Collision between Boeing 767-204, G-SATR and Boeing 737-37Q, G-ODSK, while taxiing.

Micro-summary: **This Boeing 767-204 collided with this Boeing 737-37Q while taxiing.**

Event Date: **2004-11-04 at 1620 UTC**

Investigative Body: **Aircraft Accident Investigation Board (AAIB), United Kingdom**

Investigative Body's Web Site: **http://www.aaib.dft.gov/uk/**

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ACCIDENT

Aircraft Type and Registration:	1) Boeing 767-204, G-SATR 2) Boeing 737-37Q, G-ODSK
No & Type of Engines:	1) 2 General Electric Co CF6-80A2 turbofan engines 2) 2 CFM CFM56-3C1 turbofan engines
Category:	1) 1.1 2) 1.1
Year of Manufacture:	1) 1989 2) 1997
Date & Time (UTC):	4 November 2004 at 1620 hrs
Location:	Manchester Airport, Manchester
Type of Flight:	Public Transport (Passenger)
Persons on Board:	1) Crew - None Passengers - None 2) Crew - None Passengers - None
Injuries:	1) Crew - None Passengers - None 2) Crew - None Passengers - None
Nature of Damage:	1) Left wing damaged 2) Tail damaged
Commander's Licence:	1) Airline Transport Pilot's Licence 2) Airline Transport Pilot's Licence
Commander's Age:	1) 50 years 2) 46 years
Commander's Flying Experience:	1) 8,040 hours (of which 6,234 were on type) Last 90 days - 75 hours Last 28 days - 36 hours 2) 4,070hours (of which 450 were on type) Last 90 days - 256 hours Last 28 days - 66 hours
Information Source:	AAIB Field Investigation

Synopsis

The left wing of the taxiing Boeing 767-200 struck the right horizontal stabiliser of the stationary Boeing 737-300. Both aircraft were awaiting departure from Runway 24 Left at Manchester. The investigation concluded that the B767 commander, who bore primary responsibility for collision avoidance, misjudged the available separation due to a combination of physiological limitations, distractions and a false assumption regarding his ATC clearance. Three safety recommendations are made, concerning flight crew awareness of clearance issues, recording of communications on the Airport Fire Service frequency and ATC procedures at Manchester Airport.

History of the accident

The B737-300, G-ODSK, departed from Manchester's Terminal One at 1605 hrs and was instructed by the Manchester Ground controller to taxi to holding point 'D1'. The crew was subsequently transferred to the Air 1 controller, who issued a clearance to cross Runway 24 Right and to taxi to holding point 'V5'. The general layout of Manchester Airport is shown at Figure 1 and the accident area in detail is shown at Figure 2.

