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Navigating Lancasters in WW II

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This paper describes the air navigation techniques and drills used by Lancasters of the Pathfinder Force of Royal Air Force Bomber Command in early 1945. A brief description is given of the equipment and fixing aids available to the navigator and the environment in which he worked. The paper is based on the author's personal experience and with reference to the log and chart of an operation in which he took part. A running commentary on the navigational aspects of the operation is also given.

KEY WORDS

1. Air navigation. 2. WW2 operations. 3. Historic air navigation techniques.

1. INTRODUCTION. I graduated as a navigator in December 1943 following a basic navigation course at No 5 Air Observers School of the Royal Canadian Air Force at Winnipeg. I knew that there was more training to come wherever my future duties in the Royal Air Force (RAF) lay. Within the next 10 months those of our course destined for Bomber Command, and it was the majority, completed another four courses and flew an additional 130 or so hours. My postings were an Advanced Flying Unit on Ansons (35 hours) at Dumfries, an Operational Training Unit on Wellingtons (40 hours) at Silverstone, a Heavy Conversion Unit on Stirlings (38 hours) at Wigsley and a Lancaster Finishing School (14 hours) at Syerston. We learned new navigation drills and procedures and became proficient with the then current navigation fit of the Lancaster. With 230 hours of flying and 21 years of life under my belt I was deemed ready for operations!

I will try and explain how we navigated those Lancasters. It was 60 plus years ago and there may be unintended inaccuracies and omissions in my paper although the retention of a log and chart is helpful. In writing of my war time experiences I am reminded of what a notable historian, and fellow navigator, Dr Noble Frankland, said in his "History at War", "*Whilst it is well recognized that memoirs are unreliable because of the prejudice of the authors, it is perhaps not so well understood that they are also liable to be highly inaccurate factually, even where prejudice is not involved.*" In the first chapter of the book he describes his experiences in Bomber Command and pleads guilty to an inaccuracy. As a result, he writes, he takes the assertion "*I know, I was there*" with a pinch of salt! Well, I know I was there; I shall do my best to stay within the accurate zone!

The log and chart was of an operation to the synthetic oil plant at Bohlen, to the south of Leipzig, on the night of 5/6th March 1945. By this time, after completing 24 operations with No 106, a Main Force squadron, I had been posted to a Pathfinder

(PFF) squadron – No 83 of No 5 Group based at Coningsby in Lincolnshire. As a Flare Force aircraft our task was to lay a line of flares using H2S (a map painting radar) that crossed the point chosen to be marked with Target Indicators (TIs) by low level PFF Mosquitoes. Lines of flares were laid at around 90 degrees to one another to provide the maximum illumination over the area in which the marking point lay. I seem to remember on one operation a football field was used. The marking point did not necessarily indicate the actual target – No 5 Group used a system of "offset marking" in order to preserve the TIs from bomb damage.

The navigation drill was that taught at the Pathfinder Navigation Training Unit, RAF Warboys. It was essentially a ten minute "quick fixing" drill aimed at maintaining track and timing. It varied only slightly from the standard drill used by Main Force aircraft of Bomber Command.

These notes recall the navigation equipment available, the navigation responsibilities of crew members, the preparation for a flight and the navigation procedures. I describe also the environment in which the navigator worked and give a commentary on the navigation aspects of the operation.

2. NAVIGATION EQUIPMENT AVAILABLE. The aircraft used by the squadron in March 1945 was the Lancaster Mk III. An operational crew consisted of seven members – pilot, flight engineer, navigator/plotter, set operator/bomb aimer, wireless operator, mid upper gunner, and rear gunner. Aircraft were normally identified by a squadron two-letter code plus a further letter. The three letter identification was painted in large letters on each side of the fuselage. The aircraft, whose navigation equipment I shall briefly describe, was OL-R with the manufacturer's serial number PB 136.

2.1. *Distant Reading Compass* (*DRC*). The DRC compass system consisted of a gyro magnetic master unit with repeater indicators for pilot and navigator. A Variation Setting Control (VSC) provided true course to the H2S, bombsight and the Air and Ground Position Indicators (API and GPI). A simple magnetic compass (P12) was available to the pilot to cross check with the DRC and for use if the DRC went unserviceable. Deviation cards were displayed for both compasses.

The DRC Master Unit was positioned at the rear of the aircraft. As the nearest crew member it befell the rear gunner during the pre-flight checks, and occasionally in flight, to read out on the intercom the magnetic course indicated by the Master Unit so that the various repeaters "up front" could be synchronised. For this a small brass key was used. (Navigators in WWII lost hundreds of them – I still have mine.) During WWII and up to around 1946 there was an RAF trade of Compass Swinger. From then on compass swinging became the responsibility of navigators. Swings were conducted on the ground with engines running; courses were measured using a landing compass by aligning the rotating propellers in the compass sight – and adding or subtracting 90 degrees!

2.2. *Air Speed Indicator, Altimeter, Thermometer*. Indicators for both pilot and navigator provided Indicated Air Speed (IAS) in knots, height in feet and outside air temperature in Centigrade.

2.3. *Manual Direction Finding* (*D/F*) *Loop*. The manual D/F loop was operated by the wireless operator (WOP). It could provide a passive (low accuracy) bearing of a ground radio station. The WOP could also obtain on request to a ground station the bearing of the aircraft from the station. It was not used operationally except in emergency on return.

