ISSUES ON APV/SBAS (GNSS) APPROACH PROCEDURE DESIGN STANDARDS

Jesús Pérez Ramos
Jorge Blanco Monge
Luis Pérez Sanz
Eva María García Moreno
INECO , Airspace Organization, Structuration and Design Department. Av. Partenón 4, 28042 Madrid, Spain

1. BIOGRAPHY

INECO Airspace Department is mainly involved in activities related to Instrument Flight Procedures Design, and also involved in other different activities concerning airspace organization and management, giving technical support to Aena, Spanish Air Navigation Service Provider, with which it works in close collaboration. It has recently participated in the design of LPV (Localizer Performance with Vertical guidance) experimental procedures for several Spanish airports, in the frame of Aena's research effort to assess potential benefits from a future implementation of LPV approaches. He has had also participation in the design of LPV experimental approaches in the frame of GIANT (EGNOS Introduction in the Aviation Sector) and OPTIMAL (Optimized Procedures and Techniques for IMprovement of Approach and Landing) projects.

2. INTRODUCTION

Typically, aircraft transition from route to the airport consists, firstly, on a Standard Arrival procedure (STAR) which makes aircraft descent from cruising altitude to initiate the approach procedure.

In turn, approaches have usually three phases: Initial Approach, where the main descent is performed; Intermediate Approach, where level flight is preferred, in order to allow the crew to set the adequate speed and configuration, as well as to perform the proper checks for the final descent to the runway; and Final Approach to the runway threshold (THR)

According to the nature of that final descent, the traditional classification has distinguished between Non-Precision Approach (NPA) and Precision Approach (PA).

During a NPA, aircraft approaching is only provided with lateral guidance, being itself who decide its vertical profile to a Minimum Decision Altitude/ Height (MDA/H), from which the pilot decides whether the landing continues or the approach must be aborted for whatever reason (lack of visibility, objects on the runway…)

During a PA, aircraft descending from the Final Approach Point (FAP) receives lateral and vertical guidance to follow a straight glide path to reach the Decision Altitude/Height (DA/H). Flying crew is given proportional angular deviation indication from that nominal path, both lateral and vertical. Signal in Space (SIS) for this guidance is broadcast from the ground by the Instrument Landing System (ILS), composed of two ground subsystems, that is, Localizer (LOC) for lateral guidance, located on the runway axis beyond runway end, and Glide Path (GP) for vertical guidance, located aside the runway threshold. Basically, LOC and GP signals define two planes, the intersection of which is the nominal descent path.

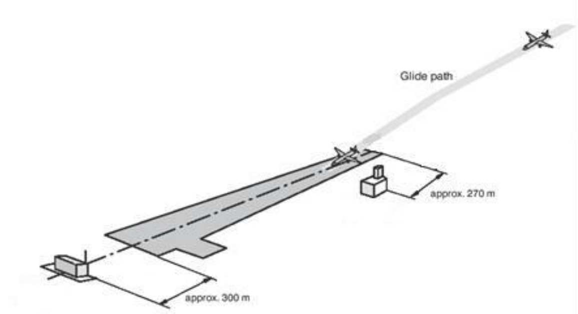

Figure 1. ILS subsystems location

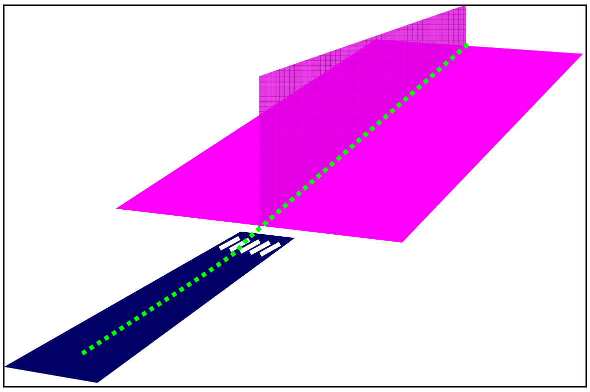

Figure 2. ILS approach path

GNSS Navigation has recently brought new types of approaches into the scene. In particular, since 2007, ICAO (International Civil Aviation Organization) PANS-OPS, Vol. II, Section 3, Chapter 5, include criteria for the design of Approaches Procedures with Vertical Guidance (APV) based on GNSS plus SBAS (Satellite Based Augmentation System). Two levels of performance, APV I and APV II are defined.