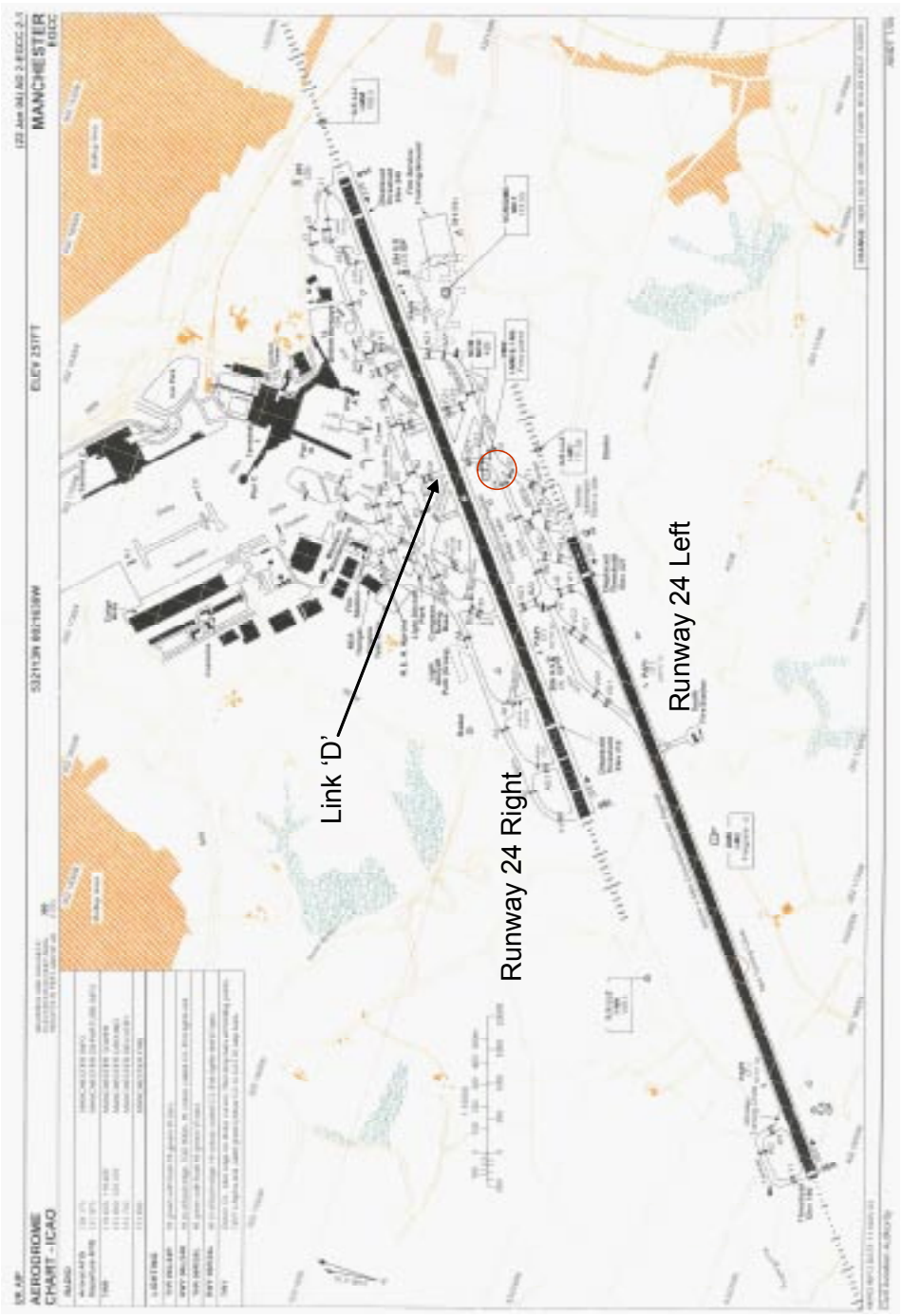

Figure 1

Manchester Airport - General layout

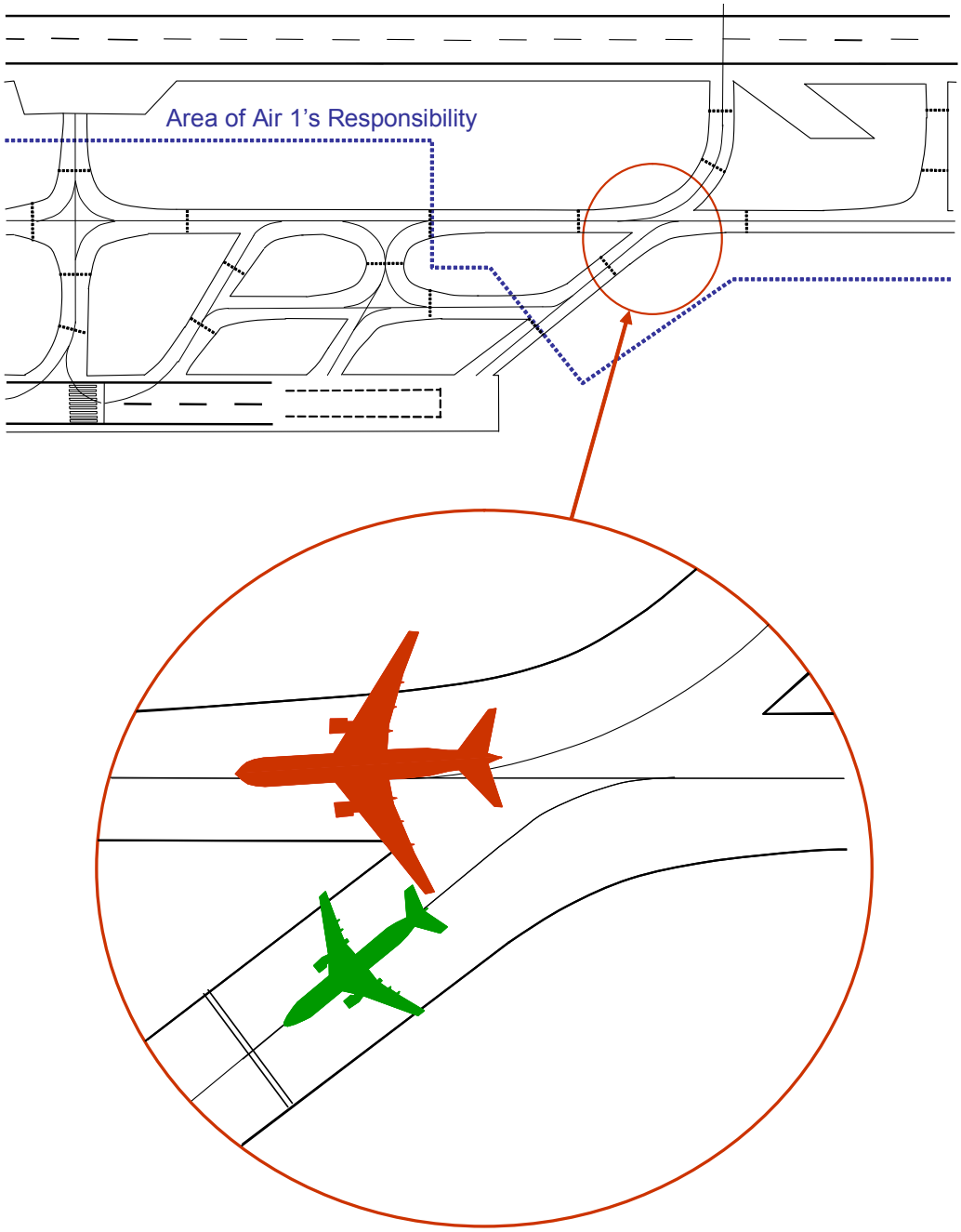

Figure 2

South Side Taxiways and Geometry of Collision

Once the aircraft had vacated Runway 24 Right, the crew was instructed to contact the Air 2 controller for Runway 24 Left. On checking in, the crew reported that they were taxiing for 'V5' but were told "…YOU CAN HOLD IN TURN NOW AT TANGO ONE PLEASE". The crew then taxied to follow a British Aerospace RJ100 which was ahead and also routing to holding point 'T1'.

The aircraft was being taxied by the commander who brought the aircraft to a stop, at what he assessed to be a safe distance behind the RJ100, and applied the parking brake. The flight deck crew completed their pre-takeoff checks and received a "cabin secure" notification from the Senior Cabin Attendant (SCA).

The B767-200, G-SATR, was being leased by its parent company to a lessee airline. The flight deck crew were employed by the aircraft operator whilst the cabin crew were employed by the lessee airline. The B767 crew reported for duty at 1430 hrs for a scheduled 1530 hrs departure for the 9 hour 17 minute flight to Goa in India. In addition to the commander and co-pilot, a second co-pilot was carried for the purpose of providing in-flight relief, so allowing an increased flight duty period. A ground engineer was also carried to meet engineering requirements down route. The second co-pilot and the ground engineer were to occupy the two flight deck observers' seats.

