DATA SUMMARY

LOCATION

Date and time	**Saturday, 15 July 2006; 10:30 h UTC**
Site	**Madrid-Barajas Airport (Madrid)**

AIRCRAFT

Registration	**HS-TGY**	**F-GOHC**
Type and model	**BOEING B747-400**	**EMBRAER EMB-135**
Operator	**Thai International Airlines**	**Régional**

Engines

Type and model	**CF6-80C2-B1F**	**ROLLS-ROYCE AE 3007A1/3**
Number	**4**	**2**

CREW

Pilot in command

Age	**58 years**	**42 years**
Licence	**ATPL**	**ATPL**
Total flight hours	**20,000 h**	**9,000 h**
Flight hours on the type	**6,187 h**	**3,500 h**

INJURIES

	Fatal	Serious	Minor/None	Fatal	Serious	Minor/None
Crew			**20**			**3**
Passengers			**310**			
Third persons						

DAMAGE

Aircraft	**Minor**	**Major**
Third parties	**None**	**None**

FLIGHT DATA

Operation	**Commercial air transport – International-Scheduled-Passenger**	**Commercial air transport – International-Scheduled-Passenger**
Phase of flight	**Taxiing to runway**	**Standing – Engines not operating**

REPORT

Date of approval	**24 October 2007**

1. FACTUAL INFORMATION

1.1. History of the flight

The Boeing B747-400 had landed at Madrid-Barajas Airport (LEMD) that morning after a flight from Rome. The aircraft was parked at stand 73. At around 9:39 h[1] the flight crew, which was the same as that of the previous flight, requested clearance for a flight back to Rome with the call sign THA943. It was a hot, sunny summer day and visibility was good. All airport taxiways and runways were dry. The flight crew had not disembarked the aircraft. They had received all the NOTAMs and applicable information after landing at LEMD. In particular, they had on board NOTAM C4125, which was in force from 0607050600 until 0608211200 stating: "WIP ON PORTION OF TWY I-8 BETWEEN STAND T12 AND T13, MAX ACFT FOR TAXIING IS A321, STANDS T12 AND T13 CLOSED".

They received clearance for start up according to slot 1005 from runway 36R and were told to contact ground. At 9:56 h the ground air traffic controller (ATCO) told them that their flight plan had been revised and a new slot 1208 was envisaged. At 10:18 h they were informed by ATC that a new slot with departure time 10:51 h was available, and were requested to call when ready to taxi according to this slot. After the accident, the crew stated that they were not in a hurry or under pressure for the subsequent takeoff. It takes around 2 hours to fly back to Rome. They were scheduled to rest in Rome, with another crew flying the next leg to Bangkok.

At 10:20:24 h the co-pilot of the aircraft, who was handling radio communications, requested push back and start up, which was approved 7 seconds later. The pilot in command was the pilot at the controls during the subsequent taxi.

At 10:25:11 h the aircraft was requested to taxi "VIA MIKE, HOLDING POINT THREE SIX RIGHT." However, by that time another aircraft (a Boeing B-767) requested push back at finger T-1, and therefore the ATCO asked the crew of the B747: "…ARE YOU ABLE TO TAXI VIA CHARLIE FOUR AND THEN MIKE TO THE RIGHT?" at 10:26:03 h. The crew answered: "OK TAKE CHARLIE FOUR AND MIKE THAI NINE FOUR THREE" at 10:26:09 h and the ATCO replied "THANK YOU" at 10:26:13.

There were no other communications between the B747 aircraft and the ATCO until 10:30:50 h, when the crew called ground ATC ("GROUND THAI NINE FOUR THREE"). The answer of the ATCO was: "THAI NINE FOUR THREE YOU WERE CLEARED TO TAXI VIA MIKE. THAT'S NOT MIKE, THAT'S INNER TAXIWAY AND I'M AFRAID IS NOT POSSIBLE TO TAXI, TO CONTINUE TAXIING…STAND BY, PLEASE". The flight crew answered "WE HIT THE AIRCRAFT THAI NINE FOUR THREE" at 10:31:07 h.

[1] All times in this report are UTC.

The general layout of the applicable part of Madrid-Barajas Airport is shown in figure 1. The aircraft had followed the approximate trajectory shown in Figure 1 by a solid line. To follow taxiway M, it should have turned to the right (as shown by a dotted line in Figure 1) upon reaching the sign on the ground (see Figure 2) but instead continued straight into taxiway I.

The construction in taxiway I had led to the deletion of the original taxiway centerline and the establishment of a new centerline that deviated to the right to avoid a spot of pavement being modified (see Figure 5).

For this reason, there was a NOTAM in force that stated that the maximum aircraft size allowable on taxiway I was that of the Airbus A-321. This NOTAM was available to the crew on board the aircraft before the flight.

