La Cerdanya COPTER LPV flight trials
Final report

Ref: HEDGE-WP2 -D2.1
Issue: 1.0
Date: 30/09/10
Number of Pages: 49
Doc. Filename: HEDGE_WP2_Final_report_v1.0.doc

<table>
<thead>
<tr>
<th>Name/Company</th>
<th>Signature</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author</td>
<td></td>
<td>30/09/10</td>
</tr>
<tr>
<td>Marc Torres, Victor Alvarez / Pildo Labs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WP Leader</td>
<td></td>
<td>30/09/10</td>
</tr>
<tr>
<td>Mercedes Reche / Pildo Labs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project coordinator</td>
<td></td>
<td>30/09/10</td>
</tr>
<tr>
<td>Nick McFarlane / Helios</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GSA Project Officer</td>
<td></td>
<td>30/09/10</td>
</tr>
<tr>
<td>Hans de With</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The project has received Community research funding under the 7th Framework Programme. This material reflects only the author's views and the Community and the GSA are not liable for any use that may be made of the information contained herein.
**DOCUMENT CHANGE RECORD**

The following table gives the history of the successive editions of the present document.

<table>
<thead>
<tr>
<th>EDITION</th>
<th>DATE</th>
<th>REASON FOR CHANGE</th>
<th>PAGES AFFECTED</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>30/09/10</td>
<td>First draft for internal review</td>
<td>All</td>
</tr>
</tbody>
</table>
# TABLE OF CONTENTS

1 INTRODUCTION ........................................................................................................................................... 7  
   1.1 General.................................................................................................................................................. 7  
   1.2 Background ......................................................................................................................................... 7  
   1.3 Document Layout ............................................................................................................................... 7  
2 REFERENCES ............................................................................................................................................... 8  
3 ABBREVIATIONS AND ACRONYMS ........................................................................................................... 9  
4 LA CERDANYA AERODROME .................................................................................................................. 10  
   4.1 Technical data of the heliport ............................................................................................................... 11  
   4.2 Current published charts ................................................................................................................... 13  
5 LPV PROCEDURE DESIGN ....................................................................................................................... 14  
6 INSTALLATION OVERVIEW ................................................................................................................... 16  
7 FLIGHT TRIALS IN LA CERDANYA .......................................................................................................... 18  
   7.1 Expected APV-I availability .................................................................................................................. 18  
   7.2 List of performed approaches ............................................................................................................. 19  
   7.3 Data analysis ....................................................................................................................................... 20  
   7.3.1 Flight path analysis .......................................................................................................................... 21  
   7.3.2 Flight deviations ............................................................................................................................. 24  
   7.3.3 EGNOS performance analysis ......................................................................................................... 27  
   7.3.4 Additional data of interest .............................................................................................................. 28  
   7.4 Pilots opinions .................................................................................................................................... 30  
8 EXPLOITATION PLAN AND USER ROADMAP ...................................................................................... 32  
9 CONCLUSIONS ........................................................................................................................................... 34  
10 APPENDIX A. CURRENT PUBLISHED CHARTS .................................................................................... 35  
11 APPENDIX B. FLIGHT DEVIATIONS ...................................................................................................... 37  
12 APPENDIX C. PILOTS QUESTIONNAIRES ............................................................................................... 43
La Cerdanya LPV flight trials

LIST OF TABLES

Table 2–1: Associated documentation ......................................................................................................................... 8
Table 3–1: Abbreviations and Acronyms .......................................................................................................................... 9
Table 4–1: General information of La Cerdanya heliport (source: [3]) ................................................................. 11
Table 4–2: Operation information and Heliport infrastructure ..................................................................................... 12
Table 7–1: APV-I availability analysis ............................................................................................................................. 18
Table 7–2: List of approaches ............................................................................................................................................ 19
Table 7–3: App1. Additional parameters ....................................................................................................................... 28
Table 7–4: App2. Additional parameters ....................................................................................................................... 29
Table 7–5: App4. Additional parameters ....................................................................................................................... 29
Table 7–6: App5. Additional parameters ....................................................................................................................... 29
Table 7–7: App6. Additional parameters ....................................................................................................................... 29
Table 7–8: App7. Additional parameters ....................................................................................................................... 30

