"THERE'S NO BLACK MAGIC IN NAVIGATION THESE DAYS!"

HISTORY OF AIR NAVIGATION

by

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and no work whatever is done on the charts in the air other than to turn the folds as necessary. Lindbergh carries the folded map in his left hand and the control stick in his right hand. Almost continually, his eye and attention are on the instrument board, on the map, or on the landscape below. To him, it is apparently no strain to keep his attention riveted to the problems of flying and navigating his plane. He appears interested every moment in comparing the objects seen below with those shown on the chart, or in some other details of flying."

In 1928, after Lindbergh, came the soloists, the most famous of which are Bert Hinkler and Amy Johnson. Both tried to set up the record for a solo flight to Australia, and both were pilots by instinct; they never really learnt navigation, but they took great care of the instruments that were given them and worked out their courses and distances very carefully. Once in flight they were so confident that they kept on, and each landing made they were sure of the next. Bert Hinkler was a constant joy to those who knew him, and his motor-bike could be heard miles away when coming to talk navigation, but no one knew much about his plans or how he did it. He had the strange skill in navigation which can be called a sixth sense, for he was rarely more than a few miles off his course, and the story of his maps is marvellous. He took the sections he needed from *The Times Atlas*, and used them as his only aid besides the compass, but he always took the biggest and best—a P.4 aperiodic compass.

Amy Johnson had the same instinct and sense of direction and always made good her courses. Indeed, as time went on she became almost perfect. Her staff work was very neat and, without disrespect to her memory as a great airwoman, it might be said the way she ran the aeroplane was like a good flight engineer. By her flight to Australia she set up the reputation of women in engineering, but she also proved that women could stand the physical exposure and had the right quality to overcome the hazards of flying. I knew Bert Hinkler and Amy Johnson from their early days to a short time before their deaths, and always found the same keenness and simplicity of purpose, to fly direct on the course laid down with confidence in their compass.

In December 1929 a new star arose in air navigation when Francis Chichester flew solo to Sydney in a Moth. Unlike Hinkler, he paid particular attention to his maps, which are still his pet hobby. In his book, *Solo to Sydney*, he says:

"My maps were going ahead well, if slowly. From London to Rangoon I obtained excellent millionth scale maps, that is of 15·83 miles to the inch; but from Rangoon to Darwin, the best I could get were 64 miles to the inch, and from Darwin onwards, 45 miles to the inch. I think I had forty-one maps altogether. The first thing to do was to mark in the position of every landing-ground I knew of. Where possible I checked up its latitude and longitude. Then I studied the maps carefully to decide definitely which route to follow. Then came meticulous perusal of the route, to decide where lay the easiest terrain for the actual flight; whether to fly on this or that side of such and such mountain or chain of hills, whereabouts to cross this stretch of water. I marked in ink the course I thought it best to follow. The experience gained through the trip round Europe made me very fussy about this. As I knew I should never have a chance of studying the day's maps before leaving the ground, I set about learning by heart as much as possible of the route before leaving England. I joined all the maps together and cut them into a strip nine inches wide, centring about the projected course. This strip I divided into five portions, small enough to fit on to the rollers of my map-case. The total length of the five pieces was 71½ feet. I went over them all, first marking the magnetic variation every few hundred miles, next working out the magnetic bearing of each change in direction; again, marking in the final compass course; again, measuring all distances. During this process, I marked off every 40th mile peg (so to speak). I have found this a valuable help in indicating approximately what one's position should be every half-hour after taking off."

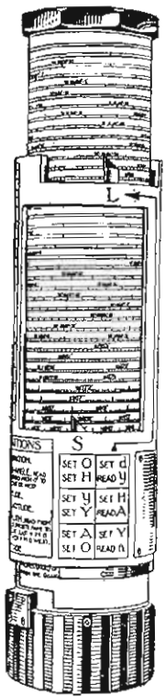
The result of this preparation was most successful, and it led to a more eventful trip in 1931 from New Zealand to Australia, in which he made a remarkable landfall on Norfolk Island by astro navigation, and is recorded in his own words with the actual plot that he made in the air.

