

HEDGE: Helicopters Deploy GNSS in Europe



Helicopter safety assessment

An overview of safety factors
impacting implementation

Ref:	HEDGE-WP1-D1.1		
Issue:	0.5	Classification:	INTERNAL/PUBLIC
Date:	23/07/10	Number of Pages:	24
Doc. Filename: HEDGE safety assessment v0.4 - clean.doc			

	Name/Company	Signature	Date
Author	Philip Church / Helios		23/07/10
WP Leader	Nick McFarlane / Helios		23/07/10
Project coordinator	Nick McFarlane / Helios		23/07/10
GSA Project Officer	Hans de With		



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.



Helicopter safety assessment

DOCUMENT CHANGE RECORD

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

EDITION	DATE	REASON FOR CHANGE	PAGES AFFECTED
0.1	28/05/10	Initial outline	All
0.2	01/07/10	Initial draft	All
0.3	08/07/10	Update following internal review	All
0.4	20/07/10	Editorial corrections	All
0.5	23/07/10	First public draft release	All

TABLE OF CONTENTS

1	INTRODUCTION	6
1.1	General.....	6
1.2	Background	6
1.3	Objectives and scope	6
1.4	Document structure	6
2	REFERENCES	7
3	ABBREVIATIONS AND ACRONYMS.....	8
4	TYPES OF APPROACHES	10
4.1	General.....	10
4.2	APV	10
4.2.1	Overview: APV SBAS.....	10
4.2.2	Overview: APV Baro.....	11
4.2.3	Benefits of APV procedures	11
4.3	PinS.....	12
4.3.1	Benefits	14
4.4	SOAP.....	14
4.4.1	Overview	14
4.4.2	Benefits	16
4.5	Summary	16
5	OPERATIONAL CONSIDERATIONS	17
5.1	General.....	17
5.2	Procedure promulgation	17
5.3	Non-instrument runways.....	17
5.4	Transition from VFR to instrument approach.....	19
5.5	Flight crew procedures	19
5.6	The Target Level of Safety (TLS)	20
5.7	Visual approach on first use	21
5.8	Navigation databases	21
5.9	SBAS availability	22
6	THE HAZARD ANALYSIS	23
6.1	General.....	23
6.2	Basis for hazard identification.....	23
6.3	Identified basic causes	24
7	NEXT STEPS.....	25



Helicopter safety assessment

LIST OF TABLES

Table 2-1: Associated documentation	7
Table 3-1: Abbreviations and Acronyms	9
Table 4-1: Summary of differences between approach procedures	16
Table 5-1: Definitions of lighting classes [Ref #12]	18
Table 5-2: Equivalent RVR for different lighting classes and DH.....	19

LIST OF FIGURES

Figure 4-1: APV SBAS approach [Ref #5].....	10
Figure 4-2: APV Baro approach [Ref #5].....	11
Figure 4-3: Comparison of NPA and APV approaches.....	12
Figure 4-4: PinS turn at the FAF.....	13
Figure 4-5: 'Proceed Visually' segment on approach chart.....	14
Figure 4-6: SOAP procedure.....	15

1 INTRODUCTION

1.1 General

This document is a deliverable prepared under Work Package 1 (Common Developments) of the HEDGE project. The report is prepared by Helios and presents an overview of safety related factors that influence the implementation of helicopter Instrument Approach Procedures (IAP) within HEDGE.

1.2 Background

Helicopters Deploy GNSS in Europe (HEDGE) is a project commissioned by the European GNSS Supervisory Authority (GSA) and part-funded under the EU's Seventh Framework Programme. The aim of the project is to develop and demonstrate new helicopter procedures as well as other EGNOS applications for general aviation. HEDGE builds on some of the outputs from the GIANT FP6 project.

To date there has been little work on the integration of EGNOS into helicopters. Helicopters have a different operating environment to fixed wing aircraft and integration is more complicated due to structure limitations and potential interference of the EGNOS signal from the rotor blades. HEDGE, amongst other objectives, therefore gathers experience of the installation and certification processes that impact helicopters to facilitate an 'easier' upgrade path by working with the regulators and aircraft manufacturers on lessons learnt.

1.3 Objectives and scope

HEDGE addresses three types of helicopter IAPs:

- Approach procedure with vertical guidance provided by SBAS (APV SBAS);
- Point-in-Space with vertical guidance provided by SBAS (Pins);
- SBAS Offshore Approach Procedure (SOAP).

The objective of this document is to present an overview of issues that would need to be considered in a local implementation of these procedures, and the possible mitigations that could be applied.

The guidance and topics presented in this report are intended to aid the development of a safety case or operational safety assessment by operators and ANSPs.

1.4 Document structure

This initial safety assessment is structured as follows:

- Section 2 contains the document references;
- Section 3 presents a list of the acronyms used;
- Section 4 discusses the different approach procedures that are implemented in HEDGE and the differences between them;
- Section 5 discusses some key considerations affecting the implementation of the different procedures;
- Section 6 presents a summary of known hazards and basic causes that could apply to an operational safety assessment;
- Section 7 identifies the next steps in the development of local safety cases or safety assessments.

2 REFERENCES

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

#	Title	Reference	Issue	Date
[1]	Procedures for Air Navigation Services – Aircraft Operations (PANS-OPS)	ICAO Doc 8168 Vol 1 and Vol 2	Fifth Edition	2006
[2]	The SBAS Offshore Approach Procedure (SOAP)	CAA Paper 2010/01	Version 1	28 May 2010
[3]	REGA SAFE - Safety Analysis in Front of Engagement - EGNOS Flight Trials	SAA-ENG-16.9	Version 01	12 January 2010
[4]	Airworthiness Approval and Operational Criteria for RNAV GNSS approach operation to LPV minima using SBAS	AMC 20-28 (draft)	NPA 2009-04	19 March 2009
[5]	RNAV Terminology – CONOPS – Appendix	Eurocontrol	-	29 January 2009
[7]	RNAV Approaches Leaflet	Eurocontrol	-	11 November 2009
[8]	UK Aviation Safety Review 2008	CAP 780	Version 1	11 November 2008
[9]	EASA Annual Safety Review 2008	-	-	21 July 2009
[10]	Operational Scenario: Hazard Identification	GIANT-WP4-ADV-D4.3.2.0	Version 0.1	07 June 2006
[11]	Operational Scenario: Initial System Safety Assessment	GIANT-WP4-ADV-D4.3.3.0	Version 0.1	04 June 2006
[12]	Common technical requirements and administrative procedures applicable to commercial transportation by aeroplane (EU-OPS)	COMMISSION REGULATION (EC) No 859/2008	-	20 August 2008