The crew encountered a number of operational problems prior to push back. The aircraft originally scheduled for the service was a 300 series B767 but was replaced by a 200 series aircraft due to maintenance activity. When the zero fuel mass was finalised it was 2,200 kg above that expected, which prevented the crew from loading the required fuel quantity for a direct flight to Goa. The commander liaised with the lessee airline's operations department with a view to organising a re-fuelling stop en-route, but was unable to establish a suitable airfield for this purpose. The operations department personnel were not sufficiently familiar with the recently introduced long-haul operations to offer the commander assistance. Problems with passengers were also encountered, including two drunken passengers who were subsequently removed from the aircraft under police escort. A positioning company captain had joined the aircraft for the flight to Goa but his suitcase had been delayed and was expected to arrive at the aircraft just before push-back, which it did.

The B767's departure was subject to a calculated take-off time (CTOT) restriction of 1619 hrs and the aircraft departed from Terminal Two at 1610 hrs with the issue of the re-fuelling stop still unresolved. The commander had decided to refuel en-route at Muscat in Oman, being aware that Muscat was suitable and had been used for this purpose some weeks earlier. However, there had not been time to amend the flight plan to reflect this course of action, nor to obtain a revised computer flight plan (CFP). The commander intended obtaining the new routing from operations once airborne and then re-filing the flight plan.

The B767 taxied to holding point 'D1', and was subsequently cleared by the Air 1 controller to cross Runway 24 Right and taxi to holding point 'T1'. Once the aircraft had vacated Runway 24 Right, the crew was transferred to the Air 2 controller for Runway 24 Left and reported to the controller that they were taxiing for 'T1'. The controller asked the crew "COULD YOU GO FROM VICTOR ALPHA ONE IN VIEW OF YOUR SLOT?" A brief discussion took place on the flight deck and the co-pilot answered "AFFIRM". The controller then said "ROGER FIRST RIGHT TURN THEN TAXI VICTOR ALPHA ONE."

The B767 commander could see the B737 holding in turn at 'T1' and, expecting to have to come to a stop behind it, had reduced taxi speed accordingly. When the revised taxi instructions were issued to the B767 crew, the commander continued taxiing to follow the marked taxiway centreline right onto 'V' Taxiway and called for the 'Before Take-off' checklist. As he did so, the co-pilot checked the taxiway chart to confirm the routing and located the appropriate checklist. Neither the commander nor the co-pilot thought that there was a problem regarding wing tip clearance between their aircraft and the B737. As the B767 was turning right onto Taxiway 'V', its left wing collided with the right horizontal stabilizer of the B737.

When the collision occurred, the B737 crew heard a loud noise, accompanied by a severe shaking. The commander had the impression that the aircraft was moving and leaning to the left, and thought initially that an undercarriage leg may have failed. However, the co-pilot then saw the B767 stationary to his right, and saw signs of damage to the B767's left wing leading edge. The co-pilot reported this to the commander and to the Air 2 controller, with a request that the Airport Fire Service (AFS) attend the scene. The B737 commander alerted the cabin crew with a public address (PA) "CABIN CREW AT STATIONS" to indicate that an emergency had occurred and to prepare them for a possible emergency evacuation. He called the SCA to the flight deck, briefed her on what had happened and instructed her to check the cabin for signs of fire. The cabin crew were seated when the collision occurred and no injuries were reported among passengers or crew.

The collision was felt but not heard on the B767's flight deck, but the commander did not realise immediately what had happened, thinking that the aircraft may have run over an object on the taxiway. The second co-pilot on the central jump seat thought that their aircraft had struck the B737 as it was the only possible obstruction, and he voiced his thought. The commander gently bought the aircraft to a stop approximately 35 m from the point of impact. When the collision occurred, the cabin crew had just finished the safety demonstration and were in the process of preparing the cabin for takeoff. The collision was felt in the cabin and likened by the SCA to running over a large pothole, but it was not severe enough to cause any of the crew to lose their footing. The SCA initiated communications with the flight deck crew via the interphone system and was told by the commander what had happened and asked to report to the flight deck. There were no reported injuries among the passengers and crew on board the B767.

In response to the transmission by the B737 co-pilot, the Air 2 controller initiated an Aircraft Ground Incident (AGI). The AFS arrived on scene approximately 90 seconds after the AGI had been initiated, and the airport fire officer established communications with the B737 crew on frequency 121.6 HMz. He informed the crew of the extent of the damage and that an immediate evacuation did not appear necessary. The flight crew shut down the left engine but the right engine was kept running to provide electrical power and to supply the air conditioning system; the APU had not been started due to possible damage in the collision. The second engine was shut down twenty minutes after the collision, prior to disembarkation of the passengers.

The B767 crew heard the transmission by the B737's co-pilot informing ATC about the collision. The commander made a PA to the passengers to inform them of the situation. After the aircraft had come to a stop, the flight crew became aware of the AFS vehicles approaching their aircraft. The commander attempted to call the AFS on frequency 121.6 MHz but received no reply and heard no other transmissions on that frequency. Knowing that the wing was damaged, the commander was aware of the possibility of a fuel leak with the attendant fire risk. He considered the possibility of an emergency evacuation but the actions of the fire crews outside the aircraft lead him to understand that the situation was not life threatening.

Soon after bringing the aircraft to a stop, the B767 commander had begun to feel unwell and subsequently fainted. The co-pilot assumed control of the aircraft and directed the SCA to give first aid to the commander. The SCA administered oxygen and the commander recovered consciousness after a short while. Meanwhile, the co-pilot successfully established communications with the AFS and continued to liaise with the Tower controller. The aircraft's APU was started and both engines were shutdown 13 minutes after the collision.

Wreckage and impact information

The two aircraft were still in the locations at which they had stopped after the accident when they were examined by the AAIB. Both nose wheels were effectively on the appropriate taxiway centerlines and the Boeing 737's nose wheel was 9.3 m from the S2 stop bar (note: this is only intended as a geographic reference, since the pilot had not positioned the aircraft using the stop bar as a guide). The Boeing 767 had continued some 35 metres after the collision, coming to rest 7.4 m beyond the V4 stop bar. Debris from the collision had blown back in the jet efflux of the Boeing 767 for about 100 m.