2.4. *Gee Mk2*. Gee was a short range hyperbolic (time difference measuring) fixing and homing aid. It was highly accurate at short range but the accuracy decreased with range where the angle of cut of position lines became small. A "black box" that, with inspired switching could enable us to tease the last fix a little later, was fitted. Gee was a first class homing aid and saved many aircraft and crews from disaster on return to base or a diversion airfield in bad weather. The Gee transmissions were coded in an attempt to deny use of the aid to the enemy.

2.5. *H2S Mk3*. H2S was a map painting radar used as a fixing aid or for blind marking. There were severe restrictions on its use in order to reduce transmissions on which fighters could home. A fix was given as bearing and distance from an identified ground feature on the plan position indicator (PPI). Alternatively a homing could be effected by flying to a set bearing and distance from a ground feature. Radar charts were not yet available. The interpretive skill of the set operator in reconciling the PPI display with standard topographical maps was the key to accurate marking or flare dropping.

2.6. *Skywave Synchronised (SS) Loran*. Loran, a late fit to the Lancaster, was an accurate long range hyperbolic navigation fixing aid similar, in principle, to Gee. Only one position line could be obtained at a time. Operating on a lower frequency it was jammable and difficult to use because of the multiplicity of sky waves visible on the display.

2.7. *Air Position Indicator (API)*. The API was a mechanical aid fed with inputs from the Air Mileage Unit (AMU) and DRC. It gave air position in latitude and longitude, read from veeder counters and was an invaluable device that avoided the inaccuracies and time consumption of a manual air plot. Deviations from planned speeds, heights and courses such as banking searches and corkscrews, that were virtually immeasurable when using a manual air plot presented no difficulty to the API. The aircraft's true course was indicated on the API, the DRC magnetic course output being corrected by the VSC installed in the navigator's compartment.

2.8. *Ground Position Indicator (GPI)*. The GPI was a mechanical aid that added a set Wind Velocity (W/V) to the air position to indicate ground position over a short period of time. The aircraft position was shown as a projected illuminated arrow on a graticule or chart pinned to the navigator's table. It was used by PFF for blind marking in conjunction with H2S. The GPI was fixed to the astrograph mounting in the navigator's compartment. It was a useful aid for local navigation, in particular bombing practice in poor visibility, and for measuring local W/Vs. With zero W/V set and, tracking over the same ground position twice, the displacement of the arrow provided a vector giving wind direction and wind effect for the time elapsed.

2.9. *Drift Recorder*. The drift recorder measured drift by observation of ground detail through a short periscope behind the navigator's position. A ground feature was traced with a pencil on a screen, its "misalignment" with an underlying graticule indicating the drift. The recorder could also be used for measuring groundspeed (G/S) but rarely was!

2.10. *Sextant Mk IX, Air Navigation Tables and Air Almanac*. Astro navigation was the last resort. It required a sextant, Air Navigation Tables (ANT), an Air Almanac (AA) and accurate time. Competent astro navigation demanded practice with calculations and plotting, familiarity with the night sky and, on the night, a clear sky. The accuracy of the resulting 3 star fix was not conducive to the track and time keeping requirements of Bomber Command. I have to confess that I never used astro navigation on operations – a tribute to the radar equipment and those who serviced it. I was fortunate in that a situation never arose in which I was forced to resort to astro as a fixing aid.

2.11. *Astro Compass*. The astro compass, that could be positioned in the astrodome, a step away from the navigator's seat, was used to obtain bearings on ground objects and to check course. For the latter, settings for the chosen celestial body were obtained from the AA. Polaris was used to give an instant check to within 2 degrees on the assumption that its azimuth was due north. (Years later I learned a way of checking to within 0·5 of a degree without the use of tables.)

2.12. *Plotting and Navigation Instruments*. The instruments used for navigation plotting were – a Dalton Computer (to solve vector triangles and speed calculations), a Douglas protractor, a long perspex ruler, dividers, pencils (lead and coloured), rubber, parallel ruler, Planisphere (Star chart), and a compass key (to synchronise compasses). An important item, but on the navigator's wrist, was an accurate watch carefully set and calibrated.

2.13. *Charts and Operational Information*. The paperwork carried by the navigator consisted of a plotting chart (1:1,000,000 Mercator), a log form, Gee and Loran charts, and a set of topographical maps to cover the mission's route. The "million" Mercator was at that time the standard plotting chart of the RAF in the European theatre. (We therefore flew rhumb lines and used the latitude "scale" for measuring distances.) The operational information carried included a schedule of diversion airfields, the Gee codings for the day, details of the "escape" route in the event of attack by enemy aircraft on base, and the colours of the day.

2.14. *The Navigation Bag*. The instruments and paperwork referred to in the preceding two paragraphs were kept and taken to the aircraft in a large thick green canvas bag – the (iconic) "nav bag". It measured about 50 cms square and 20 cms deep and was large enough to take personal items, namely the diversion kit should bad weather prevent a return to base. In a photograph, or picture, of a bomber crew walking towards their aircraft, the navigator can always be identified by his bag.

3. THE NAVIGATION TEAM. From our crew of seven I have distilled below the core navigation team. An operation was of course a great deal more than a navigation exercise and its success and the crew survival depended upon the proficiency of each crew member in his specialist function and the ability to work as a team in which mutual trust was vital. And that is not to forget the contribution of the ground crews who maintained, calibrated, tested and prepared our aircraft for flight. Air crews at that time were kept intact in so far as it was possible and we flew all our operations together except for one when a gunner was sick and an "odd bod" was provided. Many nationalities served in Bomber Command. We could only boast three – an Australian pilot, a Scots rear gunner and five Englishmen.

