GBAS/SBAS Implementation Workshop

-

SBAS LPV flight procedure design and implementation

DSNA France

Corinne Bousquet, Florence Jacolot, Benoit Roturier

4 June 2019, Seoul

CONTENT OF THE PRESENTATION

- ICAO Annex 10 requirements
- Main design differences SBAS LPV vs. BaroVNAV LNAV/VNAV
- SBAS procedure validation
- Final Approach Segment (FAS) data block
- SBAS channel
- SBAS Status and ATC
- SBAS Notam

ICAO Annex 10 requirements

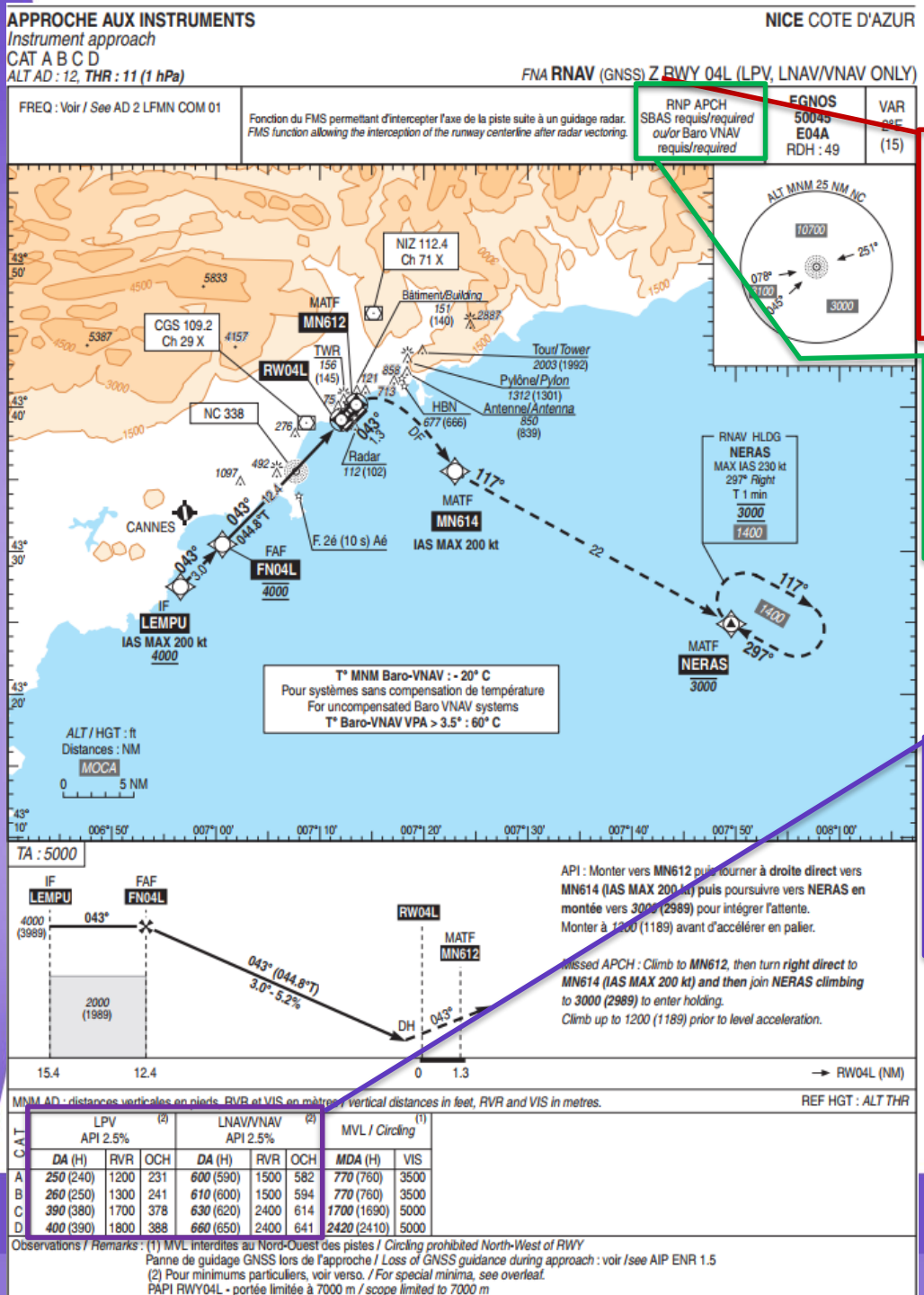
ANNEX 10 SIS REQUIREMENTS

Table 3.7.2.4-1 Signal-in-space performance requirements

Typical operation	Accuracy horizontal 95% (Notes 1 and 3)	Accuracy vertical 95% (Notes 1 and 3)	Integrity (Note 2)	Time-to-alert (Note 3)	Continuity (Note 4)	Availability (Note 5)
En-route	3.7 km (2.0 NM)	N/A	$1 - 1 \times 10^{-7}$/h	5 min	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
En-route, Terminal	0.74 km (0.4 NM)	N/A	$1 - 1 \times 10^{-7}$/h	15 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
Initial approach, Intermediate approach, Non-precision approach (NPA), Departure	220 m (720 ft)	N/A	$1 - 1 \times 10^{-7}$/h	10 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
Approach operations with vertical guidance (APV-I)	16.0 m (52 ft)	20 m (66 ft)	$1 - 2 \times 10^{-7}$ in any approach	10 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999
Approach operations with vertical guidance (APV-II)	16.0 m (52 ft)	8.0 m (26 ft)	$1 - 2 \times 10^{-7}$ in any approach	6 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999
Category I precision approach (Note 7)	16.0 m (52 ft)	6.0 m to 4.0 m (20 ft to 13 ft) (Note 6)	$1 - 2 \times 10^{-7}$ in any approach	6 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999

