Go-Arounds at Addis Ababa due VOR Reception Problems

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The following article was provided by the involved Airbus operator and has been reproduced with their agreement but has been de-identified. At the end of the article there is information on the Airbus policy concerning the use of GPS position for Terrain Awareness and Warning System (TAWS). This policy was issued in an OIT/FOT (ref: SE 999.0015/04/VHR dated 05 February 2004).

The same crew and aircraft had been scheduled to operate the flight from **** to Addis Ababa Bole Airport (HAAB) with a single en-route stop at****.

The first sector was operated without incident and, after disembarking passengers and refuelling, continued to HAAB. On arrival overhead the Addis Ababa VOR/DME (ADS 112.90 MHz), the flight was cleared to carry out a standard VOR/DME approach to runway 25L at Bole. Touchdown elevation at Bole was 7593' amsl and the MDA for the procedure 8020' amsl. There were no civilian radar facilities.

The VOR/DME indications had appeared normal up to the start of the procedure, but during the outbound leg, ADS 092° radial, an unexpected large correction left was required to acquire the radial. After flying the ADS DME 13nm arc, a left turn was made to intercept the 249° inbound QDM and descent from 11200' amsl commenced in accordance with the procedure. The VOR radial started fluctuating during the descent and eventually the indications disappeared. With no adequate visual reference, a standard missed approach was flown from a minimum altitude of 8922' amsl and the aircraft entered the hold over the ADS. Once in the hold and after confirming with Bole ATC that the VOR/DME was serviceable the crew carried out a navigation accuracy check that appeared normal and elected to carry out a further approach. Once again, the VOR indication fluctuated during the inbound leg and another missed approach was flown from a minimum altitude of 8866' amsl after which the aircraft diverted to Djibouti. A brief EGPWS "Terrain Ahead" warning occurred as the go-around was initiated.

After refuelling at Djibouti, the commander elected to use his discretion to extend the flying duty period and return to HAAB. On arrival at Bole, a daylight visual approach was flown to runway 25L and a successful landing made. It was noted during this approach that the VOR bearing information was in error up to 30° and that any attempt to fly the procedural inbound QDM would have displaced the aircraft to the North of the required track.

The commander filed an Air Safety Report (ASR) as required by the company in the event of any go-around. Normal company procedures also required an inspection of flight data from the Quick Access Recorder (QAR) as part of the follow up to any ASR and the company Flight Safety Manager carried this out.

The analysis revealed that at some point on both approaches the aircraft had passed over a ridge of high ground not normally encountered on the 25L approach. At the point at which the second go-around had been initiated the aircraft had passed over the ridge with a clearance of 55' as shown by the radio altimeter recording. At no time were the crew aware of this close proximity to the ground.

A full company investigation into the circumstances of the incident continued independently of the official investigations initiated by the state authorities concerned and with the assistance of the Airbus Flight Safety Department. Following the outcome of the company investigation, the company has put in place measures to minimise the risk of similar incidents which include:

- HAAB to be treated as a Category 'C' airport,
- Operations to HAAB to be conducted by GPS equipped aircraft only,
- Approach to be discontinued if VOR indications differ from GPS derived FMGS indications by more than 5°,
- The MDA for the 25L VOR/DME procedure raised to 9380' amsl (1790' aal) in association with a minimum visibility of 5KM,
- Approach to be discontinued if no visual contact with the runway approach lights at ADS DME 5nm (FAF). (ie MAP is ADS 5DME)

Note: The last two restrictions have since been relaxed as confidence in the "ADS VORDME was regained. The airport authorities have also installed an ILS on this runway and a new DVORDME facility in the area since this incident took place.

The incident aircraft has also been fitted with a GPS engine in the EGPWS computer as an interim measure, with a full GPS MMR upgrade scheduled for early 2005.

Navigational Considerations

All Airbus A320 aircraft are fitted with triple Inertial Reference Systems (IRS). The navigation function is performed by the dual Flight Management & Guidance Computers using the outputs from the IRS and refining the combined IRS position with radio navigation aid or GPS satellite information. The involved aircraft is not fitted with GPS satellite navigation equipment and the position refinement is taken from ground radio navigation aids only, typically DME/DME, VOR/DME or VOR/VOR crosscuts depending on local availability.

