LPV Flight Simulator
User Manual

Ref: ESSP-MEMO-20019

Version: 01-02

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The following document describes in a first place the use of the ESSP flight simulator and its different functions. The second part of the document contains a set of simple guidelines to understand some concepts related with LPV approaches.

The current version of this document corresponds with the **version 1.1** of the ESSP LPV Flight Simulator.

TABLE OF CONTENT

0 BEFORY FLYING

0.1 What is this simulator?

The flight simulator is developed using the ArcGIS API for the real world graphics and a combination of images, CSS3 and JavaScript code for adapting it to a cockpit-like environment.

Although the similarity with the reality is limited, the most important details of a LPV approach have been implemented.

The aim of the tool is to allow understanding in a simple manner what an LPV is, how it works and its similarities with an ILS approach in what regards to the pilot's operation.

Annex I: Introduction to LPV approaches is available for those unfamiliar with an LPV approach.

0.2 System requirements

System requirements	Minimum	Recommended
Devices	PC only	PC only
OS	Windows 7 or higher	Windows 7 or higher
CPU	Intel i3 @ 2 GHz	Intel Core i5 @ 2.30 GHz
Memory	4 GB	8 GB
Graphics hardware	512 MB video compatible con OpenGL	1 GB video compatible con OpenGL
Input device	Keyboard and/or joystick	Keyboard and joystick
Internet speed	5 MB/s	10 MB/s
Resolution	1024 x 768	1920 x 1080, 1366 x 768, 1280 x 1024, 1280 x 800, 1024 x 768
Web browser	Chrome 47+ Mozilla 45+	Latest version of Chrome Latest version of Mozilla

0.3 Other considerations

0.3.1 Troubleshooting and bug reporting

For any bug of trouble with the flight simulator, when complying with the requirements in section 0.2, send an email to flight.simulator@essp-sas.eu.

0.3.2 Limitations

Only a few functionalities of a real aircraft have been implemented and a lot of them only partially to reduce the complexity for the user (e.g. less controls, approximation of the flight mechanics…).

0.3.3 Updates

Updates don't require anything from the user side, since the flight simulator is fully loaded each time. The current version can be checked in the *About* tab of the flight simulator.

The user manual will be updated when needed in accordance to the published last version of the flight simulator.

1 CONTROLS

Head up

Turn left [◂] [▴ ▾] [▸] Turn right

Head down

Increase throttle [! 1] [@ 2] Decrease throttle

[P] Play/Pause

[G] Show/Hide visual aids

[C] See chart (when available)

> **Tip**: start correcting your bank angle some time before arriving to the desired heading to keep the aircraft stabilized afterwards.

2 INDICATORS

1. **Led panel**: led indicators to inform when 1) the glidepath is captured, 2) the LPV decision height minima have been reached and 3) the simulator is paused.
2. **Flight stage**: when approaching the airport while still in Terminal Area the TERM mode is activated if the distance to the destination is lower than 30NM. When the FAF is closer than 2NM, the LPV approach mode is automatically activated.
3. **Throttle**: indicates the power provided to the engine (full red indicates full throttle).
4. **LPV indicator**: indicates the lateral and vertical deviation (when available) to the desired flight path in a CDI fashion. See section 3.3 for more information.
5. **Vertical speed indicator**: indicates the current climb/descent rate. It is measured in feet/min.
6. **Altimeter**: indicates the current altitude over the sea in feet.
7. **Attitude indicator (Artificial Horizon)**: indicates the current pitch (yellow line in the middle) and bank (yellow arrow in the top) angles relative to the Earth's horizon.
8. **Airspeed indicator**: indicates the current aircraft airspeed in knots.
9. **Compass**: indicates the current heading of the aircraft.

3 HOW TO START

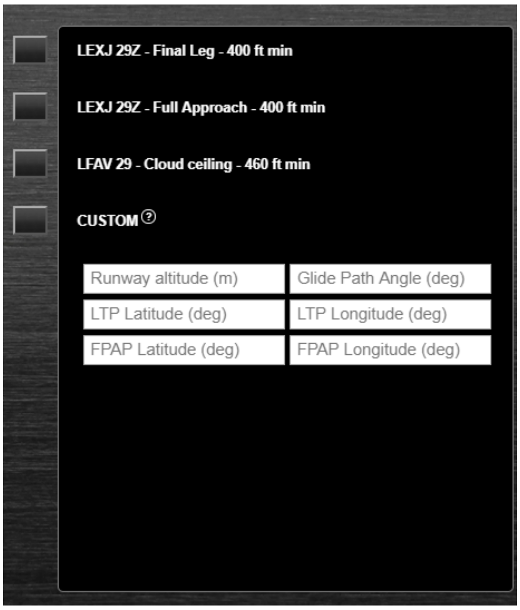
When starting the flight simulator, a loading page will be shown until the scenario is fully pre-loaded. After that, the screen shown in section 2 will appear.