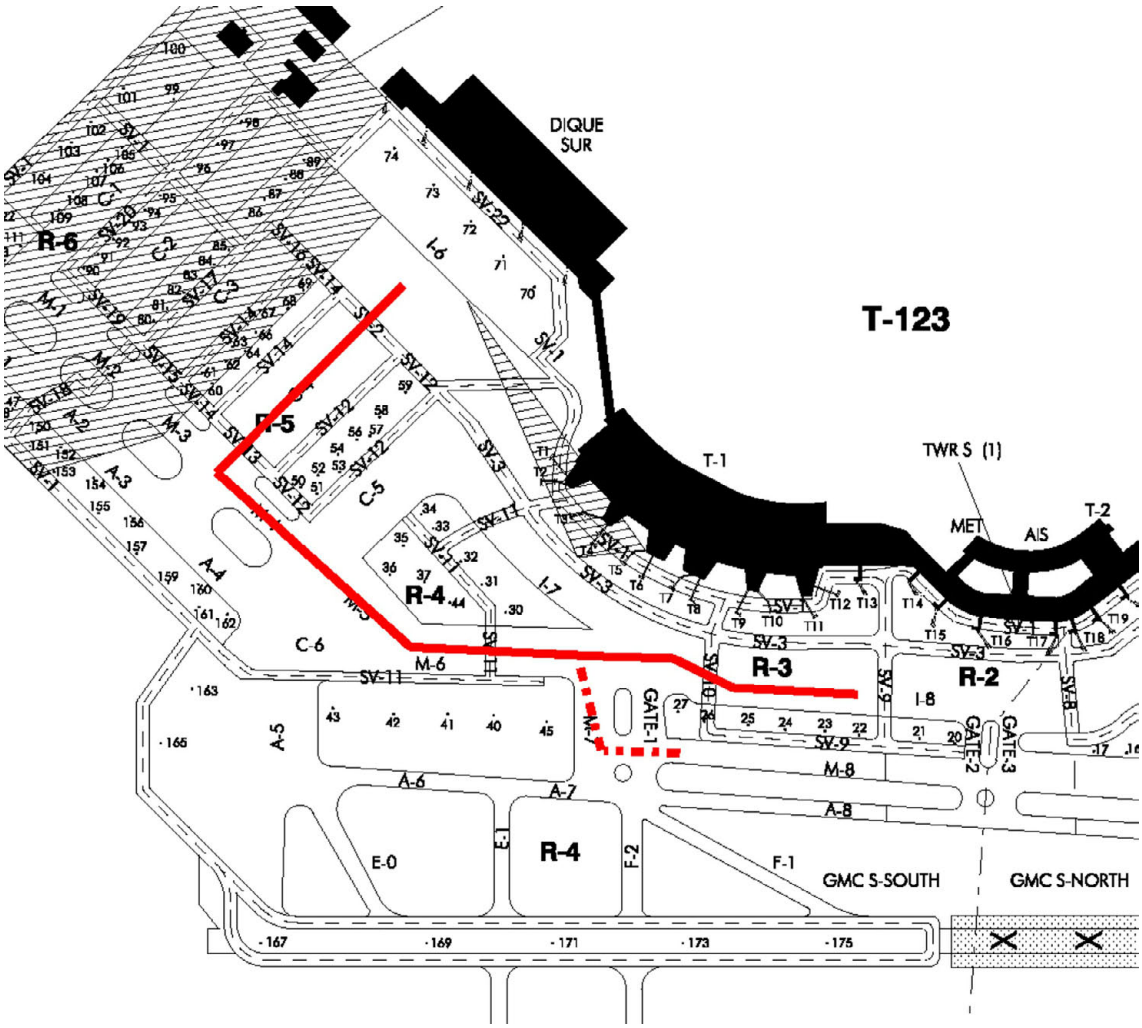

Figure 1. Approximate trajectory of the aircraft (solid line) versus intended trajectory according to the AIP taxiing instructions from Ramp 5 to runway 36R (dotted line). The ATC specifically offered the aircraft to taxi initially through C-4

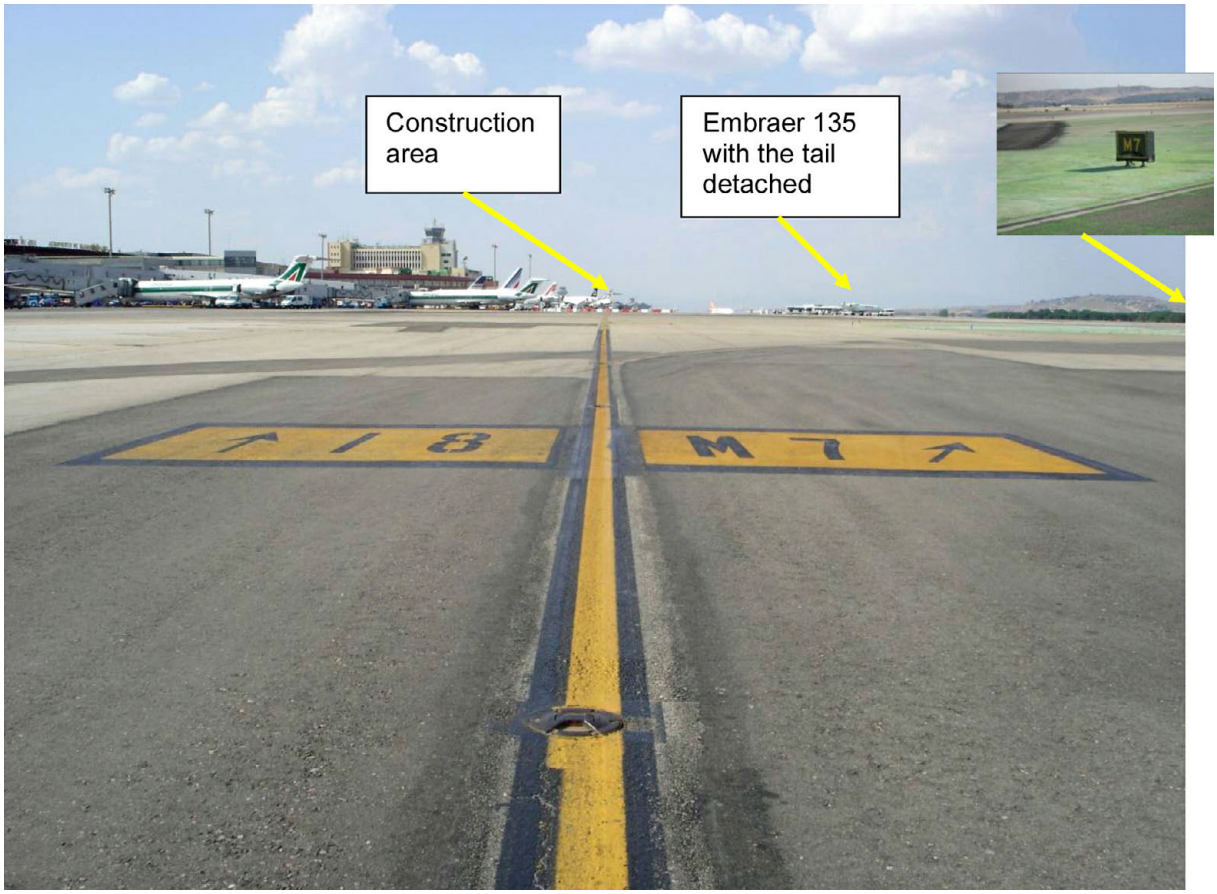

Figure 2. Horizontal mark on the taxiway at M6-M7 junction as viewed at surface level. On the left, the South Control tower can be seen. In the center background, the construction area and the damaged Embraer aircraft are visible. On the right, outside the picture, there was a vertical sign showing M-7

As the aircraft deviated from the normal taxiway centerline, following the new, modified centerline, the crew questioned their ability to clear the EMB-135 aircraft parked on stand 22 to the right of the taxiway in that zone. The copilot could see the RH wing tip of the B747 from his seat on the right side of the cockpit (see Figure 6). Both crew members recalled they were taxiing carefully at that time because the path was narrowing.

The FDR data showed a groundspeed of 6-8 kt at that time.

The captain stated that he understood the copilot thought their right wing could clear the parked aircraft. The copilot recalled saying they could possibly pass but with little clearance. He stated that at some point he said, "Stop!" and applied the brakes, but the aircraft was already very close to the EMB-135 and hit its T-tail, which completely detached and fell to the ground. The B747 suffered damage to its RH winglet. In two seconds the speed went from 6 to 0 kt, with –0.434 g of longitudinal acceleration recorded when the brakes were applied. The lateral acceleration reached –0.075 g at 10:30:38 h, possibly corresponding to the time of the collision. The highest vertical acceleration was 1.113 g at 10:30:41 h when the aircraft stopped completely.

Figure 3. Vertical signs of M-7 and GATE 1 viewed from ground level from the M-6/M-7 junction

Figure 4. Horizontal sign showing M-7 turn directed at aircraft taxiing in the opposite direction from that followed by the B-747. The construction works area and the damaged EMB-135 are noted by white arrows.