Approximately the outboard third of its right horizontal stabilizer and elevator was lying on the ground underneath the Boeing 737; there were no substantial pieces detached from the Boeing 767. It was clear that the first impact had been on the trailing edge of the left elevator of the Boeing 737, with evidence that this had forced the aircraft nose to yaw to the left a few centimetres. The left nose wheel was partially detached, apparently as a result of the sideways forces generated by this movement. There was evidence that the impact had caused the whole horizontal stabilizer to skew in the horizontal plane, since the leading edge on the right side had dug into the fuselage skin with a corresponding indentation from the elevator trailing edge on the left side, although the stabilizer had then returned to its normal position.

The Boeing 767 had less serious damage, largely confined to the outboard slat, which was in the take-off position and which had been crushed back from a point about 1.5 m from the tip. The adjacent slat also had damage as did the falsework behind. Fortunately, the main wing spar was not apparently affected.

Flight Recorders

The B737 was equipped with a 50-hour duration flight data recorder (FDR) and a two-hour cockpit voice recorder (CVR). The B767 was equipped with a 25-hour duration FDR and a thirty-minute CVR. The accident was not recovered from the CVR installed on G-SATR as it had been overwritten; the flight crew had not taken action to isolate the power to the CVR as was required by current regulations and the operator's operations manual. However, the accident was successfully recovered from the B737's CVR. Flight data was successfully recovered from both aircraft. The FDR systems on both aircraft recorded GMT from the respective captain's clock; the recorded times were found to be synchronised to within 8 seconds of each other. Times quoted are captain's clock unless stated. Ground speed was not available from the B767 FDR; approximate speeds were calculated using accelerometer data and rate of change of heading data.

Recorded data shows that the B737 was stationary with the parking brake applied at 1618 hrs. At 1619 hrs the B767 was stationary with the parking brake applied on a heading of 148º with both engines at idle waiting to cross the Runway 24 Right. Twenty seconds later the park brake was released. N1 shaft speeds for both engines were gradually increased to 55% over a 23-second period and the aircraft began to accelerate gradually. The N1's for both engines were then reduced to 46% on engine one and 42% on engine two and a further reduction was made some 5 seconds later to 42% on engine one and 35% on engine two.

As the B767 approached the right turn on a heading of 149º, the ground speed was calculated to be approximately 20 kt. As the aircraft commenced the turn the engines were reduced to idle and the aircraft began to decelerate. Both engines remained at idle for the next 18 seconds

and ground speed reduced to about 6 kt. The aircraft was then approximately half way through the turn. The N1's for both engines were then increased to 39% on engine one and 33% on engine two and the rate of heading change increased slightly, as the turn was tightened. Ground speed remained at about 6 kt.

At 1621:20 hrs, as the B767 turned onto a heading of 237º and at a ground speed of about 6 kt, a longitudinal deceleration of 0.13 'g' was recorded for a two-second period; this was believed to be the impact with the B737. The B737 recorded a peak longitudinal acceleration of 0.34 'g' and a peak lateral acceleration of 0.22 'g' at impact. Approximately 9 seconds after what was believed to be the impact point the B767 came to a stop and 9 seconds later the park brake was applied. For a further 4 minutes 50 seconds the engine N1's remained at 39% on engine one and 33% on engine two, until they were reduced to idle. The B737's engine number one was shutdown at 1630 hrs with engine number two shutdown at 1641 hrs. The B767 crew shutdown both engines at 1634 hrs.

Aerodrome information

Manchester Airport is equipped with two runways, designated Runways 24L and 24R; the terminals and main airport buildings are to the north of the runways. When the accident occurred, both runways were in use in a 'segregated' mode of operation; Runway 24R or landing aircraft and Runway 24L for departing aircraft. Aircraft taxiing for takeoff were therefore required to cross Runway 24R at one of several crossing points, designated as links 'H', 'G', 'F', or 'D'.

Runway 24L is 3,047 m in length, and has a starter extension of 150 m. There are several points of access to the runway, but it is normally entered from one of three holding points. Holding point 'VA1' provides the full declared take-off run available (TORA), 'VB1' provides a slightly reduced TORA of 2,864 m and 'T1' provides for the use of the starter extension, giving an increased TORA of 3,197 m. The UK Aeronautical Information Publication (UK AIP) states:

> *'aircraft requiring the 150 m starter extension at Tango for maximum TORA must advise delivery at the earliest opportunity'.*

The normal holding points for Runway 24L are reached by taxiways 'V', 'S' and 'T'. These taxiways are marked by centre line yellow markings, green centre-line lights and blue edge lights adjacent to sharp bends. Taxiways in the area of concern are 23 m in width.

The taxiway system to the south of Runway 24R complies with the requirements of Civil Aviation Publication (CAP) 168, '*Licensing of Aerodromes*'. This document sets out the standards required at UK licensed aerodromes relating to physical characteristics, assessment and treatment of obstacles, visual aids, rescue and fire fighting services and medical services. However, the area is subject to certain restrictions governing the size and combination of aircraft types permitted to operate thereon. These restrictions are contained in Manchester Airport's 'Manual of Air Traffic Services (MATS) Part 2', though none of the restrictions listed were relevant to this accident. Information supplied to Manchester ATC by Manchester Airport when Runway 24L was first built addresses a clearance issue for aircraft stopped to the north of Stopbar 'S2' This is designated as a CAT1/2/3 hold, intended to protect the Localiser Sensitive Area for Runway 06R. The information contains an observation that, when aircraft are holding north of 'S2', Taxiway 'V' is blocked behind. There is no ILS on Runway 24L which would require protection, and holding point 'S2' was considered very unlikely to be used for the purpose of providing protection for Runway 06R, therefore the restrictions on its use were not incorporated in Manchester's MATS Part 2.

