the inability of those who have experienced it to estimate distance under these conditions, and to be aware of terrain changes, and the separation of sky and earth." I must express my gratitude to the intelligence and initiative of this Royal Australian Air Force flight crew who knew that the conditions were substantially identical with those obtaining on the day of the fatal flight, and who saw the opportunity to demonstrate this optical phenomenon which is difficult to understand unless it has actually been seen. Here are their names and ranks:

Captain—Flight Lieutenant J. R. Howie
Co-pilot—Flight Lieutenant J. G. Thyer
Navigator—Flying Offieer C. J. McHugh
Flight Engineer—Sergeant J. P. Vellacott
Loadmaster—Flight Sergeant G. I. Pollard

They are members of No. 36 Squadron, Royal Australian Air Force.

AREAS OF PILOT ERROR SUGGESTED BY THE AIRLINE OR BY CIVIL AVIATION DIVISION

289. I now propose to set out the different aspects in which it was alleged that the pilots of TE 901 were at fault, and shall indicate my view in respect of each such allegation.

(a) It was suggested that the crew should have plotted in flight on a topographical map the co-ordinates for each position as they went along. But the captain in this case had plotted the flight path on a map before he left New Zealand, and I can see no justification for taking any further steps with regard to a map. The maps supplied by the company for the flight did not have any track marked upon it, and if Captain Collins had not plotted the track on his own maps and atlas the night before leaving, he would no doubt have checked his flight plan and no doubt plotted the co-ordinates during flight on the map supplied to him by the company. But for obvious reasons he did not need to do that. It was also suggested that the flight crew could have waited for each waypoint to be reached, and then verify the co-ordinates as appearing on the print-out in the aircraft instruments, and thus plot the track in flight, but I discount that suggestion for the same reason as already indicated. The crew had no need to plot their track on a topographical map or maps, because it had been done already.

(b) It was suggested that the crew could have checked their position at different times by looking at the print-our of latitude and longitude which is continuously available on an instrument panel. I quite agree that this would be a simple method of determining where the aircraft was at some particular moment. Even though there was no plotting table or other place for a navigator on the aircraft, the co-pilot or engineer could work out the last latitude and longitude displayed and then plot that on a map so as to give the aircraft's position, although by that time the aircraft would be many miles ahead of that position. Indeed, it seems a simple thing to do, and I have no doubt that it could be done so as to fix the position of the aircraft within a few miles by this method of marking the printed co-ordinates on a map. But the question arises as to why such a course would be adopted in the case of this particular flight, or in any

scheduled flight. This print-out is situated in the roof of the flight deck at about eye level. It contains the geographical position of the aircraft as ascertained by one of the inertial sensor units. Its purpose is to enable the crew to call up on the computer display unit the geographical position of the aircraft as fixed by the computer, and then to compare that figure with the continuous readout provided by one of the sensor units. Thus the correct functioning of the computer may be checked, and this is part of the comprehensive system of monitoring the functions of the AINS as a whole. The provision of a continuous display of latitude and longitude is not for the purpose of assisting the crew to keep plotting on maps their position. Their position is ascertained by the simple process of looking at the distance to run, and then pinpointing on their track and distanee guide where that distance is in relation to the next waypoint. I have already found that at all material times the crew were certain as to their position. If eertain as to their position, then no member of the flight crew would adopt this suggested course. To do so would be in effect to disregard the unerring accuracy of the AINS as demonstrated to these pilots for thousands of hours spent in flying DC10 aircraft, and to go back to the days of navigators.

(c) At pages 23 onwards on the brief of evidence of Mr Amies, he describes four different checks which were available to flight crews on the antarctic flights prior to the fatal flight, in respect of which there were the "incorrect" co-ordinates for McMurdo printed on the computerised flight plan. The purpose of setting out these four instrumental checks which might have been made by pilots was to answer the chief inspector's criticism that this mistake in the McMurdo co-ordinates should have gone unobserved for a period of 14 months. Mr Amies makes it clear, at paragraph 8.9 of his brief, that his detailed description of the four in-flight checks of the progress of the aircraft in relation to its flight plan, each made possible by calling up various print-outs on the CDU screens, are nor applicable to the fatal flight because in the case of that flight the co-ordinates for McMurdo had been corrected. Consequently, there is no point in my discussing the four different tests which could have been applied by previous flight crews in the manner suggested by Mr Amies. I would only say that in the case of the fatal flight the crew would without question, for this was agreed by Mr Davison, have performed the first two tests. The third and fourth tests however, depended upon the existence of a non-directional beacon at McMurdo, and this beacon had been withdrawn. However, as inferentially conceded by Mr Amies, the performance of the first two of his rests by the crew of the fatal flight would have revealed nothing, because of course, the aircraft was in fact flying in accordance with the computerised flight plan which had been handed to the crew on the morning of departure.

However, despite the fact that the four tests propounded by Mr Amies were nor applicable to the fatal flight, I have given careful attention to other checks which might have been made by Captain Collins and his crew in respect of the accuracy of the nav track as it approached and passed Cape Hallett. If it was shown that rhe crew had been able to verify the accuracy of the AINS up to and including Cape Hallett, then of course it follows that they could rightly expect that upon arrival at McMurdo there could not be a cross-track error

of anything more than 1 to 2 miles. I will now set out the nature of the consideration which I have given to this point, and the conclusions at which I have arrived.

Seeing that the AINS was set, in the case of this flight, in the "I" mode, meaning that the Navigation Computer Unit (NCU) could not receive a radio correction from a ground-based navigational station, it followed that the crew, if they visually detected a cross-track deviation from the nav track, could manually adjust the navigation computer unit so as to correct the cross-track error and relocate their position. This may only be done, however, where there is a topographical feature to be overflown by the aircraft while flying on nav track.

Since the cruising altitude of this type of aircraft will be in excess of 30 000 feet, it is not always possible to detect a cross-track error with any degree of exactness if the landmark to be overflown is not especially distinct as a landmark. Considerable emphasis was laid upon this factor by witnesses who gave evidence for the airline and for the Civil Aviation Division. An example to which they drew attention was Cape Hallett. The Cape Hallett waypoint was plotted as being the geographical location of what used to be Hallett Station which, up until some years ago, was a manned Antarctica base. The base has, however, been unoccupied for some considerable time. The waypoint immediately before Cape Hallett is the Balleny Islands and as the aircraft tracked from the Balleny Islands to the Cape Hallett waypoint it would first have to cross a considerable stretch of land known as the Pennell Coast before overflying Cape Hallett, and then turn slightly to the west to fly on nav track down to the McMurdo area. In such circumstances it might not be possible to cafculate by visual reference any cross-track deviation less than 4 or 5 miles either way.

