8	5.5	5.5	5.7

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PEQ results	
Test Subject	Q17
A	6
B	5
C	6
E	5
F	6
G	5
Average	5.5

Criteria 24 is passed as the average scores for all questions are well above 3.5.

A.3.2.17 OBJ-02.02-V3-VALP-ITSR.0205 Results

This objective concerns the IGS-to-SRAP impact on SOPs. Two criteria have been defined:

- Criteria 25 - CRT-02.02-V3-VALP-ITSR.0205-001
  Pilot actions in IGS-to-SRAP approach allow to successfully stabilize the aircraft before landing (manage energy,..).

PRQ results for FLT 2, 3, 4 / RUN 2 thr. 6		
Test Subject	Q3 (safety) Average	Q4 (workload) Average
A	6.0	6.0
B	4.5	4.3
C	6.0	6.0
E	5.3	5.3
F	6.0	6.0
G	5.1	5.1
Overall average	5.5	5.5

Criteria 25 is passed as the average scores for all questions are well above 3.5.

- Criteria 26 - CRT-02.02-V3-VALP-ITSR.0205-002
  Impact of IGS-to-SRAP approach, existing SOPs are easily manageable by pilots (no impact on task performance).

PRQ results for FLT 2, 3, 4 / RUN 2 thr. 6	
Test Subject	Q4 (workload) Average
A	6.0
B	4.3
C	6.0
E	5.3
F	6.0
G	5.1

Overall average	5.5

PEQ results	
Test Subject	Q16
A	5
B	4
C	6
E	5
F	6
G	5
Average	5.2

Criteria 26 is passed as the average scores for all questions are well above 3.5.

A.3.2.18 OBJ-02.02-V3-VALP-ITSR.0301 Results

This objective concerns the IGS-to-SRAP impact on phraseology. Two criteria have been defined:

- Criteria 27 - CRT-02.02-V3-VALP-ITSR.0301-001
  Proposed phraseology does not lead to errors related to perception & interpretation of auditory information.

PEQ results	
Test Subject	Q20
A	5
B	3
C	3
E	5
F	6
G	6
Average	4.7

Criteria 27 is passed as the average scores for all questions are well above 3.5. Test subjects B and C have some doubts about using “06” as the SRAP runway designator, which is reflected in their scores.

- Criteria 28 - CRT-02.02-V3-VALP-ITSR.0301-002
  Pilots accept and judge the proposed phraseology as being appropriate for all encountered operating conditions.

PEQ results	
Test Subject	Q20
A	5
B	3
C	3
E	5
F	6

G	6
Average	4.7

Criteria 28 is passed as the average scores for all questions are well above 3.5. Test subjects B and C have some doubts about using “06” as the SRAP runway designator, which is reflected in their scores.

Analyses of demonstration objectives based on ratings from LH and TUI

In the DEMOP and contrary to the NLR flight test campaign, it has not been described how the LH and TUI demonstration objectives have to be tested based on the ratings provided by these participants. Moreover, the test matrix – although basically the same for LH (IGS-to-SRAP 3.5 deg) and TUI (IGS-to-SRAP 3.0 deg) – differ with regard to the ones used by NLR. This means that above analyses by NLR cannot be extended by just adding the LH and TUI ratings to the equations. Therefore, separate analyses will follow below. First, the one received from LH. However, given the high ratings of LH and TUI (both PRQ and PEQ) it can be deduced that the demonstration objectives have all been met, which is in agreement with the NLR results above.

LUFTHANSA

Aircraft
A319
GLS capable, GoPro video cameras installed, no specific equipment

Crew
LUFTHANSA Test Pilot & First Officer
AIRBUS Lead Flight Test Engineer
LUFTHANSA Safety pilot (observer)

Weather
wind direction and strength in intermediate final varied from 160°-185° and 12-20kts. The aircraft operated circuits at 3000' QNH was always below the clouds with excellent visibility
sun's/light's angle of incidence during final approach to runway 05 & 06 was around 4 - 5 o'clock, thus excluding any blinding by the sun. The sun ingress on the runway changed several times during the nine approaches. Despite the temporarily broken clouds at about 4500 ft AGL with a low vertical dimension the prevailing brightness must be described as daylight

Test Matrix

Run	Approach	GS °	PAPI 05	PAPI 06	FLAPS	GW (kg)	Guidance	G/A alt / time
01	GLS Z 05	3	ON	OFF	3	50200	AP ON ATHR ON	130' 12h13
02	GLS Z 05	3	ON	ON 3.5°	3	49900	AP ON ATHR ON	150' 12h23
03	GLS X 06	3.5	ON	ON 3.5°	FULL	49400	AP ON ATHR ON	100' 12h33
04	GLS X 06	3.5	ON	ON 3.5°	3	49200	AP ON ATHR ON	100' 12h43
05	GLS X 06	3.5	ON	ON 3.5°	FULL	48800	AP OFF ATHR OFF	100' 12h52
06	GLS X 06	3.5	ON	ON 3.5°	3	48400	AP OFF ATHR OFF	100' 13h01
07	GLS X 06	3.5	ON	ON 3.5°	FULL	48000	AP OFF ATHR OFF	100' 13h10
08	GLS Z 06	3	ON	ON 3.0°	3	47700	AP ON ATHR OFF	100' 13h19
09	GLS Z 06	3	ON	ON 3.0°	FULL	47400	AP OFF ATHR OFF	250' (bird avoidance) 13h29

Flight Execution
Manual approaches for runs #5 and #6 were flown by the first officer. Manual approach for run #7 and run #9 were flown by the captain.

Given the wind conditions of the day and the approach course of 053deg, frequent use was made of speed brakes to maintain correct speed and glideslope parameters and to assure operator's stabilization criteria, especially on approaches in CONF 3 (speed brakes inhibited in CONF FULL on A319 aircraft) and with 3.5° glideslope. This may have an impact on any noise calculations.

Results
Following results are based only on crew appreciation, no correlation with any recorded data or video images has been made.
Joint point of view of both Lufthansa pilots and the Airbus flight test engineer, no divergences in opinion were noted between crew members.

Runway markings – General
The newly implemented runway markings for 06 appear in a bright white colour. The permanent markings for runway 05 are white without noticeable rubber marks. But they do not appear as bright as the new markings for the displaced runway

Runways markings in direct sunlight are more obvious than those in shade. At different times during the approaches, one threshold was in sun whilst the other was in shade. The threshold in the sun is more dominant in the field of view, even if it not the threshold associated to the aiming point of the approach

Despite of the focus on the SRAP, the pilots still perceive the short remaining runway in the subconscious mind. From the threshold of runway 06 only 1386 meters are remaining. Nevertheless, both pilots state, that this special condition did not falsify their assessment on the SRAP.

PAPI
The portable PAPI installed at runway 06 threshold was found to be extremely precise versus the GLS glideslope, whatever the approach path angle. Generally, all GLS paths to the runway were consistent with the relative PAPI indications.

The brightness of the portable PAPI for runway 06 was considerably lower than the fixed PAPI for runway 05. Whereas the fixed PAPI could be seen at all distances on the approach, whatever the lighting conditions (PAPI in sun or shade), the portable PAPI was not really visible until 7-8NM. With the portable PAPI in bright sunlight this distance was reduced as low as 5NM.

Phraseology
The proposed phraseology for landing clearance (approach clearances and traffic information clearances not used due to performing airfield circuits and being alone in the pattern) was used starting with run number 02.

After mentioning the threshold to be used by the “tower controller” (role played by flight test engineer), pilots commented that it improved their understanding which threshold to aim for. This is corroborated by visual observations made by the engineer; without landing clearance instructions for the threshold (run 01), pilots appeared to have an increased scanning pattern which covered both thresholds and showed some signs of hesitation, at least in the first part of the approach, whereas with landing clearance instruction (runs 02-09), focus was immediately given to the correct threshold.

The crew commented that an additional disambiguation could be given in the landing clearance by mentioning the side of the runway on which the relevant PAPI is located (e.g. “first threshold, PAPI left” and “second threshold, PAPI right” at EHTW), provided that the airport geography allows the first and second PAPIs to be installed on opposite sides of the runway. This could be further reinforced if PAPI location could be standardized across airports (e.g. first threshold PAPI always on the left, second threshold PAPI always on the right, or vice-versa).

Post-Runs results
Ratings from the Post-Run Questionnaire after each run are given below. The ratings for question 4 on work load and task performance were influenced by the high (tail)wind conditions while flying an IGS.

In your opinion and during the last approach, the PAPI indications were acceptable

Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Average
6	5	5	5	5	5	5	5	5	5,1

In your opinion and during the last approach, the runway markings were acceptable

Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Average
6	6	6	6	6	6	6	5	5	5,8

In your opinion and during the last approach, the level of safety of a landing would have been acceptable

Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Average
6	6	5	5	5	5	5	5	5	5,2

In your opinion and during the last approach, your workload and task performance were acceptable

Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Average
4	5	6	6	4	4	4	6	4	4,8

In your opinion and during the last approach, there were never confusion regarding which runway threshold and aiming point to use

Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Average
5	5	5	5	6	5	5	5	5	5,1

Post Experiment results (PEQ Ratings)

1. In your opinion, the runway markings and PAPI for the (IGS-to-) SRAP approaches to RWY06 are clearly distinguishable from the markings and PAPI for the conventional approaches to RWY05.

Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
				X	

The proximity of the 2500' marker for RWY05 and the threshold markings for RWY06 was potentially problematic. Could the 2500' marker be removed to help "isolate" RWY06 markings and to support a better distinction between the two threshold systems.

As observed, the end of the touchdown zone for RWY05 is somehow hidden in the threshold of RWY06.

2. In your opinion, are SRAP runway markings sufficient to not negatively impact SRAP procedures when compared to normal approaches to the conventional threshold.

Completely disagree	Mostly disagree	Slightly disagree	Slightly agree	Mostly Agree	Completely agree
			X		

For the SRAP aiming point marking, it is OK. However, more guidance is required for SRAP touchdown zone to help overshoot go-around decisions (more than just one distance marker after the touchdown point).

The test campaign aims on the SRAP concept with the focus on the markings. However, there must be an additional assessment on the landing distance: On one hand, how pilots identify the remaining landing distance for the go-around decision, on the other hand, how much remaining runway length should a SRAP provide from an operational point of view.

In flight, markings for RWY05 and RWY06 "felt right" (including both glideslopes on RWY06) but looking at pictures after the flight, it's clear there are some significant differences between the two runways. In particular, the touchdown zone for the SRAP is considerably closer to the threshold than the conventional markings on RWY05. Is this linked to the steeper approaches to the SRAP?

3. In your opinion, the simultaneous use of two PAPIs (one for each threshold) is acceptable.

Completely disagree	Mostly disagree	Slightly disagree	Slightly agree	Mostly agree	Completely agree
			X		

Some suggestions for better disambiguation:

- Only switch on the PAPI for the aiming point for which the aircraft is cleared (works well if you are the only traffic in the approach, could be confusing for multiple aircraft on parallel upper/lower glideslopes), or apply a (mechanical) filter on the PAPI so that is not easily visible to aircraft not on the glideslope linked to that PAPI (for example, PAPI only visible between 1° below and 1° above glideslope).
- Concern over the delta in perceived brightness between the two PAPIs. Both should have same, strong, brightness when perceived from the aircraft (i.e. second PAPI would have to be brighter). In the trial the second PAPI was noticeable weaker.
- In marginal visibility conditions and according to the distance between first and second aiming points, in initial phases of approach to SRAP, only the first PAPI may be visible, leading the pilot to (incorrectly) focus on it before "suddenly" discovering the second PAPI.
- In pilots' view, this subject merits a deeper study into potential optical illusions, pilot perception and "target fixation".

4. In your opinion, final approach, landing and roll-out on the conventional RWY05 are or would not have been unacceptably influenced by the additional SRAP runway markings

Completely disagree	Mostly Disagree	Slightly disagree	Slightly agree	Mostly agree	Completely agree
					X

The interpretation of the markings to use is strongly improved with a clear landing clearance.

A pilot performing a long flare to the first threshold – may be supported by degraded visual conditions or disorientation - may incorrectly interpret the second threshold as an additional touchdown zone marker and attempt to put the aircraft down even though the remaining runway distance may not be sufficient.

Discussion: reduce the number of piano keys for the second threshold (it is the aiming point marking which is more important).

5. In your opinion, final approach, landing and roll-out on the conventional RWY05 are or would not have been unacceptably influenced by the additional SRAP PAPI indications.

Completely disagree	Mostly Disagree	Slightly disagree	Slightly agree	Mostly agree	Completely agree
					X

In principle, pilots don't use PAPI indications below 200'.

6. In your opinion, the impact of the SRAP PAPI on SRAP approaches is comparable to normal approaches on the conventional threshold/PAPI.

Completely disagree	Mostly Disagree	Slightly disagree	Slightly agree	Mostly agree	Completely agree
					X

7. In your opinion, not having approach lighting/cross bars for SRAP RWY06 is acceptable under the conditions as present during the approaches

Completely disagree	Mostly Disagree	Slightly disagree	Slightly agree	Mostly agree	Completely agree
					X

Trial in daylight VMC: no lighting was used even on RWY05.
Pilots refer to experience at Tromsø (ENTC18) where there are specific green lateral lights aligned with the displaced threshold to support identification in degraded visual conditions or runway contamination.

8. In your opinion, the SRAP approaches are acceptable.

Completely disagree	*Mostly Disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
					X

Fully comparable to an approach to (for example) LEMD (all runways with significantly displaced thresholds).

9. In your opinion, SRAP operations can be managed by applying existing SOPs.

Completely disagree	*Mostly Disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
				X	

A small (one sentence or paragraph) may be required in company SOPs to highlight the importance of identifying the correct threshold (e.g. requirement to read back full landing clearance including “to second threshold”).

Last minute changes between thresholds would not be acceptable, limitation to be traced in SOPs

10. In your opinion, you were confident flying SRAP operations

Completely disagree	Mostly Disagree	Slightly disagree	Slightly agree	Mostly agree	Completely agree
			X (Captain)	X (F/O)	

This answer is strongly conditioned by performing multiple approaches to the same SRAP in a short space of time during this trial. A flight crew performing (very) occasional SRAP approaches may not feel so confident.

Especially on shorter runways pilots want to touch down when they have tarmac underneath them! There could be a tendency to "dive below" nominal glide path after passing the conventional threshold.

2400m remaining runway after the SRAP would seem like a comfortable minimum for Lufthansa single aisle operations, provided environmental conditions do not drastically increase the required landing distance.

11. In your opinion, 3.5 deg IGS-to-SRAP approaches are acceptable.

Completely disagree	Mostly Disagree	Slightly disagree	Slightly agree	Mostly agree	Completely agree
			X		

The issue is less the SRAP aspect and more the IGS aspect! The same concerns for energy management during IGS operations apply to conventional threshold as well.

Placeholder

PEQ questions 12 and 13 are not applicable to LH flight.

14. In your opinion, the impact of SRAP runway markings on (IGS-to-) SRAP approaches is comparable to normal approaches to the conventional threshold/runway markings.

Completely disagree	Mostly Disagree	Slightly disagree	Slightly agree	Mostly agree	Completely agree
					X

15. In your opinion, the impact of the SRAP PAPI on IGS-to-SRAP approaches is comparable to normal approaches to the conventional threshold/PAPI.

Completely disagree	Mostly Disagree	Slightly disagree	Slightly agree	Mostly agree	Completely agree
				X	

This is even more true after overflying the first PAPI, particularly if the second PAPI is as well calibrated as the one used for this trial.

16. In your opinion, IGS-to-SRAP operations can be managed by applying existing SOPs.

Completely disagree	Mostly Disagree	Slightly disagree	Slightly agree	Mostly agree	Completely agree
				X	

17. In your opinion, you were confident flying IGS-to-SRAP operations

Completely disagree	Mostly Disagree	Slightly disagree	Slightly agree	Mostly agree	Completely agree

The tailwind conditions of the day were too much of an influence to be able to make an answer to this question as IGS operations are very difficult to manage in such cases, even to a conventional threshold.

Confidence should be OK in headwind conditions

The combination of the tailwind and the IGS left the crew subjectively feeling that the ground speed was too high for the aircraft weight [“something felt wrong” (pilot) /”I had less time than usual during the approach to write down all the relevant information” (engineer)]

18. In your opinion, proposed phraseology for SRAP operations do not lead to errors related to perception & interpretation of auditory information.

Completely disagree	Mostly Disagree	Slightly Disagree	Slightly agree	Mostly agree	Completely agree
					X

The phraseology was good.

The mention of the first/second threshold is the most important.

No difficulty to associate lower glide slope (traffic information) with first threshold (landing clearance) or upper with second; lower/upper vs first/second allow crew to clearly distinguish between a traffic information and a landing clearance.

If PAPIs are on opposite of runway for first and second threshold, it could be possible to add that information as an additional distinguishing factor (see notes to question 1).

19. In your opinion, pilots accept and judge the proposed phraseology as being appropriate for all encountered SRAP operating conditions

Completely disagree	*Mostly Disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
					X

20. In your opinion, proposed phraseology for (IGS-to-) SRAP operations is unambiguous and acceptable.

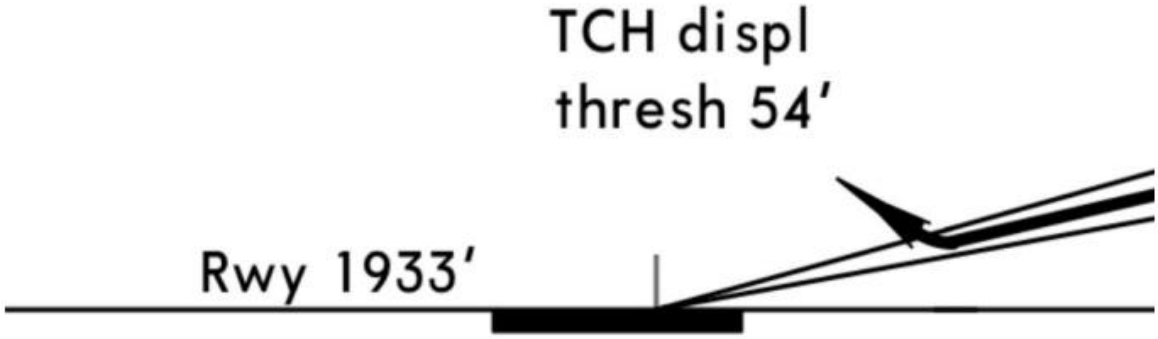
Completely disagree	*Mostly Disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
					X

One alternative may be to use the series of letters Z, Y, X for first threshold and another series for the second threshold (for example N, M, L) but this would seem unnecessary if different runway designators are used for the first and second threshold.

21. In your opinion, the approach charts provided all required information and were acceptable.

Completely disagree	*Mostly Disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
				X	

There is a difference between chart providers today for landing on displaced thresholds. Some providers shown the full length of the runway, others only the remaining runway. The charts for EHTW only showed the remaining runway from the SRAP whereas locating the touchdown point at its position on the whole runway could enhance situational awareness.
For example, LEMD ILS32L from Jeppesen (3988m runway length, displace threshold of approx. 1000m):



22. In your opinion, the (IGS-to-) SRAP RWY designation "06" was acceptable

Completely disagree	Mostly Disagree	Slightly disagree	Slightly agree	Mostly agree	Completely agree
				X	

This seems to be in line with conventions at several airports in the Lufthansa network with parallel landing airports (e.g. LFPG, LTFM, VIDP, KORD, …)

An alternative could be as used in SNOWTAMs where 50 may be added to the runway designator in case of parallel runways

Further Comments

The crew felt that some of the results could be slightly biased by the repetitive nature of some parts of the trial (for example, runs 03-09 were all to the second threshold, such that by the end of the exercise the pilots knew to always aim for SRAP and therefore discarded the first threshold). This would not be the case in genuine SRAP operations.

After overflying the first threshold the perception of both pilots was the same as approaching a "normal" displaced threshold (like Madrid).

Identification of an SRAP approach should be unambiguous. In any case an approach to a SRAP must be addressed in the approach briefing – not only in the landing distance calculation, but also with the focus on the threshold, markings and visual means, e. g. PAPI's location.

A showstopper for SRAP approaches would be ATC putting pressure on a crew to accept a SRAP approach when this would have rather marginal landing distance compared to the conventional threshold. As well as the direct safety impact, there is also a potential maintenance burden as such approaches would require increased use of braking.

Conclusions

These trials were conducted in appropriate weather conditions with excellent preparation and coordination from all parties and appropriate ground facilities (markings, PAPI, GBAS station) such that the results can be fully taken into account.

No major issue has been identified for SRAP or IGS-to-SRAP operations during this very short operational trial but obviously much more exposure would be required to generalize the conclusions or to find possible restrictions.

TUI

Aircraft was a Boeing 737 Max – 8.
Test matrix was as indicated below:

Run	Approach	GS (deg)	PAPI 05/06	FLAP	Guidance
01	GLS Z 05	3.0	ON/OFF	30	AP
02	GLS Z 05	3.0	ON/ON 3.0	30	AP
03	GLS Z 06	3.0	ON/ON 3.0	40	AP
04	GLS Z 06	3.0	ON/ON 3.0	30	AP
05	GLS Z 06	3.0	ON/ON 3.0	40	MAN
06	GLS Z 06	3.0	ON/ON 3.0	30	MAN
07	GLS Z 06	3.0	ON/ON 3.0	40	MAN
08	GLS X 06	3.5	ON/ON 3.5	30	AP

Post Run Questionnaire results:

In your opinion and during last approach, the PAPI indications were acceptable								
RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	Average
6	6	6	6	6	6	6	6	6

In your opinion and during last approach, the runway markings were acceptable								
RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	Average
6	6	6	6	6	6	6	6	6

In your opinion and during last approach, the level of safety of a landing would have been acceptable								
RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	Average
6	6	6	6	6	6	6	6	6

In your opinion and during last approach, your workload and task performance were acceptable								
RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	Average
6	6	(2) 6	6	6	6	6	6	6

In your opinion and during last approach, there was never confusion regarding which runway threshold and aiming point to use								
RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	Average
6	6	6	6	6	6	6	6	6

At the start of RUN3, it was noticed by the crew that the GLS number did not match with the one mentioned on the approach chart. The overview chart did show the correct number. After this issue was resolved by radio communication with DREAMS Ground and the correct frequency was selected, no further problems were engaged. Remainder of the approach was therefore rated 6 “completely agree”.

Post Experiment Questionnaire results:

Pilot 1 ratings in upper row, those for pilot 2 in bottom row.

1. In your opinion, the runway markings and PAPI for the (IGS-to-)SRAP approaches to RWY06 are clearly distinguishable from the markings and PAPI for the conventional approaches to RWY05.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
				X	
					X

Remarks:
Pilot 1: PAPI RWY06 on other side of RWY05.
Pilot 2: ---

2. In your opinion, are SRAP runway markings sufficient to not negatively impact SRAP procedures when compared to normal approaches to the conventional threshold.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
				X	
					X

Remarks:
Pilot 1: More or less comparable with conventional displaced threshold approaches.
Pilot 2: ---

3. In your opinion, the simultaneous use of two PAPIs (one for each threshold) is acceptable.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
		X			
					X

Remarks:
Pilot 1: I would suggest to turn off the PAPI of the inactive runway/threshold. Can be confusing. Or a very well arrival briefing is completed with focus on Threat and Error Management (TEM) accordingly.
Pilot 2: ---

4. In your opinion, final approach, landing and roll out on the conventional RWY05 are or would not have been unacceptably influenced by the additional SRAP runway markings.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
				X	
					X

Remarks:
Pilot 1: As long as the PAPI is working on the conventional runway to mitigate confusion.
Pilot 2: ---

5. In your opinion, final approach, landing and roll out on the conventional RWY05 are or would not have been unacceptably influenced by the additional SRAP PAPI indications.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
		X			
					X

Remarks:
Pilot 1: See answer #3.
Pilot 2: ---

6. In your opinion, the impact of the SRAP PAPI on SRAP approaches is comparable to normal approaches to the conventional threshold/PAPI.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
				X	
					X

Remarks:
Pilot 1: Same as answer #2.
Pilot 2: Although it would be a discussion point in the approach briefing, under threat and error management.

7. In your opinion, not having approach lighting/cross bars for SRAP RWY06 is acceptable under the conditions as present during the approaches.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
				X	
					X

Remarks:
Pilot 1: Only like the weather conditions as during the approaches. (VFR rules). Or with weather minima during non-precision approaches.
Pilot 2: See remark at question 6.

8. In your opinion, the SRAP approaches are acceptable.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
				X	
					X

Remarks:
Pilot 1: With good explanation and briefings on forehand.
Pilot 2: Managing threat and errors are important, though:
- would you use it during low vis operations?;
- can have impact on overrun warning systems;
- visual illusion, due to long “displaced threshold”;
- much closer to end of runway during roll out then used to when landing at beginning of runway.

9. In your opinion, SRAP operations can be managed by applying existing SOPs.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
				X	
					X

Remarks:
Pilot 1: Only amendment in briefing items regarding TEM.
Pilot 2: Impact on Threat and Error management.

10. In your opinion, you were confident in flying SRAP operations.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
				X	
					X

Remarks:
Pilot 1: ---
Pilot 2: ---

11. In your opinion, 3.5 deg IGS-to-SRAP approaches are acceptable.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
				X	
					X

Remarks:
Pilot 1: Yes, again with some training or briefing on forehand regarding TEM.
Pilot 2: In normal operation would fly it with Flaps 40 on 737(MAX).

Questions 12 and 13 are not applicable to the TUI flight.

14. In your opinion, the impact of the SRAP runway markings on (IGS-to-)SRAP approaches is comparable to normal approaches to the conventional threshold/runway markings.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
			X		
				X	

Remarks:
Pilot 1: On SRAP you only miss the touchdown and runway threshold markings.
Pilot 2: See remarks regarding Threat and Error management. I.e. impact on low(er) vis operations.

15. In your opinion, the impact of the SRAP PAPI on IGS-to-SRAP approaches is comparable to normal approaches to the conventional threshold/PAPI.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
				X	
					X

Remarks:
Pilot 1: The approach (beside the glide path) is the same as on the conventional RWY threshold.
Pilot 2: Again, Threat and Error management needed.

16. In your opinion, IGS-to-SRAP operations can be managed by applying existing SOPs.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
				X	
					X

Remarks:
Pilot 1: ---
Pilot 2: ---

17. In your opinion, you were confident in flying IGS-to-SRAP operations.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
				X	
					X

Remarks:
Pilot 1: Yes, regarding the maximum glide slope angle and flight characteristics of the aircraft type.
Pilot 2: ---

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18. In your opinion, proposed phraseology for SRAP operations do not lead to errors related to perception & interpretation of auditory information.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
		X			

Remarks:
Pilot 1: Sorry, I don't recall the proposed phraseology.
Pilot 2: Phraseology was not practised.

19. In your opinion, pilots accept and judge the proposed phraseology as being appropriate for all encountered SRAP operating conditions.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
		X			

One pilot did not provide a rating.

Remarks:
Pilot 1: See answer #18.
Pilot 2: See answer at question 18.

20. In your opinion, proposed phraseology for (IGS-to-)SRAP operations is unambiguous and acceptable.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
		X			

One pilot did not provide a rating.

Remarks:
Pilot 1: See answer #18.
Pilot 2: See remark question 18.

21. In your opinion, the approach charts provided all required information and were acceptable.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
			X		
				X	

Remarks:
Pilot 1: Only missing the MDA.
Pilot 2: As debriefed before, one mistake was found on approach plate during flight.

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22. In your opinion, the (IGS-to-)SRAP RWY designation "05" was acceptable.					
Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
				X	
					X

Remarks:
Pilot 1: ---
Pilot 2: ---

A.3.2.19 OBJ-02.02-V3-VALP-SRAP.0401 Results

The objective of demonstrating the SRAP interest for noise reduction is addressed through under-track and noise contour analysis of recorded flight data from the trials performed on 6th October 2021 by Lufthansa and coordinated by NLR on Twente airport (EHTW).

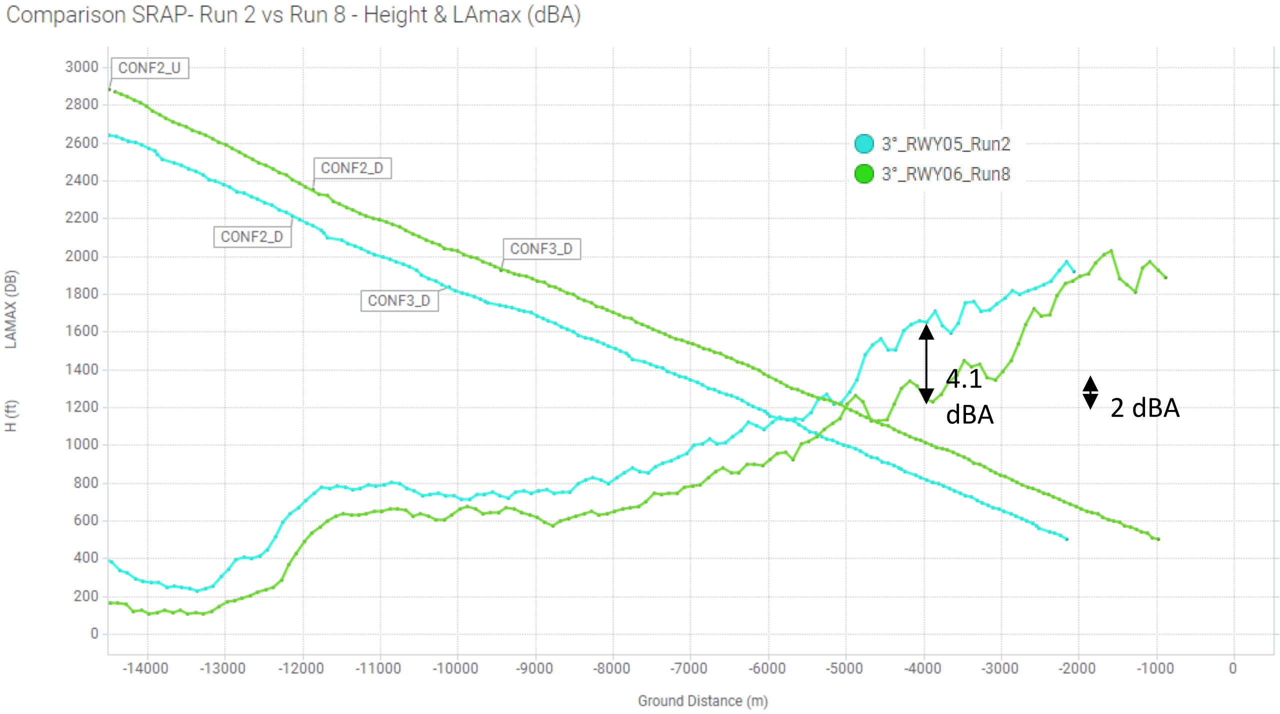
Each under-track graph displays the noise metric and the associated trajectory with matching color. Landing gear and slat/flap configuration deployment are labeled on the trajectory with tags "CONFX" for Slat/Flap and "U/D" for Up/Down landing gear status.

A.3.2.19.1 CRT-02.02-V3-VALP-SRAP.0401-001

CRT-02.02-V3-VALP-SRAP.0401-001 : Relative noise scale results positive with SRAP use

Run2 (3°; RWY 05; Reference) and Run8 (3°; RWY 06) qualify for SRAP noise impact assessment.

Run8 in green represents the SRAP approach with a glide slope of 3° onto Runway 06, while Run2 in cyan represents the reference approach with a glide slope of 3° onto Runway 05. The following graph shows the LAmax(dBA) under the aircraft track for both runs.



Under-track LAmax (dBA) of each run related to SRAP impact in terms of ground distance in meters.

The SRAP landing induces a noise reduction under-track all along the trajectory, up to 4.1dBA.

Criterion CRT-02.02-V3-VALP-SRAP.0401-001 is reached.

A.3.2.19.2 CRT-02.02-V3-VALP-SRAP.0401-002

CRT-02.02-V3-VALP-SRAP.0401-002 : Noise contours location is shifted to airport area

The following illustration shows the iso-noise contour for 70 and 75 dBA LAmax over the airport and surrounding neighborhoods for the runs related to SRAP impact. Run8 in green represents the SRAP approach with a glide slope of 3° onto Runway 06, while Run2 in cyan represents the reference approach with a glide slope of 3° onto Runway 05. Readers shall be reminded that the aircraft trajectory is truncated when it reaches an altitude of 500ft, thus the noise emitted by the aircraft below 500ft is not taken into account. However, it does not affect the analysis quality nor the observed displacement.

Satellite plots of iso-contour surfaces for 70dBA LAmax (up) and 75dBA LAmax (down) of each run related to SRAP impact.

With SRAP (in green), both 70dBA LAmax (up) and 75dBA LAmax (down) iso-contours are shifted towards the airport area. Twente Airport is mostly surrounded by forests, which might not best underline the SRAP advantage but the method can be extrapolated to any other airport which may be situated closer to populated neighborhoods.

A population count could illustrate better the advantage obtained thanks to the SRAP procedure.

Criterion CRT-02.02-V3-VALP-SRAP.0401-002 is reached.

A.3.2.19.3 CRT-02.02-V3-VALP-SRAP.0401-003

CRT-02.02-V3-VALP-SRAP.0401-003 : Average noise value is not increased

The number of runs (9) was not sufficient to perform a statistical analysis and conclude on an average noise gain. This criterion could however be addressed through noise contour area reduction, but the effective reductions are not significant enough to conclude on a visible effect.

Under-track noise level analysis shows that the footprint displacement brings an acoustic advantage on the whole sub-track. Using these results, one can conclude the average noise value is not increased.

Criterion CRT-02.02-V3-VALP-SRAP.0401-003 is reached.

A.3.2.20 OBJ-02.02-V3-VALP-ITSR.0401 Results

The objective of demonstrating the interest of IGS-to-SRAP has been addressed through under-track and contour noise analysis of recorded flight data from the same trials at Twente airport (EHTW) as in the previous objective.

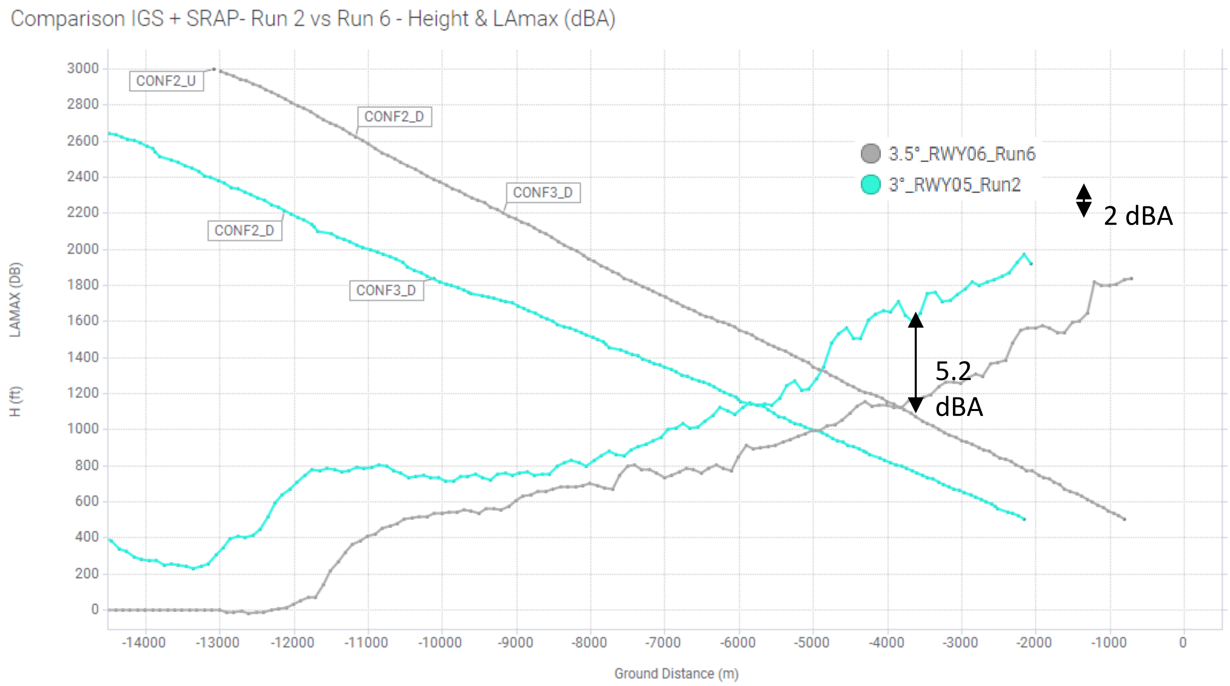
Each under-track graph displays the noise metric and the associated trajectory with matching color.The abscissa parameter is the ground distance in meters. Landing gear and slat/flap configuration deployment are labeled on the trajectory with tags “CONFX” for Slat/Flap and “U/D” for Up/Down landing gear status.

A.3.2.20.1 CRT-02.02-V3-VALP-ITSR.0401-001

CRT-02.02-V3-VALP-ITSR.0401-001 : Relative noise scale results positive with SRAP use

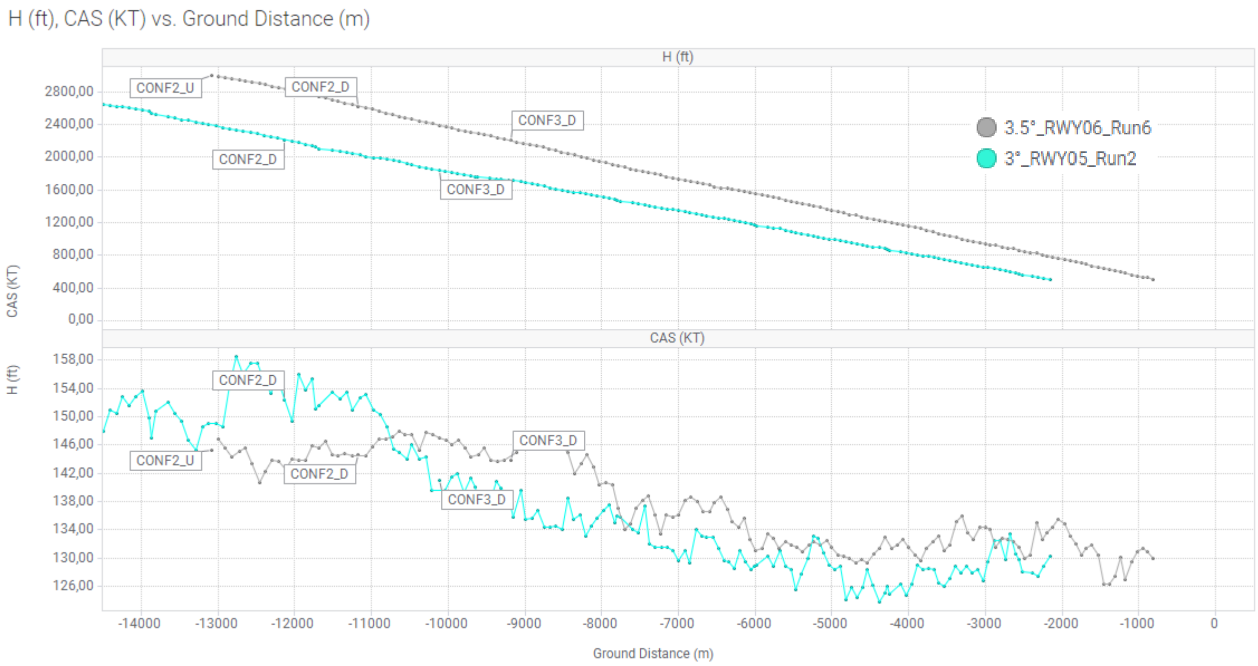
Run2 (3°; RWY 05; Reference) and Run6 (3.5°; RWY 06) qualify for IGS-to-SRAP noise impact assessment. Run6 in gray represents the IGS-to-SRAP procedure with a glide slope of 3.5° onto Runway 06, while Run2 in cyan represents the reference approach with a glide slope of 3° onto Runway 05.

The following graph shows the LAmax(dBA) under the aircraft track for both runs.



Under-track LAmax (dBA) of each run related to IGS impact in terms of ground distance in meters.

The acoustic advantage of both the SRAP and IGS method is well demonstrated here, with a constant gain ranging from 0.6dBA LAmax to 5.2dBA LAmax. Part of the acoustic gain between -11km and -13km is due to a smaller CAS (10kts less). Otherwise, the altitude difference and SRAP displacement result in a significant noise reduction under-track despite higher CAS, as shown in the following figure:



CAS (kt) of each run related to IGS-to-SRAP impact in terms of ground distance in meters.

Overall, both IGS and SRAP methods combined allow for a positive noise scale reduction.

Criterion CRT-02.02-V3-VALP-ITSR.0401-001 is reached.

A.3.2.20.2 CRT-02.02-V3-VALP-ITSR.0401-002

CRT-02.02-V3-VALP-ITSR.0401-002 : Noise contours location is shifted to airport area

The following pictures display the surface comparison for iso-contour noise level of 70dBA and 75dBA LAmax on Runway 05 and Runway 06 at Twente Airport for the runs related to IGS-to-SRAP impact.

Satellite plots of iso-contour surfaces for 70dBA LAmax (up) and 75dBA LAmax (down) of each run related to IGS-to-SRAP impact.

The gray iso-contour areas are visibly shifted towards the runway and away from populated neighborhoods compared to the cyan areas. Similarly to CRT-02.02-V3-VALP-SRAP.0401-002, a population count comparison could show the advantage brought by the combination of both IGS and SRAP methods, and could be extrapolated to other airports surrounded by a larger population.

Criterion CRT-02.02-V3-VALP-ITSR.0401-002 is reached.

A.3.2.20.3 CRT-02.02-V3-VALP-ITSR.0401-003

CRT-02.02-V3-VALP-ITSR.0401-003 : Size of noise contours is reduced with IGS-to-SRAP concept

The following table presents the noise surface reduction compared to the reference Run2.

ISO-noise level contour compared to reference Run2	Level: 70dBA (LAmax)	Level: 75dBA (LAm
3.5°_RWY06_Run6	**-29%**	**-72%**

IGS-to-SRAP iso-contour area reduction comparison.

The effective noise reduction is positive and significantly higher than the methodology uncertainty.

Criterion CRT-02.02-V3-VALP-ITSR.0401-003 is reached.

A.3.2.20.4 CRT-02.02-V3-VALP-ITSR.0401-004

CRT-02.02-V3-VALP-ITSR.0401-004 : Average noise value is not increased

The number of flights was not sufficient to perform a statistical analysis and conclude on an average noise gain. Nonetheless, when considering the under-track LAmax(dBA) noise level, one can observe the constant gain from implementing the IGS-to-SRAP method. The same observation can be made about the reduced noise iso-contour areas, which are also shifted towards the airport area and away from inhabitants.

Criterion CRT-02.02-V3-VALP-ITSR.0401-004 is reached.

A.3.3 Unexpected Behaviours/Results

A.3.4 Confidence in the Demonstration Results

A.3.4.1 Level of significance/limitations of Demonstration Exercise Results

The extend of the applicability of the Exercise 01 results depends on the way this exercise has been defined (see also DEMOP section 5.1) and performed. Especially the following items are of interest:

9. *VFR/VMC*
   The test flights have all been executed under VFR/VMC.

10. *PAPI*
    A transportable SRAP PAPI has been used for the approaches (together with the existing PAPI). Light intensity of this transportable SRAP PAPI was slightly less than the existing PAPI, but was acceptable for the tests (see also section A.5.1).

11. *Runway markings*
    The SRAP markings at Twente Airport are consistent with ICAO Annex 14 guidelines (see DEMOP section 5.1.4.2). The markings are applicable to the local situation. This situation is characterised by an LDA of 2406 m for RWY 05 and an LDA of 1386 m for RWY 06. The SRAP touchdown zone markings would have more elements on longer runways such as found at major international airports.
    In the sense that Twente Airport has a somewhat shorter runway than most major international airports, Twente Airport can be viewed as a worst case scenario for SRAP operations, as the LDA for the SRAP runway is simply smaller. The LDA for the SRAP runway at Twente Airport is sufficient for NLR's test aircraft (a business jet), relatively short for medium-haul commercial airliners such as single-aisle Airbus of Boeing commercial airliners like the aircraft from TUI FLY and LUFTHANSA as used in this exercise, and too short to land for twin-aisle commercial (long haul) airliners. However, aircraft (just) not able to land at Twente Airport SRAP 06, may (in future) well be able to land on SRAP approaches on long(er) runways at major international airports.

12. *Lighting*
    No Approach Lighting System (ALS) for the RWY06 and SRAP was implemented (in accordance with DEMOP), preventing to evaluate the solution in IMC down to CAT I minima.

13. *ATC*
    Twente Airport is an uncontrolled airfield with no ATC. Therefore, no ATC service could be provided, preventing to assess the required ATC system support (HMI) and wake minima separation management support. The specific ATC phraseology for dual threshold operations (SRAP and IGS-to-SRAP) was however simulated within the cockpit.
    The participating aircraft was segregated from other traffic and no evaluation of the advantage of the optimised wake turbulence minima applicable to dual threshold / SRAP operations was possible (in accordance with DEMOP).

14. *Wind*
    Due to operational implications (vicinity of German airspace), the SRAP runway was chosen (in the DEMOP) to be 06 (second threshold from 05), even when prevailing wind directions are from the south-west. During the test flights considerable tail wind conditions existed.

15. *Test subjects*
    Test subjects have been chosen such that a wide range of pilots were represented (see Table 14). Test subject ages ranged from in-the-20 to in-the-50 with ages in-between also covered. The flight experience of the test subjects ranged from little experienced (200 hrs) up to well experienced (>14000 hrs). Most test subjects are flying air transport type aircraft, but also test subjects flying small aircraft were included. Finally, the test subjects included both test- and regular pilots.

16. *Aircraft*
    Test flights were performed with NLR's Cessna Citation II research aircraft with the test subjects in the right hand seat. Although all test subjects are pilots, not all of them have a type rating on this aircraft. The ferry flights to Twente Airport and some first approaches (as well as thorough briefing material) were used to familiarize the test subjects with the aircraft and with (IGS-to-)SRAP operations. The questionnaire ratings are well comparable to air transport category aircraft, as the Lufthansa (A319) and TUI (B737 Max 8) flights have shown comparable ratings.

Summarizing the above, it can be concluded that the level of significance is high and that the outcomes are very useful for future implementations of the (IGS-to-)SRAP procedures, either in daily regular operations or in further testing/demonstration activities (e.g. including lighting solutions).

The extent of the applicability of the results of this demonstration exercise is affected by the following items.

For EXE-001 SRAP and IGS-to-SRAP at Twente airport:

- *Aircraft*: the tested aircraft is an Airbus A319-112 equipped with CFM56-5B6/3 engines owned and operated by Lufthansa. Different aircraft types might perform the studied procedures differently in terms of aircraft speed, engine regime or use of airbrakes, parameters that significantly affect noise.

- *Glide slope*: 3.5° in the case of IGS-to-SRAP. Different slopes might produce different results because their effect on aircraft speed, engine regime or use of airbrakes are not evaluated in this study.

- *Go-arounds*: the use of go-around instead of complete landing procedures limits the analysis to the section of the trajectory where the aircraft is over a certain height. Confidence is high from a certain distance of the airport, excluding only the zone that is very close.

- *Number of test runs*: the number of test runs is relatively small for providing a statistical analysis.

- *Absence of noise recordings*: Twente airport is not equipped to monitor noise. Noise recordings can be used not only to confirm the conclusions of the study but also to improve the quality of aircraft noise models in the application condition, which may be different to the model generation conditions.

- *Noise prediction:* noise results are based on Airbus in-house models that are calibrated on different noise measurements performed during the development of the aircraft, including flight tests, wind-tunnel tests and engine static tests.

In summary, the significance of the demonstration results is high, which can be extrapolated to other airports, but cannot be extended to other slope values (3.5° for IGS-to-SRAP) and to different aircraft types.

The absence of noise recordings reduced the precision of noise predictions, but in the majority of the results, a large noise reduction was conclusive. The mix of flights where the pilots performed standard procedures versus procedure trials raised questions during the analysis that affected the results and were proposed for further investigation.

A.3.4.2 Quality of Demonstration Exercise Results

Questionnaires have been used to collect ratings from the test subjects on the different aspects of the (IGS-to-)SRAP procedures (see section A.3.2). The ratings ranged from “completely disagree” (rated 1) to “Completely agree” (rated 6). The ratings have been averaged to arrive at the (un)acceptability of the particular questionnaire item (for the given runs as indicated in Table 13). Averages higher than 3.5 are thereby interpreted as “acceptable” or “met”, whereas averages below 3.5 are interpreted as “unacceptable” or “failed”. Most of the average scores are well above 5.5 (especially for the Post Run Questionnaires) with the lowest average scores at 4.5 (Post Experiment Questionnaire). Given that these average scores are well above 3.5, the ‘accuracy’ of the ratings is no factor and the interpretation as “acceptable/met” is justified.

(A few individual ratings in the Post Run Questionnaire scored as low as 3 – being the lowest individual score. These were however all rated by the least experienced pilot, test subject B (see Table 14). Another few individual ratings in the Post Experiment Questionnaire scored also 3 – also being the lowest score. Most of these scores concerned again test subject B, but also C and E had these scores. These scores mainly relate to the phraseology, charts and runway designation, all of which depend on personal preferences. See also A.4 item 4 below.)

Aircraft noise is sensitive to many physical variables and the error in their recording or modelling contributes to an uncertainty in the noise prediction methodology. In order to draw conclusions about the objective, the results of the study must be compared to the error of their methodology.

Most of the criteria, including the results of exercise EXE-001, presented a noise impact large enough to provide significant conclusions with a high level of confidence.

A.3.4.3 Significance of Demonstration Exercises Results

<u>Statistical significance</u>

Given the uncontrolled nature of the total set-up of the experiment – e.g. wind-, cloud-, precipitation-light- and visibility conditions were different for each flight/approach –, together with the relatively small amount of test subjects, the experiment data have not been subjected to statistical analyses other than simple comparison of average pilot ratings to critical acceptability values or reference scenario results (in accordance with DEMOP).

Statistical significance

For EXE-001 SRAP and IGS-to-SRAP at Twente airport, one test run is used to represent each procedure for each objective, therefore no statistical analysis has been performed. All test runs were performed on the same day, aircraft and runway, which reduced the variability in the parameters that affect noise: temperature, humidity, aircraft weight.

Operational significance

See heading 1 in section A.3.4 above.

For EXE-001 SRAP and IGS-to-SRAP at Twente airport, all runs correspond to one dedicated flight test, therefore the operational significance of these results is limited.

A.4 Conclusions

A.4.1 Noise

The EXE-001 demonstration exercise concludes with noise reduction due to SRAP and IGS-to-SRAP with 3.5° glide slope. Aiming for a SRAP threshold further down the runway displaces the ground noise impact area towards the airport and away from inhabitants and makes the aircraft noise benefit from the altitude difference. The IGS-to-SRAP procedure with 3.5° glide slope makes the aircraft noise benefit by increasing the altitude difference. For both SRAP and IGS-to-SRAP procedures, noise reduction is visible when looking at the LAmax levels under-track, and area shift is visible when reviewing noise contours.

All EXE-001 objectives are validated as each associated criteria has been assessed.

A.4.1 Human Performance and Safety

NLR's Cessna Citation has performed the GBAS-based (IGS-to-)SRAP flight tests in Exercise 01 at Twente Airport in the period from 28 September through 8 October 2021. In this period the experiment set-up has been checked successfully (see AN D5.1) and the test subjects have been exposed to the EAP's. The check-out consisted of multiple flight inspections to demonstrate correct set-up of the GBAS ground system (INDRA NAVIA), transportable PAPI system and additional runway markings, as well as the onboard GBAS system and MMR (EUROCONTROL). Subsequently, 6 subject pilots have flown the

(IGS-to-)SRAP approaches. Based on the ratings provided by the test subjects in the questionnaire forms, it follows that all demonstration objectives have been met. This generally implies that under VMC/VFR:

1. (IGS-to-)SRAP approaches can be safely and confidently performed without any difficulties; the procedures are straightforward and well within the capabilities of any current crew. (4.0 and 4.49 deg IGS-to-SRAP approaches, although within normal approach design criteria for the Citation and demonstrated by the Citation in Exercise 01, may require careful energy management for larger aircraft.)

2. Impact on crew coordination and work load remains within acceptable limits.

3. (IGS-to-)SRAP runway markings and PAPI are sufficiently distinguishable from existing markings and PAPI, and do not negatively impact approaches to the conventional runway. The steeper the IGS-to-SRAP approach, the better the runways can be distinguished.

4. Inclusion of “first/second runway” in the landing clearance is acceptable, whereas the choice of runway designator remains subject of personal preference: some subjects prefer e.g. “05A/B” over “05/06”. The mentioning of the first/second threshold is the most important part. There is no difficulty to associate lower glide slope (traffic information) with first threshold (landing clearance) or upper with second. “Lower/upper” vs. “first/second” allow crew to clearly distinguish between a traffic information and a landing clearance.

The environmental conditions encountered during the flight tests included bright sun shine from back to side, as well as patchy sun shine conditions on the runway markings of both conventional and SRAP runways. The tests also contained overcast situations. Furthermore, flight tests included runs with considerable tail wind components and moderate turbulence.

Although all demonstration objectives have been well met based on the questionnaire scores, the subject pilots have also provided comments (in Post Experiment Questionnaire and/or briefings) that are input to a number of recommendations as well, which are covered in the next section.

A.5 Recommendations

A.5.1 Recommendations for industrialization and deployment

A.5.1.1 Human Performance and Safety

Following recommendations are based on subject pilot notes/remarks:

1. The light intensity of the transportable SRAP PAPI turned out to be less than the conventional fixed PAPI. The SRAP PAPI became visible at 7-8 Nm out on the straight-in approach (5 Nm for bright sunshine conditions). For testing purposes this is acceptable (i.e. it does not influence the ratings) as observed by NLR test pilots during the check-out flights. However when implementing such solutions in daily operations, it is highly recommended to have both PAPI’s operating at equal brightness.

2. In case the (IGS-to-)SRAP procedures are to be performed in worse weather conditions than the VMC encountered during the tests, the use of (some kind of) SRAP approach lights is recommended.

3. For approaches to runways with conventional and (IGS-to-)SRAP procedures, it may be good for the mindset to include the runway designation also in the 500 ft call.

4. Small changes/additions to the approach briefing and crosschecks to verify the correct runway end will need to be incorporated in the SOPs.

5. 4.0 and 4.49 deg IGS-to-SRAP approaches, although within normal approach design criteria for the Citation and demonstrated by the Citation in Exercise 01, may require careful energy management for larger aircraft.

6. For a good mental picture it may be helpful to include "lower/higher glide" in traffic info messages.
7. If PAPIs are on opposite sides of the runway for first and second threshold (as was the case for EXE01), it could be possible and considered to add that information to the phraseology as an additional distinguishing factor.

