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LEONARDO Helicopters:
LH Flight Management System – PBN and GLS GAST-C Approach capability on AW1x9 helicopters

EASA, Köln – 10-11/12/2019

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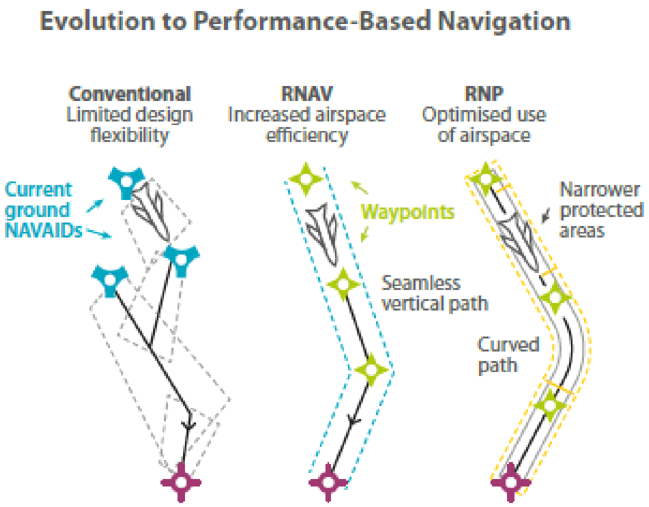
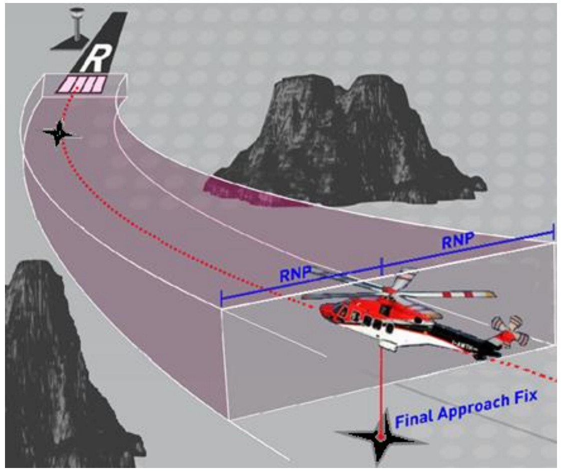
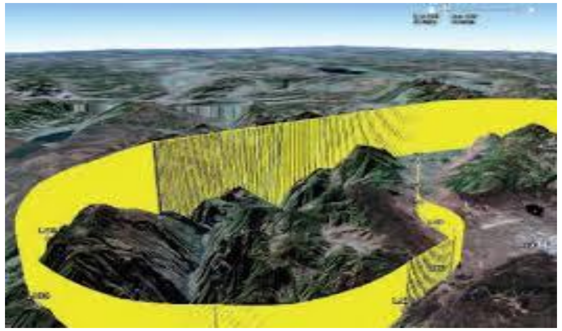
Introduction



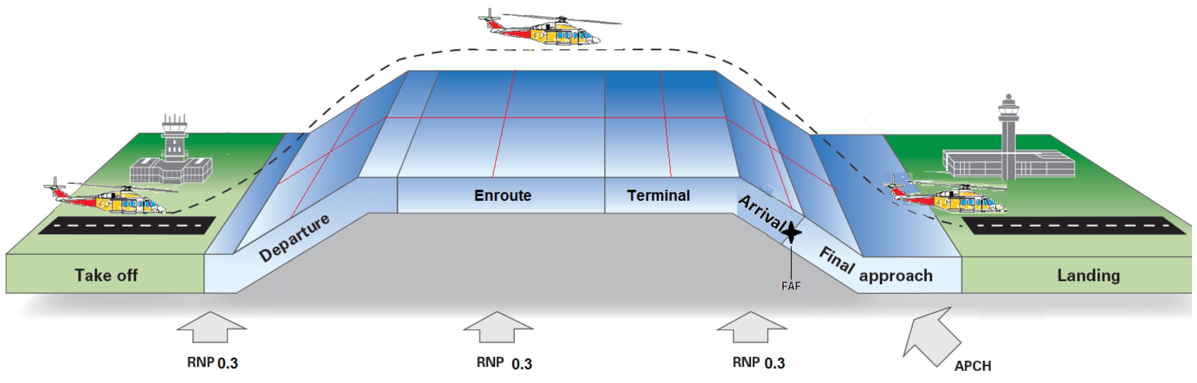
Europe and USA are moving towards implementation of PBN infrastructures as key enablers of achieving increased capacity, flight efficiency, safety and precise navigation.
The migration towards satellite based navigation (SBAS and GBAS), as primary means of navigation for both fixed and rotary wings, is the current European navigation strategy.



