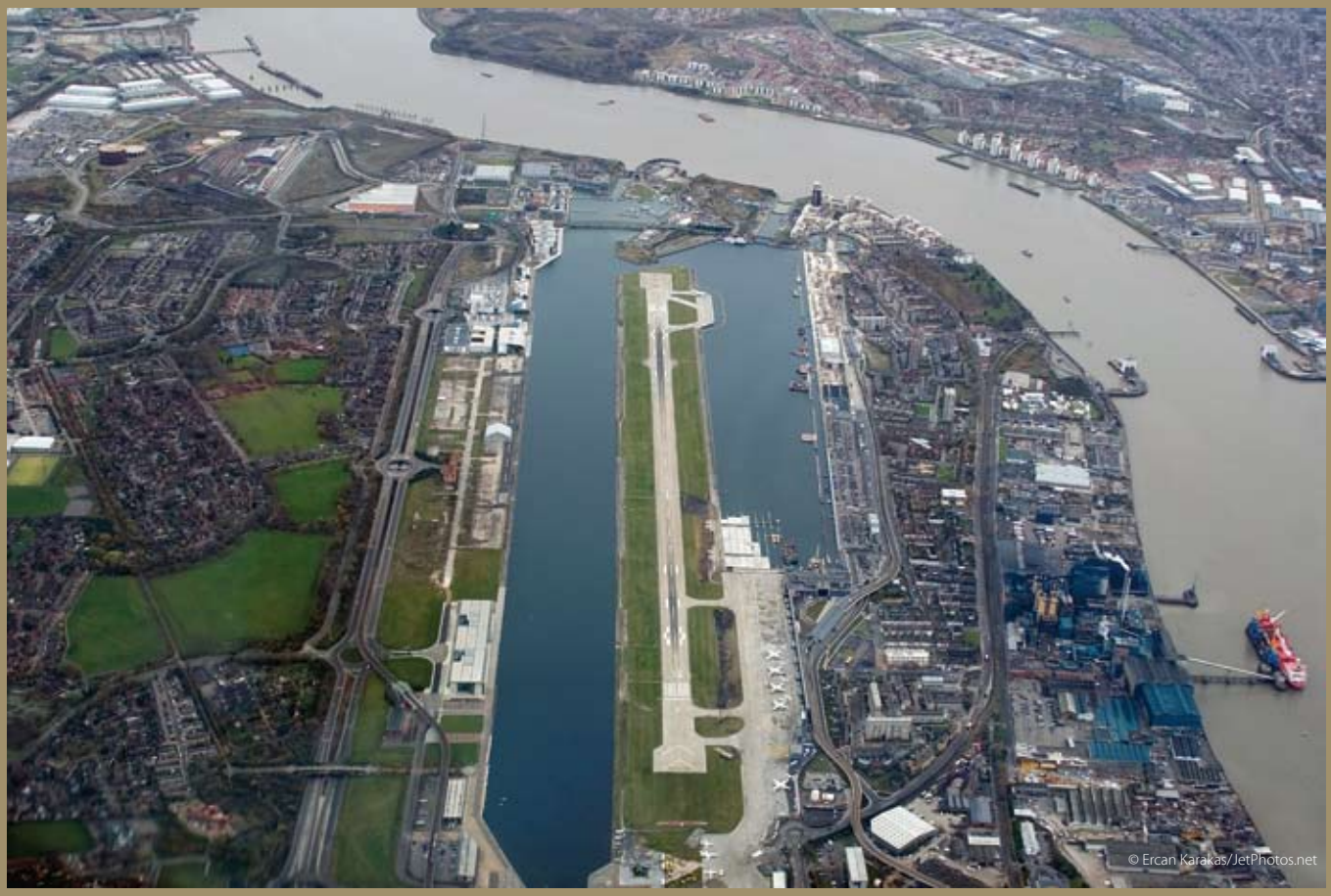
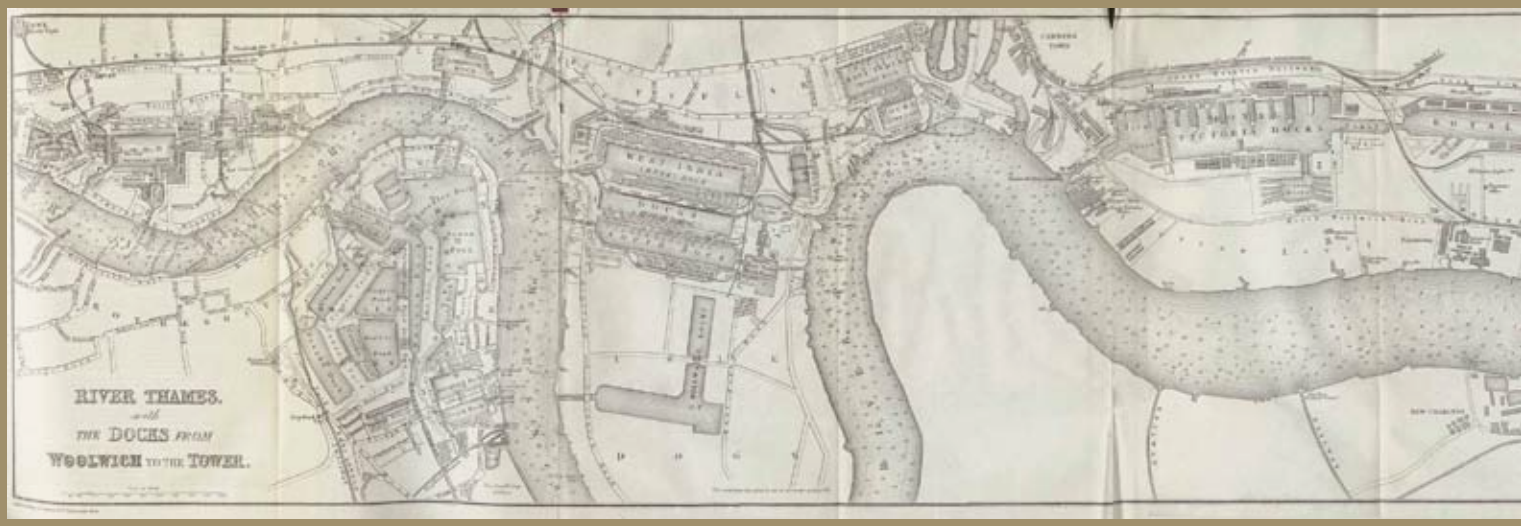
Pilots at several airports have reported navigation problems that involve erroneous heading information. Authorities blame magnetic anomalies in areas on the ground.