In (IGS-to-)SRAP charts it may be even more clear when using "2nd Threshold" in the header.

A.5.2 Recommendations on regulation and standardisation initiatives

See section Appendix E.

EUROPEAN PARTNERSHIP

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Appendix B Exercise VLD1-02 Report ISGS Frankfurt Demonstration

B.1 Summary of the Demonstration Exercise VLD1-02 Plan

B.1.1 Exercise description and scope

Summary

The flight trials were intended to cover the following SESAR solutions:

- GLS CAT II Demonstration
- Increased Second Glide Slope (ISGS)
- Extended Service Volume
- Ops Analytics environmental
- Noise assessment

The flight tests were performed by Lufthansa German Airlines and coordinated with the German Air Navigation Service Provider / ANSP DFS (Deutsche Flugsicherung) at Frankfurt Airport. 6 tail signs from Lufthansa A320 Family fleet were designated for the test flights flown by dedicated crew members.

Tailsign	Aircraft (A/C) Type
D-AIBH	A319
D-AIBI	A319
D-AIBJ	A319
D-AIZY	A320
D-AISU	A321
D-AISW	A321

GLS CAT II Demonstration

The objective of the task is to demonstrate GBAS CAT II approaches with GLS avionics equipped aircraft using the upgraded GAST C Ground Station at Frankfurt Airport.

By adding an SBAS receiver to the GBAS ground station, it allows the station to make use of the navigational service EGNOS regarding ionospheric corrections and assures specific continuity requirements. In this way, the station supports CAT II operations based on amplified CAT I (GAST C) equipment

DFS achieved the approval for the upgraded GAST C ground station and published the GLS CAT II procedures for Frankfurt Airport in July 2022.

During the trial phase Airbus has achieved the technical Certification for GBAS CAT II operation of their Airbus A320 aircraft type by the EASA in July 2022.

AIRBUS is working on the extension of the GLS CAT II capability to other A/C families. This extension requires FMA harmonisation feasibility studies which are on going.Due to pending operational approval, GLS CAT II trials were performed under simulated CAT II conditions based on the respective CAT II operational procedure of Lufthansa. The approaches were carried out with 3.0deg glide slope (GLS Z approach).

In this frame Lufthansa was aiming for the operational approval of A320 aircraft for GBAS CAT II operation. Execution of up to 30 test flights were set as the first milestone because this minimum number of flights were required by the German Civil Aviation Authority (LBA) for the operational approval of a new Low Visibility Procedure.

During the trial period **30 GLS CAT II Approaches** with automatic landing in Frankfurt were achieved.

Approach Type and RWY	**Number of Trials**
GLS Z RWY 07L	8
GLS Z RWY 07R	8
GLS Z RWY 25R	6
GLS Z RWY 25C	1
GLS Z RWY 25L	7

The following section provides an overview of the requirements for GLS CAT II in Germany. These may slightly vary in other European countries depending on the opinion of the individual regulators. Further guidance for CAT II on GAST C is available at ICAO level (currently draft version only).

Ground requirements:

- Proof of specific Continuity for CAT II instead of average Continuity (CAT I)
- Extensive limitation of the remaining error (SBAS receiver allows for monitoring of the current iono conditions)
- Ground station (Honeywell SLS-4000) in Block IIS configuration and Service Level B
- FASLAL set to 10m (instead of 40m for CAT I)
- ATC interface modified to display Service Level B as CAT II and Service Level A as CAT I
- Sufficient VDB runway coverage measured at 12ft and calculated for 36ft
- DFS CONOPS defines similar work orders as for ILS CAT II but less limitations (no protection zones, etc.)

Airborne requirements:

- Aircraft certified for GLS CAT II on GAST C (Inside landing box from CAT II DP with GAST C error characteristics, Autoland)
- Airline must have Operational Approval for GLS CAT II

No HW change or upgrade is necessary to fly GLS CAT II on GAST C on the airborne side.

Increased Second Glide Slope (ISGS)

GLS approaches with 3.0deg glide slope and 3.2deg glide slope were performed in Frankfurt for the increased second glide slope trials. Following published approach procedures for Frankfurt Airport were flown for the ISGS trials:

- GLS Z CAT I with 3.0deg glide slope
- GLS Y CAT I with 3.2deg glide slope
- GLS Z CAT II with 3.0deg glide slope

Since Automatic Landing for CAT II approaches is mandatory according to Lufthansa Standard Operating Procedures (SOP) and all aircraft assigned to the trials are not approved for automatic landing with 3.2deg glide slope, GLS Y CAT II approaches with 3.2deg glide slope were not performed.

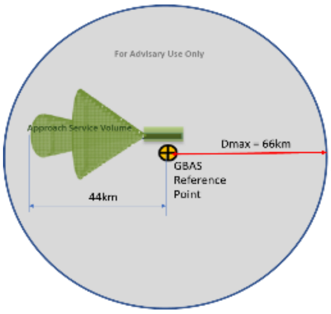
AIRBUS carries out studies for future products to improve in the approach construction and energy awareness for demanding approaches such as ISGS with different slopes and compatible with the emerging context of Continuous Descent Optimisation (CDO).

During the trial period, 37 approaches with 3.2° glideslope and 30 approaches with 3.0° glide slope were achieved:

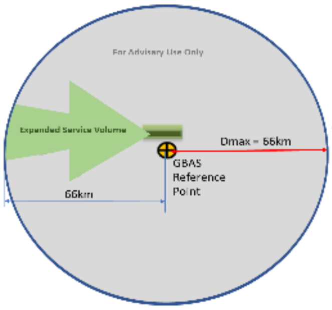
Approach Type and RWY	**Number of Trials**
GLS Z RWY 07L	8
GLS Y RWY 07 L	11
GLS Z RWY 07R	8
GLS Y RWY 07R	2
GLS Z RWY 25R	6
GLS Y RWY 25R	10
GLS Z RWY 25C	1
GLS Y RWY 25C	0
GLS Z RWY 25L	7
GLS Y RWY 25L	13

Expanded Service Volume

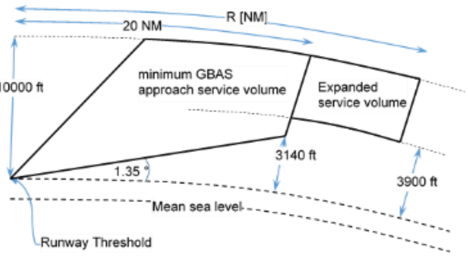
DFS implemented an Expanded Service Volume (ESV) with increased Dmax of 66km (approx.. 35NM) from the GBAS reference point to support all RWY25 GLS approaches out of higher intermediate altitudes and greater distances during independent parallel operations to avoid long low-level flights on downwind in high density traffic.



Standard VDB coverage volume



Expanded Service Volume



Vertical Profil of ESV

The ESV could only be implemented to the RWY25 approaches due to reduced VDB coverage caused by of forest west of the GBAS VDB antenna. Therefore, all RWY07 approaches are limited to the standard VDB coverage volume (20NM from threshold / 23 NM from GBAS reference point). As the Dmax of 66km is a common setting for all GLS approaches, the GBAS guidance for the RWY07 approaches beyond 20NM must be considered for information only (situational awareness).

On RWY25 GLS approaches ATC may clear aircraft already from 66km (32NM to THR) up to intermediate altitudes of 10.000ft. This potentially results in reduced fuel burn, CO2 and noise emissions.

Due to other priorities the use of ESV was demonstrated only for very few approaches during the trial period. Therefore, a quantitative assessment of the benefits is not included in this report and should be subject of further surveys.

<u>Ops Analytics Environmental</u>

Furthermore, Ops Analytics environmental performance analysis (mainly noise) on Lufthansa operations will be done, covering conventional (i.e., 3°) arrival operations for GLS CAT II demonstrations and IGS (up to 3.2°) operations being flown in GLS CAT I.

Operational Conditions

<u>GLS CAT II Demonstration</u>

All simulated GLS CAT II approaches were performed with automatic landing due to Lufthansa Standard Operating Procedures (SOP) based on an operational risk evaluation (ORE). Trials were conducted by dedicated flight crews who were asked to complete reporting sheet and questionnaire for human performance and Safety analysis after each flight.

Crew Preparation and Conditions for GLS CAT II Autoland Approaches

In reference to the operational basics mentioned in the previous chapter, procedure steps were defined before conducting the GLS CAT II Autoland Approach. Following limitations and preconditions for the Trials were defined based on the Operational Risk Evaluation

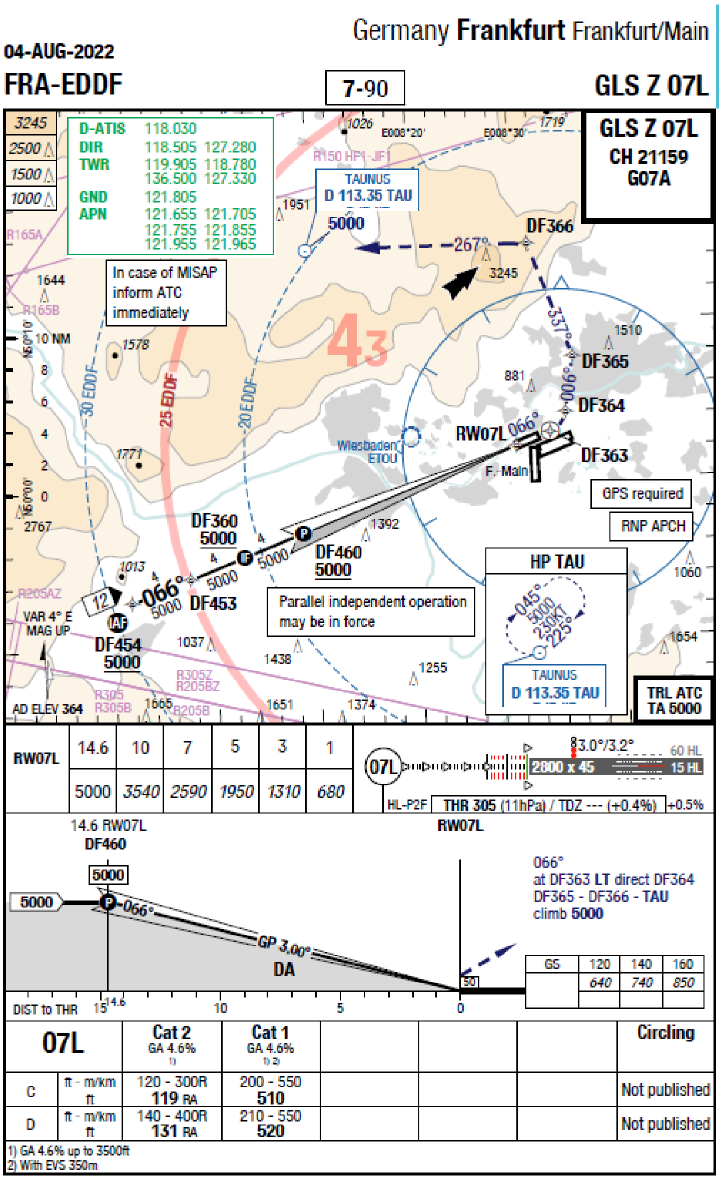
The conditions must meet to commence the trial approaches:

- minimum visibility 2000 meters
- ceiling not below 500 ft
- maximum crosswind component 15 kts (instead of certified 20 kts)
- dedicated crew member only, who have either performed the simulator instruction at Airbus or have received a briefing from another colleague with actual experience.
- there are no open or deferred TLB (Technical Logbook) complaints on GPS, FMGC or AFS.
- opposite ILS is not radiating.
- Airport/ATC confirms prior commencing approach, that GLS station is fully operational without any disturbances.
- GLS approach with Route Indicator “Z” only. (A320 Family is certified for Automatic Landing to max 3.15° Glideslope – except NEOs with 3.2°)

Ground Facility

The GBAS station for CAT I Operation has been deployed in Frankfurt in 2014. Since July 2022 it supports also CAT II Operation. The Approach Procedures were published by DFS for the Runways 07 L/C/R, 25 L/C/R with 3.0deg and 3.2deg glide slopes.

The following figure introduces a customized example GLS Z for the Runway 07 L:



Noise assessment

Demonstration scenarios

Description and naming of procedures:

- Reference GLSZ - GBAS CAT I or CAT II conventional approach (3.0 deg) to nominal threshold.
- Solution GLSY - GBAS CAT I Increased Second Glide Slope (ISGS) approach (3.2 deg) to nominal threshold.

The noise impact has been assessed at two levels:

- Flight level - selection of pairs of landings (one using ISGS GLSY procedure vs one conventional GLSZ) for the same runway (one pair per runway available) based on the analysis of the flight data recordings, in order to select profiles with similar trends in the parameters that influence noise prediction. The metrics for comparison are under-track noise levels (LAmax) and area inside iso-LAmax contours.
  - Scenario #1 - Selected pair (GLSZ vs GLSY) on 07L runway
  - Scenario #2 - Selected pair (GLSZ vs GLSY) on 25L runway
  - Scenario #3 - Selected pair (GLSZ vs GLSY) on 25R runway
  - Scenario #4 - Selected pair (GLSZ vs GLSY) on 25C runway
- Statistical level - average of under-track noise levels (LAmax) for the full set of A319-112 flights available, which comprises 65 flights. The noise value is not averaged over the whole trajectory, but at different ranges of ground distances from the runway threshold.
  - Scenario #5 - Statistics on all 65 flights

The here-above chart presents the flight ground tracks analyzed in this study. The labels indicate the name of the runways and the noise monitoring station positions.

Demonstration assumptions

Test matrix

Lufthansa provided flight data recordings for 65 A319-112 (112 (CFM56-5B6/3 engines) flights. The following figure presents the flight distribution according to runway, slat/flap (S/F) final configuration and glide slope (GLSY = 3.2°, GLSZ = 3°).

COUNTA of A/C			Approach	
A/C	runway	final S/F conf	GLSY	GLSZ
A319-112	07L	3	4	4
	07L	Full	6	5
	07R	3	1	
	07R	Full	1	6
	25C	3	1	1
	25C	Full	3	3
	25L	3	3	8
	25L	Full	3	6
	25R	Full	7	3
Grand Total			**29**	**36**

Distribution of the flight recordings in the A319 dataset, comparing the number of GLSY & GLSZ procedures

The whole of this 65 flights will be used in demonstrating criterion CRT-02.02-V3-VALP-ISGS.0401-003 (Scenario #5).

Scenarios #1 to #4 will be used for demonstration of criteria CRT-02.02-V3-VALP-ISGS.0401-001 and CRT-02.02-V3-VALP-ISGS.0401-002. The selected flights are presented in the following table:

Run	Landing weight (t)	Glide Slope (°)	Runway	Final conf Slat/Flap	Landing gear extension (km from the runway threshold)	CAT
GLSY-07L	50.4	3.2	07L	Full	11	CAT I
GLSZ-07L	51.7	3	07L	Full	10	CAT I
GLSY-25L	52.9	3.2	25L	Full	10	CAT I
GLSZ-25L	51.8	3	25L	Full	10	CAT I
GLSY-25R	55.6	3.2	25R	Full	12	CAT I
GLSZ-25R	51.2	3	25R	Full	11	CAT II
GLSY-25C	56.4	3.2	25C	Full	11	CAT I

GLSZ-25C	51.1	3	25C	Full	12	CAT I

Flight configuration

All noise assessments start from the FAP (Final Approach Point) and cover the following range of flight parameters.

Runway	FAP distance from the runway (km)	Height (ft)	Calibrated Air Speed (kts)	Slat/Flap sequence	Landing gear extension	Airbrakes extension
07L	26	4600 to 0	180 to 0	Conf 3 to full	Up to Down	No
25L	20	3700 to 0	170 to 0	Conf 3 to full	Up to Down	No
25R	26	4600 to 0	180 to 0	Conf 2 to full	Up to Down	No
25C	20	3700 to 0	170 to 0	Conf 3 to full	Up to Down	No

All the performance charts present the here-under parameters vs the ground distance (in meter):

- aircraft height in ft (H),
- engine power in % (N1K),
- calibrated air speed in kts (CAS),
- slat/flap deflection in degrees (Configuration),
- landing gear extension (Landing gear).

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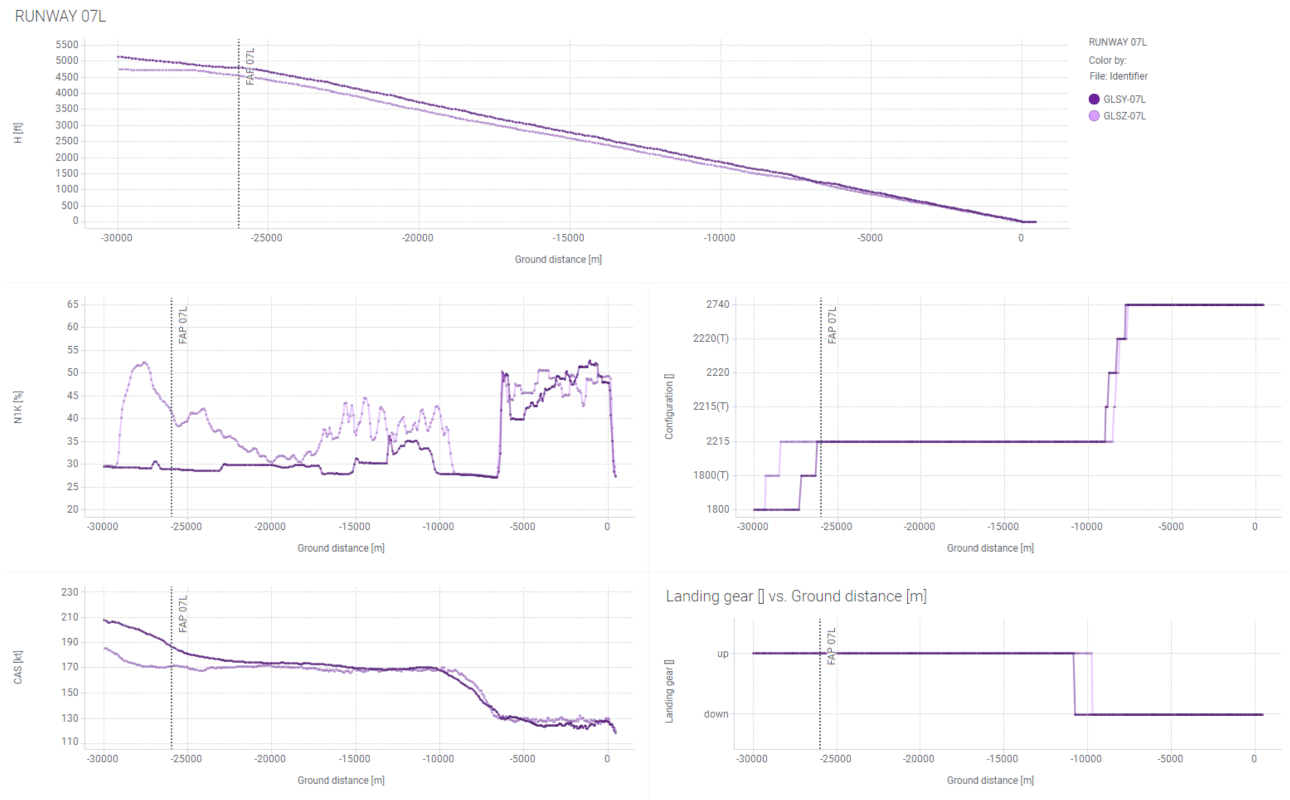
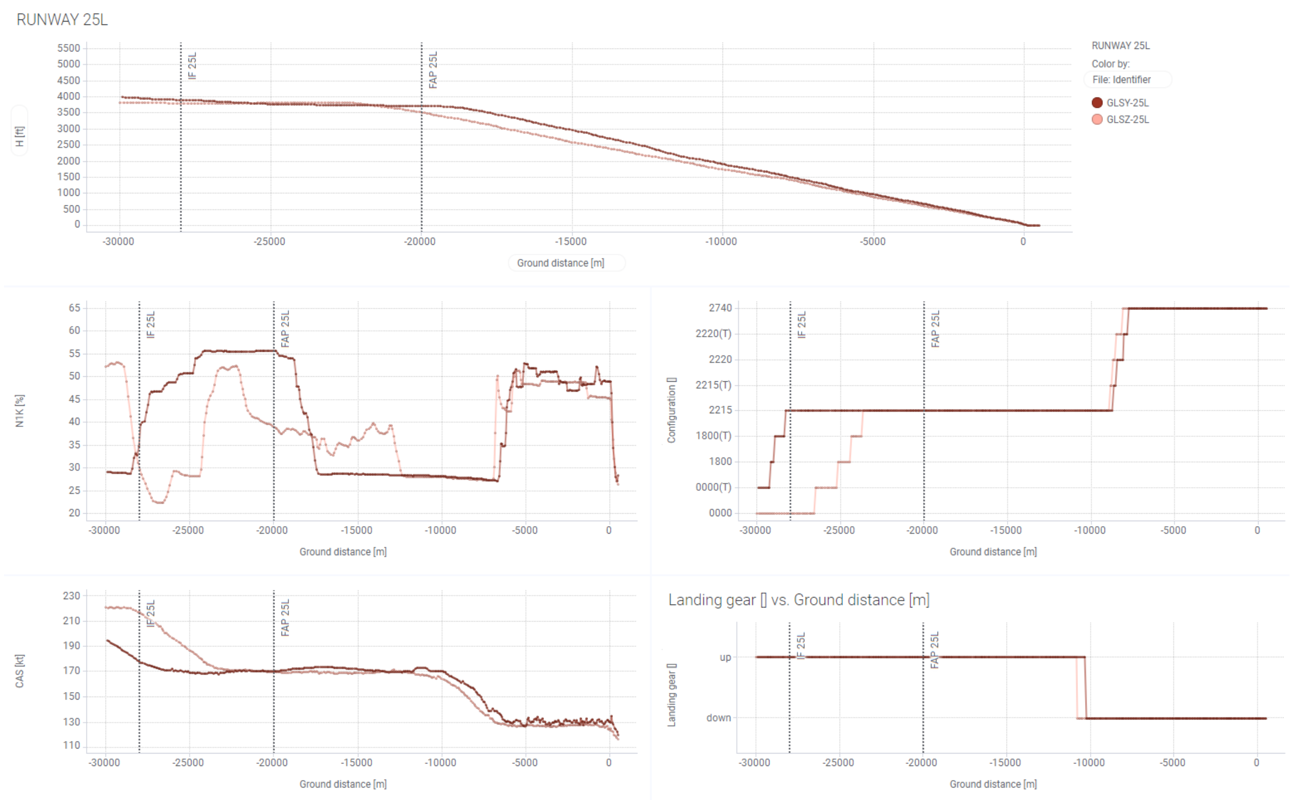
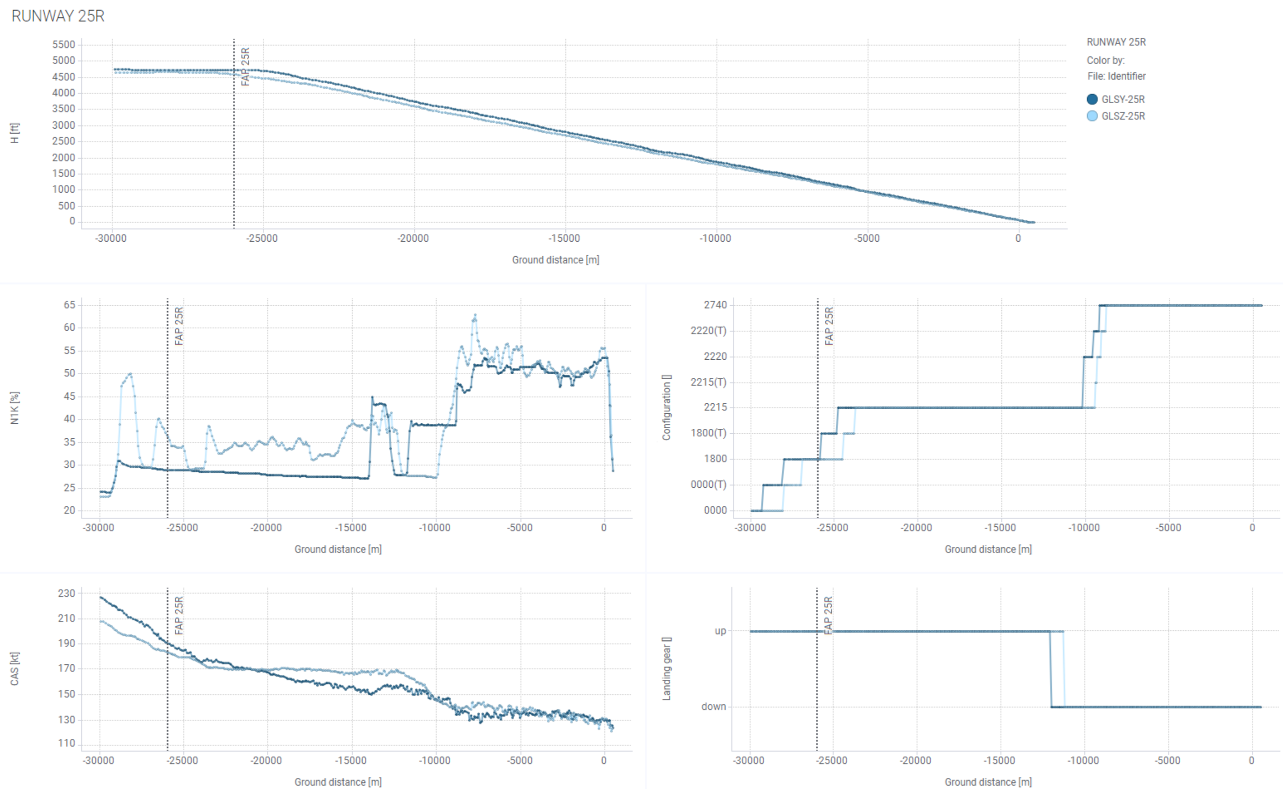


GLSY vs GLSZ flight performance comparison for 07L landings



GLSY vs GLSZ flight performance comparison for 25L landings



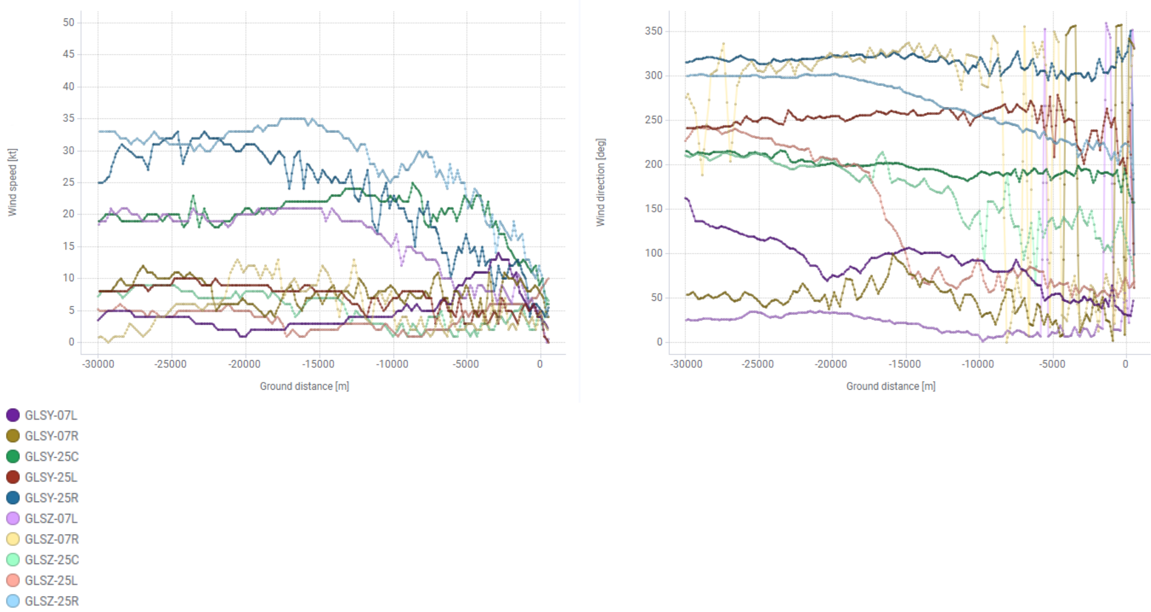
GLSY vs GLSZ flight performance comparison for 25R landings

GLSY vs GLSZ flight performance comparison for 25C landings

Weather

Airport-measured air temperature and relative humidity is presented in the following table. Noise predictions take into account temperature and humidity profiles for calculating atmospheric absorption coefficient (SAE ARP5534 method).

Run	GLSY-07L	GLSZ-07L	GLSY-25C	GLSZ-25C	GLSY-25L	GLSZ-25L	GLSY-25R	GLSZ-25R
Airport temperature (°C)	16	18	19	25	16	26	16	6
Airport relative humidity (%)	77	73	88	50	52	50	72	81



Wind speed and direction per flight

Wind speed and direction is included in the flight data recordings provided by Lufthansa. Wind effect is not taken into account for noise calculations. It is presented in order to understand flight performance profiles.

<u>Noise prediction</u>

Noise impact has been evaluated with Airbus in-house tool, performing noise predictions based on an integrated (whole aircraft including engine and airframe) noise source model. These predictions are calibrated on different noise measurements performed during the development of the aircraft, including flight tests, wind-tunnel tests and engine static tests.

B.1.2 Summary of Demonstration Exercise VLD1-02 Demonstration Objectives and success criteria

Demonstration Objective (as in section 4.4)	Demonstration Success	Coverage and comments on the coverage of	Demonstration Exercise 1 Objectives	Demonstration Exercise 1

	criteria (as in section 4.4)	Demonstration objectives (as in section 4.4)		Success criteria
OBJ-02.02-V3-VALP-IGS.0401 Reduction of the noise impact around the airports due to ISGS implementation	CRT-02.02-V3-VALP-IGS.0401-001 Relative noise scale results positive with IGS use CRT-02.02-V3-VALP-IGS.0401-002 Size of noise contours is reduced with IGS concept CRT-02.02-V3-VALP-IGS.0401-003 Average noise value is not increased	Completely Covered	Idem as OBJ-02.02-V3-VALP-IGS.0401	Idem as CRT-02.02-V3-VALP-IGS.0401-004 Idem as CRT-02.02-V3-VALP-IGS.0401-005 Idem as CRT-02.02-V3-VALP-IGS.0401-006
OBJ-02.02-V3-VALP-IGS.0402 ISGS impact on fuel burnt/emissions	CRT-02.02-V3-VALP-IGS.0402-001 Actual average CO2 Emissions per Flight is maintained or reduced with IGS use. CRT-02.02-V3-VALP-IGS.0402-002 Average Flight Duration is maintained or reduced with IGS use.	This objective was removed from the Project	OBJ-02.02-V3-VALP-IGS.0402-003 Actual average CO2 Emissions per Flight is maintained or reduced with ESV use. OBJ-02.02-V3-VALP-IGS.0402-004 Average Flight Duration is maintained or reduced with ESV use.	CRT-02.02-V3-VALP-IGS.0402-003 Actual average CO2 Emissions per Flight is maintained or reduced CRT-02.02-V3-VALP-IGS.0402-004 Average Flight Duration is maintained or reduced
OBJ-02.02-V3-VALP-IGS.0201 ISGS impact on crew task performance	CRT-02.02-V3-VALP-IGS.0201-001 Pilot succeeds to accomplish an ISGS operation without any difficulty CRT-02.02-V3-VALP-IGS.0201-002 Impact on crew cooperation and crew workload remains with acceptable limit	Partially covered	Idem as OBJ-02.02-V3-VALP-IGS.0201	Idem as CRT-02.02-V3-VALP-IGS.0201-001 Idem as CRT-02.02-V3-VALP-IGS.0201-002
OBJ-14.3-V3-VALP-0203	CRT-14.3-V3-VALP-0203-001 There is evidence that the level of operational safety is maintained and not negatively	Partially covered (slope limited to 3.15° or 3.2° , no dual PAPI)	Idem as OBJ-14.3-V3-VALP-0203	Idem as CRT-14.3-V3-VALP-0203-001 Idem as CRT-14.3-V3-VALP-0203-002

ISGS impact on safety crew perspective	impacted under IGS procedures compared to the reference scenario from the perspective of the crew CRT-14.3-V3-VALP-0203-002 Flight crew initiates the flare at the right moment during IGS operation in order to prevent hard landing CRT-14.3-V3-VALP-0203-003 Stabilization criteria are reached when pilot apply current SOPs		OBJ-14.3-V3-VALP-0203 EX2-OBJ-VLD-01-14.3-0203-001 ISGS with GLS CAT II aircraft airworthiness certification is granted by Competent Authorities (EASA) EX2-OBJ-VLD-01-14.3-0203-002 Certification for ISGS with GBAS GAST-C+ ground station for CATII operations is granted by Competent Authorities (German BAF) EX2-OBJ-VLD-01-14.3-0203-003 ISGS GLS CATII Airline (Lufthansa) Operational Approval is granted by Competent Authorities (LBA)	Idem as CRT-14.3-V3-VALP-0203-003

OBJ-14.3-V3-VALP-0204 ISGS operational feasibility from crew perspective	CRT-14.3-V3-VALP-0204-001 Pilot succeeds to manage IGS operation by applying existing SOPs CRT-14.3-V3-VALP-0204-002 Pilots are confident when flying a IGS operation	Fully covered	Idem as OBJ-14.3-V3-VALP-0204	Idem as CRT-14.3-V3-VALP-0204-001 Pilot succeeds to manage IGS operation by applying existing SOPs (including use of Autoland function) Idem as CRT-14.3-V3-VALP-0204-002
OBJ-02.02-V3-VALP-IGS.0205 ISGS impact on SOPs	CRT-02.02-V3-VALP-IGS.0205-001 Pilot actions in approach allow to successfully stabilize the aircraft before landing (manage energy,..) CRT-02.02-V3-VALP-IGS.0205-002 Impact of IGS approach, existing SOPs are easily manageable by pilots (no impact on task performance)	Fully covered	Idem as OBJ-02.02-V3-VALP-IGS.0205	Idem as CRT-02.02-V3-VALP-IGS.0205-001 Idem as CRT-02.02-V3-VALP-IGS.0205-002

B.1.3 Summary of Validation Exercise VLD1-02 Demonstration scenarios

The following table summarizes the required capabilities to conduct trial flights:

Stakeholder	Equipment	Capabilities	Location	Approaches	Status	When
Lufthansa	A320 Family	GLS, Autoland	Frankfurt / EDDF	07 L/C/R 25 L/C/R	Confirmed	Jun 22

DFS	GBAS	Upgraded GBAS GAST C CAT - II & II G/S 3.0° & 3.2°	Frankfurt / EDDF	07 L/C/R 25 L/C/R	Confirmed	Jun 22
Airbus	A320 Family	GLS Autoland	Frankfurt / EDDF	07 L/C/R 25 L/C/R	Confirmed	2022

B.1.4 Summary of Demonstration Exercise VLD1-02 Demonstration Assumptions

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
	A320 aircraft & Lufthansa	Approach Autoland	The approach and landing was performed based on Lufthansa Autoland procedure which is also applied for precision approach types for CAT II conditions	It is expected that the approach, landing and aircraft attitude are observed as usual. Crew assessment is required.	HIGH
	GBAS Ground station	Supporting CAT II approaches and high reliability	The upgraded GBAS ground station is capable to the EGNOS navigation service for ionospheric corrections and provides certain continuity requirements.	It is expected that no spatial decorrelation occurs and the equipment ensures its reliability during its use.	HIGH
	Operational Limitations	Environmental Conditions	The demonstrations approaches and landings are commenced under the specified conditions and limitations match according to the introduction in the previous chapter(s)	When the specified conditions were not existing the respective trial was skipped although the flight was originally designated and coordinated for the GLS CAT II trial	MEDIUM

Table 21: Demonstration Assumptions overview

B.2 Deviation from the planned activities

Since Automatic Landing for CAT II approaches is mandatory according to Lufthansa Standard Operating Procedures (SOP) and all aircraft assigned to the trials are not approved for automatic landing with 3.2deg glide slope, GLS Y CAT II approaches with 3.2deg glide slope were not performed.

B.3 Demonstration Exercise VLD1-02 Results

B.3.1 Summary of Demonstration Exercise VLD1-02 Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-02.02-V3-VALP-IGS.0401	Reduction of the noise impact around the airports due to ISGS implementation	CRT-02.02-V3-VALP-IGS.0401-001 CRT-02.02-V3-VALP-IGS.0401-002 CRT-02.02-V3-VALP-IGS.0401-003	Relative noise scale results positive with IGS use Size of noise contours is reduced with IGS concept Average noise value is not increased	TMA	See section B.3.2	Partially OK
OBJ-02.02-V3-VALP-IGS.0402	ISGS impact on fuel burnt/emissions	CRT-02.02-V3-VALP-IGS.0402-001 CRT-02.02-V3-VALP-IGS.0402-002	Actual average CO2 Emissions per Flight is maintained or reduced with IGS use. Average Flight Duration is maintained or reduced with IGS use.	TMA	It was not possible to measure the difference of the fuel flow	Not applicable: <u>This objective was removed from the Project</u>
OBJ-02.02-V3-VALP-IGS.0201	ISGS impact on crew task performance	CRT-02.02-V3-VALP-IGS.0201-001	Pilot succeeds to accomplish an ISGS operation without any difficulty	TMA	Pilots succeeded to accomplish 3.2 deg ISGS operation	OK

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					without any difficulty as positive responses were collected relevant for the criteria in the PR and PE questions	
		CRT-02.02-V3-VALP-IGS.0201-002	Impact on crew cooperation and crew workload remains with acceptable limit		Pilots succeeded to accomplish 3.2 deg ISGS operation without any impact on crew cooperation and crew workload	
OBJ-14.3-V3-VALP-0203	ISGS impact on safety crew perspective	CRT-14.3-V3-VALP-0203-001	There is evidence that the level of operational safety is maintained and not negatively impacted under IGS procedures compared to the reference scenario from the perspective of the crew Flight crew initiates the	TMA	Pilots succeeded to accomplish 3.2 deg ISGS operation without any impact on safety as positive responses were collected relevant for the criteria in the PR and PE questions	OK

		CRT-14.3-V3-VALP-0203-002	flare at the right moment during IGS operation in order to prevent hard landing		Pilots succeeded to accomplish 3.2 deg ISGS landings without any hard landing reported. All landings where within the normal distribution range	
		CRT-14.3-V3-VALP-0203-003	Stabilization criteria are reached when pilot apply current SOPs		Pilots succeeded to accomplish 3.2 deg ISGS landings without violating the stabilization criteria according to the SOP	
OBJ-14.3-V3-VALP-0204	ISGS operational feasibility from crew perspective	CRT-14.3-V3-VALP-0204-001	Pilot succeeds to manage IGS operation by applying existing SOPs	TMA	Pilots succeeded to manage IGS operation by applying existing SOPs (including use of Autoland function)	OK
		CRT-14.3-V3-VALP-0204-002	Pilots are confident when flying a IGS operation		Pilots were confident when flying a IGS operation	

OBJ-02.02-V3-VALP-IGS.0205	ISGS impact on SOPs	CRT-02.02-V3-VALP-IGS.0205-001 CRT-02.02-V3-VALP-IGS.0205-002	Pilot actions in approach allow to successfully stabilize the aircraft before landing (manage energy,..) Impact of IGS approach, existing SOPs are easily manageable by pilots (no impact on task performance)	TMA	Pilots succeeded to accomplish 3.2 deg ISGS landings with successfull y stabilizing the aircraft before landing Pilots succeeded easily to accomplish 3.2 deg ISGS operation according to existing SOPs	OK

Table 22: Exercise 1 Demonstration Results

B.3.1.1 Results per KPA

Noise

This demonstration exercise doesn't conclude to an evident noise reduction due to ISGS with 3.2° glide slope as not all criteria are met.

It was expected that, between two landings with similar performance, the aircraft altitude difference (150-200ft) would bring a noise impact at ground. However, when comparing pairs of similar flights performed in operational conditions, a large dispersion in the speed and engine power management appears, which could be some major contributors to noise. This complicates the noise assessment of the sole glide slope effect.

When comparing pairs of flights which are chosen for their similarity, there can be a noise reduction under-track of up to 4 dBA (LAmax), but noise reduction is not consistent over all the trajectory nor all cases. Criterion 1 is concluded as 'Partially OK'. It has been observed that engine power management profile is different between ISGS (3.2°) and conventional (3°) procedures, which was not expected. Further investigation should be done to clarify if these differences in engine power management are a direct consequence of glide slope or due to another reason (environmental conditions, type of guidance, etc…).

The comparison of the size noise contours, performed on the same pairs of flights, did not show a consistent improvement. Criterion 2 is concluded as 'NOK'. The variations in noise contour size are small and in both directions (noise improvement and detriment). The variations are considered of the same magnitude as our prediction uncertainty.

Only average noise under-track is consistently reduced by ISGS with 3.2° glide slope, although this reduction is small (< 1 dBA). Criterion 3 is concluded as 'OK'."

B.3.1.2 Results impacting regulation and standardisation initiatives

The results may be useful for European Airlines applying for a GLS CAT II Operational Approval at their individual regulators as a guideline for:

- Acceptance requirements for OPS Approval
- Criteria for pilot training requirements for GLS CAT II

B.3.2 Analysis of Exercises Results per Demonstration objective

B.3.2.1 OBJ-02.02-V3-VALP-IGS.0402 ISGS impact on fuel burnt/emissions

<u>This objective was removed from the Project</u>

B.3.2.2 OBJ-02.02-V3-VALP-IGS.0201 ISGS impact on crew task performance

To evaluate Crew Task Performance, impact on Safety, Operational Feasibility and impact on SOPs, pilots were asked to fill in the following questionnaire:

OPERATIONAL

During your flight today:		YES	NO	N/A	If NO, please detail
1.1	Have you been able to fly the ISGS procedures with normal and expected system behaviour?	☐	☐	☐	
1.2	Have you observed any difference with ILS Approach?	☐	☐	☐	(If yes)
1.3	Was the approach capability AUTO LAND in the FMA appropriate for Cat2 operation?	☐	☐	☐	

1.4	Did you notice any change in the amount of ATC communications compared to routine operations?	☐ Increase ☐ Decrease	☐ No		
1.5	When flying the GLS CAT II Autoland, did you encounter unexpected banks on short final?	☐	☐	☐	(If yes)
1.6	When flying the GLS CAT II Autoland, did you encounter abnormal flare on short final?	☐	☐	☐	(If yes)
1.7	When flying the GLS CAT II Autoland, did you encounter abnormal touch down?	☐	☐	☐	(If yes)
1.8	When flying the GLS CAT II Autoland, did the aircraft land on center line?	☐	☐	☐	
1.9	When flying the GLS CAT II Autoland, did the aircraft land in the touchdown zone?	☐	☐	☐	

SAFETY

Compared to routine operations:		**YES**	**NO**	**N/A**	**If NO, please detail**
2.1	Did you perceive that the ISGS flight trials have negatively influenced flight safety in any stage of the flight?	☐	☐	☐	(If yes)
2.2	Did you perceive that the ATCO's in contact during the flight were fully aware of the operational scenario of the flight trials?	☐	☐	☐	

WORKLOAD

During your flight, compared to routine operations:		**YES**	**NO**	**N/A**	**If YES, please detail**
3.1	Did you notice any difference in task sharing?	☐ Increase ☐ Decrease	☐		
3.2	Did you notice any differences in your workload levels?	☐ Increase ☐ Decrease	☐		
3.3	If you answered YES to question 3.1 or 3.2, did this affect your overall performance?	☐	☐	☐	
3.4	If you answered YES to question 3.1 or 3.2, what type of workload difference did you experience?	☐ mental ☐ physical ☐ physiological ☐ other (**please detail below**) ☐ N/A			

3.4	If you answered YES to question 3.1 or 3.2, did you feel that, due to increased/decreased workload levels, safety was ever compromised?	☐	☐	☐	

WORKING METHODS

	During your flight:	**YES**	**NO**	**N/A**	**If NO, please detail**
4.1	Were you required to alter your routine working methods in order to fulfill your duties?	☐	☐	☐	
4.2	If you answered YES to question 4.1, was operational information, provided before the flight, exhaustive with regards to - roles and responsibilities, - working methods and - operational requirements?	 ☐ ☐ ☐	 ☐ ☐ ☐	 ☐ ☐ ☐	
4.3	If you answered YES to question 4.1, did you feel that, due to alteration of working methods, safety was ever compromised?	☐	☐	☐	
4.4	Was the information provided before the flight trial sufficient to safely perform the flight?	☐	☐	☐	
4.5	Did you perceive any improvement with regards to flight efficiency?	☐	☐	☐	

All Results are based on the information from the pilot's questionnaires and Reporting Sheets! 28 Crewmember have filled in the questionnaire. The answers are shown in the following:

OPERATIONAL

During your flight today:		YES	NO	N/A	If NO, please detail
1.1	Have you been able to fly the ISGS procedures with normal and expected system behaviour?	**28**	**0**	**0**	
1.2	Have you observed any difference with ILS Approach?	**0**	**28**	**0**	(If yes)
1.3	Was the approach capability AUTO LAND in the FMA appropriate for Cat2 operation?	**28***	**0**	**0**	
1.4	Did you notice any change in the amount of ATC communications compared to routine operations?	Increase: 0 Decrease: 0	**NO: 28**		
1.5	When flying the GLS CAT II Autoland, did you encounter unexpected banks on short final?	**0**	**28**	**0**	(If yes)
1.6	When flying the GLS CAT II Autoland, did you encounter abnormal flare on short final?	**0**	**28**	**0**	(If yes)
1.7	When flying the GLS CAT II Autoland, did you encounter abnormal touch down?	**0**	**28**	**0**	(If yes)
1.8	When flying the GLS CAT II Autoland, did the aircraft land on center line?	**28 (+/- 2 Meter left or right of Centerline)**	**0**	**0**	
1.9	When flying the GLS CAT II Autoland, did the aircraft land in the touchdown zone?	**28**	**0**	**0**	

SAFETY

Compared to routine operations:		YES	NO	N/A	If NO, please detail
2.1	Did you perceive that the ISGS flight trials have negatively influenced flight safety in any stage of the flight?	0	28	0	(If yes)
2.2	Did you perceive that the ATCO's in contact during the flight were fully aware of the operational scenario of the flight trials?	28	0	0	

* a synchronization of the modes analogous to ILS was desired

**however some Pilots reported lower thrust settings during ISGS Operation which increases flight efficiency.

CRT-02.02-V3-VALP-IGS.0201-001 Pilot succeeds to accomplish an ISGS operation without any difficulty

Pilots succeeded to accomplish 3.2 deg ISGS operation without any difficulty as positive responses were collected relevant for the criteria in the PR and PE questions

The flight tests were conducted with commercial flights. All pilots reported no differences from normal operations. All ISGS flights were successfully conducted without any special events or incidents.

CRT-02.02-V3-VALP-IGS.0201-002 Impact on crew cooperation and crew workload remains with acceptable limit

Pilots succeeded to accomplish 3.2 deg ISGS operation without any impact on crew cooperation and crew workload

The flight tests were conducted with commercial flights. All pilots reported no differences from normal operations. There were no differences in crew workload reported. Crew cooperation remained the same. All ISGS flights were successfully conducted without any special events or incidents.

B.3.2.3 OBJ-14.3-V3-VALP-0203 ISGS impact on safety crew perspective

CRT-14.3-V3-VALP-0203-001 There is evidence that the level of operational safety is maintained and not negatively impacted under IGS procedures compared to the reference scenario from the perspective of the crew

Pilots succeeded to accomplish 3.2 deg ISGS operation without any impact on safety as positive responses were collected relevant for the criteria in the PR and PE questions

The flight tests were conducted with commercial flights. All pilots reported no differences from normal operations. There was no impact on safety under IGS procedures. All ISGS flights were successfully conducted without any special events or incidents.

CRT-14.3-V3-VALP-0203-002 Flight crew initiates the flare at the right moment during IGS operation in order to prevent hard landing

Pilots succeeded to accomplish 3.2 deg ISGS landings without any hard landing reported. All landings where within the normal distribution range

The flight tests were conducted with commercial flights. All pilots reported no differences from normal operations. All landings were reported to be within normal limits and no hard landing was triggered by the Flight Warning Computer. All ISGS flights were successfully conducted without any special events or incidents.

CRT-14.3-V3-VALP-0203-003 Stabilization criteria are reached when pilot apply current SOPs

Pilots succeeded to accomplish 3.2 deg ISGS landings without violating the stabilization criteria according to the SOP

The flight tests were conducted with commercial flights. All pilots reported no differences from normal operations. All Approaches were flown within the SOP stabilization criteria (Indicated Air Speed, Vertical Speed, lateral- and vertical deviation, Power setting and Landing Configuration within limits below 1000ft height). No exceeding of SOP criteria was reported.

B.3.2.4 OBJ-14.3-V3-VALP-0204 ISGS operational feasibility from crew perspective

CRT-14.3-V3-VALP-0204-001 Pilot succeeds to manage IGS operation by applying existing SOPs

Pilots succeeded to manage IGS operation by applying existing SOPs (including use of Autoland function)

The flight tests were conducted with commercial flights. Pilots have not experienced any difficulties in applying the existing SOPs for ISGS operation. Except AUTOLAND was not used for ISGS because aircraft was not approved to fly 3.2° with AUTOLAND.

CRT-14.3-V3-VALP-0204-002 Pilots are confident when flying a IGS operation

Pilots were confident when flying a IGS operation

The flight tests were conducted with commercial flights. All pilots reported that they flew the ISG procedures with confidence. There were no doubts about the feasibility of the procedures

B.3.2.5 OBJ-02.02-V3-VALP-IGS.0205 ISGS impact on SOPs

CRT-02.02-V3-VALP-IGS.0205-001 Pilot actions in approach allow to successfully stabilize the aircraft before landing (manage energy,)

Pilots succeeded to accomplish 3.2 deg ISGS landings with successfully stabilizing the aircraft before landing

The flight tests were conducted with commercial flights. All pilots reported no differences from normal operations. All Pilots reported that their actions in approach allowed to successfully stabilize the aircraft before landing (manage energy,) with the Standard Operational Procedures.

CRT-02.02-V3-VALP-IGS.0205-002 Impact of IGS approach, existing SOPs are easily manageable by pilots (no impact on task performance)

Pilots succeeded easily to accomplish 3.2 deg ISGS operation according to existing SOPs

The flight tests were conducted with commercial flights. All pilots reported no differences from normal operations. All SOPs were met without any difficulty. No negative impact on task performance was reported,

B.3.2.6 OBJ-02.02-V3-VALP-ISGS.0401 Results

The ISGS objective has been addressed through under-track and contour noise analysis of recorded flight data from landings to Frankfurt Airport.

Each under-track graph displays the predicted noise metric (LAmax) without units and the associated trajectory (height profile in ft) with matching color. The steeper 3.2° landing is always represented by a darker color and the reference 3° by a lighter color. Landing gear and slat/flap configuration deployment are labeled on the trajectory with tags “CONFX” for Slat/Flap and “U/D” for Up/Down landing gear status.

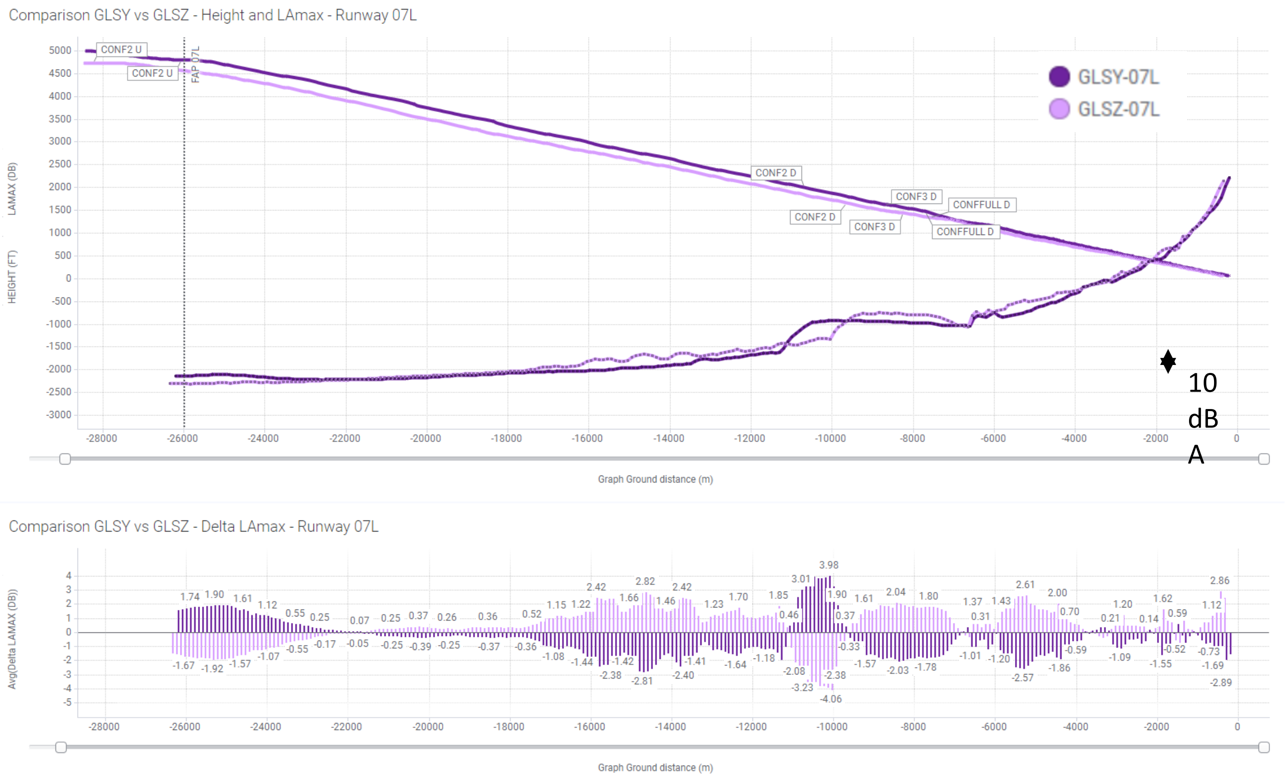
CRT-02.02-V3-VALP-ISGS.0401-001

CRT-02.02-V3-VALP-ISGS.0401-001 : Relative noise scale results positive with ISGS use

This criteria is evaluated through the analysis of Scenarios #1 to #4, all of them comparing selected pairs of similar flights in terms of the parameters that influence noise prediction.

To support the visual analysis of the parameters of influence in noise, a data relationships analysis is performed. For this analysis, linear regressions are performed for all combinations of aircraft performance parameters (directly over the microphone) vs LAmax (dimensional or dimensionless), comparing linear regression coefficients. The 3 most influential parameters are presented for each scenario.