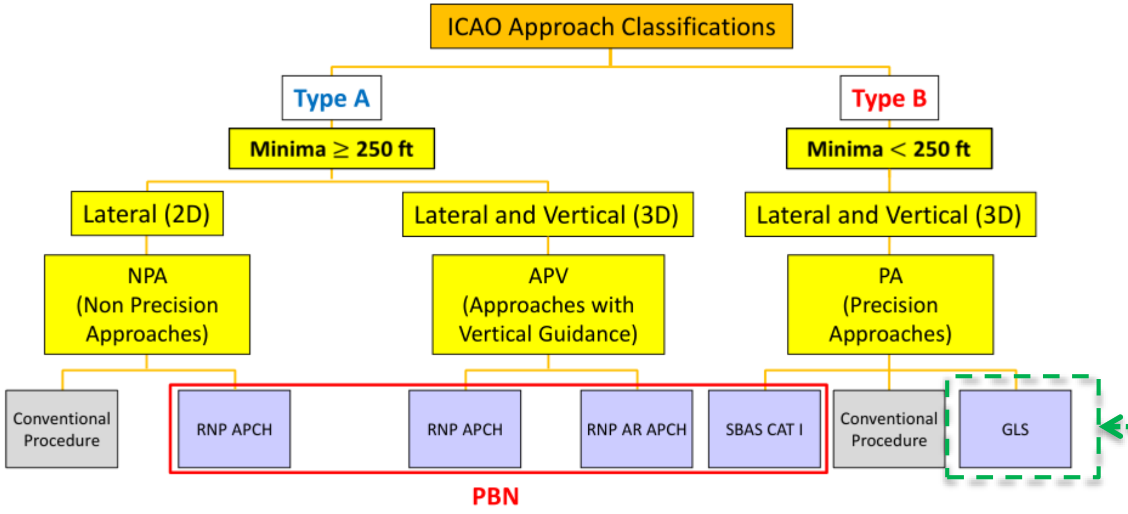
- The implementation of PBN enables the design of helicopter's IFR routes at very low level, based on the ability of suitably-equipped rotorcraft to navigate very accurately using current GPS/SBAS constellations.
- These low-level IFR routes can be directly linked to dedicated Point-in-Space (PinS) arrival and departure procedures, where published, enabling simultaneous non-interfering (SNI) operations.
- The Pins can provide also a better access to several rotorcraft suitable landing locations (e.g hospitals helidecks)



PBN capability on AW1x9 LH Helicopters (1/2)



- The LH (Leonardo Helicopters) IFR products AW1x9 (AW189, AW169, AW139 and AW109SP) have today "fully certified" PBN capabilities from **RNP2** to **RNP0.3** and **RNP AR APCH** up to RNP0.3 minima.



In addition to the PBN capabilities the AW189 is the first helicopter in the world certified for GLS GAST-C precision approach capability (GBAS). This capability will be soon available on AW169 as well.

PBN capability on AW1x9 LH Helicopters (2/2)

Summary of LH AW1x9 and FMS types:

AW109: Genesys AeroSystems FMS –
Level A FMS sw –
Configuration Class Gamma TSO C146 –
Dual TSO C146 GPS SBAS receivers
Dual 4-axis Automatic Flight Control System

RNP2 to **RNP0.3** and **RNP AR APCH** up to RNP0.3 minima.

AW139: Honeywell Primus EPIC FMS –
Level C FMS sw –
Configuration Class Delta 4 –
Dual TSO C145c GPS SBAS receivers
Dual 4-axis Automatic Flight Control System

RNP2 to **RNP0.3** and **RNP AR APCH** up to RNP0.3 minima.

AW169: LHD FMS – Level B FMS sw –
Configuration Class Beta 3 –
Dual TSO C145c GPS SBAS receivers
Dual 4-axis Automatic Flight Control System

RNP2 to **RNP0.3, A-RNP** and **RNP AR APCH** up to RNP0.3 minima.
RNP AR APCH *less than 0.3/MA less than 1.0 and GLS GAST-C approaches planned within next major aircraft software development and certification*

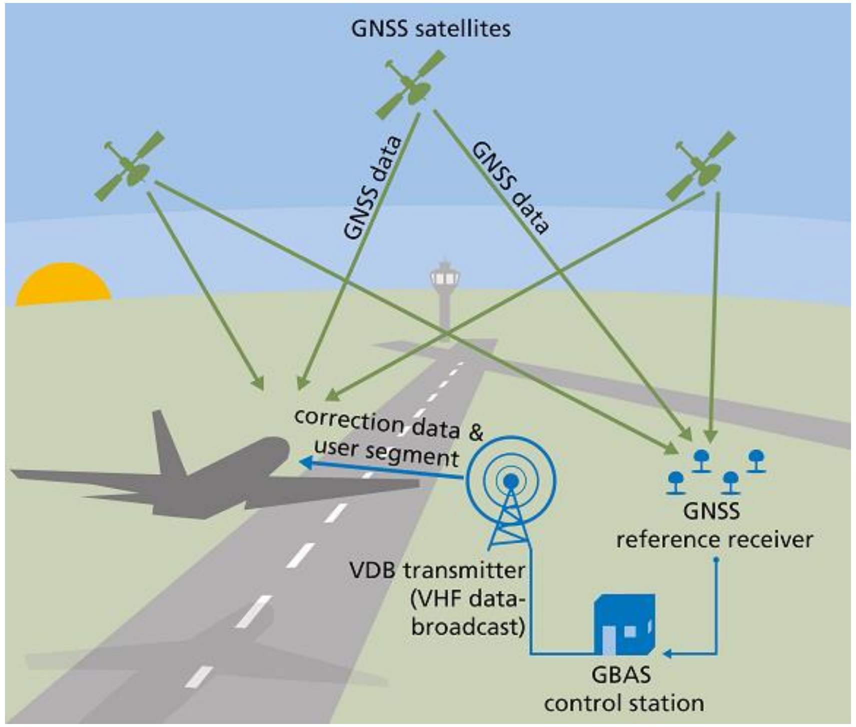
AW189: LHD FMS – Level B FMS sw –
Configuration Class Beta 3 – Multi Sensors
Dual TSO C145e GPS SBAS/GBAS receivers
Dual 4-axis Automatic Flight Control System

RNP2 to **RNP0.3, A-RNP** and **RNP AR APCH** up to RNP0.3 minima.
GLS GAST-C Approach capable since Sept. 2019

New AW189/AW169 GBAS GLS GAST-C Approach Capability (1/2)

- The helicopter operation such as the HEMS\SAR ones are prone to weather conditions and today are conducted mainly under VFR.
- When a helicopter is dispatched, usually under challenging environmental conditions, it is because the mission requires it and there are no other means to execute the mission.
- With a **GBAS station installed** at an airport or heliport close to hospitals or helipads (one **GBAS station can serve multiple GLS approaches** within its maximum operating radius) and a **GBAS capable helicopter**, the **mission success** after critical operations such as medical evacuation or rescue operations, can be increased with an additional precise landing capability
- **For that purpose LH has modified AW189 and AW169 FMS to enable also GAST-C GLS precision approach**.

