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ROYAL AIRCRAFT ESTABLISHMENT

TECHNICAL REPORT No. 65061

EVALUATION OF THE FERRANTI MINIATURE PLATFORM - TYPE A

PART I

PREPARATORY DOCUMENT FOR THE SHORT RANGE TRIALS

[U]

by

S. G. Smith, B.Sc. I.E.E. Dept. R.A.E. Farnborough

Flt. Lt. G. P. Gibb, R.A.F. Navigation and Radio Divison
A. & A.E.E. Boscombe Down

MINISTRY OF AVIATION
FARNBOROUGH HANTS

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SUMMARY

The aims of the short range flight trials of the Ferranti Miniature Platform are given, and the methods to be employed are described, together with a description of the equipments to be used. The spheres of responsibility of the various co-operating parties are laid down. The appendices, contain a detailed description of the platform system and associated equipment.

Departmental Reference No. IEE 82

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1 INTRODUCTION

In 1963 a contract was placed by the Ministry of Aviation with Ferranti (Edinburgh) Ltd. for the supply of two models of their Type A miniature inertial navigation system, designated FMP-A. These systems were not intended for use with specific aircraft projects but for research and development of miniature inertial systems.

The design of the stable platform and associated computing system and electronics (see appendix A) was undertaken by Ferranti Ltd., as a private venture and the first model was produced also as a private venture. This was flight tested by Ferranti in a Dakota aircraft in 1963.

The second model to be made - the first model on the M.O.A. contract - was delivered to R.A.E., Farnborough in May, 1964 for laboratory testing and subsequently to A.&A.E.E., Boscombe Down for flight trials.

2 THE SHORT RANGE TRIALS

The short range trials of the FMP system are intended to investigate the performance of the system in a manoeuvrable aircraft both as a navigator over relatively short ranges from Base and as an attitude reference when subjected to aircraft manoeuvres. The aircraft to be used is Canberra PR3 - VX 181 based at A.&A.E.E., Boscombe Down. Longer range navigation aspects of the system will be investigated at a later date.

3 THE AIMS OF THE TRIALS

The aims of the trials are three in number. They are to determine the performance of the platform.

(i) As an attitude reference when subjected to aircraft manoeuvres such as turning, rolling, looping and LABS.

(ii) As a navigation equipment giving positional information.

(iii) As a self aligning system, particularly with respect to alignment in azimuth.

4 TRIALS METHODS

4.1 Attitude assessment

The method of attitude assessment is that described in reference 1 and follows the system used in the trial of the FSP type 100 platform[2]. A brief resume is as follows:-

Before and after each manoeuvre, during nominally straight and level flight, at altitudes between 250 ft and 400 ft the sea horizon is photographed by two cameras, one aligned to the fore and aft axis of the aircraft and the other to the athwartships axis. Simultaneous trace recordings are taken of the platform's pitch and roll outputs.

During the manoeuvre recordings are taken of various system outputs (see appendix C).

Subsequent analysis of the photographs and recordings enables any adverse affect of each manoeuvre on the platform to be seen and also facilitates reconstruction of each manoeuvre.

4.2 Position information assessment

The method of checking the platforms performance as a navigator is to compare simultaneous recordings of the output from the platform and an accurate radio fixing aid. The radio aid used for this trial is the FPS 16 precision radar at R.A.E. Aberporth. A preliminary trial of the radar fixing procedure has been successfully completed[3] by A.& A.E.E.

4.3 Initial alignment assessment

The performance of the self alignment system determines the performance of the system as a navigator, and so is of particular interest in the evaluation of the navigation performance.

The system has to align itself both to the vertical and also to true North. Thus the assessment falls into two parts.

4.3.1 Alignment to the vertical

The system outputs are recorded on a ground based recorder housed in a van which is parked near the aircraft before flight. The records are the same as are normally taken during laboratory tests, and comparison with laboratory records gives the effect on alignment of an unsteady base, due to aircraft motion as result of wind and personnel movement, as opposed to the fixed base used in the laboratory.

4.3.2 Alignment in azimuth

An error in the alignment of the platform Y axis to true North has the effect of causing navigation errors which are a function of range flown and appear as an across track position error. However a more direct means of obtaining the accuracy of alignment is by surveying the heading of the platform case on the ground and comparing this with the heading as given by the platform azimuth readout when alignment is completed.

At the request of the R.A.E., Ferranti have fitted a viewing window on the outer case and a mirror on the outer roll gimbal, and R.A.E. have fitted a further mirror to the outer case. The latter mirror gives the datum from which the azimuth readings may be taken, after a laboratory check showed that the internal anti-vibration mountings introduce no significant error.

The accurate synchro mounted on the azimuth gimbal is fed to a fixed synchro control transformer connected in parallel to the normal repeater control transformer. The fixed synchro rotor output is then demodulated and read as a d.c. signal on a valve voltmeter. The fixed receiver is set up to give zero output on a specified heading ($172^{\circ}29'$) and the output calibrated in the laboratory over a range of $\pm 5^{\circ}$ about this heading.

When the system alignment is completed in the aircraft, which may be heading in any convenient direction, the system is switched to NAVIGATE mode and then the platform, on the end of a long cable, is removed from the aircraft and placed on a tripod in such a way that the mirror is aligned to the specified direction. This is checked by a theodolite which is placed on a surveyed bearing picket point. With perfect gyro-compassing the output of the azimuth synchro should then be zero, and any deviation from zero represents the error in azimuth alignment.

The same procedure is repeated after flight, before the system is shut down. Any change in the error is an indication of the apparent drift of the azimuth gyro during flight due to true drift and computational errors. The effect of this on the navigation performance may be then computed.

5 ENVIRONMENTAL MONITORING

Should any anomalous results be obtained then it is important to relate these to environmental conditions. Two features of the environment are being recorded.

(1) The steady accelerations applied to the system as measured by the platform accelerometers, are recorded on the airborne trace recorder during manoeuvres.

(2) The temperatures inside the electronic unit are also recorded together with current supplied to platform temperature controller. The temperatures at the four corners of the system rig which is mounted in the flare bay are displayed in the navigators position.

6 THE INSTRUMENTATION

The instrumentation is divided into five parts, that on the system rig, that in the navigator's cockpit, the aircraft camera system, the height transducer, and the ground recorder system. Block diagrams are given in Figs 1 and 2.

6.1 Rig instrumentation

The system rig is described in Appendix B. Besides the FMP system and power supply it also contains the recorder junction box, which receives and scales the signals to be recorded and a 12 channel photographic trace recorder. This recorder is used during flight and records eleven functions plus a time reference/event marker trace. Details of the functions are given in Appendix C.

6.2 Instrumentation in the navigators cockpit

The instrumentation contained in the navigator's position comprises

1 Navigation system control unit. (See Appendix D)

2 Photographic Auto-observer containing
(a) Latitude and Longitude repeater unit
(b) Watch

3 Control switches for power to platform, platform heating and cameras

4 Recorder ON/OFF switch

5 Camera and tone release controls

6 Temperature indicator

7 Warning lamp indicating standby power fuse blown

8 Power switch for heating mats on electronic units

6.3 The aircraft Camera System

In addition to the auto-observer A4 camera an F24 camera is mounted in the nose viewing the forward horizon and another F24 camera is mounted in the navigator's cockpit viewing the port horizon. The whole system is controlled by a Type 35 No. 8 camera control.

6.4 The height transducer

The platform computer requires a knowledge of the approximate height of the aircraft. This is derived by a follow up servo slaved to a barometric height transducer (ALTITUDE and AIRSPEED UNIT MK.II) mounted in the nose compartment of the aircraft and connected to the aircraft static pressure line.

6.5 The ground instrumentation

The ground instrumentation is housed in a Morris Utilibus vehicle and comprises a six channel Cambridge potentiometric recorder which is fed via an impedence converting buffer amplifier which is common to all six channels. Scaling of the recorded variables is done by a system of resistance attenuators mounted with the amplifier. Details are given in Appendix E.

7 RUN-UP PROCEDURE

An exact run-up schedule will be drawn up for use before all flights. This will be compiled at a trial run-up in the aircraft, but an outline is shown at Appendix G.

8 MANOEUVRE LIMITS

It was found in laboratory tests of the platform that under certain conditions the gimbal system could topple in the looping manoeuvre. It is therefore necessary to restrict the aircraft pitch rate in the loop or LABS manoeuvres to be less than 10°/sec. This corresponds to approximately 3.5 'G' normal acceleration at 400 kts T.A.S. at the vertical portion of the loop and proportionately lower 'G' values at lower T.A.S.

