AIRCRAFT INCIDENT REPORT 4/98

# Air Accidents Investigation Branch

Department of the Environment, Transport and the Regions

# AIRPROX (C) : Boeing 747 and Gulfstream G IV

## Report on an incident near Lambourne VOR on 3 July 1997

This investigation was carried out in accordance with
*The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996*

London: The Stationery Office

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**Department of the Environment, Transport and the Regions**
**Air Accidents Investigation Branch**
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**Hampshire GU14 6TD**

13 August 1998

*The Right Honourable John Prescott MP*
*Secretary of State*
*for the Environment, Transport and the Regions*

Sir,

I have the honour to submit the report by Mr R StJ Whidborne, an Inspector of Air Accidents, on the circumstances of an AIRPROX incident in the London TMA near Lambourne VOR on 3 July 1997

I have the honour to be
Sir
Your obedient servant

**K P R Smart**
Chief Inspector of Air Accidents

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# GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

| | | |
|---|---|---|
| AAIB | - | Air Accidents Investigation Branch |
| ACAS | - | Airborne Collision Avoidance System |
| agl | - | Above ground level |
| AIRPROX | - | Aircraft proximity |
| AIP | - | Aeronautical Information Publication |
| APHAZ | - | Aircraft Proximity Hazard |
| ANO | - | Air Navigation Order |
| AOC | - | Air Operator's Certificate |
| ATC | - | Air Traffic Control |
| ATSSD | - | Air Traffic Services Standards Department |
| ATMS | - | Air Traffic Management System |
| AUW | - | All up Weight |
| CAA | - | Civil Aviation Authority |
| CAP | - | Civil Aviation Publication |
| CHIRP | - | Confidential Human Factors Incident Reporting Programme |
| CPA | - | Closest Point of Approach |
| DETR | - | Department of the Environment, Transport and the Regions |
| FDR | - | Flight Data Recorder |
| FL | - | Flight Level |
| FM | - | Flight Manual |
| IAS | - | Indicated Air Speed |
| ICAO | - | International Civil Aviation Organisation |
| IMC | - | Instrument Meteorological Conditions |
| JAAP | - | Joint Airprox Assessment Panel |
| JAWG | - | Joint Airprox Working Group |
| LATCC | - | London Area and Terminal Control Centre |
| MATS | - | Manual of Air Traffic Services |
| MTCA | - | Medium Term Conflict Alert |
| MOD | - | Ministry of Defence |
| MHz | - | Mega Hertz |
| NATS | - | National Air Traffic Services Limited |
| nm | - | nautical miles |
| PMS | - | Performance Management System |
| QNH | - | Corrected mean sea level pressure |
| RA | - | Resolution Advisory |
| SID | - | Standard Instrument Departure |
| SLP | - | Speed Limit Point |
| SMF | - | Separation Monitoring Function |
| SMS | - | Safety Management System |
| SSC | - | System Safety Case |
| STAR | - | Standard Terminal Arrival Route |
| STCA | - | Short Term Conflict Alert |
| SRG | - | Safety Regulation Group |
| SSR | - | Secondary Surveillance Radar |
| RT | - | Radio Telephony |
| TA | - | Traffic Advisory |
| TC | - | Terminal Control |
| TCAS | - | Traffic Alerting and Collision Avoidance System |
| TMA | - | Terminal Control Area |
| USC | - | Unit Safety Case |
| UTC | - | Coordinated Universal Time |
| VOR | - | VHF omni directional radio beacon |
| VHF | - | Very High Frequency |
| VMC | - | Visual Meteorological Conditions |

## Air Accidents Investigation Branch

## Aircraft Incident Report No: 4/98 (EW/C97/7/1)

| | |
|---|---|
| Operator: | i) Japan Airlines (JAL)<br>ii) ITT Corporation |
| Aircraft Type and Model: | i) Boeing 747-300<br>ii) Gulfstream IV |
| Nationality: | i) Japan<br>ii) United States |
| Registration: | i) N213JL<br>ii) N153RA |
| Location of incident: | 14 nm east of Lambourne VOR<br>between Flight Level 120 and 115<br>Latitude: 51° 38.73' North<br>Longitude: 000° 34.2' East |
| Date and Time: | 3 July 1997 at 1443 hrs<br>All times in this report are UTC |

## Synopsis

The investigation was conducted by Mr R StJ Whidborne (Investigator in Charge), Mr A F Rhodes (Operations) and Mr R J Tydeman (Operations). The investigation was assisted by Ms D A Westley, an Air Traffic Control specialist employed by the Directorate of Safety and Operations of the National Air Traffic Services Limited (NATS), who was appointed by the Secretary of State under Regulation 8(8) of the Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996.

A loss of separation occurred between a Boeing 747-300 (B 747) and a Gulfstream IV (G IV) in the London Terminal Control Area, which is Class A controlled airspace. The B 747 was en route from Kansai, Japan, to London (Heathrow) Airport; the G IV was en route from Olbia, in Sardinia, to London (Luton) Airport.

The B 747 began its descent after entering the UK Upper Information Region (UIR) from Holland and was controlled through the Clacton Sector for arrival at London Heathrow. It was cleared initially to Flight Level (FL) 290 then FL 150, and later to FL 110, whilst routing direct to the Lambourne VOR and maintaining 290 kt. On making contact with Heathrow

Intermediate North Director the B 747 was cleared to descend to FL 90, to leave Lambourne on a heading of 270°, and to reduce speed 'now' to 210 kt.

The G IV entered the UK FIR from France and was controlled through the Lydd Sector for arrival at Luton via the Detling VOR. When the G IV contacted the Lambourne controller it was level at FL 130 and was permitted to maintain high speed whilst given a radar heading of 340°, it was subsequently cleared to FL 120.

As the G IV reached FL 120 the pilot reported that his Traffic Alerting and Collision Avoidance System (TCAS) was indicating traffic in his one o'clock position. The controller initially thought that there was 1,000 feet vertical separation between the two aircraft and declared this, but he then gave the G IV avoiding action, after the pilot reported that the traffic was 300 feet below him, to turn to the left which took it out of the path of the B 747.

At the same time the B 747 crew complied with the first of two TCAS Resolution Advisory (RA) messages. The first instruction was to climb followed by a subsequent instruction to descend. Subsequent analysis of the recorded radar data showed the closest proximity of the two aircraft was 0.83 nautical miles (nm) horizontally with vertical separation of 100 feet; the next element of the recorded radar data indicates that the vertical separation had then increased to 200 feet with the horizontal separation reducing to 0.66 nm.

The following causal factors were identified:

1. The B 747, having left FL 120 then stopped descending some 300 feet below this level whilst reducing speed from 290 kt to 210 kt. FL 120 was assigned to the G IV by the bandboxed Terminal Control North East Departures/Lambourne controller before the proper vertical separation had been established after its direct routing towards Luton had brought it into lateral conflict with the B 747.

2. The North East Departures / Lambourne controller did not apply the procedure given in MATS Part 1 regarding level assessment of SSR Mode C (height information) when giving clearance to the G IV to FL 120. The controller should have waited for the B 747 to have had a readout of at least FL 116 (400 feet below the vacated level) before clearing the G IV to descent. The controller then did not monitor the Mode C readout of the B 747 to ensure that it was 'continuing in the anticipated direction'.

3. Despite reporting to the Heathrow Intermediate North controller that the aircraft had vacated FL 120, the B 747 did not descend at the minimum rate mandated for the UK and detailed in the UK Air Pilot (500 ft/min). If it was not possible to comply with this requirement, the crew were required to inform the controller but did not do so.

4. The Heathrow Intermediate North controller, unaware that the aircraft speed was 290 kt, called for a combined speed and level change which resulted in the B 747 having a minimal rate of descent while its speed reduced.

5. The B 747 crew did not report their speed control, which had been imposed by Clacton SC, to the Lambourne Sector, thereby allowing the controllers to assume a standard speed of 250 kt.

6. Since the TCAS manoeuvre was not fully co-ordinated by both aircraft's TCAS, one of which was not selected to TA/RA, the B 747's initial RA reduced the separation distance.

Five safety recommendations are made.

# 1 Factual information

## 1.1 History of the flight

### 1.1.1 Controller identification

The B 747 had been controlled by the Clacton Sector controller (CLACTON SC) before he released it to the Lambourne Sector controller (TC LAM). At the time of the incident it was receiving an ATC service from the Heathrow Intermediate North Director (LL INT N).