Table 2-1: Associated documentation

3 ABBREVIATIONS AND ACRONYMS

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

Acronym	Meaning
ALS	Approach Lighting System
AMC	Acceptable Means of Compliance
APV	Approach with Vertical Guidance
BALS	Basic Approach Lighting System
CFIT	Controlled Flight into Terrain
DA / DH	Decision Altitude / Decision Height
EASA	European Aviation Safety Agency
EGNOS	European GPS Navigation Overlay Service
ESARR	European Safety Regulatory Requirements
EU	European Union
FAF	Final Approach Fix
FALS	Full Approach Lighting System
FATO	Final Approach and Take Off area
GIANT	GNSS Introduction in the Aviation Sector
GSA	Galileo Supervisory Authority
HEDGE	Helicopters Deploy GNSS in Europe
HIALS	High Intensity Approach Lighting System
IAF	Initial Approach Fix
IALS	Intermediate Approach Lighting System
IAP	Instrument Approach Procedure
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
LNAV	Lateral Navigation
LPV	Localizer Performance with Vertical guidance
MAC	Mid-Air Collision
MAP	Missed Approach Point
MDA / MDH	Minimum Descent Altitude / Minimum Descent Height
MIALS	Medium Intensity Approach Lighting System
NALS	No Approach Lighting System
NSA	National Supervisory Authority
PBN	Performance Based Navigation



Helicopter safety assessment

Acronym	Meaning
PinS	Point-in Space
QNH	Atmospheric Pressure (Q) at Nautical Height
RNAV	Area Navigation
RTCA	Radio Technical Commission for Aeronautics
RVR	Runway Visual Range
SBAS	Satellite Based Augmentation System
SOAP	SBAS Offshore Approach Procedure
TLS	Target Level of Safety
VFR	Visual Flight Rules

Table 3-1: Abbreviations and Acronyms

4 TYPES OF APPROACHES

4.1 General

Within HEDGE three types of instrument approach procedures are being trialled. They are:

- Approach procedure with vertical guidance provided by SBAS (APV SBAS);
- Point-in-Space with vertical guidance provided by SBAS (Pins);
- SBAS Offshore Approach Procedure (SOAP).

This section describes these approaches, how they are used and the benefits of each of them.

4.2 APV

An Approach Procedure with Vertical Guidance (APV) is a continuous descent approach procedure with vertical and lateral guidance. There are two types of APV approach: APV SBAS and APV Baro. Only APV SBAS procedures are being trialled within HEDGE; however, for completeness, both are described below.

4.2.1 Overview: APV SBAS

APV SBAS approach is an SBAS-enabled approach similar to an Instrument Landing System (ILS) approach. It is flown in the same way as an ILS and has similar performance. The lateral accuracy is equivalent to an ILS localiser and the guidance is provided against a geometric path in space. Both vertical and lateral guidance is provided by SBAS-augmented GNSS. The approach is flown to a given Decision Height (DH) with the lowest possible DH of 250 ft which is significantly lower than possible for Non-Precision Approaches (NPA).

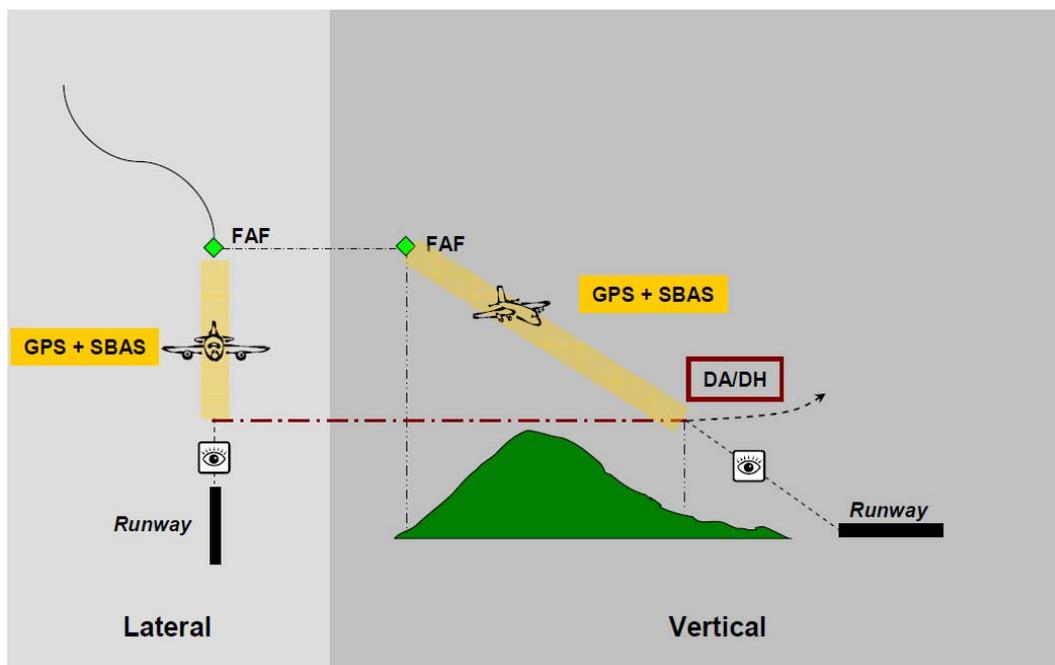


Figure 4-1: APV SBAS approach [Ref #5]

4.2.2 Overview: APV Baro

APV Baro (or APV Baro-VNAV) is a straight-in approach procedure with vertical guidance provided from the onboard barometric altimeter and horizontal guidance via GNSS (which may include SBAS augmentation). The approach is conducted to the Decision Altitude/Height (DA/DH), at which point visual contact with the runway is required. The navigation system presents to the pilot a computed vertical guidance referenced to a specified vertical path angle (VPA), nominally 3°; the procedure is illustrated in Figure 4-2.