AIRPORT MAGNETISM





BY LINDA WERFELMAN

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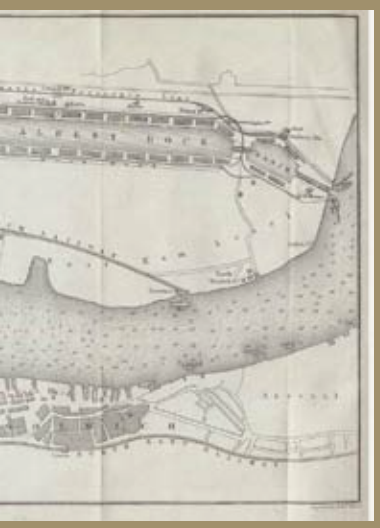
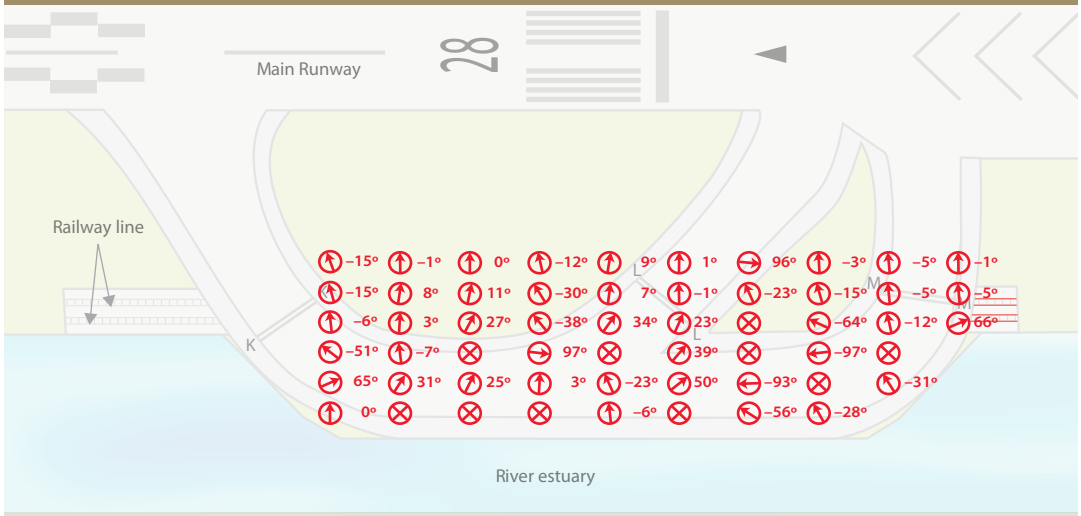
At London City Airport, the remains of bollards like this one have been linked to magnetic anomalies and aircraft navigation problems.