Scenario #1 - Selected pair (GLSZ vs GLSY) on 07L runway



GLSY and GLSZ vertical and LAmax profiles comparison, on runway 07L

For this scenario, the following observations are highlighted:

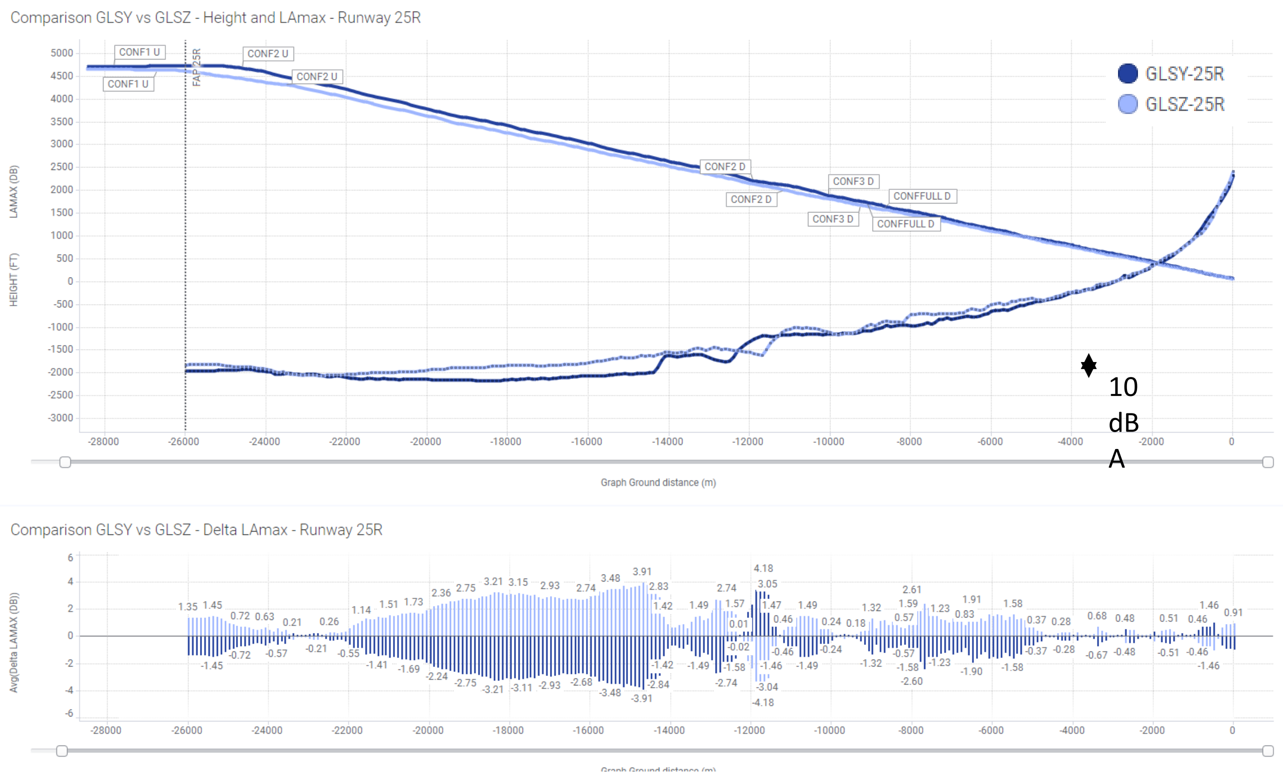
- GLSY (3.2° ISGS) landing is slightly noisier (up to 1.9 dBA) during 2km after the FAP interception, probably due to the higher speed which generates more aerodynamic noise.
- Afterwards, the GLSY is quieter (up to 2.8 dBA), until the landing gear extension. A part of this noise reduction could be explained by an engine power stabilized in idle, while GLSZ approach uses what seems to be adapted thrust to maintain its glide slope.

- As landing gear and slat/flap are extended earlier on this GLSY flight, these important noise sources penalyze this procedure around 11km from the runway threshold, despite a higher aircraft height

The data relationship analysis highlights the influence of speed but cannot confirm a linear relationship with engine regime to be stronger than the effect of height.

Influence in ∆ LAmax **GLSY vs GLSZ**	1st parameter of influence	2nd parameter of influence	3rd parameter of influence
Runway 07L	∆ Mach (R^2 = 0.34)	**∆ Height (R^2 = 0.13)**	**∆ N1 (R^2 = 0.04)**

Scenario #3 - Selected pair (GLSZ vs GLSY) on 25R runway



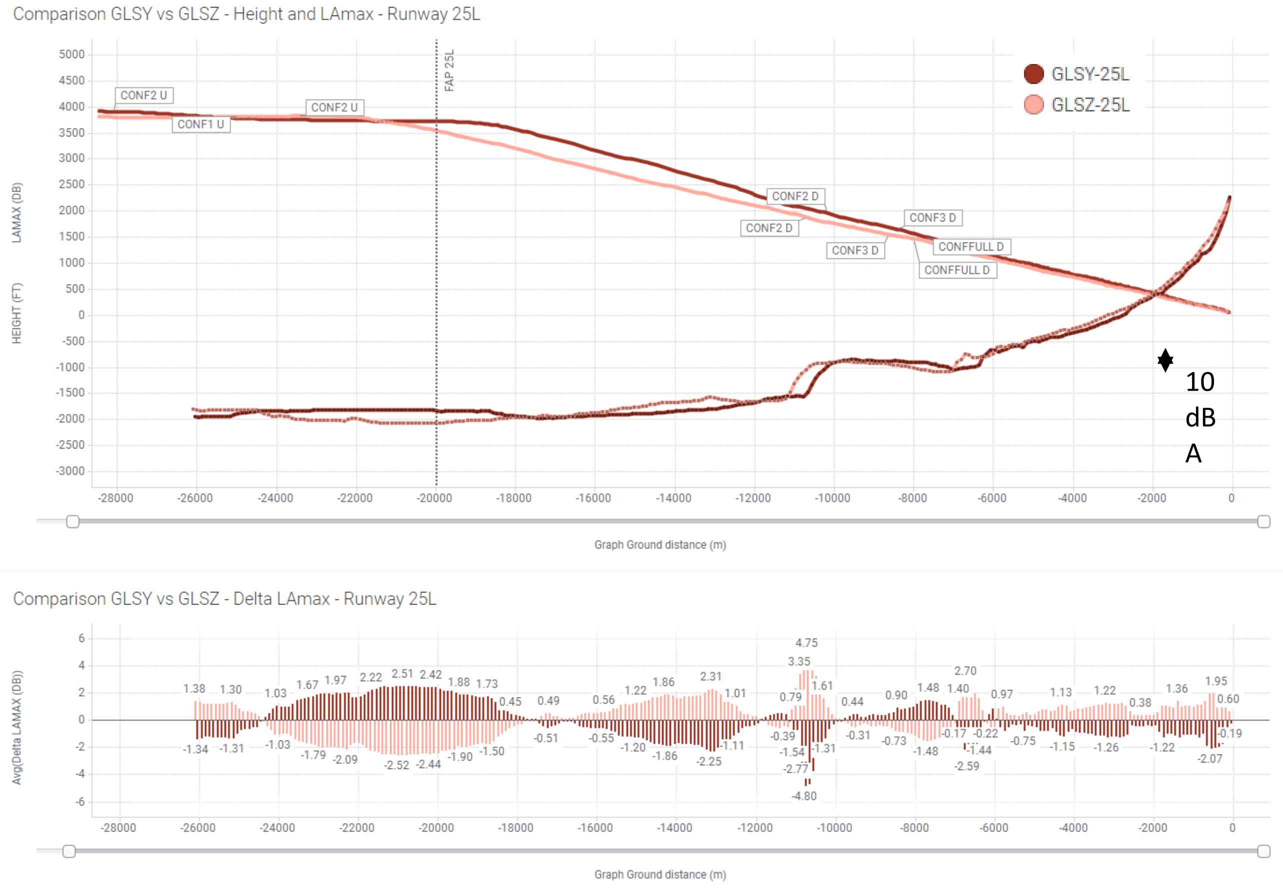
GLSY and GLSZ vertical and LAmax profiles comparison, on runway 25R

For this scenario, with the exception of the time of landing gear deployment (earlier on GLSY than on GLSZ flight), the environmental assessment shows a general noise reduction under-track with ISGS use (GLSY), reducing up to 4 dBA, mainly between the FAP and 14km from the runway threshold.

This time, data relationship analysis confirms the importance of speed, but also that the effect of ΔN1 in noise is of the same order as the effect of Δheight.

Influence in Δ LAmax **GLSY vs GLSZ**	1st parameter of influence	2nd parameter of influence	3rd parameter of influence
Runway 25R	Δ Mach (R^2 = 0.32)	**Δ Height (R^2 = 0.22)**	Δ N1 (R^2 = 0.22)

Scenario #2 - Selected pair (GLSZ vs GLSY) on 25L runway



GLSY and GLSZ vertical and LAmax profiles comparison, on runway 25L

For this scenario, the GLSY (3.2° ISGS) landing brings a noise reduction up to 2 dBA between the FAP interception (20km to runway threshold) and the landing gear extension.

There is a leveled flight phase before the FAP interception that is not considered as part of the landing procedure and is not considered in the data relationships analysis, although it appears in the graph.

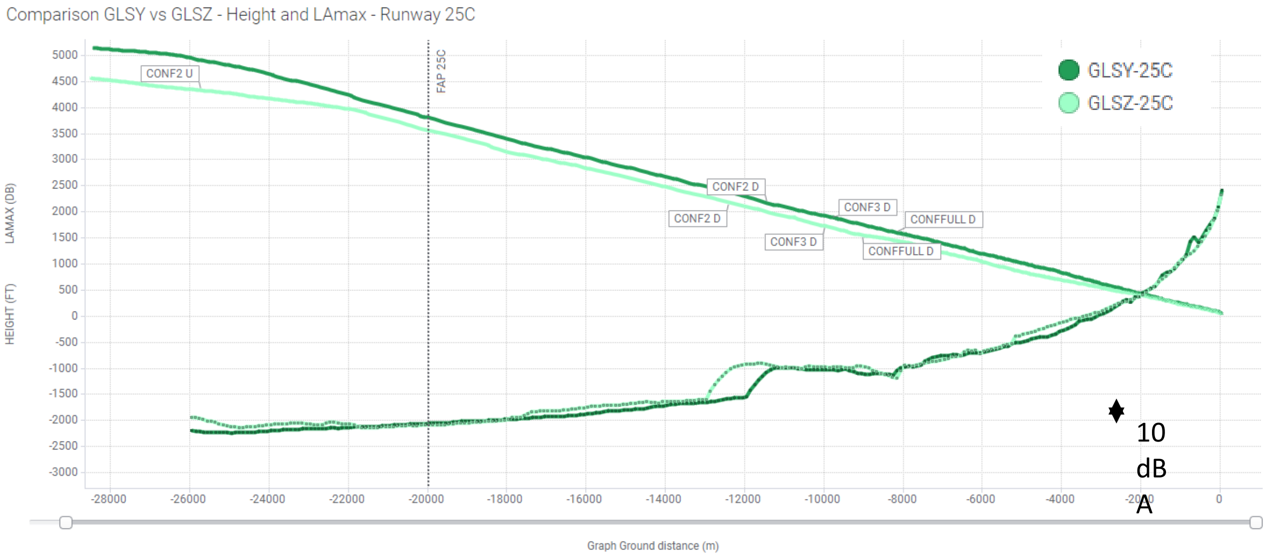
Again, this noise gain is not only correlated with the height of the aircraft, but for both height and engine power profiles. Two observations sustain this hypothesis:

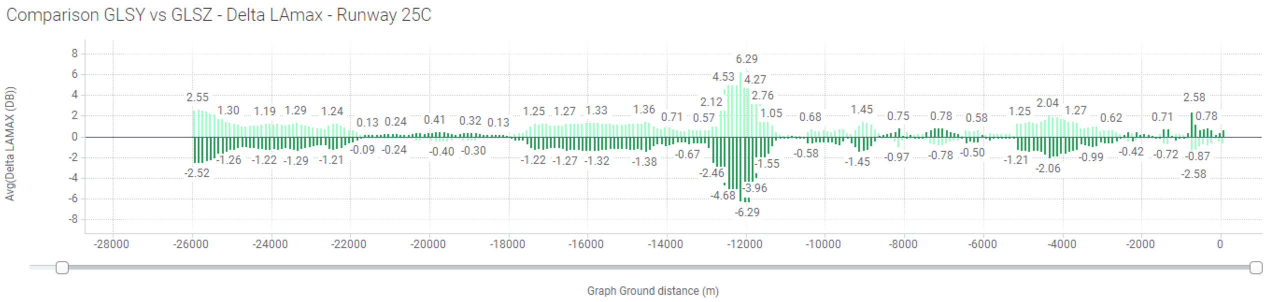
- For GLSY, engine power (N1) remained stable around idle thrust, while in GLZ thrust varied more strongly until 13km from the runway threshold.
- Under the part of the trajectories where aircraft speed and engine power are exactly similar, which correspond to where only the altitudes differ (~250ft), the noise delta is around zero.

The data relationship analysis confirms the influence of engine power setting, as ΔN1 appears to be strongly influential in ΔLAmax and several times more important than Δheight.

Influence in △ LAmax **GLSY vs GLSZ**	1st parameter of influence	2nd parameter of influence	3rd parameter of influence
Runway 25L	**△ N1 (R^2 = 0.50)**	△ Incidence (R^2 = 0.29)	**△ Height (R^2 = 0.10)**

Scenario #4 - Selected pair (GLSZ vs GLSY) on 25C runway





GLSY and GLSZ vertical and LAmax profiles comparison, on runway 25C

For this scenario, the GLSY (3.2° ISGS) landing brings a noise reduction up to 1.3 dBA between the FAP interception and the landing gear extension.

This noise gain seems to be explained by the differences in both altitude and engine power profiles, from a visual analysis. There is a specific case for the noise bump around 13km, which is due to an earlier GLSZ landing gear deployment.

The part of the ground track between the FAP interception (20km) and 18km from the runway threshold is interestant as both flights performance are very similar in terms of speed and engine power. The sole parameter influencing the noise here is the aircraft altitude difference induced by the 3.2° glide slope. The delta LAmax on this specific part is below the noise prediction uncertainties. The GLSY noise gain could be considered as equal to zero.

The data relationship analysis confirms that the influence in ΔLAmax of engine power setting (N1K) is larger than height, although the difference is not as clear as in Scenario #2.

Influence in Δ LAmax **GLSY vs GLSZ**	1st parameter of influence	2nd parameter of influence	3rd parameter of influence
Runway 25C	**Δ N1K (R^2 = 0.19)**	Δ Height (R^2 = 0.11)	Δ CAS (R^2 = 0.05)

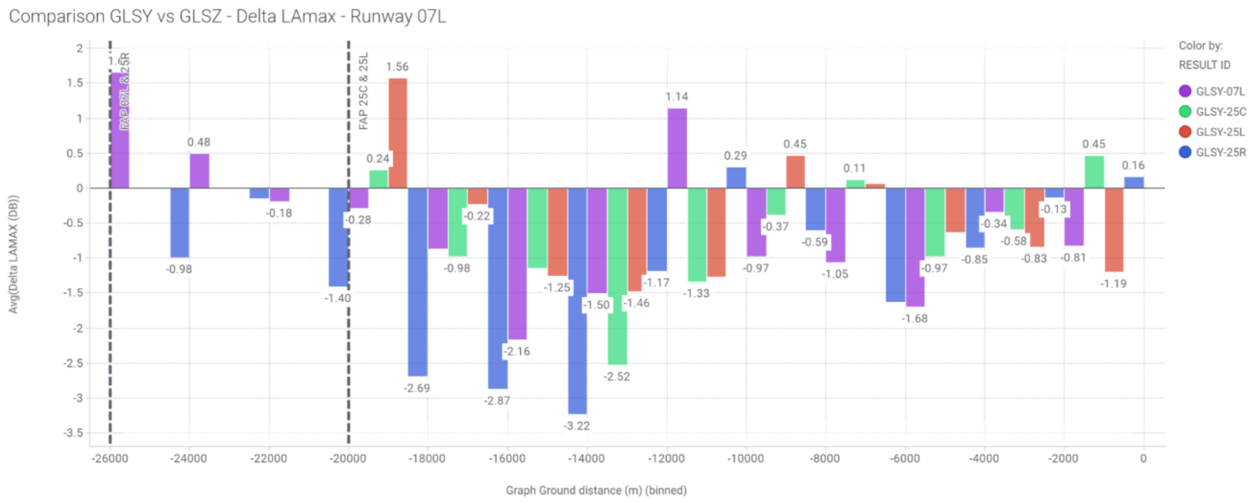
Overall analysis:

Criterion CRT-02.02-V3-VALP-ISGS.0401-001 (Relative noise scale results positive with ISGS use) is partially reached.

In general, there is a relative noise reduction (up to 4 dBA) associated with the ISGS use in all scenarii.

However, in several scenarii, this noise reduction is suspected to be issued from a difference in engine power. The engine power profile is more often stabilized in idle in GLSY (ISGS 3.2°) data recordings, in opposition to a noisier adaptive thrust profile in GLSZ (3°) data recordings. The assumption of the more extensive use of adaptive thrust in GLSZ procedures could not be confirmed with the available data. However, if it were to be true, these different power setting profiles could biaise the glide slope noise impact assessment.

A further investigation should be done in order to know if these different engine power management are a consequence of the different glide slope or of another reason (environmental conditions, type of guidance, etc…).



Comparison GLSY and GLSZ: ΔLAmax under-track on scenarii #1 to #4

A summary of the results of the data relationships analysis:

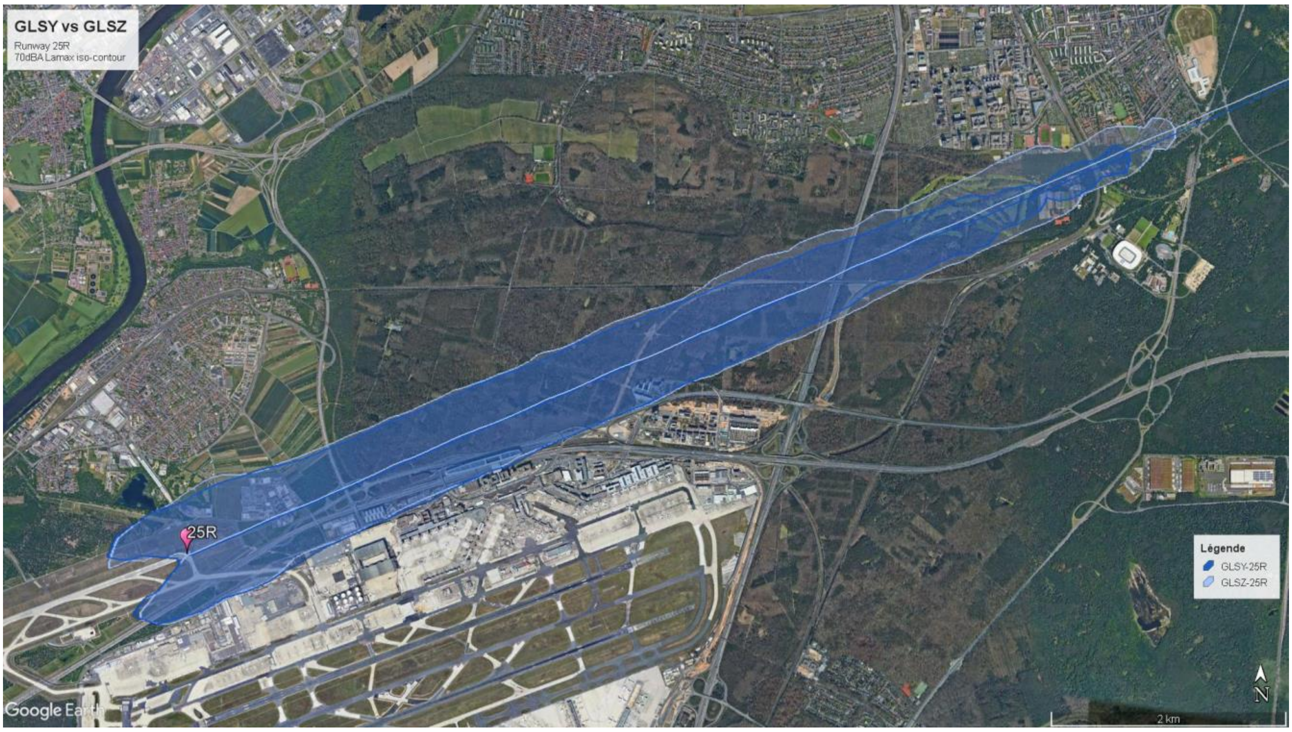
Influence in Δ LAmax **GLSY vs GLSZ**	1st parameter of influence	2nd parameter of influence	3rd parameter of influence
Runway 07L	Δ Mach (R^2 = 0.34)	Δ Distance to RWY (R^2 = 0.23)	**Δ Height (R^2 = 0.13)**
Runway 25L	**Δ N1 (R^2 = 0.50)**	Δ Incidence (R^2 = 0.29)	**Δ Height (R^2 = 0.10)**
Runway 25R	Δ Mach (R^2 = 0.32)	**Δ Height (R^2 = 0.22)**	Δ N1 (R^2 = 0.22)
Runway 25C	**Δ N1K (R^2 = 0.19)**	Δ Height (R^2 = 0.11)	Δ CAS (R^2 = 0.05)

Summary table of parameters with more influence in ΔLAmax (GLSY vs GLSZ)

CRT-02.02-V3-VALP-ISGS.0401-002

CRT-02.02-V3-VALP-ISGS.0401-002 : Size of noise contours is reduced with ISGS concept

Surface variation GLSY vs GLSZ in km²	ISO LAmax = 65 dBA	ISO LAmax = 70 dBA	ISO LAmax = 75 dBA	ISO LAmax = 80 dBA	ISOLAmax = 85 dBA
Runway 07L	+2% +0.3 km²	-10% -0.6 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Runway 25L	+6% +0.7 km²	+6% +0.4 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Runway 25R	-5% -0.8 km²	-15% -1.0 km²	-9% -0.2 km²	< 0.1 km²	< 0.1 km²
Runway 25C	+4% +0.5 km²	+3% +0.1 km²	+9% +0.2 km²	+14% +0.1 km²	< 0.1 km²



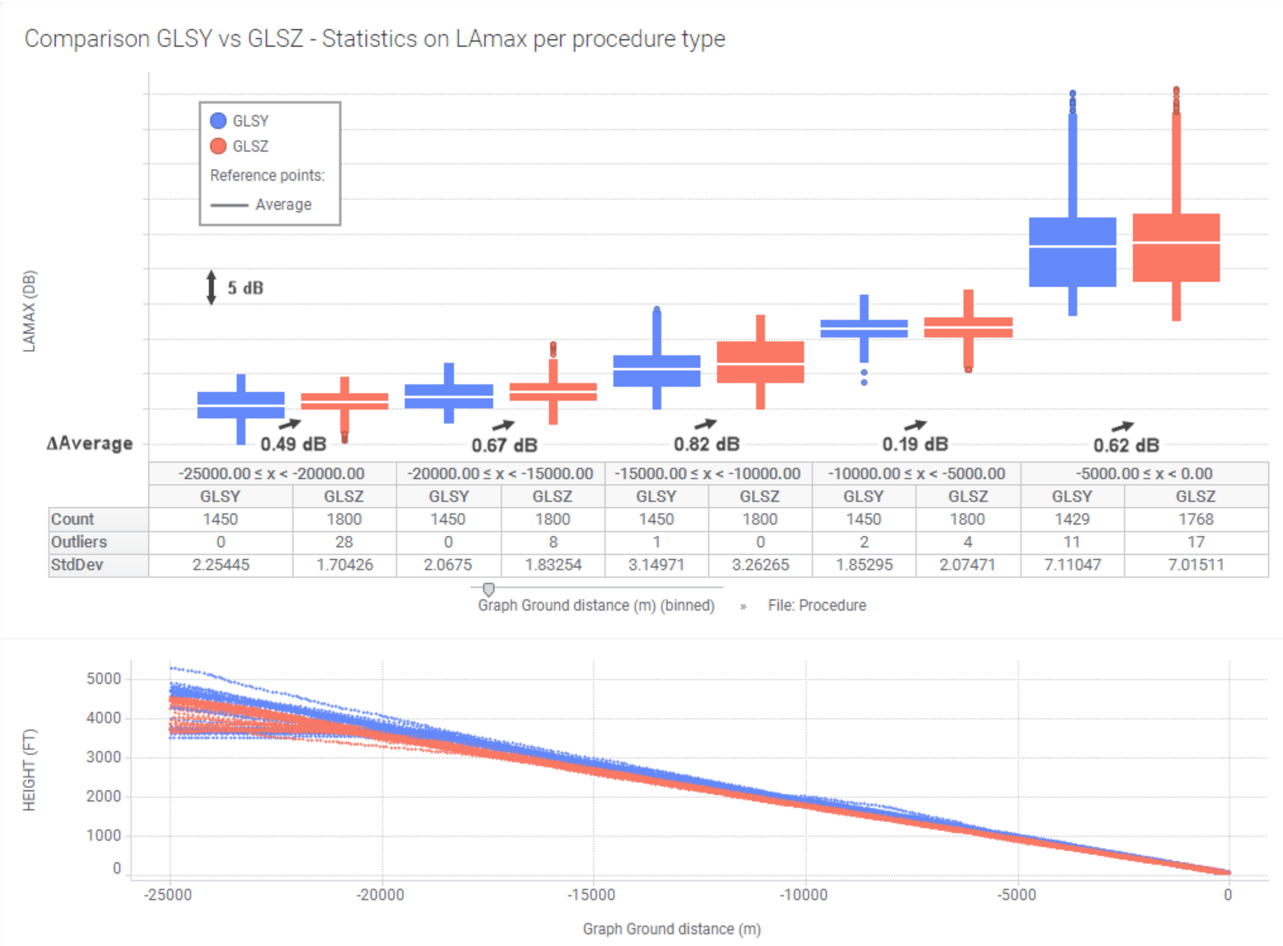
GLSY and GLSZ 70dBA LAmax iso-noise contour comparison, on runway 25R

The areas between different noise contours corresponding to iso-LAmax values are compared for the same set of flight pairs studied for the previous criteria. This assessment shows only a small difference between ISGS GLSY (3.2°) and conventional GLSZ (3°) flights, with absolute differences between two pairs of contour areas being less than 1 km². This order of magnitude is small with regards to noise prediction uncertainty, which leads to conclude that both procedures produce noise contours of similar size.

Criterion CRT-02.02-V3-VALP-ISGS.0401-002 (Size of noise contours is reduced with ISGS concept) is not reached.

CRT-02.02-V3-VALP-ISGS.0401-003

CRT-02.02-V3-VALP-ISGS.0401-003 : Average noise value is not increased



Comparison of GLSY and GLSZ average LAmax on scenario #5 comprising all 65 flights

Distance to RWY threshold	-25km < x < -20km	-20km < x < -15km	-15km < x < -10km	-10km < x < -5km	-5km < x < 0km

Average LAmax variation GLSY vs GLSZ	**-0.49 dB**	**-0.67 dB**	**-0.82 dB**	**-0.19 dB**	**-0.62 dB**

For the demonstration of this criteria, averages of under-track noise levels (LAmax) are compared at 5 different ranges of distances from the runway threshold. The grouping of the data according to distance to runway is done to average noise levels of similar magnitude. It has been verified that the number of groups created does not affect general conclusions.

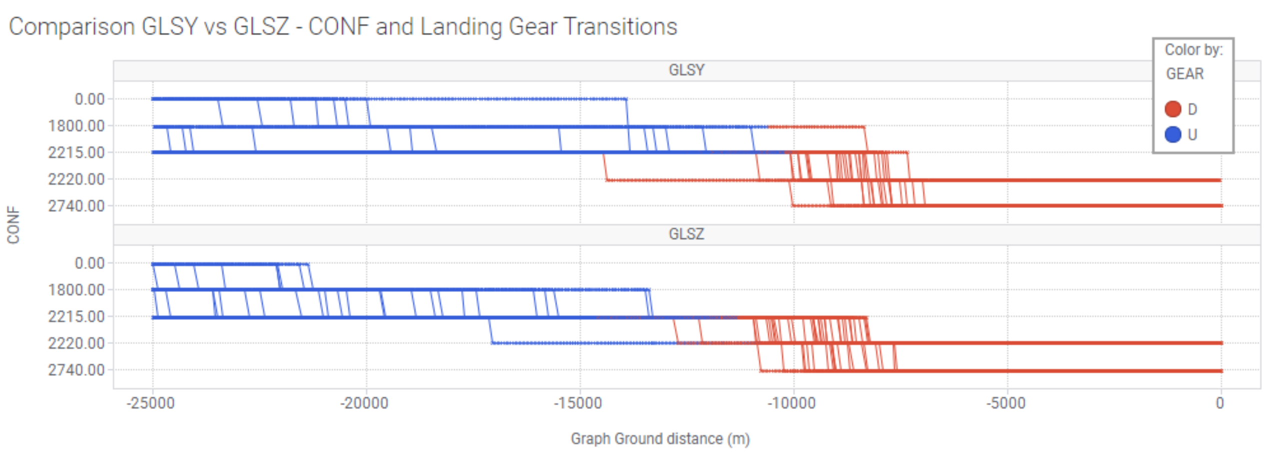
The 65 available A319-112 flights are taken into account to perform two separate average values, one average for ISGS GLSY (3.2°) flights and another for conventional GLSZ (3°) flights. This larger set of flights comprises approaches to different runways and at a variety of meteorological conditions.

Results show average noise in ISGS is lower in all the different zones under-track up to 25km to the runway threshold. The benefit of ISGS in average noise is between 0.2 and 0.8 dB (LAmax) depending on the zone.

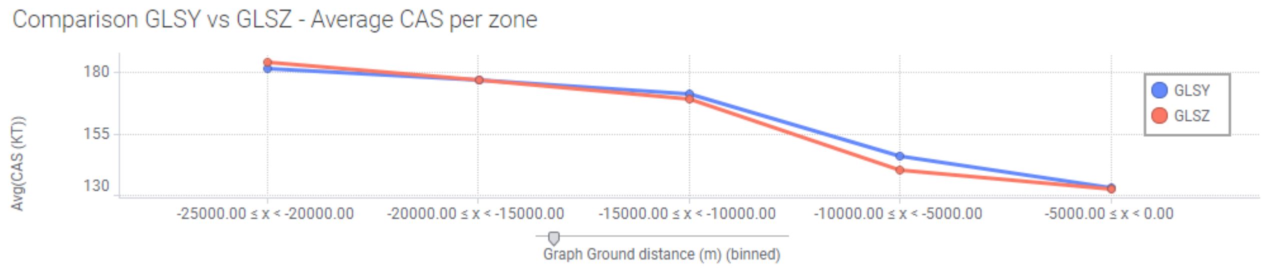
Criterion CRT-02.02-V3-VALP-ISGS.0401-003 (Average noise value is not increased) is reached.

The analysis of aircraft performance in the full set of flights shows the following trends:

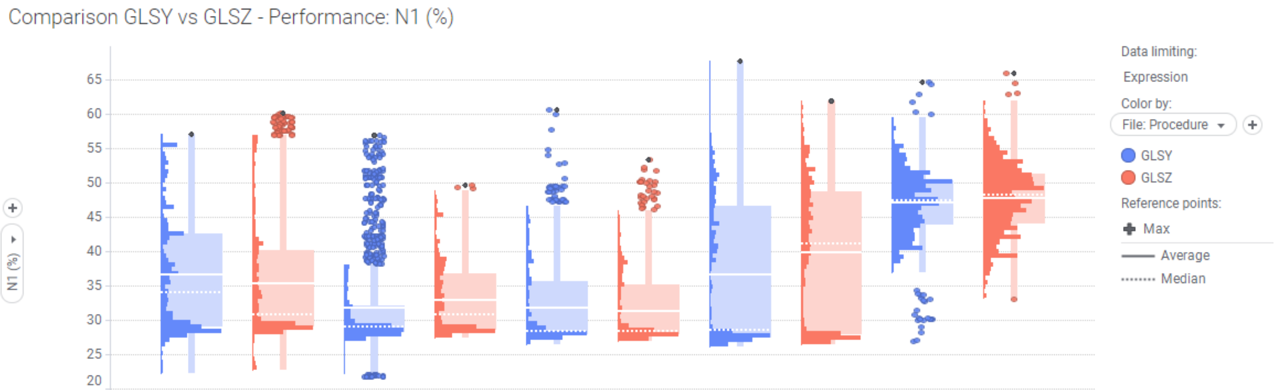
- Part of the trajectories show the aircraft on leveled flight when overflying the zone (-25km < x < -20km), which influences average noise results.
- ISGS GLSY flights tend to deploy slats, flaps and landing gear later (by looking at transitions), which is beneficial in terms of noise.
- In average, ISGS GLSY flights are in overflying the zone (-10km < x < -5km) at a higher speed (CAS), which is in general negative in terms of noise. This fact is consistent with the findings in average LAmax, explaining the smaller benefit in this zone. In the other zones, the average speed is similar for both procedures.
- As opposed to the analysis by pairs of trajectories, a statistical look at the engine regime (N1) did not show any trend that can be related to the average noise results.



Comparison of GLSY and GLSZ aerodynamic configuration and landing gear positions



Comparison of GLSY and GLSZ average CAS on scenario #5 comprising all 65 flights



	-25000.00 ≤ x < -20000.00		-20000.00 ≤ x < -15000.00		-15000.00 ≤ x < -10000.00		-10000.00 ≤ x < -5000.00		-5000.00 ≤ x < 0.00	
	GLSY	GLSZ	GLSY	GLSZ	GLSY	GLSZ	GLSY	GLSZ	GLSY	GLSZ
Count	1554	1879	1631	1970	1705	2081	2056	2571	2226	2686
Outliers	0	49	237	3	39	30	0	0	29	5
Avg	36.5671	35.2983	31.6834	32.9103	31.8309	31.3346	36.6209	39.7891	47.0637	47.74
Median	34.06	30.75	29	30.72	28.44	28.38	28.56	41.19	47.38	48.25
Max	57.06	60.19	56.94	49.63	60.69	53.38	67.75	61.94	64.75	65.94

Comparison of GLSY and GLSZ statistics on engine regime (N1) on scenario #5 comprising all 65 flights

B.3.3 Unexpected Behaviours/Results

No unexpected behaviours to be underlined.

B.3.4 Confidence in the Demonstration Results

B.3.4.1 Level of significance/limitations of Demonstration Exercise Results

Flight Trials were performed at the beginning of the Trial Period under simulated GLS CAT II conditions under CAT I weather conditions because of the following reasons:

- Aircraft Certification for GLS CAT II approaches were still in progress
- GBAS Ground Station approval was still in progress

- Operational approval for GLS CAT II approaches were still in progress

Since no technical changes needed to be done on board of the aircraft and on ground, flight trials could be started. During the flight trial period, aircraft certification and ground station approval have been achieved. Operational approval is aimed for end of 2022.

Noise assessment

The extent of the applicability of the results of this demonstration exercise is affected by the following items.

For EXE-002 ISGS at Frankfurt airport:

- *Aircraft*: all flights analyzed correspond to different Airbus A319-112 equipped with CFM56-5B6/3 engines and operated by Lufthansa. Different aircraft types might perform the studied procedures differently in terms of aircraft speed, engine regime or use of airbrakes, parameters that significantly affect noise.
- *Glide slope*: 3.2° for ISGS. Different slopes might produce different results because their effect on aircraft speed, engine regime or use of airbrakes are not evaluated in this study.
- *Commercial flights:* there was a large diversity in the test population, which encompassed different runways, weather conditions, aircraft weights… and a large variability in the aircraft performance parameters that affect noise.
- *Mix of visibility conditions*: flights in CAT I conditions are compared to CAT II, which has an influence on the operation of the aircraft.
- *Mix of standard procedures with procedural trials*: in this exercise, a different use of engine power between both types of procedures was observed, which could be caused by different pilot behavior due to the fact that procedure trials were compared to typical operations.
- *Number of test runs*: the number of test runs was relatively large but not large enough to remove some parameters as variables of the analysis, such as runway or visibility conditions.
- *Absence of noise recordings*: although Frankfurt airport is equipped with noise monitoring stations, noise recordings were not available for their use in this study.

In summary, the significance of the demonstration results is high, which can be extrapolated to other airports, but cannot be extended to other slope values (3.2° for ISGS and 3.5° for IGS-to-SRAP) and to different aircraft types.

The absence of noise recordings reduced the precision of noise predictions, which affected the ability to conclude on some criteria. The mix of flights where the pilots performed standard procedures versus procedure trials raised questions during the analysis that affected the results and were proposed for further investigation.

B.3.4.2 Quality of Demonstration Exercise Results

Flight Trials were demonstrated by revenue flights on published procedures within operational environment.

Noise assessment

Aircraft noise is sensitive to many physical variables and the error in their recording or modelling contributes to an uncertainty in the noise prediction methodology. In order to draw conclusions about the objective, the results of the study must be compared to the error of their methodology.

Some of the results of exercise EXE-002 have been inconclusive because the noise impact was small in comparison with the error in the methodology. This is probably related to the smaller difference in glide slope angle. However, a calibration with noise measurements performed during the trials, with few microphones located under the ground track, could have decreased the noise source model uncertainties. Unfortunately, the noise data recorded by Frankfurt stations have not been available for this study.

B.3.4.3 Significance of Demonstration Exercises Results

Flight Trials demonstrated the ability for GLS CAT II Operation of aircraft with GLS CAT I equipment.

Flight Trials demonstrated the ability to start an approach out of higher altitudes (7000ft).

Noise assessment

Statistical significance

For EXE-002 ISGS at Frankfurt airport, the number of test subjects is of a medium size but of a large operational diversity: different runways, days (weather), routes (weight), visibility conditions. It was found that there were not enough flights to reduce the number of variables and present a statistical analysis. Both an analysis one-to-one and a statistical analysis are proposed, depending on the success criterion that was evaluated.

Operational significance

For EXE-002 ISGS at Frankfurt airport, commercial flights were analyzed, therefore the operational significance is very high. There was a large diversity in the test population, which encompassed different runways, weather conditions, aircraft weights, etc.

B.4 Conclusions

GLS CAT II Trials

Flight Trials demonstrated the ability for GLS CAT II Operation of aircraft with GLS CAT I equipment on a GAST C ground station which is upgraded with an SBAS Receiver. On the basis of these flight trials, Lufthansa is seeking operational approval from the Luftfahrt Bundesamt (German Federal Office of Civil Aviation)

Expanded Service Volume

Flight Trials demonstrated the applicability of Expanded Service Volume of the GBAS System in an operational environment by using Dmax of the GLS range. With the support of ESV, low level flights can be avoided during high traffic periods.

Human Performance and Safety

All demonstrated flight trials on ISGS and GLS CAT 2 have shown no impact and no degradation at all in human performance and safety.

Participating pilots reported no differences in workload and task sharing. No change in routine working methods was also indicated by the flight crews. Flight and landing behaviour of aircraft was not affected as well. It was also reported that no impact on safety was observed.

Noise assessment

This demonstration exercise doesn't conclude to an evident noise reduction due to ISGS with 3.2° glide slope.

B.5 Recommendations

B.5.1 Recommendations for industrialization and deployment

-

The introduction of GBAS to low visibility operations (LVO) can be considered as a relevant milestone. The results of fast time simulations (Appendix G) indicate promising benefits in terms of traffic throughput and airport capacity during LVO compared to existing ILS procedures. At airports where weather conditions do not force CAT III guidance, GLS CAT II is meaningful to be deployed as the number of capable aircraft is increasing with the renewal of fleets in the coming years.

GLS CAT II on GAST C including ISGS can be seen as step towards GAST D, enabling LVO with very oversee able effort on the airborne side for a great number of mainline aircraft, provides environmental benefits (noise, gas emissions), and potentially increases arrival capacity at congested airports.

B.5.2 Recommendations on regulation and standardisation initiatives

On the ground side with the German type approval for the Honeywell SLS-4000 Block IIS configuration as a baseline the way should be paved for other European ANSPs to achieve approvals from their individual regulators.

Airbus has achieved GLS CAT II EASA certification for their A320 Family models and is continuing seeking approval for other models.

Appendix C Exercise VLD1-03 Report - ISGS Ciampino Demonstration

C.1.1 Exercise description and scope

This flight trials campaign was aimed at demonstrating in the real operating environment the potential benefits derived from the ISGS (Increased Second Glide Slope) concept implementation, assessing noise benefits, and potential impact on Human Performance and Safety.

More in detail, the objectives were:

- Designing, coding and validating of different ISGS (SBAS-based) approach procedures;
- In-depth analysis of the ISGS approach procedure charts details:
    - Evaluation of need to indicate into the procedure chart the approach path (e.g. angle) and related supporting navigation guidance;
    - Specifically highlight of the glide path angle in case it's significantly different compared to the conventional one (e.g. more than 3.5°)
- Evaluation of Noise reduction ascribable to the implementation of the new ISGS approach procedures
- Evaluation of impact on Pilot workload in carrying out new ISGS approach procedures in the demo operating environment
- Evaluation of need to inform the Flight Crew about the discrepancies from visual aid references when not specifically adapted to ISGS procedures.

The Human Factors and Safety assessment for the mixed approach procedures (conventional 3.0 deg on primary runway aiming point versus the ISGS on secondary runway aiming point) is out of scope.

The Human Factors and Safety assessment for the ATC is out of the scope as explained in section C.3.4.

C.1.2 Summary of Demonstration Exercise VLD1-03 Demonstration Objectives and success criteria

Demonstration Objective (as in section 4.4)	Demonstration Success criteria (as in section 4.4)	Coverage and comments on the coverage of Demonstration objectives (as in section 4.4)	Demonstration Exercise 3 Objectives	Demonstration Exercise 3 Success criteria
OBJ-02.02-V3-VALP-ISGS.0401 Reduction of the noise impact around the airports due to ISGS implementation	**CRT-02.02-V3-VALP-ISGS.0401-001** Relative noise scale results positive with ISGS use **CRT-02.02-V3-VALP-ISGS.0401-002**	Fully Covered	**EX3-OBJ- VLD-01-003-001** same description as **OBJ-02.02-V3-VALP-ISGS.0401**	**EX3- CRT-VLD-01-003-011** **EX3- CRT-VLD-01-003-012** **EX3- CRT-VLD-01-003-013** same descriptions as

	Size of noise contours is reduced with ISGS concept **CRT-02.02-V3-VALP-ISGS.0401-003** Average noise value is not increased			**CRT-02.02-V3-VALP-ISGS.0401-001** **CRT-02.02-V3-VALP-ISGS.0401-002** **CRT-02.02-V3-VALP-ISGS.0401-003**
OBJ-02.02-V3-VALP-ISGS.0201 ISGS impact on crew task performance	**CRT-02.02-V3-VALP-ISGS.0201-001** Pilot succeeds to accomplish an ISGS operation without any difficulty **CRT-02.02-V3-VALP-ISGS.0201-002** Impact on crew cooperation and crew workload remains with acceptable limit	Fully Covered *(*CRT-02.02-V3-VALP-ISGS.0201-002: only qualitative assessment and crew cooperation only addressed by Honeywell and ENAV flight trials) (standard operation for Falcon)*	**EX3-OBJ- VLD-01-003-002** same description as **OBJ-02.02-V3-VALP-ISGS.0201**	**EX3- CRT-VLD-01-003-021** same descriptions as **CRT-02.02-V3-VALP-ISGS.0201-001** **CRT-02.02-V3-VALP-ISGS.0201-002** **New Description**: *Impact on crew cooperation and crew experienced workload is considered acceptable*
OBJ-02.02-V3-VALP-ISGS.0202 ISGS impact on cockpit HMI	**CRT-02.02-V3-VALP-ISGS.0202-001** HMI is usable by flight crew **CRT-02.02-V3-VALP-ISGS.0202-002** HMI is useful to flight crew **CRT-02.02-V3-VALP-ISGS.0202-003** HMI supports the application of the procedure	Fully Covered only by Honeywell Flight trial as no new HMI expected by Dassault and ENAV. *(*Subjective/qualitative assessment)*	**EX3-OBJ- VLD-01-003-004** same description as **OBJ-02.02-V3-VALP-ISGS.0202**	**EX3- CRT-VLD-01-003-041** **EX3- CRT-VLD-01-003-042** **EX3- CRT-VLD-01-003-042** same descriptions as **CRT-02.02-V3-VALP-ISGS.0202-001** **CRT-02.02-V3-VALP-ISGS.0202-002** **CRT-02.02-V3-VALP-ISGS.0202-003**
OBJ-14.3-V3-VALP-ISGS.0203 ISGS impact on safety crew perspective	**CRT-14.3-V3-VALP-ISGS.0203-001** There is evidence that the level of operational safety is maintained and not negatively impacted under ISGS procedures compared to the reference scenario from the perspective of the crew	Partially Covered	**EX3-OBJ- VLD-01-003-006** same description as **OBJ-02.02-V3-VALP-ISGS.0203**	**EX3- CRT-VLD-01-003-061** **New Description**: *There is evidence that Flight Crew's subjective and positive feedback concerning the level of safety for ISGS procedures is not degraded*
OBJ-14.3-V3-VALP-ISGS.0204 ISGS operational feasibility from crew perspective	**CRT-14.3-V3-VALP-ISGS.0204-001** Pilot succeeds to manage ISGS operation by applying existing SOPs **CRT-14.3-V3-VALP-ISGS.0204-002** Pilots are confident when flying a ISGS operation	Fully Covered *(* only qualitative assessment)*	**EX3-OBJ- VLD-01-003-008** same description as **OBJ-02.02-V3-VALP-ISGS.0204**	**EX3- CRT-VLD-01-003-081** **EX3- CRT-VLD-01-003-091** same descriptions as **CRT-02.02-V3-VALP-ISGS.0204-001** **CRT-02.02-V3-VALP-ISGS.0204-002**

C.1.3 Summary of Validation Exercise VLD1-03 Demonstration scenarios

The flight campaign had the purpose of demonstrating the benefits arising from the implementation of the concept of ISGS Increased Second Glide Slope, through the evaluation of KPAs such as noise impact and Human Performance, Safety.

The following table summarises the involved flights for the different partners.

Stakeholder	AC type	Capabilities	Location	Approaches	Status	When
ENAV	P180	SBAS	Ciampino	16	Confirmed	nov-21
DAV	Falcon 7x/8x	SBAS	Ciampino	14	Confirmed	Nov 21
HONEYWELL	Embraer 170	SBAS	Ciampino	32*	Confirmed	April 2022

Table 23: Live flight trials Agenda Exercise 003

* Honeywell flight crew performed 32 approaches in total, out of which 2 were executed in a rather experimental way with inappropriate initial conditions; and therefore, in order not to negatively affect the remaining results, these were excluded from the remaining analyses.

C.1.3.1 Reference Scenario(s)

<u>**Reference Scenario**</u> reproduced the inbound/outbound operations to/from Ciampino airport without the ISGS concept under assessment:

Scenario	Sectors involved	Airport	Runways in use	Approach Chart Name	Notes
<u>**Reference**</u>		LIRA	ARR: RWY 33 DEP: RWY 33	LIRA RNP Z RWY33	Aircraft carry out the LPV approach with GA3.5° (current PAPI configuration at 3.5°)

Table 24: Reference scenario Exercise 003

C.1.3.2 Solution Scenario(s)

<u>**Solution Scenarios:**</u> included the inbound operations to Ciampino airport including ISGS procedures. The proposed demo configuration for Ciampino were the following one:

- **Solution Scenario #1:** ISGS 3.9° with current PAPI installed as-is (3 white lamps and 1 red lamp).
- **Solution Scenario #2:** ISGS 4.4° without PAPI

Scenario	Sectors involved	Airports	Runways in use	Approach Chart Name	Notes
Solution Scenario#1		LIRA	ARR: RWY 33 DEP: RWY 33	LIRA RNP Y RWY33	ISGS approach procedure with 3.9° with current PAPI set at 3.5° (3 white lamps and 1 red lamp)
Solution Scenario#2		LIRA	ARR: RWY 33 DEP: RWY 33	LIRA RNP X RWY33	ISGS approach procedure with 4.4° without PAPI

Table 25: Solution Scenarios Exercise 003

C.1.4 Summary of Demonstration Exercise VLD1-03 Demonstration Assumptions

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
ASM-VLD-01-003-001	Current ATC tool	Ground Tools/Technology:	The exercise have been conducted in coordination with the current ATC system available in Roma TMA airspace and at Ciampino Airport Control Towers	It was expected to assess the benefits derived from the implementation of the new ISGS approach procedures in the real operating environment	HIGH
ASM-VLD-01-003-002	LIRA RWYs Operative CONF	Airport operative CONF configuration	The exercise on the RWY 33 have been conducted in VMC	It was essential that the flight trial took place under VMC conditions in order to guarantee the level of safety for the “experimental” activities	LOW

ASM-VLD-01-003-003	LIRA RWYs Operative CONF	Minimum airport operating conditions	Take-off and landing on RWY 15/33 are allowed on the following conditions: • with RWY dry: max cross wind component: 20 kt • with RWY wet: max cross wind component: 15 kt with RWY contaminated: max cross wind component: 10kt	These minimum operating conditions for the runway 15/33 have been established by the National Authority.	LOW
ASM-VLD-01-003-004	LIRA RWYs Operative CONF	Local traffic regulations	This exercise aimed to assess the benefits derived from the ISGS (Increased Second Glide Slop). The Runway preferential use is in accordance with AIP Italia AD 2 1-12.	The operative configuration which was considered during the simulation is the follows: • LIRA RWY 33: ARR/DEP. This Operative CONF allowed to manage the arrival and departing traffic to Ciampino airport (LIRA) with new ISGS approach procedures in the real	HIGH

				operating environment. In case of LIRA RWY 15: ARR/DEP, in specified slots and traffic permitting, the " experimental " activities could be managed on RWY 33	

Table 26: Demonstration Assumptions overview

C.2 Deviation from the planned activities

ENAV was able to perform 14 approaches instead of the 20 planned, while DASSAULT was able to perform 14 approaches instead of 10-12 approaches planned. Honeywell was able to perform 30 approaches instead of planned 25.