The G IV had been receiving an ATC service from the Lydd Sector controller who released it to the Lambourne Sector controller (TC LAM). At the time of the incident the positions were 'bandboxed'[1] as TC Sector North East Departures / Lambourne controller (TC NE / LAM).

The sequence of handovers was thus:

<u>B 747</u> ——»Clacton ——»Heathrow Intermediate North<br>
——»<br>
Lambourne<br>
——»<br>
<u>G IV</u> ——»Lydd -----»became* NE Departures/Lambourne<br>
Δ

Δ = Time of AIRPROX<br>
* = Bandboxed

### 1.1.2 The Boeing 747

The B 747 on a flight from Kansai, Japan, to London (Heathrow), began its descent at 1427 hrs after entering the UK FIR from Holland. It was cleared to FL 150 by the CLACTON SC with instructions to report the speed control of 290 kt, which had been imposed at 1432 hrs, to TC LAM. On transfer to TC LAM the pilot reported leaving FL 192 for FL 150 but neglected to inform the controller of the speed control. The flight was given a radar heading and further descent in stages to FL 120. Before reaching this level the B 747 was given descent clearance to FL 110 and cleared direct to the LAM VOR. At 1441:32 hrs the flight was released to the LL INT N controller before TC LAM was 'bandboxed' with TC NE.

At 1441:49 hrs the B 747 crew established communication with the LL INT N controller. On receipt of this initial call LL INT N issued the following clearance,

[1] Positions may be 'bandboxed' at times of light workload. Two adjacent sectors are controlled by a single controller who also has the option of cross-coupling the respective radio frequencies. Pilots receiving a service from a bandboxed position will be unaware of any change other than perhaps noticing additional traffic using the cross coupled frequencies.

"DESCEND TO FL90 AND LEAVE LAMBOURNE HEADING 270°, REDUCE SPEED NOW TO 210 KNOTS". At this stage the B 747 was beyond the selected range of LL INT N's radar display and remained so until after the incident.

1.1.3 The Gulfstream IV

The G IV on a flight from Olbia, Sardinia, to London (Luton), entered the UK UIR from France through the LYDD sector and was cleared from overhead Abbeville to route via DETLING on a Lorel 3E arrival (refer to paragraph 1.10.3). Subsequently, the flight was requested to expedite its descent to FL 130 to be level at DETLING and was later cleared to the position BOYSI which is within the northern part of the London Terminal Area. To achieve the descent profile required by LYDD SC the flight had maintained a rate of descent of over 4,000 ft/min. At 1441 hrs the G IV contacted the TC LAM controller when at FL 130 and was permitted to maintain high speed. At 1442:15 hrs it was given a heading of 340° in order to provide a shorter routing to Luton. Luton inbound flights are often handled in this manner, however, on this occasion the assigned heading placed the G IV on a track which resulted in a conflict, in plan, with the B 747. At this stage standard vertical separation existed but at 1442:38 hrs the G IV was cleared to descend to FL 120. The aircraft was in receipt of a radar control service from TC NE / LAM at this time since the two sectors had been combined (bandboxed).

1.1.4 The loss of separation

The aircraft were converging at right angles to each other, the B 747 on a westerly track towards LAM VOR and the Gulfstream on an assigned radar heading of 340°. The respective tracks and relevant timings are shown in Appendix 1. The B 747 had been transferred to LL INT N from TC LAM descending to FL 110 and was then further cleared by LL INT N to FL 90 whilst attempting to decelerate. When TC NE / LAM considered that the B 747 had vacated FL 120, based on his observation of the flight's Mode C readout on his radar display, he cleared the G IV to that level. However, whereas the G IV descended rapidly to FL 120 the B 747 actually stopped its descent at FL 117 resulting in a serious loss of separation. TC NE/LAM was first warned of the developing situation by the crew of the G IV who relayed information generated by their TCAS[2]; the LL INT N controller was alerted by the activation of the Short Term Conflict Alert[3] (STCA): 'avoiding action' instructions were then issued to both flights. Vertical separation was further reduced when the B 747 climbed back to FL 122, in response to a RA message generated by the TCAS. The minimum separation

[2] For a description of this equipment see paragraph 1.6.3. TCAS refers to the equipment fitted to both aircraft. ACAS refers to the generic collision avoidance system. Throughout this report the terms are used in the appropriate context i.e ACAS for the system and TCAS for the aircraft equipment.

[3] For a description of this equipment see paragraph 1.18.1.

was 0.83 nm horizontally and 100 feet vertically. Four seconds later the vertical separation increased to 200 feet with a corresponding horizontal separation of 0.66 nm.

1.1.5 The TCAS event

The B 747 was in level flight at FL 117 when its TCAS issued a Traffic Advisory (TA) at 1443:20 hrs; the associated TCAS display indicated that there was traffic approximately 3 nm to the left and 300 feet above. The crew were unable to see this traffic since they were in cloud at the time. The G IV was maintaining a high forward speed and was descending to FL 120 at a rate of approximately 2,000 ft/min. The TCAS reacted to this traffic by issuing a 'CLIMB' RA to the crew of the B 747 whose handling pilot disconnected the auto pilot and followed the climb instruction; the TCAS then reversed its RA to 'DESCEND'. The aircraft reached a maximum altitude of FL 122 before commencing the descent. The aircraft was subsequently given avoiding action by the ATC controller. The crew did not inform ATC of the TCAS event.

The G IV, which had been maintaining high speed as instructed by ATC, was levelling at FL 120 when the crew received a TA for traffic which was indicating 300 feet below them in their one o'clock position at a range of about 3 nm. The pilot queried this traffic with ATC but was told that it was 'maintaining a thousand feet below'. The controller later stated at interview that in giving this information he may have misread the Mode C Secondary Surveillance Radar labels as '107' instead of the actual '117', possibly as a result of some label overlap on his display. The pilot pointed out that the traffic was indicating about 300 feet difference and TC NE / LAM, realising that this was in fact the situation, then gave him avoiding action via a turn to the left. The TCAS on the G IV aircraft did not issue an RA, probably because it was selected to TA (see paragraph 1.6.3 for a fuller explanation).

Neither crew saw the other aircraft prior to the incident. As the crew of the G IV entered the left turn onto 250°, as instructed by ATC, they saw the other aircraft briefly before it went back into cloud. The crew of the B 747 were in the descent element of the RA when they briefly saw the other aircraft in a left turn. One of the pilots of the B 747 estimated that the other aircraft was approximately 200 metres (0.1 nm) away with 100 feet to 200 feet vertical separation; he could clearly see the belly of the G IV aircraft. Analysis of data from Debden radar for each aircraft suggest that the minimum distances occurred at 14:43:58 hrs, when the lateral separation was 0.83 nm with 100 feet vertical separation, and at 14:44:02 hrs, when the lateral separation had reduced to 0.66 nm and the vertical separation was now 200 feet. However, these separations are based on interpolations of the raw data and may not accurately reflect the true separations.

## 1.2 Injuries to persons

There were no injuries.

## 1.3 Damage to aircraft

Not applicable.

## 1.4 Other damage

Not applicable.

## 1.5 Personnel information

The flight crews of the two aircraft involved in the incident were correctly licensed, medically fit and properly rested to perform their duties. Both aircraft crews were familiar with operations in the London TMA.

### 1.5.1 North East Departures Sector Controller NE (TC NE)

Male aged 27 years

Operational experience: Two years at the unit with 8 months experience on the position (NE Departures).

Time on duty: 2 hours 13 minutes

Time since last break: 10 minutes

### 1.5.2 Heathrow Intermediate North Director (LL INT N)

Male aged 29 years

Operational experience: Heathrow Approach for two years and six months; previously at Gatwick

Time on duty: 1 hour 43 minutes

Time since last break: 20 minutes

### 1.5.3 Lambourne Sector Controller (TC LAM)

Female aged 28 years

Operational experience: One year 11 months in the position

Time on duty: 2 hours 13 minutes

Time since last break: 9 minutes

### 1.5.4 Training

The training of controllers has to match the requirement to deliver a safe and efficient service against rising traffic levels. After 'ab initio' training, specific role training, generally Area or Aerodrome in the first instance, is provided up to validation. Thereafter there is a continuous process of assessing individual controller's operational competence. CAA licensing requirements call for controllers to practice emergency and incident handling on an annual basis using simulators.

1.5.5 Controller familiarisation

ATC controllers are encouraged to familiarise themselves with the working environment of the modern flight deck. During training, students on the NATS Student Controller Training Course are given 15 hours of flying training in a two week familiarisation module. In addition an Airline Awareness Course is also given to student controllers. It includes Flight Management System simulator experience and includes two European familiarisation flights. Training for a Private Pilot's Licence is no longer available. NATS also provide a two week Customer Awareness Course for more experienced controllers. During their service controllers may undertake familiarisation flights on a voluntary basis.