- *Navigator/Plotter*. The navigator/plotter prepared a flight plan and chart. He navigated the aircraft to the target and its safe return to base using PFF navigation drills whilst maintaining briefed tracks, height and timing.

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- *Pilot*. The pilot, normally designated the aircraft captain, flew the aircraft as required by the navigator/plotter – i.e. course, indicated airspeed and height. In this he was assisted by an auto pilot.
- *Set Operator/Bomb Aimer*. The set operator/bomb aimer provided H2S, Gee, and Loran fixes as requested by the navigator/plotter – and perhaps even a rare pinpoint by map reading. Using H2S he directed the pilot for the flare drop.
- *Wireless Operator*. The wireless operator was not part of the normal navigation team but in an emergency he could obtain W/T and D/F bearings, homings and possibly fixes. Regrettably these were mostly inaccurate and unreliable but often life saving.

4. PRE-FLIGHT PREPARATION.

4.1. In *the Briefing Room*. At a "pre-briefing", before the main crew briefing, navigators prepared their charts and completed the flight plan for the operation. The route was plotted on the 1:1,000,000 Mercator in ink. (Biros had not yet been invented so the old fashioned fountain pen must have been used.) The turning points were lettered A, B and so on. At each a small box was drawn in which was entered the flight plan Estimated Time of Arrival (ETA). The distance to go to the next turning point was marked on the tracks every 50 nms to facilitate the measurement of the distance when "DR'ing" ahead. The half degree isogonal (lines of equal magnetic variation) points were marked with a coloured arrow to indicate where the VSC should be changed. The positions at which "old" and "new" window should be dispensed were plotted and shown as a coloured arrow – blue for "old" window, red for "new". The initial "offset" air position was estimated and plotted for the start of the flight – the technique of "offsetting" the air position will be explained under PFF navigation drills.

The flight plan section of the log was then completed, the tracks and distances having been measured on the chart. Courses, True Airspeeds (TAS), G/S and timings for each leg were calculated using meteorological W/V and temperatures, for the briefed heights. The time for each leg, the time of take off, and times at each turning point were then calculated from the briefed Time on Target (TOT). We added 2 minutes per hour to the flight plan times to provide some time to spare. It was more difficult to make up time than to waste it if one was to maintain the briefed track. I believe that for flight planning the climb we used the air temperature (for TAS) and the W/V at 2/3 of the height.

It is worth a mention at this point of the navigation symbols used in 1945. The air position was represented by a small triangle (Δ), a DR position by a small square (□) and a fix by a cross (+). Three small arrows were drawn on the wind vector in the direction from the air position to the fix, one arrow indicated the air plot and two the track. In Bomber Command we had not yet graduated to the Most Probable Position (MPP). We also flew courses and turned port and starboard. It is worth mentioning that tracks and bearings were measured "true" and that "true" courses were flown, although perversely magnetic bearings were shown on the target maps issued at briefing. GMT was always used. The log form used by the Pathfinder Force differed from the standard RAF form. The headings of the columns were as shown in Figure 1.

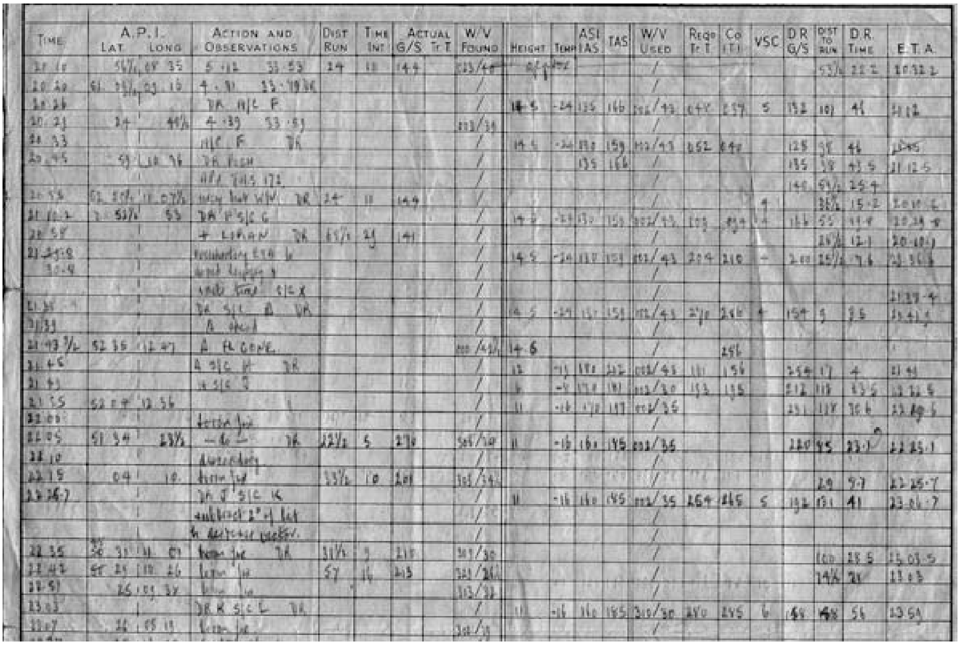

Figure 1. The Pathfinder Log Form – an extract from the mission to Bohlen on 5th March 1945.