At the time when this type of evidence was being given the knowledge I had of the read-out from the black box—which would indicate whether or not the aircraft was on nav track at each waypoint—was only available for the last 30 minutes of the fatal flight. I therefore asked for information as to what had been revealed by the black box print-out in relation to Cape Hallett. The answer was that the aircraft had been flying on nav track as it approached Cape Hallett but that the pilot had switched the navigation system into heading select for a short period and had flown slightly away from nav track for the purpose, so it was thought, of providing passengers with a better opportunity of taking photographs. Then, as soon as Cape Hallett had been overflown, the nav mode had been re-armed and the aircraft had continued on nav track right on down to the point where Captain Collins had again switched to heading select in order to commence his two orbits.

The black box had also confirmed that Captain Collins had not "manually up-dated" the NCU at any time. This tended to confirm that he had identified the aircraft as flying on nav track as it approached Cape Hallett although, as the witnesses had said, it might not have been possible for him to have identified a cross-track error of more than 4 or 5 miles either way. But there were further features about the nav track which were significant. First of all, there was the Balleny Islands waypoint. As the aircraft approached the Balleny Islands the crew would see in front of them that these islands

were aligned more or less at right angles to the approach to the aircraft. The three main islands of the Balleny group, reading from left to right as viewed from the flight deck, would be Sturge Island, Buckle Island and Young Island. These islands are exactly in line. The distance from Sturge Island across to Young Island is 75 miles. Buckle Island lies between Sturge Island and Young Island at a point a little to the right of centre. Sturge Island is approximately 20 miles in length, Buckle Island about 7 miles and Young Island about 20 miles. It happened that the waypoint for the Balleny Islands was Buckle Island, being the centre one of the three. Therefore as the aircraft approached the Balleny Islands, it would be a simple matter for the crew to make a visual fix of the line of the nav track for, in the absence of a cross-track error, the aircraft would be flying directly at the centre island of the three and Buckle Island would obviously be an unmistakeable landmark. But as we know, the NCU was not manually up-dated at any stage. Consequently the inescapable inference is that the aircraft was flying on nav track as it reached the Balleny Islands waypoint.

Then the auto-pilot would alter course to the east, from a heading of 349.5° grid to 322.4° grid, and after covering 367 miles would overfly Cape Hallett. The crew would therefore be entitled to expect that after 367 miles any possible cross-track drift at the Cape Hallett waypoint would be non-existent or minimal, having regard to the absence of any significant cross-track drift at Buckle Island. When the aircraft crossed the Cape Hallett waypoint the crew no doubt could see that the track was directly over that waypoint, and this is what they would have expected in view of the fact which I have just mentioned. They would not expect any significant cross-track drift. Then after operating in heading select for the brief period disclosed by the black box, the nav mode was re-armed and the aircraft flew on towards the McMurdo area. As previously indicated, the crew would not then expect any significant cross-track error at their destination waypoint.

But I have given careful consideration to the position of Coulman Island which is located about 60 miles to the approximate south of Cape Hallett. If reference is now made to fig. 3, page 14, which shows the false track relied upon by Captain Collins as opposed to the real track, it will be seen that the false track passes directly over the centre of Coulman Island which is about 27 miles long, and which at its widest point, is about 7 to 8 miles across. Seeing that the aircraft was flying on an actual track which took it just over the eastern edge of Coulman Island, then it might be expected that the air crew would have observed that the track previously plotted by Captain Collins was different from the actual track of the aircraft. The difference at that point might have been as much as 4 to 5 miles. In addition, there seems to be clear evidence from the passengers' photographs taken in this general area, that there was no cloud. But the explanation for the obvious failure of the crew to observe the deviation from the plotted track at Coulman Island is to be found, I think, in the point that the crew did not have at their disposal any map of the large scale depicted by fig. 3, page 14. They had, first of all, the topographical map supplied to them at flight despatch on the morning of the flight, but all the probabilities are that no track was plotted on this map because of the fact that Captain Collins had the

night before already plotted the track of the aircraft, on his own maps, through all waypoints including the final leg to McMurdo. He would have used, in respect of the complete track from Cape Hallett to McMurdo, one or other of the very large maps which he had, and although I have never seen those maps, it is possible that they were of such a scale that Coulman Island would have been more or less obliterated by a line drawn through it from Cape Hallett to McMurdo.

Then there is page 184 of the atlas taken with him by Captain Collins on the flight. Here, Coulman Island is shown as something more than a dot, but unfortunately, the 27 mile length of the island runs approximately along the nav track which would have been plotted by Captain Collins, and having made the experiment myself on page 184, the track plotted on the atlas would only have shown it passing over Coulman Island at some undefined point, and the fact that the plotted track was 4 to 5 miles to the right of where the aircraft was actually flying would certainly not be apparent on this map, which is at a scale of 1:10 million. Finally there is the map of the McMurdo region shown on page 185 of the atlas, but this map of course does not commence until just north of Beaufort Island and Coulman Island is not shown.

I therefore consider that despite the most careful plotting by Captain Collins on either of his two large maps and on page 184 of his atlas, there was no means of ascertaining by checking the path of the aircraft over Coulman Island that there was in fact a 4 to 5 miles deviation off the track which Captain Collins had drawn. Then there is the point that the real track of the aircraft was directly over Franklin Island which is situated 57 miles to the approximate north of Beaufort Island. If therefore Franklin Island had been visible to the air crew they would clearly have seen that the aircraft was flying directly over Franklin Island, whereas a reference to the plotted track drawn by Captain Collins would have shown that his nav track ought to have been taking him about 15 miles to the west of Franklin Island. This point was given careful consideration by Mr R. B. Thomson, but he discovered that there were no passengers' photographs of Franklin Island, and he deduced from this that at this point Franklin Island was covered by cloud. This indeed accords with the general picture of the weather in the area at that particular time. The cloud cover was extensive from a point some distance to the north of Franklin Island and remained extensive until some distance south when it began to disintegrate, and then there occurred the thin widely dispersed layers of cloud which created the large cloud breaks which Captain Collins saw as he approached Beaufort Island.

It was not suggested to me at the hearing that the flight crew should have detected the divergence between any track which they may have plotted and the real track of the aircraft by reference either to Coulman Island or to Franklin Island, but I thought it right to make it clear that I have myself investigated these two possibilities.

So, in the final result, the evidence appears to establish that the aircraft was on nav track as it crossed the Balleny Islands, and that it was on nav track as it flew over Cape Hallett, with the result that the crew, as I have said before, with only 337 miles to run, could therefore not have anticipated any significant cross-track drift as

they flew down McMurdo Sound towards the Dailey Islands waypoint. In addition, it was not possible to detect any divergence between the plotted track and the actual track of the aircraft by reference to Coulman Island, Franklin Island or Beaufort Island, for the reasons which I have already discussed.