Results of Compass Deviation Study



Note: Numbers indicate the degree, plus or minus, of compass deviation. The symbol "⊗" indicates that magnetic field deviation in this area was too strong for measurement.

Source: U.K. Air Accidents Investigation Branch

Figure 1

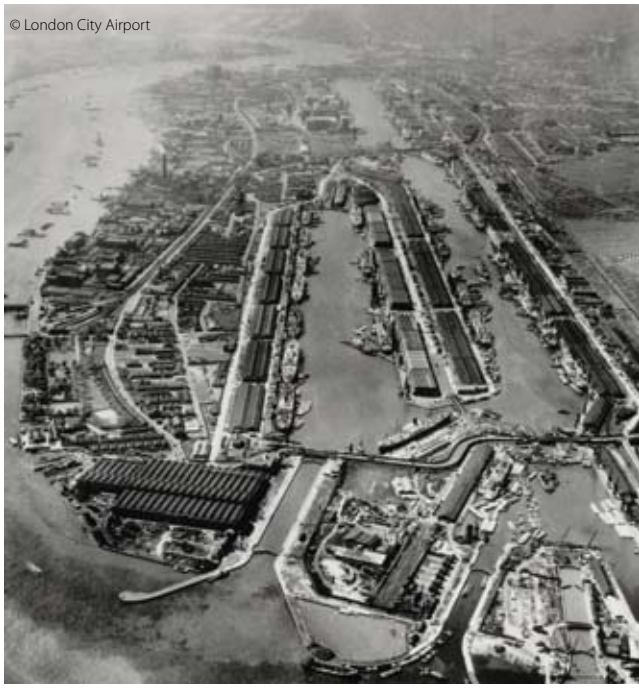
Magnetic anomalies in runway holding areas have caused events involving significant navigation problems for aircraft departing from several airports in Europe and the United States, a report by the U.K. Air Accidents Investigation Branch (AAIB) says (see "When North Becomes South …" p. 20).

The AAIB report focused on an Oct. 31, 2006, event in which the crew of a Raytheon Hawker 800XP, after departure from London City Airport (LCY) for a flight to Brussels, Belgium, observed a 60-degree difference between headings indicated on the two primary flight displays (PFD 1 and PFD 2), and a 15-degree difference between the heading displayed on PFD 1 and the combined standby instrument. Red FD flags appeared on the PFDs, and both flight directors were "unavailable," the report said.

The pilots, in compliance with the emergency procedures section of the quick reference handbook, selected AHRS 1 (attitude and heading reference system 1) as the source for both sets of flight instruments. After 10 minutes, the problem had not been resolved, and the pilots — the only people in the airplane — received radar vectors for their return to LCY.

Earlier, on the ground at LCY, the pilots had observed AHRS and HDG (heading) red flags on both PFDs, indicating that heading indications were unreliable, the report said.

"The pilots commented that this was a 'known fault' at LCY which they thought was associated with 'metal in the taxiway pilings,'" the report said.



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When North Becomes South …

Earth, with its core of iron and nickel, behaves like a spherical magnet, surrounded by a magnetic field that resembles the magnetic field associated with a dipole magnet — that is, a magnet with a north pole and a south pole.[1,2]

The magnetic field varies in intensity from place to place and also over time. The U.S. National Geophysical Data Center (NGDC) says that the intensity is so irregular that "it must be measured in many places to get a satisfactory picture of its distribution." Measurements of its intensity, and various components of intensity, along with other factors, are obtained via satellites, at about 200 magnetic observatories around the world.

A device called a dip needle identifies the north magnetic pole as the place where the north end of the needle is down; at the south magnetic pole, the north end of the dip needle is up.

