THE TYPE OF AIRCRAFT INVOLVED IN THE ACCIDENT

76. The registered designation of the aircraft was ZK-NZP. It was a McDonnell-Douglas DC10–30 wide-bodied jet airliner. It was imported into New Zealand on 14 December 1974. There was issued in respect of the aircraft at all times the necessary Certificate of Airworthiness, and it was maintained at all times in strict accordance with the manufacturer's specifications. Indeed, the maintenance schedules drawn up and adopted by the airline were regarded by the manufacturers as being exemplary. At all times throughout the flight and terminating with its impact with the mountain side, the aircraft was operating perfectly in every respect.

77. There was nothing in the design or capabilities of a DC10-30 which made it in any way inappropriate as the vehicle for these sightseeing flights. In this respect, I had the advantage of hearing evidence from Mr L. S. H. Shaddick, who is an Inspector of Air Accidents within the United Kingdom Accidents Investigation Branch of the Department of Trade. He is a qualified DC10 pilot. He regarded the DC10 as being a highly manoeuvreable wide-bodied jet equipped with one of the most advanced inertial navigation systems yet introduced, and although the aircraft had obvious limitations as a sightseeing aircraft in view of the fact that it was not designed for that purpose, he was of the opinion that the aircraft and its equipment were suitable for antarctic scenic flights. The aircraft was performing with maximum efficiency in all its systems right throughout the flight. Its design made it suitable for flights of this kind.

THE NAVIGATION SYSTEM IN A DC10-30 AIRCRAFT

78. The navigation system in this type of aircraft is a variety of the widely used inertial navigation system. But the DC10 equipment is the most advanced type of INS system in present use. The technical description of the system as installed in DC10-30 aircraft is the Area Inertial Navigation System (AINS). The nature of this system and the manner of its operation was comprehensively described by Mr W. K. Amies at paragraphs 4.1 onwards of his prepared brief of evidence.

79. The word "area" which precedes the words "inertial navigation system" means the ability of the system to navigate over pre-determined tracks within prescribed accuracy tolerances without the need to overfly navigation aids located on the ground and operated by radio transmission. The AINS can therefore navigate the aircraft from one position to another, either automatically or by providing steering signals to the pilot which he can follow when manually flying the aircraft. The system operates by inserting into computer equipment on board the aircraft a series of waypoints based upon pre-determined co-ordinates of latitude and longitude. The first co-ordinates represent the location of the airfield from which the aircraft will depart, and the final co-ordinates are the destination co-ordinates.

80. The knowledge of the aircraft's in-built navigation system as to the aircraft's geographical position in flight is achieved in this manner. The AINS components include either two or three inertial sensor units. In the case of the DC10 there are three such units. Each one operates independently. Each contains three accelerometers fitted to what is called a "platform" and mounted on a gyroscopic unit. As from the moment the aircraft moves from its starting point the three accelerometers record every subsequent movement as related to the three dimensions of space by

reference to the altered position of the aircraft in relation to its geographical starting point. The sensor unit will therefore record the distance travelled over the globe, the direction of travel, the speed of travel, and every direction of travel. As stated previously, each sensor unit operates independently. Each is therefore capable of independently determining the aircraft's position. However, the combined output of navigation information provided by the three sensor units is fed into computer units in the aircraft. These units compute the average of the three sets of navigational data being continuously received from the sensor units, and in this manner the position of the aircraft is calculated every fifth of a second. There is a reason for the installation of more than one sensor unit in the inertial navigation system. First of all, it is possible that a sensor unit may develop a malfunction. Secondly, the microscopic programming of the silicon chip, which is the basis for the whole system, may not be mathematically exact and in practice each of the sensor units will produce data which vary very slightly from each of the others. Hence the function of the computer unit which receives the product from the three sensor units and prints out the average of the three sets of calculations. In addition, if one of the units should develop a malfunction during the flight, the aircraft computer detects the malfunction, eliminates the information being received from that unit, and then notifies the pilot by a light on the instrument panel that one of the units has now been discarded for navigational purposes.