New AW189/AW169 GBAS GLS GAST-C Approach Capability (2/2) – Benefits overview



The following benefits or Enhanced Capabilities already recognized by aviation community for GBAS, can also be realized for rotorcraft operations in particular for airport with SNI (Simultaneously Non Interfering) aircraft-rotorcraft operations:

- Flexible approach geometries:
  - ✓ GLS programmable touchdown point with variable glide slope very useful for H/C (e.g. above 3 deg) when operating simultaneously with fixed wing.
  - ✓ Mitigate noise
  - ✓ Avoid runway/airport constructions/obstructions
- Enable Efficient Flight Path:
  - ✓ Reduce Fuel Consumption
  - ✓ Minimize the emissions
- Serves All Runway/helipad Ends:
  - ✓ Reduce Maintenance costs;
  - ✓ Increase Precision approaches

New AW189/AW169 GBAS GLS GAST-C Approach Capability (2/2)

Additional possible future GBAS applications for helicopters:

- **Offshore operations** could be considered for the use of GBAS approach capability.

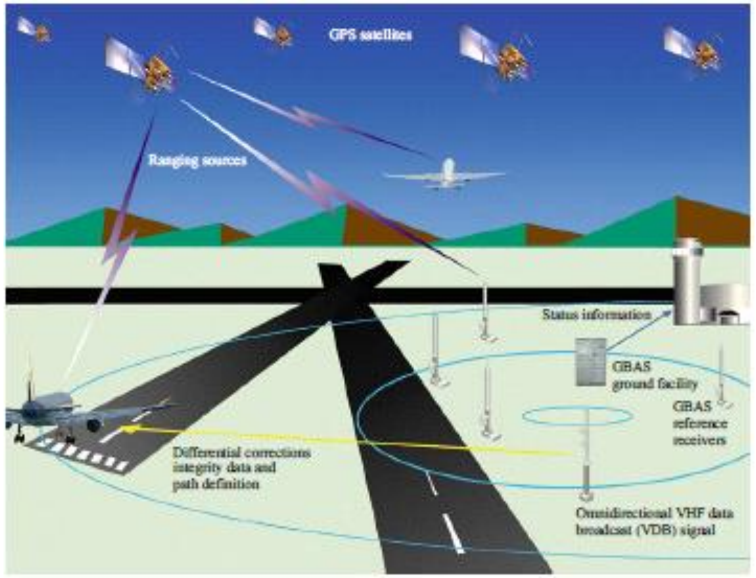
  As above, GBAS provides the capability to improve the effectiveness of offshore helideck operations as well as return flights to a small heliport in inclement weather and IMC conditions especially for world places not covered by SBAS coverage.

- Better Airport Accessibility for rotorcraft operations in **Low visibility Environments** (and more options for **alternate** destination) thanks to CAT I capabilities: the CAT I improves the IFR flight planning options allowing the inclusion of ***"additional Alternate"*** airport/heliport as destination.

GBAS Principle: short review (1/2)

- The GBAS systems are fielded at airports to support precision approaches and landings in civil aviation operations. A Ground Based Augmentation System (GBAS) augments the existing GNSS used in local airspace by providing corrections to aircraft in the vicinity of an airport in order to improve the accuracy and provide integrity of its GNSS navigational position.

- The GBAS generates differential corrections for GPS pseudorange (L1 C/A code) signals based on measurements taken at known (reference) locations so the reference measurements are monitored to protect against GPS and GBAS faults or anomalies.



- The goal of GBAS implementation is to provide an alternative to the Instrument Landing System (ILS) supporting the full range of approach and landing operations.

- CAT-I GBAS is referred to internationally as GBAS Approach Service Type-C (GAST-C) (CAT-I minima **– 200 ft DH**).

- GBAS provides its service to a local area of approximately a **23 nautical mile radius**.

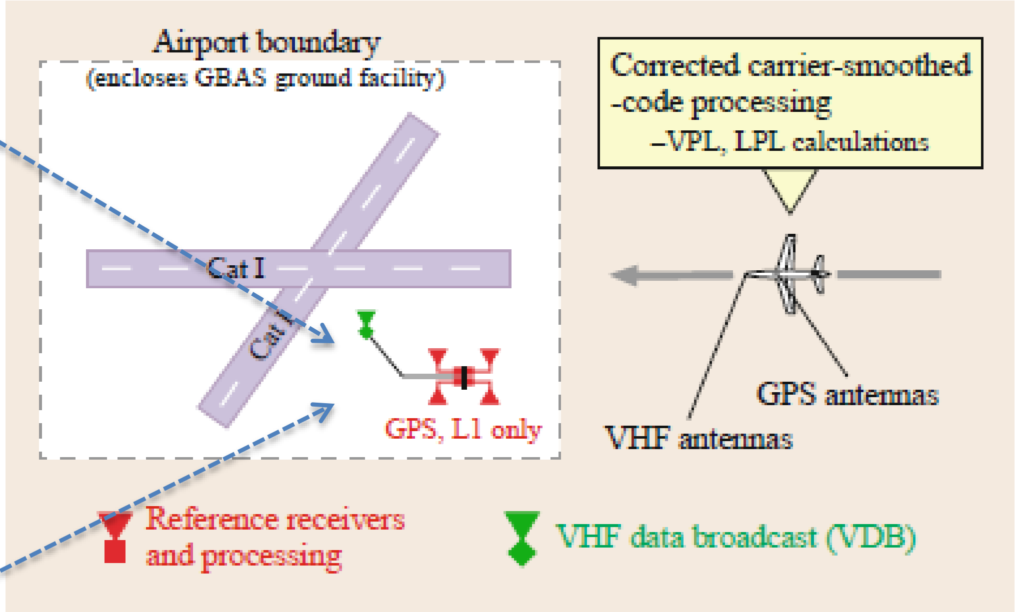
GBAS Principle: short review (2/2)

