CANARIAS Project

CO2 And Noise Approach Reduction for International Aviation Sustainability

Demonstration Report

Document information	
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Task contributors	
Aena; Airbus Prosky; Thomas Cook; Norwegian Air Shuttle; and Novair.	

Abstract

This document illustrates the Demonstration Report for the CANARIAS Project, highlighting the purpose and execution of the demonstrations exercises, assessment and methodology of collected data, and the obtained results.

A handful of the targeted number of demonstration flights was achieved, however providing proof-of-concept design and operational solutions at the terrain-challenged airports of Lanzarote (GCRR) and La Palma (GCLA) airports.

The results of the project highlight imminent need in the short-term to implement RNP-AR procedures at both airports for accessibility, approach stability, trajectory repeatability, obstacle protection, and safety enhancement. Operators and Air Traffic Controllers trained for the demonstration flights confirmed that the specific design of the STARs and above all the Approaches at both airports match what is needed within their respective environment.

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Rational for rejection

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Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground.

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Executive summary

The CANARIAS project stands for "**C**O_2 **A**nd **N**oise **A**pproach **R**eduction for **I**nternational **A**viation **S**ustainability". This project is led by a Consortium formed between Airbus ProSky, Aena (Spain's air traffic service provider), Air Berlin, easyJet and Thomas Cook Airlines.

During the development of the project, two of the consortium airline operators were unable to provide input for the required exercises, and their activities were partly covered by two participant operators: Norwegian Air Shuttle and Novair.

The objectives of the CANARIAS project were:

- To demonstrate reduction of CO_2 emissions by achieving track mile savings together with Continuous Descent Operations compared to the published conventional procedures;
- To support the optimization of the Canarias Flight Terminal Area using PBN;
- To improve access to La Palma and Lanzarote airports by using RNP AR procedures;
- To reduce the noise impact, where possible, over populated areas using optimized vertical profiles.

The CANARIAS initiative introduced in Spain a proven advanced form of GNSS based precision operation by designing, validation and flying specific approach trajectory specifically studied for the particularities of the terrain surrounding and in the vicinity of the airports in question. The designs of the RNAV STARs and RNP-AR approaches for the arrival to runway 21 of Lanzarote (GCRR) airport and for the arrivals to runways 01/19 of La Palma (GCLA) airport were thought in a way to take full advantage of the RNP capabilities for a large variety of aircraft (CAT A-D), including consortium and participant operators flying A320 family and B737NG aircraft.

Even though the designs (included Technical reports) were fully validated on certified Full Flight Simulators, one of the objectives of the CANARIAS project was to gather live data from the operators through approximately 100 revenue flight demonstrations, and compare the results to data representing conventional flown procedures. In addition, Radar Tracking methodologies and resulting data was also envisioned to validate and compare the results obtained from the aircraft live data.

The project included training of local Air Traffic Control personnel to handle efficiently and without disruption the mix of RNP and non-RNP capable aircraft during the flight demonstrations and necessary for a hopeful full implementation of the designs at Lanzarote and La Palma.

The demonstration flights were planned to be carried out under Visual Meteorological Conditions, with an agreed communication process and phraseology between operators and Air Traffic Controllers, in block periods spanning approximately 12 months. In lieu of external and internal factors affecting the project, the flight demonstrations commenced later than expected and lasted for 4 months only, reducing significantly the margin available for the Consortium and participant operators to fly the PBN procedures. On the other side, the outcome of the project highlighted additional benefits provided by the designs, and recommendations for future demonstration activities of this sort by SJU and member participants.

The project was divided into seven work packages and distributed in three phases to be completed within 24 months. Phase 1 addressed the procedures designs, testing and validation; Phase 2 addressed the flight demonstration activities and analysis of the results; and Phase 3 addressed the communications and public relations activities.

The CANARIAS project is part of the Atlantic Interoperability Initiative to Reduce Emissions programme, aiming to reduce CO_2 emissions, capitalize on today's aircraft technology, and accelerate the uptake of ATM best practices. CANARIAS demonstrates measurable immediate benefits at hand that can be used to improve operations efficiency, tackle some of today's shortcomings from regulators, and induce a deployment of GNSS Based Procedures across Europe.

1 Introduction

1.1 Purpose of the document

This document provides the Demonstration report for the CANARIAS project at Lanzarote and La Palma airports. It describes the implementation process and the results of demonstration exercises defined in the Demonstration Plan (Ref: [6]), benefits, lessons learnt, and recommendations for future similar activities.

1.2 Intended readership

The SESAR Joint Undertaking (SJU) and in particular the SJU's points of contact and reviewers assigned to the CANARIAS project shall document themselves with the contents of this document as it provides a detailed analysis regarding the use of RNAV STARs and RNP-AR approaches for the arrival to runway 21 of Lanzarote airport and for the arrivals to runways 01/19 of La Palma.

In addition, the document highlights the challenges dealing with the design and implementation of RNP AR procedures in terminal airspaces, challenges of conducting flight trials and considerations in introducing RNP AR procedures at airports with challenging terrain; all remarks that could be treated as inputs and risk identification means administrators of current and future similar projects.

1.3 Structure of the document

The document is divided in the following sections:

- Section 1: Introduction;
- Section 2: Presents how this project and the planned demonstration activities are related with the SESAR program and the objectives of the ANSP (Aena);
- Section 3: Explains the programme management;
- Section 4: Provides an overview of the exercise executions;
- Section 5: Illustrates the exercise results, and project's conclusion;
- Section 6: Summarizes the project's communication activities
- Section 7: Presents next steps, overall lessons learn and recommendations that can be useful for other similar projects; and to be conducted in order to finalize the project;
- Section 8: Provides the list of applicable and reference documents.

1.4 Glossary of terms

Continuous Descent Approach (CDA). An approach, enabled by airspace design, procedure design and ATC facilitation, in which an arriving aircraft descends continuously, to the greatest possible extent, by employing minimum engine thrust, ideally in a low drag configuration, until the final approach fix /final approach point.

1.5 Acronyms and Terminology

Term	Definition
ACC	Area Control Center
AIRE	Atlantic Interoperability Initiative to Reduce Emissions
ANSP	Air Navigation Service Provider
ARR	Arrival
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
ATS	Air Traffic Services
CAT	Category
CDA	Continuous Descent Approach
CTR	Control Zone
DEP	Departure
DFDR	Digital Flight Data Recorder
DMU	Data Management Unit
DOD	Detailed Operational Description
E-ATMS	European Air Traffic Management System
E-OCVM	European Operational Concept Validation Methodology
ESSIP	European Single Sky Implementation Plan
FAP	Final Approach point
FIR	Flight Information Region
FL	Flight Level
FMS	Flight Management System
GCLA	La Palma Airport (ICAO Code)
GCRR	Lanzarote Airport (ICAO Code)
GNSS	Global Navigation Satellite System

Term	Definition
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
KPA	Key Performance Area
KPI	Key Performance Indicator
LoA	Letter of Agreement
MSL	Mean Sea Level
OFA	Operational Focus Areas
PBN	Performance Based Navigation
P-RNAV	Precision RNAV
QAR	Quick Access Recorder
RNAV	Area Navigation
RNP	Required Navigation Performance
RNP APCH	Required Navigation Performance Approach
RNP-AR	Required Navigation Performance with Authorization Required
RWY	Runway
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
STAR	Standard Arrival Route
ToD	Top of Descent
TWR	Tower
VPA	Vertical Path Angle
VSS	Visual Surface Segment
WP	Work Package

2 Context of the Demonstrations

2.1 Scope of the demonstration and complementarity with the SESAR Programme

The scope of the CANARIAS project was to design, test and validate RNP STARs and RNP-AR approaches for the arrival to runway 21 of Lanzarote airport and for the arrivals to runways 01/19 of La Palma airport. The measurable objectives were to demonstrate a reduction of track miles in lieu of optimized vertical and horizontal paths translated into a reduction of fuel consumption (therefore CO_2 emissions), and reduction of noise (where possible) compared with conventional arrival procedures currently in use.

Other expected benefits, which were proven in this project, included improvement to airport access, optimization of the TMA airspace by taking full advantage of aircraft RNP capabilities, and appropriate preparation and training of local ATC personnel for the flight trials. PBN based procedures have proven to reduce ATC workload under set conditions and amount of required communications over the radio allowing controllers to focus more on monitoring and supervision.

The Spanish DGAC and AESA are working in close collaboration with Aena on the implementation of PBN in Spain, specially the implementation of RNAV1 and RNP APCH procedures based on GNSS, which establishes the framework for the use of GNSS systems for navigation application in Spain. This very important approval, based on a strategy proposed by Aena and in line with ICAO mandate for the implementation of GNSS based procedures, paths the way and perfectly embeds the CANARIAS project within the international programme for the reduction of aircraft emissions, AIRE.

The Spanish authorities together with Aena have developed a PBN Implementation Plan for Spain, regarding the approach phase of flight in line with ICAO recommendations (A37-11) to promote the deployment of RNP APCH procedures in every instrument runways. The PBN Implementation Plan covers the different phases of flight, route (RNAV 5), TMA (RNAV 1) and approach (RNP APCH 3 minima).

CANARIAS demonstrated, with limited flights and based on the comments of operators and Air Traffic Controllers, the value that PBN can provide at terrain-challenged airports by using optimized and specifically studied repeatable trajectories in combination with navigation accuracy and on-board technological advances. This is in line with AIRE's objectives to produce constant step-based improvements to be implemented, as quickly as possible, after the projects conclusion in order to contribute to the achievement of environmental savings, and safety.

Demonstration Exercise ID and Title	**EXE-01.01-D-001 : RNP Operations at GCLA** **EXE-01.01-D-002 : RNP Operations at GCRR** *(Note: Refer also to Project demonstration plan 01.01 Edition 01.02.00)*
Leading organization	Airbus ProSky and Aena
Demonstration exercise objectives	Design and validate RNP STARs and RNP AR Approaches to Runway 01 and Runway 19 at La Palma airport (GCLA). Design and validate RNP STARs and an RNP AR approaches to Runway 21 at Lanzarote airport (GCRR).
OFA addressed	02.01.01 Optimized RNP Structures 02.02.01 CDA
Applicable Operational Context	La Palma and Lanzarote airports; Canarias TMA;

	Canarias ACC.
Demonstration Technique	**Design:** Approved Design Tools (E.g. Geotitan) **Demonstrations:** Revenue flights **Output:** Data analysis and comments/recommendations
Number of trials	**GCLA: 4** (Norwegian) **GCRR**: 2 (Novair), 1 (Norwegian), 1 (Thomas Cook)

Table 1 - Exercises Overview

3 Programme management

3.1 Organization

The Consortium of the CANARIAS project was composed by five (5) members: Aena, Airbus ProSky, Air Berlin, easyJet, and Thomas Cook Airlines UK.

Additional two operators, Norwegian Air Shuttle and Novair were incorporated into the project at the end of 2012 / beginning of 2013 upon agreement from the general Consortium members. The role of both operators in the project development phase and demonstrations proved to be essential in lieu of two Consortium member operators unable to continue participating in the project.

Per the SESAR Integrated Flight Trials and Demonstrations Activities Agreement for the CANARIAS Project (Ref: [5]) and the related Consortium agreement (Ref: 03072012), Quovadis (from here on referred to as “Airbus ProSky”) acted as project “Coordinator”, while Aena, Air Berlin, easyJet, and Thomas Cook Airlines UK acted as “Consortium Members”. With the agreement of SJU and the project Consortium Members, Novair and Norwegian Air Shuttle acted as participant members of the project, in which they attended at key meetings, advised and reviewed pertinent documentation, and participated in the validation and flight demonstration of the envisioned procedures during the second phase of the project.

Within this project organization, Airbus ProSky was responsible for most project management tasks, particularly acting as the Focal Point interface with the SJU. This included, within other activities, submission of deliverables, quarterly progress reporting, notification of significant project achievements, risk assessment, coordinating communications activities within the consortium, and organization of project meetings.

Figure 1 displays an overview of the project organization:

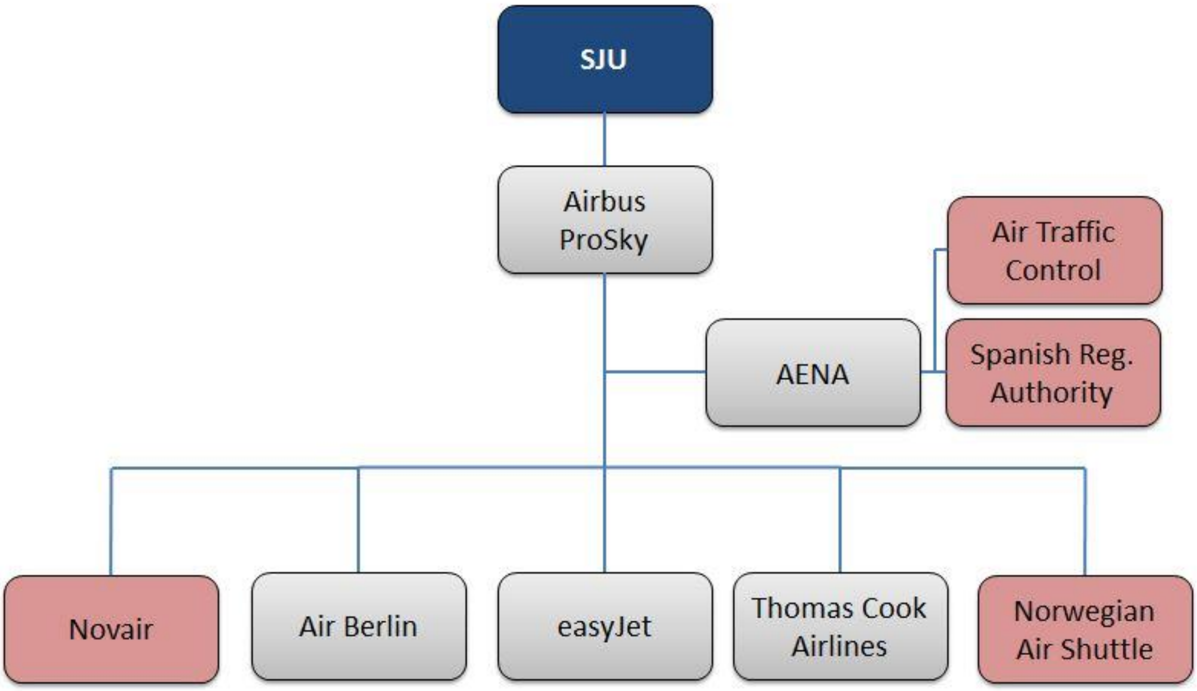


Figure 1 - Project organization

Note: The Spanish Regulatory Authority (DGAC and AESA) were not member parties of this project. However they were duly informed by Aena (focal point of contact liaising directly with both Authorities) of the status of the project and demonstration activities, and therefore displayed in the organization illustration.

Table 2 below illustrates the focal points assigned by each Consortium Member at the start of the project. Norwegian Air Shuttle and Novair have been added per their entry as participant members.

	Project Focal Point	Technical Focal Point	Financial Focal Point
Aena	[redacted]	[redacted]	[redacted]
Airbus ProSky	[redacted]	[redacted]	[redacted]
Air Berlin	[redacted]	[redacted]	[redacted]
easyJet	[redacted]	[redacted]	[redacted]
Thomas Cook	[redacted]	[redacted]	[redacted]
Participant Members			
Norwegian Air Shuttle	[redacted]	[redacted]	N/A
Novair	[redacted]	[redacted]	N/A

Table 2 - CANARIAS Project Focal Points

3.2 Work Breakdown Structure

The CANARIAS project was divided into eight (8) work packages, one which was the overall project management (refer to Figure 2 below). Each work package was led by a Consortium Member with the contribution of other project members and participants.

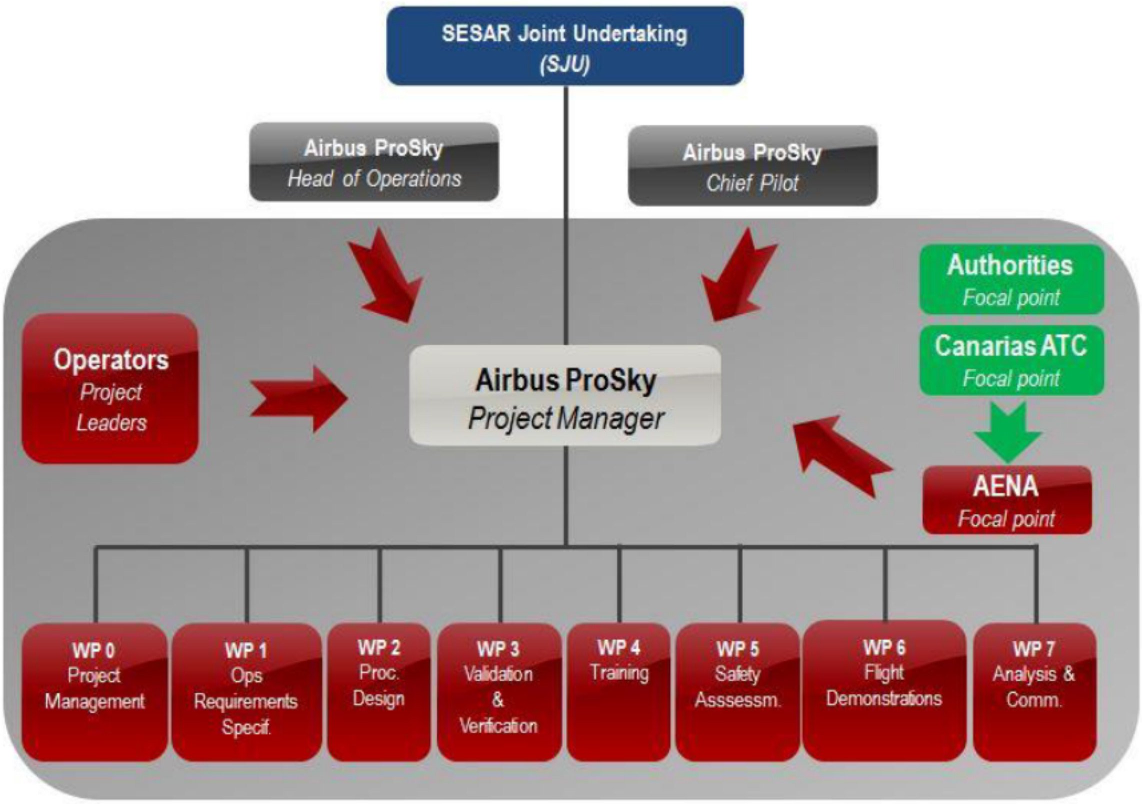


Figure 2 – Work breakdown structure of CANARIAS

The work packages were distributed into three (3) distinct project phases. Figure 3 illustrates the planned and effective dates of the execution of each phase per the tasks required to be completed prior to moving to the next phase. Indeed, there was a significant delay in moving to Phase two (2) (Demonstration Flights), which is explained in subsequent sections of this document.

WP0 (Project Management) was present in all three phases, and thus not displayed in the illustration below.

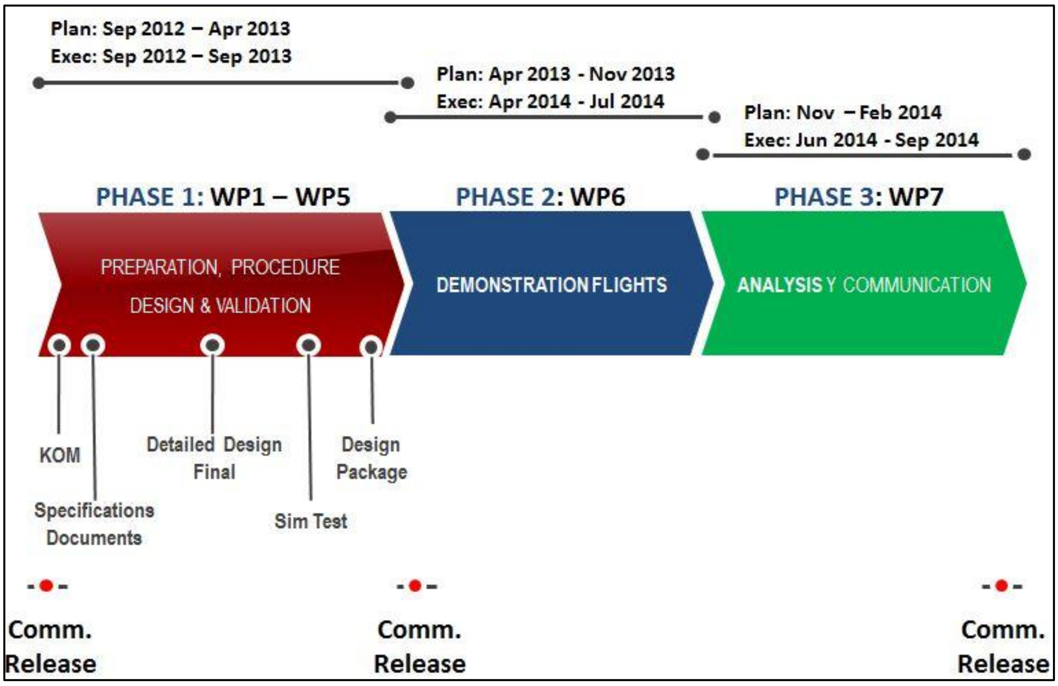


Figure 3 – Work package distribution of CANARIAS Project

Phase 1 of the project was comprised WP1 to WP5, which included overall project management (WP0), procedures design work, safety assessments, and development of operational procedures prior to commencement of the flight demonstration activities. Figure 4 displays the work development and particular milestones that took place during Phase 1 of the project.

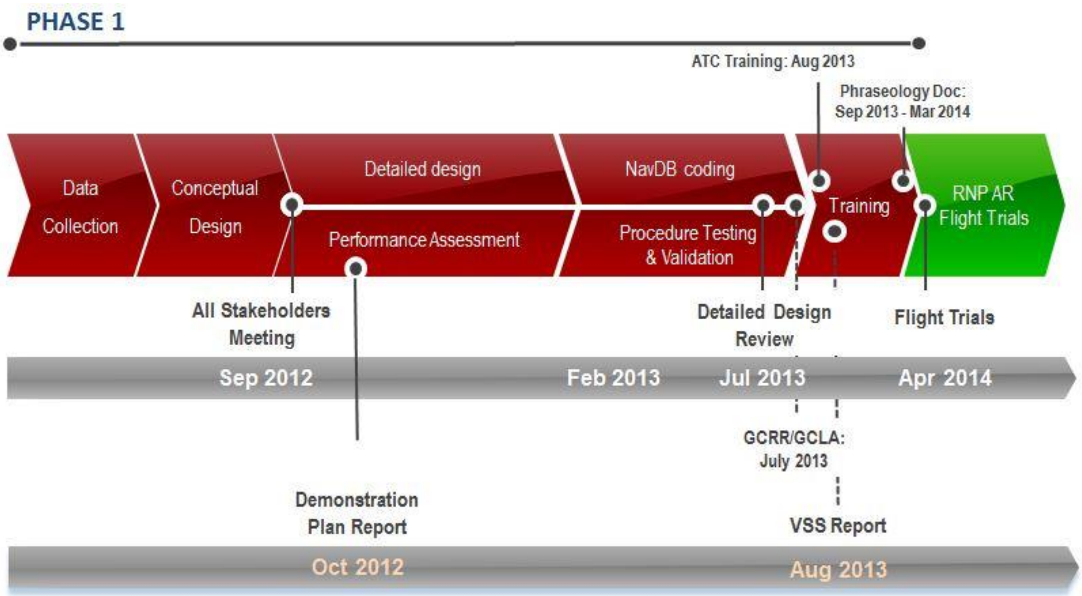


Figure 4 – Phase 1 activity for CANARIAS Project

WP0 (Project Management) concentrated on the overall management and coordination activities of the project, most importantly interfacing with the SJU on behalf of the Consortium Members. Control of the project deadlines, milestones and accomplishments, budget actions, risk management, communications activities and deliverables submission was included as part of this WP.

- Airbus ProSky, as project coordinator, led WP0.

WP1 (Operations requirements specifications) defined the ANSP (Aena) and the airlines operational needs, assessment of local RNP AR regulations, and the requirements for the flight demonstration activities. The main deliverable for this work package was a Project Specifications document detailing the factors and criteria agreed between all project parties for the design of the procedures at La Palma and Lanzarote airports.

- Airbus ProSky and Aena both led WP1;
- Contributors included the remaining Consortium Members and participating airlines.
- Specifications Document final delivery and acceptance by all parties: January 2013.

WP2 (Procedure design) addressed the design of the flight procedures at both airports. The conceptual design was discussed during the Kick-Off Meeting in September 2012, was frozen and reflected in a Specifications Document (output WP1) prior to the start of the detailed design.

The deliverables of this work package were inter-related to the tasks in WP3 as design and testing are two parallel activities. The combine deliverables included: Procedure technical reports, production of navigation database coding and charts resulting from the detailed design work. The final designs for GCLA and GCRR, and related material was analyzed, further tested, and validated by the Consortium Members and participant members prior to the start, during and after the ground and flight simulation tests.

- Airbus ProSky and Aena both led WP2;
- Contributors included the remaining Consortium Members and participating airlines.
- GCRR and GCLA Final Reports: July 2013
- VSS Report: Aug 2013

WP3 (Validation and verification) addressed in parallel to WP2 the ground validation, flight simulator, and aircraft performance tests required as retro-alimentary inputs for the trajectory designs and for the generic Flight Operations Safety Assessment (FOSA) document delivered in WP5 (See Appendix E). The validation and verification tests carried out on A320 and B737 representative simulator devise ensured that the designed procedures were flyable under the agreed parameters.

The deliverables of this work package included the simulator validation test results, and were input for the technical documentation delivered as part of WP2.

- Airbus Prosky led WP3 (A320 Simulator testing) in close collaboration with Norwegian Air Shuttle (B737NG testing) Simulators), Thomas Cook (A320 simulator validation) and Novair.

  Note: The B737NG testing was originally due to be carried out by Consortium Member Air Berlin. Due to unforeseen circumstances, Norwegian (under no obligation) proposed and agreed to carry out the testing for the benefit of the overall project in line with the upcoming demonstration flights.

- Contributors included Consortium Member Aena, airlines and participating airlines.

WP4 (Training) defined the necessary flight crew training to be delivered by the operators participating in the flight demonstrations, and delivered to the Air Traffic Controllers the training requirements and practice for the successful implementation of the flight demonstrations.

The outcome of the testing in WP3 included recommendations in the FOSA regarding necessary training / knowledge items particular for the RNP AR approaches at GCLA and GCRR for operators to disseminate and train the crews. The outcome of the ATC training on location provided the baseline for a Flight Trial “Phraseology and Flight Demonstration Implementation Document” to be agreed between the ATC, the ANSP, and operators prior to the start of the demonstration flights. The latter document took longer than expected to be agreed and implemented, one of the main reasons why the demonstration flights originally scheduled to commence in October 2013 didn’t start before April 2014.

- Airbus Prosky led the ATC Training in WP4.
- AENA led the Phraseology Document exercise in close collaboration with Airbus ProSky.
- Contributors to the output of WP4 included Consortium Member Thomas Cook and project participants Norwegian Air Shuttle and Novair.

WP5 (Safety Assessment) addressed the activities required to produce the generic Flight Operation Safety Assessment document for GCLA and GCRR in parallel to the results of WP2 and WP3. It also addressed and important document, not foreseen at the start of the project, which was an aeronautical technical study regarding obstacles penetrating the designed trajectories Visual Surface Segment at both GCLA and GCRR (in particular), and resulting mitigation measures to be taken into consideration in the delivered technical documentation and charts, and most importantly in the FOSA for crew awareness. A final output of WP5 was a Canarias TMA Impact assessment of the designed trajectories.

- Airbus Prosky and Aena led WP5 delivery of the VSS report.
- Airbus Prosky WP5 delivery of the Generic FOSA report for GCRR (See Appendix E).
- Airbus Prosky and Aena led WP5 delivery of the Generic FOSA report for GCLA (See Appendix E).
- Aena led the Canarias TMA Impact safety assessment of the procedures.

WP6 (Flight Demonstrations and Evaluation) was the identified work package of Phase 2 of the CANARIAS project. The original plan was to have a minimum of 100 total demonstration flights for the RNP procedures at GCLA and GCRR combined. The operators accomplished only a total of eight (8) demonstration flights (4 at GCLA and 4 at GCRR).

The aircraft equipment utilized on these flights was based mainly on operator’s availability and a matching trained crew to carry out the flight demonstrations. Environmental factors (such as predominant winds) played a key role in the demonstration flights at GCRR, and the initial unavailability of operators flying to GCLA played a key role in the demonstrations at CGLA.

There was no effect during the flight trial period due to availability of trained Air Traffic Controllers.

The deliverable of this work package included comparison from aircraft Flight Data outputs and Radar captured data for conventional and RNP AR flights.

- Airbus Prosky, Aena and Consortium operator (Thomas Cook Airlines) led WP6.
- Contributors to the output of WP6 included participant project operators Norwegian Air Shuttle and Novair.
- EUROCONTROL provided collaboration via the utilization of the V-PAT analysis Tool.

WP7 (Analysis and Communication) was the identified work package of Phase 2 dedicated to the Awareness & Dissemination activities related to the CANARIAS project. Figure 5 below provides a view of the milestone related project communications. See also Section 0 of this document for further details.

Figure 5 – Milestone Communication activities for CANARIAS project

- Airbus Prosky led WP7.
- Contributors to the output of WP7 included Consortium Members Aena and Thomas Cook, and project participants Norwegian Air Shuttle and Novair.

3.3 Deliverables

The CANARIAS Kick-Off meeting took place on 24th September 2012 at Aena's premises in Madrid. The following dates were met for the various deliverables.

Deliverable Name	Date
Demonstration Plan (A1)	December 2012 (approved in January 2013)
KOM Minutes of meeting	September 2012
Acceptance Review #1	nil
Procedure Technical Reports (Ops Package)	July 2013
ATC Training (Specific)	September 2013 (3 days On location)
FOSA (Generic)	GCRR: October 2013 GCLA: January 2014
Aeronautical Study on Visual Surface Segment for GCLA and GCRR	May 2013
Technical Review	July 2013
Start of flight trials	April 2014
Flight Demo Review	nil
Final Review	October 2014
Demonstration Report (B1)	September 2014 (Initial)

Table 3 - Formal deliverable dates

3.4 Risk Management

A risk is any foreseeable circumstance that might affect the project in a negative way, and which shall be identified as early as possible in order to plan mitigation actions and reduce or eliminate the risk altogether where possible.

A Consortium member was assigned the management of each identified risk. Below is the table with the risks identified per work package during the development of the project, and dully identified in the project Quarterly Reports.

WP	ID	Risk description	Probability assessment (Low / Medium / High / Very high)	Severity assessment (Low / Medium / High / Very high	Mitigation actions	Owner
WP 1	**1.1**	The members of the Consortium do not agree on the project planning and execution.	Low	Medium	Assure planning before KoM and A.1 delivery.	**APS** Mitigated - end of 2012
WP 2	**2.1**	The members of the consortium do not agree on the conceptual designs / request a change of airport.	Low	High	Ensure that airline's operational input is considered prior to the conceptual designs and during the detailed designs	**APS and Aena** Mitigated – July 2013
WP 2	**2.2**	Spanish Regulatory and Safety Authorities do not accept the RNP AR designed procedures and mitigation means for the obstacles penetrating the Visual Surface Segment at both GCRR RWY 21 and GCLA RWY 01.	Medium	High	VSS assessment report including mitigation procedures and explanation to the authorities that RNP AR procedures, compared to conventional procedures, provide enhanced trajectories, detailed design with obstacle protection areas, required crew training and minimum operational equipment	**APS and Aena** (Mitigated – October 2013 with VSS report and with the ATM impact assessment in March 2014.
WP 6	**6.1**	The aircraft operated by the Consortium members are not equipped / capable to fly RNP AR procedures.	Low	High	Liaise with operators to ensure that relevant equipment will be available for the demo. Flights.	**Operators** Mitigated – April 2014
WP 6	**6.2**	Operations requirements by the Spanish Regulatory Authorities for the demo flights cannot be met by operators.	Low	High	Work with operators and local authorities to ensure that flights are carried out in VMC conditions. Provide necessary documentation to Authorities (if necessary).	**Operators** (Mitigated – April 2014)
WP 6	**6.3**	Trained ATC personnel do not authorize RNP AR procedures during demo flights. (i.e. Traffic constraints do not allow)	Low	High	Aena to liaise with ATC and provide advanced flight schedules to help operators receive proper clearance during the demonstration flights.	**Operators** Mitigated – April 2014
WP 6	**6.4**	Flight trials at La Palma cannot be implemented	Medium	High	Air Berlin was the only operator in the	**APS**

		due to lack of operators in the project flying to this destination.			CANARIAS project flying to La Palma compared to the ones flying to Lanzarote. This created an inherent risk for the flight trials. Norwegian started operations to La Palma in June 2014 and provided flight trial data.	Partly Mitigated – July 2014
WP 7	**7.1**	Figures retrieved from Flight Data captured by operators during the RNP AR demo flights is not comparable to Flight Data captured for conventional procedures.	Low	Medium	Ensure that operators capture as much FDM data as possible prior to RNP AR trials. Consortium Member Thomas Cook provided 16 Conventional Flights for comparison. However, due to few RNP AR operations at GCRR, the comparable data is extremely limited. Participant Member Norwegian Airlines provided RNP AR data for GCLA but it can only be compared to small amount of conventional data to same destination.	**APS and Operators** Partly Mitigated – July 2014

Table 4 - Identified and reported project risks

Risk 1.1 (WP1) was mitigated by the end of 2012 as the Consortium Members agreed on the project planning and execution during the KoM.

Risk 2.1 (WP2) was mitigated during the Critical Review Meeting / Detailed Design Review Meeting held in Madrid on the 10th of July 2013. Airbus ProSky also received the signed specifications documents by all Consortium Members.

Risk 2.2 (WP2) identified during the Quarterly Report of the 1st Quarter 2013 was considered to be mitigated after completion of the meeting between Aena and the Spanish Safety Agency regarding the start of the demonstration flights, and provision of the ATM impact assessment. VSS study was also presented to the authorities.

Risk 6.4 (WP6) was identified in Quarterly Report number 4 as a significant risk and was partly mitigated with the eventual initial flights at GCLA completed by Norwegian Air Shuttle.

La Palma:

Currently Air Berlin was the only operator of the CANARIAS project flying to La Palma airport, which posed an inherent risk to the demonstration flights. On-going talks started with Thomas Cook for a potential participation of Condor to carry out the GCLA flight trials which would help reduce the severity of this risk (or mitigate altogether). However flights didn't take place. Norwegian Air Shuttle initially stated that they would not carry out flight trials to La Palma being a new airport destination but eventually they did as the approach design was more appropriate than the one currently published in the AIP.

Lanzarote:

Risk was raised in the possibility of not completing the flight demonstrations: Novair finalized its flights for the season (only two flight trials completed due to the delayed start of the exercise). Norwegian Air Shuttle would try to continue the flight trials from its Gatwick base. The demonstration

Due to the limited amount of flights operating to Lanzarote, the light trials relied on three main random factors: Thomas Cook flight schedule, predominant winds to runway 21, and traffic.

Risk 7.1 **(WP7)** was identified and set as a priority at an early stage of the project as some Consortium and participant operators had provided a small amount of base line data, which was not enough and had to be validated and compared to the ones of the RNP flight demonstrations. The risk was partly, but not completely mitigated as some operators were not able to provide enough base line data, and a small amount of demonstration flights were carried out hindering the necessary amount of comparable data for appropriate results and conclusions per the set objectives.

4 Execution of Demonstration Exercise

4.1 Exercise Preparation

The preparation activities included all those necessary to prepare the design, assessment, validation and implementation of the RNP procedures. These include:

- Determining the operational needs, TMA and environmental considerations to propose optimal solutions and design of optimized RNP flight paths;
- Assessing ATCOs constraints and needs to define the desired solution that will fit with local traffic management strategies, and enable TMA capacity increase when using the RNP arrival tracks;
- Assessing the local regulations to agree on acceptable regulatory baselines with the local authorities prior to approval and full implementation of the procedure upon project completion;
- Assessing local requirements and constraints and thus ensure that the planned procedures can be easily implemented in the airport environment (i.e.: obstacles, noise-sensitive areas, airspace constraints).
- Agree with the operators the considerations and assumptions of the flight data to be captured during flights completed using the conventional procedures applicable to the airport, and those completed using the RNP AR flights during the demonstration phase of the project.
- Coordination with the ATS Canary Region.
- ATCO's to provide direct clearances, traffic permitting.