The approach loaded by default is a VTF approach in Santander (LEXJ). To change the selected approach, the "Approaches" tab must be clicked and a menu will appear with the available predefined approaches and the custom approaches menu.

To load any of the predefined approaches, simply click its corresponding button on the left of the approaches' panel.

To load a custom approach, fill properly every field of the *Custom Approaches* section (see section 5.4) and, after that, press the corresponding button in the left of the *Custom Approaches* label.

After loading any approach, press P (play/pause) to start flying.



4 HOW TO FLY AN LPV APPROACH

4.1 Standard approach

Standard LPV approaches are defined by an initial segment starting at an IAF (Initial Approach Fix), followed by an intermediate segment starting at an IF (Intermediate Fix) and the final segment starting at the FAF (Final Approach Fix) which must be sequenced in this order.

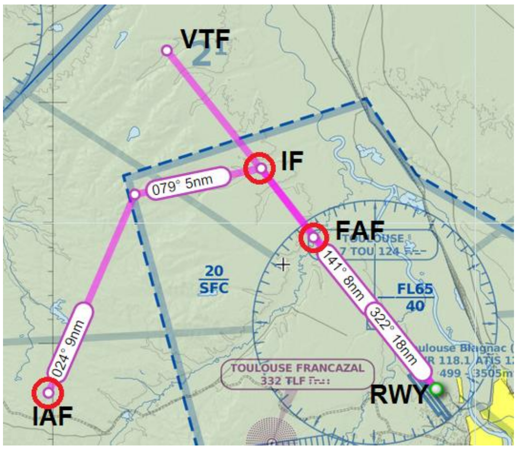
Since it is a GNSS approach, lateral guidance is provided at any time of the approach. The vertical glidepath (and therefore the vertical guidance) appears when the aircraft is entering the FAS and close enough to the FAF[1].

In this flight simulator, approaches are loaded as vector to final (VTF) by default (see section 6), so only those labelled as "Full approach" allow flying through the different initial and intermediate waypoints of the approach defined in the aeronautical chart.

[1] Most common navigation systems today provide "indicative" vertical guidance during the initial and intermediate segments too but the functionality is not provided in this simulator for educational purposes.

4.2 VTF (Vector To Final)

VTF approaches are defined as the final approach segment extended over the FAF and thus as a longer glidepath which allows air traffic controllers to increase the traffic flow.
Since there are no intermediate waypoints, pilots should intercept the glidepath from a distance point and from below (following the ATC indications) and then follow the glidepath as detailed in section 3.3.
In this flight simulator, approaches are loaded as VTF by default to reduce the time necessary to land. Thus, the glidepath is activated on every simulation since the starting point is very close to it. Only in those scenarios where the standard approach is flown (including initial and intermediate segments), the glidepath, and therefore the vertical guidance, is not automatically activated until the final segment.



4.3 Following the glidepath

When flying a VTF approach or when the aircraft is close enough to the FAF in a standard approach, both needles (vertical and horizontal) will be shown in the LPV indicator, which means that flying though the glidepath is possible.
To be in the desired flight path, both needles should be right in the middle of both axes (see Figure 2). When any of them (or both) is not aligned, the pilot should steer the aircraft in the direction of the needle's deviation ("*chase the needle*").
For example, in Figure 1 the aircraft is flying below the glidepath (the horizontal line is above the middle) and a little bit into the left of the glidepath (the vertical line is in the right of the middle).
The circles in the indicator are related to the FSD, as defined in Annex II, where the circles that are further away represent the maximum FSD at each moment.

Figure 1: not aligned with the glidepath

Figure 2: aligned with the glidepath

Tip: If the FAF has not yet been reached and the glidepath is above the aircraft (see Figure 1), the pilot may decide to maintain the altitude instead of climbing given that, at some point, the glidepath will be intercepted.

5 AVAILABLE SCENARIOS

5.1 Santander (LEXJ) RWY 29Z – Final Leg (VTF)

The starting point is placed a few miles away from the FAF to allow the pilot enough time to get closer to the glidepath and stabilize the aircraft before reaching the FAF.
The lateral deviation from the localizer shown by the vertical CDI bar should be corrected as soon as possible, while the vertical one can be corrected immediately or not, depending if the pilot wants to climb or just maintain altitude until the horizontal bar of the LPV indicator descends and the glidepath is intercepted.
Taking into account that in the flight simulator a Cessna 182 is being used, it is recommended to climb only a bit since it doesn't have enough power to climb fast.

5.2 Santander (LEXJ) RWY 29Z – Full Approach

The starting point is placed very close to the IAF, the first point of the approach as defined in the aeronautical chart (see Appendix C).
The lateral deviation is always available and the altitude should be checked in the chart. The sequencing between waypoints is done automatically once the aircraft gets close enough to the next waypoint (IAF → IF → FAF).
The glidepath will appear once the aircraft is closer than 2 NM from the FAF and, at this point, the vertical deviation will be shown and the GP indicator will be lighted up.
Once the glidepath is captured, follow the indications as defined in section 4.3.

