INCIDENT

Aircraft Type and Registration:	Boeing 737-500, SP-LKA
No & Type of Engines:	2 CFM 56-3C1 turbofan engines
Year of Manufacture:	1992
Date & Time (UTC):	4 June 2007 at 1007 hrs
Location:	On departure from London Heathrow Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 89
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	55 years
Commander's Flying Experience:	15,000 hours (of which 9,000 were on type) Last 90 days - 270 hours Last 28 days - 65 hours
Information Source:	AAIB Field Investigation

Synopsis

Just after takeoff from Runway 09R at London Heathrow Airport (LHR), the pilots noticed that most of the information on both of the Electronic Attitude Director Indicators (EADI) and Electronic Horizontal Situation Indicators (EHSI) had disappeared. The aircraft entered Instrument Meteorological Conditions (IMC) at about 1,500 ft aal, and the co-pilot had no option but to fly using the standby attitude indicator and standby compass. He experienced difficulty in following radar headings. The aircraft returned to land at LHR after a flight of 27 minutes.

The investigation determined that an incorrect stand position had been entered into the Flight Management System (FMS) during the pre-flight procedure.

History of the flight

The crew flew from Warsaw to LHR and, after landing, taxied the aircraft to Stand 114 where the engines were shut down at 0838 hrs. During the turnround, the pilots carried out a 'fast realignment' procedure for the two Inertial Reference Systems (IRSs), which required a ground position to be entered. This was done by the co-pilot on the Flight Management Computer (FMC) Control Display Unit (CDU) using the commercial chart Stand 114 position as the reference. However, although the value of the co-ordinates entered was correct, the longitude was entered as East instead of West. The longitude co-ordinate thus entered was 000° 26' 53.72" E, a point 0.886º/33.5 nm to the east of the actual aircraft position.

The aircraft, using callsign Lot 282, pushed back for the return flight to Warsaw and the engines were started, at 0943 hrs. Lot 282 was given taxi instructions and, at 1000 hrs, arrived at the holding point for Runway 09R and stopped on a heading of 224ºM. At 1005 hrs, ATC instructed Lot 282 to give way to another aircraft and to taxi to holding point November Bravo 11.

The aircraft was given clearance to line up and was taxied onto the runway. The departure clearance was for a BPK5J Standard Instrument Departure (SID). The co-pilot was the handling pilot. Immediately after takeoff, at 1009 hrs, the pilots noticed that there was almost no information on their EHSIs and EADIs; they described the displays as 'blank', Figure 1.

Approximately 40 seconds after takeoff, the aircraft entered cloud at around 1,500 ft aal and the co-pilot had no option but to fly using the standby attitude indicator and standby compass for attitude and heading reference; the airspeed and altitude indications were unaffected. The autopilots were not available but autothrottle remained available and in use.

The flight deck instrument layout, including the location of the standby instruments, is shown in Figures 2a and 2b.

As the aircraft climbed through an altitude of 3,000 ft, the commander contacted London Terminal Control North East (TCNE) Departures on 118.825 MHz and advised that the aircraft had a 'navigation problem'. The controller asked if the aircraft was able to fly a heading of 055º and the commander replied that they could. The heading was assigned and the commander was instructed to maintain 6,000 ft. However, after about 30 seconds, the controller called Lot 282 and advised that the aircraft appeared to be tracking north. The reply from the commander was unintelligible and the controller said he would call the aircraft back. The controller now dealt with several other aircraft before calling Lot 282 again. He advised the commander that the aircraft was tracking northwest and instructed him to 'FLY A HEADING OF ZERO FIVE ZERO DEGREES THAT'LL BE A RIGHT TURN OF APPROXIMATELY 90 DEGREES'. Lot 282 acknowledged the instruction but, a minute later, the controller noticed the aircraft was tracking

