GBAS Certification of the Leonardo AW189 Helicopter with the CMC Electronics CMA -6024 GLSSU

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1. **Leonardo Helicopters and CMC Electronics**

Leonardo Helicopters is a leading global helicopter manufacturer supplying an extensive range of civil and military helicopters covering all of the standard weight categories. The AW169, AW189 and AW139 family has been developed with the same design philosophy, certification and safety standards.

CMC Electronics is a major supplier of ARINC-743A/B/C compliant GPS receiver avionics and provides the CMA-3024 (ARINC-743A), CMA-5024 (ARINC-743B) and the CMA-6024 (ARINC-743C). CMC’s GPS receivers have been integrated into various Leonardo helicopters from initial design, to certification, to active service.

2. **Introducing The New AW-189 Helicopter**

The AW189 is an 8.6-ton class helicopter complementing the Agusta-Westland product family of dual-use helicopters. The AW189 is designed to meet or exceed the customer’s needs for performance, affordability, mission reliability and dependability for either civil or para-public and governmental passenger transport operations; EMS (emergency medical service); offshore, oil and gas; search and rescue (SAR); corporate and VIP; law enforcement as well as homeland security.

![Figure 1: AW189 Helicopter in SAR and Corporate Configurations.](image)

The AW189 meets and exceeds the latest design and operational requirements (CS/FAR29, Regulations for Air Operations) as well as OGP guidelines. It has achieved EASA certification in February 2014 and FAA certification in February 2015. The AW189 operates in offshore, SAR, utility and VIP roles in various environmental conditions all over the world.

The AW189 features an advanced cockpit with a state-of-the-art avionics suite minimizing pilot workload and enhancing situational awareness.

![Figure 2: AW189 Glass Cockpit](image)
The AW189 avionics are a fully integrated system comprising four 8” x 10” color Active Matrix Liquid Crystal Displays (AMLCDs), a dual 4-axis dual-duplex Automatic Flight Control System (AFCS), a dual FMS (Flight Management System) with on-board RNP Performance and Monitoring Alerting system that guarantees any RNP navigation specification included in PBN manual (4th Ed.) up to 0.3, HTAWS. It is integrated with situational awareness information on cockpit displays (radar, TCAS II, synthetic vision, HTAWS, etc.), and includes an integrated redundant aircraft management and monitoring system with HUMS function.

The AW189 and AW169 FMSs are compliant with A-RNP, RNP1, RNP2, RNP0.3 for “all phases of flight”, RNP APCH with LNAV or LNAV/VNAV minima, RNP APCH with LPV/LP minima, RNP AR APCH with RNP minima down to 0.3nmi, P-RNAV/RNAV-1 and B-RNAV/RNAV5 navigation specification for IFR navigation. This includes the management of terminal procedures as SID, STAR, PinS departure and approach types PinS, RNAV(GNSS), RNAV(RNP) types, in addition to non-precision approaches based on VOR, VOR/DME, ILS/LOC, DME, NDB and NDB/DME, and with both LP/LPV and GLS approach capability.

With pilot, crew and passenger comfort in mind, the AW189 features advanced cabin climate control, it has a built-in APU and the preflight climate can be controlled without powering the rotor engines regardless of external climate extremes.


Since the beginning of the rotorcraft era, the HEMS/SAR (helicopter emergency/search and rescue) helicopters have been dispatched whenever medical evacuation, C-SAR (Combat SAR), or any emergency situation require immediate safety-of-life relief. Helicopters have the unique capability to safely land in remote and challenging areas but most particularly on hospital helidecks, in temporary relief areas and forward operating bases that may or may not have temporary helipads close to the critical area in need. In many situations, these critical operations are affected by weather and require visual metrological conditions (VMC) during the final segment of the descent.