The APV Baro procedures do not have a FAF or a MAPt identified. The lowest possible DH is 300ft which is slightly more than for APV SBAS and marginally less than for NPA when the OCA/OCH is calculated from the APV Obstacle Assessment Surfaces (OAS). The obstacle surfaces are similar to those for ILS but are based on the accuracy afforded by the GNSS horizontal guidance.

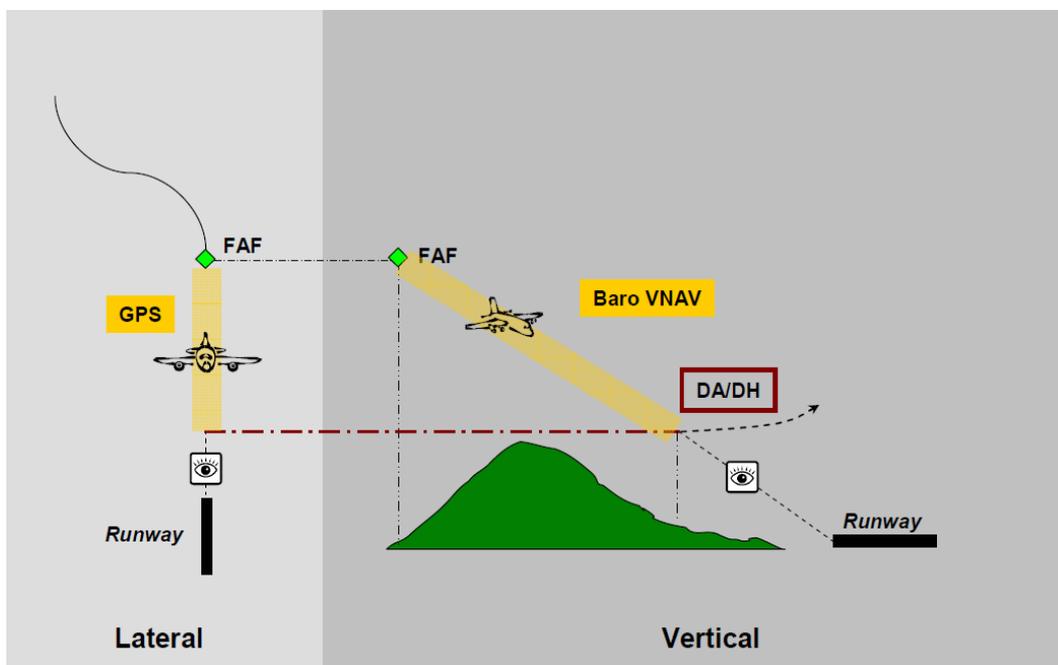


Figure 4-2: APV Baro approach [Ref #5]

4.2.3 Benefits of APV procedures

Of the three approach types described in this document, APV is the only one that can be flown by fixed wing aircraft. APV allows an ILS-like approach without requiring additional ground infrastructure at the aerodrome (albeit to higher minima). Hence it provides significant cost savings to the aerodrome if it chooses to provide APV instead of ILS.

In addition, APV realises significant safety benefits compared to non-precision approach (NPA) procedures by providing vertical and lateral guidance to avoid the traditional step downs illustrated in Figure 4-3. In a NPA step down approach, an aircraft follows a series of steps based on minimum obstacle clearance heights to descend to the minimum descent altitude. This approach has been shown to induce a high flight crew workload and an accident rate five times higher than when flying a precision approach. This is one of the reasons why the ICAO 36th General Assembly adopted the resolution for States to replace NPA with APV by 2016.

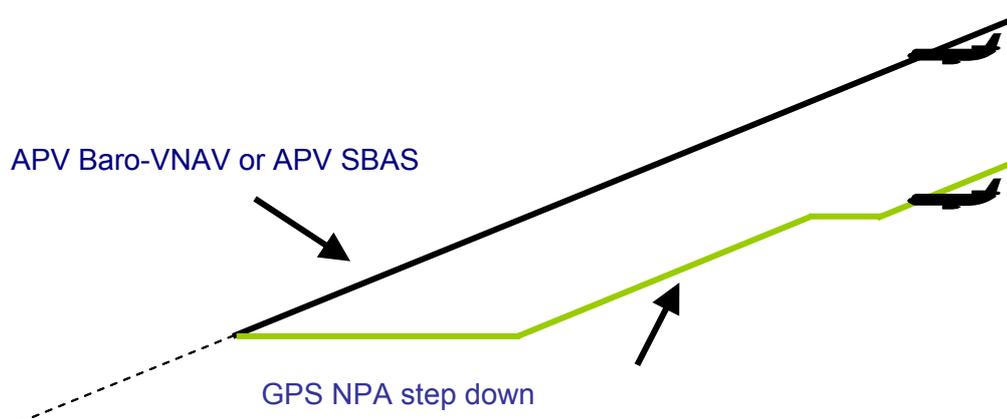


Figure 4-3: Comparison of NPA and APV approaches

An advantage of APV SBAS over APV Baro is that in the latter, an aircraft is reliant on its onboard barometer together with atmospheric pressure data (QNH) from ATC to calculate altitude. Any errors in the QNH setting could lead to an inaccurate altitude being calculated. SBAS provides an independent system in which barometric data can be used as a cross check for altitude limits.

4.3 PinS

The PinS (Point in Space) procedure is an approach procedure for helicopters only and is designed for landings where conventional navigation is not available, such as helipads in remote or built up areas. The approach procedure is aligned with the missed approach point and not necessarily with the flight approach and take-off area (FATO). The approach consists of initial, intermediate, final approach and missed approach segments, as described below.

- **Initial approach segment:** The initial approach segment is designed for aircraft flying at speeds up to 120Kts, although a speed of 90kts may be specified where an operational requirement exists, and the length of the segment should not exceed 10NM. The optimum descent gradient is 6.5% with a recommended maximum gradient of 10%, although gradients of up to 13.2% may be used where an operational requirement exists.
- **Intermediate approach segment:** The intermediate approach segment is between the Intermediate Fix (IF) and the Final Approach Fix (FAF). Its optimum length is 3NM and, as for the Initial Approach Segment, may be designed for aircraft flying at speeds of up to either 120 or 90Kts. The segment is used to prepare aircraft speed and configuration for landing and should therefore ideally be flat. If a turn at the final approach fix is necessary, it must not exceed 60° as shown in Figure 4-4.