Figure 1

Representation of 'blank' EADI

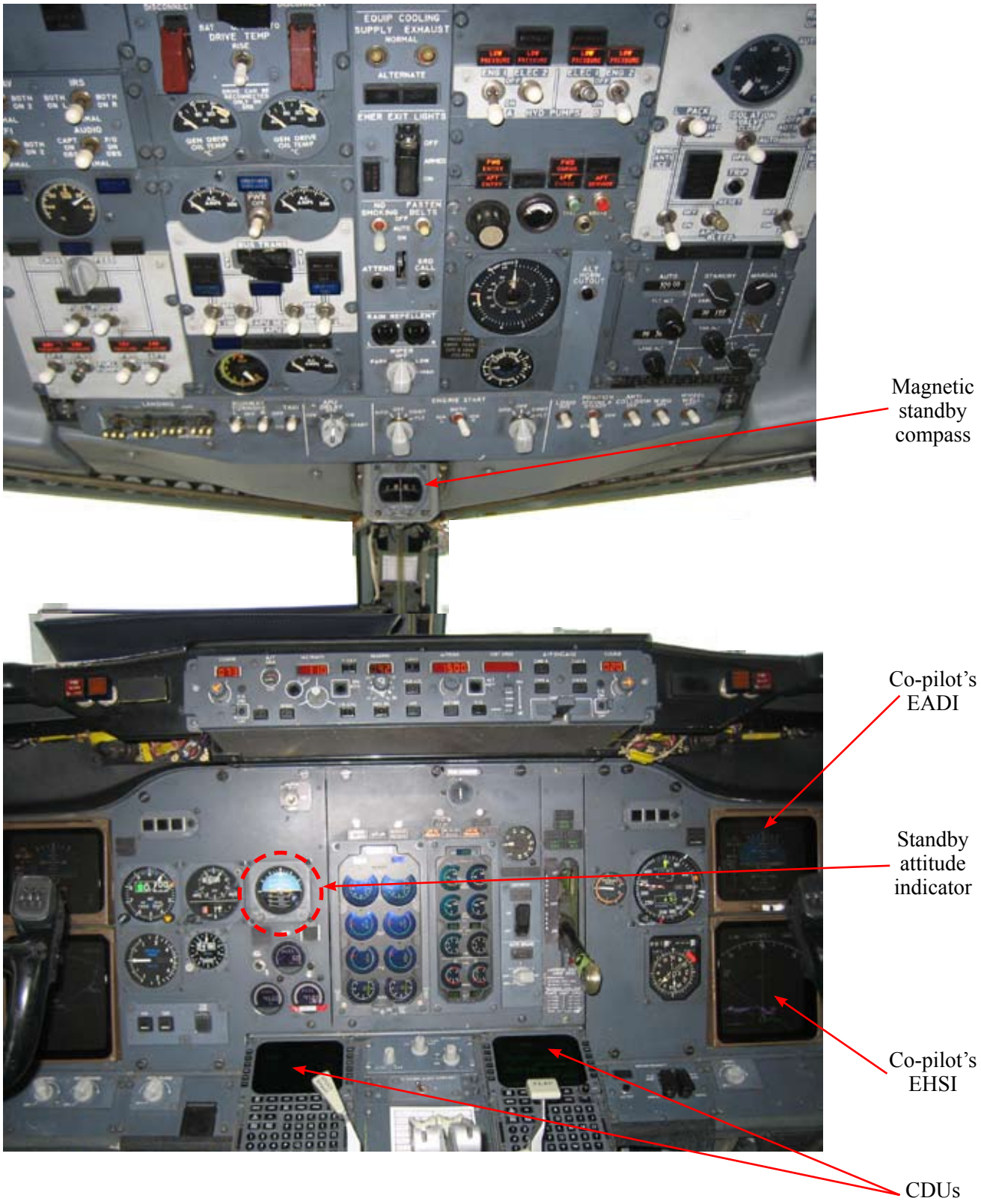

Figure 2a

Flight instruments layout, SP-LKA

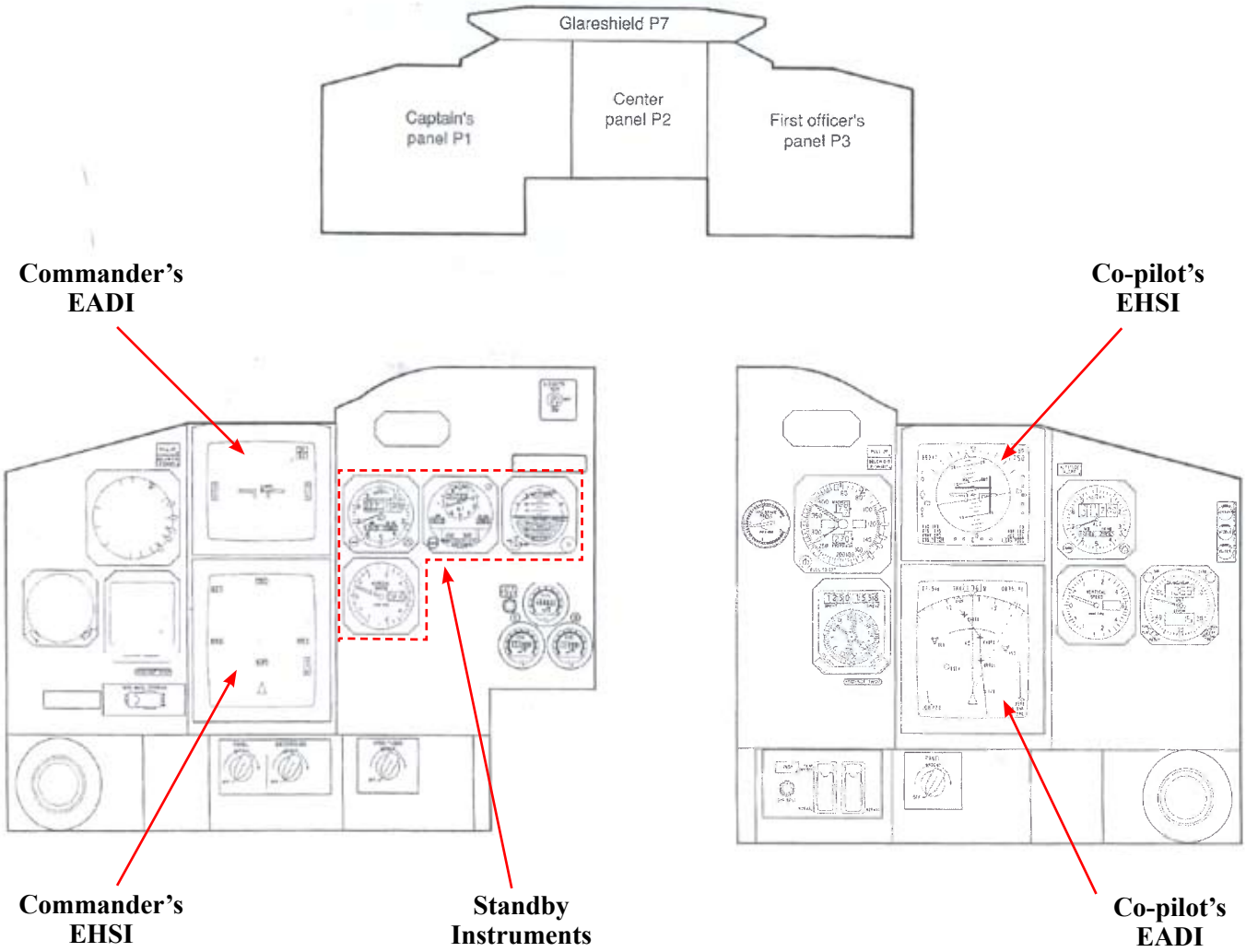

Figure 2b

Instrument panel layout

approximately west. At this stage there were a number of exchanges between Lot 282 and the controller in which it was apparent that the commander, who was making the radio calls, was not able to understand some of the instructions. A transcript of these exchanges is provided at Table 1.

The controller then asked for the crew's intentions and, after another exchange, the commander decided to return to LHR. Heading and altitude instructions were given. The altitude instructions were complied with and gradually the aircraft began to follow the headings. Figure 3 is a view of the aircraft's radar track, overlaid with some relevant communications.

At 1022 hrs, the controller handed Lot 282 over to a dedicated controller on a discrete frequency. The new controller issued heading instructions and asked the crew if they were able to fly an ILS; the commander replied that they could. Further heading instructions, together with altitude and speed instructions were given. Altitude and speed were complied with but the aircraft continued to respond to heading instructions slowly and erratically. The controller attempted to

TO	FROM	RECORDED INTELLIGENCE
LOT 282	LONDON	AND LOT TWO EIGHT TWO I SEE YOU HAVE NAVIGATION PROBLEMS YOU APPEAR TO BE TRACKING TO THE WEST NOW
LONDON	LOT 282	TURNING R-ER RIGHT ON ER WEST LOT ER TURNING LEFT ON WEST LOT S -ER TWO EIGHT TWO
LOT 282	LONDON	LOT TWO EIGHT TWO CAN YOU CONTINUE A RIGHT TURN A RIGHT-HAND TURN OF ONE EIGHTY DEGREES
LONDON	LOT 282	TURN ER RIGHT NINETEEN DEGREES LOT ER TWO EIGHT TWO
LOT 282	LONDON	LOT TWO EIGHT TWO ONE HUNDRED AND EIGHTY DEGREES TO THE RIGHT
LONDON	LOT 282	TO THE RIGHT ONE EIGHTY DEGREES LOT ER TWO EIGHT TWO
LOT 282	LONDON	AND LOT TWO EIGHT TWO WHAT HEADING DO YOU THINK YOU'RE FLYING AT THE MOMENT
LONDON	LOT 282	NOW IS ER HEADING F -THREE THREE ZERO[1]
LOT 282	LONDON	-KAY LOT TWO EIGHT TWO RIGHT TURN NOW HEADING ZERO NINER ZERO DEGREES
LONDON	LOT 282	TURN ER RIGHT ON HEADING ZERO NINE ZERO DEGREES
LOT 282	LONDON	AND LOT TWO EIGHT TWO I SEE YOU HAVE NAVIGATION PROBLEMS DO YOU HAVE ANY OTHER PROBLEMS FLYING YOUR AIRCRAFT
LONDON	LOT 282	ER ONLY THE NAVIGATION

[1] During this exchange the controller asked the commander what heading he thought the aircraft was on, and the reply was 'THREE THREE ZERO', whereas in fact at this time the aircraft was heading approximately 030º.

Table 1

R/T communications: Lot 282 and North East Terminal Control between 1014 hrs and 1016 hrs

vector the aircraft to the west on a heading of 260º, to allow for an extended final approach track, but the aircraft maintained a heading of south and cut across the localiser course for Runway 09L at 90º. The commander then reported that he had "GLIDESLOPE ONLY, NO DIRECTION". The controller asked the crew to turn left on to a northerly heading, which was achieved, and then on to a heading of 060º, to intercept the localiser. However, the aircraft continued to fly north and again passed through the localiser at 90º; the commander again reported that he had "NO DIRECTION ONLY GLIDESLOPE".