Over the past years, several HEMS and SAR missions had been cancelled due to poor weather conditions which exceed VFR operating limits. Please find below a picture of the kinds of airport and heliport weather conditions (below VFR limits) that can cause a helicopter SAR and EMS mission to be aborted or canceled.
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. There is also an implicit expectation that the mission will be 100% successful and that expectation is flowed down to the aircraft, its avionics and its crew.

To enhance the mission success of the AW189 and AW169 aircraft, Leonardo Helicopters has modified its FMS to enable GAST-C GLS precision approach. The latest AW189 GAST-C GLS precision approach capability upgrade release is currently EASA certified, the AW169 certification is in progress and will be ready with the next upgrade release. Note that both helicopters are already certified for ILS CAT I minima and LPV200 approach. This upgrade adds GLS GAST-C (CAT I minima) precision approach capability and allows the AW189 and AW169 helicopters to conduct GLS GAST-C CAT I precision approaches. It means that precision approaches after critical operations, such as medical evacuation, rescue operations, etc. could be conducted safer and easier in All weather conditions through additional IMC CAT I minima performance capability. Leonardo Helicopters is committed to constantly improving the mission success of its aircraft.

As a result, IMC conditions could be met with precision approach (PA) minima for landing with ILS, LPV and now GLS. With a GBAS station installed at an airport or heliport or any possible location, one unique GBAS station can serve multiple GLS approaches for helidecks close to and in sight of but within its $D_{\text{MAX}}$ (maximum operating radius). This scenario can extend AW189/AW169 helicopter operations especially for EMS or SAR missions, increasing mission success with a precise landing capability. In the case of EMS, victim survival is measured in minutes between injury and medical treatment and indeed, every second counts.

Offshore operations are considering the use of GBAS approach capability. As above, GBAS provides the capability to improve the effectiveness of offshore operations as well as return flights to a helideck in inclement weather and IMC conditions. Clearly, GBAS can improve overall helicopter mission success.
4. The GBAS Installation

Dual GLSSU CMA-6024 receivers are installed on the AW189 and AW169 aircraft and they provide the aircraft PVT navigation solution to dual/independent FMS for lateral and vertical guidance (LG and VG), dual ADS (air data system), dual AHRS and dual AFCS systems. In the case of SBAS navigation and SBAS LP/LPV, the CMA-6024 is installed as a TSO C145e Class Beta 3 configuration. The FMS generates the LG and directly steers the aircraft for en-route, departure, terminal and approach either NPA/RNP (AR) APCH or LP/LPV200. From the terminal area, the FMS generates the VG to fly fully coupled approaches. Regarding the pitch control in approach, the FMS is able to decelerate following a pilot-defined deceleration down to $V_{\text{mini}}$ IAS speed.

Both CMA-6024 GLSSUs are connected to a dedicated VDB (VHF data broadcast) antenna, bottom-mounted below the tail to receive the broadcast GBAS data from a GBAS ground station.

The single, dedicated GBAS VDB antenna is installed and its output is signal split between the two CMA-6024 GLSSUs. With the CMA-6024 VDB receiver parameter $X=9$, the CMA-6024 easily meets and exceeds all VDB performance requirements. The antenna provides a reasonable overall gain pattern in the horizontal plane and meets the antenna horizontal gain pattern performance requirements.

The CMA-6024 GLSSU is certified to TSO-C145e Beta-3, TSO-C146e Delta-4, TSO-C161a as a GAEC-C/G1 and TSO-C162a. The VDB receiver within the CMA-6024 is a RTCA/DO-253D Class B receiver with $X=9$, $Y=0$, and $Z=15$ over the full operating temperature range from -55 to +75 degrees Celsius. Some GAST-D capability is included in the current certified product such as authentication. The entire CMA-6024 is designed to Design Assurance Level A (DAL-A) and will have full GAST-D GAEC-CD/G1 capability in the future once all certification requirements are released by the authorities.