Main Design differences : SBAS LPV vs. BaroVNAV LNAV/VNAV

APV SBAS AND APV BARO



A single chart :

- Same name for AIP and ATCO's clearance
- Same trajectory (same WPs)
- Same vertical depiction(FAF and final slope)

PBN Box requesting onboard

- Either SBAS
- Or BaroVNAV capacity

Different values of operational minima:

- **Lowest OCH for LPV** vs LNAV/VNAV
- No info charted on SBAS performance

APV SBAS VS APV BARO : FLYING FINAL SLOPE

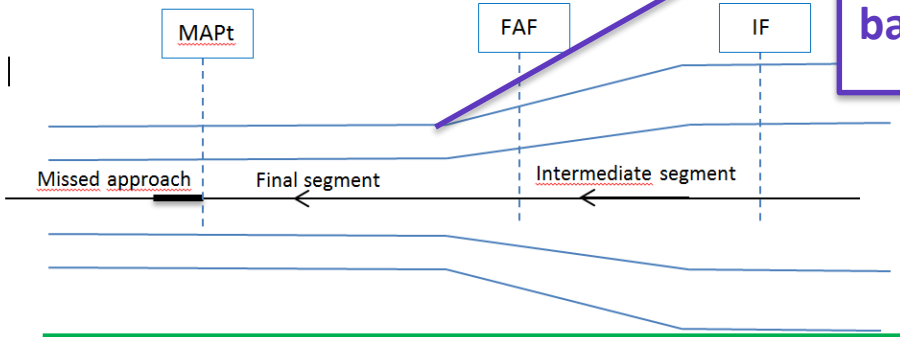
	QNH	Temperature	Radar vector to final
APV SBAS	Not affected	Not affected	Similar to LOC
APV Baro VNAV	Based on QNH	Affected	Constraint (FAF altitude +/- 200 ft)

Pilots feedback:

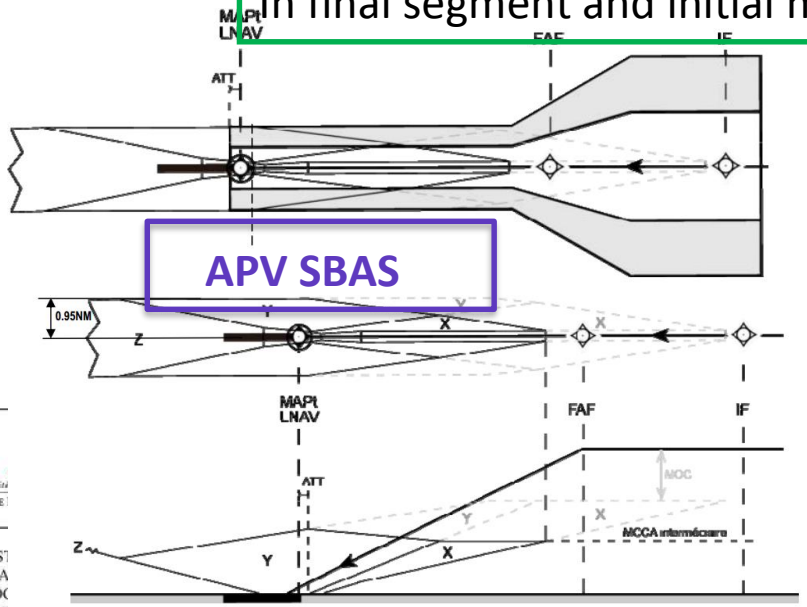
- APV SBAS final slope often better than ILS glide path (more stable)
- APV Baro VNAV can be affected by temperature (and obviously as well by QNH mis-setting)
  - High temp : too steep
  - Low temp: too low

APV SBAS VS APV BARO : PROTECTION AREAS

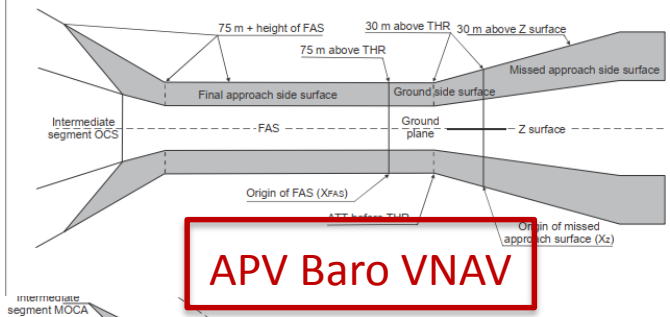
similar lateral protection areas based on LNAV criteria



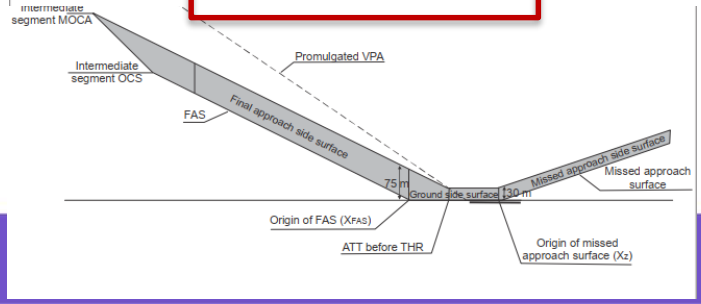
Different set of vertical surfaces to assess obstacles
In final segment and initial missed approach



APV SBAS



APV Baro VNAV



APV BARO PROCEDURE DESIGN CRITERIA

Design criteria are described in PANS OPS Part III, Section 3, Chapter 4

Chapter 4

APV/BAROMETRIC VERTICAL NAVIGATION (BARO-VNAV)