(d) It was contended that the crew should not have relied upon the AINS because of the tolerance of error which the system contains. The Director of Civil Aviation, for example, propounded a theory which would give the system a possible error of about 15 miles left or right, as it arrived in the McMurdo area. All such considerations, though possible in theory, are without practical foundation. I have indicated the extreme accuracy of the AINS system. Captain Collins and First Officer Cassin had flown between them some thousands of hours, and had seen the system proved to be of extreme accuracy over all that time. The crew in my opinion was perfectly entitled to rely upon the AINS to take them, on the approach to McMurdo Sound, within a mile or two either side of a line representing the nav track.

(e) It was submitted that the crew should not have relied on the AINS for any let-down procedure. In this respect reliance was placed upon that part of the operation manual for the airline which does not permit a descent for landing purposes to be made in reliance on the AINS. I should have thought that this was a superfluous indication to pilots flying into airports. The pilot in such a case flies towards the runway in reliance upon the ground aids situated at the airport, and there could surely be no question of him using the AINS in order to bring himself into a landing position in any designated airport. In the present case therefore, it was sought to assimilate this process to a let-down to an altitude which would permit the aircraft to overfly Scott Base at about 1500 feet. There is no similarity at all in the two procedures. All that was done in this case was for the crew to rely upon the AINS to take the aircraft to the 40-mile wide opening of McMurdo Sound, and then to descend under radar surveillance and in VMC, and then level out at 1500 feet in clear air. I can see not the slightest objection to using the refined accuracy of the AINS for this simple manoeuvre. It is not a question of having to fix an exact point such as a landing field. The target being aimed at, as I say, was 40 miles wide. I observe that Major Gumble (pilot of the C-141 Starlifter) says in his sworn deposition taken in the United States that he was navigating his Starlifter on the INS system as he approached Byrd Reporting Point, but that he was at the same time also utilising the radar terrain mapping system of his aircraft. He says that he would not rely upon the INS alone because it only had a dual system. I notice, however, that when Major Gumble was interviewed on the morning after the disaster, he in fact said, as appears at paragraph 1.7.2 of the chief inspector's report:

> "At the time we were navigating entirely by the INS (inertial navigation system). We maintained 16 000 feet until McMurdo picked us up on radar; as I remember, this was at about 38 miles."

As in the case of anyone who has spent all his working life in the courtroom, I am very inclined to attach more weight to what a witness says at the time of the event, rather than what he says a long time afterwards in consequence of a legal appraisal of his position or

the position of his employers. By the time Major Gumble signed his deposition in California it was, of course, very much in the interest of the United States Navy to attribute negligence to Captain Collins.

(f) It was suggested by Captain Wilson, who had been in charge of the RCU briefing, that there was a possibility that the crew knew their exact course, that is to say, they knew that the aircraft was programmed to fly on a collision course with Mt. Erebus. Captain Wilson supported this suggestion by pointing out that if Captain Collins thought he was in the centre of McMurdo Sound when he decided to fly away, then this decision would not have carried any urgency in view of the wide area of flat ground which would have surrounded the aircraft at that time. (T 1256). I said to Captain Wilson after he made this observation that I agreed with him that the decision to fly away was ultra cautious if indeed Captain Collins had believed he was in McMurdo Sound. (T 1278—9) Captain Wilson agreed with this opinion. However, I will go no further into this allegation that Captain Collins may have known the true nav track. It seemed to me to be a very remarkable thing for an experienced officer such as Captain Wilson to make the suggestion that the air crew flew deliberately at 1500 feet on a known collision course with the mountain. I need say no more about it.

(g) It was stated by the Director of Civil Aviation that in his opinion the whiteout phenomenon did not exist in this case, or if it did exist, then it played no part in the accident. This of course required him to give some explanation as to why both pilots made coincidentally the same type of gross visual error. He suggested that each may have become afflicted by some mental or psychological defect which controlled their actions. This involved the startling proposition that a combination of physical and psychological malfunctions occurred simultaneously to each pilot. I was surprised to find that a person with the status of the director should advance a suggestion which is so palpably absurd.

(h) Then it was suggested that the pilot should not have let down from 17 000 feet to 3000 feet, in an area in which there was known high terrain in the vicinity, without some visual fix. Again, this suggestion was founded upon the false proposition that the air crew were "uncertain" as to their position. If the pilots knew exactly where they were, and saw before them, as they did see, many square miles of flat sea ice visible through very large cloud breaks, then I can see not the slightest objection to circling the aircraft down one and then two descending orbits, operating all the time in clear air, so as to level out, still in clear air, in a position where they still saw on all sides many miles of flat sea ice over an area of 30 or 40 square miles which they had swept visually as they descended. That decision could not possibly have been wrong, bearing in mind the unimpaired visibility which they had. There could be no question of there being any obligation to get some visual fix prior to let-down, when they were letting down in clear air, and with this wide panorama of flat sea ice perfectly visible below them, and when indeed they were not going forward but were orbiting downwards so as to lose height from 17 000 feet to 3000 feet without progressing forward at all.

So this particular theory of pilot error, in my opinion, is also without foundation. I think it harks back to the system operated in the days before the AINS was used. It predicates the presence of a

navigator who would be seated in his plotting table, and working out as best he could the approximate present position of the aircraft. That would depend upon how right the navigator had been in his prior calculations, and what chance he had had to check succeeding positions by reference to visual landmarks and either the sun or the stars and to what extent his dead reckoning calculations had been affected by wind currents. All this has no application whatever to current navigation of jet aircraft by these unerring and sophisticated aids. The inertial sensor units cannot be wrong. The location of the aircraft is exactly where they say it is, when the aircraft is flying on nav track. On heading select, or on manual control, a visual fix or a ground-based aid is required, if the aircraft is not flying VMC. But Captain Collins was flying in VMC throughout, as even Captain Gemmell eventually accepted, and this meant 20-kilometre visibility. But as it happened, he did make a "visual fix".

The "visual fix" was obtained, in the concerted belief of all members of the flight crew, not long after the aircraft levelled out at 3000 feet, locked back on its nav track, and began to descend. Clearly visible ahead were the two black shorelines of Cape Tennyson and Cape Bird, mistaken by the pilots for Cape Bird and Cape Bernacchi. The plotted flight path on the map showed the nav track to be passing about midway between the two latter landmarks, and the crew could see that the actual path of the aircraft was similarly directed about midway between the two capes which they could see ahead. In addition to this, there was the "distance to run" figure on the HSI indicator on the instrument panel. In fact, this displayed the distance to run to the TACAN waypoint, whereas the crew believed, in terms of the information supplied at their briefing, that it referred to the distance to run to the "false" waypoint just to the west of the Dailey Islands. The figure displayed at about 5 miles from the axis of the visible shorelines of Lewis Bay would be 35 miles (there being a forward error in this respect of 3.1 miles) and by referring to the plotted track on their map or maps, the crew would see a DME of 35 miles at about 13 miles from the Cape Bird—Cape Bernacchi axis.