The controller now advised Lot 282 that he would give radar vectors until visual contact with the runway was established. He issued 'start and stop' turn instructions and a further descent clearance. At 1032 hrs, the commander reported "RUNWAY IS THE GROUND IN SIGHT" and was cleared for a visual approach to Runway, 09L. However, the controller noticed that the aircraft continued to track to the south of the airfield and asked the commander to confirm that they were approaching Runway 09L. The commander replied it was not in sight and, a moment later, that he was now visual for Runway 09L. At 1034 hrs, the controller issued a landing clearance for Runway 09L. In

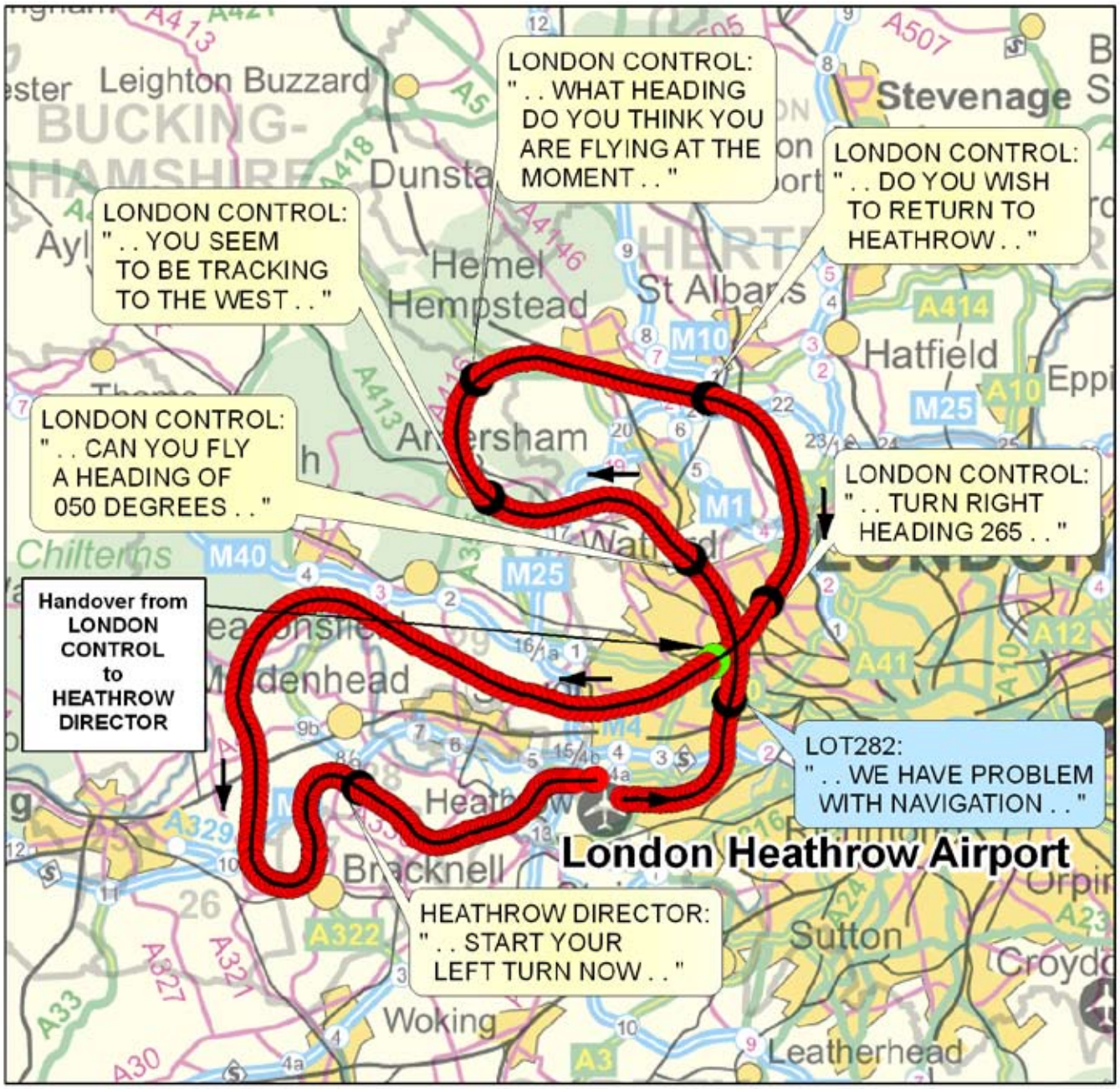

Figure 3

Radar track of LOT 282

the meantime, the ATC Ground Supervisor became concerned that the aircraft appeared as though it might be landing on Runway 09R, and asked for the traffic to be cleared from the runway. In the event, at 1035 hrs, the aircraft landed on Runway 09L and taxied to a parking stand.

Post flight

The passengers disembarked and a maintenance engineer, sub-contracted to the operator, attended the aircraft. The pilots advised him that the navigation systems all appeared to be operating normally and, with no fault now apparent, the aircraft was prepared for

dispatch. However, the locally based engineer was not qualified to clear the Technical Log entry made by the crew relating to the event, and the aircraft was delayed until an appropriately qualified engineer arrived from the operator.

Aircraft navigational equipment description

The aircraft is equipped with an Electronic Flight Instrument System (EFIS) and standby attitude, altitude and airspeed instruments. A direct reading magnetic standby compass is mounted above the glareshield on the windscreen's centre post.

Two independent IRSs are installed and one FMC. IRSs are controlled through a Mode Select Unit (MSU), with system information being displayed on an IRS Display Unit (ISDU) located on the aft overhead panel, Figure 4.

The IRSs provide attitude, heading, acceleration, vertical speed, ground speed, track, present position and wind data to the aircraft systems. They are the sole source of attitude and heading information, with the exception of the standby instruments.

An IRS must be initialised with present position information before it can function in the navigation (NAV) mode. This data is normally entered by a crew member through the FMC CDU, although it can also be entered through the ISDU and the aircraft must be stationary whilst the IRSs align. This may take up to 10 minutes. However, during 'transit' turnarounds, a 30 second fast realignment and zeroing of groundspeed error may be carried out. The procedure for this is to switch both IRSs from NAV to ALIGN, and then to enter the aircraft's current position into the 'box prompts' provided on the Position Initialisation page of the FMC; NAV is then re-selected on the MSU and alignment is completed after approximately 30 seconds. If an entered position is not within 4 nm of the airport position, a FMS alerting message VERIFY POSITION is displayed on the CDU scratchpad. This message can be cleared by pressing the CLR key on the CDU. Whenever an FMA alerting message is generated, there is an associated amber message light on the pilot's instrument panel and a MSG light on each CDU.

If the aircraft moves before alignment is complete, an FMS alerting message IRS MOTION is displayed in the CDU scratchpad. This message can be cleared by pressing the CLR key on the CDU. The ALIGN light on the MSU will flash and will not stop flashing until the mode select switch is moved to OFF. After 30 seconds the mode select switch may be moved to ALIGN or NAV to reset the alignment.

There are two internal IRS comparison tests. Firstly, if the entered position does not agree with the last position, to within one degree of longitude and half a degree of latitude, then the test will fail. In this case the ALIGN lights will flash to alert the crew. If the same position is re-entered then the alignment process will begin. Secondly, the entered latitude and the system-computed latitude are compared. If this test fails, the position may be re-entered but if it again fails, the ALIGN light and the FAULT light on the MSU will illuminate as a steady light.

If the aircraft is in flight and the NAV mode is lost, attitude and heading information can be recovered by selecting attitude (ATT) on the MSU. After approximately 30 seconds of straight and level un-accelerated flight, the attitude reference will return. Heading can also be recovered by manually entering the current heading, although, if this is done, periodic cross-checks are required to correct for drift.