Figure 5. The layout of the accident area in detail. The original I-8 taxiway centerline is shown in blue. It was displaced 11 m to the right (dotted line) due to the construction work in the area, enclosed by a purple line. According to the AIP taxiing instructions, the aircraft should have turned right to M-7 after the M-6/M-7 junction, as shown in the picture

Figure 6. View from the copilot side of the wingtip of the accident aircraft

The EMB-135 had the pilot in command, copilot and a flight attendant on board at the time, and they were waiting for the passengers to arrive by bus and board the aircraft for the next flight. The aircraft was powered at that time, but the engines had not been started and the radio was off. The cargo door was open but there were no people on the ground working in that area of the aircraft. The captain felt the hit and a strong movement of the fuselage. They cut all the power when they realized their aircraft had been hit.

The ATCO called airport personnel to assess the situation. At 10:32:17 h she said to the flight crew of the B747: "YOU WERE CLEARED VIA MIKE TAXIWAY. I DIDN'T SEE YOU BEFORE TO ADVISE YOU SIR".

The crew shut down the engines at approximately 10:36:40 h but powered up the aircraft auxiliary power unit in order to maintain services to the aircraft and passengers onboard. The B747 was later towed to another parking area and the damaged winglet was removed. It flew back on a revenue flight the next day. The EMB-135 suffered major structural damage.

When the CIAIAC was notified of the accident by phone later that morning, it immediately requested that the flight recorders be preserved as they would be required for the investigation. However, the cockpit voice recorder remained powered for more than two hours after the event and therefore the relevant information was recorded over (see Section 1.3 below).

1.2. Personnel information

1.2.1. *B747 Pilot in command*

Sex, age:	Male, 58
Nationality:	Thailand
Licence:	ATPL
Type rating:	PIC B747. He had been a B747 captain for three years
Total flight time:	20,000 h
Flight time on type:	6,187 h (all as captain)
Hours during the last 30 days:	79 h
Hours last 7 days:	14 h
Hours last 72 h:	13 h
Start of current duty period:	5:45 h
Previous rest period:	46 h

The captain had previously flown to Madrid-Barajas Airport on 25-3-2006 and had departed again on 30-3-2006. In the last year, he had flown to Madrid three times, including the flight the day of the accident.

1.2.2. *B747 First officer*

Sex, age:	Male, 34
Nationality:	Thailand
Licence:	ATPL
Type rating:	First officer B747. He had been a B747 first officer for five years
Total flight time:	9,000 h
Flight time on type:	5,000 h (as first officer)
Hours during the last 30 days:	89 h
Hours last 7 days:	36 h

Hours last 72 h:	13 h
Start of current duty period:	5:45 h
Previous rest period:	46 h

The first officer had previously flown to Madrid-Barajas Airport in March 2006 (not with the captain of the accident flight). During the last year, he had flown to Madrid twice, including the flight the day of the accident.

1.2.3. *Ground movement air traffic controller (ATCO)*

Sex, age:	Female, 47
Nationality:	Spain
Licence:	Air traffic controller
Rating:	The first rating was obtained in 1990. The Madrid-Barajas Aerodrome rating was obtained in 1995
Medical check:	Valid until 13-9-2006
Experience in current position:	More than 11 years
Start of current duty period:	7:00 h UTC (9:00 h local time)
Previous rest:	19 h

1.3. Flight recorders

1.3.1. *Cockpit voice recorder (CVR)*

The B747 aircraft had an Allied Signal 980-6022-001 solid-state cockpit voice recorder (CVR), S/N 1605. It records 30 minutes of digital sound on four channels (CM-1, CM-2, CM-3 and cockpit area microphone) and two hours of digital sound in two additional files. One of those files ("mixer") jointly records the last two hours of the CM-1, CM-2 and CM-3 channels, and the other file ("full") records the last two hours of sound from the cockpit area microphone.

The CVR was downloaded and it was found that the information relative to the moment of the impact of the aircraft had been recorded over because it had remained powered for more than two hours afterwards.

The flight crew stated that they were not aware of procedures for the flight crew or ground maintenance personnel to disconnect the CVR after an incident to preserve the data. There is no circuit breaker readily available to the crew to stop the recording of the CVR while the aircraft is powered.

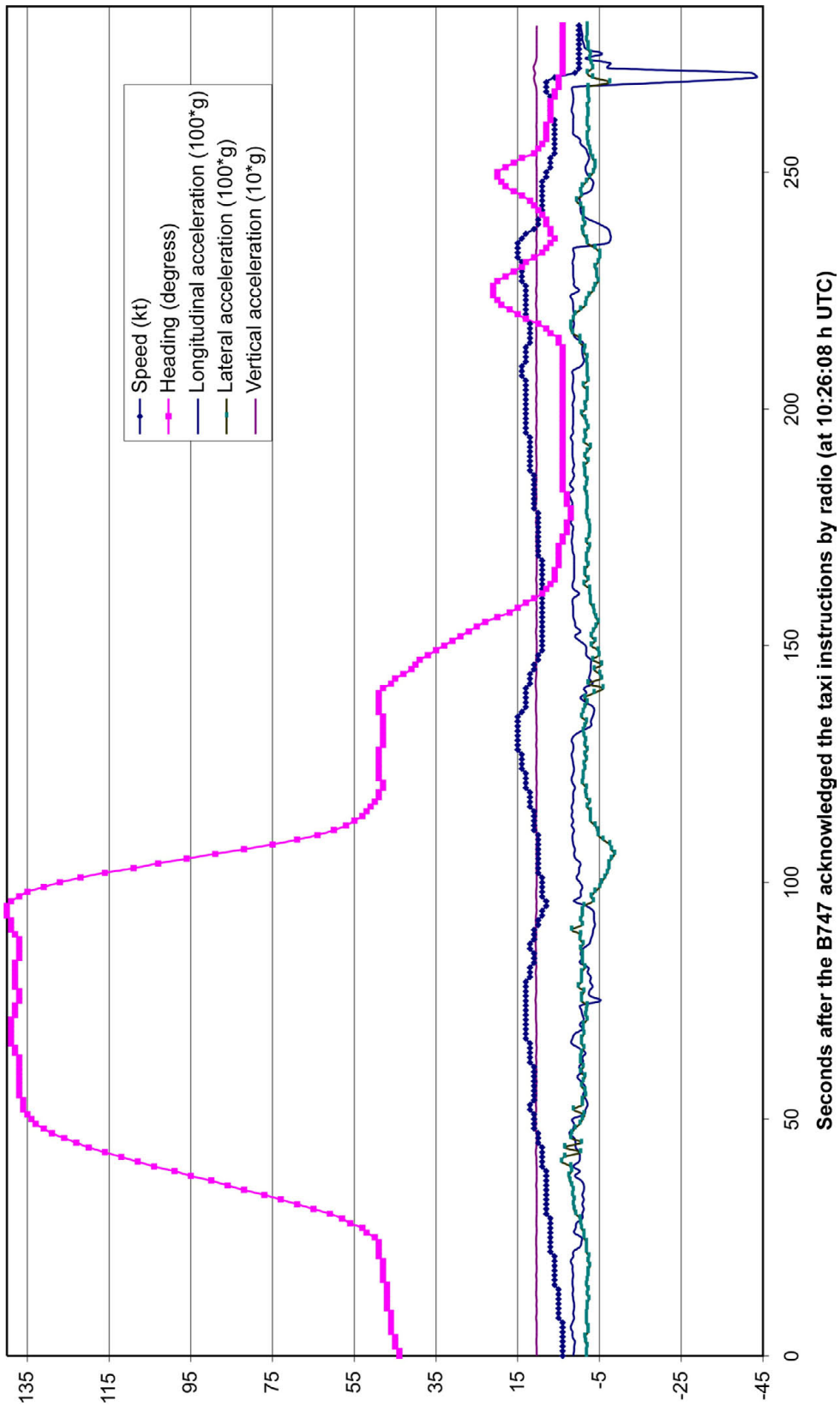

Figure 7. Two graphs prepared from FDR data. Heading shows the turns carried out by the aircraft. Negative longitudinal acceleration means that brakes were applied