LIST OF FIGURES

Figure 4-1 Cerdanya aerodrome location .................................................................................................................. 10
Figure 5-1 Experimental LPV procedure for HEDGE flight trials at LECD (version 8.0) .................. 15
Figure 6-1: Equipment assembly. Basic scheme........................................................................................................... 16
Figure 6-2: Platform position scheme ........................................................................................................................... 17
Figure 7-1: DOP for CER01 ............................................................................................................................................ 18
Figure 7-2: Horizontal trajectories ............................................................................................................................... 20
Figure 7-3: Final Approach Segment trajectories (3D view) ...................................................................................... 20
Figure 7-4: App1. Plan view of A/C flight path ......................................................................................................... 21
Figure 7-5: App1 A/C Altitude profile ........................................................................................................................... 21
Figure 7-6: App2. Plan view of A/C flight path ......................................................................................................... 21
Figure 7-7: App2 A/C Altitude profile ........................................................................................................................... 21
Figure 7-8: App4. Plan view of A/C flight path ......................................................................................................... 22
Figure 7-9: App4 A/C Altitude profile ........................................................................................................................... 22
Figure 7-10: App5. Plan view of A/C flight path ....................................................................................................... 22
Figure 7-11: App5 A/C Altitude profile ........................................................................................................................... 22
Figure 7-12: App6. Plan view of A/C flight path ....................................................................................................... 22
Figure 7-13: App6 A/C Altitude profile ........................................................................................................................... 22
Figure 7-14: App7. Plan view of A/C flight path ....................................................................................................... 23
Figure 7-15: App7 A/C Altitude profile ........................................................................................................................... 23
Figure 7-16: App1. Horizontal and vertical deviations ............................................................................................... 25
Figure 7-17: App5. Horizontal and vertical deviations ............................................................................................... 25
Figure 7-18: xPL during App1 ..................................................................................................................................... 27
La Cerdanya LPV flight trials

Figure 7-19: xPL during App2 ................................................................. 27
Figure 7-20: xPL during App4 ................................................................. 28
Figure 7-21: xPL during App5 ................................................................. 28
Figure 7-22: xPL during App6 ................................................................. 28
Figure 7-23: xPL during App7 ................................................................. 28
Figure 10-1: Aeroports de Catalunya Chart ......................................... 36
Figure 11-1: App1. Horizontal and vertical deviations .................... 37
Figure 11-2: App2. Horizontal and vertical deviations .................... 38
Figure 11-3: App4. Horizontal and vertical deviations .................... 39
Figure 11-4: App5. Horizontal and vertical deviations .................... 40
Figure 11-5: App6. Horizontal and vertical deviations .................... 41
Figure 11-6: App7. Horizontal and vertical deviations .................... 42
1 INTRODUCTION

1.1 General

The document is a deliverable of the 7th Framework Programme “HEDGE: Helicopter Deploy GNSS in Europe”. This document includes the outputs generated by Work Package 2:

- WP2.1. Operational Concept/procedure design
- WP2.2. Avionics preparation and installation
- WP2.3. Demonstration
- WP2.4. Exploitation and user roadmap

1.2 Background

The new EGNOS GPS Augmentation Systems will allow helicopter operators to fly under a greater range of daylight conditions and visibilities. It is for this reason that Mountain Rescue operators are very interested in this new system, expecting more operational flexibility and an increase in safety.

Within HEDGE WP2, the partners have equipped the Eurocopter AS350 B3 helicopter from TAF Helicopters for EGNOS and conduct demonstrations of some LPV approaches to the Cerdanya aerodrome with experimental equipment.

1.3 Document Layout

This document contains 6 sections:

- Section 1 is this introduction.
- Section 2 and Section 3 present the references, abbreviations and acronyms used in this document.
- Section 4 briefly describes the scenario selected for the design of the LPV approach.
- Section 5 gives an overview of the procedure designed for the Helipad located in La Cerdanya aerodrome.
- Section 6 shows the installation carried out in the helicopter of TAF to perform the flight trials.
- Section 7 is dedicated to the analysis of the flight trials. The flight path followed by the pilots, and the flight technical error has been computed. Pilot’s opinions are included in the end of chapter 7.
- Section 8 contains the exploitation plan and user roadmap, focusing on the most important blocking points.
- Section 9 contains the main findings and conclusions.
2 REFERENCES

The following table shows the associated documentation referenced in this document.

<table>
<thead>
<tr>
<th>#</th>
<th>Title</th>
<th>Issue</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HEDGE proposal</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>APV SBAS approach training course (HEDGE WP1.3)</td>
<td>V2</td>
</tr>
<tr>
<td>3</td>
<td>Fitxa técnica Heliport de la Cerdanya (DPTOP)</td>
<td>N/A</td>
</tr>
<tr>
<td>4</td>
<td>Flight Conditions for permit to Fly (EASA Form 18B)</td>
<td>10003775</td>
</tr>
<tr>
<td>5</td>
<td>HEDGE WP4 Final report</td>
<td>V02</td>
</tr>
</tbody>
</table>

Table 2–1: Associated documentation
### 3 ABBREVIATIONS AND ACRONYMS

The following table shows the abbreviations and acronyms used in this document.