9 POST FLIGHT CHECK

On arrival of the aircraft at the dispersal point after the sortie, the ground recording system will be reconnected. Provided that the system is still operating satisfactorily, the platform will be removed and the azimuth check repeated. This will give a check of azimuth drift during flight.

10 SPHERES OF RESPONSIBILITY

There are three groups concerned in this trial. Their responsibilities are as follows.

10.1 Messrs. Ferranti (Edinburgh) Ltd., are responsible for the maintenance of the platform system units. They will also provide such technical assistance during the course of the trial as is required by R.A.E. and A.& A.E.E.

10.2 R.A.E., Farnborough, I.E.E. Department, are responsible for the scientific aims of the trial.

I.E.E. are also responsible for the provision of the flying rig, navigators control unit, remote Lat/Long. display, ground recording system and the provision of the airborne trace recorder.

10.3 A.& A.E.E., Boscombe Down, are responsible for the testing of the equipment in an operating environment.

A.& A.E.E. are also responsible for the installation of the rig in aircraft VX 181, flying and day-to-day co-ordination of the trial, loading, removing and processing all recordings (including CEC recorder).

10.4 R.A.E. and A.& A.E.E. will jointly be responsible for the analysis of all recorded data, R.A.E. being mainly concerned with the detailed performance of the platform and A.& A.E.E. with the operating performance of the system.

10.5 Part II of the evaluation of the Ferranti Miniature platform, a report of the trial, will be issued jointly by R.A.E. and A.& A.E.E.

11 SPECIFICATION

There is no detailed specification for the performance of the FMP Type A. However, in order to determine the necessary performance and resolution of the trials instrumentation, the Ferranti specification for the FMP system produced against OR 356 has been taken as a guide.

This specification stated that following a normal alignment by gyro-compassing on land the position information will have an error build up of 2.5 nm/hr (2σ) assuming that the aircraft has a velocity of 500 kts. on a heading of 045°T at 45° Latitude.

Appendix A

THE FERRANTI INERTIAL NAVIGATION SYSTEM

1 THE PHYSICAL UNITS

The Ferranti inertial navigation system, as delivered to M.O.A. follows fairly closely the proposals made by the company in 1963 for a navigation system for the Buccaneer and P1154.

The system consists physically of four units

1 The platform
2 The platform electronics
3 The navigation computer
4 The power unit

The construction of all units other than the platform, is designed to give accessibility and ease of maintenance rather than small size. Conventional components in a spaced layout are used giving rise to somewhat large assemblies.

1.1 The Platform

The platform is a four gimbal unit, the stable element of which carries three gyros type 2519 made by Ferranti Ltd., and three accelerometers type 2401 made in the U.S.A. by Kearfott Ltd.

The gimbal arrangement is in the conventional order of azimuth, inner roll, pitch and outer roll. The inner gimbals are driven by direct drive A.C. motors, mounted with the gimbal bearing and slip rings in a removable gimbal bearing pack. A synchro is mounted with bearings and slip rings as another pack and each gimbal is supported by one motor and one synchro pack.

The inner cluster, or stable element, is completely enclosed in a metal canister which forms the inner roll gimbal. A recirculating fan mounted in the cluster stirs the gas filling, thus presenting a uniform environment for the inertial components independent of the heading attitude.

The inner cluster also carries the electronics associated with a proportional temperature controller and preamplifiers for the pick-offs of the gyros and accelerometers.

The complete gimbal assembly is mounted in a frame on which is mounted the size 11 outer roll servo motor generator and output synchro. The motor drives the outer roll gimbal through gears, this arrangement being dictated by the torque requirements for outer roll.

The outer frame is anti-vibration mounted inside a sealed container which houses a second fan and temperature controller, operating by controlling the flow of cooling air through a heat exchanger. The entire platform unit is sealed and filled with helium at normal atmospheric pressure.

1.2 <u>The platform electronics</u>

The electronics associated with the gimbal stabilisation, gyro motors etc. are contained in a single unit. In detail the functions included in the unit are:

1 Accelerometer capture amplifiers
2 20 kc/s carrier oscillator
3 Servo amplifiers for azimuth, inner roll and pitch servos
4 Gyro spin motor supplies

1.3 <u>The navigation computer</u>

The navigation computer unit contains the first stage integrators, second integrators and associated circuits. It also contains the timing unit and sequence unit for the erection systems. The normal controls for the system are mounted on a removable front panel but for these trials this is removed and a remote unit is connected.

The units contained in the computer box are:

1 Two first stage integrators of the "Miller" type
2 Various unity gain computing buffer amplifiers
3 Azimuth rate servo repeater, for cross-product calculation.
4 Two second stage integrators. The latitude integrator also serves as a trimming integrator during the alignment phases.
5 Precision voltage supplies for energising computing potentiometers
6 Height repeater, and multiplier for height rate
7 Precision components board, containing plug in units for setting mid-latitude and alignment modes
8 Timing and sequence control unit for the alignment system

1.4 <u>The platform power unit</u>

The platform power supplies for the sub-units are derived from a 115 v 400 c/s three phase supply which in these trials is given by an electronic static inverter. Various power lines for platform and computer are generated in the power unit, which contain fuses, relays and switches associated with these supplies.

The power unit also contains the azimuth repeater servo and amplifier, the outer roll servo amplifier, and the heading error demodulator.

The units are:

1 Input switches, fuses and control relays
2 Main power supply unit, with secondary fuses
3 Azimuth repeater and servo amplifier
4 Heading error demodulator
5 Outer roll servo amplifier

2 THE NAVIGATION SYSTEM

The navigation system is based on the assumption that the platform axes are aligned to the mass-attraction vertical and to true North, and is designed to maintain the axes in their orientation wherever the platform moves.

The accelerometer outputs are corrected for coriolis acceleration effects and are integrated to give changes in the inertial velocities from base. Earth's rate at base is added and the inertial velocities are divided by the earth's radius (corrected for height) and used to process the vertical gyros.

Earth's rate, at present position, is subtracted from the inertial velocities to give ground speeds. These are scaled to give rates of change of latitude and longitude which are integrated by electro-mechanical integrators to give changes in latitude and longitude from base. The rate of change of the direction of true North is computed and is used to process the azimuth gyro.

All functions of latitude are computed by power series approximation (to the second order) in terms of a mid-latitude and changes from this mid-latitude. Plug in units to change the mid-latitude used are available, each giving an operational range of $\pm 12^{\circ}$ of latitude, centred on the mid-latitude.

The earth radius terms in computing angular rates are corrected for height by means of potentiometers mounted on a height servo shaft slaved to barometric height.

3 THE ALIGNMENT SYSTEM

Alignment of the FMP navigator is performed in a series of stages which are controlled by an automatic system on a pure time interval basis, other than the requirement to reach operating temperature. A manual system for stepping through the sequence is provided for laboratory use, but is not available in the flight trials.

The sequence is best described as a table, see Table A1.

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Appendix A

TABLE A1 ALIGNMENT SEQ

Stage	Ferranti No.	Operations	Azimuth Rate Servo	Longitude Integrator	Latitude Integrato
OFF	1	All power off	- -- - -		
1	2	1. Rapid heaters on. (Automatically turned off when case reaches operating temperature and gyro temperature control enters normal operation) 2. Platform pitch and inner roll levelled by connecting accelerometers direct to servos. Outer roll locked to case and azimuth to external synchro by servo loops. 3. Gyros caged 4. Spin motor off		Drift Compensation	
2	3	1. Spin motor ON 2. Pitch and inner roll and azimuth as previous stage. 3. Outer roll slaved to inner roll pick-off.	Set to steady state azimuth torquing rate		Drift Compensati
3	4	1. Platform gimbals gyro stabilized 2. Acceleration torque gyros via second order loop to level system. 3. Gyro max. torque set high. 4. Vertical loop gain set to give natural frequency 16 $\sqrt{2}$ x Schuler (÷ 22s)		Earth's rate terms set up	
4	6	1. Gyro max. torque rate reduced to normal operation 2. Vertical loop gain reduced to give 11.3 Schuler.			
5	7	1. Gyro compassing loop connected 2. Platform slewed in azimuth to bring North velocity to zero. - - - - - - - - - - - - - - - - 1. Gyro compassing loop nearly settled 2. N/S gyro trimmed by pseudo gyro compass circuit	Cross product terms shaft locked	Earth's rate terms fine setting	- - - - - N/S gyro trim set
6	12	1. Minimum time in mode 5 completed.			