While the DEMOP provided draft approach procedure for Ciampino exercise, the final approach procedures tested in Ciampino demonstration are provided below:

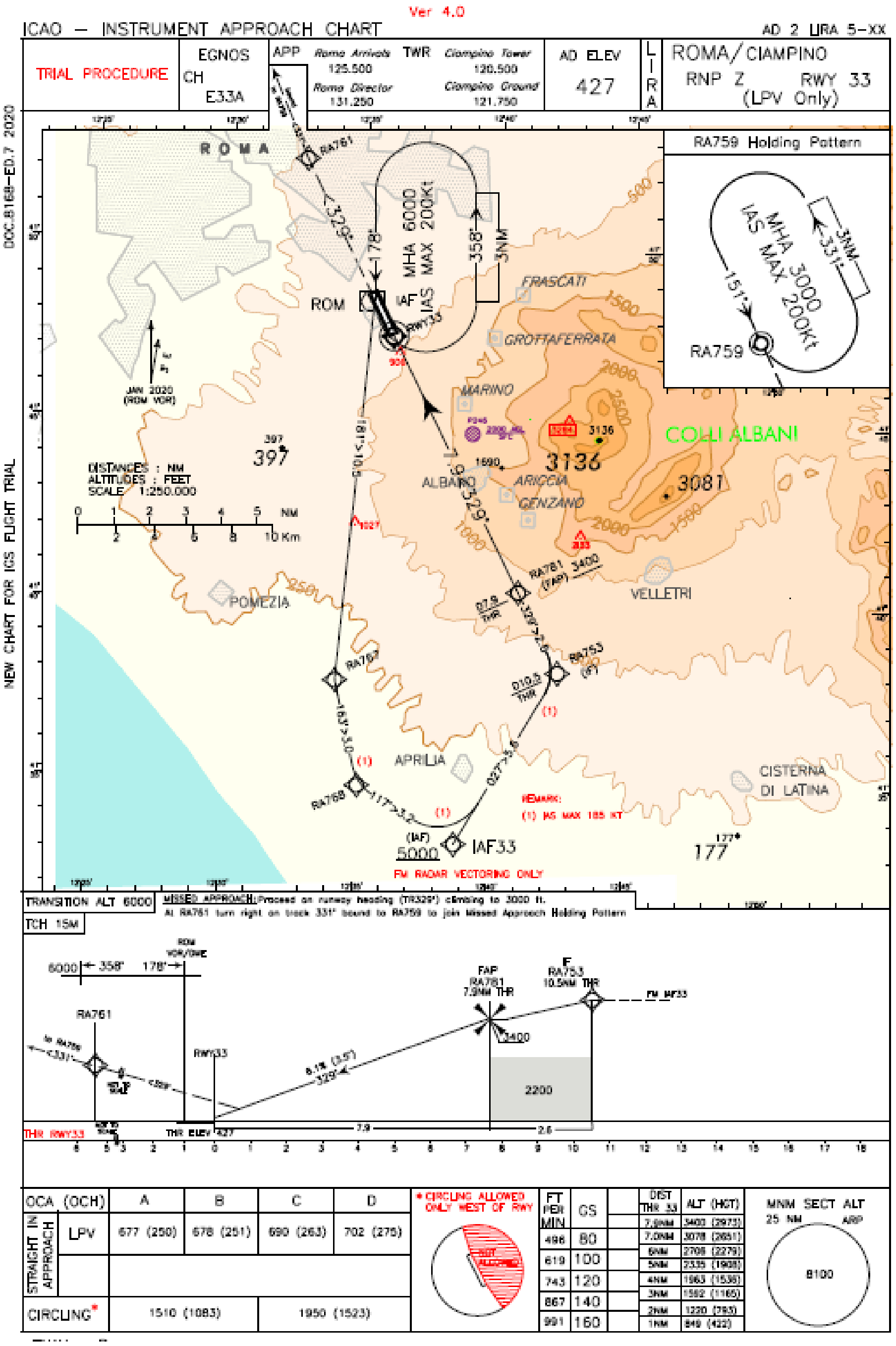


Figure 3 LIRA RNP Z – 3.5°

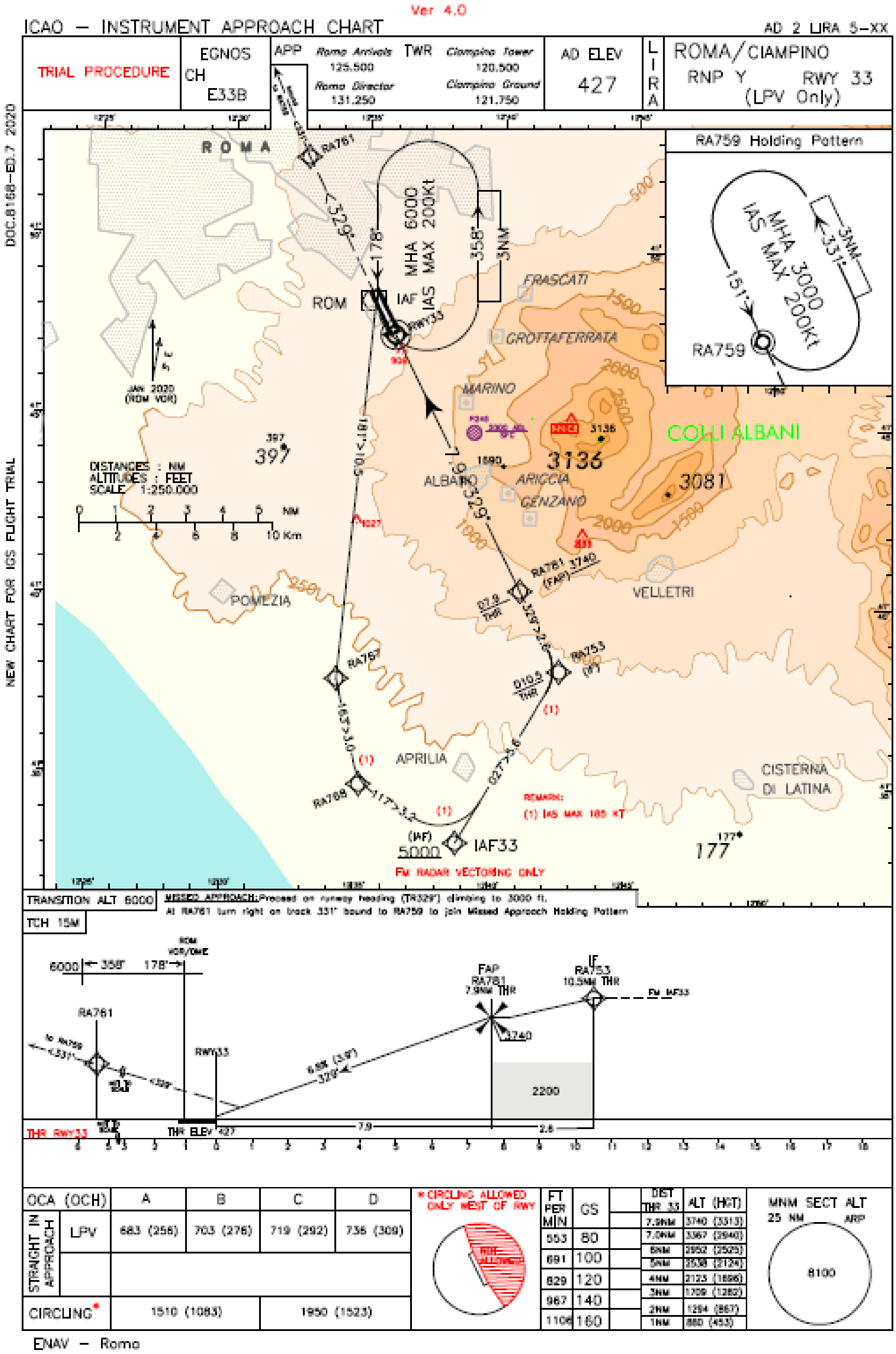


Figure 4 LIRA RNP Y – 3.9°

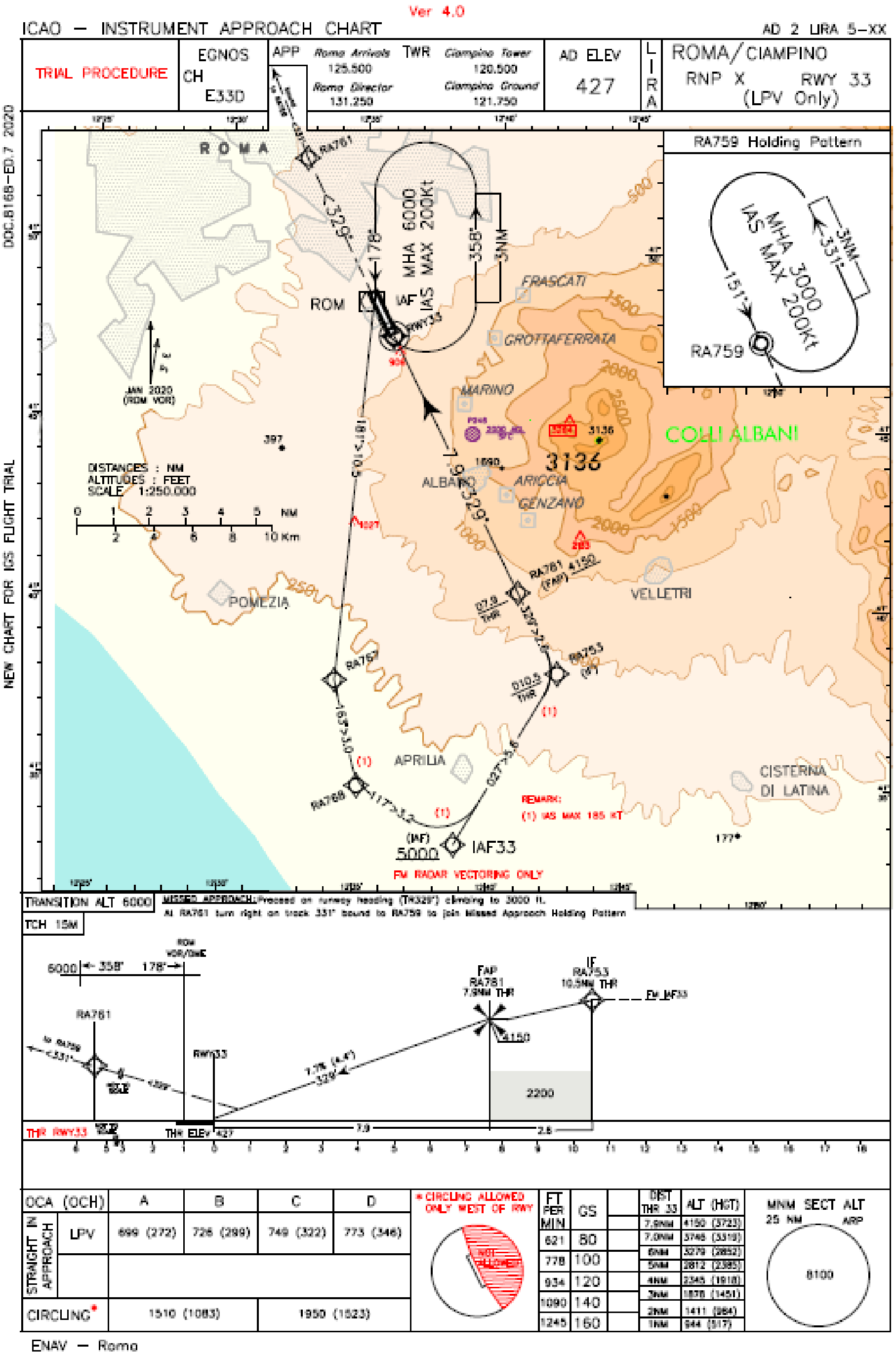


Figure 5 LIRA RNP X – 4.5°

C.3 Demonstration Exercise VLD1-03 Results

C.3.1 Summary of Demonstration Exercise VLD1-03 Demonstration Results

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Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-02.02-V3-VALP-ISGS.0401	Reduction of the noise impact around the airports due to ISGS implementation	**CRT-02.02-V3-VALP-ISGS.0401-001**	Relative noise scale results positive with ISGS use	High complexity TMA/ Medium airport	The ISGS procedures provide positive relative noise scale results: ▪ for the 3.9° approach path : up to 4dBA on the first part of the final approach (depending on the moment where the landing configuration is extended) and 1 dBA when the aircraft is stabilized in the approach configuration ▪ for the 4.4° approach path : up to 4dBA on the first part of the final approach and 3dBA when the aircraft is stabilized in the approach configuration	ok

		CRT-02.02-V3-VALP-ISGS.0401-002	Size of noise contours is reduced with ISGS concept	High complexity TMA/ Medium airport	The 65 dBA (LA,MAX) noise contour for the reference approach runs (RNAV Z in orange) and the ISGS runs (RNAV Y in blue and RNAV X in green) is considered as representative metric. The size of the noise contour is reduced in average for the flights by 27% for the 3.9° approach and by 44% for the 4.4° approach	OK
		CRT-02.02-V3-VALP-ISGS.0401-003	Average noise value is not increased	High complexity TMA/ Medium airport	See above criteria **CRT-02.02-V3-VALP-ISGS.0401-002 & CRT-02.02-V3-VALP-ISGS.0401-001**	OK
OBJ-02.02-V3-VALP-ISGS.0201	ISGS impact on crew task performance	**CRT-02.02-V3-VALP-ISGS.0201-001**	Pilot succeeds to accomplish an ISGS operation without any difficulty	High complexity TMA/ Medium airport	Acceptance, usability and confidence have been positively addressed (see section C3.2.2	OK
		CRT-02.02-V3-VALP-ISGS.0201-002	Impact on crew cooperation and crew workload remains with acceptable limit	High complexity TMA/ Medium airport	The goals (in relation to the execution of the final ISGS approach procedure from Flight crew point of view) of the team in support of the successfully completion the ISGS operations were clearly defined without introducing room for confusion teamwork was at excellent level and not affected at all The overall perceived workload remained at acceptable level BEDFORD scale mean value for each scenario, reference and solutions, is below or at 3	OK
OBJ-02.02-V3-VALP-ISGS.0202	ISGS impact on cockpit HMI	**CRT-02.02-V3-VALP-ISGS.0202-001**	HMI is usable by flight crew	High complexity TMA/ Medium airport	Current implementation of Energy Management tool shows usability limits with impact on easy-to-use aspects. Collected flight demo data will be used for further improvements.	POK
		CRT-02.02-V3-VALP-ISGS.0202-002	HMI is useful to flight crew	High complexity TMA/ Medium airport	Energy Management is useful according to 17 out of 23 answers	OK

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		CRT-02.02-V3-VALP-ISGS.0202-003	HMI supports the application of the procedure	High complexity TMA/ Medium airport	12 out of 23 answers were rather positive on the effectiveness of the HMI for the ISGS procedure	POK
OBJ-14.3-V3-VALP-ISGS.0203	ISGS impact on safety crew perspective	**CRT-14.3-V3-VALP-ISGS.0203-001**	*There is evidence that Flight Crew's subjective and positive feedback concerning the level of safety for ISGS procedures is not degraded*	High complexity TMA/ Medium airport	The majority of pilots "Agree" and the remaining part "Strongly agree" that the overall level of safety was at least as the today operations during the execution of the ISGS operations	OK
OBJ-14.3-V3-VALP-ISGS.0204	ISGS operational feasibility from crew perspective	**CRT-14.3-V3-VALP-ISGS.0204-001**	Pilot succeeds to manage ISGS operation by applying existing SOPs	High complexity TMA/ Medium airport	The most of the 9 pilots that answered the PEQ strongly agree and the remaining agree that the ISGS operations can be managed by current SOPs	OK
		CRT-14.3-V3-VALP-ISGS.0204-002	Pilots are confident when flying a ISGS operation	High complexity TMA/ Medium airport	The most of the 9 pilots that answered the PEQ strongly agree and the remaining agree that they felt confident during the execution of ISGS	OK

Table 27: Exercise 3 Demonstration Results

C.3.1.1 Results per KPA

ENAV flight crew performed a total number of 14 approaches split on 2 days (on the 22nd and 29th of November 2021) and detailed in the following table:

Approach number	Procedure	DAY
1	RNP Z (3.5°)	22/11/2021
2	RNP Z (3.5°)	
3	RNP Y (3.9°)	
4	RNP Y (3.9°)	
5	RNP Y (3.9°)	
6	RNP Y (3.9°)	
7	RNP Y (3.9°)	
8	RNP Y (3.9°)	
9	RNP Y (3.9°)	
10	RNP Y (3.9°)	
11	RNP X (4.4°)	29/11/2021
12	RNP X (4.4°)	
13	RNP X (4.4°)	
14	RNP X (4.4°)	
15	RNP X (4.4°)	
16	RNP X (4.4°)	

Table 28 ENAV Live trial Approaches

The live trials involved 3 pilots, 1 of which was participating to both the sessions.

DASSAULT flight crew performed a total number of 14 approaches at an average landing weight (80-85% MLW) split on 2 days (on the 23rd and 29th of November 2021) and detailed in the following table:

DAY	Approach number	Procedure	Description	Start altitude at IAF33
23/11/2021	1	RNP Z (3.5°)	Glide interception in level Flight	5000
	2	RNP Y (3.9°)	Delayed decelerating approach	5000
	3	RNP X (4.4°)	Glide interception in level Flight	5000
	4	RNP Z (3.5°)	Glide interception in level Flight	6000
	5	RNP Y (3.9°)	Glide interception in level Flight	6000
	6	RNP X (4.4°)	Glide interception in level Flight	6000
	7	RNP X (4.4°)	Delayed decelerating approach	5000
	8	RNP X (4.4°)	Delayed decelerating approach	6000
29/11/2021	9	RNP Y (3.9°)	Glide interception in level Flight	5000
	10	RNP Z (3.5°)	Continuous Descent from IAF	6000
	11	RNP Y (3.9°)	Continuous Descent from IAF	6000
	12	RNP X (4.4°)	Continuous Descent from IAF	6000
	13	RNP X (4.4°)	Anticipated deceleration	6000

	14	RNP Z (3.5°)	Anticipated deceleration	6000

Table 29 DASSAULT Live trial Approaches

The flight trial involved 4 pilots, 2 pilots for each day.

During the first day, both pilots hold successively the function of the Pilot Flying (in charge of Piloting, Requests for airplane configuration changes and Navigation) while the other pilot was the Pilot Monitoring (in charge of Communications and Management of the airplane systems). During the second day, all approaches were performed by the same pilot.

The pilots applied two strategies to intercept the glideslope (in level flight or following a continuous descent) and followed the Standard Operations Procedures (see figures xx and xx).

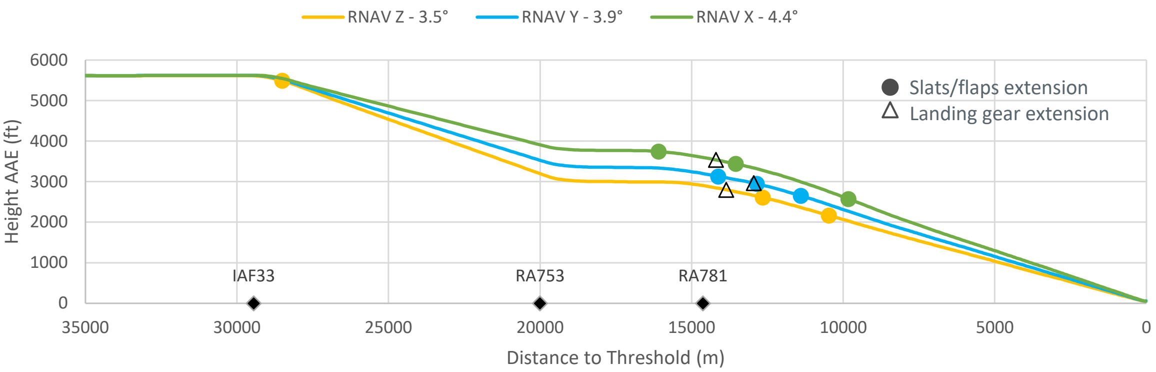

Figure 6 : Glide interception in level flight – IAF at 6000 ft MSL

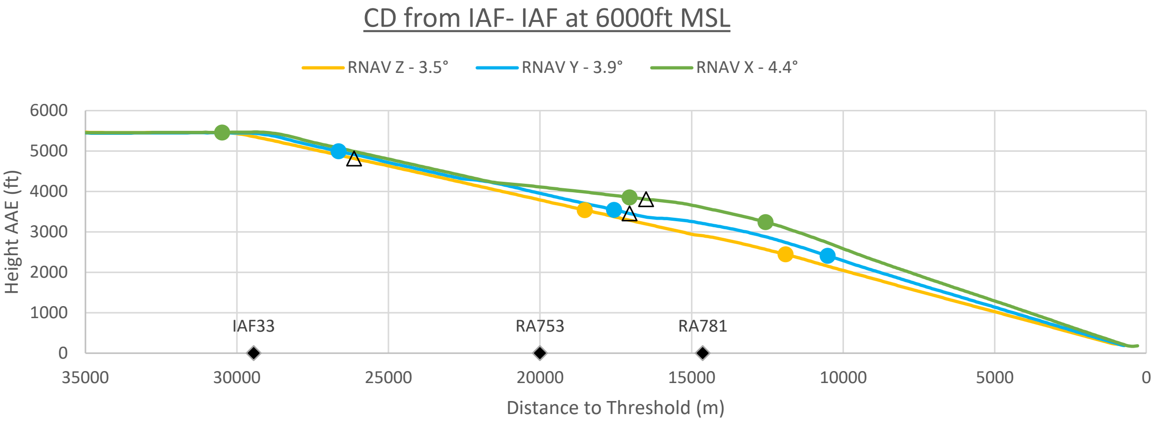

Figure 7 : Continuous descent from IAF – IAF at 6000 ft MSL

Additionally, the pilots applied a delayed or an anticipated deceleration on some approaches to establish the noise impact of such procedures.

Previously, DASSAULT flight crew performed the existing published approaches (one on runway 33 on 9th july 2021 and one on runway 15 on 11th june 2021) to establish noise footprint before IGS implementation.

Honeywell flight crew performed a total number of 30 approaches split into 4 days (April 25 – 28, 2022) and detailed in the following table:

Approach number	Procedure	Tool Used during the approach	DAY
1	RNP Z (3.5°)	Energy Management system	25/04/2022
2	RNP Z (3.5°)	Energy Management system	
3	RNP Y (3.9°)	Energy Management system	
4	RNP Z (3.5°)	Standard displays	
5	RNP Z (3.5°)	Energy Management system	
6	RNP Y (3.9°)	Energy Management system	
7	RNP X (4.4°)	Energy Management system	
8	RNP Y (3.9°)	Standard displays	26/04/2022
9	RNP Z (3.5°)	Energy Management system	
10	RNP Y (3.9°)	Energy Management system	
11	RNP X (4.4°)	Energy Management system	
12	RNP X (4.4°)	Standard displays	
13	RNP Z (3.5°)	Energy Management system	
14	RNP Y (3.9°)	Energy Management system	
15	RNP Y (3.9°)	Energy Management system	
16	RNP Z (3.5°)	Energy Management system	27/04/2022
17	RNP Y (3.9°)	Energy Management system	
18	RNP X (4.4°)	Energy Management system	
19	RNP Z (3.5°)	Energy Management system	
20	RNP Z (3.5°)	Energy Management system	
21	RNP Y (3.9°)	Energy Management system	
22	RNP X (4.4°)	Energy Management system	
23	RNP Y (3.9°)	Standard displays	
24	RNP X (4.4°)	Energy Management system	28/04/2022
25	RNP Z (3.5°)	Energy Management system	
26	RNP Y (3.9°)	Energy Management system	
27	RNP X (4.4°)	Energy Management system	
28	RNP Z (3.5°)	Standard displays	
29	RNP X (4.4°)	Standard displays	
30	RNP Y (3.9°)	Standard displays	

Table 30 Honeywell Live trial Approaches

The test involved 2 pilots. During the flight test, the Pilot Flying piloted the aircraft and called for configuration changes during approach. Pilot Monitoring communicated with the ATC, monitored system, and responded to the Pilot Flying`s configuration requests. Pilots interchanged roles so one pilot took the role of the Pilot Flying on first and fourth day. The other pilot was Pilot Flying on second and third day of the flight test.

During the flight trial, Honeywell evaluated new prototype of the Energy management system on the approach from Top of Descent to the stabilization gate altitude. The Energy Management has been used by the Pilot Flying during 23 out of 30 total flown approach. 7 approaches have been flown with standard display settings.

After all approaches, the Post Approach Questionnaire was conducted by the pilot flying (30 responses). After each day, the pilot flying performed the Post Evaluation Questionnaire (4 in total).

C.3.1.1.1 Human Performance

A Human Performance Assessment has been carried out for the ISGS operations at 3.9° descent angle and 4.4° descent angle compared to a reference scenario with 3.5° approach on RWY33 of Ciampino airport.

The Human Performance Assessment evidences have been based on the analysis of pilot's feedback collected through questionnaires and debriefing to address HP objectives and success criteria as well as HP issued and benefits drafted during the planning phase.

9 Pilots have been interviewed/questioned in the debriefings/questionnaires to collect quantitative and qualitative data to feed the human performance assessment. The pilots have run a total number of 60 approaches: 17 approaches were performed to test the reference scenario at 3.5° in order to have reference point to measure the differences with the introduction of the solutions, 23 approaches were performed to assess the 3.9° ISGS solution and 20 approaches were performed to assess the 4.4° ISGS procedure.

The debriefing sessions took place just after the execution of the live trials on the 22, 23 and 29 November 2021 and 25, 26, 27 and 28 April 2022 involving HP experts, pilots and technical experts.

2 sets of questionnaires were prepared to be filled-in by the flight crew:

- Post Approach Questionnaires (PAQ): to be filled-in at the end of each approach in order to collect the pilots immediate and punctual feedback on the specific flown approach. The questionnaire was provided for both the reference and solutions scenarios in order to have a comparative assessment at human performance level and to collect quantitative data in relation to key indicators such as workload and situation awareness. The PAQ was filled in by the Honeywell Pilots Flying and by the Dassault Pilots Flying immediately after the performed approach during repositioning to next approach, while ENAV and DASSAULT flight crews provided feedback about the planned PAQ during the debriefing sessions.
- Post Experiment Questionnaire (PEQ): to be filled-in at the end of the flight trial in order to collect the overall subjective feedback on the experimented approaches and thus on the ISGS operation which the pilots were exposed. All the 9 participating pilots have filled-in the questionnaire, even if the DASSAULT flight crew was provided with a subset of questions instead of the full questionnaire as agreed in advance with the DASSAULT team. In particular questions about operating methods, energy and flare management and team were not addressed by the DASSAULT team as no new Functions have been developed (neither energy management new function, nor Flare guidance).

Both questionnaires are provided in Appendix E.

The questionnaires have been analyzed and complemented by the debriefing subjective feedback to obtain the HP quantitative and qualitative results to address the arguments (as established in the HPAP):

- Arg. 1.2: Operating methods (procedures) are exhaustive and support human performance.
- Arg. 1.3: Human actors can achieve their tasks (in normal & abnormal conditions of the operational environment and degraded modes of operation).

- Arg. 2.3: The design of the human-machine interface supports the human in carrying out their tasks.

All the flight crew of ENAV, DASSAULT and Honeywell flights provided very positive feedback on the experimented ISGS operations at Ciampino airport for both the experimented angles of descent at 3.9° and 4.4° respect to the reference at 3.5° and also respect to the standard approach of 3.0° (feedback based on the flight crew daily experience): the overall perception was that the procedures have no specific difficulties respect to the day-to-day operations and the reference scenario and are even improving the final approach phase respect to the current approach procedure available for RWY33 at Ciampino airport.

The execution of all the flights went as planned without any unexpected event affecting the results.

The level of confidence, acceptance and usability was extremely high and there was no negative impact on crew workload or crew situation awareness during the flight execution.

ENAV and Honeywell flight crew also performed stress tests of the approach procedures to experiment different speed, aircraft configuration and conditions and final approach phase was always smooth and easy.

The only difference that was underlined by both the ENAV and DASSAULT flight crew was in relation to the energy management and configuration that might be more critical for aircraft types of bigger size respect to the ENAV and DASSAULT flight test aircraft and might slightly affect the energy management workload. On the other side, the Honeywell flights proved, that ISGS (3.9° and 4.4°) procedures do not bring any significant difficulties to manage the energy on the approach with a bigger aircraft (Ejet-E170) as well. Also, the coordination with ATC was very good and easy, with a smooth insertion of the flight tests within the arrival sequence at Ciampino airport. ENAV flight crew underlined a possible decrease in Radio Telephony communication with ATC, more due to the specific case of Ciampino airport current conditions rather than to the ISGS concept: indeed, the current final approach procedure at RWY33 of Ciampino airport requires periodic reporting from the flight crew that is not required with the new proposed approach procedure design.

The proposed design of the ISGS procedure for both experimented angles of descent was very comfortable and fluid and the provided speed constraints were helpful to anticipate the management of the approach.

Crew cooperation was not impacted at all and the only aspect to be underlined during the briefing was the energy management considering the external conditions was very easy (e.g. no adverse meteo conditions, smooth insertion in the sequence etc.).

Current SOPs were applied during the flights without any specific issue.

About PAPI set at 3.5° for RWY33, the ENAV and DASSAULT flight crew did not underline any issue for the lack of visual aids for the specific conditions of the trial: at 3.9° descent angle they had the 3 white lamps and 1 red lamp as guidance while at 4.4° descent angle they had no guidance at all. In contrary, Honeywell pilots strongly suggested having PAPI information charted in the navigational approach charts to prevent any confusion for the flight crew.

While three out of seven pilots found it "acceptable only because it was a trial. In normal operations it MUST be synchronized" or "appropriately charted in navigation approach charts", most pilots stated that this was not disturbing the approach as the flight crew was already informed and briefed about that, especially for the DASSAULT flight crew that reported they usually don't use the PAPI guidance.

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Furthermore, it should be considered that ISGS procedure were flown using SBAS that provide precision vertical guidance and can be considered as a fundamental enabler for such kind of approaches.

All the flight crew from ENAV, DASSAULT and Honeywell did not underline any differences between the 2 experimented slopes except that for the higher slope energy management and configuration might slightly increase the workload.

C.3.1.1.2 Safety

Safety analysis has been based on the perceived level of safety addressed during the debriefing with the participating pilots and with specific questions in the post experiment and post approach questionnaires.

The participating pilots stated that safety was not impacted at all from Crew Perspective and the overall perception was very good as the today operations. Being the flight crew briefed about the PAPI not providing guidance for the 4.4° final approach procedures and limited guidance for 3.9° final approach procedure, the pilots did not underline specific safety issue about. The perceived level of safety was as the today operations.

C.3.1.1.3 Energy Management

The Energy Management system has been tested only by the Honeywell flight crew during 23 approaches. It needs to be noted, that it is an experimental prototype with known limitation, which needs to be considered during the result interpretation. The Energy Management system seems to be useful during ISGS procedure, especially during the approach to an unfamiliar airport in bad weather. However, current prototype needs to be refined to improve the level of usability and effectiveness, how it supports the crew during ISGS procedures.

C.3.1.1.4 Flare Assistant

The Flare Assistant was implemented on the Honeywell primary flight. However, due to safety reasons, pilots did not look at the primary flight display during the flare phase of flight. Therefore, the post evaluation video review was conducted with 2 pilots. Pilots were asked to observe 4 recorded ISGS approaches captured during the Rome trials, where primary display with the Flare Assistant is visible. Pilots feedback suggests that the Flare Assistant could be useful and could effectively support pilot during ISGS procedures, if usability of the system were improved and especially, if flare related cues were provided on the head-up instead of the head-down display.

C.3.1.2 Results impacting regulation and standardization initiatives

No objectives linked to regulation and standardization was addressed in EXE003

C.3.2 Analysis of Exercises Results per Demonstration objective

C.3.2.1 OBJ-02.02-V3-VALP-ISGS.0401 "Reduction of the noise impact around the airports due to ISGS implementation" Results

The objective has been evaluated through the DASSAULT live trials. The evaluation of the noise benefits principle linked to overall geometrical effects, enabled by ISGS, are reported in Part IV ENVAR. This also take into account ENAV and HONEYWELL trials.

- CRT-02.02-V3-VALP-ISGS.0401-001 Relative noise scale results positive with ISGS use
    - Dassault flights

<u>Effect of the Standard Operations Procedures</u>

The IGS procedure's effectiveness was assessed by comparing the noise levels generated during a IGS run (3.9° or 4.4° approach angle) to the noise levels generated during the reference run (3.5° approach angle) under the final approach.

The flight test aircraft Falcon 8X S/N 401 was equipped with a full flight test installation allowing acquiring parameters of the trajectory required to compute the airframe and engine noise (distance to runway threshold, altitude, speed, engine power and position of the flaps, airbrakes and landing gear).

Figures 9 and 10 show the difference in the maximum value of the noise perceived ($L_{A,MAX}$ in dBA) under the glide path at a given distance to the runway threshold during the final approach (from 15km to the runway threshold) for a 3.9° approach and a 4.4° approach respectively.

After each run, the pilots have performed a go-around below the published minima (approx. 1100m from threshold for category C aircraft). Consequently, the part of the approach affected by the increase of thrust has been removed from the noise analysis.

Whatever the scenario, the ISGS procedures provide positive relative noise scale results:

- for the 3.9° approach path : up to 4dBA on the first part of the final approach (depending on the moment where the landing configuration is extended) and 1 dBA when the aircraft is stabilized in the approach configuration
- for the 4.4° approach path : up to 4dBA on the first part of the final approach and 3dBA when the aircraft is stabilized in the approach configuration

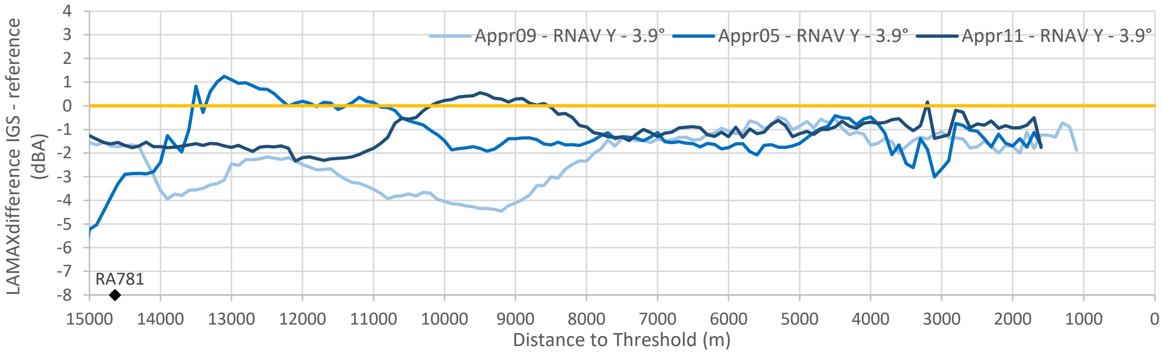


Figure 8 – Falcon 8X - noise benefit under glide path – IGS RNAV Y (3.9°)

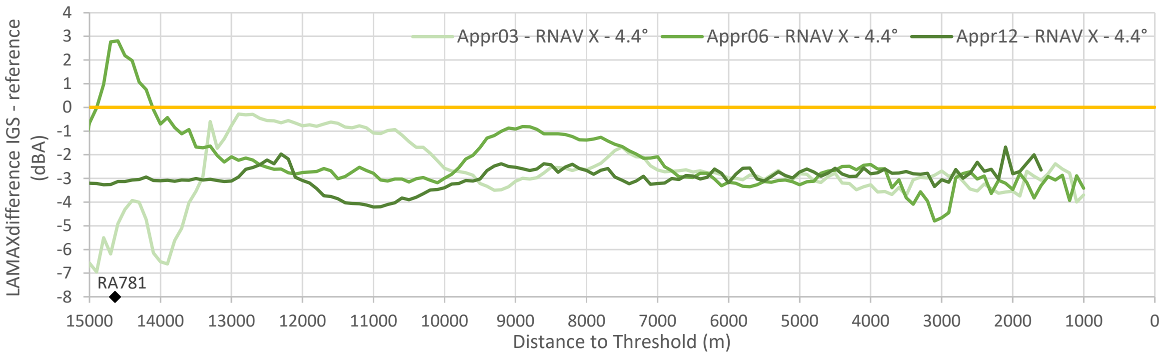


Figure 9 – Falcon 8X - noise benefit under glide path – IGS RNAV X (4.4°)

The greatest benefit (3dBA all along the final approach) was obtained during approach #12 on the 4.4° approach slope. The final approach was intercepted following a continuous descent computed by the FMS and the landing gear and SF2 configuration were deployed just before the glide slope interception.

<u>Effect of a delayed decelerating approach</u>

Figure 11 shows that even if ISGS procedures provide the same noise benefit when applying a delayed deceleration approach procedure (-2.0dBA at the same speed between the decelerating approach Appr#02 at 3.9° and the decelerating approach Appr#08 at 4.4°), it requires to extend the flaps and landing gear at low height and high speed which yields to higher airframe noise.

Therefore, it is preferable to start the deceleration at a higher altitude to obtain a further 5dBA noise reduction at the same height (see noise reduction between Appr#08 and Appr#12).

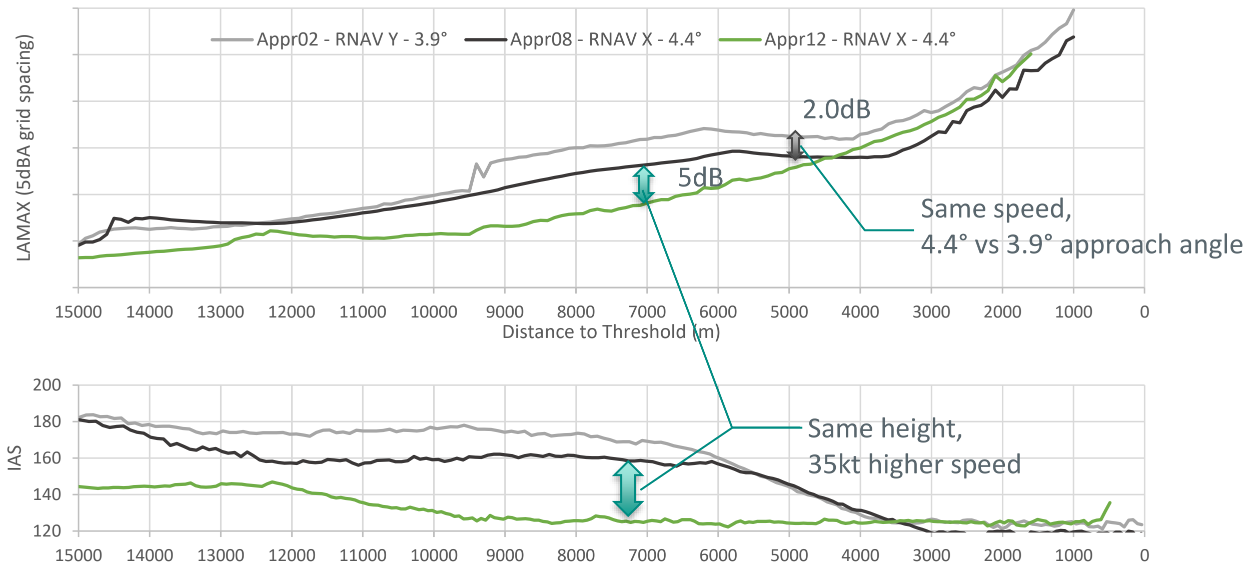


Figure 10 – speed and noise levels under glide path of a stabilized approach compared to a delayed deceleration approach– IGS RNAV X (4.4°)

Moreover, as the deceleration capability is reduced on a steeper flight path, the risk of an unstable approach increases if the pilot is required to maintain a speed greater than the required landing speed down to a too low height.

Therefore, airport speed requirements such as « Maintain 160kt until 4 NM » are not recommended when using an ISGS procedure.

- CRT-02.02-V3-VALP-ISGS.0401-002 Size of noise contours is reduced with ISGS concept
    - Dassault Flights

The following figure shows the 65 dBA ($L_{A,MAX}$) noise contour for the reference approach runs (RNAV Z in orange) and the ISGS runs (RNAV Y in blue and RNAV X in green). The size of the noise contour is reduced in average for the flights by 27% for the 3.9° approach and by 44% for the 4.4° approach.

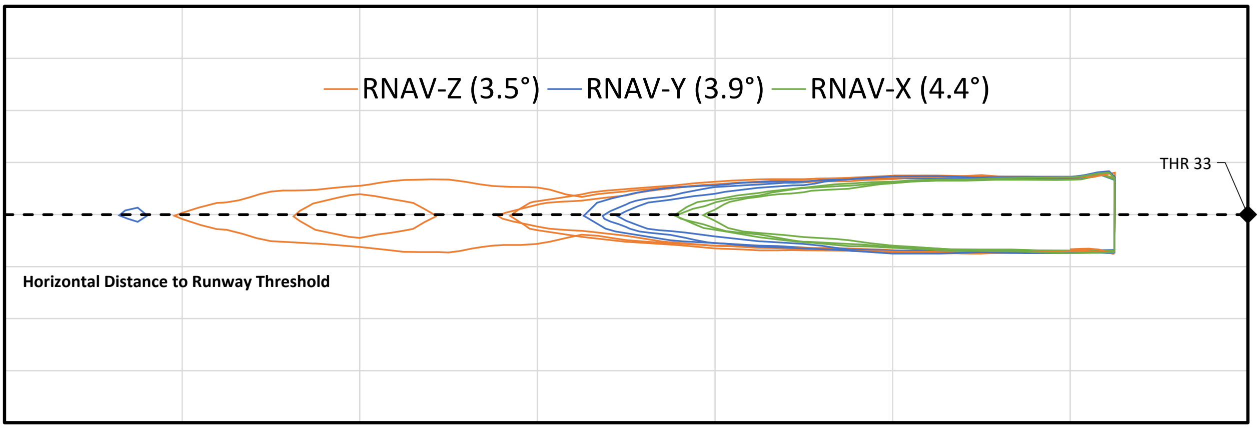


Figure 11 – Falcon 8X - 65 dBA $L_{A,MAX}$ noise contour

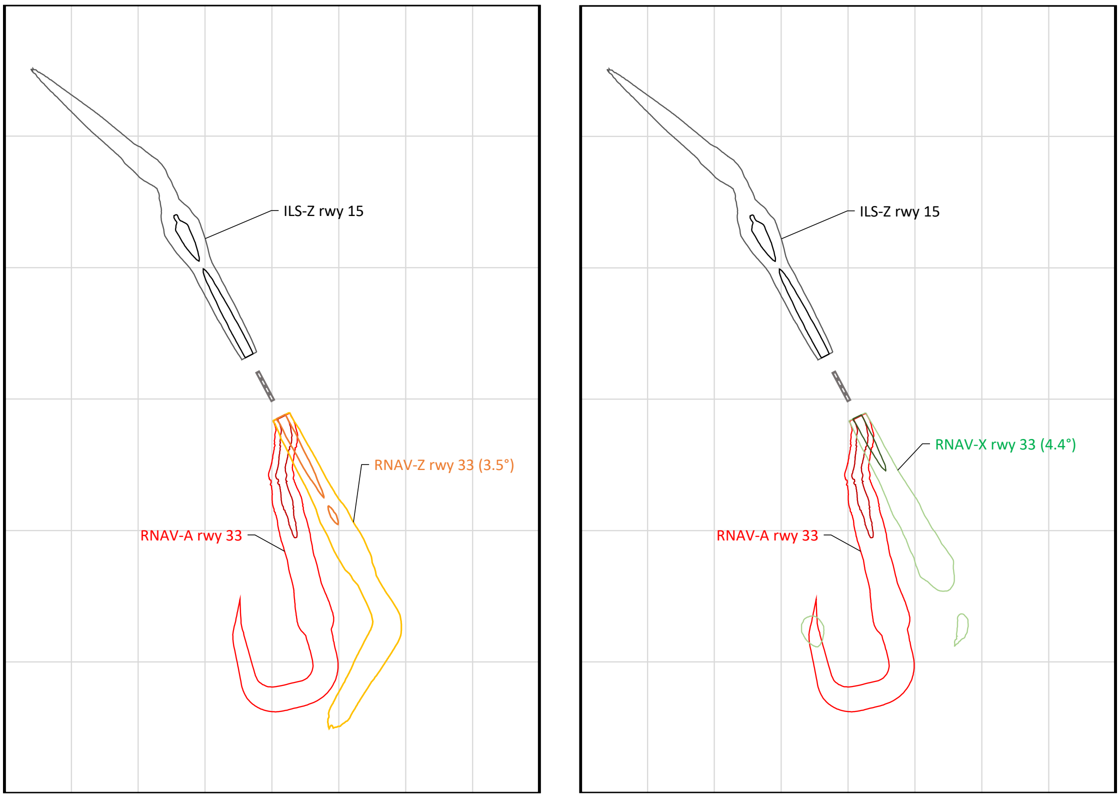
The table below shows that the size of noise contour is always reduced with ISGS concept for both the experimented angles of descent at 3.9° and 4.4° respect to the reference at 3.5°.

	>55 dBA	>60 dBA	>65 dBA	>70 dBA	>75 dBA
RNAV-Y (3.9°)	-19%	-11%	-27%	-14%	-34%
RNAV-X (4.4°)	-24%	-29%	-44%	-40%	-63%

Table 31 – Falcon 8X – percentage variation in ISGS noise contour area respect to the reference at 3.5°

In comparison to the existing RNAV-A rwy 33 approach procedure, the implementation of the RNAV-Z (3.5° glideslope) would reduce the size of the 55dBA noise contour by 15% and the size of the 65dBA noise contour by 28% (see figure below).

Furthermore, as the noise generated by this new approach procedure would affect a different population located around the different ground track, the implementation of the ISGS concept would enable to reduce the impact of this new ground track. Indeed, the implementation of the RNAV-X (4.4° glideslope) would reduce the size of the 55dBA noise contour by nearly 40% and the size of the 65dBA noise contour by nearly 60%.



- CRT-02.02-V3-VALP-ISGS.0401-003 Average noise value is not increased

The criteria is considered as successfully met on the basis of the above provided results.

C.3.2.2 OBJ-02.02-V3-VALP-ISGS.0201 “ISGS impact on crew task performance” Results

- CRT-02.02-V3-VALP-ISGS.0201-001 Pilot succeeds to accomplish an ISGS operation without any difficulty

The criteria have been addressed through post experiment questions and the debriefing both involving all the 9 participating pilots that provided positive feedback about the accomplishing of ISGS operations and did not underline any issue affecting the final approach operations.

Acceptance and usability have both been positively addressed: as it can be observed in the following graph, all the pilots agree or strongly agree that 3.9° ISGS operations are acceptable and usable respect to the experimented 3.5° operations.

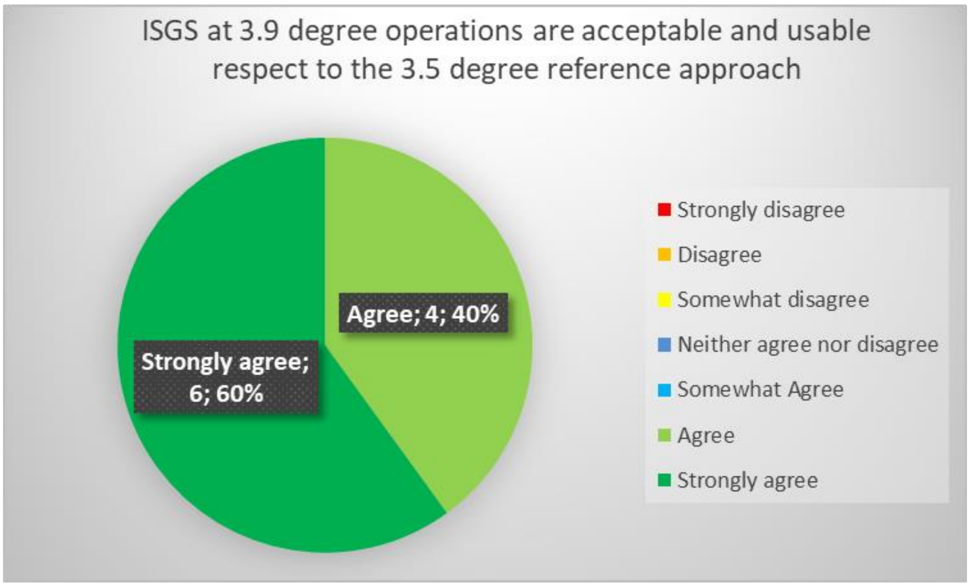


Figure 12 ISGS at 3.9 degree operations are acceptable and usable respect to the 3.5 degree reference approach - PEQ

Same results have been observed for the 4.4° ISGS operations respect to the 3.5° operations, with a 55% of "strongly agreeing" on the acceptability and usability of the solution, 18% "agree" and the remaining 27% "somewhat agree" as it can be seen in the following picture:

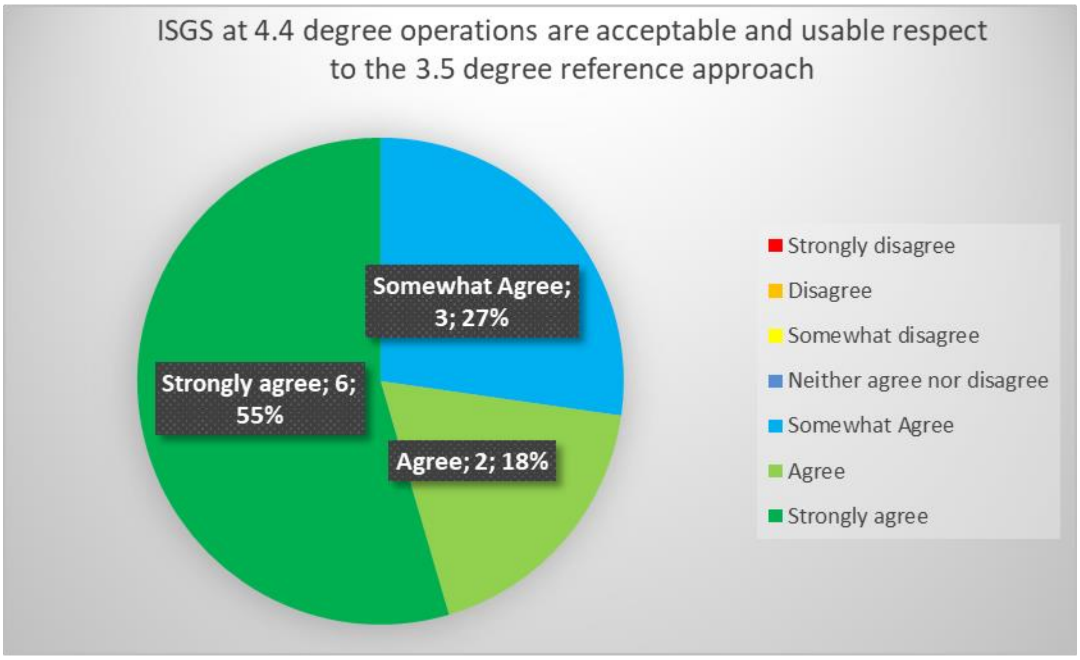


Figure 13 ISGS at 4.4 degree operations are acceptable and usable respect to the 3.5 degree reference approach - PEQ

Further positive evidences have been registered in the post approach questionnaire answered by the 3 DASSAULT pilots flying the approach (DASSAULT and ENAV flight crew provided feedback about the

PAQ during the debriefing) and 2 Honeywell pilots (PAQ done by Pilot Flying after every 30 approaches) as it can be seen in the following picture:

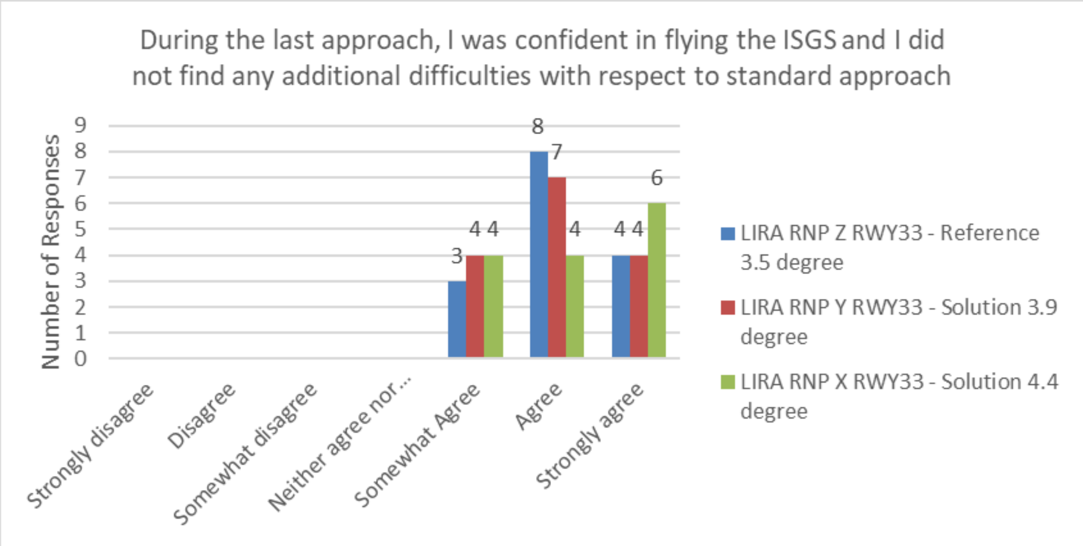


Figure 14 During the last approach, I was confident in flying the ISGS and I did not find any additional difficulties with respect to standard approach PAQ

Indeed, the above plots, it can be observed no differences in the level of confidence and in the capability to perform the ISGS at 3.9° and 4.4° respect to the reference at 3.5° operations, with all the responses spread on the scale form “Somewhat agree to the “Strongly Agree”, which clearly indicating the successful addressment of the criteria.

- CRT-02.02-V3-VALP-ISGS.0201-002 Impact on crew cooperation and crew workload remains with acceptable limit

The crew cooperation was addressed in the debriefing for all the participating pilots and in the post experiment questionnaire only by the 3 ENAV and 2 Honeywell pilots (together 8 responses after each flight), but the collected results are both in agreement on the crew very good cooperation level, meaning that the experimented ISGS operations have not introduced any issue or differences on the crew cooperation respect to the reference scenario, neither to the daily pilot experience.

Indeed, as it can be observed in the following figure, the goals of the team (in relation to the execution of the final ISGS approach procedure from Flight crew point of view and the required flight crew coordination and briefing) in support of the successfully completion the ISGS operations were clearly defined without introducing room for confusion:

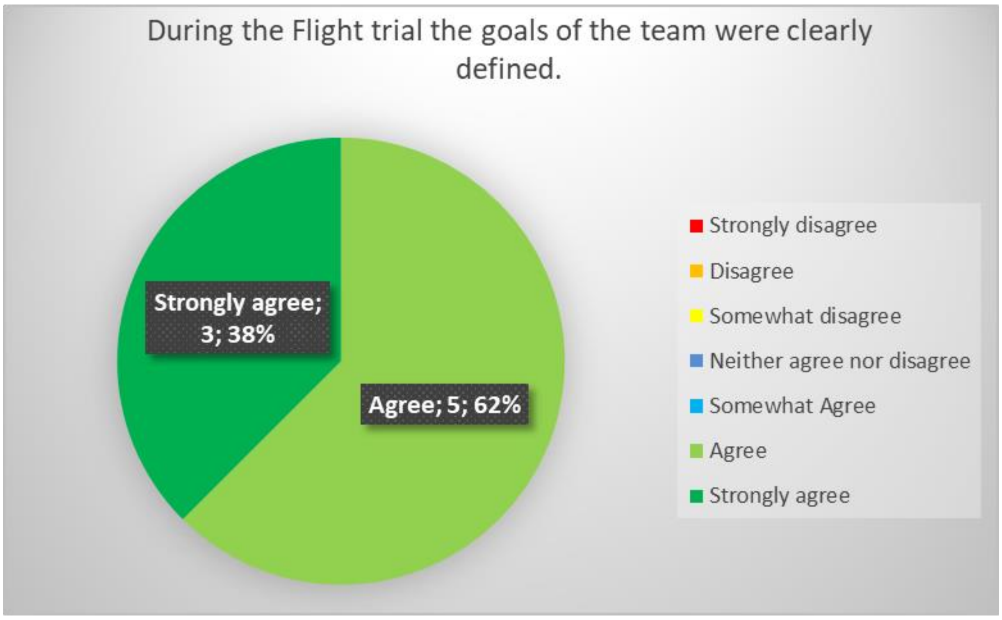


Figure 15 During the Flight trial the goals of the team were clearly defined - PEQ

Also, the teamwork was at excellent level and not affected at all as it can be seen in the following picture:

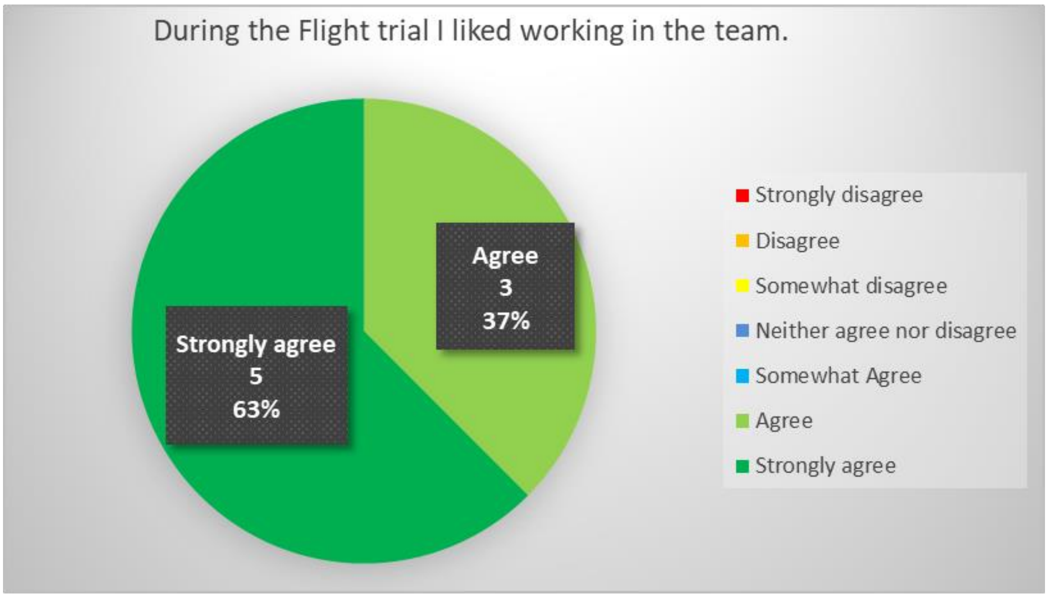


Figure 16 During the Flight trial I liked working in the team – PEQ

The overall perceived workload remained at acceptable level, as it can be observed in the following post experiment question answered by all the participating pilots, with 5 responses fixed on the “Acceptable”,1 on the “Slightly Light”, 3 on “Light” and 2 on “Very Light” responses on a scale of 7 points:

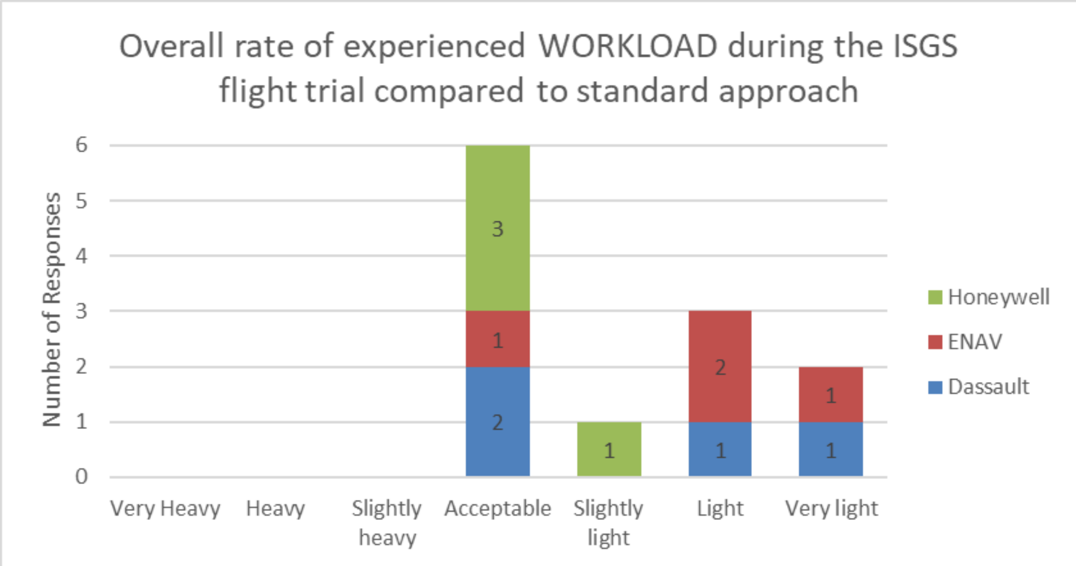


Figure 17 Overall rate of perceived WORKLOAD during the ISGS flight trial compared to standard approach – PEQ

Workload was also measured in the post-approach questionnaire to get the level of perceived workload for each single approach procedure in order to obtain comparable results between reference and solution scenario.