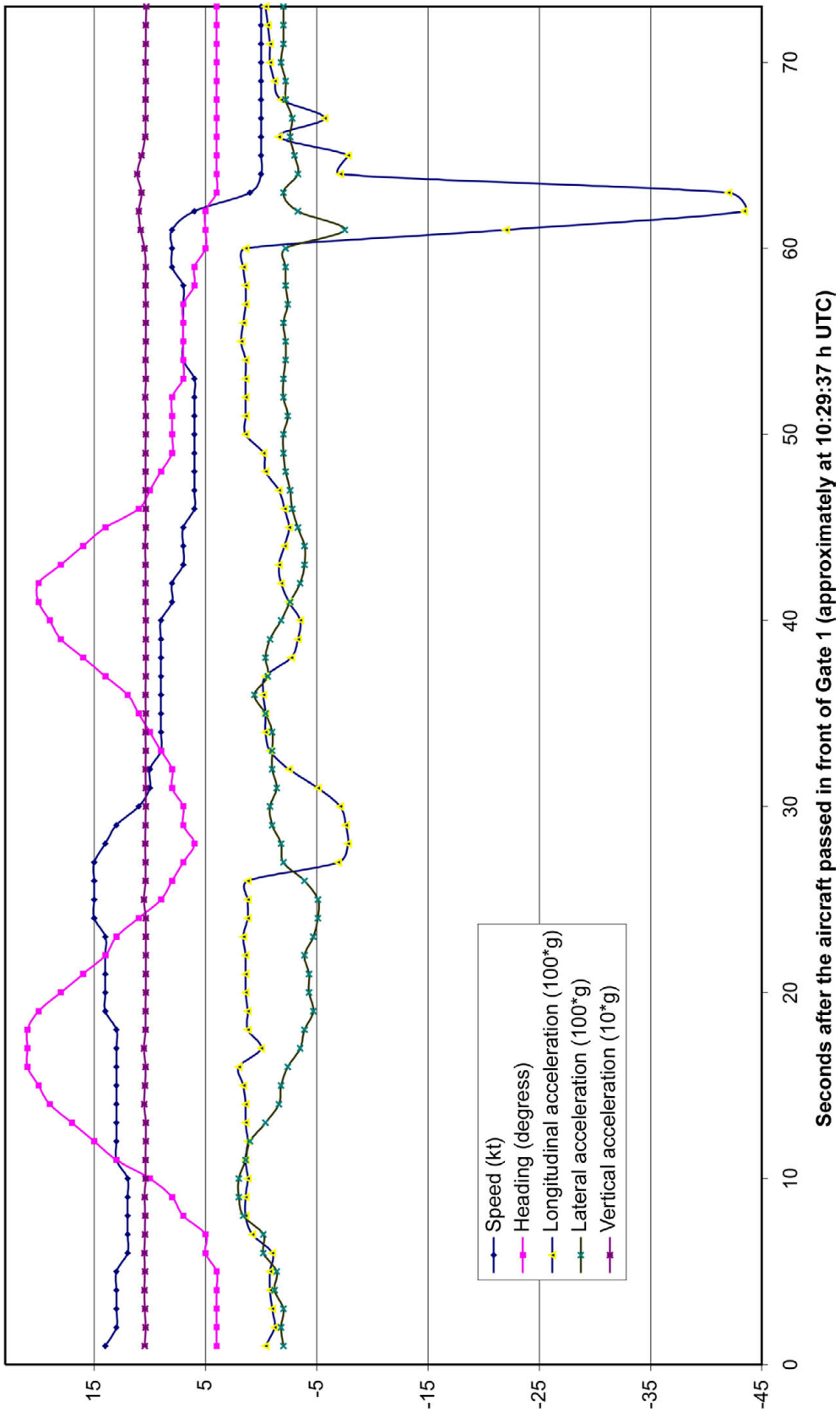

Figure 7. *Continuation*

1.3.2. *Flight data recorder (FDR)*

The B747 aircraft had an Allied Signal solid state FDR, P/N 980-4700-042, S/N 1605. The data was downloaded and it was found that the moment of the accident had been recorded correctly and the relevant parameters were useful to the investigation.

Figure 7 shows two graphs with the most important parameters of the FDR. The first graph shows the movement of the aircraft after it started taxiing forward, after the flight crew said on the radio: "OK TAKE CHARLIE FOUR AND MIKE THAI NINE FOUR THREE". The other graph shows in detail the last minute prior to impact, after the approximate moment the aircraft passed in front of Gate 1.

The aircraft was in constant motion from the time it started taxiing, i.e. they never stopped at any intersection until they applied the brakes after the collision. The push back and taxi was normal. At 10:30:00 h the speed of the aircraft was 15 kt which is normal for the operation being conducted. As the aircraft approached the deviated centerline area of I-8, it reduced speed down to 6-8 kt while turning. At 10:30:41 h the speed was zero because the impact had already happened and the crew applied brakes. The rest of the taxi had been normal.

1.4. Operational procedures

The operator's Flight Operations Manual (FOM), Section 3.1.5, 8.3, edition 2, effective 24 May 2002, contained procedures and guidelines for taxiing. It stated that:

> "The P-i-C [pilot in command] is solely responsible for ensuring that the aircraft does not come in contact with any object while being maneuvered under its own power...Checklist reading shall not be initiated nor continued until taxi orientation assistance is no longer necessary. This is of particular importance when operating in adverse conditions, i.e., low visibility, unfamiliar airport, congested area, etc. All pilots must have the airport chart readily available when taxiing. The aircraft shall normally not be taxied closer than one-quarter wingspan from any hindrance. Taxi guidelines/markings do not always ensure adequate hindrance clearance and shall be used with caution. Whenever doubt exists, request assistance from ground. During taxiing, it is the duty of the pilot occupying the RP seat to inform the LP any time the aircraft comes closer than one-quarter wingspan to the obstruction on the right side of the aircraft. RP shall also assist LP by advising taxiway name and direction, where appropriate...The aircraft should not taxi or hold so close to an active runway that a danger of collision exists, in case a landing or departing aircraft is leaving the runway... Taxi guidelines vary from place to place and do not always ensure adequate hindrance free clearance. They shall be used with caution as a guidance to aircraft positioning."