1

TABLE A1 ALIGNMENT SEQUENCE

Azimuth Rate Servo	Longitude Integrator	Latitude Integrator	Lat/Long. Display	Navigation Control		Notes
				Unit Display	Background	
				WU	AMBER	1. N.C.U. until operating temperature reached.
	Drift Compensation		Enter present latitude and longitude	SBY	AMBER	2. If platform is at operating temperature. 3. Move to position 2 determined by delay of 1½ mins. or operational temperature being reached, whichever is greater.
Set to steady state azimuth torquing rate		Drift Compensation		RU	AMBER	1. Time in position 2, 1½ mins.
	Earth's rate terms set up			AL1	RED AMBER	1. N.C.U. background in RED if position insertion switch is not in COMPLETED position. AMBER otherwise. 2. System holds in position 3 unless position insertion switch is in COMPLETED position. 3. Time in position 3, 1½ mins. or until released by P.I. switch.
				AL2	AMBER	1. Time in position 4, 7½ mins.
Cross product terms shaft locked	Earth's rate terms fine setting	N/S gyro trim set		GYC	AMBER	1. Time in position 5(i), 7½ mins. 1. Time in 5(ii), 7½ mins - Total time position 5, 15 mins.
				GYC	GREEN	1. Background changing to GREEN indicates system aligned

TABLE A1 ALIGNMENT SEQUENCE (Con

Stage	Ferranti No.	Operations	Azimuth Rate Servo	Longitude Integrator	Latitude Integrator
7	10	1. Navigate mode 2. Vertical loops set to 1 x Schuler 3. Azimuth precessed to keep North stabilized.	Set to Earth rate + transport rate	Giving present position	Giving present position
8	Rundown	1. All system power switched OFF 2. Sequence unit resets back through stages 7 to OFF			

1

TABLE A1 ALIGNMENT SEQUENCE (Continued)

uth e vo	Longitude Integrator	Latitude Integrator	Lat/Long. Display	Navigation Control Unit Display	Navigation Control Background	Notes
o n + port	Giving present position	Giving present position	Present position indicated	NAV	GREEN	
			Position at pushing RD button	Various	BLUE	1. N.C.U. indicates stages as reset on BLUE background. 2. BLUE 'RUNDOWN' lamp lights until OFF is reached when indicator and lamps extinguish. 6 mins. to switch OFF.

Appendix B

THE SYSTEM RIG

The system rig was designed by I.E.E. Department, Royal Aircraft Establishment, Farnborough, and consists of an aluminium alloy frame designed to carry the platform, its associated electronics and computer, recording equipment and power supply. The rig is mounted on a steel carrier which then engages with the bomb slip in the flare bay of the aircraft (Fig. 2). Photographs showing the system rig are given in Fig. 4.

The various items carried by the rig are given BOX numbers to follow the Ferranti practice.

BOX 01	C.E.C. photographic recorder	
BOX 02	Recorder junction box. Contains scaling networks for recorder galvanometers, control circuits for recorder lamp and synchro demodulators for bank and elevation recording.	
BOX 03	Power switch	
BOX 04	Diodes and fuse for automatic reversion to standby	
BOX 05	Standby battery	
BOX 06	Static inverter EKCO type 222 500 vA 3ø 115 v 400 c/s for all system	
BOX 07	Connector panel for ground recorder and boost heat power	
BOX 08	All aircraft connections	
BOX 09(a)	Fuse panel for d.c. lines	
BOX 09(b)	Fuse panel for external a.c. lines and changeover switch for blower unit	
BOX 10	Power factor correction capacitors for blower fan	
BOX 11	Reservoir capacitor for static inverter	
BOX 12	Differential synchro unit to align G4B datum and platform azimuth datum	
BOX 20	Blower unit type LK804-X3 for supply of cooling air to platform	
BOX 21	Platform	Units supplied by Ferranti Ltd.
BOX 22	Platform electronics	
BOX 23	Platform power supply	
BOX 24	Platform navigation computer	

It should be noted that the rig carries reserve power in case of failure of the primary aircraft supply and gives approximately 30 mins. reserve at high altitude and somewhat longer time at lower altitudes when the flare bay temperature rises toward normal.

To combat the effects of low temperatures on the electronic systems heater mats are fitted to the top and bottom of boxes 22, 23 and 24. These are thermostatically controlled at +10°C and are powered by a single phase 115 v 400 c/s supply from the aircraft. It was subsequently found necessary to fit heater mats to the platform as well, as the heat loss from the platform was greater than expected.

A block diagram of the rig is included in Fig. 1.

Appendix C

THE AIRBORNE RECORDER SYSTEM

The airborne recorder is a twelve channel photographic recorder Type 5-118 AP.3 made by C.E.C. (Consolidated Electrodynamics Corporation). On $3\frac{1}{2}$" paper it is able to record eleven functions plus a time/event marker. The recorder body, housing the galvanometers and lamp is permanently mounted in the rig. The magazines, which also contain drive motors, are removable. Two magazines are used which run at different speeds, viz. $\frac{1}{8}$" and $\frac{1}{2}$" per second. Each magazine holds 60 ft of paper, giving approximately 96 mins. of recording at $\frac{1}{8}$"/sec or alternatively 24 mins. at $\frac{1}{2}$"/sec.

Fifteen functions are available in the recorder junction box for recording. Eleven of these are selected by wiring the galvanometer feeds inside the box. Changing functions merely involves removing the appropriate loads and reconnecting them to alternative pins in the junction box.

The functions available for recording are:

1 Platform temperature control current
2 Box 22 temperature
3 Box 23 temperature
4 Box 24 temperature
5 NS accelerometer output
6 EW accelerometer output
7 NS inertial velocity
8 EW inertial velocity (minus base inertial velocity)
9 EW ground speed
10 Azimuth precession rate
11 Error between azimuth of platform and given datum synchro
12 +9v reference voltage
13 -9v reference voltage
14 Height pot output from Alt and Airspeed Unit
15 Height servo output

In the initial phases of the trial the functions recorded are:

Channel	Function	Approx. Scale	Full scale range
1	Time and Camera event		
2	X acceleration (E/W)	3.5 g/in	± 4.5g
3	Y acceleration (N/S)	3.5 g/in	± 4.5g
4	Azimuth precession rate	2°/hr/in	± 2.5°/hr

Channel	Function	Approx. Scale	Full scale range
5	Bank	5.1°/in	± 6.4°
6	Elevation	5.4°/in	± 6.75°
7	Platform temperature control current	100 mA/in	0.250 mA
8	Box 22 temperature		0 - 20°C
9	X velocity (E/W)	750 fps/in	
10	Box 23 temperature		0 - 20°C
11	Y velocity (N/S)	750 fps/in	
12	Box 24 temperature		0 - 20°C

Full scale deflection is approximately ±1.25"

Appendix D

NAVIGATORS CONTROL UNIT AND LATITUDE/LONGITUDE REPEATER UNIT

As supplied by Ferranti, control of the platform was performed by use of a control panel on the front face of Box 24, the navigation computer. Output of position is by reading "gas-meter" type dials mounted in Box 24 and read from the top. These facilities were not suitable for use in the Canberra flare bay, so remote units were constructed by I.E.E. Department, Royal Aircraft Establishment.

1 NAVIGATOR'S CONTROL UNIT

By removing the test facilities and the azimuth datum synchro, and by combining most of the indicator lamps into a central display, the control panel of the system was reduced to a box 4" x 5" deep, suitable for mounting in the navigator's cockpit. The unit has the following control and displays.

1. Three buttons, marked START, NAV, RUNDOWN. These control the various phases of operation of the system.
2. A toggle switch, marked "POSITION SET" and "POSITION SET COMPLETED" and two rotary switches marked LAT/FAST-SLOW-OFF-LONG/FAST SLOW and DEC-OFF-INC
   These are used for the insertion of base position into the computer.
3. Two warning lamps, marked INT. END STOP which lights if a fault develops in the position computer and RUNDOWN which lights when the system is switched off and the automatic alignment system is resetting to the START condition.
4. A central projection display which indicates by a series of symbols on coloured backgrounds the state of the system. These are given in TABLE 1.

1.1 Operation of the N.C.U.

After power is applied to the rig, the aircraft compass system should be set to the true aircraft heading. The platform system is then switched on by pressing the red START button, whereupon the control display should light with the symbols WU or SBY on an AMBER background.

When operating temperature has been reached in the platform the display will change to RU on AMBER background, and after 1½ mins will change to ALI.

If position has not been inserted and the switch is in POSITION SET position, the background will be RED and the system will hold in this position. Otherwise the background will be AMBER, and at the completion of 1½ mins. delay and if the switch is in the "COMPLETED" position, the indicator will change to AL2 on an AMBER background. After 7½ minutes the indicator will change to GYC on AMBER, and after a further 15 mins. the background will change to GREEN, indicating that the alignment is completed. Pressing the NAV button will switch the system to the normal navigating mode, and the display will show NAV on a GREEN background.