5.3 Valenciennes (LFAV) RWY 29 – Final Leg (VTF) with cloud ceiling

Everything is exactly like in the VTF approach of Santander (see section 5.1) but in this case there is a cloud ceiling right above the decision height (460 ft). This means that landing successfully is possible only following the LPV indications.
Another difference is that, in this case, the aircraft starts much higher and therefore there is no need for climbing to intercept the glidepath.

5.4 Custom approaches

This option allows flying an LPV anywhere in the world by introducing some reference points as defined in Annex II.
It is important to note that obstacles and other information required to design an LPV approach are not considered by this custom approaches tool.
The steps required to create a customized LPV approach are defined in section 6.

6 HOW TO CREATE A CUSTOM SCENARIO

Creating a new LPV procedure requires a lot of information such as obstacles, existing procedures and distances to adapt it to the airport's environment as defined in Annex II.
To simplify the process, some assumptions have are made by this tool which only requires two points to basically define the runway's heading, altitude and threshold location as well as the glidepath angle.

The requested points are the LTP (Landing Threshold Point) which is located right at the beginning of the runway and the FPAF (Flight Path Alignment Point) which is located at the end of the runway.

To get these points' coordinates there are two options:

1. Look at the official chart should the approach be published: there are hundreds of LPVs published which are not loaded by default in the flight simulator. These points can be easily found by searching in the corresponding AIP pages. Depending on the country, this information is publicly available at a particular website, or accessible through the centralised Eurocontrol EAD portal. An updated map with the published LPVs in Europe can be found here.

2. Get the points from ArcGIS Online or any other online maps' service. For example, with ArcGIS Online clicking on the "Measure" button and then in the third button, the latitude and longitude of any point appears:

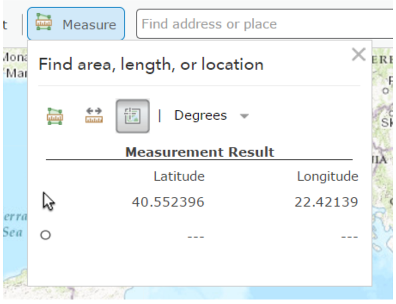
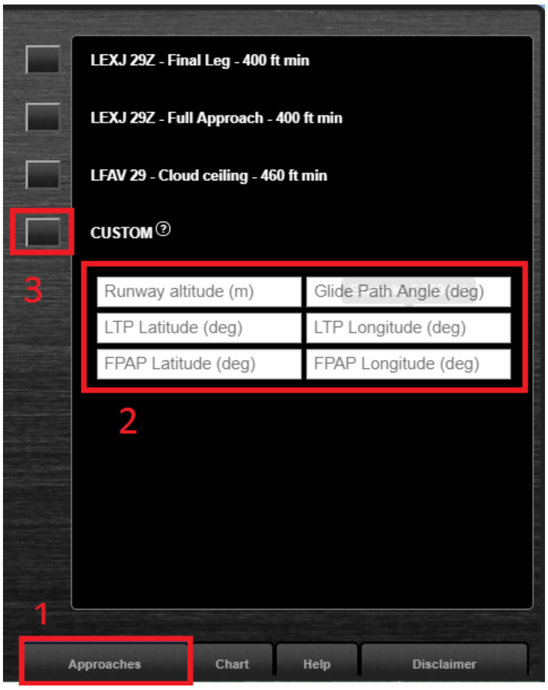


Figure 3: Location tool in ArcGIS Online

The altitude of the runway/airport can be found in many places like the national AIP, Wikipedia, etc. with a simple search on the internet.

The usual glidepath angle is 3º, but sometimes it needs to be steeper in order to avoid some obstacles around the airport or for noise abatement reasons.

Once all these points have been obtained, click on the *Approaches* tab, fill every field on the *Custom Approaches*' section and click its corresponding button in the left of the panel as indicated in the image below.



ANNEX I: INTRODUCTION TO LPV APPROACHES

What are LPV approaches?

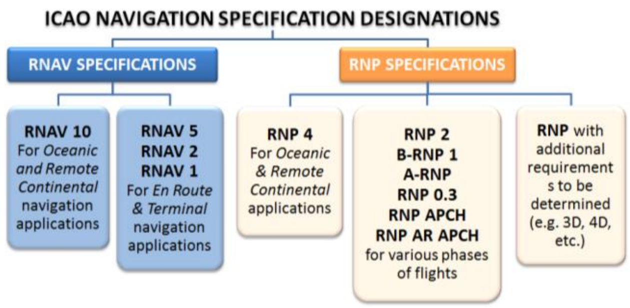
Technically known as RNP Approach (RNP APCH) procedures down to LPV minima, LPVs were introduced within the PBN concept as new approach operations based on SBAS, a technology providing augmentation to GNSS systems like GPS. This type of approaches allows for ILS look-alike instrument approach procedures down to a decision height as low as 200ft without the need of any ground infrastructure installation. As of December 2017, there are over 390 LPV procedures and 112 EGNOS-enabled APV-baro procedures published in Europe with plans for more than 1000 by the end of 2020 (see map available here).