The flight was made on April 1, 1931, between Norfolk Island (8,000 acres) and Lord Howe Island (3,200 acres), both islands in the Tasman Sea, which is part of the Pacific between New Zealand and Australia.

The distance flown was only 575 statute miles—trivial for a modern bomber pilot, of course; but the interest lay in the duration of the flight, 7 hours 40 minutes, compared with the 9½ hours' petrol which could be carried, in that the nearest

land if the island was missed lay more than 400 miles further on, and in that the navigation had to be done by the pilot in the open cockpit of a Gypsy I Moth.

The slow speed was partly due to the unbalanced airscrew damaged by chopping wave crests while trying to take off from the open Pacific round Norfolk Island; the resultant vibration made it impossible to write if touching any part of the aircraft.



BYGRAVE SLIDE RULE

The navigation comprised an air plot started afresh from the D.R. position at the end of each hour. The D.R. position was amended when possible by sun position-lines, of which five were obtained using a marine-type box sextant and the sea horizon. The sun observations were relied on completely, and post-flight checking showed this was justified in that none could have been more than $3\frac{1}{2}$ miles in error.

The method of making a sun observation was to pre-compute the sun's altitude and azimuth—in one case 6 hours in advance—and plot a datum position-line through the assumed position. Of course the altitude could not be observed at the exact instant of the pre-computation but allowance for this was made according to the known rate of change of altitude of the sun at the time and in the area. The difference between the (corrected) observed and pre-computed altitudes gave an actual position-line a corresponding distance away from the datum one and parallel with it. The pre-computing was done by means of the cylindrical Bygrave position-line slide rule of which one cylinder has a scale 56 feet long. (This instrument still provides the favourite means of reducing a sight for one R.A.F. navigator, namely, A.V.M. D. C. T. Bennett, the pathfinder A.O.C.)

One to three sun-shots were taken at each observation. Judging the drift by eye, treble drift observations were made every half-hour and the mean of the two W/Vs found used to decide the hourly D.R. position. The drifts were plotted on the chart itself and this is almost the only respect in which the navigation differed from to-day's Coastal Command navigation drill. As a result of this method a succession of hourly W/V vectors were

shown on the chart which enabled the pilot to forecast the next hour's W/V by eye. Marking the W/V vectors with 3-stroke arrows shows an interesting conformance with the latest R.A.F. practice.

The method of plotting the wind was:

Plot the course-line YX from the last D.R. position Y and mark off the next hour's air distance = YX along it. From the air position X at the end of this course-line draw an arc UY of an air-speed circle of radius equal to the hour's air distance. Plot course-lines UX, etc., from the circumference of the air-speed circle to its centre, X, the air position, courses being those on which the drift was measured, namely 30° to port and 30° to starboard. Plot drift-lines UT, YT, etc., one side or other of each course-line according to the drift observed; the three drift lines meet in a point, T, or form a cocked hat.

Some points about the actual navigation:

Immediately after taking off from A, the sun's bearing at the objective O at a time 6 hours later, i.e. $1\frac{1}{4}$ hours before the E.T.A. at O, was computed and a position-line OP plotted on the chart. P was now an earlier objective and selected so that the required track to it was 10° to one side of the direct track to the island.

The 00.00 G.M.T. air position was plotted, X (note that it was labelled 12.00 G.M.T. by mistake). Course-lines 30° to starboard (UX) and the other 30° to port were plotted, and the drift lines on each course (UT, etc.) were plotted. These gave a D.R. position at 00.00 G.M.T. at Z, using the first half-hour's W/V found; using the second half-hour's W/V found, the 00.00 G.M.T. D.R. position was T. W was accepted as the mean 00.00 G.M.T. D.R. position and a fresh air-plot started from it.