Air Traffic Control Procedures

Under Manchester Airport's 'segregated' runway operation, each runway is controlled by one of two controllers, designated Air 1 and Air 2, each with the call-sign "Manchester Tower." The Air 1 controller is responsible for arrivals on Runway 24R and the Air 2 controller is responsible for departures from Runway 24L. The Air controllers sit at adjacent positions in the Visual Control Room (VCR) of the ATC tower, which is situated within the terminal complex. Outbound aircraft are routed initially towards a crossing point for Runway 24R by a Ground Movement Controller, who sits on a raised platform behind the two Air controllers. When an aircraft is approaching Runway 24R it is transferred to the Air 1 controller who is responsible for issuing a crossing clearance for Runway 24R. The crossing clearance includes a clearance limit, which will be a holding position beyond the runway and is written on the aircraft's Flight Progress Strip (FPS) by the Air 1 controller when the clearance is issued. The responsibility for a section of the taxiway system south of Runway 24R is allocated to the Air 1 controller. This area, which is depicted on the diagram at Appendix 2, incorporates links 'DZ', 'FZ' and 'HZ', and taxiways 'V' and 'S' as far as stop bars 'V5' and 'T1'. Manchester Airport's MATS Part 2 states:

> *"Air 1 is responsible for the control of surface movements of all aircraft, vehicles and personnel wishing to operate within the delegated taxiway area" and that "Air 1 is responsible for assisting in preventing collisions in the delegated taxiway area."*

With regards to transferring of aircraft to Air 2, the manual states *"When crossing traffic is clear of conflictions…. control of the crossing traffic and the FPS may be transferred to Air 2*." Once the aircraft has vacated Runway 24R it is transferred to the Air 2 controller and the FPS is passed by hand between the controllers. The MATS Part 2 states *"Crossing clearance shall only be issued to the aircraft when there is sufficient room for the aircraft to vacate the runway and taxi clear of the CAT 1 holding point after crossing.* The MATS Part 2 further states *"Air 2's priority is to vacate the delegated area of taxiway to enable Air 1 to continue crossing traffic."* On transfer, the Air 2 controller issues the taxiing aircraft with a clearance limit, taking into account a number of variables. These may include: the sequence aircraft are transferred, the type of departure, wake turbulence considerations, requests for the starter extension and approved departure times.

Meteorological information

A weather observation was taken at Manchester Airport immediately after the accident. The surface wind was from 250º (M) at 12 kt and visibility was greater than 10 km. Some cloud was reported at 2,600 ft, with more extensive broken cloud at 5,600 ft. The surface temperature was +10º C and the QNH was 1021 mb. The taxiways and runways were dry. The time of sunset at Manchester Airport on 4 November 2004 was 1632 hrs.

Air Traffic Controllers' actions

At the time of the accident, all ATC equipment relative to the task of the two Air controllers was serviceable. At 1618 hrs the Air 1 controller issued the B767 with a conditional crossing clearance for Runway 24R, with a clearance limit of 'T1'. The controller was aware that the aircraft was subject to a take-off time of 1619 hrs and verbally informed Air 2 of this, but was confident that the aircraft would be able to depart within the permitted time extension of 10 minutes. The controller's normal practise was to transfer control of the aircraft to Air 2

as soon as the tail was clear of Runway 24R, which she would assess visually. She reported that use of the Surface Movement Radar (SMR) encouraged a 'heads down' approach which she tried to avoid. The controller annotated the clearance limit of 'T1' on the FPS and passed it to the Air 2 controller.

The Air 2 controller had previously amended the clearance limit for the B737 from 'V5' to 'T1'. When the B767 called on frequency he asked the crew if they could accept a departure from 'VA1' and, when they said they could, had instructed the B767 to turn right onto Taxiway 'V' and to taxi to 'VA1'. At this time the Air 2 controller, who later assessed his workload as "moderate," was also arranging separation of two other aircraft which had non-compatible departure routings.

The controller stated later that it was not normal practise for Air 2 to be 'pre-warned' about an aircraft unless time was a critical factor or if the pilot had requested the starter extension, in which case this information would normally be passed by the Ground Movement Controller. In this case, he was unaware of the B767 until it was transferred to him by Air 1. The controller thought that, had he known about the B767 in advance, he may have sent the BAe RJ100 to 'VB1' to avoid a build up of traffic at 'T1'. In the event, when the B737 was transferred to him, he saw no advantage in sending the aircraft to 'V5' as it had been originally cleared, so amended the clearance limit to 'T1'.

Other controllers at Manchester were asked how they allocated clearance limits to departing aircraft, and the responses varied. One controller would always clear aircraft to 'VA1' or 'VB1' initially, unless otherwise requested, in order to 'fill-up' the available space and leave 'T1' free for any aircraft specifically requesting it. Another controller would attempt to sequence aircraft in the most suitable stream taking into account the planned departure routing. The Air 2 controller at the time of the accident would normally clear all aircraft to 'T1' unless there was a specific reason to do otherwise. When Runway 24 L was first opened, general guidelines for controllers in respect of the south side taxiways were issued but were not adopted as formal policy.

Surface Movement Radar (SMR)

Manchester airport is equipped with SMR which was serviceable at the time of the accident. The SMR was recorded and available for replay. An SMR display is situated at each Air controller's position and may be set to show all of the manoeuvring area or zoomed into any desired part thereof. One of the Air 1 controller's responsibilities as defined in MATS Part 2 is the monitoring of SMR, although this is not listed as a responsibility of the Air 2 controller, since it is primarily used during Low Visibility Operations, in which case dual runway operations would cease. MATS Part 2 states:

> *"...the Surface Movement Radar (SMR) must not be used to relieve pilots and drivers from any of their responsibilities for avoiding collisions on the ground".*

Published information

Civil Aviation Publication (CAP) 637 '*Visual Aids Handbook*' gives advice and guidance for pilots and other personnel engaged in the handling of aircraft. Under the heading *"Paved Taxiway Markings"* it includes the following:

> *"Taxi Holding Positions are normally located so as to ensure clearance between an aircraft holding and any aircraft passing in **front** of the holding aircraft, provided that the holding*

*aircraft is properly positioned **behind** the holding position. Clearance to the rear of any holding aircraft cannot be guaranteed. When following a taxiway route, pilots are expected to keep a good lookout and are responsible for taking all possible measures to avoid collisions with other aircraft and vehicles."*

The Air Navigation Regulations, Rule 37 "Right of way on the ground" contains the following text:

"Notwithstanding any air traffic control clearance it shall remain the duty of the commander of an aircraft to take all possible measures to ensure that his aircraft does not collide with any other aircraft or with any vehicle."