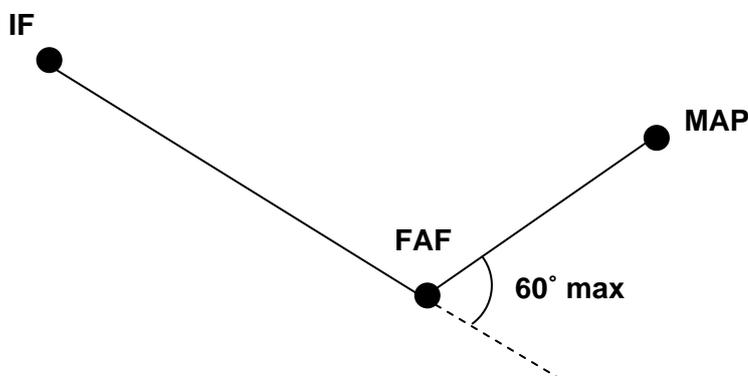


Figure 4-4: PinS turn at the FAF

- **Final Approach Segment:** The final approach segment is the leg between the FAF and Missed Approach Point (MAP). The approach is to a point in space, and the pilot must either be able to establish visual contact and continue to the landing, or else initiate a missed approach procedure.

The final approach segment has an optimum length of 3.2NM and gradient of 6.5% (although gradients of up to 13.2% may be authorised) and is designed for helicopters flying at speeds of up to 70Kts. A minimum obstacle clearance of 75m is required in the primary area tapering to zero at the outer edge of the secondary area.

- **Missed approach segment:** The Missed Approach segment begins at the MAP. At this point, the flight crew decides whether to land or execute the MAP. Two procedures exist if the pilot decides to proceed to landing from the MAP: Proceed VFR or Proceed Visually.
 - Proceed Visually: The flight path to the landing area must be marked on the approach chart (illustrated in Figure 4-5) and the pilot must acquire and maintain visual contact with the Flight Approach and Takeoff Area (FATO). Obstacle clearance from the MAP to the landing point is the pilot's responsibility, with no possibility of a missed approach procedure in this segment.
 - Proceed VFR: If the route marked on the flight plan does not terminate at the FATO then the pilot must proceed under VFR with either the visibility and ceiling required on the approach chart or those required by air law. Once again, the pilot is responsible for the clearance of obstacles and terrain from the MAP to the landing site, which is not required to be in sight from the MAP.

If the flight crew decide to execute a MAP, there are two different procedures possible - a straight missed approach and a turning missed approach. The nominal climbing gradient for both such procedures is 4.2%, although higher gradients are possible where approval exists. The speed for the final missed approach is 90Kts, although reduced speeds as low as 70Kts may be used, providing that this is clearly indicated.

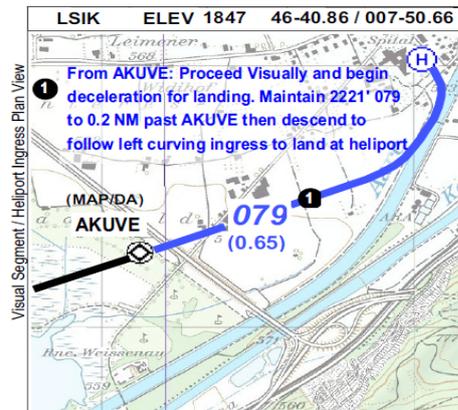


Figure 4-5: 'Proceed Visually' segment on approach chart

4.3.1 Benefits

The PinS procedure is a specific helicopter approach procedure defined as such within ICAO Doc 8168. It permits a much steeper approach than APV procedures with gradients of up to 13.2% depending on changes in direction between each of the approach segments. This has a major advantage of allowing the helicopter to land in unconventional environments, such as in mountainous areas or urban environments, whilst maintaining required obstacle separations that could not be possible with a shallower approach. The route during the final segment between the MAP and the landing site is chosen by the pilot and thus allow some flexibility in the adjustment of flight path depending on conditions.

4.4 SOAP

4.4.1 Overview

The SBAS Offshore Approach Procedure (SOAP) was developed for helicopters serving North Sea oil rigs. The procedure provides:

- a consistent instrument approach procedure to any helideck;
- accurate lateral and vertical guidance capable of driving an autopilot;
- flexibility in approach track to any given platform.

The SOAP approach is illustrated in Figure 4-6.