The operator's Aircraft Operations Manual (AOM), Section 3.3.1 "Flight procedures, taxiing", edition 3 effective on 15 May 2001, also had procedures for maneuvering the B747-400 on the ground. It stated:

> "Taxi with caution. Due to the flight deck height above ground, the aircraft appears to be moving slower than actual. Therefore, there is a tendency to taxi faster than desired. This is particularly true when turning off the runway after landing... Because of the shape of the fuselage and location of the flight deck, there is a large area near the aircraft where objects on the ground cannot be seen. This is particularly true when looking across the flight deck. Exercise particular

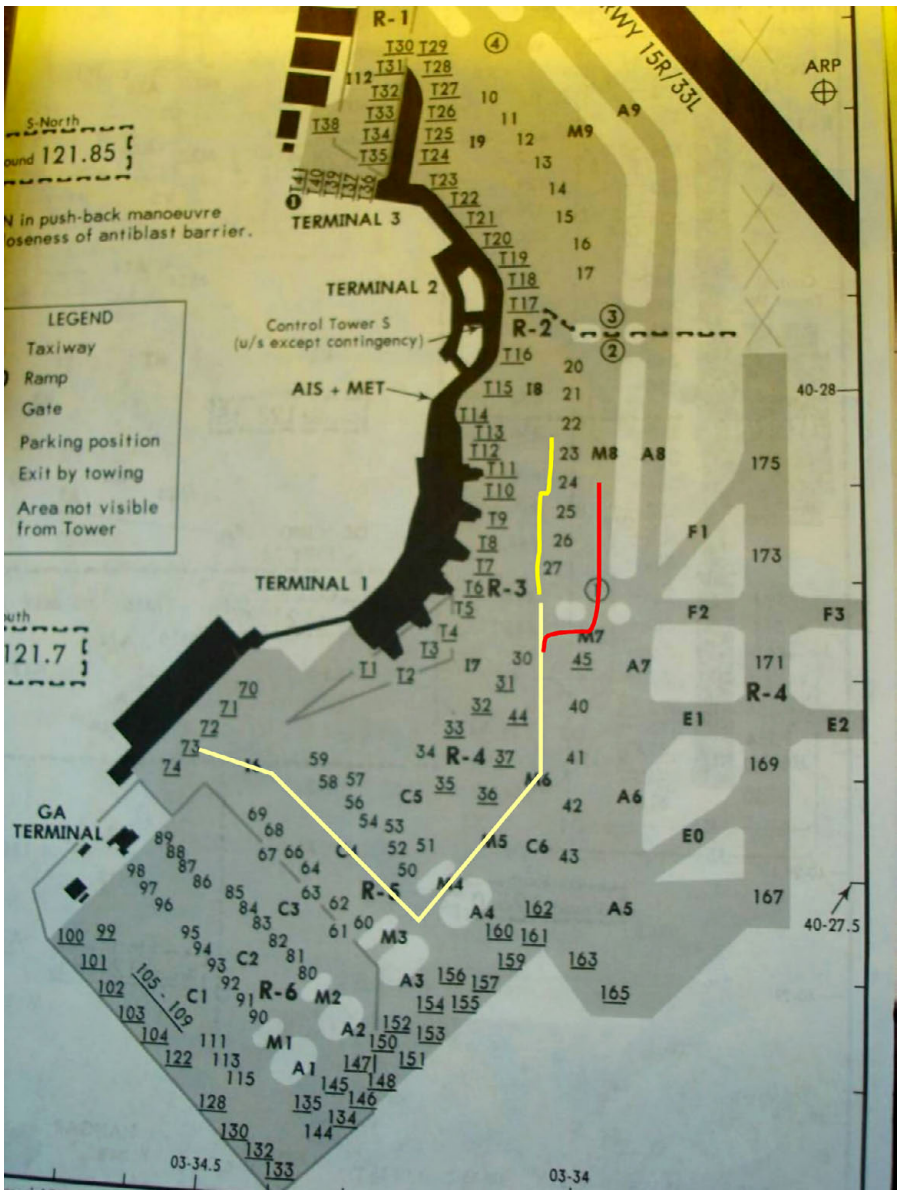

Figure 8. The Jeppesen chart that was on board. The actual path they followed is shown in yellow. The path the B747 aircraft should have followed is shown in red. The Jeppesen chart includes the number 1 inside a circle, meaning "Gate 1"

caution when maneuvering in congested areas...**Note:** Do not divert from the primary task of safely taxiing the aircraft. The flight crew should avoid all unnecessary activities and duties that can be performed at another time. Whenever in doubt, STOP."

The FOM also contained procedures for the use of flight and voice recorders on page 5 of Section 3.2.1, edition 3, effective 31 October 2002, which stated: "...In the event of an occurrence of a serious nature (accident or major incident), the P-i-C shall ensure that both the flight recorder and the voice recorder are removed and secured for the subsequent investigation...Note that the voice recorder will normally continue to run after parking. To preserve the accident/incident recording, it is necessary to pull the circuit breaker immediately after parking."

The flight crew had a Jeppesen chart on board of Madrid-Barajas Airport (see Figure 8). The chart's level of detail for the ground movement area was far less than that of the Spanish AIP (see Figure 1).

The company had a daily flight to Madrid-Airport. They considered this airport as a Type B airport, i.e. a moderately difficult airport to operate in. Therefore, they required their flight crews to have flown there at least once in the past 12 months. Both the captain and first officer had previously flown to Madrid in March 2006, around four months before the date of the accident.

1.5. Airport information

Madrid-Barajas airport has four runways. Traffic into and out of the southern apron uses taxiways I, M and A. Taxiway I (inner) is the closest to the terminal buildings and A the furthest. To continuously follow every taxiway starting from the parking positions in the areas R-4 and R-5 requires several 90° turns, i.e. the taxiways do not follow a smooth, continuous line.

Taxiway M had both horizontal and vertical signs. Those signs had the appropriate size and color. Toward the end of M-6 there were horizontal signs with arrows to show the direction to M-7 or I-8 (see figure 2). The arrow on the M-7 sign was at 45° and therefore was not in compliance with the rule that requires an arrow at 90° for taxiways that are perpendicular.

There was also a vertical sign with the legend "M-7" to the right of the M-6/M-7 junction (see figures 2 and 3).

There was another vertical sign showing "GATE 1" in the next taxiway junction (see figure 3). The position of GATE 1 can be seen in the AIP chart in figure 1 and in the Jeppesen chart in figure 8.

After the M-7/I-8 horizontal sign, there was no other horizontal sign showing I-8 up to the construction work area. There were signs with arrows showing the direction of "I-7", "M-7" and "GATE 1" advising that turns were needed to enter those taxiways or gate but those were aimed at aircraft taxiing in the opposite direction, and therefore the crew of the B747 could only see those signs backwards as shown in figure 4.

There was construction work being carried out on taxiway I-8 on the day of the accident. This taxiway has a width of 76 m. The drawing of Figure 5 shows the layout of the construction work that had led to the modification of the taxiway centerline, which was displaced 11 m to the right leaving 27 m of available distance from the new centerline to the parking position of the EMB-135.

