SERIOUS INCIDENT

Aircraft Type and Registration:	Airbus A340-313, G-VAIR
No & Type of Engines:	4 CFM56-5C4 turbofan engines
Year of Manufacture:	1997
Date & Time (UTC):	27 April 2008 at 0218 hrs
Location:	Nairobi Airport, Kenya
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 14 Passengers - 108
Injuries:	Crew - None Passengers - None
Nature of Damage:	Minor scratches to left aft lower fuselage
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	14,250 hours (of which 9,667 were on type) Last 90 days - 108 hours Last 28 days - 41 hours
Information Source:	AAIB Field Investigation

Synopsis

During the final stages of landing at Nairobi (NBO) the flight crew lost visual references, during which time the pilot flying made a left rudder pedal input. A go-around was initiated. However, the aircraft touched down and the left main landing gear ran off the paved runway for a distance of 180 m. No significant damage occurred. The Ministry of Transport (Air Accident Investigation Department) of Kenya delegated the entire investigation to the UK AAIB and appointed an Accredited Representative to assist with the subsequent enquiries.

At an early stage of the investigation the AAIB issued a Special Bulletin to publicise factual information available at that time. Due to the inability to obtain pertinent information related to a number of areas of inquiry, the Chief Inspector of Air Accidents has ordered that this report be completed as a Bulletin rather than an Inspector's Investigation.

Five Safety Recommendations are made.

History of the flight

G-VAIR was scheduled to operate a London Heathrow (LHR) to Nairobi (NBO) passenger flight. The crew reported for duty at 1745 hrs and the flight was uneventful until the landing.

The 0100 GMT ATIS obtained by the crew for NBO before the top of descent reported the wind to be from 040° at 3 kt with 7 km visibility, broken cloud at 1,600 ft, temperature and dewpoint 15°C and QNH 1020. The crew carried out an area navigation (RNAV) standard arrival procedure to join the ILS for Runway 06. All navigation aids at NBO were reported to be serviceable. The ATIS weather was confirmed with Approach Control at 0153 hrs during the early part of the RNAV arrival. At 0210:03 hrs Approach passed information to G-VAIR that an aircraft ahead had reported the landing visibility as 3,000 m with a cloudbase of 300 ft agl. Approach then transferred the aircraft to Tower.

At 0210:43 hrs G-VAIR was cleared to land by NBO Tower and the controller advised: "THE VISIBILITY REPORTED AS 3000 M LAND AT YOUR OWN DISCRETION WIND 050 AT 05 KT". The First Officer, who was pilot flying (PF), re-briefed the go-around actions and the approach was continued with the autopilot and autothrottle engaged. The crew stated that they became visual with the runway at a height of between 300 and 200 ft. At the decision height of 200 ft, both pilots had more than the minimum visual reference required and could see "all the approach lights and a good section of runway lights". The autopilot was disconnected at 100 ft radio altitude and the PF began to flare the aircraft between 75 and 50 ft radio altitude. The aircraft floated at around 20 ft for a few seconds before it entered an area of fog and the PF lost sight of the right side of the runway and the runway lights. The commander also lost sight of the right side of the runway.

The aircraft touched down in a normal attitude but on the main gear only; the body and nose gear did not contact the ground throughout the event. The PF was not aware that the aircraft was moving laterally on the runway, but the commander became aware of the left runway edge lights moving rapidly closer to him before he lost the lights completely and was only aware of their position by the glow of the lights illuminating the fog. The commander called "go-around" and the PF immediately advanced the thrust levers from idle to full thrust. G-VAIR became airborne after a period of just under five seconds on the ground. The gear retracted normally and the crew continued with the go-around, climbing to an altitude of 9,000 ft to enter the hold. During the ground roll the crew had heard and felt a rumbling and suspected that the aircraft might have departed the left side of the declared runway although they did not believe that the aircraft had left the paved surface. The aircraft entered the hold while the crew considered their options. Having decided to divert to Mombasa the commander informed ATC that they may have run off the runway side and that they wished to divert to Mombasa. The First Officer remained as PF for the diversion, which was followed by a normal, day VMC landing.

Ground marks

Having been advised of the possibility that the aircraft had run off the runway an inspection by Nairobi Airport staff confirmed the presence of a set of landing gear tracks running off to the left of the paved surface. They believed these had been made by the main gear of G-VAIR. The marks started 800 m from the threshold of Runway 06 and continued towards the edge of the runway for 160 m. From that point the marks from the left main gear passed over a runway light (which had been destroyed) before continuing off the paved surface and then curving right to run approximately parallel with the runway for 180 m. The set of marks from the right main gear did not quite leave the paved surface (stopping 5 cm from the edge of the paved shoulder) although they were off the declared runway surface. The airport staff provided a diagram depicting the ground marks and this is shown in Figure 1. Photographs of the ground marks were also taken at six hours and 14 days after the event. These are shown in Figures 2 and 3 respectively.