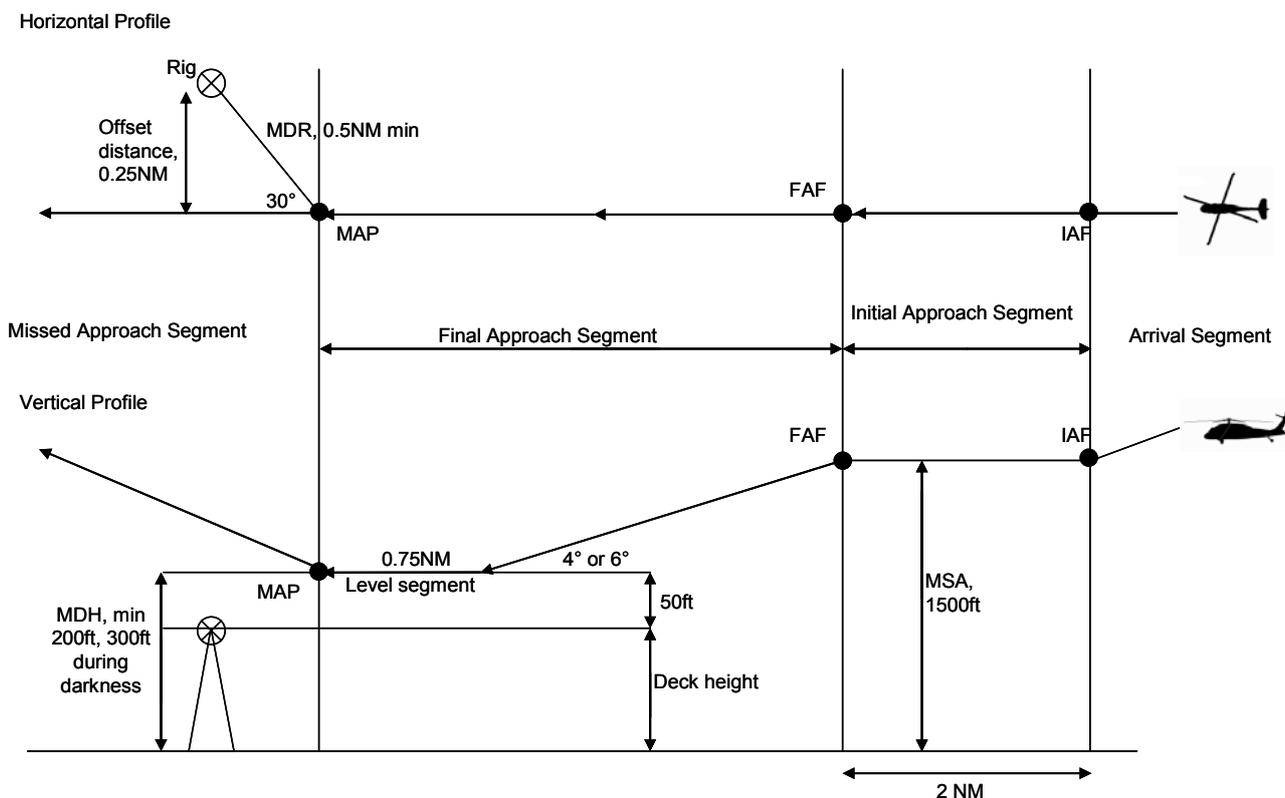


Figure 4-6: SOAP procedure

- **Arrival Segment:** The destination oil rig location is established and the helicopter descends to the minimum safe altitude of 1500ft. Once the helicopter reaches the Initial Approach Fix (IAF) it enters the Initial Approach Segment.
- **Initial Approach Segment:** The helicopter aligns itself on the final approach heading and decelerates to the final approach speed between 60kts and 80kts – depending on the environment and the capabilities of the helicopter. During this time the crew will use the helicopter’s weather radar to check the system-generated final approach and missed approach areas and verify that they are clear of significant radar returns (obstacles). On reaching the Final Approach Fix (FAF), the helicopter enters the Final Approach Segment.
- **Final Approach Segment:** The helicopter begins its descent to the Minimum Descent Height (MDH), which is defined as the height of the rig’s helideck plus 50ft, with a minimum value of 200ft in daylight and 300ft at night. The descent angle can vary depending on the elected final approach speed. Once the helicopter reaches the MDH, it flies a level segment during which the pilot and co-pilot attempt to acquire visual contact with the rig.
- **Missed Approach Procedure:** If visual contact is made, the helicopter will reach the Missed Approach Point (MAP) and turn heading toward the oil rig conducting a visual approach and landing. If visual contact is not made, the helicopter will continue straight ahead and climb at the steepest safe angle to the Obstacle Free Sector - the area defined out to 1km from the helipad guaranteed to be clear of fixed obstacles.

Throughout the SOAP procedure, lateral guidance is provided by EGNOS. Vertical guidance is provided by the helicopter’s altimeter during the arrival and initial approach segments and by EGNOS backed up by radar altimeter during the final approach segment.



Helicopter safety assessment

4.4.2 Benefits

The SOAP procedure is designed for helicopters in an offshore environment and facilitates a straight missed approach procedure through the offset of the approach from the rig. The major advantage of SOAP is enhanced safety. Unlike PinS and APV procedures, the approach is in relation to the rig, rather than using a set of fixed waypoints. Thus the flight crew are able to choose their approach heading, taking into account wind direction or the position of nearby obstacles. Similarly, if the rig moves, the same procedure may still be flown as the new position of the rig may be input and a new procedure calculated.

4.5 Summary

The following table summarises the differences between the approaches.

	APV	PinS	SOAP
Type of aircraft	Fixed or rotary wing	Rotary wing only	Rotary wing only
Possible vertical minima	Not lower than: - 250ft (using SBAS) - 300ft (using Baro)	Not lower than: - 250ft (using SBAS) - 300ft (using Baro)	Not lower than: - 200ft in daylight - 300ft at night
Typical uses	Runway straight in approaches	Cross runway approaches, medical heliports, high obstacle environments	Offshore oil rigs

Table 4-1: Summary of differences between approach procedures

5 OPERATIONAL CONSIDERATIONS

5.1 General

This section discusses the operational considerations that may have to be addressed as a result of implementing any of the approaches presented in Section 4. These operational considerations have been identified within the HEDGE trials and while they are not in themselves hazards or risks, they potentially impact the ability to implement the procedure at an aerodrome or heliport and must therefore be considered when assessing implementation options as part of the local implementation safety case.

5.2 Procedure promulgation

Before any procedure can be used on the aircraft it has to be available to the flight crew for selection from the navigation database. Navigation databases are provided by organisations approved under an EASA Type 2 Letter of Acceptance that reflects the commitment of the database supplier to adhere to the requirements of RTCA DO-200A. Basically this means that the organisation has sufficient quality and control procedures in place to ensure that aeronautical data handled in the development of the databases is unaltered from the data received.

Navigation databases are based on the information contained within the State AIP, as required by ICAO Annex 15. Since the State AIP is the official publication means for aerodrome procedures, in order for the procedure to be promulgated for international transport, the procedure must be published in the AIP. As such, this requires that the procedure be tied to an aerodrome that is published in the AIP; if the aerodrome is not in the AIP then the approach procedure will also not appear in the AIP.

For the aerodrome to be published with an ICAO aerodrome designator the aerodrome must comply with the requirements of ICAO Annex 14 and it may be that it is not possible or feasible to adapt the landing area to comply with these requirements. Promulgation of a procedure in these circumstances requires an operator specific instrument flight procedure and navigation database. This is still published according to the requirements of Annex 15; however, it is limited to a single operator(s) at an aerodrome within a State. This immediately restricts the application of the instrument flight procedure and it must then be clear whether the purpose of the instrument flight procedure is of limited benefit for national flights or required due to safety concerns.