Therefore, I-8 had the limitation of A-321 as the biggest aircraft that could use the taxiway, because the actual width available on that taxiway was 54 m. ICAO Annex 14, paragraph 3.10.2, requires a taxiway strip width of 52 m for a C code-letter aircraft like the A-321 (the actual span of this aircraft is 34.1 m).

Parking positions 20 to 25 had not been removed from service and aircraft F-GOHC was parked at stand 22. There were no additional provisional signs installed as a result of the construction work.

When asked, the airport did not provide any official reports of other large aircraft that had missed the correct taxiway and inadvertently entered taxiway I-8 in the previous months.

Madrid-Barajas airport did not have a selective taxiway centerline lighting system, in which a centralized airport system switches on the green centerlines of the taxiways to be used to follow a concrete taxi clearance given by the ATC. There were no plans or intentions to install such a system in the future.

1.6. ATC information

Madrid-Barajas Airport has three air traffic control towers. There are four areas of ground movement control (GMC): GMC-West, GMC-East, GMC-Central and GMC-South. Every area is in turn divided into two sectors (North and South) and therefore there are a total of 8 radio frequencies for ground movement control. The different sectors can be seen marked by slotted lines on the AIP ground movement chart (see Figure 1).

The South Control Tower is only used for ground movement control in the southern part of the airport. The area controlled by this tower is in turn divided into two sectors: GMC-S-South (121.7 MHz) and GMC-S-North (121.85 MHz).

There are normally three air traffic controllers in the South Control Tower at any given moment. One ATCO controls the north sector (121.85 MHz), another the south sector (121.70 MHz) and the third controller acts as supervisor. There is normally another technician in the tower to help with flight plans, progress strips, and other non-radio related tasks. The most congested area for ground movements in the South Control Tower sector is located to the left of the control tower, with several taxiway intersections receiving departure and arriving traffic.

Depending on the expected traffic or specific circumstances, at certain times on some days both frequencies of GMC-S are unified to the single frequency 121.85 MHz and both sectors GMC-S-South and GMC-S-North are handled by the same ATCO. This happens in low traffic conditions, and this arrangement saves taxiing aircraft the need to make a frequency change from GMC-S-South to GMC-S-North.

This was the configuration being used the day of the accident. Initially there were four ATCOs assigned to the service. However, the day before one of the controllers was assigned to the north control tower. Therefore, three ATCOs ended up providing service the day of the accident. Each ATCO's work schedule consisted of controlling aircraft for 1 h, then providing assistance in the tower (performing some coordination tasks) for 1 h, and then resting for 1 h.

At the time of the collision, there were two air traffic controllers in the tower and another technician not involved in air traffic control activities. Therefore, the B747 aircraft was instructed by Madrid-Barajas-Clearance to contact 121.85 (the only available frequency) from the beginning, although it was parked in the south part of the sector.

Only one of the two air traffic controllers was actually talking on the radio and looking outside to control the aircraft. The other ATCO was acting in a supporting role. The technician was not looking outside, as that was not his duty. It is a visual control room and the area of the accident is visible from the tower (see figures 1 and 2 to see the tower position in relation to the accident site).

At the time of the accident there were at least 5 aircraft taxiing in the area controlled by the South Control Tower.

After the clearance given to the B747 aircraft to taxi to 36R via Mike, the ATCO proceeded to handle the other aircraft in the area of T29 and T31, i.e. looking to the left side of the tower. When she saw the B747 again she was surprised to find it inside the I-8 construction area and advised it that it was not allowed to taxi there. However, the accident had already happened by that time. As stated above, 4 min and 37 sec had elapsed between the latest communication ("THANK YOU") and the instant the flight crew called ATC again, probably to inform that they had had an accident.

There are certain areas of the apron that cannot be seen from the South Control Tower and they are marked in the AIP Ground Movement Chart (see Figure 1). The area where the accident took place is relatively close to the tower and is not marked as "blind" in the AIP. The surface radar is displayed on screens in the tower. There is no requirement to use the surface radar under normal visual conditions, as happened the on the day of the accident. The ATCO was looking outside to control aircraft as it was a day with perfect visibility.

1.7. Applicable regulations for ground movement control

The "Reglamento de Circulación Aérea" ("Air navigation rules") in effect in Spain at the time of the accident included the following information:

The "Servicio de control de tránsito aéreo" is defined as a service provided to:

"1) avoid collisions:

a) between aircraft, and
b) in the maneuvering area, between aircraft and obstacles;

2) to expedite and allow the orderly flow of air traffic."

The maneuvering area is defined as that part of the aerodrome that is to be used for takeoff, landing and taxiing of aircraft, excluding the aprons.

Section 4.5 "Aerodrome control service" includes the following paragraphs regarding the control functions:

"4.5.4.1. The aerodrome controllers shall keep constant surveillance over all the visible flight operations being carried out in the aerodrome or its surroundings, including aircraft, vehicles and personnel that are in the maneuvering area, and shall control the traffic in accordance with the procedures included herein and with all applicable air traffic regulations. "

"4.5.10. (Control of taxiing aircraft) Control de las aeronaves en rodaje.

4.5.10.1. Durante el rodaje la visión del piloto es limitada. Es necesario por lo tanto, que las dependencias de control de aeródromo cursen instrucciones concisas y suficiente información al piloto para ayudarle a determinar la debida vía de rodaje e impedir colisiones con otras aeronaves u objetos." ("During taxiing, the pilot's field of vision is limited. Therefore, it is necessary for the aerodrome control facilities to provide the pilot with enough information through concise instructions to help

him determine the appropriate taxi path and avoid collisions with other aircraft or objects.")

One paragraph of ADJUNTO 3 of the "Air Navigation Rules", devoted to the surface movement radar "RADAR DE MOVIMIENTO EN LA SUPERFICIE" (SMR), to be used within its limitations in low visibility conditions, at night or when considered necessary, states that "Independientemente de la información recibida del controlador, derivada del uso del SMR, el piloto es responsable del rodaje hasta el límite de autorización especificado por el controlador y de evitar colisiones con otras aeronaves u objetos." ("Regardless of the information received from the controller, derived from the use of the SMR, the pilot is responsible for taxiing up to the clearance limit specified by the controller and for avoiding collisions with other aircraft or objects.")

This radar is not normally used under visual conditions as happened the on the day of the accident.

The AIP Spain of Madrid-Barajas airport stated:

"GROUND MOVEMENT.

A.- Except for rescue and fire fighting vehicles in the performance of their specific missions, all surface movements of aircraft, towed aircraft, personnel and vehicles on the maneuvering area are subject to previous ATC clearance.

B.- Barajas Ground Movement Control (GMC) is responsible for:

a) The control of every aircraft, personnel and vehicle movement within the maneuvering area except for the runway or runways in use.
b) Issuing clearances and instructions for towed push-back and taxiing of aircraft.
c) Reporting the stand positions assigned to the aircraft by Centro de Gestión Aeroportuaria (CGA)...

...C.- Unless another route is advised by GMC, aircraft will follow one of the appropriate STANDARD TAXIING ROUTES shown below."