4.2 Exercise Execution

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise start analysis date	Actual Exercise end date
EXE-01.01-D-001	RNP STARs and RNP-AR approaches demonstrations into RWY 01/19 of La Palma airport (GCLA)	Oct 2012	Aug 2014	Jul 2014	Sep 2014
EXE-01.01-D-002	RNP STARs and RNP-AR approach demonstrations into RWY 21 of Lanzarote airport (GCRR)	Oct 2012	Aug 2014	Jul 2014	Sep 2014

Table 5 - Exercises execution/analysis dates

The CANARIAS project was launched on 24 of September 2012 in Madrid with the participation of the Consortium Members, with a maximum duration of 24 months. The demonstration flights into Lanzarote and La Palma were due to be performed between September 2013 and April 2014, but they started in Lanzarote in April 2014 after a delay of 7 months, and in La Palma in July 2014 after a delay of 10 months.

A total of four (4) demonstration flights where performed at Lanzarote due to predominant wind conditions not feasible for RWY 21, and four (4) demonstration flights where performed at La Palma due to the initial unavailability and then late start of available operations by a project member to GCLA.

Due to operational requirements and external factors to the project (mainly weather and operator availability), the flight demonstrations started approximately 7 months later than originally planned.

The flight demonstrations were suspended under agreement by the Consortium and SJU in Mid-September 2014 for two main reasons:

- Operators could not guarantee a dedicated number of demonstration flights to La Palma.
- Additional demonstration flights could not be guaranteed to Lanzarote due to the predominant winds for RWY 03; while winds for RWY 21 are mainly predominant during the winter season (last available demonstration flight into GCRR took place on 21/04/2014.

Besides the above mentioned reasons, a possible extension of the flight demonstration period was discarded as TMA in Canarias has changed at the end of September 2014, creating a potential hazard for controllers to operate the updated TMA and demonstration flights at same time

As a result, it is noted that availability of scheduled flights and operators matching a qualified aircraft and qualified crew, adequate runway in use, and availability of Visual Meteorological Conditions, contributed to the decision to suspend the flight demonstrations.

Along the duration of the project, a tight planning and optimal cooperation between the Consortium Members, Participant operators and ATC was required to successfully execute the flight demonstrations and retrieve appropriate data for analysis. The Consortium Leader continuously monitored and reminded the project participants of the tight planning.

In order to have a wide picture of the activities that had to be completed before during and after the demonstration flights, it is necessary to understand the step by step process of the procedure design, and the geographical context (and area limits) in which these procedures were implemented. The intended and final ways in which data was due to be captured to meet the objectives of the project is explained within each exercise (Refer to Section 0 of this document.

The procedure design process is composed of the conceptual design and the detailed design. When tasked to design procedures, a conceptual design is performed for each airport taking into account the environmental constraints together with the ANSP's and operator's requirements. Items such as the aircraft models, speeds, ATC procedures, AIP information, and operational constraints are all factors taken into consideration during the conceptual design. These design(s) are then presented and discussed during the Kick-Off Meeting.

After presentations and discussions between the interested parties, the conceptual design, project objectives, project planning, applicable regulations were summarized and included in a Project Specifications document, which was agreed and validated formally by all stakeholders on the 21st of January 2013 prior to the start of the detailed design.

During the detailed design of the procedures, the project managers from Airbus ProSky and AENA and procedure designers had to ensure that the intended trajectories took into consideration all constraints identified in the conceptual design, ensure paths were flyable and complied with the performance of the aircraft types intended for the procedures. Each flight leg of the procedure was checked to ensure that the aircraft was capable to fly the different constraints (altitude, speeds, and turn radius). No significant changes between the conceptual design and the detailed design took place, which meant that the methodology and final conceptual designs for both airports were deemed adequate and appropriate by all stakeholders.

Each RNP AR instrument procedure was thoroughly evaluated in a representative simulator to:

- Verify the fly ability of new designed instrument procedure;
- Define adequate normal and abnormal flight crew procedures;
- Validate the FMS navigation database coding; and
- Evaluate the absence of TAWS warning when the aircraft is on the nominal flight path.

The effect of the aircraft behavior was taken into consideration and evaluated in variable conditions such as normal or rare wind and temperature conditions (Maximum and Minimum per the RNP AR designs and as stated in the procedure technical reports).

Testing and validation of the designed procedures was completed on Airbus A320 simulators at the Airbus Training Center in Toulouse, and on CAE 737NG Simulator in Oslo (Norway). Additional testing was carried out by Novair, Thomas Cook, and Norwegian Air Shuttle prior to the start of the demonstration flights.

A detailed design review meeting and project review meeting was held with all involved parties on 4th June 2013 to conclude on the particularities of the final design and procedure trajectories prior to final coding and charting. In addition a technical report and a flight operation safety assessment were produced for each airport providing pertinent information for the ANSP and operator to prepare training items for crews and ATCOs, and for the authorities (when involved) to deliver any authorizations required by the interested parties upon successful completion of a flight (FFS or live) demonstration. Table 6 provides a summary of the GCLA and GCRR design package deliverables to SJU and the Consortium.

Airport	Design Technical Report	NDB Coding	Charts	FOSA
GCLA	14th June 2013	14th June 2013	14th June 2013	7th March 2014
GCRR	4th September 2013	5th September 2013	9th September 2013	8th October 2013

Table 6 - Design Package Deliverables

4.2.1 Exercise execution – Flight Data

To achieve the objectives of the project, consortium and member airlines were asked to provide flight data for a minimum of 10 conventional flights. Selected conventional data was provided by three operators to establish an initial methodology for comparison with the data captured during the RNP AR demonstration flights planned.

For details on the data capture methodology, refer to Section 5.1.4.2 of this document.

4.2.2 Exercise execution – V-Pat Analysis

The V-PAT tool, which stands for **V**ertical **A**pproach **A**nalysis **T**ool, is a metrics tool for analyzing vertical approaches developed in a way to enable users assessing flight performance individually as well as overall statistical results for large datasets. The tool, used in the AIRE Programme, operates with ASTERIX surveillance data or CFMU correlated position reports.

V-PAT utilized set parameters to assess the performance of flight approaches such as fuel burn for each arrival (based on BADA model), CO2 emissions, noise impact and comparison as well as visual data for routes and vertical profiles flown in the approach. All these features, together with a highly automated work environment, made V-PAT a potential appropriate tool for the CANARIAS project exercises analysis.

The analysis of V-PAT targeted the comparison of routes, vertical profiles, fuel burn rates, CO2 emissions and noise estimations between a selection of conventional flights and a selection of the executed flight trials for which data was retrieved from the ASTERIX surveillance data. The objective of these comparisons was to assess the potential benefits of the RNP procedures against the conventional ones.

Due to impossibility to identify by date the initial specific conventional flights provided by the operators as baseline data, a random selection of potential comparable flights was retrieved via the ASTERIX surveillance data which not necessarily provides the expected comparable results. Currently further analysis is underway, and results are expected to be received by the end of October 2014.

4.2.3 Exercise execution – Phraseology

To mitigate the impact of introducing new trial procedures within an operational TMA, a specific phraseology document was created and agreed between the CANARIAS Consortium members, participating operators, and ATC. The objective was to set an agreed process for the execution of the demonstration flights, implemented through ATC training and trial operations, without increasing workload on both parties.

Below is an illustration of the developed phraseology document implemented in the CANARIAS Project, which we believe could be replicated in future demonstration activities of this sort.

4.2.3.1 Phraseology for the CANARIAS Demonstrations (En route)

The following ATC phraseology has been developed and used for the CANARIAS TRIALS in the route phase.

ATC ROUTE:	CREW:
	CREW: Flight (Call sign and Number) over (Entry point), requesting **Trial RNAV Approach** to (Airport) Example: "Norwegian 9651 over ORTIS, requesting **Trial RNAV Approach** to La Palma RWY01"
ATC Route Flight (Call sign and Number), roger, cleared to (IAF) via (STAR) Example: "Norwegian 9651, roger, cleared to XISLA via ORTIS 1X Standard Arrival"	
NOTE: ✓ Normally the collateral (CASABLANCA/LISBON) should have been informed, if not, ATC will rapidly inform to the ATC Service Supervisor. ✓ The authorized STAR will be used exclusively for the CANARIAS trials. The identifier of the CANARIAS STARS may vary with respect to the ones currently published in the Spanish AIP.	
GCRR RWY 21 Case	
	Crew: Norwegian 9651 over (entry point), requesting Trial RNAV Approach to Lanzarote RWY21 Example: "Norwegian 9651 over DEVLA, requesting Trial RNAV Approach to Lanzarote RWY21"
ATC Route: Norwegian 9651, roger,), roger, cleared to (IAF) via (STAR) Example: "Norwegian 9651, roger, cleared to KLATO via DEVLA 1R Standard Arrival"	

ATC ROUTE:	CREW:
	Crew: Norwegian 9651 proceeding direct to /heading (point/heading cleared by Casablanca), requesting Trial RNAV Approach to Lanzarote RWY21 Example: "Norwegian 9651 proceeding direct to LZR, requesting Trial RNAV Approach to Lanzarote RWY21"
ATC Route: Norwegian 9651, roger, after (entry point) cleared to RR488 via (STAR) Example: "Norwegian 9651, roger, after TERTO cleared to RR488 via TERTO 1R Standard Arrival"	
	CREW: Flight (Call sign and Number), request descend Example: "Norwegian 9651, request descend"
ATC ROUTE: Flight (Call sign and Number), roger, descend to (Flight Level) Example: "Norwegian 9651, roger, descend to Flight Level 250"	
ATC ROUTE: Flight (Call sign and Number), contact approach (frequency) Example: "Norwegian 9651, contact approach frequency 133.675"	
NOTE: For **Continuous Descent** procedures **there should be no shortcuts** once the descent is initiated.	

Table 7 - CANARIAS Phraseology: En route

4.2.3.2 Phraseology for the CANARIAS Demonstrations (Approach)

The following ATC phraseology has been developed and used for the CANARIAS TRIALS in the approach phase.

ATC APPROACH:	CREW:
	CREW: Flight (Call sign and Number), reaching (cleared Flight Level), requesting Trial RNAV Approach to (Airport, RWY) <u>Example:</u> "Norwegian 9651 reaching Flight Level 250, requesting Trial RNAV Approach to La Palma runway 01"
ATC APCH: Flight (Call sign and Number), roger, descend to (flight Level/Altitude), report when in VMC. <u>Example:</u> "Norwegian 9651, roger, descend to Flight Level 100, report when in VMC".	
NOTE: It is mandatory that the crew declares he/she is in VMC. It is a safety requirement for the flight trials. In case the crew would not be or could not maintain VMC, the approach will not be performed and this traffic will be treated as a nominal one using the published procedures.	
	CREW: Flight (Call sign and Number), can maintain VMC <u>Example:</u> "Norwegian 9651, can maintain VMC"
ATC APCH: Flight (Call sign and Number), roger, cleared to visual approach Runway XX. Maintain own separation from preceding (aircraft type and wake turbulence category as appropriate) [CAUTION WAKE TURBULENCE] <u>Example:</u> "Norwegian 9651, roger, cleared to Visual approach to La Palma Runway 01". "Maintain own separation from preceding (aircraft type and wake turbulence category as appropriate) [CAUTION WAKE TURBULENCE]"	

<table>
<tr><th>ATC APPROACH:</th><th>CREW:</th></tr>
<tr><td></td><td>CREW:
Flight (Call sign and Number), roger, we are cleared to visual approach Runway XX. I will proceed with Trial RNAV Approach to La Palma Runway XX
<u>Example:</u>
“Norwegian 9651, roger, we are cleared to Trial RNAV Approach to La Palma Runway 01”</td></tr>
<tr><td colspan="2">NOTE:
✓ The Word “TRIAL” is mandatory in the phraseology when requesting the authorization and it must not be omitted.
✓ CANARIAS IAC procedures include a range of the temperatures to perform the approaches. These must be taken into account (see sections 5.1 and 5.2). Information is particularly relevant for aircraft equipped with uncompensated Baro-VNAV systems. It remains the crew’s responsibility to be ensure that prior to starting the approach the temperature is within the stated range.
✓ The limit altitude for reporting VMC conditions for the CANARIAS trials will be 5000 ft. for both GCLA and GCRR airports.</td></tr>
<tr><td>ATC APCH:
Flight (Call sign and Number), contact (Airport) Tower on (Frequency)
<u>Example:</u>
“Norwegian 9651, contact La Palma Tower on frequency 118.9”</td><td></td></tr>
</table>

Table 8 - CANARIAS Phraseology: Approach

4.2.3.3 Phraseology for the CANARIAS Demonstrations (Approach) Procedure Cancelation

There are several scenarios to be considered which may require a cancellation of a CANARIAS approach:

- Not possible to maintain VMC: This situation will mean to cancel the approach.

  Pilot intentions will be required.

- RNAV (RNP) navigation not possible: This situation will mean to cancel the approach.

  The traffic in this situation will follow the published procedures. The RNAV (RNP) missed approach will not be used. ATC will provide the suitable instructions for guarantying the safety and the traffic will be reintegrated in the nominal operation.

- Violation of the trials parameters: In case of violation of the trials parameters, the approach will be cancelled.

  Unless specific ATC instruction, the RNAV approach could be tried again. This situation could mean to follow ATC instructions towards the published RNAV holding pattern or to follow the suitable RNAV missed approach. Crews are trained to revert to the nominal procedures at any time. This action will only be executed when considered essential.

4.2.3.4 Phraseology for the CANARIAS Demonstrations (Missed Approach

In such a case an operator operating a CANARIAS demonstration flight requires to carry out a Missed Approach / Go Around, the designed RNP AR missed approach can be utilized.

Unless there are particular exceptional circumstances, flying the RNP AR missed approach will not be required a new ATC instruction or new phraseology.

4.3 Deviations from the planned activities

4.3.1 Deviation - VSS assessment and mitigations

During the detailed design stage of the procedures for La Palma and Lanzarote, designers highlighted that an unexpected study covering obstacles penetrating the Visual Surface Segment would be required. Further and based on the recommendations of applicable design documentation, Airbus ProSky and Aena agreed that in an eventual implementation of the procedures the Local Authorities would require a similar study, which per se required a significant amount of time to complete.

The VSS report was one of the reasons why the design of the procedures and presentation to the Local Authorities took longer than expected (Ref: [9]).

A report (Ref: [9] of 8th of May 2013) was developed covering the VSS assessment and proposed mitigations for the scenarios considered in the CANARIAS Project. This document was treated as a potential future requirement from AESA for these scenarios which are well known for obstacles penetrations in the VSS.

VSS penetration of current operational NDB instrumental approach procedure for RWY01 at La Palma had been assessed by Aena previously through an aeronautical study (REF: [10]) which demonstrated that the operational safety is completely guaranteed. In lieu of this, the CANARIAS Project team decided to address the VSS assessment from the early stages of the RNP AR procedure design in order facilitate the potential implementation of such procedures in the future.

Spain is now facing the situation of implementing RNP / RNP AR procedures at airports where there are VSS obstacle penetration. As stated in ICAO Doc. 8168 during such situations, an aeronautical study is required in order to assess safety and operational impact under these circumstances. As Aena faced this situation for the first time in the design of PBN procedures, this report proved to be very helpful establishing a starting point of discussion with Spanish AESA.

Currently, there is major uncertainty about what to include in such aeronautical studies and how to mitigate the VSS penetrations. This VSS reports was a step forward to find a satisfactory solution with AESA in the future.

ICAO Doc. 9905 “Required Navigation Performance Authorization Required (RNP AR) Procedure Design Manual” does not specify neither the definition nor dimensions of Visual Segment Surfaces. For this reason, the CANARIAS procedures designer considered the current available guidance material from ICAO and FAA and specific consultancy processes were set out with the IFPP experts groups.

For the final procedures design phase at La Palma, only the VSS based on FAA criteria was considered as it is correlated with the RNP AR APCH philosophy and the existing conventional VSS assessments was a valid starting reference whenever the ICAO VSS criteria wanted to be used for the RNP AR procedures.

In the case of Lanzarote, interpretation of Doc. 8168 was taken primarily assessing a higher VPA, threshold displacement, or a mixture of both. Since options were limited and obstacles slightly penetrated the VSS close to the runway, operational and non-operational mitigation measures were put in place, including charting the obstacles and specific debrief for crews.

Considering the scenarios of the CANARIAS project, the VSS report aimed to provide AESA with the required information to address the selection of the most suitable RNP AR approach procedures to be tested in Full Flight Simulators and then via demonstration flights at La Palma and Lanzarote.

The VSS report developed in the frame of the CANARIAS Project is considered absolutely necessary by Aena. This will ensure to have a starting point for a future implementation of the scenarios following the established procedures.

4.3.2 Deviation – Phraseology Documentation and Safety Assessment for Demonstrations

The review and approval of both the Phraseology Document and preparation of the final generic Flight Operations Safety Assessment for La Palma RNP AR procedures suffered unexpected delays which ultimately lead to a late start of the flight trials.

During the development of Phase 1 of the CANARIAS project, the Consortium was unable to foresee the complexity of the internal approval process within the ANSP. Delay for operators to provide necessary feedback and information was also a factor contributing to this deviation from the original plan. The plan was to have all documentation ready for a demonstration plan commencing in October 2013 (ultimately starting in April 2014). The delay was duly noted in the Quarterly Report and addressed in the risks of the project.

Consortium member Aena carried out an internal safety assessment to guarantee that the flight trials were completely safe and they did not represent a functional change in the TMA by carrying them out in visual conditions. The following activities were completed to this effect:

- Operational coordination activities with the collateral:

  The coordination and responsibility transfers required between the Canarias ACC and collateral (Casablanca ACC, Lisboa ACC, La Palma TWR, and Lanzarote TWR) were established through phone coordination or existing agreement letters (no modification of the LoA's in force was necessary).

- Phraseology:

  Definition of phraseology to be used by the airborne crews and ATC personnel involved in the flight trials, for the route phase as well as for the approach. The word "TRIAL" was defined as mandatory in the authorization request and also the pilot declaration of being in VMC conditions (limit altitude to report VMC conditions was defined as 5000ft. for both airports).

- Generic FOSA (Flight Operations Safety Assessment):

  As stated in ICAO Doc. 9613 (PBN Manual) regarding the RNP AR APCH, FOSA studies were completed for both La Palma and Lanzarote (See Appendix E). Among other aspects, mitigation ways for the potential effects of deviations in the Doc. 9905 (RNP AR procedures design) in the procedures design were established, specially the penetrations in the VSS for Lanzarote RWY 21.

- Study of the impact in the ATC system (SACTA):

  Aiming to assure the compatibility of the flight trials with the conventional traffic, several simulations were carried out with a satisfactory output, showing the complete compatibility of both traffics. Since the procedures for the demonstration activities were not published in the Spanish AIP, and therefore were not in the flight plans, the database of the system was updated to provide this information and visual aid to the ATC.

Following are fragments from the completed safety assessment, and safety conclusion statement necessary to start the flight demonstrations.

Provided that:

- The RNP AR APCH flight trials for La Palma and Lanzarote airports will be done only under VMC conditions, and therefore ATC will authorize visual approach.
- The minimum altitudes for the trial approaches are above the minima of the sectors established for vectoring in the radar chart published in the Spanish AIP.
- There is appropriate radio and radar coverage in the area where the trials will be executed.

- The arrival and approach charts developed for the trials, will not be published in the AIP-Spain and will be distributed only to the operators involved in the trials, possible confusion with the companies not part of the CANARIAS Project will be avoided.
- All the charts distributed to pilots and ATC will contain the notes “EXPERIMENTAL CHART” and “ONLY FOR FLIGHT TRIALS” or “NOT FOR OPERATIONAL USE”.
- The pilot will always include the Word “TRIAL” when requesting the authorization and will declare he is under VMC conditions.
- Trials will be always subject to ATC authorization, and this will be issued only when traffic conditions are appropriate to not interfere with the conventional Canarias TMA traffic.
- There will be no changes in AIP-Spain, or in flight plans, or in existing agreement charts or in standard operational procedures. Therefore, the normal operation of Canarias ACC will not change.
- As stated in ICAO Doc 9613, FOSA studies have been completed for the RNP AR APCH (See Appendix E).
- RNP AR APCH maneuvers have been designed following the ICAO Doc. 9905, and where was not possible to satisfy the recommendations, associated mitigation actions have been established in the FOSA studies.
- Arrival procedures trajectories will be included in the local maps of SACTA, in order to provide information and visual aid to ATC.
- The Canarias operational personnel will be informed of the flight trials through a specific operational communication letter (which will specify the flight procedures, flight conditions, phraseology, information added to local SACTA maps, etc.) distributed at least 10 days before the trials start.

The execution of the flight trials planned in the CANARIAS project does not imply a significant change in the Canarias TMA normal operation, and therefore additional actions regarding operational security are not needed.

4.3.3 Deviation –Operators not able to carry out demonstration flights at GCRR

Due to operational requirements, external factors to the project (i.e. weather) and as mentioned in Section 4.3.2 the delayed approval of the Phraseology Document to be used during the flight trials (released in March 2014), the flight trials to Lanzarote began seven (7) months later than planned missing the crucial winter season which is the period of time in which predominant winds favor RWY 21.

This particular item was identified in the A1 Demonstration Plan, Table 2: Summary of the scope for GCRR RNP procedures (Reference [6]), in which it was stated that “Predominant winds do not favor RWY 21 during most of the year, therefore data collection on conventional flights depends this factor”. In this same document within Section 5.2.1.5.1 - Reference & Solution Scenarios, it was indicated that According to available statistics, during 2011 there were approximately 24945 approaches combined between RWY 03 and RWY 21, of which only 6.6% pertained to the latter runway due to the average predominant surface wind conditions favoring RWY 03.

The effect was that one Consortium operator was able to carry out only one RNAV flight to RWY 21. In addition, a second Consortium operator flying daily to GCRR was unable to carry out the flight demonstrations for unforeseen circumstances. Two participant operators were able to carry out very limited amount of demonstration flights as their scheduled flights to GCRR were due to be over in April. The combination of these factors were detrimental to the amount of flights that could have been recorded in the little time available, and was duly noted by the Consortium Leader to SJU and the Consortium members in repeated occasions.

In summary, four (4) flight trials took place between the April / May 2014 period after which no other flight trials took place due to the predominant winds.

Main issues encountered during the demonstration period included:

- Availability of capable aircraft to fly RNAV procedures.
- Adequate runway in use (RWY 21).
- Weather and wind suitable for a VMC approach.

Even though significant data comparing reduced track miles and fuel consumption might not be present, Thomas Cook and Novair recommend the implementation of the RNAV procedure to Lanzarote RWY 21 for accessibility, predictability stability, and safety reasons which in itself constitute a success for the project (refer to Section 7.3.1 of this document).

4.3.4 Deviation – Lack of Operators to carry out demonstration flights at GCLA

Contrary to the environmental constraints at Lanzarote RWY 21, La Palma contemplated the demonstration activities to take place at both runway ends, increasing the chances of having at least 50 demonstration flights completed within the set period of time.

The project started with an inherent risk (dully identified in the various Quarterly reports to SJU), by having only one Consortium operator flying to this destination. For unforeseen circumstances, this operator was not able to provide flight data, and had to retrieve from the demonstration activities in January 2014.

Research for available participant operators flying to GCLA and willing to carry out the flight demonstrations and provide base line and RNAV flight data was very challenging. Norwegian Air Shuttle agreed to carry out the flight demonstrations, except that their scheduled called a start of operations in the summer of 2014. An additional factor was that this was a new destination for Norwegian Air Shuttle, and management crews would need to agree flying trial flights into a new destination adding a potential risk factor.

Said this, Norwegian Air Shuttle preferred the RNAV procedures over the conventional ones based on their stability, predictability and additional safety margins compared to the former. Norwegian Air Shuttle was able to carry out four (4) demonstration flights to RWY 01 at La Palma between the periods July-September 2014.

In summary, the lack of Consortium and participant operators flying to La Palma was detrimental for the execution of the demonstration flights. Even though significant data comparing reduced track miles and fuel consumption might not be achieved as an objective, Norwegian Air Shuttle strongly recommends the immediate implementation of the RNAV procedures at La Palma for accessibility, predictability stability, and safety reasons which in itself constitute a success for the project (refer to Section 7.3.1 of this document).

4.3.5 Deviation – Lack of comparable base line data for GCLA and GCRR

The demonstration activities for Lanzarote RWY 21 and La Palma RWY 01/19 expected the operators to start collecting and processing specific data from conventional procedures as soon as the project Consortium agreed on the output indicators.

For GCRR, a Consortium operator provided data for 16 conventional flights to RWY 21, one participant operator provide 2 conventional flights, and a final participant operator provided 1 conventional flight to RWY 21. One Consortium operator was unable to provide flight data due to unforeseen circumstances. The base line data was not provided as expected prior starting the flight demonstrations.

For GCLA, the inherent risk at the start of the project having only one operator flying to this destination, which for unforeseen circumstances was not able to provide flight data, promoted the situation of having no base line data for this airport. Participant operator Norwegian Air Shuttle was able to provide only one (1) conventional base line flights to RWY 01 since it started operating to this airport during the summer of 2014.

The lack of volume base line data to Lanzarote RWY 21 and to La Palma RWY 01 and RWY 19 (even though no RNP AR demonstration flights landed on this runway) resulted in diminished significant comparable data to RNP AR demonstration flights.

In addition, the conventional data is “de-sensitized”, meaning that information (such as date of flights) is removed from the data. This created an inherent risk for V-PAT analysis as most conventional flights cannot be retrieved using ASTERIX surveillance data, and comparison was carried out to a random similar flight operating to the airport.

5 Demonstration Exercise report

5.1 Demonstration Exercise Report

5.1.1 Exercise Scope

5.1.1.1 Exercise Level

The demonstration exercise of CANARIAS project covers RNAV STARs and RNP-AR approaches demonstrations into RWY 21 of Lanzarote airport and RWY 01/19 of La Palma airport.

5.1.1.2 Description of the Operational concept being addressed

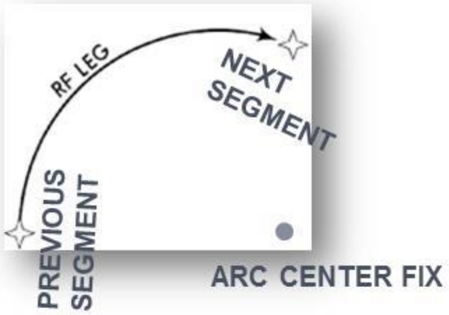
The introduction of PBN is a proven-concept that allows many operational benefits for all aviation stakeholders: Airlines, air traffic management organizations, airports, and communities.

ICAO Resolution A37-11 urges States to build and deploy a PBN implementation plan / roadmap by 2016 including Performance-Based Navigation (PBN) Approaches with Vertical Guidance (APV). SESAR in Europe and Next Generation Air Transportation System (NextGen) in the US are based on the application of PBN, and this concept is already a proven reality in many countries worldwide even though deployment in some regions has not been as extensive as in others. It is very important that the implementation focuses on quality rather than quantity.

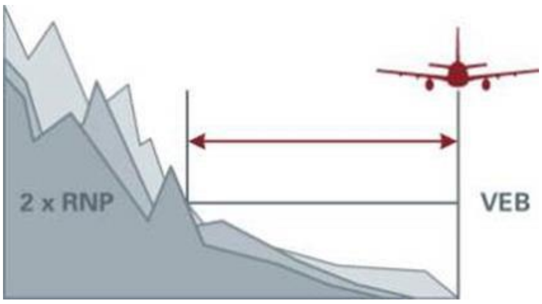
In lieu of to the flexibility and characteristics offered by GNSS based RNP and RNP AR procedures, these were considered an optimal and necessary solutions for both La Palma and Lanzarote exercises to meet the set objectives offering stable, managed, repeatable and purposely studied trajectories.

An RNP AR procedure has one of the following characteristics:

- Reduced RNP values lower than 0.3 NM in approach (down to 0.1 NM) or lower than 1 NM in missed approach and/or departure;
- Curved flight path after FAF (RF legs);



- Reduced obstacle protections, at 2xRNP, without buffers laterally and using a VEB vertically.



Procedural and operational improvements within busy TMAs as expected in the CANARIAS project, are covered by SESAR Traffic Synchronization Priority Business Needs, more precisely by OFA 02.01.01, OFA 02.02.0.

5.1.1.3 Demonstration objectives and hypothesis

The **first objective (OBJ-01.01-1)** of the demonstration exercises was to achieve fuel savings and CO_2 emissions reduction by utilizing RNP STARs and RNP AR approach procedures at La Palma and Lanzarote airports.

Based on the preliminary studies, it was expected that between 15-25NM and 10NM were going to be saved with the procedures at La Palma and Lanzarote respectively. Pertinent analysis from KPI measurements obtained from FDM during the flight demonstrations were due to be compared to FDM results obtained from flights using conventional STARs and approach procedures. The analysis will be presented in average form, segregated through determined common factors.

Operators and trained ATCOs were expected to provide their comments to certify the successful use of RNP STARs and RNP AR approaches as a viable solution for fuel savings and emissions reductions at the mentioned airports.

Finally it was also expected that approximately 50-100 kg of fuel per flight at La Palma and 40-80 Kg of fuel per flight at Lanzarote would have been saved.

Achievement of objective: **Partial** (due to amount of flight demonstrations completed)

Considering only 4 demonstration flights achieved at Lanzarote RWY 21, results indicate savings of 17-20 NM and approximately 49-64 kg of fuel (100 kg considering weighted average) from TERTO Entry Waypoint compared to the conventional procedures. Results are in line with approximate savings predicted in the demonstration plan. Savings from DEVLA Entry waypoint cannot be verified as only one demonstration flight was carried out, and there is no conventional data for comparison. Refer to Sections 5.1.4.2.2 and 5.1.4.3 for details.

For La Palma, considering that only 4 demonstration flights were completed and one conventional flight is available for comparison, RNAV results indicate savings of 292-313 Kg of Fuel and approximately 34-38NM compared to the conventional procedure. Refer to Section 5.1.4.2.1 and 5.1.4.3 for details.

The **second objective (OBJ-01.01-2)** addresses the Canarias flight terminal area improvement using PBN, reinforcing the current CDO operations and the use of optimized tracks achieved with RNP AR procedures. Aena and Airbus Prosky would assess the benefits provided by the proposed procedures in terms of TMA optimization from entry point to landing at GCLA and GCRR, and statistics of diverted or cancelled flights compare to the existing conventional operations.

Achievement of objective: **Completed**

The objective predicted CDO operations, considering the particularities of the vertical path calculations of the aircraft on board FMS. Results of the demonstration flights at Lanzarote indicate a reduction of the Level-Off time, which concludes that the optimization of the tracks and calculated ToD by the FMS formulates a continuous descent patch compared to the vectoring during a conventional approach.

In the case of GCLA, the result is more evident, by which an aircraft carrying out conventional DME ARC for the approach had a level-off, and the RNAV procedure didn't.

The **third objective (OBJ-01.01-3)** was set to improve access to La Palma and Lanzarote airports by using RNP AR procedures. In lieu of the challenging terrain present at both airports and the limited NDB conventional procedures available, the design flexibility offered by RNP AR procedures combined with the on-board technology and crew training would provide optimized horizontal and vertical paths studied precisely to avoid limiting obstacles and ensure a smooth stabilized transition to touchdown.

RNP AR designs were also expected to provide better minima helping to avoid flight diversions and cancellations during challenging weather conditions. Positive feedback from operators on the RNP AR approaches compared to the existing conventional procedures is important for the achievement of this objective.

Achievement of objective: **Completed**

Access was indeed improved at both airports. Refer to comments from operators in Section 7.3.1 and feedback from the ANSP in Section 5.1.5.2 of this document.

In terms of Minima, at GCLA RWY01 the minima for CAT C aircraft was reduced from 1600ft to 836ft and for RWY19 the minima was reduced from 1530ft to 764ft. For GCRR RWY21, the CAT C aircraft minima was cut by +1000 ft: from 2020 ft to 940ft.

The **fourth objective (obj-01.01-4)** was to reduce the noise impact, where possible, over populated areas using optimized vertical profiles. Based on the radar track outputs provided by AENA during the flight demonstration trials into GCLA and GCRR, modeling tools would be used to show the noise impact of RNP AR approaches flown near identified communities compared to the average conventional procedures currently flown.

Achievement of objective: **Not conclusive**

ASTERIX Radar Data from the conventional and flight demonstration trajectories is being gathered for analysis by the V-PAT Modeling Tool. It is expected that the noise impact should be reduced at GCRR due to the final approach trajectory being to the North of the city (upwind) compared to the conventional circle-to-land approach. For GCLA the Noise impact should vary little as the final approach trajectories are over the sea.

5.1.2 Conduct of Demonstration Exercise EXE-01.01-D-001

RNP STARs and RNP-AR approach demonstrations into RWY 01/19 of La Palma airport (GCLA)

5.1.2.1 Approach Design

5.1.2.1.1 Optimization of lateral flight track:

RNP AR approaches allow to design optimized curved paths, to join the required entry points (CANARIAS: the transfer points at the FIR boundary) to arrive on the final axis.

Because the aircraft is stabilized at the FAP on a lateral and vertical guidance, and because it is possible to design curved paths after the FAP in RNP AR procedures, it is not required to design an approach with a long straight-in segment of 5-10 nm.

From the designs and testing, the long straight-in segment was not an optimal solution at La Palma RWY 19 due to adjacent terrain (also the main reason why an ILS approach is not present on this runway). A long straight-in segment would have been possible for RWY 01, but the RNP AR concept allows shortening the approach procedure which was an optimal solution for this runway.

For particularities on the operational concept addressed and RNP AR procedures, refer to section 5.1.1.2 of this document.

Taking benefit of RNP AR trajectory advantages and safety benefits, the concept applied to La Palma was to design RNAV STARs and RNP AR trajectories to RWY 01 and RWY 19 with RNP levels set to:

- RNP 1.0 until initial approach fix;
- RNP 0.3 during approach;
- Gradual increase from RNP 0.3 to RNP 1.0 on the missed approach.

5.1.2.1.2 GCLA Conventional Procedures

La Palma airport currently offers limited scenario for instrument based approaches mainly due to the complexity of the terrain surrounding the airport with a very steep terrain profile and penalizing obstacles.

The available published Instrument Flight Procedures (IFP) are really limited, based on NDB, with high minima, final approach not aligned with the runway centerline, with no vertical guidance and not optimized. These limitations make La Palma a self-justified scenario for the implementation of RNP AR approaches.