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/C</td>
<td>Aircraft</td>
</tr>
<tr>
<td>AGL</td>
<td>Above Ground Level</td>
</tr>
<tr>
<td>APV</td>
<td>Approach Procedure with Vertical guidance</td>
</tr>
<tr>
<td>DA/H</td>
<td>Decision altitude</td>
</tr>
<tr>
<td>EGNOS</td>
<td>European Geostationary Navigation Overlay Service</td>
</tr>
<tr>
<td>FMS</td>
<td>Flight Management System</td>
</tr>
<tr>
<td>GEO</td>
<td>Geostationary satellite</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>HPL</td>
<td>Horizontal Protection Level</td>
</tr>
<tr>
<td>HRP</td>
<td>Helipad Reference Point</td>
</tr>
<tr>
<td>LPV</td>
<td>Localizer Performance with Vertical guidance</td>
</tr>
<tr>
<td>MAP</td>
<td>Missed Approach Point</td>
</tr>
<tr>
<td>PVT</td>
<td>Position, Velocity and Time</td>
</tr>
<tr>
<td>PRN</td>
<td>Pseudorandom Noise</td>
</tr>
<tr>
<td>SBAS</td>
<td>Satellite Based Augmentation System</td>
</tr>
<tr>
<td>RTCA</td>
<td>Radio Technical Commission for Aeronautics</td>
</tr>
<tr>
<td>TSO</td>
<td>Technical Standard Order</td>
</tr>
<tr>
<td>VFR</td>
<td>Visual Flight Rules</td>
</tr>
<tr>
<td>VPL</td>
<td>Vertical Protection Level</td>
</tr>
<tr>
<td>xPL</td>
<td>Protection Levels</td>
</tr>
</tbody>
</table>

*Table 3–1: Abbreviations and Acronyms*
4 LA CERDANYA AERODROME

La Cerdanya aerodrome is the site chosen to perform the flight trials within the scope of HEDGE work package 2. It is located in the North of Catalonia, into Pyrenees. The area is well communicated with Barcelona (through the south) and Toulouse (through the north) which are roughly at 150 km.

![Cerdanya aerodrome location](image)

The heliport has a strategic role for tourism and for mountain rescue activities.

Some general information of the aerodrome is provided in the next sections.
4.1 Technical data of the heliport

<table>
<thead>
<tr>
<th>General information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heliport name</strong></td>
</tr>
<tr>
<td><strong>City</strong></td>
</tr>
<tr>
<td><strong>Province</strong></td>
</tr>
<tr>
<td><strong>Autonomic Region</strong></td>
</tr>
<tr>
<td><strong>Holder</strong></td>
</tr>
<tr>
<td><strong>Holder address</strong></td>
</tr>
<tr>
<td><strong>Holder phone</strong></td>
</tr>
<tr>
<td><strong>Aerodrome manager</strong></td>
</tr>
<tr>
<td><strong>AIP publication</strong></td>
</tr>
<tr>
<td><strong>Restrictions</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heliport reference point</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UTM X(m)/LONG</strong></td>
</tr>
<tr>
<td><strong>ED50 UTM (31T)²</strong></td>
</tr>
<tr>
<td><strong>ED50 LONG/LAT¹</strong></td>
</tr>
<tr>
<td><strong>WGS84 UTM (31T)²</strong></td>
</tr>
<tr>
<td><strong>WGS84 LONG/LAT²</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shape</th>
<th>TLOF</th>
<th>FATO</th>
<th>Security Area</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dimensions</strong></td>
<td>20x20m</td>
<td>40x40m</td>
<td>45x45m</td>
</tr>
<tr>
<td><strong>Additional information</strong></td>
<td>Hydraulic concrete</td>
<td>Hydraulic concrete/ grass</td>
<td>Grass</td>
</tr>
</tbody>
</table>

**Table 4–1: General information of La Cerdanya heliport (source: [3])**

¹ Laid out from [4]
² Converted from ED50 reference
<table>
<thead>
<tr>
<th>Operation information</th>
</tr>
</thead>
</table>
| Reference Temperature                                      | 27°C  
| Main frequency band                                        | 129.825 MHz  
| Secondary frequency band                                   | 130.300 MHz  
| Main Landing course                                        | 07  
| Main Lifting-off course                                    | 25  
| Secondary Landing course                                   | 25  
| Secondary Lifting-off course                               | 07  
| Declared distances                                         |  
| - TODAH                                                    | 80 m  
| - RTODAH                                                   | 40 m  
| - LDAH                                                     | 80 m  
| Visual aids                                                |  
| - Wind sleeve                                              | Yes  
| - Heliport beacon                                          | No  
| - HAPI                                                     | No  
| Lighting                                                   |  
| - TLOF border lights                                       | No  
| - TLOF reflectors                                          | No  
| - FATO border lights                                       | No  
| - Approach lighting system                                 | No  
| Signalling                                                 |  
| - Heliport identification                                  | Yes  
| - TLOF signal                                              | Yes  
| - FATO signal                                              | Yes  
| - Aiming point                                             | No  
| - Approach and L.O. chevrons                              | Yes  
| - Taxiways signals                                         | No  
| - Taxiways border signals                                  | No  
| - Parking signals                                          | No  
| Heliport infrastructure                                   |  
| Fuel deposit                                               | 1x5.000 l  
| Electric power                                             | Yes  
| Power generation                                           | No  
| Water                                                      | No  
| IAS                                                        | Yes  
| Hangars                                                    | No  

Table 4–2: Operation information and Heliport infrastructure
4.2 Current published charts

There are two published charts:

- Jeppesen Visual Approach Chart
- Aeroports de Catalunya Visual Approach Chart

Both charts are included into Appendix A: Current published Charts.
5 LPV PROCEDURE DESIGN

A LPV approach procedure has been designed to the helipad located inside the airfield. The most important considerations are:

- The procedure meets ICAO PANS-OPS vol.2. requirements
- Procedure is restricted to CAT H aircrafts
- Arrival segment is not defined. The arrival until IAF should be done in VFR
- Final approach segment considerations:
  - Small offset angle: 0.5 degrees
  - Limitation of IAS during FAS: 70 knots
- Minima is set at 464 ft above aerodrome elevation
- The missed approach should be started when reaching the minimums (OCH)
- There is no Holding designed for this flight trial procedure.