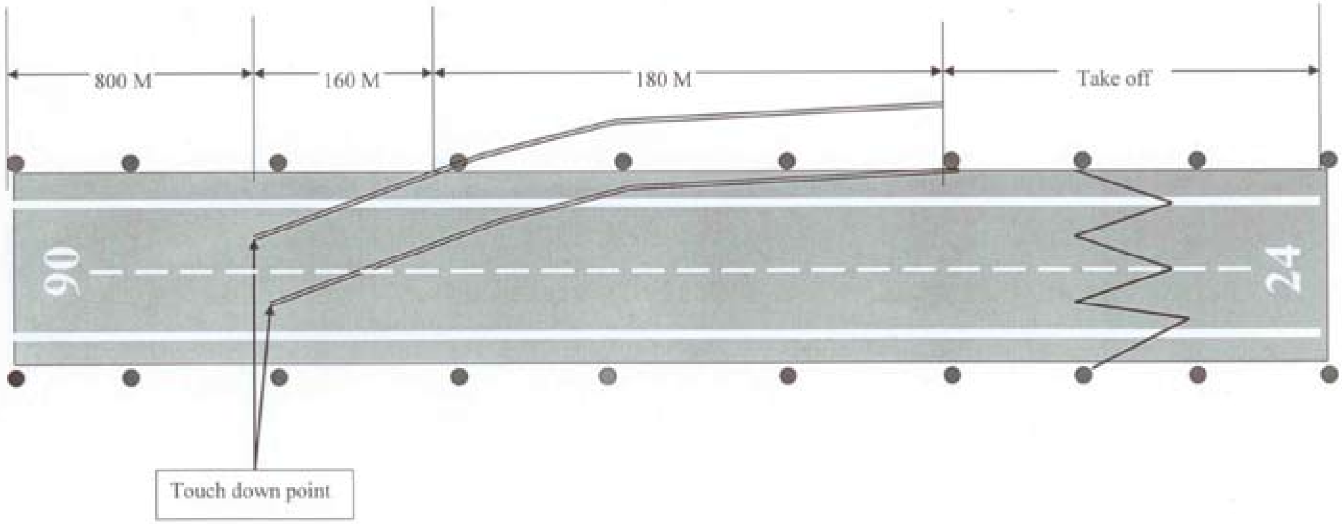

Figure 1

Diagram depicting ground marks

Figure 2

View towards the touchdown point

Figure 3

Left hand runway edge markings for Runway 06 with G-VAIR left main gear tyre tracks visible

Damage to aircraft and infrastructure

Aircraft inspections were carried out at Mombasa in accordance with the aircraft Approved Maintenance Manual (AMM). During initial inspections mud spray was noted on the fuselage and left horizontal stabiliser. After washing the aircraft, minor scratches were discovered on the lower left fuselage. These were assessed as paint chips and minor abrasions within the limits laid down in the AMM. The outboard left aft wheel on the left main gear had slight damage to the sidewall but was within AMM limits. As a precaution this wheel assembly was replaced on return to London Heathrow. At Nairobi, one runway edge light was destroyed.

Flight recorders

The aircraft was fitted with a solid-state Cockpit Voice Recorder (CVR) which recorded the last two hours of flight crew speech and cockpit area microphone (CAM) sounds, a solid-state Flight Data Recorder (FDR) with a capacity for recording over 25 hours of data, and a Quick Access Recorder (QAR) that recorded data onto a removable optical disk.

Following the incident, the operator requested that the CVR, FDR and QAR optical disk be removed from the aircraft. However, due to a lack of replacement units at Mombasa, it was decided to conduct a non-revenue flight back to Heathrow with the recorders installed, but with the circuit breakers for the CVR pulled to preserve the two-hour recording. The FDR and QAR were allowed to record during the flight in the knowledge that the recordings of the incident would not be overwritten during the flight back to Heathrow, given the duration of the flight and the recording capacity of the recorders.

Although the CVR circuit breakers (CBs) had been 'pulled and collared' at Mombassa as requested, the recording was inadvertently overwritten at Heathrow during subsequent attempts made by the operator to download the FDR, and during which the circuit breaker had been reset.

Data from the QAR, normally used to support the operator's Flight Data Monitoring (FDM) programme, was replayed by the operator and problems were found with a number of recorded parameters that were essential to this investigation. However, these parameters had been recorded correctly on the FDR.

The FDR recorded information from a large number of flight data and discrete parameters, including relevant air data, engine, control surface and cockpit controls.

Relevant recorded information

A time history of the relevant flight parameters during the approach and aborted landing at Nairobi is shown at Figure 4. The data presented starts at 02:17:40 UTC, 42 seconds before touchdown, with G-VAIR at approximately 450 ft agl, autopilots 1 & 2 engaged and automatic throttle system (ATS) engaged and active in SPEED mode, on the ILS approach to Runway 06. At this point, the aircraft's descent rate was about 800 ft/min, the computed airspeed was a nominal 135 kt, flaps and slats extended (32º and 24º respectively) and the landing gear was down (not shown).

The aircraft continued descending on the ILS with minor variations in heading of ±2º to the runway heading. At approximately 90 ft agl, wings level and 4º nose-up pitch attitude, both autopilots were disengaged (Point A) with multiple FO sidestick inputs and some left rudder following. The ATS remained engaged and active.

Between 40 and 50 ft agl, the PF initiated the flare by briefly pulling back on the side stick (see Point B).