In practice a shortage of trained controllers combined with the requirements of their job means that few controllers manage to achieve flight deck experience on a modern flight deck. It is this type of experience which will be of most benefit to controllers operating within Terminal Control (TC) to give them an understanding of the problems which can be encountered as flight crews comply with ATC instructions. Equally, flight crews need to be familiar with the problems encountered by ATC staff controlling a busy segment of airspace.

Dissatisfaction with the existing arrangements and the need for improved familiarisation training was identified in a number of reports submitted by controllers to the Confidential Human Factors Reporting Programme (CHIRP)[4]. Issues Nos. 42 and 43 of 'Feedback', CHIRP's monthly publication, reported on the practical difficulties of arranging familiarisation flights for controllers and commented on the rare attendance of flight crew in ATC units. Most common obstacles were time pressures on work schedules, lack of status as supplementary crew members for the observing controllers, and lack of duty time combined with allowances to facilitate such activity. The reports commented on the mutual benefit both to pilots and controllers of a structured system of familiarisation training.

## 1.6 Aircraft information

1.6.1 Boeing 747-300

The 747-300 aircraft was standard for the type and was fitted with a Performance Management System (PMS). The purpose of the PMS is to allow the pilot to

[4] The Confidential Human Factors Reporting Programme is a confidential reporting process which is complementary to other methods of reporting and is available to flight crew and ATC controllers. Those reports which are published in Feedback are disidentified prior to publication.

enter, store and modify en route the intended vertical profile of the aircraft. This can be achieved by entering the required speed and/or altitude and then following the flight director commands either through the autopilot or in manual flight. When in a descent mode the PMS will prioritise speed: i.e. if a descent and a speed reduction is entered the PMS will command the speed reduction whilst maintaining essentially level flight and then, once the speed is achieved, it will command the descent.

When decelerating the use of speedbrake with flaps is prohibited. Thus if instructed to decelerate from 290 kt to 210 kt the optimum procedure for the crew would be to close the throttles and select speedbrakes until approaching the minimum manoeuvre speed for the clean configuration when the speedbrakes would be stowed and flap 1 selected. In this instance the aircraft was at an estimated AUW of 258 tonnes which relates to a $V_{REF}$ of 143 kt, the associated minimum manoeuvre speed for the clean configuration was therefore 223 kt. However, because the aircraft was in icing conditions the crew would have been unable to close the throttles fully since a minimum of 50% N1 is required when above 10,000 feet in such conditions. The limiting speed for the selection of flap 1 was 275 kt.

1.6.2 Gulfstream IV

The G IV was equipped with a Honeywell digital integrated flight control system which would normally command a 3° descent profile when in the descent. When descending at 300 kt this would equate to approximately 2,000 ft/min rate of descent.

1.6.3 Airborne Collision Avoidance System

The TCAS alerts the crew to traffic that may present a collision threat and provides the crew with a vertical avoidance manoeuvre. TCAS is independent of, but does not replace, the ground based ATC system. The TCAS equipment uses the transponder to interrogate the transponders of other aircraft in the vicinity to determine their range, bearing and altitude. TCAS generates a Traffic Advisory (TA) when another aircraft becomes a potential threat, no manoeuvres are required for a TA. If the confliction continues and becomes an imminent threat, a Resolution Advisory (RA) is generated. The RA provides a vertical restriction or manoeuvre to maintain or increase separation from the traffic.

The TCAS operating mode is controlled from the transponder panel. TCAS is normally operated in the TA/RA mode. However, provision is made to allow operation in the TA only mode in order to prevent undesired RAs: e.g. during engine out operations when the aircraft may be unable to follow a climb command. Both aircraft in this instance were equipped with TCAS using the current software standard, referred to as 'Version 6.04A (enhanced)'.

The crew of the B 747 had their TCAS equipment selected to the TA/RA mode since they received both sets of instructions to which they responded promptly and correctly. The crew of the G IV could not confirm the TCAS selection at the time of the incident, although their normal procedure was to select TA/RA prior to take off and they had no reason to deviate from this on this particular flight. When this crew received the initial TA they queried the vertical separation with ATC and it was this which alerted the controller to the need for avoiding action. However, the G IV crew did not receive an RA at all. Moreover, the logic embedded within the current TCAS software does not allow for reversals in RAs during encounters with other TCAS equipped aircraft operating in the RA mode yet in this case such a reversal occurred. It is therefore apparent that the TCAS in the G IV was being operated in the TA only mode at the time of the incident. It should be noted that, at the time of the incident, the carriage and use of TCAS in UK airspace was not mandatory for any category of aircraft.

## 1.7 Meteorological information

The synoptic situation at 1400 hrs on the day of the incident comprised an area of low pressure centred over northern England with an unstable southerly airflow over the area. The weather consisted of scattered showers with visibility of 15 to 20 km or more. The mean sea level pressure was 1006 mb and the temperature at 12,000 feet was -12°C. The cloud base was scattered at 2,000 feet and broken at 5,000 feet with tops about 12 to 16,000 feet amsl. The wind at 10,000 feet was 220°/25 to 30 kt; at 18,000 feet it was 200° /20 to 30 kt. Both aircraft were in cloud at the time of the AIRPROX.

## 1.8 Aids to navigation

The G IV had been instructed to maintain a radar heading given by the controller. The B 747, from flight deck interpretation of ground based navigation aids, was tracking towards the LAM VOR. The performance and accuracy of navigational aids were not relevant to the circumstances of the incident.

## 1.9 Communications

On entering the UK FIR the B 747 was controlled by the LATCC Clacton Westbound Sector and the G IV was initially controlled by the Lydd Sector. Both flights were released by their respective controllers to the Lambourne Sector who in turn transferred the B 747 to the Heathrow Intermediate North controller and the G IV remained with Lambourne which was then bandboxed with TC North

East Departures as TC NE / LAM. After the AIRPROX had occurred the B 747 was handed over to Heathrow Final Director and the G IV to Luton Approach control.

Relevant extracts from the recorded transcripts involving the above controller positions (except for Luton) are shown in Appendix 2.

## 1.10 Aerodrome information (Air Traffic Control environment)

### 1.10.1 Statistics

In the calendar year 1997 LATCC provided an ATC service to 1,579,034 General Air Traffic flights within controlled airspace. Of these flights 928,661 operated within the London TMA. In the same period, 25 AIRPROX reports were filed within the TMA of which 16 were AIRPROX (C)[5] incidents. Four have already been reviewed by the Joint Airprox (C) Assessment Panel (JAAP). They considered that three of these were Category 'C' (no risk of collision) and one was Category 'B' (possible risk of collision). One of the remaining AIRPROXs relates to this particular incident and another, involving a Boeing 737 and a BAe 146, was investigated by the AAIB whose report was published in April 1998[6]. Six of the remaining ten incidents involved horizontal separations of greater than 1 nm but have yet to be reviewed and categorised by the JAAP.

### 1.10.2 The London Terminal Control Area

The London TMA (Terminal Manoeuvring Area, subsequently redesignated Terminal Control Area) airspace complex has evolved over a period of more than forty years and is established to enable aircraft operating into and out of the various London airports to be provided with a controlled, known traffic environment. Air Traffic Services within the London TMA are provided by the National Air Traffic Services Limited (NATS) from the London Area and Terminal Control Centre (LATCC) at West Drayton. The design and establishment of the airspace is the responsibility of the Civil Aviation Authority's Directorate of Airspace Policy and consists of Class A airspace with varying base levels extending to an upper level of FL 245 (Class A airspace requires all aircraft within it to operate according to the Instrument Flight Rules under an air traffic control separation service). Currently, the airspace covers an area which generally encompasses the London Heathrow, London Gatwick, London Luton, London Stansted and London City airports together with their associated instrument holding areas and the surrounding airspace is divided into a number of air traffic control (ATC) sectors.

[5] A controller initiated report. See paragraph 1.17.3 for a full description of the procedure.