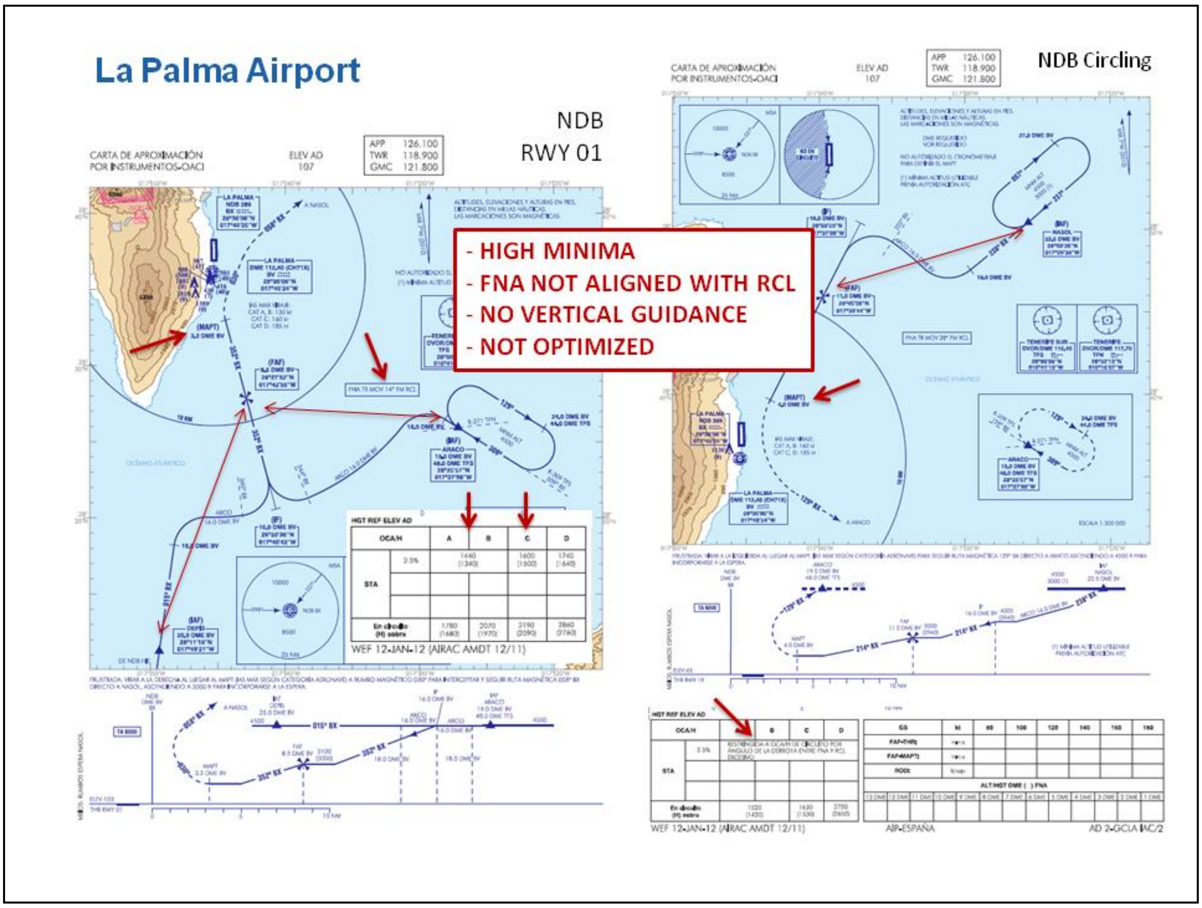


Figure 6 - GCLA Conventional approaches

5.1.2.1.3 GCLA New RNAV1 STARs

One RNAV1 Standard Arrival for each runway was proposed to connect the TMA limit point ORTIS to the correspondent IAF.

Both STARs can be seen in Figure 7 highlighted in Red.

XISLA is a new Initial Approach Fix located on the existing STARs KONBA3V and ORTIS3V (BRNAV). This new waypoint was added in these two STARs to shorten the RNP AR approach trajectory to RWY 01 rather than proceeding extra miles to IAF ARACO. Note that naming code of STARs KONBA3V and ORTIS3V was not modified.

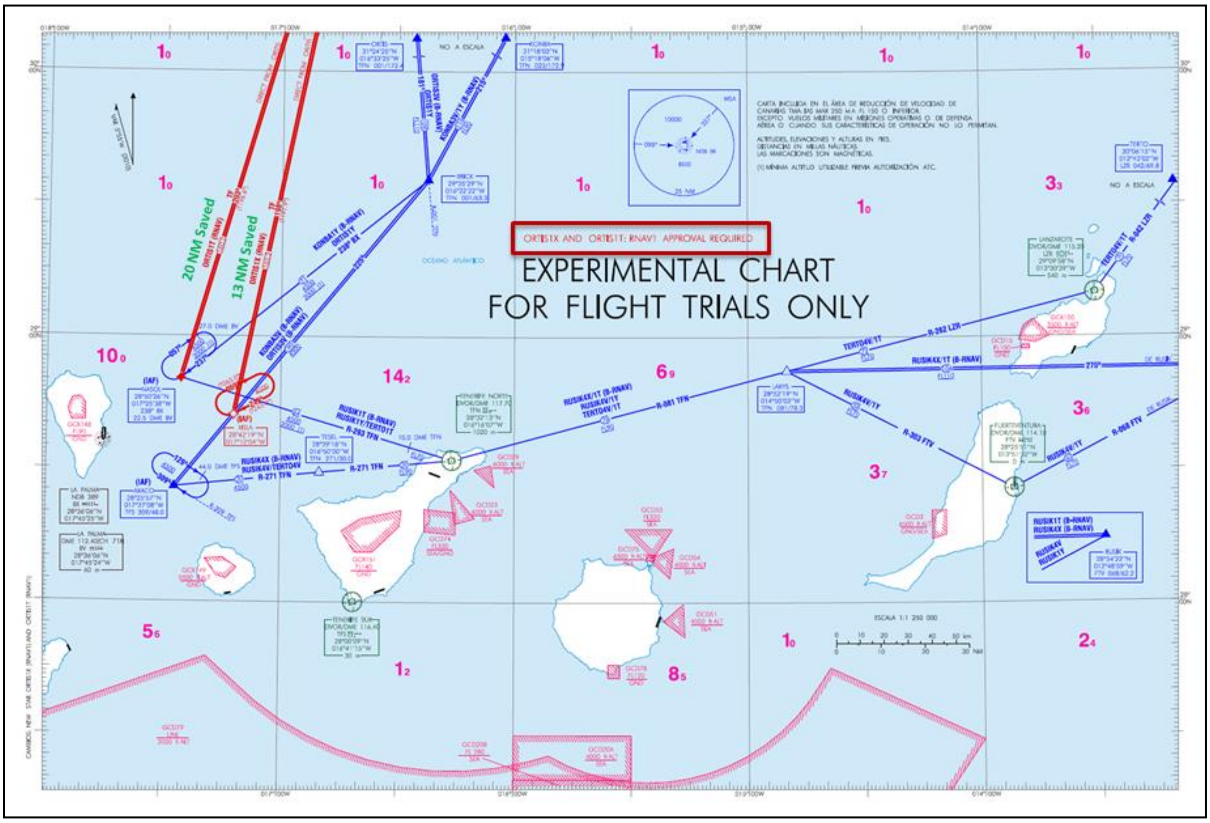


Figure 7 - GCLA new RNAV1 STARs

- ORTIS 1X (RNAV) to New IAF XISLA, by a TF: 13 NM Saved.
- ORTIS 1T (RNAV) to IAF NASOL, by a TF: 22 NM Saved.

The mentioned STARs were only available for the CANARIAS Flight Demonstrations.

5.1.2.1.4 GCLA RNAV RWY 01 and RWY 19 vs. Conventional Approaches

The RNAV trajectory design process evaluated the current IFP published procedures identifying the VSS restrictions which triggered the VSS report mentioned in Section 4.3.1 of this document of this document.

For RWY 01 four (4) trajectory design proposals were presented, and for RWY 19 two (2) trajectory design proposals were presented all with two RNP Values (RNP 0.1 and RNP 0.3) and associated lines of minima.

After evaluating the VSS the following two procedures were selected, and finally established as the final GCLA RNAV trajectories in the CANARIAS Project:

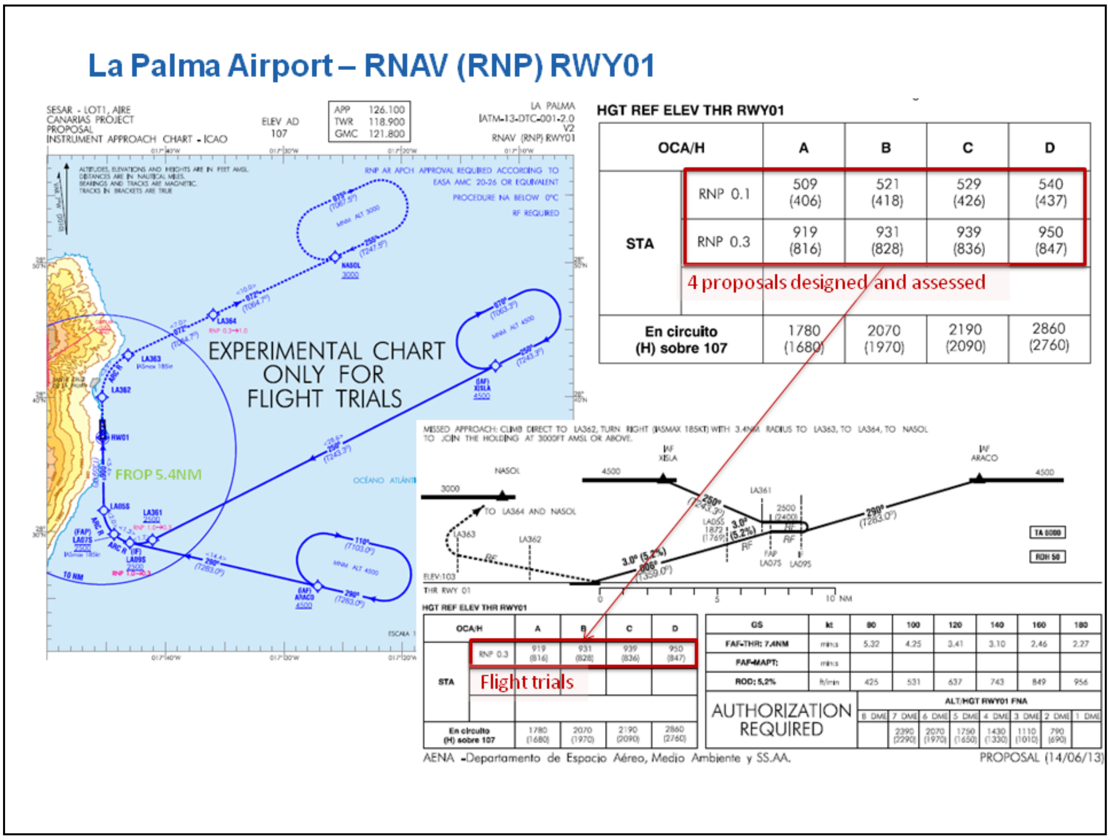


Figure 8 - GCLA RNAV (RNP) RWY 01 Approach Chart

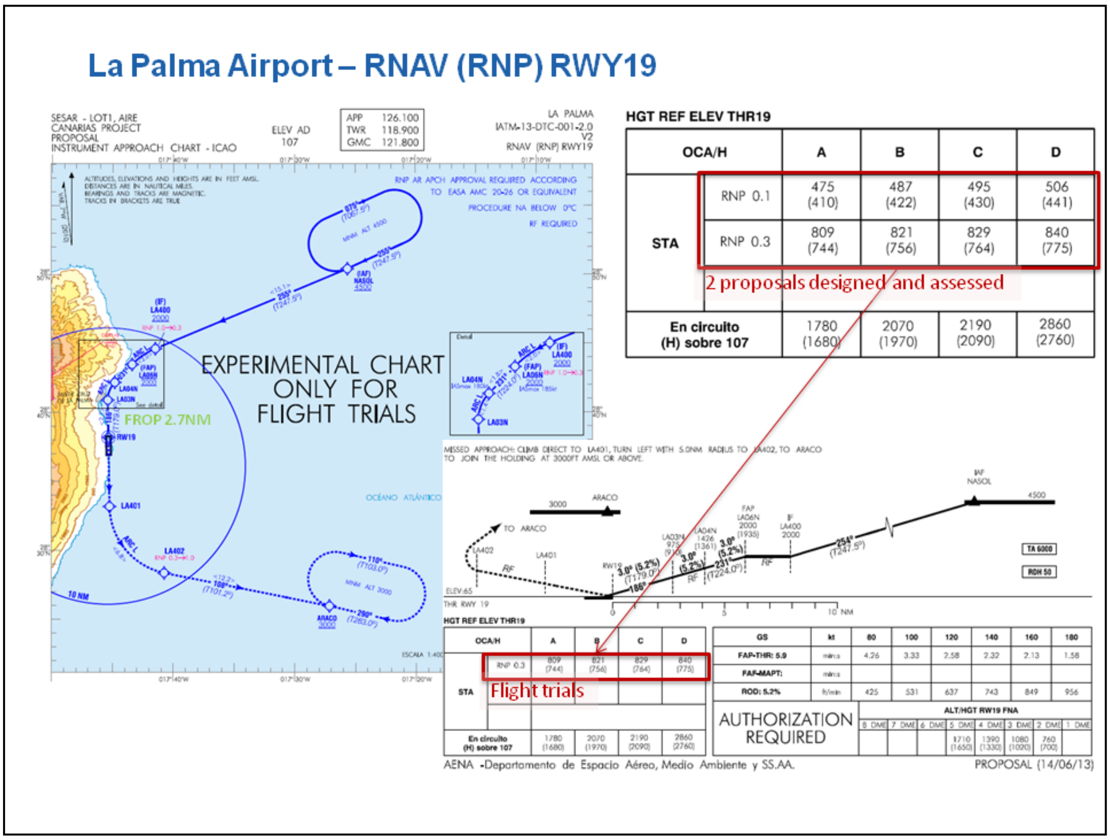


Figure 9 - GCLA RNAV (RNP) RWY 19 Approach Chart

As illustrated in Figure 8 and Figure 9, the initial trajectory design proposals envisioned RNP values of 0.1 and 0.3. Based on the indications from operators regarding available aircraft equipment, only the trajectory with RNP value of 0.3 was implemented in the CANARIAS project.

However, in a situation of full implementation and publication the trajectory with an RNP value of 0.1 and associated minima would be re-assessed to publish both options since the later resulting minima is lower than the trajectory with an RNP value of 0.3 which may benefit capable operators.

The new RNP AR procedures show a significant improvement to the accessibility of the runways. Benefits include:

- Lower minima (For example):
  - RWY 01 OCH for Cat C aircraft was reduced from 1500ft to 836ft.
  - RWY 19 OCH for Cat C aircraft was reduced from 1530ft to 764ft.
- No VSS penetration.
- Final approach aligned with the runway centerline.
- Vertical guidance.
- Trajectory repeatability and less distance flown

Besides the improved access to the airport, the new procedures improve the operational safety, allow for a potential reduction in fuel burn and environmental impact.

Figure 10 and Figure 11 illustrate a comparison between the current published IFP and the new RNP AR procedures assessed in the CANARIAS Project. As depicted, there is an important saving in distance, and the difference in minima provides a clear advantage.

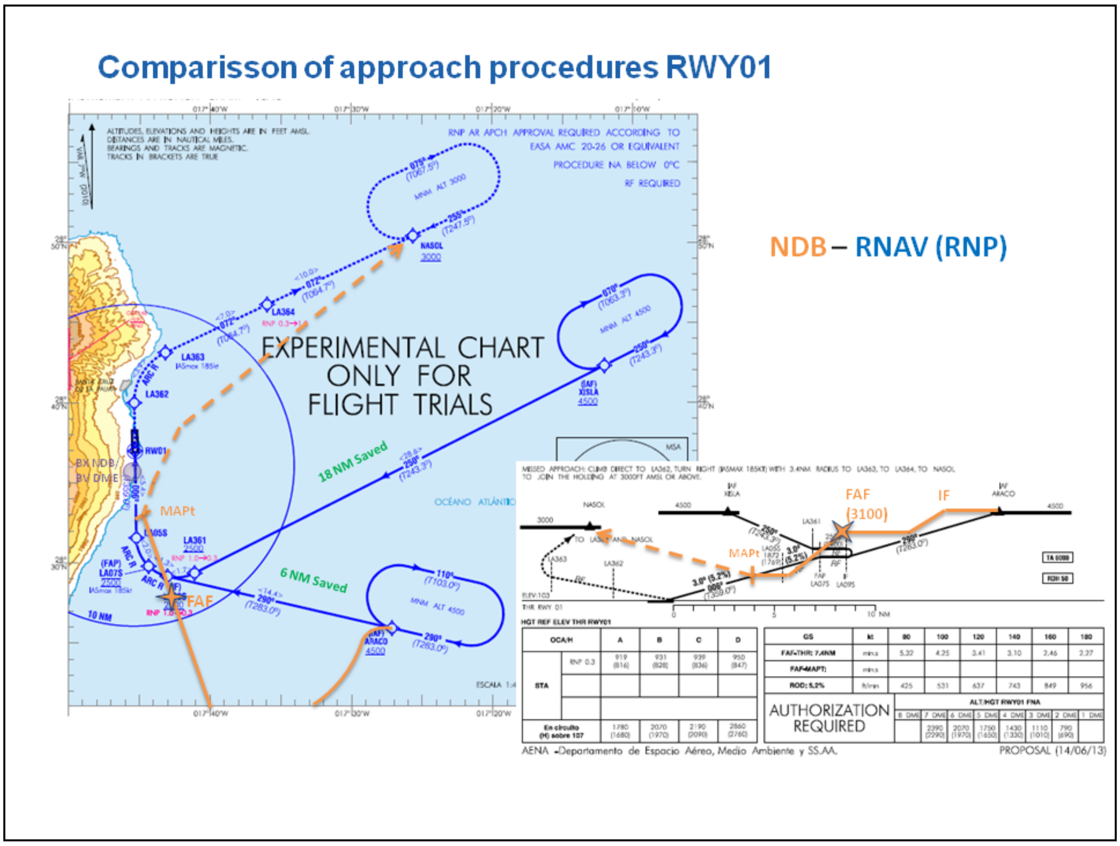


Figure 10 - GCLA RNAV RWY 01 vs. Conventional Approach

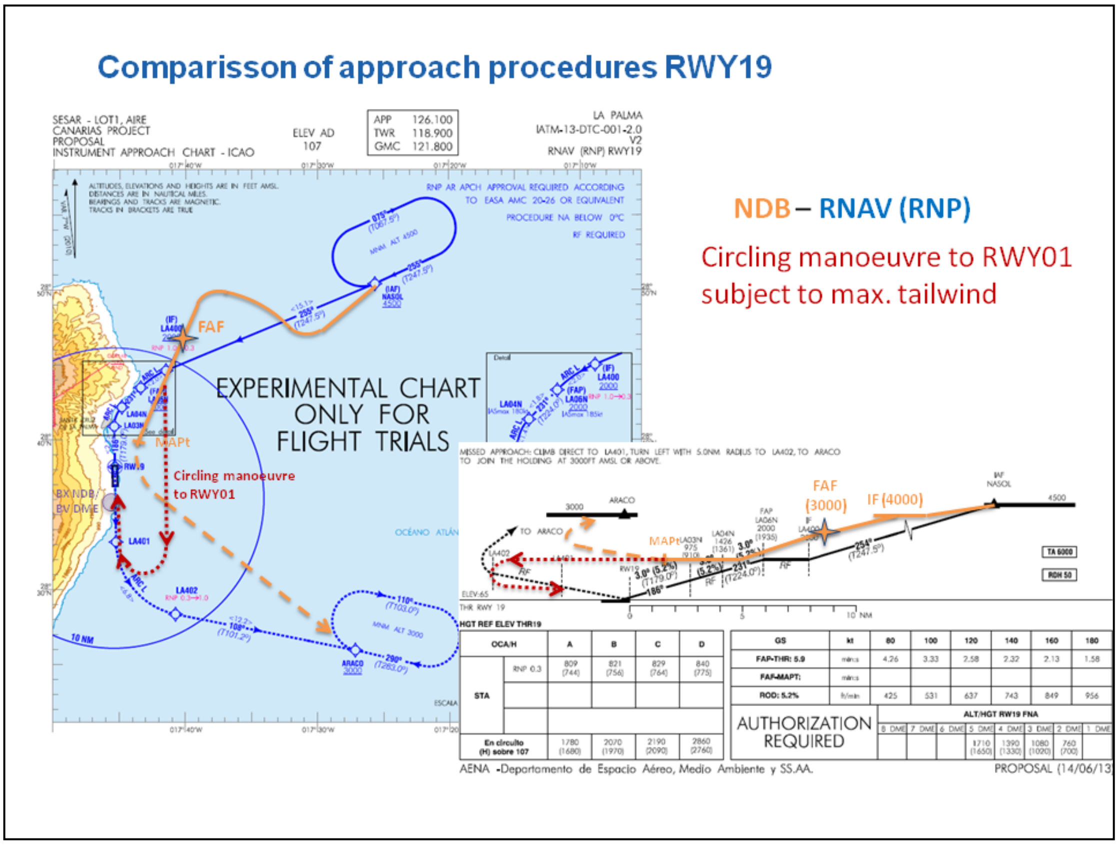


Figure 11 - GCLA RNAV RWY 19 vs. Conventional Approach

5.1.2.1.5 Optimization of vertical profile:

On top of optimizing the lateral track, it is essential that the RNP AR design includes vertical profile optimization. This is achieved by allowing the various aircraft to fly the procedure whilst descending on their optimized descent profile, which is the one calculated by their on-board FMC. This includes:

- Descending at or close to the aircraft's optimal calculated TOD (Top of Descent).
- Avoiding unnecessary altitude constraints that would force the aircraft to descend too low, or stay too high, and then have either an unnecessary level-off or on the other hand an excessive energy level to cope with (i.e. use of speed brake, increase of fuel burn, etc…).
- Avoiding unnecessary speed constraints that would result in aircraft's early speed reduction and as a result an increase of overall flight time and reduction in fuel burn efficiency.

For La Palma RNP AR approaches, the optimization of the vertical path was achieved by the design itself as no particular ATC altitude constraints were required to be added. The design takes into consideration the Minimum Obstacle Clearances, and the resulting optimization of the design path is already included.

To ensure measuring appropriate Continuous Descent operations, the agreed demonstration flight operations plan and phraseology allowed the operators to indicate the moment they wanted to start their descent based on the optimized ToD point calculated by the FMS, rather than ATC indicating when to descend (sometimes aircraft may be kept in cruise longer than required increasing the fuel burn).

Also to ensure compatibility with category A-D aircraft types, a standard jetliner (A320) was used as a reference. The ideal (unconstrained) profile for the A320 was computed using its FMS and checks were made to verify that the FMS computed profile of a different aircraft, for example a B737NG, would not be affected by the mentioned constraints (i.e. "AT" constraint on the FAP), and that the computed path was similar or close to the profile of the A320.

Refer to the exercise results in Section 5.1.4.2.1 for the average Level-Off distances, which in simple terms indicate the time and distance the aircraft flew at a level altitude after the ToD.

5.1.2.2 Design validation

Once the detailed design of the La Palma RNAV STARs and RNP AR procedure was frozen (meaning no changes to the trajectories) and agreed by all the stakeholders, the STARs and Approach trajectories were coded and tested on both the A320 and B737 NG Full Flight Simulator by expert procedure development pilots.

The first GCLA A320 Flight Simulator session was carried out in the Toulouse Airbus Training Centre on the 12th of April 2013. The validation resulted in a small TAWS warning on the approach to RWY 19, which triggered a slight re-design of the Radius-to-Fix (RF) leg prior to the final straight segment to the runway.

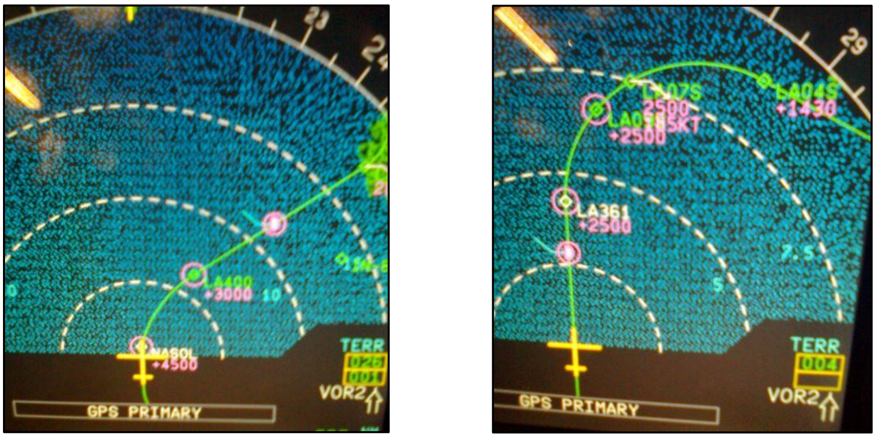


Figure 12 - GCLA Flight Simulator Validation

The updated design was tested on a second A320 Flight Simulator session in the Toulouse Airbus Training Centre on the 7th of June 2013 together with the GCRR RNAV RWY 21 procedure. Validation was successful with no remarks. An AENA representative was present at the validation.

A third and final Flight Simulator session was carried out at the CAE Oslo Training Centre on the 24th of June 2013 to validate the GCRR and GCLA RNAV procedures on the B737NG. This testing was carried out with Norwegian Air Shuttle and the validation was successful with no remarks.

Additional testing of the GCLA RNAV procedure was conducted by participant operator Norwegian Air Shuttle prior to the start of the demonstration flights. No remarks were raised.

The Detailed Design Review was carried out in combination with the project review meeting in Madrid on the 10th of July 2013. Results of the testing were presented, followed by the delivery to the CANARIAS Consortium and SJU of Design Package (Procedure Technical Reports [Ref [7]], Charts and procedures coding).

5.1.2.3 Training

5.1.2.3.1 Air Traffic Controller Training

A specific GNSS and RNAV training was provided to CANARIAS ATC personnel on location between the 17th and the 19th September 2013. The program, detailed below, was carried out under the guidelines of ICAO Doc. 9613 VOL II, implementing RNAV and RNP operations.

The main outcome of the training was to ensure that the ATC personnel were able to correctly handle the mix of RNAV versus Non-RNAV capable traffic during the flight demonstrations at both La Palma and Lanzarote airports.

The program was divided into three areas:

I. Core training

a. How area navigation systems work (in the context of each navigation specification):

i) Include functional capabilities and limitations of this navigation specification;

ii) Accuracy, integrity, availability and continuity;

iii) GPS receiver, RAIM, FDE, and integrity alerts;

iv) Waypoint fly-by versus fly-over concept vs RF (and differences in turn performance);

b) Flight plan requirements;

c) ATC procedures:

i) ATC contingency procedures;

ii) Separation minima;

iii) Mixed equipage environment;

iv) Transition between different operating environments; and

v) Phraseology.

II. Training specific to this navigation specification

a. RNAV and RNP STARs, SIDs, related control procedures:

i) Radar vectoring techniques;

ii) RF leg limitations and airspeed constraints;

iii) Open and closed STARs;

iv) Altitude constraints; and

v) Descend/climb clearances;

b. RNP-AR approach and related procedures;

i) Including T and Y approaches

ii) Approach minima

iii) Additional requests for altimeter settings

c. RNAV 1, RNP 1, and RNP-AR Approach related phraseology;

d. Impact of requesting a change to routing during a procedure.

The training program was delivered as follows:

Day 1

09:00-09:30 Welcome & Introductions

09:30-10:00 Introduction to Canarias Project

10:00-10:30 PBN Overview

11:00-11:30 break

11:30-13:00 Aircraft Positioning & PBN

13:00-14:00 lunch

14:00-15:15 GNSS Accuracy and Integrity

15:15-15:45 break

15:40-17:00 PBN Manual

Day 2

09:00-09:30 Review/questions

09:30-11:00 RNAV Navigation & RNP Navigation Specifications

11:00-11:30 break

11:30-13:00 PBN Advantages for ATC

13:00-14:00 lunch

14:00-15:15 PBN Approaches

15:15-15:45 break

15:45-17:00 La Palma and Lanzarote STARS

Day 3

09:00-10:30 La Palma and Lanzarote Approaches

10:30-11:00 break

11:00-13:00 PBN SIDS, STARS, Approaches & Flow Integration Methods

13:00-14:00 lunch

14:00-15:00 Review

5.1.2.3.2 Air Traffic Controller training comments

During the training sessions the ATC personnel was very proactive and many open points were clarified. Highlights of the most relevant of items and questions include:

- It was clarified that the procedures based on PBN reduce significantly the amount of communications between ATC and aircraft since waypoints are already loaded in the FMS database and the procedures are fully managed with automation, within other factors. Reduced communication allows ATC to focus more on monitoring and supervision tasks, and reduces radio congestion.
- ATC specifically asked if their personnel was required to be aware or know the navigation system which the aircraft is basing the procedure. It was clarified that this is not relevant to ATC as it is a crew responsibility to know what operations the aircraft and the crew are certified for.
- ATC asks about possible conflicts with the current departures through the STARs of the Canarias TMA. The project team explained that the CANARIAS approach procedures were designed to not modify the current arrival procedures, but remarked that with the implementation of RNAV in the Canarias TMA it won’t be necessary to overfly the islands as the need to navigate via ground based NAVAIDS is eliminated.

5.1.2.3.3 Crew Training

Consortium and project participant operators were responsible to provide the required RNAV and RNP AR training to its crews, including debriefing on specificities of the RNP AR operations at La Palma.

5.1.2.3.3.1 GCLA RNAV (RNP) RWY 01/19- Non-operational Mitigation Measures

GCLA RNAV (RNP) RWY 01

RNP 0.3 proposals for La Palma RWY 01 has the 8 artificial obstacles penetrating the VSS whose height above threshold elevation is below 15m.Therefore according to ICAO Doc. 8168 criteria (see. I-4-5 paragraph 5.4.6.4) they may be disregarded.

No mitigations actions are needed since VSS is considered not penetrated

GCLA RNAV (RNP) RWY 19

Using the same argument as for GCLA RNAV (RNP) RWY 01, no mitigations are required since VSS is considered not penetrated.

5.1.2.3.3.2 GCLA RNAV (RNP) RWY 01/19- Operational Mitigation Measures

- Use of the on-board indication of the lateral (LDEV) and vertical (VDEV) deviation, the crew can realize early any deviation from the nominal path and proactively take corrective action.
- GCLA RNAV (RNP) RWY 01/19 approach considerations:
  - Monitor/anticipate tail wind influence.
  - Be prepared to use speed brakes when necessary; be also prepared to extend flaps and gear early.
  - Operators shall establish the relevant recommendations for identification (location and lighting of critical obstacles) and avoidance procedures in a crew briefing.
- GCLA RNAV RNP (RWY 01) missed approach / go-around considerations and particularities:
  - The Missed approach segment has a 185kts speed constraint placed until the end of the RF (LA363), which should be present in the coding of the database. However it remains the crew responsibility to managed de Slats/Flaps retraction schedule to ensure that the aircraft maneuvering speed stays below the indicated constraint of 185 kts until the end of the RF leg.

5.1.2.4 Safety assessment

Safety assessments have been prepared from perspectives of different participants, with any risks respectively addressed.

The Flight Operational Safety Assessment (FOSA) is a key part of an RNP AR procedures operational evaluation, and is a support document for an eventual authorization by the National Aviation Authority (if required by the published regulation).

A FOSA is recommended to be conducted for each RNP AR approach procedure where the more stringent aspects of the nominal procedure design criteria are applied, or where the application of the default procedure design criteria is in an operating environment with special challenges or demands.

The FOSA is only required where there are more stringent aspects in implementing standard procedures such as:

- RF legs after FAF;
- Missed Approach with RNP less than 1.0;
- Final approach RNP less than 0.3 or;
- Where the operational environment present special hazards (wind shear, canyons, turbulence, etc...).

A FOSA should also be conducted when operational requirements for RNP AR APCH result in a change or adjustment to the design criteria of the procedure, aircraft requirements or crew procedures (training required). The FOSA should where necessary that for applicable situations identified mitigations are implemented to meet the safety criteria. The assessment should give attention to the inter-dependence of the elements of procedure design, aircraft capability, crew procedures and operating environment.

- Airbus Prosky and Aena prepared a generic Flight Operational Safety assessment (FOSA) as guidance for the operators carrying out demonstration flights at La Palma (See Appendix E).
- Airbus ProSky and Aena prepared a Safety Assessment and VSS analysis (Refer to Section 4.3.1), based on the FOSA (See Appendix E) and internal considerations.

Note: Purpose of the FOSA and high-level description is provided in Section 5.1.2.4 of this document.

- Aena prepared a safety assessment regarding the impact of the flight trials in the Canarias TMA airspace (Ref: [11]) presented in Section 4.3.2 of this document.

5.1.2.5 Approval – demonstration flights

During the development of the CANARIAS project, Aena kept informed the Spanish Authority (AESA) about the project scope and activities. Several meetings were coordinated in order to explain the CANARIAS project and present the VSS studies and designed procedures for the demonstration flights. In addition, Aena communicated to AESA all project news and provided complete information on the project activities and status of the demonstration flights.

Outside of the frame of the CANARIAS Project, Aena and AESA run a *PBN Implementation Working Group* that supports PBN implementation in the Spanish airspace. Some of the CANARIAS project communications were carried out via this working group.

The flight trials phraseology was common for both La Palma and Lanzarote, further explained in Section 4.2.3 of this document. Deviations of the demonstration flights due to the phraseology agreement are detailed in Section 4.3.2.

Upon provision to the Local Authorities of the project documentation and participant operator's qualifications for review; upon agreeing with the Air Traffic Controllers and operators the phraseology to be utilized during the flight demonstrations (refer to Section 4.3.2); authorization for the demonstrations flights to La Palma was provided by the CANARIAS Consortium on the **1st of April 2014,** and the first flight took place on 18th of July 2014.

5.1.2.6 Flight trials

La Palma contemplated the demonstration activities to take place at both Runways 01/19, increasing the chances of having at least 50 demonstration flights completed within the set period of time.

As explained in detail in the Deviations from the planned activities (Refer to Section 4.3.4), the project started with an inherent risk (dully identified in the various Quarterly reports to SJU), by having only one Consortium operator flying to this destination.

After a significant delay in the execution of the flight demonstrations, Norwegian Air Shuttle successfully operated with B737-8 aircraft a small amount of RNAV demonstration flights to La Palma RWY 01 within the remaining project timeframe:

1. 18th of July 2014.
2. 29th August 2014
3. 5th September 2014
4. 12th September 2014

La Palma was a new destination airport for Norwegian, and the RNAV procedures proved to be the preferred option over the conventional procedures once the demonstration flights started.

Results of the flight trials are provided in Section 5.1.4.2.1 of this report.

5.1.3 Conduct of Demonstration Exercise EXE-01.01-D-002

RNP STARs and RNP-AR approaches demonstrations into RWY 21 of Lanzarote (GCRR).

5.1.3.1 Approach Design

5.1.3.1.1 Optimization of lateral flight track:

RNP AR approaches allow to design optimized curved paths, to join the required entry points (in CANARIAS the transfer points at the FIR boundary) to arrive on the final axis.

Because the aircraft is stabilized at the FAP on a lateral and vertical guidance, and because it is possible to design curved paths after the FAP in RNP AR procedures, it is not required to design an approach with a long straight-in segment of 5-10 nm. From the various designs and testing, the latter was not an optimal option at Lanzarote RWY 21 (also the main reason why an ILS approach is not present at this terrain-challenging airport).

For particularities on the operational concept addressed and RNP AR procedures, refer to section 5.1.1.2 of this document.

At present, the conventional approach at Lanzarote requires basically a “circle to land approach” to RWY 21, which some operators have decided to prohibit during night operations (refer to statements in Section 7.3.1 of this document).

In August 2011 Airbus launched a worldwide program to support PBN implementation with a focus on “RNP to replace Circle-to-Land”, therefore an initiative for Circle-to-land removal by fully managed PBN procedures.

Airbus intent is to have both a “Train the Trainer” and regional approach and to cooperate with local Authorities and airlines in order to facilitate the PBN deployment. Airbus Safety has launched

ICAO controlled flight into terrain (CFIT) studies have shown that runway-aligned approaches (LNAV only) are 25 times safer than circling approaches, and that once some form of vertical guidance is added to approaches the safety margin is increased again by a factor of 8[1].

Taking benefit of RNP AR trajectory advantages and safety benefits, the concept applied to Lanzarote was to design RNP STARs and RNP AR trajectories to RWY 21 with RNP levels set to:

- RNP 1.0 until initial approach fix;
- RNP 0.3 during approach;
- Gradual increase from RNP 0.3 to RNP 1.0 on the missed approach.

Procedures to RWY 03 were not part of the scope of the project.