APV/SBAS flight path is analogue to an ILS PA. It consists on a straight descent from the Intermediate Approach minimum altitude to the runway. This descent path is typically aligned with the runway axis (although a small offset up to 5º is permitted). Nominal Glide Slope is 3º.

But, contrary to ILS, in the APV/SBAS case the final descent path geometry is preloaded in the airborne data base, instead of being broadcast from ground facilities and constructed in space by means of radiation diagrams. Then GNSS/SBAS avionics calculates aircraft position; that position is compared with the stored nominal path to be followed, and deviation indication is given to the crew.

Final Approach Segment (FAS) Data Block corresponding to the desired approach is selected by the crew from the airborne data base, in a way similar to the conventional ILS frequency tuning. Deviation indication is also in an ILS "look-alike" manner. In fact, the whole operation is meant to be quite similar to ILS, in order to ease a smooth and friendly introduction of this kind of approaches.

However, it is important to notice that, although SBAS receiver mode for the APV approach is designed 'PA Mode', APV is NOT a PA approach, as SBAS Signal in Space (SIS) requirements for APV are less demanding than those for PA, according to ICAO Annex 10. Consequently, minimum DH for APV is intended to be higher than PA DH. While APV approaches can be carried down to a 250ft DH at the least, ILS CAT I operations can be carried down to 200ft.

Type of Operation	Horizontal Accuracy	Vertical Accuracy
APV-I	16.0m (52ft)	20m (66ft)
APV-II	16.0m (52ft)	8.0m (26ft)
Cat-I	16.0m (52ft)	6.0m to 4.0m (20ft to 13ft)

Operation	Horizontal Alert Limit	Vertical Alert Limit
APV-I	40m (130ft)	50m (164ft)
APV-II	40m (130ft)	20m (66ft)
CAT I	40m (130ft)	15m to 10m (50ft to 33ft)

However, it is worth to mention that there are also ongoing efforts in order to standardize APV approaches down to 200ft in the future.

In summary, APV/SBAS approach procedures bring geometric lateral and vertical guidance (angular) during final approach operations, without the need for a ground based radio navigation facility like the Instrument Landing System (ILS). Basically, current ICAO philosophy and standards for the design and obstacle assessment of APV/SBAS approaches are quite similar to those for ILS.

APV/SBAS approaches are intended to be implemented mainly in runways where an ILS system is not suitable for whatever reason (space, money…). They are also considered a proper back-up for ILS Precision Approaches (PAs) in case of an ILS outage, potentially allowing better (lower) operational minima than conventional Non-Precision Approaches (NPAs).

However, according to the experience gained by INECO from some experimental designs performed in several Spanish airports, the expectable minima improvement compared with conventional NPA due to the introduction of vertical guidance, could be compromised in the case of some obstacle rich environments, because of certain limitations in current APV/SBAS design standards.

3. OBSTACLE ASSESSMENT

ICAO PANS-OPS Obstacle Assessment Surfaces (OAS) and obstacle assessment methodology for APV/SBAS approaches, are both based and derived directly from the ILS OAS method.

OAS are a set of surfaces defined around the runway, which are used for obstacle assessment, in order to obtain an Obstacle Clearance Altitude/Height (OCA/H) for the intended approach. DA/H will be never lower than this OCA/H value.

3.1. ILS

ILS CAT I OAS are composed of six sloped plane surfaces, symmetrically displayed around the runway (called W, X, Y, and Z), plus the horizontal plane containing the runway threshold.

Planes are defined by the A, B, and C coefficients in the plane formula: z=Ax+By+C, considering a coordinate system centered in the runway threshold, with the 'x' axis parallel to the runway, positive against the approach.