The system is switched off at any stage by pressing the RUNDOWN button. This cuts power to all the system except the sequence unit. The central display will show the stage of alignment reached on a BLUE background and the BLUE "RUNDOWN" lamp will light. The sequence unit then runs back through the alignment sequence, taking approximately ½ minute per step and indicating the stages on the central display. When it reaches the OFF position the power to the sequence circuit is also removed, resulting in a complete system switch off and extinguishing of the N.C.U. displays.

<u>NOTE</u>: If power is removed from the system other than by RUNDOWN then it cannot be restored except by pushing the RUNDOWN button, (although the N.C.U. will indicate normal operation) allowing the sequence unit to run back to OFF and then pushing the START button. The START button has no affect unless the system is in the OFF state.

2 <u>THE LATITUDE AND LONGITUDE DISPLAY UNIT</u>

The lat/long. display unit is designed to repeat the displays shown by the second integrators in BOX 24, the navigation computer.

The displays are servoed to a synchro which rotates one revolution per minute of arc of latitude or longitude, and show the number and fractions of minutes of arc from a datum position which for these trials corresponds to 40° 00'00" N,00° 00'00" W. The sense of the displays is such that they increase for travel in North and West directions. The remote displays are initially synchronised with the main integrators before mounting the rig in the aircraft. Thereafter all setting of the integrators is performed by observing the remote display.

During the alignment sequence the displays are set to present position by slewing the main system integrators by means of the switches on the N.C.U. Two slewing rates are available, in each channel.

A power interlock system is set so that the FMP system cannot be switched on unless the lat/long. repeater is connected. This was designed to prevent desynchronising the display from the main integrators.

Appendix E

THE GROUND RECORDING SYSTEM

The ground recording system is intended to be used to monitor the alignment of the platform system and to check the operation after flight. The equipment consists of:

1. A six channel potentiometer recorder (CAMBRIDGE INSTRUMENTS TYPE DE) which samples six quantities in an eighteen second cycle. The six channels are recorded as coloured dots on 8 inch wide paper.
2. A buffer amplifier (DYMEC TYPE DY-2460A with plug in unit M4) which is used as a unity gain impedance converter. The single amplifier is used to buffer each channel in turn, and presents an input impedance of the order of 10^{10} ohms whilst driving the recorder at an impedance of a few milliohms.
3. Scaling networks to give appropriate scaling of the recorded signals.
4. A datum synchro, set to the survey heading, so as to produce an output from the platform heading error demodulator which is zero if the gyro-compassing is perfect, and a d.c. signal proportional to the error if it is not.
5. A selector switch to allow the G4B synchro to be used in place of the built in datum for the initial system alignment.
6. A valve voltmeter (PHILLIPS TYPE GM 6020) to read to gyro-compassing error.

The recording equipment is housed in a Morris Utilibus vehicle which can also be used to carry the complete FMP system in its airborne rig. A single cable connects the recording system to the aircraft rig, and another cable couples the main power supply, which is ½ amp. at 230V 50 c/s. An alternative 50 c/s supply from a battery driven rotary inverter is available in the van when the main supply is not available.

Quantities available to be recorded by the ground system are:

1. NS accelerometer output
2. EW accelerometer output
3. NS 1st stage integrator O/P
4. EW 1st stage integrator O/P
5. EW ground speed
6. Azimuth precession rate

7 Azimuth error signal
8 Height servo O/P
9 Height from Alt/AS unit
10 +9v reference voltage
11 -9v reference voltage

Experience in the laboratory has shown that it is sufficient to record only four of these signals. The others are available by changing over leads in the box holding the scaling networks. The functions recorded are:

TABLE 2

CHANNEL	COLOUR	FUNCTION	SCALE (FSD)
1	RED	AZ PREC.	$\pm 25^{\circ}$/hr biased by 10°/hr.
2	BLACK	ZERO	
3	GREEN	NS INT. O/P	±1 v (ALIGN) ± 5 kts (CHECK) ±50 kts (ALIGN) ±500 kts (FLIGHT)
4	MAUVE	ZERO	
5	ORANGE	EW INT. O/P	as CH 3
6	BLUE	AZ ERROR	±200 arc mins.

Appendix F

TECHNIQUE FOR OBTAINING ERRORS IN POSITION

1 This technique was evolved during a trial in May and June 1964 at A. & A.E.E., Boscombe Down. The aircraft was Canberra PR3 VX 181.

2 The aircraft equipment is as follows:

- a Tone release circuit
- b Standard aircraft VHF unit
- c T35 No.8 camera control
- d A4 camera photographing platform position

3 The ground equipment is as follows:

- a FPS 16 radar
- b FPS 16 recorders
- c Century Timing unit (CTU)

(a–c) All at R.A.E. Aberporth

4 Referring to fig. 7 the sequence using a 30 second time interval is as follows:

t = o T35 pulse transmitted to tone release circuit. 1KC tone pulse is transmitted on VHF carrier. Leading edge of this pulse triggers CTU and FPS 16 recorders at Aberporth.

t = +1 Tone switches off and in doing so operate a relay which fires the A4 camera, simultaneously marking an event in the CTU trace.

t = +2 FPS 16 recorders switch off.

5 A "fit of best straight line" technique around the event marker is used to produce datum derived aircraft positions for t +1, t + 31 etc. and thus synchronised platform and aircraft positions are obtained every 30 seconds.

6 The trials flight route is shown in fig. F2 and consists of four runs each approximately 150 miles in length, (A to B, B to C, C to A and A to B). A 7 minute orbit is flown at the end of each run to allow resetting of FPS 16 recording system.

7 The positions in Aberporths range co-ordinate (x, y, z) are processed by a ground computer to obtain aircraft position in a form directly comparable with the platform position output of departure in minutes of lat. and long. from the reference datum

$$40^\circ\ 00.00'\ N,\quad 00^\circ 00.00'\ W.$$

8 The following results can be extracted from this comparison:

a N/S channel position error of the platform

b E/W channel position error of the platform

c Radial position error of the platform

d Error rates of a, b and c.

Appendix G

OUTLINE OF THE PLATFORM RUN-UP PROCEDURE

1 The aircraft will be parked at the dispersal near to the point from which accurate bearings may be taken.

2 Ground power, 28v d.c., is connected to the aircraft and 115v 400 c/s 3 phase a.c. to the boost heat connector of the rig.

3 The navigator will select "Position Set" on the Navigator's control unit then switch on 28v d.c. to rig. He will then push the "START" button on the N.C.U.

4 When the N.C.U. indicator indicates RU (run-up) on the AMBER background the navigator will set the Latitude and Longitude readings of the remote display panel to base values by means of the slewing switches on the N.C.U.

5 When this has been completed, the navigator will then place the "POSITION SET" switch in the "COMPLETE" position. Alignment will not proceed until this is done.

6 The system then will complete the alignment, including azimuth alignment by gyro-compassing, indicating the completion of the sequence by displaying the letters GYC on a GREEN background.

7 When the alignment is complete, the navigator will press the "NAV" button on the N.C.U. The system will then be in the NAVIGATE mode.

8 The platform will then be removed from the rig whilst still running, and be placed on a tripod stand near the aircraft.

9 It will then be turned onto a specified heading (checked by the theodolite) and the output of the azimuth check system will be noted.

10 The platform will then be replaced in the aircraft rig.

11 The ground recording system and 115v boost heat supply will be disconnected.

12 The aircraft is then free to proceed with the sortie.

REFERENCES

No.	Author	Title, etc.
1	J. S. Preston	Trial of a photographic attitude and heading reference technique. A.&.A.E.E. Report AAEE/Tech/228/NAV July 1964
2	J. S. Preston, and R. H. Evans	Evaluation of a stable platform Type FSP 100 in a manoeuvrable aircraft. Report No. A.A.E.E./Tech/240/Nav. (R.A.E. Tech. Note I.E.E.23) April 1964
3		Trial Specification for FPS 16 Radar procedure trials A.A.E.E. Trial Specification No. X0412 March 1964