- A **GBAS Ground Facility** typically is composed by:
  - three or more GPS antennas
  - ground central processing system,
  - VHF Data Broadcast (VDB) transmitter

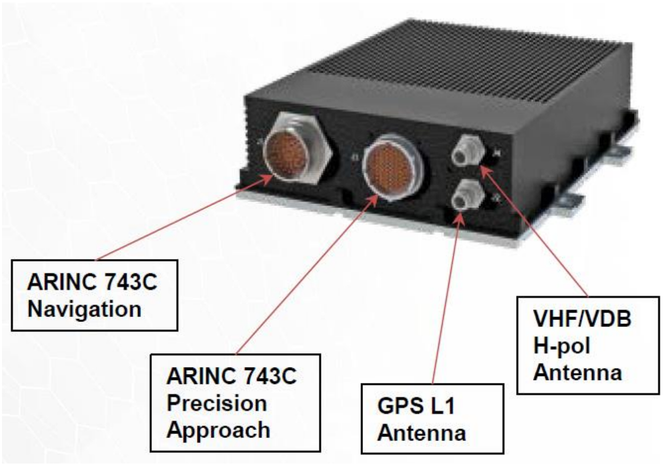
  all locally situated on or near an airport.

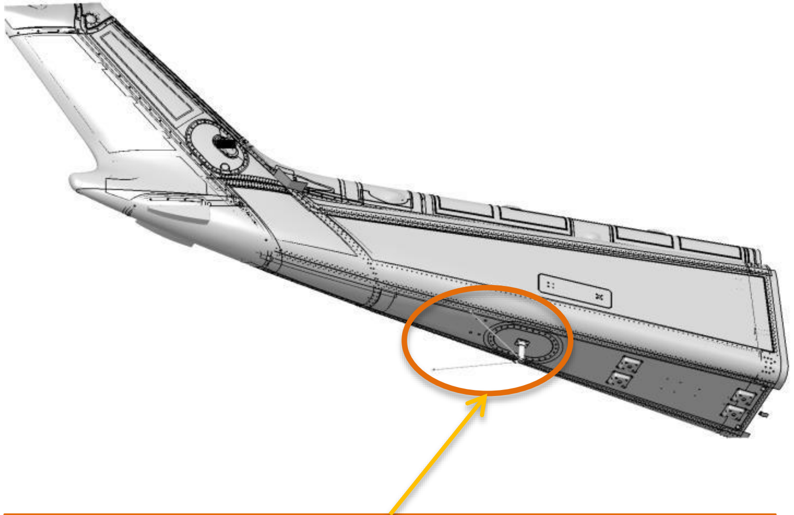
- **GBAS airborne** equipment consist of:
  - GPS antenna,
  - VHF antenna,
  - GNSS receivers (VDB and GPS signals) capable to receive GBAS messages.

- In GBAS system, a master control processor typically located near or next to the reference receivers collects the receiver measurements and determines the pseudorange corrections and correction rates to broadcast to a/c for each satellite approved for use.



GBAS installation on AW189/AW169 helicopters (1/2)





GBAS (VHF/VDB) antenna on helicopter tail for maximum Line of Sight capability

- Dual *CMA-6024* GPS receivers are installed on the AW189 and AW169 aircraft and provide the aircraft PVT (Position-Velocity-Time) navigation solution to dual/independent FMS for lateral and vertical guidance.
- Both *CMA-6024* GPS receivers are connected to a dedicated VDB (VHF Data Broadcast) antenna, bottom-mounted below the tail to receive the broadcasted GBAS data from a GBAS ground station.
- The *CMA-6024* GPS receiver is certified to ETSO-C145e, ETSO-C146e, ETSO-C161a and ETSO-C162a, showing DAL-A compliance.
  - Moreover the VDB receiver within the *CMA-6024* is a RTCA/DO-253D Class B receiver with X=9, Y=0 (minimum and maximum signal power at the VDB antenna) over the full operating temperature range.

GBAS installation on AW189/AW169 helicopters (2/2)

GLS approach process *step-by-step*:

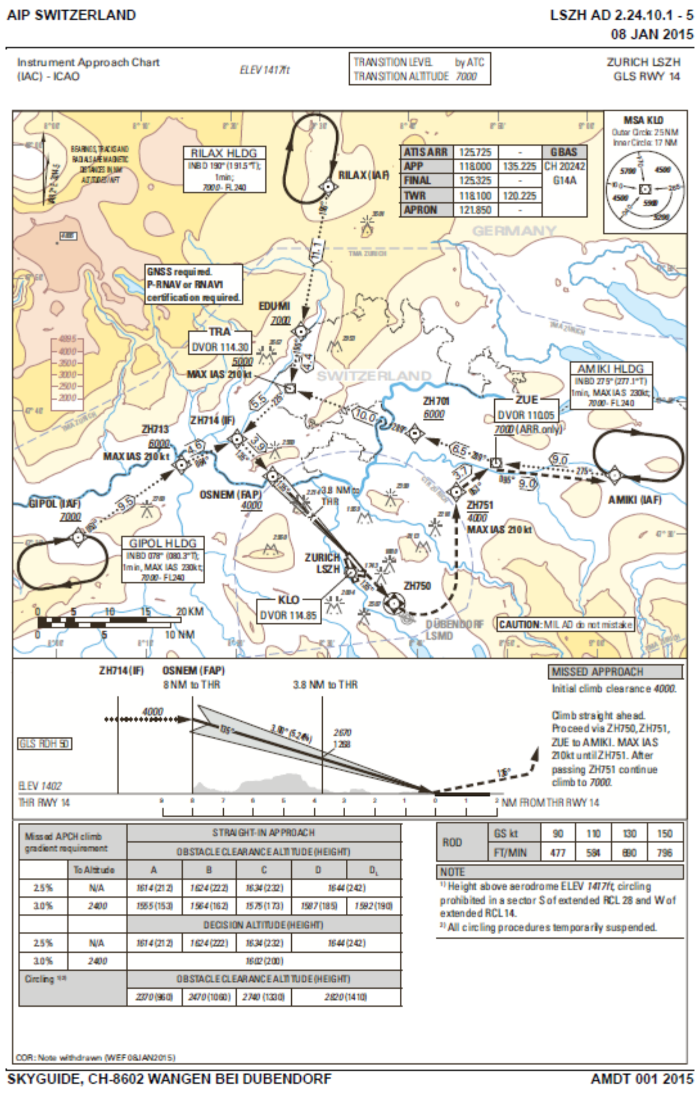
1. In the case of GLS selected by the pilot, the AW169 and AW189 FMS provides the GBAS tuning number to dual GPS: the same number included in the approach chart.

2. The GPS will tune its internal VDB receiver, selects the required GBAS ground station and process the specific GBAS ground station data to produce the GBAS guidance positioning solution and the GLS look-alike LOC and GS guidance deviation.

3. The FMS then provides this ***look-alike* pseudo-LOC and pseudo-GS** guidance to dual AFCS (Automatic Flight Control) and dual PFD (Primary Flight Display) systems.

In summary: the AW189/169 integrated FMS and CMA-6024 GPS comprise of a modern state-of-the-art GBAS GLS airborne system.

GLS GAST-C Flight Test Result – Selected airport



The selected GBAS airport was the Zurich airport. The GLS approach chart for runway 14 is shown in the figure.

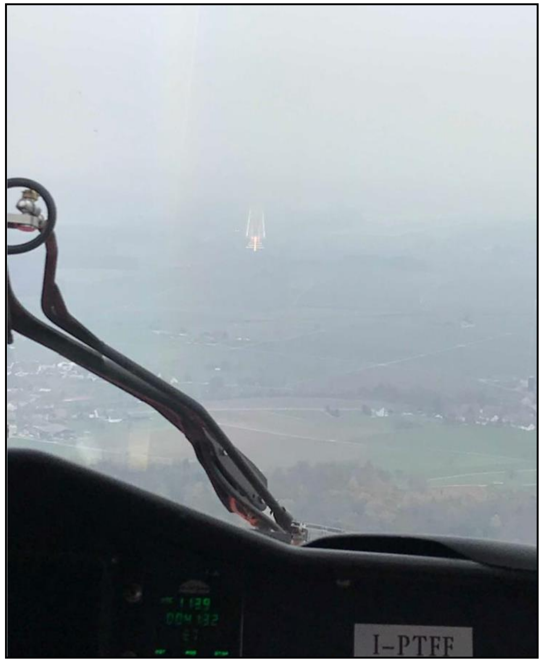
The **GBAS channel ID** (20242) and **Reference Path ID** (G14A) are reported in approach chart.

More details for curious…

Zurich RW14 GLS approach main parameters:

- Standard 3 degree glide path angle descent.
- GBAS antenna located north of airport close to the RW14 threshold
  - ✓ Transmitted power is approximately 46-48dBm (<10Watts),
  - ✓ GBAS channel corresponds to 114.05MHz.
- Maximum Use Distance, $\mathbf{D_{MAX}}$ **is 42km**,
- Vertical Alert Limit is 10m,
- Lateral Alert Limit is 40m,
- Approach TCH (Threshold Crossing Height) is 50ft.

GLS GAST-C Flight Test Result (1/4) – Flight activity



The flight test campaign for GLS GAST-C approach certification credit required a large amount of flight test scenarios to demonstrate how:

- ✓ the aircraft GLS system,
- ✓ the FMS, AFCS and CDS systems,
- ✓ the GPS receivers,

are performing under a variety of operational conditions, normal, rare but normal, and non-normal conditions.

- On 20 November 2018 LH flew, with AW189 P5, four consecutive GLS approaches on RW14 of Zurich airport from IF @4000 ft for the first time.
- During this flight trial a couple of pictures have been taken by the Leonardo Helicopters’ experimental flight crew.
- These two pictures show, also visually confirmed by the test pilots, perfect lateral runway center line and vertical alignment during the entire 3-degree GPA (Glide Path Angle) approach.