The measurements were based on the BEDFORD 10 points scale and total number of responses were 44.

The mean value of the results per scenario have been graphed in the following picture where the comparison among the different scenarios have been provided:

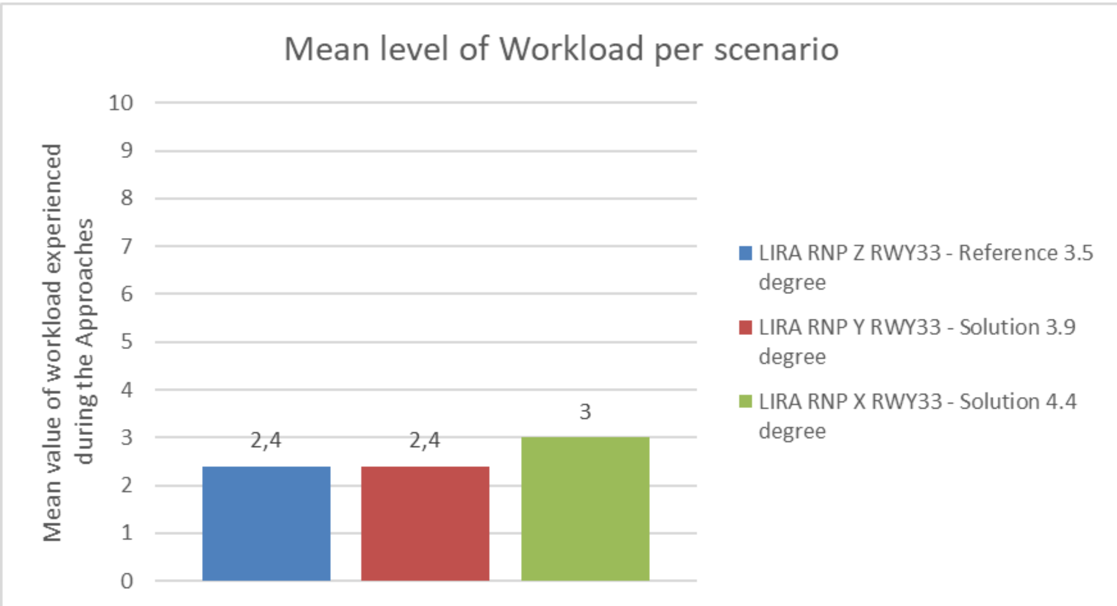


Figure 18 Mean level of perceived workload - BEDFORD scale – PAQ

Looking at the results based on the BEDFORD scale, a confirmation of the acceptability of the perceived workload can also be observed as the mean value for each scenario, reference and solutions, is below or at 3, meaning that at the end of each approach the perceived workload was between the levels "low" or "enough spare capacity for all desirable additional tasks was available" with a very slight increase in the 4.4° ISGS solution (level 3) possibly due to the energy management and configuration slight increase required attention.

- Comments provided by pilots further confirm the results and are hereafter reported:
- "Same workload respect to standard approach"
- "The very low workload was also due to the fact that:
- Weather was ok; no wind and no rain
- -ATC was very helpful
- after the first approach, the following 7 ones were not "surprising" (we were trained)"
- After the first approach No more "discovery" effect.

The experiences Radio-Telephony load was also acceptable for all the pilots, with the majority of responses the "agree" and the remaining on the " strongly agree" answers to the statement "The R/T load experienced during the Flight trial was acceptable" collected through a 7-points scale question in the post experiment questionnaire completed by all the 9 pilots (two responses from Honeywell pilots were collected after each flight) , as it can be seen in the following picture:

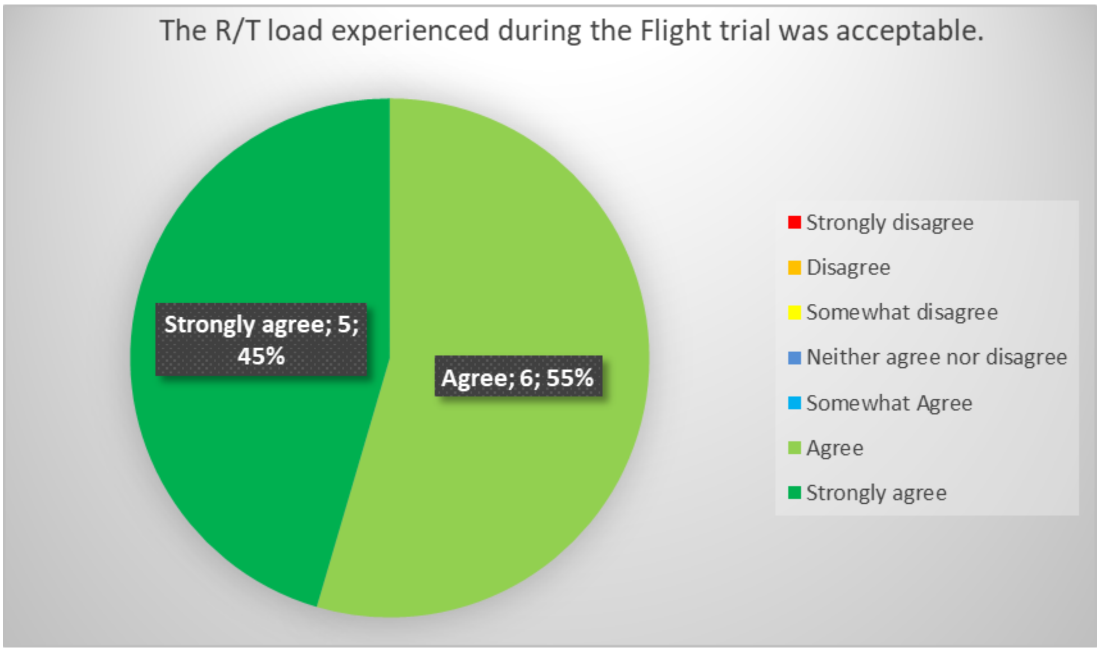


Figure 19 R/T Load - PEQ

C.3.2.3 OBJ-02.02-V3-VALP-ISGS.0202 "ISGS impact on cockpit HMI" Results

During the flight trials, Honeywell evaluated two systems, which could improve the flight crew performance during the ISGS procedures. The Energy management system on the approach from Top of Descent to the stabilization gate altitude and the Flare Assistant.

The Energy management was used by the Pilot Flying during 23 out of 30 flown approaches. 7 approaches were flown without the Energy management tool. Two notes need to be emphasized regarding the Energy management prototype:

- Note 1: the Energy Management Tool was an experimental prototype, and it included few known limitations which negatively affected how the data were presented on the display, resulting in deteriorated perception of the tool by pilots.
- Note 2: specific comments regarding the Energy Management Human-machine interface and suggestions for improvements were collected and will be used to further improve the prototype. These are not disclosed publicly in this document.

The Flare Assistant was tested during 4 approaches, which end up with landing. The HMI was provided on the head-down display, where pilot flying is not looking during flare operation. Therefore, post evaluation review of the recorded screens was conducted with 2 pilots, who participated on trials. Two solutions containing 4.4 degree solution and two with 3.9 degree solution were replayed for pilots, who observed, filled questionnaires and provided aural comments.

Results for both systems are presented for all following objectives:

- CRT-02.02-V3-VALP-ISGS.0202-001 HMI is usable by flight crew

A) Energy Management

Two questions have been answered after each approach. Answers to both indicates that current implementation of Energy Management tool shows usability limits with impact on easy-to-use aspects. Collected flight demo data will be used for further improvements. Specifically, 16 out of 23 answers on the direct question if the usability of the Energy Management HMI is acceptable, were fluctuating from Strongly disagree to Somewhat disagree. That finding is consistent with the second question, where only 8 out of 23 answers rather agreed, that information provided by the system were clear and easily understandable. 11 answers were negative and 4 neutral with an answer: "Neither agree nor disagree".

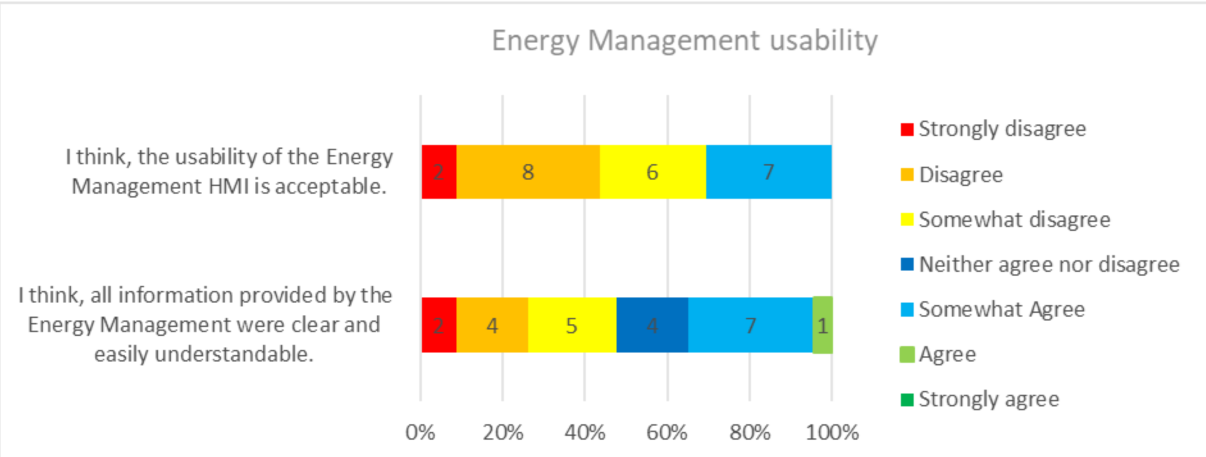


Figure 20 Usability of the Energy Management system – PAQ

B) Flare Assistant

After every approach replay, both pilots provided answers to two questions regarding usability. Mostly negative results (fluctuating from “Strongly disagree” to “Somewhat disagree”) suggest that Flare Assistant usability should be improved with respect to the symbology, its visibility and saliency on the display. Some fine-tuning and polishing of the algorithm, which would make the movement of the symbol smoother, were also suggested in comments.

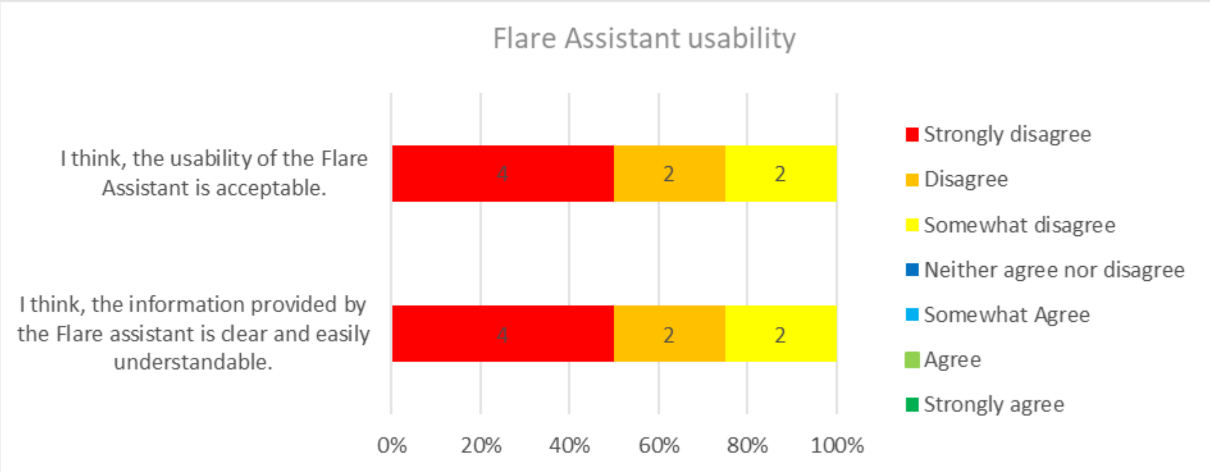


Figure 21 Usability of the Flare Assistant system - video review

- CRT-02.02-V3-VALP-ISGS.0202-002 HMI is useful to flight crew

A) Energy management

One question regarding the usefulness of the Energy Management system during ISGS procedures, has been asked after every approach. The rating shows, that 17 out of 23 answers tent to agree, that Energy Management is useful. With general comment, that the Energy Management is beneficial in case of steeper approach procedures at unknown airports and in bad weather conditions. 4 answers disagreed with that statement and 2 were “Neither agree nor disagree”.

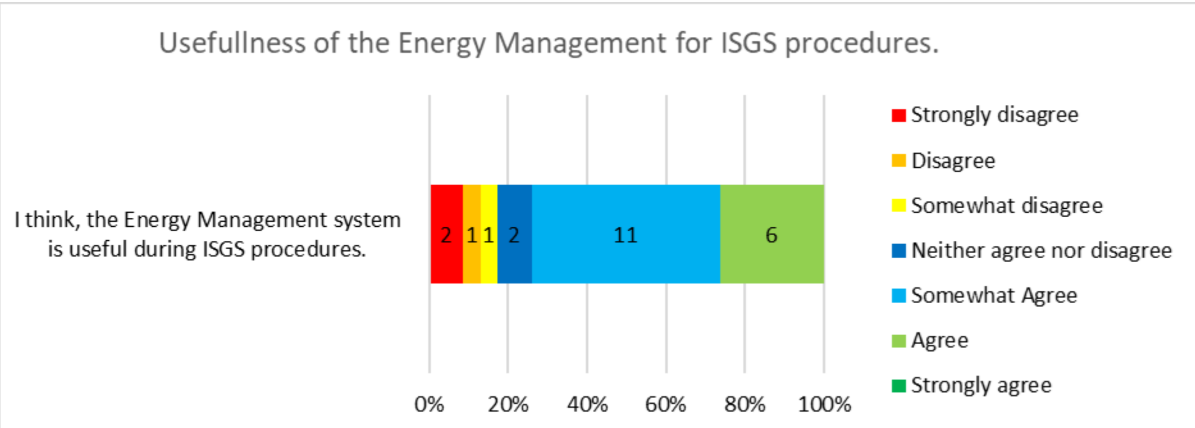


Figure 22 Usefulness of the Energy Management system – PAQ

B) Flare Assistant

Responses to the question regarding potential usefulness of the Flare Assistant for the ISGS procedures were rather positive. 6 out of 8 responses are fluctuating from “Neither agree nor disagree” to “Agree”. Overall, pilots would consider the Flare Assistant as a useful tool for ISGS procedures if the prototype worked correctly and usability limitations were corrected as suggested above.

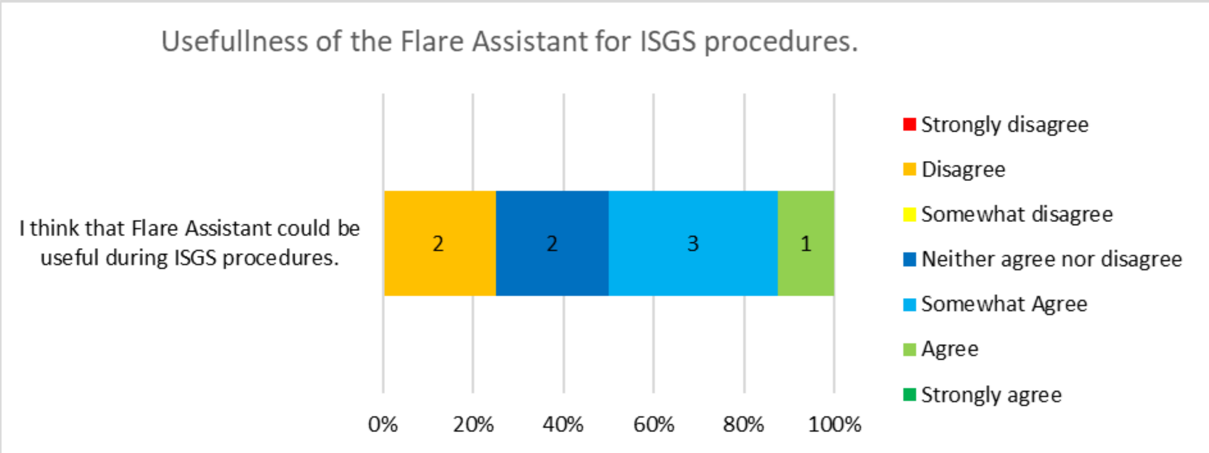


Figure 23 Usefulness of the Flare Assistant system - video record

- CRT-02.02-V3-VALP-ISGS.0202-003 HMI supports the application of the procedure

A) Energy management

One question covered the effectiveness of the Energy Management HMI for the ISGS procedures. The answers are impacted by the poor usability of the current system, which was also described in the above (section CRT-02.02-V3-VALP-ISGS.0202-001). 12 out of 23 answers were rather positive fluctuating between “Somewhat agree” and “Agree”. 10 out of 23 were rather negative and 1 was undecided.

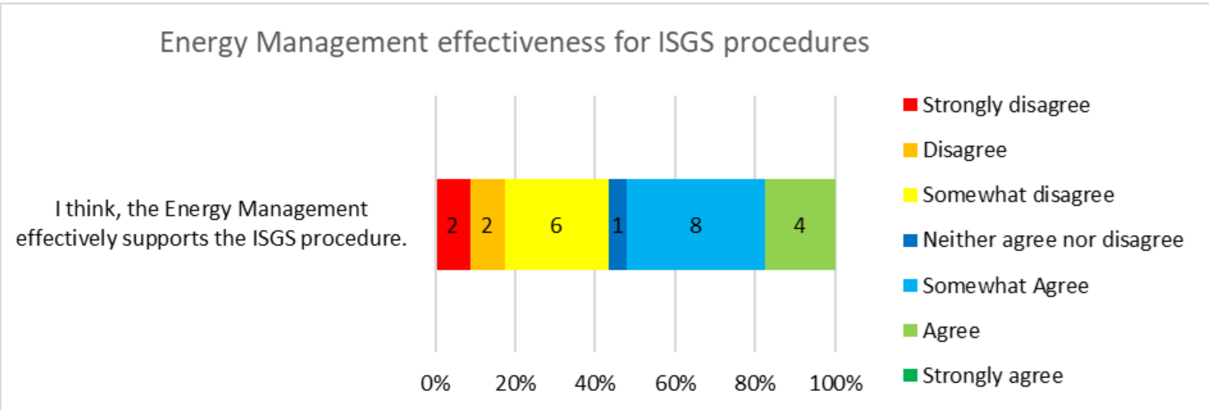


Figure 24 Effectiveness of the Energy Management for ISGS procedures – PAQ

B) Flare Assistant

Pilots feedback suggested the Flare Assistant would be effective tool to manage the ISGS procedures (6 out of 8 responses are fluctuating from “Neither agree nor disagree” to “Agree”), if the usability of the tool were improved, as noted above already. Also, pilots commented, that the primary flight display (head-down diplay) is not the appropriate location, where pilots look during flare operation. The head-up display is the best place to present the flare cue.

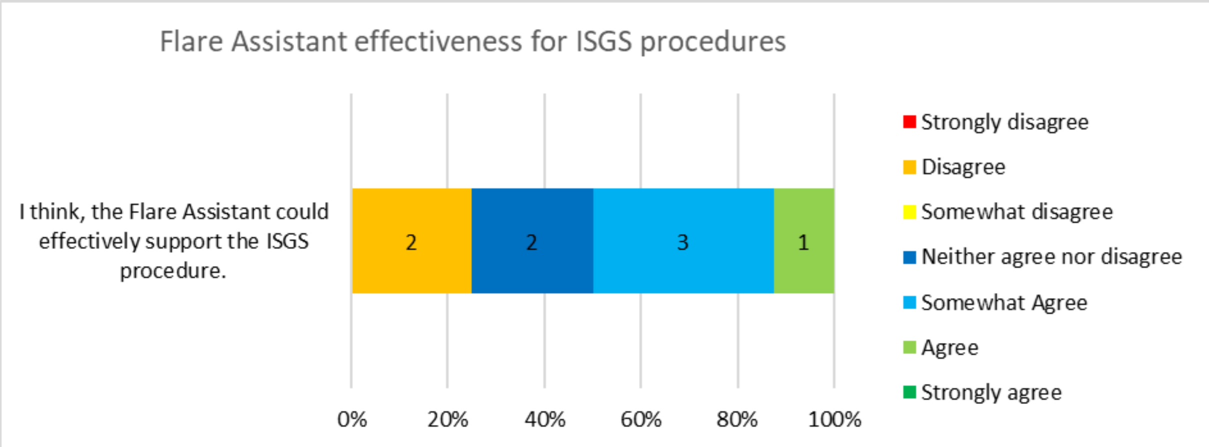


Figure 25 Effectiveness of the Flare Assistant for ISGS procedures - video record

C.3.2.4 OBJ-14.3-V3-VALP-ISGS.0203 "ISGS impact on safety crew perspective" Results

- CRT-14.3-V3-VALP-ISGS.0203-001 There is evidence that Flight Crew's subjective and positive feedback concerning the level of safety for ISGS procedures is not degraded

The perceived level of safety was measured through specific questions in the PEQ completed by all the 9 participating pilots (each Honeywell pilot gave two inputs – after each flight day) and in the PAQ completed by 3 DASSAULT pilots.

As it can be seen in the following PEQ picture the majority of pilots "Agree" and the remaining part " Strongly agree" that the overall level of safety was at least as the today operations during the execution of the ISGS operations:

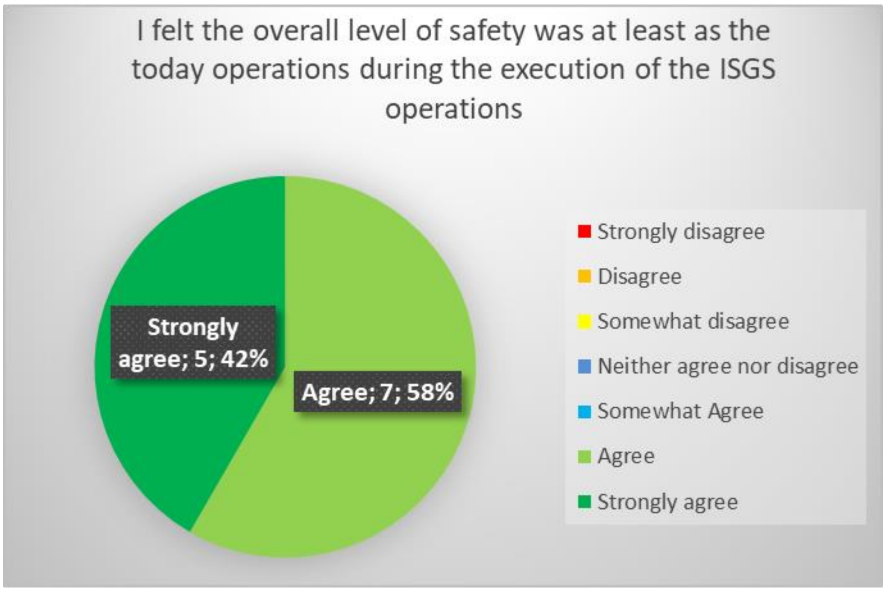


Figure 26 Overall perceived level of safety – PEQ

The results are confirmed also for each approach were for all the scenarios, reference and solutions, the answers from 3 DASSAULT and 2 Honeywell pilots fluctuate between strongly agree and somewhat agree on the acceptability of the level of safety as it can be observed in the following picture:

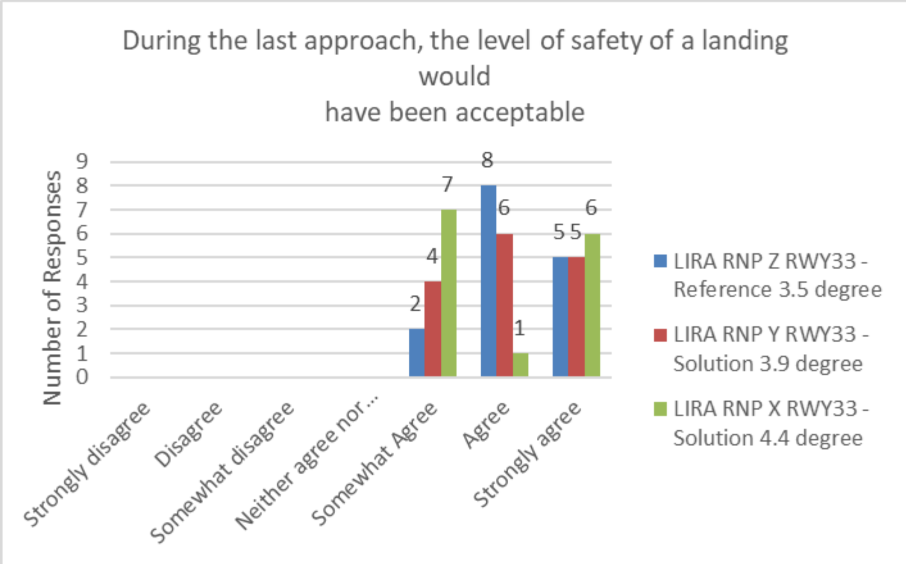


Figure 27 Perceived level of safety per scenario – PAQ

Considering the above picture provides the comparison against the reference scenario, the string result can be read as that the ISGS operations do not affect safety at all for the specific case of Ciampino trial conditions respect to the reference scenario.

Indeed, also the potential for human error was assessed in the PEQ completed by all 9 pilots (each Honeywell pilot gave two inputs – after each flight day) and is hereafter provided:

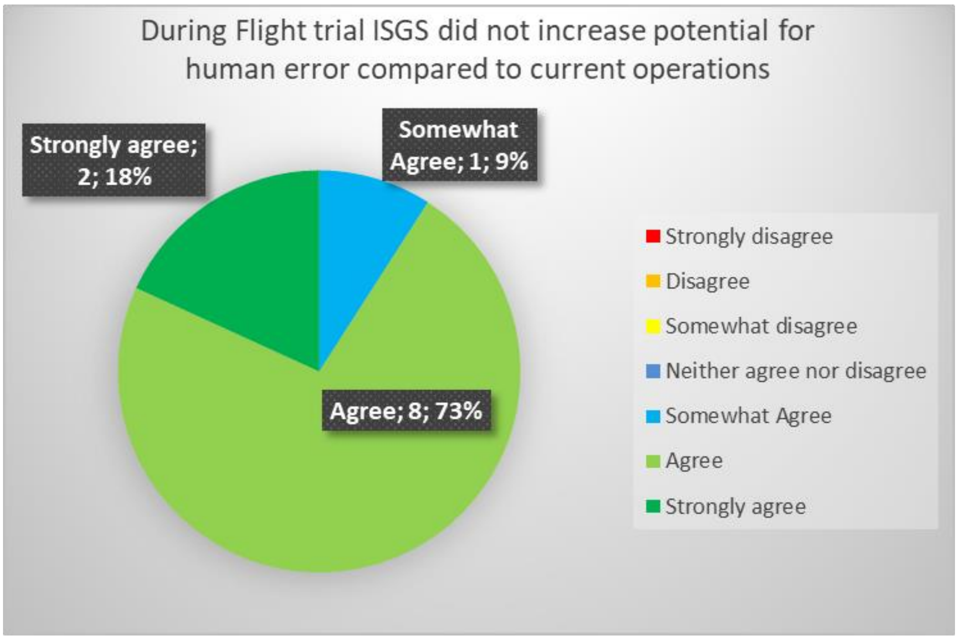


Figure 28 Potential for Human Error – PEQ

The situation awareness perceived during the trials was always at acceptable level as it can be seen from the picture below based on the answers provided in the PEQ by 9 participating pilots (each Honeywell pilot gave two inputs – after each flight day):

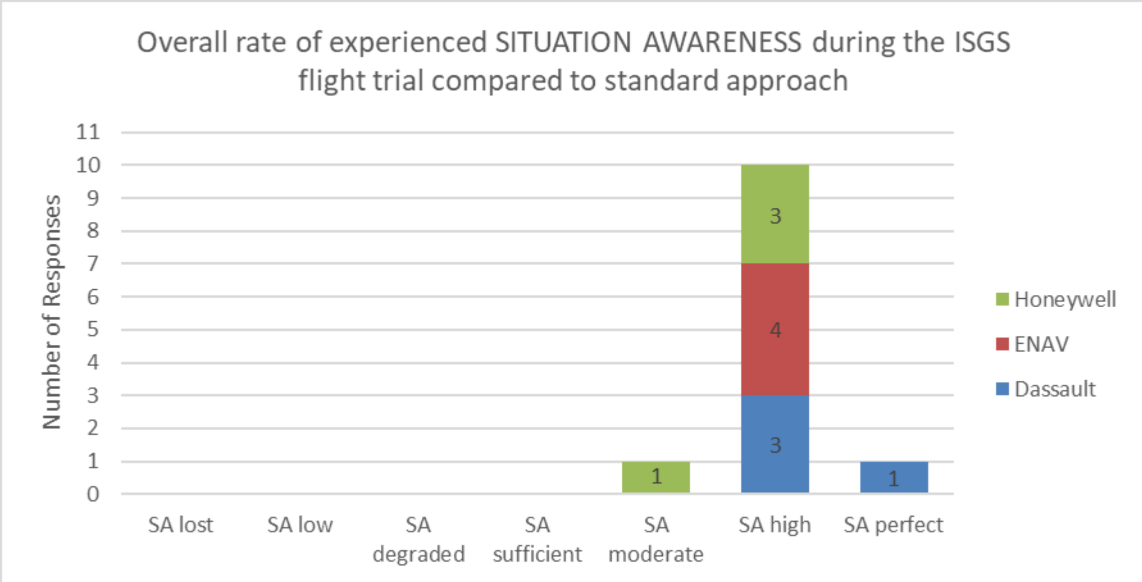


Figure 29 Overall rate of perceived situation awareness – PEQ

Indeed, most of the responses are on “SA High” response with 1 response on “SA perfect” and “SA moderate”, meaning that the introduction of ISGS operations has not affected the situation awareness in the specific conditions of Ciampino trial. This conclusion is also observable in the measured situation awareness at the end of each approach based on the China lake 10 points scale.

Looking at the PAQ mean value (based on the 3 DASSAULT and 2 Honeywell pilots’ responses) for the scenarios (Reference, 3.9° ISGS solution, 4.4° ISGS solution) of the perceived level of the situation awareness it is clear that there is no difference among scenario with the level fixed around the ”8.7, which can be concluded as a “very good” point:

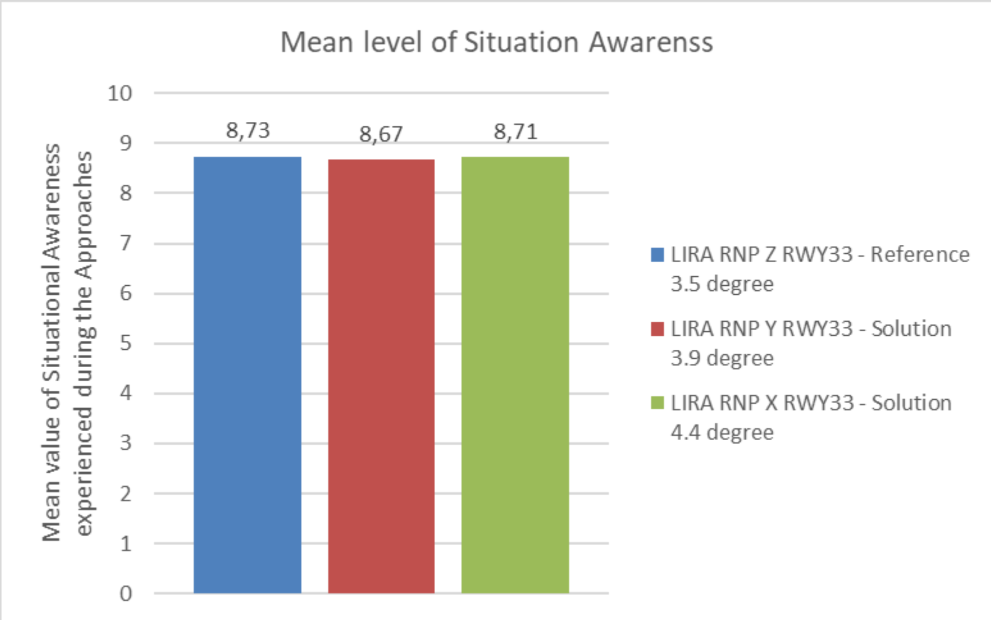


Figure 30 Mean level of perceived situation awareness per scenario – CHINA LAKE scale PAQ

C.3.2.5 OBJ-14.3-V3-VALP-ISGS.0204 "ISGS operational feasibility from crew perspective" Results

The results show that the ISGS experimented operations at Ciampino airport are operationally feasible.

Indeed, all the participating pilots somewhat agree, agree or strongly agree that the approach charts were complete and exhaustive. It needs to be noted, that pilots emphasized the request to have information about the PAPI charted in the navigation charts for all approach angles.

Also, the information was complete and exhaustive as it can be seen in the following pictures from the PEQ:

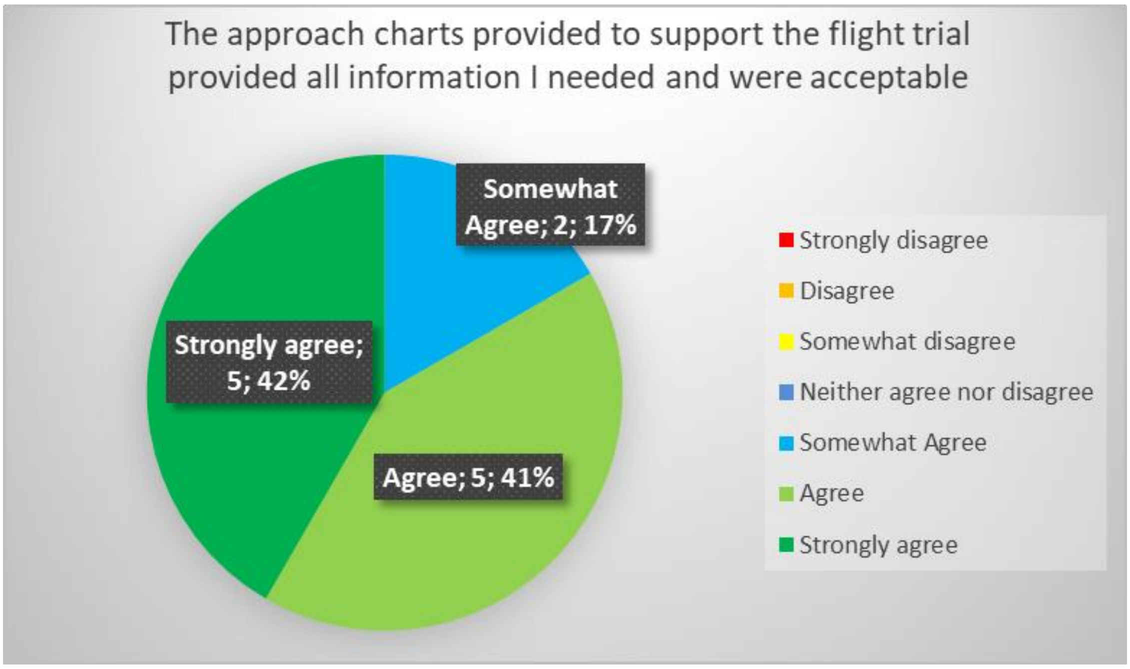


Figure 31 Approach charts – PEQ

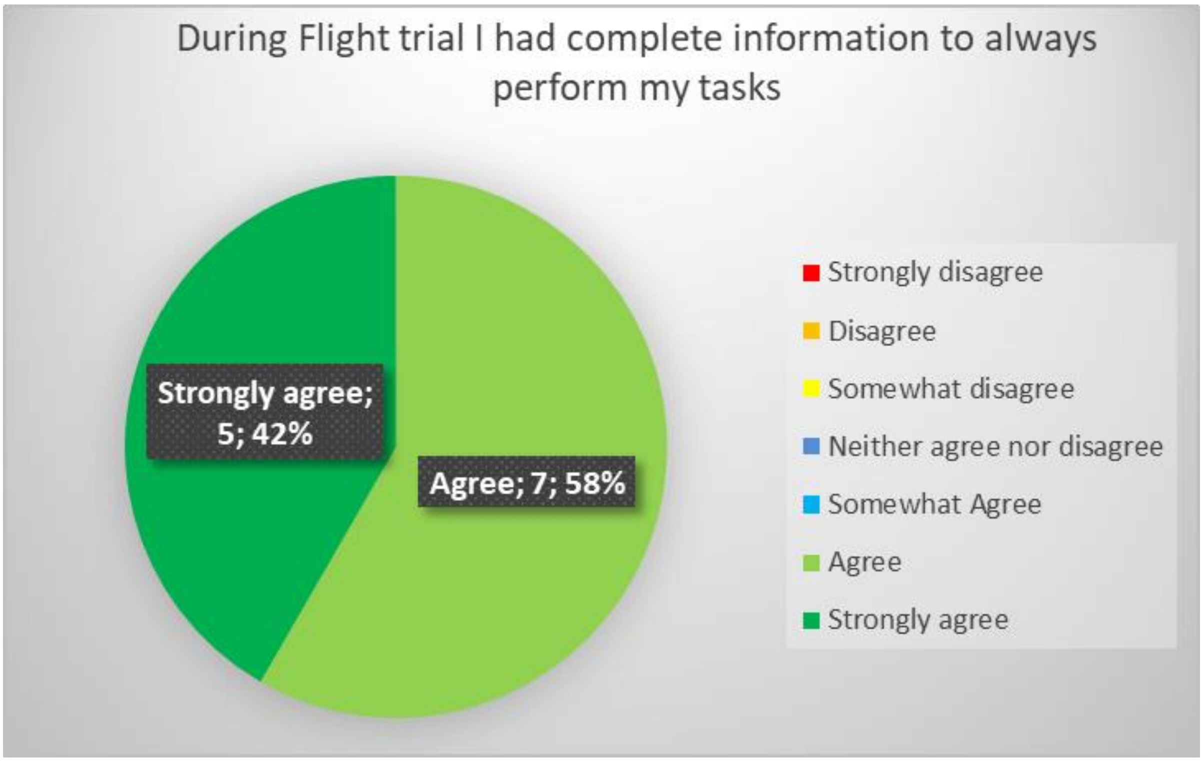


Figure 32 Complete information – PEQ

PAPI indications did not generate issue in majority of cases of Ciampino trial conditions as it can be observed in the following post approach question' plot completed by 3 DASSAULT and 2 Honeywell pilots after every approach

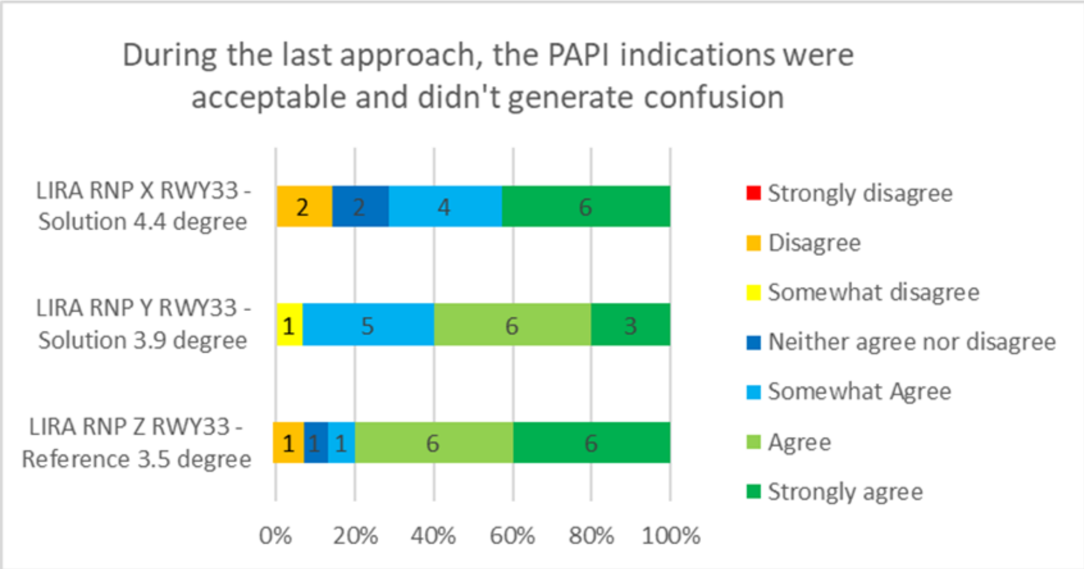


Figure 33 PAPI information – PAQ

As stated above, the PAPI information on increased glide slope was missing in the charts. That is why a significant portion of the answers to the following questions were negative. 5 out of 11 answers state that PAPI indication in case of 3.9 degree slope generated confusion:

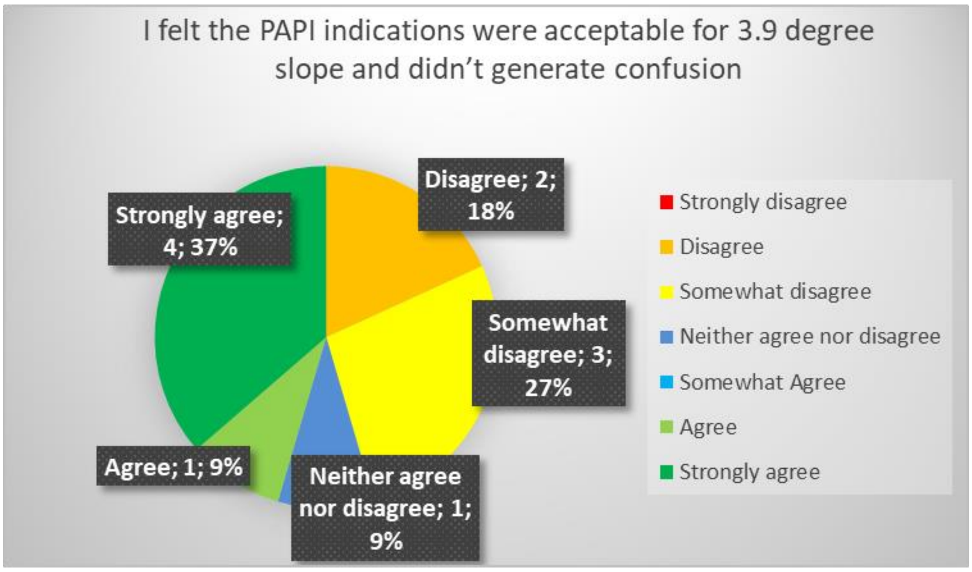


Figure 34 PAPI information 3.9° ISGS solution – PEQ

In case of 4.4 degree slope, the confusion was rated even worse compere to 3.9. In this case, 6 out of 10 collected answers stated, that PAPI brings confusion:

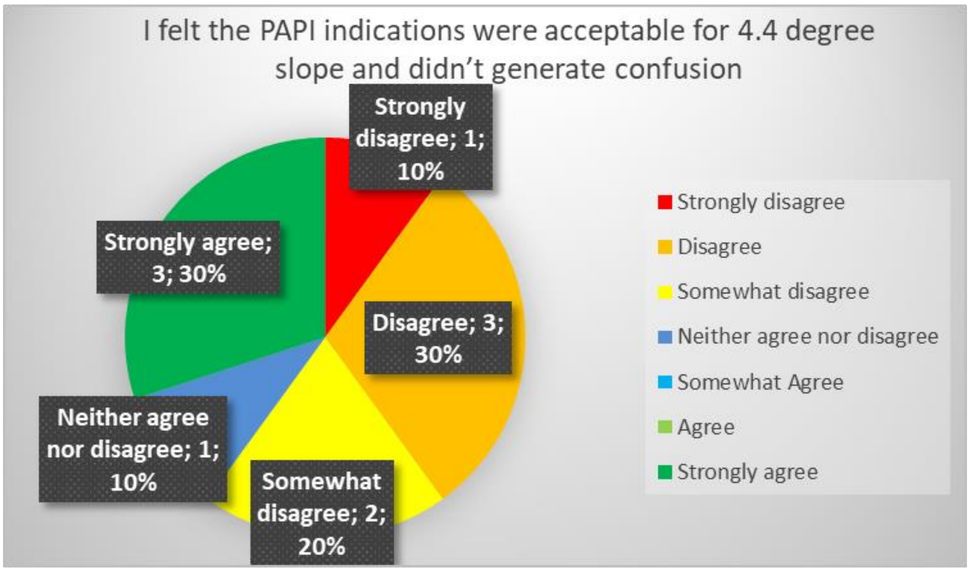


Figure 35 PAPI information 4.4° ISGS solution – PEQ

These results shall be read in conjunction with the provided comments.

- "Regarding PAPI: this is an issue created by the test itself and does not reflect operational conditions. In case of publication only two angles should be selected, with a maximum of 0.5 degrees of difference (e.g. 3.9 and 4.4). In such case a PAPI set to 3.9 can still provide guidance for the aircraft flying the 4.4 degrees glide path."
- "It is acceptable only because it was a trial. In normal operations it MUST be synchronized"
- The PAPI angle vs. glide slope is not published in charts. It should be clearly identified, what pilots should expect to see PAPI when flying steeper approach.
- If there is a way to make the PAPI reflect the glideslope flown, this would be great (3.5, 3.9, 4.4)
- Glide slope vs. Visual glide slope not published in charts.
- Vertical Angle for the visual path should be charted.
- "We flew 3 lights white and 1 light red above the normal PAPI glide"
- "PAPI has not been used. All I needed to monitor the approach was in the normal cues of the Head Up Display"
- "Not observed. Approach performed without"
- "Not in the piloting loop"
- "No confusion during the approach. From minima, could be tempted to reach PAPI path by pushing a bit but ok"
- "Pilot barely see the PAPI but indication did not any generate confusion at all"
- "Well visible; No confusion"

These not fully agreed results among pilots might be read considering that in the specific case of Ciampino trial the limited or unavailable PAPI visual guidance was not an issue, but this result is not applicable to the daily operations. Also, it needs to be underlined that, considering the DASSAULT, Honeywell and ENAV flight decks are different, different avionics might yield to different results.

Energy management during the flare for both the solutions 3.9° ISGS and 4.4° ISGS is acceptable looking at the following pictures from the PEQ completed only by the 3 ENAV and 2 Honeywell pilots (it was considered not relevant for DASSAULT pilots):

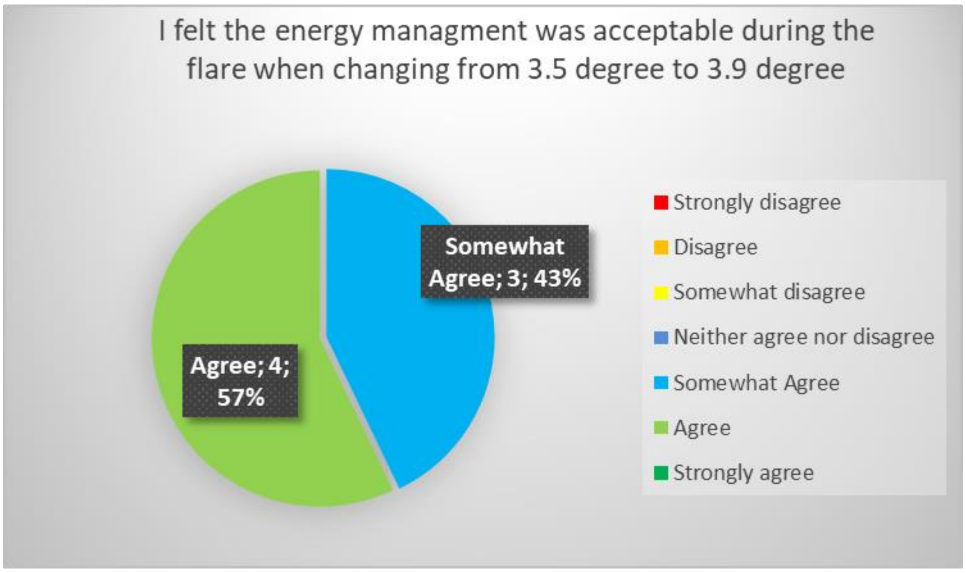


Figure 36 Energy management 3.9° ISGS solution – PEQ

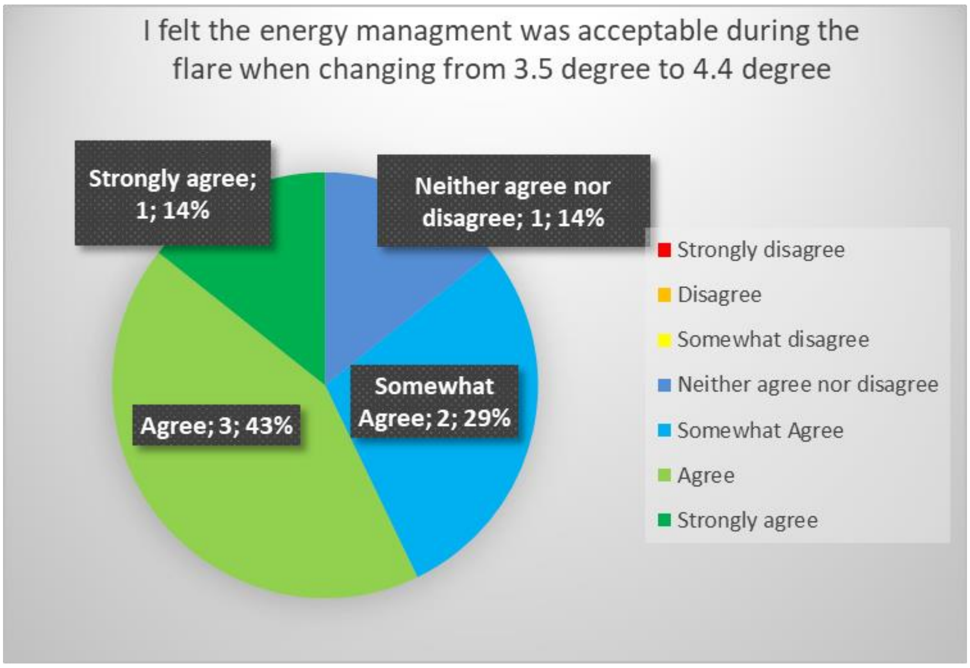


Figure 37 Energy management 4.4° ISGS solution – PEQ

In particular, some pilots mentioned that energy management was not an issue in the case of ENAV and DASSAULT live trials considering the category of used aircraft, but the results might not be the same for aircraft of bigger category. However, the Honeywell trials have proved that the energy management is not an issue either with a bigger aircraft (Embraer 170).

In addition, the design of the procedure with the provided speed constraints helped the energy management during the approach as reported by some pilots during the debriefing.

For the training adaptations, not clear results have been collected among all the pilots in the PEQ. It should be noted that the majority of answers (8 out of 10) indicated that no additional training is needed. 2 out of 10 answers, however, indicated that some training is needed. Results can be seen in the following picture:

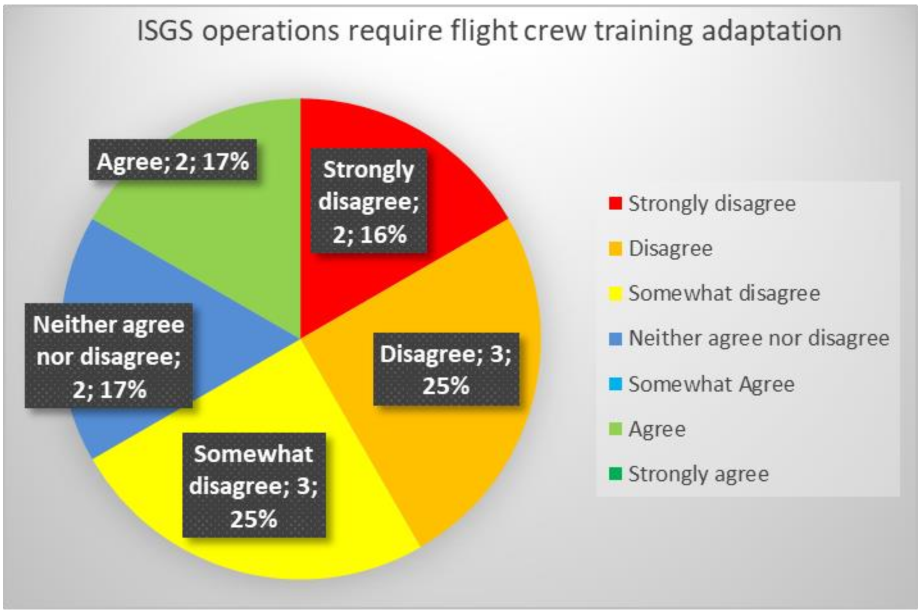


Figure 38 Flight crew training adaptation – PEQ

Also, 6 out of 8 answers indicated that new skills are not needed to perform the ISGS procedure:

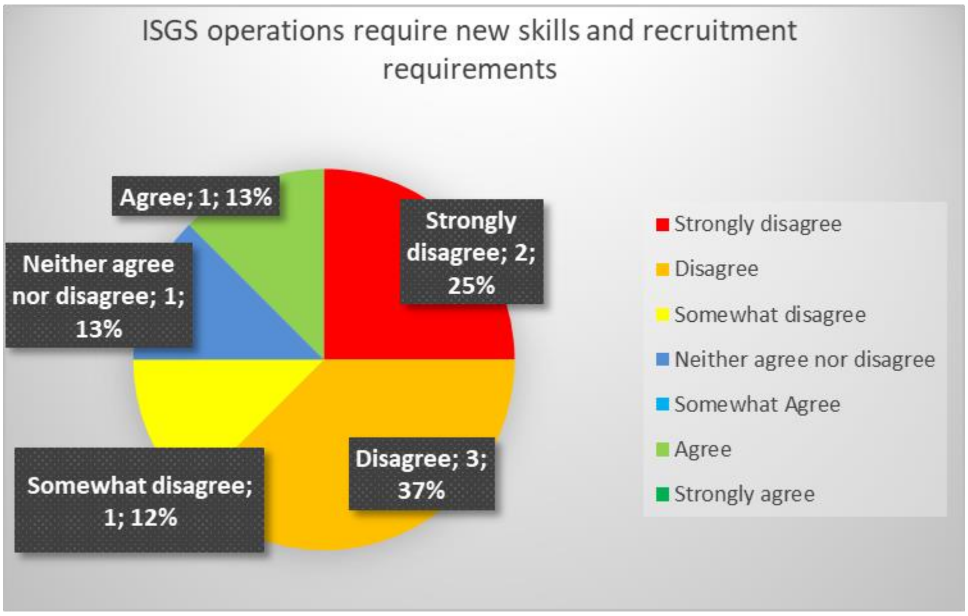


Figure 39 Skill and recruitment requirements – PEQ

But considering general comments:

- "These approaches are to be considered normal (they are all below 4.5°). Operational choice to implement one of the 3 possible GP angles should take into consideration that energy management is easier at 3.5 and 3.9°"
- "This ISGS is equal to all other RNP approach, already included in the standard training for pilots. Need only an updated briefing for aircraft configuration and energy management. The procedure is well better than the actual RNP in force."

it might be concluded that the ISGS operations can be considered as standard procedure without affecting training and skills, neither recruitment. This statement was also confirmed in the 5 debriefing sessions and possible issue are only in relation to aircraft configuration and energy management that should be updated in the briefing.