![Figure 5: The CMA-6024 GPS/SBAS/GBAS and VDB Receiver System](image)

The CMA-6024 receiver is designed for retrofit or new built aircraft and can support a variety of VDB antenna installations. The CMA-6024 VDB was designed to have a high sensitivity and very wide dynamic range to accommodate various installations.

The CMA-6024 produces a navigation and a guidance position solution (these are identical only when in SBAS precision approach mode). The ILS/DME look-alike LOC, GS and DTG are based on the FAS and on the guidance positioning solution. The navigation solution is available on the navigation bus while the guidance solution is available on the approach bus. The LOC, GS, and DTG are also output on the approach bus.

The CMA-6024 enters SBAS PA mode when either a FAS or a LP/LPV tuning number and SBAS service provider ID are provided. The CMA-6024 becomes armed for GBAS PA whenever a GBAS tuning number is provided. As installed in the AW169 and AW189:
• In the case of LP/LPV, the AW169 and AW189 FMS provide the LP/LPV tuning number and SBAS service provider to the CMA-6024. As conditions permit, the CMA-6024 produces a PA-mode Beta-3 guidance positioning solution and when in the SBAS PA-mode, the navigation and guidance positioning solutions are identical. The AW-169 and AW-189 FMS uses the PA-mode Beta-3 navigation solution and its LP/LPV FAS to generate the look-alike LOC and GS guidance solution.

• In the case of GLS, the AW169 and AW189 FMS provides the GBAS tuning number to the CMA-6024. The CMA-6024 will tune its VDB receiver, select 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 solution. The CMA-6024 then provides this look-alike LOC and GS guidance solution to the AW169 and AW189 FMS. The navigation position solution is based on GPS/SBAS ("non-PA mode" Beta-3).

As described above, this is one particular configuration of the CMA-6024. This receiver is a very flexible and configurable GPS/SBAS/GBAS navigation and precision approach system that can accommodate many Leonardo helicopter architectures and integrations.

The Leonardo Helicopters’ FMS is integrated within the dual Aircraft Mission and Management Computer (AMMC), which is a dual independent, redundant, hot-standby system. The AMMC performs a number of functions, including condition monitoring, communications, surveillance, performance, maintenance monitoring and, of course, dual independent FMS functions. There are two AMMCs, each manages all of the avionics functions, both operate in parallel and contain the same information. Each AMMC hosts an independent FMS function therefore there are two fully FMS providing navigation and RNP performance alerting and monitoring.

Both FMS compute and output the flight deviation data to Cockpit Display System (CDS) and lateral and vertical steering to AFCS by using their own navigation database. The FMS directly provides the pilot, with all messages and flight deviation data required for monitoring the aircraft navigation and approach operations on the FMS CDS and on the MCDU alerts. Both FMS independently compute RNP performance monitoring and alerting functions for any RNPx navigation specification as foreseen by PBN manual. In addition, the FMS compare navigation, deviation data and autopilot steering continuously to ensure the absence of hazardously misleading information.

In summary, the AW189 integrated FMS and CMA-6024 GLSSU comprise of a modern state-of-the-art GBAS GLS airborne system. This system was designed to meet all GAEC-C/G1 approach requirements as per the RTCA/DO-253D including any known revisions that will be published.

5. Actual Airport Flight Test Results

The selected GBAS airport was the Zurich airport. The GLS approach chart for runway 14 is shown in the figure below. The GBAS channel ID (20242) and reference path ID (G14A) are reported in approach chart. The helicopter was the Leonardo AW189 prototype helicopter.
Figure 6: Zurich LSZH GLS RW14 Approach
The Zurich RW14 GLS approach is a standard 3-degree glide path angle. The flight test has been conducted flying to AMIKI initial approach fix (IAF) point. The GBAS antenna is located north of airport close to the RW14 threshold and its transit power is approximately 46-48dBm. The GBAS channel corresponds to 114.05MHz. The main parameters defining the Zurich GLS approach are:

- Maximum Use Distance, $D_{max}$ is 42km,
- Vertical Alert Limit is 10m,
- Lateral Alert Limit is 40m,
- Approach TCH (Threshold Crossing Height) is 50ft.