GLS GAST-C Flight Test Result (2/4) – Some performance plots …

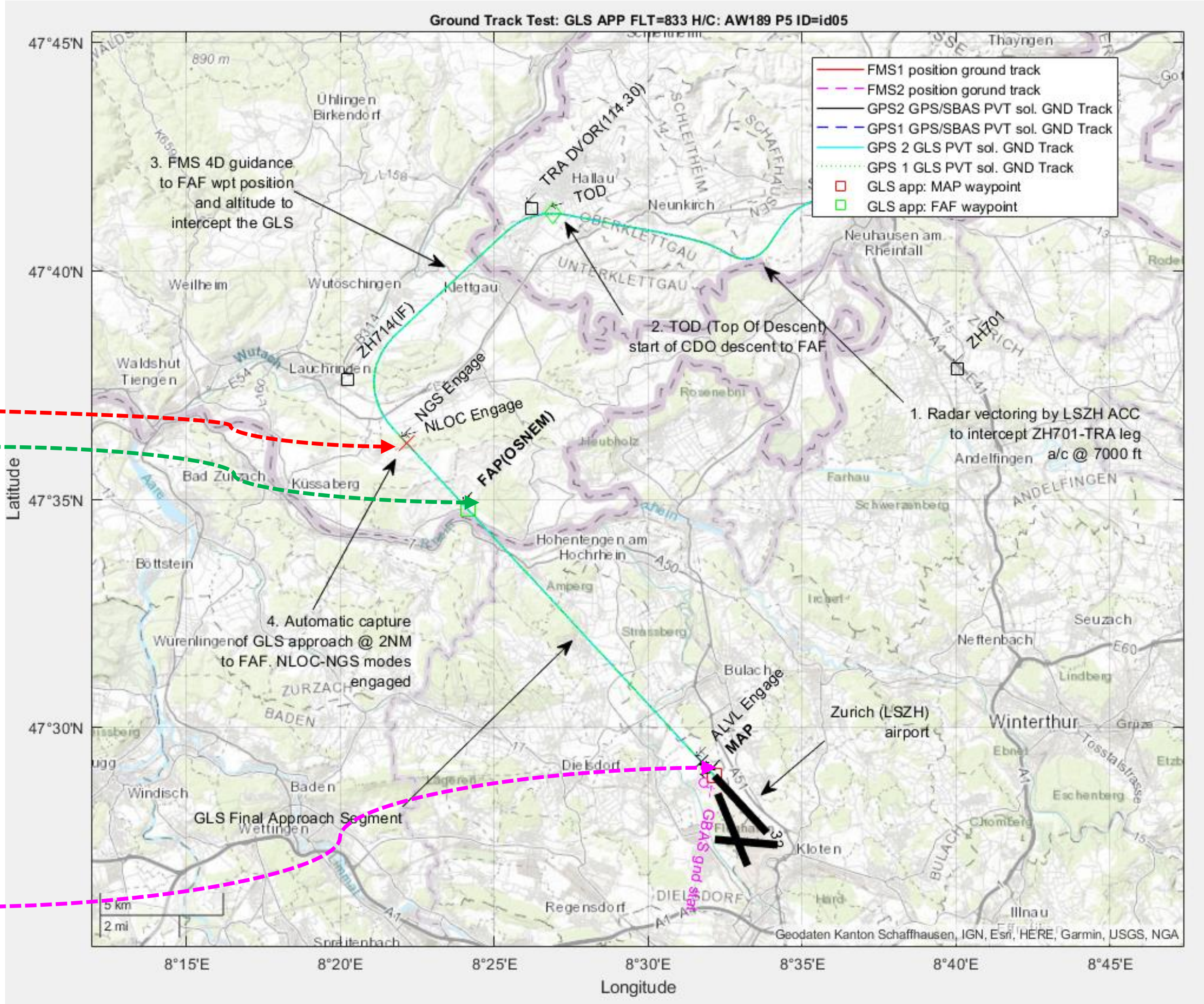
GBAS Flight Path:

1. **Start**: initial segment of the approach at the AMIKI (IAF). a/c capture between TRA – ZH701 wpts leg.
2. **Approach**: started from a 7000ft altitude with a CDO (Continues Descent Operation) down to the FAF waypoint altitude
3. **Guidance to FAF**: GPS lateral guidance and APV Baro-VNAV vertical guidance.
4. **Guidance to MAP**: GPS generated GLS look-alike LOC and GS deviations

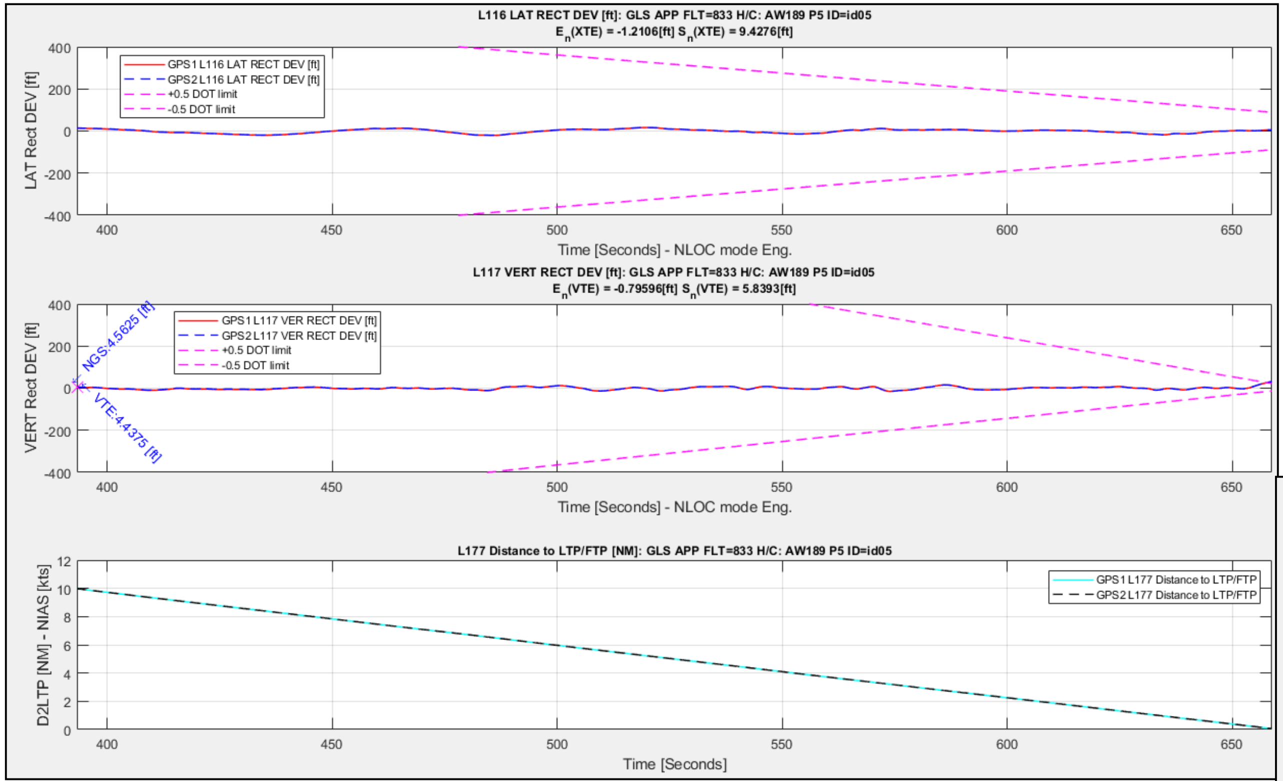
   Note: Capture at 2NM (**Red Cross**) before the **FAF waypoint** with minimum lateral and vertical deviations.