Lanzarote: Runway 21 View

Figure 13 - GCRR RWY 21 View

[1] Working Paper A37-WP/138, Performance-based navigation – the implementation challenge

5.1.3.1.1.1 GCRR Conventional Procedures

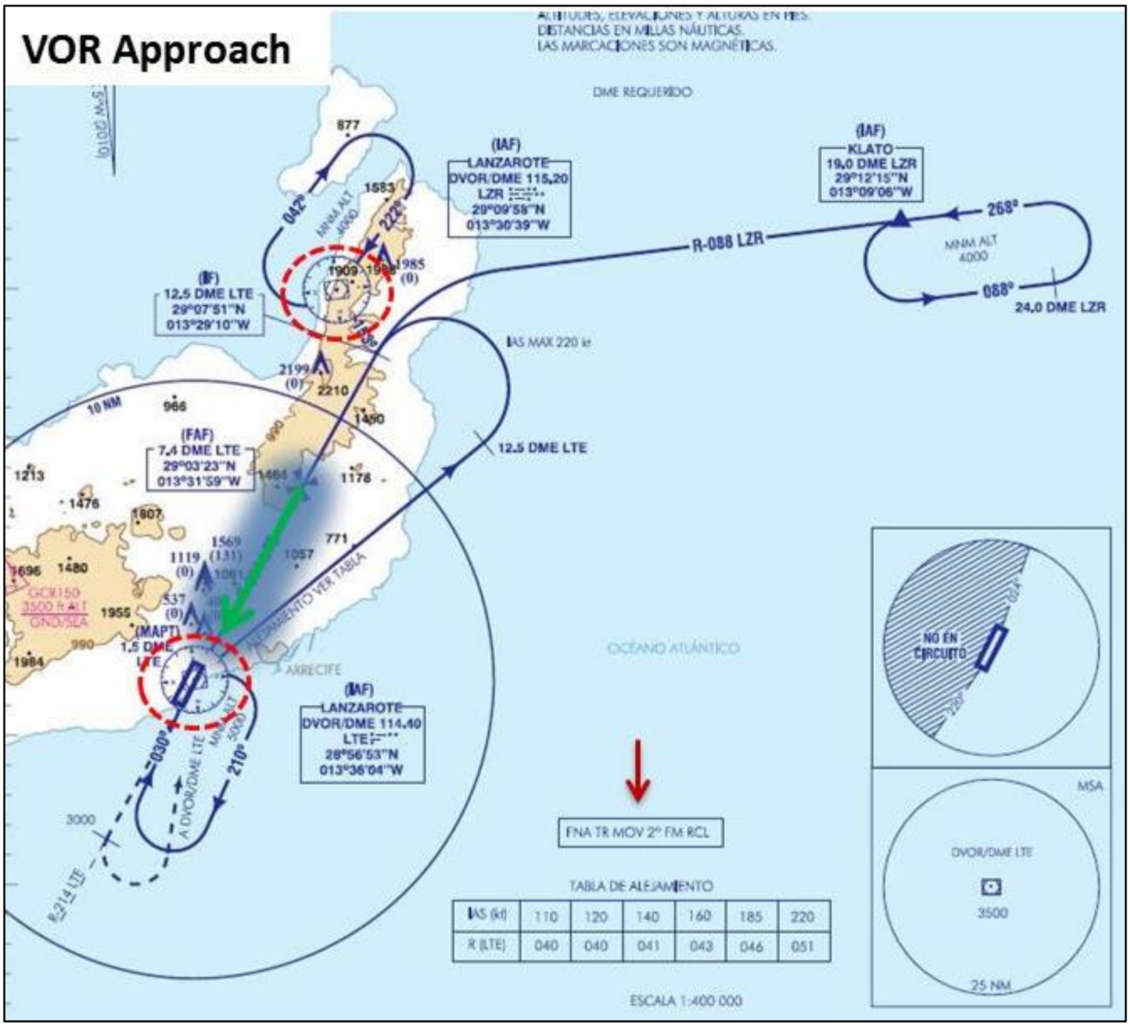
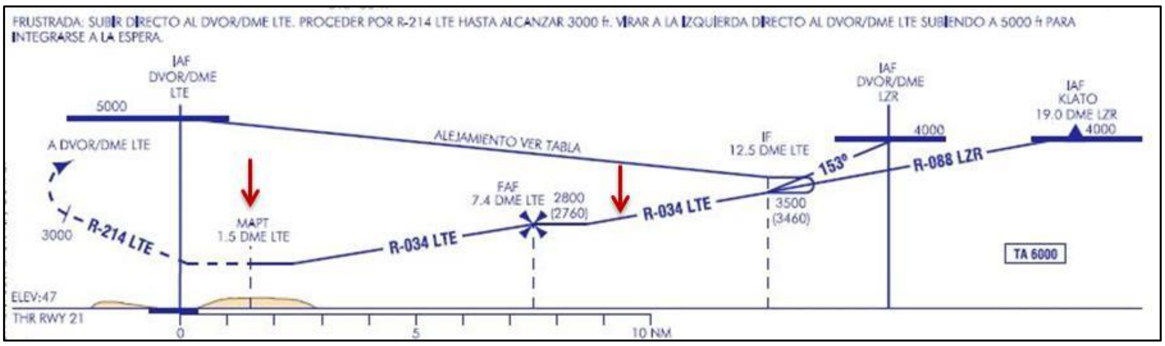


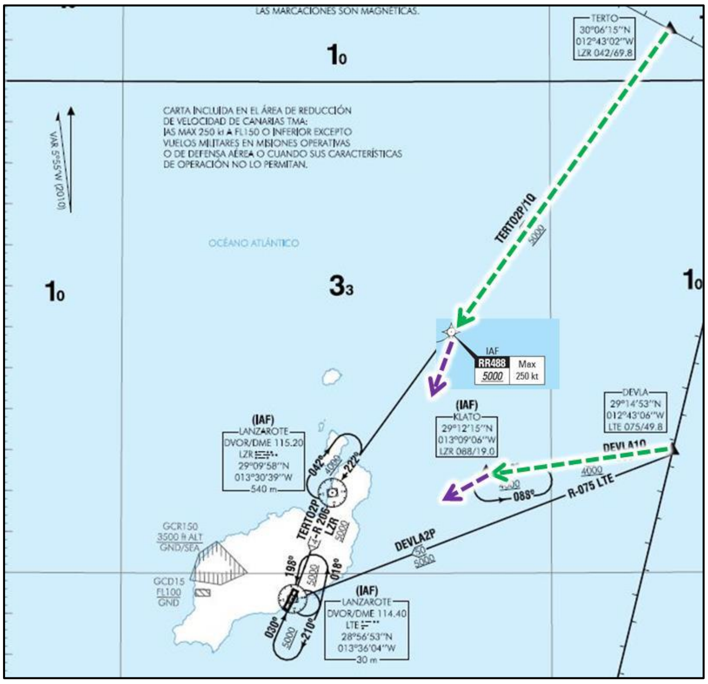
Figure 14 - GCRR RWY 21 Conventional approach

OCA/H		A	B	C	D
STA	2.5%	RESTRINGIDA A OCA/H DE CIRCUITO POR VULNERACIÓN VSS			
En circuito (H) sobre		1780 (1740)		2020 (1980)	

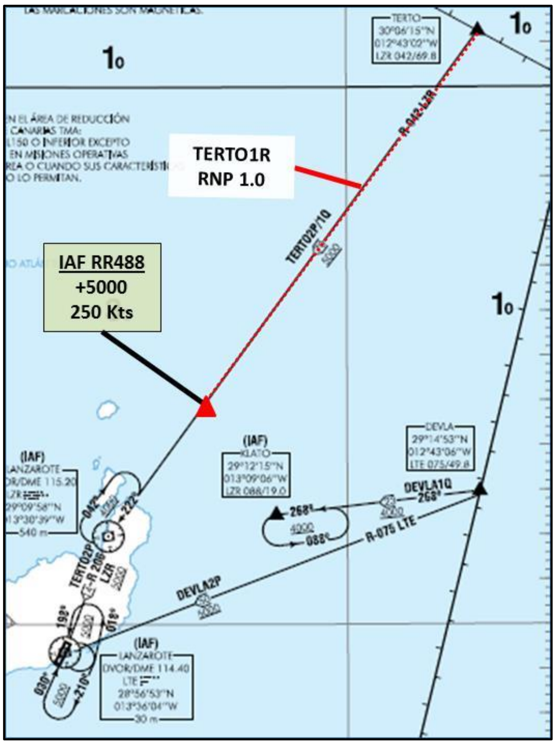
- High Minima.
- Final Approach not completely aligned with Runway Centerline.
- No vertical guidance.
- Not optimized.

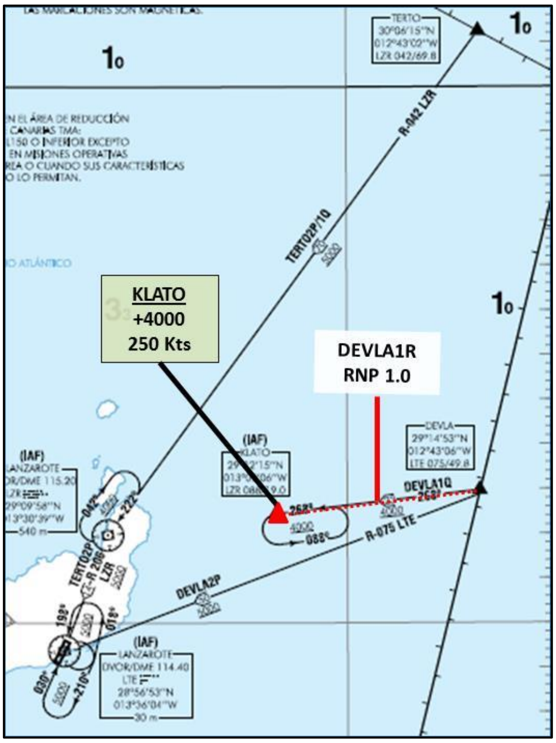


5.1.3.1.1.2 GCRR New RNP1 STARs



- TERTO 1R (RNAV) to New IAF RR488: 25 NM Shorter between Entry Waypoint and IAF.
- DEVLA 1R (RNAV) to KLATO (IAF): No Difference
- IAF RR488 and IAF KLATO allow arriving aircraft for a dedicated approach to RWY 21 (No circling).
- STARs Available only for CANARIAS Flight Demonstrations.





RNP1 STAR from TERTO: TERTO1R

- Same trajectory as TERTO2P/1Q but terminating at RR488)
- TERTO is the measuring point for the comparison of the fuel consumption.

RNP1 STAR from DEVLA: DEVLA1R

- Overlay of the existing DEVLA1Q
- DEVLA is the measuring point for the comparison of the fuel consumption.

5.1.3.1.1.3 GCRR RNAV RWY 21 vs. Conventional Approach

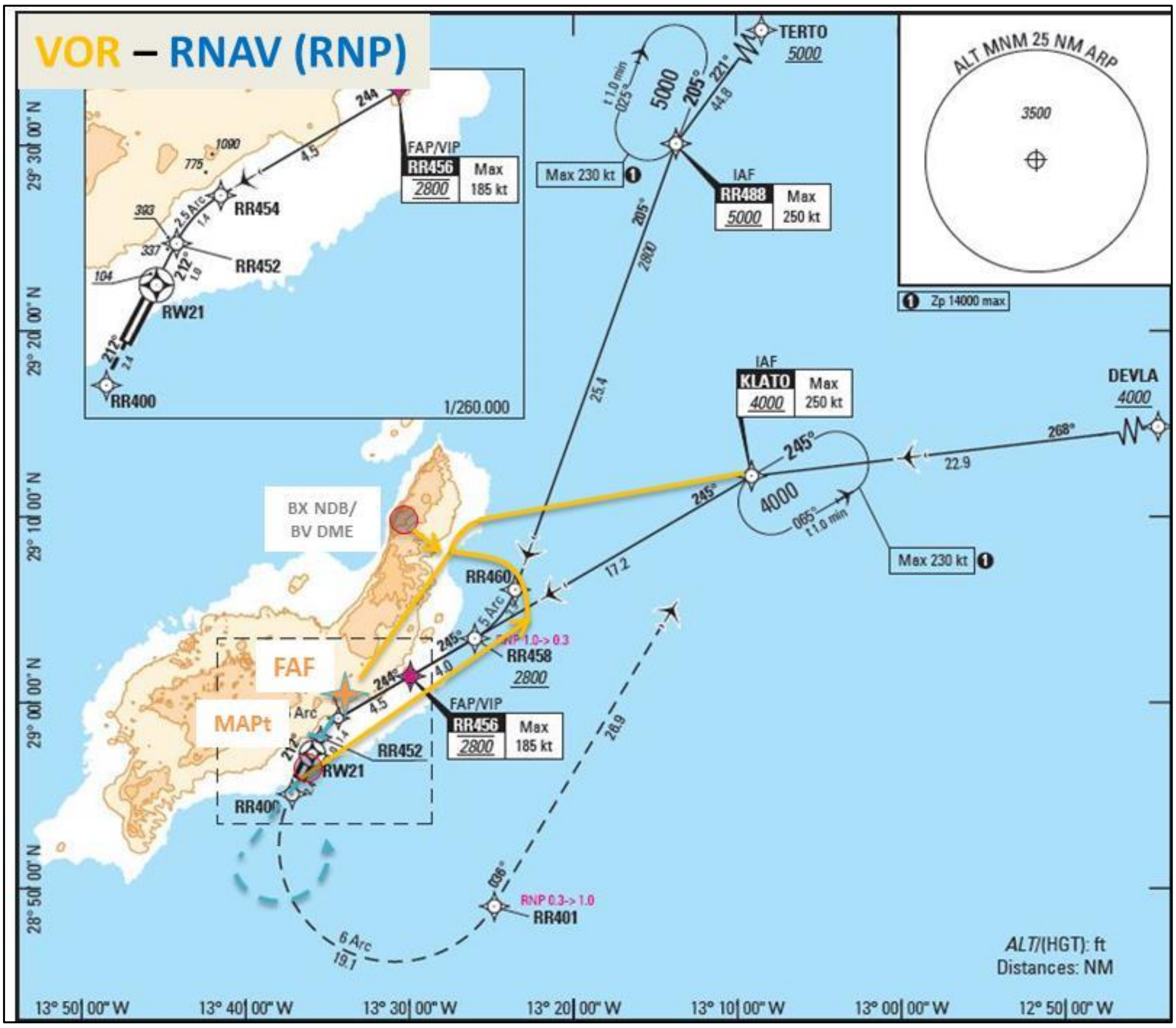
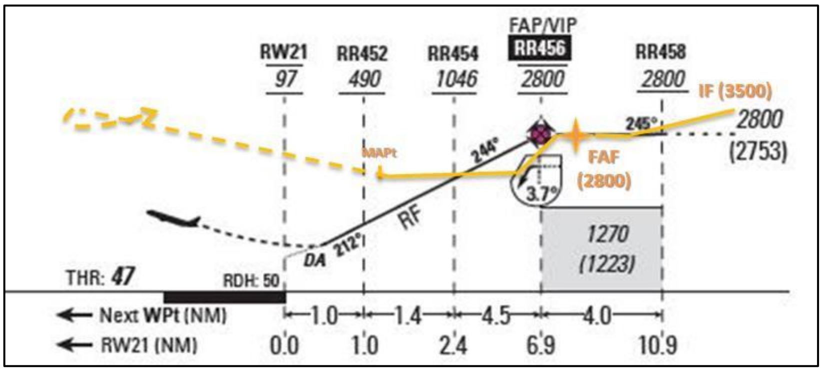


Figure 15 - GCRR RNAV RWY 21 vs. Conventional Approach



	MA Climb Gradient	CAT C		CAT D	
		OCA (H)	RVR	OCA (H)	RVR
RNP 0.3	2.5%	940 (893)	4000	952 (905)	4300

CAT C Minima cut by +1000ft.

Flight demonstrations shall only use the RNP AR 0.3 minima (design also contemplates an RNP AR 0.1 trajectory and minima for potential future implementation).

5.1.3.1.1.4 GCRR RNAV (RNP) RWY 21 Approach Chart

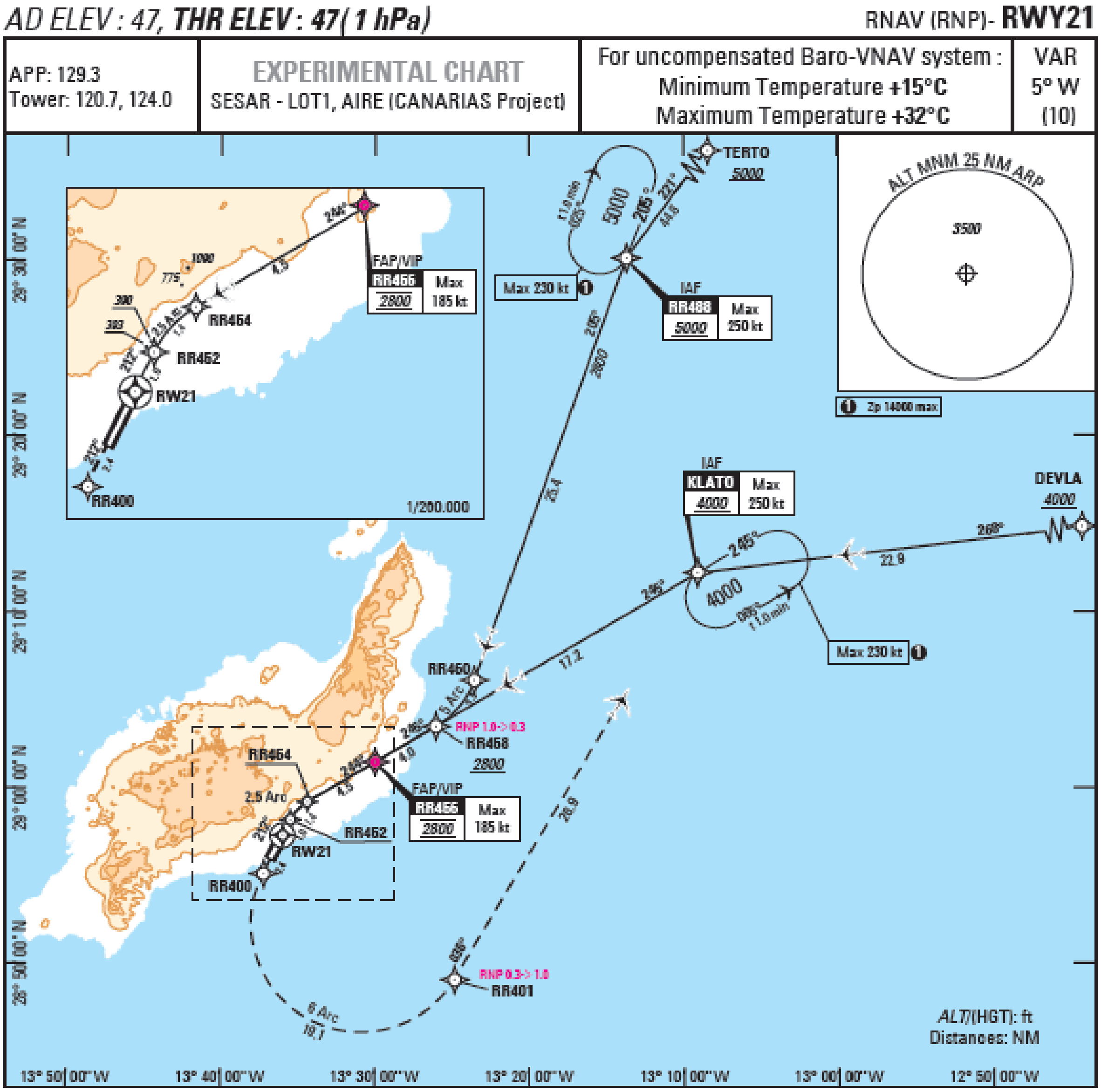
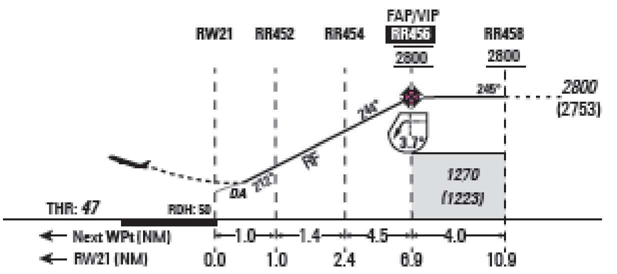


Figure 16 - GCRR RNAV (RNP) RWY 21 Approach Chart

CAUTION: Visual Segment Surface (VSS) penetrated by terrain up to 393ft AMSL.

NOT FOR OPERATIONAL USE

: first edition QUOVADIS® GéoTITAN® & AIP



Missed APCH:

Climb to 4000ft via the RNAV(RNP) missed approach to KLATO.

	MA Climb Gradient	CAT C OCA (H)	CAT C RVR	CAT D OCA (H)	CAT D RVR
RNP 0.3	2.5%	940(893)		952(905)	

AUTHORIZATION REQUIRED

5.1.3.1.1.5 Lanzarote RWY 21 RNAV Design particularities:

- Lower minima
- Avoids obstacles in VSS
- Final Approach Segment aligned with runway centerline.
- Vertical and horizontal guidance.
- Trajectory repeatability.
- Flight distance reduced.

5.1.3.1.1.6 Lanzarote RWY 21 RNAV Design main benefits:

- Enhanced airport accessibility
- Operational safety improvement
- Fuel costs savings (i.e. reduced chance of a Missed Approach due to unstable approach)
- Environmental impact reduction

5.1.3.1.1.7 Lanzarote RWY 21 Design Process

The KoM in September 2012 established the baseline of the conceptual design of the RNAV STARs and RNP AR approach trajectories to Lanzarote.

Finally it was decided and noted in the specifications document approved by all Consortium and participant members that TERTO and DEVLA were designated as the start waypoints of the RNAV STARs.

Two (2) IAFs were established for the design: KLATO (current IAF) and RR488 (New IAF).

During the detailed design exercise, and in lieu of the challenging terrain present on the intermediate and final approach areas, it was decided to design six (6) RNP AR Approach trajectories with different RF radius and TF segments on the final approach path and choose the most appropriate of the lot. All of the procedures were tested in a representative Full Flight Simulator device. Five (5) of the designed approaches were deemed appropriate by showing: good aircraft energy management; flyable, stable and comfortable.

The following table summarized the results of the tests, dully reported in the simulator reports.

App.	RNP Value	Expected DA	Ops. DA	Final RF Radius	Final TF length	Test Result
RNAV-21Z	0.30 Nm	1270 Ft	1270 Ft	3 Nm	3.4 Nm (longest)	OK
RNAV-21X	0.30 Nm	1270 Ft	1600 Ft	3 Nm	1.5 Nm (shortest)	OK
RNAV-21W	0.30 Nm	1270 Ft	1600 Ft	1.7 Nm	1.5 Nm (shortest)	AVERAGE. Speed at RF only for CAT C
RNAV-21Y	0.30 Nm	1270 Ft	1600 Ft	2.6 Nm	1.8 Nm	OK

RNAV-21V	0.10 Nm	570 Ft	570 Ft	2.6 Nm	1.8 Nm	OK
RNAV-21U	0.30/0.10	952 Ft	TBD	2.5 Nm	1.0 Nm	OK

Table 9 - Summary GCRR Designs Tests

None of the tested approach producer produced any TAWS.

RNV 21-W resulted in good aircraft energy management, except on the tight RF of 1.7 NM radius which was flyable only at a max speed of 150kts (CAT C) and produced a slight right X-TRK of 0.10 NM. It was eliminated from Coding and no longer an option.

RNAV21-Z was a good option due to the long final TF, but obstacles penetrate the VSS.

Between RNAV 21-X/-Y/-V/-U, **RNAV 21-U** was proposed as the final procedure option as it avoided obstacles penetrating the VSS.

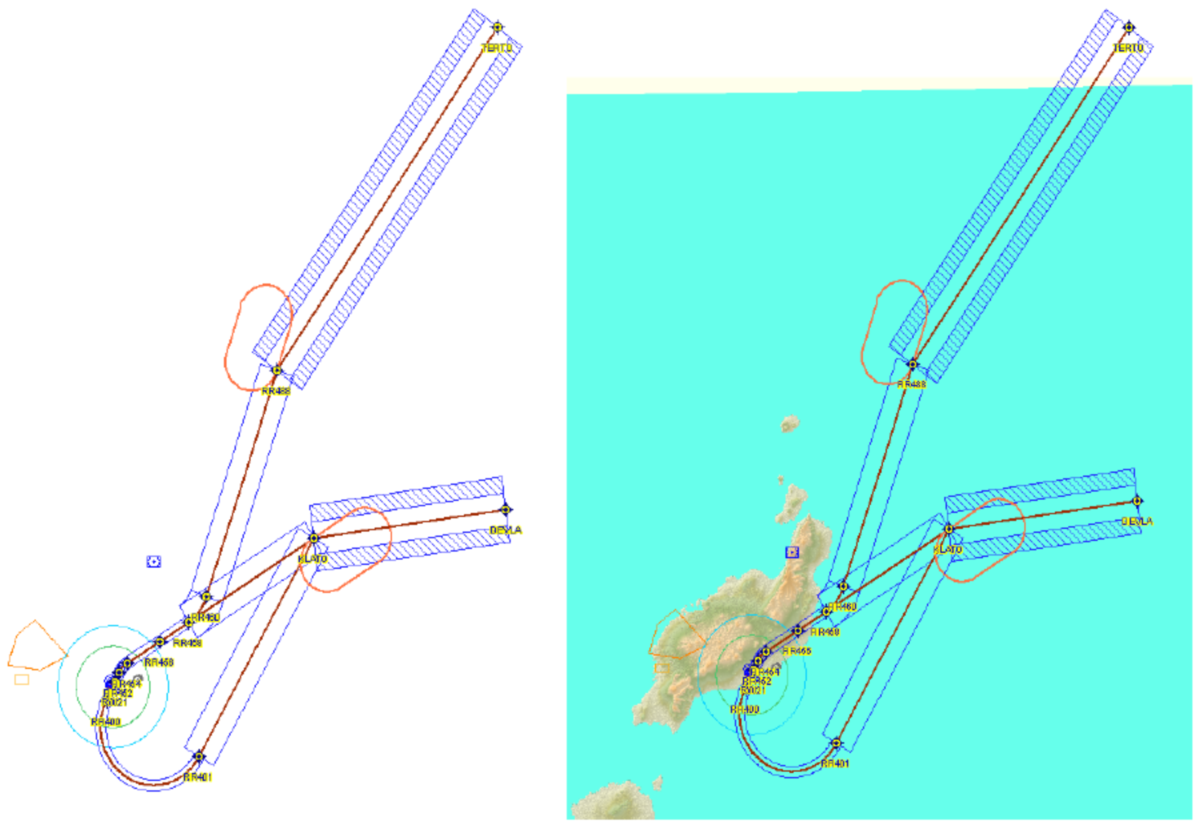


Figure 17 - Detailed Design GCRR RNAV STAR and RNP AR App. RWY 21-U

GCRR RNAV 21-U became what today is known as RNAV (RNP) RWY 21. The latter was utilized for the fight demonstrations.

Some particularities of this design include:

- RNV 21-U RNP AR approach with RNP value of 0.3 NM (also studied with an RNP value of 0.1 NM) was designed and VSS assessed to avoid OBS 719 with an RF turn with a 32° change track between the last 2 TFs.

- RNV 21-U was validated in A320 and 737 FFS. The TF segment after the RF turn is 1.0Nm, and the RF has a radius of 2.5 NM (instead of 2.6 NM).
- Tracks from IAF RR488 and IAF KLATO provided good Energy Management (tested at minimum temperature (15 Degrees Celsius) and Max Temperature (32 Degrees Celsius) for Energy Management.
- AENA presented this design option to the Spanish Safety Agency at the end of May 2013 for information purposes.

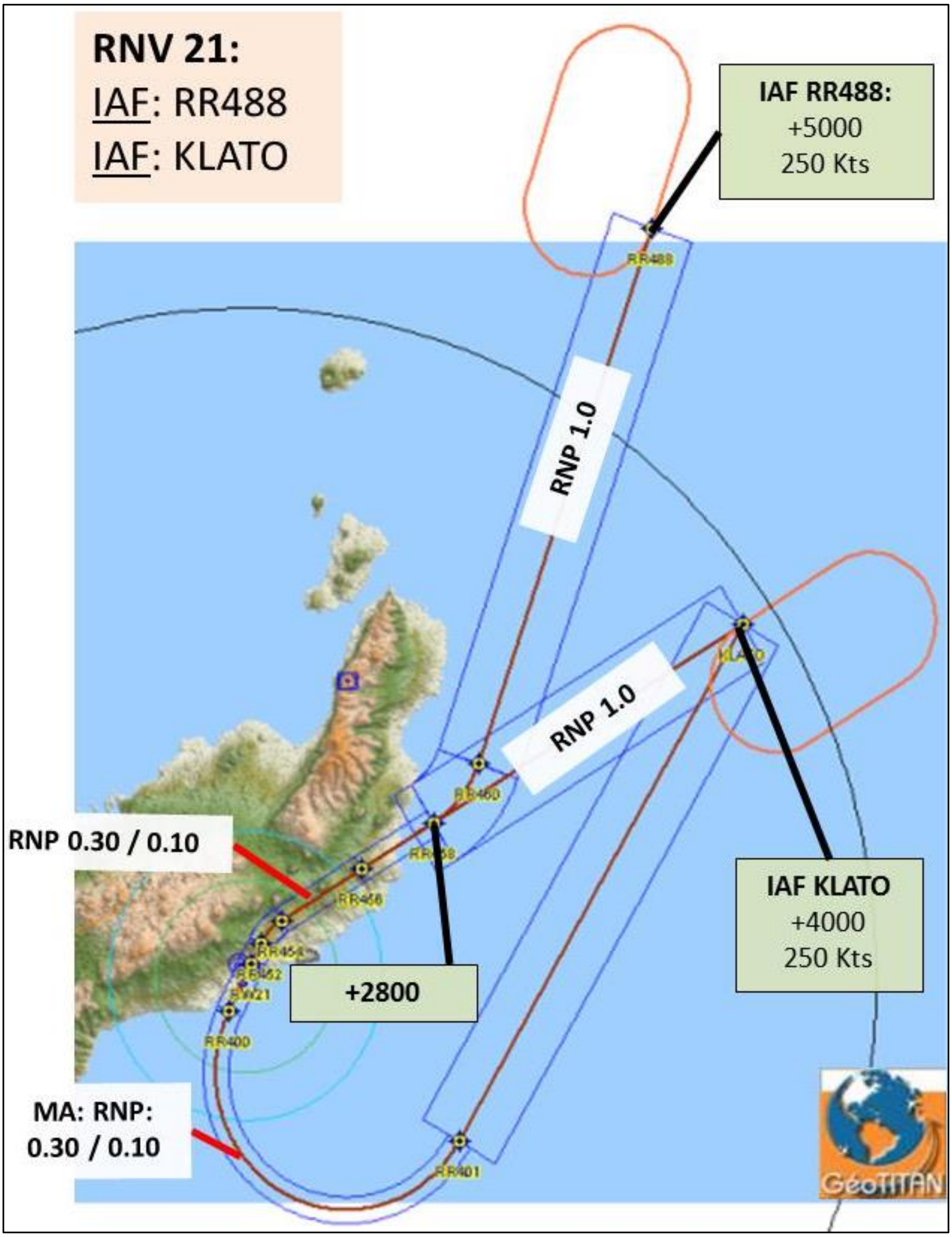


Figure 18 - Detailed Design GCRR RNP AR App. RWY 21

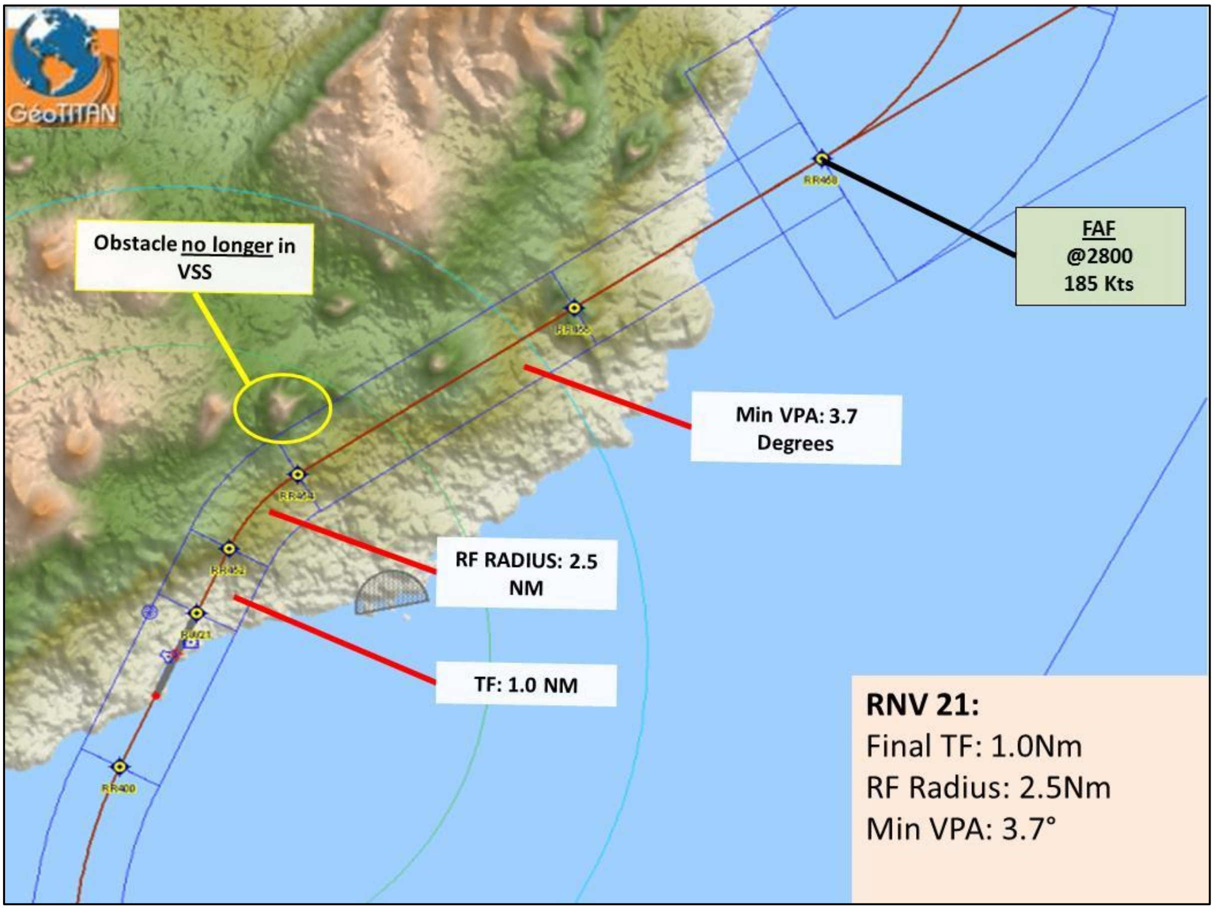
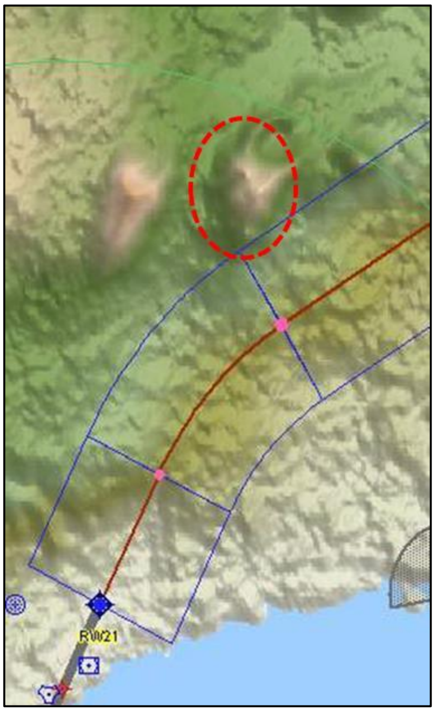


Figure 19 - Detailed Design GCRR RNP AR App. RWY 21 - Zoom

Figure 19 displays a zoomed view of the final approach segment of the RNP AR trajectory.

5.1.3.1.1.8 Lanzarote RNAV 21 – Obstacles in the VSS and design particularities



Final TF: 1.0Nm

RF: 2.5Nm radius (comfortable)

Min Temp: 15°C

RNP AR 0.3 approach path was designed helping avoid the little hill to the north by implementing an RF turn with a 32° change track between the last 2 TFs.