4.2. *In the Aircraft*. Pre-Flight Checks as promulgated in AP2062, Pilot's and Engineer's Notes for the Lancaster Mk III were carried out in the aircraft before and at take off. The checks, as I remember them, were relatively short and conducted from memory and mnemonic. (No doubt that is why on my first operation I forgot to set the VSC – it would have been a significant 10 W at base in 1945.) On the navigation front the DRC and repeaters were synchronised and cross checked with the pilot's magnetic compass. The correct functioning of the API, Gee, and Loran was also checked but not the H2S – its transmissions could have afforded evidence of a pending operation.

5. PATHFINDER NAVIGATION TECHNIQUES AND DRILL.

I have no printed record of the PFF navigation techniques and drills. As far as I remember printed notes were never produced for the use of navigators. We were indoctrinated by lecture at the PFF Navigation Training Unit and subsequently through assessment of our logs and charts by the squadron navigation leader. An analysis of the log and chart, however, enables me to provide the main features.

The technique was essentially a quick fixing drill in which a Gee, H2S, or Loran fix was obtained every 10 minutes together with an air position. These were plotted and the Track Made Good (TMG), G/S, W/V, and ETA for the next turning point were calculated using this and the previous 20 minute fix. If necessary a DR position 6 minutes ahead was found by using a forward calculated air position and the last W/V, or by TMG and G/S, in order to alter course and/or airspeed to maintain track limits, timing and the next turning point. (A 6 minute calculation involved using tenths of air, ground or wind speed – a simple mental process.). I see from my log and

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chart that ETAs were calculated to a decimal point of a minute and W/V to 0·5 of a degree and knot.

If fixing aids were unavailable through unserviceability, beyond range, or jammed, the drill was to continue to calculate 10 minute DR positions using the last W/V found, modified by met information, and possibly an astro position line – this gave an appreciation of the effects of course and airspeed deviations.

Accurate navigation, in particular track keeping and timing, was dependent upon using the most recent W/V as measured between the latest and the 20 minute-old fix. This would normally involve, with its inherent errors, the resetting of the API every 20 minutes to a forward calculated air position. Whilst the resetting knobs were depressed the API was not measuring or recording the change of air position and it was always possible for the navigator to calculate or inject the wrong settings. To avoid these errors the Pathfinder Force evolved a method of offsetting air positions that obviated or reduced the need to reset the API. The drill used an initial offset air position and a system of vectoring. The initial offset air position was established by estimating an average W/V for the whole flight and plotting the air position downwind from base for a distance of half the wind effect for the whole flight. The theory was that the API air position would move upwind with ever shortening vectors. At mid-flight the vector would be at its shortest, the air position being nearest to the ground position of the aircraft. Thereafter the API air position would continue to move upwind and at the end of the flight be, in theory, as far upwind as it was downwind at take off. At each fix a vector would be drawn between the fix and the air position as given by the API. This vector would then be transferred to the API air position 20 minutes later to establish an "actual air position" – the W/V was then measured between that air position and the fix. Coloured pencils were used to assist identification of vectors – red, green and blue at the 10 minute fix intervals. Because the API uses the secant of the (indicated) latitude to calculate the longitude a limit was set on the latitude difference between the actual ground and the air position as indicated on the API. From memory I believe this was 1·5 degrees of latitude.

Figure 2 illustrates a section of my chart from which the transfer of vectors and the 20 minute W/Vs, found at 10 minute intervals, can be seen. The due east track at latitude 50N between 02E and 05E and part of the onward track to point D are shown as is, in the bottom left corner, a portion of the return track to point B and onwards to A (Reading). On the easterly track fixes were plotted at 18.38, 18.48, 18.58, and 19.08. Matching air position readings from the API form an air plot from which the coloured vectors can be seen transferred on a 20 minute cycle – for example the red vector at 18.48 is moved to 19.08 to establish a 20 minute air position that with the 19.08 fix gives a 20 minute W/V of 006/45.

If one found oneself more than 5 miles off track immediate action was taken to regain the 5 mile limit. We had some "rule of thumb" means of quickly regaining or paralleling track. I cannot recall these rules although to parallel track an alter course of the track error was almost certainly used. To lose or gain time airspeed would be adjusted. Time could also be wasted by "dog legging", the time on each leg equal to the time required to be lost. Timing could also be regained by judiciously under or overshooting turning points depending upon the angle of entry into the new track. You had to watch the distance you could get off track and the angle of approach to the new track so as to reduce collision risk.

