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TERMINATION REPORT
ON THE
GG63 MINIATURE STABLE PLATFORM
FOR THE
ASTRA VERTICAL AND HEADING REFERENCE
SYSTEM
OF THE
CF-105 AVRO ARROW AIRCRAFT
CR-ED 1065 June 16, 1959

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Signature B.M. Suchulan Rank S/L

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GG63 MINIATURE STABLE PLATFORM

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MILITARY PRODUCTS DOCUMENT CR-ED 1065

JUNE 16, 1959

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ILLUSTRATIONS

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FOREWORD

This represents one of four documents related to the Astra Vertical and Heading Reference System as prepared by Honeywell Controls Limited in accordance with the requirements of Section 2(a) of Contract CD/DRB 819009/0013/719-16-30-601, DDP Serial Number 2-PF-8-13.

It is recommended that this report be read in conjunction with the following Honeywell Controls Documents:-

CR-ED 1041 Termination Report on the DG6000 Three Axis Repeater for the Astra Vertical and Heading Reference System of the CF105 Avro Arrow Aircraft

CR-ED 1066 Termination Report on the Stabilization Repeater for the Astra Vertical and Heading Reference System of the CF105 Avro Arrow Aircraft

CR-ED 1067 Termination Report on the Platform Computer for the Astra Vertical and Heading Reference System of the CF105 Avro Arrow Aircraft

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2 BACKGROUND

2.1 Need for All-Attitude Master Reference

The need for a miniature all-attitude master reference had been evident for some time before the development for the Arrow Aircraft was started. Modern high performance aircraft were increasing the premium on size and weight of aircraft equipment, as well as in their ability to operate under the most adverse environmental conditions. Miniature floated gyro developments had made the development of a small, light-weight stable platform of sufficient ruggedness and accuracy feasible for use in indication, bombing manoeuvres, autopilot reference and missile applications.

2.2 Design Concepts

The design of the master reference system required the simultaneous consideration of a multitude of requirements, many of which were conflicting. In the remaining part of this section, mention will be made of the more important of these considerations, and how any conflicts were resolved.

The following features were considered basic requirements for the master reference or vertical and heading reference system:-

a) An accurate earth reference coordinate system must be established for comparison with aircraft coordinates.

b) An accurate means must be established for platform gimbal position indication.

c) The platform shall be small and light.

d) The platform shall allow full manoeuverability freedom (all-attitude).

e) The platform gyros shall be negligibly affected by temperature, altitude, moisture, shock and vibration.

f) The platform must operate directly from the aircraft A-C power supply.

g) The platform shall be potentially operable in aircraft up to Mach 3 or 4 with no limitations on performance due to platform components.

2.3 Platform Design Considerations

This section discusses in a qualitative manner the major considerations for the design of the miniature all-attitude stable platform.

2.3.1 Mechanization of the Platform

A four gimbal platform with one servo-driven auxiliary gimbal is a minimum requirement to provide complete freedom of air frame manoeuvering without gimbal lock. The platform described was pivoted from the inside out in heading, inner roll, elevation and outer roll. All gimbals had complete 360° freedom, with the exception of the limited freedom inner roll gimbal. The outer roll gimbal (Auxiliary Gimbal) was driven from a synchro transmitter on the inner roll gimbal so as to maintain inner roll normal to the pitch gimbal. Indicator requirements determined the order of the gimballing. The arrangement of the platform is shown pictorially in Figure 1.

A complete dynamic analysis of the four gimbal stable platform was performed and involved the determination of the input signal to each gimbal torque motor. For the three inner loops, the general torque motor inputs were expressed as a function of the gyro output signals and relative gimbal attitudes. The outer gimbal torque motor input was expressed as a function of the inner roll relative angle and the relative gimbal attitudes.

In connection with platform gimballing and servos, it was pertinent to consider whether the platform could be stabilized primarily by the inertial rigidity of the gyros, or whether the gyros must be used merely as a sensing device with the platform gimbals positioned by a servo system. Direct stabilization using the inertial rigidity of the gyro first looked quite attractive because of the less severe servo requirements. However, a thorough analysis was performed and the conclusion was reached that the complexity of obtaining adequate damping in the platform gimbal loop outweighed the apparent advantages of direct gyroscopic platform stabilization.

It was Honeywell's conclusion that only a floated gyro would adequately fulfill the requirements for accuracy, small-size and almost complete immunity to environmental conditions. Further, if the platform itself was to be free from the effects of moisture, altitude and salt spray, it must have an environmental proof seal that can be removed for servicing. Environmental proof sealing was selected in lieu of hermetic sealing since it would provide easier fabrication and service, and since a true hermetic seal is not required to obtain the best possible results from a platform. The benefits of a true hermetic seal are lost in a container with any appreciable amount of organic material present.

The recently designed Miniature Integrating Gyro (MIG) was the obvious choice for stabilizing the platform. The MIG is a floated gyro of extremely high quality and ruggedness. The GG49 MIG is about 1.75 inches in diameter and 2.6 inches long. It weighs about 8 ounces. Random drifts under trim approach 0.1 degrees per hour.

There are basically two possible arrangements for the components on the central platform. One of these takes the shape of a dumbbell and is particularly applicable when the components may be divided into two groups of almost equal size and weight. This configuration will allow the smallest possible complete platform to be assembled around it, as long as the inner roll gimbal is allowed only limited freedom. However, the complexity associated with this configuration also makes it the most expensive and difficult to manufacture. The other arrangement of the components on the central platform is obtained by arranging all of the parts in essentially a short cylinder with the smallest possible diameter. This is simple and economical, and the penalty in size and weight is not great. The cylindrical configuration was, therefore, proposed for this sytem.