Different to other designed and tested approaches (i.e. APP RNV 21-W), the TF segment after the RF turn is 1.0Nm, and the RF has a radius of 2.5 NM (instead of 1.7 NM).

Both factors were tested for aircraft energy management, and deemed optimal and acceptable.

In reference to the VSS, the final RNAV 21 trajectory design is still slightly affected by obstacles in the vicinity of the airport and runway threshold.

There are mainly three obstacles penetrating the VSS: 719 (Terrain with Beacon), 926 (road) and 928 (Spot height).

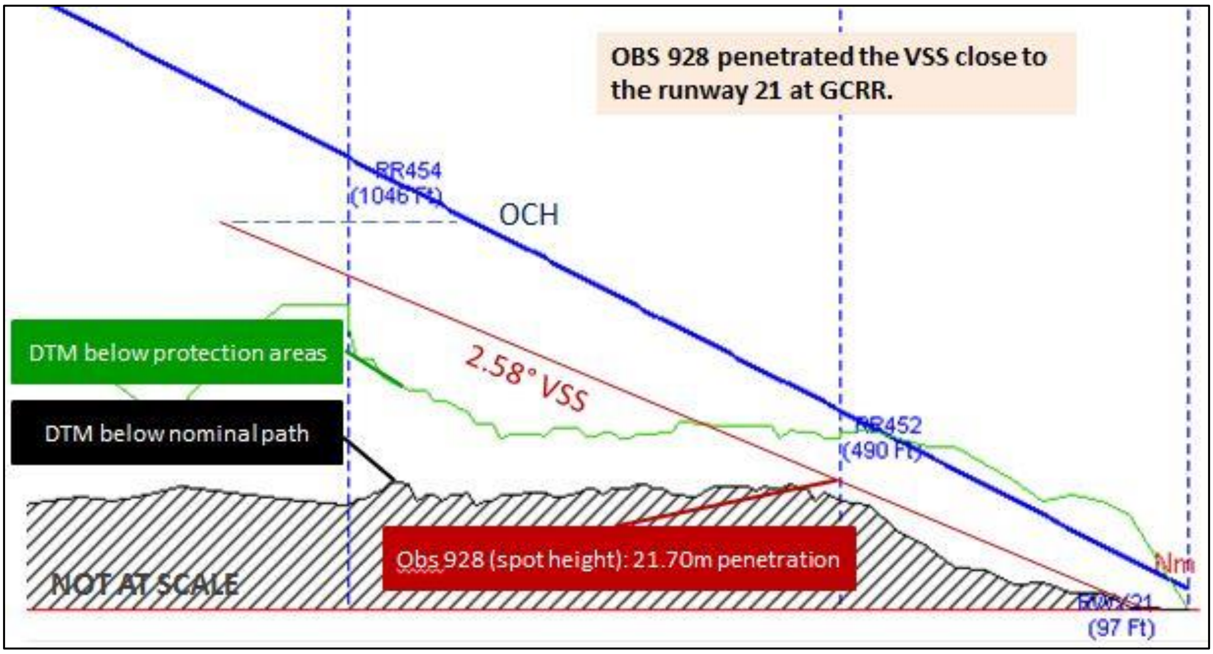


Figure 20 - Detailed Design GCRR RNAV RWY 21 – VSS vertical view

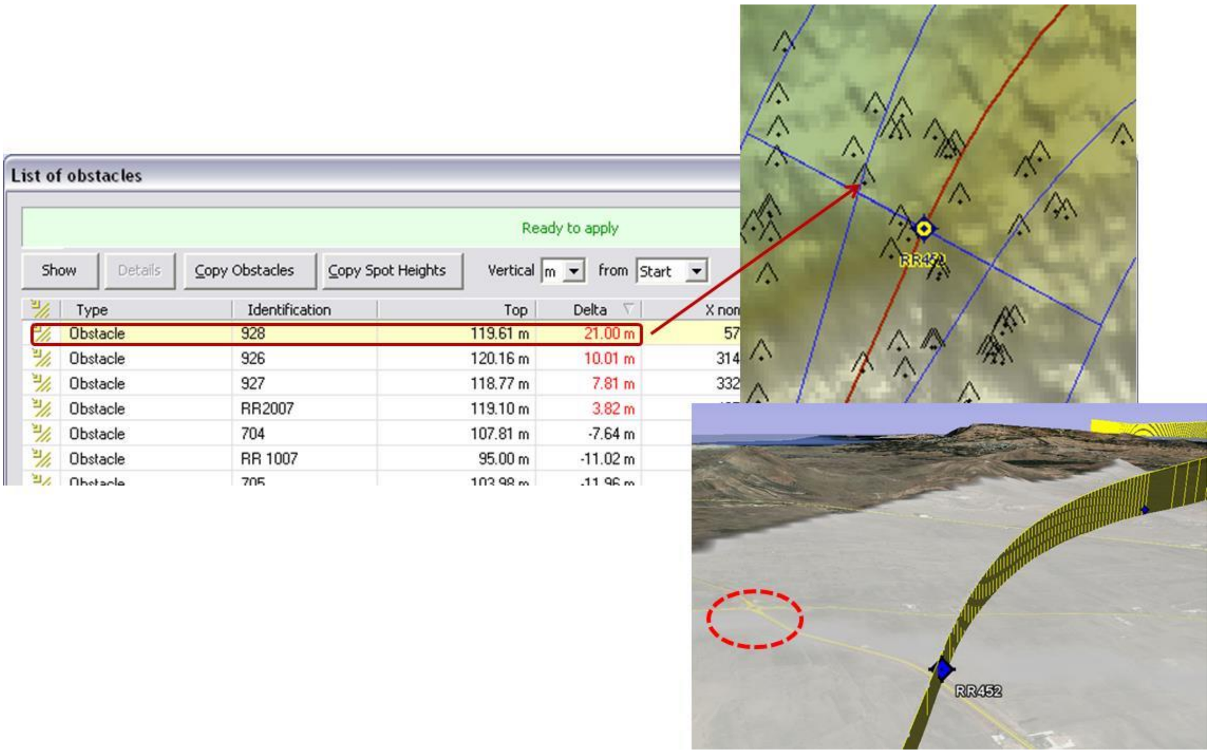


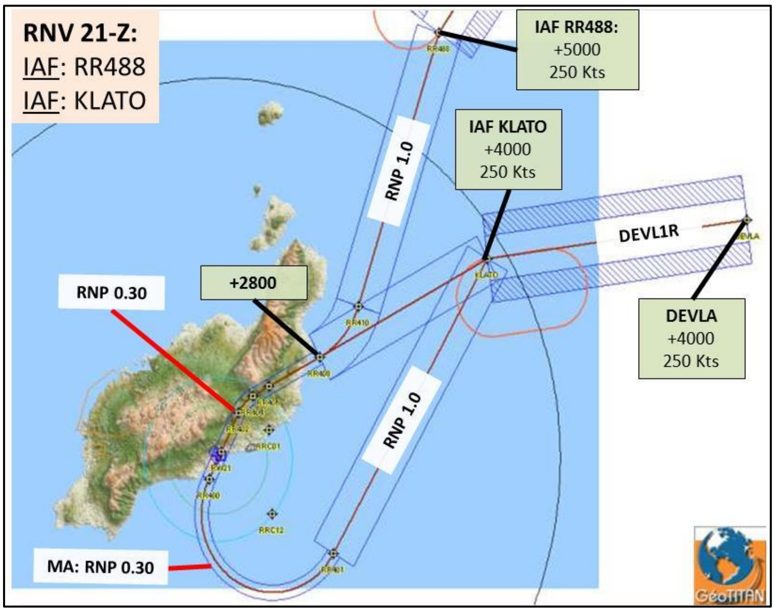
Figure 21 - Detailed Design GCRR RNAV RWY 21 – VSS plan view

Analysis of these obstacles and proposed operational mitigations were assessed with Aena and presented to the Local Authorities. These are included in the FOSA and as part of the pilot required briefing and awareness for GCRR RNP AR operations (See Appendix E).

Following are the designed and tested RNP AR Approach options for GCRR RWY 21 which led to the final design:

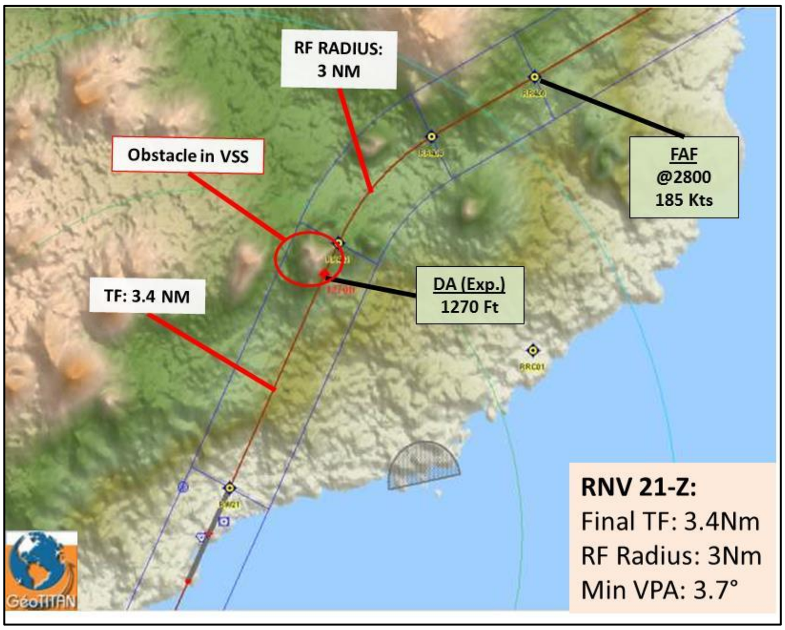
- RNAV RWY21-Z
- RNAV RWY21-X
- RNAV RWY21-Y
- RNAV RWY21-V
- RNAV RWY21-W

5.1.3.1.1.9 APP RNAV-21Z (RNP AR 0.30) - Concept



Test Results

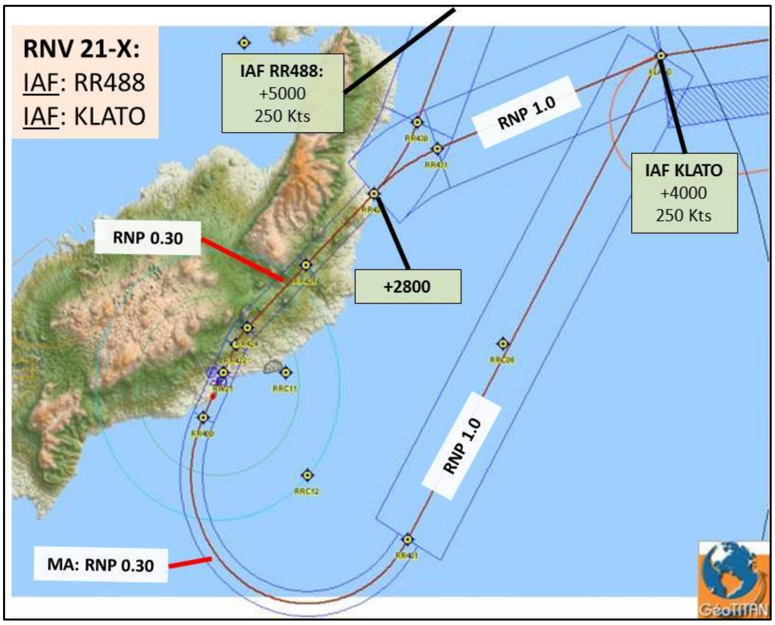
- Stable Approach.
- Energy Management Good.
- Long stable final straight-in segment.
- Tested at ISA +15 and ISA -8 with no TAWS.
- Obstacles penetrate the VSS.



Particulars

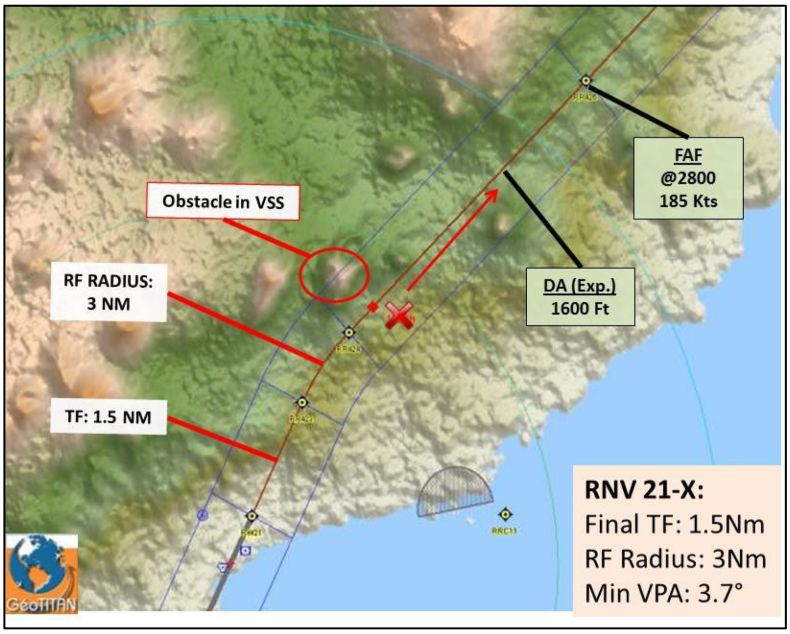
- FAF Alt is 2800 ft with max speed of 185kts.
- Expected DA 1270 ft located after the final RF.
- Longest final TF of the tested procedures: 3.4 NM.
- Min VPA is 3.7°.

5.1.3.1.1.10 APP RNAV-21X (RNP AR 0.30) - Concept



Test Results

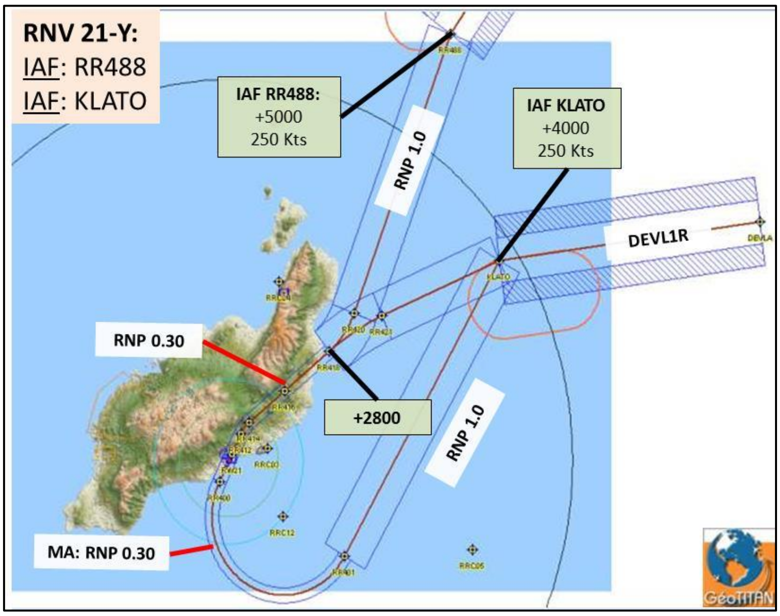
- Stable Approach.
- Energy Management Good.
- Shortest final straight-in segment (1.5 NM) prior to RNV 21-U
- Tested at ISA -8 with no TAWS
- Obstacles penetrate the VSS.



Particulars

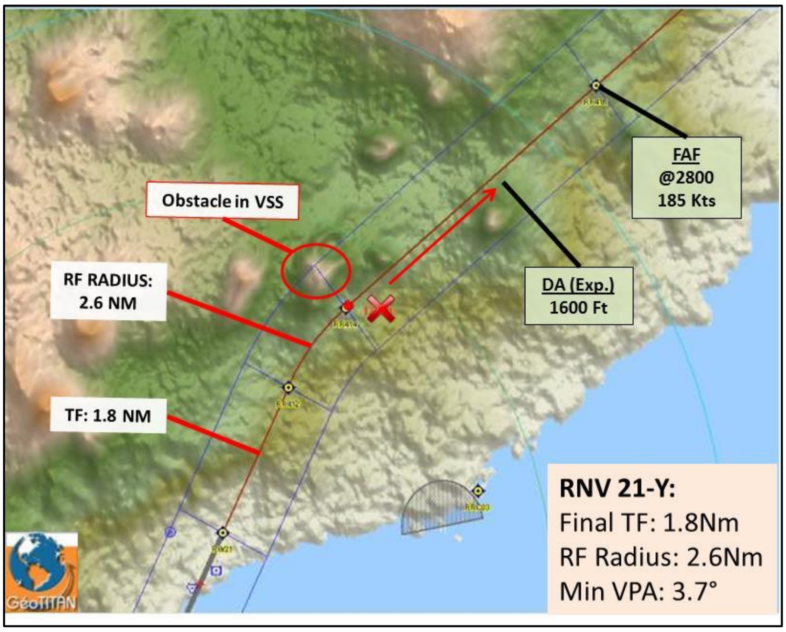
- FAF Alt is 2800 ft with max speed of 185kts.
- Calculated DA was approx. 1270 Ft (prior to final RF).
- DA potentially requires pushing back by 0.6 NM to avoid M/A entering the RF in case A/C is not fitted with NAV Mode in GA.
- Shortest final TF of the tested procedures (1.5 NM) prior to RNV 21-U.
- Min VPA is 3.7°.

5.1.3.1.1.11 APP RNAV-21Y (RNP AR 0.30) - Concept



Test Results

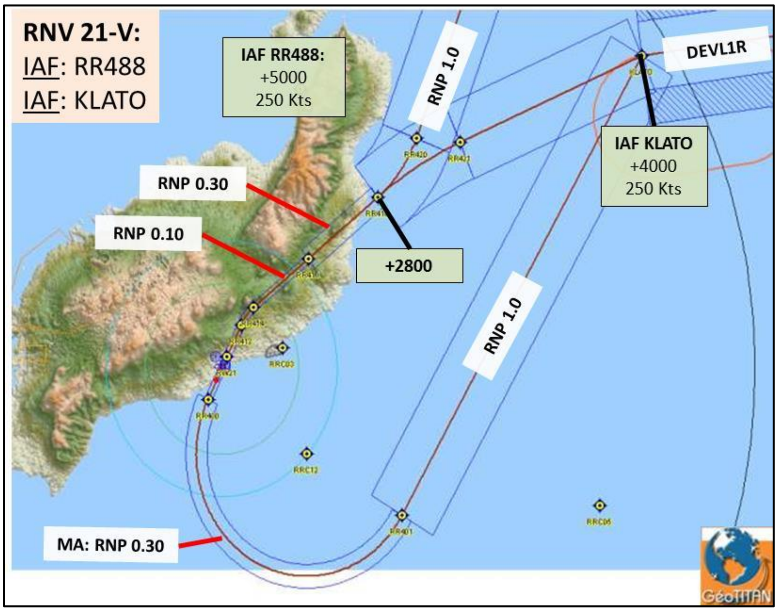
- Stable Approach
- Energy Management Good
- Straight-in segment (1.8 NM)
- Tested at ISA -8 with no TAWS
- Obstacles penetrate the VSS.



Particulars

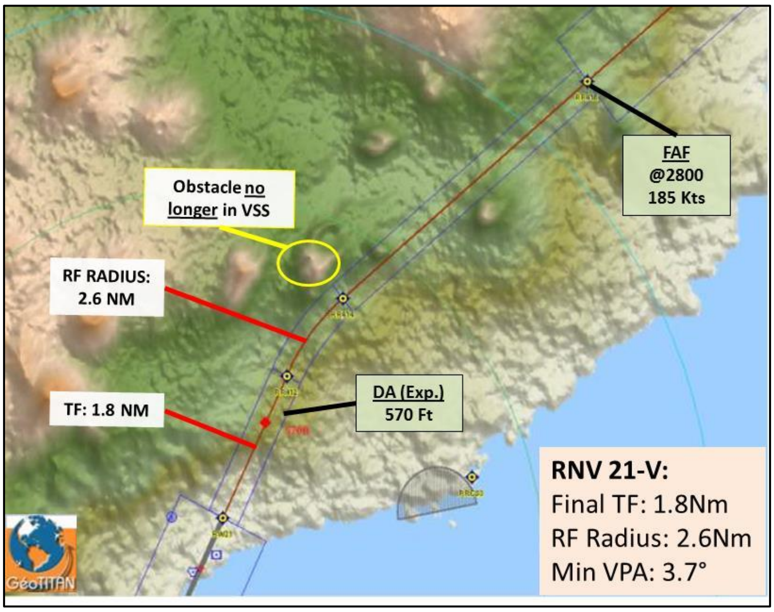
- FAF Alt is 2800 ft with max speed of 185kts.
- Calculated DA was approx. 1270 Ft (entering final RF).
- DA potentially requires pushing back by 0.6 NM to avoid M/A entering the RF in case A/C is not fitted with NAV Mode in GA.
- Min VPA is 3.7°.

5.1.3.1.1.12 APP RNAV-21V (RNP AR 0.10) - Concept



Test Results

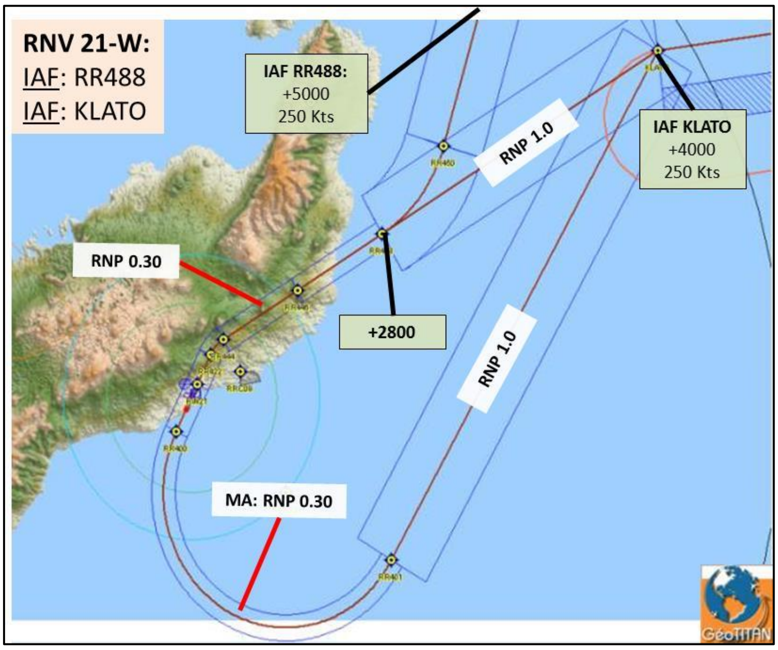
- RNP AR 0.1 (Same track as RNAV 21-Y).
- Stable Approach.
- Energy Management Good.
- Straight-in segment: 1.8 NM.
- Tested at ISA -8 with no TAWS.
- Obstacles penetrate the VSS only close to the runway.



Particulars

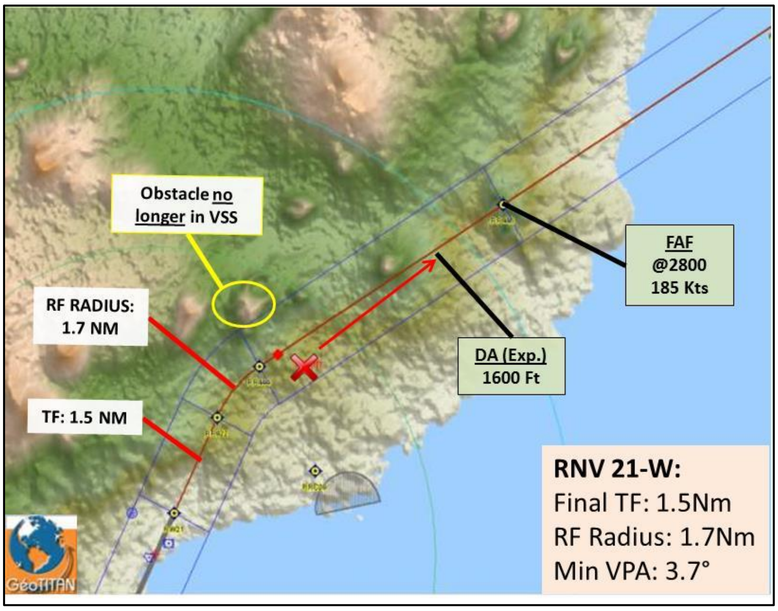
- FAF Alt is 2800 ft with a max speed of 185 kts.
- Calculated DA is approx. 570 Ft (after the final RF).
- Min VPA is 3.7°
- Obstacle adjacent to the RF no longer penetrates the VSS. Nevertheless, obstacle penetrates the VSS close to the runway.

5.1.3.1.1.13 APP RNAV-21W (RNP AR 0.30) - Concept



Test Results

- Stable Approach.
- Energy Management Good. Other tested approaches preferred.
- Straight-in segment: 1.5 NM
- Final RF Max Speed 150kts (CAT C).
- Tight RF created a slight right X-TRK of 0.10 NM.
- Tested at ISA -8 with no TAWS.



Particulars

- FAF Alt is 2800 ft with a max speed of 185kts.
- Calculated DA was approx. 1270 Ft (entering final RF).
- DA potentially requires pushing back by 0.6 NM to avoid M/A entering the RF in case A/C is not fitted with NAV Mode in GA.
- Obstacle adjacent to the RF no longer penetrates the VSS.
- Tight RF (1.7 NM).
- Min VPA is 3.7°.

5.1.3.1.2 Optimization of vertical profile:

Refer to Section 5.1.2.1.5 of this document on the explanation of vertical profile optimization. The same principle as for La Palma was applied to Lanzarote RNP STARs and RNP AR approaches to RWY 21.

In lieu of the optimization of the horizontal and vertical paths with the RNP AR trajectory, the minima for RWY 21 was cut **by over 1000 ft (by half)** for both Category C and D aircraft.

The optimization of the vertical path for RWY 21 at GCRR was achieved by the design itself, considering that no particular ATC altitude constraints were required to be added, but instead the constraints were dictated by the Minimum Obstacle Clearances due to the challenging terrain during the final approach path and the missed approach.

Equally to what was explained earlier for La Palma in Section 5.1.2.1.5, the agreed demonstration flight operations plan and phraseology allowed the operators to indicate the moment they wanted to start their descent based on the optimized ToD point calculated by the FMS, rather than ATC indicating when to descend (sometimes aircraft may be kept in cruise longer than required increasing the fuel burn).

The RNP AR approaches designed for Lanzarote RWY 21 are only available for category C and D aircraft types as shown in the Minima Table of the chart (La Palma RNP AR designs are available for Category A to D aircraft types). To ensure compatibility with category C-D aircraft types, a standard jetliner (A320) was used as a reference. The ideal (unconstrained) profile for the A320 was computed using its FMS and checks were made to verify that the FMS computed profile of a different aircraft, for example a B737NG, would not be affected by the mentioned constraints (i.e. “AT” constraint on the FAP), and that the computed path was similar or close to the profile of the A320.

Refer to the exercise results in Section 5.1.4.2.2 for the average Level-Off distances, which in simple terms indicate the time and distance the aircraft flew at a level altitude after the ToD.

5.1.3.2 Design validation

Once the detailed design of the RNP 1 and RNP AR procedures was frozen (meaning no changes to the trajectories) and agreed by all the stakeholders, the STARs and Approach trajectories were coded and tested on both the A320 and B737 NG Full Flight Simulator by expert procedure development pilots.

The first GCRR A320 Flight Simulator session was carried out in the Toulouse Airbus Training Centre on the 13th of February 2013. Five (5) set of initial designs were tested to define the best final trajectory.

Figure 22 - GCRR Flight Simulator Validation

A second A320 Flight Simulator session was carried out in the Toulouse Airbus Training Centre on the 7th of June 2013 in which the final GCRR RNAV RWY 21 and GCLA RNAV RWY 01/19 were validated. Validation was successful with no remarks. An AENA representative was present at the validation.

A third and final Flight Simulator session was carried out at the CAE Oslo Training Centre on the 24th of June 2013 to validate the GCRR and GCLA RNAV procedures on the B737NG. This testing was carried out with Norwegian Air Shuttle and the validation was successful with no remarks.

Additional testing of the procedures was conducted by participant operators Thomas Cook, Norwegian and Novair prior to the start of the demonstration flights. No remarks were raised.

The Detailed Design Review was carried out in combination with the project review meeting in Madrid on the 10th of July 2013. Results of the testing were presented, followed by the delivery to the CANARIAS Consortium and SJU of Design Package (Procedure Technical Reports [Ref [8]], Charts and procedures coding).

5.1.3.3 Training

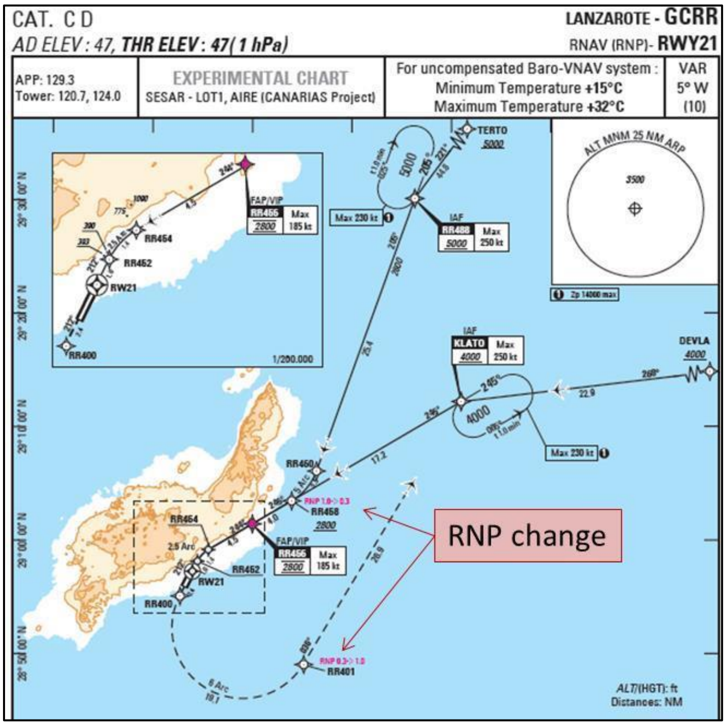
5.1.3.3.1 Air Traffic Controller Training

Refer to Section 5.1.2.3 regarding the ATC training provided under the guidelines of ICAO Doc. 9613.

5.1.3.3.2 Crew Training

Equally as for La Palma, the Consortium and project participant operators were responsible to provide the required RNAV and RNP AR training to its crews, including debriefing on specificities of the RNP AR operations at Lanzarote.

Per the analysis of the Full Flight Simulator sessions and items highlighted in the generic FOSA, GCRR training recommendations and briefing for Pilots using RNP AR procedures included:

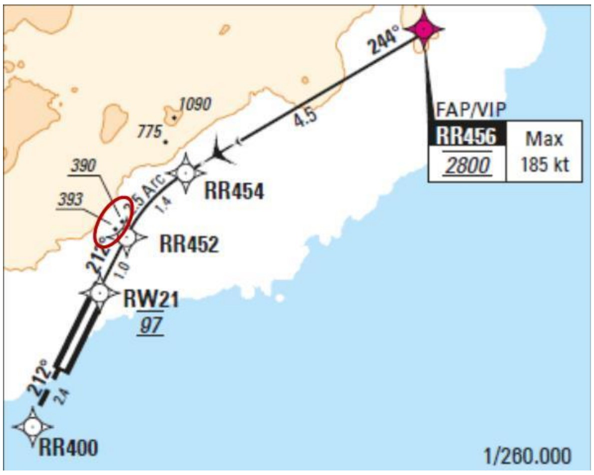


Training Items

- IAFs are RR418 and KLATO.
- Procedure RNP:

  1.0 from RR418/KLATO to RR458,

  0.3 from RR458 till runway (MAPt).
- Minimum temperature of the procedure: 15°C.
- VPA in final is 3.7 ° in ISA conditions.
- Use Minima for RNP 0.3 ONLY.
- Do not use PAPI except as described later.



VSS penetration in final approach RNAV (RNP) RWY21:

In final, Visual Segment Surface (VSS) penetrated by terrain up to 393ft AMSL.

5.1.3.3.2.1 RNAV (RNP) RWY21- Non-operational Mitigation Measures

- Disclaimer in the approach chart (Example of approach penetrating the VSS: APV SBAS Les Eplatures (LSGC). Switzerland).
- Obstacles detailed information in the AIP ("Plano de obstaculos de aeródromos").
- Publication of specific AIC.
- Lighting the obstacle.
- To inform operators about the position of the obstacles.

5.1.3.3.2.2 RNAV (RNP) RWY21 – Operational mitigation measures

- Use of the on-board indication of the lateral (LDEV) and vertical (VDEV) deviation, the crew can realize early any deviation from the nominal path and proactively take corrective action.
- Additional mitigation measures for obstacle awareness, especially if they are located within the Visual Surface Segment include:
  - Critical obstacles in the VSS should be charted, and should be part of the crew briefing.
  - Critical obstacles in the VSS should be light for night operations (easier identification).
- This glide path angle indicated by the PAPI is presently used for the visual final of the circling approach to RWY 21. This can be used as an additional means of mitigation as follows:
  - The PAPI is used to indicate any glide path deviation to the crew, reinforcing the on-board indication of the VDEV.
  - In the crew briefing of the procedure, it will be noted, that the "On glide path indication" given by the PAPI constitutes the lowest possible flight path. (Any indication "Below Glide Path" requires an immediate go-around).

VPA in final is **3,7 °** in ISA condition
(equal to lowest design temperature)

Use of PAPI:

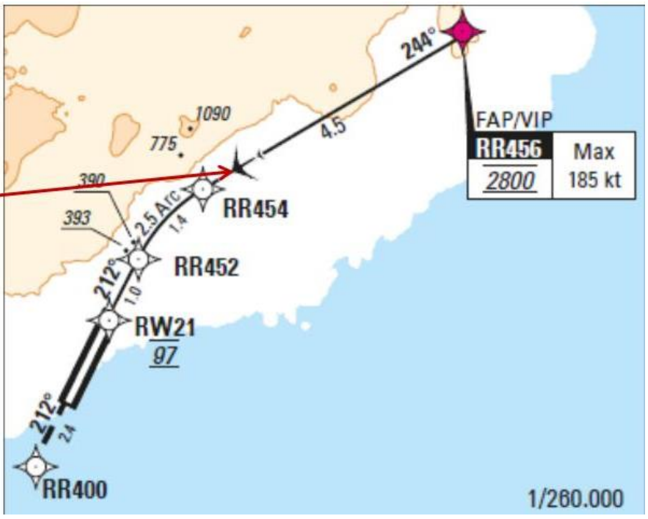
If PAPI shows "on-slope"
The aircraft is at the lowest allowable path

If PAPI shows "below slope"
Perform go-around
as obstacle clearance to the terrain
penetrating the VSS is marginal

- Take into account missed approach / go-around considerations and particularities:

Immediately verify LNAV guidance (NAV mode) in case of missed approach.

DA is before the RF to final:
Approximate position of aircraft at DA



5.1.3.4 Safety assessment

Safety assessments have been prepared from perspectives of different participants, with any risks respectively addressed.

- Airbus Prosky prepared a generic Flight Operational Safety assessment (FOSA) as guidance for the operators carrying out demonstration flights at Lanzarote.
- Airbus ProSky and Aena prepared a Safety Assessment and VSS analysis (Refer to Section 4.3.1), based on the generic FOSA (See Appendix E) and internal considerations.

  Note: Purpose of the FOSA and high-level description is provided in Section 5.1.2.4 of this document.
- AENA prepared a safety assessment regarding the impact of the flight trials in the Canarias TMA airspace (Ref: [11]) presented in Section 4.3.2 of this document.

5.1.3.5 Approval – demonstration flights

The process of communications to the Spanish Authorities about the flight demonstrations at Lanzarote airport, and pertinent operator's documentation is explained in Section 5.1.2.5 of this document.

The flight trials phraseology was common for both La Palma and Lanzarote, further explained in Section 4.2.3 of this document. Deviations of the demonstration flights due to the phraseology agreement are detailed in Section 4.3.2.