Within HEDGE, the PinS and SOAP procedures are being trialled and published to heliports that are not necessarily consistent with all the requirements of ICAO Annex 14 (for example, hospital roof heliports may not comply with ICAO Annex 14) and neither are the heliports identified by an ICAO designator in order to be published within the AIP. Consequently, any procedures to these locations (whether as part of the flight trials and validation tasks or for operational use) will result in operator-specific instrument approach procedures.

5.3 Non-instrument runways

The implementation of an instrument approach procedure to an aerodrome requires the applicable runway to be recognised as an instrument runway. The requirements for the designation between an instrument and a non-instrument runway are specified within ICAO Annex 14. Amongst other requirements, the runway width and length are the primary drivers to determine whether the runway could be considered for designation as an instrument runway before infrastructure requirements such as lighting are assessed.

The APV SBAS approach is an instrument approach and therefore the runway end that the procedure is applied to must be recognised as an instrument runway. If it is currently designated a

non-instrument runway, then the re-designation must be coordinated with the National Safety Authority (NSA) and regulator as additional requirements on aerodrome facilities may also be required. For example, additional runway and approach lighting and rescue and fire fighting capabilities may be required.

When considering instrument runways within ICAO Annex 14, there is also a distinction between non-precision runways and precision runways. This distinction has traditionally been based on the type of instrument approach available at a runway end with only ILS, MLS and GBAS being recognised as precision approach systems. An APV SBAS procedure although providing the aircraft with vertical and lateral guidance (as for precision approaches contrasted with non-precision approaches which provide lateral guidance only) is not recognised as a precision approach. This in turn means that some of the precision approach lighting and runway requirement restrictions do not apply to an APV SBAS approach.

However, from a safety perspective, the requirements for lighting and runway designation need to be carefully considered to minimise risks associated with, for example, Controlled Flight Into Terrain (CFIT). The APV approach vertical guidance minimises the risk of CFIT yet the procedure is still dependent on flight crew correctly setting local QNH and thus the correct Decision Height (DH). This is important as a correct DH setting will impact the point at which flight crew will execute the missed approach or be able to visually acquire the runway and commence landing. The potential lack of lighting will limit the ease with which this acquisition occurs and when combined with the lower DH afforded by APV SBAS may result in a significant RVR penalty that operationally would reduce the benefits realised through the implementation of the APV approach. EU-OPS, for example, places the following requirements based on DH versus RVR when aligned with approach lighting.

<i>OPS Class of Facility</i>	<i>Length, configuration and intensity of approach lights</i>
FALS (full approach light system)	ICAO: Precision approach CAT I Lighting System (HIALS 720 m ≥) distance coded centreline, Barrette centreline
IALS (intermediate approach light system)	ICAO: Simple approach lighting system (HIALS 420-719 m) single source, Barrette
BALS (basic approach light system)	Any other approach lighting System (HIALS, MIALS or ALS 210-419 m)
NALS (no approach light system)	Any other approach lighting system (HIALS, MIALS or ALS < 210 m) or no approach lights

Table 5-1: Definitions of lighting classes [Ref #12]

Applied to the RVR and DH, for an ICAO Doc 8168 compliant procedure with a DH or MDH of between 251 and 260 feet the EU-OPS RVR requirements in meters are as follows in Table 5-2.



Helicopter safety assessment

<i>Class of Lighting Facility</i>	<i>FALS</i>	<i>IALS</i>	<i>BALS</i>	<i>NALS</i>
<i>RVR in metres</i>	600	800	1 100	1 300

Table 5-2: Equivalent RVR for different lighting classes and DH

The values in Table 5-2 are minimum values across the different aircraft approach classifications. The maximum for approach classifications A/B is 1500 m and for C/D is 2400 m which together quite clearly illustrate the potential impact of implementing approach procedures for APV SBAS at aerodromes with limited approach lighting facilities.

In conclusion, to implement APV SBAS approaches, the runway must be designated an instrument runway, and although lack of approach lighting does not preclude implementation, lack of lighting could place significant operational restrictions on the use of the procedure or aerodrome. The justification for this restriction should be examined from both a safety and cost benefit perspective.

5.4 Transition from VFR to instrument approach

Under current guidelines, the flight crew should notify ATC when an aircraft currently being flown under VFR rules wishes to conduct an instrument approach. This requirement is to ensure that ATC are able to inform the flight crew if a supporting navigation aid has rendered the procedure unavailable.

The instrument approach procedures in HEDGE are based on SBAS as the primary navigation aid, although in some instances a missed approach procedure may be provided through a conventional navigation aid (i.e. NDB). In addition, the instrument approach may be conducted to an aerodrome/heliport at which there is no ATC service. Whilst the SBAS signal will be monitored on the aircraft instrumentation and will alert the flight crew of the availability of the SBAS signal and hence the flight procedure, there is no means on board the aircraft to inform the flight crew of the unavailability of any terrestrial navigation aids on which the missed approach procedure may depend.

Given that the airborne equipment will only monitor for the unavailability of the SBAS signal, the safety assessment needs to be determine whether the requirement to inform ATC of a transition from VFR to use of an IAP will apply when implementing any of the SBAS procedures described in Section 4.

5.5 Flight crew procedures

The flight crew procedures need to be adapted according to the instrument approach being implemented. For APV SBAS procedures, flight crew training must to comply with the requirements of EASA AMC 20-28¹; APV BARO procedures are covered under EASA AMC 20-27. However, the general principles that are contained within the two AMCs apply regardless of the approach being undertaken.

HEDGE has produced generic material that provides a foundation for the classroom training requirements for flight crew. This is consistent with the requirements from the AMCs, although additional customisations will be required to tailor it to the particular avionics systems used. In addition to the theoretical training, flight crew are also required to have practical training using a

¹ AMC 20-28 is still in draft format. It is expected that the final version will be accepted in November 2010.

simulator, training device or training in an aircraft before the flight crew can be operationally approved to conduct the approach.