Protection criteria depending on low temperature consideration:

- **Lowest temperature allowed** published

Warning on the effect of high temperature on final slope

T° MNM Baro-VNAV : - 20° C
Pour systèmes sans compensation de température
For uncompensated Baro VNAV systems
T° Baro-VNAV VPA > 3.5° : 60° C

DH limited to 250ft

APV SBAS PROCEDURE DESIGN CRITERIA 1/2

Design criteria are described in PANS OPS Part III, Section 3, Chapter 5 very similar to ILS criteria

Chapter 5

SBAS NON-PRECISION APPROACH, APPROACH WITH VERTICAL GUIDANCE AND PRECISION APPROACH CATEGORY I PROCEDURES

Two sets of criteria depending on the performances of the SBAS system lead to :

- APV SBAS (minimum DH : 250ft)
- SBAS Cat I (minimum DH : 200ft)
  - **For SBAS Cat I: two design solutions available, but ILS Collision Risk Model generally leads to lowest OCH**

SBAS procedure validation

APV SBAS VS APV BARO VNAV : PROCEDURE VALIDATION

APV SBAS :

- Ground validation, but no systematic flight validation in France, since a trust process has been built for major items:
  - procedure design
  - aeronautical data bases
  - obstacle data bases
- **FAS DB : key element requiring a specific validation process**
  - See next slides

APV Baro VNAV :

- Ground validation sufficient
- No specific need for final segment validation (no FAS DB)

FAS DB : from design to validation and publication

LPV FAS Datablock

TABLE D-1 FINAL APPROACH SEGMENT (FAS)

Data content	*Bits used*	*Range of values*	*Resolution*
Operation type	4	0 to 15	1
SBAS provider ID	4	0 to 15	1
Airport ID	32	-	-
Runway number *(Note 1)*	6	0 to 36	1
Runway letter	2	-	-
Approach performance designator	3	0 to 7	1
Route indicator	5	-	-
Reference path data selector	8	0 to 48	1
Reference path identifier	32	-	-
LTP/FTP latitude	32	± 90.0 °	0.0005 arcsec
LTP/FTP longitude	32	± 180.0 °	0.0005 arcsec
LTP/FTP height	16	-512.0 to 6041.5 m	0.1 m
ΔFPAP latitude	24	± 1.0 °	0.0005 arcsec
ΔFPAP longitude	24	± 1.0 °	0.0005 arcsec
Approach threshold crossing height (TCH)	15	0 to 1638.35 m (0 to 3276.7 ft)	0.05 m (0.1 ft)
Approach TCH units selector	1	-	-
Glidepath angle (GPA)	16	0 to 90.0 °	0.01°
Course width at threshold *(Note 1)*	8	80.0 to 143.75 m	0.25 m
ΔLength offset	8	0 to 2032 m	8 m
Horizontal Alert Limit (HAL)	8	0 to 51.0 m	0.2 m
Vertical Alert Limit (VAL) *(Note 2)*	8	0 to 51.0 m	0.2 m
Final approach segment CRC	32	-	-

Note 1: When the runway number is set to 00, then the course width field is ignored and the course width is 38 meters.

40 bytes

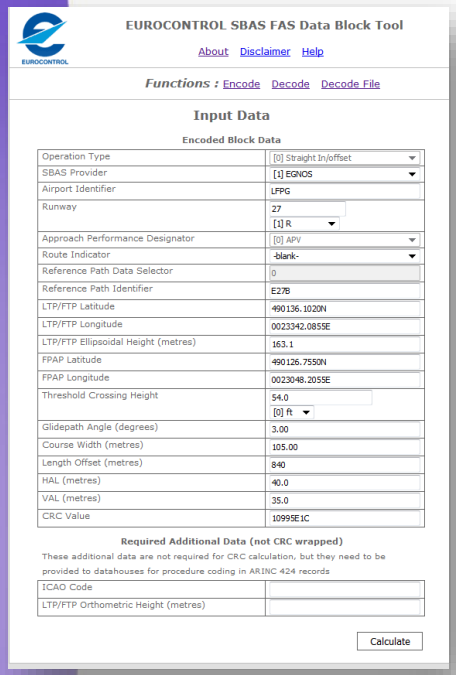
12 bytes for Identification

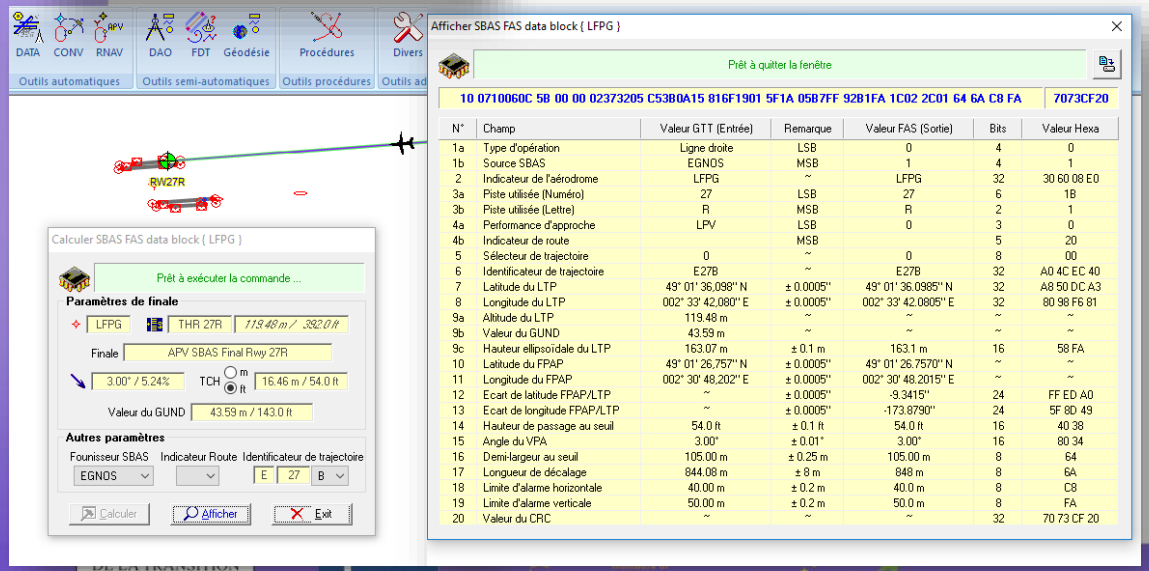
22 bytes coding for the Geometry of the Final Approach Segment