During the second hour a mistake was made of plotting both of the drift lines for the centre course to starboard instead of port. It looks, however, as if the pilot realized the mistake at the time even though he did not rub out the wrong lines, because the D.R. position he chose is at the intersection of the two accurate drift-lines of the second half-hour's observation. The numbering of the various drift-lines suggests he thought that too many lines were spoiling the plot. At any rate from then on he gave up plotting six drift-lines per hour and only plotted the mean of each pair; in fact, next hour he determined the D.R. position at B without plotting any drift-lines. Perhaps it was unnecessary with the drift nil on the flight course and only 3° on the courses to port and starboard.

The sun was now nearly on the beam and two observations gave position-lines EF and CD. These were important because the pilot relied on them for checking deviation, there having been no opportunity to swing the seaplane on this heading. The pilot accepted G as the 02.00 D.R. position instead of B, 21 miles to the north, and assumed this was due to a 5° compass deviation. From then on he subtracted 5° from each magnetic course to obtain the correct compass course.

MN was the pre-computed datum position-line for the 02.10 G.M.T. sun observation. Five hours after the start, sun observations were again made; the first of these, JK, at 04.00 G.M.T., showing that the corresponding D.R. position at H was 22½ miles in error.

An 05.00 sun observation put the aircraft on QR, 26 miles short of the line OP through the island. This was accepted as correct, disregarding the D.R. position, S, of the same time, and the pilot continued the same course as before until he reckoned to have reached OP, when he altered course 55° to port to fly along PO.

At 05.20.15 G.M.T. another sun observation confirmed that the aircraft was on PO all right.

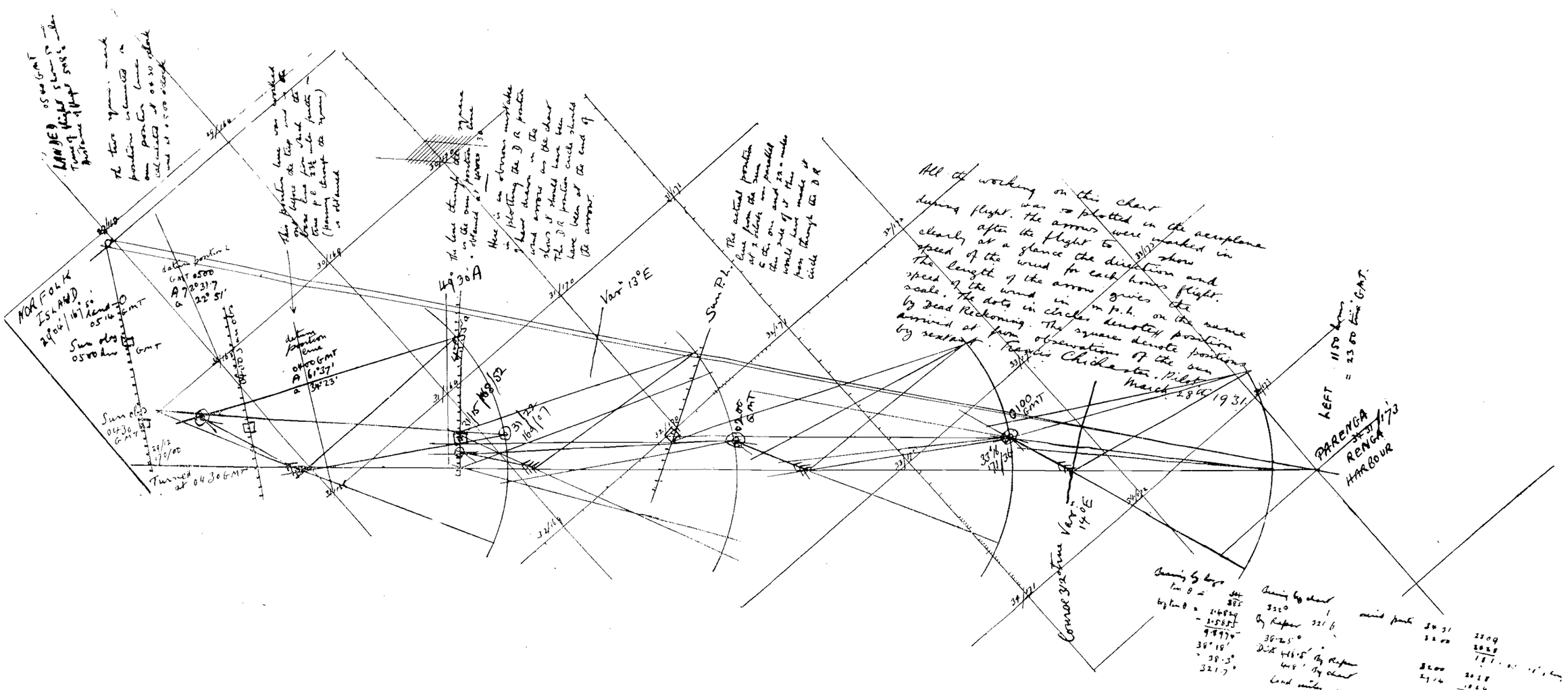
The weather was now getting bad, the last two sun observations being taken through lucky gaps, one actually while turning to keep the sun in view.