Practical and theoretical training courses are not yet fully established but when developed will be consistent with the ICAO approach specifications. Whilst all flight crew training will be developed in collaboration with the NSA, it becomes more important when the IAP being implemented varies from the standard approach requirements defined by ICAO (typical of an operator specific IAP) or is not yet defined by ICAO – as is the case of the SOAP procedure within HEDGE which is neither defined or has ICAO PANS-OPS procedure design specifications. Any flight procedure that has a variation from ICAO design specifications must be reviewed with the NSA, and accordingly, a customised training package may be required specific to the particularities of the procedure highlighting differences in symbology, notation, menus, reversion procedures and troubleshooting that flight crew need to be familiar with before conducting any operational instrument flight procedure. In conclusion, the safety assessment should determine whether the procedure requirements will allow a standard commercial training package to be utilised or whether a customised training package will have to be developed to cater for the particular variances of the procedure being implemented.

5.6 The Target Level of Safety (TLS)

Safety cases developed for the implementation of any of the instrument approach procedures mentioned within this document have to address operations under nominal and non-nominal conditions in addition to the practical implementation, transition and maintenance steps. In essence, the nominal case requires evidence that the procedures and the approach concept, when all is working as intended, are safe. The evidence for the non-nominal conditions requires a safety assessment considering the failure modes and conditions seeking to ensure that the failure rate when combined with the consequences of the failure is acceptable or tolerable. The non-nominal safety assessment must comply with the guidelines of ESARR 4 to demonstrate acceptance compared to a TLS.

ESARR 4 provides guidance on the use of risk assessment and mitigation, including hazard identification, in Air Traffic Management (ATM) when implementing new features or changes to the ATM system. In defining the risk classification scheme, ESARR 4 requires the setting of a TLS for setting safety objectives based on risk. The aircraft and its flight make up a part of the overall ATM risk and as such, the TLS chosen is a portion of the overall ATM risk. When the TLS is chosen it must be representative of the environment and operations in which the procedure and aircraft will be flown. For example, comparing the risks associated with helicopter operations in the North Sea (HEDGE WP3 – SOAP) to those at an ICAO Annex 14 aerodrome (HEDGE WP5 – Poland) involve two completely different operations in different environments with different types of aircraft. Consequently, it would not be appropriate to choose the same TLS for each when also considering that the available aerodrome infrastructure and obstacle environment are also different.

Statistics are widely available that illustrate the differences in accident rates available for commercial aircraft operations when compared to those of business and general aviation or helicopter operations^{2, 3}. These, in the absence of more specific information, could provide a basis for setting the TLS for the particular operation subject to the agreement of the NSA to both the approach and consistency with the national safety case development requirements. The TLS needs to consider the portion of accidents as applicable to the relevant phase of flight, which in the case of

² See: http://www.easa.europa.eu/essi/documents/AnnualSafetyReview2008_en.pdf [Correct 01/07/2010]

³ See: <http://www.caa.co.uk/docs/33/cap780.pdf> [Correct 01/07/2010]



HEDGE is the approach or landing phases of flight. This being the case, it is necessary that accident rates used to define the TLS are based on sufficient data and the supposition that the introduction of the APV SBAS, PinS with SBAS or the SOAP procedure will not increase the likelihood of an accident compared to the historical trend.

5.7 Visual approach on first use

The principles of following ILS guidance to an aerodrome are the same from one aerodrome to another aerodrome. The aircraft is guided down a glide slope that is extrapolated from a point 50' above the threshold. The APV SBAS approach presents ILS look-a-like guidance and therefore it is reasonable to assume that on any straight-in approach the flight crew procedures will be the same for connecting to and flying the guidance; the aircraft/aircrew will always come down to a DH with the runway in front of them.

Typically, AOCs require that the first time any new instrument approach is flown at an aerodrome it is flown in visual conditions. Once it has been flown in visual conditions and the approach verified, it is available within the operating company for qualified aircrew and aircraft to use. Aircrew and aircraft have to be qualified – for example – to fly an ILS CAT I approach. Given the similarities with the ILS and the APV SBAS approach it would be expected that an AOC would operate a similar policy – an APV SBAS approach must be flown for the first time in visual conditions and once validated may be available for any qualified aircrew.

The SOAP procedure, while different to an APV SBAS approach in that the approach is to the side of the target oil rig, nevertheless always has the oil rig similarly positioned; it is always located right of track at the MAP.

This is completely different to the PinS procedure. In the PinS procedure, the helipad may be to the left or right of the MAP as connection from the MAP to the helipad is via a visual segment. Therefore, even when flight crew are qualified to fly PinS approaches, if they are flying a new PinS approach procedure the helipad may be in an unexpected position or difficult to locate. For this reason, an assessment needs to be made prior to implementing the PinS approaches whether each flight crew, regardless of their qualification, flies the PinS procedure under VMC conditions on first use.

5.8 Navigation databases

Unlike conventional instrument approaches in which the guidance on the final approach is computed from a signal received from an ILS, VOR, DME or NDB, all the HEDGE approaches are RNAV approaches. On an RNAV approach the waypoints are calculated from known geographical features or navigation aids or determined with respect to a known map base. As the aircraft is flying from point-to-point rather than from navigation aid to navigation aid, as for conventional navigation, the quality of the aeronautical data supporting the approach becomes more critical.

The validity of the aircraft database is on the basis of the AIRAC cycle as defined by ICAO Annex 15. Because of the critical nature of the data to the safety of the aircraft with respect to terrain and obstacles it is necessary that the aircraft only commences any of the HEDGE approaches when the aircraft navigation system is loaded with a valid database. Since using RNAV for the approach raises the reliance on the navigation database it is more crucial that the database is correct and the safety assessment should establish the aircraft operator's ability to source and maintain the navigation database with mitigating actions provided if the loaded database is found to be outdated.

5.9 SBAS availability

The availability of conventional navigation aids is alerted to flight crew through the use of NOTAMs. Typically, the loss of a conventional navigation aid will only impact aerodromes or airspace dependent on that navigation aid. With the use of SBAS, any loss of change of performance will be widespread affecting the whole of the coverage volume. Discussions are still on going to determine whether a NOTAM on the change of status of SBAS is required. However, the loss of SBAS would mean that all the flight procedures trialled by HEDGE would be unavailable, immediately placing restrictions on the operation of aircraft.