81. There is on the instrument panel a display unit which reveals to the pilot information being collected by the sensor units and monitored by the computer navigation unit. The pilot can produce a number of different displays on the control and display unit (CDU) but at the present moment I do not need to refer to the different types of information which are available to the pilot. The AINS, operating in the manner which I have briefly described, may be locked into the steering controls of the aircraft so that the aircraft can be flown automatically from one waypoint to another. In order to arm this system, the pilot pushes a button marked "nav" on a particular panel, and the aircraft will then navigate itself along the programmed flight path from one waypoint to another. As the aircraft approaches the next waypoint, the pilot can see on his display panel not only the present latitude and longitude of the aircraft, but also the number of miles before the next waypoint is reached. Then, upon arrival at the geographical position of the next waypoint and assuming that the aircraft has been programmed to then fly on a different heading, the aircraft will automatically roll in the appropriate direction and will then intercept and follow the prescribed track to the next waypoint.

82. The pilot can disengage the AINS from the steering system of the aircraft by selecting a mode other than the nav mode. Normally this is done by selecting the HDG SEL (heading select) mode and the pilot then selects a new heading which the aircraft will now follow. The pilot can then select further new headings as occasion requires, and the aircraft will then automatically follow each change of direction. One conventional circumstance in which the pilot will disengage the nav mode and instruct the auto-pilot to fly on a different heading is when he sees by his weather radar, or observes visually, a cloud formation which he desires to avoid. He will then, by using the heading select system, navigate the aircraft around the cloud formation and when he has done so he will then adjust the heading select system so as to produce a course which will once more intercept the programmed nav track. Having thus directed the aircraft

back towards the nav track he then arms the nav mode again. As soon as the aircraft intercepts the nav track it will roll towards and on to the exact course of the nav track and will thereafter maintain that course without deviation.

83. The above procedure, which I have described in simple terms and without alluding to certain refinements which form part of the system, was followed by Captain Collins as his aircraft approached Ross Island. From Cape Hallett southwards, the aircraft had been flown on nav track, this being confirmed by the print-out from the black box. Then, when the display panel told him that the aircraft was about 40 miles from its destination waypoint, he found a large break in the clouds through which the sea ice was plainly visible. Then, as duly recorded by the black box and confirmed by the CVR, Captain Collins disengaged the nav track in order to bring the aircraft down through the large cloud-break in two descending orbits, the object being to descend from 17 000 feet to 3000 feet whilst still maintaining the same approximate distance from McMurdo. By using the heading select mode, the course of the aircraft was directed into the two descending orbits, the different headings being successively set in order to bring about the two complete turns. Then as the aircraft straightened up at the conclusion of the second orbit on its heading select course, taking it approximately due south, Captain Collins again armed the nav mode. The aircraft then continued on until it intercepted the nav track and it then locked on to the nav track and stayed there until the aircraft struck the mountain.

84. The AINS navigates an aircraft, as I have said earlier, with incredible accuracy. When the aircraft is flying over terrain which contains ground stations transmitting navigation radio signals, the pilot can determine his course by reference to these radio transmissions. There are commonly two types of navigational aids available from ground stations. One is a VHF (very high frequency) omnidirectional range station which is known as a VOR station. Basically, the VOR provides 360 different courses which radiate from the station like spokes from the hub of a wheel. These courses, known as radials, are identified by the magnetic bearing of the station. A pilot can determine which radial he is flying on and his instruments will tell him not only what that radial is but whether he is heading to or from the VOR station. In addition, he is able to determine his distance from the VOR by signals received from another aid called the distance measuring equipment (DME) which is usually co-located with the VOR. When operating within the range of VOR/DME stations, the AINS is switched into what is termed the radio-inertial (R-I) mode. By this means the computer system of the aircraft may be corrected by radio signals if the geographical position which it displays is not exactly in accordance with the position revealed by the VOR/DME station. The three inertial sensor systems are not themselves affected by such signals. They continue to operate independently of any influence outside the aircraft, but the computer presentation of the average results of the three systems can itself be adjusted. In these circumstances, it is not possible for the AINS to display an incorrect position of any consequence.