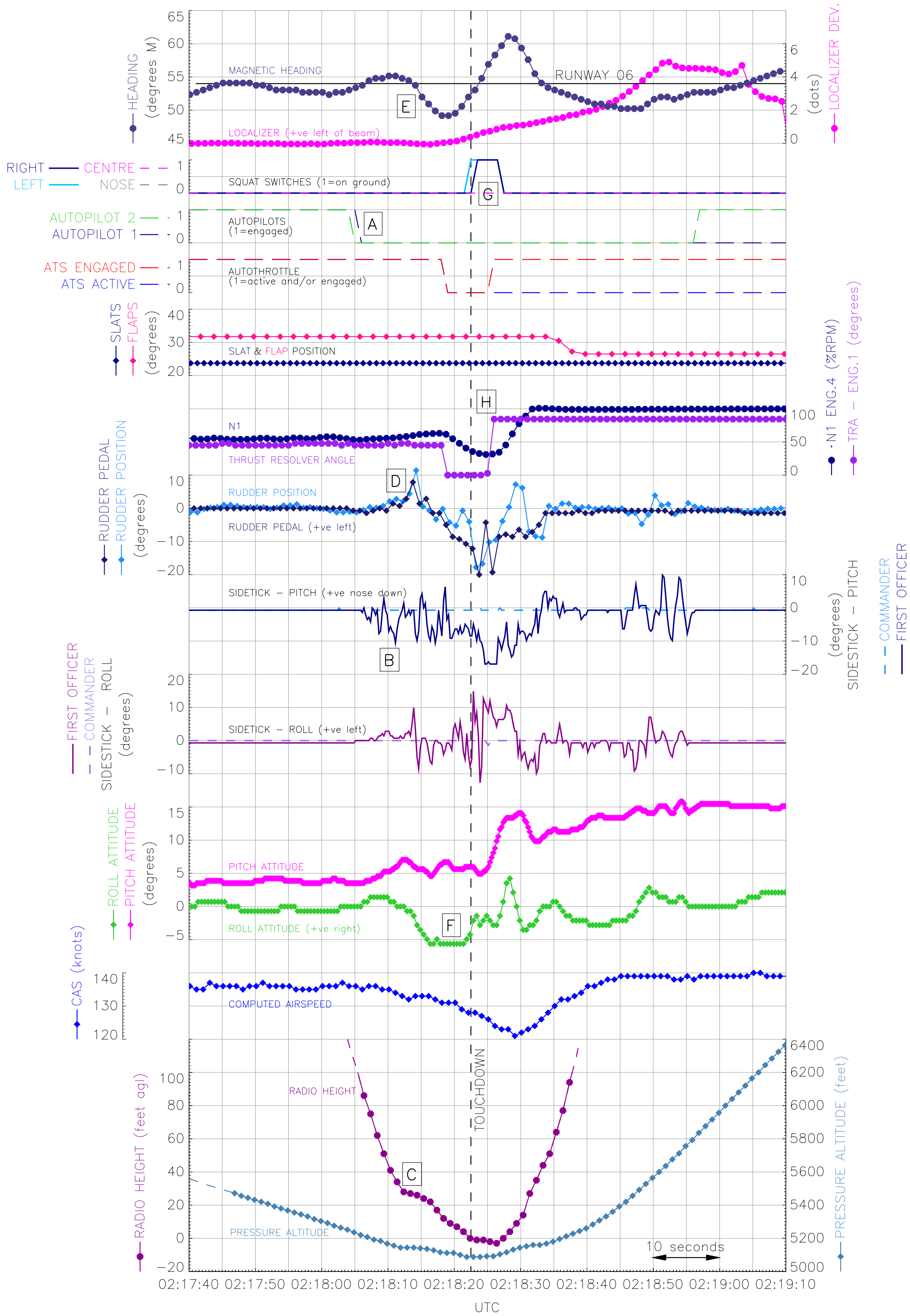

Figure 4

Salient FDR Parameters
(Serious Incident to G-VAIR on 27 April 2008)

This momentarily pitched the aircraft to 7º nose up, and reduced the rate of descent to about 60 feet/minute as the aircraft passed through 30 ft agl (Point C). The FO then put in a 10º left side-stick[1] input followed by an 8º right input, during which the FDR recorded an 8º left rudder pedal[2] input being made (Point D), causing G-VAIR to roll left and drift to the left of the runway centreline (Point E).

The PF continued to make further pitch and roll stick inputs and, as the aircraft passed through 17 ft agl, all engines were throttled back to idle, causing the ATS to drop out automatically. Right rudder inputs were also made that slowed the drift to the left; however, the aircraft remained left wing down till touchdown (Point F).

Touchdown occurred 10 seconds after the flare was initiated, still left of the runway centreline with only the main gear making contact with the ground and the left gear touching down first (Point G). The airspeed at touchdown was 128 kt, with a recorded vertical acceleration of 1.1g (not shown).

The main gear remained on the ground for about five seconds during which TOGA thrust was selected (Point H). A pitch attitude of 13.5º was recorded as the aircraft rotated. The subsequent climb, diversion to and landing at Mombasa were uneventful.

Loss of CVR recordings

The earliest recordings on the two-hour CVR started 35 minutes after the incident. The flight time from Nairobi to Mombasa was only 80 minutes, including five minutes of taxiing at Mombasa; therefore, only the last 45 minutes of the 80-minute flight had been recorded, followed by 75 minutes of recordings while the aircraft was on the ground at Mombasa, and then Heathrow with electrical power on.

In accordance with the operator's procedure to preserve recordings made by flight recorders following an incident, the CBs for the CVR were pulled when the aircraft was on the ground at Mombasa. However, this was done the following day once the aircraft had been put in 'Airworthiness Hold' and ground checks, including engine idle runs, were being carried out prior to its flight back to Heathrow. The aircraft was powered for a total of 40 minutes, during which the CVR was recording, before the CVR CBs were pulled ready for the flight back to Heathrow.

The remaining 35 minutes of the recording was made while the aircraft was on the ground at Heathrow. A request was made for the CVR and FDR to be removed from the aircraft; however, the engineers were unable to get access to the CVR, which was located in the rear bulk hold, because of baggage being unloaded. In the meantime, rather than immediately remove the FDR, the engineers decided to follow their normal maintenance procedure following an incident, of downloading the recorder data onto a flash memory card, with the FDR still on the aircraft. These downloads were done in accordance with Airbus AMM 31-33-00-710-807 which required electrical power on the aircraft and both of the CVR CBs to be pulled and collared. However, problems were experienced with the download so the engineer in charge decided to reset the CVR CBs. The problems continued for a further 35 minutes until the data was finally downloaded, throughout which the CVR was recording. The aircraft was then powered-down and the FDR and CVR subsequently removed.

Since this incident, the operator has taken a number of actions, including changes in procedures, for the

Footnote

1 The maximum side-stick input is ±20.5º.
2 The maximum rudder pedal input is ±30º.

preservation of recorded data following a serious incident or accident. These are:

1. Notice to Aircrew, Reference 52/9 Issue 1, issued 13 May 2009 through 13 November 2009, entitled '*Preservation of data following a serious incident or accident*' – issued to advise all aircrew of their responsibilities to preserve recorded data in the event of a serious incident or accident, particularly with respect to the CVR. It also details the requirement to make a technical log entry for the removal of the recorders. The intention is for this procedure to be replaced by a permanent procedure in the next revision of their Operations Manual.

2. Quality Notice, QN/GEN/142, issued 6 May 2009, entitled '*Preservation of data following a serious incident or accident*' – issued to remind all engineers of their responsibility to preserve data in the event of a serious incident or accident, particularly with respect to CVR recordings. This also details the requirement to make a technical log entry for the removal of the recorders.

3. The aircraft hold procedure detailed in the Quality Notice, QN/GEN/117 (issued 24 August 2007), has been modified to include the requirement to pull and collar the CVR CBs and the making of a technical log entry. This procedure is to be made a permanent procedure (EDP 1.77) by inclusion in the next revision (due July 2009) of their Engineering Department Procedures (EDP). In the meantime the modified procedure has been issued as an Airworthiness Department Temporary Local Operating Instruction.

4. Also to be included in the next revision of the EDP is Issue 6 of EDP 4.39 entitled '*Retention of aircraft parts/documents which are subject of an MOR or ASR*'. This will include all of the new information included in QN/GEN/142.

QAR parameter recording issue

Once the aircraft had returned to Heathrow, the optical disk from the QAR was removed and downloaded by the operator. On examination of the data it became apparent that the commander's and FO's side-stick pitch input parameters, essential parameters for the investigation, were not being recorded correctly.