Eurocontrol’s FAS Data Block Tool Calculation Prototype was used. The data were made available to Jeppesen for coding.

The approach plate is provided in the next page.
Figure 5-1 Experimental LPV procedure for HEDGE flight trials at LECO (version 8.0)
6 INSTALLATION OVERVIEW

The main requirement for the installation of the equipment is to avoid as much as possible the modification of the current configuration of the helicopter.

It is proposed to use a standalone platform to interfere the minimum with the rest of the equipment on-board. This platform includes:

- Garmin GNS480 GPS/SBAS TSO 146 certified receiver
- Septentrio PolaRx2 GPS/SBAS receiver

For flight demonstrations, it is not expected that any part of the helicopter is going to be modified except the antenna plug, where a splitter will be installed in order to connect the SBAS receiver.

Current Nav Indicator (CDI/VDI) is plugged to the GNS480 receiver during flight trials.

![Figure 6-1: Equipment assembly. Basic scheme](image-url)
The platform is located on two of the rear passenger seats. Complete cushions of these seats have been removed, and the platform is fixed to the helicopter using the freight tie-down rings.

![Platform position scheme](image)

Figure 6-2: Platform position scheme
7 FLIGHT TRIALS IN LA CERDANYA

7.1 Expected APV-I availability

Before the flight trials the local APV-I availability in the area was simulated using a predictive RAIM algorithm developed by PildoLabs R+D department. The analysis was performed at the approach waypoints, considering also the following conditions:

- A digital terrain model\textsuperscript{3} was used to simulate the local conditions of the area, as for example the masking caused by the mountainous environment.
- The GPS almanac was downloaded from the U.S. Coast Guard Navigation Center website.
- The simulation was carried out for a 24 hours dataset, with samples every 5 minutes.

The obtained results are summarised in Table 7–1:

<table>
<thead>
<tr>
<th>Waypoint</th>
<th>APV-I Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>CER01</td>
<td>100%</td>
</tr>
<tr>
<td>CER02</td>
<td>100%</td>
</tr>
<tr>
<td>CER03</td>
<td>100%</td>
</tr>
<tr>
<td>CER04</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 7–1: APV-I availability analysis

As it is shown in the above table, APV-I availability is of 100% for all the waypoints of the approach. The estimated horizontal and vertical errors were also estimated at the FAP (CER01). Next figures summarises the results for the whole day:

![Figure 7-1: DOP for CER01](image)

These simulations ensured that EGNOS SIS would enable an APV-I level of service at La Cerdanya aerodrome during the whole day.

\textsuperscript{3} Provided by the Catalan Institute of Cartography
7.2 List of performed approaches

The flight programme consisted of 7 approaches starting at the IAF. When reaching the minimums, either a landing to the helipad or a missed approach\(^4\) was conducted.

<table>
<thead>
<tr>
<th>Approach Code</th>
<th>Date</th>
<th>Start time (GPS)</th>
<th>Start time (UTC)</th>
<th>End time (GPS)</th>
<th>End time (UTC)</th>
<th>Procedure starting</th>
</tr>
</thead>
<tbody>
<tr>
<td>App1</td>
<td>20/07/2010</td>
<td>206370</td>
<td>9:19:15</td>
<td>207160</td>
<td>9:32:25</td>
<td>IAF or before</td>
</tr>
<tr>
<td>App2</td>
<td>20/07/2010</td>
<td>207260</td>
<td>9:34:05</td>
<td>208080</td>
<td>9:47:45</td>
<td>IAF or before</td>
</tr>
<tr>
<td>App3</td>
<td>20/07/2010</td>
<td>208410</td>
<td>9:53:15</td>
<td>209200</td>
<td>10:06:25</td>
<td>-</td>
</tr>
<tr>
<td>App4</td>
<td>20/07/2010</td>
<td>209280</td>
<td>10:07:45</td>
<td>210240</td>
<td>10:23:45</td>
<td>IAF or before</td>
</tr>
<tr>
<td>App5</td>
<td>20/07/2010</td>
<td>210420</td>
<td>10:26:45</td>
<td>211290</td>
<td>10:41:15</td>
<td>IAF or before</td>
</tr>
<tr>
<td>App6</td>
<td>20/07/2010</td>
<td>211380</td>
<td>10:42:45</td>
<td>212360</td>
<td>10:59:05</td>
<td>IAF or before</td>
</tr>
<tr>
<td>App7</td>
<td>20/07/2010</td>
<td>212590</td>
<td>11:02:55</td>
<td>213340</td>
<td>11:15:25</td>
<td>IAF or before</td>
</tr>
</tbody>
</table>

Table 7–2: List of approaches

The data analysis consists of the analysis of the data recorded during the flights using the GNS480.