85. In the case of the antarctic flights, DC10 aircraft would only be within range for a very short time of VOR/DME stations located in New Zealand. Consequently, the AINS system was in practice switched into the "I" (inertial) mode. When operating in this mode, the AINS will still navigate the aircraft with extreme accuracy. The accuracy of the system in the "I" mode is guaranteed by the manufacturers to be 95 percent. Where

there are three inertial sensor units operating, as in the case of a DC10 aircraft, the maximum possible lateral error will be 1.153 nautical miles for each hour of flight. But it is found in practice that variations, even of this slight degree, do not occur, and in the case of the fatal flight the aircraft struck the mountain at a point only 1.2 miles to the east of the programmed nav track even though there had been no VOR/DME update or corrections during the 5 -hour flight from Auckland. All this, of course, is of vital significance when it is recalled that Captain Collins relied upon the nav track to guide the aircraft on a course which he believed was taking him down the approximate centre of McMurdo Sound which is approximately 40 miles wide except at the point between Cape Royds and Cape Bernacchi when the distance narrows for a mile or two to 32 miles before again widening to 40 miles. Evidence given by operational pilots before the Commission established that on long flights from Auckland to Honolulu or from Singapore to Auckland the AINS system always brings the aircraft to its destination at a point which does not vary by more than a mile left or right of the nav track.

86. Despite suggestions to the contrary which I shall deal with in due course, there can be no valid reason, having regard to the long experience of Captain Collins in flying DC10 aircraft, for him to have been in any doubt about the accuracy of the flight path dictated by the AINS as the aircraft approached the entrance to McMurdo Sound. Past experience had demonstrated that any ultimate positional error on the part of the AINS could not be more than about a mile east or west, and such a deviation was irrelevant having regard to the flat plateau, 40 miles in width, down which the aircraft would fly towards its destination waypoint.

87. I have just referred to suggestions which were made in the course of the evidence that Captain Collins was not justified in relying upon the accuracy of the AINS as he approached McMurdo Sound when the Sound itself, and Ross Island, was entirely enveloped in cloud. In this respect, those who criticised the reliance by Captain Collins upon the AINS not only referred to the AINS not being authorised as a descent procedure for landing, but also concentrated upon the fact that the manufacturer's specifications for the equipment only provided for a system accuracy of 95 percent.

88. The accuracy of the system depends upon how many of the inertial sensor platforms are installed. Aircraft using this navigation system may be equipped with a single inertial platform or a dual platform or a triple platform. The DC10 is equipped with a triple inertial platform and the provision of a triple inertial system considerably narrows down the range of error. With a single inertial system there is a possible error of 2 nautical miles per hour, with a dual system 1.414 nautical miles per hour, and with the triple system 1.153 nautical miles per hour. These figures apply when the AINS is set in the "I" mode meaning thereby, as explained previously, that the navigation computer unit will not receive radio updates from VOR/DME stations. It was therefore suggested in evidence that after the DC10 on the fatal flight had arrived at McMurdo, it would have been flying for 5 hours and would have accumulated a potential for error of five times 1.153 nautical miles, which might be rounded off at 6 miles.

89. As Mr Amies said in his Brief of Evidence (para. 5.11) it is common for Air New Zealand DC10 aircraft flying the Los Angeles/Tahiti route, to be in the "I" mode for periods up to 7 hours but that experience shows

that it has been found normal for the system to be operating "well within the specified tolerance when operating under those conditions". This was also the experience of the pilots who gave evidence before the Commission. It will be remembered that Captain Spence reported, following the initial flight to Antarctica, that there had been a discrepancy on the return flight of only 3 nautical miles after a flight of over 3000 nautical miles "without a radio update into the AINS".

90. The Director of Civil Aviation felt himself entitled to postulate a theory that after a flight of over 10 hours' duration, pilots would have to allow for tolerance of plus or minus 20 nautical miles of cross-track error, and plus or minus 20 nautical miles of directional track error. This calculation proceeded upon the basis that there was only one inertial sensor platform in operation. When it was pointed out to the Director by Mr Baragwanath in cross-examination that the DC10 contained a triple system, the Director was thereupon constrained to agree that the maximum possible cross-track error, after a total flight of 10 hours, could only be 12 miles and that upon arriving at McMurdo from Auckland, involving a flight of 5 hours, the maximum positional error with the navigation system flying in the "I" mode could only be 6 miles.

91. I only mention this incident as demonstrating the earnest desire of the Director to rebut the suggestion that a DC10 pilot is entitled to rely upon the AINS producing a result, even in the "I" mode, which almost exactly coincides with the geographical position of the aircraft upon arrival at its destination. As I have said, it was distinctly proved that this has been the experience of Air New Zealand pilots flying on long sectors, and I have referred already to the evidence of Mr Amies in relation to the Los Angeles/Tahiti route where the "R-I" mode is not available for many hours.