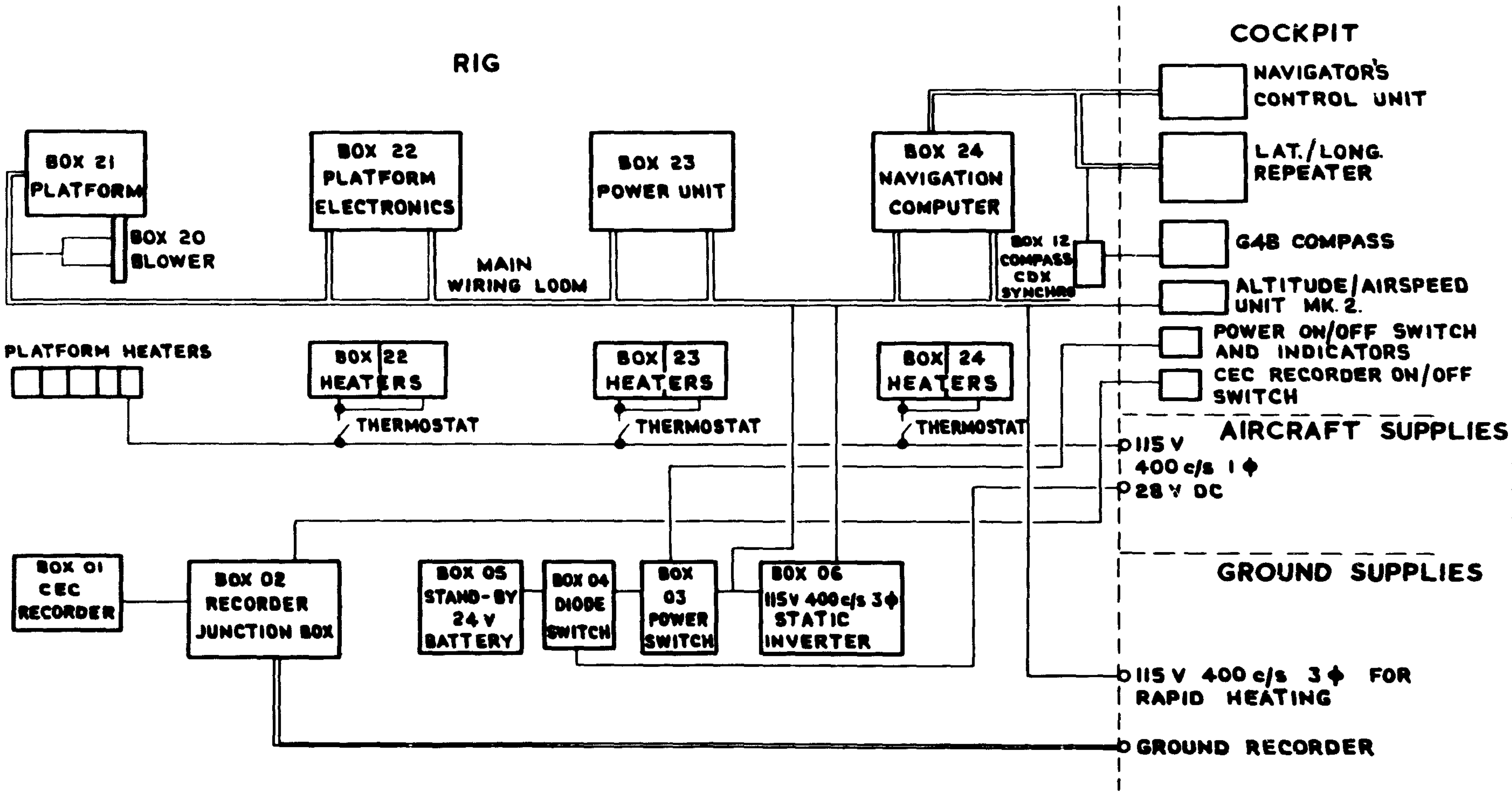

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FIG. 1 SYSTEM RIG BLOCK DIAGRAM