- CRT-14.3-V3-VALP-ISGS.0204-001 Pilot succeeds to manage ISGS operation by applying existing SOPs

The most of the 9 pilots that answered the PEQ strongly agree and the remaining agree that the ISGS operations can be managed by current SOPs as it can be observed in the following pictures, meaning that for the case of Ciampino trial experience there is no need of updating current SOPs:

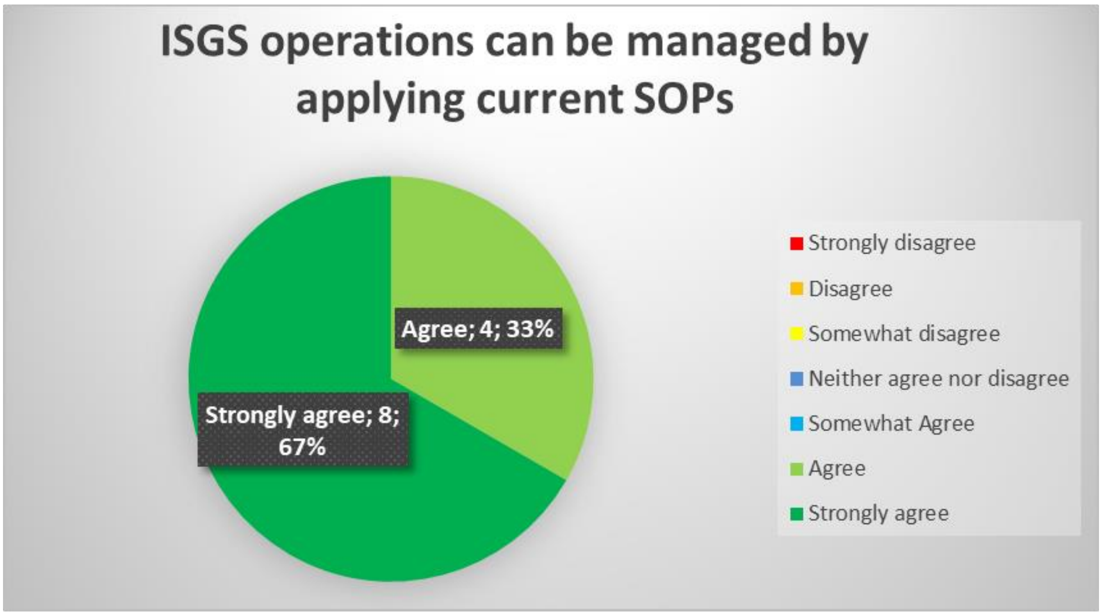


Figure 40 Current SOPs – PEQ

DAV's pilots highlighted during the debriefing that "apart the way to manage the energy and anticipate the flaps extension, there is no difference with standard operations. Therefore, it is not necessary to modify current SOPs".

This anticipation is confirmed by the analysis of the runs performed on Falcon 8X. Figure 39 shows that height at which the pilot commanded the deployment of the flaps and the landing gear to configure the aircraft for landing increases with the glide path angle. The pilot initiated the configuration for landing at the glide slope interception height. The aircraft was stabilized at an average value of 1800ft for the three glide path angles, i.e. above the stabilization height of 1000 ft IMC and 500 ft VMC.

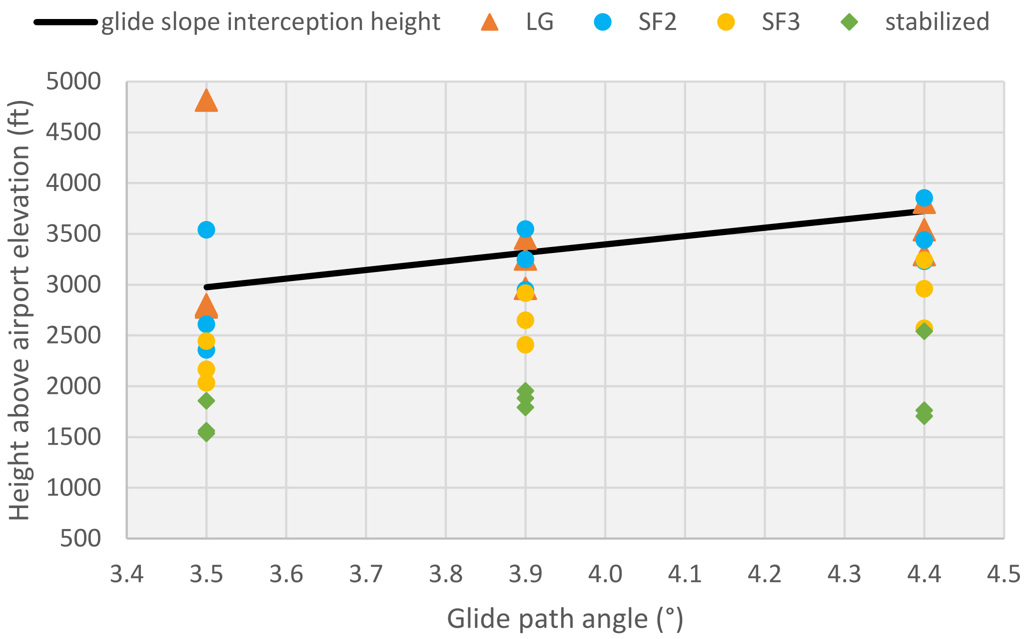


Figure 41 Flaps & landing gear extension height - Dassault Falcon 8X flight tests

- CRT-14.3-V3-VALP-ISGS.0204-002 Pilots are confident when flying a ISGS operation

The level of confidence was extremely high, as reported in the debriefing by all the 9 participating pilots. This result is also confirmed in the PEQ completed by all the pilots and hereafter provided:

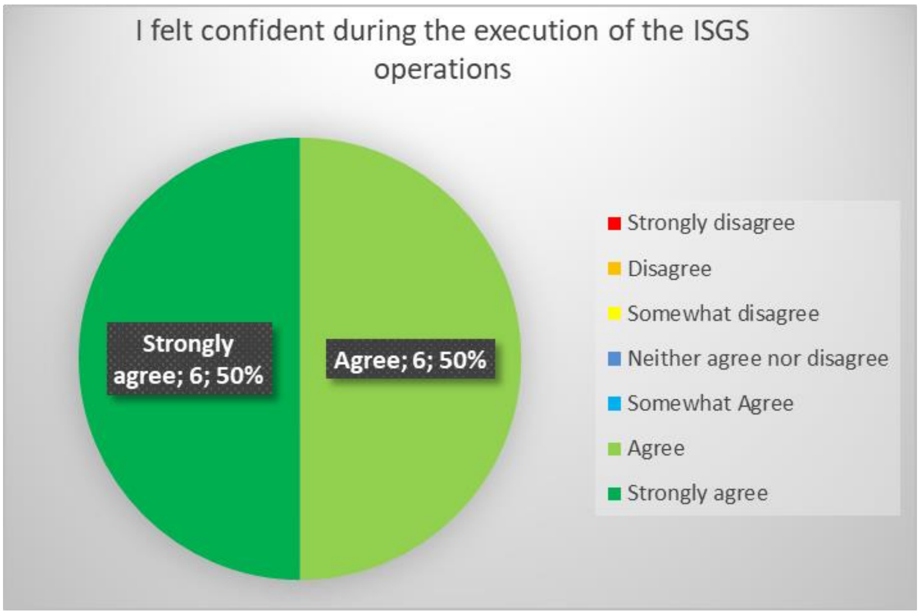


Figure 42 Level of confidence – PEQ

On the other hand, it can be concluded that the level of confidence was the same for all the ISGS experimented operations, considering the answers provided by the 3 DASSAULT and 2 Honeywell pilots in the post approach questionnaire and hereafter plotted:

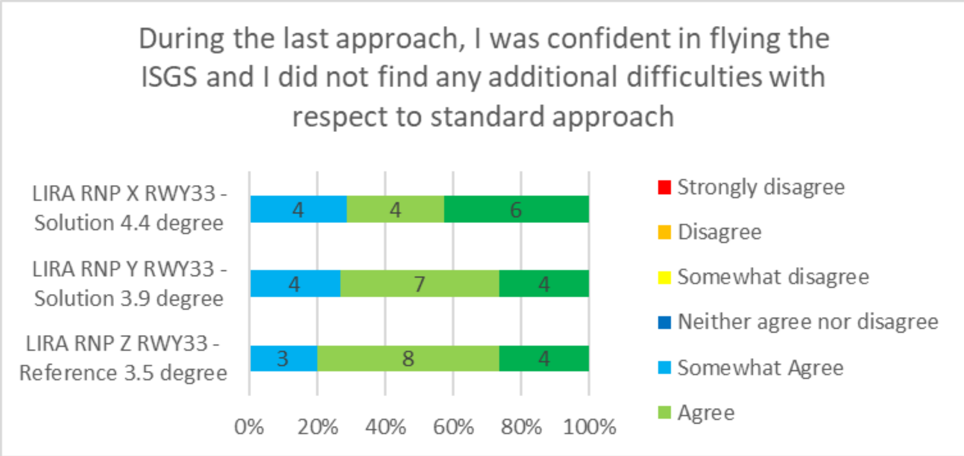


Figure 43 Level of confidence – PAQ

C.3.3 Unexpected Behaviours/Results

No unexpected behaviours to be underlined.

Honeywell trials did not detect any unexpected behavior or potential errors in the ISGS procedures.

C.3.4 Confidence in the Demonstration Results

C.3.4.1 Level of significance/limitations of Demonstration Exercise Results

The flight test aircrafts used to comply with demonstration activities are representative of commercial/production aircraft cockpit.

In addition, they are equipped with specific and peculiar instrumentation (SBAS capable), needed to perform the relative flight experimental activities.

It was not possible to use a second PAPI in Ciampino due to safety risks impact on the operational environment and the impossibility to command 2 different PAPIs by an Air Traffic Controller.

The flight trials have been managed applying current standard spacing required on RWY33 of Ciampino airport that is 10/15 NM (depending on local coordination): due to final ISGS approach segment length and the standard spacing of RWY33 the testing aircraft have never been on the final approach segment at the same time of other daily traffic, that anyway has been managed st the same time of the testing aircraft, being the Ciampino airport an operational airport hosting commercial flights.

The ISGS approach charts at the time of the flights have not been published, the approach procedures have been flown by the live trials cleared at pilot discretion, and since this affects the HP and SAF assessment of ATC side and there were no other expected changes to approach and tower controllers working methods in the specific context of Ciampino, no ATC related objectives have been addressed and no measurement for ATC have been conducted.

Honeywell Flare Assistant was tested during 4 approaches, which end up with landing. Also, the HMI was provided on the head-down display, where pilot flying is not looking during flare operation. Therefore, post evaluation review of the recorded screens with Flare Assistant was conducted.

C.3.4.2 Quality of Demonstration Exercise Results

There were no specific issues or constraints affecting the data collection in addition to what described in section C.3.

The collected data and the analyzed results are based on the subjective experience and perception of the participating test pilots in the specific context of the demonstration exercise. The results and the data have been collected in an accurate manner and there is a high confidence on the provided feedback, but of course the results are strictly dependent on the condition and context of Ciampino demonstration.

C.3.4.3 Significance of Demonstration Exercises Results

The demonstration exercise has been conducted on an operational airport hosting conventional traffic at the same time of the testing aircraft with testing aircraft proving an operational significance equivalent to the daily operations, of course with the limitations already mentioned in section C.3.4.1 and C.3.4.2.

A significant number of total run have been conducted considering the 3 testing aircraft of ENAV, DASSAULT and HONEYWELL as well as a significant number of pilots have been involved, but it cannot be considered that the results have statistical significance. Considering the demonstration technique (flight trials) and the executed numbers of runs it is judged the results have a high level of significance.

C.4 Conclusions

C.4.1 Noise benefit

Clear noise benefits have been measured from the Dassault live trial. The ISGS procedures provide positive relative noise scale results:

- for the 3.9° approach path : up to 4dBA on the first part of the final approach (depending on the moment where the landing configuration is extended) and 1 dBA when the aircraft is stabilized in the approach configuration
- for the 4.4° approach path : up to 4dBA on the first part of the final approach and 3dBA when the aircraft is stabilized in the approach configuration

The 65 dBA (LA,MAX) noise contour for the reference approach runs (RNAV Z in orange) and the ISGS runs (RNAV Y in blue and RNAV X in green) is considered as representative metric. The size of the noise contour is reduced in average for the flights by 27% for the 3.9° approach and by 44% for the 4.4° approach.

C.4.2 Human Performance and Safety

For the airborne part, considering the measured results it can be concluded that in the specific case of Ciampino trials executed by ENAV, DASSAULT and Honeywell flight crew the experimented ISGS operations can be treated as standard operation without introducing any HP and safety issue respect to the day to day operations.

For the ATC/aerodrome part, these results of course are relevant for the specific context of the flight trial on Ciampino airport that has been conducted considering the limitations reported in section C.3.4

C.4.2.1 Energy Management

The Energy Management system has been tested only by the Honeywell flight crew during 23 approaches. It needs to be noted, that it is an experimental prototype with known limitation, which needs to be considered during the result interpretation. The Energy Management system seems to be useful during ISGS procedure, especially during the approach to an unfamiliar airport in bad weather. However, current prototype needs to be refined to improve the level of usability and effectiveness, how it supports the crew during ISGS procedures.

C.4.2.2 Flare Assistant

The Flare Assistant was implemented on the Honeywell primary flight. However, due to safety reasons, pilots did not look at the primary flight display during the flare phase of flight. Therefore, the post evaluation video review was conducted with 2 pilots. Pilots were asked to observe 4 recorded ISGS approaches captured during the Rome trials, where primary display with the Flare Assistant is visible. Pilots feedback suggests that the Flare Assistant could be useful and could effectively support pilot during ISGS procedures, if usability of the system were improved and especially, if flare related cues were provided on the head-up instead of the head-down display.

C.5 Recommendations

C.5.1 Recommendations for industrialization and deployment

C.5.1.1 Noise

Based on demonstrated NOISE benefits, it is recommended to push as soon as possible for the deployment of ISGS as a complement to PBN IR procedures . This would allow operational gain (i.e. curfew reduction) to operators that can fly such increased glide slope and environmental benefits to cope with the green deal.

For aircraft already able to approach up to -4.4° in normal operation (such as business jets), quick win for noise reduction could be achieved on secondary airport and SBAS procedures.

C.5.1.2 Human Performance and Safety

Ciampino experience from ENAV, DASSAULT and Honeywell flight crew have not introduced need for additional recommendation respect to previous V3 phase.

One recommendation relates to the PAPI information, which needs to be addressed and charted properly in the navigation approach charts so that flight crew can be briefed ahead of the approach and have a correct expectation what kind of visual information they see out-the window during steeper approach. The PAPI out-the window needs to be aligned with charts. It must be adjustable on the ground to reflect steeper approaches, or it needs to be clearly stated that pilots will experience inconsistency during steeper glide slope.

Specific attention is required for Energy Management and Aircraft configuration for big size aircraft, however even bigger aircraft and flight crew are capable to manage the energy during ISGS procedures effectively.

Moreover, as the deceleration capability is reduced on a steeper flight path, the risk of an unstable approach increases if the pilot is required to maintain a speed greater than the required landing speed down to a too low height. Therefore, airport speed requirements such as « Maintain 160kt until 4 NM » are not recommended when using an ISGS procedure.

Energy Management and Flare assistant prototypes should be further refined and assessed.

Specific assessment is recommended on the local test environment before deploying ISGS: a local safety and human performance assessment is recommended to assess possible safety and human performance (airborne and ground) issues dependent on the characteristics of the operational environment.

C.5.2 Recommendations on regulation and standardization initiatives

Ciampino experience from ENAV, DASSAULT and Honeywell flight crew have not addressed specific regulation or standardization initiatives.

Specific regulation or standardisation initiatives are addressed in Appendix F of the DEMOR.

Appendix D Exercise VLD1-04 Report - ISGS Twente Demonstration

D.1 Summary of the Demonstration Exercise VLD1-04 Plan

D.1.1 Exercise description and scope

The Exercise 04 scope can be found in the DREAMS DEMOP (version 00_01_00) section 5.4.1. In the remainder of this appendix, the designation “DEMOP” is used exclusively to refer to this particular version. This version was the one active at the time of performing Exercise 04.

D.1.2 Summary of Demonstration Exercise VLD1-04 Demonstration Objectives and success criteria

The Exercise 04 scope can be found in the DREAMS DEMOP section 5.4.3.

D.1.3 Summary of Validation Exercise VLD1-04 Demonstration scenarios

The Exercise 04 scope can be found in the DREAMS DEMOP section 5.1.4.

D.1.4 Summary of Demonstration Exercise VLD1-04 Demonstration Assumptions

The Exercise 04 scope can be found in the DREAMS DEMOP section 5.4.5.

D.2 Deviation from the planned activities

Shakedown of the ISGS PAPI system was planned for 1 day (22 June 2022) as the PAPI system has been used before in Exercise 01 in 2021. However, the shakedown actually took three days (22-24 June 2022) as some features of the PAPI system were changed (in order to improve the system when compared to Exercise 01). Also, the aircraft experienced a malfunction upon start up, which required a system replacement and consequently resulted in a later take-off on the first shakedown day. Finally, the aircraft had to land first at Twente Airport in order to drop off an inclinometer (required for PAPI alignment activities), which was mistakenly forgotten in the PAPI delivery by the supplier. Following PAPI related items were – in chronological order – responsible for the extended shakedown period:

- Alignment
  For purposes of easier alignment of the PAPI units, the units were now fitted with tripods. Fixed to the tripods were two metal plates on which the inclinometer was to be positioned in order to align the PAPI unit in two axes. However, these alignment devices seemed not to be calibrated: the four light units had different angles between the light beam and the alignment devices.
  As a solution, the alignment was done by directly placing the inclinometer on top of the light unit housing (like was done in Exercise 01). However, to be able to do this, the glare shields had to be removed first. This method turned out to work well and had no influence on the intensity as perceived by the pilots, which for the red-white colour-coding was okay.

- Width
  It turned out that in order to get good and consistent colour transitions per light unit, the beam width had to be slightly increased. See Table 32, which does not take into account the individual light unit corrections used during the tests.

ICAO						Wider beams				
GPA	**L4**	**L3**	**L2**	**L1**		**GPA**	**L4**	**L3**	**L2**	**L1**
3.0	**3.6**	**3.3**	**2.7**	**2.4**						
3.5	**4.1**	**3.8**	**3.2**	**2.9**		**3.5**	**4.5**	**4.0**	**3.0**	**2.5**
4.0	**4.7**	**4.3**	**3.7**	**3.3**		**4.0**	**5.0**	**4.5**	**3.5**	**3.0**
4.5	**5.2**	**4.8**	**4.2**	**3.8**		**4.5**	**5.5**	**5.0**	**4.0**	**3.5**

Table 32: PAPI alignment angles (L1 being the outer light unit and L4 the one closest to the runway)

- Colour-coding
  The shakedown continued by testing the red-green colour-coding. However, the intensity and transitions between the colours turned out to be poor with some reflections. Comparison of the red-white with the red-green elements showed that the red-green elements had two additional, convergently-placed shielding plates inside (not only between the two colours) which were assumed to be left-overs from its original HAPI function. Unfortunately, these additional shields could not be removed, however, they could be positioned parallel to each other. This turned out to be the solution for both the poor intensity and colour transitions/reflections.

The extended shakedown period resulted in five flying days with test subjects: 27 June through 1 July 2022.

Flying day 1 – 27 June 2022
Two test subjects and four flights in total. For flight 2, lamps 1 and 3 were exchanged in order to have best results: red intensity of lamp 3 was lower and therefore placed at lamp1 position (lamp 4 being the lamp closest to the runway). This setup was maintained for the remainder of the test program.
In flight 2, run number 7 was skipped because in run 5 there were already 4 reds on the ISGS PAPI. Run 7 has been skipped on more flights.
Prior to flight 4, the ISGS PAPI colour-coding had to be changed from red-white to red-green. This was performed under overcast/drizzle conditions. During flight 4, the weather improved and occasional sunshine developed in the area. This caused the moisture inside the ISGS PAPI light units 1, 2 and 3 – as a result of the exchange of the light elements under moist conditions – to condensate on the lenses. This influenced the last two runs of flight 4 in a negative way.

Flying day 2 – 28 June 2022
Two test subjects and four flights in total. The morning session with one of the two subjects was additionally planned in order to (partly) make up for the longer shakedown period. This first flight of the day was slightly delayed, in order for the condensation to evaporate. To this end, the light unit elements were removed from the housing, so that the ambient air/wind could enter the units.
On flight 7 (third flight of the day), the first four approaches were mistakenly flown with an ISGS PAPI alignment of 4.5 degrees instead of 3.5 degrees.

Flying day 3 – 29 June 2022
Planning was to have another 4 flights and 2 test subjects, however, the aircraft experienced a malfunction upon landing and was grounded at Twente Airport. The broken part happened to be on stock in NLR's hangar at Rotterdam and was flown-in with a small aircraft together with an engineer. Problem was solved in the afternoon, however, the second test subject for this day had to be cancelled.

Flying day 4 – 30 June 2022
As planned, there were two flights with one test subject by NLR and a single flight by TUI's B737 Max 8. Due to delay of the TUI flight from Amsterdam, part of the programme was flown with both aircraft in the circuit at Twente Airport. Although this increased the work load for the ground support personnel at the ISGS PAPI, the runs were performed without any problems. The order of the runs for the NLR aircraft were however shuffled in anticipation of the delayed TUI aircraft, thereby minimizing the required effort of the ground personnel.

Flying day 5 – 1 July 2022
As planned, there were four flights with two test subjects.

D.3 Demonstration Exercise VLD1-04 Results

D.3.1 Summary of Demonstration Exercise VLD1-04 Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
EX3-OBJ- VLD-01-003-002	ISGS impact on crew task performance	EX3- CRT-VLD-01-003-021	Pilot succeeds to accomplish an ISGS operation without any difficulty	Airport - Other	See D.3.2.1	OK
		EX3- CRT-VLD-01-003-022	Impact on crew cooperation and crew workload remains within acceptable limit	Airport - Other	See D.3.2.1	OK
EX3-OBJ- VLD-01-003-006	ISGS impact on safety crew perspective	EX3- CRT-VLD-01-003-061	There is evidence that Flight Crew's subjective and positive feedback concerning the level of safety for ISGS procedures is not degraded	Airport - Other	See D.3.2.2	OK
EX3-OBJ- VLD-01-003-008	ISGS operational feasibility from crew perspective	EX3- CRT-VLD-01-003-081	Pilot succeeds to manage ISGS operation by applying existing SOPs	Airport - Other	See D.3.2.3	OK
		EX3- CRT-VLD-01-003-091	Pilots are confident when flying	Airport - Other	See D.3.2.3	OK

			an ISGS operation			

Table 33: Exercise 4 Demonstration Results

D.3.1.1 Results per KPA

Safety

The ISGS approaches have been performed at Twente Airport under VMC and daylight conditions with NLR's Cessna Citation II research aircraft. Twente Airport is an uncontrolled VFR-only airport.

Under above conditions, and judging from the test subjects' questionnaires, the ISGS approaches are acceptable. The approaches could be flown safely and without confusion on which approach and PAPI to use. Perceived situational awareness was good. The PAPI indications from the PAPI that is not used, are not compromising safety. The ISGS PAPI is helpful for outside visual guidance during the ISGS approach. The test subjects were comfortable with flying an approach with two PAPI's active at the same time. Overall, test subjects have indicated that they have flown all approaches to the ISGS configured runway (i.e. both conventional 3.0 deg as well as IGS 3.5, 4.0 and 4.49 deg approaches while both PAPI's are active) safely and with confidence. The procedures are straightforward and well within the capabilities of any current crew. Note however that for 4.0 and 4.49 deg ISGS approaches, although within normal approach design criteria for the Citation and demonstrated by the Citation in EXE04, may require careful energy management for larger aircraft.

Finally, a subset of the ISGS approaches have also been flown by a Boeing 737 Max (TUI) for glide path angles 3.0 and 3.5 deg. Crew's safety perception for these approaches were in line with those stated in above paragraph.

Human Performance

The ISGS approaches have been performed at Twente Airport under VMC and daylight conditions with NLR's Cessna Citation II research aircraft. Twente Airport is an uncontrolled VFR-only airport.

Under above conditions, the impact of ISGS approaches on work load and task performance remained within acceptable limits. The existing SOPs could be used, however, a crew briefing item on which PAPI to use, should be added and trained.

In EXE04, two PAPI colour coding configurations have been used: Red-White and Red-Green. With regard to the preference for either the red-white or red-green colour-coding of the ISGS PAPI, it turns out hard to come to a firm conclusion based on the results/data of Exercise 04. Questionnaire scores are so close to each other, that none of the two has a clear preference. From the scores, it turns out that red-white is slightly preferred when looking at safety, but that red-green is slightly preferred when looking at work load. But again, the differences are so small as to prevent a clear-cut answer on preference. Most indicative on this matter is the overall average score for PEQ Question 4, which directly asks the preference-question, being 3.9 which is only marginally above the cross-over value of 3.5. This indecisiveness for colour-coding preference is also reflected in the comments given by the test subjects on the questionnaires. It seems that in terms of contrast red-white is slightly preferred, while in terms of awareness/mental picture red-green is slightly preferred.

D.3.1.2 Results impacting regulation and standardisation initiatives

Results impacting regulation and standardization initiatives for ISGS operations can be subdivided into two new features. These features are deemed necessary or supportive to safely fly ISGS procedures in general and the EXE04 flight tests in particular and have therefore been applied during the EXE04 flight tests at Twente Airport. All these features were well accepted by the test subjects during EXE04.

Second PAPI

In order to provide the crew with outside visual vertical guidance also when flying an 3.5, 4.0 or 4.49 ISGS approach, a second PAPI is positioned next to the aiming point on the opposite side of the runway. This second PAPI – simultaneously active with the conventional PAPI – was well received by the test subjects (see section D.3.1.1). The second PAPI was tested with two colour coding configurations: Red-White and Red-Green. On average, test subjects had no particular preference for either of these colour coding configurations (see section D.3.1.1).

Approach charts

Approach charts were drafted for the EXE04 approach procedures. These charts include information on the position and indication of both the conventional and ISGS PAPI's. Furthermore, the charts contain a caution box, outlined in red, indicating to the crew that two PAPI's are active. The box also contains information on which PAPI to disregard for the particular approach.

See also section E.2.

D.3.2 Analysis of Exercises Results per Demonstration objective

The Flights/Runs in this appendix section concern the flights performed with NLR's Cessna Citation II research aircraft (registration PH-LAB). For reasons of convenience, the Test Matrix, PRQ and PEQ are copied here:

Test Matrix

RUN NR	RWY	GPA [deg]	ISGS PAPI [- deg]	Remarks	Quest.
1	05 or 23	3.0	ON – 3.5	Familiarization	NO
2	05 or 23	3.0	OFF	Reference Run	YES
3	05 or 23	3.0	ON – 3.5		YES
4	05 or 23	3.5	ON – 3.5		YES
5	05 or 23	3.0	ON – 4.0		YES
6	05 or 23	4.0	ON – 4.0		YES

7	05 or 23	3.0	ON – 4.5		YES
8	05 or 23	4.49	ON – 4.5		YES

- Runs may be repeated as required (run 1 optional)
- Fixed PAPI must be ON for all runs
- Fixed PAPI intensity as required (SCD)
- ALS as required (OFF, LOW of HIGH intensity, SCD)

PRQ

1. In your opinion and during the last approach, the **PAPI** indications were acceptable.
2. In your opinion and during the last approach, there was never **confusion** regarding which PAPI to use.
3. In your opinion and during the last approach, the level of **safety** of a landing would have been acceptable.
4. In your opinion and during the last approach, your **workload** and **task performance** were acceptable.

PEQ

1. In your opinion, the simultaneous use of two PAPIs is acceptable.
2. In your opinion, the position of the second PAPI (IGS) on the opposite side of the runway when compared to the first PAPI (conventional) is acceptable.
3. In your opinion, the red-green colored PAPI for IGS is acceptable.
4. In your opinion, the red-green colored PAPI for IGS makes it better distinguishable from the conventional PAPI and is therefore preferred over a red-white colored IGS PAPI.
5. In your opinion, the level of operational safety during an IGS approach/landing/go-around is not negatively impacted by the dual PAPI operation when compared to a conventional approach/landing/go-around with only one conventional PAPI switched on.
6. In your opinion, the level of operational safety during a normal 3 degree GP approach/landing/go-around is not negatively impacted by the dual PAPI operation when compared to a conventional approach/landing/go-around with only one conventional PAPI switched on.
7. In your opinion, IGS operations can be managed by existing SOPs.
8. In your opinion, you were confident in flying IGS operations.

Each question of the PRQ and PEQ could be answered by checking one of six boxes:

- 1. Completely disagree
- 2. Mostly disagree

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- 3. Slightly disagree
- 4. Slightly agree
- 5. Mostly agree
- 6. Completely agree

For the evaluation of the results, these six answers were given the respective values of 1 (completely disagree) to 6 (completely agree). A particular criteria is therefore considered "passed" when the average values of the particular set of questions (for the particular set of runs – see Table 34) all exceed 3.5 and considered "failed" when one or more questions score on average below 3.5.

	CRITERIA	RESEARCH QUESTION	PRQ	PEQ	RUN	2	3	4	5	6	7	8
1	EX3- CRT-VLD-01-003-021	Does Pilot succeed to accomplish an ISGS operation without any difficulty?	1,2,3,4	1,2,3,4			x	x	x	x	x	x
2	EX3- CRT-VLD-01-003-022	Does impact on crew cooperation and crew workload remain within acceptable limit?	4			x	x	x	x	x	x	x
3	EX3- CRT-VLD-01-003-061	Is there evidence that the level of operational safety is maintained and not negatively impacted under ISGS procedures compared to the reference scenario from the perspective of the crew?	3	1,2,3,4,5,6		x	x	x	x	x	x	x
4	EX3- CRT-VLD-01-003-081	Does pilot succeed to manage ISGS operation by applying existing SOPs?		7				x		x		x
5	EX3- CRT-VLD-01-003-091	Are pilots confident when flying an ISGS operation?		8			x	x	x	x	x	x

Table 34: Mapping between demonstration exercise objectives and research questions

Before the results are analysed for each demonstration objective in the current chapter, first an overview is given of some general data/information concerning the flight tests:

An overview and some anonymous information of the test subjects that took part in the experiments with the PH-LAB is given in Table 35.

Test Subject	Age	Test pilot	Total flt hrs	A/c type	Remarks
A	40-50	No	9500	B744, B737, E190, B777/787	
B	40-50	Yes*	8800	B744, B737, F70/100	*) Acceptance pilot F70/100
C	20-30	No	220	DA42, SE	
D	50-60	No	17000	MD11, B737, B744, B777/787	
E	50-60	Yes*	10500	B757/767, B744	*) Research pilot 1997-2010
F	30-40	No	3500	B737, F16	
G	40-50	No	7600	B737, E175/190, F50, P3	
H	30-40	No	4000	B737, F16	

Table 35: Overview test subjects on PH-LAB

The PRQ en PEQ scores are given per test subject in respectively

Table 36 and Table 37.

Post Run Questionnaire results

Q1 =	PAPI	1 =	completely disagree
Q2 =	confusion	2 =	mostly disagree
Q3 =	safety	3 =	slightly disagree
Q4 =	workload/task performace	4 =	slightly agree
		5 =	mostly agree
		6 =	completely agree
		x =	not flown
		-- =	flown, but no PRQ (unplanned)
		/ =	flown, but no PRQ (planned)

FLT1/2 RUN	GPA	ISGS PAPI
1	3.0	ON-3.5
2	3.0	OFF
3	3.0	ON-3.5
4	3.5	ON-3.5
5	3.0	ON-4.0
6	4.0	ON-4.0
7	3.0	ON-4.5
8	4.5	ON-4.5

ONLY DIFFERENCE FLT1-2: ISGS PAPI COLOUR CODING

RED-WHITE

RED-GREEN

Test subject A

FLT 1 (R-W) *(colors too dim and hardly distinguisable)*

RUN	1	2	3	4	5	6	7	8
Q1	x	x	2	3	2	2	x	3
Q2	x	x	5	5	5	5	x	5
Q3	x	x	5	5	5	5	x	5
Q4	x	x	5	3	4	4	x	4

FLT 2 (R-G)

RUN	1	2	3	4	5	6	7	8
Q1	/	6	6	6	6	6	6	6
Q2	/	6	6	5	6	4	4	4
Q3	/	6	6	5	6	4	4	4
Q4	/	6	6	5	6	4	5	5

Test subject B

FLT 1 (R-G) *(run 6 and 8, condensation in Lamp 1, 2 and 3)* *(green not distinguishable as 'Green', only visible at short final)*

RUN	1	2	3	4	5	6	7	8
Q1	x	6	5	3	5	1	x	1
Q2	x	6	6	5	5	1	x	2
Q3	x	6	6	6	6	4	x	5
Q4	x	6	6	6	6	5	x	5

FLT 2 (R-W)

RUN	1	2	3	4	5	6	7	8
Q1	/	6	5	5	5	5	x	5
Q2	/	6	6	5	5	5	x	5
Q3	/	6	6	6	6	6	x	6
Q4	/	6	6	6	6	6	x	5

Test subject C

FLT 1 (R-W)

RUN	1	2	3	4	5	6	7	8
Q1	x	6	3	4	5	5	x	5
Q2	x	6	4	4	5	5	x	5
Q3	x	6	5	5	5	5	x	4
Q4	x	5	5	5	5	4	x	4

FLT 2 (R-G) *(more effort needed for 4 deg approach, but has nothing to do with papi)*

RUN	1	2	3	4	5	6	7	8
Q1	/	6	5	5	5	5	5	5
Q2	/	6	4	4	4	4	5	5
Q3	/	6	5	5	5	5	5	4
Q4	/	5	5	4	5	3	5	4

Test subject D

FLT 1 (R-G)

RUN	1	2	3	4	5	6	7	8
Q1	x	x	6	6	6	5	x	6
Q2	x	x	6	6	6	6	x	6
Q3	x	x	6	6	6	6	x	6
Q4	x	x	6	6	6	5	x	5

(Papi mistakenly set at 4.5 i.s.o. 3.5 deg)

FLT 2 (R-W) *(papi strength weak, visible from 800' and lower okay)*

RUN	1	2	3	4	5	6	7	8
Q1	/	6	6	5	x	6	x	x
Q2	/	6	6	6	x	6	x	x
Q3	/	6	6	6	x	6	x	x
Q4	/	6	6	6	x	6	x	x

Test subject E

FLT 1 (R-W) *(ISGS papi visibility was good, better than first flight, maybe because of clouds)*

RUN	1	2	3	4	5	6	7	8
Q1	x	6	6	6	6	6	6	6
Q2	x	6	6	6	6	6	6	6
Q3	x	6	6	6	6	6	6	6
Q4	x	6	6	6	6	6	6	6

FLT 2 (R-G)

RUN	1	2	3	4	5	6	7	8
Q1	/	6	6	4	6	4	x	4
Q2	/	6	6	6	6	6	x	6
Q3	/	6	6	6	6	5	x	5
Q4	/	6	6	6	6	6	x	5

Test subject F

FLT 1 (R-G)

RUN	1	2	3	4	5	6	7	8
Q1	x	6	6	6	6	6	x	6
Q2	x	6	6	6	6	6	x	6
Q3	x	6	6	6	6	6	x	6
Q4	x	6	6	6	6	6	x	6

FLT 2 (R-W)

RUN	1	2	3	4	5	6	7	8
Q1	/	2	2	6	6	5	x	6
Q2	/	2	6	6	6	6	x	6
Q3	/	6	6	6	6	6	x	6
Q4	/	6	6	6	6	6	x	6

Test subject G

FLT 1 (R-W)

RUN	1	2	3	4	5	6	7	8
Q1	x	6	6	4	6	6	x	6
Q2	x	6	5	4	6	6	x	6
Q3	x	6	6	6	6	6	x	6
Q4	x	6	6	5	6	6	x	6

(green lamps hard to see with green grass behind)

FLT 2 (R-G) *(ISGS papi intensity too low (visible from 600'-1000' onward) especially lamp 1)*

RUN	1	2	3	4	5	6	7	8
Q1	/	6	--	1	6	3	6	4
Q2	/	6	6	6	6	6	6	6
Q3	/	6	6	4	6	6	6	6
Q4	/	6	6	6	6	6	6	6

Test subject H

FLT 1 (R-G) *(green lights difficult to see till 2Nm)*

RUN	1	2	3	4	5	6	7	8
Q1	x	x	6	6	6	6	6	6
Q2	x	x	6	6	6	6	6	6
Q3	x	x	6	6	6	6	6	6
Q4	x	x	6	6	6	6	6	6

FLT 2 (R-W)

RUN	1	2	3	4	5	6	7	8
Q1	/	6	6	6	6	6	6	6
Q2	/	6	6	6	6	6	6	6
Q3	/	6	6	6	6	6	6	6
Q4	/	6	6	6	6	6	6	6

Table 36: Post Run Questionnaire scores per test subject

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In

Table 36, the two flights per test subject are designated FLT1 and FLT2. Note that these designations do not correlate to first and second flight. The order of the two flights was chosen based on operational circumstances, visibly to minimize the number of times the ISGS PAPI units had to be realigned.

Post Experiment Questionnaire results												
	A	B	C	D	E	F	G	H	TUI		Average	
Q1	5	4	5	6	5	6	6	6	6		5.4	
Q2	6	5	5	6	6	6	6	6	6		5.8	
Q3	6	1	6	5	5	6	4	4	5		4.7	
Q4	6	1	2	5	5	3.5	--	2	3		3.4	(3.9)
Q5	5	5	5	6	5	6	6	6	6		5.6	
Q6	5	5	5	6	5	6	6	6	6		5.6	
Q7	2	5	4	6	4	6	6	6	6		5.0	
Q8	5	5	4	6	6	6	6	6	6		5.6	

Table 37: Post Experiment Questionnaire scores per test subject

Comments by the test subjects:

1. In your opinion, the simultaneous use of two PAPIs is acceptable.
   A. Which approach/PAPI will be used must be known to the crew well in time, to allow for a timely crew briefing. No last minute changes (by ATC).
   B. Only if both PAPI's have the same intensity. The mobile PAPI was in some approaches only visible at short final and not giving [*unreadable word*] info.
   C. [*Translated from Dutch*] Agree. However, when the difference in angle is just 0.5 degrees, it can be confusing… but when the PAPI that has to be neglected is fully white/red/green, it is okay.
   D. Yes. In our setup and with our briefing + exposure no problems were encountered.
   E. It is acceptable as long as the pilot is aware of the situation before the approach is started, and the situation is studied and briefed.
   F. If properly briefed which PAPI to follow, I see no issues.
   G. ---
   H. As long as you are aware of which PAPI you need to focus, the other is not hampering at all.

2. In your opinion, the position of the second PAPI (IGS) on the opposite side of the runway when compared to the first PAPI (conventional) is acceptable.
   A. As long as the crew has had enough time to both build the mental picture.
   B. In itself, the position is ok.
   C. [*Translated from Dutch*] When you want to land on the same spot, you have to. Deviating the location from your landing point is undesirable.
   D. With proper app charts and warnings/explanations on the chart. Prior knowledge is imperative especially when transition from IMC to VMC is made at low altitude.
   E. It is the most logical position, where you expect it to be.

F. ---
G. ---
H. ---

3. In your opinion, the red-green colored PAPI for IGS is acceptable.
   A. (Based on today) I found green/red is even better distinguishable than white/red or yellow/red.
   B. I have not seen any green lights. Possible (partly) due sun, moist air (refraction) and low light intensity and green background (grass). Outer lights were weaker than inner lights.
   C. [*Translated from Dutch*] This led to no confusion whatsoever.
   D. Contrast difference between red/green lights is less than traditional white/red thus requiring a small amount of extra time & attention to interpret visual G/P. Also deviations from correct G/P are a little harder to interpret with transition red/green – green/red lights. But all well within operational confines.
   E. It is acceptable, preferably all 4 lights should become visible at the same time to prevent “guessing” of the indication.
   F. The strength of the PAPI lights could be better.
   G. The green light vs. green grass is hard to see on initial approach. On the other hand it gives a better contrast compared with the white lights on the LH PAPI.
   H. The green lights are difficult to see during daytime and when the PAPI’s are in a field. Inside 2nm it was good enough.

4. In your opinion, the red-green colored PAPI for IGS makes it better distinguishable from the conventional PAPI and is therefore preferred over a red-white colored IGS PAPI.
   A. See previous remark.
   B. See previous answer.
   C. Red white is slightly better.
   D. More than acceptable, however maybe a total different colour ref, say magenta/green even better to show that ISGS PAPI is completely different from standard PAPI.
   E. Not sure if green lights visibility is better than white lights. A different colour (green) helps awareness about which PAPI to use.
   F. Left or right PAPI is clear enough, but a second discriminator doesn’t hurt anyone.
   G. True if brightness would be better. Hard to tell from this experiment due to low intensity of test set & light nr 1 not showing green all the time.
   H. Not during daytime and when placed in a field.

5. In your opinion, the level of operational safety during an IGS approach/landing/go-around is not negatively impacted by the dual PAPI operation when compared to a conventional approach/landing/go-around with only one conventional PAPI switched on.
   A. Good briefing and mental preparation is key. However, if one PAPI could be switched off, that is even better.
   B. Not due PAPI, but steep approaches in itself are prone for hard landings (especially in dark).
   C. ---
   D. No problem during our VMC operation.
   E. As long as adequate awareness exists and as long as the situation is properly briefed.
   F. ---

G. Confusion possible when such far off from flight path that both PAPI's show full red or full white.
H. ---

6. In your opinion, the level of operational safety during a normal 3 degree GP approach/ landing/go-around is not negatively impacted by the dual PAPI operation when com-pared to a conventional approach/landing/go-around with only one conventional PAPI switched on.
   A. Same as 5.
   B. As long as you know which PAPI is valid.
   C. [*Translated from Dutch*] No, this is only a matter of getting used to.
   D. No problem during our VMC operation.
   E. Idem.
   F. Many airfields/rwy's only have 1 PAPI.
   G. ---
   H. ---

7. In your opinion, IGS operations can be managed by existing SOPs.
   A. Dual PAPI OPS does require training & change of SOP's (mandatory crew briefing item), and maybe adding a awareness call during approach.
   B. + extra briefing items.
   C. [*Translated from Dutch*] SOP's yes, but it should be trained.
   D. A briefing (on paper) would suffice and give enough knowledge and awareness.
   E. ---
   F. ---
   G. Yes, perhaps add extra call e.g. "RH PAPI".
   H. ---

8. In your opinion, you were confident in flying IGS operations.
   A. Yes, because this flight had the full awareness on the dual PAPI's and we did not come in after a red-eye oceanic night flight 😉
   B. Inside monitoring of the vertical path is crucial.
   C. [*Translated from Dutch*] But this has to do with my (lack of) experience as well.
   D. ---
   E. ---
   F. ---
   G. ---
   H. ---

9. General comments:
   A. 1) Apart from the dual PAPI use, it might be a challenge to fly a 4.5 deg glide path, especially when currency on steeper than usual approaches is low.
      2) Both PAPI's should be equal in brightness otherwise attention is drawn to the brighter one.
   B. Also the mobile PAPI red/white lights were weaker than fixed PAPI, especially the outer lights. Steep approach capability is very much aircraft dependent, you should have the option to correct when high in energy, which is a challenge for modern a/c.
   C. [*Translated from Dutch*]

See comment at point 1.
Furthermore, a clear communication in the cockpit and with ATC is required (just like the approach plates should be clear).
To my opinion, additional training is required for 4.5 deg approaches (regardless of the extra PAPI).

D. Flying VMC and beginning the instrument approach on correct G/P makes it easy to pick correct PAPI as only one confirms correct visual G/P. I wonder how this is interpreted when becoming visual later on at lower altitude during the approach in IMC, and having a deviation from (above/below) correct approach G/P? For someone doing this for the first time without adequate awareness could lead to confusion.

E. ---

F. ---

G. [*Translated from Dutch*]
1. Use of two PAPI's was easier than I thought it would be. I never felt any confusion that I was looking at the wrong PAPI. An SOP call ("RH PAPI" or "LH PAPI") is a suggestion to add at the start of the approach.
2. The use of the green PAPI I found difficult to evaluate due to the low intensity of the test set. On the one hand I think it gives a good contrast with regard to the white lights of the opposite PAPI, thereby providing an extra barrier not to take the wrong PAPI. On the other hand I found green an awkward colour as it did not contrast well against the green grass in the background. To my opinion this can be mitigated with sufficient light intensity of the PAPI.
3. When you are high with respect to both PAPI's, you see – with use of the white lights – 4 whites on both sides on both PAPI's. I can imagine, when work load is high to get back onto the glide path, that at that moment you may pick up the wrong PAPI. Colour contrast could help with this, so yet another reason to give the extra PAPI another colour than white.

H. ---

Weather conditions and runway used during the flights:

27 June 2022
Flight 1 (RWY23) – overcast conditions, with now and then some drizzle or light rain
Flight 2 (RWY23) – overcast conditions, with now and then some drizzle or light rain
Flight 3 (RWY23) – overcast conditions, with now and then some drizzle or light rain
Flight 4 (RWY23) – partly sunshine

28 June 2022
Flight 5 (RWY23) – CAVOK, clear sky
Flight 6 (RWY23) – CAVOK, clear sky
Flight 7 (RWY23) – Few, broken, sunny
Flight 8 (RWY23) – Few, broken, sunny

29 June 2022
Flight 9 (RWY05) – clear sky > cirrus > broken (alto)cumulus
Flight 10 (RWY05) – broken altocumulus > few altocumulus

30 June 2022
Flight 11 (RWY05) – Few 050, visibility >10k
Flight 12 (RWY05) – Few 050, visibility >10k
Flight TUI (RWY05) – Few 050, visibility >10k

1 July 2022
Flight 13 (RWY23) – Scattered 030, visibility >10k
Flight 14 (RWY23) – Broken 030, visibility >10k
Flight 15 (RWY23) – Few 030, visibility >10k
Flight 16 (RWY23) – Few 040, visibility >10k

D.3.2.1 EX3-OBJ-VLD-01-003-002 Results

This objective concerns the impact on crew task performance. Two criteria have been defined:

- Criteria 1 - EX3-CRT-VLD-01-003-021
  Pilot succeeds to accomplish an ISGS operation without any difficulty

PRQ results for FLT 1 AND 2 / RUN 3 thr. 8 (i.e. both red-white and red-green PAPI colour coding combined)				
Test Subject	Q1 (PAPI) Average	Q2 (confusion) Average	Q3 (safety) Average	Q4 (workload) Average
A	4.4	4.9	4.9	4.6
B	4.0	4.5	5.7	5.7
C	4.7	4.5	4.8	4.5
D	5.8	6.0	6.0	5.8
E	5.5	6.0	5.8	5.9
F	5.5	6.0	6.0	6.0
G	4.8	5.7	5.8	5.9
H	6.0	6.0	6.0	6.0
Overall average	5.1	5.4	5.6	5.5

PRQ results for red-white PAPI only / RUN 3 thr. 8				
Test Subject	Q1 (PAPI) Average	Q2 (confusion) Average	Q3 (safety) Average	Q4 (workload) Average
A	2.4*	5.0	5.0	4.0
B	5.0	5.2	6.0	5.8
C	4.4	4.6	4.8	4.6
D	5.7	6.0	6.0	6.0
E	6.0	6.0	6.0	6.0

F	5.0	6.0	6.0	6.0
G	5.6	5.4	6.0	5.8
H	6.0	6.0	6.0	6.0
Overall average	5.0 (5.4)	5.5	5.7	5.5
*) ISGS PAPI is dim and colours hard to distinguish. A not fully charged battery is believed to be the reason for this. Without this score, the overall average increases to 5.4.				

PRQ results for red-green PAPI only / RUN 3 thr. 8				
Test Subject	Q1 (PAPI) Average	Q2 (confusion) Average	Q3 (safety) Average	Q4 (workload) Average
A	6.0	4.8	4.8	5.2
B	3.0*	3.8	5.4	5.6
C	5.0	4.3	4.8	4.3
D	5.8	6.0	6.0	5.6
E	4.8	6.0	5.6	5.8
F	6.0	6.0	6.0	6.0
G	4.0	6.0	5.7	6.0
H	6.0	6.0	6.0	6.0
Overall average	5.1 (5.4)	5.4	5.5	5.6
*) ISGS PAPI is weak and only visible at short final. Condensation within the light units 1, 2 and 3 caused this problem. See also the description of flights in section D.2. Without this score, the overall average increases to 5.4.				

PEQ results				
Test Subject	Q1	Q2	Q3	Q4
A	5	6	6	6
B	4	5	1*	1*
C	5	5	6	2**
D	6	6	5	5
E	5	6	5	5
F	6	6	6	3.5
G	6	6	4	--
H	6	6	4	2**
Average	5.4	5.8	4.7 (5.3)	3.4 (3.9)
*) These scores are due to the condensation problem, see comments in previous table. Without these scores, the overall averages increase to 5.3 and 3.9 respectively. **) This test subject likes red-white colour-coding (slightly) better.				
PEQ questions 1. In your opinion, the simultaneous use of two PAPIs is acceptable. 2. In your opinion, the position of the second PAPI (IGS) on the opposite side of the runway when compared to the first PAPI (conventional) is acceptable. 3. In your opinion, the red-green colored PAPI for IGS is acceptable. 4. In your opinion, the red-green colored PAPI for IGS makes it better distinguishable from the conventional PAPI and is therefore preferred over a red-white colored IGS PAPI.				

Criteria 1 is passed as the overall average scores for all questions are (well) above 3.5. Pilots indicate they can fly ISGS approaches without any difficulty.

From the PRQ scores, there is no significant difference between the red-white and red-green colour-coding (i.e. the overall averages are basically the same/comparable). From the PEQ, it follows that there is a slight preference for the red-green colour-coding (i.e. the overall average of 3.9 is only just over the cross-over value of 3.5). Nevertheless, the preference of colour-coding is not directly related to the criteria of flying ISGS without any difficulty. Both colours provide good PRQ ratings. Therefore, again, Criteria 1 is passed.

- Criteria 2 - EX3-CRT-VLD-01-003-022
  Impact on crew cooperation and crew workload remains within acceptable limit

PRQ results for FLT 1 and 2 / RUN 2 vs. RUN 3 thr. 8 (i.e. both red-white and red-green PAPI colour coding combined)		
Test Subject	Q4 (workload) RUN 2 (Reference) Average	Q4 (workload) RUN 3 thr. 8 (ISGS) Average
A	6.0	4.6
B	6.0	5.7
C	5.0	4.5
D	6.0	5.8
E	6.0	5.9
F	6.0	6.0
G	6.0	5.9
H	6.0	6.0
Overall average	5.9	5.5

PRQ results for red-white PAPI only / RUN 2 vs. RUN 3 thr. 8		
Test Subject	Q4 (workload) RUN 2 (Reference) Average	Q4 (workload) RUN 3 thr. 8 (ISGS) Average

A	X* (6.0)	4.0
B	6.0	5.8
C	5.0	4.6
D	6.0	6.0
E	6.0	6.0
F	6.0	6.0
G	6.0	5.8
H	6.0	6.0
Overall average	5.9	5.5
*) Not flown. The score of the other flight's reference run can be taken, which is 6.0. With that score, the overall average remains 5.9.		

PRQ results for red-green PAPI only / RUN 2 vs. RUN 3 thr. 8		
Test Subject	Q4 (workload) RUN 2 (Reference) Average	Q4 (workload) RUN 3 thr. 8 (ISGS) Average
A	6.0	5.2
B	6.0	5.6
C	5.0	4.3
D	X* (6.0)	5.6
E	6.0	5.8
F	6.0	6.0
G	6.0	6.0
H	X* (6.0)	6.0

Overall average	5.8 (5.9)	5.6
*) Not flown. The score of the other flight's reference run can be taken, which is 6.0 for both. With that scores, the overall average becomes 5.9.		

Criteria 2 is passed as the average scores for all questions are well above 3.5. Pilots indicate that crew coordination and work load remain within acceptable limits. Although the workload scores decrease with respect to the reference run (irrespective of colour-coding), they all remain very acceptable. The decrease in scores seems to be a fraction less for red-green colour-coding, which means that the red-green colour-coding is very slightly preferred in terms of workload when compared to the red-white colour-coding.

D.3.2.2 EX3-OBJ-VLD-01-003-006 Results

This objective concerns the ISGS impact on safety from the crew perspective.

- Criteria 3 - EX3-CRT-VLD-01-003-061
  There is evidence that Flight Crew's subjective and positive feedback concerning the level of safety for ISGS procedures is not degraded.

PRQ results for FLT 1 and 2 / RUN 2 vs. RUN 3 thr. 8 (i.e. both red-white and red-green PAPI colour coding combined)		
Test Subject	Q3 (safety) RUN 2 (Reference) Average	Q3 (safety) RUN 3 thr. 8 (ISGS) Average
A	6.0	4.9
B	6.0	5.7
C	6.0	4.8
D	6.0	6.0
E	6.0	5.8
F	6.0	6.0
G	6.0	5.8
H	6.0	6.0

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Overall average	6.0	5.6

PRQ results for red-white PAPI only / RUN 2 vs. RUN 3 thr. 8		
Test Subject	Q3 (safety) RUN 2 (Reference) Average	Q3 (safety) RUN 3 thr. 8 (ISGS) Average
A	X* (6.0)	5.0
B	6.0	6.0
C	6.0	4.8
D	6.0	6.0
E	6.0	6.0
F	6.0	6.0
G	6.0	6.0
H	6.0	6.0
Overall average	6.0	5.7
*) Not flown. The score of the other flight's reference run can be taken, which is 6.0. With that score, the overall average remains 6.0.		