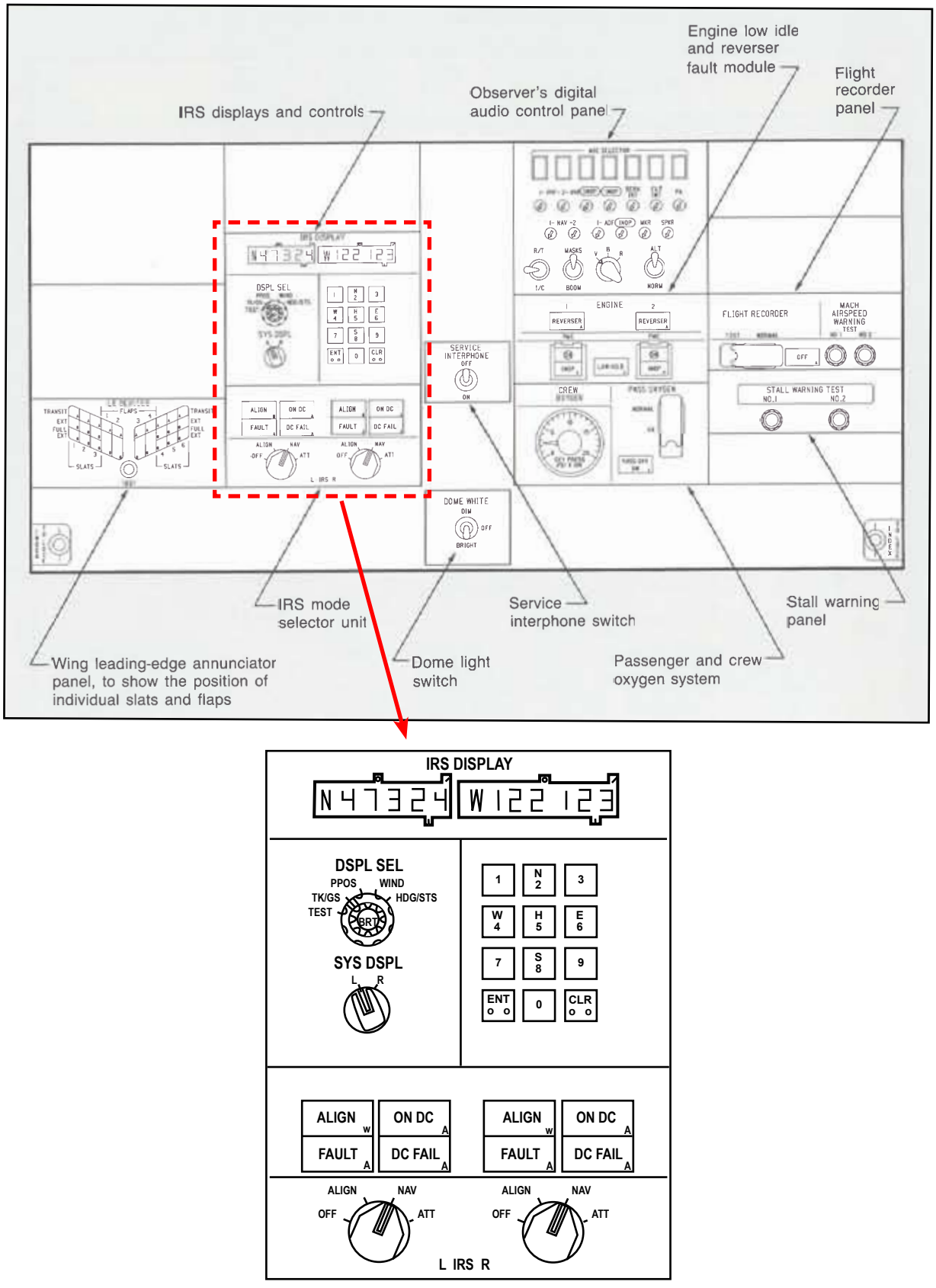

Figure 4

Location of the IRSDU on the aft overhead panel

This particular aircraft was fitted with a single FMC. IRS data is supplied to the FMC and used to calculate the 'FMS position'; no updating from radio sources is possible on the ground. When a TO/GA switch is pressed on takeoff, the FMS position updates automatically but, if the IRS position is not valid, this feature will not work.

The normal display on the pilot's EHSIs for departure would be the MAP mode. To be able to display ILS information on the EHSI, either full compass rose or expanded ILS mode needs to be selected. However, without valid IRS data, the EHSI displayed information is limited to the ILS course (LOC) and beam (G/S) scales. ILS information may also be displayed on the ADI. Although the aircraft was delivered with a Standby Horizon Indicator that could display ILS data, the indicator fitted to SP-LKA at the time of the incident was not capable of displaying such data.

Manufacturer's data

The aircraft manufacturer conducted an analysis of the data from the FDR and concluded that the failures reported were as a result of the aircraft having departed with the IRSs in ALIGN mode. They supplied the following information:

> *'If the IRU data is Non Computed Data (NCD) as we assumed due to IRU being in ALIGN mode, EFIS will remove IRU related data but it will not display IRU related Flags on EADI or EHSI. With IRU data being NCD, EFIS will remove horizontal line, pitch lines, roll pointer and sky/ground shading from the EADI. Flight path angle, Acceleration, Pitch Limit display and TCAS RA commands are also removed from EADI.*
>
> *If the IRU data is INVALID or FAILURE WARN (FW), then EFIS response will be similar to IRU data being NCD except that EFIS will display ATT Flag on EADI, HDG Flag on EHSI. We expect EHSI VOR Flag will also be displayed as HDG data to VHF Nav receivers will be FW.'*

At 1006 hrs, the heading and attitude parameters supplied to the FDR became NCD. These parameters did not recover until after engine shutdown at the end of the flight. At 1007 hrs, with the aircraft at the hold prior to takeoff, the FDR recorded a new Flight Management System (FMS) aircraft position, whose co-ordinates related to a point in the vicinity of Stand 114 at LHR. There was no further change of the recorded FMS position after this time.

Aerodrome information

London Heathrow Airport has two parallel easterly runways, designated 09R and 09L. In normal two runway operation, one runway is used for landing aircraft and the other for departing aircraft.

All the international airports in the London area are located close[1] to the Prime Meridian (0º). The aerodrome reference point for LHR is 51° 28.39 N, 000° 27.41 W, and for Stand 114, 51° 28' 17.68" N, 000° 26' 53.72" W. There are a few other major international airports in Europe and one in Africa which also lie within half a degree, east or west, of the Prime Meridian.

Footnote

[1] ie, London Heathrow, London Luton, London Stansted, London Gatwick and London City Airports are all within 30' of longitude of the Prime Meridian.

Radio telephony communications

International standards

The requirements for language proficiency for operational personnel are detailed in ICAO Annex 1. In 2003, ICAO set a deadline of March 2008 for proficiency in Level 4 (operational) and above English for all pilots flying international routes, and ATC controllers serving international airports and routes. The proficiency scale ranges from Level 1 to Level 6, with guidelines published for pronunciation, fluency, structure, vocabulary, comprehension and interaction. ICAO will require that Level 4 pilots are reassessed on their abilities every three years, Level 5 pilots every six years, while at Level 6, no further assessment of a pilot's English language ability is deemed necessary. Thus, the Level 4 (operational) proficiency is considered as a minimum 'stepping stone' to higher levels.

Although the main benefit of high international standards of aviation English is that communications between aircraft and controllers are fully understood, particularly when non-standard words and phrases are used, it also has the benefit of increasing the situational awareness of flight crews in relation to other aircraft, both in the air and on the ground.

For those States not able to comply by March 2008, full implementation is due to be completed by March 2011. The Polish Civil Aviation Office (CAA) are due to specify a date by which they will comply with the ICAO requirement for English language proficiency.

General

Recordings of the communications between the aircraft and ATC were available for the investigation. The quality of the transmission signal was good but a number of the exchanges were misunderstood, probably as a result of language difficulties.

Air traffic control

After takeoff on the incident flight, the commander first contacted TCNE at 1012 hrs and advised that he had a 'navigation problem'. At this time the TCNE sector was busy and the controller was operating under a high workload. The controller issued heading instructions to Lot 282 and continued to control other aircraft in the sector. As Lot 282 tracked north instead of north-east it came into conflict with another aircraft and this resulted in a Short Term Conflict Alert (STCA) being activated. The conflict was resolved by revised instructions being given to the other aircraft.

When the controller realised that Lot 282 was not following its assigned heading, he contacted the aircraft again and issued further heading instructions. However, it became apparent that Lot 282 was having difficulty following these instructions. Later, the controller asked Lot 282 whether there were any other problems and received the reply 'only navigation problem'.

Once the decision had been made that the aircraft would return to LHR, a handover to a dedicated controller was implemented. However, the full extent of the difficulty that the aircraft was having in complying with ATC instructions was not passed on to the dedicated controller. He attempted to vector Lot 282 to the west, to intercept the localiser course for the ILS approach to Runway 09L, but the aircraft did not comply with the heading instructions and tracked south across the localiser for Runway 09L at a 90 degree angle. The controller then attempted to guide Lot 282 back towards the localiser, by giving a north-easterly heading, but this was also unsuccessful. He then started to give 'start and stop' turn instructions and descended the aircraft to 1,500 ft. This put Lot 282 into a position from which the crew could visually acquire the airfield.