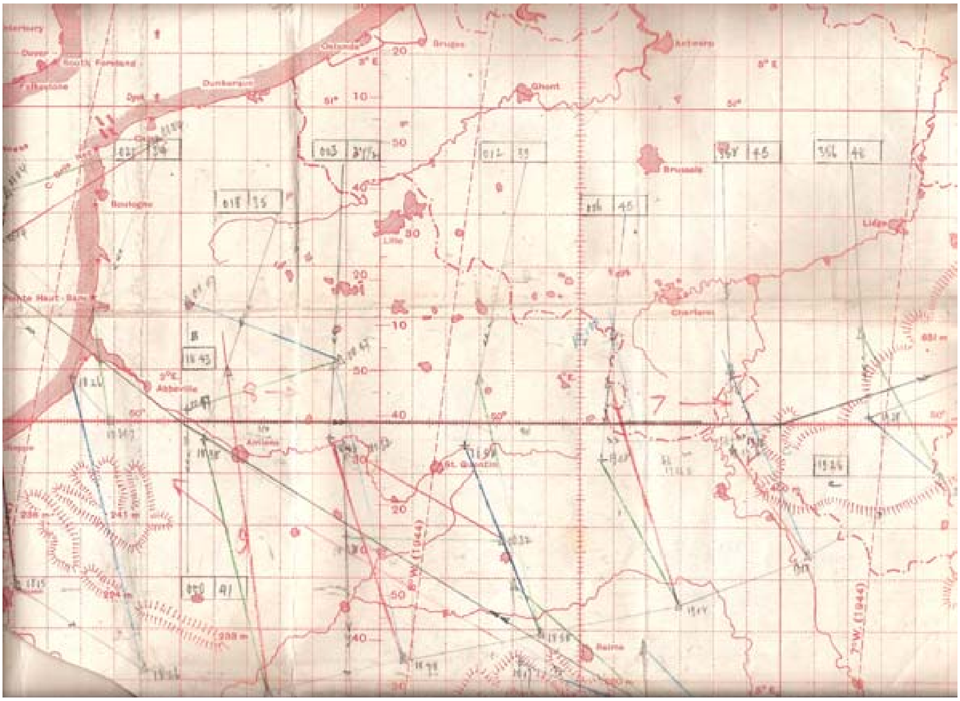

Figure 2. Section of chart used on the mission to Bohlen on 5th March 1945.

Navigation on the climb was not a rewarding process knowing that the W/V was changing with height and that errors in subsequent DR navigation might occur. Fortunately the API coped with the changes of TAS that occurred. One hoped that having reached cruising altitude good fixes would be obtained.

The log shows occasional checks of TAS calculated from API air positions; it does not show course checks but both magnetic and true courses were passed to the pilot and a cross-check made as a matter of routine between the magnetic compass (P12) and the DRC. A course check using the astro compass would (unfortunately) have been a rare event. A cross-check between the DRC master unit and the pilot's magnetic compass was always made before take off.

Safety heights were not normally a consideration until return to base or diversion airfield. I believe the drill was to add 500 ft to the highest ground within 20 or so miles of track. The normal practice to approach and locate base was by means of a homing along a Gee lattice line. This was very accurate and would place an aircraft well within the boundary of the airfield.

6. THE ENVIRONMENT.

6.1. *Flying Conditions*. Until the target, R/T silence was maintained. The Main Force aircraft remained silent until their return on approaching base. PFF aircraft used R/T during the marking procedures. Engine start, taxi and take off times were given at briefing. Ground control was exercised and take-off permission

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given by means of Verey pistols and Aldis lights. In flight there was little scope for avoiding bad weather if track and timing were to be maintained. The navigation had to ''tolerate'' tactical manoeuvres such as a banking searches and, if attacked, a corkscrew. Fortunately we never corkscrewed in anger although I experienced it in fighter affiliation exercises. At the entry into the dive one had somehow to prevent the navigation instruments on the table from flying upwards. In the translation from the dive to the climb both navigator and instruments were kept firmly in place. Turbulence, often from other aircraft was common and made plotting difficult. Anti aircraft fire was to be expected. PFF aircraft, ahead of the bomber stream, attracted radar controlled fire that was very accurate. Fighter activity by March 1945 had lessened but was still a significant hazard.

6.2. *Sound.* The only sound insulation between the four Rolls Royce (RR) Merlin engines and the navigator was afforded by the leather helmet inset with padded intercom earphones. With the helmet off crew members had to shout loudly to be heard. After landing the ''ringing'' in one's ears lasted several hours. Many Lancaster aircrew suffered from high tone deafness, the ''Lancaster ear'' as I have heard it called.

6.3. *Heat.* The Lancaster sported a hot air system operated by the wireless operator. It produced a subtle uncomfortable mix of hot and cold air. The outside temperature on this flight at 14,500 ft was – 24°C and yet I do not remember wearing any flying clothing over my battle dress other than flying boots. I suppose there was some warmth in the parachute harness. I cannot remember how we used the ''Mae West'' but I am sure we would have worn it on a flight with a sea crossing. We were issued with an inner and an outer flying suit and inner silk and outer leather gloves – they came in useful for post war motorcycling. The oxygen mask, that contained the microphone for the aircraft's intercommunication system (intercom) would have been worn closely fitted and continuously at this height. At very cold temperatures the breath would form icicles on the mask.

6.4. *Light.* A small (24 V) angle poise lamp provided illumination of the navigator's table.

6.5. *Radio Frequency Transmissions.* In the course of an operation many different types of transmissions including H/F (W/T), VHF (R/T) and centrimetric band (H2S) emanated from an operational Lancaster. The effect of radio frequency energy on aircrew was not an issue and nothing, so far as I know, was counted. I wonder how the energy in the navigator's compartment that spilled from the H2S scanner would compare with that from a mobile phone.

6.6. *Odour.* The Lancaster had a unique smell of fuel and aircraft dope.

6.7. *Comfort Calls.* An Elsan was situated at the rear of the aircraft just forward of the rear gunner. Its use would necessitate being off intercom, on emergency oxygen, climbing over the main spar, and staggering rearwards in darkness, probably in bumpy conditions. I never used it during my tour of operations (my longest trip was 10 hours and 5 minutes).