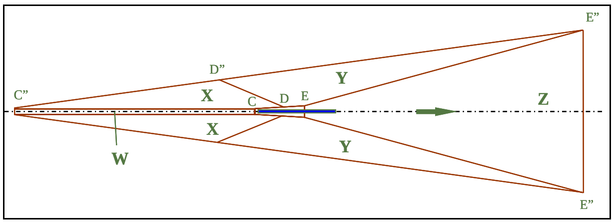

Figure 3. ILS OAS template – Top view

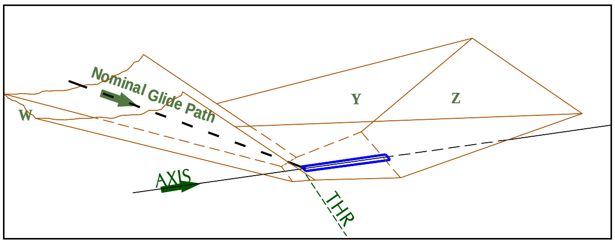

Figure 4. ILS OAS around Final Approach - 3D view

Coefficients depend mainly on the distance LOC-THR, aircraft categories, glide path angle, or minimum Missed Approach climb gradient.

OAS system was developed by means of a statistics method based on gathered actual data. They contain the isoprobability curves which correspond to a 1E-7 operational safety target (one accident every 1E7 approaches). They protect not only the final approach, but also an initial dead reckoning missed approach climb during missed approach.

Only obstacles penetrating OAS have to be considered to establish the procedure minima due to obstacles, OCA/H.

Therefore, the lower OAS are above terrain, the more restrictive (higher) minima may be obtained, because more obstacles can potentially penetrate the surfaces.

OCA/H is set adding a Height Loss (HL) value to the highest obstacle penetrating the OAS. That HL value takes into account that aircraft aborting the approach, takes time and descent from the moment that missed approach is decided, to the moment that configuration has changed and climb is initiated. HL values depend on aircraft category.

Operational minima for this kind of approach are charted under the designation 'LPV'.

3.2. APV OAS DERIVATION

Given ILS OAS, ICAO PANS-OPS derives APV OAS as follows.

Taking into account that Vertical Alert Limits (VAL) for SBAS SIS serving an APV approach are more conservative that those for Cat I, original ILS X OAS planes are displaced vertically according to that VAL difference, in order to keep the safety target. For this process, a nominal 12m VAL is considered for ILS CAT I (compared with the 50m/20m for APVI/APVII respectively). Displacement is hence equal to 'VAL minus 12m'.

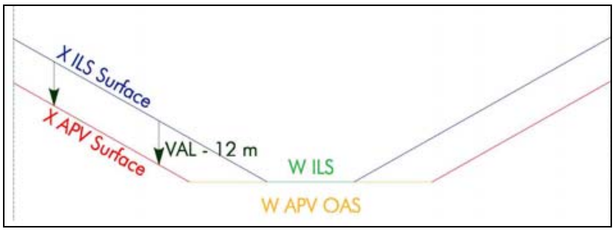

Figure 5. APV OAS derivation

Regarding the surfaces on the runway center line, APV OAS include W' and W.

W' is obtained considering a lowered Vertical Path Angle (VPA) corresponding to a full scale deflection (0.75VPA) flight path, lowered by the VAL.

Further from the runway, where ILS W is lower than this W', ILS W is considered.

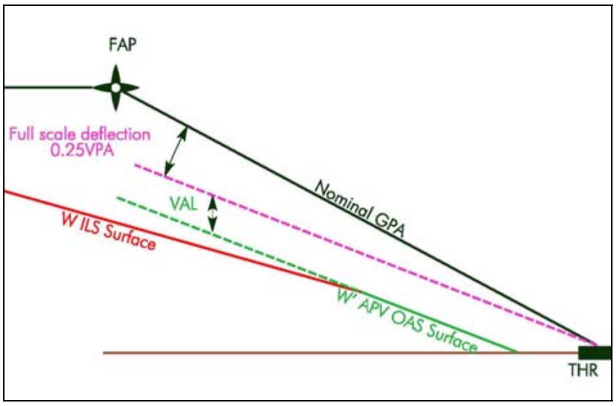

Figure 6. APV OAS W' plane

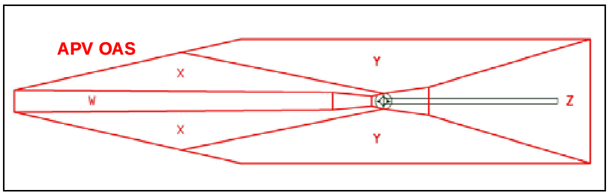

Figure 7. APV OAS Template

OAS also protect initial Missed Approach climb. ILS CAT I OAS contour extends to reach 300m over threshold level, widening laterally. However, APV OAS extend laterally to a certain constant width. This difference comes from the fact that in the ILS, that very first climb is performed without any guidance, whereas there is RNAV guidance to initiate the APV/SBAS Missed Approach.