Throughout the flight, the crew did not request, and ATC did not offer Lot 282 any weather information or positional information other than, on one occasion, ATC advised the distance to go to Runway 09L.

Recorded information

The aircraft was fitted with a 25-hour Universal Flight Data Recorder (UFDR) and a 30-minute Cockpit Voice Recorder (CVR). Both recorders were removed from the aircraft and successfully downloaded at the AAIB. The CVR circuit breaker was not pulled immediately after the aircraft parked and consequently the CVR recording contained only post-landing cockpit sounds and crew speech. This had overwritten recordings from the incident flight. Data, however, was recovered for the flight from the FDR.

Primary and Secondary Surveillance Radar (SSR) data had been recorded for the incident flight, and provided information about position, altitude and speed. The selected altitude and speed (IAS, TAS and Mach No) originated from the Mode S transponder on the aircraft and form part of the Alternative Downlink Aircraft Parameters (DAP) set of parameters. The other parameters of the Alternative DAP set, ie, roll angle, true track angle and magnetic heading, normally provided by the aircraft's IRUs, were unavailable. Figure 3 shows the aircraft's track (derived from the radar data) together with extracts from the radio transmissions between the aircraft, London Control and Heathrow Director.

A time history of salient parameters from the FDR for the incident flight is shown at Figure 5, starting three minutes before the shutdown at the end of the previous flight. Of note is the following:

- the difference in recorded longitude between the shutdown at 08:40:13 hrs and start-up for the incident flight at 09:44:41 hrs
- the loss of IRU sourced data at 10:06:38 hrs, while the aircraft was in the hold area for Runway 09R
- a step change in the FMS aircraft position at 10:07:47 hrs, which remained constant for the rest of the flight

The recorded positions from the FMS at shutdown from the previous flight, together with the FMS position at start-up and at the hold for the incident flight, are given in Table 2 and illustrated in Figure 6. The difference between these points is the change in longitude from West (positioning the aircraft at Heathrow) to East (positioning the aircraft in the River Thames, east of Tilbury). Other positions of note in Table 2 are when the aircraft was at the hold and when this position was updated.

The FMS position is recorded every second on the FDR at a resolution of 2.7466E-03°, which equates to 305 m in latitude and 190 m in longitude, at a latitude of 51.47°). This manifests itself as a course and stepped track when

UTC TIME (HH:MM:SS)		FMS POSITION (WGS84) Latitude	Longitude
08:40:13	[shutdown]	N 51°28'06.73"	W 0°26'51.71"
09:44:41	[startup]	N 51°28'16.62"	E 0°26'51.71"
10:07:47	[at hold]	N 51°27'56.85"	E 0°24'23.39"
10:07:48	[updated position at hold]	N 51°28'16.62"	W 0°27'01.59"