Results:

- Tracks from both GPS are perfectly synchronized with each other
- The **Red Cross** on the map plot represents the GLS approach position where the selected GPS provided direct guidance (LOC and GS) both in the horizontal and vertical planes at a continuous 20Hz rate to both FMS systems.
- From the **Red Cross** to **Red square** (MAP): 10NM of GLS final approach segment. The GBAS station position **in magenta circle**.

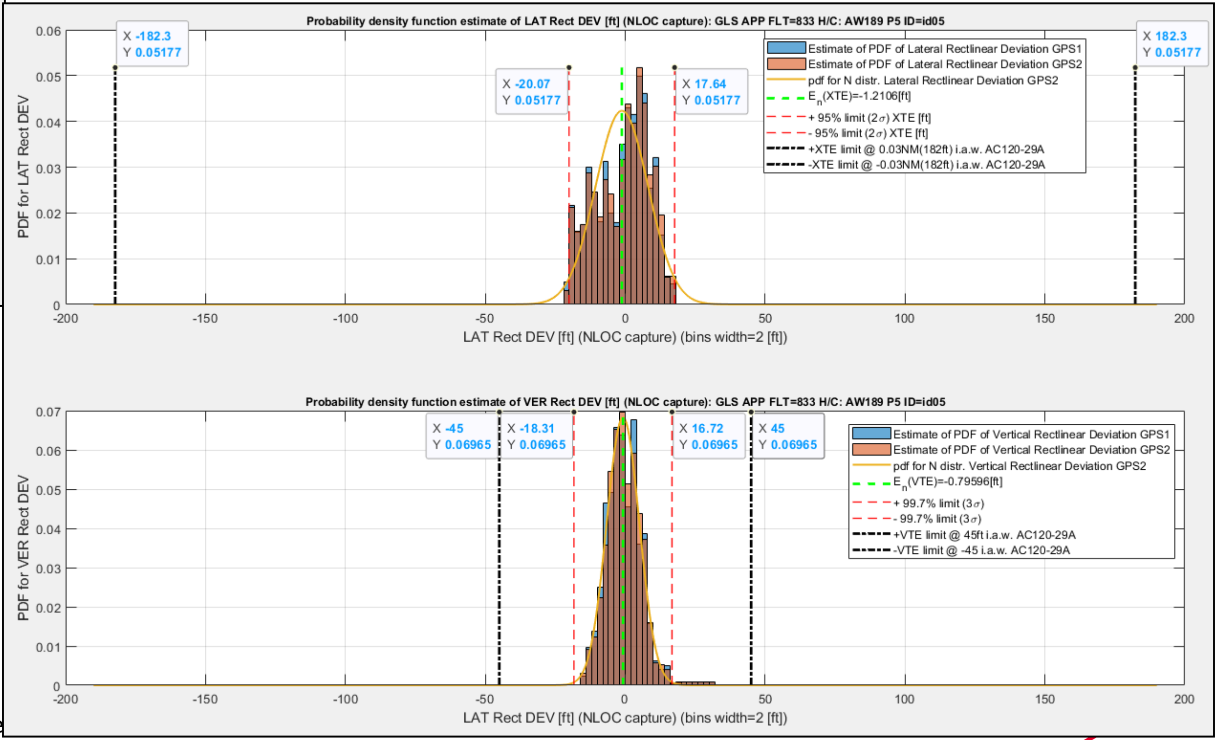


GLS GAST-C Flight Test Result (3/4) – Some performance plots …



The plots display the linear, lateral and vertical deviations during the final approach segment to RW14 GLS approach at the Zurich airport.