The taxi instructions were as follows (Note: parking stand 73, where the aircraft was initially parked, belongs to Ramp 5 or R-5 which is located in Terminal 1-2-3 or T123). Note that three steps are necessary to formulate the taxi instructions from R-5 to runway 36R:

To RWY 36R from T123:

The same routes for RWY 36L, up to M-17. From M-18, ..., M-31, NY-13, Y-1 or M-18, ..., M-32, N-13, Y-2 or M-18, ..., M-33, B-13, Y-3.

To RWY 36L from T123:

R7: E-3, F-4, F-3, F-2, Gate 1, M-8, ..., M-17, R-5 or R-6 or R-7, R-8, Z-2. Stands 201, 202, 204, 206, 207, 209, 211, 214 and 218 direct to E-2, F-4, F-3, F-2, Gate 1, M-8, F-2, Gate 1, M-8, ..., M-17, R-5 or R-6 or R-7, R-8, Z-2.

R6 till R3: The same route for RWY 33L up to taxiway M-7, M-8, ..., M-17, R-5 or R-6 or R-7, R-8, Z-2.

...

To RWY 33L from:

R7: E-3, E-4.
Stands 201, 202, 204, 206, 207, 209, 211, 214 and 218 direct to E-2, E-3, E-4.

R6: C-1 or C-3, taxiway M-1 ... M-7, A-7, E-1,..., E-4; or by (stands 86 to 89, both included) I-6, C-5, M-5, M-7, A7, E-1,..., E-4.

R5: C-3 or C-5, taxiway M-3 ... M-7, A-7, E-1,..., E-4; or by (stands 73, 74 and 69) I-6, C-5, M-5, M-7, A-7, E-1,..., E-4.
In R6 and R5, aircraft which are in stands 134 to 162 (both included) and need push-back to leave them, will head SW along taxiway A, taxiing by the first possible intersection to taxiway M.

2. ANALYSIS

2.1. Flight preparation

The flight crew of the B747 stated that during the flight preparation before the departure for Rome, they were not in a hurry. They were adequately rested and there was no pressure to comply with duty time limitations.

They had the appropriate NOTAMS on board, including one that advised that large aircraft were not allowed on taxiway I-8 due to construction. However, a lot of NOTAMS were in effect. It would have been helpful had flight dispatch remarked this important feature to the aircrew at the departure briefing, to call their attention to the restricted area or taxiway. Therefore, a safety recommendation is issued in this regard.

There was only one ATC frequency available for ground movement control in the South part of the airport and the flight crew made the appropriate radio contacts with clearance and ground facilities.

From the information provided in the previous sections, it seems the flight crew was correctly cleared by ATC to taxi to runway 36R "via M". According to the AIP, although it was necessary to read the information in three steps, this implied following I-6, C-5, M-5, M-7, M-8, …M-17, M-18, ..., M-31, NY-13, Y-1 or M-18, ..., M-32, N-13, Y-2 or M-18, ..., M-33, B-13, and Y-3. This set of instructions did not mention M-6. The path to be followed was complex and involved two consecutive 90° turns to follow the M taxiways. It seems these instructions were not adequately reviewed by the crew in preparation for taxiing. In any case, a safety recommendation is issued to AENA to review the arrangement of these instructions to make them easier for flight crews to follow.

2.2. Taxi maneuver

At the beginning there was a slight deviation from the published taxiing instructions since, due to the presence of other aircraft, ATC offered HS-TGY B747 flight crew the option of using C-4 instead of I-6 and C-5, which they accepted.

During the taxi, the following three instants have been identified in which the accident could have been avoided if the appropriate warnings had been issued:

a) When, between M-5 and M-7, the flight crew did not execute a 90° turn at the M-6/M-7 junction and continued straight to I-8.
b) When they entered the construction area, which implied deviating to the right side of the taxiway centerline. Had the flight crew recalled the NOTAM restricting the use of I-8 due to work in progress, the aircraft could have been stopped when the construction barriers were noticed.
c) When they approached the parking position of the Embraer 135. Had the clearance between both aircraft been considered hazardous or in doubt, the aircraft could have been stopped right there in application of the company's operational procedures.

To signal the turn required at point a) above, the following facilities were available:

- The chart the crew had on board (see Figure 8). It has been determined that this chart was not detailed enough to provide an accurate position of the aircraft along the complex network of Madrid-Barajas airport, specifically within several conflicting platform zones, such as those near M-6, M-7 and M-8. The airport charts used by the crew should allow any given restricted or forbidden airport zone to be quickly and easily located so as to avoid it. A safety recommendation is issued to the operator in this regard.
- The horizontal sign painted on the ground (see Figure 2). It has been determined that, although the sign did not exactly comply with the norms of the AENA manual (i.e. the arrow pointing to M-7 was at a 45º angle with the taxiway axis instead of 90º)

it was enough to advise the crew that a turn was needed. At any rate, AENA should ensure that all the signs at Madrid-Barajas airport are in accordance with applicable norms.

- The vertical M-7 sign located to the left side of this taxiway (see Figure 2). This sign complied with the required norms. However, its size makes it difficult to see from a distance.

There was also another vertical sign "GATE 1" that could have warned the crew that the required taxi path was not being followed.

The flight crew did not see the signs and did not adequately follow the published taxi instructions. The absence of the CVR recording prevented an evaluation of the cockpit conditions or the identification of any distraction that could have affected the crew at that time. Although the operator had adequate procedures in place to preserve the flight recorders after an incident, it seems the flight crewmembers were unaware of this fact. Therefore, a safety recommendation is issued in this regard.

To avoid the condition described in bullet b) above, in addition to the use of NOTAMs to advise the flight crews involved, a useful safety measure could have been to provide provisional visual signs to advise of the maximum span allowed in that taxiway (in this case, the Airbus A-321 was the biggest aircraft allowed in I-8). AENA already has standardized signs for this purpose (see Figure 9) and therefore a safety recommendation is issued in this regard.

The displacement of the centerline reduced the clearance safety margins even for aircraft with wingspans shorter than that allowed by the NOTAM. Therefore, another possible safety measure would have been to close the parking positions in the area while construction was in progress. However, parking positions are in high demand at major airports and it is normal to maximize the use of all available positions.

A selective taxiway centerline lighting system would also have reduced the possibility of mistakes when taxiing from any stand to the active runway.

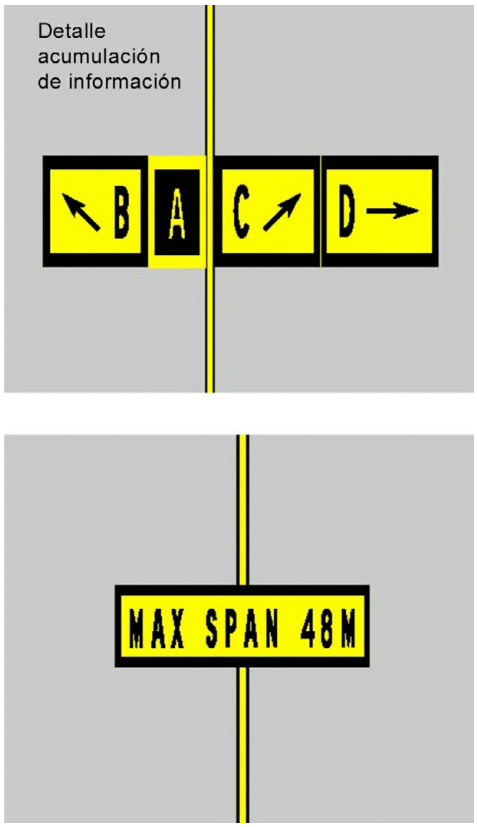

Figure 9. Signs from manual the AENA[2]

[2] Manual Normativo de Señalización en Área de Movimiento Edición, enero 2001, AENA.