[6] AAIB Bulletin No 4/98

The ATC task is to integrate the flightpaths of aircraft arriving at and departing from the various airports with those of overflying aircraft and those wishing to join the airways system in the London area. Appropriate separation standards are applied throughout. The complex nature of the operation is eased by the use of Standard Terminal Arrivals (STARs) and Standard Instrument Departures (SIDs) which specify predetermined tracks and altitudes to be flown by arriving and departing traffic. Normal ATC co-ordination procedures are augmented by the use of 'Standing Agreements', these allow aircraft to enter the airspace of an adjacent sector without individual co-ordination as long as certain conditions regarding altitudes or flight levels, routings etc, are met. Standing Agreements are fundamental to the operation of a busy ATC unit such as LATCC, since they facilitate the flow of traffic between sectors working on the basis of what a controller expects from an adjacent sector, without the need for individual telephone co-ordination. Within this environment controllers are also required to exercise tactical control of the situation using radar facilities to ensure that safe and efficient use is made of the airspace.

1.10.3 Standard Terminal Arrival Route (STAR) for Luton

The LOREL 3E STAR is in place to facilitate the safe handling of aircraft inbound to London Luton Airport (the destination of the G IV) and London Stansted Airport from the south which need to cross the predominantly eastbound/westbound flow of the LATCC Terminal Control North East (TC NE) sector. An extract from the UK Aeronautical Publication (AIP), showing STARs via LOREL (east) and STARs via LAMBOURNE, which were current at the time of the incident, is shown at Appendix 3.

Aircraft following the STAR are required to be at specified levels (published in the 'descent planning' table of the STAR charts) in order to comply with the relevant Standing Agreement. For aircraft following the LOREL 3E STAR, the Standing Agreement into the receiving TC sector requires an aircraft to be level at FL 130 by Detling. The Lydd sector controller, controlling the G IV, was tasked with ensuring that the flight achieved this requirement. The TC NE sector controller is required to ensure that FL 130 is available for traffic routing on a LOREL 3E STAR.

1.10.4 Short Term Conflict Alert

Short Term Conflict Alert (STCA) is an automated system which alerts controllers to potential conflicts between aircraft using the radar display. As the name suggests STCA is designed to look for conflicts in the short term, i.e. the next two minutes. STCA has been gradually introduced into more complex airspace in the UK and has been covering operations in the London Terminal Control Area since November 1995.

STCA is designed to improve safety by alerting air traffic controllers to potential conflicts involving at least one aircraft under their control. STCA recognises an aircraft under ATC control by reference to its Mode A code. Conflict alert warnings will only be given for two aircraft where at least one is controlled from an ATC centre equipped with STCA.

To assist flexibility within the NATS system distinct 'regions' of airspace are defined. Typical STCA region types are 'en route', TMA, advisory, approach, departure, and stack. Different STCA software parameter values can be set for each STCA region type; these will depend on the airspace and the separation standards applied.

Alerting aircraft are identified on the radar display by flashing target labels in colours to denote the severity of the conflict. Low severity alerts are shown in white and high severity alerts are shown in red. A separate pop-up conflict alert list on the controller's screen allows rapid identification of aircraft in conflict. This is particularly useful if target labels are overlapping.

LL INT N recalled that the STCA had immediately displayed in red, denoting a high severity alert. An analysis of the recordings of the STCA system relating to this encounter was conducted by the Department of Technical Research and Development of NATS using radar data from the incident. This indicated that the alert would have gone straight to red because of the late stage at which the situation went from a safe to an unsafe condition. The analysis notes that the B 747 was level at about FL 117 whilst the G IV was descending towards FL 120. The aircraft were converging laterally, however, the G IV was initially predicted to pass safely beneath the B 747 before lateral separation fell below the STCA linear prediction alerting criteria (2.0 nm for TMA regions). When the G IV slowed its rate of descent and began to level at FL 120 STCA 'imminent' linear prediction conditions were met and an alert immediately declared. The alert continued as the aircraft closed laterally with less than 500 feet vertical separation. The alert stopped as both aircraft had begun lateral avoidance manoeuvres. Furthermore, STCA has no knowledge of cleared levels and therefore could not predict that the G IV would level until the manoeuvre had begun. The analysis assessed that STCA had performed in accordance with its specification.

The next generation of system 'safety nets', which includes medium term conflict detection, is being developed in conjunction with European partners. This is being developed to detect potential separation conflicts between approximately 2 and 20 minutes ahead of Closest Point of Approach (CPA).

1.10.5 Separation Monitoring Function

Separation Monitoring Function (SMF) has been in service at LATCC since December 1993. It continuously and automatically monitors the separation between transponding aircraft and will detect any breach of pre-defined separation criteria that takes place within the coverage of the LATCC en route radar system. SMF is not a Collision Avoidance System. The equipment provides post-event notification to assist in determining circumstances and factors that led to the loss of separation. The equipment uses radar to determine the horizontal separation between aircraft, and transponder mode C to measure the vertical separation. At the time of this incident the equipment was set to detect any pairs of aircraft simultaneously within 2 nm and 600 feet of each other.

Filtering and categorisation is used to identify instances where the use of reduced separation is permitted. Any breach of the pre-determined criteria which cannot be attributed to any known ATC procedure is automatically notified within 5 minutes to unit managers, enabling the investigative process to commence. A printed diagram, depicting the aircraft involved in both the horizontal and vertical plane, can be produced for every loss of separation detected by SMF. The aircraft have different plot symbols which are updated every 4 seconds. The callsigns of the aircraft and the location of the incident are shown at the bottom of the diagram. The SMF listing and diagrams for this incident are shown at Appendix 4.

## 1.11 Flight recorders

The flight recorders fitted to both aircraft were not removed for analysis. Adequate data for the investigation was available from the recordings of ATC RT frequencies and secondary radar returns.

## 1.12 Wreckage and impact information

Not applicable.

## 1.13 Medical and pathological information

Not applicable.

## 1.14 Fire

Not applicable.

## 1.15 Survival aspects

Not applicable.

## 1.16 Tests and research

### 1.16.1 TCAS simulation

This AIRPROX incident was evaluated on a TCAS simulator operated by the Defence Evaluation and Research Agency and located at Malvern, Worcestershire. The simulator utilises the same software as that installed on the airborne equipment. The validity of this simulator has been verified by evaluating a large number of known models and comparing the output to those of the known events. Whilst there is a reasonable level of confidence in the fidelity of the simulation it is sensitive to slight variations in the input data which in this instance was recorded radar data. The TCAS algorithms evaluate the data once every second whereas the rate of acquisition of the radar data is dependent on the rate of rotation of the radar head which is typically once every 8 or 9 seconds. Missing data is therefore obtained by interpolation and consequently its accuracy cannot be assured.

When this particular TCAS event was first simulated, the radar data used was that which had been remotely transmitted to Malvern and this resulted in a 'DESCEND' RA. The simulation was later run using the radar data which had been impounded at LATCC and this resulted in an initial 'CLIMB' RA which then reversed to a 'DESCEND' RA thereby recreating the event as described by the crew of the B 747. The difference in the result of these two simulations is due to slight differences in the input data. Although both sets of data originated from Debden radar, the recording impounded at LATCC and the local recording at Malvern have different time stamps associated with the plots. This difference resulted in slightly different trajectory reconstructions. The consequence was that both simulations adjudged that a crossing 'CLIMB' RA provided the better separation. However, the LATCC based simulation has a high confidence in the conflicting aircraft's tracked vertical rate and issued the RA promptly, which, as the encounter developed and the conflicting aircraft levelled off, reversed to a 'DESCEND' RA. The Malvern based simulation has a lower level of confidence in the vertical profile and, due to a bias within the algorithms against crossing RAs with a low confidence level, delayed issuing the RA. When the RA reversed in sense it was no longer a crossing RA and so it was then issued as a 'DESCEND' instruction.

### 1.16.2 Aircraft simulation

The flight profile of the B 747 during the period prior to the TCAS event was investigated in a full flight simulator. This modern simulator was equipped with an aircraft standard PMS equivalent to that fitted to the incident B 747. The aircraft parameters and environmental conditions were simulated to match those occurring at the time of the AIRPROX.

The PMS had a default setting to command a speed reduction to less than 250 kt when descending below FL 100. In order to ensure that this was not a factor in the flight profile, the simulator was allowed to descend from FL 150 to FL 80 with an initial airspeed of 290 kt and the default speed reduction armed. The airspeed of 290 kt was maintained with a steady rate of descent until FL 111 when the rate of descent reduced to 1,000 ft/min and the airspeed slowly reduced to 250 kt by FL 105. This default setting did not contribute to the flight profile of the incident B 747 when it levelled at FL 117.