Slow changes in the measurements indicate that magnetic field strength may be declining, and that the magnetic poles are moving.

Data indicate that, over time, Earth's magnetic field has been through cycles of strengthening and weakening, and that its polarity has changed — that is, the north and south magnetic poles have reversed.

"Based on measurements of … Earth's magnetic field taken since about 1850, some paleomagnetists estimate that the dipole moment will decay in about 1,300 years," the NGDC says. Even if a reversal begins, "it would still take several thousand years to complete. We expect Earth would still have a magnetic field during a reversal, but it would be weaker than normal, with multiple magnetic poles."

The consequences? "Radio communication would deteriorate, navigation by magnetic compass would be difficult and migratory animals might have problems," the NGDC says.

— LW

Notes

1. U.S. NGDC. Geomagnetic Field: Frequently Asked Questions. <www.ngdc.noaa.gov/geomag/faqgeom.shtml>.
2. Layton, Julia. *How Stuff Works: What Is a Geomagnetic Substorm?* <http://science.howstuffworks.com/geomagnetic.htm>.

The red flags disappeared as the airplane was lined up on Runway 28, but after departure, the pilots could not control the airplane's heading while using the autopilot "because neither of the heading selector bugs would move in response to rotation of the heading selector control."

During the investigation, the AAIB was told of several similar events that had been detailed in mandatory occurrence reports (MORs) submitted to the U.K. Civil Aviation Authority (CAA) by operators and air traffic controllers at the London Terminal Control Centre. The MORs described navigation problems experienced by the crews of Hawker 800s, Cessna Citations and Fokker 50s after departure from LCY's Runway 28.

"The first such occurrences, mostly to Fokker 50 aircraft, were attributed to poor compliance by pilots with assigned routings," the report said. "An ATC [air traffic control] Occurrence Report into an incident on 23 September 2003 noted that failure to follow the correct SID [standard instrument departure] route was 'an increasingly regular occurrence' involving aircraft departing Runway 28 at LCY."

The CAA responded to the series of MORs with an investigation of the possibility of problems involving the London VOR (VHF omnidirectional radio). No problems were found.

The AAIB investigation examined the history of LCY, which opened in 1987 on the site of what once was a shipping dock. Railway lines had run between two rows of warehouses; only some of the lines were removed before construction of the airport.

In addition, large cast iron bollards — used to tie up ships — had been mounted along the dock walls. The report said, "These bollards were similar to icebergs — what was visible above the dock wall was about a fifth of the size of what was below the wall." When the airport was built, the sections of the bollards that were above the dock wall were removed, but the sections below the wall remained.

In 2003, an aircraft holding area was built atop numerous steel-encased concrete piles that had been sections of an out-of-service oil pipeline. The area included old railway lines and lower sections of cast iron bollards, neither of which were removed.

"A walk around the Runway 28 holding area with a hand-held magnetic compass by an AAIB inspector showed that there were some large and strong magnetic anomalies that made the compass needle deviate by up to plus or minus 60 degrees," the report said.

Engineering surveys were conducted within the Runway 28 holding area, 1.4 m (4.6 ft) above the surface, to measure "magnetic signature" — characteristics including the intensity and orientation of the magnetic field at a specific site — and compass deviation — the number of degrees that a magnetic compass deviates from magnetic north — at dozens of points within the Runway 28 holding area. The survey

found compass deviations of as much as 97 degrees (Figure 1, p. 19).

The surveys concluded that the compass deviation problems at LCY are "caused by several ferrous magnetic signature anomalies, primarily emitted as a vertical component from the 68 piled-beam structures situated under [the] Runway 28 holding area."

In addition, the surveys identified other sources of magnetic anomalies from the remains of the bollards under the holding area, from steel-reinforced concrete in the holding area and from the railway lines below the holding area.

Problems Elsewhere

AAIB investigators found that similar occurrences had been reported at several other airports, including Stockholm Arlanda in Sweden, George Bush Intercontinental Airport (IAH) in Houston and LaGuardia Airport in New York.

At Stockholm Arlanda, pilots reported compass deviations while taxiing to Runway 01/19, the report said, and a subsequent investigation found that magnetic anomalies were to blame.