LPV within the PBN concept

The PBN concept, published within the Performance-Based Navigation Manual (Doc 9613) - 4th edition, 2013 [RD-1], defines performance requirements for aircraft navigating on an ATS route, terminal procedure or in a designated airspace.

Through the application of Area Navigation (RNAV) and Required Navigation Performance (RNP) specifications, PBN provides the means for flexible routes and terminal procedures helping the global aviation community to reduce aviation congestion, save fuel, protect the environment and maintain reliable, all-weather operations, even at the most challenging airports. It provides ANSP and operators with greater airspace design flexibility and better operating returns while increasing the safety of regional and national airspace systems.

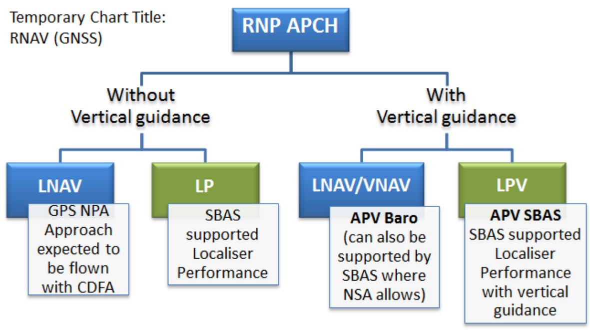
GNSS is identified as a key enabler for most of the navigation specifications defined. Notably SBAS and therefore EGNOS is a key enabler for procedures based on the RNP APCH Navigation Specification. The following figure shows in a schematic way the ICAO PBN Navigation Specification classification included in the PBN manual.



Source: Adapted from Eurocontrol

RNP APCH procedures allow four minima lines: LP, LNAV, LNAV/VNAV and LPV. The RNP APCH procedures are published on charts with the title RNAV (GNSS) RWY XX, which will change to RNP RWY XX by 2020.

The following figure shows the different RNP APCH procedures included within the RNP APCH navigation specification:



LPV benefits

LPV approaches enabled by the EGNOS Safety-of-Life (SoL) service provide the following general benefits compared to conventional NPAs:

- Minima reduction, currently down to 250ft and as low as 200ft in specific locations based on the LPV-200 Service Level, which allow successful approaches and increase accessibility in conditions that would otherwise disrupt operations compared to conventional NPAs.
- Safety increase thanks to temperature and barometric independent vertical guidance provided to the aircrew during the approach. This makes the approach easier to fly and reduces the risk of controlled flight into terrain (CFIT).
- Operational Benefits:
  - Reduces trajectory dispersion (predictability and noise footprint reduction);
  - CDO techniques (fuel consumption reduction and noise footprint reduction);
  - More flexible use of airspace;
  - Improved situational awareness;
  - LPVs offer straight-in approaches in some cases where this is not otherwise possible with conventional NPAs and they also allow the offset (angle) as in some ILS approaches;
  - LPVs offer the potential to remove circling approaches.
- Infrastructure rationalization:
  - LPV approaches will be most beneficial at runway-ends where there is no ILS already available;
  - Potentially enabling VOR, NDB, ILS removal/back-up reducing the associated installation and maintenance costs (in accordance with airlines equipage and/or interests).

ANNEX II: DESIGN OF LPV APPROACHES

Information contained in this annex comes from the Minimum Operational Performance Standards (MOPS) for GPS/WAAS airborne equipment – DO 229D [RD-1].

Final Approach Segment

The final approach path shall be defined by the FPAP, LTP, TCH and the glidepath angle. The threshold is located as the LTP if it is co-located with the runway and FTP if it is displaced from the runway. The glidepath angle is defined relative to the local tangent plane of the WGS-84 ellipsoid.