So when approaching Lewis Bay, the crew saw the identical land features, to the left and right, which they were expecting to see in McMurdo Sound once they descended below the overcast. And the distance out from the "false" waypoint would be sufficiently similar when visually checking the plotted track at a speed of 5 miles per minute. Thus the "visual fix" was complete.

(i) The next allegation was that the flight crew made a serious and inexplicable error in not identifying Beaufort Island during the course of the two orbits. It was alleged that the position of Beaufort Island would have indicated to the flight crew that they were on the eastern side of the island, whereas if the aircraft was flying on the course assumed by Captain Collins, then it should have been to the east of the orbiting sequence performed by the aircraft.

This submission is answered by reference to fig. 13, page 116, and fig. 14, page 117. These two diagrams show the orbiting sequence in McMurdo Sound where Captain Collins thought it was being performed, and the orbiting sequence just north of Lewis Bay where in fact it was being performed. If one looks at fig. 13, page 116, which represents the orbiting sequence in McMurdo Sound, it will be seen

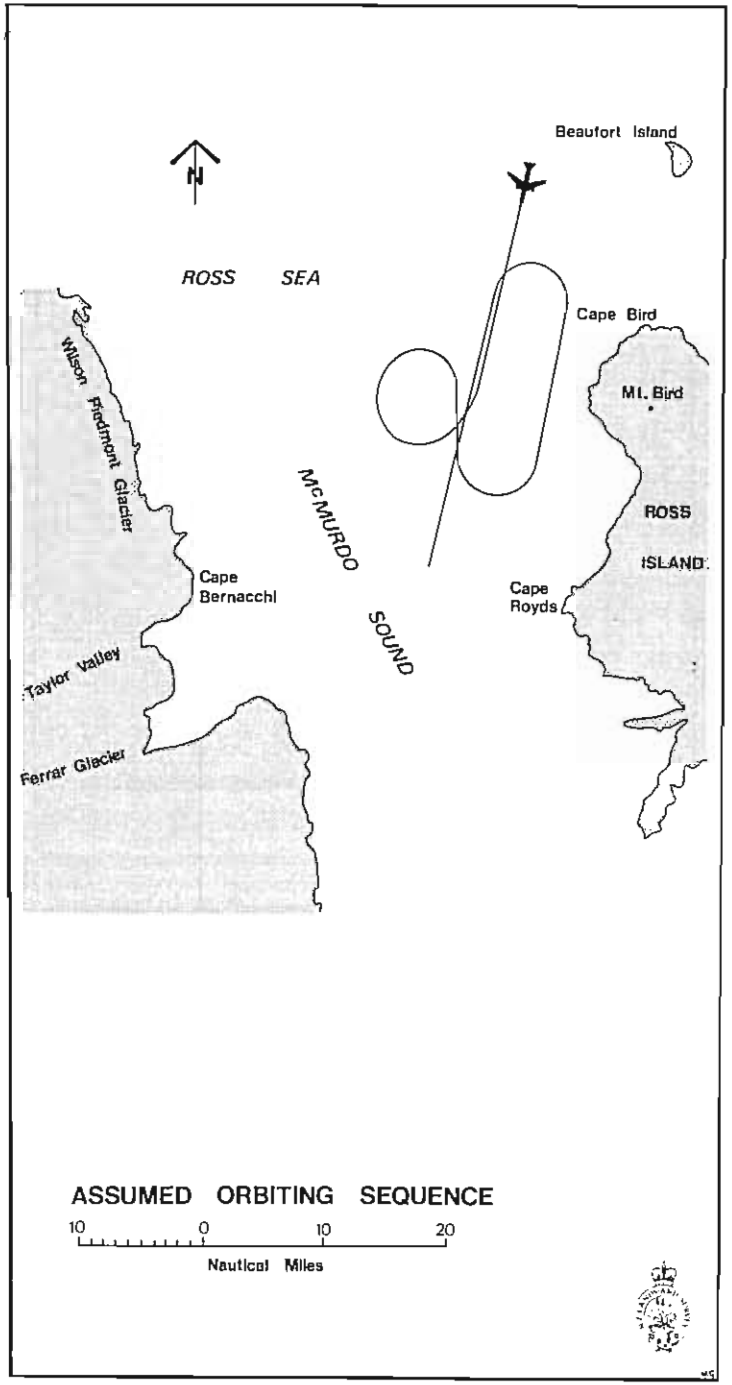

FIGURE 13

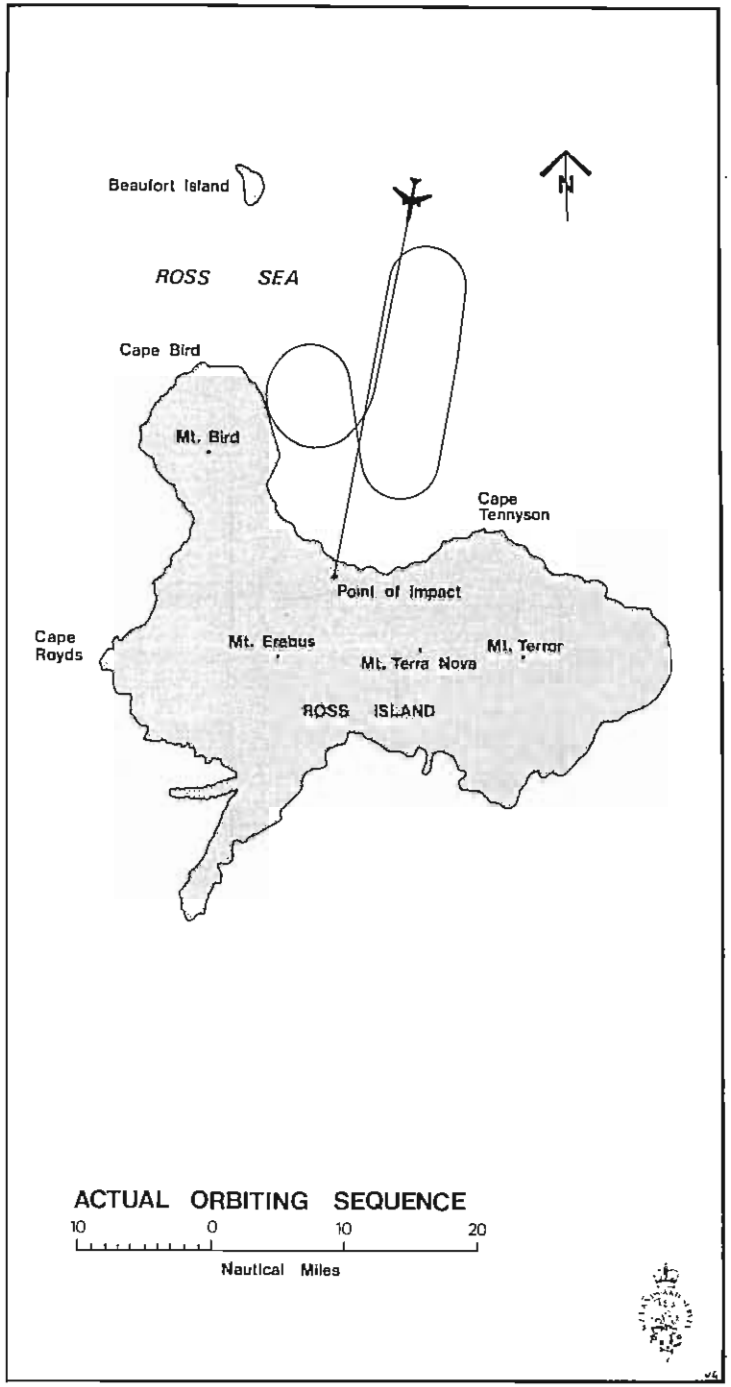

FIGURE 14

straight away that Beaufort Island is located well to the east of the position of the aircraft. For example, at the most northern point of the first right hand orbit, Beaufort Island would be situated 27 miles to the north-east. Halfway along the northern track of the second orbit Beaufort Island would be situated 20 miles to the north-east, and even at the most northern point of the second orbit, Beaufort Island is still 13 miles away to the north-east. It therefore follows that because Captain Collins believed that his nav track was taking him down the centre of McMurdo Sound, no one on the flight deck would ever identify any island on or near their path as being Beaufort Island. They would all be aware that it was far away to the north-east, and I venture to say, that although no direct reference is made to the point in the CVR transcript apart from Mr Mulgrew's remark about "land ahead", the five persons on the flight deck undoubtedly saw Beaufort Island, and mistook it for a different island altogether, probably, as Mr Shannon thought, Dunlop Island, which is off the Victoria Land coastline. Anyhow, in the minds of the crew the island which they must have seen could not possibly have been Beaufort Island, because as previously indicated, the latter landmark would be many miles away in quite a different location.

This suggestion of error on the part of the flight crew in not identifying Beaufort Island will therefore be seen to be the result of an apparent confusion of mind on the part of its proponents.

(j) The next allegation was that having levelled out at 3000 feet Captain Collins should not have elected to fly on towards what was described as an area of poor or deteriorating visibility. This is the aspect referred to by the chief inspector in his report, as being the "probable cause" of the accident. The substance of the chief inspector's allegations in this respect is that Captain Collins should have decided to climb away about 2 minutes before he did. But again this depends upon the essential pre-condition that the crew was "uncertain" of its position, and this latter postulate is of course quite wrong. Also, it involves the equally wrong proposition that the aircraft was flying towards an area of poor or deteriorating visibility. On the contrary, as I have indicated already, the crew saw in front of the aircraft a long flat vista of snow-covered ground extending for very many miles. There was no suggestion at all in the passengers' photographs or anywhere else, that there was poor visibility ahead. Prints of those passengers' photographs taken to left and right of the aircraft only seconds before impact, showing the shorelines of Cape Tennyson and Cape Bird respectively, are very indistinct, but this does not mean that the visibility was any worse than appears in the clear view of Beaufort Island taken shortly before. The "last-second" negatives were developed from film which was still opposite or nearly opposite the lens aperture of the camera at the time of impact and was infiltrated by light when the cameras sustained damage, a point which I have verified with the D.S.I.R. What the captain saw, without doubt, was either an imperfectly defined horizon, or no horizon, and a complete absence of any landmarks in the distance. In addition, he could not raise the Ice Tower for a radar fix. That was why he decided to fly away. I therefore regard this suggested element of pilot error, and it was the one in the end fixed upon by the chief inspector, as being not supported by the evidence.