The simulator was repositioned in level flight at FL 120 and 290 kt and was then commanded to descend to FL 90 at 210 kt. The speed of 210 kt was not accepted by the PMS which recognised the minimum speed in the clean configuration of 223 kt and so 225 kt was entered until flap 1 could be selected. It was noted that the PMS always prioritised the speed reduction above the descent command. Once the required parameters were entered the subsequent flight profile was timed with 50% N1 maintained on the engines to provide anti-icing protection. The simulator commenced a very shallow descent of about 150 ft/min and slowly reduced speed. After 60 seconds the airspeed was 250 kt at FL 119 and flap 1 was selected, after 120 seconds the airspeed was 225 kt at FL 114.

The simulator was then repositioned to FL 120 at 290 kt from where it was commanded to enter a descent to FL 110, thus more closely matching the flight profile of the incident B 747. As it left FL 120 the speed reduction of 225 kt was entered followed by the command to descend to FL 90. In this instance the simulator levelled at FL 117 and followed a deceleration rate that was a close approximation to the previous test. The use of speedbrake to 250 kt, prior to the selection of flap 1, made little difference to the rate of deceleration. In a subsequent test the simulator was controlled through the autopilot / flight director mode controls on the glareshield, rather than through the PMS, with the pilot prioritising speed; the deceleration rates were once again similar to the initial test.

## 1.17 Organisation and management information

### 1.17.1 Manual of Air Traffic Services

The Manual of Air Traffic Services Part 1 (MATS Part 1) contains instructions that are applicable to all air traffic control units. The following extracts are relevant to this AIRPROX (C):

MATS Part 1

Section 1, Chapter 3, Paragraph 5 - Changing Levels

'An aircraft may be instructed to climb or descend to a level previously occupied by another aircraft provided that:

a) a vertical separation already exists,

b) the vacating aircraft is proceeding to a level which will maintain vertical separation, and

c) either:

(i) the controller observes that the vacating aircraft has left the level, or

(ii) the pilot has reported vacating the level.'

Section 1, Chapter 5, Paragraph 9 - Level Assessment using Mode C

'An aircraft which is known to have been instructed to climb or descend may be considered to have left a level when the Mode C readout indicates a change of 400 feet or more from that level and is continuing in the anticipated direction.'

Supplementary Instruction No 1 of 95:

**'SPEED RELATIONSHIPS AND SPEED CONTROL**

**Speed Control Technique**

'It is important to give crews adequate notice of planned speed control. Descents will be planned at a given speed and rate, but some changes requested by ATC will make a difference. High descent rates and low airspeeds are not normally compatible. Restrictions issued while the descent is in progress will cause problems to the crew. Any significant speed reductions may require the pilot to level off to lose speed before returning to the descent. Advance planning is even more important with heavy jets. At the bottom of a high speed descent their inertia will be great and both time and distance will be needed to reduce speed for ATC purposes.

**Summary**

- Give crews notice of any planned speed restrictions/control
- Do not ask pilots to 'slow down and go down'

Supplementary Instruction No 3 of 1997:

**'USE OF STANDARD RTF PHRASEOLOGY BY CONTROLLERS**

Attention is drawn to the need for the use of standard phraseology when an appropriate 'standard phrase' exists. This is particularly important when the pilot involved is not speaking his or her native tongue. Several incidents, some involving losses of separation have occurred when controllers have modified the standard phraseology when communicating.

Controllers are also reminded that they are required to listen to and verify the accuracy of readbacks by pilots. This is particularly important when either conditional clearances are issued or the transmission contains more than one level or heading; As a guide, a controller should not include more than 3 items of information that require a read back. If there is a language difficulty than this number must be reduced, if necessary items passed and acknowledged singly.'

1.17.2 UK Aeronautical Information Publication (AIP)[7]

The following information to pilots concerning 'Minimum Rates' was set out in RAC Section 3-1-16, paragraph 6.1:

'In order to ensure that controllers can accurately predict profiles to maintain standard vertical separation, pilots of aircraft commencing a climb or descent in accordance with an ATC clearance should inform the controller if they anticipate that their vertical speed during the level change will be less than 500 feet per minute or, if at any time during such a climb or descent, their vertical speed is in fact less than 500 feet per minute.'

1.17.3 Reporting and investigation of AIRPROX

1.17.3.1 Reporting

AIRPROX incidents may be reported by either pilots or controllers. Depending on their origin the reports are investigated by the Joint Airprox Section of the Directorate of Airspace Policy, CAA in the case of pilot reports and by the Safety Regulation Group of the CAA, under the provisions of the Mandatory Occurrence Reporting (MOR) scheme, in the case of controller reports. Where the circumstances appear to have involved a serious risk of collision, in other words where an accident nearly occurred, the incident may be investigated by the AAIB under the provisions of the Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996. All three investigation bodies may make recommendations to prevent a re-occurrence of similar incidents.

Instructions for the reporting and investigation of AIRPROX are given in the UK Aeronautical Information Publication (UK AIP) Section RAC 3-1. The same information is repeated in the UK Aeronautical Information Circular (AIC) 105/1995 (Pink 118) 16 November 1995. Extracts taken from the UK AIP are reproduced at Appendix 5.

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[7] A completely revised edition of the UK AIP was published in January 1998. References relevant to this incident are taken from the AIP extant at the time

1.17.3.2 Investigation processes

In the latter part of 1997 a study was commissioned jointly by the DETR and the Ministry of Defence to examine existing arrangement for the investigation of AIRPROX incidents and to recommend any improvements. The terms of reference given to the review included:

> 'The review should examine the current processes used by the Joint Airprox Working group (JAWG) and Joint Airprox Assessment Panel (JAAP), identify their strengths and weaknesses, and consider whether the interests of aviation safety would be better served by combining their activities in a single body covering the various types of AIRPROX occurrence.'

In anticipation of the conclusions and recommendations of the review, this report simply notes the current position in relation to AIRPROX investigations.

1.17.4 Airborne Collision Avoidance Systems

At the time of the incident there was no mandatory requirement for the fitment or use of TCAS by aircraft operating in UK airspace. In November 1995, Ministers from European Civil Aviation Conference (ECAC) states adopted a common policy agreeing in principle that TCAS II be mandated for carriage and use in ECAC airspace from 1 January 2000. The CAA position, including an implementation schedule by weight category and passenger seating configuration, is given in AIC 26/1996 dated 26 March 1996. The AIC noted 'UK air operators of qualifying aircraft are encouraged to modify them accordingly in the intervening period. Approximately 30% of such aircraft already have TCAS II installed.'

Guidance on the non-mandatory use of Airborne Collision Avoidance Systems (ACAS) in UK FIR and UIR is given in the UK AIP.

The UK AIP Section RAC 3-1 states:

> '15.1 General
>
> 15.1.1 The Civil Aviation Authority's position on ACAS is to permit operation of suitably equipped and operated aircraft in UK Airspace. The Traffic Alert and Collision Avoidance System - TCAS II is accepted as a suitable system provided its installation is certificated by the State of Registry, and that its operation by flight crew is in accordance with instructions for the use of this equipment specified in their company's operations manual.

15.2 Traffic Advisories (TA) and Resolution Advisories (RA) and Air Traffic Control (ATC)

15.2.1 Traffic Advisory (TA)

15.2.1.1 ATC does not expect pilots to take avoiding action on the basis of TA information alone. Requests for traffic information should not be made unless the other aircraft cannot be seen and the pilots believe their aircraft is about to be endangered.

15.2.2 Resolution Advisory (RA)

15.2.2.1 ATC expects pilots to respond immediately to a RA. If required, avoiding action should be the minimum necessary for conflict resolution. ATC should be informed as soon as possible of any deviation from an ATC clearance.

15.2.2.2 Pilots should be aware that any deviation from an ATC clearance has the potential to disrupt the Controllers tactical plan and may result in a reduction of standard separation between aircraft other than those originally involved. It is vital that flight crew maintain a good look out and return to their original flight path as soon as it is safe and practical to do so.'

1.17.5 Safety Management System

The Safety Regulation Group (SRG) of the CAA has, since 1991, accepted a Safety Management System (SMS) [Safety Case] based approach as an acceptable means of compliance with Article 77 of the Air Navigation Order and SRG requirements. NATS, as a service provider, began the introduction of a formal SMS in 1991. The first approval based upon the safety case, SMS regulatory approach was awarded to NATS for one of its ATS units in late 1993.

The NATS SMS spans all NATS activities. It provides a clear definition of its policy and general approach to safety. It defines safety management principles including best practices that are implemented within the organisation. It allocates safety accountabilities at all levels of the organisation. Safety management procedures are described, emphasising the proactive management of safety.

The safety of present operations is reviewed and monitored through a number of NATS SMS principles and procedures e.g. safety performance monitoring and trend analysis, lessons learned from incident investigations, internal audits and SRG audits. In addition promotion of a safety culture encourages the reporting of safety concerns.