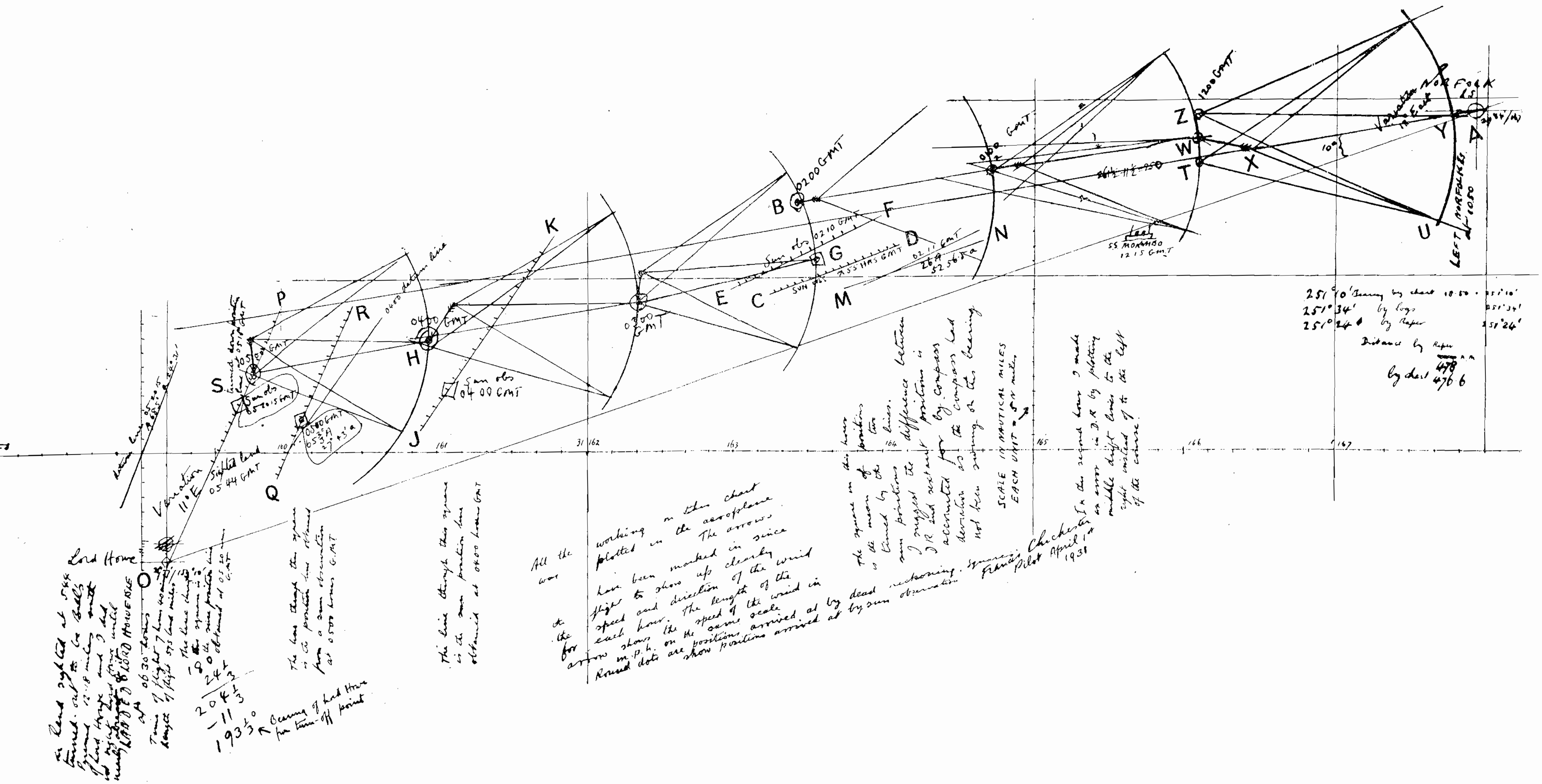
A large rock, 12 miles south of the objective island, was sighted ahead at 05.44 and mistaken for the island itself; which was not seen till abeam 5 miles to starboard at 06.25 G.M.T.; it had been completely hidden in a heavy squall. The seaplane was alighted on the island lagoon at 06.30 after a flight of 7 hours 40 minutes.