(k) It was alleged that the crew descended below the officially approved minimum safe altitude either of 16 000 feet or 6000 feet and that this was the predominant cause of the accident. Although the chief inspector referred from time to time in his report that descent to 1500 feet, even though suggested and authorised by McMurdo Air Traffic Control, was in breach of the MSA rules officially in force; nevertheless the chief inspector recognised that there were pilots who evidently had misinterpreted the conditions surrounding descent to 6000 feet as if they referred only to a cloud break procedure, and did not prevent descent to any lower altitude consistent with air safety.

The Civil Aviation Division, not unnaturally, placed the breach of its MSA conditions in the forefront of its case. The airline witnesses also, for a considerable period of time, were inclined to rely strongly upon descent below 6000 feet as being in breach of the airline's rules and consequently as amounting to a decisive cause of the disaster. However, after the Commission had been sitting for many weeks it was for the first time revealed by the evidence of Captain Wilson that when briefing air crews for Antarctica flights in 1978 and 1979 he had told them that the practice on antarctic flights was to descend to whatever level was authorised by McMurdo Air Traffic Control, and he said in his brief of evidence that he did not indicate any criticism of this course.

This new aspect of the RCU briefing was a most surprising revelation. I noticed that it occurred at the very end of Captain Wilson's prepared brief. Without wishing to appear too pedantic, I also observed that this significant concession appeared to have been added to the end of the brief with a different typewriter, so that the decision to reveal this information was not only very late in the day but also seemed to have the hallmarks of a last-minute decision. It also appeared that the chief inspector had not been appraised of this unwritten feature of the antarctic briefings. I have already referred briefly to this disclosure in paragraph 168 above, and that it had not been previously mentioned to the chief inspector. So here there had been, up until this point, a sedulous reliance by the airline and by Civil Aviation Division upon a breach by Captain Collins of the prevailing MSA rules, that breach being treated as if it obliterated each and every error that might have previously been made by the airline or by Civil Aviation Division. But as from the time of Captain Wilson's admission, the MSA defence, if I may call it that, could not prevail against Captain Collins.

In the final submissions for the airline it was admitted that there were a number of pilots who testified that in VMC conditions they considered it permissible to descend below 6000 feet outside the specified safety sector. It was submitted that Captain Wilson had been under a misconception when he appeared to share the same opinion. Captain Wilson had said:

> "In a visual strictly visual VMC letdown providing the weather was clear, very good weather, ceiling and visibility unlimited, and provided that the Captain received permission of McMurdo, he could have descended outside that particular segment." (T 1224)

The submissions for the airline went on to assert (at para. 7.85) that Captain Collins had carried out his descent outside the specified sector and below 6000 feet "which, on the face of it, constituted a breach of the briefing instructions". This latter submission is plainly

wrong. When Captain Collins decided to descend to 1500 feet in VMC conditions, with the specific authority of McMurdo Air Traffic Control, he was in fact acting in accordance with the authority given to him at his RCU briefing.