The Manual of Air Traffic Services (MATS) Part 1 states the responsibilities of an aerodrome controller concerning aircraft, vehicle and obstructions on the manoeuvring area. The manual states:

"Aerodrome control is responsible for issuing information and instructions to aircraft under its control to achieve a safe, orderly and expeditious flow of air traffic and to assist pilots in preventing collisions between ... aircraft and vehicles, obstructions and other aircraft on the manoeuvring area"

Flight crew training

There is limited information available to flight crews to assist them to judge wing tip separation from fixed or stationary obstacles. Guidance for pilots from the aircraft manufacturer is contained in the aircraft's Flight Crew Training Manual. The manual describes the turning radius of the aircraft and the area 'swept' by the wing tip, with a caution that turns away from obstacles should not be commenced if the obstacle is within 15 ft (4.6 m) of the wingtip or within 45 ft (13.8 m) of the nose.

The wingtips of the B767 are not normally visible from the captain's seat. This and other limitations preclude the use of flight simulators for effective training in this regard. However, the commander had received training to improve his awareness of the position of the wing tips, during which an instructor stood ahead of the aircraft in line with the wing tip. This allowed the pilot to select a suitable reference to allow him to judge the line the wing tip would take. Enquiries with other operators confirmed that training regarding wing tip clearance was often limited to a discussion of the subject. In most cases flight crew are cautioned that if clearance is ever in doubt, the aircraft should be stopped and additional measures, such as 'wing walkers' employed.

Prior to promotion to the rank of captain, the B767 commander had no experience of taxiing large transport aircraft. This is not unusual, since many such aircraft are either not fitted with a steering tiller at the co-pilot's station, or their operators choose to limit the occasions when the co-pilot is allowed to taxi the aircraft.

The need for avoidance of possible distractions during the taxi phase of flight is routinely stressed during training and in operators' manuals. The B767 operator's Operations Manual contained the following guidance to flight crews:

"In congested areas or in the proximity of obstructions, checks will be delayed until safe taxiing conditions permit. The RHS (right hand seat) pilot will assist in keeping a lookout and will not allow copying clearances or reading the checklist to degrade this function".

Human factors

The commander of the B737 had stopped his aircraft at what he considered to be a safe distance from the aircraft in front which was holding at 'T1'. Although the aircraft stopped short of holding point 'S2', this holding point was not being used, was never referred to by ATC and was not a factor in the commander's decision to stop where he did.

The B767 commander believed that his aircraft was guaranteed safe separation provided that he taxied on the marked taxiway centre line. He did not fully appreciate that the marked centreline provides protection only from fixed obstacles and from other aircraft in the limited cases detailed in CAP 637. The commander also believed that the Air 2 controller would not have issued the revised taxi instruction if there was any doubt about the available separation. Although the crew had agreed between them that the available take-off distance from 'VA1' was sufficient, the commander was not convinced of this fact and, as he continued taxiing, mentally resolved to review the performance figures prior to committing to take off.

The judgement of separation between objects at the distances involved in this accident cannot be precise, and is reduced still further in this case by additional factors. Firstly, the wing tip is some considerable distance behind the commander and cannot be seen. Secondly, the commander's attention is not focused exclusively on the other aircraft, but also to his right, in the direction of the taxiway. The commander recalled looking at the B737's vertical stabiliser as he passed, which would have been a more prominent obstacle than the horizontal stabiliser.

The B767 commander was subject to a medical examination by the CAA's Medical Division. This established that his post accident faint was due to shock and that no underlying medical condition existed that could have contributed to the accident.

Previous recommendation (96-43)

The AAIB investigated a similar accident at Heathrow Airport on 23 November 1995 in which the wing of a taxiing Airbus A340 struck the tail of a Boeing 757 which was stationary and some way short of a taxiway holding position. As a result of this investigation, the AAIB made the following recommendation to the CAA (Recommendation 96-43):

> *"The CAA should, in liaison with the appropriate ICAO committees, consider what action may be taken in the longer term to ensure that flight crews of large public transport aircraft are better able to achieve a positive clearance between their aircraft and others while manoeuvring on the ground."*

The CAA accepted this recommendation and advised that:

> *"It will seek to have this issue raised within ICAO and will draw to the attention of ICAO any particular measures, identified as a consequence of this accident, which might help to minimise problems of this nature. In the mean time the Authority is publishing, early in 1997, a Visual Aids Handbook which will give guidance to pilots on the interpretation of aerodrome visual aids, including taxiway markings."*

The Visual Aids Handbook (CAP 637) was published in 1997 and will be subject to an update in 2005.

The UK CAA raised the issue with the ICAO Air Navigation Bureau, with a request that the subject of ground collisions be addressed globally. The ICAO Airport Design Study Group was tasked to consider the matter through its various working groups and, as part of that process, the UK CAA continued to submit working

papers to the ICAO Visual Aids Panel. These actions were complementary to an ongoing ICAO review of Surface Movement Guidance and Control Systems (SMGCS). It was recognized that current SMGCS were not always capable of providing the necessary support to aircraft operations in order to maintain required capacity and safety levels, especially under low visibility conditions. In 2004 ICAO issued Document 9830, "*Manual of Advanced Surface Movement Guidance and Controls Systems*" (A-SMGCS). The A-SMGCS concept makes use of modern technologies to provide increased safety and airport capacity, particularly in low visibility operations, through automation and a high level of integration between the various functionalities. However, A-SMGCS remains at an early stage of development. When implemented, it will enhance the 'see and be seen' principle but will not relieve the aircraft commander of the responsibility for safe manoeuvring of his aircraft.