NOTE: A technical problem with the logging software interrupted the data collection during Approach number 3 (App3). Therefore the data concerning App3 is not presented on the following sections of this report.

\(^4\) It was not flown the full missed approach segment of the procedure.
7.3 Data analysis

The data analysis consists of the analysis of the data recorded during the flights using the GNS480. Next figures show the trajectories flown during the approaches.

![Figure 7-2: Horizontal trajectories](image)

![Figure 7-3: Final Approach Segment trajectories (3D view)](image)
7.3.1 Flight path analysis

The following figures present the flight trajectories of the demonstrations together with the waypoints and heliport reference point (HRP). It can be seen how the aircraft successfully accomplished the operations up to the OCA/H values, when either a missed approach was performed (App1, App5) or a landing was conducted (App2, App4, App6, App7).

In the profile view, next reference altitudes have been plotted:
- 2255 m (7400 ft): which is the minimum altitude to fly the initial and intermediate segments,
- 1239 m (4066 ft): which is the minima (OCA) of the procedure, and
- 1098 m (3601 ft): which is the heliport altitude.
La Cerdanya LPV flight trials

1.6 1.65 1.7 1.75 1.8 1.85 1.9

42.32 42.33 42.34 42.35 42.36 42.37 42.38 42.39 42.4 42.41

Figure 7-8: App4. Plan view of A/C flight path

1.6 1.65 1.7 1.75 1.8 1.85 1.9

42.32 42.33 42.34 42.35 42.36 42.37 42.38 42.39 42.4 42.41

Figure 7-9: App4 A/C Altitude profile

1.6 1.65 1.7 1.75 1.8 1.85 1.9

42.32 42.33 42.34 42.35 42.36 42.37 42.38 42.39 42.4 42.41

Figure 7-10: App5. Plan view of A/C flight path

1.6 1.65 1.7 1.75 1.8 1.85 1.9

42.32 42.33 42.34 42.35 42.36 42.37 42.38 42.39 42.4 42.41

Figure 7-11: App5 A/C Altitude profile

1.6 1.65 1.7 1.75 1.8 1.85 1.9

42.32 42.33 42.34 42.35 42.36 42.37 42.38 42.39 42.4 42.41

Figure 7-12: App6. Plan view of A/C flight path

1.6 1.65 1.7 1.75 1.8 1.85 1.9

42.32 42.33 42.34 42.35 42.36 42.37 42.38 42.39 42.4 42.41

Figure 7-13: App6 A/C Altitude profile
The figures above show that the trajectories followed by the helicopter are in line with the designed procedure, both in terms of waypoint coordinates and vertical profile. In some occasions however, and mainly during the first approaches, the pilots tended to perform the fly-by turn at the IAF (fly-by turn) earlier than necessary. On the other hand, from the IF (CER02) ahead, the alignment with the final approach segment was very accurate.

During the initial and intermediate segments, it can be observed that the helicopter is almost always above the minimum altitude (7400 ft or 2255 m). Only during the first approach, the h/c flow 125 ft (40 m) below the minimum required value. This value only represents the 13% of the Minimum Obstacle Clearance considered when designing the procedure (300 m in accordance with ICAO regulations), which demonstrates that safety is maintained at all times. It must be kept in mind that the reference altitude followed by the pilots during these segments of the approach is not the CDI/VDI, but the barometric altimeter.

In the altitude profile pictures it is shown that all the descent paths of the final approach segment are very constant and stable, even though the speed limitation of 70 knots. This behavior can also be observed at Figure 7-3.

As for the Missed Approach point, it must be noted that:
- The height loss of the aircraft in App5 is negligible;
- App1 should not be taken into consideration for this analysis, since when reaching the minimums the pilots kept the helicopter performance waiting for instructions from the flight engineer.
7.3.2 Flight deviations

To have a clearer picture of the deviations of the helicopter during all the approaches, the horizontal and vertical deviations have been computed with respect to the desired flight path. This is presented in the following figures.

The distances in the vertical axis represent the horizontal or vertical Flight Technical Error (FTE) in meters. Hence, the FTE is provided as guidance information to the pilot during the flight, while the NSE and TSE can only be determined using truth reference after post-processing the data. NSE values have been considered negligible in this report.

Figures located in the left show the deviations of the h/c during all the approach segments, whereas the figures located just next to them (in the right side) show more precisely the deviations during the FAS (Final Approach Segment).