The Leonardo Helicopter 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 as well as the CMA-6024 GLSSU receiver are performing under a variety of operational conditions, normal, rare but normal, and non-normal conditions.

The specific results of the AW189 helicopter GLS approach flight test approach to the Zurich airport RW14 under normal flight conditions with a descent from 7000ft altitude to the MAP waypoint altitude with the “AMIKI” as the IAF are authorized for publication and are presented below.

The authorized results include the aircraft ground track, from initial and intermediate to final approach segments, measured by both CMA-6024 GLSSU receivers on board, the lateral and vertical deviations performance and the lateral and vertical protection levels in comparison with lateral and vertical alert limits dynamically computed by both CMA-6024 GLSSU receivers.

The first plot shows the aircraft ground track from the intercept of initial segment of the approach at the AMIKI IAF. The aircraft started the approach from a 7000ft altitude with a CDO (Continues Descent Operation) down to the FAF waypoint altitude under GPS lateral guidance and APV Baro-VNAV vertical guidance. The plot shows the capture under the FMS 3-D guidance using the CMA-6024 generated GLS look-alike LOC and GS at 2nm to the FAF waypoint with minimum lateral and vertical deviations. From the mapping plot, all of the tracks from both CMA-6024 GLSSUs are perfectly synchronized with each other in particular from the red-cross to the MAP waypoint (10nm of GLS final approach segment). The Red Cross on the map plot represents the GLS approach position where the selected CMA-6024 GLSSU provided direct guidance (LOC and GS) both in the horizontal and vertical planes at a continuous 20Hz rate to both FMSs.
The plot displays the Zurich GBAS station position (in magenta) and RW14 runway (black segment) for reference in respect with the a/c ground track.

The plots below 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 integration of the CMA-6024 receiver with the AW189 helicopter in a real approach scenario.

The top and middle plots display the lateral and vertical performance respectively during the final segment. Both 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 $E[X_{TE}] = -1.2ft$; for vertical $E[V_{TE}] = -0.8ft$) with a very small standard deviation value below 10ft (for lateral $\sigma[X_{TE}] = 9.4ft$; for vertical $\sigma[V_{TE}] = 5.8ft$).
The same consistent CMA-6024 performance has been observed during other AW189 GLS approach flight trials during Q4 2018 and Q1-Q2 2019 flight trials. The GLS look-alike LOC and GS performance is stable, consistent and repeatable without significant deviations from the indicated course path from 1000ft HAT (Height Above Touchdown), to 700ft HAT, and to 200ft HAT, as required for GLS CAT-I minima certification in accordance with AC 120-29A. All of the flight data show full compliance with the required performance meeting or exceeding CAT-I minima requirements.

In the figure below, 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 GLSSU in function of a/c distance to LTP/FTP point in accordance with DO-253D (the magenta lines on top and middle plots).
Typical RSL and EVM in dB versus time plots for entire flight (tag the pictures below in time with RSL and EVM values)

The CMA-6024 also provides real-time Received Signal Level (RSL) in dBm and Error Vector Magnitude (EVM) in dB as measured by the CMA-6024 at its VDB antenna port for each VDB time slot, time-slot-to-time-slot. The RSL is the actual signal power that is received and the EVM is a power ratio between the data signal error and the ideal D8PSK modulated signal. This data is accurate to 3dB and allows monitoring of the VDB signal as received from the GBAS ground station. During the LSZH RW14 GLS approaches into Zurich airport, the RSL and the EVM were recorded to verify the quality of the VDB signal received by both CMA-6024 GLSSUs installed on the AW189 helicopter.