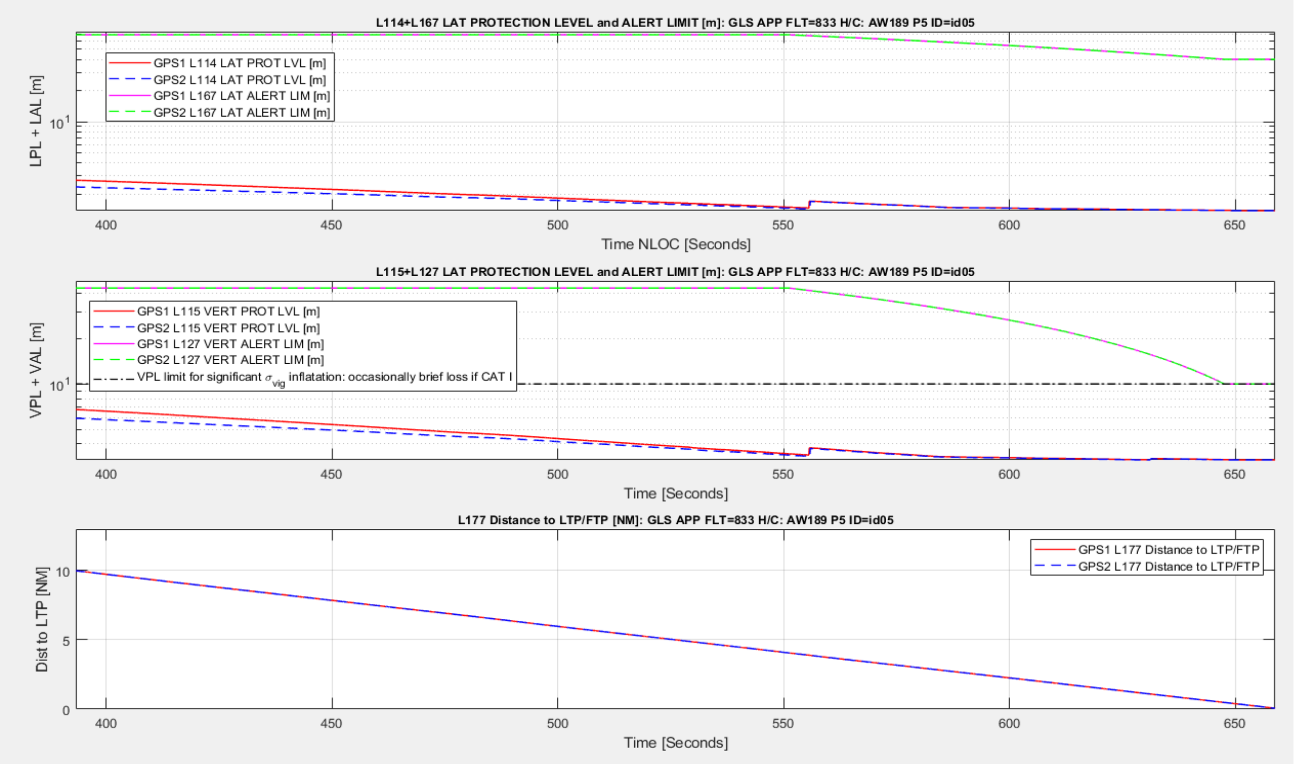
These plots provide the performance evidence of the excellent and precise 4-D guidance in real GLS approach scenario.



Some performance results in details …

- The top and middle plots show an excellent flat trend along the 10NM course down to the MAP waypoint and altitude.
- Both deviations show a mean value **below 1.5ft** (*for lateral E[XTE] = -1.2ft; for vertical E[VTE]=-0.8ft*); with a very small standard deviation value **below 10ft** (*for lateral σ[XTE] = 9.4ft; for vertical σ [VTE]=-5.8ft*).
- The plots on the right provide performance against AC120-29A requirements.

GLS GAST-C Flight Test Result (4/4) – Some performance plots …



Details of Integrity level reached of GLS during approach:

The GBAS integrity, specifically the horizontal and vertical protection levels (red lines in top and middle plots), are plotted and compared with the dynamic lateral and vertical alert limits computed by GPS in function of a/c distance to Runway 14 point of Zurich GLS approach in accordance with DO-253D (the magenta/green lines on top and middle plots).

→ **The system is really capable to steer as PA (Precision Approach) down to 200 ft minima (Cat. I).**

Test results Conclusion:

- The same consistent performance has been observed during other AW189 GLS approach flight trials.
- The GLS performance is stable, consistent and repeatable without significant deviations from the indicated course according to HAT (Height Above Touchdown) ranges as required for GLS CAT-I minima certification in accordance with AC 120-29A.

GLS GAST-C Key benefits for helicopter operations

- GBAS enables h/c Precision Approach operations where existing already certified ILS or LPV-200 PinS approach capability are inadequate or impossible;
- GBAS can enable Precision Approach procedures with Cat.I in several worldwide areas not covered by SBAS (Russia, Australia, offshore areas,…)
- GBAS improves overall flight safety enabling Precision Approach to runways or helipads in challenging VMC or adverse weather conditions (“additional Alternate”)
- GBAS improves mission success in case of approach to whatever helipad within the coverage of an existing GBAS station (ex. Milan S.Raffaele Hospital helipads close to Milan Linate airport)

Summary and Conclusions

- The ICAO Global Air Navigation Plan (GANP) gives strategic guidance for regional and national air navigation planning for civil aviation. In line with the ICAO strategic objectives, PBN implementation is the GANP's highest priority.
- In EU and US the evolution of aeronautical navigation foresees the migration towards satellite-based navigation as primary means of guidance and an Airspace structure and flight procedures based on PBN applications.
- The current Leonardo AW1x9 civil fleet is fully compliant to several latest ICAO CNS requirements, in particular the AW1x9 products are certified for a wide range of PBN specifications from RNAV 5 to RNP 0.3 all phases of flight to RNP AR.
- In addition to PBN applications based on SBAS, GBAS has a significant role to play in helicopter operations worldwide. Leonardo recognized GBAS usefulness, particularly for improving and enhancing helicopter mission success.

A glance at the future …

The future Leonardo Helicopters developments in the navigation domain will include:

- New **DFMC** (Dual Frequency Multi Constellation) receivers (L1 and L5 on GPS, Galileo and BeiDou) that will bring more robustness to the navigation solution to support and improve all the current PBN applications, **GAST-F** and **ARAIM** included.
- Approach and Departure procedures based on very low RNP (e.g. RNP AR 0.1 minima in REGA ARIOS project).
- D-GLS (Differential-GPS Landing System) for "Tactical/Precision" approach operations on not-prepared landing site.

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