Fig.1

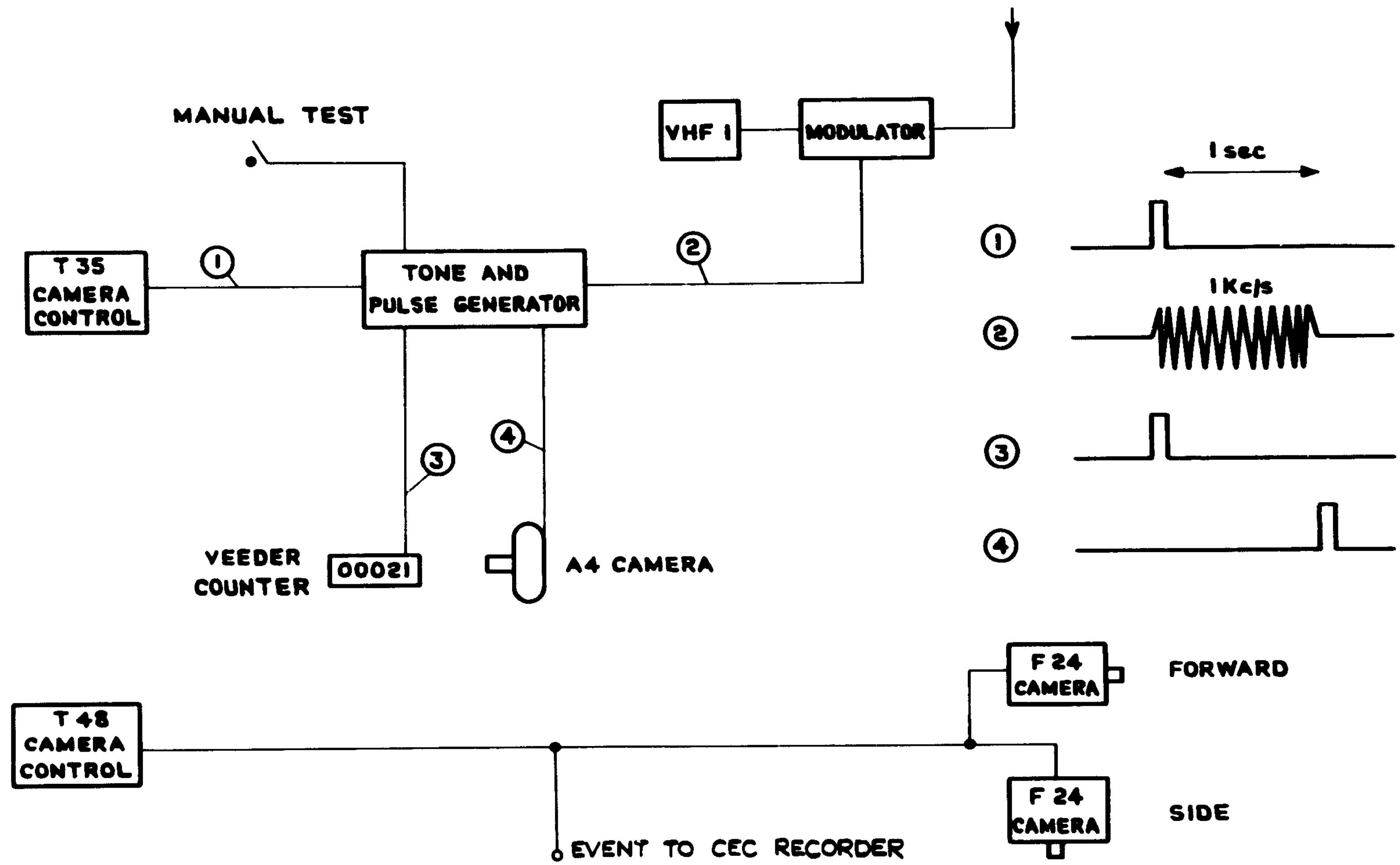

FIG. 2 AIRCRAFT CAMERA AND TONE SYSTEM

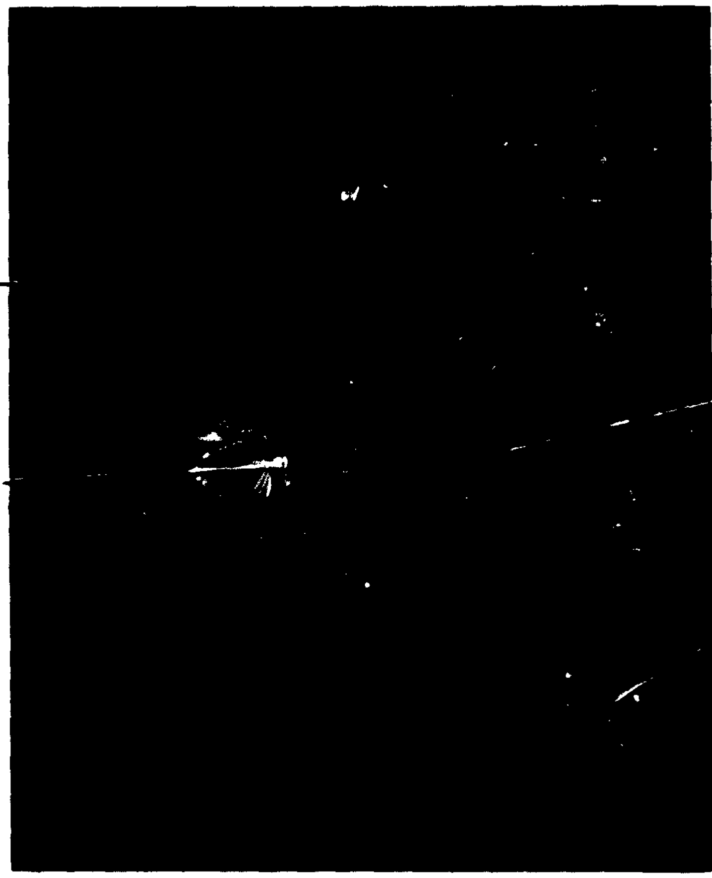

Fig.3 System rig in aircraft flare bay

Fig. 4a

Neg. No. C381

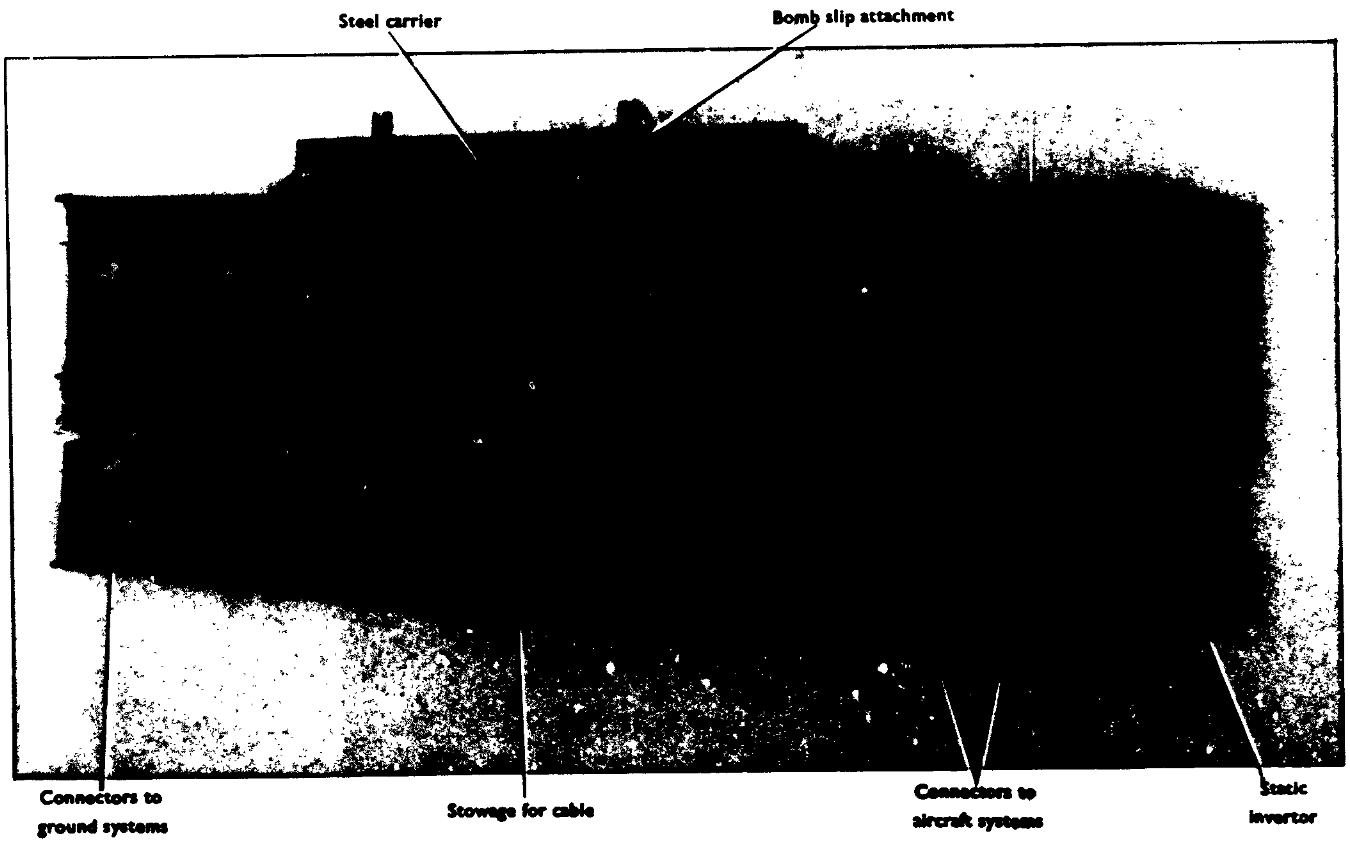

Fig.4a Starboard side of system rig

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Fig. 4 b & c