The report said that, during refurbishment of the taxiway, it was found that steel nets that had been used for pavement reinforcement were "notably harder to bend than the material commonly used for this purpose, and exhibited permanent magnetism." The AAIB quoted a Swedish report as saying that there were no magnetic anomalies associated with the steel nets usually used for reinforcement "but that permanent magnetic steel nets constituted a significant source of interference."

No further problems were reported after the runway was refurbished, the report said.

At IAH, published information warns of magnetic anomalies that may affect compass heading immediately before, during and after takeoff on Runway 15L/33R and on two taxiways, the report said.

"When contacted by the AAIB, a representative of the airport operator commented that he thought that IAH was the only airport with this problem," the report said. He said that the anomalies were first observed after the airport blasted small steel balls against the surface of Runway 15L to remove paint and rubber.

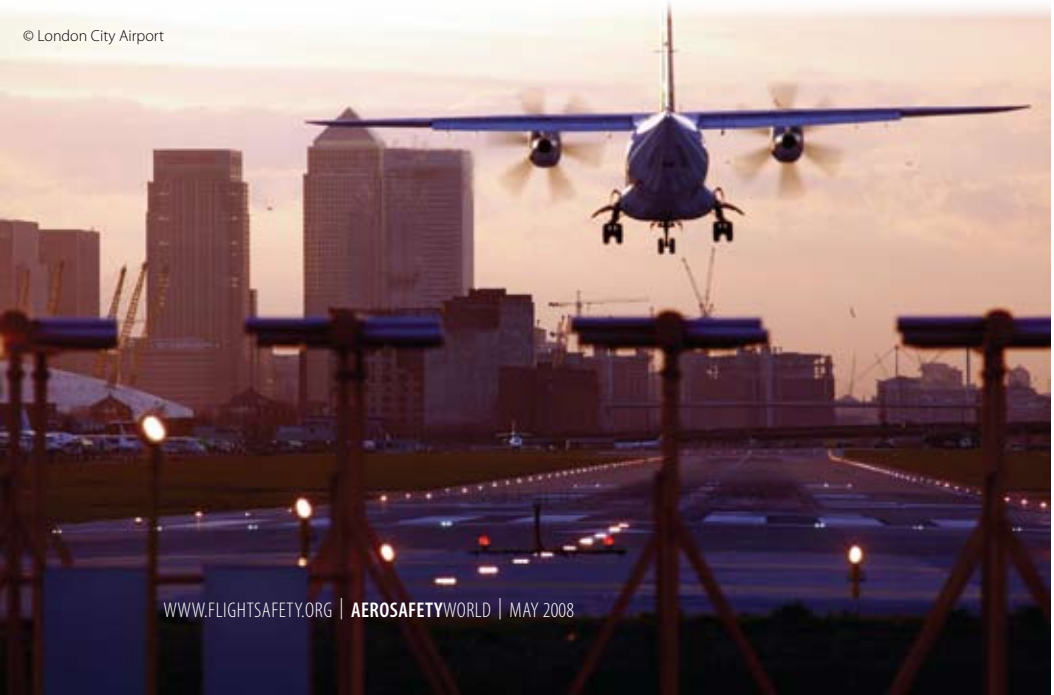
"The impact of the steel balls with the runway surface had magnetized the steel reinforcement embedded in the concrete," the report said. "Subsequently, aircraft with flux valve detectors mounted in the wing tips would experience a magnetic deviation of between 40 degrees [and] 90 degrees. Several aircraft aborted their takeoffs. Those that departed either returned to the airport or regained normal compass indications shortly afterwards."

The airport operator's attempt to neutralize the magnetic field in the area was "partially successful," the report said, and the magnetic anomaly dissipated with time. Pilot awareness of the risk reduced the frequency of occurrences, and "there have been no further reports for several years," the report said.

The AAIB report cited a description of the LaGuardia problem that was the subject of a report submitted in April 1994 by a first officer on an unidentified aircraft to the U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS). The first officer said that, during a takeoff roll on Runway 31, the crew observed an erroneous reading of 350 degrees on both of the airplane's horizontal situation indicators (HSIs) and its two radio magnetic indicators (RMIs). The crew re-set the instruments, and further operations were normal, the report said.[1,2]

"We learned later that the gate we had parked at prior to our departure had produced gross compass swings in the past on some aircraft," the first officer's report said. "Evidently, some magnetic anomaly is present there, producing as much as 40 degrees of compass swing. A subsequent rapid departure does not give the compass system time to re-sync to the correct heading, and if the crew doesn't catch it, a problem after departure can develop."