In the area of Addis Ababa the only suitable radio navigation aid was the "ADS" VOR/DME located between the two runways at Bole Airport at position N08 58.7 E038 47.9. It follows, therefore, that any error in the transmitted data from this VOR would result in a corresponding error in the computed FMGC position. Such errors could result from faulty operation of the VOR/DME facility, radio frequency interference with the transmitted data or anomalous radiation caused by local terrain (sometimes referred to as "scalloping").

The possibility of faulty airborne equipment had to be considered but this is unlikely as similar anomalous VOR indication behaviour was observed during a subsequent approach by another A320 fitted with a GPS. This latter occurrence was witnessed by the Flight Safety Manager.

The incident was discussed with the Director of the Air Operations and Navigational Aids Department (DONAD) and the Head of Safety Investigations of the Ethiopian CAA. The former stated that he was not aware of any other reports of problems with the ADS VOR but that an investigation would be carried out in response to this particular report. On the following day a verbal report was received that an examination

of the VOR transmitter had revealed a 2°error in the radiation pattern and that an alternative transmitter was in service. Calibration of the alternative transmitter appeared to have been by pilot report from GPS equipped inbound aircraft and it was stated that the pattern was correct.

At a subsequent meeting with the Flight Safety Officer of Ethiopian Airways it was stated that there had been concerns from Ethiopian Airways pilots that the inbound leg of the 25L VOR/DME procedure was "taking aircraft too far north of the ideal track". It was not clear whether these concerns had been relayed to the Ethiopian CAA, although it was stated that Ethiopian Airlines was putting pressure on the CAA too install an ILS for this runway prior to the rainy season that starts around July/August.

The following day, the company Flight Safety Manager was subsequently contacted by Bole ATC and advised that the ADS VOR had been taken out of service following a fault caused by the heavy rain that had occurred during that evening. The company flight for that day had already departed and was diverted to Khartoum. A further call from Bole ATC confirmed that the VOR was back in service and fully serviceable. The diverted flight arrived at HAAB with no reported problems.

Addis Ababa Bole International Airport (HAAB)

Bole Airport is located on the south western outskirts of the city of Addis Ababa, Ethiopia. The airport reference co-ordinates shown on the EAG Aerad chart are: N08 58.7 E038 47.9

Addis Ababa is situated on the Ethiopian plateau at an elevation of 7600' amsl and is surrounded by areas of high ground rising to approximately 11000' amsl.

The airport has been undergoing significant development in recent years and has recently seen the construction of a new terminal building and the new 07R/25L runway. The new runway lays parallel to and approximately 400m south of the original 07L/25R. The ADS VOR was moved to its current location south of the two runways during the development.

In current operations 07R/25L is used as the main runway with the old runway designated as taxiway "Foxtrot". However, 07L/25R is still used as an active runway by local traffic.

The only instrument approach procedures currently available to the operator at the time were the VOR/DME procedures for 25L and 25R. Landings on runway 07R are achieved by carrying out the 25L VOR/DME procedure and breaking left for a visual circling approach to 07R. The Ethiopian CAA has promulgated a GPS/RNAV procedure for runway 07R and will shortly promulgate one for 25L. The involved operator does not currently hold an approval for GPS/RNAV approaches. Full ILS procedures for both 25L and 25R are now promulgated.

In addition to the ADS VOR, there were two MF locator beacons, 'AB' 333 KHz and 'BL' 352 KHz, situated on the original ILS approach path to 25R. There were no ILS procedures promulgated for the airport at the time, although the original 25R ILS localiser was believed to be still radiating on 110.3 MHz. New aids have now been installed as stated above.

Terrain Considerations

The airport is situated on a relatively flat plain at 7600' amsl. The level of the plain rises gradually to the east attaining an elevation of approximately 8500'amsl 15nm from the airport. There are significant high peaks around the airport as follows:

- 10535' amsl 010°T / 8nm
  Bearings and distances are approximate
- 9646'amsl 025°T / 11nm
  from VOR/DME position
- 10167' amsl 120°T / 11.5nm
- 9200' amsl 230°T / 9nm

There is a significant ridge running approximately 135°T from the first of the above peaks and running out into the plain at about 6nm from the VOR. This ridge is the one referred to in later sections of this report. A further ridge runs approximately 215°T from the same peak towards the eastern outskirts of the city. This runs out into the plain approximately 3.5nm north of the airport.