Upon provision to the Local Authorities of the project documentation and participant operator's qualifications for review; upon agreeing with the Air Traffic Controllers and operators the phraseology to be utilized during the flight demonstrations; authorization for the demonstrations flights to Lanzarote was provided by the CANARIAS Consortium on the **1st of April 2014,** and the first flight took place on 11th of April 2014.

5.1.3.6 Flight trials

The Lanzarote exercise execution contemplated 50 demonstration flights to be completed within the set period to Runway 21. There was no RNAV design contemplated for RWY 03, even though yearly predominant winds serve the latter.

As explained in detail in the Deviations from the planned activities (Refer to Section 4.3.3) and duly reported in the project Quarterly Reports, various external factors to the project, including wind conditions and the late start of the demonstration flights, had an important effect on the amount of flight demonstrations carried out at GCRR.

A total of Four (4) RNAV demonstration flights were carried out at Lanzarote RWY 21:

1. 11th April 2014 (Novair - A321)
2. 14th April 2014 (Thomas Cook – A321)
3. 21st April 2014 (Novair - A321)
4. 21st April 2014 (Norwegian Air Shuttle- B737-8)

After the 21st of April 2014 no other demonstration flights were carried out mainly due to:

- Predominant winds to GCRR were for RWY 03, expected to change only during the winter.
- Two participant airlines stopped scheduled flights to Lanzarote for the summer season.

Operators that carried out the RNAV demonstration flights into Lanzarote preferred this option over the conventional procedures (refer to statements in Section 7.3.1 of this document).

Results of the flight trials are provided in Section 5.1.4.2.2 of this report.

5.1.4 Exercise Results

The following sub-sections provide combined flight trial results for Lanzarote and La Palma.

5.1.4.1 General

The following sections provide the results of the La Palma and Lanzarote flight demonstrations conducted between April 2014 and September 2014, data analysis, and overall results

5.1.4.2 Data capture methodology

One of the objectives of the CANARIAS project was to demonstrate reduction of CO_2 emissions by achieving track mile savings together with Continuous Descent Operations compared to the published conventional procedures. A direct way to achieve this objective was to compare the fuel consumption of aircraft flying the published conventional procedures versus the fuel consumed flying the RNP AR designed procedures. The analysis would take into consideration the optimized horizontal and vertical profile of the proposed solutions at GCLA and GCRR.

Today there are a variety of interpretations on how to compare two different flight profiles, but no common agreed methodology is available as a baseline for analysis. Per other similar project (i.e. AMBER), a methodology was selected based on the available data operators could capture, and that was comparable on a wide order of magnitude. As any methodology, it has pros and cons, but it is believed that for the purpose of this analysis the methodology is deemed acceptable.

Key indicators for the analysis were:

- Air distance flown;
- Flight time;
- Fuel consumption
- Equivalent CO_2 emissions derived from fuel burn measure; and
- Level-off cumulated distance and time.

Project Consortium and participant operators were asked to capture raw data for at least 10 conventional flights flown, and the same raw data for the RNAV trajectories flown during the demonstration flights.

The specific de-identified conventional and RNAV raw data was then provided by each operator as an average in the following table format:

Entry Waypoint	Flights (count)	Duration (min)	Fuel (kg)	Air Distance (NM)	Level-off Air Distance (NM)	Level-off Duration (min)	Flights with Level-off (count)	% of all	Planned LDG RWY	Actual LDG RWY	Missed APP or GA
XX	XX	XX X	XXXX	XX.X	XX X	XX.X	XX	XX%	XX	XX	XX%
XX	XX	XX X	XXXX	XX.X	XX X	XX.X	XX	XX%	XX	XX	XX%
Grand Total	**XX**	**XX.X**	**XXX**	**XX.X**	**XX.X**	**XX.X**	**XX**				**XX**
Average		**XX.X**	**XXX**	**XX.X**	**XX.X**	**XX.X**	**XX**	**XX %**			

Table 10 - Operator Flight Data Output format

To achieve the above illustrated outputs for each flown procedure, several indicators were downloaded and analyzed. For data recording the existing Flight Data Monitoring system was used, consisting of on-board quick access recorder and computer infrastructure at the operator's locations. Such solution provides the most exact and reliable figures, without workload increase for the participating flight crews.

The following table displays a partial list of raw data fields that were useful for the analysis (data fields may vary depending on the aircraft type):

Time (secs)	Altitude Baro Setting F/O	Altitude Baro Setting Capt
ATS Active	ATS Engaged	Auto Speed Control
PFD Selected Speed	PFD Selected Speed (APP only)	Selected Altitude (Manual)
Selected Decision Height	Selected FPA	Selected Heading
Selected Track	Selected Vertical Speed	Flap Lever Position (actual)
Flap Lever Position (gated)	Slats Position (Vfe)	Flaps Position (Vfe)
Fuel Flow Eng 1	Fuel Flow Eng 2	Reverser Deployed Eng 1
Reverser Deployed Eng 2	Altitude Standard	Ground Speed
Heading (displayed)	Indicated Airspeed	Mach (derived)
Mach Selection	Radio Altitude 2	Radio Altitude 1
True Airspeed (derived)	Vertical Speed (derived)	Air / Gnd
Gear Selection Up	Present Position Latitude	Present Position Longitude
Wind Speed	Wind Direction True	Gross Weight

Table 11 - Flight data recorder fields

These fields helped derive information conclusive for the analysis such as:

Fuel Used Eng 1	Fuel Used Eng 2	Cumulative Air Distance
Cumulative Fuel	Cumulative Level Time	Cumulative Level Distance

The method used for indicators calculation and comparison between conventional and RNP AR approaches was to capture data before the ToD, and starting the comparison from the ToD paying attention to the Entry Waypoints (waypoint where the STARs commence), common to both the Conventional and RNAV designed procedures.

When passing over the Entry waypoint, particularly in the Lanzarote scenario, the aircraft was already in descent. Due to the small amount of flight demonstrations carried out at GCLA and GCRR, it was not possible to establish with relevant data if being in descent prevents realistic comparison of the optimized ToD calculated by the FMS for the RNP AR profile trajectory. However, measuring from a set waypoint common to both trajectories (and the reason why the RNAV STARs were designed from such waypoints) provides a realistic scenario for the comparison.

To illustrate a wide comparison of results from different points of the flight (ToD, Entry Waypoint, and Equivalent Air Distance), the results allow to:

- Observe the benefits of both shorter tracks and continuous descent profile;
- Compare RNP AR arrivals (overflying actual waypoints) to conventional arrivals which sometimes are vectored direct to the airport or runway threshold, without overflying an actual entry point.

The extracted data was planned to be filtered in order to exclude traffic congestion hours, flights with unusual holdings or go-around and arrivals in high winds. However not enough baseline and RNP AR flight data was gathered to carry out this exercise.

Level-off calculations where performed by using manual processing. In the analysis, a level-off is considered flying at a "level" (the same) altitude for at least 30 seconds duration. The used method resulted in margin of vertical speed for level-off selection of < 200 ft/m. The method is considered accurate enough for obtaining acceptable level-off distance and duration values. The level-off information is important to compare, where applicable, the continuous descent profile between the published conventional procedures versus the RNP STARs and RNP AR procedures designed for the flight trials.

The expected V-PAT analysis results (refer to Section 4.2.2 for details on purpose of the tool), should allow to validate the obtained results in the above analysis where ASTERIX surveillance data or

CFMU correlated position reports are available for the conventional and RNAV data sets utilized in the main analysis.

5.1.4.2.1 La Palma (GCLA) RWY 01 Analysis Results

The key results for La Palma are provided in the following sub-sections:

5.1.4.2.1.1 GCLA - Norwegian Air Shuttle (B737-8)

GCLA Conventional arrivals:

Entry Waypoint: ORTIS3V (IAF:XISLA)	Conventional flights count	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
From ORTIS	N/A						
From ToD							
From XISLA							

Note: Conventional data is not comparable because IAF XISLA is a new waypoint not present in the conventional procedures, but only available for the RNP AR designs.

Entry Waypoint: ORTIS3V (IAF ARACO)	Conventional flights count	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
From ORTIS	*NO RAW DATA FROM ENTRY ORTIS						
From ToD	1	30:24	649.6	152.5	2.2	00:42	100%
From ARACO		10:28	342.1	31.1			

Note: *Conventional data provided did not contain information starting from ORTIS Entry waypoint.

GCLA CANARIAS RNP arrivals:

Entry Waypoint: ORTIS1X (IAF:XISLA)	CANARIAS flights count	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
From ORTIS	1	*NO RAW DATA FROM ENTRY ORTIS					
From ToD		22:42	346.8	121.5	0.0	00:00	0%
From Average Conventional ToD		21:50	336.5	114.8			
From XISLA		**11:00**	**246.0**	**40.1**			
From Average Air Distance equivalent to Conv. ToD		N/A					

Note: *RNAV demonstration flight data did not contain information starting from ORTIS Entry waypoint, nor from the equivalent Conventional ToD Air Distance.

Entry Waypoint: ORTIS1X (IAF: ARACO)	CANARIAS flights count	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
From ORTIS	3	NO RAW DATA FROM ENTRY ORTIS					
From ToD		22:37	365.1	121.2	0.0	00:00	0%
From Average Conventional ToD		22:14	357.5	118.3			
From ARACO		**07:12**	**195.6**	**23.7**			
From Average Air Distance equivalent to Conv. ToD		RAW DATA not representative		152.5	RAW DATA not representative		

Note: *RNAV demonstration flight data did not contain information starting from ORTIS Entry waypoint nor from the equivalent Conventional ToD Air Distance.

Differences (Conventional Vs. RNP):

	Entry Waypoint: ORTIS IAF Conv.: ARACO) Vs. IAF RNAV: ARACO	*Time*	*Fuel*	*Air dist*	*Level-off*	*Level-off time*	*Flights with level-off*
		min	*kg*	*NM*	*NM*	*min*	*%*
	From ORTIS	**RAW DATA NOT AVAILABLE FOR COMPARISON**					
1	RNAV ToD Vs. Conventional Average ToD	-0:07:47	-284.4	-31.3	-2.2	-0:00:42	-100%
2	From Average Conventional ToD	-0:08:10	-292.1	-34.2			
3	**From ARACO**	**-0:03:16**	**-146.6**	**-7.4**			
4	From Average Air Distance equivalent to Conventional ToD	**DATA not comparable**					

Note: Numbers on the left side of the table are correlated to the numbers in Figure 23.

Graphic Illustration of Differences (Conventional Vs. RNP):

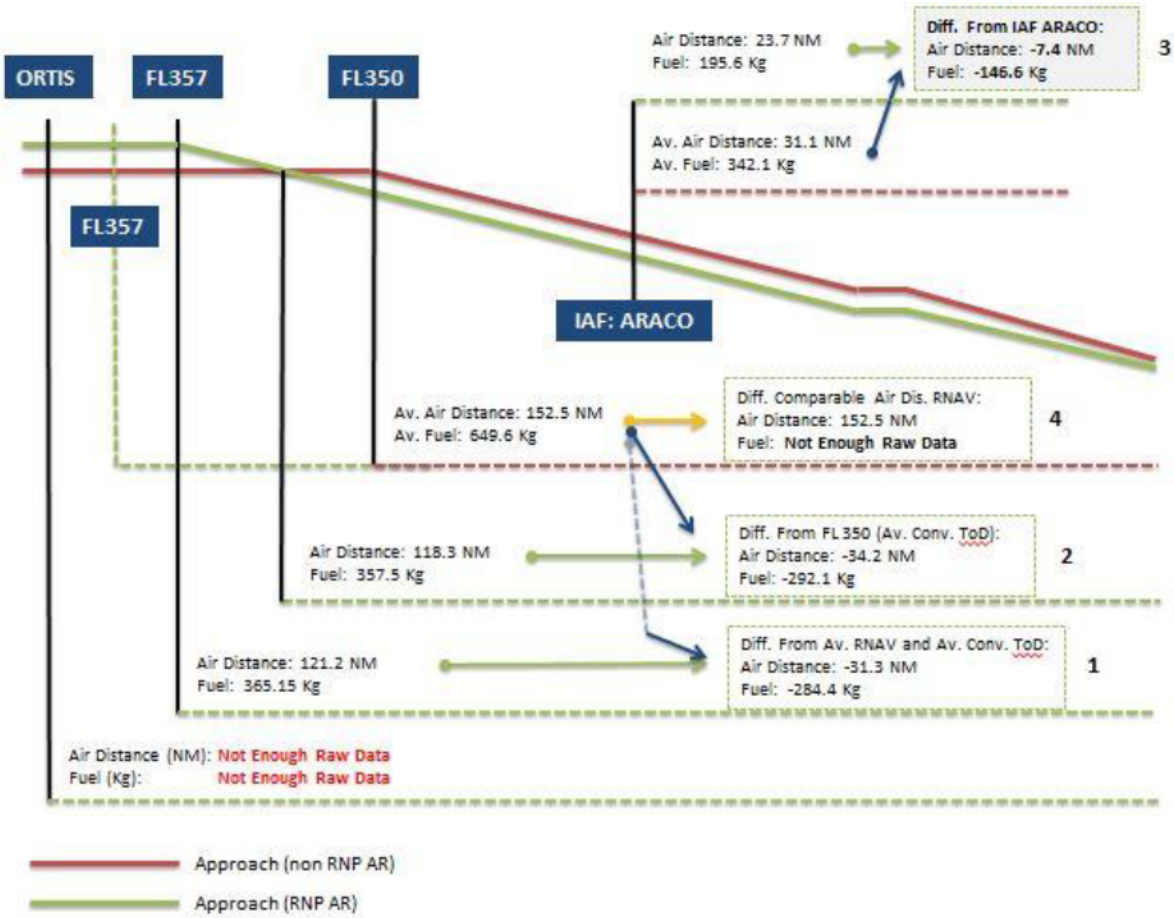


Figure 23 - GCLA Illustration Conv. Vs. RNP – ORTIS (IAF ARACO)

Entry Waypoint: ORTIS IAF Conv.: ARACO Vs. IAF RNAV: XISLA	*Time*	*Fuel*	*Air dist*	*Level-off*	*Level-off time*	*Flights with level-off*
	min	*kg*	*NM*	*NM*	*min*	*%*
From ORTIS	**RAW DATA NOT AVAILABLE FOR COMPARISON**					
RNAV ToD Vs. Conventional Average ToD	-0:07:42	-302.8	-31.0	-2.2	-0:00:42	-100%
From Average Conventional ToD	-0:08:34	-313.1	-37.7			
From XISLA	**+0:00:32**	**-96.1**	**9.0**			
From Average Air Distance equivalent to Conventional ToD	**DATA not comparable**					

Entry Waypoint: ORTIS IAF RNAV: XISLA Vs ARACO	*Time*	*Fuel*	*Air dist*	*Level-off*	*Level-off time*	*Flights with level-off*
	min	*kg*	*NM*	*NM*	*min*	*%*
From ORTIS	**RAW DATA NOT AVAILABLE FOR COMPARISON**					
RNAV ToDs	-0:00:05	-18.4	-0.3	0.00	0:00	0%
From Average Conventional ToD	-0:00:20	-21.0	-3.5			

Note: Results in table above are displayed in Figure 24.

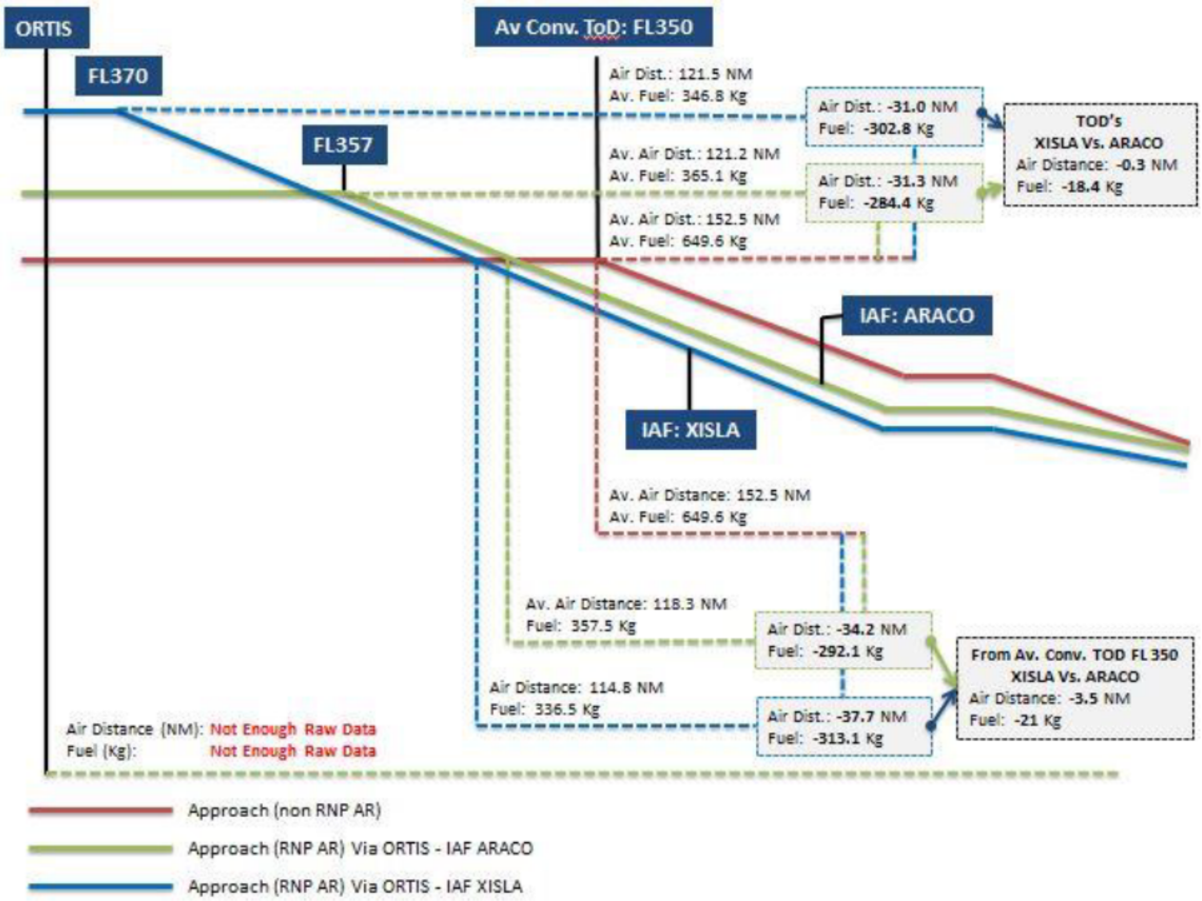


Figure 24 - GCLA Illustration Conv. (IAF ARACO) vs. RNP (IAF ARACO Vs. IAF XISLA)

5.1.4.2.1.2 GCLA – Summary of Results

During the CANARIAS project demonstration flights at GCLA, a continuous observation process was implemented over trials operational execution from both pilot and air traffic controller perspectives. No outstanding operational observations where received from the pilot side. No reports on operational problems where received from air traffic controllers. Only comment is that sometimes the intended phraseology for the demonstration flights was not completely followed.

Based on the aircraft recorded and air traffic control radar recorded data, La Palma RNP arrivals indicate a precise execution of the procedure from the IAF following the prescribed flight track.

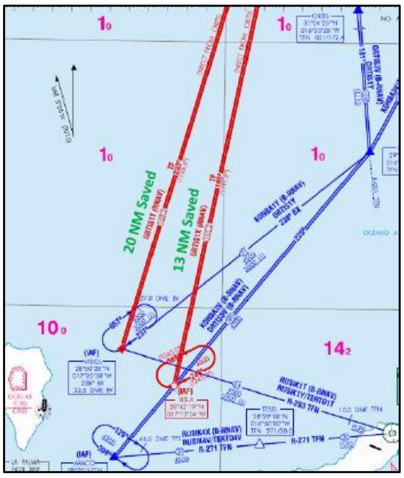
Based on the analysis of the La Palma demonstration flights and in consideration of the analysis limitations, the following can be concluded:

- Norwegian Air Shuttle was the only CANARIAS participant operator flying to La Palma, a new destination for the airline since June 2014.
- Available flights are only for RWY 01. No conventional or RNAV demonstration flights were carried out to RWY 19.

STAR

ORTIS is the entry waypoint common to both the conventional (ORTIS3V) and RNAV (ORITS1X) STAR trajectories.

RNAV STAR ORTIS1X to new IAF XISLA was expected to provide savings of approximately 13 NM compared to conventional STAR ORTIS3V ending at IAF ARACO.



Conventional and RNAV flights supported raw data starts after Entry Waypoint ORTIS. As a result, it is not possible to carry out a high level comparison between flights and verify STAR savings.

In addition, it seems that the four demonstration flights followed STAR ORTIS3V and none followed STAR ORTIS1X.

One (1) demonstration flight utilized IAF XISLA, and three (3) demonstration flights utilized IAF ARACO.

Initial Approach Fixe (IAF)

- In the absence of data from Entry Waypoint ORTIS, the analysis concludes on comparison from ToDs, average conventional ToD, IAF's.
- XISLA is the new IAF placed on the current conventional STAR ORTIS3V to reduce track miles approaching RWY 01 instead of using IAF ARACO.
- Three (3) demonstration flights using IAF ARACO are compared to the only conventional flight to IAF ARACO (refer to *Figure 23*).
    - Comparing from the conventional ToD:
        - ✓ **Air Distance is reduced by 34.2 NM**
        - ✓ **292.2 Kg of less fuel consumed.**

- Comparing from IAF ARACO:
  - ✓ **Air Distance is reduced by 7.4 NM**
  - ✓ **146.6 Kg of less fuel consumed.**
  - ✓ **No level-off is present** (reflecting the elimination of the level-off within the DME ARC of the conventional procedure – See ***Figure 25***).

Figure 25 – GCLA IAF ARACO: Conv. vs. RNP AR RWY 01

- One (1) demonstration flight using IAF XISLA is compared to the only conventional flight to IAF ARACO.
  - Comparing from the conventional ToD:
    - ✓ **Air Distance is reduced by 37.7 NM**
    - ✓ **313.1 Kg of less fuel consumed.**
    - ✓ **No level-off is present** (reflecting the elimination of the level-off within the DME ARC of the conventional procedure).

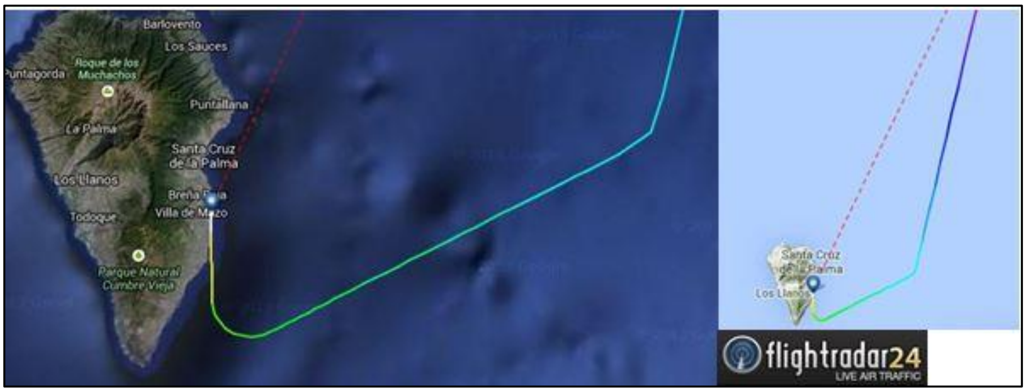


Figure 26 - GCLA IAF XISLA: RNP AR RWY 01

- When comparing the results from the RNAV demonstration flight using IAF XISLA and the three (3) demonstration flights using IAF ARACO from the same ToD (Conventional ToD: FL350), the difference is savings is minor mainly due to the optimized descent profile calculated by the FMS (refer to ***Figure 24***):
  - ✓ **Air Distance using XISLA is reduced by 3.5 NM**
  - ✓ **21.0 Kg of less fuel consumed.**
  - ✓ **No level-offs present** (optimization of vertical profile by the FMS).

5.1.4.2.2 Lanzarote (GCRR) RWY 21 Analysis Results

The key average results for Lanzarote are provided in the following tables:

5.1.4.2.2.1 GCRR – Novair (A321)

GCRR Conventional arrivals:

Entry Waypoint: TERTO N30 06, W012 43	Conventional flights count	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
From ToD	2	24:38	421.00	132.18	3.34	00:52	50%
From TERTO		21:12	364	107.14			

Entry Waypoint: DEVLA N29 14, W012 43	Conventional flights count	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
From ToD	No DATA						
From DEVLA							

GCRR CANARIAS RNP arrivals:

Entry Waypoint: TERTO N30 06, W012 43	CANARIAS flights count	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
From ToD	1	26:36	440.14	142.845	0.46	00:08	100%
From Average Conventional ToD		23:12	358.40	117.214			
From TERTO		**18:52**	**315.08**	**86.789**			
From Average Air Distance equivalent to Conventional ToD		25:12	395.82	132.166			

Entry Waypoint: DEVLA N29 14, W012 43	CANARIAS flights count	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
From ToD	1	27:36	593.8	138.4	5.82	02:16	100%
From Average Conventional ToD		N/A					
From DEVLA		**16:32**	**452.02**	**62.44**			
From Average Air Distance equivalent to Conventional ToD		N/A					

Differences (Conventional Vs. RNP):

	Entry Waypoint: TERTO N30 06, W012 43	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
1	RNAV ToD Vs. Conventional average ToD	+0:01:58	+19.14	+10.67	-2.88	-0:00:44	N/A
2	From Average Conventional ToD	-0:01:26	-62.60	-14.96			
3	**From TERTO**	**-0:02:20**	**-48.92**	**-20.35**			
4	From Average Air Distance equivalent to Conventional ToD	-0:00:34	-25.18	-0.01			

Note: Numbers on the left side of the table are correlated to the numbers in Figure 27.

Entry Waypoint: DEVLA N29 14, W012 43	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
	min	kg	NM	NM	min	%
	DATA NOT COMPARABLE					

Graphic Illustration of Differences (Conventional Vs. RNP):

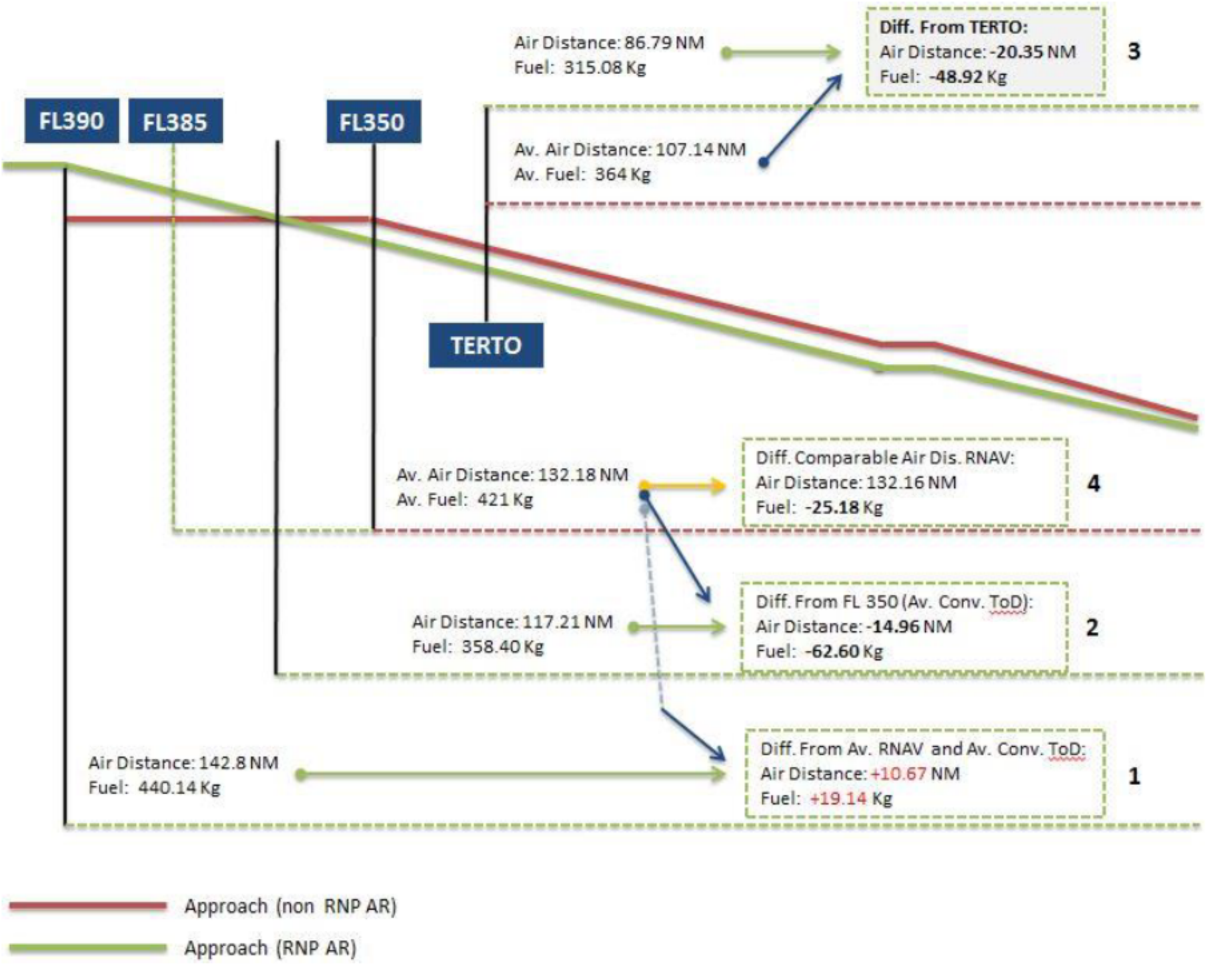


Figure 27 - GCRR Illustration Conv. vs. RNP – TERTO (Op 1)

5.1.4.2.2.2 GCRR - Thomas Cook (A321)

GCRR Conventional arrivals:

Entry Waypoint: TERTO N30 06, W012 43	Conventional flights count	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
From ToD	16	25:04	531.8	124.1	6.7	02:02	100%
From TERTO		21:12	475.6	95.7	6.5	02:00	100%

Entry Waypoint: DEVLA N29 14, W012 43	Conventional flights count	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
From ToD	No DATA						
From DEVLA							

GCRR CANARIAS RNP arrivals:

Entry Waypoint: TERTO N30 06, W012 43	CANARIAS flights count	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
From ToD	1	22:04	495.07	118.16	10.78	02:56	100%
From Average Conventional ToD		21:28	481.79	113.56			
From TERTO		**16:59**	**411.76**	**79.05**			
From Average Air Distance equivalent to Conventional ToD		22:53	496.56	124.24	15.44	03:32	

Entry Waypoint: DEVLA N29 14, W012 43	CANARIAS flights count	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
From ToD	No DATA						
From Average Conventional ToD							
From DEVLA							
From Average Air Distance equivalent to Conventional ToD							

Differences (conventional Vs. RNP):

	Entry Waypoint: TERTO N30 06, W012 43	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
1	RNAV ToD Vs. Conventional average ToD	-0:03:00	-36.70	-5.98	-2.88	-0:00:54	N/A
2	From Average Conventional ToD	-0:03:36	-49.98	-10.58			
3	**From TERTO**	**-0:04:13**	**-63.84**	**-16.67**	**4.30**	**-0:00:56**	
4	From Average Air Distance equivalent to Conventional ToD	-0:02:11	-35.20	0.10	8.79	-0:01:30	

Note: Numbers on the left side of the table are correlated to the numbers in Figure 28.

Entry Waypoint: DEVLA N29 14, W012 43	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
	min	kg	NM	NM	min	%
	DATA NON COMPARABLE					

Graphic Illustration of Differences (Conventional Vs. RNP):

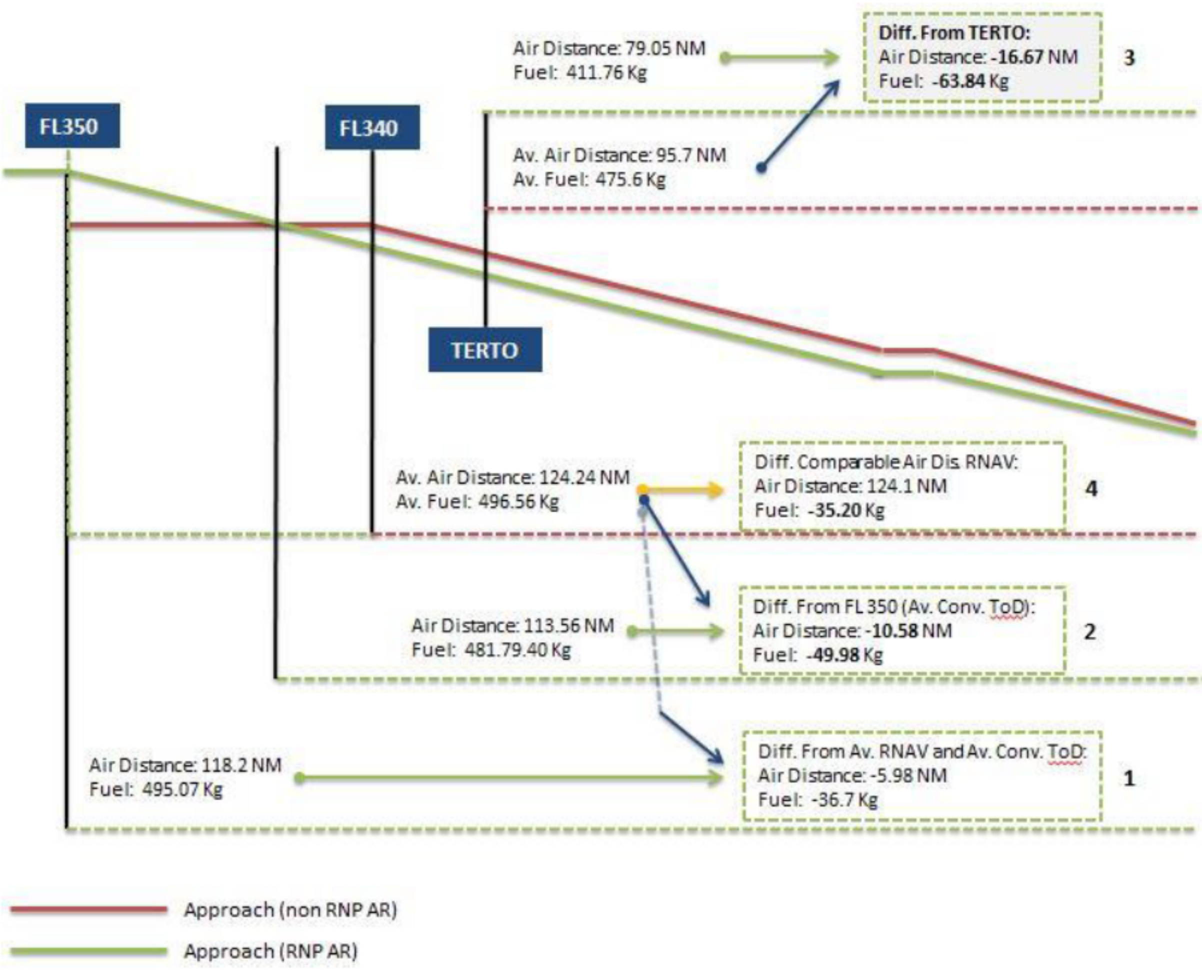


Figure 28 - GCRR Illustration Conv. vs. RNP – TERTO (Op 2)

5.1.4.2.2.3 GCRR - Norwegian Air Shuttle (B737-8)

GCRR Conventional arrivals:

Entry Waypoint: TERTO N30 06, W012 43	Conventional flights count	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
From ToD	1	22:05	271.5	113.4	0.00	00:00	0%
From TERTO		18:53	247.1	89.7	0.00	00:00	0%

Entry Waypoint: DEVLA N29 14, W012 43	Conventional flights count	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
From ToD	No DATA						
From DEVLA							

GCRR CANARIAS RNP arrivals:

Entry Waypoint: TERTO N30 06, W012 43	CANARIAS flights count	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
From ToD	1	25:03	291.01	130.59	0.00	00:00	0%
From Average Conventional ToD		23:24	278.40	118.59			
From TERTO		**18:33**	**235.02**	**85.48**			
From Average Air Distance equivalent to Conventional ToD		22:40	266.80	113.39			

Entry Waypoint: DEVLA N29 14, W012 43	CANARIAS flights count	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
From ToD	No DATA						
From Average Conventional ToD							
From DEVLA							
From Average Air Distance equivalent to Conventional ToD							

Differences (conventional Vs. RNP):

	Entry Waypoint: TERTO N30 06, W012 43	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
		min	kg	NM	NM	min	%
1	RNAV ToD Vs. Conventional average ToD	+0:02:58	19.6	17.2	0.00	00:00	0%
2	From Average Conventional ToD	+0:01:19	6.9	5.2			
3	**From TERTO**	**-0:00:20**	**-12.1**	**-4.3**			
4	From Average Air Distance equivalent to Conventional ToD	+0:00:35	-4.7	0.0			

Note: Numbers on the left side of the table are correlated to the numbers in Figure 29.