The final submissions for Civil Aviation Division proceeded upon the simple and unqualified basis that the MSA conditions laid down by the division had been contravened, not only in the present case but in previous cases. That of course may be a material factor as between the division and the airline, although I have already expressed my reservations as to the division's alleged lack of knowledge of the levels at which pilots flew in 1978 and in 1979 in the McMurdo area. But I am concerned here, of course, with the position as between the airline and its pilots and there can be no doubt, upon all the evidence, that the pilots were in fact authorised at the RCU briefings in 1978 and 1979 to descend below 6000 feet in VMC conditions to any altitude authorised by McMurdo Air Traffic Control. This allegation of pilot error must accordingly fail.

(l) It was submitted that the crew of the fatal flight would have been able to see the profile of the mountain ahead by referring to the screen of the radar installation carried on the aircraft. This suggestion had its origin in the following two excerpts from the chief inspector's report:

"1.8.9 The aircraft was equipped with a Bendix RDR IF radar which had a digital indication. This equipment has both "weather" and "mapping" modes. Although it is not approved as a navigation aid, some pilots of previous antarctic flights reported that the radar indications of high ground correlated well with the contours which they observed visually in VMC. Expert opinion from the aircraft manufacturers was that the high ground on Ross Island would have been clearly indicated by the "shadow effect" had either pilot studied the radar presentation during the aircraft's descent to the north of the island.

"3.36 The aircraft's radar would have depicted the mountainous terrain ahead."

When the chief inspector gave evidence on this aspect of the matter he was cross-examined as to the identity of the person from McDonnell-Douglas who had indicated the opinion that the high terrain of Ross Island would have been visible on the aircraft's radar. The chief inspector was not able to recall the name of the man in question, although I naturally accept without hesitation that the chief inspector was indeed given this information by a radar expert from McDonnell-Douglas.

I am bound to say that at first sight this proposition seemed perfectly sound. Everyone has a general knowledge of how radar works. A series of intermittent radio pulses are transmitted from the radar installation and as the radio waves strike an object in the distance they will be deflected back towards the radar screen and the location of the identified object will show up as a "blip" on the radar screen. The exact distance and bearing of the object can be ascertained by looking at the screen. I could not see why Captain Collins and the crew had not identified the mountain ahead of them on their radar screen. But then, as the hearings continued, there was evidence given which seemed to exhibit the theory in a new light.

This was the evidence of Captain Lawson who had been the original RCU briefing supervisor but who, at the time of the hearing before me, had reverted to the status of a line pilot. He was called as a witness by the airline for the primary purpose of explaining the original RCU briefing procedures and the manner in which the briefing material was constructed, and he had also described the two flights which he had been on to Antarctica. He had not been briefed by the airline to say anything about the radar installation with which DC10 aircraft are equipped, but he was cross-examined on the point. Here are some of the questions and answers under cross-examination:

"Q. Finally on the two flights that you made what did the aircraft radar depict as you were coming south from Hallett towards McMurdo?

A. From the best of my recollection the picture depicted ground cover and in many cases the sea ice. In all cases I believe the sea ice.

Q. Did Erebus stand out, do you remember?

A. No more than any other ground cover.

Q. Was it evident upon the radar screen as being terrain?

A. It would have been evident as terrain only, yes.

Q. And with your experience of other high ground would the shadow indicate that it would be high terrain rather than sea ice?

A. No.

Q. Do you say that no different picture is conveyed on the radar screen of a mountain like Erebus as compared with sea ice?

A. That is not uncommon.

Q. Dealing with your own experience down there, was there a difference on the radar with high terrain such as Erebus and the return from the sea ice?

A. To the best of my recollection, no.

Q. The difference between high land such as Erebus on the one hand and the sea ice or the ice shelf on the other hand, did you see a difference between them on either of the two occasions?

A. Not that I would place any reliance on.

Q. Well, radar interpretation has its problems, doesn't it?

A. Very much so.

Q. Would Franklin Island and Beaufort Island and Ross Island fall within what you have just said to us?

A. I would be surprised with the radar equipment we have on board the airplane that such definition would be able to be had with any certainty.

Q. I am not talking about radar as a primary aid. You have told us it is of some assistance for picking up coastlines and islands. Is there anything about those three islands I have mentioned that would take them outside the ambit of what you have just said?

A. No, because I believe the sea ice and pack ice would make this difficult to interpret." (T 858-860)

This evidence, given by a very experienced pilot, seemed totally at variance with the information which the chief inspector had received

from the radar expert at McDonnell-Douglas and, of course, the latter information was hearsay from an unknown person. But the Director of Civil Aviation had strongly supported the chief inspector's view. I therefore decided that because Mr Baragwanath and I were required to travel to the United States in order to interview a group of United States Navy witnesses who could not be interviewed anywhere else, we would use the opportunity of taking up this radar question with the Avionics Division of the Bendix Corporation, which is the manufacturer of the radar equipment upon DC10 aircraft.

On 31 October 1980 I paid a visit to the Avionics Division of the Bendix Corporation situated at Fort Lauderdale, Florida. I there saw the director of engineering and the manager of the design systems. I raised with them the theory advanced by the Director of Civil Aviation, the information apparently given to the chief inspector, and the current doubts expressed by at least one of the operational pilots. I also referred to the fact that Major Gumble, who was the pilot of the C-141 which was following TE 901, had said to me in California that he got a good picture of the terrain from his weather radar when set in the mapping mode although it seemed that the radar return on his aircraft had been interpreted by two experienced navigators who were on the flight deck. It seemed also that these navigators were familiar with the region.

The answer I got from Bendix was enough to clarify the situation. First of all, with regard to the C-141, I was told that the weather radar on this aircraft was not as sophisticated as the radar installed in the DC10, but gives a better mapping return. In other words, although the C-141 radar was not as efficient at detecting clouds containing rain precipitation, it gave a better terrain picture than the DC10 radar, therefore the C-141 would get a better terrain return than the DC10.

I was then given an explanation as to the function of weather radar in general. The primary purpose of this DC10 radar is to detect the level of rain precipitation in cloud because it is the water content in the cloud which warns a pilot of impending turbulence. The radio waves emanating from the aircraft's radar system are programmed towards ascertaining the presence of moisture, and if possible, moisture alone. When they strike raindrops in the cloud the radar screen on the aircraft receives a clear echo. The radar beam will give a medium return from rock or earth but the return which it gives from the sea will depend upon whether the sea is calm or disturbed. If there are waves, then the return from the sea is quite good because the beam strikes the angled surface of a wave and a reasonably good echo is received. On the other hand, if the water is calm then the radar beam tends to slide off the calm water and travel onwards, and the return received on the aircraft radar is correspondingly blurred and uncertain. When the radar beam comes upon a conjunction of land and sea, it readily distinguishes between the water and the ground and a good terrain outline is obtained, because this radar set is programmed to search for water, and also if there is a hill behind the shoreline the beam will produce a shadow effect on the screen which will indicate the presence of that hill. However, in the present set of circumstances, the conjunction of land

and ice, or shoreline and ice, raises a special problem and evidently causes a drastic reduction in the quality of the return from the radar whether in its mapping mode or in its weather mode.