2 bytes for the required SBAS performances

4 byte CRC - integrity

FASDB generation tools

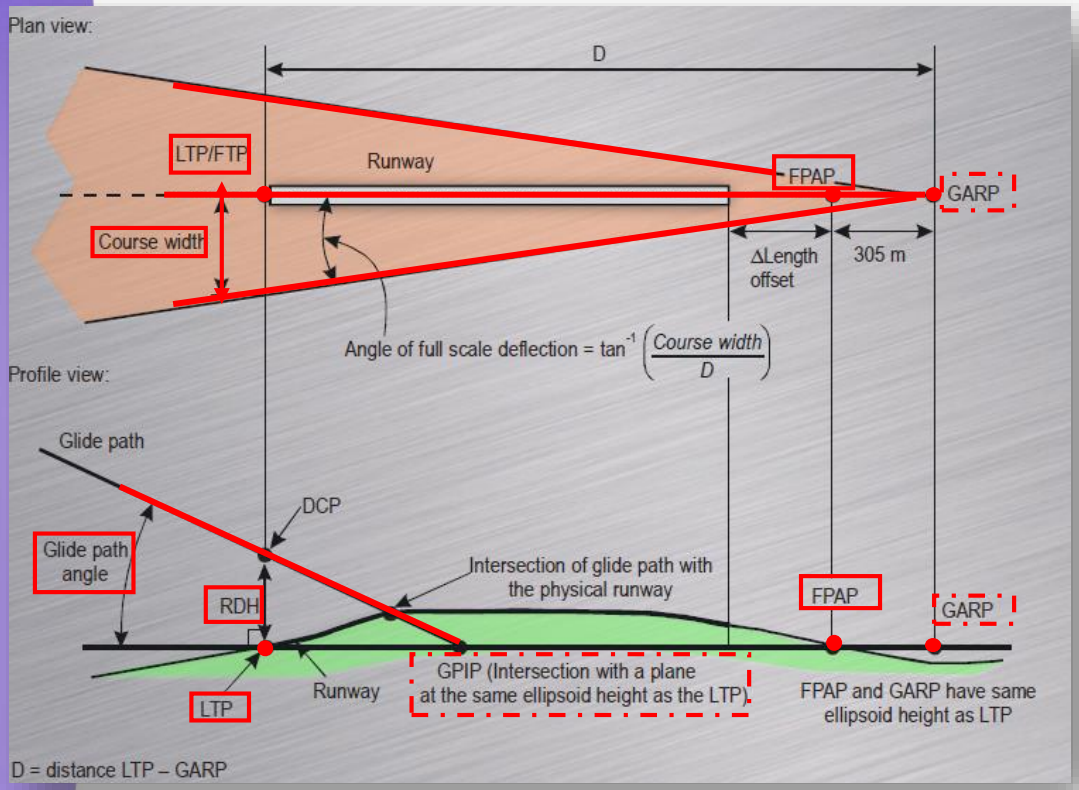




- **EUROCONTROL SBAS FAS Data Block Tool**
  - https://fasdb.eurocontrol.int/fasdb/app/about.htm
  - Checks for ranges of values
  - Computes CRC
  - Generates .PDF, .TXT, .BIN files
  - DOES NOT check consistency of data

- **CGX AERO GéoTITAN®** LPV FAS Data Block module
  - Computes automatically FASDB parameters from LPV design
  - Checks for ranges of values
  - Computes CRC
  - Generates .PDF, .BIN files

FASDB design



Parameters	Va
Operation Type	0
SBAS Provider	1 (EGNOS)
Airport Identifier	LFPG
Runway	27
Runway Letter	1 (Right)
Approach Performance Designator	0
Route Indicator	
Reference Path Data Selector	0
Reference Path Identifier	E27B
LTP/FTP Latitude	490136.1020N
LTP/FTP Longitude	0023342.0855E
LTP/FTP Ellipsoidal Height (metres)	163.1
FPAP Latitude	490126.7550N
Delta FPAP Latitude (seconds)	-9.3470
FPAP Longitude	0023048.2055E
Delta FPAP Longitude (seconds)	-173.8800
Threshold Crossing Height	54.0
TCH Units Selector	0 (feet)
Glidepath Angle (degrees)	3.00
Course Width (metres)	105.00
Length Offset (metres)	840
HAL (metres)	40.0
VAL (metres)	35.0

Integrity : 10E-8. LTP and FPAP coordinates must be aligned with the runway.