This problem, however, was already known to Airbus who first became aware of it in April 2006 following complaints from an operator. The problem was traced back to the Data Management Unit (DMU) by Honeywell, the unit's manufacturer, and an interim fix was developed and made available to any operator who contacted them reporting the same problem.

A final fix was developed by Honeywell and published in Honeywell Service Bulletin (SB) No. 967-051X-002-31-15, which detailed the update and installation of the DMU software. The Honeywell SB was then incorporated into the Airbus SB No. A340-31-4104 entitled '*Indicating/Recording Systems – Install Acms Enhanced Dmu Software Step 5.0 For A340 With Cfmi Engines'*, dated November 2007.

The operator of G-VAIR was unaware of the QAR problem until it received the Airbus SB in November 2007, which was subsequently embodied fleet-wide on 13 January 2009.

Go-around training

In March 2008, one month before the G-VAIR event, the UK CAA issued a Flight Operations Communication (FODCOM 11/2008)[3]. A CAA review of Operational Flight Data Monitoring (OFDM) information had shown that there was a '*significant*' trend developing in go-around incidents which was not being adequately covered by pilot training. This FODCOM recognised that routine recurrence training for pilots focused on the go-around from instrument minima usually with one engine inoperative. In order to provide more varied scenarios for go-arounds during operators' training programmes the FODCOM recommended that:

> *'The practice of go-arounds with all engines operating from other than at Decision Altitude should be carried out regularly. As a minimum, this should be included in the operator's three-year training programme but should not be too prescriptive in detail. Unplanned go-arounds should be included to verify pilot understanding of Standard Operating Procedures (SOPs). This would enable operators to vary the training in order that it encompass a variety of circumstances including:*
>
> *a) above Decision Altitude and above the platform altitude in the Missed Approach Procedure;*
>
> *b) between Decision Altitude and touchdown; and*
>
> *c) after touchdown.'*

As the FODCOM had only been issued one month prior to the G-VAIR event the PF had not yet received this additional training. His last recurrent training had been in December 2007, before the FODCOM was issued, and as such he would expect to complete his next set of recurrent training (which would include the additional training identified) in June 2008. He also commented that late go-arounds are not unusual at the operator's home base, however these would not be from such a low height. The operator's Flight Crew Training Manual defines a rejected landing as a go-around manoeuvre initiated below the minima. Training for rejected landings was conducted as part of Category 2/3 operations, but these approaches would always be flown by the commander with the use of automatics.

Following the overrun of an Embraer ERJ-170, the National Transportation Safety Board (NTSB) recommended, in their report published on 15 April 2008, that the Federal Aviation Administration (FAA) improve the training of pilots for rejected landings below 50 ft following rapid reduction in visual cues. It recommended that the FAA:

> *'Require 14 Code of Federal Regulations Part 121, 135, and Part 91 subpart K operators to include, in their initial, upgrade, transition, and recurrent simulator training for turbojet airplanes, (1) decision-making for rejected landings below 50 feet along with a rapid reduction in visual cues and (2) practice in executing this maneuver. (A-08-16)'*

Operator assessment for Nairobi

Before commencing operations to NBO in 2007 the operator conducted an audit of the airfield and its infrastructure. During the audit under '*conditions of surfaces and lighting'* the auditor commented that:

Footnote

3 http://www.caa.co.uk/docs/33/FOD200811.pdf.

> *'Very Heavy rubber deposits on the 06 thresholds. KAA have removal machine but they have only been successful with cleaning more recent rubber deposits. They say that the older deposits have somehow bonded with the runway surface and are resistant to removal. It may ultimately require local resurfacing.*
>
> *Runway centreline markings – SATIS'*

The operator's audit did not identify the runway lighting position or ATC low visibility procedures as being an issue. In the airfield charts provided for Nairobi the operator included the advice:

> *'The weather can include morning fog (especially Nov-Mar) at our planned arrival time…. Additionally the ATIS has been reported as unreliable, and so crews should note that conditions may not be as they expect.'*

> *'Potential Safety Hazards – Fog and thunderstorms possibly unannounced.'*

Airfield information

Runway surface

Runway 06 at Nairobi is declared as 4,117 m long by 45 m wide. It consists of a grooved asphalt surface with 7.5 m asphalt shoulders either side to give a total paved width of 60 m. Two weeks after the incident to G-VAIR, an AAIB Inspector, in conjunction with the Kenyan Accredited Representative, conducted a visual inspection of the runway condition. The touchdown zone area of Runway 06 appeared heavily contaminated with rubber deposits which partially obscured the runway centreline markings. A photograph of this area is shown in Figure 5.

Figure 5

Contamination in touchdown zone area of Runway 06

As part of the inspection it was intended to assess the friction levels of the runway surface, in particular those areas which appeared to be heavily contaminated. However, no calibrated grip testing equipment was available at that time.

Section 7.9 of ICAO Annex 14, Volume I requires that States specify two friction levels as follows:

> *'a) a maintenance friction level below which corrective maintenance action should be initiated; and*
>
> *b) a minimum friction level below which information that a runway may be slippery when wet should be made available.'*

Although requested, no evidence was provided to the investigation that friction tests had ever been conducted. On 18 September 2008, in response to questions from the Kenyan Accredited Representative, the KAA responded that they were "*setting up a procedure for testing the grip levels on the runway and will be updating you on the progress*." By 1 July 2009 no further information had been received on this subject.

Runway lighting

The Runway 06 edge lighting consisted of raised lamps set at the edge of the paved area, a distance of 7.5 m from the edge of the 45 m declared runway strip. This appeared to be at variance with the ICAO Annex 14 Standard which stipulates a maximum distance of 3m from the edge of the runway for edge lighting. The runway had no centreline lighting, nor was it required by ICAO Annex 14. Once it became apparent during the investigation that the position of the runway edge lights was not in accordance with ICAO Annex 14, the operator amended their Company Brief for NBO to draw attention to this fact and to emphasise that:

> *'the absence of centreline lights in combination with the position of the runway edge lights can cause confusing visual clues at DA.'*

The runway lighting was observed by an AAIB inspector during a night arrival two weeks after the incident. During a good-visibility arrival, turning from base leg to final, the runway lighting had a ragged appearance. A UK CAA expert from Aerodrome Standards was of the opinion that this ragged appearance may have been caused by the rotational alignment of individual lights not being uniform.