The FSD (Full Scale Deflection) of the CDI/VDI is also plotted in the left figures, both in the horizontal and the vertical domain. These curves indicate the value of the deviations that the helicopter would have had with respect to the approach path if the CDI/VDI needles had been totally deflected. As can be seen, the FSD are not constant, and they change between linear and angular along the approach, following the requirements laid down in RTCA DO-229C.
La Cerdanya LPV flight trials

Figure 7-16: App1. Horizontal and vertical deviations

Figure 7-17: App5. Horizontal and vertical deviations
NOTE: Almost all the approaches present similar deviations (the order of magnitude of the deviations is very similar). Therefore above are only presented the figures with regard to App1 and App5. Please refer to Appendix B to see the information about all the approaches flown.

The figures presented above prove that the approaches were flown smoothly thanks the good ability of the pilots and the easy flyability of the procedure.

It is shown that the horizontal FTE when arriving to IAF sometimes is near 1000 meters, but it decreases rapidly becoming lower than 500 during the intermediate segment of the approach (from CER02 to CER03). The alignment with the final approach track during the intermediate segment is perfectly executed: after the FAP, horizontal deviation during the final approach segment are always kept below 70 meters.

On the other hand, the values obtained of vertical FTE are even lower. Vertical guidance (LPV mode) entered after passing the IF of the approach (CER02). During the intermediate segment the pilots flow at the minimum altitude published in the procedure, so the deviation during that segment should not be taken into consideration for the analysis. During the final approach segment, the vertical behavior of the helicopter is very constant, obtaining vertical deviations always below 30 meters.

7.3.2.1 CDI/VDI performance

In this section it is analyzed the deviation of the aircraft with respect to the Full Scale Deflection of the CDI/VDI, both in the horizontal and the vertical domain. In other words, next figures show the position of the CDI/VDI needles during the Final Approach Segment of the LPV approach. Positive values in the horizontal axis mean the needle is on the right side of the centre (h/c is on the left side of the desired flight path) and positive values in the vertical axis mean the needle is on the up side of the centre (the helicopter is below the desired glide path).

![Figure 7-18: App1. CDI/VDI performance. Zoom plot on the right.](image-url)
7.3.3 **EGNOS performance analysis**

The performance of EGNOS was very good during all the flight campaign. As it is shown in the following figures, both the horizontal and vertical protection levels computed by the GNS480 were never higher than 20 m.
### 7.3.4 Additional data of interest

Additional parameters such as ground speed, climb rate or dilution of precision (horizontal and vertical) have been extracted from the data recorded for each segment of all the approaches. Next tables summarises the results:

<table>
<thead>
<tr>
<th>ALTITUDE (feet)</th>
<th>GNS SPEED (kts)</th>
<th>CLIMB RATE (ft/min)</th>
<th>CLIMB GRADIENT (ft/NM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>initial AS</td>
<td>int AS</td>
<td>FAS</td>
</tr>
<tr>
<td>average</td>
<td>7506</td>
<td>7585</td>
<td>5779</td>
</tr>
<tr>
<td>min</td>
<td>7277</td>
<td>7491</td>
<td>4083</td>
</tr>
<tr>
<td>max</td>
<td>7781</td>
<td>7781</td>
<td>7491</td>
</tr>
</tbody>
</table>

| HDOP | 0,906 |
| VDOP | 1,313 |

Table 7–3: App1. Additional parameters
### La Cerdanya LPV flight trials

#### Table 7–4: App2. Additional parameters

<table>
<thead>
<tr>
<th>ALTITUDE (feet)</th>
<th>GNS SPEED (kts)</th>
<th>CLIMB RATE (ft/min)</th>
<th>CLIMB GRADIENT (ft/NM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>initial AS</td>
<td>int AS</td>
<td>FAS</td>
</tr>
<tr>
<td><strong>average</strong></td>
<td>7558</td>
<td>7601</td>
<td>5743</td>
</tr>
<tr>
<td><strong>min</strong></td>
<td>7476</td>
<td>7440</td>
<td>4070</td>
</tr>
<tr>
<td><strong>max</strong></td>
<td>7687</td>
<td>7701</td>
<td>7440</td>
</tr>
</tbody>
</table>

HDOP 0,906  
VDOP 1,094

#### Table 7–5: App4. Additional parameters

<table>
<thead>
<tr>
<th>ALTITUDE (feet)</th>
<th>GNS SPEED (kts)</th>
<th>CLIMB RATE (ft/min)</th>
<th>CLIMB GRADIENT (ft/NM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>initial AS</td>
<td>int AS</td>
<td>FAS</td>
</tr>
<tr>
<td><strong>average</strong></td>
<td>7594</td>
<td>7585</td>
<td>5765</td>
</tr>
<tr>
<td><strong>min</strong></td>
<td>7497</td>
<td>7469</td>
<td>4132</td>
</tr>
<tr>
<td><strong>max</strong></td>
<td>7684</td>
<td>7657</td>
<td>7528</td>
</tr>
</tbody>
</table>