- **LTP**: at landing threshold; LTP ell. **Height** is **WGS84** and the **unique** vertical reference, pay attention to datum used when using local references (WGS84)
- **FPAP**: at End of Runway or **computed** (305m in front of LLZ, or placed for 6° aperture)

FASDB validation

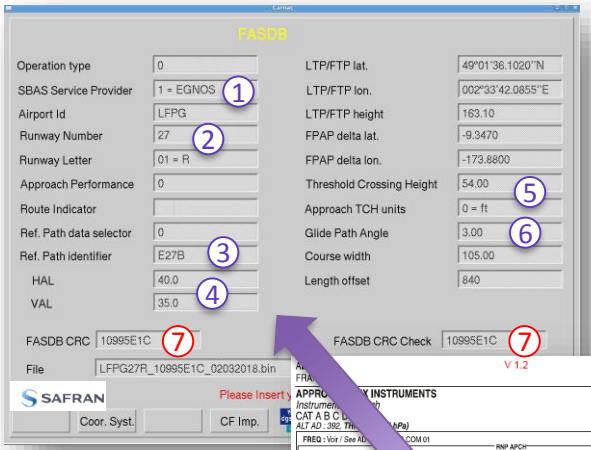
- **Each item of the FASDB must be checked for consistency with airport, runway, and designed procedure**

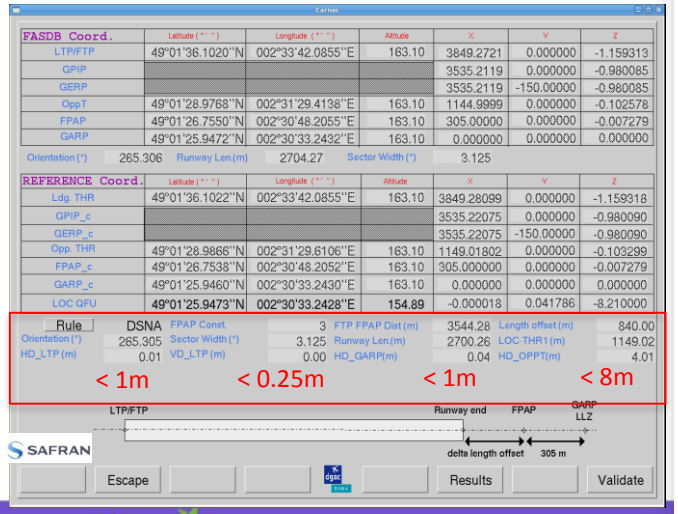
1. By **G**round and **F**light **Validation** as detailed in ICAO **doc 9906 vol5**
   - Ground Validation: FASDB consistency with procedure design (Identification fields, GPA, HAL,VAL)
   - Flight Validation: flyability, alignment with the underlying FAF-MAPt leg
2. By **G**round and/or **F**light **Inspection** as detailed in ICAO **doc 8071 vol2**
   - An **assessment of the accuracy of the LTP and FPAP coordinates** shall be made
     - **Direct** assessment: by a surveyor, *but FPAP is sometimes not a physical point*
     - **Indirect**: by Flight inspection methods using a Flight Inspection aircraft and FIS
   - **In flight**:
     - Computation of **achieved GPA, TCH, alignment** using Truth reference
     - No need to validate SBAS performances (performed by ground segment)
     - but to check the correct reception of SBAS signal of all GEOs and achieved performances compared to foreseen **HAL and VAL** in particular in mountaineous regions or close to SBAS coverage borders
     - And GPS L1 interferences free

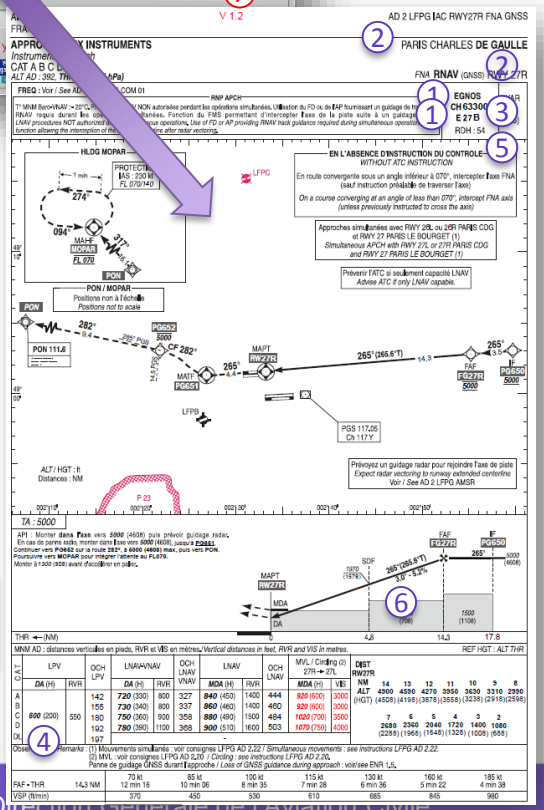
DSNA FASDB validation process

- **1/ Ground validation of the FASDB by the DSNA Flight Inspector Engineer:**
  - **FASDB/ Chart consistency**
  - **CRC check**

  - LTP and FPAP **coordinates check versus** airport **WGS84 database**
    - ***CARNAC*** SAFRAN tool used - predefined set of *rules*
    - Computes automatically **hor. and vert. errors** between LTP, FPAP FPAP coordinates and Length Offset ***vs*** runway and LLZ coordinates
    - Tolerances: H=1m, V=0.25m (from doc 8071vol2)