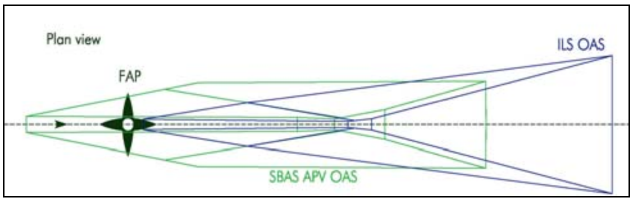

Figure 8. APV vs ILS OAS

3.3. APV OAS ISSUE

Both for ILS and APV/SBAS surfaces around final descent (W and X) rise to reach Intermediate Approach minimum altitude minus the MOC (Minimum Obstacle Clearance) set for the intermediate phase. OAS extension enter Intermediate Approach to meet intermediate protection areas. Intermediate protection areas take into account only Lateral Navigation (LNAV). Obstacle assessment philosophy before the APV segment is completely different. Basically, it grants a MOC for the minimum flight altitude over all the obstacles in the Intermediate Approach area.

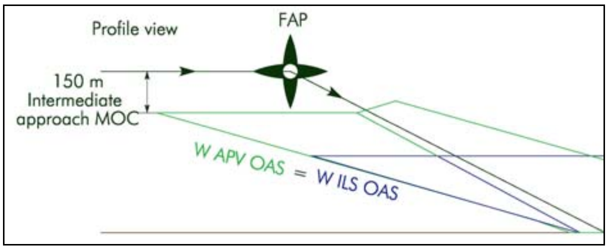

Figure 9. OAS extend into Intermediate App

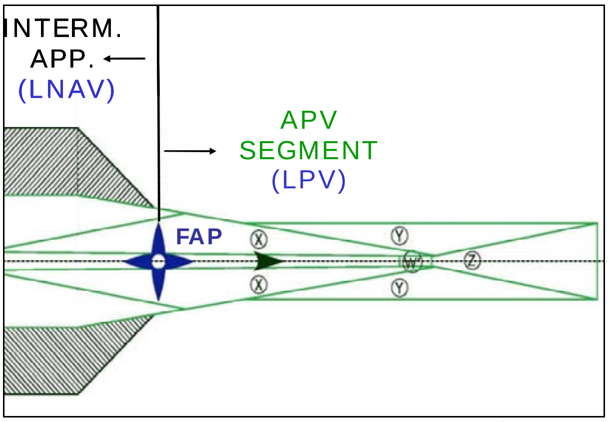

Figure 10. Intermediate Approach. Areas interface

This extension of OAS into the previous segment, try to protect the maneuver in case of an early start of descent, below the nominal Glide Path.

ILS and APV OAS falling into the Intermediate Approach are lower than the minimum intermediate height minus the MOC (see Figure 9). That means that some high obstacles in the Intermediate Approach, although cleared for that previous phase, could penetrate OAS, hence being critical for the APV procedure minima.

ICAO PANS-OPS allows to overcome this situation in the case of ILS. Provided that the point where Final Approach starts (FAP) can be perfectly identified, aircraft can be kept from an early descent bellow intermediate minimum before that point. According to that, design criteria for ILS permits to define a Step Down Fix (SDF) at the FAP location, curtailing OAS extension into de Intermediate Approach. A 15% slope plane from the FAP cut the OAS then.

ILS FAP definition implies a tolerance, both lateral and "along-track" (ATT), which depends on the navigation aid used to set its position. For instance, it can be defined by a DME indication (currently many ILS facilities include a Distance Measure Equipment indicating distance to threshold), or by a radio beacon to be overflown during the approach.

FAP tolerance is taken into account when defining the 15% slope plane.