1.17.5.1 Safety assurance

ATS safety assurance is provided through safety cases. The safety case provides a documented account of the evidence, arguments and assumptions to show that system hazards have been identified and adequately controlled, both in operational and engineering areas and that qualitative and quantitative safety requirements are achieved. The NATS SMS forms the basis upon which a model is being produced by Eurocontrol as the standard for wider implementation across Europe. The NATS SMS, with constant development, is under frequent review by both NATS and the SRG.

Two kinds of safety case, which are different management tools each serving a different purpose, are identified. They are system safety cases (SSC) and unit safety cases (USC).

System safety cases

The objective of a SSC is to present sufficient evidence and reasons to show that a planned system change to the operational environment is adequately safe to be introduced into operational service. These are prepared for all new ATC Systems and maintained throughout their operational life. The structure and content of a SSC varies according to the size and scope of the planned change.

Unit safety case

The objective of the USC is to present sufficient evidence that the operational safety of a unit is adequate for its defined role. It provides assurance to the unit operational managers and the regulator. Furthermore, the USC provides the focal point through which SRG approval is awarded and maintained. LATCC, including AC and TC operations, Heathrow and Gatwick have approved USCs.

1.7.5.2 Precedents

With acceptance of SMS based approval (since 1991) it was deemed unrealistic to demand retrospective safety assessment of a long standing service such as LATCC AC. In this case the USC primarily argued the adequacy of the operation in place at the time based upon the past historical performance. In the case of LATCC TC a SSC existed for the move of the TMA function into the new TC operations room at LATCC in October 1993. The SSC addressed all the risks associated with the new equipment and changes to ATC procedures. Thus the USC provided an argument based upon a mixture of past historical performance and the SSC.

## 1.17.6 Human Factors

The International Civil Aviation Organisation (ICAO) published a series of digests dealing with human factors in aviation. Digest No. 8[8] deals specifically with Human Factors in Air Traffic Control. Several of the topics covered are pertinent in the context of this incident. Chapter 5 of ICAO Circular Human Factors Digest No. 8 deals with 'The Human Element - Specific Attributes' and discusses the attributes of Stress, Boredom, Fatigue, Confidence and Complacency. In discussing Error Prevention it particularly notes:

> 'Human beings are fallible, and air traffic controllers remain fallible and subject to error no matter how experienced and proficient they become. While every effort should be made to prevent human error, it is not sensible to predicate the safety of the ATC system on the assumption that every human error can be prevented. Some errors will occur and the system must remain safe when they do, by being designed to be error-tolerant.'

[8] Circular 241-AN/145 published in 1993

## 2 Analysis

### 2.1 General

This analysis is in three parts. The first part examines this particular AIRPROX in which a number of factors relating to procedures and human factors contributed to the loss of separation. The second part of the analysis examines existing and proposed equipment which may assist pilots and controllers in the maintenance of mandatory traffic separation. These are the technical solutions to human fallibility. The third part examines the systematic safeguards against simple operating lapses and procedural errors which formed the basis of this particular AIRPROX.

### 2.2 The loss of separation

#### 2.2.1 The tactical situation

The aircraft were brought into lateral proximity as a result of the G IV being given a direct routing towards its destination, Luton, on a track that crossed that of the B 747. The crew of the B 747 did not report the speed control, as requested, when handed over to TC LAM and accordingly the controller could not pass it on to LL INT N. Both controllers thought that, in accordance with the procedure, the B 747 would be at the correct speed, less than 250 kt, by the Speed Limit Point (SLP), which is 12 miles east of LAM VOR (see STARS via LAMBOURNE at Appendix B). However, these set procedures are varied by controllers for tactical reasons and the system thus comprises a mix of procedure and traffic management. This calls for some judgement on the part of controllers but it is essential that their information is accurate and up to date. In this case the lack of speed control reporting deprived the controllers of a full understanding upon which to base their tactical planning.

Once TC LAM had cleared the B 747 to contact LL INT N there was little other traffic and so the controller briefed TC NE on the traffic situation, arranged to 'bandbox' the positions (as TC NE/LAM) and went off duty for a short break.

LL INT N was unaware of the high energy state of the B 747, which was not yet showing on his radar display. Therefore, even had he wished to do so, he could not select a display of its ground speed.[9] However, he was entitled to expect it to be at 250 kt in the absence of any speed control report. If he had known the actual speed (290 kt), his instruction to 'slow down and go down' may have appeared to him to have been obviously inappropriate. His initial clearance to the

[9] It is not normal practise to select the ground speed display since it tends to obscure the SSR labels.

B 747 was made up of three parts: a descent to FL 90, instructions to leave Lambourne on a heading of 270° and the requirement to reduce speed 'now' to 210 kt. The pilot entered the descent and speed reduction into the Performance Management System (PMS) which, by design, prioritised the speed reduction. Whilst attempting to achieve this deceleration the PMS commanded a reduction in descent rate such that the aircraft levelled at FL 117 for the 50 second period prior to the TCAS instructions. The crew of the B 747 did not inform the controller that they had ceased descending.

At the same time, and knowing that the B 747 had been cleared to FL 110 before being passed to LL INT N, TC NE/LAM cleared the G IV to descend to FL 120 although it had not yet achieved the mandatory 400 feet descent from FL 120 that would allow him to clear another aircraft to that level. Shortly afterwards, when the G IV crew queried their TCAS indication with him, he stated at interview after the incident that it was possible that he misread the SSR label as '107' (i.e. 10,700 feet) instead of '117' (i.e. 11,700 feet), thus explaining his impression of at least 1,000 feet vertical separation which he initially reported to the G IV.

Both aircraft were fitted with TCAS and it was because of the information provided by this equipment that the G IV crew first alerted ATC to the loss of separation when they reported traffic indicating in their one o'clock 300 feet below them. Subsequently the B 747 crew obeyed an RA to 'CLIMB' and then to 'DESCEND' as the equipment reacted to a rapidly changing situation in which the G IV had been descending at a high rate before levelling at FL 120. Perversely, for a collision avoidance system, the RA messages actually reduced the separation values, however, since one of the TCAS units was operating in the 'TA only' mode, a co-ordinated vertical manoeuvre between the two aircraft was not available. Meanwhile, LL INT N had his attention drawn to the conflict by the 'Red' alert of the STCA. Because of the range setting he had selected, the B 747 was not yet showing on his screen. However, he was able to confirm the identity of the conflicting aircraft from the alert listing on screen and promptly issued an avoidance turn to the B 747, which was under his control. Following the TCAS report by the G IV, TC NE/LAM now recognised the conflict and issued a prompt avoidance turn.

### 2.2.1 Procedures and regulations

Supplementary Instruction No. 3 of 1997 in MATS Part 1 includes guidance to controllers on readbacks by pilots and the number of instructions issued together when there is a language difficulty. No more than three items which require a readback are to be given, and if there is a language difficulty then this number must be reduced. Study of the transcript of communications between the B 747 and the LL INT N controller show that in the main the Japanese crew had no difficulty in communication. Close study of the instruction passed at 1441:58 hrs revealed a difficulty in reading back the three instructions which were passed. The instructions "DESCEND TO FLIGHT LEVEL NINE ZERO AND LEAVE LAMBOURNE ON HEADING TWO SEVEN ZERO DEGREES REDUCE YOUR SPEED NOW TO TWO TEN KNOTS" was read back as follows "JAPANAIR FOUR TWO ONE ROGER DESCEND TO NINE THOUSAND TO NINE THOUSAND LEAVE ERRR LAMBOURNE HEADING TWO SEVEN ZERO DESCEND ERR SPEED REDUCE TO TWO ONE ZERO KNOTS". The controller quickly confirmed that the cleared level was FL 90 and not nine thousand feet. Given the need to understand and execute these three instructions, albeit routine in nature, it is to the credit of the B 747 crew that they were quickly acknowledged and followed. Nevertheless, the delivery together of three items of information was not helpful. It is recommended that the CAA should reconsider the analysis which led to Supplementary Instructions No 3 of 1997 to see whether, in the light of this incident, any amendment is necessary. [Recommendation 98-35]

During investigation of the incident the LL INT N controller said that his use of the word 'now', in ordering the speed reduction, had no significance to him and he was unaware that he had used the word. It is noteworthy that in a later instruction (just before 1445 hrs) the controller said "STOP YOUR DESCENT NOW FLIGHT LEVEL ONE HUNDRED." On both occasions that the word 'now' was used it can be seen that its position in the sentence gives a certain rhythm and, to an English native tongue, is used as much as a punctuation device as a command. However, those for whom English is a second language, are likely to interpret each word literally and therefore in this case the controller's instruction for speed reduction probably received a greater emphasis than he had intended.