When the radar beam strikes ice the quality of the return will depend upon whether there is a water film on top of the ice caused by some degree of melting. If the beam strikes ice with water on its surface then a reasonably good return will be received. If on the other hand the beam strikes ice which is totally dry then the beam, or rather the radio waves which comprise the beam, will be absorbed by the ice surface and will penetrate the dry ice. The more they penetrate the dry ice the more power they lose. If the radio waves strike a damp layer somewhere in the ice, then they will impart an immediate return to the aircraft's radar, but it will be a fairly weak return. If, however, there is no damp ice layer beneath the surface then the radio waves will continue on into the ice and be absorbed by it, and the ultimate return will be either highly attenuated or non-existent.

The reason for the difference between a return from rock and a return from dry ice is that the radio waves act rather like light waves. A light wave will not penetrate rock, but it will penetrate ice. So with a radio wave. Since there is no humidity in Antarctica, there being less moisture on that continent than in the Sahara desert, it follows that both the ice and the snow will normally be totally dry.

If, therefore, one recalls the type of antarctic terrain over which the radar beam in this case was travelling, then the radar beam would penetrate pack ice and would slide over any intervening flat water which it then encountered. Then, as the aircraft got closer to Ross Island and a solid ice shelf was encountered, the radar beam would penetrate the solid ice just as it had penetrated the pack ice. Then, when the radar beam struck the ice-covered slopes of the mountain, it would again be absorbed by the dry ice and in the result the pilot of the DC10 would get approximately the same return from the mountain side as he had been getting from the pack ice and from the ice shelf itself. In other words, the return would be substantially the same as he had been receiving from the time when the pack ice first came within range of the radar beam. Therefore, the pilot would not detect from his radar that he was approaching solid terrain. This fully accorded with the practical experience of Captain Lawson as described in his evidence, from which I have quoted.

The explanation above given is the reason why radio altimeters are unreliable in Antarctica and Arctic regions. The radio waves descending vertically will be absorbed by snow and ice, and in an area where there is very thick snow the radar beam will penetrate the snow and will give a false reading on the radio altimeter. This is also the reason why there is a special warning to pilots contained in the Bendix handbook (produced as **Exhibit 42**) which deals with the operation of the DC10 weather radar. The warning relates to the possible presence of ice crystals in the air. The pilot may see on his weather radar a clear picture of clouds ahead, and he will estimate that he can climb over the clouds. But there is a danger that the area above the clouds may be filled with ice crystals formed by the freezing of raindrops as they are propelled upwards by the wind inside the cloud. Ice crystals in the air are productive of substantial turbulence, but the radio waves from the radar will travel through

the ice crystals and not produce any return on the radar screen. The radar beam will therefore travel on, disregarding the ice crystals, until it reaches some cloud far ahead which is within its range. So, unless the pilot is alert to the ice crystal danger to which I have referred, he can fly into apparent clear air above clouds and encounter severe turbulence.

The Bendix handbook also contains the following warning, at pages 26–27:

> "Dry snowfall has not been detected with any success on weather radar. However, the lightest shade returns, under appropriate atmospheric conditions, can depict the presence of steady moderate to heavy wet snow. Such echoes are not readily obvious and require experience with the display before they can be readily identified."

The result of all this is that in the opinion of the Bendix experts, relating to the case of TE 901, the pilot may have received some kind of return on his radar (if set in the mapping mode) but the return would be so blurred and so attenuated as to give no reliable indication of terrain. If it were not for the preceding pack ice and ice shelf, then the pilot might see that there were some solid structures far below him and in his path. But, as stated previously, the prior returns off pack ice, calm water, and ice shelf, would mask any return received from the mountain because the latter would look like the previous returns from the pack ice.

It might be possible, so the experts said, for a pilot to note a slight change in the return from high ice-covered terrain as opposed to that received from adjacent shelf and pack ice by reason of the "shadow" effect, but the latter would be distorted and unclear. If the pilot had been in the area before, he might be able to discern that there was either some type of high terrain or at least suspected terrain ahead. But he would only deduce this by reason of the fact that he had flown over the area before. That is, although his eyes would see the same type of blurred return which he had been obtaining from pack ice, his pre-existing knowledge of the terrain would cause him mentally to reject those parts of the picture which did not resemble the known terrain, and his identification of terrain would therefore depend not upon his view on the screen but upon his prior knowledge of the area which he was approaching.

The same principle, so it was said, would apply to the terrain mapping described by Major Gumble. His navigators had flown towards Ross Island before. Their particular set would give a better terrain return than the DC10's set, but nevertheless it would not be very satisfactory. However the navigators, being aware of what they were approaching, would again be able to interpret what they were seeing as solid terrain, providing they disregarded those aspects of the map which did not coincide with what they knew was there.

So in the result, the effect of the Bendix evidence was that not only would the DC10 weather radar (set in the mapping mode) give a return hard to distinguish from pack ice, but that type of return would tend to confirm in the captain's mind that he was in fact flying over pack ice in the centre of McMurdo Sound, if indeed that is where he believed he was.

I asked what the position would be if the aircraft had been flying directly at Mt. Erebus at 2000 feet with the radar set in the

"weather" mode, seeing that the mapping mode would be of no assistance at that low altitude. The Bendix opinion was that because the slopes of the mountain side were covered in snow and ice which was totally dry, then the return from the mountain would be nil. This particular radar equipment is programmed, as stated already, only to detect moisture and for reasons given previously it would give a return off any high terrain composed of rock or earth, but a thick coating of dry snow and dry ice on the northern slopes of Mt. Erebus would cause the radar beam to be totally absorbed and make it impossible for any return to be received. However, I was told that there had been no specific experiments in this field and the experts were prepared to concede the possibility, although they did not really believe in it, of some kind of "shadow" effect but did not believe that this hypothetical return would represent any warning of high ground so far as the air crew was concerned.