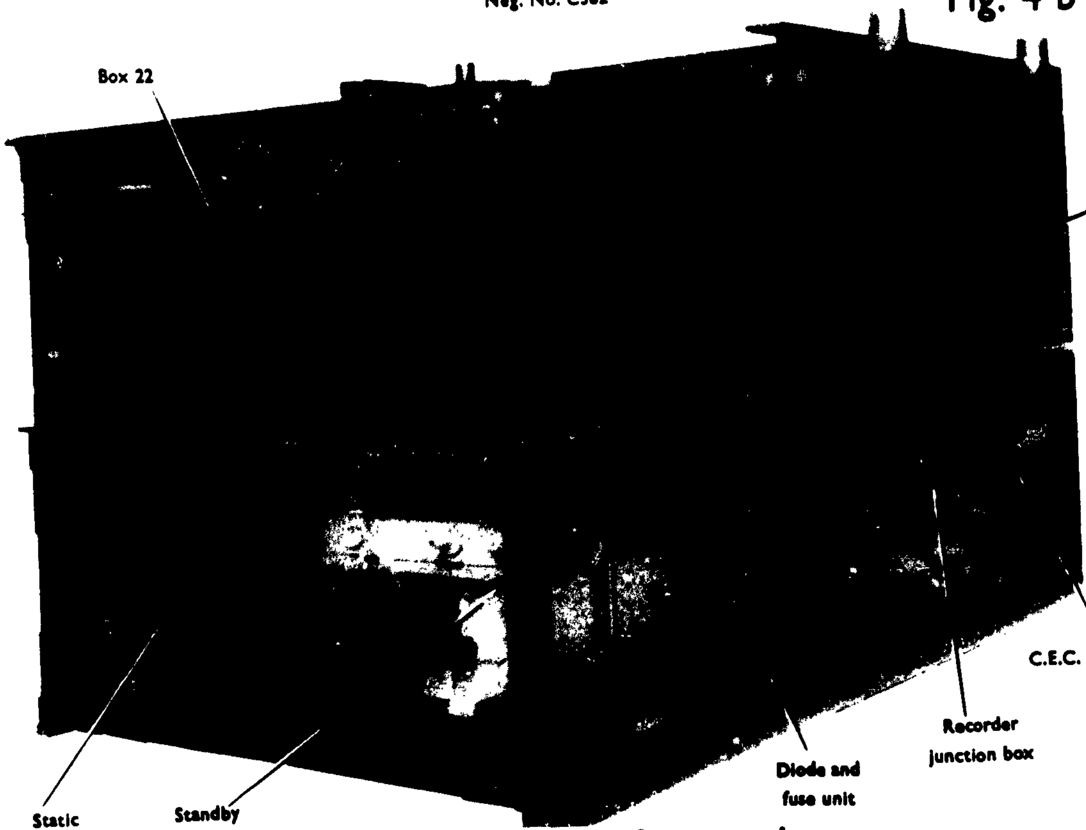

Fig.4b Front end of system rig

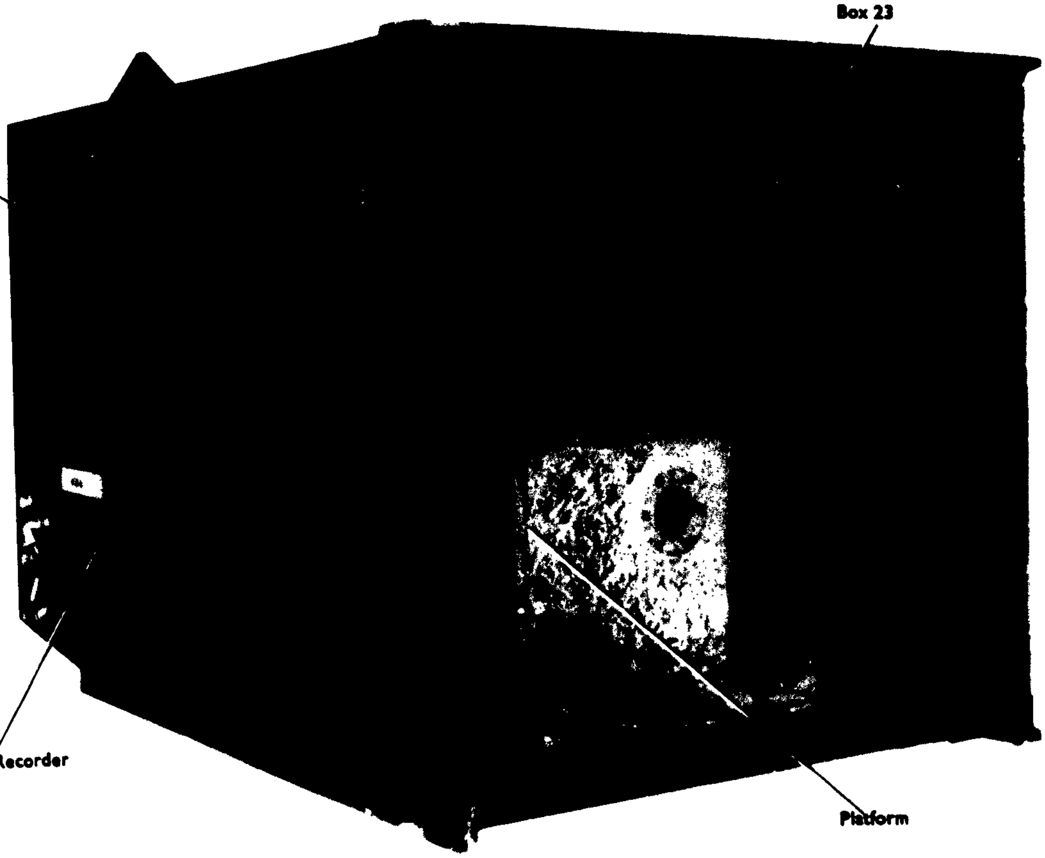

Fig.4c Rear end of system rig

Fig.5

Neg. No. C383

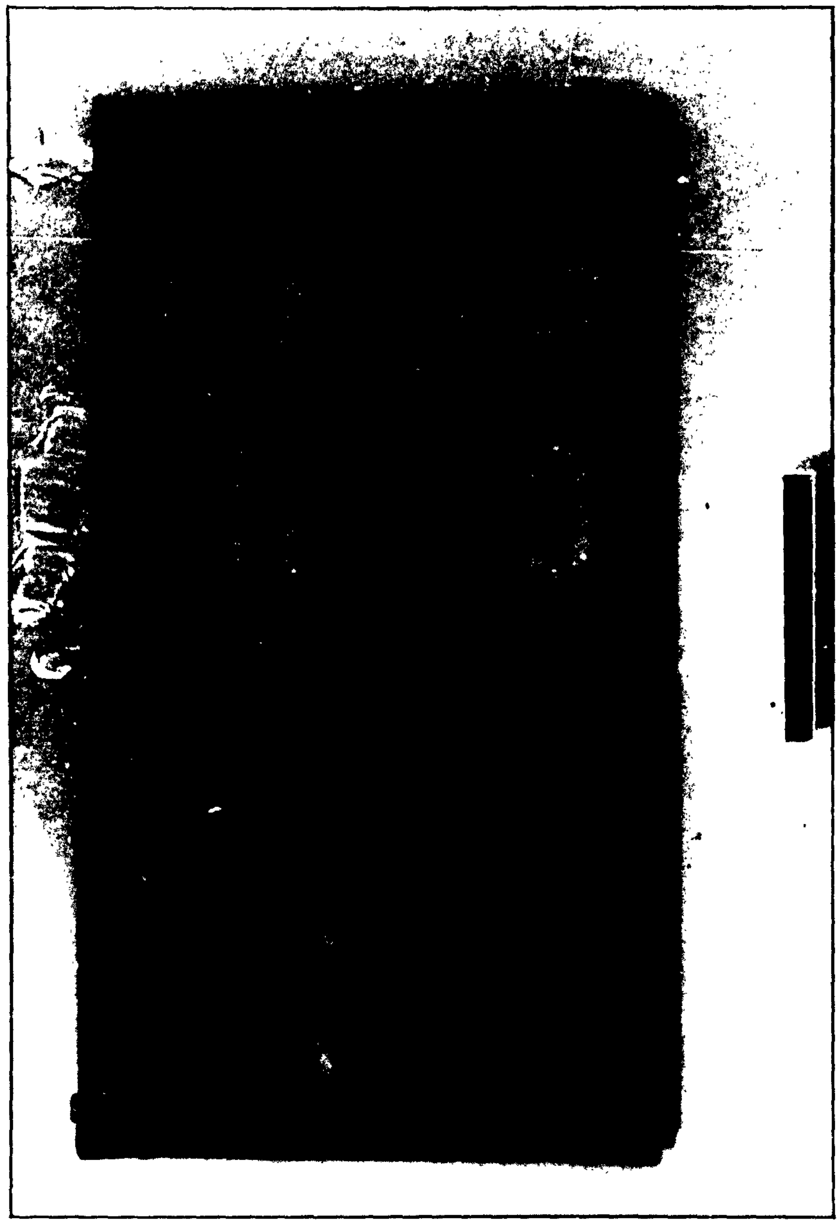

Fig.5 Navigators control unit and lat/long repeater

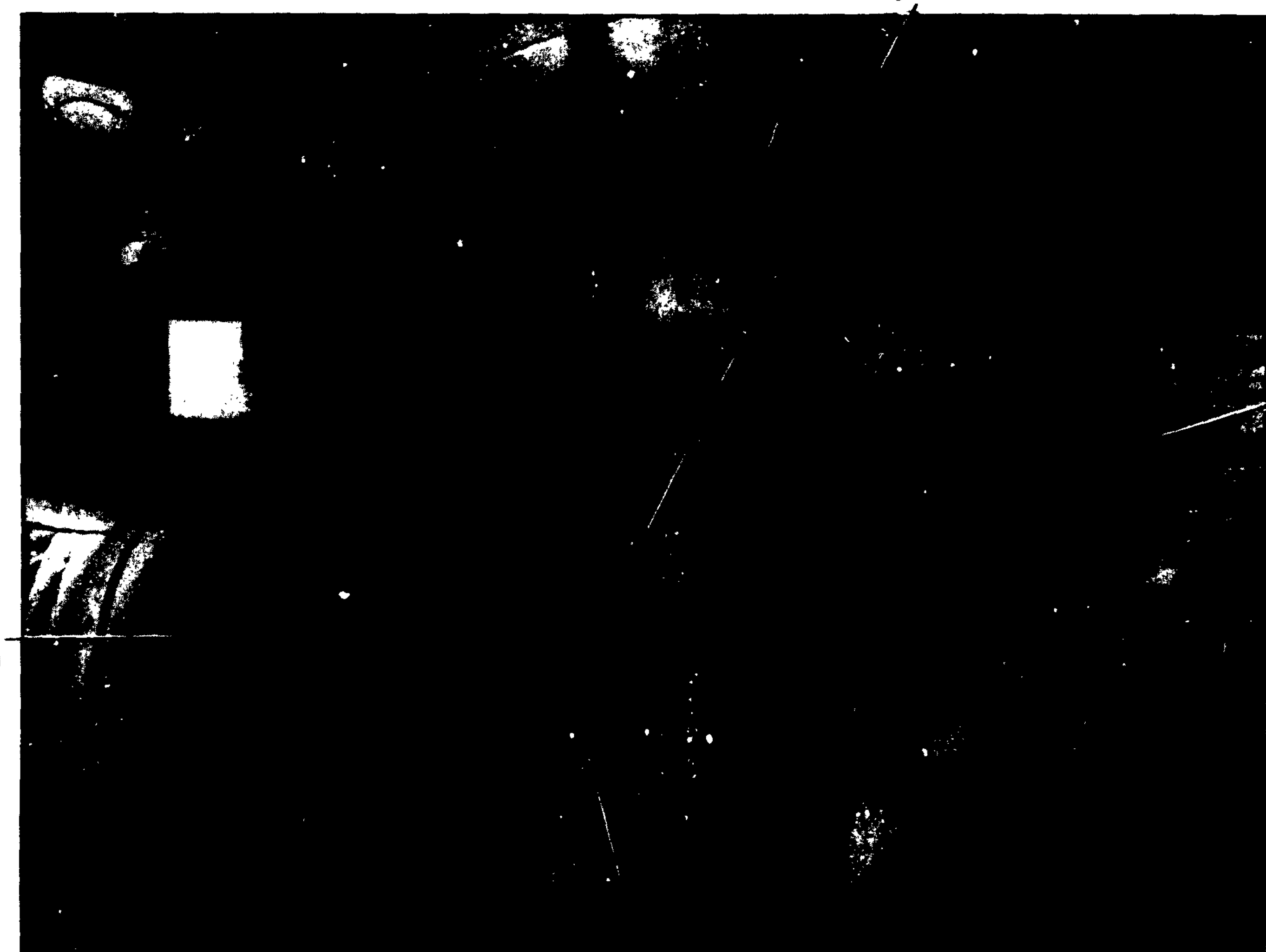

Fig.6 Ground recording system