2.2.1.2 Aircraft performance in the descent

A variety of tests were performed in the full flight simulator in order to understand more fully the flight profile of the B 747 whilst its crew attempted to comply with the controller's instructions. With limitations prohibiting the simultaneous use of flaps and speedbrakes coupled with the necessity to provide engine anticing protection through a relatively high minimum power setting the task of decelerating the aircraft from high speed was obviously a time consuming one. However, the crew were asked to complete this deceleration whilst in a descent. The simulator results indicate that in that flight regime a reduction from 290 kt to 210 kt cannot be achieved in less than 120 seconds in level flight. This is irrespective of whether the PMS prioritises the speed, as it is programmed to do, or whether the pilot does so by responding to the instruction to reduce speed 'now'. The guidance contained in the Supplementary Instruction 1/95 relating to speed control techniques for controllers is therefore correct.

2.2.1.3 Aircraft performance - minimum rates of climb or descent

The crew of the B 747 flew level at FL 117 for a period of 50 seconds prior to the event having been given a clear instruction to descend, however, they did not inform the controller that they were no longer descending. Under the provisions of the UK AIP, pilots of aircraft commencing a climb or descent in accordance with an ATC instruction are required to inform the controller if at any time during such a manoeuvre the vertical speed is less than 500 ft/min. The lack of such a report by the B 747 crew, which was required under the circumstances, therefore contributed to this AIRPROX incident.

2.2.2 Human factors

2.2.2.1 Error prevention and tolerance

The control of air traffic in a busy TMA such as London is a challenging environment in which to work. Most controllers seem to relish the challenge and strive towards an ever more efficient service to the flights they control. It is probable that these conditions in themselves contribute to the general high level of achievement. Any excessive competitive element appears to be well controlled by the safety system. Commercial pressure to increase traffic flow was not a feature of this particular incident which occurred at a time of low traffic level, i.e. there was no overload.

As in other areas of civil aviation, the possibility of human error is always present. The ICAO Circular 'Human Factors in Air Traffic Control' states '.......it is not sensible to predicate the safety of the ATC system on the assumption that every human error can be prevented.' Given this reality, an adequate safety system including a 'safety net' is essential. The NATS Safety Management System including equipment safeguards is discussed in paragraphs 2.4 and 2.3 respectively.

2.2.2.2 Familiarisation training for controllers

Despite the advice given in Supplementary Instructions No 1 of 1995: Do not ask pilots to 'slow down and go down', LL INT N appears to have overlooked the problem that his three part instruction to the B 747 was likely to cause. Greater familiarity with the flight deck operation of aircraft such as a B 747-300 could only benefit the controller's appreciation of the situation. Similarly, pilots would benefit from a close understanding of the ATM system. Whilst familiarisation training is encouraged by NATS management it is presently unstructured and under resourced. The CAA, in conjunction with the various ATS providers, should ensure that controllers are familiar with those operating characteristics of the aircraft for which they are likely to be responsible and which affect the provision of ATS. Consideration should be given to suitable methods which may include the use of simulators and familiarisation flights as a means of achieving this objective. [Recommendation 98-36]

## 2.3 Avionics and electronic equipment

### 2.3.1 TCAS

An analysis was conducted of the TCAS avoidance manoeuvre carried out by the B 747. It is probable that the initial 'CLIMB' RA was derived from the observed high descent rate of the G IV which the equipment would assume would continue, since it was unaware of the other aircraft's cleared altitude. This descent rate would have been approximately 2,000 ft/min because the G IV flight management system would command a 3° descent profile regardless of the aircraft's speed which at this time was approximately 300 kt.

When the B 747 TCAS equipment observed that the G IV had levelled at FL 120 and, therefore, that by climbing it was liable to collision it then issued a reversed RA to 'DESCEND'. At the time of the CPA the two aircraft were 0.83 nm apart horizontally and 100 feet apart vertically. Avoidance was as a combined result of the TCAS RA and the turn given to the G IV by TC NE / LAM.

The current TCAS software does not allow for reversals in RAs during encounters with other TCAS equipped aircraft operating in the RA mode. Avoiding manoeuvres are co-ordinated between aircraft which both have selected TA/RA on their TCAS. If this situation had existed in this incident the 'CLIMB' RA given to the B 747 would not have occurred and the CPA would have been greater. The maximum benefit of TCAS will depend on optimum usage of TA/RA selections.

TCAS is a proven aid in collision avoidance. By 1 January 2000 its use in ECAC airspace will be mandated for the larger types of aircraft. In this case its availability was fortuitous, being fitted to both of the aircraft involved in the AIRPROX, probably because the aircraft operated from time to time in the US where mandatory provision has been required for some years. Increasing use of the equipment by European operators, including 30% of UK air operators' qualifying aircraft in 1996, reflects the perceived safety benefit of such systems.

In anticipation of the mandatory use in ECAC airspace of this highly desirable safety aid, consideration should be given now to the optimisation of its operation. In particular the optimum use of TA/RA selections will need to be considered. It is therefore recommended that the CAA, in conjunction with other ECAC members should revise the UK AIP relating to the present and future operation of TCAS, taking account of the relevant ICAO Standards and Recommended Practises. [Recommendation 98-37]

2.3.2 SMF and STCA

SMF is not a Collision Avoidance System. The equipment provides post event notification to assist in determining circumstances and factors that led to the loss of separation and as such is a valuable tool.

Short Term Conflict Alert (STCA) is designed to alert controllers to potential conflicts between aircraft via the radar display. LL INT N recalled that the STCA had immediately displayed in red rather than the SSR labels flashing white initially. This was later confirmed by the simulation conducted by the Department of Technical Research and Development of NATS using radar data from the incident. Therefore, in this instance, in which the aircraft proximity was extremely close, the STCA provided little useful warning of a potential conflict and the concept of a safety net for the controller was minimal. This was not an equipment or design shortcoming but rather the inability of the current conflict alert system to provide sufficient warning in this particular scenario. Indeed up until a short time before the encounter the equipment was predicting a safe condition; it was the dynamics of the G IV levelling off, which could not be known beforehand by STCA, that changed the conditions. If an effective Medium Term Conflict Alert system (MTCA) had been available, with the capability of looking more than 2 minutes ahead, then the confliction leading to this AIRPROX may have been predicted at an earlier stage but the problems of excessive or 'nuisance' warnings are well recognised. It is therefore recommended that NATS should re-evaluate the performance and operational use of the current STCA equipment in order to ensure that the maximum amount of warning, consistent with traffic density, is provided to controllers. [Recommendation 98-38]. Furthermore, NATS should ensure that the development and introduction of an effective MTCA system is given a high priority [Recommendation 98-39]. These two measures, taken together, should provide a more effective 'safety net' for controllers.

## 2.4 Safety Management Systems and Safety Cases

2.4.1 Safety Cases and Safety Analysis

The NATS developed Safety Management Systems for ATMS are relatively recent and are an appropriate and logical approach to the assurance of safety in a complex process such as air traffic management in the London TMA. The system focuses both upon change and present operations. However, it cannot be regarded as a panacea and the probability of human error (see paragraph 2.2.2.1) must be balanced with the error tolerance of the system. The SMS provides a formal framework against which all forms of hazard, including human error, can be identified and managed so that they can be reduced, as far as practicable, to a tolerable level. The use of NATS SMS and safety cases for the approval and ongoing safety regulatory oversight of NATS operations and other units is also a satisfactory approach.

The ingredients of this AIRPROX include procedural errors by a flight crew and controllers (human error) combined with limited error tolerance of the system (STCA and TCAS). The SMS should allow lessons to be learned leading to preventative measures.

2.4.2 Statistics

The number of AIRPROX incidents in the London TMA is relatively small. In 1997 there were 16 AIRPROX (C) reports from a total of 928,661 flights. The category of risk assessed for each incident will vary from 'no risk of collision' to 'actual risk of collision'. As a general rule any loss of separation detected by the SMF will give rise to a report and this equipment was set to function when aircraft were within 2 nm and 600 feet of each other. Any loss of separation is more significant than the actual proximity of the encounter since it reveals a breakdown in the safety system. Although a margin for error may be designed in to the system, which itself should be error tolerant, reports of AIRPROX are the current indicator of system safety. This incident, involving a proximity of 0.63 nm and 200 feet, was closer than most of the reported incidents but it also included significant features relating to the performance of the 'safety net' (STCA and TCAS) such that a detailed investigation was warranted.