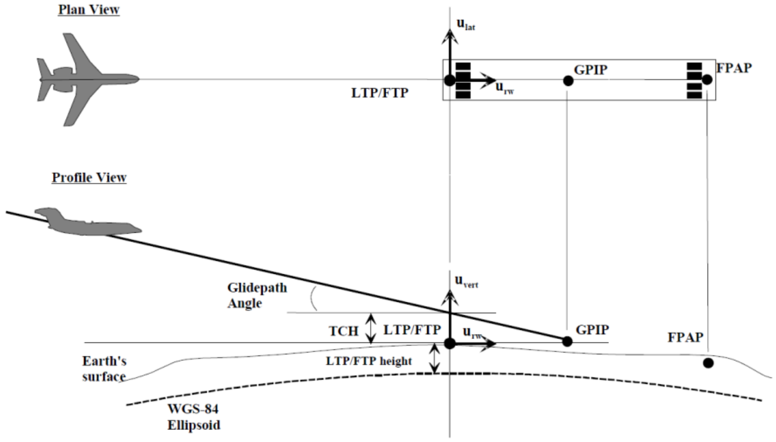


Figure 4: Final Approach Segment definition

Full Scale Deflection

The lateral deviation is defined in figure 3 for LPV approaches in VTF. If a VTF has not been selected, the lateral deviation shall be as follows:

a) On the approach side of the FAF, the deviation shall be either:
    a. Prior to 2 NM from the FAF, the deviation shall be linear, with FSD of 1 NM. Between 2 NM from the FAF and the FAF, the deviation shall gradually change to the FAS lateral deviation; or
    b. The deviation shall be the FAS lateral deviation.
b) Between the FAF and the LTP, the deviation shall be the FAS lateral deviation.
c) Between the LTP and a point that is prior to the GARP by a distance equal to either 305m plus the Length Offset, the deviation shall be either the FAS lateral deviation or linear with FSD for a cross-track error of ± Course Width.
d) Beyond this point, the deviation shall be linear with FSD of 0.3NM.

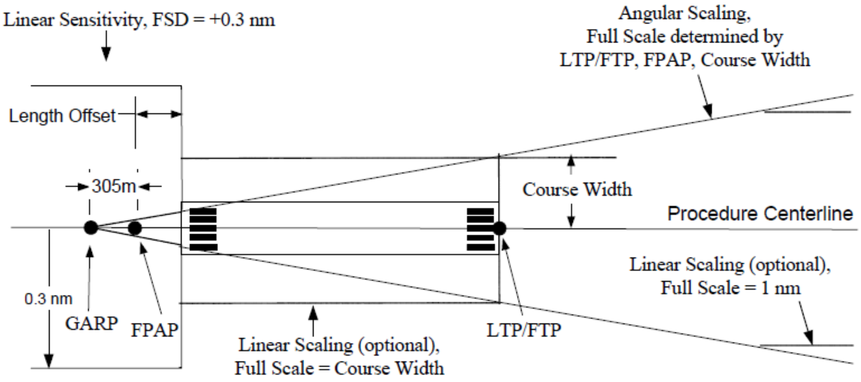


Figure 5: VTF Final Approach Segment Lateral Deviations

The final approach segment vertical deviation is defined to be proportional to the angle measured at the origin between the aircraft and the point on the vertical deviation reference surface that is closest to the aircraft, with FSD at glidepath angle ± 0.25 degrees.
Optionally, the FSD may be linear starting at the point where the angular FSD is equal to the linear FSD (15m for LPV).

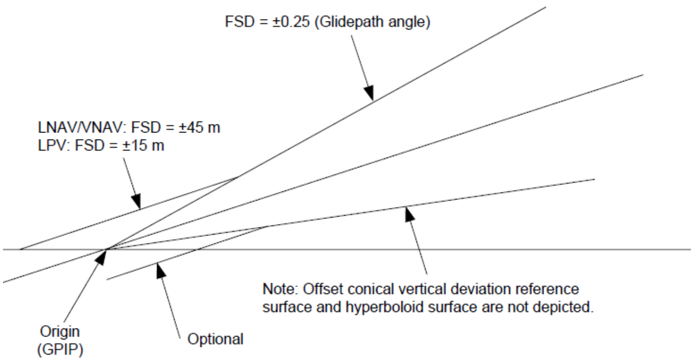


Figure 6: Final Approach Segment Vertical Deviations

APPENDIX A ACRONYMS

Acronym	Description
AIP	Aeronautical Information Publication
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATS	Air Traffic Service
APCH	Approach
ARP	Airport Reference Point
RNAV	Area Navigation
CDO	Continuous Descent Operations
CFIT	Controlled Flight Into Terrain
DA(H)	Decision Altitude/Height
EC	European Commission
EGNOS	European Geostationary Navigation Overlay Service
GSA	European GNSS Agency
ESSP	European Satellite Services Provider S.A.S.
EU	European Union
FAF	Final Approach Fix
FAS	Final Approach Segment
FPAP	Flight Path Alignment Point
FSD	Full Scale Deflection
GARP	Geometric Approach Reference Point
GNSS	Global Navigation Satellite System
GP	Glide Path
GPS	Global Positioning System
HAL	Horizontal Alert Limit