Entry Waypoint: DEVLA N29 14, W012 43	Time	Fuel	Air dist	Level-off	Level-off time	Flights with level-off
	min	kg	NM	NM	min	%
	DATA NON COMPARABLE					

Graphic Illustration of Differences (Conventional Vs. RNP):

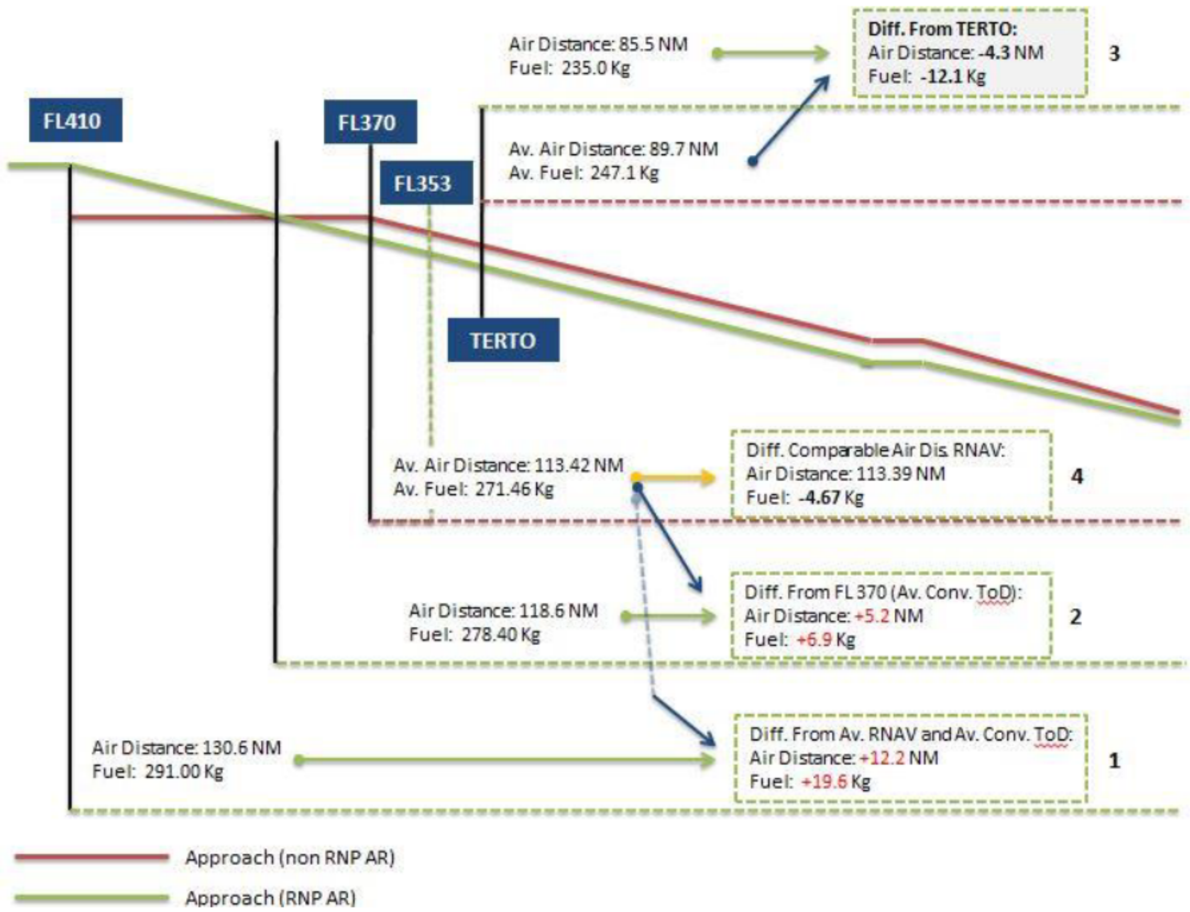


Figure 29 - GCRR Illustration Conv. vs. RNP – TERTO (Op 3)

5.1.4.2.2.4 GCRR – Summary of Results

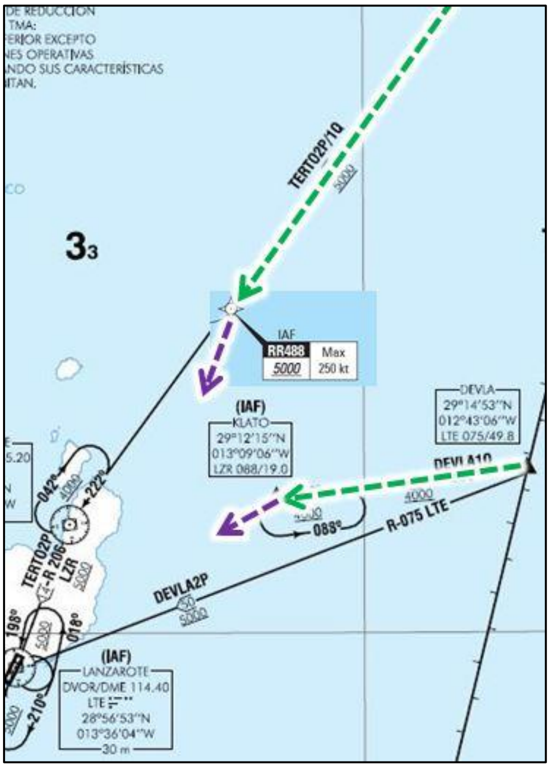
During the CANARIAS project demonstration flights at GCRR, a continuous observation process was implemented over trials operational execution from both pilot and air traffic controller perspectives. No outstanding operational observations where received from the pilot side. No reports on operational problems where received from air traffic controllers.

Based on the aircraft recorded and air traffic control radar recorded data, Lanzarote RNP arrivals indicate a precise execution of the procedure following the prescribed flight track.

Based on the analysis of the Lanzarote RWY 21 demonstration flights and in consideration of the analysis limitations, the following can be concluded:

- Three (3) RNP demonstration flights were carried out by A321 operators, and one (1) RNP demonstration flight was completed by a B737NG operator. Of these demonstrations, three (3) were completed using Entry Waypoint TERTO (North), and one from Entry Waypoint DEVLA (East).
- 18 conventional flights from A321 operators and one (1) conventional flight from a B737NG operator were provided by for comparison.
- Due to the amount of demonstration flights, the results should be considered representative, but not conclusive.

<u>STAR</u>



TERTO is the entry waypoint common to both the conventional (TERTO2P) and RNAV (TERTO1R) STAR trajectories.

DEVLA is the entry waypoint common to both the conventional (DEVLA1Q) and RNAV (DEVLA1R) STAR trajectories.

Conventional and RNAV flights raw data indicate that the aircraft is already in descent at Entry Waypoints TERTO and KLATO.

In the absence of the filed flight plans, it is assumed that aircraft flew TERTO2P and TERTO1R arrivals, but this cannot be confirmed.

<u>Initial Approach Fixe (IAF)</u>

- The analysis concludes on comparison from ToDs, average conventional ToD, IAF's for flights from Entry Waypoint TERTO. Due to the absence of conventional data from entry waypoint DEVLA, the available RNAV flight demonstration cannot be compared.
- RR488 is a new IAF placed on the current conventional STAR TERTO2P where the RNP AR approach trajectory to RWY 21 starts.
- Three (3) demonstration flights from TERTO entry waypoint with A321 aircraft were compared to 17 conventional flights from the same entry waypoint (refer to Figure 27 and Figure 28).

- Comparing from the conventional ToD (FL340-FL350):
  - ✓ **Air Distance is reduced between by 11-15 NM**
  - ✓ **50-63 Kg of less fuel consumed.**
  - ✓ **Level Offs were reduced by approximately 2.9 NM.**
- Comparing from Entry Waypoint TERTO (aircraft already in descent):
  - ✓ **Air Distance is reduced by 17-20 NM**
  - ✓ **49-64 Kg of less fuel consumed.**
  - ✓ **Level Offs were approximately reduced between 2.9 – 4.3 NM.**

Figure 30 - GCRR RNP AR RWY 21 - A321 Operator

- One (1) demonstration flights from TERTO entry waypoint with B737-8 aircraft was compared to One (1) conventional flight from the same entry waypoint (refer to ***Figure 29***):
  - Comparing from the conventional ToD (FL370):
    - ✓ **Air Distance was increased by 5.2 NM**
    - ✓ **7 Kg of more fuel was consumed.**
    - ✓ **Level Offs were kept at 0** (one flight comparison is not enough to be conclusive, however this can be explained by the vertical profile computed by the B737-8 for the RNAV procedure, and a continuous descent provided to the aircraft for the conventional flight).
  - Comparing from Entry Waypoint TERTO (aircraft already in descent):
    - ✓ **Air Distance is reduced between by 4 NM**
    - ✓ **12 Kg of less fuel consumed.**
    - ✓ **Level Offs were kept at 0**

  Note: Additional conventional and RNAV demonstration flights data would be required for the B737-8 operations at Lanzarote to provide more conclusive results. Based on the available flight, when compared to the A321 operations the benefits for the 737-8 in terms of air distance and fuel saving are not that evident.

5.1.4.3 Results per KPA

Based on the preliminary studies of GCLA indicated in Project demonstration plan 01.01 Edition 01.02.00, it was expected that the RNAV procedures would save 25NM for RWY 01 and 15NM for RWY 19. In addition it was expected to save approximately 50-100 kg of fuel per approach.

Demonstration results show a saving of approximately **34-38NM** and **292-313 Kg** of Fuel for **RWY 01**.

Demonstration Exercise ID and Title	EXE-01.01-D-001 : RNP Operations at GCLA	
Expected results per KPA	Environment (Fuel Burn per flight)	50-100 kg per arrival (TBC)
	Track Miles reduction from North	RWY 01: 25NM. RWY 19: 15NM.
	Safety	RNP AR fully managed approaches which add a degree of safety compared to NDB approaches.
	Capacity	Increased capacity of the TMA (TBC).
	Cost Reduction	Fuel burn savings and better consumption planning by operators.

In reference to GCRR, it was expected per the preliminary studies mentioned in Project demonstration plan 01.01 Edition 01.02.00, that the RNAV procedures would save 10NM for RWY 21 and reduce fuel consumption by approximately 40-80 kg per approach.

Demonstration results show a saving of approximately **14NM** and **100 Kg** of Fuel for **RWY 21**.

Demonstration Exercise ID and Title	EXE-01.01-D-002 : RNP Operations at GCRR	
Expected results per KPA	Environment (Fuel Burn per flight)	40-80 kg per arrival (TBC)
	Track Miles reduction	RWY 21: 10NM.
	Safety	RNP AR approaches which add a degree of safety compared to VOR and circle to land approaches.
	Capacity	Increased capacity of the TMA and airport de-congestion (TBC).
	Cost Reduction	Fuel burn savings and better consumption planning by operators.

5.1.4.3.1 Environmental benefits:

5.1.4.3.1.1 GCLA Environmental benefits (B737NG)

La Palma procedures environmental benefits (based on four demonstration flights completed):

Entry ORTIS (IAF ARACO):

B737NG	flight count	fuel kg	CO2 kg
ORTIS3V (Conv from ToD)	1	649.6	2039.7
ORTIX1X (RNAV from Av. Conv. ToD)	3	357.5	1122.6
Difference		**-292.1**	**-917.2**

Note: 1 kg of fuel = 3.14 Kg CO_2.

Entry ORTIS (IAF XISLA):

B737NG	flight count	fuel kg	CO2 kg
ORTIS3V (Conv. from ToD to IAF ARACO)	1	649.6	2039.7
ORTIX1X (RNAV from Av. Conv. ToD to IAF XISLA)	1	336.5	1056.5
Difference		**-313.1**	**-984.1**

Note: 1 kg of fuel = 3.14 Kg CO_2.

Considering the point of measurement being the Average Conventional ToD, the RNAV procedure from Entry Waypoint ORTIS via IAF ARACO seem to provide important savings regarding fuel consumption and CO_2 compared to the conventional procedure. Even if only 1 flight performed the ORTIS1X RNAV RWY 01 approach during the flight demonstrations, the result is reliable since the lateral trajectory and the vertical profile hardly vary between 2 approaches performed on the same RNAV (RNP) approach.

RNAV procedure from Entry Waypoint ORTIS via IAF XISLA provides even more savings compared to the conventional procedure to IAF ARACO.

Results would be more representative if measurements could be taken directly from Entry Waypoint ORTIS.

5.1.4.3.1.2 GCRR Environmental benefits (A321 and B737NG)

Lanzarote procedures environmental benefits (based on four demonstration flights completed):

Entry TERTO (IAF RR488):

	A321			B737NG		
	flight count	fuel kg	CO2 kg	flight count	fuel kg	CO2 kg
TERTO2P (Conv from TERTO)	17	*463.2	1454.5	1	247.1	775.9
TERTO1R (RNAV from TERTO)	2	*363.4	1141.1	1	235.2	738.5
Difference		**-99.8**	**-313.4**		**-11.9**	**-37.37**

Note: 1 kg of fuel = 3.14 Kg CO_2.

*Weighted averages based on data provided.

Entry DEVLA (IAF KLATO):

A321	flight count	fuel kg	CO2 kg
DEVLA1Q (Conv. from DEVLA)	0	-	-
DEVLA1R (RNAV from DEVLA)	1	452.02	1419.3
Difference		**-**	**-**

Note: 1 kg of fuel = 3.14 Kg CO_2.

Considering the main point of measurement being Entry Waypoint TERTO, where based on the data the aircraft are already in descent, the RNAV procedure via IAF RR488 seem to provide important fuel savings regarding fuel consumption and CO_2 emission compared to the conventional procedure.

Only one demonstration flight was carried out with the B737NG, and the savings are not as evident as for the ones carried out with A321 aircraft. Analysis of additional conventional flights and demonstration flights may corroborate, or not, the results.

Since the approach trajectory passes north of the City, it is expected that Noise would be reduced compared to the conventional approach that calls for a circle to land trajectory south of the city.

Regarding DEVLA, no conclusive analysis can be provide since only one RNAV flight took place from this Entry Waypoint and no conventional data is available for comparison. The main reason is that all of the operators participating in the demonstration flights fly inbound from the North and not the East (where DEVLA is located). The demonstration flight took place due to a special ferry flight incoming from Greece).

5.1.4.3.2 Track mile savings

5.1.4.3.2.1 GCLA Track mile savings (B737NG)

La Palma procedures track mile savings (based on four demonstration flights completed):

Entry ORTIS (IAF ARACO):

B737NG	flight count	Time Min	Air Distance NM
ORTIS3V (Conv from ToD)	1	30:24	152.5
ORTIX1X (RNAV from Av. Conv. ToD)	3	22:14	118.3
Difference		**-08:10**	**-34.2**

Entry ORTIS (IAF XISLA):

B737NG	flight count	Time Min	Air Distance NM
ORTIS3V (Conv. from ToD to IAF ARACO)	1	30:24	152.5
ORTIX1X (RNAV from Av. Conv. ToD to IAF XISLA)	1	21:50	114.8
Difference		**-08:34**	**-37.7**

In line with the Environmental benefits illustrated earlier for GCLA, the RNAV procedure from Entry Waypoint ORTIS via IAF ARACO reduce significantly the time of the approach and air distance compared to the conventional approach (also via IAF ARACO). The result is even better when using RNAV procedure from Entry Waypoint ORTIS via IAF XISLA

5.1.4.3.2.2 GCRR Track mile savings (A321 and B737NG)

Lanzarote procedures environmental benefits (based on four demonstration flights completed):

Entry TERTO (IAF RR488):

	A321			B737NG		
	flight count	Time Min	Air Distance NM	flight count	Time Min	Air Distance NM
TERTO2P (Conv from TERTO)	17	21.12	*97	1	18:53	89.7
TERTO1R (RNAV from TERTO)	2	*17:56	*82.9	1	18:33	85.48
Difference		**-03:16**	**-14.1**		**-00:20**	**-4.3**

*Weighted averages based on data provided.

Entry DEVLA (IAF KLATO):

A321	flight count	Time Min	Air Distance NM
DEVLA1Q (Conv. from DEVLA)	0	-	-
DEVLA1R (RNAV from DEVLA)	1	16:32	62.44
Difference		**-**	**-**

In line with the Environmental benefits illustrated earlier for GCRR, the RNAV procedure from Entry Waypoint TERTO via IAF RR488 reduce the time of the approach and air distance compared to the conventional approach.

No conclusive results can be provided for DEVLA due to the unavailability of conventional flight data.

5.1.4.3.3 Results impacting regulation and standardization initiatives

Aena states that the deployment of RNP procedures presented in the CANARIAS scenarios are referred in its PBN plan and they will provide great advantages and improve accessibility at both airports.

The Spanish DGAC and AESA are working in close collaboration with Aena on the implementation of PBN in Spain, specially the implementation of RNAV1 and RNP APCH procedures based on GNSS.

A PBN Implementation Plan for Spain has been developed and, regarding the approach phase of flight, it is in line with ICAO recommendations (A37-11) to promote the deployment of RNP APCH procedures in every instrument-based runway. The PBN Implementation Plan covers the different phases of flight, route (RNAV 5), TMA (RNAV 1) and approach (RNP APCH 3 minima).

Regarding the current regulation in force, it allows the implementation of RNP AR procedures by the ANSP in the Spanish airspace. However, as no RNP AR has been implemented in Spain so far, and considering that the procedures designed in the CANARIAS project have obstacles penetrating in the VSS; an extensive effort would be required from Aena and AESA in order to implement such procedures.

Said this, for this implementation process the work carried out in the CANARIAS project will be very useful and of great help as a first step. Moreover, Spanish operators will have to work with AESA on the guidance material for obtaining the approval to fly RNP AR in Spain.

5.1.4.3.4 Unexpected Behaviors/Results

During the eight (8) demonstration flights, there was no unexpected behavior of the aircraft on the trajectories. On the contrary, crews and controllers highlighted the stability and repeatability of the intended track all the way to the Runway Thresholds.

The resulting benefits between the conventional and RNAV results at Lanzarote with the B737NG differ from the results obtained with the A321 aircraft. Further conventional flights using the B737NG would be advised to have a better understanding if the provided conventional flight is representative for the comparison.

5.1.4.3.5 Quality of Demonstration Results

The quality of the overall results obtained in CANARIAS flight demonstrations at Lanzarote and La Palma is good.

The QAR data provided by Airbus and Boeing operators is accurate, providing meaningful fuel consumed and distance results. Formulas had to be utilized to calculate the cumulative data included in the final results.

The expected V-PAT analysis of the demonstration flights may provide additional input regarding the quality of the data overall results.

5.1.4.3.6 Significance of Demonstration Results

Even though the quality of the demonstration results at Lanzarote and La Palma is considered good, the amount of completed flight demonstrations falls short of the objective of at least 50 flight trials per airport, and the provided data for conventional flights is short of the necessary to have an appropriate baseline for comparison.

As such, the results cannot be considered conclusive, but rather indicative of the set expectations.

However, the initial results are promising per the intended objectives, and the project has a major potential for a successful implementation.

5.1.5 Feedback from the exercise

5.1.5.1 Feedback from the pilots

At the start of the demonstration flights, the following impressions were provided by some crews:

“I just got an e-mail from the Captain, and he said that there was 20-30 kts crosswind-but the flight guidance took him very accurate to 50 ft over the threshold as expected. It was "normal operation". (April 21st 2014)

“I have talked to them and it was "very smooth", "normal operations", "no issues at all" etc.”. (April 14th 2014)

“…have already spoken to captain. His words were that ‘it was just like the simulator’!”. (April 14th 2014)

Refer to section 7.3.1 of this document for overall comments from operators.

5.1.5.2 Feedback from the ANSP

Aena is working on the implementation of RNP procedures within those scenarios that may solve current operational problems, accessibility to airports, and increase in safety.

The outputs from CANARIAS Project demonstrate the value of PBN and the benefits of optimized tracks in combination of navigation accuracy. These procedures have demonstrated to provide a better accessibility to these airports by more stabilized and safe approaches, with lower minima, increasing this way safety and repeatability of operations.

The CANARIAS flight trials results, Safety Assessments, VSS studies, ATC and crews positive feedback will contribute to reinforce the arguments for the implementation of these procedures in the short term.

During the demonstration activities, Air Traffic Controllers provided comments and impressions regarding the flown procedures at both airports. The overall impression was very positive, ATC personnel showed their satisfaction with the new procedures. Following a selection of quotes and comments:

- *“I watched directly on the radar screen and descend was perfect, continuous, without steps until touchdown. Great!*
- *“ATC personnel were really amazed during the trials; the final curved leg, the accuracy overflying the line, the low level of communications we need, etc.”* [redacted], about the first trial approach to GCRR RWY21
- “The coordination was nice and the pilot´s intentions absolutely clear. They completed the APP RNP RWY21 until minima, and then turned left to join right-hand circuit to land RWY03 visually.”
- “No too much delay for other traffic, but I think will be difficult to do with more traffic in the APP Sector. There were only three traffic behind “XXX” and no departing traffic.”

- *"It has been very interesting for the controllers as well. There was expectation in the OPS Room. It´s really amazing to see the traffic flying exactly "over the line" and reach over 1.000 ft DA."* [redacted], about a trial approach to GCRR RWY21

Regarding the project ending before the completion of the expected number of demonstration flights, ATC personnel reflected their disappointment:

"It's a pity, this project opened a way to have a reference of this operation in order to make easier the future potential implantation, also the link with the TMA change to be effective this year was very interesting. The lack of a RNP approach by now, leads to an underutilized scenario with a huge potential. In my opinion, the CANARIAS work shouldn't stop here"

[redacted]**, about a trial approach to GCRR RWY21**

5.1.5.3 Feedback from the supervising Authority

During the CANARIAS project discussions, AESA communicated to Aena their thoughts of a lack of a SESAR frame work that harmonizes flight trials carried out in SESAR projects.

Our understanding is that AESA missed some set of rules and recommendations in order to execute the demonstrations safely, especially where these demonstrations involve commercial flights. This lack of guidance was remarked several times by AESA within the project discussions.

Moreover, it would have been recommendable to involve AESA earlier in the project as there is a feeling of lack of communication and transparency regarding their involvement. As a recommendation for similar projects, the authorities should be officially part of the project.

6 Communication Activities

Activity	When	Responsible	Where	Exp. Cost	Directly Targets
Press release	Project Announcement (Post KoM)	QUOVADIS – with input and/or participation from partners.	n/a	n/a	-6000+ contacts of the Airbus Prosky Group - ATM Industry - Trade Publications
Press release, project description	03/12/2012	Aena	Website and own means	n/a	- Spanish Authorities - ATM Industry - General Public
Press release	Initiation of Revenue Flight Trials (Exp. Mid 2013)	QUOVADIS and all Consortium Members	n/a	n/a	-6000+ contacts of the Airbus Prosky Group - ATM Industry - Trade Publications
Press release	Project Conclusion	QUOVADIS – with input and/or participation from partners.	n/a	n/a	-6000+ contacts of the Airbus Prosky Group - ATM Industry - Trade Publications
APS Website	1Q 2013	QUOVADIS – with input and/or participation from partners.	n/a	n/a	Approx. 10,000 hits/month
All CANARIAS Consortium Members	(same timing of press releases)	CANARIAS Consortium Members	n/a	n/a	CANARIAS Consortium Members employees
All CANARIAS Consortium Members (Airmail or Email distribution)	(same timing of press releases)	CANARIAS Consortium Members	Airmail – print edition / Email distribution – electronic version	n/a	CANARIAS Consortium Members employees

Activity	When	Responsible	Where	Exp. Cost	Directly Targets
Contribution to SESAR Demonstration Activity Annual report	Q4 2013		By email		SESAR and AIRE partners
Participation in the SJU yearly communicatio ns event for the Integrated Flight Trials and AIRE	Q1 2013	TBD	Brussels		Other projects in the Integrated Flight Trials and AIRE programmes
Final Dissemination Workshop	October 2014 (TBD)	QUOVADIS – with participation from partners.			TBD
Standard Airbus ProSky Group Internal Communicatio n	To be discussed with Airlines involved in the project	QUOVADIS – with input and/or participation from partners	n/a	Cost of HR	Airbus ProSky Group
Airbus ProSky Group Newsletter	To be discussed with ANSPs involved in the project	QUOVADIS – with input and/or participation from partners	n/a	Cost of HR	- Airbus ProSky Group
Press release, flight trials and project conclusions	Planned for December 2014	Aena	Website and own means	n/a	- Spanish Authorities - ATM Industry - General Public

6.1 Communication – Post KoM

Per the project's communications plan schedule, a post kick-off meeting communication was produced and distributed as a press release. The article was released via the Airbus ProSky network (4300+ contacts), and mentioned separately in a dedicated Airbus press release as one of the seven SJU demonstration projects in which Airbus was participating.

ONLINE:

Airbus:

Title: "ATM teams from Airbus and EADS to participate in seven SESAR JU Integrated Flight Trials"

Date: 8th of November 2012

Link: http://www.airbus.com/presscentre/pressreleases/press-release-detail/detail/atm-teams-from-airbus-and-eads-to-participate-in-seven-sesar-ju-integrated-flight-trials/

Airbus ProSky:

Title: "Quovadis Selected by SESAR JU to Lead Stakeholder Consortium in Integrated PBN Flight Trials in Canary Islands"

Date: 12th of November 2012

Link: http://www.airbusprosky.com/news/press-releases/510-quovadis-canarias.html

Aviation Today

Title: "Quovadis to Lead Canary Island PBN Flight Trials"

Date: 12th of November 2012

Link: http://www.aviationtoday.com/av/topstories/Quovadis-to-Lead-Canary-Island-PBN-Flight-Trials_77780.html#.UMiTz6yUhNR

Air Traffic Management:

Title: "Quovadis to lead SESAR team in PBN trials"

Date: 12th of November 2012

Link: http://www.airtrafficmanagement.net/2012/11/quovadis-to-lead-sesar-team-in-pbn-flight-trials/

ATC Network

Title: "Quovadis Selected by SESAR JU to Lead Stakeholder Consortium in Integrated PBN Flight Trials in Canary Islands"

Date: 12th of November 2012

Link: http://www.atc-network.com/News/42974/Quovadis-Selected-by-SESAR-JU-to-Lead-Stakeholder-Consortium-in-Integrated-PBN-Flight-Trials-in-Canary-Islands-

Link: http://www.atc-network.com/Publication/804/ATC-Network-Bulletin-Issue-116-November-2012

Airport-Technology

Title: "Quovadis Selected by SESAR JU to Lead Stakeholder Consortium in Integrated PBN Flight Trials in Canary Islands"

Date: 13th of November 2012

Link: http://www.airport-technology.com/news/newsquovadis-sesar-jus-pbn-flight-trials-canary-islands

Aviation-Technology

Title: "Quovadis Selected by SESAR JU to Lead Stakeholder Consortium in Integrated PBN Flight Trials in Canary Islands"

Date: 17th of November 2012

Link: http://www.aviation-technology.me/news/Quovadis-Selected-by-SESAR-JU-to-Lead-Stakeholder--n1.html

ATC Global Insight

Title: "Quovadis leads PBN flight trials in the Canary Islands"

Date: 20th of November 2012

Link: http://www.atcglobalhub.com/page.cfm/Action=library/libID=5/listID=4/libEntryID=1670

Actualidad Aeroespacial

Title: “Aena participa en un proyecto europeo para mejorar los aterrizajes”

Date: 4th of December 2012

Link: http://www.actualidadaeroespacial.com/?view=noticias&id=50bd9a6a0c956&viewTemplate=1

PRINT:

Diario de Avisos

Title: “El aeropuerto participará en un proyecto tecnológico Europeo”

Date: 4th of December 2012

Section: La Palma

Pages: 4

Jane’s Airport Review:

Release: TBD

ATM Magazine:

Release: TBD

CANSO Airspace:

Release: TBD

METRICS:

LinkedIn Groups

Views: 346 Impressions

Airbus ProSky e-mail metrics:

Sent: Total of 4,345 contacts.

Views: 2,674 opened e-mails.

Aena presented a press note during the project, published in its own media means, covering the overall project in 2012:

http://www.Aena.es/csee/Satellite/Aena/es/Prensa_FA/1237559757791/1237548097783/

6.2 Communication – Start of Demonstration Flights

For the CANARIAS start of the flight trials, a major press release by Airbus and Airbus ProSky was delivered, which was replicated in various portals:

- http://www.airtrafficmanagement.net/2014/05/airbus-prosky-Aena-score-sesar-canarias-success/
- http://www.ihsairport360.com/article/4204/canarias-completes-maiden-test
- http://www.airbusprosky.com/news/press-releases.html
- http://www.airbus.com/no_cache/newsevents/news-events-single/detail/the-airbus-prosky-led-canarias-project-marks-key-milestone-in-effort-to-improve-two-canary-islands-a/?
- http://newsrender.barhashing.com/trend/Canarias

- http://www.airline92.com/index.php?option=com_content&view=article&id=3619:airbus-prosky-y-Aena-lideran-el-proyecto-sesar-canarias-&catid=1:noticias&Itemid=55

6.3 Communication – End of Project

The CANARIAS Consortium plans to provide a final press release in 2014 announcing the end of the project with major outcomes and next steps.

7 Next Steps

7.1 Conclusions

The CANARIAS project highlighted the benefits offered by dedicated RNAV STARs and RNP AR approach trajectories necessary in two terrain challenging airports. The benefits includes continuous descent trajectories based on the optimized ToD calculated by the on-board FMS, shorter tracks optimized in consideration of adjacent obstacles, stabilized approaches aligned with the runways, and lower minima. Overall, these characteristics increase the safety of daily operations, and reduce the environmental impact of aviation on the community.

Considering that the number of demonstration flights fell short of the required 50 per airport, the obtained results are very encouraging, and above all the designs can be immediately implemented.

Main results include:

- Shorten flight tracks
- Optimized descent profile
- Reduction of flight time, fuel burn and CO_2 emissions.

Following is a sum-up table of project results (detailed results are described in Sections 5.1.4.2.1 and 5.1.4.2.2 of this document):

Entry	Differences (from Conventional procedures)						
	CO2 emissions		*Time*		*Air distance*		*Flights with level-off*
	kg	*%*	*min*	*%*	*NM*	*%*	*%*
GCLA - ORTIS (IAF ARACO)	**-917.2**	-45%	**-08:10**	-26%	**-34.2**	-22%	-100%
GCLA - ORTIS (IAF XISLA)	**-984.1**	-48%	**-08:34**	-28%	**-37.7**	-25%	-100%
GCRR - TERTO (Via RR488)	**-313.4**	-22%	**-03:16**	-15%	**-14.1**	-15%	-84%
GCRR - DEVLA (via KLATO)	**-**	-	**-**	-	**-**	-	-

Table 12 - Summary of CANARIAS project results

GCLA

Demonstration results for La Palma show a saving of approximately **34-38NM** and **292-313 Kg** of Fuel for **RWY 01**.

The RNAV procedure from Entry Waypoint ORTIS via IAF ARACO seem to provide important savings regarding fuel consumption and CO_2 compared to the conventional procedure.

RNAV procedure from Entry Waypoint ORTIS via IAF XISLA provides even more savings compared to the conventional procedure to IAF ARACO.

Results would be more representative if measurements could be taken directly from Entry Waypoint ORTIS.

GCRR

Demonstration results for Lanzarote show a saving of approximately **14NM** and **100 Kg** of Fuel for **RWY 21**.

The RNAV procedure from Entry Waypoint TERTO via IAF RR488 seem to provide important fuel savings regarding fuel consumption and CO_2 emission compared to the conventional procedure.

Only one demonstration flight was carried out with the B737NG, and the savings are not as evident as for the ones carried out with A321 aircraft (table above shows savings based on the A321 demonstrations). Analysis of additional conventional flights and demonstration flights may corroborate, or not, the results.

Regarding DEVLA, no conclusive analysis can be provide since only one RNAV flight took place from this Entry Waypoint and no conventional data is available for comparison.

The training provided to the Air Traffic Controllers per the guidelines of IACO Doc. 9613, provided to be very useful and necessary to ensure that operators were able to carry out the demonstration flights at both Lanzarote and La Palma. This training will be also very useful in a potential implementation of the procedures, as it was tailored under the “train the trainer” concept which is the overall belief of providing knowledge and continuity of operations.

7.1.1 Benefits of the CANARIAS project

- Operational benefits:

  The work carried out in the CANARIAS project highlights the great operational benefits that the GNSS based procedures can provide within challenging scenarios as the ones studied in this project. The demonstration results, the ATC experience and feedback, the crew opinions, the project partner’s work, etc…; showed improvements in terms of safety, fuel usage reduction, and improved accessibility to the airports. The CANARIAS project outputs consolidate AENA’s commitment for PBN implementation in Spain.

- Starting point for a real implantation:

  The work carried out by the CANARIAS Consortium, some of which was not planned initially as previously explained, will be of great help for the potential future implementation of RNP AR procedures, not only in the CANARIAS scenarios.

- VSS study developed that reinforces the implementation:

  The VSS study developed in the framework of the project establishes a first milestone for the potential future implementations of RNP AR procedures with infringed VSS in the CANARIAS scenarios but also in other Spanish airports. The work that Airbus ProSky and Aena carried out will help find a solution for similar implementations in the future.

- Positive work with ATC with good feedback:

  The CANARIAS Consortium considers very positive the work done in collaboration with the ATC personnel, and the feedback received from the training sessions as well as from the flight demonstrations. Per the experience gathered by ATC personnel within the CANARIAS scenarios, implementation of this type of procedures shall become factual.

- Positive feedback from crews:

  Consortium member and participant operators found the designed procedures to be easily flown in simulated environment. The demonstration flights were deemed “uneventful”, “easy to fly”, and appropriate, even considering the minimum VPA of 3.7° at Lanzarote at ISA conditions. When a procedure is easy to fly, it is deemed a success as it does not add any complication factor in challenging environment. Feedback of operators calls for an immediate implementation of the procedures at Lanzarote and La Palma.

7.2 Lessons learnt and recommendations

The following provides some elements of lessons learnt and recommendations for possible similar projects and future SESAR SJU demonstration activities based on the experience of the CANARIAS project.

7.2.1 Overall

Importance of stakeholders' cooperation and involvement

The CANARIAS project designs, validation, testing and training were successfully achieved thanks to good general teamwork between all project stakeholders. The demonstration flights fell short of the objectives in part due to unforeseen external factors (i.e. predominant winds), but also due to the retrieval from operators committed to complete demonstration flights.

Stakeholders need to have a clear understanding of what their involvement will be throughout the project, the effect of their commitment to all team members. Communication on project progress and delays, difficulties, and risk mitigations are necessary.

In reference to the CANARIAS project and for possible other similar projects of PBN implementation in Europe, the following stakeholders need to be involved throughout the execution of the project:

- The operator(s)
- The ANSP
- The local authority(s)

A kick-off meeting should present the project objectives, and should allow for everybody to agree on the general design and execution objectives resulting in a project specifications document.

Note: *A pre-kick off meeting supported by SESAR could help to establish grounds and responsibilities for the project before the project actually starts.*

Regular progress meetings need to be organized so that all stakeholders are well informed of the progress of the project, and of the difficulties that others may encounter in their own respective tasks.

An important lesson learnt is "redundancy": A demonstration scenario shall not rely only on one operator, but at least on two operators.

7.2.2 Design of the procedures

Short lateral track

The design of the procedures should be carefully studied and agreed by the project stakeholders. For particular projects such as CANARIAS which considered environmental objectives such as track miles reduction and fuel / CO_2 savings, designing the shortest possible track should be avoided and rather consider a design of trajectories that are comfortable, flyable, and optimized.