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Fig.6

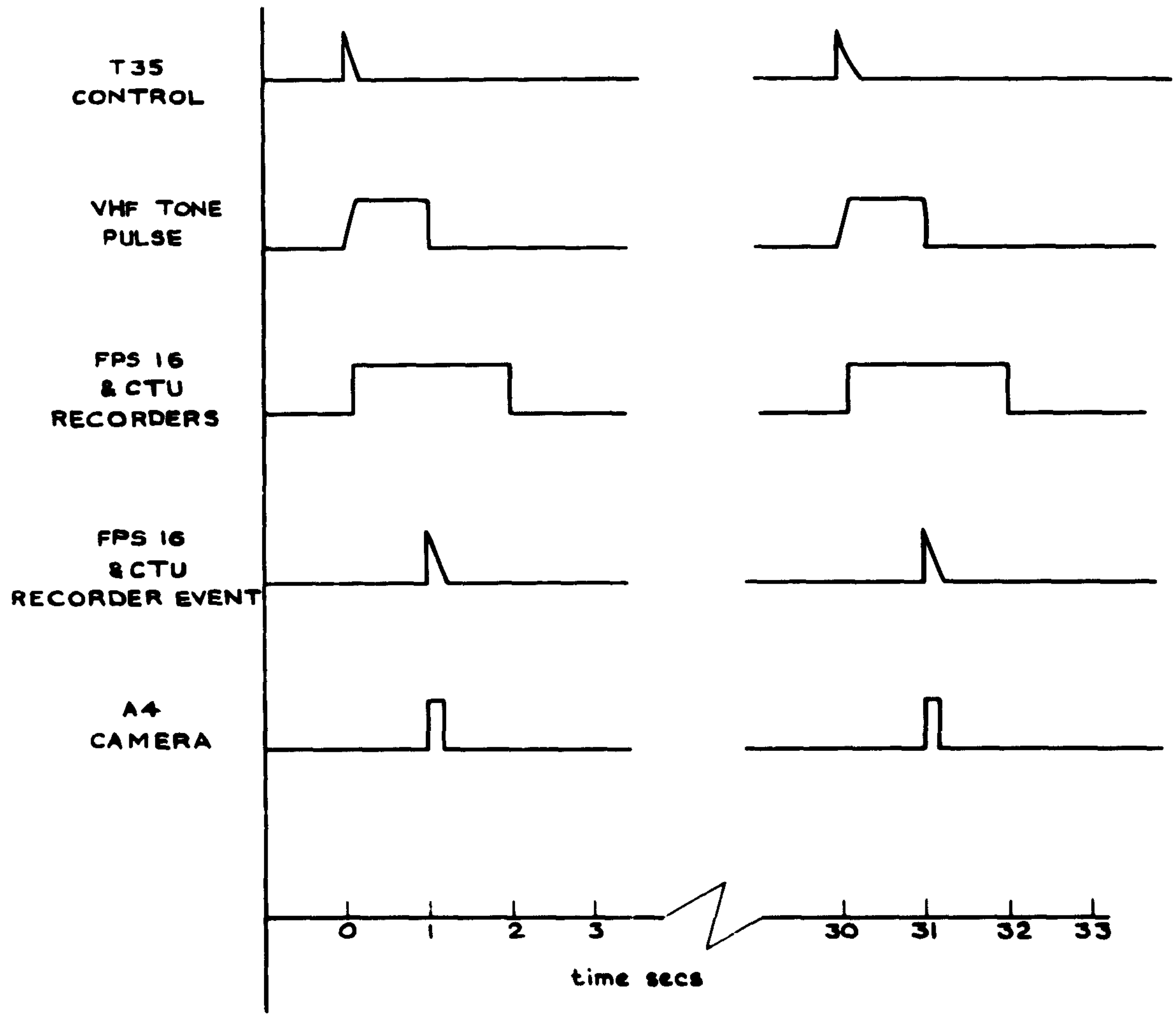
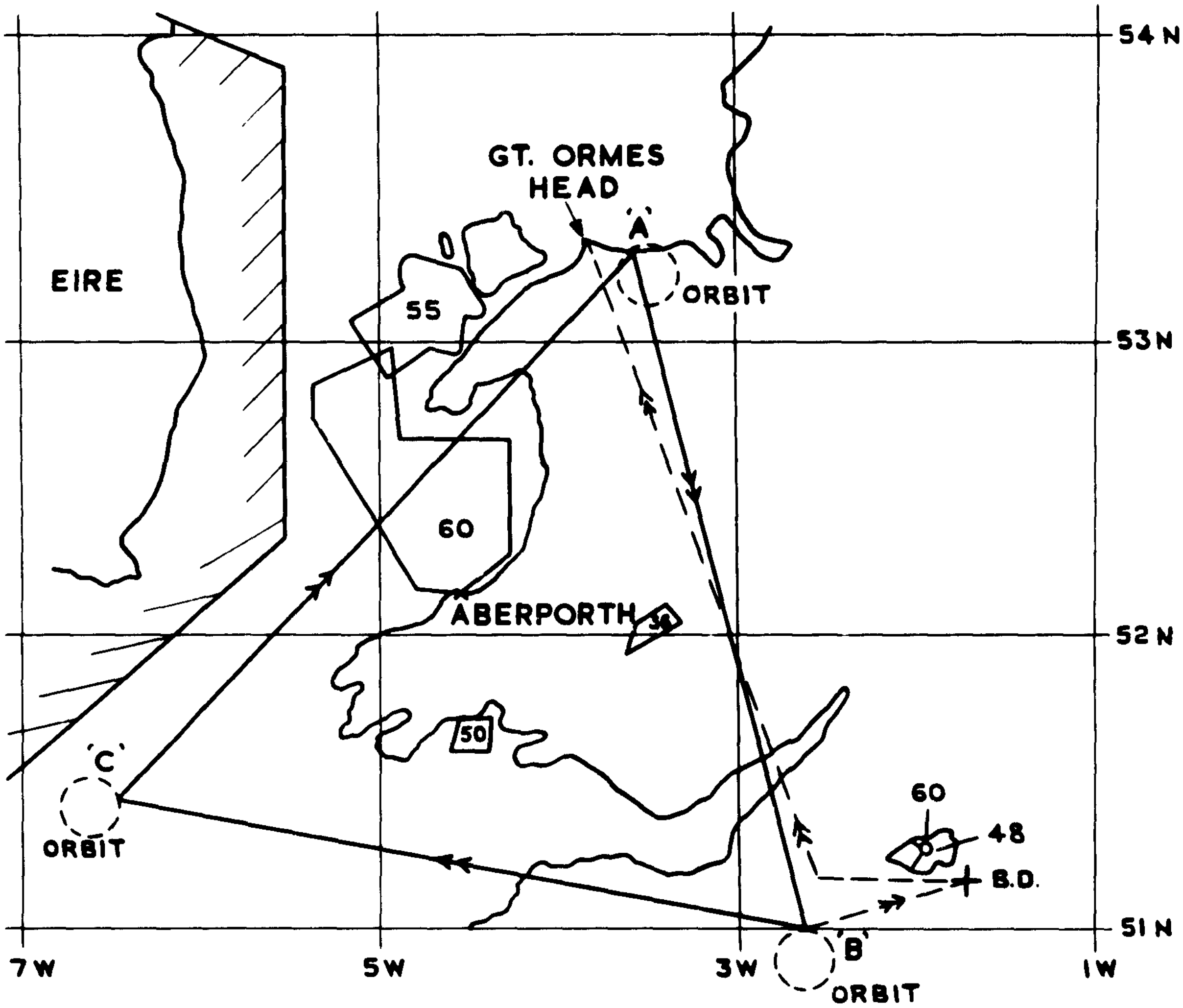


FIG. 7 TIMING SEQUENCE FOR CAMERA AND TONE



NOTE :-

A	BEARS	027·1° T / 156,810^{x}	FROM OPO
B	"	132·3° T / 200,194^{x}	"
C	"	239·7° T / 170,592^{x}	"

FIG. 8 TRIALS FLIGHT ROUTE

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