Acronym	Description
IAF	Initial Approach Fix
ILS	Instrument Landing System
IF	Intermediate Fix
ICAO	International Civil Aviation Organization
LNAV	Lateral Navigation
LP	Localiser Performance
LPV	Localiser Performance with Vertical guidance
LTP	Landing Threshold Point
MOPS	Minimum Operational Performance Standard
NM	Nautil Mile
OCA(H)	Obstacle Clearance Altitude (Height)
PBN	Performance Based Navigation
RNP	Required Navigation Performance
RWY	Runway
SoL	Safety of Life
SBAS	Satellite Based Augmentation System
TCH	Threshold Crossing Height
TERM	Terminal
VTF	Vector To Final
VAL	Vertical Alert Limit
VNAV	Vertical Navigation
WAAS	Wide Area Augmentation System
WGS	World Geodetic System

APPENDIX B REFERENCE DOCUMENTS

[RD-1] Performance-Based Navigation (PBN) Manual (Doc 9613). - 4th edition, 2013

[RD-2] DO-229D – Minimum Operational Performance Standards for GPS/WAAS airborne equipment

APPENDIX C AERONAUTICAL CHARTS

AIP
FRANCE

AD 2 LFAV IAC RWY29 GNSS
02 FEB 17

APPROCHE AUX INSTRUMENTS
Instrument approach
CAT A B C
ALT AD : 165, ***DTHR : 159 (6 hPa)***

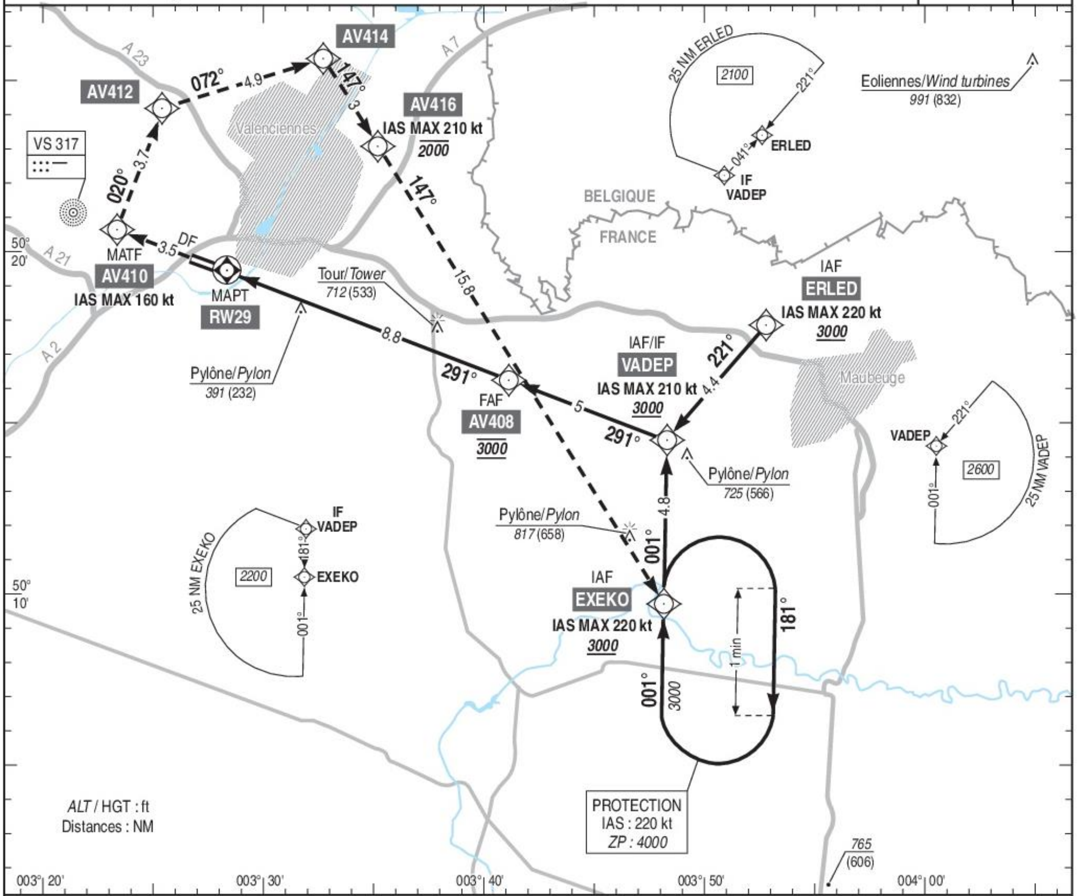
VALENCIENNES DENAIN

RNAV (GNSS) RWY 29

APP : LILLE Approche/*Approach* 126.475 (dans les limites TMA LILLE/*within TMA LILLE limits*)
TWR : NIL (AD non contrôlé/*AD not controlled*)
AFIS : VALENCIENNES Info 122.6
Absence ATS : **A/A** FR seulement. Obtenir le QNH de LILLE sur ATIS LILLE 119.325 ou auprès de LILLE Approche 126.475
A/A *FR only. Obtain LILLE QNH from LILLE ATIS 119.325 or from LILLE Approach 126.475*