Less challenging scenarios shall be considered in countries where PBN is not common and local authorities are still in learning mode. Lanzarote, due to its particular challenging terrain, posed definite challenges for a much needed procedure. Probably La Palma was a more appropriate scenario to start with.

Vertical profile and altitude constraints

One of the potential benefits of implementing PBN procedures is the capacity to perform the approach in a continuous descent operations (CDO) mode. However, airspace management and ATC considerations usually dictate that altitude constraints be implemented for easier airspace organization and strategic separations of traffic. The design phase should ensure that these altitude constraints will not prevent aircraft of various performances to operate the procedure in continuous descent. In particular it is advised to:

- Avoid "AT" constraints, and prefer "AT OR ABOVE" constraints;
- Avoid as much as possible "constraining" constraints (i.e. altitudes that will impose level-off or earlier descents with shallow paths);

- Avoid keeping the aircraft high until close to the arrival. The final effect is a steeper and non-optimal descent to reach the final altitude possibly using additional means to reduce speed or increase the descent rate such as speedbrakes and landing gear early use.
- Avoid early and unnecessary speed reductions which usually translates into sub-optimal descent paths (i.e. descent at 220KT is shallower and less fuel efficient than at 250kt).

7.2.3 Aircraft and Aircrew

A major challenge of implementing RNP AR procedures, even during demonstration flights, is to have aircraft and aircrew qualified to carry out such operations.

For non-equipped or non-capable aircraft fleets, getting systems upgrade, or a certification to operate RNP AR approaches under a given regulation may involve important costs, and a certain delay in the overall implementation process.

Fortunately in the CANARIAS project all of the operators that completed the flight trials had both aircraft and aircrew qualified for RNAV operations. The Ops Spec documents were even provided to the Spanish Authorities for peace of mind. In addition, all of the operators carried out extra checks of the intended procedures in their own simulators, provided briefing to crews, had the databases appropriately coded and check every cycle, and printed their own charts.

However it is a major recommendation that before engaging in these types of projects, operators carefully and concisely consider the aspects required for the intended operation and associated costs to determine whether the project is feasible and viable for them. This is important for non-equipped fleets for the intended operation.

In addition, aircrew training and qualification is an important consideration regardless if the demonstration flights are carried out in visual conditions. These demonstration flights shall be flown and completed like if it was a real operation to ensure that the output is realistic, measurable, and appropriate. Associated aircrew training costs and constraints need to be considered since it will be a pre-requisite for the start of the operations, even in a trial mode.

7.2.4 Authority

To guarantee the success of such demonstration projects, a pro-active and continuous involvement of the supervising authority(s) must be ensured from the start. Not only it may ease processes along the implementation path, but it is an incentive for all stakeholders to achieve the intended objectives. This is also the opportunity to pass along know-how across project participants for implementation of similar scenarios at other airports.

Typically, if the demonstrations are conducted in a country where little previous PBN experience exists, the local authority(s) will need to process and study regulations in order to allow the implementation of RNP technology and eventually approve the flight demonstration. This task may appear overwhelming, it may induce reluctance to carry on, and/or unexpected delays may appear at some stage eventually having an effect or posing a risk in the overall project implementation.

Generally local authority(s) work on regulatory frameworks to establish rules and boundaries for the implementation of an intended operation. In the case of the CANARIAS project, this regulatory framework did not exist. Some authority(s) may not be comfortable allowing the completion of flight demonstrations using revenue flights which is allowed as a visual approach.

The CANARIAS demonstration scenarios were executed after preparing and presenting a safety assessment (Refer to section 4.3.2 of this document). In addition written rules were established, including the completion of flight demonstrations exclusively in VMC conditions, without implying changes to normal daily operations in the TMA, and with an agreed phraseology document.

A major recommendation for future similar SESAR SJU demonstration projects is to establish a framework that harmonizes flight demonstrations, is supported by EASA, and is agreed in ante-prima with the local authority(s) where the scenarios are intended to be completed.

7.2.5 ANSP

In a typical RNP deployment project, the Air Navigation Service Provider (ANSP) needs to be involved in all stages of the development and final implementation. At the end of the day, if Air Traffic Controllers do not have the correct training or knowledge to handle the intended type of traffic flying such specific procedures, the lack of comfort will lead them to not approve the operation regardless if the fleet and aircrew are capable and trained to fly the trajectories.

The CANARIAS Consortium member was Aena, the ANSP. The continuous support of Aena along the project was very important, not only being responsible for the design of the La Palma procedures, but also in coordinating the phraseology document with the Air Traffic Controllers.

Following are some points that were important for the start of the CANARIAS demonstration flights:

- Air Traffic Controllers were involved in the design of the procedure at both Lanzarote and La Palma as their inputs were essential for an efficient design that was appropriate for the intended TMA and types of operations. Separation strategies were implemented at the procedure level to minimize the work of the controllers during the demonstration flights and in an eventual final deployment of the procedures (i.e. Conventional SIDs versus RNP AR approaches, separation between approaches, crossing points, etc…).
- Air Traffic Controllers were briefed on what RNP operations are, and what kind of implications and advantages will results on their daily work.
- Air Traffic Controllers were provided adequate theoretical and practical training on RNP operations under the guidelines of ICAO Doc. 9613 by an experiences instructor. In particular simulation scenarios involving RNP traffic, and RNP versus non-RNP traffic were considered to familiarize personnel with potential particular situations requiring specific actions.
- Aena conducted a safety assessment anticipating the possible implications of introducing new procedures with the existing operations of the airspace. The conclusions of the safety assessment where that the CANARIAS procedures for La Palma and Lanzarote did not constitute a functional change in the TMA.
- A phraseology document was agreed between the operators and air traffic controllers, setting clear rules for the safe and successful operation of the demonstration flights.

An important recommendation for future SESAR JU demonstration flights is that the ANSP and controllers are actively involved in the design and deployment of the procedures. The likelihood is that without both stakeholders, the demonstration flights will not take place.

7.2.6 RNP AR Implementation Steps in Spain – High-level

The scenarios covered in the CANARIAS project, among others, are part of the previously mentioned PBN Plan in Spain. This work is currently being carried out in collaboration with the Spanish DGAC and AESA concentrating initially on the implementation of RNAV1 and RNP APCH procedures based on GNSS. Besides this and with the regulation in force, it is feasible to implement RNP AR procedures in the Spanish airspace.

The steps for a typical implementation are somehow consistent in all countries. Variance may be dictated based on the design regulation and operations approval documentation in use, particular requirements set by the local authorities, and the status of RNP experience of that particular country. In Spain, the implementation steps include:

- Design of the RNP AR procedures based on the RNP AR Procedure Design Manual, ICAO Doc 9905. The use of this document is pending approval by the Spanish Authorities.
- Development of any additional studies required by the Local Authorities (i.e. Integration of the VSS aeronautical study prepared and presented for the CANARIAS scenarios; required safety assessments, etc…).
- The implementation process should be accompanied with discussions in the dedicated working groups, as the PBN Implementation Working Group run by Aena and AESA.

- Once the procedures are approved by AESA and published in the AIP-Spain, any RNP AR approved operator may fly those procedures.
- Depending on the regulation in force, typically the RNP AR Operations Approval granted to an operator requires also a statement / permission from their own Local Authority to fly specific RNP AR procedures at an airport. This means that the operator should present a FOSA to their Authority to show compliance with any particularities identified for the intended operation and seek final authorization.
- Spanish operators will have to work with AESA on the guidance material for obtaining the Operations Approval to fly RNP AR procedures. This operations approval will likely based on the EASA guidance material AMC 20-26 - Airworthiness Approval and Operational Criteria for RNP Authorization Required (RNP AR) Operations.

7.2.7 Flight trials execution

The CANARIAS demonstration scenarios required the flights to be executed exclusively under Visual Meteorological Conditions (VMC). This requirement was put in place since the start of the project as it was neither planned nor possible to go through a complete RNP AR approval process that allowed the execution of the demonstration flights under Instrument Meteorological Conditions.

Limitations put in place included the reporting by operators of VMC AT OR ABOVE 5000ft for both La Palma and Lanzarote scenarios, and crews had to specify that they were and could “maintain” VMC along the intended track. The word “TRIAL” was also mandatory in the phraseology when requesting authorization to perform a demonstration flight, and operators (especially if not baro-aided) had to observe the temperature limitations stated in the RNP AR approach charts prior requesting and starting the approach (Refer to Section 4.2.3 of this document for further details).

Operators were also required to provide in advance their flight demonstration schedules for Air Traffic Controllers to prepare their workload and ensure a successful execution of the intended operation. These schedules were also intended to help identify the flights to be extracted via ASTERIX data for V-PAT modelling analysis.

The generic FOSA for both La Palma and Lanzarote provided important information for operators regarding particularities of the approaches, and crews were briefed to fly the procedures adequately, precisely, and with the outmost professionalism that characterized the operators participating in the CANARIAS demonstration project. The outcome of the executed demonstration flights demonstrates the overall effort put in place by the operators, whose recommendation is to implement the procedures at both airports within the shortest time possible.

Recommendations and lesson learnt from the CANARIAS project include:

- As mentioned earlier, a regulatory framework providing oversight on demonstration flight should be discussed and considered between the stakeholders at an early stage of the project. This will ensure that flight demonstrations start on schedule upon completion of previous milestones, and regulatory authorities feel comfortable with the intended objectives.
- Continuous feedback from the operators on the progress of the flight demonstrations is of outmost importance to keep track of the completed flights, impressions, and particularities encountered during the operation.
- A demonstration flight “modus operandi”, such as the phraseology document agreed between controllers and operators in the CANARIAS project, shall be established at an early stage of the project. Reaching an agreement of this type is not straightforward as it takes into consideration various aspects of the daily operations within the airspace. Also, crews have to be briefed in advance and thoroughly to ensure execution of the demonstration flights as intended.
- It is expected that operators that have committed in completing demonstration flights, and sharing flight data for analysis, do so. Incentives shall be considered at SJU level for project participant operators (non-project members) that are willing to execute the demonstration flights and share data to help achieve the intended objectives. The CANARIAS project was affected by the former and blessed by the latter.

7.2.8 Data measurement

In order to achieve factual scenario comparison objectives such as reduced track miles, fuel saving and noise reduction, it is important to decide from an early stage on how data will be captured and which data will be used to compare conventional to RNP approaches.

Due to the particularities of current flight recording systems, the first consideration is what data is the aircraft able to record and then downloaded for post-flight analysis. Essential recorded data such as position, speed, altitude, fuel burn, should be available for analysis.

The CANARIAS project took time in the agreement on the minimum parameters for data recording, and the methodology to be utilized for analysis. Processing and re-computation of data allowed to:

- Determine the Entry Waypoint of conventional and RNP arrivals, at both La Palma and Lanzarote scenarios;
- Calculate the level-off cumulated times and air distances (time spend in level flight in excess of 30s); and
- Calculate the cumulative air distance flown during the approach and cumulative fuel consumed from specific points.

The expected results from V-PAT modelling tool obtained from radar exported data should validated the output results from the manual flight data analysis provided by the operators, and/or help explain any differences.

Lessons learnt from the CANARIAS project and recommendations for future similar SJU demonstration trials:

- Operators participating in demonstration projects and expected to provide flight recorded data, or average results, should secure the support of their internal stakeholders to do so and honor their commitment with all stakeholders. The CANARIAS project was very much affected by this situation. The project required flight data output to corroborate a thesis and expected scenario results.
- There is a need to have a common harmonized minimum data requirement and processing methodology for flight data analysis across all demonstration projects. It is recommended that SJU established or provides guidance options to ensure common comparable results. Today not one processing methodology is considered better than another, especially when using theoretical models or manual processing. Data analysis also requires time for processing and available resources, something that not all operators have at avail and which should be established at the start of the project.
- V-PAT modelling tool seems to have a great potential. Project stakeholders should agree, where possible, to share raw flight data and help validate the theoretical results obtained from ASTERIX radar data output.

7.2.9 Communication

Communications on project objectives, milestones and final results are important to promote aeronautical system modernization and innovations for environmental benefits and sustainability based on the SESAR objectives.

Communication should target both the aviation community and the general public. In the case of CANARIAS, several communications activities were carried out mainly via press releases and replicated internet links.

Recommendations and lessons learnt from the CANARIAS project:

- Operators participating in demonstration flights should try their best to record particularities of the demonstration flights which can be used to promote innovations offered by the intended operations.

- All Consortium Stakeholders shall commit form the start of the project to promote the objectives and scope of the demonstrations within their organizations. This helps keep motivation and expectations high with a clear vision of reaching intended objectives.

7.3 Next steps

7.3.1 Steps following CANARIAS project in La Palma and Lanzarote

The results of the demonstration flights at both GCLA and GCRR, even though not conclusive based on the completed number of demonstration flights, provided immense benefits in accessibility to both terrain-challenged airports, stability in the approaches, reduction of approach minima, repeatability of trajectories, and optimization of vertical paths.

As explained in section 5.1.4.3.3, Aena has a PBN implementation plan in place in Spain and is currently working with the National Authorities to deploy the scenarios considered in this plan. The scenarios covered in the CANARIAS project are considered in the plans as potential future implementations and the work developed in the frame of this project is envisaged to be very useful for those implementations.

Operators that flew the demonstration flights agree in the immediate implementation of the designed scenarios at La Palma and Lanzarote. Following are their comments:

Thomas Cook (Lanzarote)

“This approach was trained in the simulator for all Airbus crews as part of our PBN continuation training (integrated into training matrix). Although only conducted once operationally (when the commander reported that it was just like the simulator and there were no operational issues at all), we did get a lot of feedback from the simulator exercise. Overwhelmingly the pilots were impressed at how easy it was to fly and the transition from ‘instrument’ to ‘visual’ presented no problems.

Our experience of many years’ worth of ACE operations would suggest that aligning the STAR with an appropriate RWY21 solution would save track miles by:

- Providing a known flight path to allow optimum FMS energy management
- Making it easier for ATC to space aircraft (and for flight crew themselves) so as to facilitate flow of aircraft during peak times
- Reducing likelihood of Go Around due to a. lack of visual cues b. unstable approach c. baulked approach due congestion
- Allows the optimum runway for departure to be used when wind is not limiting.

Furthermore, we should remember that currently there is no runway approach to 21 at ACE. This trial demonstrated that it is possible to produce an approach that was easy to fly and satisfied all terrain clearance issues. RWY 21 has significant terrain challenges on the extended centerline that were completely mitigated by the RNP approach. Like other airlines, Thomas Cook does not currently allow night landings on RWY 21 at ACE; we would be happy to allow night operations in future if this (or similar) procedure was available.

Consequently Thomas Cook Airlines strongly supports work to continue on PBN based solutions for both flight safety and flight efficiency benefits”.

Novair (Lanzarote)

“We have flown into Lanzarote for many years and have flown the new RNP AR approach to Runway 21. Traditionally, we have flown the VOR approach to Runway 21, which is slightly offset of the runway centerline. The coding of the VOR procedure in the aircraft Flight Management System (FMS) does not allow the flight crew to have guidance all the way to the runway threshold.

The new RNP AR approach is coded in the aircraft FMS in such a way that it gives lateral and vertical guidance throughout the whole procedure, guiding the pilots all the way to the runway threshold with very high lateral and vertical accuracy. The final turn aligns the aircraft perfectly on the extended runway centerline. This allows the flight crew to fly stable and efficient approaches to Runway 21 at Lanzarote.

The RNP AR procedure was very well received amongst the pilots, the flyability is excellent and it is enhancing flight safety when operating into Runway 21 compared to the conventional procedure.

We strongly support official publication of the procedure".

Norwegian Air Shuttle (La Palma)

"As an airline we see the implementation of RNP AR approaches replacing regular non precision approaches as a leap forward.

GCLA this is class one example. S14 is the first season we operate to La Palma. We have received a number of reports regarding the limited NAV Aids found at this aerodrome in combination with experienced mechanical turbulence.

Norwegian Air Shuttle did originally not plan to utilize the Visual RNAV approaches for S14 as GCLA was a new aerodrome in our route inventory. But after the first few pilot reports we went to the simulator and flew the approaches again.

We consider the RNAV visual (RNP AR) approaches to GCLA RWY01/19 to be the better approach procedure by far. The RNP approaches to GCLA RWY01 conducted by Norwegian Air Shuttle have produced good stable approaches along a very accurate prescribed track.

AENA along with Spanish authorities should as soon as possible aim for publication and utilization of the Visual RNAV procedures to La Palma. This will definitely increase the safety level when flying approaches into GCLA".

In reference to the GCRR scenario, since the predominant winds during most of the year are for RWY 03 it would be recommended to design dedicated RNP procedures to this runway during the implementation. Additional studies and options should be provided by the local authority(s) to reduce the close in –obstacles close to the threshold of RWY 21 which is having an important payload effect on aircraft departing RWY 03.

7.3.2 Other similar projects in Europe

The CANARIAS project demonstrated that it is possible to implement a successful PBN project with clear and quantified positive outcomes for the airlines, for the communities, for the environment, and in a relatively short period of time. This project experience has also helped to build experience, transfer know-how and confidence in this proven method of flying. The outcome of the project will certainly play a positive role within the PBN implementation in Spain.

Similar projects promoting PBN to demonstrate benefits for the environment and sustainability of the aviation industry could be considered in other countries which have little or no experience with PBN implementation. RISE project supported by SESAR has been launched recently under a similar concept precisely to promote PBN in Europe.

As of a year and a half ago, PBN implementation in Central America was sporadic. With the financial support of an operator, and for the benefit of all aviation users, several PBN projects are under completion where local authority personnel, ATCOs, designers, crews, and inspectors are becoming more confident with this historic change in the aviation industry. This is in line with the ICAO mandate to have GNSS based approaches in all instrument runways by 2016.

PBN procedures can achieve great benefits, if and only if:

- Developed with all stakeholders' inputs from the very beginning.
- Properly designed and validated.
- Thinking out of the box with procedures appropriate to the environment and fleet where they are deployed.

Getting the benefits will require change of practices:

- Regulatory material and quality processes are defined.
- Operational approval ensures that the required level of safety for the overall operation is achieved.
- Appropriate training from all stakeholders is required (flight crews, flight inspectors, ATC, procedure designers).

8 References

8.1 Applicable Documents

[1] EUROCONTROL ATM Lexicon

https://extranet.eurocontrol.int/http://atmlexicon.eurocontrol.int/en/index.php/SESAR

8.2 Reference Documents

The following documents provide input/guidance/further information/other:

[2] ATM Master Plan (https://www.atmmasterplan.eu).

[3] Operational Focus Area, Programme Guidance, Edition 03.00.00, date 4.05.2012.

[4] SJU Communication Guidelines.

[5] SESAR Integrated Flight Trials and Demonstrations Activities Agreement – CANARIAS Project LOT1 1 - AIRE, Ref SJU/LC/0177-CTR.

[6] A1 CANARIAS Demonstration Plan, Project Number 01.01, Edition01.02.00.

[7] La Palma Airport New Star and RNP AR APCH to RWY01 & 19, IATM-13-DTC-001-2.0, 14/06/2014.

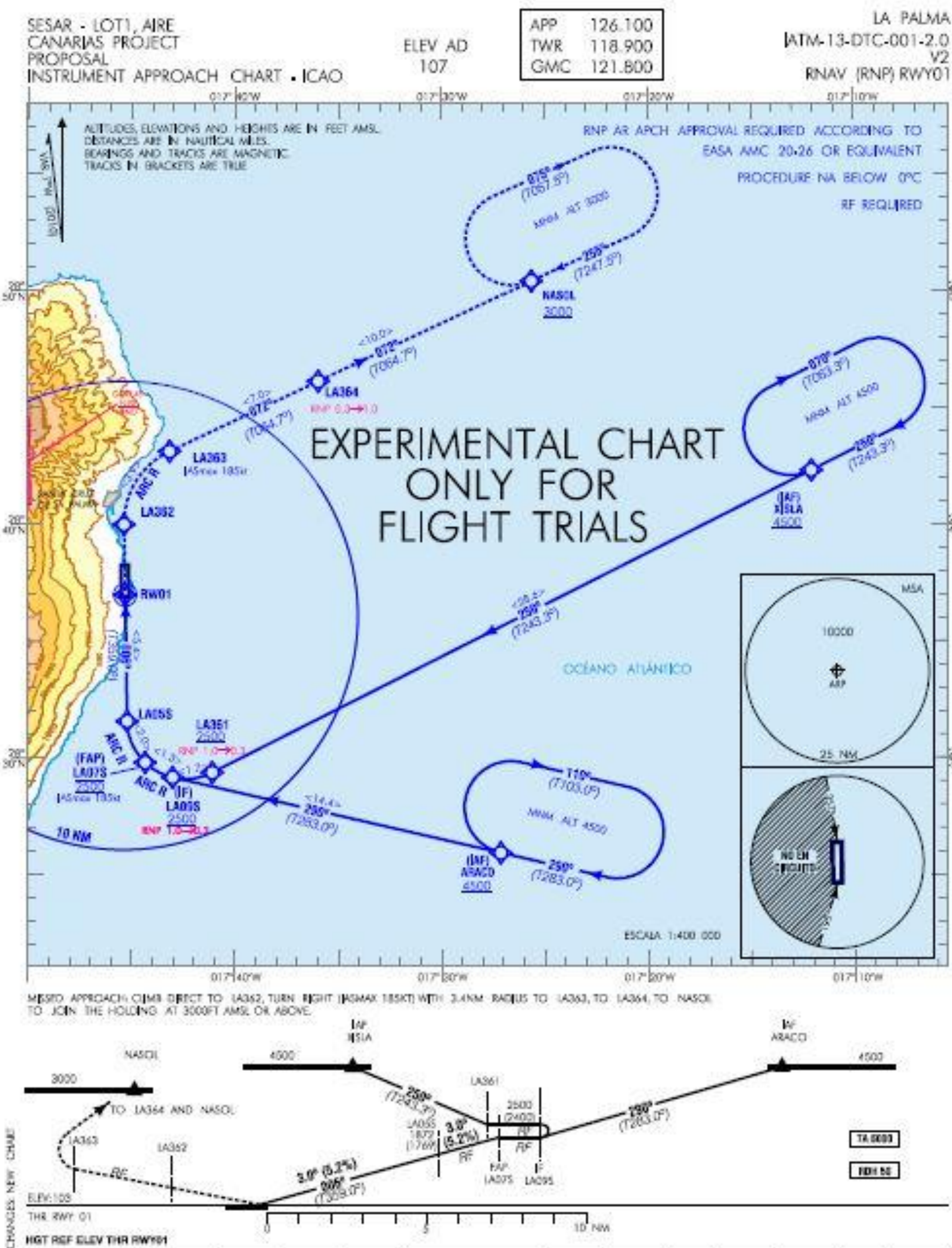
[8] Lanzarote Airport Procedural Technical Report - SJUACE_RNP_AR_011

[9] VSS Report (Ref: RNP AR APCH VSS Report for the CANARIAS project. Assessment and Mitigation Proposals. 08/05/2013)

[10] NDB Instrument Approach VSS - Estudio Aeronáutico sobre la vulneración de la VSS de la RWY 01 en el Aeropuerto de La Palma - 29/01/2010

[11] Aena Safety Assessment (Proyecto CANARIAS - Pruebas en vuelo RNP AR - RG01140034 / FAJ. 27/02/2014).

Appendix A GCLA RNAV (RNP) RWY01 Approach chart



OCA/H		A	B	C	D
STA	RNP 0.3	919 (814)	931 (828)	939 (836)	950 (847)
En circuito (H) sobre 107		1780 (1680)	2070 (1970)	2190 (2090)	2860 (2760)

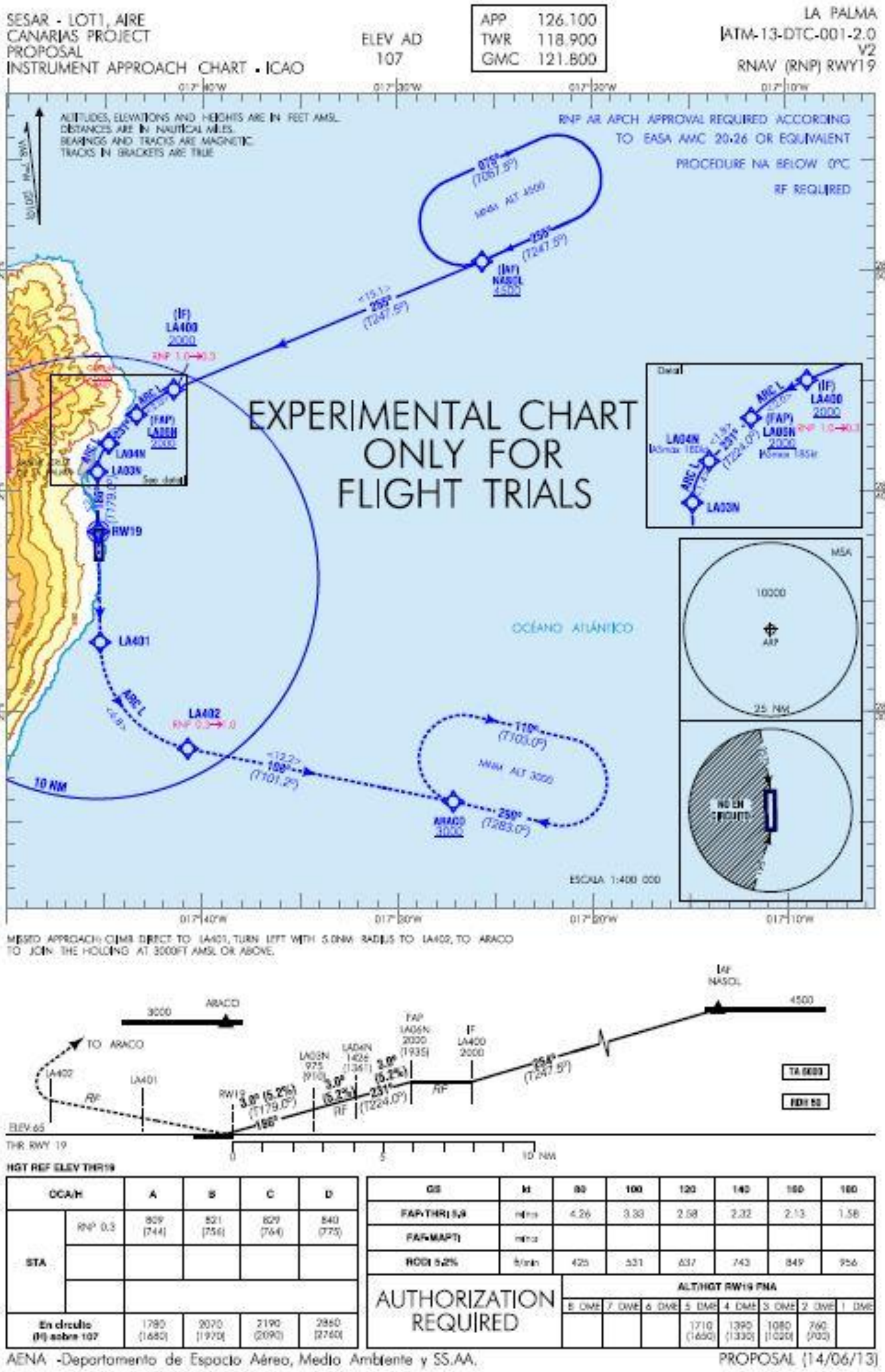
GS	kt	80	100	120	140	160	180
FAF-THR: 7,4NM	min:s	5.32	4.25	3.41	3.10	2.46	2.27
FAF-MAPT:	min:s						
ROD: 5.2%	ft/min	425	531	637	743	849	956

AUTHORIZATION REQUIRED

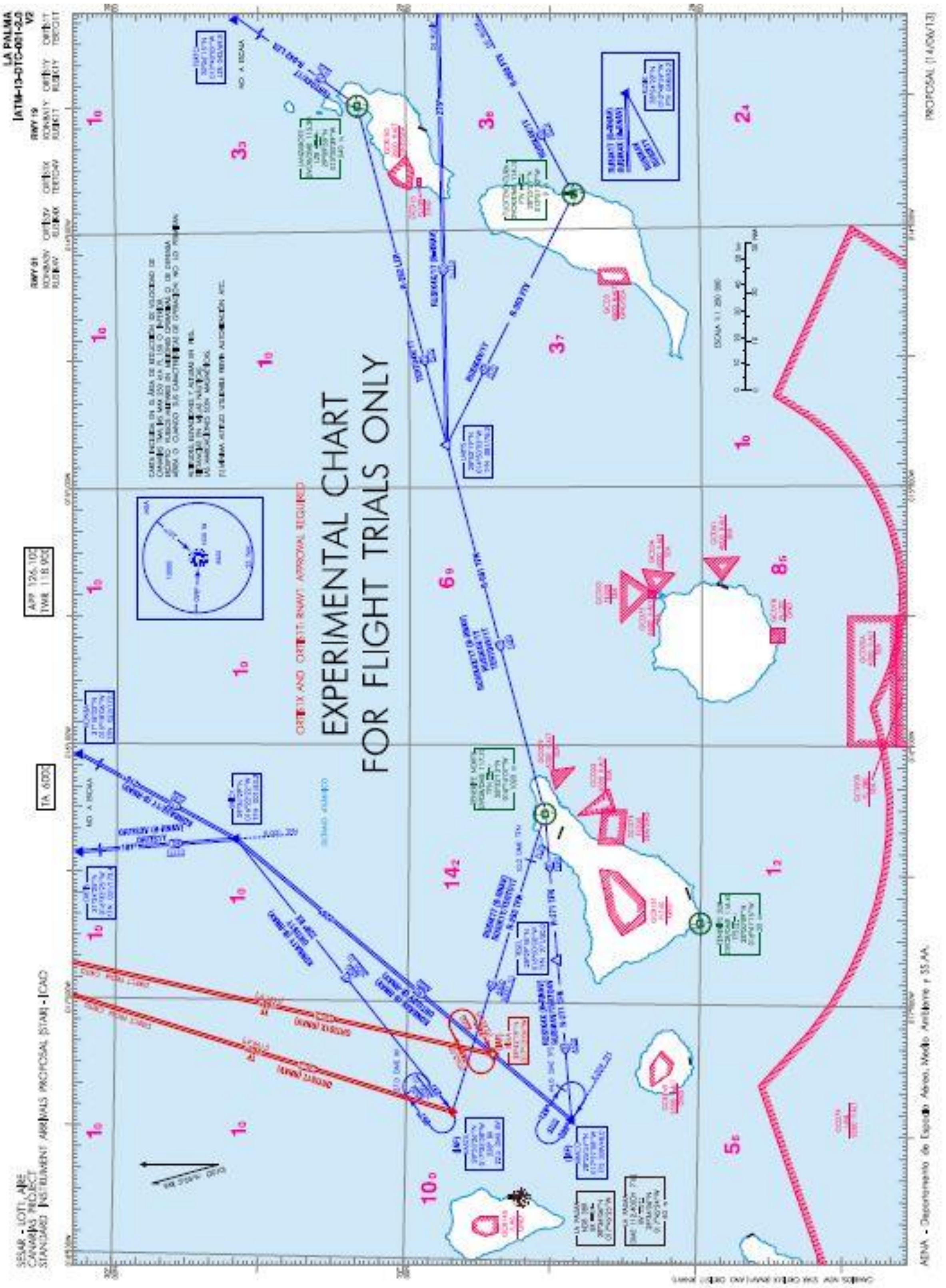
ALT/HGT RWY01 FNA							
8 DME	7 DME	6 DME	5 DME	4 DME	3 DME	2 DME	1 DME
	2390 (2290)	2070 (1970)	1750 (1650)	1430 (1330)	1110 (1010)	790 (690)	

AENA -Departamento de Espacio Aéreo, Medio Ambiente y SS.AA. PROPOSAL (14/06/13)

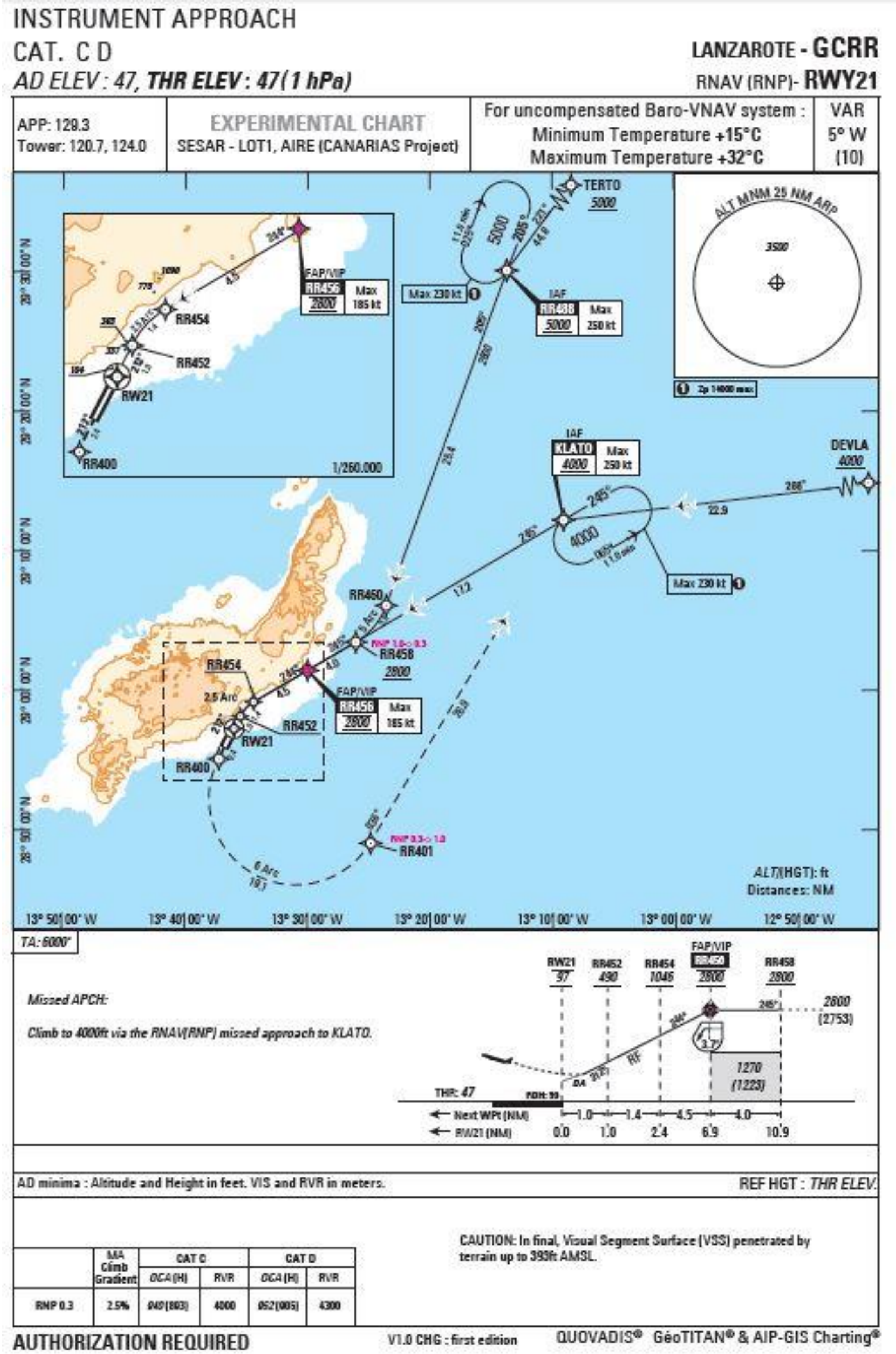
Appendix B GCLA RNAV (RNP) RWY19 Approach chart



Appendix C GCLA RNAV STAR chart



Appendix D GCRR RNAV (RNP) RWY21 Approach chart



	MA Climb Gradient	CAT C OCA (H)	CAT C RVR	CAT D OCA (H)	CAT D RVR
RNP 0.3	2.5%	940 (893)	4000	952 (905)	4300

Appendix E GCLA and GCRR Generic FOSA

GCLA_RNP_AR_ FOSA_v1.0.pdf

GCRR_RNP_AR_FOSA_V1.0.pdf

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