The Bendix people also made this point. They said that in all probability the radar set on the aircraft was either in the weather mode or was on stand-by at a time when the aircraft was still a long way out from Ross Island. Then, when the captain saw the gap in the clouds and the sea below, and began his orbiting procedure to fly down to the height recommended by Air Traffic Control, there would be no point in switching the radar over to the mapping mode. He would not be interested in the mapping mode if he could actually see the area of pack ice and water towards which he was descending. But suppose that he switched the radar on to the mapping mode once he had levelled out at about 3000 feet or thereabouts. Then he would be flying too low for the mapping mode to be of any assistance because all he would get would be an insignificant return at the very bottom of his radar screen. So in the end, even if one presumed that the radar was set in the mapping mode, as from a long way back in the approach towards Ross Island, a captain who had not been in the area before would not receive any radar echo clear enough to warn him that there was any high terrain in his path.

I discovered at Bendix that this special feature of the DC10 radar in ice-covered terrain had been notified to McDonnell-Douglas when they made an inquiry of Bendix some time after the disaster. It was also ascertained at a later stage that the chief inspector had also been appraised of this information. I also found, again at a later stage, that the airline had been made aware by McDonnell-Douglas of the same information.

While I did not expect the airline to produce evidence from Bendix which tended to absolve the air crew from any degree of fault, in that radar echoes returned by this special type of radar from dry snow and dry ice are nil, nevertheless it was unfortunate, in my opinion, that the chief inspector did not disclose these special features of the DC10 radar in his report. He should not have said, as previously quoted, "The aircraft radar would have depicted the mountainous terrain ahead". In the opinion of the Bendix avionic specialists—and they are world experts—that statement was not correct.

The only conclusion I can reach upon this branch of the case is that the air crew would not have detected on their radar screen from a long way out, whether the radar was set in the weather or the mapping mode, any high terrain in their path because such terrain

was covered with snow and thick ice which is totally dry. Once the aircraft began its descending orbits and the crew could see below and ahead these expanses of pack ice many square miles in extent, their attention would presumably be concentrated on a visual lookout and they would not be concerned with studying radar returns. But even if they did look at the radar after it had levelled out on its final course towards Mt. Erebus then it is not possible to say, in the absence of actual experiment with this type of radar, whether they would have seen any return at all. All the scientific probabilities are, in accordance with the evidence of Captain Lawson, that radar in the mapping mode might detect the difference between the sea water and pack ice, but once solid ice had been reached it would not reveal the existence of any high ground ahead. Once sea water had disappeared, then the radar returns would probably be nil.

Consequently the simple thesis that the air crew could have seen Mt. Erebus on the specialised radar equipment installed in the aircraft is not established. All this shows the danger of hearsay evidence. There is no substitute for making direct inquiries from the person or persons who have the information.

(m) The final allegation of pilot error against the air crew lay in the suggestion that when manually inserting the waypoints for the flight into the aireraft computer, the crew should have noticed that there was now a difference between the destination co-ordinates and those appearing on the flight plan produced at the briefing session of which a copy had almost certainly been in the possession of Captain Collins when he plotted his flight track the night before the fatal flight. Although the meridian of longitude had been adjusted by only two digits out of five, the parallel of latitude had also been adjusted by a change of one digit and by the addition of another. Seeing that Captain Collins had been working the night before on the previous destination co-ordinates, I felt obliged to give this partieular matter eareful consideration.

It is perfectly true that the flight plan provided on the morning of the flight contained very large numbers of mathematical digits covering not only the geographical position of the waypoints but also track and distance information, flight levels, fuel calculations and the like. But the opportunity was certainly there for Captain Collins to have noticed that the destination co-ordinates appeared to be different from those on which he had been working the night before. He would have been required, no doubt, to have been the possessor of a very accurate memory but he was described to me as having been a very methodieal man. Of course he may not himself have been concerned in the insertion of the co-ordinates. This may have been done by First Officer Cassin and First Officer Lucas, or by First Officer Cassin and Flight Engineer Brooks. This is one of the things which no one will ever know. But even if Captain Collins had himself participated in the insertion into the aircraft computer of all the figures on the flight plan, it is reasonably certain that it would never have crossed his mind that any waypoint on a standardised flight plan had been changed, and his long experience in the AINS method of navigation would render it inconceivable to him that the position of any waypoint could possibly have been changed without his knowledge. As Captain Gemmell himself said in evidenee, when he learned about the transposition of the co-ordinates for the waypoint, and the non-disclosure to the air crew, it came as a "bombshell", a clear indication of the practical impossibility that

such a thing could happen without the air crew being told. In these circumstances, and bearing in mind the doubt which exists as to whether Captain Collins himself was involved in the insertion of the waypoint, I cannot accept this allegation as being an indication of error on the part of the pilot-in-command.

290. Such is the catalogue of pilot error which comprises, to the best of my recollection, a total of the acts or omissions in respect of which the air crew of TE 901 were alleged to have been at fault. I find that none of them has been established to my satisfaction.

McMURDO AIR TRAFFIC CONTROL

291. One of my terms of reference requires me to investigate and report upon whether the disaster may have been eontributed to by an act or omission on the part of the air traffic controllers at McMurdo in respect of any function which they had a duty to perform or which good aviation practice required them to perform. I was therefore required to give some attention to the activities of the McMurdo Air Traffie Control on the day in question.

292. It appeared that the material witnesses who had been on duty at Mac Centre and the Iee Tower on 28 November 1979 were no longer located in Antarctica but were back in the United States. Following a series of negotiations between the New Zealand Ministry of Foreign Affairs and the State Department of the United States, it was finally settled that I could interview specified United States Navy personnel who had been members of the Air Traffic Control system at Antarctica on the date in question, but that they would only be available for interview or for the taking of evidence in the United States. Additionally, it was laid down by the State Department that these United States witnesses were not to be interviewed except in the presence of a United States Navy legal adviser. The adviser nominated for this purpose was Lieutenant-Commander E. A. Fessler, a lawyer who is a member of the Judge Advocate General's Department of the United States Navy. Lieutenant-Commander Fessler was very co-operative in arranging appointments for Mr Baragwanath and me to interview such United States Navy witnesses as were available. The witnesses were interviewed in the presence of Lieutenant-Commander Fessler at Port Hueneme, near Los Angeles, and in Washington D.C., and their statements were later reduced by Lieutenant-Commander Fessler to the form of sworn depositions and in due course the depositions were transmitted to New Zealand.

293. The content of the United States Navy evidence may briefly be stated. Technical details were given of the radio facilities available at McMurdo for air-ground communication. The high frequency radio (not dependent upon line of sight) was operated from Mac Centre, whieh forms part of the MeMurdo Base eomplex. The very high frequency radio (dependent upon line of sight) was available on one frequency at both Mac Centre and the Ice Tower, on another frequency at the Ice Tower only, and on a third (guard) frequency at both Mac Centre and the Ice Tower. On the common frequencies both Mac Centre and the Ice Tower could hear communications between the other and aircraft. There also existed between Mac Centre and the Ice Tower FM links.