Photographs of the edge lighting were shown to an expert in runway lighting systems. He commented that, in the photograph shown in Figure 6 below, the glass on the lamp appeared "frosted" which would diffuse the light adversely affecting its output. He also commented that, in one photograph he was shown (Figure 7), the lamp appeared to be misaligned and also that he would have expected to see reference markings to the runway centre line and a unique identifier for each lamp neither of which was visible in the photographs.

The AAIB has offered to conduct a photometric survey of the runway lighting at NBO, but, to date, this offer has not been taken up.

Weather reporting

An Automated Weather Observation System (AWOS) was installed at Nairobi. This system was certified as operational by the manufacturer and accepted into service on 31 October 2006. In addition to sending data to the meteorological office on the airfield it had the capability to provide instantaneous Runway Visual Range (RVR) to the ATC tower as well as other weather information. The display for this system was positioned next to the tower controller's communications desk, as shown in Figure 8.

Figure 6

"Frosted" edge light

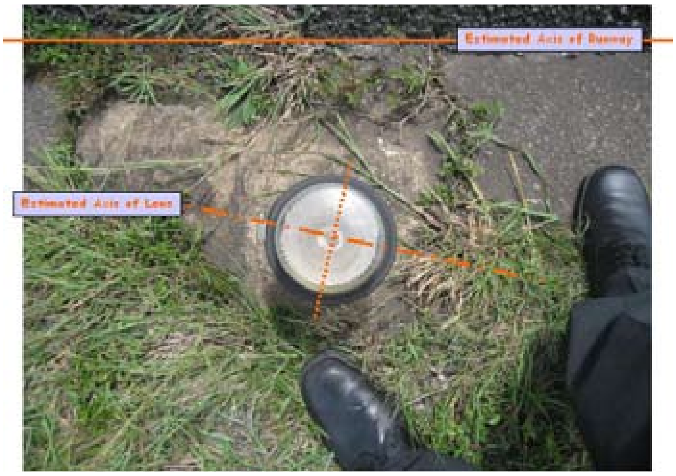

Figure 7

Example of edge light misalignment

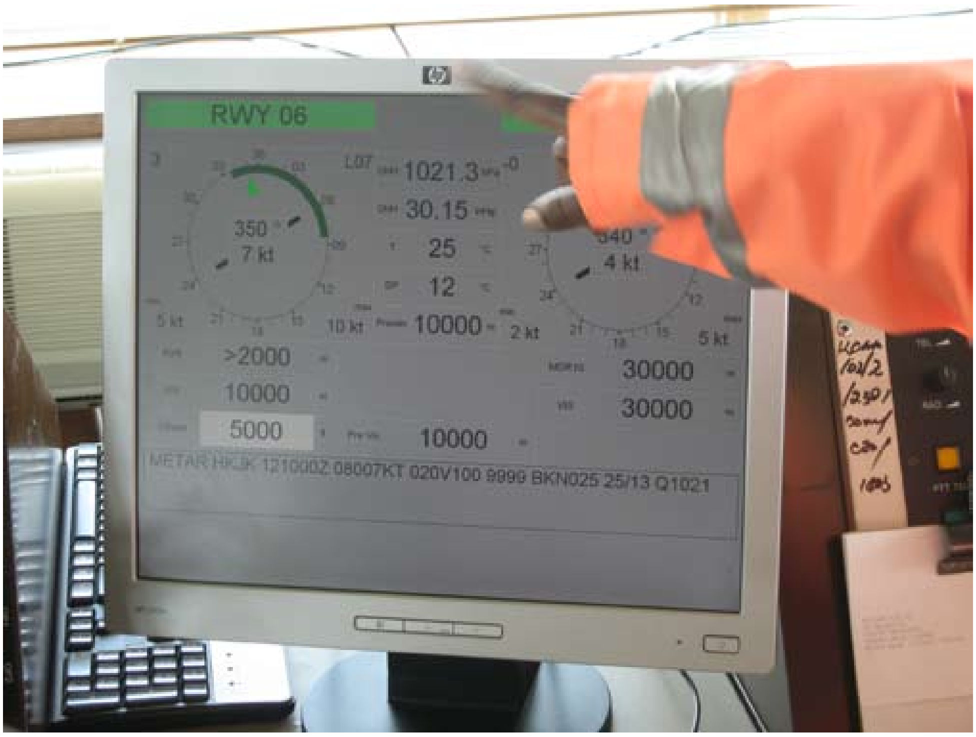

Figure 8

AWOS display in the tower

The RVR sensing system comprised a LT31 transmissometer with a LM21 background luminescence meter positioned near the touchdown zone of Runway 06. According to the system manufacturer the architecture of the AWOS was such that the data recorded in the system memory would have been the same as that displayed on the controller's monitor. There was no direct connection between the AWOS and the control for runway lighting intensity. During its installation, the AWOS was set up to calculate RVR based on a lighting intensity of 100%, in accordance with ICAO Standards. However, should a reduced lighting intensity be selected by ATC, ICAO requires an adjustment to be made in the way that RVR is calculated. In the absence of an automatic system, this would have had to have been done manually by ATC.

Following this event, the memory of the AWOS was downloaded and the manufacturer provided assistance to interpret the recorded information. The AWOS recorded both a Meteorological Optical Range (MOR) and RVR at one minute intervals, with each reading being calculated as an average over the preceding minute. An extract of the recording is shown in Table 1. Note that the times recorded by the AWOS are not synchronised to, but are accurate to within approximately one minute of, UTC. At 0210 hrs the system recorded an RVR of 2100 m (2300 m MOR). For the next three minutes the RVR varied around 1600 m before reducing to 800 m (200 m MOR) at 0214 hrs. The RVR reduced further to 550 m (150 m MOR) at 0216 hrs. The system recorded, and therefore should have displayed, a minimum RVR of 600 m around the time of G-VAIR's attempted landing.

Time	RVR_1A	MOR_1A
27/04/2008 02:08	2100	2400
27/04/2008 02:09	2100	2300
27/04/2008 02:10	2100	2300
27/04/2008 02:11	1600	500
27/04/2008 02:12	1700	550
27/04/2008 02:13	1600	500
27/04/2008 02:14	800	200
27/04/2008 02:15	650	150
27/04/2008 02:16	550	150
27/04/2008 02:17	600	150
27/04/2008 02:18	600	150
27/04/2008 02:19	600	150
27/04/2008 02:20	600	150
27/04/2008 02:21	600	150
27/04/2008 02:22	700	150
27/04/2008 02:23	1000	250
27/04/2008 02:24	1300	400
27/04/2008 02:25	1000	250
27/04/2008 02:26	1000	250
27/04/2008 02:27	1000	300
27/04/2008 02:28	800	200

Table 1

Extract from AWOS recording

The UK Met Office, in relation to the rapid change in visibility shown on the AWOS data, commented that:

> "such changes in visibility (the rapidity of the change in RVR) should be considered realistic in that patches of mist and particularly fog can quickly envelope sensors as the mist/fog is moved with the wind."