Communications

After the collision both aircraft established communications with the AFS on frequency 121.6 MHz, which is an aeronautical radio frequency dedicated to this purpose but which is not an ATC frequency. The aircraft flight crews discussed with the airport fire officer the damage to their aircraft and possible evacuation considerations. Had an evacuation become necessary it is possible in this case that it would have been initiated at the request of the AFS. Frequency 121.6 MHz was not recorded at Manchester. There is no requirement for it to be recorded, although it is recommended in CAP 168. This denied the investigation valuable information and could equally hamper future investigations. A safety recommendation is made in this regard.

Analysis

The flight crew's actions

Both aircraft were serviceable and their crews were adequately rested and close to the beginning of their duty periods. The accident occurred in fine weather conditions and although sunset was approaching, the B767 commander did not consider the light conditions to be a factor in the accident. The B737 commander was entitled to stop his aircraft where he did and bore no responsibility for the clearance, or lack of it, between his aircraft and any passing behind. As the B737 was stationary, the assessment of separation and ultimately the responsibility for collision avoidance rested with the B767's crew and in particular the commander, who was taxiing the aircraft. All three flight crew on the B767's flight deck thought that the wing tip clearance was adequate, therefore this analysis concentrates initially on the procedural, environmental and human factors which may account for this fact.

Analysis of the SMR and the nature of the damage to both aircraft indicated that the B767 was on or very close to the marked taxiway centre line during the turn and at the point of collision. The aircraft would therefore have begun to turn away from the B737 when it was still some distance from it. As the turn continued, the B737 would have moved into the commander's left side window, giving him the impression that his aircraft was moving away from the B737 when the wingtip was still, in fact, moving towards it. As the tail of G-ODSK moved further aft, the task of monitoring it and looking ahead and to the right to follow the taxiway would have become increasingly difficult, with the commander having to monitor two points separated by about 150º. It is not certain that the pilot was physiologically equipped to assess the separation between a wing tip which he could not see and which was behind him, and the tail of

the B737, particularly when his taxi route was turning away, albeit gradually, from the stationary aircraft. Additionally, the B737's fin and rudder would be far more obvious than the horizontal stabiliser, due to the aspect of the latter, yet the tip of the horizontal stabiliser would have been some 6 m closer to the B767 than the rearmost part of the aircraft's fin and rudder.

Swept wing aircraft are subject to a phenomenon known as 'swept wing growth' or 'wing creep'. This occurs during a turn when the wing tip describes an arc greater than the normal wingspan due to the geometry of the aircraft and the arrangement of the landing gear. It is one of the reasons for the manufacturer's caution in the Flight Crew Training Manual. Although this effect is less noticeable at the moderate curvature of turn in this case, it still served to erode the perceived wing tip clearance.

The crew of G-SATR had experienced a busy dispatch with a number of operational problems, some of which continued to occupy the commander's mind up to the point of the accident. There was also an element of time pressure on the crew. Being initially cleared to 'T1', they would have been aware of the two aircraft ahead of them, and therefore that time was available to complete pre take-off tasks, such as configuring the aircraft for an air conditioning 'packs off' takeoff and completing the before take-off check list. The change of clearance to 'VA1' with the implied early departure re-instated the time pressure on the crew and served to generate further distractions. The first officer wished to check the taxiway route to 'VA1' and consulted his chart in the critical moments leading up to the collision. He also had to locate the 'before take-off' checklist in response to the commander's request, which he had just done when the collision occurred. According to their company's operations manual, the crew would have been expected to delay non essential activities such as reading checklists until clear of the congested area, thus allowing both pilots to give their full attention to the safe manoeuvring of the aircraft.

The time between ATC's enquiry about the suitability of 'VA1' and the co-pilot's response was very short, supporting the commander's recollection that the second co-pilot, who was familiar with Manchester, had said straight away that it was acceptable and that the other two crew members had concurred. However, the commander was not satisfied that this was the case and mentally resolved to check the available runway distances from 'VA1' before accepting a departure clearance. In fact, the aircraft performance figures calculated by the crew were based on departure from 'VA1', though the commander was not sure of this at the time. The B767's operator had introduced take-off performance figures from 'T1' which would have allowed the aircraft to fly direct to Goa, though these figures had not been issued at the time of the accident. If the commander had believed that a take-off from 'T1' was necessary, he should have notified ATC in advance as required by the AIP. As he had not notified ATC of this, it was reasonable for the controller to expect the crew to accept a departure from 'VA1'.

When G-SATR was re-cleared to 'VA1', the commander's expectation was that it would be safe to taxi as cleared. Both he and the rest of the crew believed that clearance would be assured provided that the aircraft stayed on the marked taxiway centreline. It became clear during the course of the investigation that this expectation is not uncommon among professional pilots, despite the information to the contrary published by the CAA, and a safety recommendation is made in this regard. In this case, the expectation would have been reinforced by the controller's statement "IN VIEW OF YOUR SLOT…" since

this would suggest to the commander that the controller also believed that there was sufficient clearance to pass the B737 as otherwise he would not, in the minds of the crew, have issued the revised instruction. The second co-pilot, who was occupying an observer's seat was not directly occupied with pre-take-off preparations but his perception of the available separation may have been influenced by the fact that he was not at his usual position on the flight deck.