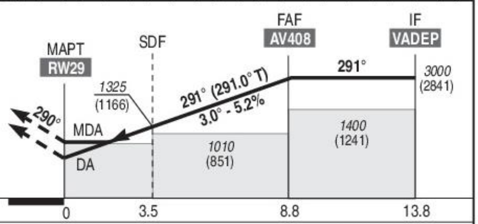
EGNOS
96141
E29A
RDH : 50

VAR
0°
(15)



API : Monter direct **vers AV410 (IAS MAX 160 kt)**. Sauf instruction du contrôle, tourner à **droite** vers **AV412** puis vers **AV 414,** puis vers **AV 416,** en montée vers ***2000*** (1841) **MAX (IAS MAX 210 kt)**, puis monter vers **EXEKO** et intégrer l'attente à ***3000*** (2841).
Monter à *1300* (1141) avant d'accélérer en palier.

Missed APCH : Climb direct to ***AV410 (IAS MAX 160 kt)****. Except ATS instructions, turn* ***right*** *to* ***AV412****, then to* ***AV414****, then to* ***AV416*** *climbing up to* ***2000*** *(1841)* ***MAX (IAS MAX 210 kt)*** *then climb up to* ***EXEKO*** *to enter holding at* ***3000*** *(2841). Climb up to 1300 (1141) prior to level acceleration.*



MNM AD : distances verticales en pieds, RVR et VIS en mètres./*Vertical distances in feet, RVR and VIS in metres.* REF HGT : *ALT DTHR*

CAT	LPV		OCH	LNAV OCH : 478		MVL/Circling (1)		MVL/Circling (1) absence ATS	
	DA (H)	RVR		***MDA*** (H)	RVR	***MDA*** (H)	VIS	***MDA*** (H)	VIS
A	***460*** (300)	1400	275	***640*** (480)	1500	***790*** (630)	1500	***890*** (730)	1500
B			284		1500	***790*** (630)	1600	***890*** (730)	1600
C			294		2200	***1160*** (960)	2400	***1220*** (1060)	2400

DIST RW 29 NM	**2**	**3**	**4**	**5**	**6**	**7**	**8**
ALT	***850***	***1160***	***1480***	***1800***	***2120***	***2440***	***2760***
(HGT)	(691)	(1001)	(1321)	(1641)	(1961)	(2281)	(2601)

Observations/*Remarks* : (1) MVL CAT C interdite au Nord de la piste / *(1) Circling CAT C prohibited North of RWY.*
Panne de guidage GNSS lors de l'approche / *Loss of GNSS guidance during approach* : Voir/*see* AIP ENR 1.5.

		70 kt	85 kt	100 kt	115 kt	130 kt	160 kt
FAF - DTHR	8.8 NM	7 min 31	6 min 11	5 min 16	4 min 35	4 min 03	3 min 17
VSP (ft/min)		370	450	530	610	690	850