Terrain information is provided for the crew by the following:

- EAG Aerad charts N1/N2

these show "safety contours" and Sector Safe Altitudes for the four prime sectors within 25nm of the aerodrome reference point. At Addis, the SSA for all sectors is shown as 13500'. No detailed terrain information is shown.

- EAG Aerad Terrain Chart

A large scale chart showing the main features in a large area around Addis. No fine detail of terrain around the airport is shown.

- Military ONC Chart

A 1:1000000 scale chart of the region

The involved aircraft is fitted with a Honeywell Enhanced Ground Proximity Warning System (EGPWS) with software to standard 428. The EGPWS computer has been removed from the aircraft and an attempt made to download event data from it. This was initially unsuccessful due to a fault condition at the time of removal. The unit was returned to the OEM who achieved a download in his workshop. During the subject approaches and go-arounds the crew heard only one EGPWS alert, a "Too Low Terrain" call just after initiation of the second go-around believed to have been triggered by the Terrain Clearance Floor mode. The QAR recorded a short duration Mode 4 "Too Low Terrain" warning at about the same time.

This photograph shows the NW to SE ridge running down towards the approach path. It was taken from near the village of Leghedadi 10nm NW of the airport looking WSW from a range of approximately 5nm.

This picture shows the same ridge from a range of about 8nm from the NW of Leghedadi.

Terrain Profiles

The following approach and terrain profiles were derived using the data from the QAR. The pressure altitudes recorded have been corrected for a QNH of 1027 HPa for Figure 1 and 1029 HPa for Figures 2 & 3.

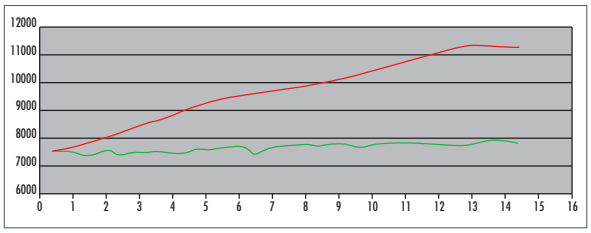

Figure 1

Figure 1 shows the profiles for the approach carried out on the return from Djibouti which was carried out visually. The terrain profile is typical for a correct approach path with the characteristic gentle slope of the plain from west to east. Other characteristic features are the river valley at 6.5D and the double depression on the final approach to the threshold.

The distance scale on this figure can be directly related to DME distance from the "ADS". In Figures 2 & 3, the 13nm marker can be taken as 13D from the "ADS", but other distances do not relate to DME as the aircraft was not flying towards the DME facility. The distances have been corrected to take account of the varying groundspeed during each approach.

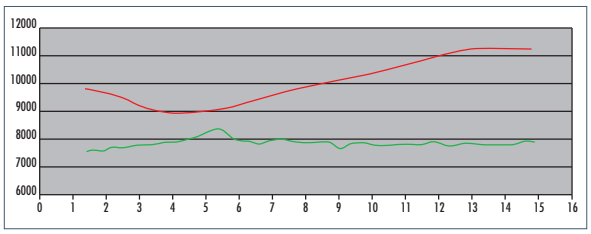

Figure 2

Figure 2 shows the profiles for the first approach at HAAB. Notable points are the non-sloping nature of the terrain between 15nm and 6nm and the high point at just over 5nm. There is also a marked valley at 9nm and a lesser one at 6.5nm.

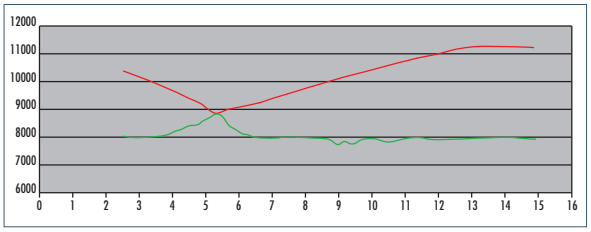

Figure 3

Figure 3 shows the profiles for the second approach at HAAB. Here, the notable points are again the flat terrain between 15nm and 7.5nm and the high point at just over 5nm. The river valley is still apparent at 9nm, but has split into two. The terrain clearance at the point of go-around is 55'.