## 2.5 AIRPROX investigation

At the time of the incident there were two separate processes for the investigation of AIRPROX (P) and AIRPROX (C). In addition, some of the more serious incidents are investigated by the AAIB. The effective investigation of accidents and incidents is an essential prerequisite to the prevention of occurrences in the future. In 1997 the DETR and the MOD arranged to review the existing procedures and, at the time of this report, the conclusions and recommendations of the review team are not known.

The establishment of such a review of the investigation process for both types of AIRPROX suggests an awareness that there may be some safety benefits to be had from revised arrangements. Were it not for the existing review, this investigation would have examined such arrangements in the light of this and other incidents to see if the safety issues could be adequately addressed under present arrangements. Accordingly no recommendation is made at this time.

## 2.6 Summary

A combination of factors led to this serious loss of separation. The B 747 crew had not reported its speed, as instructed, when changing ATC frequencies and subsequent controllers were unaware of its high energy state. When asked to 'go down and slow down' the B 747, for reasons directly related to its energy management, ceased descending and flew level whilst reducing its airspeed from 290 kt to 210 kt. However, the crew did not inform ATC that they had ceased descending, as UK procedures required them to do. Meanwhile, TC NE was attempting to expedite the G IV's flight towards Luton and had already departed from the STAR by allowing a direct routing at high speed. This brought the G IV into lateral conflict with the B 747 and it was the assignment of FL 120 to the G IV, without the required indication that the level had been properly vacated by the B 747 which allowed the confliction.

The design of the Air Traffic Management System (ATMS) remains safe so long as the procedures are followed implicitly by pilots and controllers alike. However, variation of the published procedures, such as the imposition of speed control and clearance for direct routings, are permitted for tactical reasons provided appropriate co-ordination between controllers is carried out. The expeditious flow of traffic may be thus enabled. If this flexibility is to be maintained then the error tolerance of the ATMS must be assured. A major component of this assurance is the 'safety net' and those elements which are not human based comprise the STCA and TCAS. This incident has shown potential weaknesses which can be safeguarded by more rigid adherence to procedures and enhancement of the existing technology based alerting systems. Recommendations for both of these objectives have been made.

## 3 Conclusions

### (a) Findings

*ATC controllers*

1. The ATC controllers and flight crews were properly qualified, competent and adequately rested at the time of the incident.

2. Traffic conditions in the LATCC TC airspace were light at the time of the incident and the AIRPROX did not result from an overload situation.

3. The fact that the Lambourne sector was 'bandboxed' with North East Departures (TC NE/LAM) at the time of the incident was not a contributory factor.

4. TC NE/LAM did not notice that the B 747 had stopped descending and therefore the recently vacated level (FL 120) was not yet available to the G IV.

5. LL INT N could reasonably have expected the B 747 speed to be 250 kt in the absence of any contrary report. His instruction to 'reduce speed now to 210 knots' was therefore modest compared to the actual requirement (from 290 kt). Nevertheless, in instructing the B 747 to 'slow down and go down' LL INT N overlooked the effect of these instructions on such types of aircraft, including problems associated with their energy management.

6. Periodic familiarisation with modern flight decks and procedures, as part of their validation process, would enhance the understanding of controllers. Confidential reports suggest that a number of controllers wish to receive such familiarisation training on an official basis.

*B 747 operation*

7. The crew of the B 747 were properly licensed, qualified and adequately rested to perform the flight.

8. The crew of the B 747 did not report the speed control, as requested, when handed over to TC LAM and consequently the controller could not pass this information on to LL INT N.

9. In order to achieve the selected speed reduction, the B 747 PMS caused the aircraft to fly level at FL 117 for some 50 seconds before its TCAS instructed a climbing avoidance manoeuvre. The crew did not inform the controller that they had ceased descending and were not achieving the expected rate of descent of at least 500 ft/min.

10. The instruction to reduce speed 'now' may have been interpreted literally by the B 747 crew in prioritising that requirement. This was not the controller's intention.

*Electronic equipment*

11 All radar and communication systems serving LATCC TC at the time were fully serviceable.

12. Although the TCAS equipment fitted to the B 747 operated normally, the RA instruction actually reduced the separation distance because of the particular circumstances of the encounter. These comprised the high descent rate of the G IV and the lack of a co-ordinated vertical manoeuvre since RA was not selected on both devices.

13. Collision avoidance was as a combined result of the TCAS and the turn given to the G IV by the controller which the crew executed with commendable haste.

14. The carriage and use of TCAS was not mandated at the time of the incident but its availability and use by both aircraft was fortuitous.

15. The STCA performed to its specification for this encounter. The particular circumstances and manner in which the encounter developed limited the equipment's ability to give more that an immediate, high severity red alert.

16. If a Medium Term Conflict Alert had been available and in service, with the ability to detect potential separation conflicts greater than two minutes ahead, the confliction which led to this AIRPROX may have been predicted at an earlier stage.

*Management and organisation*

17. In relation to the total number of flights within the London TMA the number of AIRPROX (C) incidents is relatively small. Investigation of those reported reveal few with such close proximities as this incident.

18. The NATS developed SMS represents an appropriate approach to the assurance of safety and management of risk in a complex process such as air traffic management in the London TMA. The use of NATS SMS and safety cases for the approval and ongoing safety regulatory oversight of NATS operations and other units is also a satisfactory method of demonstrating compliance with the requirements.

19. Existing arrangements for the investigation of AIRPROX (P) and (C) are under review at the behest of the DETR and the MOD. Revised arrangements have the potential to address the safety issues more effectively.

20. The ATMS 'safety net', designed to provide continued safety assurance following procedural lapses, was unable to prevent the loss of separation because the STCA could only provide a very late warning and the TCAS manoeuvre was not fully co-ordinated between the conflicting aircraft.

**(b)** **Causes**

The following causal factors were identified:

1. The B 747, having left FL 120 then stopped descending some 300 feet below this level whilst reducing speed from 290 kt to 210 kt. FL 120 was assigned to the G IV by the bandboxed Terminal Control North East Departures/Lambourne controller before the proper vertical separation had been established after its direct routing towards Luton had brought it into lateral conflict with the B 747.

2. The North East Departures / Lambourne controller did not apply the procedure given in MATS Part 1 regarding level assessment of SSR Mode C (height information) when giving clearance to the G IV to FL 120. The controller should have waited for the B 747 to have had a readout of at least FL 116 (400 feet below the vacated level) before clearing the G IV to descent. The controller then did not monitor the Mode C readout of the B 747 to ensure that it was 'continuing in the anticipated direction'.

3. Despite reporting to the Heathrow Intermediate North controller that the aircraft had vacated FL 120, the B 747 did not descend at the minimum rate mandated for the UK and detailed in the UK Air Pilot (500 ft/min). If it was not possible to comply with this requirement, the crew were required to inform the controller but did not do so.

4. The Heathrow Intermediate North controller, unaware that the aircraft speed was 290 kt, called for a combined speed and level change which resulted in the B 747 having a minimal rate of descent while its speed reduced.

5. The B 747 crew did not report their speed control, which had been imposed by Clacton SC, to the Lambourne Sector, thereby allowing the controllers to assume a standard speed of 250 kt.

6. Since the TCAS manoeuvre was not fully co-ordinated by both aircraft's TCAS, one of which was not selected to TA/RA, the B 747's initial RA reduced the separation distance.

## 4 Safety recommendations

The following safety recommendations are made:

4.1. The CAA should reconsider the analysis which led to Supplementary Instructions No 3 of 1997 to see whether, in the light of this incident, any amendment is necessary. [Recommendation 98-35]

4.2 The CAA, in conjunction with the various ATS providers, should ensure that controllers are familiar with those operating characteristics of the aircraft for which they are likely to be responsible and which affect the provision of ATS. Consideration should be given to suitable methods which may include the use of simulators and familiarisation flights as a means of achieving this objective. [Recommendation 98-36]

4.3. The CAA, in conjunction with other ECAC members should prepare UK AIP instructions relating to the present and future operation of TCAS, taking account of the relevant ICAO Standards and Recommended Practises. [Recommendation 98-37]

4.4 NATS should re-evaluate the performance and operational use of the current STCA equipment in order to ensure that the maximum amount of warning, consistent with traffic density, is provided to controllers. [Recommendation 98-38]

4.5 NATS should ensure that the development and introduction of an effective MTCA system is given a high priority. [Recommendation 98-39]

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