HDOP 1  
VDOP 1,406

#### Table 7–6: App5. Additional parameters

<table>
<thead>
<tr>
<th>ALTITUDE (feet)</th>
<th>GNS SPEED (kts)</th>
<th>CLIMB RATE (ft/min)</th>
<th>CLIMB GRADIENT (ft/NM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>initial AS</td>
<td>int AS</td>
<td>FAS</td>
</tr>
<tr>
<td><strong>average</strong></td>
<td>7629</td>
<td>7625</td>
<td>5757</td>
</tr>
<tr>
<td><strong>min</strong></td>
<td>7574</td>
<td>7466</td>
<td>4105</td>
</tr>
<tr>
<td><strong>max</strong></td>
<td>7690</td>
<td>7692</td>
<td>7466</td>
</tr>
</tbody>
</table>

HDOP 0,9657  
VDOP 1,2746

#### Table 7–7: App6. Additional parameters

<table>
<thead>
<tr>
<th>ALTITUDE (feet)</th>
<th>GNS SPEED (kts)</th>
<th>CLIMB RATE (ft/min)</th>
<th>CLIMB GRADIENT (ft/NM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>initial AS</td>
<td>int AS</td>
<td>FAS</td>
</tr>
<tr>
<td><strong>average</strong></td>
<td>7626</td>
<td>7617</td>
<td>5744</td>
</tr>
<tr>
<td><strong>min</strong></td>
<td>7542</td>
<td>7379</td>
<td>4077</td>
</tr>
<tr>
<td><strong>max</strong></td>
<td>7716</td>
<td>7682</td>
<td>7379</td>
</tr>
</tbody>
</table>

HDOP 0,813  
VDOP 1
### 7.4 Pilots opinions

Two pilots from TAF Helicopters and one pilot from REGA had the opportunity to fly the procedure.

Despite the EASA safety requirements, all the pilots were IFR rated, VFR pilots were not allowed to conduct the trials.

The total flight time of the campaign was 6.5 hours (including transfer flights to/from La Cerdanya), allowing the execution of 8 approaches (one of them was flown when arriving to La Cerdanya without the logging system connected) in VFR/VMC conditions. The helicopter used for the flights was an Eurocopter AS350-B3 certified only for VFR operations. The helicopter was not equipped with autopilot so all the approaches were flown manually by the crew.

Before launching HEDGE project, the pilots were not familiar with LPV approaches or with EGNOS for rotorcrafts. For this reason, the theoretical pilot training material and the different briefings performed before the flights were essential to the success of the trials.

The pilots felt the approach maneuver easier than expected, and the navigation system very accurate. Also the workload for the crew was lighter or similar than a NPA procedure such as VOR or NDB.

In the procedure chart the descent rate table was not depicted, and the pilots thought that this information could be very useful, especially because of the speed limitation of 70 knots in the final approach segment.

With regard to the sensibility and the angular precision, the CDI Bar moved very slowly, and this was strange to the pilots. Their opinion was that it could be useful to check the instrument in a normal ILS to compare the accuracy. Taking into account that the helicopter did not have AP or SAS (stability-augmentation and autopilot system), it was a highly precise GPS approach according to the pilots opinion.

Pilots also pointed out that the helicopter was only VFR equipped and did not have an autopilot. Hence, it is no adequate for IMC flight and requires higher piloting skills.
They also noted that at the specified altitudes, especially for the Missed Approach, with a target altitude of 10000 ft, and at the IAF, at 7400 ft, it might be **dangerous to fly in winter time without de-icing systems**. It requires also a powerful 2-engine helicopter to achieve the OEI service ceiling and go around climb gradient.

According to pilots opinion, that the **minima of the procedure is too high** taking into account that the valley where the airport is located is very wide.

Pilots questionnaires are attached at the end of this document in the Appendix C.
8  EXPLOITATION PLAN AND USER ROADMAP

Based on the experience gathered during the development of this work package, it is important to stress the main problems to take into consideration for the formal implementation and further development of LPV approaches for rotorcrafts:

ICAO PANS-OPS criteria not enough developed

The LPV approach procedure to the helipad in La Cerdanya has been designed in accordance with the fifth edition of ICAO PANS-OPS vol. II. The only criteria already completed for flying with SBAS is the APV (Part III, Chapter five). This chapter is mainly dedicated to APV approaches for fixed-wing aircraft and it only includes some minor considerations for helicopter approaches.

A kind of operation that will bring more benefits to the heliports located in mountainous areas is the LPV PinS approach (a point into space approach vertically guided using SBAS). Part IV of ICAO PANS-OPS vol. II is exclusive for designing procedures for rotorcrafts, but today the criteria for LPV PinS is still under development by the ICAO IFPP working groups and it probably will not be available before 2012.

The current criteria itself, including the PinS criteria, is too restrictive to design an IFP in very rough areas. Initially, the objective of the WP was to design a LPV approach in Vielha (a VFR helipad located inside the Pyrenees). It was nevertheless impossible to obtain an acceptable minima designing the procedure in accordance with ICAO PANS-OPS criteria. Therefore, in the near future could be worthy to start thinking in the extension of the RNP AR criteria for rotorcraft using SBAS.