DSNA FASDB validation process

2/ taxi the Flight Inspection aicraft along the runway

Δhgt =9.22ft =2.81m

FPAP GARP

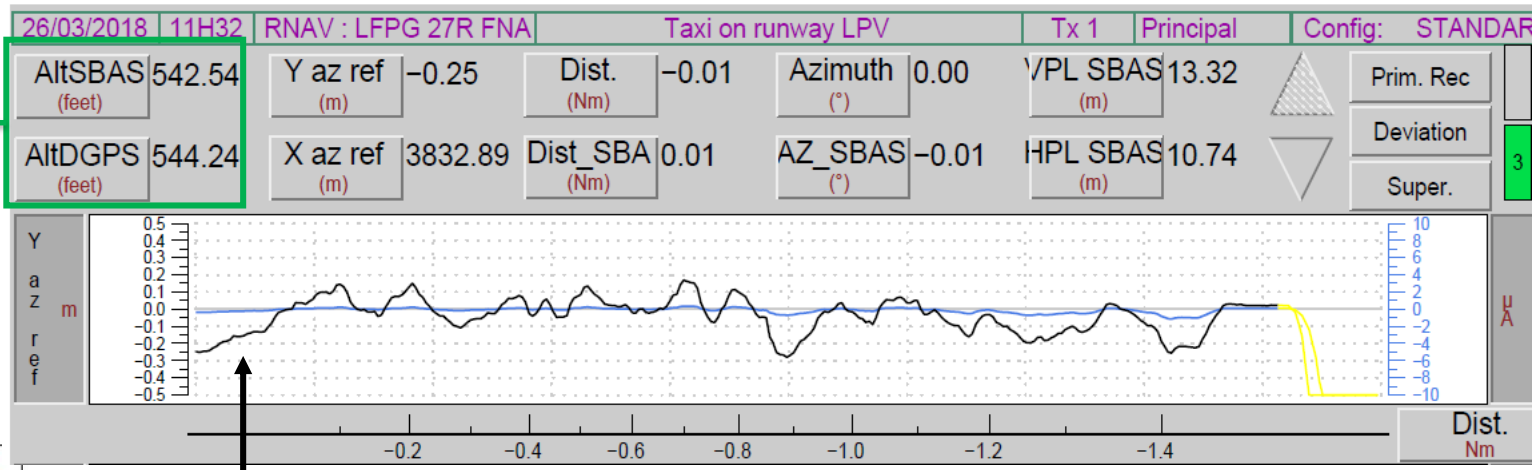
AltDGPS = 544.24ft

AltSBAS = 542.54ft

ΔDGPS <1ft (0.33m)

ΔSBAS < 7 ft (~2m)

FASDB LTP ell. height +antenna hgt = 163.10m + 2.81m= **544.33ft**

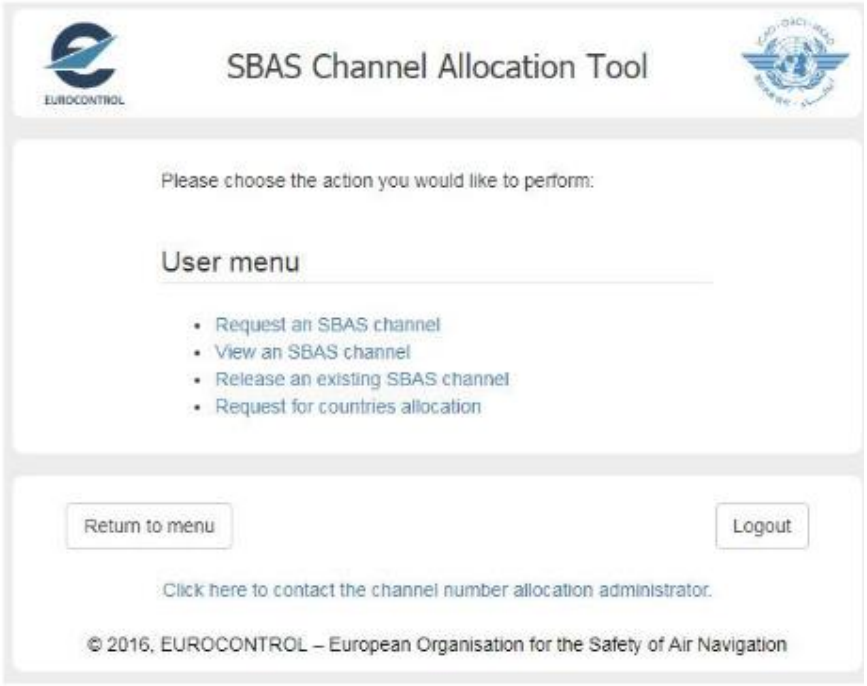


Y_az_ref: Lateral displacement of aircraft from centre line while taxiing from one threshold to the other wrt to LTP-FPAP geodetical line – if it is not biased or divergent and remains <0.5m, LTP and FPAP coordinates considered fully validated

SBAS Channel

SBAS channel allocation

- SBAS Channel numbers range from **40000 to 99999 (single use in the world)**
- **FAA** used to manage the **world Master Database** for ICAO initially
- **At the beginning of EGNOS SoL, a list of 100 channel numbers** were allocated to France, as first European state to publish LPV – today 230 channels used



- Since EGNOS LPV have spread in Europe, **EUROCONTROL is now SBAS Channel manager**
- **ECTRL** developed **a web based tool**
- **Login** given to 1 nominated state representative
- **To be Replaced** by **ICAO tool** next summer

SBAS real-time operational status and ATC

LATEST ANNEX 10 AND PBN STATEMENTS

- **PBN status monitoring is an area of work which might require significant resources from States, and where divergence of interpretation had been noted by ICAO in the past**
- **Thus the Navigation System Panel of ICAO has recently proposed updates to ICAO Annex 10 (cf. State letter in progress):**

CHAPTER 2. GENERAL PROVISIONS FOR RADIO NAVIGATION AIDS

. . .

2.3 Provision of information on the operational status of radio navigation services

2.3.1 Aerodrome control towers and units providing approach control service shall be provided with information on the operational status of radio navigation services essential for approach, landing and take-off at the aerodrome(s) with which they are concerned, on a timely basis consistent with the use of the service(s) involved.