With the operational problems, performance queries and flight deck activity, it is probable that, as the commander continued taxiing his aircraft on the revised routing, he was suffering from a degree of quantitative overload which would have narrowed his attention and made a misjudgement of the available separation more likely. The commander's perception of the problem was also influenced by past experience. The commander had extensive experience of taxiing on the centreline and thus far this had proved to be a safe thing to do. His experience, the ATC clearance, the visual cues and the distractions combined to produce a mental model of the situation which was incorrect. However, distractions during the taxi phase are not uncommon and procedures are normally developed to reduce distractions to a minimum. In this case, the distractions for the crew during the turn were partly self generated in that they were unsure of the take-off performance parameters and had initiated a checklist at an inappropriate moment.

Air Traffic Control

The Air Navigation Order places the responsibility for collision avoidance whilst on the ground with the aircraft commander, notwithstanding any ATC clearance. However, both MATS Part 1 and Manchester's MATS Part 2 also place a responsibility on controllers to assist pilots in avoiding collisions. The investigation therefore also examined to what extent the controllers concerned could or should have assisted the commander of G-SATR in this case, and what part ATC procedures at Manchester may have played in the accident.

Manchester's MATS Part 2 describes that part of the south side taxiway system which is delegated to Air 1 and places the responsibility for assisting in preventing collisions within that area to the Air 1 controller. It also states that crossing traffic may be handed over to Air 2 when it is *"clear of conflictions"*. If handover to Air 2 should occur before the aircraft reaches its clearance limit, as is frequently the case, then it would be reasonable to assume that the responsibility to assist in prevention of collisions also transfers to Air 2, though this is not explicitly stated in MATS Part 2. As the Air 1 controller therefore technically retains responsibility for the traffic, it is questionable whether the Air 2 controller should be able to revise the clearance limit on anything other than safety grounds. Additionally, a factor in Air 1's choice of clearance limit would be the requirement to avoid congestion on the south side, so allowing the controller to continue to cross aircraft. As Air 1 has more situational awareness regarding aircraft that are waiting to cross the runway than Air 2, this would further suggest that a change to the clearance limit should not be made on ground of convenience.

One of the effects of the Air 2 controller's change of clearance limit for the B737 was to create a potential congestion in the area adjacent to link 'D' which was being used by Air 1 as a main crossing point for Runway 24R. This was not the controller's intention, as he expected the B737 to move further forward before stopping, though there was no guarantee of this. Although the revised clearance may have been more convenient for the aircraft concerned, it was contrary to the controller's priority as described in MATS Part 2 to vacate the area of Air 1's responsibility and so enable

Air 1 to continue to clear traffic across Runway 24 Right. As the area of Air 1's responsibility extends to holding point 'T1', it may be expected that Air 2 would feed aircraft towards 'VA1' and 'VB1' initially, which would also keep 'T1' free for those aircraft specifically requesting it in accordance with the AIP. In clearing the B767 to 'VA1', the controller was attempting to relieve the congestion, though this was apparently driven more by the take-off time consideration.

From the control tower, the view would have been almost directly stern-on to the B737. It would have been difficult for the Air 2 controller to determine, either visually or using SMR, if the B737 was stationary or moving forward slowly. The controller stated that, had he known that insufficient separation may have existed between the two aircraft, he would not have issued the revised taxi instruction or added a caution to that effect, and expect the B767 commander to continue taxiing when he was able, though he was not required to do either. Just as the commander of G-SATR had an expectation that separation existed because he had been cleared by ATC, so the controller had an expectation that the commander would assess the separation for himself and not proceed unless it was safe to do so. The difference is that the B767 commander's expectation was based on a false assumption while the controller's expectation was based on an awareness of the commander's own responsibility for safe manoeuvring.

The SMR did show the potential problem but was not routinely used in fair weather conditions for separation purposes, nor was it required to be. This is understandable, as the SMR has limitations and controllers could not monitor the whole manoeuvring area, issuing cautions when thought necessary, as then the absence of a caution would itself imply that clearance was assured. Nevertheless, the SMR is an aid and could conceivably be used by controllers in certain situations to assist in the prevention of collisions on the ground. Therefore the MATS Part 2 statement that the SMR *"...must not be used to relieve pilots...from any of their responsibilities for avoiding collisions on the ground"* could be considered to be at variance with the instructions elsewhere to controllers concerning their own responsibilities to assist pilots in avoiding collisions.

Limitations applicable to holding point 'S2' were omitted from MATS Part 2, on the basis that the holding point is not used. However, the information may have provided controllers with an awareness of a likely problem should an aircraft be stationary or slow moving in the vicinity of 'S2', as was the case in this accident. A safety recommendation is made concerning the south side holding points and associated procedures.

Conclusion

The accident was due to the left wing of G-SATR striking the horizontal stabiliser of G-ODSK as a result of insufficient separation between the two aircraft. Notwithstanding any ATC clearance, the Air Navigation Order places the responsibility for collision avoidance on the ground with the commander of the aircraft. The B767 commander's misjudgement of the clearance between the aircraft was probably due to a combination of physiological limitations, distractions due to operational and time pressures, and a false assumption that his ATC clearance implied that separation would be assured. The Air 2 controller had no reason to believe that the B767 commander would not see and take into account the presence of the B737. Whilst the investigation highlighted some procedural and operational inconsistencies with air traffic control procedures, these are not judged to have been causal factors to the accident.

Safety Recommendations

The following safety recommendations are made:

Safety Recommendation 2005-124

The Civil Aviation Authority should consider publicising the circumstances of this accident with a view to raising flight crews' awareness of their responsibilities for collision avoidance during taxiing as detailed in CAP 637 and the Air Navigation Order.

Safety Recommendation 2005-125

The Civil Aviation Authority should consider mandating the recording of frequency 121.6 MHz at those airfields where provision of the frequency is required.

Safety Recommendation 2005-126

Manchester Airport Air Traffic Control should review local working practises with regard to the south side taxiways to ensure that they are standardised and accurately reflect the requirements of MATS Part 2. Furthermore, MATS Part 2 should be reviewed to ensure that the fullest information on the south side taxiways is included to assist controllers.