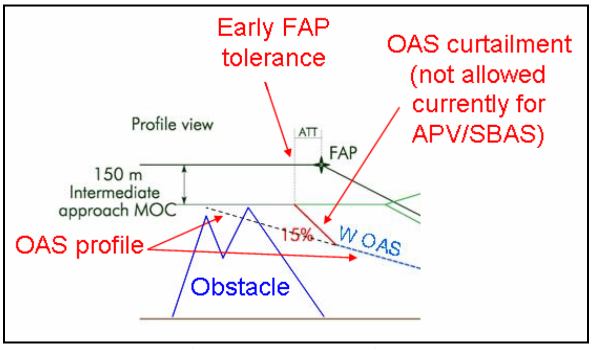

Figure 11. APV OAS issue

Obstacles before and below that 15% plane can be ignored in the OAS evaluation.

In the case of an APV/SBAS approach, despite the fact that FAP location can be perfectly identified, current standards for APV/SBAS procedure design do not cover this same option. ICAO PANS-OPS Volume II, Part III, Section 3, Chapter 5.4.2 estates that "For navigation database coding purposes, the waypoint located at the FAP shall not be considered as a descent fix. The APV OAS surfaces extend into the intermediate approach segment but not beyond this segment".
Given this, many obstacles under the intermediate segment, while overcome in an ILS OAS study, should be taken into consideration in the case of APV/SBAS obstacle assessment, potentially bringing much higher minima to the approach than expected.

This situation can cause severe penalties when designing APV/SBAS approaches for complex and mountainous scenarios, where terrain under the approach path keeps high before the final descent.

3.4. EXAMPLES

INECO has been collaborating with Aena (Spanish air navigation service provider) in a research effort regarding NPA-APV comparison in terms of minima, for several Spanish airports.
During this work, it was detected that, for certain scenarios, the problem explained above compromised expectable minima improvement by APV/SBAS implementation. In some of them, like San Sebastian Airport, great expectations were put in the potential APV contribution.

3.4.1. San Sebastián RWY 04

San Sebastián airport is a very mountainous scenario, also suffering severe bad weather constrains frequently.

Current instrument approach to RWY 04 is an extremely complex NPA VOR procedure, implying a high workload for flying crews. It has also very high published OCA/H, 3500ft/3490ft.

ILS is not an option for this scenario due to the lack of terrain available around the runway.

Figure 12. San Sebastian RWY 04

Therefore, APV appears as a possible option to improve instrument approach conditions there.

Considering an APV approach which meets current standards, estimated OCA/H would be around 2700/2689ft and 2727/2716ft for CAT A and CAT C aircraft respectively. That means that minima keep very high and penalizing, despite the fact that vertical guidance is introduced in the scene.

However, if a SDF was considered in the FAP and OAS were curtailed, minima could be reduced to 1600/1589ft, which means a great improvement from current values.

3.4.2. Granada RWY 27

Also in the case of Granada RWY 27 terrain is very irregular and mountainous bellow approach path.

While the Granada RWY 09 has both NPA and PA available for landing, there are not instrument approaches published for RWY 27 in the Spanish Aeronautical Information Publication (AIP) yet. This means a great lack of flexibility in the airport configuration.

In this scenario, OAS curtailment would allow optimum APV minima: OCA/H would be 2115/255ft for CAT A aircraft, and 2146/286ft for CAT D aircraft. However, if current standards are met and OAS are extended into the Intermediate Approach, APV approach simply is not an option for this scenario.

4. CONCLUSIONS

According to the experience gained by INECO from the experimental designs performed in several Spanish scenarios, the expectable minima improvement compared with conventional NPA due to the introduction of APV/SBAS approaches, could be compromised in the case of some obstacle rich environments. Limitations in current APV/SBAS design standards may put these approaches further from ILS than expected.

Even if APV/SBAS approaches are standardized down to a 200ft minimum DH in the future (hence equaling ILS CAT I approaches), this issue can make results for APV design quite different than those for ILS in some cases.

It would be advisable that current data base codification constraints avoiding OAS curtailment during APV/SBAS procedure design are studied and eliminated.

5. REFERENCES

- *ICAO Obstacle Clearance Panel OCP-14 meeting material, March 2005*
- *ICAO Procedures for Air Navigation Services – Aircraft Operations (PANS-OPS), 5th Edition*
- *ICAO Annex 10, Aeronautical Telecommunication, 6th Edition*