PRQ results for red-green PAPI only / RUN 2 vs. RUN 3 thr. 8		
Test Subject	Q4 (safety) RUN 2 (Reference) Average	Q4 (safety) RUN 3 thr. 8 (ISGS) Average
A	6.0	4.8
B	6.0	5.4
C	6.0	4.8

D	X* (6.0)	6.0
E	6.0	5.6
F	6.0	6.0
G	6.0	5.7
H	X* (6.0)	6.0
Overall average	6.0	5.5
*) Not flown. The score of the other flight's reference run can be taken, which is 6.0 for both. With that scores, the overall average remains 6.0.		

PEQ results						
Test Subject	Q1	Q2	Q3	Q4	Q5	Q6
A	5	6	6	6	5	5
B	4	5	1*	1*	5	5
C	5	5	6	2**	5	5
D	6	6	5	5	6	6
E	5	6	5	5	5	5
F	6	6	6	3.5	6	6
G	6	6	4	--	6	6
H	6	6	4	2**	6	6
Average	5.4	5.8	4.7 (5.3)	3.4 (3.9)	5.6	5.6
*) These scores are due to the condensation problem, see comments in previous table. Without these scores, the overall averages increase to 5.3 and 3.9 respectively.						

**) This test subject likes red-white colour-coding (slightly) better.
PEQ questions 1. In your opinion, the simultaneous use of two PAPIs is acceptable. 2. In your opinion, the position of the second PAPI (IGS) on the opposite side of the runway when compared to the first PAPI (conventional) is acceptable. 3. In your opinion, the red-green colored PAPI for IGS is acceptable. 4. In your opinion, the red-green colored PAPI for IGS makes it better distinguishable from the conventional PAPI and is therefore preferred over a red-white colored IGS PAPI. 5. In your opinion, the level of operational safety during an IGS approach/landing/go-around is not negatively impacted by the dual PAPI operation when compared to a conventional approach/landing/go-around with only one conventional PAPI switched on. 6. In your opinion, the level of operational safety during a normal 3 degree GP approach/ landing/go-around is not negatively impacted by the dual PAPI operation when com-pared to a conventional approach/landing/go-around with only one conventional PAPI switched on.

Criteria 3 is passed as the average scores for all questions are (well) above 3.5. Pilots indicated that safety is not an issue. Although the safety scores decrease with respect to the reference run (irrespective of colour-coding), they all remain very acceptable. The decrease in scores seems to be a fraction less for red-white colour-coding, which means that the red-white colour-coding is very slightly preferred in terms of safety when compared to the red-green colour-coding. For the overall average score on PEQ Q4 (3.9), see description at criteria 1.

D.3.2.3 EX3-OBJ-VLD-01-003-008 Results

This objective concerns the ISGS operational feasibility from the crew perspective.

- Criteria 4 - EX3-CRT-VLD-01-003-081
  Pilot succeeds to manage ISGS operation by applying existing SOPs.

PEQ results	
Test Subject	Q7
A	2*
B	5
C	4
D	6
E	6
F	6
G	6
H	6
Average	5.0
*) Test subject A commented: “Dual PAPI OPS does require training & change of SOP’s (mandatory crew briefing item), and maybe adding an awareness call during approach?”	
PEQ question 7. In your opinion, IGS operations can be managed by existing SOPs.	

Criteria 4 is passed as the overall average score is well above 3.5, however, the SOP may/should be slightly amended by inclusion of mandatory briefing item and possibly an awareness call as indicated by one of the test subjects.

- Criteria 5 - EX3-CRT-VLD-01-003-091
  Pilots are confident when flying an ISGS operation.

PEQ results	
Test Subject	Q8
A	5
B	5
C	4
D	6
E	6
F	6
G	6
H	6
Average	5.6
PEQ question 8. In your opinion, you were confident in flying IGS operations.	

Criteria 5 is passed as the average scores for all questions are well above 3.5. Pilots indicated that they are confident when flying ISGS operations.

D.3.3 Unexpected Behaviours/Results

See section D.2.

D.3.4 Confidence in the Demonstration Results

D.3.4.1 Level of significance/limitations of Demonstration Exercise Results

The extend of the applicability of the Exercise 04 results depends on the way this exercise has been defined (see also DEMOP section 5.4) and performed. Especially the following items are of interest:

17. *VFR/VMC*
    The test flights have all been executed under VFR/VMC during daylight.

18. *PAPI*
    A transportable ISGS PAPI has been used for the approaches (together with the existing PAPI). Overall light intensity of this transportable ISGS PAPI was slightly less, for both red-white and red-green colour-coding, than the existing PAPI, but was acceptable for the tests (see also section D.5.1) as was concluded by the pilots after the shakedown flights. During overcast situations and with fully charged batteries, the ISGS PAPI's brightness was perceived by the pilots as practically equal to the existing PAPI.

19. *ATC*
    Twente Airport is an uncontrolled airfield with no ATC. Therefore, no ATC service could be provided, preventing to assess the required ATC system support (HMI) and wake minima separation management support.

20. *Wind*
    Contrary to Exercise 01, this exercise has used both runway 05 or 23 in accordance with the wind direction during the tests.

21. *Test subjects*
    Test subjects (8 in total) have been chosen such that a wide range of pilots were represented (see Table 35). Test subject ages ranged from in-the-20 to in-the-50 with ages in-between also covered. The flight experience of the test subjects ranged from little experienced (200 hrs) up to well experienced (>17,000 hrs). Most test subjects are flying air transport type aircraft, but also test subjects flying small aircraft were included. Finally, the test subjects included both regular pilots as well as a former research pilot and an former acceptance pilot.

22. *Aircraft*
    Test flights were performed with NLR's Cessna Citation II research aircraft with the test subjects in the right hand seat. Although all test subjects are pilots, not all of them have a type rating on this aircraft. The ferry flights to Twente Airport and some first approaches (as well as thorough

briefing material) were used to familiarize the test subjects with the aircraft and with ISGS operations. The questionnaire ratings are well comparable to air transport category aircraft, as the TUI (B737) flight has shown comparable ratings.

Summarizing the above, it can be concluded that the level of significance is high and that the outcomes are very useful for future implementations of the ISGS procedures, either in daily regular operations or in further testing/demonstration activities (e.g. under IMC conditions).

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D.3.5 Quality of Demonstration Exercise Results

Questionnaires have been used to collect ratings from the test subjects on the different aspects of the ISGS procedures (see section D.3.2). The rating scale ranged from “completely disagree” (rated 1) to “Completely agree” (rated 6). The ratings have been averaged to arrive at the (un)acceptability of the particular questionnaire item (for the given runs as indicated in Table 34). Averages higher than 3.5 are thereby interpreted as “acceptable” or “met”, whereas averages below 3.5 are interpreted as “unacceptable” or “failed”. Most of the overall average scores are 5.0 or higher (especially for the Post Run Questionnaires) with the lowest overall average score at 3.9 (Post Experiment Questionnaire Q4). This score relates to the preference in colour-coding. Given that most of these average scores are well above 3.5, the ‘accuracy’ of the ratings is no factor and the interpretation as “acceptable/met” is justified. Only for the colour-coding this means that a preference is not clearly marked.

D.3.6 Significance of Demonstration Exercises Results

Statistical significance

Given the uncontrolled nature of the total set-up of the experiment – e.g. wind-, cloud-, precipitation- light- and visibility conditions were different for each flight/approach –, together with the relatively small amount of test subjects (8 in total), the experiment data have not been subjected to statistical analyses other than simple comparison of average pilot ratings to critical acceptability values or reference scenario results (in accordance with DEMOP).

Operational significance

See D.3.4.1.

D.4 Conclusions

Exercise 04 has been performed in the period 22 June – 1 July 2022. The total setup including ISGS PAPI with red-white and red-green colour coding has been checked during the shakedown period from 22-24 June 2022 and found acceptable for the start of the experiment flights, which subsequently took place from 27 June – 1 July 2022.

Exercise 04 has been performed mainly with NLR's Cessna Citation II research aircraft PH-LAB. A total of eight test subjects have flown the test matrix from the right hand seat twice, once for each colour coding. A total of 31:20 hrs have been flown. TUI FLY performed a single flight with 6 approaches on 30 June 2022 to/from Amsterdam Airport Schiphol.

Based on the pilot questionnaires and comments thereon, the following conclusions can be drawn.

The ISGS PAPI was not always as good as the existing PAPI. This was caused by lighting conditions (clear skies with full sun shine)and the contrast with the surrounding terrain (mostly grass), which at some runs caused the ISGS PAPI to be visible/usable from 2 Nm onwards. Also battery performance was suspected to influence the brightness (best on first flights of test subjects), as was lamp 3 (for white/red colour-coding), which seemed to have less red in it (and for that reason was placed in position 1, i.e. outer position, which normally shows white when on glide path). With fully charged batteries and overcast weather, the ISGS PAPI was demonstrated during the shakedown period to be only marginally less bright than the existing PAPI (see Figure 44).

Figure 44: Short final on steep approach at Twente runway 23 with ISGS red-green PAPI on right hand side.

Some runs were influenced by the above PAPI shortcomings, however, overall, the setup was acceptable for most of the runs and provided useful and sensible ratings and remarks from the test subjects.

In general, the ISGS approaches with a second active PAPI (on the opposite side of the existing PAPI) were acceptable and could be flown without any difficulty in VMC/daylight conditions. The test subjects indicated that they were confident in flying the ISGS operations. That means it could be flown safely and within acceptable crew cooperation and work load boundaries. The existing SOP's could be used, however, a crew briefing item on which PAPI to use, should be added and trained.

With regard to the preference for either the red-white or red-green colour-coding of the ISGS PAPI, it turns out hard to come to a firm conclusion based on the results/data of Exercise 04. Questionnaire scores are so close to each other, that none of the two has a clear preference. From the scores, it turns out that red-white is slightly preferred when looking at safety, but that red-green is slightly preferred when looking at work load. But again, the differences are so small as to prevent a clear-cut answer on preference. Most indicative on this matter is the overall average score for PEQ Question 4, which directly asks the preference-question, being 3.9 which is only marginally above the cross-over value of 3.5. This indecisiveness for colour-coding preference is also reflected in the comments given by the test subjects on the questionnaires. It seems that in terms of contrast red-white is slightly preferred, while in terms of awareness/mental picture red-green is slightly preferred.

D.5 Recommendations

D.5.1 Recommendations for industrialization and deployment

Based upon the input from the test subjects, the following recommendations are given:

- In follow-up projects on this matter, the additional PAPI should be totally comparable with the existing, fixed PAPI, in terms of intensity and power supply (use of batteries is not recommended).
- The ISGS procedures with two active PAPI's should also be checked in IMC and poor light/visibility conditions. More specific example for further investigation: becoming visual at low altitude in IMC approach with deviation (above/below) from correct glide path. This may lead to confusion.
- During ISGS approaches with two active PAPI's, no last minute changes (e.g. by ATC) should be made.
- Consider the use of two totally different colours for the ISGS PAPI (e.g. magenta-green) so that it even better shows that the ISGS PAPI is totally different.
- An awareness call on which PAPI to use during approach may be helpful.

D.5.2 Recommendations on regulation and standardisation initiatives

Appendix E Standardisation and Regulatory evolution needs

E.1 Introduction

E.1.1 Purpose of the DEMOR Appendix

The purpose of this Appendix document, developed by EUROCONTROL as leading the Tasks T03.04 on ISGS and T05.04 on SRAP and IGS-to-SRAP, is identify the expected standardisation and regulatory evolution needs, which will support and enable the future deployment of the operational solutions addressed and demonstrated within VLD1-W2 DREAMS project:

- PJ.02-W2-14.3 Increased Second Glide Slope (ISGS)
- PJ.02-W2-14.2 Second Runway Aiming Point (SRAP)
- PJ.02-W2-14.5 Increased Glide Slope to Second Runway Aiming Point (IGS-to-SRAP)

This document aims at presenting a summary of the activities undertaken during the project in relation to the regulatory evolution, as part of the Task T03.04 on ISGS and T05.04 on SRAP and IGS-to-SRAP. EUROCONTROL who has been leading the tasks, conducted an initial information to the regulatory bodies such as EASA & ICAO and some aviation authorities, about the solution design elements and their expected impact on the existing provisions (such as for the visual aids), as well as produced generic safety cases on the necessary adaptation of wake turbulence minima for the respective solutions.

E.1.2 Scope

This document addresses the ATM ground-based elements which are supporting the solutions and present:

- the related operational aspects (incl. procedure, minima, phraseology, visual aids, charts, flight operations), which can have an impact on existing standards and regulatory provisions.
- the initial contacts undertaken with international authorities and standardization bodies (with a focus on EASA and ICAO) for regulatory evolution of ATM
- the identification of key regulatory references which will need to be updated in view of integrating the necessary adaptation of aerodrome runway infrastructure, air traffic procedures and separation minima;
- the initial action regarding the drafting of generic safety cases by EUROCONTROL providing safety assurance about the adaptation of wake turbulence minima for ISGS, SRAP or IGS-to-SRAP.

E.1.2.1 SESAR Solutions addressed by VLD

For detailed description of the SESAR Solutions addressed by the VLD01, please refer to the section 3.2 of the VLD01 Demonstration Report Part 1.**Intended readership**

There are various Stakeholders intended as primary readers of this appendix, gathering external stakeholders and project Stakeholders:

- EASA is the European Aviation Safety Agency, and is in charge of developing Acceptable Means of Compliance to European aviation regulation
- ICAO is the International Civil Aviation Organization, which mission is to provide a harmonised regulatory framework ensuring that international civil aviation may be developed in a safe and orderly manner, as established by the Chicago Convention on International Civil Aviation.
- ICAO EUR/NAT regional office, is in charge of the complementary provisions applicable to European / North Atlantic region
- European ATM Standards Coordination Group (EASCG is entrusted by the European Commission to primarily perform standardization and regulation mapping tasks, as well as development of a European ATM Standardisation Rolling Development Plan (RDP).
- EUROCONTROL, the European Organisation for the Safety of Air Navigation, who is supporting these bodies in the development of acceptable means of compliance and guidance materials

E.1.4 Background

This document builds on the work performed in SESAR 2020 wave 1 and wave 2, as well as the work undertaken under this project VLD1-W2 DREAMS

- SESAR 2020 W1 PJ02-02 Enhanced Approach Procedures (EAP) solutions, reaching V3 ongoing maturity
  - D2.1.01 - PJ02-02 OSED-SPR-Interop Part I - Edition 00.01.00
  - D2.1.02 - PJ02-02 TS - Edition 00.01.03
  - D2.1.04 - SESAR PJ02-02 VALR - Edition 00.01.00.
- SESAR 2020 W2 PJ.02-W2-14.2 SRAP, 14.3 ISGS and 14.5 IGS-to-SRAP solutions, reaching V3 maturity

Please note that H2020 IR PJ.02-W2-14.2, 14.3 and 14.5 solutions were developed in parallel on the same solutions as VLD01 and inputs from these solutions have been used whenever possible.

The abovementioned research and development activities lead to anticipate regulatory and standardization needs.

E.2 Standardization and regulation impacts [WP5 TASK T05.04 and WP 3 TASK T03.04]

This section identifies impacts of the Increased Glide Slope (IGS), Second Runway Aiming Point (SRAP) and Increased Glide Slope to Second Runway Aiming Point (IGS-to-SRAP) on existing standards and EASA or

ICAO regulatory provisions. As explained in the demonstration plan (DEMOP), this section is intended to present design elements related to approach procedures design criteria, separation minima, phraseologies, or visual aids, which have a direct operational (including safety) impact, the related regulatory impact and evolution need as well as initial engagement with bodies and Stakeholders communication actions which were undertaken under T03.04 and T05.04 of the WP3 on ISGS and WP5 on SRAP and IGS-to-SRAP respectively.

E.2.1 Operational and regulatory impact

The ISGS, SRAP and IGS-to-SRAP solutions necessitate a number of adaptations to the ATC operations, flight operations and aerodrome infrastructure, and a harmonised set of regulatory provisions is key to ensure interoperability for flight crews and traffic.

The following operational or technical impact area are reviewed hereafter:

E.2.1.1 ATS Approach Procedure Design

E.2.1.1.1 ISGS

The ISGS is a published procedure independent of the one for the nominal threshold. The procedure publication uses standard convention, using a specific letter to the runway and procedure navigation guidance designator.
ISGS is intended to be flown down to CAT I minima, and supported by approach with vertical guidance (GLS, RNP SBAS or Baro-V-NAV).

The design of the approach procedure with steeper glide slope angle (up to 4.49deg maximum) considered standards of the ICAO Doc 8168 PANS-OPS criteria for obstacle clearance and protection of the arrival segments.

The design of the GLS or RNP (LPV, LNAV-VNAV) procedures supporting ISGS shall be compliant with ICAO Doc 8168 and shall be validated in accordance with the Instrument Flight Procedure process specified in ICAO Doc 9906.

Both the increased and nominal glide slopes remained, as per demonstrations, within the same nominal approach flight track, and provided, in case of the same threshold, additional obstacle clearance.

The Doc 8168 PANS-OPS comes also with a limitation having its origins in the ICAO Annex 10, Volume 1: "*an ILS glide path/MLS elevation angle in excess of 3.0° is used only where alternate means available to satisfy obstacle clearance requirements are impractical*". When the increase in glide slope is considered for either ISGS or IGS-to-SRAP, this limitation should be considered for removal, as the increase of the glide slope angle results from operational reasons but not the one that are obstacle-related.

Moreover, ISGS does not foresee 'steep' approaches with specific certification process, as the second glide slope angle will not exceed 4.49deg. The primary conventional approach procedure remains unchanged and always available.

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The ISGS seeks to deliver operational benefits in terms of noise reduction for part of the traffic only, while the remaining of the traffic continues to fly the conventional approach.
ICAO documents such as PANS-OPS are designed to reply to the needs of all ICAO member states as the lowest common denominator. Deviations are accepted if local conditions require and safety is maintained.

E.2.1.1.2 SRAP

The SRAP is a published procedure independent of the one for the nominal threshold. The procedure publication uses standard convention, using a specific letter to the runway and procedure navigation guidance designator.
SRAP is intended to be flown down to CAT I minima, and supported by approach with vertical guidance (GLS, RNP SBAS or Baro-V-NAV).

When designing the SRAP or IGS-to-SRAP procedures the location of the second threshold and aiming point, the current and future taxiway layout of the aerodrome shall be taken into consideration for facilitating runway vacation.

For SRAP, as the second runway threshold (aiming point) is displaced compared to the nominal one, the approach procedures remained within the zones protected by the approach procedures to the first threshold.

However, the missed approach segment of the IGS or SRAP or IGS to SRAP approach procedures need to be further considered and potentially re-designed, as the missed approach procedure shall be de-conflicted for interferences between the conventional threshold and for the SRAP threshold (e.g. a left/right turn on the SRAP while the standard MAP is straight).

From the human performance perspective, there are several recommendations, which were identified as good practices to follow:

- Naming and coding of the approach procedures, which clearly distinct the different thresholds and glide slops;
- minima published on the chart;

E.2.1.1.3 IGS-to-SRAP

The validations assumed the impact as a combination of the two preceding descriptions. Further analysis might be required for full spectrum of impacts in the case of IGS-to-SRAP.

E.2.2 Traffic separation

E.2.2.1 ISGS

Due to the vertical difference between the two final approach segment, and the mixed modes of operations, the aircraft flights positioned on the ISGS glide are flying above those flying on the conventional (e.g., ILS) glide, when both are descending.
Because vortices are sinking (and also rebounding back to about their generation altitude when generated close to the ground), the probability to encounter a wake generated by a preceding aircraft following a lower glide is lower when following an upper glide compared to that when both are following the same

glide. When significant altitude difference is observed, the flights on the upper glide are therefore better protected in terms of WVE risk and the wake separation minima can be expected to be reduced. When operating ISGS, significant glide altitude difference is only observed far away from the runway threshold. At typical altitude for wake separation design (i.e., around one generator wing span altitude and below) the glide difference is low and tends to zero at the aiming point. Because wake separation minima are applicable all along the final approach, **no separation reduction can be allowed when operating ISGS behind conventional approach**.
Conversely, **aircraft flying on a conventional 'lower' approach behind a preceding aircraft flying on the increased second glide slope upper glide are more exposed to wake vortex encounter and some wake separation need to be increased**.
When two succeeding flights are following the same approach procedure (conventional or ISGS), no glide altitude will be observed and the wake separation minima are therefore not changed.
Based on these arguments and using a relative approach with current operations as baseline, a methodology for wake separation design for ISGS operation has been established in order to maintain acceptable wake turbulence encounter risk.

The wake separation minima for ISGS operation in combination with a conventional glide are determined based on the following principle:

- For a pair for which both aircraft follow the same glide (either conventional or ISGS), the wake separation minima are not modified compared to the currently applied separation scheme.
- For a pair for which the leader aircraft follows a conventional glide and the follower follows an upper ISGS glide, the wake separation minima are not modified.
- For a pair for which the leader aircraft follows an upper ISGS glide and the follower follows a lower conventional glide, the wake separation minima are increased

Based on PJ02-02 analysis, the intersection between the median wake (i.e. p50) decay evolution corresponding to RMC=0.04 and the circulation threshold provides the wake separation time minima for each category pair. The results are provided in Table 38.

Leader/ Follower	Super	Upper Heavy	Lower Heavy	Upper Medium	Lower Medium	Light
Super	152	198	235	257	308	325
Upper Heavy		148	190	210	277	305
Lower Heavy		88	142	168	239	288
Upper Medium			74	89	128	157
Lower Medium			53	67	109	144
Light			53	67	109	144

Table 38: Wake time separation minima [s] for operation of leader on an upper glide and follower on a lower glide

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There is therefore a need to adapt the wake turbulence separation when operating with ISGS, and to take into account the position/flow procedures by the leader and follower aircraft types.

E.2.2.2 SRAP

When using SRAP or IGS-to-SRAP procedure, the aircraft flights positioned on the "upper" glide are flying above those flying on the conventional (e.g., ILS) glide, when both are descending.
Because vortices are sinking (and also rebounding back to about their generation altitude when generated close to the ground), the probability to encounter a wake generated by a preceding aircraft following the conventional approach is lower when following the Enhanced Approach Procedure compared to that when following the conventional approach procedure. They are therefore **better protected in terms of WVE risk and the wake separation minima can be expected to be reduced**.
Conversely, aircraft flying on the conventional approach behind a preceding aircraft flying on the enhanced approach upper glide are more exposed to wake vortex encounter and some wake separation need to be increased.
W**hen two succeeding flights are following the same approach procedure (conventional or SRAP/IGS-to-SRAP), no glide altitude will be observed and the wake separation minima are therefore not changed.**
The wake vortex encounter risk related to the EAP concepts therefore depends on the difference in altitude of the glides of the two approach procedures. This altitude difference also depends on the uncertainty in aircraft vertical positioning when flying on the conventional (e.g., where ILS is used for navigation and surveillance) or on an EAP glide (where ILS, GBAS, SBAS, or RNAV is used for navigation and surveillance).
Based on these arguments and using a relative approach with current operations as baseline, a methodology for wake separation design for each EAP operation is here established.
Because the wake separation minimum reduction/increase related to a given EAP concept directly depends on the glide altitude difference and because that glide altitude difference can be obtained using different parameters of the EAP concepts, all analyses are performed depending on the mean altitude difference between the two considered glides at a certain position. For instance, a same altitude difference can be obtained with SRAP (playing with the aiming point displacement) or IGS-to-SRAP (playing with both the aiming point displacement and the increased glide slope).
The reasoning behind the glide altitude difference (i.e., the investigated EAP concept and parameter values) is then no required and not mentioned in this report. However, the navigation uncertainty related to the used navigation system (GBAS, SBAS or RNAV) has an impact on the wake risk.

The wake separation design will hence be provided by altitude difference and by navigation system.
determined based on the following principle:

- For a pair for which both aircraft follow the same glide (either conventional or EAP), the wake separation minima are not modified compared to the currently applied separation scheme.
- For a pair for which the leader aircraft follows an upper EAP glide and the follower follows a lower glide, the wake separation minima are increased
- For a pair for which the leader aircraft follows a conventional glide and the follower follows an upper glide, the wake separation minima are reduced depending on the glide altitude difference at one wingspan altitude of the conventional glide.

Given the influence of multiple factors (distance between the aiming points, vertical guidance navigation accuracy, final approach glide slope angle), a separation computation tool has been developed by

EUROCONTROL to calculate the separation delta times, to be increased or reduced depending on the leader-follower cases, and their related wake turbulence categories.

This tool is available as part of the PJ.02

There is therefore a need to adapt the wake turbulence separation when operating with SRAP or IGS-to-SRAP, and to take into account the position/flow procedures by the leader and follower aircraft types.

E.2.3 ATC procedure and HMI support

The approach Controller remains responsible of assigning the traffic onto an ISGS or SRAP procedure, managing the adapted (wake turbulence) separation, trajectory in case of radar vectoring, and the ATC speed instructions. The need for displaying to the Controllers the interception points respective for each procedure shall be evaluated as part of the local deployment, such that the visual references are operationally relevant and unambiguously presented without e.g. cluttering on the controller air surveillance display.

The ANSP shall inform Airspace Users (e.g. via AIC) about the availability of SRAP, IGS or IGS-to-SRAP procedures, highlighting their differences from the conventional approaches (including applicable separation minima, location of the second aiming point, landing distance available etc.). Flight Crew shall be informed about discrepancies from visual aid references when not specifically adapted to increased glideslope procedures.

The ATCO local Standard Operation Manuals or Procedure shall include following elements:

1. Times of activity or inactivity, which are considering the following conditions for application:
   - Limitations related to weather, which are considering the need to maintain Visual meteorological conditions;
   - Availability of guidance and navigation means;
   - Targeted type of traffic
   - ATC training and competences.

2. Separation minima for each combination (SRAP or IGS-to-SRAP Approaches) of published approach procedure with different glideslopes, taking into account the associated navigation means and corresponding vertical accuracy around the published profile, for
   - Leader and follower on same glideslope;
   - Leader upper glide - follower lower glide;
   - Leader lower glide - follower upper glide.

E.2.4 Phraseology

E.2.4.1 ISGS

Due to the 'mixed' mode of operations, where some traffic will be assigned to the ISGS while other may remain on the conventional approach, in order to provide the Flight Crew with an information about the relative position of the preceeding traffic on final, it is foreseen that the Tower Controller will provide a traffic information at first contact with Tower.

This will be based on standard phraseology for the traffic information sequence, adding an indication if the preceeding traffic is on the 'Lower Glide' or 'Upper Glide'.

For example:

TWR Unit (at first contact*): Eurobird 321, you are number 2, preceding traffic is an Airbus 350 on the Lower glide*

E.2.4.2 SRAP

The concluded validation exercises and demonstration exercises propose to add to the approach and landing clearances an additional element, clearly indicating the runway threshold the crew would be aiming. Specifically, the validation exercises results propose to add "first threshold" or "second threshold" phrases to the approach and landing clearances.
An equivalent information could be provided through association of the lower glide slope (traffic information) with first threshold (landing clearance) or upper with second; lower/upper vs first/second allow crew to clearly distinguish between a traffic information and a landing clearance.
Both proposals will increase situational awareness and support disambiguation.

For example:

At first contact with Tower:

Eurobird 321, you are number 2, preceding traffic is an Airbus 350 on the Lower glide

At landing clearance by Tower

Eurobird 321, wind xx deg / yy knots, runway XX, first/second threshold, cleared to land

Similarly, an additional information presenting PAPI location could be given in the landing clearance by mentioning the side of the runway on which the relevant PAPI is located (e.g. "first threshold, PAPI left" and "second threshold, PAPI right"). However this was not part of the evaluation so far.

E.2.4.3 IGS-to-SRAP

The impact will be the same as for SRAP.

E.2.5 Aerodrome Visual Aids

E.2.5.1 ISGS

E.2.5.1.1 Second PAPI

For ISGS, based on the PJ02-W2 validation results, a second PAPI is deemed necessary and proposed to be located on the opposite side of the one for the conventional threshold.

The ISGS Ciampino trial, with SBAS LPV procedures, and either 0.4deg or 0.9deg increase (3.9deg and 4.4deg, above the 3.5deg baseline) was however successfully conducted without an additional PAPI. However this was conducted in test conditions with fully briefed (test) Pilots, and the conclusions on the subject might therefore not necessarily be generalised and valid for larger group of commercial air traffic/Pilots. An alternative to the second PAPI for part of the traffic, may also rely on the use of operational credit thanks to on-board cockpit guidance technologies, which can be available on some traffic / aircraft models and operator fleet.

In case of dual PAPI set-up, both PAPI needs to operate at equal brightness.

The situational awareness could be further reinforced if PAPI location could be standardized across airports (e.g. nominal 3.0deg glide slope PAPI always on the left, second PAPI always on the right)

Two options are left for the light colours: standard with red and white, or an alternative with red and green.
In both flight simulation exercise and flight trials demonstration exercise made at Twente under T03.06, the Crew expressed a slight preference from a mental workload perspective for the alternative red/green colour scheme, provided that both colours and both PAPI will be operating at equal brightness.

For the design specification, please refer to the ISGS Twente Demo Exercise report section and PJ02-W2-14.3 ISGS VALR

E.2.5.2 SRAP

E.2.5.2.1 Runway Marking

The SRAP markings are consistent with ICAO Annex 14 guidelines (see DEMOP section 5.1.4.2).

As commented by EASA: as European airport have airlines/Pilots from all over the world, the design should remain compliant with ICAO standards

Discussion: reduce the number of piano keys for the second threshold (it is the aiming point marking which is more important).

For the design specification, please refer to the SRAP Twente Demo Exercise report section, and PJ02-W2-14.2 SRAP VALR

E.2.5.2.2 Runway threshold identification

The SRAP relies on a specific (second) threshold identification, with a number increment from the first (conventional) threshold.

For the design specification, please refer to the SRAP Twente Demo Exercise report section, and PJ02-W2-14.2 SRAP VALR

E.2.5.2.3 PAPI

For SRAP, a second PAPI is proposed to be located on the opposite side of the one for the conventional threshold.

Both PAPI needs to operate at equal brightness.

The situational awareness could be further reinforced if PAPI location could be standardized across airports (e.g. first threshold PAPI always on the left, second threshold PAPI always on the right.

For the design specification, please refer to the SRAP Twente Demo Exercise report section, and PJ02-W2-14.2 VALR

E.2.5.2.4 Dual Approach Lighting System (ALS)

The SRAP Approach Lighting system, down to CAT I minima are consistent with ICAO Annex 14 provisions applicable for the conventional threshold.

For the design specification, please refer to the PJ02-W2-14.2 SRAP VALR

E.2.5.2.5 Runway conditions using Global Reporting Format (GRF)

Additional markings/lights on the existing runway, negatively affects the runway surface friction specifications (especially in wet conditions).

Dual thresholds also has implications for GRF reporting on contaminated runways

Question: do we need double GRF reporting with SRAP (one per runway threshold)

E.2.6 Flight management

E.2.6.1 ISGS

The impact depends on the type of aircraft and the ISGS slope

- For the business jet aircraft such as Dassault Falcon, which participated to the ISGS Ciampino trial, operations with slope up to 4.49deg are feasible based on current certification basis
- For the regional jet aircraft such as the Embraer 170, which participated to the ISGS Ciampino trial, and for slope around 4.0deg or more up to 4.49deg, energy management and flare assistance to Crews were evaluated
- For the large single-aisle passenger aircraft such as Boeing 737 Max 8 and Airbus 319, which participated to the ISGS or IGS-to-SRAP Twente trial, operations with slope up to 3.5deg were conducted without energy management and flare assistance functions

  For operators that would like to use a flare assistance or a EM assistance for ISGS, flare assistance or EM assistance can already be certified following current certification basis.

- During presentations of the ISGS solution & VLD1 activities, Euro Cockpit Association (ECA) raised that 4.0 and 4.49 deg approaches may require careful energy management for larger aircraft
- IFALPA highlighted needs for robust safety considerations/mitigations regarding slope above 3.5deg for ISGS, and avoid in this case Glide Slope interception from above, as well as operations under tailwind conditions

E.2.6.2 SRAP

- IFALPA highlight needs for robust safety considerations/mitigations regarding reduced LDA (tailwind, wet runways,..) for SRAP, and slope above 3.5deg for ISGS, and consider risks with tailwind conditions
- As a part of pre-implementation assessment, it could be required to check if the shorter LDA related to SRAP permits operations on the wet RWY for the applicable aircraft categories.

E.2.7 Aeronautical information

E.2.7.1 ISGS

The ISGS approach chart shall be specific to one final approach path and supporting navigation guidance mean.

The position and colour of the associated PAPI shall be indicated on the chart
A caution box (red square) will indicate the presence of dual PAPI and to disregards the one which is wrongly set.
For example: *Caution two PAPI, disregard the left-hand PAPI set of 3.0deg*, or *Caution two PAPI, disregard the right-hand PAPI set of 3.x deg (on the chart for the conventional approach)*

For the design specification, please refer to the ISGS Twente Demo Exercise report section and PJ02-W2-14.3 ISGS VALR

E.2.7.2 SRAP

The SRAP or IGS-to-SRAP approach chart shall be specific to one final approach path (i.e. touchdown aiming point) and supporting navigation guidance mean.

The position and colour of the associated PAPI shall be indicated on the chart
A caution box (red square) will indicate the presence of dual threshold and the distance between the two. For example: *Caution two threshold, distance 1100m*

For the design specification, please refer to the SRAP Twente Demo Exercise report section, and PJ02-W2-14.2 VALR

E.3 Regulatory references impact

On the basis of the preceding review of the operational impact, the following regulatory reference are identified as being subject to evolution:

For Air Traffic Management aspects (Wake minima, phraseology, Procedure and Aeronautical Information)

- **EU Reg 2017/373 Part-ATS**
- **EU Reg 2017/373 Part-AIS**
- ICAO **Doc 4444** PANS-ATM

For aerodrome aspects (Visual Aids)

- **EU Reg 139/2014**
- **ICAO Annex 14**

For flight ops aspects (Visual Aids)

- **EASA Reg 923/2012 SERA**
- **EASA All Weather Operations (AWO)**
- **ICAO Doc 8168 PANS-OPS**

E.4 Identify REG evolution need

Based on the operational / regulatory impact, and related references, the following regulatory evolution needs are identified, with the corresponding international regulatory bodies

E.4.1 EASA Part-ATS and ICAO PANS-ATM

- Development of corresponding AMC into the Part-ATS of regulation EC. 2017/373 Common requirements for Air Traffic Management / Air Navigation Service
  - for wake turbulence minima (ref. Requirement ATS.TR.220 Application of wake turbulence separation): based on generic safety cases on the evolution of wake turbulence separation minima associated to Enhanced Approach Operations (EAO), to be submitted for EASA regulatory approval
  - for ATC procedure & phraseology
- Proposal for Amendment of the ICAO Document 4444 PANS-ATM
  - with the EASA AMC on wake turbulence separation minima
  - provisions for ATC procedure & phraseology

E.4.2 EASA Reg 139/2014 and ICAO Annex 14

- Development of requirements for visual aids supporting EAO and integration into EC. 139/2014 on Aerodromes
- Proposal to Amendment ICAO Annex 14 with provisions for visual aids, supporting EAO based on EASA requirements

E.5 Engagement with REG bodies

Along the VLD1-W2 DREAMS project, EUROCONTROL has initiated a number of

E.5.1 ICAO

ADOP/eVAWG

A presentation has been made on 2nd September 2022 to the ICAO Visual Aid Working Group (VAWG) through an online meeting, about the ISGS, SRAP and ISG-to-SRAP solution development under PJ02, the resulting proposed design from the validation exercises under PJ02-02 and the VLD1-W2 DREAMS demonstration plans.

Some concerns were expressed by the UK CAA and IFALPA, to ensure that the steeper approach profiles will remain compatible with aircraft energy management capabilities and FMS capabilities.

Questions were also raised about the relationship with the former HALS-DTOP (High Approach Landing System – Dual Threshold Operations) project and trial which took place in the early 2000s at Frankfurt, that lessons learned have been taken into account and the solutions to overcome the challenges which eventually prevented to continue to full operational use.

It was answered that the HALS-DTOP was involving parallel approaches to Closely Spaced runway, unlike SRAP on single runway, however the principle of reducing the wake separation as the Light and Medium wake category aircraft fly on the 'upper' glideslope and the larger Heavy aircraft remain on the 'lower' glideslope is similar as for SRAP.

It is understood that a key challenge was on the ATC side regarding the ability to manage the more complex wake separation scheme. As part of the SRAP solution, it is intended to take advantage of an adaption of the ORD tool which directly provide the Approach and Tower ATCOs with an visual indication of the applicable separation minimum to be applied. The PJ02-02 validation exercise with ATC real-time simulation has confirmed the usability and acceptability of the ORD tool to assist in the SRAP traffic separation management

ICAO EUR/NAT Performance-Based Navigation Coordination Task Force (PBNC TF)

A presentation was delivered to the ICAO PBNC-TF session on 15th December 2022, focusing on the SRAP & IGS-to-SRAP Twente flight trial. Similar concerns as previously were expressed to ensure that the steeper approach profiles will remain compatible with aircraft energy management capabilities, and similar questions were raised about the relationship with the former HALS-DTOP.

ICAO EUR/NAT Regional Working Group for Airport Operations (RWGAO)

A presentation on the ISGS, SRAP and IGS-to-SRAP solution was delivered to the newly established ICAO RWGAO on 28th January 2022, gathering representatives from ECAC States, as well as from EASA and EUROCONTROL.

The following questions / observations were raised by State CAAs from the audience:

- Have the human factors been taken into account during the elaboration of the assessment of this projects?
    - Answer from EUROCONTROL: Yes, HF have been addressed as part of PJ02 and VLD1 projects, with detailed HP Assessment report as Annex to the OSED of the respective solution, as well as HP objectives under the PJ02-02/PJ02-W2 validation and VLD1-W2 demonstration exercises

- Thank you for the interesting presentation. Will duplication of visual aids confuse the pilots?
    - Answer from EUROCONTROL: The duplication of runway marking, PAPI, and Approach Lighting system has been the subject of dedicated and extensive validation with full flight cockpit simulation involving type-rated Airline Pilots, with evaluation of different design options, and concluding on the acceptability of the proposed design

- In order to avoid confusion and differentiate between the two thresholds, why not adding a letter to the runway identification marks for example "Z" like the IFP for the same QFU?
    - Answer from EUROCONTROL: adding a letter is already used to differentiate procedure with different slope angle, the SRAP validation has concluded that using a Runway number increment looks the better option, although not optimal

- Does adding additional markings/lights on the existing runway, negatively affects the runway surface friction specifications (especially in wet conditions).

- Answer from EUROCONTROL: this has not yet been assessed and will need to be further subject to live trials

- Dual thresholds also has implications for GRF reporting on contaminated runways.
- What is the impact on GRF? Do we need double GRF reporting with SRAP (one per runway e.g THR 05/06)
  - Answer from EUROCONTROL: the impact on GRF has not yet been assessed and will need to be further evaluated in next maturity phased including live trials

- What is the impact on OLS surfaces when a runway has two thresholds?
  - Answer from EUROCONTROL: this has not yet been assessed and will need to be further evaluated in next maturity phased including live trials

- ICAO: No update of ICAO EUR Doc 7030 (Reg supp) should be envisaged as the solutions should primarily align with ICAO Annexes/ PANS
  - Answer from EUROCONTROL: Ok, noted.

- SRAP difference from HALS/DTOP?
  - see previous answer about difference between HALS-DTOP and SRAP

- As European airports have airlines/Pilots from all over the world, we should remain compliant with ICAO standards
  - Answer from EUROCONTROL: this is the design philosophy followed for SRAP ALS, PAPI and marking design with duplication of standard provision)

- Both ISGS and SRAP solutions would needs robust operational safety considerations/mitigations regarding reduced landing distance and some operational conditions, such as tailwind or wet runways for SRAP, and slope above 3.5deg for ISGS
  - Answer from EUROCONTROL: both SRAP & ISGS are published procedures, SRAP can be seen as operating with a displaced threshold, while only selected traffic will be proposed to fly the ISGS (there are already steeper approach profiles published and flown today across Europe), following coordination with the operators.

E.5.2 EASA

Presentation at PJ02-W2- 14.2/14.3/14.5 flight simulation open day, which took place on 1st June 2022 at Lufthansa Aviation Training in Frankfurt.

Similar to before, questions were raised about

- What is the impact on OLS surfaces when a runway has two thresholds ?
- What is the impact on GRF?
- What is the impact on the published missed approach procedures (MAP), in case of two thresholds, each with a different MAP ?

These topics are still subject to further evaluation in next maturity phase including live trials from V4/TRL7 onwards.

E.6 Initiate STD/REG development

E.6.1 EUROCONTROL generic safety case on Wake minima

Regarding the adaptation of wake turbulence minima for ISGS and for SRAP/IGS-to-SRAP, EUROCONTROL has developed two safety cases reports:

- **Wake Turbulence Separation Minima for Increased Second Glide Slope (ISGS), EUROCONTROL Safety Case report**

- **Wake Turbulence Separation Minima for Second Runway Aiming Point (SRAP), Increased Glide Slope to Second Runway Aiming Point (IGS-to-SRAP) and Closely Spaced Parallel Runway with staggered thresholds (CSPR-ST), EUROCONTROL Safety Case report**

It is the intention to submit these safety case reports to EASA for review and recommendations, and in support of drafting future AMC to EU Reg. 2017/373 Part-ATS.
A review and position by EASA is then expected to facilitate the use of the adapted wake minima during future live operational trials.

E.6.2 Visual Aids design

For ISGS, the dual PAPI system has been evaluated as part of the ISGS Twente demo exercise (T03.06). The set-up design characteristics and evaluation results can be found in the DEMOR and, and, together with the solution PJ.02-W2-14.3 OSED & TS requirements, are the basis for further live operational trials, with expected related development of design specifications as future acceptable for compliance under EASA (Reg 139/2014) and/or ICAO (Annex 14) framework, possibly within awarded HERON project to SESAR3 Digital Sky Demonstrator (DSD).

For SRAP and IGS-to-SRAP, the design of the runway marking, and second PAPI has been evaluated as part of the SRAP / IGS-to-SRAP Twente demo exercise (T05.02). The set-up design characteristics and evaluation results – noting the minimum distance between the two threshold set to 1100m – can be found in the DEMOR and, together with the solutions PJ.02-W2-14.2 / 14.5 OSED & TS requirements, are the basis for further live operational trials, including the evaluation of dual Approach Lighting System (ALS), with expected related development of design specifications as future acceptable for compliance under EASA (Reg. EU 139/2014) and/or ICAO (Annex 14) framework.

Appendix F Final HONEYWELL Energy Management Prototype Testing Report

F.1 Description of the final Honeywell exercise

Final Honeywell energy management prototype testing report is considered as integral part of SESAR VLD1 DREAMS Demo Report (D1.4) agreed to be added after DEMOR submission. Details on energy management function/prototype are included directly in original DEMOR itself.

F.1.1 Exercise description and scope

In April 2022 Honeywell supported VLD1 Dreams ISGS demonstration in Ciampino by flying 23 approaches where, beside other, Honeywell collected in-flight data and pilot's feedback of the Energy Management (EM) prototype. Based on the results included in Appendix C it was decided to further improve EM prototype and conduct another Honeywell internal flight test to validate those improvements.

The expected outcome of this final flight test was to evaluate and gather the data for EM functionality in realistic environment. The data shall be used in next steps towards final development and certification.

In addition, the feedback from regulatory authority (FAA) was gathered during the demonstration at Grant County International Airport (KMWH) airport.

Summarized, the purpose of the internal Energy Management 2022 Flight Test #2 is:

1. Improved EM algorithms and HMI in-flight validation and data collection
2. Perform a validation with subject pilots and collect feedback

The summary of flight test objectives is provided in Table 39.

F.1.2 Summary of Honeywell final EM flight demo objectives and success criteria

Objective/Sub-objective		DESCRIPTION	Success criteria
#	Name		
Objective 1 - On path / On Speed			
EM1	On FMS path / On FMS Speed	Aircraft performs standard approach on FMS speed and vertical profile. Crew follows EM cues as needed.	• Stable at 1000ft AGL latest. • Algorithm and HMI outputs behaviour is stable. • Intended function criteria are met.
Objective 2 - On path / Above speed			
EM2A	On FMS vertical profile / Clean config until final	Aircraft performs standard arrival / approach on FMS vertical and speed profile. At base turn the speed will be reduced to clean speed in MAN speed mode. When at predefined DTD and established on final track, deceleration to Vapp is initiated by setting the FMS speeds and using appropriate configuration changes.	• Stable at 1000ft AGL latest. • Algorithm and HMI outputs behaviour is stable. • Intended function criteria are met.
EM2B	On FMS vertical profile / Faster at Approach Deceleration Point	Aircraft performs standard approach on FMS vertical profile but in MAN speed mode. The selected speed is above the predefined descent speed. At Approach deceleration point, the deceleration to Vapp is initiated.	• Stable at 1000ft AGL latest. • Algorithm and HMI outputs behaviour is stable. • Intended function criteria are met.
Objective 3 - Above path / On speed			
EM3A	Above path / On speed Stable at the gate	Aircraft performs standard approach on FMS speed profile but above FMS vertical profile. At given FPL point, the airplane starts descent to the original vertical profile.	• Stable at 1000ft AGL latest. • Algorithm and HMI outputs behaviour is stable. • Intended function criteria are met.
EM3B	Above path / On speed	Aircraft performs standard approach on FMS speed profile but above FMS vertical profile. When EM algorithm indicates	• Unstable at 1000ft AGL latest.

	Unstable at the gate	unstable at the gate, the airplane starts descent to the original vertical profile.	• Algorithm and HMI outputs behaviour is stable. • Intended function criteria are met.
Objective 4 - Above path / Above speed			
EM4A	Above path / Clean config until final	Aircraft performs standard approach on FMS speed profile but above FMS vertical profile. At given FPL point, the airplane starts descent to the original vertical profile. At base turn the speed will be reduced to clean speed in MAN speed mode. When at predefined DTD and established on final track, deceleration to Vapp is initiated by setting the FMS speeds.	• Stable at 1000ft AGL latest. • Algorithm and HMI outputs behaviour is stable. • Intended function criteria are met.
EM4B	Above path / Faster at Approach Deceleration Point	Aircraft performs standard approach / arrival but above the FSM vertical profile and faster than FMS speed in MAN speed mode. At given FPL point, the airplane starts descent to the original vertical profile keeping the selected speed. At Approach deceleration point, the deceleration to Vapp is initiated.	• Stable at 1000ft AGL latest. • Algorithm and HMI outputs behaviour is stable. • Intended function criteria are met.
Objective 5 – Changes to FMS flight plan			
EM5	Changes to FMS flight plan	At predefined point modify the FMS flight plan (direct to WPT, shortcut in FPL, procedure change, RWY change) and perform the changes using CR-LNAV functionality.	• Stable at 1000ft AGL latest. • Algorithm and HMI outputs behaviour is stable. • Intended function criteria are met.

Table 39 Demonstration objectives - Honeywell US flight demo November 2022

F.1.3 Summary of validation exercise demonstration scenarios

For purpose of the test there has been assembled a test matrix consisting of different test conditions (variables) for each objective and system under test. In addition to variables presented in the test matrix above, the different take-off weight of the airplane needs to be taken in consideration (light / heavy). The test matrices consist of following test conditions:

1. Approach RWY – indicates which runway will host the test approach at given airport.
2. Approach type – indicates what approach type will be executed. The approaches varied in glideslope angle (3-4°), FAF distance from the runway threshold and transition waypoint.
3. Ready conditions:
    a. Waypoint – indicates what the start point of the flight plan will be utilized
    b. Altitude – indicates what altitude is required at the start point of the flight plan
    c. Speed – indicates what speed / speed mode is required at the start point of the flight plan
4. On condition:
    a. Relative position to FMS path – indicates whether the vertical position of the aircraft on or above FMS vertical profile.
    b. WHEN – indicates what position or condition starts the test.

Test scenarios were conducted using the custom procedures developed for Winslow airport (KINW) and published approaches for the Moses Lake - Grant County International Airport (KMWH). The flight test profiles chart depiction is presented on the figures below.