To avoid the condition described in bullet c) above, it would be useful for the operator to cover this aspect in its Crew Resource Management training to highlight the need to stop the aircraft whenever there is a doubt about the clearance with obstacles while taxiing on the ground, taking into account that there are limitations regarding the ability of flight crews to monitor wingtip separation from obstacles in large aircraft, particularly in those with swept wing.

2.3. ATC surveillance

When the aircraft was facing situations b) and c) above, there was another protection barrier that could have avoided the accident: if ATC personnel or other airport staff or observers had noticed the unusual situation of a B747 entering I-8 (especially under construction conditions) and had advised the flight crew to stop. By the time the ATCO saw the aircraft after the flight crew called her the accident had already happened.

The aircraft was taxiing the wrong way for approximately 400 m, at a mean speed of 13 kt, i.e. it could have spent around 1 minute in that situation. Unfortunately, at that moment the only ATCO in charge of the south ground movement control was looking at the other side of the airport.

The ATIS report did not include any mention of the restricted area of I-8. The ATCO instructions did not mention this restriction either, as was normal in all ground movement control communications. ATC informed that there are always a large number of special conditions affecting the airport, and it is not feasible to include that information in the radio communications to remind the pilots. This is left to the NOTAMs issued by the airport.

The aircraft was carrying out a "visible flight operation" in the maneuvering area (a taxiway leading to the runway). Therefore, it should have been subject to a "constant surveillance" according to section 4.5.4.1 of the Air Traffic Rules. It is obvious that in practice it is impossible to have a constant visual contact with every aircraft taxiing in a major airport. It would be necessary to have an ATCO for every aircraft in the area. However, the intent of the regulations is to have as much oversight of the operations as possible from the control tower. The unified frequency condition of the GMC at the time of the accident resulted in only one ATCO working the two sectors of the south part of the airport, and therefore the overall surveillance was reduced. This was due to the expected low traffic workload that day, and also had the benefit of avoiding an additional frequency change for the flight crews. In any case, it would be recommendable that the conditions for unifying the frequencies in the south ground movement control be carefully reviewed, and a safety recommendation is issued to AENA to ensure that ground movement control

always has the required resources to provide the highest possible level of surveillance over operations.

3. CONCLUSION

3.1. Findings

- The flight crew was adequately qualified and rested for the flight.
- Aircraft B747 HS-TGY was correctly cleared to taxi to runway 36R.
- The aircraft inadvertently entered taxiway I-8. This taxiway was not included in the standard taxi path to runway 36R published in the AIP. The arrangement of the taxi instructions of the AIP is considered complex.
- Additionally, taxiway I-8 was at the time of the accident authorized for use only by aircraft with a wingspan equal to or lower than that of the A-321 because, due to construction works, a detour to the right of the centerline of this taxiway had reduced the available width of the taxiway.
- The restriction on the use of taxiway I-8 had been published through NOTAM 4125/06, which was on board the aircraft at the time of dispatch. The restriction of the taxiway was not included in the information given by the ATIS.
- The airport chart of the AIP was correct and had enough detail to adequately identify every taxiway.
- The Jeppesen chart provided by the operator to the flight crew lacked enough detail to easily identify the adequate taxiway path.
- The horizontal and vertical signs showing taxiway M-7 were adequate in size, color and location. However, the horizontal sign showing the need to make a right turn to enter M-7 had an arrow at 45° instead of 90° as required by AENA norms.
- The right wing of the B747 stroke the tail of the EMB-135, which was correctly parked, due to insufficient separation between the two aircraft.
- The ground air traffic control of Madrid-Barajas airport did not monitor the progress of the aircraft as it inadvertently entered and progressed through taxiway I-8.
- The aircraft was carrying out a "visible flight operation" in the maneuvering area (a taxiway leading to the runway). Therefore, it should have been subject to "constant surveillance" according to section 4.5.4.1 of the Air Traffic Rules.
- There was only an air traffic controller on the radio controlling the aircraft at that time in the South tower of Madrid Barajas because the radio frequencies of the two South taxi sectors had been unified.
- The B747 flight crew had some doubts of the available clearance as they were approaching the EMB-135. However, from the cockpit of such a large, swept-wing aircraft, it was difficult to judge the exact clearance.
- The flight crew did not adequately follow the instructions in the operator's Flight Operations Manual (FOM), which stated: "the aircraft shall normally not be taxied closer than one-quarter wingspan from any hindrance. Taxi guidelines/markings do not always ensure adequate hindrance clearance and shall be used with caution. Whenever doubt exists, request assistance from ground."

3.2. Cause

It is considered that the accident probably happened because, after the B747 aircraft inadvertently entered taxiway I-8, the flight crew did not adequately assess the lack of clearance of the right wing of their aircraft with the tail of an aircraft that was parked on the right side of that taxiway.

The air traffic control service could not advise the flight crew they had entered taxiway I-8 because the aircraft's progress was not monitored for more than a minute.

4. SAFETY RECOMMENDATIONS

REC 43/07. It is recommended that Thai Airways International modify its flight dispatch procedures to ensure that relevant taxi information is specifically highlighted to flight crews.

REC 44/07. It is recommended that Thai Airways International ensure that the airport ground movement charts provided to its flight crews have adequate detail to facilitate accurate compliance with ATC instructions.

REC 45/07. It is recommended that Thai Airways International use the circumstances of this accident in its flight Crew Resource Management training to further highlight the need to stop the aircraft whenever there is a doubt regarding clearance with obstacles while taxiing on the ground.

REC 46/07. It is recommended that Thai Airways International remind its flight crews of the procedure to be applied after an incident or accident in order to preserve the data recorded on the flight data recorders.

REC 47/07. It is recommended that AENA revise the AIP taxi instructions for Madrid-Barajas Airport in order to provide an independent and separate set of instructions for taxiing from every terminal area to every runway threshold.

REC 48/07. It is recommended that AENA review the horizontal signs at Madrid-Barajas airport to ensure they comply with applicable norms.

REC 49/07. It is recommended that AENA establish procedures to ensure that construction zones within the airport's maneuvering area be provided with suitable provisional markings to clearly show the flight crews the aircraft restrictions affecting the zone.

REC 50/07. It is recommended that AENA assures that the ATIS includes reference to closed or restricted areas regarding aircraft taxiing at Madrid-Barajas Airport.

REC 51/07. It is recommended that AENA establish suitable procedures to unify the ground movement control frequencies in the South part of Madrid-Barajas Airport, to ensure that the highest practical level of surveillance of taxiing aircraft is provided at all times.