Note.— Guidance material on the application of this Standard in the case of PBN-based operations supported by GNSS is contained in the Performance-based Navigation (PBN) Manual *(Doc 9613).*

LATEST ANNEX 10 AND PBN STATEMENTS

- **PBN Manual guidance to be udated in relation with the updated Annex 10 as follows, within the next edition of PBN manual (work in progress by PBN SG):**

« (…)There are a number of specific features of PBN approaches which render operational status monitoring neither practical nor required for PBN operations, whether the service is assessed essential or non-essential (…)”

SBAS NOTAM

NOTAM

SBAS NOTAM shall be issued by the SBAS service provider

- For any LPV procedure, based on Airport Reference Point location
- Information of predicted unavailability of SBAS service
- In Europe, NOTAM service is available to ANSPs through the EGNOS Working Agreement, built on bilateral basis with ESSP

ABAS NOTAM required to assess lack of RAIM capability

- EAD European system issues both type of NOTAMs

	ABAS NOTAM	SBAS NOTAM
APV SBAS procedure	✓	✓
APV Baro VNAV procedure	✓	

SBAS Legal recording

LEGAL RECORDING

Broadcast SBAS signals shall be recorded by the SBAS service provider

- To be used in case of incident/accident where SBAS might have contributed to
- In Europe, the legal recording service is available to ANSPs through an EGNOS Working Agreement, built on bilateral basis with ESSP

Conclusion

MULTIDISCIPLINARY APPROACH RECOMMENDED

DSNA experience was that setting-up a Task Force to support and consolidate the new LPV publication process is the most efficient:

- Procedure designers
- AIS experts
- GNSS specialists
- Air traffic controllers
- Pilots (test pilots)
- Aircraft / Avionic manufacturers
- Flight inspection specialists

Implementation of APV SBAS procedure from definition to publication including training of controllers and designers

Complementary slides

Use of SBAS information for terminal area trajectories

IN TERMINAL AREA

For aircraft equipped with SBAS receiver,

- vertical position
  - is computed using SBAS signals **ONLY along the final** segment
  - is provided by the **altimeter** on any other part of the trajectory
- horizontal guidance
  - Is based on **angular deviation** along the final axis
  - Is based on **linear** deviations on any other segment

The final segment is designed with **geometric vertical guidance**
Depending on SBAS signal performances, final segment may **be similar to ILS** final segment

IN TERMINAL AREA

	Navigation specification	SBAS main benefits
Departure	RNP1, RNAV1	-----
Arrival	RNP1, RNAV1	------
Approach	RNP APCH	In final approach and straight missed approach

APPROCHE AUX INSTRUME

Instrument approach

CAT A B C D

ALT AD : 479, ***DTHR : 464 (17 hPa)***

ATIS DEAUVILLE : 119.175
APP : DEAUVILLE Approche/*Approach*
TWR : DEAUVILLE Tour/*Tower* 118.3

NSTRUMENTS

h

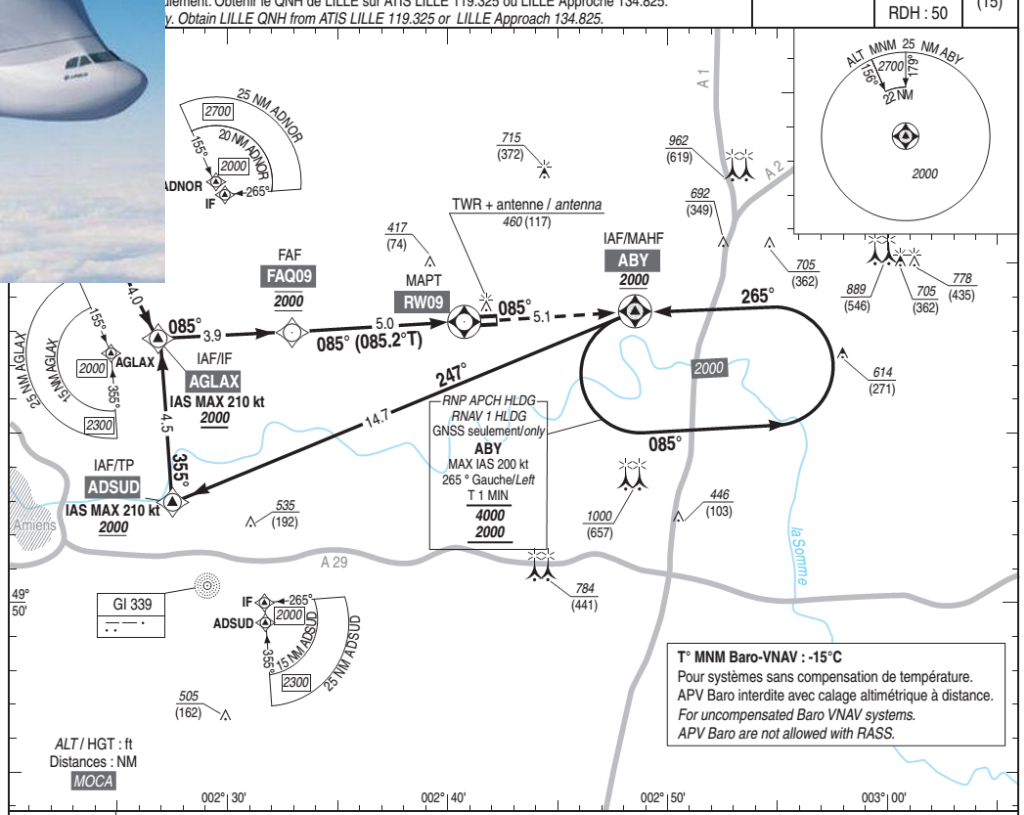
ALBERT BRAY

3 (12 hPa)

RNAV (GNSS) RWY 09

pproach 134.825
er 119.650
n 119.650
ulement. Obtenir le QNH de LILLE sur ATIS LILLE 119.325 ou LILLE Approche 134.825.
y. Obtain LILLE QNH from ATIS LILLE 119.325 or LILLE Approach 134.825.