Table 2

SP-LKA FMS positions at Heathrow

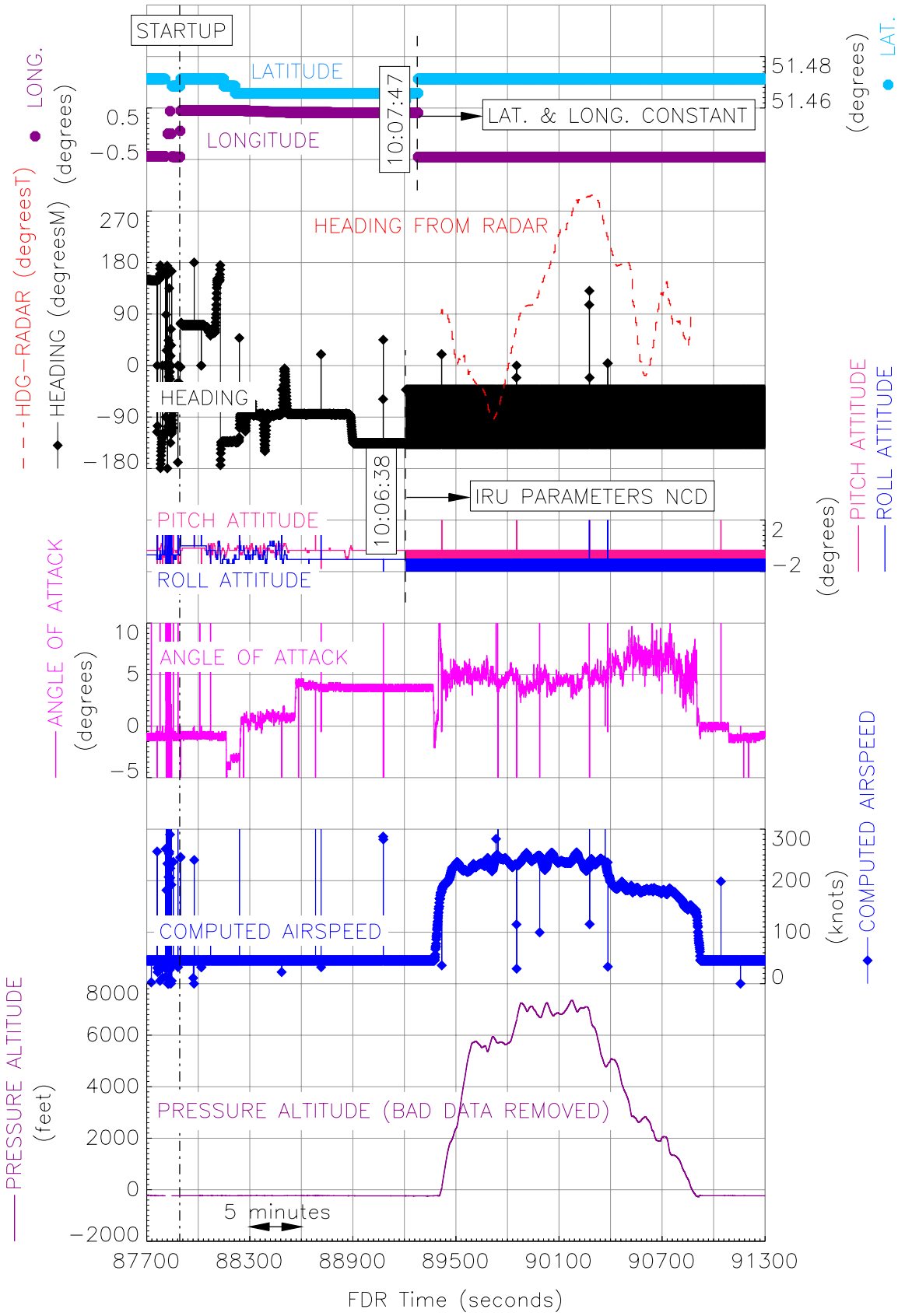

Figure 5

A time history of salient parameters from the FDR

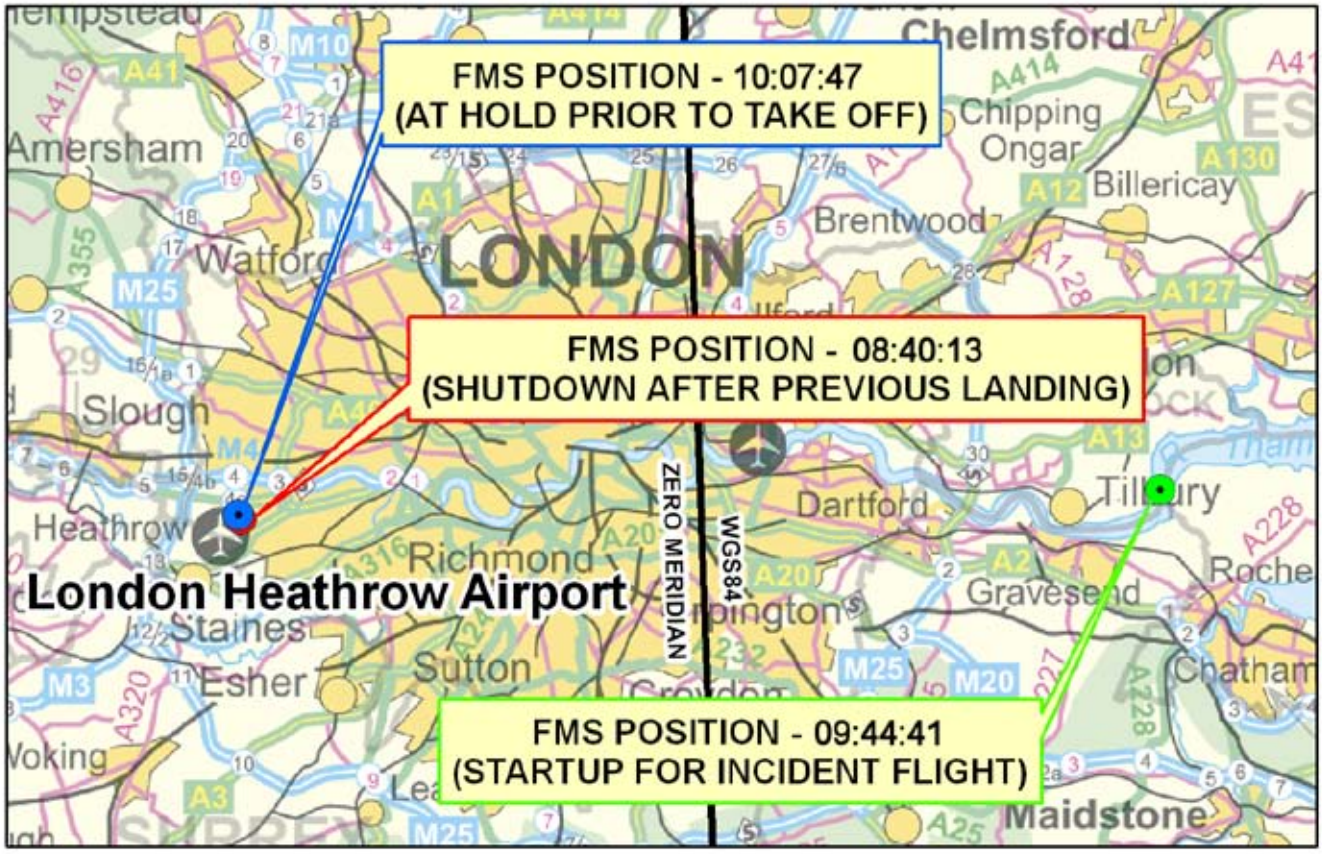

Figure 6

FMS positions at Heathrow

plotted, as the aircraft moves another 305 m or 190 m in latitude and longitude respectively, from the last recorded position. This is seen in Figure 7a, which shows the aircraft's ground track (in red) as it taxied to the stand after the landing from the previous flight. Figure 7a also shows a plot of the ground track derived from groundspeed and heading. The difference between the two illustrates the FMS position error at the end of the flight[2].

Figure 7b shows the FMS position track (in green) for the incident flight as the aircraft taxied from the stand to the holding point for runway 09R. Figure 7c shows these same positions plotted after being transposed in longitude (ie correcting for the east/west difference at startup) together with a plot of the ground track derived from groundspeed and heading (blue). A single point (blue) in Figure 7c (adjacent to the terminal) represents the updated FMS position when the aircraft was at the holding area.

Figure 8 shows some FDR parameters in detail, starting with the aircraft at the hold. At 10:06:25 hrs **[A]**, the brakes were released and the aircraft moved slowly forward, turning to the left though 224ºM before the heading and other IRU sourced parameters became NCD **[B]**. At 10:07:20 hrs, the commander **[C]** transmits a reply to ATC just before reapplying the brakes and stopping at hold NB11 **[D]**. While waiting at this point, the aircraft's position is updated in the FMS **[E]**. This position remains fixed as the brakes are released 30 seconds later **[F]** and the aircraft lines up and takes off from Runway 09R.

Footnote

[2] The flight recorder system records heading from the general purpose output bus of either the left or right EFIS, depending on the Captain's selection, which, for this flight, had been switched to the left EFIS. The left IRU is the source of heading, pitch and roll information to the left EFIS.

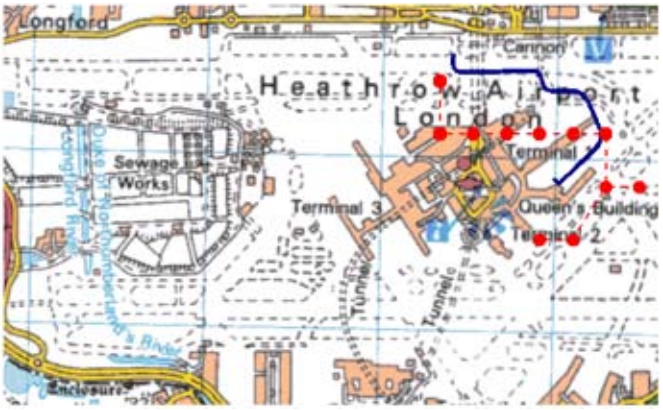

Figure 7a

Figure 7b

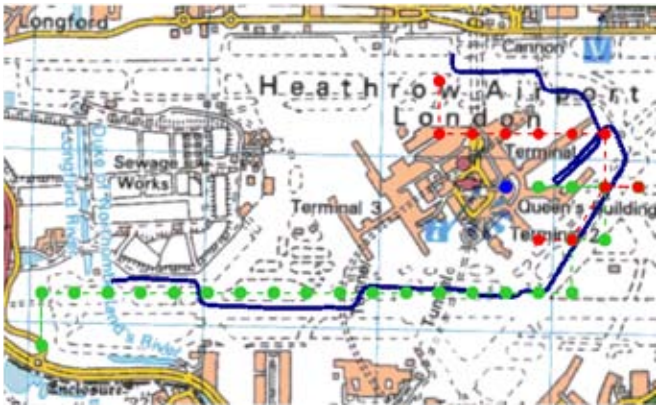

Figure 7c

GROUND TRACK
FMS POSITION - PREVIOUS FLIGHT
FMS POSITION - INCIDENT FLIGHT STARTUP & TAXI
FMS POSITION - TAXI (TRANSPOSED IN LONGITUDE)
FMS POSITION - UPDATED POSITION AT HOLD

Information from the pilots

The pilots were interviewed by the AAIB some three hours after the incident. The following account of events was compiled using information provided by the crew during AAIB interviews, operator's interviews, through the operator's internal reporting procedures and subsequent questions.

The commander had been flying this aircraft type for this operator for fifteen years. The co-pilot had been flying the type for six years. Everything had been normal on the inbound flight.

A fast realignment was carried out on the stand at Heathrow by the co-pilot before pushback, using the stand position obtained from a commercial chart. There were no abnormalities and the position did not need to be re-entered. There was no problem during the taxi and no attempt was made to re-align the IRSs before departure. At the holding point the attention of the pilots was on the other traffic in the vicinity of the aircraft and not necessarily on the flight instruments.

