Traps and Pitfalls 2026 Edition

Stefan Jagieniak

Senior Software Engineer
Aerodata AG
Braunschweig, Germany
Phone: +49 531 2359-135
E-mail: stefan.jagieniak@aerodata.de

Frank Musmann

Project Manager
Aerodata AG
Braunschweig, Germany
Phone: +49 531 2359-341
E-mail: frank.musmann@aerodata.de

ABSTRACT

During flight inspection (FI) missions, surprising or unexpected results may appear. A typical situation for this might happen during the commissioning of a brand new, accurate FI System. Its results are compared to those of a well known, but ageing system, which had been approved and even certified decades ago. The typical consequence is to blame the new system, because the legacy one had been accepted and therefore is assumed to be correct.

Current FI systems should be more sensitive on detecting errors compared to systems installed in airliner aircraft, which intend to provide guidance even in case the signal is not perfect. This may lead to the situation that FI reveals a problem that some cockpit installations do 'smooth away'. Even legacy FI systems are just not able to detect all existing problems.

This paper depicts some real cases from more than 30 years of experience. Physical effects are explained. Real cases for traps and pitfalls in flight inspection are given based on the following examples:

- Glidepath: Airliners report hard landings despite flight inspection being within tolerance
- VOR: Wrong FMDR values
- GBAS: All data flagged invalid

INTRODUCTION

Over the years, various unexpected flight inspection results have been reported and analyzed. These were caused by failures in the flight inspection equipment, faults within navigation aids, and confusion by the involved personnel – in increasing frequency of occurrence.

As it is common in aviation, it is important to learn from these issues to avoid them from happening again. Along with previous papers (ref. [1], [2] and [3]), this paper details some real-world challenges observed over the last years.

HARD LANDINGS AND GLIDE PATH

Airline pilots complained about repeated hard landings when landing at a specific airport. Subsequently, the regulator complained about the correctness of the flight inspection and claimed the glidepath structure tolerance lines being wrong for flight inspections of instrument landing systems (ILS). It took some analysis to come from this early conclusion back to the real problem, which turned out to be totally unrelated to flight inspection.

The recorded data from the specific flight inspection (as displayed in Figure 1) showed a rather high threshold crossing height (TCH), but with corresponding glide path deviations (as visible in Figure 2). Consequently, the glide path error was perfectly within the limits.

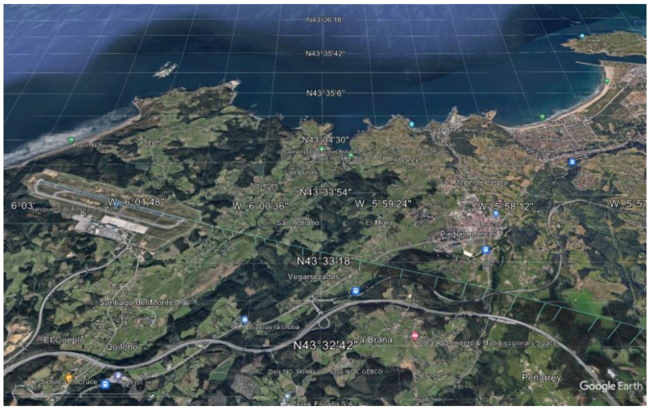

Figure 1: Recorded Approach During Flight Inspection

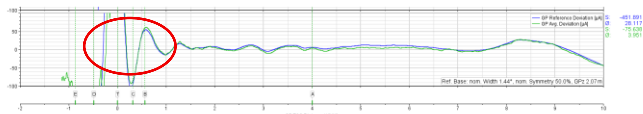

Figure 2: Glide Path Deviations (Measured vs Reference)

Figure 3 shows the glideslope deviation over the approach. The glideslope was intercepted at approximately 8 NM out and was stable until approximately 1 NM before the threshold. At that time, the aircraft started to fluctuate around the glideslope signal significantly, crossing the threshold too high before touching down with a higher-than-normal vertical speed. This aligns well with the reported hard landings.

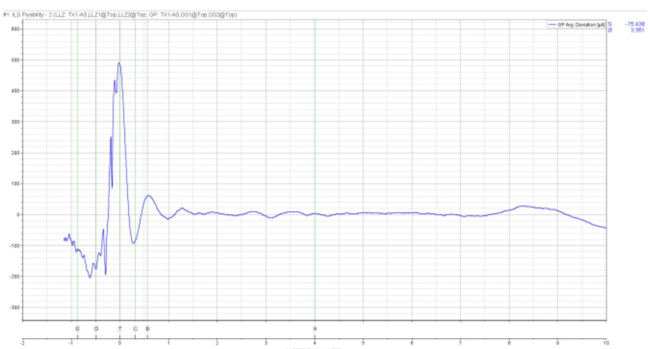

Figure 3: Peak in Vertical Flight Path Before Landing

The core question here is why the aircraft flew this way – despite the glideslope not being the reason for this.