Aircraft Position

The only position information available from the QAR was the recorded FMGC latitude and longitude. Since the FMGC position was IRS position corrected by radio position and the only radio position was based on the suspect VOR/DME facility, no reliance can be placed on the accuracy of the recorded position information.

One point of interest was the behaviour of the recorded FMGC position immediately after each go-around. The standard missed approach procedure for the 25L VOR/DME approach states "Left (max 185kt) as soon as practicable onto ADS 193R to 13500 5910 then right to ADS and hold or as directed". (EAG Aerad Chart N1 dated 20 FEB 03). On both go-arounds the recorded heading information suggests that the aircraft followed this procedure. The FMGC position data, however, indicates a right turn immediately after each go-around followed later by an abrupt left turn onto a southerly track.
The crew report stated that during each approach the VOR indications were lost just prior to the go-around, but came back as the go-around proceeded. During the approach made by the GPS fitted aircraft the following behaviour was observed:

- During the outbound leg of the procedure, the VOR bearing information correlated with the GPS derived FMGC data on the Navigation Display (ND).
- As the aircraft turned left to intercept the 249°M track inbound to the VOR, the beam bar initially moved in as expected to near centre.
- As the wings were levelled on a heading that should have followed the correct track, the beam bar moved back out to the right and settled at about half to two thirds full scale deflection.
- The crew flew by visual reference to the runway using the GPS derived navigation data to follow the correct inbound track and the VOR indication remained steady at the deflection stated above.
- At about 3.5D, the beam bar quickly moved back to the central position.

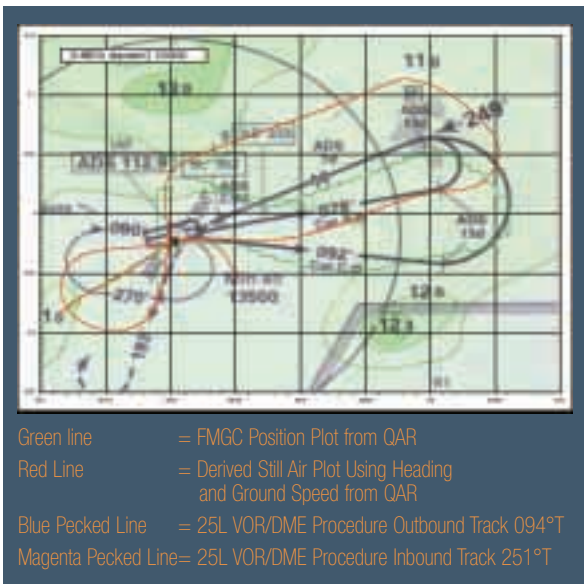

Figure 4

The two approaches flown during the incident flight were both conducted in IMC with only one glimpse of ground lights during the first approach.

Figure 4 on shows the track for the second approach.

Initially, as the procedure is commenced, the FMGC track and still track appear to be following the procedural 094°T track. The FMGC track then starts to deviate to the south and the aircraft is turned left to correct taking the still air track to the north of the required track. This correction brings the FMGC position slowly back to the required track, but the still air track is moving well north.

Airbus Policy

This Airbus policy is concerning the use of GPS position for TAWS operations. Note that the TAWS is also known as EGPWS (Enhanced Ground Proximity Warning System) or T2CAS (Traffic and Terrain Collision Avoidance System).

The TAWS computer has an internally loaded terrain database and uses position information from the FMS. The FMS uses ADIRU position and radio position update. It can also use a GPS position source when available.
The use of the GPS with multimode receivers (MMR) provides improved navigation and surveillance functions. Therefore Airbus strongly recommends the use of a GPS source in the global architecture of the TAWS system.

Airbus offers an upgrade package that includes installation of 2 multimode receivers (MMR) and 2 GPS antennas.
However some aircraft configurations may need upgrade of other aircraft equipment to make full benefit of the MMR system. The Airbus upgrade services will define everything needed during the RFC/RFO process.

For more information see OIT/FOT ref SE 999.0015/04/VHR, dated 05 Feb 2004

SAFETY FIRST

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