Notifications on the status of SBAS are available to the public through the ESSP website. In the absence of a NOTAM advising of the loss of SBAS coverage within a particular region, it should be considered whether there should be a requirement on the flight crew to check the status of SBAS prior to conducting any flight operations. This would be similar to the practice of checking for potential RAIM holes when aircraft are utilising air routes and NPAs dependent on GPS navigation. Flight crew commencing an approach to an uncontrolled aerodrome would expect to be notified by the airborne equipment in the event of a sudden loss of SBAS service whilst flying the approach. However, procedures should be included to cover for this event or the risk disregarded by the safety assessment prior to implementation of the SBAS dependent approach.

6 THE HAZARD ANALYSIS

6.1 General

Some work has been undertaken within HEDGE to conduct hazard analyses on a flight trial by flight trial basis. However, in the implementation of the operational procedures a more formal assessment will be required. This section discusses the basis for the hazard identification and presents some of the generic hazards that will be applicable to all the instrument approach procedures.

Numerous publically available safety assessments have been undertaken for the approach procedures trialled within HEDGE. These include:

1. GIANT APV SBAS (LPV) Safety Assessment⁴;
2. UK CAA SOAP Safety Assessment⁵;
3. Eurocontrol Generic APV SBAS (LPV) Safety Assessment⁶;
4. Eurocontrol Generic APV BARO (VNAV) Safety Assessment.

The information that is presented in this section presents a high level overview of the hazards identified within these assessments.

6.2 Basis for hazard identification

The exact hazard description depends on where in the basic cause to consequence chain the hazard is chosen. The basic causes that lead to the hazard will generally be the same in the traditional fault tree and event tree analysis regardless of where the final hazard is placed. However, as noted in Section 4, a simple assessment of the non-nominal performance and likelihood of an accident occurring is not sufficient to demonstrate that operations remain safe under the nominal performance of equipment, human actors and the EGNOS signal.

Previous safety assessments have shown that the worst case consequences of a failure under non-nominal performance will be either:

1. A collision with another aircraft whilst on the approach (Mid Air Collision (MAC)); or
2. A collision with terrain or an obstacle whilst on the final approach (Controlled Flight Into Terrain (CFIT)); or
3. A runway excursion or hard landing (Landing Accident (LA)).

These consequences could be taken as the hazard with mitigations assessed separately, or split further to assess the high level causes of these consequences. As noted, a significant amount of work has already been completed to look at the operational hazards that could result in any of these consequences. Eurocontrol work on the generic APV SBAS Safety Assessment identified the following basic operational hazards.

1. Wrong approach selected and initiated (amongst a set of selectable approaches);
2. Failure to laterally intercept the final approach track;
3. Fly low while intercepting the final approach path (vertical profile);
4. Attempt to intercept the final approach path from above (vertical profile);

⁴ See: <http://www.gnss-giant.com/tmp/public/83AD1EECC7A01A5DAD16A1477D1A716/GIANT-WP4-ADV-D4.3.2.0.pdf> [Correct 30/06/2010]

⁵ See: <http://www.caa.co.uk/docs/33/2010001.pdf> [Correct 30/06/2010]

⁶ Both the Eurocontrol APV BARO and APV SBAS Safety assessments are available through the Eurocontrol RNAV Approach Task Force (RATF) OneSky Team. Revised versions are under development.

5. Incorrect final approach path;
6. Failure to follow the correct final approach path;
7. Descending below DA without visual;
8. Failure to execute correct Missed Approach.

6.3 Identified basic causes

Having established the operational or logical hazards that together contribute to one or more of the worst case consequences, a combination of a top down and bottom up safety allocation is required to identify the basic causes of the hazard. Within HEDGE, the following is a short list of applicable basic causes.

1. Failure of the EGNOS receiver;
2. Failure of the EGNOS signal;
3. Navigation database failure;
4. Flight crew error in use of the EGNOS equipment;
5. Flight crew error in setting the QNH;
6. Flight crew selection of the wrong procedure;
7. Procedure publication error;
8. Procedure validation errors;
9. Database packing error;
10. Incorrect QNH supplied to flight crew;
11. Incorrect supplied AIP runway threshold data;
12. Incorrect lateral intercept;
13. Incorrect vertical intercept;
14. Failure to disconnect procedure.

Establishing the failure rates for each of these basic causes needs to be completed on the basis of operational evidence or expertise and should be validated as much as possible against equipment standards, human factors studies and mandatory occurrence reports.

7 NEXT STEPS

Prior to the implementation of an operational instrument approach from any of the procedures defined in Section 4, it is necessary for the procedure owner/implementer and aircraft operator to develop a complete safety case. This needs to consider all the topics identified in Section 5 in addition to all the hazards, consequences and basic causes presented in Section 6 as well as any others that are identified. Alternatively, a modification to an existing safety assessment may be suitable depending on the similarities between the operations and environment. In any case, an assessment of such hazards and basic causes will be a combination of a quantitative and qualitative approach.

The development of such a safety case is not a simple undertaking and must have the support of the regulator and NSA within whose remit the procedure is being implemented. It must also be developed in a consultative manner involving the aerodrome, operator, regulator and ATC as appropriate. The following is a list of steps that the procedure owner/implementer should complete to demonstrate that the establishment of the instrument approach procedure is acceptably safe and that in operation is acceptably safe:

1. Establish a Concept of Operations (CONOPS) describing the traffic environment, ATC services, equipment requirements, and flight procedures within which the instrument approach procedure will be implemented.
2. Establish that given the CONOPS, the instrument approach can be implemented and in its designed state will be acceptably safe.
3. Conduct a detailed hazard and risk analysis starting with those identified in Section 6 to illustrate that even under failure conditions the instrument approach will continue to be safe. This can be done through either a full quantitative or qualitative approach or in a comparative assessment when a similar instrument procedure exists. For example, a comparison of ILS to APV SBAS when implemented within an environment that already supports ILS.
4. Develop a detailed plan for implementation showing how any identified safety requirements will be achieved. This includes how the procedure is designed and developed, how the aircraft installation is installed and certified, how flight crew are training and certified and how the procedure is published.
5. Develop a transition plan to enable the smooth role out of the procedure, including identifying the procedures for updating aircraft navigation databases and activating the published procedure.
6. Demonstrate that during operation sufficient cross checks and procedures are established to enable effective reporting and correction of any detected or reported faults. This includes establishing a mechanism by which the developed safety case can be maintained in accordance with the requirements of ESARR 4.