Certification of Helicopters need

Most of helicopter operators in Spain have their fleet and crew only VFR certified. Only for special operations (i.e. night VFR, emergency flights, etc.), IFR Helicopter and crew is mandatory.

In addition, some operators do not want to invest in SBAS capable equipment until useful procedures are available and published for them.

IFR-procedures implementation blocking points

In certain states of Europe, the procedure to implement IFR procedure is very strict. For instance, here are listed some of the points to deal with (also included in the HEDGE WP4 final report, see [5] for further details):

- **IFR in uncontrolled airspace**: in small aerodromes without control, IFR procedures are not allowed. In Spain AFIS is sufficient, but this would mean a very high cost for most of heliports because of their low number of movements per day. To handle this situation in remote areas with very low traffic it is proposed to use the Air to Air frequency to notify all the users that there’s an aircraft that is going to perform an approach. There is a lot of work to do at a political level to move forward on this issue.

- **Education for the Regulator on new procedures**: Lack of know how and human resources on the state regulators side very often prevent timely implementation of new procedures and their publication. Outdated laws and regulations not rarely dating from 20 years ago slow down progress and transition to more performing procedures. The lead of technical potential over regulation standards has become unacceptable.

- **SBAS as sole / primary mean of navigation**: The day EGNOS will be accepted as primary mean for navigation, minimum equipment requirements for navigational equipment have to
be amended. It will have to be defined to what degree the requirement for “traditional” navigation equipment (ILS, VOR and ADF) as redundancy can be reduced since functional SBAS equipment and procedures effectively can be considered redundant. Getting rid of old and heavy “traditional” IFR equipment would reduce weight, fuel consumption, costs and increase space available on board with zero impact on safety.

- **Dedicating an ICAO 4 letter code to Landing zones:** For the planning of a procedure and its use it gets collocated to a locality and allocated a abbreviation. Ideally a 4 letter ICAO code according DOC 7910. In some countries hospital heliports are designated as non specific landing sites. They do not or just partially meet the requirements according ICAO Annex 14 for VFR heliports. Even though PANS-OPS only requires the correct physical dimensions for a Point in Space-Procedure, state regulators link the allocation of a ICAO 4 letter code to a compliance with ICAO Annex 14. Similar difficulties concern permanently installed oil rigs in the north sea. A clear and straightforward statement regarding allocation of ICAO 4 letter codes without depending on compliance with ICAO Annex 14 is essential.
9 CONCLUSIONS

The LPV flight procedure for La Cerdanya (LECD) has shown that tangible operational benefits can be obtained, e.g. approach down to 464 ft AGL.

The EGNOS availability performance APV-I was fully accomplished in all the approaches. EGNOS system has been capable of providing excellent aircraft guidance, appreciated by the pilots and the benefits have been recognised by TAF and REGA personnel.

Minor considerations were arisen from the pilots and technicians from TAF and REGA regarding the chart and the flyability of the procedure, but the main conclusion was that the procedure was very easy to fly. This is confirmed by the post-trial data analysis, that shows how the FTE of the pilots is kept very low during the entire approach.

ICAO should move forward as quickly as possible in the final approval of the “LPV PinS” criteria to ease the formal introduction of these approaches. In general, in complex scenarios, a PinS approach has more benefits than a fixed-wing standard direct procedure. Also the RNP AR concept (curved approach in the final approach segment) might be the easiest solution in particular cases. The extension of the RNP AR concept for rotorcraft using SBAS will provide a solution for the roughest environments.

In addition, on the regulator side there are many issues on the table to be solved urgently (i.e. the introduction of IFP in uncontrolled airspace) which basically depend on political wills. Otherwise, this would be an additional reason which will make more difficult the implementation of the system (in terms of avionics upgrade and helicopter certification if needed).
10 APPENDIX A. CURRENT PUBLISHED CHARTS

Jeppesen chart
Figure 10-1: Aeroports de Catalunya Chart
11 APPENDIX B. FLIGHT DEVIATIONS

(Please refer to section 7.2.2 for further details)

![Graphs showing horizontal and vertical deviations](image)

Figure 11-1: App1. Horizontal and vertical deviations
Figure 11-2: App2. Horizontal and vertical deviations
Figure 11-3: App4. Horizontal and vertical deviations
Figure 11-4: App5. Horizontal and vertical deviations
Figure 11-5: App6. Horizontal and vertical deviations
Figure 11-6: App7. Horizontal and vertical deviations
12 APPENDIX C. CDI/VDI PERFORMANCE

(Please refer to section 7.3.2.1 for further details)

Figure 12-1: App1. CDI/VDI performance. Zoom plot on the right

Figure 12-2: App2. CDI/VDI performance. Zoom plot on the right

Figure 12-3: App4. CDI/VDI performance. Zoom plot on the right
La Cerdanya LPV flight trials

Figure 12-4: App5. CDI/VDI performance. Zoom plot on the right

Figure 12-5: App6. CDI/VDI performance. Zoom plot on the right

Figure 12-6: App7. CDI/VDI performance. Zoom plot on the right
13 APPENDIX D. PILOTS QUESTIONNARIES