6.8. *In-Flight Catering!* I believe a cheese or corned beef sandwich and a large thermos of tea to be shared among the crew were frequently on the menu. Possibly, occasionally, some boiled sweets and a bar of chocolate were provided.

6.9. *Medical.* A comprehensive first aid kit was carried that included morphine ampoules. Aircrew had special dispensation to administer morphine. ''Wakey wakey'' (possibly amphetamine) pills were available for those that had difficulty staying awake. I don't recall using air pills for air sickness but I occasionally suffered from it as I am sure many other aircrew did.

7. THE MISSION.

7.1. *The Aircraft Involved.* The operation to Bohlen on the night of 5^{th} March 1945 was conducted by 248 Lancasters and 10 Mosquitoes of No 5 Group of Bomber Command. Of the Lancasters I would estimate that around 28 were Pathfinders from 83 and 97 Squadron, also from Coningsby. The 10 Mosquitoes of 627 Squadron, one of which was flown by the Master Bomber, would all have been PFF aircraft. They were based at nearby Woodhall Spa.

7.2. *Brief Summary of the Route.* The route ran from Coningsby to Reading and then SE crossing the English coast near Eastbourne. Beyond the French coast the route turned due E along the 50N parallel just north of Amiens to 05E where it turned ENE crossing the Rhine between Bonn and Koblenz. At 07 30E the route turned NE in the direction of Magdeburg. About 15 nms before Magdeburg a turn to the SE and then SW took us around Halle and Leipzig with a due W approach to the target. The route out of the target was almost due S from 51 11N to 49N at a fast descent from 14,500 ft to 6,000 ft with Chemnitz to port and crossing the Czechoslovak border. At 49N the route turned W with Augsburg to port and Stuttgart to starboard. A long haul to the WNW took us past Strasbourg, Nancy, and Reims. We then retraced our outward route passing Amien, Abbeville, Eastbourne and Reading and on to base. The flight plan distance was 1524 nms. A description of the activity on each leg now follows.

7.3. *Base to Reading* (*A*). (Track 197 Distance 103 nms) We took off from Coningsby at 17.03 GMT and set course (S/C) at 17.10 climbing to 3000 ft on the first leg to Reading (A). My log records the intended S/C time as 17.26. This time would be based on flight plan times plus 2 minutes per hour – we would clearly have a good deal of time to lose. At an IAS of 150 kts we arrived at Reading 12 minutes ahead of our planned time. On this first leg we measured a W/V of 336/25 against a met forecast of 330/26.

7.4. *A to 50N 02E* (*B*). (Track 128 Distance 142 nms) The next leg on which we climbed to 5000 ft took us from Reading across the coast near Eastbourne to 50N 02E (B). Part of this leg is shown in Figure 2. We reduced our IAS to 140 kts (against a planned 150 kts) in order to lose time. We were obtaining good Gee fixes every 10 minutes. The last W/V calculated on this leg was 018/35 against a met forecast of 360/36. We were now 10 minutes ahead of planned time.

7.5. *B to 50N 05E* (*C*). (Track 090 Distance 115 nms) On this leg, the whole of which is shown in Figure 2, we climbed to 8000 ft and reduced the IAS to 135 kts. We also flew a "dog leg" of 3 minutes each leg to lose a further 3 minutes. We "dog legged" to starboard turning first 60 degrees, then 120 port and then 60 starboard to resume our original course. We were getting good Gee fixes and our last W/V on this leg was 006/45 against a met wind of 360/45. We were now 7 minutes ahead of planned time. I notice, although it may not be visible on the reproduced chart, that, on the basis of the TMG and measured G/S, I established a DR position on the next track extended backwards. I established the time to go to the alteration of course to maintain the new track. In addition to the quick fixing navigation drill shown on this leg some minor detail can be seen – the coloured arrows at the position where the

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VSC was to be reset, the 50 and 100 nm points from turning point C and the boxed flight plan ETAs near the turning points.

7.6. *C to 50 30N 07 20E* (*D*). (Track 071 Distance 95 nms) Turning point D was exactly on the Rhine between Koblenz and Bonn. We were now 4 minutes early with a last W/V on that leg at 19.50 of 357/50.5 against a met of 360/58. The chart shows that on this leg I was losing the 10 minute rhythm of the fixing and its accuracy. This may have been because the first effects of jamming were being felt or because the Gee reception was poor. We commenced dispensing "old" window at 06E, some 60 nms from the Rhine. We dispensed, by position and rate, to a laid down program, two types of window or chaff – new and old. I cannot remember which unfortunate crew member was responsible for feeding the window dispenser. We were not briefed on the details of the window dispensing program although we knew it was based on intelligence regarding the location and frequencies of the enemy search radars and anticipated fighter reaction. Examination of the chart shows that on the outward flight we dispensed "old" and, on the inward, "new" window. I conclude from this that on the outward flight we aimed to confuse ground radars and on the homeward, airborne radars. This action by the Bomber Force was a minor part of a highly sophisticated Electronic Counter Measure (ECM) plan.

7.7. *D to 50 45N 0920E* (*E*). (Track 080 Distance 83·5 nms) We now climbed to 14,500 ft. Shortly after reaching D, at 08E, we stopped dispensing window. The last Gee fix at 20.29 put us 8 nms to the NE of point E (at 09 26E), 3 minutes ahead of time. The angle of cut of the Gee lattice lines was very small at this range and the system was probably being jammed. A fix at 20.20 was not used because it was, no doubt, considered unreliable. The last measured W/V at 20.29 was 003/39 against a forecast of 360/47. Note that Figure 1 shows log entries from 20.10 to 23.37.