Everything on the aircraft appeared normal until just after rotation when the EADIs and the EHSIs 'blanked',

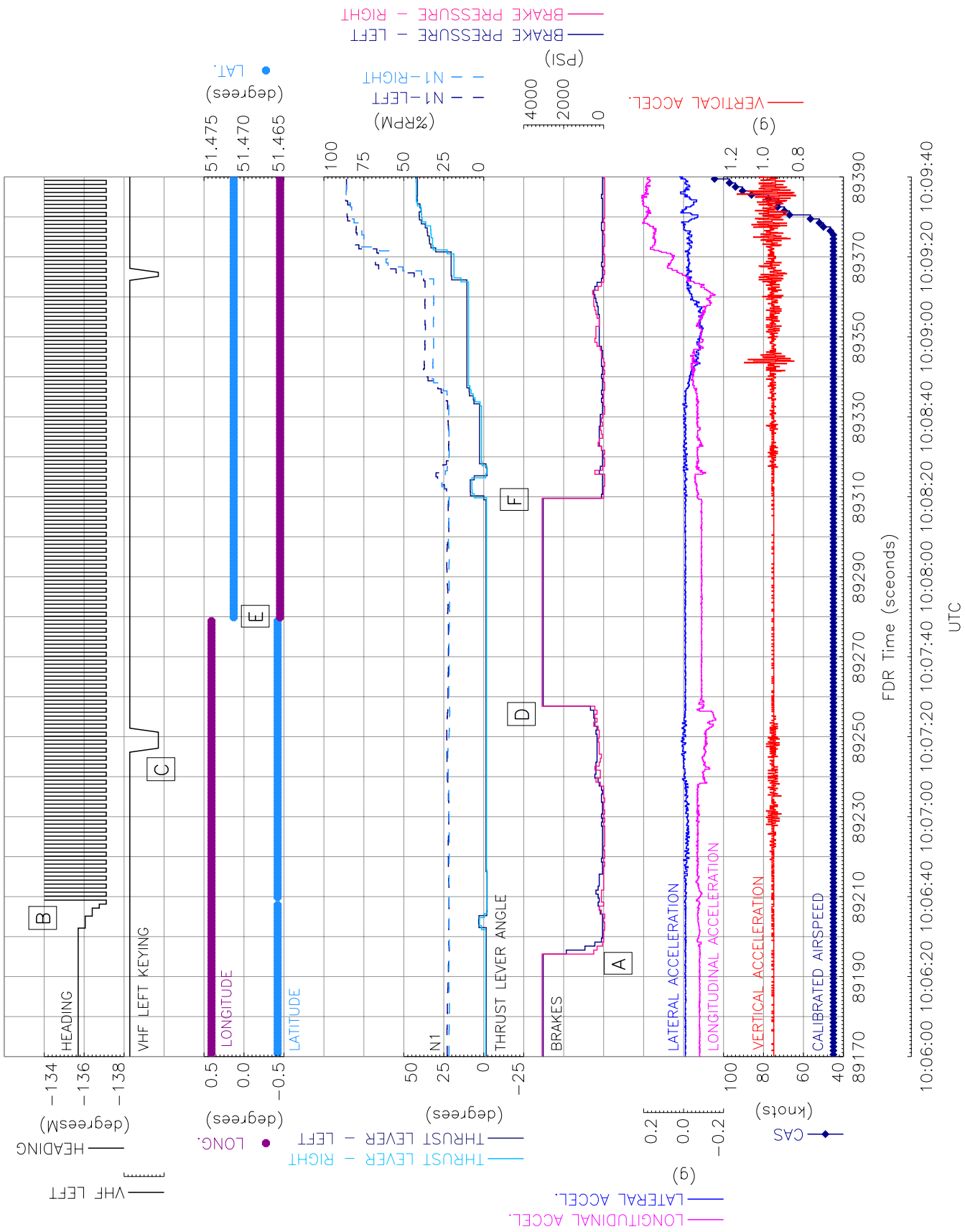

Figure 8

Selected FDR parameters

although the speed tape remained available. Both FMC CDUs also 'blanked'. There were no associated warnings or cautions at this point, nor any throughout the rest of the flight.

The co-pilot continued to fly the aircraft by reference to the standby instruments. The commander decided not to take control so that he would have extra capacity to deal with the problem. He made contact with ATC and said that the aircraft had a 'navigation problem' but did not declare an emergency because he felt that the situation did not warrant it.

The autopilots were not available but the autothrottle was operative. The commander looked up at the overhead panel and noticed that there were no lights on the IRSDU and that the whole unit was dark and appeared to be unpowered. It was decided, when it became apparent that the flight could not continue, that the aircraft would return to LHR. The aircraft was in IMC from shortly after takeoff until a short time before landing. ATC gave the aircraft radar vectors until visual contact was established. The commander considered that ATC were helpful throughout the flight.

After landing, the aircraft taxied to a parking position and, just as it came to a stop, the instruments returned to normal. After shutdown the pilots were told by a cabin crew member that a passenger had been using a mobile telephone before takeoff and considered that it was possible the telephone had interfered with the navigation systems.

Engineering examination

The aircraft operator sent two experienced avionic engineers to LHR and, together with the AAIB, the aircraft manufacturer and the operator's Maintenance Control staff, carried out very extensive testing of the aircraft's navigation systems. No faults were found. The following day, the aircraft was flown on a non-revenue flight to the operator's maintenance base in Warsaw. A further two days of intensive system testing was carried out but no fault could be found or induced. As a precaution, the operator replaced both IRS units and sent them to the manufacturer's repair facility in the UK. No faults were found in either unit. The aircraft was returned to revenue service and has been operating satisfactorily with no further navigation system faults being reported.

Analysis

General

There were two main sources of information regarding the events on this flight: the recorded data and the reports from the pilots. In some respects, the information from the two sources was not consistent. The aircraft manufacturer was not able to suggest any failure, or combination of failures, which would have caused the events to occur as the pilots described them, and no technical defects were discovered during the examination of the aircraft and its navigational equipment. In summary, no technical cause for the loss of the navigational data could be found. Thus, there remains a discrepancy between the pilots' recollections and the recorded events.

The single error made by the co-pilot during the pre-flight preparation initiated the subsequent problems. This was the use of 'E' instead of 'W' when the longitude co-ordinates were entered into the FMS. The airports around London, because of their proximity to the Prime Meridian, can lead flight crews to make such co-ordinate entry errors of this nature. It is of note that the operator's route network is such that there are few destinations to the west of the Prime Meridian and hence the majority of longitude co-ordinates that need to be entered would be 'eastings'.

Because the geographic error was less than 1º, the only alert apparent to the crew would have been a VERIFY POSITION scratchpad message. The co-pilot did not recollect having seen the message, a message that can easily be cleared and which might have been dismissed as an automated response, without consideration of the reason for the message. While the aircraft was taxiing, the IRSs were in NAV mode, evidenced by the taxi route having been accurately recorded as a series of headings and groundspeeds, Figure 7c. However, all the recorded evidence, and the analysis from the manufacturer, suggests that the aircraft took off without the IRSs being in NAV mode. Therefore, it is highly likely that they were either in ALIGN mode or OFF. The investigation has attempted to explain how this might have occurred.

Pre-takeoff

At 1000 hrs, the aircraft stopped short of Taxiway Y on a heading of 224º. At 1006 hrs, the FDR data recorded the IRS derived parameters as NCD. This is the point at which the IRSs were probably selected from NAV mode. Shortly after this, the recorded FMS position changed to that of Stand 114, after which it did not change again for the remainder of the flight. The only source of position information for the FMS at this stage of flight, with the aircraft on the ground, was either from IRSs or from a manual crew entry. The recorded evidence is consistent with a manual entry of the new position into the FMS or the ISDU, but the pilots state that this did not occur.

While taxing to the runway, the pilots would not have expected to have seen the departure route on their EHSI MAP displays, because they were most likely selected to a short range, with heading up, and their departure route would lay behind them. However, when the aircraft was waiting near the hold, it was on a heading of 224º, and it should have been possible for the pilots to have seen at least the start of the route displayed. However, if the route was not represented, this might have acted as a mental trigger for a pilot to attempt to re-enter a position. In this situation, should a pilot attempt a fast realignment of the IRSs, he would need to have selected ALIGN before entering the new position, and then re-select NAV; there should be no movement of the aircraft throughout the process until alignment is completed.

At 1005 hrs, ATC issued an instruction to Lot 282 to give way to another aircraft and then to taxi to the hold at NB11. At 1006 hrs, the aircraft started to move slowly and, within a few seconds, the recorded IRS parameters became NCD. Therefore, it would appear that at just the time when the IRSs were apparently being re-aligned, the aircraft started to move. The aircraft stopped moving at 1007:20 hrs and at 1007:50 hrs it was recorded that the FMS position changed. Thus, the realignment of the IRSs while the aircraft was moving would explain why the IRS parameters remained NCD and the FMS position did not update.