The main cause of this confusion was the dominant source of vertical guidance information. While the glide path signal of the ILS receiver is used for most of the approach, the radar altimeter becomes the dominant vertical guidance source close to the threshold. Accordingly, the recorded output of the radio altimeter was analyzed. Figure 4 shows the difference between the pressure altitude and the radar altimeter measurements, so effectively the measured terrain elevation underneath the approach path.

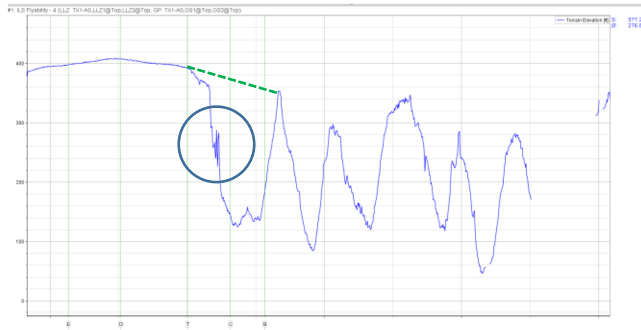

Figure 4: Terrain Elevation Underneath Approach Path

The terrain elevation shows significant valleys between hills shortly before the threshold. In addition, very near to the threshold some signal fluctuations can be observed. By looking at the aerial image in Google Earth (as shown in Figure 5), a rather deep valley with steep elevation gradients (depicted in blue) can be identified easily by the serpentine-style road. In addition, installed radar reflectors can be seen (within the green circle).

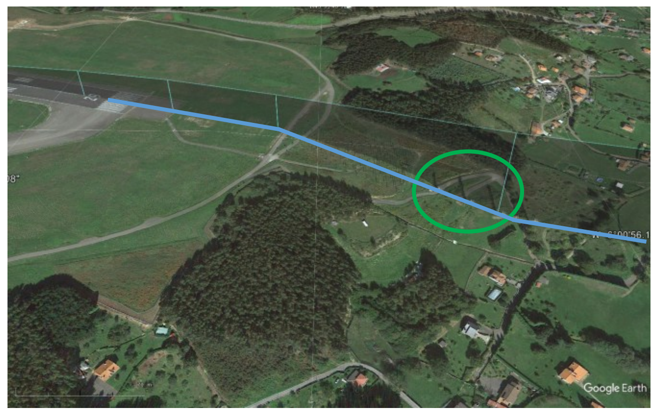

Figure 5: Aerial Image of Final Approach
Blue: Approximate Terrain Gradients
Green: Installed Radar Reflectors

As it turned out, the radar reflectors (which, according to older aerial images, had been in place for years) were not overly effective in smoothing the elevation profile for the radar altimeter, which in turn mainly indicated the actual terrain instead.

Accordingly, the autopilot increasingly uses the radar altimeter readings as it gets closer to the ground, which causes the airplane to oscillate vertically at low altitudes, contributing to the reported hard landings.

INCONSISTENT VOR FMDR MEASUREMENTS

During the initial commissioning of a Doppler VOR facility, a flight inspection service provider noted strange deviation ratio measurements of the frequency modulation (FM), but only for this specific VOR. This measurement (also called FM deviation ratio – FMDR) is shown in Figure 6 and differs significantly from the nominal reference value of 16.

Figure 6: Screenshot Showing Excessive VOR Deviation Ratios

At the same time, the customer reported that another flight inspection system did not notice any significant disagreements.

Due to this occurring only at one single VOR station and the two flight inspection receivers on board reporting invalid but differing FMDR values, Aerodata suspected an error within the VOR installation and asked the customer to check the VOR video signal on the oscilloscope, which (as visible in Figure 7) turned out to be significantly distorted.

Figure 7: Oscilloscope Screenshot of the Distorted VOR Video Signal

Based on this, the customer initiated a detailed inspection of the VOR installation, which found an incorrect cable connection within the VOR station. After this was fixed, a new flight inspection was conducted, which confirmed that the observed problem was fixed. The FMDR (as shown in Figure 8) was measured close to the nominal value of 16.0 and the VOR video signal (as shown in Figure 9) no longer showed any distortions.

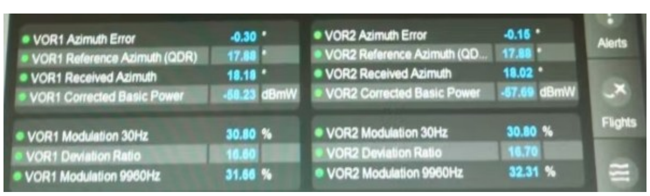

Figure 8: Screenshot Showing Nominal Deviation Ratios

Figure 9: Oscilloscope Screenshot of the Corrected VOR Video Signal

This once more confirmed the sensitivity of modern flight inspection equipment to errors on the ground side, but also the possible differences between different flight inspection equipment.