7.8. *E to 51 52N 11 30E* (*F*). (Track 048 Distance 101 nms) From here the navigation was by DR. We were still ahead in time, and at point E with little scope remaining for losing time. We dropped our IAS to 130 kts giving a TAS of 159 kts but even so our ETA at F was 3.5 minutes early. Approaching point F the set operator provided a Loran fix. Its logging indicates that it was not available until after point F. Loran was a relatively new fit in Lancasters and we had only just begun to gain experience in its use. I recall that it was a difficult beast to use at night because of multiple sky waves and it took, compared with Gee, a long time to obtain a fix. Position lines were obtained singly and it was necessary to transfer the first position line on the Loran chart by track and ground speed or obtain two readings that were then averaged. We dispensed "old" window for a distance of about 60 nms either side of the 10E meridian. A log entry at 20.45 records an API check giving a TAS of 172 kts. The chart shows a DR position just north of point F at 21.10 – 6 mins early. These inconsistent ETAs must have been somewhat disconcerting.

7.9. *F to 51 34N 12 54E* (*G*). (Track 109 Distance 55 nms) This leg took us past the heavily defended areas of Halle and Leipzig. We commenced again the dispensing of "old" window. We maintained an IAS of 130 kts as opposed to the planned 155 kts in order to lose time. I used a W/V of 002/43 that I presume was my last wind modified by the met forecast. The required ETA at point G was 21.33 and my DR ETA was now 21.29.8. There were only 35 nms to the target beyond point G and so we decided to overshoot the turning point. My log says, "Overshooting ETA to avoid Leipzig and waste time". We were, according to the DR, some 4 nms starboard of track and 15 nms from Leipzig. This was a very heavily defended area flakwise.

I can't quite understand my concern at avoiding Leipzig. Our track kept us well clear although no doubt its defences extended well outside the city. We reached our DR position for the next turn at 21.34.5. Although our planned ETA at the "overshoot" point was 21.33 we were now positioned some 5 nms along our new track and within 2 minutes of the planned time. As a point of interest on examining my log I notice that on the approach to point F and just after, three ETAs were logged as 20.10.1 and 20.10.2 at F and 20.29.8 at G. These times should have been prefixed 21 and not 20. The "mistake" did not affect the navigation – I can only put it down to a highly stressed navigator. There would have been, at this stage in the flight, a great deal of activity beyond the blackout curtain – enough to suggest that I was not after all in the DR Trainer!

7.10. *G to 51 11N 12 48E* (*X*). (Track 204 Distance 25·5 nms) X was the last turning point before the run in to the target. Because of the overshoot at the last turning point we were some 5 nms to port of the planned track giving a slightly longer, hopefully by 2 minutes, run in. We maintained an IAS of 130 kts.

7.11. *X to Target Bohlen at 51 11N 12 22E.* (Track 270 Distance 9 nms) We were due at X at 21.40 and the target at 21.43. Our DR position for the turn in to the target was about 5 nms east of X and we turned at 21.38 giving an ETA at the target of 21.42. There was now no scope for further correction although we were still at 130 kts IAS against a planned 150. The log states "21.39 Target ahead" and "21.43.5 Flares gone". Having struggled to lose time we were in the event half a minute late! The log makes no mention of how we aimed the flares. I would presume that they were released blind using H2S. This would have been the first and last occasion on the flight when H2S was used – it served as a beacon for night fighters. At about this time selected PFF aircraft would have been transmitting their latest found W/Vs on W/T to Group Headquarters. These were averaged and assessed by the met and Air Staff and a W/V passed back to the Master Bomber via a (W/T equipped) Lancaster. This W/V, possibly modified to take into account the "offset" of the TI's from the target, would then be passed by R/T to the Main Force and used as the bombing wind on the Mk XIV bombsights.

7.12. *Target to 50 55N 12 31E* (*H*). (Track 161 Distance 17 nms) Presumably released by the Master Bomber we executed a port turn of 130 degrees and descended at 180 kts to 11,000 ft. From here on my chart does not show planned ETAs and so I presume that so long as we adhered to the planned route timing was not significant. The chart indicates "stop old" (window) at point H.

7.13. *H to 49 00N 11 50E* (*J*). (Track 193 Distance 118 nms) We set course from our DR position H at 21.49 at a height of 11,000 ft and an IAS of 170 kts. I was on DR navigation using the W/V of 000/30 – this was the W/V found at the target and modified for our new height. The set operator was now busy at the Loran and passed me a first fix for 22.05. This placed us (with some relief) within a mile of track and gave a W/V of 306/34. The next fix at 22.15 confirmed our track keeping, gave a W/V of 303/34.5 and an ETA at J of 22.26. On this leg our orders were to dispense "new" window until 50N.

7.14. *J to 48 25N 08 40E* (*K*). (Track 254 Distance 131 nms) We altered course for K at our ETA of 22.26 still at 11,000 ft and now at 160 kts. A Loran fix at 22.26 put us 3 nms from the turning point. A further three Loran fixes at approximately 10 minute intervals confirmed our track keeping. The consistency of the W/Vs from these fixes (and calculated G/Ss and ETAs) suggested their accuracy. The W/Vs were 309/30, 329/36.5 and 313/32. At the ETA of 23.03 we reached DR position K and altered course for the next leg. We were at that time dispensing "new" window. I must say that the "quick fixing" on Loran by our set operator was most commendable. On this leg the length of the air position vectors should have led to the resetting of the API. I notice, however, that to avoid resetting I subtracted 2 degrees of latitude. This was not in the book and would have incurred a small error in the measurement of longitude. I suspect that at this point I was struggling with the DR and did not wish to manually reset the API.