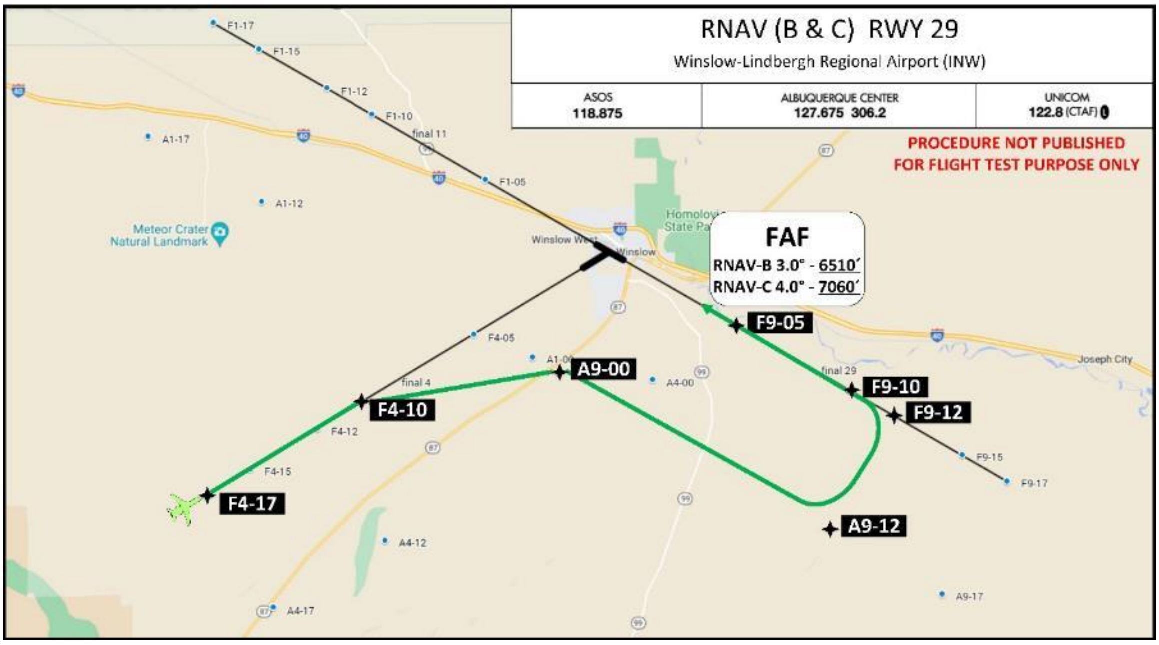


Figure 45 KINW RWY29 RNAV-B & C flight test profile

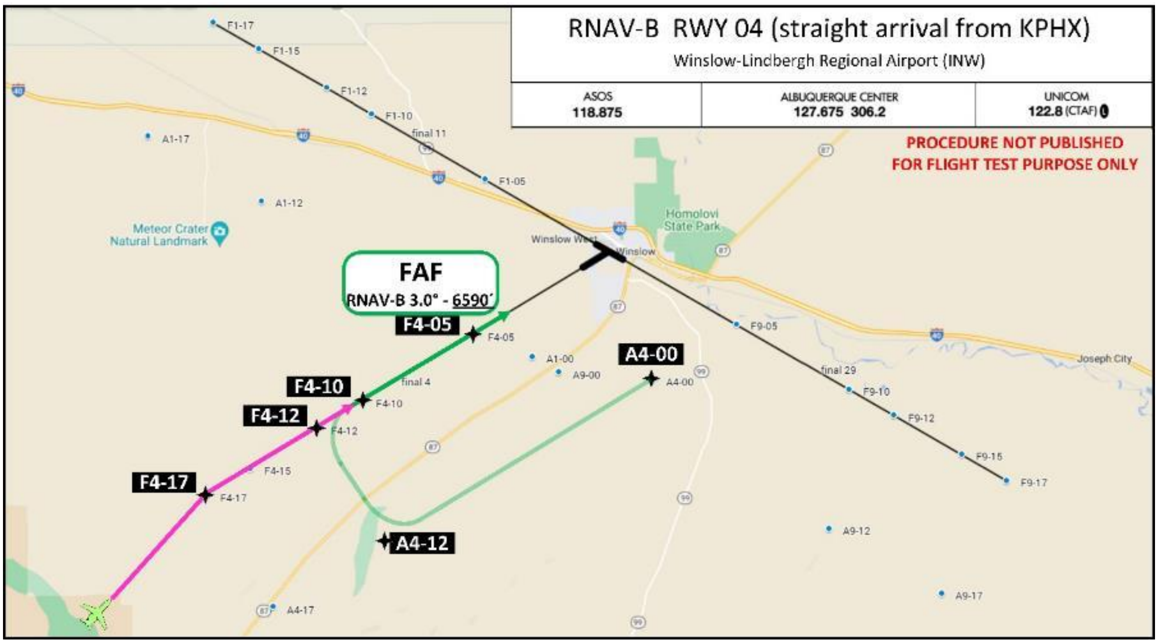


Figure 46 KINW RWY04 RNAV-B flight test profile

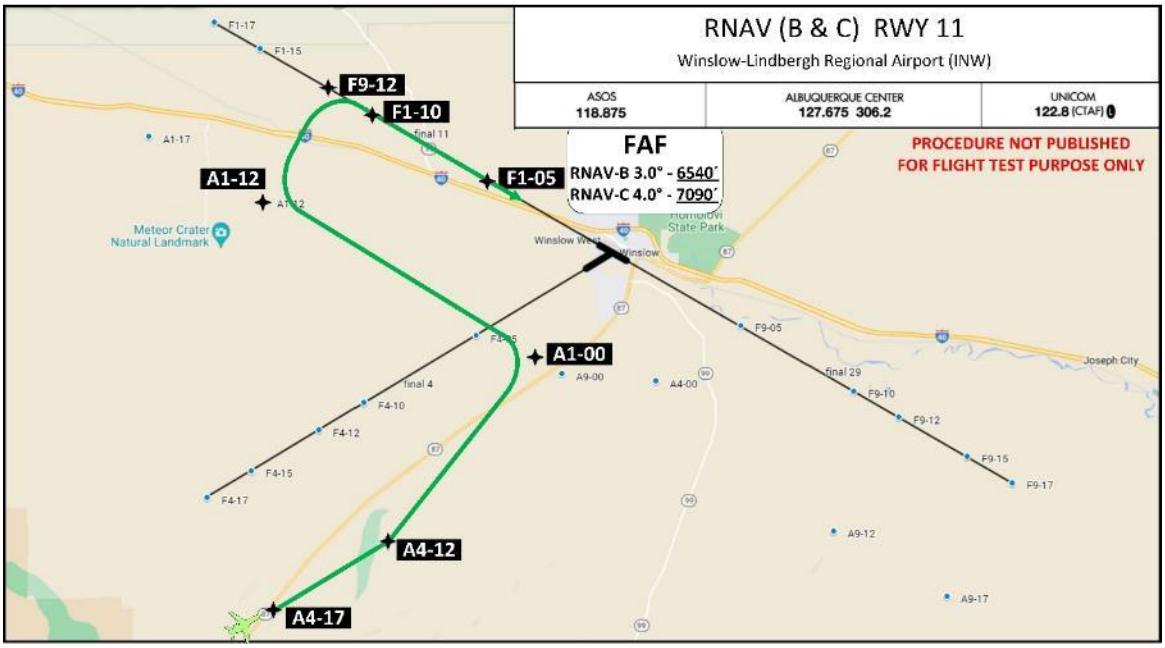


Figure 47 KINW RWY11 RNAV-B & C flight test profile

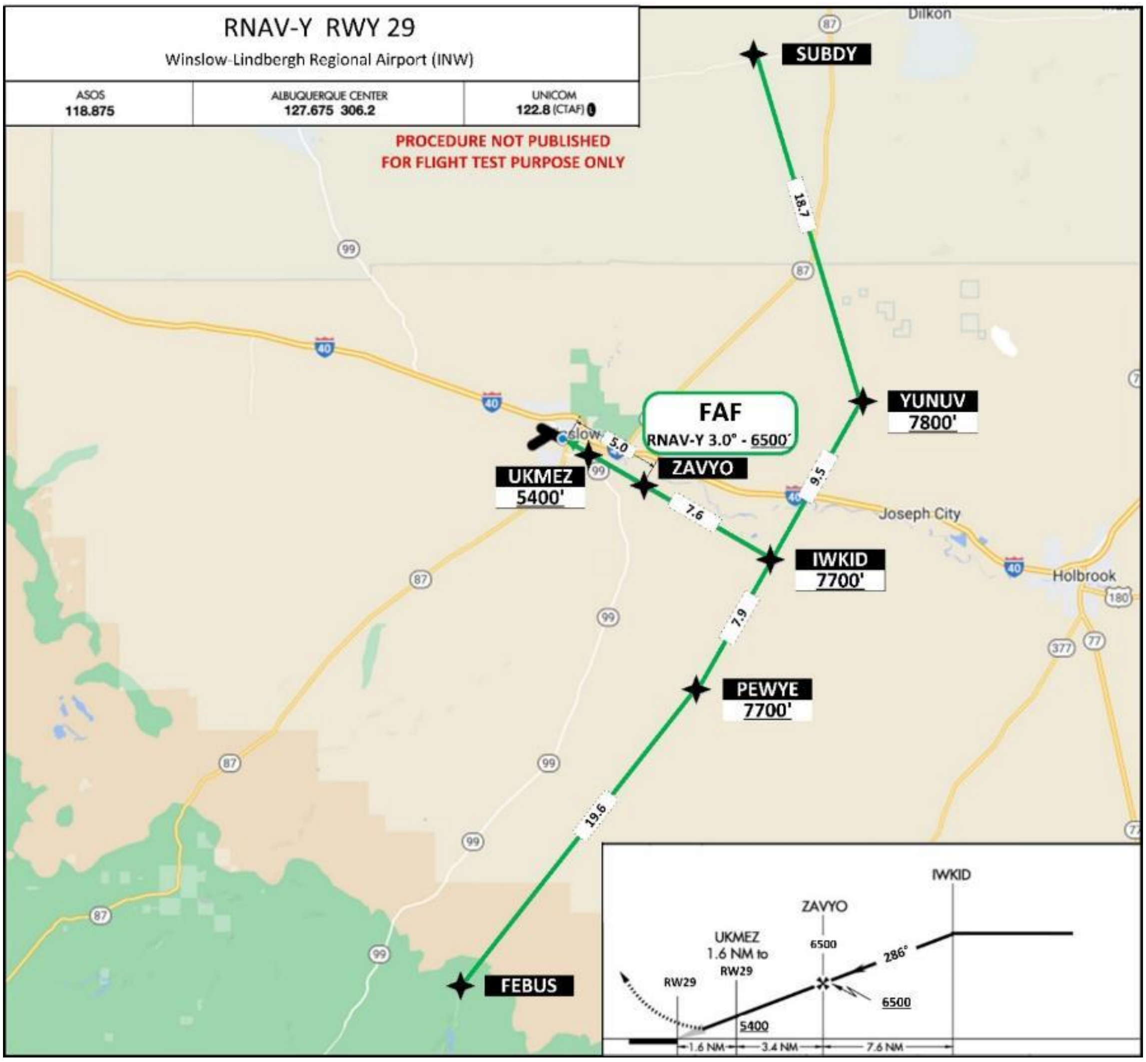


Figure 48 KINW RWY29 RNAV-Y flight test profile

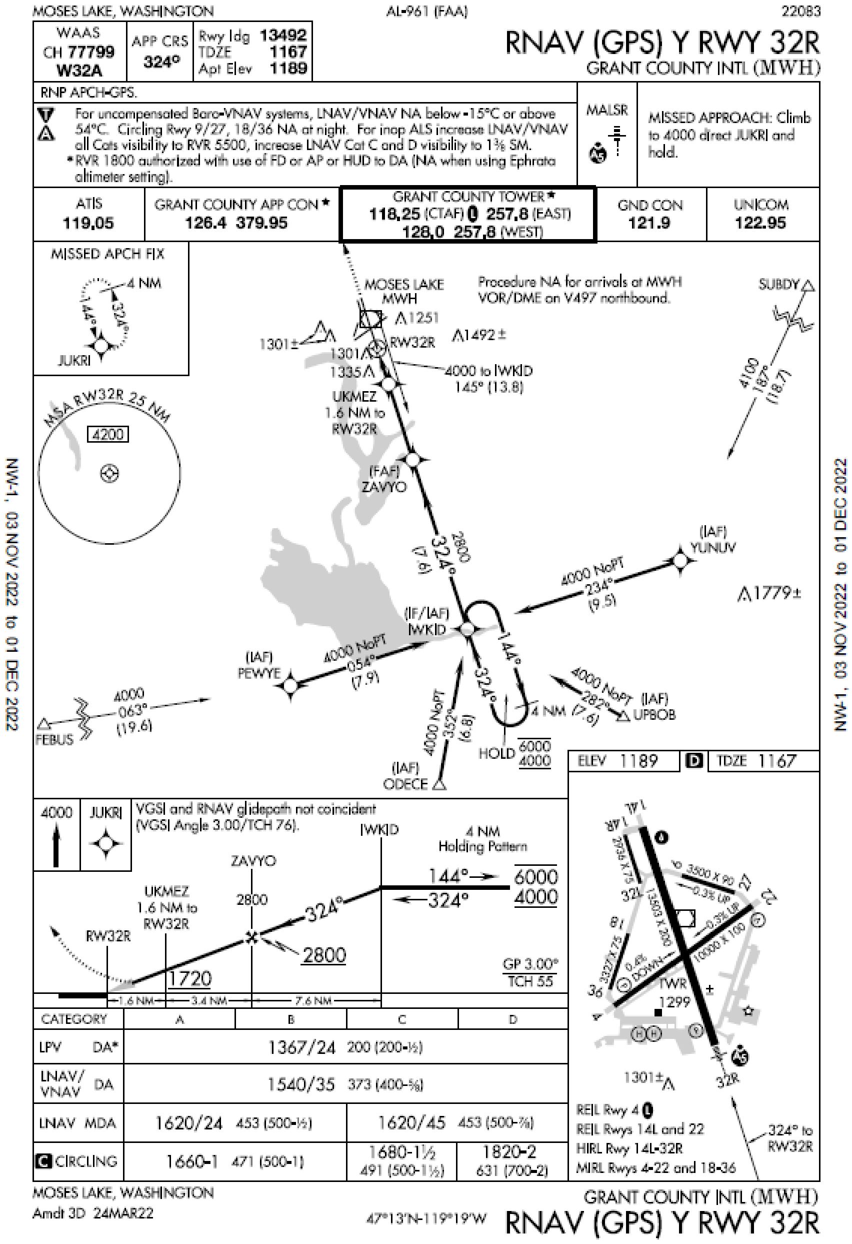


Figure 49 KMWH RWY32R RNAV-Y flight test profile (transitions FEBUS and SUBDY)

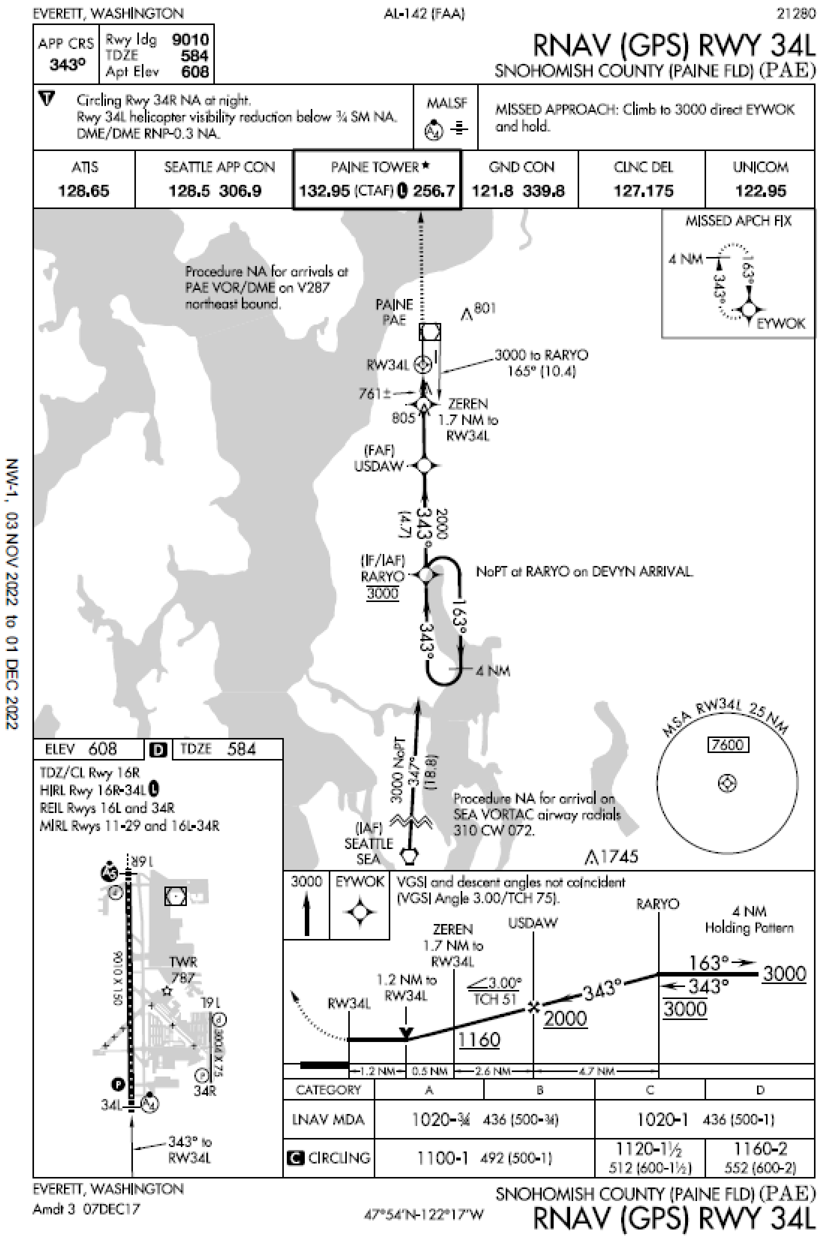


Figure 50 KPAE RWY34L RNAV (GPS) flight test profile (transitions RARYO)

F.2 Deviations from the planned activities

No deviations from planned activities were applied during this flight test.

F.3 Demonstration exercise results

F.3.1 Summary of demonstration exercise results

The aircraft selected for this flight campaign is the Honeywell's Embraer regional jet ERJ 170-100LR (E-Jet) with tail number N170EH based at Phoenix Sky Harbor (KPHX). The E-Jet is equipped with Honeywell's digital backplane bus named ASCB, allowing direct access to aircraft system and state parameters such as GPS latitude and longitude positions, air data information, EGPWS geometric altitude, attitude, on-board inertial sensor data, etc.

The campaign was held between 28th October and 16th November 2022. The total flight time was 27:59 hours while 56 approaches executed during 12 flights. The data such as aircraft digital bus, cockpit display video recordings and HF questionnaires were successfully collected.

As mentioned earlier, the purpose of the 2nd Energy Management Flight test was to validate the improvements made to EM prototype since the Ciampino Flight Test campaign at Ciampino execution. The high-level outcomes from the EM#2 Honeywell internal flight test are:

- The EM prototype has shown higher stability in its output behavior compared to March/April campaign.
- The improvements to HMI (PFD & MFD) were accepted as step forward to valuable tool for crew decision.
- The EM prototype behaved as expected during the nominal scenarios (Objective EM1)
- The EM prototype behavior during the delayed deceleration scenarios (Objective EM2 and EM4) wasn't partially as expected due to high sensitivity on gust wind environment, procedure construction and crew capacity to execute additional tasks on final.
- The EM prototype behavior during the delayed descent and FPLN modification scenarios (Objective EM3, EM4 and EM5) wasn't partially as expected due to limitation of drag model used for computation and real aircraft deceleration.

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-02.02-V3-VALPISGS.0202	ISGS impact on cockpit HMI	**CRT-02.02-V3- VALP-ISGS.0202- 001**	EM HMI is usable by flight crew	TMA	EM HMI usability has been further updated and improved. Nevertheless, need for improvements in FMS messages was identified.	POK
		CRT-02.02-V3- VALP-ISGS.0202- 002	EM is useful to flight crew	TMA	Energy Management is useful according to the collected results.	OK
		CRT-02.02-V3- VALP-ISGS.0202- 003	EM HMI supports the application of the procedure	TMA	EM HMI supports intended function Modified algorithm and HMI on displays improved the crew awareness about timing of configuration changes when performing IGS procedures	OK

Table 40 Update of ISGS exercise results

EUROPEAN PARTNERSHIP

Co-funded by the European Union

F.3.2 Analysis of exercise results per demonstration objective

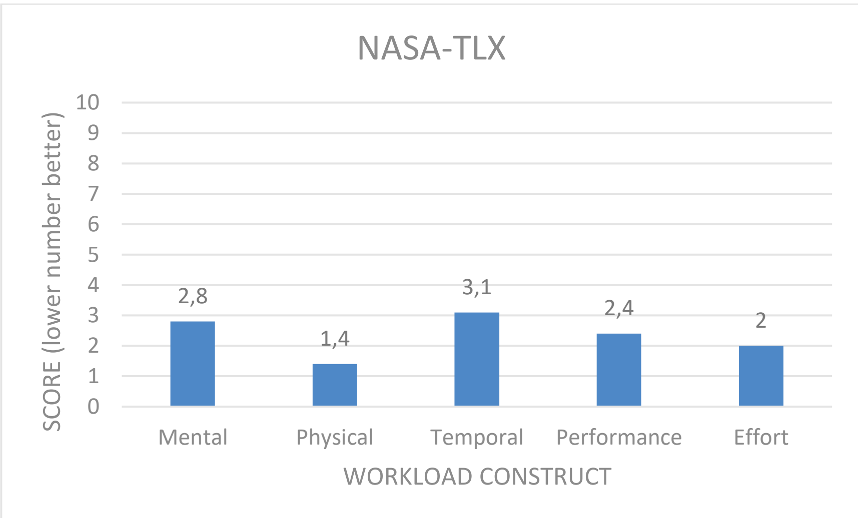
Energy management was used by the Left Seat Pilot Flying during the flown approaches. 56 approaches were flown using the Energy Management tool at 3 airports (KINW, KMWH, KPAE) with 4 Honeywell and 2 FAA Test Pilots. Two notes need to be emphasized regarding the Energy management prototype:

- Note A: The Energy Management Tool was an experimental prototype, and it included few known limitations which affected how the data were presented on the display, resulting in deteriorated perception of the tool by pilots.
- Note B: Specific comments regarding the Energy Management human-machine interface and suggestions for improvements were collected and will be used to further improve the prototype. These are not disclosed publicly in this document.

The figure below shows the location of the prototype displays installed in the E170 test aircraft.

Table 41 E170 cockpit during EM demonstration

At the completion of an approaches, pilots were asked to complete a NASA TLX workload questionnaire. In general, the rating between 3 – 4 is considered as an acceptable in NASA TLX scale with respect to the workload. Results collapsed across all pilots and all approaches are reported below.



F.3.3 Unexpected behaviours/results

The prototype did not have full drag models. In operation, and certain situations, the recommendations and predictions were not aligned with expected behaviour.

F.3.4 Conclusions and recommendations

The testing provided support of the Energy Management intended function. Additional research is needed to include additional drag models from the OEM. Also needed is additional human factors indication harmonization between FMS and displays. For example, in today's FMS installations, some FMS may include energy prompts in the scratchpad like "Activate Approach Speeds". Human Factors research should be further conducted to determine if new messages for energy recommendations be included in FMS messages, on the display, or duplicated.

F.3.5 Next steps towards cockpit energy management assistant deployment

The next steps for Energy Management deployment can be high level summarized as follows:

- Finish up design improvements and testing for the EM function in accordance with findings identified within E170 flight tests and demos. This includes:
    - Improvement of drag component of the performance model
    - Harmonization of FMS – Displays messaging
    - Approach OEM to discuss certification of Energy Management function for Embraer regional aircraft
- Based on the discussion with OEMs and further business decisions, to expand the Energy Management function to wider portfolio of the aircraft types and cockpit suites:
    - Expand to more NG FMS equipped platforms under Honeywell Primus® Epic (exact aircraft type is not specified yet, however full list of Primus® Epic equipped aircraft can be found here),
    - Expected is to develop energy management assistant for Airbus cockpit in coming years.

Maturity status for A/C-86 (On-board assistance to aircraft energy management):

- EM on Embraer 170, after improvements identified in last flight demonstrations, plan is to have it available on NG FMS core with entry to service from 2025-2026.
- EM on Airbus, if agreed with Airbus and after dedicated re-design per Airbus requirements as well as adaptation of the Airbus FMS platform, development phase and testing, the EM function could target an FMS update by ~2030.
- Boeing – plans still to be defined.

Appendix G FS Fast-Time Simulation ILS CAT II vs. GBAS CAT II EDDF RWY25

G.1 Introduction

This report is covering all content and scenarios simulated for project AirTOp121-GBAS II. It is intended to be used as a working paper to reproduce certain questions and answers given during the simulation project.

From an ANSP perspective, one of the advantages of GBAS can possibly be an increase of runway capacity during Low Visibility Operations (LVO). During LVO the main parameter limiting the landing capacity of a runway system is the runway occupancy time (ROT). 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. Therefore, the ROT is reduced for aircraft on a GBAS-approach.

To evaluate the differences between GBAS and ILS and the potential benefits of GBAS during LVO, several simulations have been conducted by DFS fast-time simulation unit.

In addition to a former simulation project conducted in 2018 (AirTOp93), that was comparing the consequences of solely GBAS CAT II (100% GBAS) and solely ILS CAT II operations (100% ILS), this simulation project was analysing the effects of different grades of GBAS-equipment between 0 and 100%. So, the assessment goes away from a pure black and white view to a more sensitive consideration considering an ascending grade of GBAS-equipment from time to time.

In general, fast-time simulations however can only answer these questions when considering certain assumptions. Thus, the results are qualitative tendencies instead of quantitative facts. The following section provides an overview on setup and assumptions used for the simulations.

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G.2 Methodology

G.2.1 Simulation model

DFS Deutsche Flugsicherung GmbH uses the state-of-the-art simulation tool AirTOp (Air Traffic Optimizer), the worldwide leading simulation tool, to assess and optimise procedures at airports and airspace structures. Unlike other simulation tools, simulations with the AirTOp system can display the movements of aircraft in a manner like the display of an air traffic controller working position.

G.2.2 Simulation coverage

The simulation contains only arrivals to runway 25R of EDDF.

As outer system boundary arrivals are introduced into the simulation around 20NM before the Initial Approach Fixes (IAF), then fly on Standard Instrument Arrival Routes (STARs) by using a vectoring area to reach the runway. The arrival procedures (UNOKO25N, ROLIS25N, KERAX25N) have been implemented into the simulation according to German AIP. All aircraft are fed from virtual holdings into the TMA with a pre-separation of 15NM.

The inner system boundary of the simulation model is the end of the two runway exits P24 and P16 connecting the runway system with taxiway system.

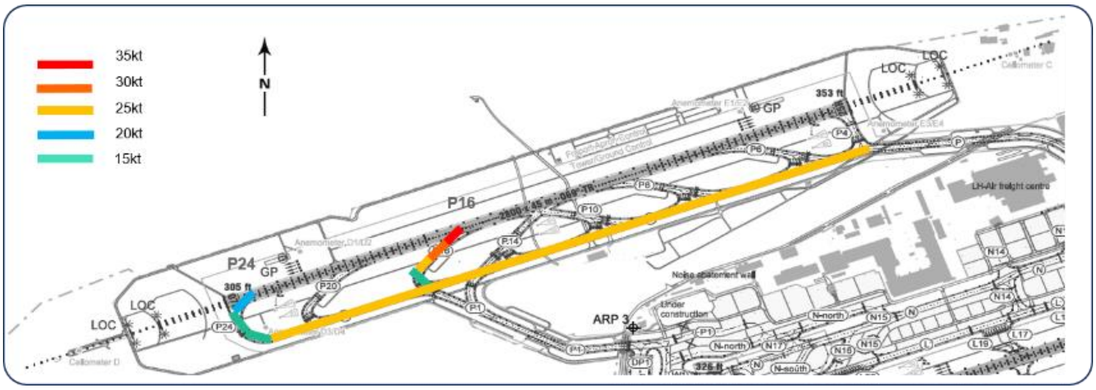

Figure 1: Runway 25R with color-coded taxi speeds used for the simulation

G.2.3 Traffic sample

To ensure a permanently high demand, a forecast flight schedule for year 2022 with a basic capacity of 110 movements per hour was taken as a basis (assumptions from the time before the COVID-19 pandemic).

To ensure that traffic can still be handled under low visibility conditions, the flight schedule was reduced by 10% to a value of 100 movements per hour at a maximum.

All aircraft restricted to the southern runways 25L and 25C have been removed from the simulation. Interaction between arrivals and departures have not been analysed as the simulation does not regard departures.

Finally, the flight plan for simulation contains 412 arrivals for runway 25R. 22,8% of the approaching aircraft are wake turbulence category (WTC) Heavy.

In principle all aircraft are supposed GBAS capable, so not only specific fleet or airline groups.

G.2.4 Low visibility operations

Definitions for low visibility operations with ILS

Obstacle Free Zone (OFZ):

- The OFZ shall be clear at the time the approaching aircraft is overhead threshold.
- The OFZ is considered to be clear if the aircraft is 150m abeam the centreline (CAT II/III Stop).

Sensitive Area (SA) CAT II:

- For the Localizer SA the succeeding aircraft shall not be closer than 2NM when the preceding is turning off from centreline.
- For the Glidepath SA the succeeding aircraft shall not be closer than 2NM when the preceding is overhead the threshold.

If the above-mentioned conditions are not met, a missed approach must be flown.

Critical Area (CA) CAT II:

- For the Localizer CA the succeeding aircraft shall not be closer than 4NM when the preceding is turning off from centreline.
- For the Glidepath CA the succeeding aircraft shall not be closer than 15NM when the preceding is overhead the threshold.

If the above-mentioned conditions are not met, a missed approach must be flown.

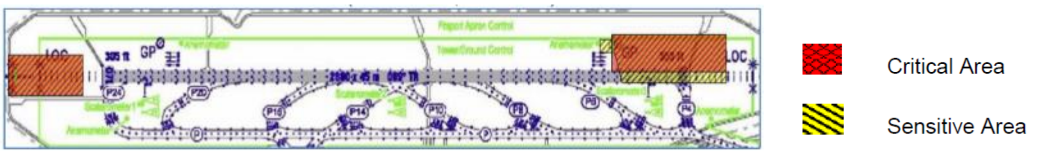

Figure 2: ILS protection zones RWY25R for Wake Turbulence Category (WTC) Light and Medium

For Light and Medium aircraft, the Sensitive Area is only relevant for the glidepath → no aircraft allowed between 2NM final and threshold.

The Critical Area (LOC and GP) is outside the runway and does not need to be considered.

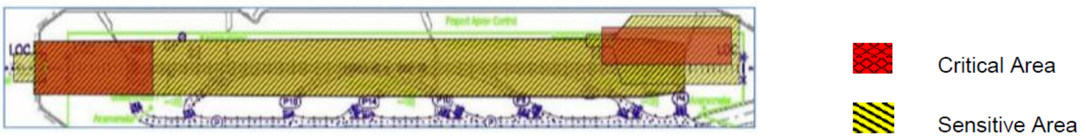

Figure 3: ILS protection zones RWY25R for Wake Turbulence Category (WTC) Heavy

No approaching aircraft is allowed between 2NM and threshold until the preceding aircraft is still inside the Sensitive Area (LOC and GP).

In the simulation Heavy aircraft are vacating via P24 and are inside the Critical Area of the Localizer thus, no aircraft allowed between 4NM final and threshold.

The Critical Area of the GP is not penetrated at any time.

➔ Assumption for the simulation: the width of the CA/SA is equal the width of the OFZ (150m left and right of the centreline).

Definitions for low visibility operations with GBAS

Obstacle Free Zone (OFZ):

- The OFZ shall be clear at the time the approaching aircraft is overhead threshold.
- The OFZ is considered to be clear if the aircraft is 120m abeam the centreline (CAT II/III Stop).

Sensitive Area (SA) /Critical Area (CA) CAT II:

- No protection zones applicable for GBAS

Landing Clearance Line CAT II:

- If an aircraft is inside the landing clearance line the succeeding aircraft shall not be closer than 0.6NM from threshold.

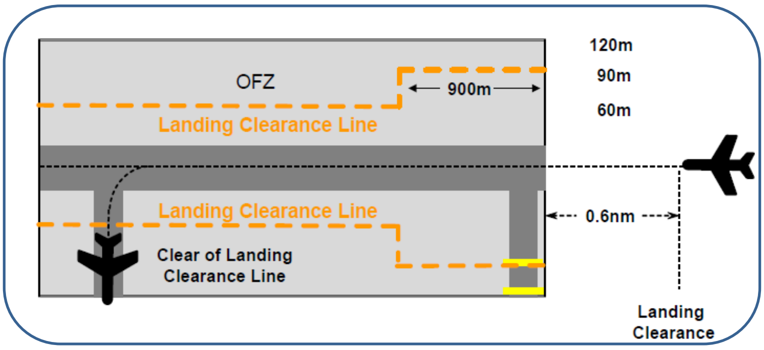

Figure 4: Landing Clearance Line [ICAO EUR Doc 013, Guidance on AWO Edition 5, Sept. 16]

The landing clearance line has been modified to a parallel line with 90m distance from centreline for simplification purposes and in order to achieve conservative simulation results.

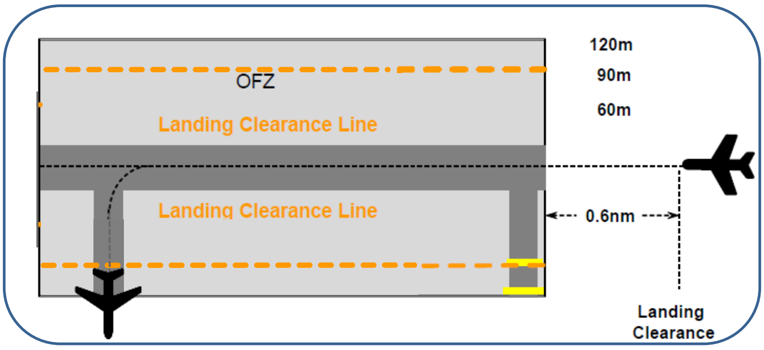

Figure 5: Modified Landing Clearance Line used for the simulation

G.2.5 Separation criteria

ILS CAT II Procedures:

To comply with the criteria mentioned above the following optimal separation has been chosen:

The previous simulation project AirTOp93 showed that all WTC Heavy aircraft fulfil the 4NM-criteria in case they are separated by 8NM. For the WTC Medium, nearly all aircraft fulfil the 2NM-criteria, therefore the separation of 5NM has been maintained.

Both separation values, 8NM for WTC Heavy aircraft and 5NM for WTC Medium aircraft came out of workshops with operational experts focussing on their experience and operations during CAT II low visibility operations (see red marking in Figure 6 for ILS).

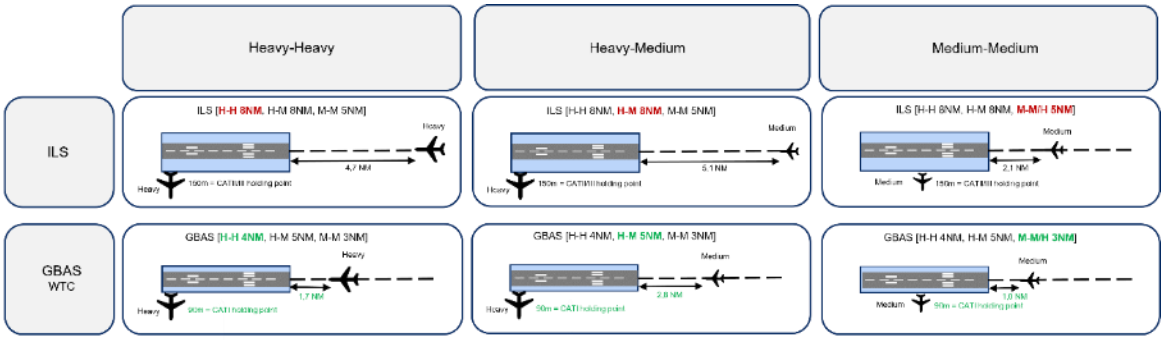

Figure 6: Assumed separation criteria for ILS- and GBAS-constellations in the simulation

GLS CAT II procedures:

Due to missing Critical- and Sensitive Areas in the case of GBAS procedures the Landing clearance can be issued at a later point in time (reduced distance to 0.6NM). When applying the Landing Clearance Line the preceding aircraft vacates the runway earlier. This effect leads to a greater distance to threshold for the succeeding aircraft and can be used to reduce separation.

Previous simulation project AirTOp93 showed that this criterion is fulfilled in case aircraft are separated by MRS (Minimum Radar Separation), e.g. separating two WTC Heavy aircraft 4NM and two WTC Medium aircraft 3NM (see green marking in Figure 6 for GBAS).

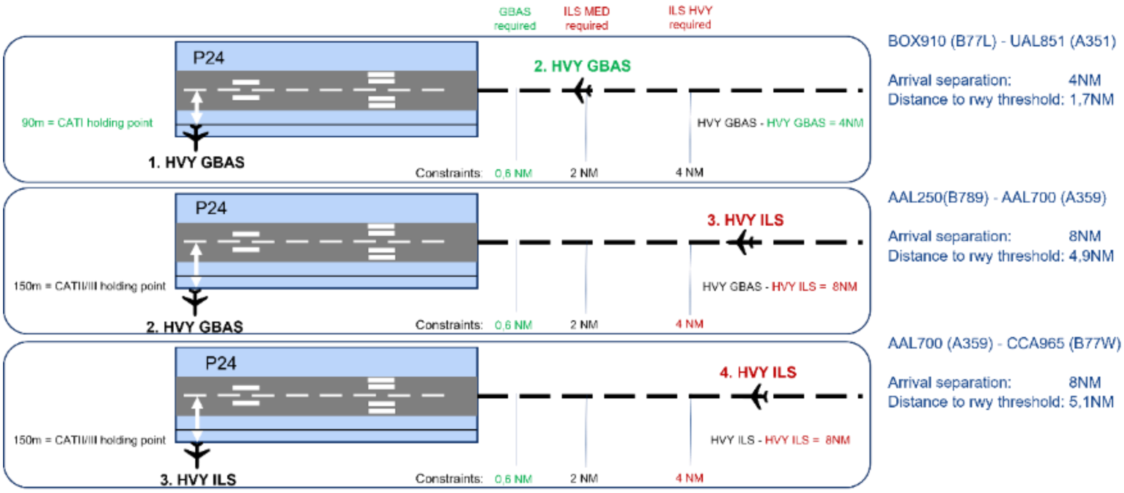

Figure 7: Separation and complexity due to different traffic constellations with WTC Heavy aircraft

Figure 7 shows different separation criteria and complexity due to different traffic constellations. Apart from the point that different aircraft types, so different wake turbulence categories, must be taken into account for separation the different aircraft equipment, ILS or GBAS-capable, leads to an increased complexity of high number of different constellations. As an example, the illustration shows for three different traffic constellations with only Heavy aircraft, Heavy GBAS vs. Heavy GBAS, Heavy GBAS vs. Heavy ILS and Heavy ILS vs. Heavy ILS the variation of separation considering the criteria mentioned in chapter 2.4. Figure 8 shows different separation criteria in case medium aircraft have to be considered in the arrival sequence additionally.

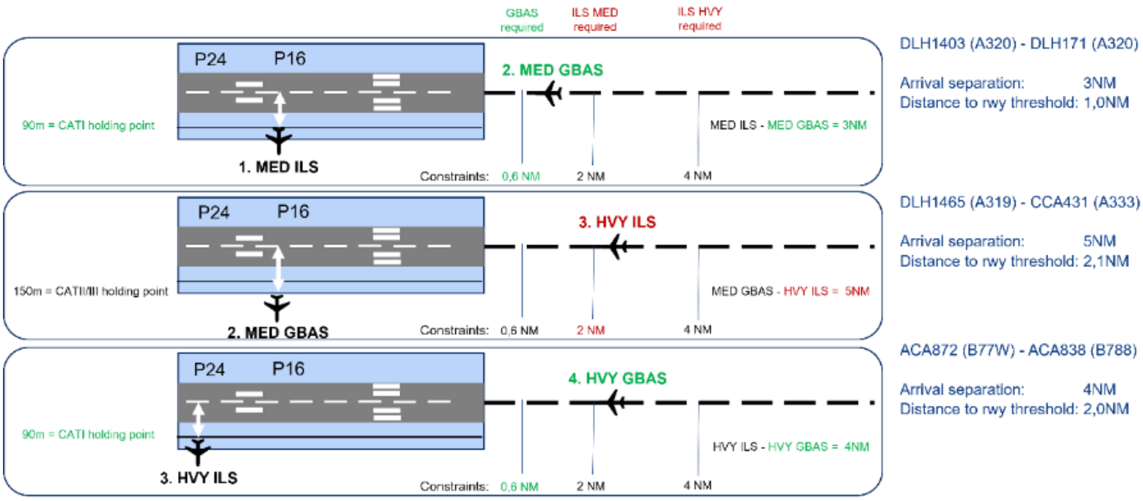

Figure 8: Separation and complexity due to different traffic constellations with WTC medium aircraft

G.3 Simulation scenarios

In total the simulation project contains six different simulation scenarios.

Scenario	REF GBAS 0	ORG1 GBAS 10	ORG2 GBAS 30	ORG3 GBAS 60	ORG4 GBAS 80	ORG5 GBAS 100
Equipment level	0%	10%	30%	60%	80%	100%
Heavies level	22,8%	22,8%	22,8%	22,8%	22,8%	22,8%
Runway Exit-usage (HVY) Runway Exit-usage (M/L)	100% P16 100% P24	100% P16 100% P24	100% P16 100% P24	100% P16 100% P24	100% P16 100% P24	100% P16 100% P24
Max. vacating speed (HVY) Max. vacating speed (M/L)	35kts P16 20kts P24	35kts P16 20kts P24	35kts P16 20kts P24	35kts P16 20kts P24	35kts P16 20kts P24	35kts P16 20kts P24
Traffic mix	0% Departures	0% Departures	0% Departures	0% Departures	0% Departures	0% Departures

Table 1 shows the scenarios conducted during the simulation project. There is just one parameter that changes from one scenario to another, which is the grade of GBAS-equipped aircraft in the different simulation scenarios:

Scenario	REF GBAS 0	ORG1 GBAS 10	ORG2 GBAS 30	ORG3 GBAS 60	ORG4 GBAS 80	ORG5 GBAS 100
Equipment level	0%	10%	30%	60%	80%	100%
Heavies level	22,8%	22,8%	22,8%	22,8%	22,8%	22,8%
Runway Exit-usage (HVY) Runway Exit-usage (M/L)	100% P16 100% P24	100% P16 100% P24	100% P16 100% P24	100% P16 100% P24	100% P16 100% P24	100% P16 100% P24
Max. vacating speed (HVY) Max. vacating speed (M/L)	35kts P16 20kts P24	35kts P16 20kts P24	35kts P16 20kts P24	35kts P16 20kts P24	35kts P16 20kts P24	35kts P16 20kts P24
Traffic mix	0% Departures	0% Departures	0% Departures	0% Departures	0% Departures	0% Departures

Table 1: Simulation scenarios with different grades of GBAS-equipment

The number of scenarios and therefore steps with increased GBAS-equipped aircraft were defined by the customer in advance.

G.4 Evaluation criteria

Various evaluation criteria are possible for evaluating and comparing different simulation scenarios when conducting a fast-time simulation with AirTOp.

As it is the goal of this simulation to measure the effect of an increased GBAS-equipment level of aircraft, evaluation criteria relating the runway capacity are of main interest for this analysis. Parameters such as traffic throughput and the delay situation during operations make it possible to measure the effects and potential of different circumstances and to compare different approaches with each other.

Throughput

The main evaluation criteria of this simulation are the determination of the traffic throughput. It is determined by the number of aircraft landing within a certain time interval. The counting of the arriving aircraft takes place when they are touching down on the runway.

Delay

Delay, in this context arrival/sequencing delay, is the time an arriving aircraft is delayed by means of air traffic control, such as vectoring, speed control and usage of holding patterns.

Both evaluation criteria, throughput and delay, are processed in each 10-minute rolling hour. A rolling hour means, that every 10 minutes a new 60-minutes period starts, for example the value at 09:10 is the sum of the movements between 08:10 and 09:10 UTC.

G.5 Simulation results

Comparing the throughput of the six simulation scenarios during times of high traffic (traffic peaks at 11:00, 15:00 and 20:00) there is a wide range from 6 to 10 movements depending on the GBAS equipment level. During these peaks the throughput variates from 27 (0%-scenario) to 37 movements per hour (60%-, 80%-, 100%-scenarios). From these results, that in some scenarios with more GBAS-equipped aircraft the traffic demand of 37 movements is served as requested. In other scenarios with less proportions of GBAS equipped aircraft the flights are shifted in later traffic valleys, causing delay (cf. throughput valleys at 13:00 and 16:00 in Figure 9).

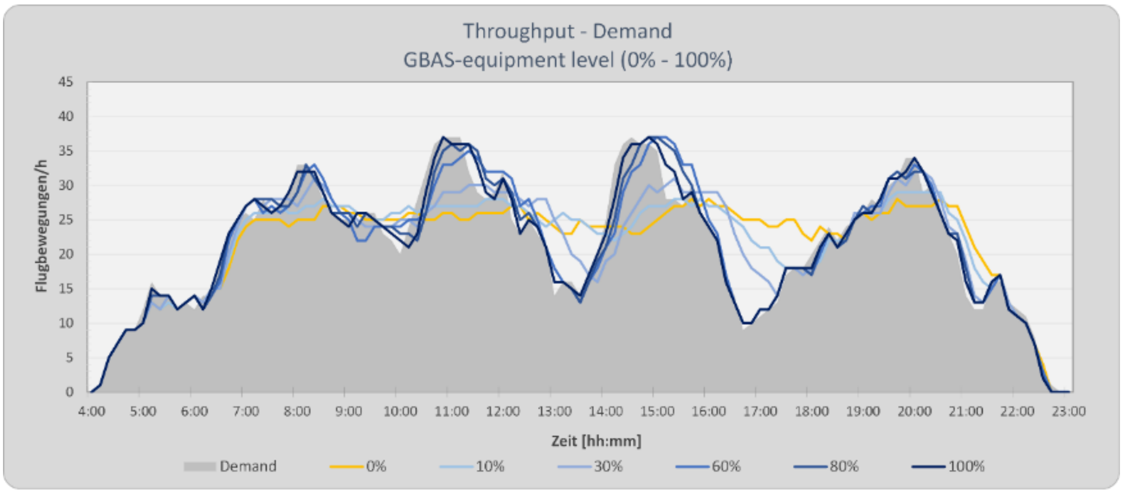

Figure 9: Throughput and demand due to GBAS-equipment level in simulation scenarios

Comparing only the throughput of both simulation scenarios with an assumed GBAS equipment level of 30 and 60%, a significant improvement of up to 6 additional movements can be seen only in this iteration step. While the runway throughput is capped at a GBAS-level of up to 30% at around 30 movements per hour, the demand in the scenarios with a GBAS-level of 60% and more can be operated as required in almost all traffic peaks.

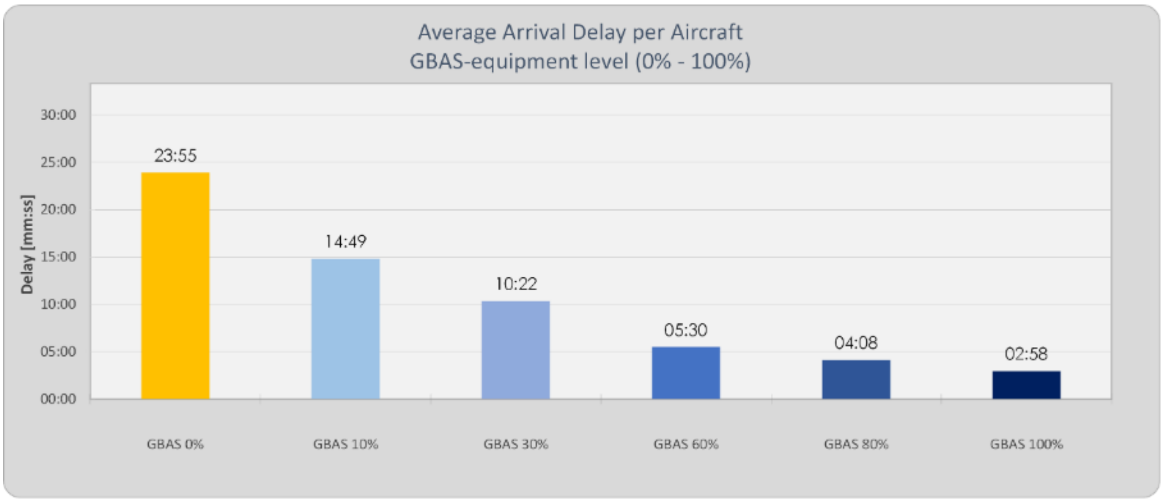

Figure 10: Average Arrival Delay due to GBAS-equipment level in simulation scenarios

As obvious in figure 10, with increasing GBAS equipment the arrival delay decreases from 23:55 minutes (0%) to 02:58 in the scenario assuming full GBAS-coverage (100%). In the scenario with 41 GBAS equipped aircraft (10%) arrival delay is already reduced significantly by almost 10 minutes to a value of 14:49 minutes, with a proportion of 30% GBAS equipped aircraft even to 10:22 minutes. Furthermore, the arrival delay is significantly reduced when assuming an increased GBAS equipment of 60%. Comparing the 30%- and 60%-scenario, the delay is almost halved to a value of 05:30 minutes. In contrast to this behavior the effect of the further increase in the GBAS proportion to 80% and more (100%), is comparatively small.

Scenario	REF GBAS 0	ORG1 GBAS 10	ORG2 GBAS 30	ORG3 GBAS 60	ORG4 GBAS 80	ORG5 GBAS 100
Equipment level	0/412	41/412	124/412	248/412	331/412	412/412
Max Demand	37	37	37	37	37	37
Max Throughput	28	29	32	37	37*	37
Avg Sequenzing Delay	23:55	14:49	10:22	05:30	04:08	02:58

* Im Szenario GBAS 80 werden zu Zeiten der Nachmittagsspitze kurzzeitig in einem rollierenden Stundenintervall 38 Flugbewegungen abgewickelt

Table 2: Survey of simulation scenarios and results within this simulation project

Table 2 shows the scenarios with its defined equipment levels as well as the simulation results with the assumed demand, runway throughput an arrival delay in a survey.

G.6 Conclusion

The result of the simulation runs show that an increase of capacity is most likely when using GBAS CAT II approach procedures instead of ILS CAT II.

Considering the assumed framework GBAS CAT II represents a significant gain compared to ILS CAT II in terms of throughput and delay. This is in the simulation already the case if a small proportion of aircraft are equipped with GBAS, e.g., 10% or 30%. With an equipment level of 60%, the throughput can be significantly increased, and the traffic can be handled almost as required (Demand 37 = Throughput 37) with a significantly reduced delay situation of round about 5 minutes compared to the other scenarios with a lower GBAS equipment level. The further increase of GBAS equipped aircraft to 80% and 100% does not lead to a further increase in runway throughput, apart from the fact that the traffic peaks are operated most likely as demanded. Delay decreases, though at a comparatively low level, in the range of 4 minutes and below. Looking at the results in their entirety, it can be said that the step from a GBAS equipment level of 30% to 60% has a very positive effect on the throughput, whereas the delay can be significantly reduced quite at lower equipment levels in the range of 10% or 30%.

The reasons for this increase of capacity are the missing protection zones for GBAS operations and the Landing Clearance Line concept, that allows the aircraft 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.

When interpreting the simulation results, it should be kept in mind that all values are based on one specific flight plan with rigid rules and that the assumptions that were made are largely theoretical. It is also not clear whether the assumed volume of traffic, despite the reduction that has already taken place, corresponds to a realistic scenario under low visibility conditions. In these bad weather conditions, ground-based processes and procedures of the system partners must also be considered accordingly. In addition, the focus of the present studies has been exclusively on runway 25R of EDDF.

Apart from this the results are also dependent on various factors, such as the traffic mix, the selected RWY-exits and the taxiing speeds. To investigate the effectiveness of these parameters and to be able to make valid statements, a coordinated implementation plan for GBAS should be clarified.

Nevertheless, the presented results of this report demonstrate that there is a positive tendency for greater capacity when using GBAS instead ILS in low visibility conditions.

Appendix H ENERGY BALANCE SUMMARY

In order to tackle aviation's future challenges, aircraft need to fly as energy-efficient as possible. This does not only comprise technical development but also operational means, by which the energy efficiency of the aircraft can be increased through avoiding unnecessary waste of energy. Such operational means can be applied already with today's aircraft and can thus immediately increase the energy efficiency of today's aircraft without extensive technical changes. On the other hand, the further reduction of noise emissions of aircraft in the vicinity of airports is another important factor for future aviation. Increased glideslope angles during final approach are one operational means to reduce the noise emissions from aircraft. However, the increase of the glideslope angle must not negatively affect the aircraft's ability to fly energy-efficiently.

In order to assess the ability of modern transport aircraft to fly energy-efficient approaches with increased glideslope angles, DLR evaluated energy envelopes by using a backwards simulation of idle approaches. Energy-efficient approaches are defined here as those, that a) are completely performed with engines in idle until reaching the final approach speed, b) reach the final approach speed at 1,000 ft above ground and not earlier, and c) are completely performed without using airbrakes to decelerate the aircraft. The approaches were simulated following the standard approach procedure in terms of the configuration sequence (scheduling of flap and gear deployment). For Airbus aircraft e.g., it is intended to intercept the glideslope with Conf 2 (or Conf 1 if possible) and gear up. Also, the threshold for the use of airbrakes was chosen so that the aircraft does not accelerate at any point during the approach. In real flight slight accelerations are indeed acceptable if the speed remains below the respective maximum flap speed. However, for reasons of comparability the threshold was set here to zero acceleration.

Energy envelopes are the boundaries in the space of glideslope angle and glideslope intercept speed, within which it is possible to perform the final approach in an energy-efficient manner, following the definition given above. Hence, it does not mean, that outside the energy envelopes, it is not possible to perform the approach safely, but that either the final approach speed is reached too early (before reaching 1,000 ft above ground) or it is necessary to use airbrakes in order to decelerate the aircraft to final approach speed. Figure 51 gives an example of an energy envelope for the Airbus A320.

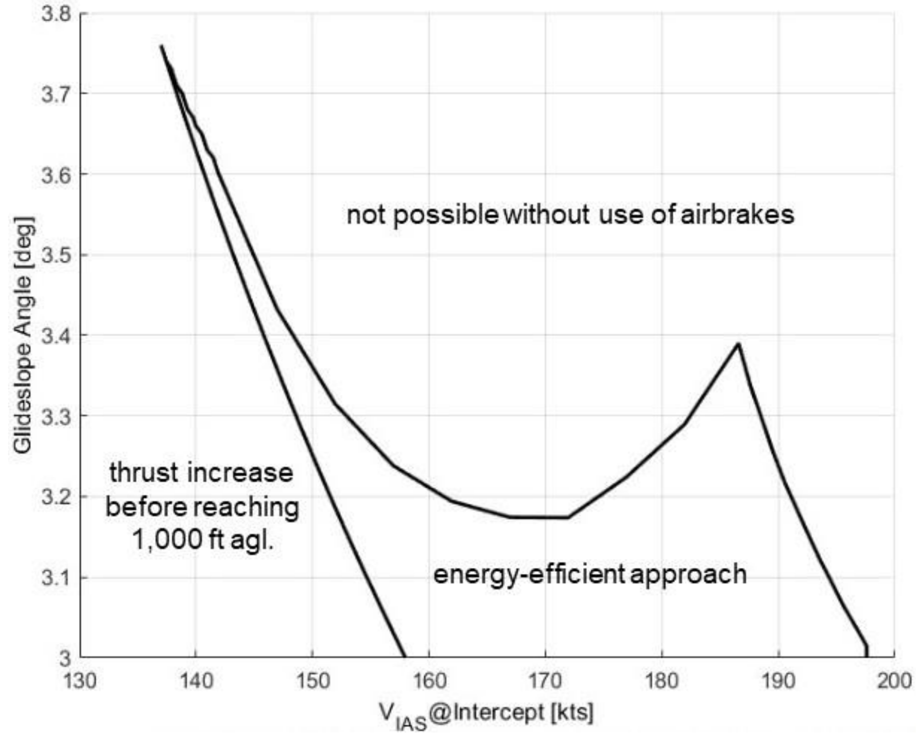

Figure 51: Exemplary energy envelope for energy-efficient approaches of the A320 (aircraft mass: 55 t, intercept altitude: 3,000 ft, no wind) - Data presented in figure not verified by AIRBUS

The energy envelopes were evaluated for various aircraft types (A319, A320, A321 representing narrow-body aircraft and B787-9 representing heavy wide-body aircraft). Two different types of aircraft performance model were used. For the aircraft of the A320 family a so-called trimmed polar model, which utilises trimmed drag polars and an accurate idle thrust model, was used. This model can be regarded as acceptably accurate. In case that no such model is available, the Aircraft Noise and Performance (ANP) database of Eurocontrol can be used as well. For the evaluation of the B737-800 and the B787 the ANP model was used. This model can be regarded as acceptably accurate for typical approach speeds and glideslope angles. For larger glideslope angles and non-typical approach speeds the accuracy of the ANP model is degraded.

The results of the approach calculations have been verified against existing real flight data and show an acceptable level of conformity. The verification was performed for the A320 (with a trimmed polar model) and B737-800 (with ANP) and for approaches with glideslope angles of 3° and 3.2° as only for these aircraft types and glideslope angles real flight data were available. The comparisons to the real flight data showed a sufficient accuracy. For this reason, it can be expected that the results are also acceptably accurate for higher glideslope angles and for other aircraft types, as long as the used performance model is acceptably accurate. This might not be the case for the ANP model with large glideslope angles.

The parameters that influence the shape of the energy envelope, such as aircraft mass, glideslope intercept altitude or wind have been varied for the mentioned aircraft types in order to show the sensitivity of approaches with increased glideslope angles against these parameters. Furthermore, the variation of fuel consumption within the energy envelope has been assessed for the A320 as exemplary aircraft. Noise immissions could not be assessed quantitatively here, but a qualitative discussion on the variation of noise immissions within the energy envelope is given. It is shown that the minimum fuel consumption within the energy envelope is for high intercept speeds and large glideslope angles. Although no quantitative assessment could be performed, the qualitative analysis of noise immissions shows that the minimum noise immissions within the energy envelope lies at least not in the area of the minimum fuel consumption. For this reason, it can be expected that the final approach cannot be optimized with respect to both noise and fuel consumption, but that these parameters have to be traded against each other. However, it can be expected that generally IGS is beneficial for both, even the optimal intercept speed might be different for minimum fuel consumption and minimum noise.

The envelopes show that the influence of the aircraft mass on the maximum energy-efficiently achievable glideslope angle depends on the intercept speeds. While for high intercept speeds lighter aircraft can fly steeper approaches, heavier aircraft can fly steeper approaches at lower intercept speeds. The energy envelopes also show that it is favourable to have lower intercept altitudes at higher glideslope angles as a higher intercept altitude decreases the maximum energy-efficiently achievable glideslope angle for a given intercept speed. With increasing intercept altitude the remaining distance to decelerate the aircraft to final approach speed (to be reached at 1,000 ft above ground!) increases. Therefore, the range of intercept speeds, within which energy-efficient approaches are feasible, moves towards higher speeds. Hence, the maximum glideslope angle, with which energy-efficient approaches are still feasible, decreases for a given intercept speed. The variation of wind reveals the strong influence of wind on the ability of aircraft to fly approaches energy-efficiently. Head wind shifts the energy envelope towards higher glideslope angles, but also towards higher intercept speeds. This is caused by two different reasons. On the one hand, wind changes the ground speed (as aircraft fly with the same airspeed regardless the wind speed), which inevitably changes the flying time for the same ground distance. On the other hand, with a given glideslope angle wind changes the aerodynamic flight path angle through the air, which influences the deceleration rate of the aircraft. Hence, with increasing headwind the aerodynamic flight path angle is shallower, so that the aircraft can decelerate better. This leads to a higher achievable glideslope angle.

The analysis of the variety of influencing parameters shows that for some aircraft types a kind of energy assistance system, which enables pilots to fly energy-efficiently even with increased glideslope angles and under the various and changing conditions in real flight can be beneficial (such as the one developed by DLR called LNAS - Low Noise Augmentation System). Without such an assistance system the risk may arise at least for some aircraft type that the increase of the glideslope angle will lead to a larger number of non-energy-efficient approaches, resulting in unnecessary noise immissions and/or fuel consumption.

The work described here is documented in detail in a separate document:

Vechtel, D., Pauly, P., "Development of an energy-based speed envelope for increased glideslope angles", DLR internal report DLR-IB-FT-BS-2022/38, Braunschweig, 2022

The document is publicly available via the DLR document repository (https://elib.dlr.de/187727/).

EUROPEAN PARTNERSHIP

Co-funded by the European Union