The first officer's report said that the operator had subsequently warned its pilots about the possibility of



compass problems at that particular gate. The AAIB report said that the airport operator had not said whether any remedial action had been taken.

Another pilot — a captain on a McDonnell Douglas MD-80 — had filed a similar report with ASRS about an event in January 1994.[3]

In this report, not cited by the AAIB, the captain said that, although the HSI compass heading had been "reasonably normal" when the airplane was in position on Runway 13, during the takeoff roll, "I noticed briefly what appeared to be a 15-degree to 20-degree heading split. With our flight directors and autopilot unusable at this time, we continued our takeoff and departure."

He said that the crew considered rejecting the takeoff but continued because weather and visibility were good and the problem was expected to be brief.

"All takeoffs from Runway 13 at LaGuardia that I have made recently have had compass problems — magnetic deviations," he said. "I am sure that I am not the only [pilot] to have had these problems. … Under bad weather/visibility, this can be dangerous."

The ASRS report said that Runway 13 and Runway 22 — where the captain said he had experienced similar anomalies — are constructed, in part, on steel and reinforced concrete piers.

The AAIB report said that, although magnetic anomalies have been reported at airports around the world, LCY has been the scene of the greatest number of reported events.

One operator of Hawkers and Citations that were involved in a number of the events subsequently issued memos to its pilots, describing the techniques to be used in its various aircraft to cope with the problem.

The AAIB said that, when flight crews have complied with recommended procedures, a "temporary residual deviation" sometimes has continued to affect aircraft operations but typically has not interfered with the aircraft's ability to follow an assigned route.

"In cases where deviations from the assigned route became problematic for pilots and ATC, it is likely that the condition was exacerbated by the manner in which the crew dealt with the anomaly," the report said.

For example, in some cases, crews have not completed the recommended procedures before takeoff, and as a result, "the heading reference system was not in a mode which could provide meaningful heading information," the report said.

The report characterized as "severe" the effects of local magnetic anomalies on Earth's magnetic field at some points within holding areas at LCY.

"Most aircraft have magnetic flux valves fitted on the undersides of the wing tips … [to] sense … Earth's magnetic field and by electrical/electronic circuitry, realign the aircraft's compass systems," the report said. "An electrical limiter is installed into the flux valve system that limits the rate of realignment of the aircraft's compasses to, generally, 3 degrees a minute. This allows aircraft to transit areas of magnetic anomalies at airports without any significant realignment input into the compass systems. However, if an aircraft is stationary in an area of magnetic anomaly, then the amount of compass realignment is directly proportional to the length of time that the aircraft is stationary and the strength and orientation of the magnetic anomaly in that area. … At [LCY], an aircraft that is stationary at Hold M for 10 minutes could have both compasses realigned by up to 30 degrees — the P1's 30 degrees to the left and the P2's 30 degrees to the right. Once the aircraft leaves the hold [area] and enters the runway for departure, it could take up to 10 minutes for the compasses to realign to magnetic north."

No International Requirements

The investigation revealed that no national or international requirements exist for evaluation of the effects of magnetic anomalies at airports or for mitigation of those effects, the report said. As a result of the investigation, the AAIB recommended that the International Civil Aviation Organization amend Annex 14, *Aerodromes*, "to highlight the importance of ensuring that no airport infrastructure is allowed to alter significantly the local Earth's magnetic field density in areas where aircraft hold prior to departure."

The AAIB issued similar recommendations to the European Aviation Safety Agency and the CAA, calling on them to require action by airport operators.

Other recommendations said that the CAA should publish a warning about the magnetic anomalies at LCY in an amendment to the Aeronautical Information Package, should require LCY to "mitigate the effects of the magnetic anomaly," and should require operators at LCY to provide their pilots with information on the problem and pilot procedures for mitigating its effects. The CAA accepted the recommendations. ●

This article is based on U.K. AAIB Aircraft Incident Report No. 1/2008 (EW/C2006/10/10).

Notes

1. NASA ASRS. "Magnetic Mystery." *Callback* No. 190 (February 1995).
2. NASA ASRS. Report no. 269103. April 1994.
3. NASA ASRS. Report no. 260698. January 1994.