The takeoff

When the IRSs are in ALIGN mode (IRSs data being NCD), the EFIS displays will show very limited information, Figure 1. For approximately two minutes before LOT 282 took off, the pilots' displays were probably in this condition. As the pilots were busy watching for other traffic and lining the aircraft up on the runway, it is possible neither one looked at the displays during this period. As the aircraft accelerated along the runway, it is likely that the commander's attention would have been focussed on his ASI. It was probably only when the aircraft rotated on takeoff that the co-pilot would have looked down or seen that no attitude or navigational information was available.

The commander reported that the IRSDU was not illuminated and appeared not to be powered. There would not usually be any lights showing on this panel during flight, unless a failure light is triggered. However, there is also a display on the IRSDU which shows the aircraft's position in digital form, and this may be selected to a number of different information sources. With the IRSs in ALIGN mode for an extended period, it would be expected that the ALIGN lights would flash.

Difficulties experienced by the pilots

The pilots appeared confused by what had occurred and had to fly the aircraft in IMC using only the standby instruments for heading and attitude reference. Pilots of modern EFIS equipped aircraft do not routinely fly their aircraft using a basic instrument presentation and without a map display. When suddenly presented with such a situation, pilots will need time to adapt their instrument scan and a higher level of crew co-ordination to enable them to conduct a safe instrument approach. The commander also had some difficulty with comprehending comprehending and communicating with ATC. At the time, his workload was high and he was under stress, both factors which would have contributed to his problem.

When the co-pilot realised that the normal heading and attitude references were not available, he quickly reverted to using the standby instruments. The commander decided that the co-pilot should continue to fly the aircraft to allow himself extra capacity to manage the failure. After takeoff, with the aircraft in a climbing attitude and about to enter cloud, visual references would have been limited. The standby attitude instrument is small and located on the left side of the flight deck, making it difficult to use from the co-pilot's side. The heading reference was obtained from the standby compass, an instrument which is relatively easy to read in straight and level flight but difficult in turns. To turn onto a specific heading it is generally necessary to use a timed turn technique. Furthermore, because the compass card is vertically mounted, the direction of turn is often misinterpreted. This was demonstrated when, for the first few heading instructions from ATC, the aircraft turned in the opposite direction. In contrast, the normal instruments were available for altitude and speed, and instructions relating to these were complied with throughout.

During the flight the pilots continued to have difficulty in complying with heading instructions and were not able to fly the aircraft to intercept the ILS course to Runway 09L. To attempt an intercept with the navigation system in this degraded configuration, without direct heading reference, would require a high level of crew co-ordination. In fact, because of the non-compliance with the heading instructions, the aircraft crossed the ILS course at 90º, which would have made the task of intercepting it almost impossible. The pilots had little idea of their position and, after a few minutes, they were entirely dependent on ATC for their navigation. ILS DME range information was available but the pilots were offered no information from ATC, other than track miles to run, about their geographical location. It would have helped their situational awareness if their location relative to the airport and updated weather information had been given to them. Eventually, once the pilots established visual contact with the ground and then the airport, they were able to locate the runway.

Air traffic control

The TCNE departure controller at LHR already had a high workload at the time this incident started and the declared 'navigation problem' was more severe than he

anticipated. He stated afterwards that, if the pilot had said there was an 'instrument problem', then his own response might have been different. Furthermore, the aircraft did not declare a MAYDAY, even when asked specifically if there were any other problems. It is possible that, at this stage, the commander did not realise that his aircraft was not following ATC instructions. When it became apparent to the controller that the aircraft was not complying with heading instructions, it should have been an indication that the problem was more severe than he had thought initially.

The elapsed time from the declaration of the navigation problem until the handover to the dedicated controller was 10 minutes. When the dedicated controller took over from the TCNE departure controller, he did not have a full knowledge about the aircraft's lack of response to heading instructions. He therefore continued to give vectors to the aircraft, expecting that his instructions would be followed. He was also advised by the commander that the aircraft would be able to conduct an ILS approach. When the aircraft failed to comply with the assigned heading, and crossed through the localiser at a range of 14 nm, his plan to establish the aircraft gradually was compromised. He turned the aircraft back towards the airport onto a new intercept heading, but this made the task more difficult because the aircraft was closer to the airport with fewer track miles to run. The commander had advised that he had 'no direction, only glideslope' and, while receiving vectors, the aircraft crossed through the localiser three times. The controller then started to give 'start and stop turn' instructions which eventually succeeded in placing the aircraft in a position from which visual contact with the airport could be maintained.

While the aircraft was being vectored, it was getting nearer to the airport and was descending, under ATC instructions, without following any recognised procedure. This was an undesirable situation and was only resolved because visual contact was established by the pilots. The situation arose because ATC did not initially understand the nature of the aircraft's problem; this was compounded by the difficulty of obtaining information from the pilots because of their limited command of English. The commander did not declare a MAYDAY, so the aircraft was not treated as an 'emergency' aircraft. However, it should have been possible for ATC to have recognised earlier that the aircraft was not able to comply with instructions, even if the pilots appeared to think otherwise, and to have treated it as though a MAYDAY had been declared.

Aircraft

The position entered by the pilots at LHR had a longitude error of less than one degree; there was no latitude error. The FMC would have recognised the entry made when the aircraft was on stand as incorrect, because the location entered was more than 4 nm from the airport, and would have generated a VERIFY POSITION message on the 'scratchpads' of the CDUs. There is no 'attention getter' for this message and it may be easily cleared by either pilot pressing the CDU CLR key. Scratchpad messages can appear very frequently in some phases of flight. It is likely that they are sometimes cleared by pilots as an automated action, without the content having been given sufficient consideration. On this occasion, it is possible that either the message was not seen, or it was seen but was deleted without any further action being taken. The IRS internal comparison tests would both have been passed, the first because the longitude error was less than one degree and the second because there was not any latitude error. The IRS would, therefore, have completed its alignment and the FMS could have appeared to the pilots to have been operating normally with the EADI and the FMC CDU displaying all the usual information. The EHSI display, assuming it was in MAP mode and set

to a short range, would not have shown the runway and departure route. However, at this stage there is normally only a limited amount of information in view, so it may not have looked noticeably different from usual. Had a cross-check of the departure route been carried out prior to leaving the stand, this would have shown up the error, but otherwise the pilots would probably not have specifically referred to the EHSI while manoeuvring on the ground.

Other

Although much of the difficulty in R/T communication may be explained by the added workload and stress on the pilots, this incident shows the problems that can arise when there is a lack of understanding between controllers and flight crews. The introduction of language proficiency standards should ensure that all operational personnel are qualified to a minimum and competent standard required for the task being undertaken.

The fact that a passenger may have been using a mobile telephone before takeoff is not likely to have had any bearing on this event, as the erroneous FMS position was entered when the aircraft was at the stand, before the passengers had boarded the aircraft. Furthermore, shortly after the time at which the IRS NAV function was lost, the position of the FMS was updated with a position close to the original stand position at Heathrow. This position could only have been manually generated and entered.

Conclusion

A fairly simple error in the pre-flight procedure of entering the aircraft's position into the IRS went undetected and led to a serious incident. Better cross-checking procedures, either when initially entering data or by conducting a check of the entered route against that displayed on the map, would have prevented the situation from developing.

This incident demonstrates how reliant pilots may become upon the FMS, and how essential it is to ensure that the system is provided with accurate data.

Safety action

In an event such as this, it is clear that ATC may not be able to rely upon pilots for information about the aircraft's status, and their ability to fly the aircraft accurately, with degraded instrumentation. The crew of Lot 282 were not able to communicate adequately the nature and extent of their problem. Following their own investigation into this incident, the air traffic service provider has made several recommendations, one of which is that the circumstances of this event should be used for their internal training purposes. The service provider is also looking at the possibility of liaising with operators to enable controller training instructors to gain experience by observing Line Orientated Flight Training (LOFT) training sessions.

The operator is considering reminding its pilots of the necessity to use extra caution when manually entering latitude and longitude co-ordinates when at locations close to the Prime Meridian. Also, the operator is considering revising its pilot training to highlight the benefits of declaring an emergency in such circumstances.

Because these actions have already been initiated by the organisations concerned, no Safety Recommendations are made.