The RSL and EVM corresponding to Zurich GBAS VDB ground station transmitter antenna were recorded with respect to time for both CMA-6024 GLSSU VDB receivers. The recordings for RW14 GLS approach from the AMIKI IAF waypoint started at 15nm away from then to the GBAS ground station. This approach transition requires two ninety-degree left turns before the aircraft is aligned to the final approach course. These two turns require a flight condition with an aircraft roll angle of approximately 15 degrees. This provided the opportunity to verify the signal receiver capability of both CMA-6024 receivers as well as the AW189 installation. Note that the aircraft (and the VDB antenna) is not pointed at the GBAS ground station as it would normally be during final approach segment. The data shows an excellent RSL and EVM data in terms of power and quality of VDB signal regardless of aircraft orientation.

The actual plots and data are confidential and proprietary to Leonardo, these data cannot be shared; however, it is sufficient to report that the VDB performance either met or exceeded performance expectations and certification requirements.
6. Flight Crew Impressions

During one of the several GLS approaches on the Zurich airport RW14 of Zurich airport a couple of pictures have been taken by the Leonardo Helicopters’ experimental flight crew. The pictures below show the initial and final moments of the final approach course towards RW14 GLS approach to the airport. The two pictures show, also visually confirmed by the Leonardo Helicopters test pilot and flight test engineer, perfect lateral runway center line and vertical alignment during the entire 3-degree GPA (Glide Path Angle) approach.

![Figure 10: Out-of-Cockpit Photograph during GLS RW14 Approach, November 20th, 2018.](image)

There is an overall consensus among the members of the flight crew: the performance was outstanding.
7. Closing Remarks

GBAS has a significant role to play in helicopter operations worldwide. Leonardo recognized GBAS usefulness, particularly for improving helicopter mission success.

Simply stated: GBAS enhances overall helicopter mission success. Mission success is the most critical factor to the dispatch of any helicopter – a helicopter is dispatched when the need is greatest – the mission must be a success.

The Leonardo AW189 is the world’s first GBAS equipped and certified helicopter. The AW169 will be the next one. More helicopters are planned. Leonardo intends to provide the most capable and the most mission-success oriented helicopters in the world.

In conclusion, the authors believe that the key aspects of a helicopter GLS GAST-C approach capability can be summarized below:

- GBAS enables helicopter precision approach operations where existing already certified ILS or LPV-200 PinS approach capability is inadequate or impossible;
- GBAS improves overall crew safety below VFR limits and enables precision approaches to runways or critical helipads and helidecks in challenging VMC or adverse weather conditions or worse, into a “black-hole” approach at night (emergencies happen at any time of day or night);
- GBAS could be crucial for saving lives in case of SAR/HEMS operations on airports or heliports equipped with a GBAS ground station for quickest recovery to the nearest hospital or /medical service.

A helicopter with GLS capability offers a wide spectrum of uses, some of which are:

- SAR and HEMS approach to runways or helipads in remote areas for MEDIVAC, anytime and anywhere;
- Civil applications such as precision approach for offshore or small airports or heliports not covered ILS or SBAS;
- Civil (non-military, non-government) precision approach into military or secure airports or basecamps for which a-priori approach databases may not or may never be available, but where a simple GBAS tuning number might be.

Author Information:

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John Studenny – John Studenny is the Director of Aviation GNSS Products at CMC Electronics. He contributed and oversaw the preparation and release of RTCA/DO-229D (SBAS) and he has been serving at the RTCA as co-chair of Sub-Committee 159, Working Group – 2. He obtained his B. Eng., M. Eng., and Ph.D. degrees from McGill University (Dept. of Electrical Engineering), also taught Modern Control System (H₂, frequency-domain control and estimator/observer design). His technical interests and experience include GPS receiver design, various GPS algorithm designs, GPS-IMU Kalman filter design and integration, Doppler radar velocity sensor design, spread-spectrum radar altimeter design, microwave landing system algorithm design, and acousto-optic electronic warfare receiver design.