92. During my visit to the United Kingdom with Mr Baragwanath I arranged to obtain, through the co-operation of Mr Shaddick of the United Kingdom Air Accidents Branch, a quantity of printed information as to extensive tests which have been made for some years involving the evaluation of inertial navigation systems. I need not go at this stage into the complex data which was recorded in respect of the North Atlantic Region and the difference between aircraft with triplicated inertial systems and those with dual systems, nor with the difference in accuracy which was ascertained depending whether a flight was east-bound or west-bound. As a matter of interest, radial error rates averaged 2.1 nautcial miles per hour on east-bound flights as compared with 1.15 nautical miles per hour on west-bound flights, even though west-bound flights were about one hour longer in duration.

93. The result of these assessments and of others which I obtained were summarised on my behalf in a memorandum prepared by the United Kingdom National Air Traffic Services. They calculated that the maximum possible radial error on the fatal antarctic flight of 28 November 1979, taking into account navigation in the "I" mode, could not exceed 4 nautical miles. Here is the final paragraph of the text of this memorandum, which is dated 6 November 1980:

> "If INS navigation played any part at all in the causes of the accident I should have expected its un-updated radial error to have been of the order suggested above (i.e. in the range of 0 to 6 or 7 nautical miles for a single INS, in the range of 0 to 5 nautical miles for a dual installation where the outputs are averaged, or in the range of 0 to 4 nautical miles for a triple installation where the outputs are averaged)."

94. In addition to summaries of the accuracy of the INS method of navigation on trans-Atlantic routes, I was also supplied with printed details of a special test run by the European Organisation for the Safety of Air Navigation which took place in March 1980. The navigational results of this special flight were distributed on 27 June 1980. The flight was made with a DC10 aircraft which left Paris on 3 March 1980 and flew to Abidjan, which is on the Ivory Coast of West Africa. The outbound flight included a landing part of the way to Abidjan. The inbound flight took place on 4 March 1980 and was made direct from Abidjan to Paris over a route involving 3000 miles. For the major part of each journey the AINS was in the "I" mode through lack of VOR/DME radio aids, and this was one of the reasons for the selection of this particular north-south route as a test of the AINS system.

95. On arrival at Abidjan the average of the differences of the three inertial sensor systems after 9 hours 25 minutes comprised 4.2 minutes of longitude and 3 minutes of latitude. On the inward flight, which was direct from Abidjan to Paris, the differences between the three platforms averaged 1.5 minutes of longitude and 2.3 minutes of latitude which, in that part of Europe and the Continent, represent approximately 1 mile and 2 miles respectively. This may usefully be compared with the flight of TE 901 from Auckland to McMurdo, involving the same distance of 3000 miles, when the NCU cross-track error was 1.2 miles and when the distance error was 3.1 miles.

96. I only refer to the Paris-Abidjan-Paris test flights as they were on a north-south axis over a 3000 mile route and confirmed, in the final result, the evidence of airline pilots in their evidence before me as to the minimal degree of radial error which their experience has led them to expect when operating flights over long sectors.

97. Captain Collins had a total flying time of 11 151 hours, including 2872 hours on DC10 aircraft. First Officer Cassin had a total flying time of 7934 hours, including 1361 hours on DC10 aircraft. Their navigation experience with the AINS, considered both separately and jointly, would have led them to check any cross-track error at Buckle Island, an exact target in the centre of the Balleny Islands waypoint, and then at the Cape Hallett waypoint, and that same experience would have led them to rely upon the aircraft developing not more than a 2 nautical mile cross-track deviation upon arrival at McMurdo. Such a deviation would be immaterial having regard to the approximate 40 mile width of McMurdo Sound. As already indicated, the actual cross-track deviation on impact was only 1.2 nautical miles. Each of the pilots was therefore, in my opinion, entirely justified in placing this degree of reliance upon the nav track as they approached the McMurdo area.

COCKPIT VOICE RECORDER SYSTEM

98. The aircraft was equipped with a recording system whereby whatever was said on the flight deck was recorded by a sensitive microphone situated in the roof of the flight deck. Its location is at a point between and fractionally behind the seats of the pilot and co-pilot. Since the flight engineer will be sitting at the instrument panel located in the centre of the flight deck just behind the two pilots, the microphone will pick up fairly clearly whatever is said by any one of the three men. In