MISSING GBAS OUTPUTS

During the initial commissioning of a ground-based augmentation system (GBAS), the modern flight inspection GBAS receiver (AD-GBAS-0100) did not output any GBAS solution, despite good reception of the signals from the global navigation satellite systems (GNSS) and the VHF Data Broadcast (VDB), so that the station could not be accepted by the flight inspection crew.

The used AD-GBAS-0100 receiver uses multiple ARINC 429 output channels for its outputs, which are recorded by the automatic flight inspection system (AFIS). A thorough analysis of this case was conducted, using the recorded data.

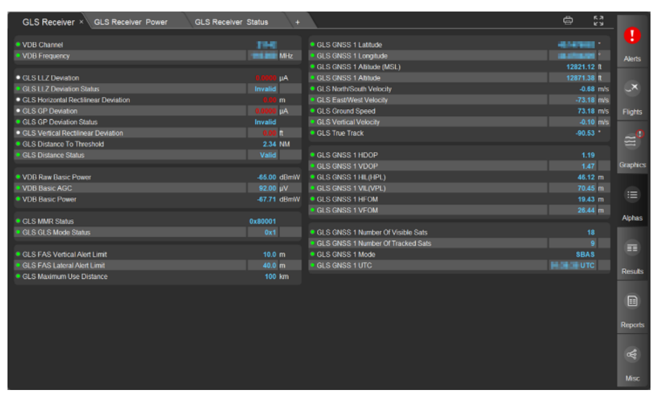

Figure 10: GBAS Deviations Invalid (red)

First, as shown in Figure 10, a replay of the data confirmed that the GBAS receiver did not output any valid GBAS deviations, but had sufficient VDB and GPS (incl. SBAS) reception. The cause for this unexpected behavior could not be found based on the parameters displayed within the software alone, so that a deep analysis of the recorded data was conducted.

To further assess the behavior of the flight inspection GBAS receiver, a more detailed analysis of the diagnostics outputs of the receiver was conducted outside the AeroFIS software. The receiver itself outputs various additional status messages with differing content, which were analyzed carefully.

The only indication of a problem in this data was eventually found in a status message regarding the authentication service, in which the 'Differential Correction Magnitude Check' (DCMC) was found to be failed.

The GBAS authentication service (as required by DO-253D [4]) is a multi-layer algorithm intended to add protection from malicious attacks via additional VDB data. The AD-GBAS-0100 flight inspection GBAS receiver is based on TSO-approved equipment designed to support the GBAS Approach Service Type (GAST) D for future CAT-II/III operations. This includes the necessity for the receiver to support the GBAS authentication service, which is purely optional for GAST-C only receivers, but mandatory for equipment intended to support GAST-D. The differential correction magnitude check belongs (with numerous other algorithms) to this authentication service, but must be checked even if the authentication itself is not activated by the ground facility.

The DCMC is an algorithm intended to limit the maximum horizontal position difference due to the correction data received via VDB. This 'horizontal position differential correction magnitude' (HPDCM) is compared to a fixed limit of 200 m, which will never be exceeded under normal operating conditions. However, this monitor check failed for this specific flight inspection. Further analysis with two independent GBAS processing tools (Pegasus by Eurocontrol and TriPos by the Technische Universität Braunschweig) confirmed this behavior.

The GBAS standards clearly state that a GBAS receiver shall perform this check even if the authentication service is not active, and shall not output any valid GBAS deviations after this check fails "so long as the approach remains selected". (ref § 3.4.9.5, [4]) As flight inspection operations usually check one specific approach, the approach selection of the flight inspection GBAS receiver never changed. Subsequently, no GBAS deviations were provided for the whole flight.

While this analysis could explain what happened exactly and that the receiver did exactly what it should do, the root cause for this could not be determined directly. Subsequently, the raw VDB data from the ground station was analyzed in deep detail outside of the AeroFIS software.

The GBAS ground station under flight inspection was of non-western type, supporting Glonass next to GPS. While the VDB Message Type (MT) 4 (for approach information) did not show any flaws, the station and integrity parameters (contained in MT2) and the differential corrections (in MT1) were found to expose anomalous characteristics.

The MT2 VDB messages from the ground station contain different parameters, which are used by the GBAS receiver to ensure overall integrity. The values displayed in Figure 11 show periods with normal operations next to periods with anomalous behavior. This was the first indication that something within the GBAS ground station was not behaving as expected.