The chart is photographed exactly as made during the flight, except that lines and letters are inked over to show up in the photograph.

To understand the polar flights to the north of 1925, 1926 and 1927, one must recall the dramatic race to the South Pole of Amundsen and Captain Scott, in which expeditions immense human effort and dramatic loss of life was experienced to mark the position of the South Pole. The exact navigation made by the Norwegian and British expeditions have recently been set out in the *Royal Geographical Mazagine* by Mr. Hinks, and the explanation given is a most valuable contribution to the science of navigation.

Amundsen was a man who never explored any place where


NORFOLK ISLAND
Sun P.L.
Var. 13°E
Var. 14°E
PARENGA
RENGA
HARBOUR
All the working on the chart was plotted in the aeroplane during flight. The arrows were marked in after the flight to show clearly at a glance the direction and speed of the wind for each hour's flight. The length of the arrow gives the speed of the wind in m.p.h. on the same scale. The dots in circles denote position by Dead Reckoning. The square denote positions arrived at from observation of the sun by sextant. Francis Chichester. Pilot. March 28th 1931.



LEFT NORFOLK IS 1050
NORFOLK IS
Variation 11° East
1200 GMT
1215 GMT
0200 GMT
Sun obs 0210 GMT
0300 GMT
0400 GMT
0400 datum line
Sun obs 0400 GMT
Sighted land 0544 GMT
Variation 11°E
Lord Howe
A B C D E F G H J K M N O P Q R S T U W X Y Z
SCALE IN NAUTICAL MILES
251° 0' Bearing by chart
251° 34' by logs
251° 24' by Raper
Distance by Raper 478
by chart 476.6
In the second hour I made an error in D.R by plotting middle drift lines to the right instead of to the left of the course.
All the working on this chart was plotted in the aeroplane. The arrows have been marked in since the flight to show up clearly the speed and direction of the wind for each hour. The length of the arrow shows the m.p.h. on the speed of the wind in the same scale. Round dots are positions arrived at by dead reckoning. Squares show positions arrived at by sun observation.
Francis Chichester Pilot April 1st 1931
The line through this square is the sun position line obtained at 0400 hours GMT
The line through this square is the position line obtained from a sun observation at 0500 hours G.MT
Bearing of Lord Howe from turn-off point