7.15. *K to 48 50N 05E* (*L*). (Track 280 Distance 148 nms) At 23.07 we took our last Loran fix that put us 5 nms starboard of track. The air position vector had by this time become unmanageable and the API had to be reset. We stopped dispensing Window at 07E. Our TMG took us over Strasbourg and at 23.27 at 07.20E we got our first Gee fix – always a satisfying moment. From here it was 10 minute fixing and at 23.57 we were 3 nms due north of L and to starboard of track. Three minutes later we intersected our next track and altered course for the turning point.

7.16. *L to B*. (Track 301 Distance 136 nms) It was now plain sailing with consistently good Gee fixing. Still at 160 kts indicated and 11,000 ft W/Vs varied in direction between 351 and 358 degrees and speed between 41 and 45 knots. Passing over Amiens we arrived at B at 00.44 some 6 hours after we had passed over it on the outward flight. A portion of this track can be seen at the bottom left hand corner of Figure 2. A fix at 00.32 at 49 38N 02 50E may just be visible with its associated air positions and wind vector to the S – the box in which the W/V would be recorded is not shown – it was in fact 358/42.

7.17. *B to A* (*Reading*). (Track 307 Distance 142 nms) The navigation on this leg seemed to slip a little in that my fixing was now every 20 minutes and that I allowed the TMG to veer a little to starboard no doubt in the full knowledge that I was cutting a corner that would get us back to base a little earlier. We touched the SW outskirts of London passing over Slough and probably High Wycombe where our masters slept. At 00.41 we intercepted our final track to base and descended to 5000 ft.

7.18. *A to Base*. (Track 017 Distance 103 nms) Clearly impatient to get home we were now at 5000 ft and an IAS of 180 kts with an ETA of 02.11. After two Gee fixes at 01.42 and 01.57, with no associated W/Vs calculated, we positioned ourselves on the Gee lattice line for base where we arrived at 02.11, landing at 02.19 – a flight of 9 hours 16 minutes. After a debriefing it was bed with four RR Merlins still ringing in the ears. The next briefing, for our 3rd operation in 4 days, was less than 12 hours away although we were not alerted until later. For 18/- shillings (90p) a day we were good value.

8. SUMMARY OF ACTIVITY.

I thought it would be interesting to tot up the navigation activity – the number of fixes, air and DR positions, W/Vs, and ETA revisions on the 9 hour 16 minute flight:

- Fixes
  - Gee 34
  - Loran 7
  - Pinpoints 1 (at target!)

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- Air Positions
  - 44 API readings
  - 88 Plotted (The transfer vector technique required 2 plotted air positions)
- DR Positions
  - 13 Plotted
- W/Vs
  - 35 Found
- ETA Revisions
  - 44 Calculated

9. SOME THOUGHTS – 62 YEARS ON. The notion did not cross my mind on the 5th March 1945 that 62 years later my log and chart would feature in an article written for an Institute dedicated to the cause of Navigation but not yet created, and for a readership the majority of whom were not yet conceived. Had it done so I would have improved my plotting, my writing and possibly my calculations. I am surprised by their number and those of the log entries involved and the consequent opportunities for mistakes even if there were no external distractions. Getting the latest W/V was clearly the name of the game. Gee, Loran and the API were the essential equipments for Bomber Command navigation. Without these aids, (and their serviceability) especially in difficult weather and changing wind conditions, operations at long range, where Oboe and GH were unavailable, would have been impossible. Unfortunately H2S was no longer used for fixing purposes in early 1945 – it was the Luftwaffe's ideal bomber locator.

Timing was difficult and without quick fixing even more so. On this operation the routing around Leipzig that consisted of short legs with large changes of direction made timing and track keeping tricky. On the other hand there were considerable tactical advantages for the Main Force behind us.

The Gee and Loran fixes gave consistent W/Vs throughout the flight that matched the forecast winds well. This suggests stable weather conditions that were not always the case. Bomber Command suffered on many occasions in unsettled, rapidly changing situations – as with Nurnberg on 30/31st March 1944 when 95 aircraft were lost.

I notice from the flight plan that the details for the return flight had not been entered in the log. This was probably because there was insufficient time between briefing and take-off to do all the calculations. They were not necessary but it is interesting that we took off not knowing the planned length of the mission. We probably had the full 2154 gallons of fuel – an unforgettable figure – and no doubt we were safely in the hands of the Air Staff planners. It was always a nervous race for the navigator to complete the flight plan by take-off.

Martin Middlebrook and Chris Everitt in their "Bomber Command War Diaries" record for this operation that the target area was covered by cloud but that some damage was caused to the refinery. They also record that of the 248 Lancasters 4 were lost.

From memory, and a contemporary log and chart, that was how I "did it" in 1945 and how thousands of other navigators also "did it". Although I have concentrated on the navigational aspects of the operation its success (including survival) depended

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upon the competence of each of the seven individual crew members. They may not all have been included in my "core navigation team" but each and every one contributed critically to the overall success of the mission.

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