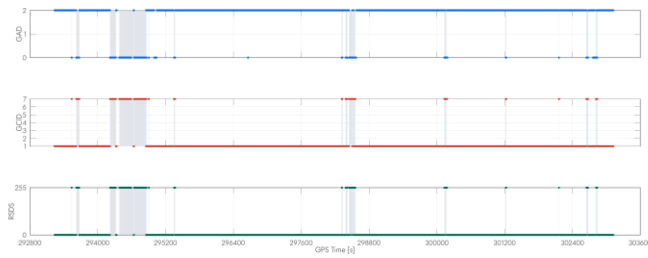

Figure 11: Received MT2 Integrity Parameters

This was confirmed by a deep analysis of the differential corrections being broadcast in the MT1 messages by the ground station. As shown in Figure 12, the differential corrections also showed strong diverging behaviors for different times.

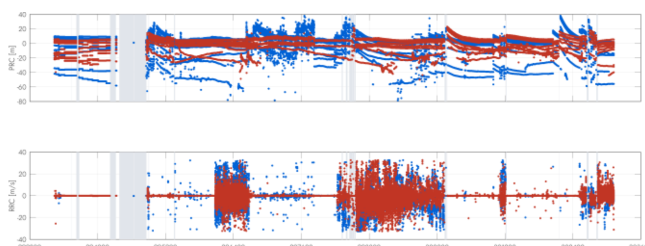

Figure 12: Received MT1 Pseudorange Correction (PRC) and Range-Rate Correction (RRC) Values. (Blue: GPS, Red: GLONASS)

For compensating differences between the time of reception and time of applicability of the differential corrections, the transmitted modified Z-count and the individual range-rate corrections (RRC) are being transmitted within the MT1 messages. The transmitted modified Z-counts and the respective time differences to the time of reception are shown in Figure 13.

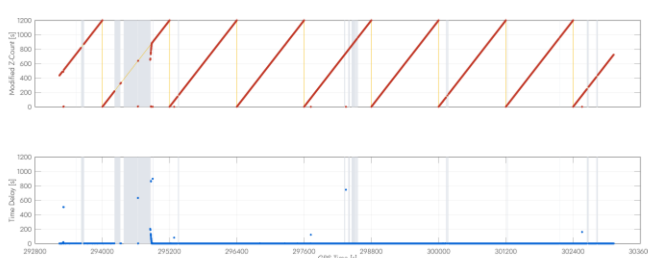

Figure 13: Received MT1 Timing Values

Here, the time offset between the applicability of the differential corrections and the reception time exceeds 800 s at one point. For this point, the transmitted range-rate corrections are multiplied with this delay, resulting in excessive differential corrections, which in turn let the DCMC algorithm fail here.

To conclude, both the flight inspector and the GBAS receiver acted correctly here. The overall performance of the GBAS ground facility was not sufficient for regular operation. The GBAS station transmitted invalid VDB data which prevented the modern flight inspection GBAS receiver from outputting its GBAS solution.

If this station had been inspected using legacy GBAS equipment, this would most probably not have been detected. As mentioned before, legacy equipment is not required to perform the differential correction magnitude check and would have output valid GBAS solutions continuously in this situation.

This underlines the dependence of flight inspections on the equipment used, and that legacy equipment would flawlessly operate with the flawed ground station. Only the additional checks of modern equipment were able to detect these errors of the ground station, which were not covered by the (already finished) approval of the ground installation.

In addition, it is important to note here that such persistent errors flags in the receiver can only be reset by changing the selected approach. Flight inspection operators are advised to change the tuning of the GBAS receiver manually in case of similar observations.

SUMMARY

From time to time, real-world flight inspections result in ambiguous observations, which must be analyzed in detail to understand the root causes. Three different issues were described and analyzed. For best understanding, all available information must be used and taken into the actual context of the inspection, especially if anything (on the ground or the airplane side) has changed lately. In addition, particularly the comparisons of different types of equipment (e.g. legacy vs. new or analog vs. digital) often lead to confusion due to different characteristics and results.

To summarize, the authors would like to give the following tips to flight inspection operators:

- If the numbers look weird, visualize the signal and check if its waveform is as expected.
- Think outside the box (illegal terrain vs. correct GP signal).
- Complex systems (like GBAS) have complex failures, all details matter.

REFERENCES

[1] S. Jagieniak, *“Traps and Pitfalls in Flight Inspection”*, IFIS 2016, Belgrade, Serbia, 2016

[2] S. Jagieniak, *“More Traps and Pitfalls”*, IFIS 2018, Monterey, 2018

[3] S. Jagieniak, *“Traps and Pitfalls reloaded“*, IFIS 2024, Nagoya, Japan, 2024

[4] Radio Technical Commission for Aeronautics (RTCA), *“DO-253D: Minimum Operational Performance Standards for GPS Local Area Augmentation System Airborne Equipment”*, July 2017