SERVICE DE L'INFORMATION AERONAUTIQUE

API	IDENT	VSS
X	X	X

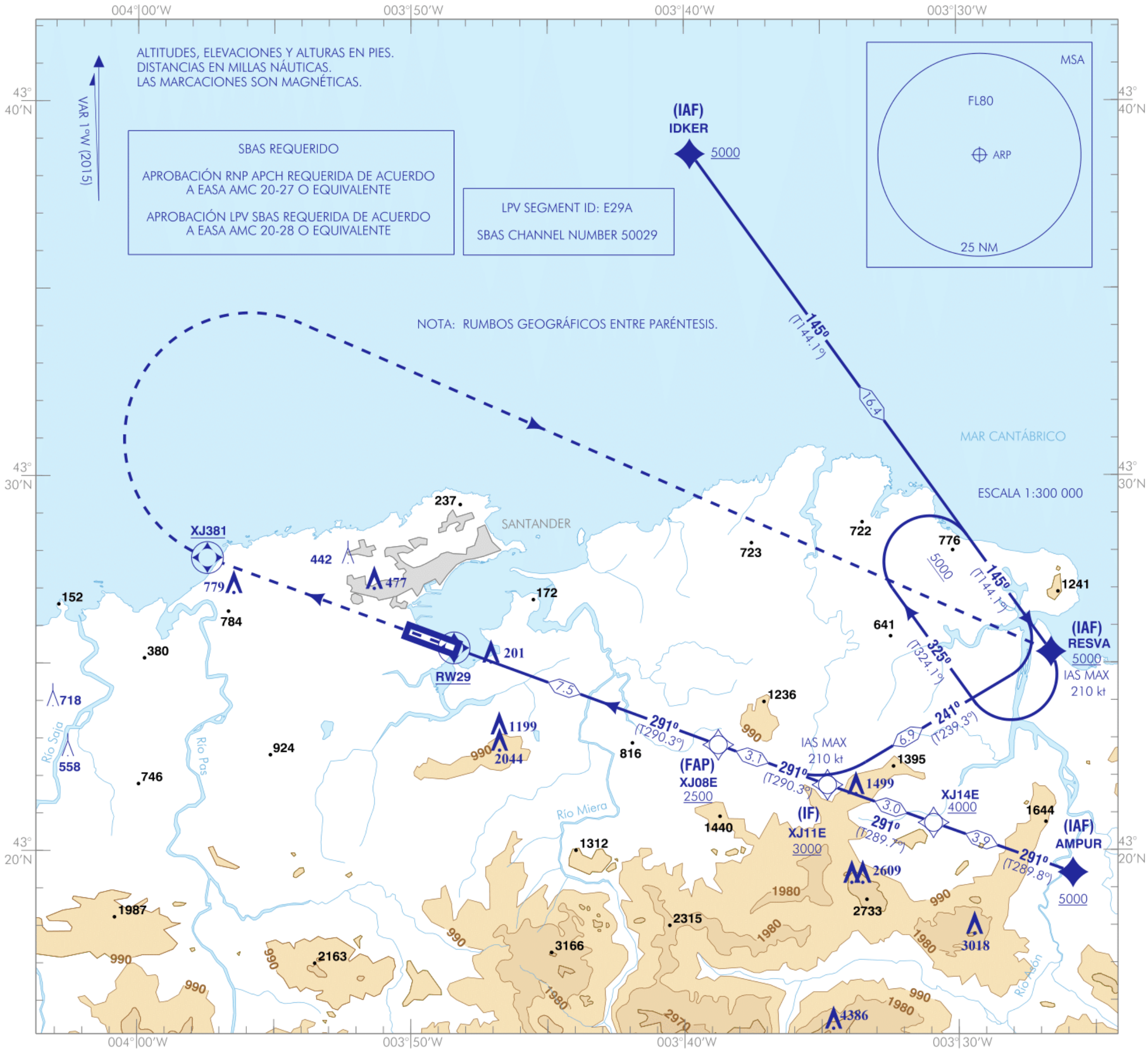
AMDT 02/17 **CHG :** Altitude minimale TAA EXEKO.

CARTA DE APROXIMACIÓN
POR INSTRUMENTOS-OACI

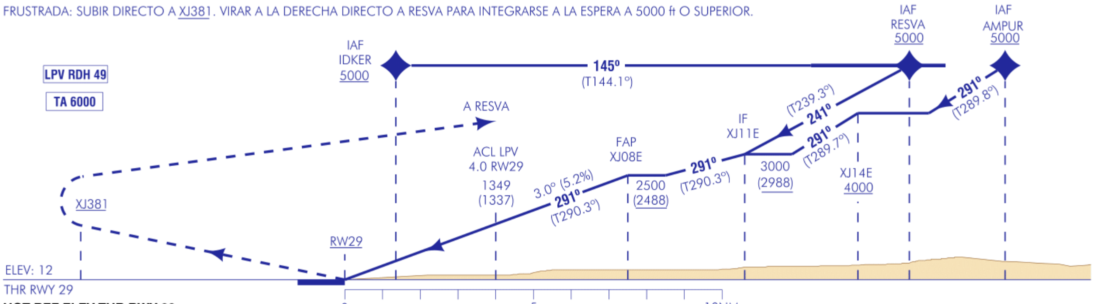
ELEV AD
16

APP 118.375
TWR 118.100
GMC 121.700

SANTANDER/Seve Ballesteros-Santander
RNAV (GNSS) Z
RWY 29



FRUSTRADA: SUBIR DIRECTO A XJ381. VIRAR A LA DERECHA DIRECTO A RESVA PARA INTEGRARSE A LA ESPERA A 5000 ft O SUPERIOR.



CAMBIOS: ESPERA EN RESVA, OBSTÁCULOS, COTAS, SIMBOLOGÍA.

OCA/H			A	B	C	D
STA	LPV	2.5%	377 (365)	389 (377)	397 (385)	408 (396)
En circuito (H) sobre 16			820 (810)	2010 (2000)	2500 (2490)	

GS	kt	80	100	120	140	160	180
FAP-THR: 7.5 NM	min:s	5:38	4:30	3:45	3:13	2:49	2:30
FAP-MAPT:	min:s						
ROD: 5.2%	ft/min	425	531	637	743	849	955

ALT/HGT RW29 FNA

13 NM	12 NM	11 NM	10 NM	9 NM	8 NM	7 NM	6 NM	5 NM	4 NM	3 NM	2 NM	1 NM
						2340 (2330)	2010 (2000)	1680 (1670)	1350 (1340)	1030 (1020)	710 (700)	

WEF 02-FEB-17 (AIRAC AMDT 15/16) AIP-ESPAÑA AD 2-LEXJ IAC/9.1