The recorded surface winds for ten minutes either side of the incident were between 4 kt and 7 kt from between 040° and 096° (approximately 20 degrees left to 35 degrees right of runway track).

Regarding the RVR capability of the AWOS, the Kenyan Accredited Representative advised that his

> "understanding of the situation is that the automatic system had been installed in the Tower but the controllers had not been trained on it. It is, therefore, possible that the duty controller did not make any reference to it during this incident. This issue is being addressed between ATC and Met".

He further advised that ATC relied on receiving pilot reports and half hourly METARs in order to pass on weather information to flight crews.

It is understood that, as part of the installation contract, the system manufacturer provided maintenance and operation training to the Met personnel at NBO, but not to the Tower controllers.

Runway visual range (RVR)

RVR is defined in ICAO Annex 3 Chapter 1 as

> *'the range over which the pilot of an aircraft on the centre line of a runway can see the runway surface markings or the lights delineating the runway or identifying its centre line.'*

The ICAO Manual of RVR Reporting also states that

> *'the reported RVR value is intended to represent how far a pilot can see down a runway.'*

RVR is not a measurement of one specific parameter, but is an assessment based on calculations that take into account various factors and utilise a number of constants. Should the actual conditions vary from those allowed for in the constants then the calculation of RVR will be erroneous. One parameter which may vary from that predicted is lighting intensity, and the ICAO Visual Aids Panel (1970) suggests an allowance of 20% be made due to contamination and ageing of runway edge lights.

One technique used to determine RVR uses a transmissometer to measure the transmittance of the atmosphere. RVR is then calculated by taking into account the measured value of transmittance, the characteristics of the runway lights and the expected detection sensitivity of the pilot's eye under the prevailing conditions of background luminance. This was the method being used at Nairobi on 27 April 2008.

Runway lighting - ICAO requirements

Standards for airfield ground lighting are defined by ICAO Annex 14. In relation to runway and approach lighting it states in Section 10.4 that:

'A light shall be deemed to be unserviceable when the main beam average intensity is less than 50 % of the value specified in the appropriate figure.

A system of preventive maintenance of visual aids shall be employed to ensure lighting and marking system reliability.

The system of preventive maintenance employed for a precision approach category 1 shall have as its objective that, during any period of category 1 (CAT 1) operations, all approach and runway lights are serviceable, and that in any event at least 85 per cent of the lights are serviceable….'

Sections 10.4.3-10.4.9 discuss category two (CAT2) and category three (CAT3) operations. These sections recommend:

'in-field measurement of intensity, beam spread and orientation of lights included in approach and runway lighting systems…. Should be undertaken by measuring all lights, as far as practicable, to ensure conformance with the applicable specification…'

ICAO Annex 14 specifies characteristics of each type of runway light in terms of isocandela diagrams (Figure 9 refers) which define the required beam shape and intensity. Annex 14 also specifies required colour and setting angles of the emitted light and maintenance performance levels for individual fittings and overall serviceability of a lighting system. Any individual light fitting is deemed unserviceable when the light intensity is less than 50% of specification.

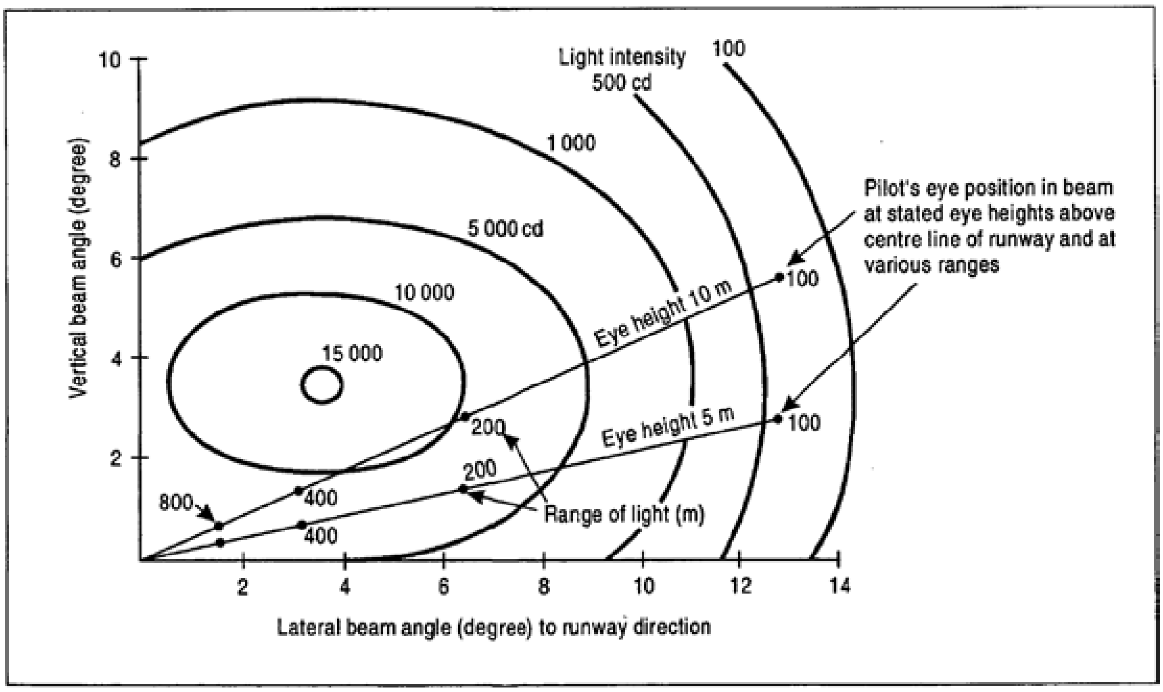

Figure 9

Isocandela diagram for a runway edge light taken from ICAO Manual of Runway Visual Range Observing and Reporting Practices, Third Edition 2005. (Doc 9328 AN/908)

As can be seen from the diagram there is a very narrow field where the light focuses its maximum beam intensity. Small variations in orientation result in disproportionately large decrements in light output.