RNP APCH	EGNOS Ch 43692 E09A RDH : 50	VAR 0° (15)

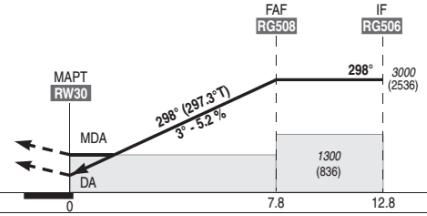


T° MNM Baro-VNAV : -15°C
Pour systèmes sans compensation de température.
APV Baro interdite avec calage altimétrique à distance.
For uncompensated Baro VNAV systems.
APV Baro are not allowed with RASS.

TA : 5000

API : Monter dans l'axe. A **RG510**, en montée vers ***3000*** (2536), tourner à **gauche** pour rejoindre directement **XASUD** et intégrer l'attente associée (**IAS MAX 210 kt**).
Monter à *1300* (836) avant d'accélérer en palier.

Missed APCH : Climb straight ahead. At ***RG510****, up to* ***3000*** *(2536), turn* ***left*** *to reach directly* ***XASUD*** *and join associated holding (****IAS MAX 210 kt****).*
Climb up to 1300 (836) prior to level acceleration.



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

CAT	LPV		OCH LPV	LNAV / VNAV OCH : 412		LNAV OCH : 412		MVL/*Circling*	
	DA (H)	RVR		***DA*** (H)	RVR	***MDA*** (H)	RVR	***MDA*** (H)	VIS
A	***730*** (260)	800	260	***880*** (420)	1500	***880*** (420)	1500	***930*** (470)	1500
B	***740*** (270)	900	270					***970*** (500)	1600
C	***750*** (280)	900	280					***1070*** (600)	2400
D	***760*** (290)	900	289					***1170*** (700)	3600

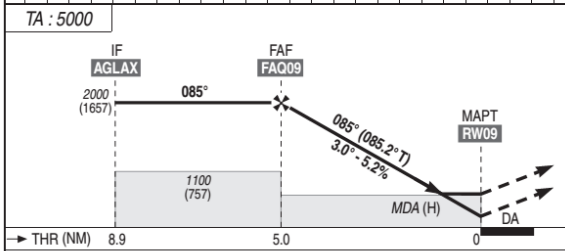
T° MNM Baro-VNAV : -15°C

DIST RW30 NM	7	6	5	4	3	2
ALT (HGT)	***2746*** (2282)	***2427*** (1963)	***2109*** (1645)	***1790*** (1326)	***1472*** (1008)	***1153*** (689)

Observations/*Remarks* : Panne de guidage GNSS lors de l'approche / *Loss of GNSS guidance during approach* : voir/*see* AIP ENR 1.5

		70 kt	80 kt	90 kt	100 kt	110 kt	120 kt	130 kt	150 kt	170 kt	180 kt
FAF - MAPT	7.8 NM	6 min 41	5 min 51	5 min 12	4 min 41	4 min 15	3 min 54	3 min 36	3 min 07	2 min 45	2 min 36
VSP (ft/min)		370	420	480	530	580	640	690	800	900	960

TA : 5000



API : Monter vers **ABY** en montée vers ***2000*** (1657), puis intégrer l'attente ABY ou **suivre instructions du contrôle.**
Monter à ***1300*** (957) avant d'accélérer en palier.

Missed APCH : Climb direct to ***ABY*** *climbing up to* ***2000*** *(1657), then enter ABY holding pattern or* ***proceed according ATC instructions.***
Climb up to ***1300*** *(957) prior to level acceleration.*

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

CAT	LPV		OCH LPV	LNAV/VNAV		OCH LNAV VNAV	LNAV OCH : 357		MVL/*Circling* (1)		MVL/*Circling* (1) absence ATS HJ seulement/*only*	
	DA (H)	RVR		***DA*** (H)	RVR		***MDA*** (H)	RVR	***MDA*** (H)	VIS	***MDA*** (H)	VIS
A			248			227		1500	***900*** (550)	1500	***1070*** (720)	1500
B	***650*** (300)	1400	258	***650*** (300)	1400	239	***700*** (360)	1500	***920*** (570)	1600	***1090*** (740)	1600
C			268			251		1600	***1090*** (750)	2400	***1260*** (920)	2400
D			278			271		1600	***1110*** (770)	3600	***1280*** (940)	3600

DIST RW09 NM	5	4	3	2	1
ALT (HGT)	***1980*** (1637)	***1670*** (1327)	***1350*** (1007)	***1030*** (687)	***710*** (367)

Lessons learned

From pilots and ATC point of view

PILOTS AND ATCOS

SBAS procedure allow use of an extended final axis (LOC):

- VTF function onboard
- Display of the extended final axis for the pilots
- ATCO can use radar instruction to lead aircraft to final axis

SBAS Final slope can start at the final altitude (not only at FAF)

- No influence of temperature
- No QNH dependant

APV Baro Final segment starts only **at FAF at promulgated altitude**

PILOTS AND ATCOS

ATCO can use radar instruction to lead aircraft to final SBAS axis:

- As flexible and easy as ILS

ATCO deliver a clearance based on « RNAV approach »

- not need realtime information on the SBAS system
- RNAV procedure provided on ATIS message as main procedure in service