Runway lighting maintenance

The UK CAA, in conjunction with other UK government agencies, sponsored a research programme during the 1990s into the maintenance and quality of Aeronautical Ground Lighting (AGL). Prior to this study, the UK accepted practices for the maintenance of lighting were a combination of block (or bulk) change, where a batch of lamps is replaced or light housings refurbished after a set period of time, and spot replacement where an individual lamp is changed when it is observed that it has failed completely.

Block change maintenance is a technique which remains an ICAO accepted practice at CAT 1 airfields. It assumes that all light fittings and lamps deteriorate uniformly with time whereas spot replacement assumes that the lighting quality remains essentially constant up until the time that the lamp fails and is extinguished.

The initial target of the research programme was to develop a mobile photometric measurement system. This system was specifically designed to measure accurately and rapidly the performance of aerodrome lighting systems against the ICAO Annex 14 standards for beam intensity and orientation by using an array of light sensors either fixed in a hand-held frame or, in later models, towed behind a vehicle.

This system was tested at a number of UK airports. The study showed that at one airfield, following total refurbishment, 20% of the fittings were below ICAO standards, and that after six months 50% of the fittings were considered unserviceable. In addition it was found that lamps can run with very low output for a considerable time before finally failing and hence there is a risk of operating below ICAO serviceability levels for extended periods.

Differential maintenance

Following the UK CAA research study the technique of differential maintenance was developed. This involves conducting routine photometric surveys of the airfield lighting and changing lamps and light fittings when certain trigger values are reached. As a consequence, the lighting quality never falls below ICAO standards for extended periods and maintenance costs can be reduced as serviceable fittings or lamps are not replaced needlessly.

The UK CAA report identified a number of electrical, optical and physical reasons for variation in lighting quality;

a) High-intensity lighting is powered from constant current sources in order to provide stable light output. Light output is very sensitive to changes in operating current and a 6% reduction in current can result in a 25% reduction in light output.

b) Airfield lighting is designed to produce a narrow high intensity beam. The required beam characteristics are achieved by means of a compact optical system in which the lamp filament is located at the focal point of a lens system. Any movement of the filament from the focal point will alter the beam orientation and probably the spread. Movement of the lamp in its holder or filament sag have been found to produce azimuth and elevation variations of up to 5°. Dirt and contamination were found to cause up to a 40% loss in output, surface pitting from jet blast up to 45% and the lens mounting up to 30% (not all losses were found in a single unit).

c) Azimuth errors in excess of 3.5° were found during the study.

d) Lamp life itself was not considered in tests; however, filament sag was expected to increase as lamps age which would change beam orientation.

The UK CAA provides guidance on lighting maintenance to licence holders in document CAP 168 - Licensing of Aerodromes:

> *'12.1.5 The conventional AGL maintenance strategies of block change, or change on failure, have been shown to be inadequate with many of the lamps failing to meet the required standard either immediately or shortly after the maintenance activity (see paragraph 12.3.8). Lamps and associated equipment do not age at a uniform rate and consequently only limited benefit is achieved from a routine block change. On the other hand, if the performance of individual lights is allowed to decay until lamp failure occurs, then each light will be operating below the required standard for a substantial percentage of its life. Both strategies result in the possibility of entering LVPs with the installation operating below the required serviceability levels. Routine and regular targeted maintenance procedures are essential if this scenario is to be avoided.*
>
> *12.1.6 The performance of lights can change rapidly, especially at large aerodromes with high movement rates. Therefore, it is important to assess performance accurately on a regular basis and act upon the information collected. The frequency with which such assessments should be undertaken is dependent upon the type and age of the installation, maintenance policy adopted, movement rates and prevailing weather conditions. Typically, a weekly survey, with associated maintenance, has been found to be adequate for a major aerodrome.'*

The UK CAA does not differentiate between airfield categorisation regarding the type of maintenance activity required. CAP 168 details the standards required and allows airfields to develop their own strategies for ensuring compliance:

> *'12.2.2 The objectives…specifically target precision instrument approach runways and operations in low visibility. For precision instrument approach runways the CAA expects the aerodrome authority to provide evidence that the performance of the associated AGL meets the requirements for all weather operations… One method of providing such evidence is to carry out regular measurements of the photometric performance (i.e. the luminous intensity, beam coverage and alignment) of the AGL when in service.'*

Lighting at Nairobi

The Kenya Airports Authority (KAA) reported that the plan for management of lighting at NBO relied on twice-daily inspections of the general airfield lighting and bulk replacement of lamps to ensure uniform lighting. They advised that maintenance personnel were required to check light orientation on a routine basis. The AAIB have been unable to obtain copies of these maintenance procedures or records of any recent inspections carried out.

Previous incident

In January 2007 a Dutch registered MD-11 landed on NBO Runway 06 at night in heavy rain. The aircraft departed from the left side of the runway in a similar position to G-VAIR. The MD-11 crew regained the runway brought the aircraft to a halt and no serious damage occurred. The report into this incident was conducted by the operator of the aircraft with oversight from the Dutch Safety Board. The report produced on 5 October 2007 made the following recommendations:

> '1- *Inform the Kenyan Authorities about the (in) visibility of the center line in the touch down zone of runway 06 in NBO as a result of rubber deposits. Request the Authorities to have the center line cleaned.*
>
> 2 - *Inform the Kenyan Authorities that the absence of center line lights in combination with the position of the runway edge lights of runway 06/24 in NBO, caused visual illusion of the flight crew which is considered a contributing factor to this incident. Recommend to install center line lights on the runway.*
>
> 3 - *Inform the Kenyan authorities that the position of the runway edge lights of the runway is not according ICAO standard. Recommend to have the runway edge lights repositioned.'*

The Dutch operator commented that they visited the Kenya CAA and Kenya Airport Authority on 29 February and 1 March 2008 to discuss the report with them. However, since then they have received no further communication on the matter.

ATC personnel

At the time of the incident a trainee Air Traffic Control Officer (ATCO) was on duty under the supervision of a qualified ATCO. Having rested for 18 hours, both had reported for duty at 1600 hrs and thus were about 10.5 hours into a 12 hour shift when the event occurred. A review of the ATC tapes in conjunction with the ATC unit manager confirmed that the trainee complied with unit standard operating procedures.

Action taken by the Kenya Airport Authority

During July 2008 the runway edge and centrelines were repainted. In October 2008 the KAA informed the investigation that, previously, they had been periodically removing rubber deposits from the runway touchdown area using a chemical process. However, the chemical stock at NBO had run out and an order for a restock had not been completed. The KAA stated that they were in the process of inviting tenders for a new supply of chemical as a short-term measure. They also stated their intention to resurface the runway in order to rehabilitate the grip levels in the touchdown area and that, during that work, the runway lighting would be repositioned in order to comply with ICAO Annex 14.

Discussion

The loss of visual references during the flare is a complex event. Sudden changes in RVR can occur due to the natural variability in the density of fog. The phenomenon of rapidly-forming drifting fog during the wet season at Nairobi is not fully understood. In addition, although advisories to pilots caution about such phenomena for certain times of the year it can occur outside those periods, depending on the climatic conditions. A modern instrumented RVR system capable of immediately displaying changing visibility was installed at NBO 18 months before this incident. However, its value was limited as, due to the absence of appropriate training on the AWOS, information from that system was not passed to flight crews and pilot-assessed visibility from several minutes earlier was routinely relayed instead. Therefore the following Safety Recommendation is made:

Safety Recommendation 2009-069

It is recommended that the Air Traffic Controllers at Nairobi International Airport are provided with appropriate training in the use of the Runway Visual Range measuring equipment which is a function of the Automated Weather Observation System installed at the airport.

Despite offers for a photometric survey to be carried out by the UK AAIB, the quality of the lighting at Nairobi could not be scientifically assessed. However, as a subjective observation, the lighting units seen during the AAIB visit appeared to have variable brilliance and their positioning was not in compliance with ICAO Standards. Therefore the following Safety Recommendations are made:

Safety Recommendation 2009-070

It is recommended that the Kenya Airports Authority review their maintenance programme for runway lighting at Nairobi International Airport to ensure that runway lighting quality complies with ICAO Standards.

Safety Recommendation 2009-071

It is recommended that the Kenya Airports Authority take action to ensure that the positioning of the runway edge lights at Nairobi International Airport complies with ICAO Standards.

The Kenya Airports Authority has already indicated its intention to reposition the runway edge lighting as part of broader runway rehabilitation work. In the meantime, until the runway edge lights have been relocated, it would seem prudent to alert operators using NBO of the non-standard positioning of the edge lights. Therefore the following Safety Recommendation is made:

Safety Recommendation 2009-072

It is recommended that the Kenya Airports Authority notify all aircraft operators using Nairobi International Airport of the fact that the runway edge lights are positioned 7.5 m away from the edges of the declared runway surface rather than the maximum of 3 m specified by ICAO.

In this incident, had the deteriorating RVR figures been passed to the crew it is unlikely that they would have made a significant change in their approach strategy as the recorded RVR remained above CAT1 limits. The decision to continue the approach was made at decision height with the required visual references and the autopilot was disconnected for a manual landing. Instances of loss of visual references during the landing phase are relatively rare, but not unknown, and occur due to a variety of causes. In the case of this aircraft it could not be determined whether the loss of visual reference was due to a localised area of denser fog, a localised reduction in the quality of runway lighting, or a combination of both.

Two seconds before touchdown the aircraft was on the ILS centreline with a heading 3° right of the runway heading. Two seconds after the aircraft touched down it had begun to deviate to the left of the localiser, tracking 3° left of runway heading and the thrust levers had been advanced fully. Within this four second period the crew had to recognise that the aircraft was drifting from the centreline, decide whether to go-around and then execute that decision. Although speed of reactions are variable, in the time available, the fact that the commander called for the go-around which then had to be carried out by the PF, makes it likely that the go-around decision was made just before the aircraft touched down. The aircraft continued to deviate to the left of the centreline while the engines spooled up to go-around thrust and the aircraft was brought broadly parallel with runway heading through the application of right rudder pedal.

Go-around training

The UK CAA FODCOM highlights areas which would enhance pilot training. As this FODCOM had only been issued one month before the G-VAIR event, the PF had not had the opportunity to receive the additional training suggested. As such the efficacy of this training in relation to this event cannot be assessed. The FODCOM training does not require a change in visual conditions during the go-around. However, operators who have access to high-fidelity simulation may wish to consider adding this factor into their training programmes as the area of difficulty for this crew, and for the crew involved in the NTSB report referred to earlier, was the loss of visual references almost at the point of touchdown. This could occur due to either changing meteorological conditions or a simple failure of runway lighting. This incident also reinforces the generic advice that crews should remain 'go-around minded' throughout the landing phase.

Runway surface

Of limited consequence to this investigation, the level of contamination seen on the surface of Runway 06 and the lack of any evidence that grip testing had been conducted was of concern. It was considered that the quantity of rubber deposition may reduce the available friction and braking action for landing aircraft on Runway 06, whilst aircraft conducting a rejected takeoff on the reciprocal runway (Runway 24) in wet conditions could suffer a significant loss of braking effectiveness. In the absence of routine grip testing it is unlikely that an airport authority can determine the condition of the runway with regard to either "slippery when wet" or maintenance planning levels. Therefore the following Safety Recommendation is made:

Safety Recommendation 2009-073

It is recommended that the Kenya Airports Authority initiates routine testing to monitor runway friction levels at Nairobi International Airport in order to ensure compliance with the standards required by ICAO.

Conclusions

The aircraft departed the left side of the runway as a result of the PF's rudder pedal inputs during the flare which were made during a period when the crew reported that they lost their visual references. In such cases, at this critical phase of flight, it is important that flight crews can recognise and react in a timely manner to unexpected events. The crew recognised the deviation and carried out the initial actions of the go-around within two seconds of the aircraft touching down. This suggests that the decision to go-around had been made before the aircraft actually touched down. The reason for the loss of visual references could not be conclusively proven, but it was considered that local changes in fog density together with variability of runway lighting quality were a factor. The excursion was contained and damage was limited by the timely application of corrective rudder combined with the decision to go-around. However, the aircraft's left main landing gear did run off the side of the runway for 180 metres.

Training for rejected landings is now routinely carried out by UK carriers both during type conversion and recurrent training and, as such, no further safety recommendations were considered necessary.