2.3.2 Mechanical Design

2.3.2.1 Gimbal Configuration

Because of the considerable reduction in size and weight obtainable through the use of a rectangular gimbal configuration rather than a spherical gimbal configuration such a rectangular configuration was chosen. Vibration testing indicated little difference existing between the rectangular and spherical configurations.

2.3.2.2 Gimbal drive motors

DC direct drive motors were chosen over geared drive torque motors because of the higher torquing capabilities at a reduced power level. It was noted that the use of a geared-drive torque motor had a slight weight advantage over the use of a direct drive torque motor; however, the gear-drive resulted in a platform package increased in volume by more than one and one-half times that of the direct drive.

2.3.3 Gimbal Pickoffs

It was concluded that it was not practical to use potentiometer type pickoffs on the gimbals to provide angular information and synchros were, therefore, selected. Weight and size considerations dictated the use of pancake type synchros.

2.3.4 Repeating of Platform Angles

Since synchro transmitters alone would not be able to drive an indicator with the required accuracy, a repeater servo was required to repeat platform angular positions for each axis. These three repeater servos were packaged together into the DG6000A-1 Three-Axis Repeater.

To provide correct information to the platform gimbal servo motors, at all airframe attitudes, pitch and roll gyro information must be resolved according to heading angle. Also, a four gimbal platform requires the introduction of elevation angle information into the outer gimbal loop for stabilizing purposes; this information was supplied by a secant potentiometer. Thus heading and elevation information is required for proper operation of the platform itself.

Initially, it was decided that this heading and elevation information would be supplied by a separate platform repeater. Subsequently, it was decided to place the resolver and secant potentiometer on the Three-Axis Repeater. However, further modifications of system requirements dictated that the resolver and secant potentiometer be placed on the heading and elevation gimbals respectively of the platform proper.

2.3.5 Platform Component Packaging

At the outset it was planned that the platform and its associated circuitry would be packaged together. However, further consideration indicated that the platform and circuitry should be packaged in two basic modules;

a) The mechanical platform itself, consisting of the gimbal structure, gimbal servo motors, gimbal transmitters, gyros and accelerometers.

b) The platform amplifier assembly containing the associated electronics.

This separation resulted in maximum flexibility. In order to reduce further the size and weight and to improve reliability, increase resistance to shock and vibration, and reduce power consumption, transistor amplifiers were used for all functions of the basic platform. Each of the individual circuits in the platform amplifier assembly were potted in hermetically sealed modules, thus allowing any circuits to be removed and replaced, without disturbing others.

2.3.6 Power Supply Compensator

Gyros of reasonable precision must usually be operated on a power supply which is regulated in both frequency and voltage. This necessitates a precision power supply which is usually quite complex and a potential reliability problem. To overcome this, Honeywell developed a simple magnetic device which enables the gyro to be precisely compensated for earth rate, Coriolis acceleration signals, and aircraft velocities, even with the power supply of poor frequency and voltage regulation. This device produces a direct current output that varies as a linear function of applied AC frequency but is not sensitive to applied AC voltage. This frequency sensitive direct current is used as a torque reference current. Since the angular momentum of the gyro wheel operating at its synchronous speed also varies as a linear function of frequency and is insensitive to applied voltage, quite adequate regulation was obtained with this type of compensator.

2.3.7 Shock Mount Considerations

Although it was initially considered desirable to provide shock isolation mounts on the platform, it was found that degradation of platform accuracy could result in two ways:

a) Hysteresis and unequal spring rates of the individual mounts effectively changed the platform alignment relative to the air frame during and after linear accelerations.

b) Individual mounts invariably resonated at slightly different frequencies and with differing damping.

The net result is an artifical input to the platform under extreme vibration conditions. On the basis of these considerations then, the platform was to be mounted directly to the air frame.

Honeywell was cognizant of the fact that when any gimbal device is suspended by pivots and the compliances of the gimbals are not the same in all directions, then applied linear vibrations will be rectified and will produce a constant turning moment on the gimbal. Anisoelastic torques were, therefore, kept below a level compatible with the torque capabitilies of the gimbal servo motors.

2.4 System Design Considerations

The following sections will describe those aspects of the Vertical and Heading Reference System which have bearing on the overall system.

2.4.1 Erection Systems

Theoretically, there is only one method (using inertial means alone) of maintaining a perfect vertical reference in a manoeuvering aircraft. That is by using a Schuler, or earth's radius pendulum associated with a drift-free gyro stabilized platform. Maintaining a perfect vertical even with this system requires the use of ideal components. A true undamped Schuler system was discarded as a practical erection system for this platform, since it is not practical for making navigational computations with anything except gyros with exceptionally low drift rates and with accelerometers and integrators of extreme linearity. In addition, if a Schuler system loses power in flight, it is essentially impossible to erect and trim the platform to any reasonable degree of accuracy.

Having discarded a true Schuler system as a practical erection system, it was necessary to review other possibilities. These were; a first order system other than a Schuler type, forms of second order systems, or third order systems. As would be expected, the size, complexity, accuracy, and cost all increased with the order of the system. Each system had its advantages and disadvantages, and the best system for a given application could only be determined after the requirements were specified.

With the above factors in mind the decision was made to employ a first order erection system using floated pendulous accelerometers. A first order system is made by directly connecting the proportional accelerometer signal to the gyro torquer. A filter-limiter amplifier was proposed to prevent false erection during turns and linear accelerations. The GG56 Accelerometer was proposed for the system.

Subsequently, further studies concluded that the accelerometers and the associated electronics could be replaced with cheaper and lighter mercury switches without significantly compromising quality of performance. Elimination of this hardware made space for other components and enabled the platform computer (to be discussed later) to be eliminated entirely. This design change led to a net saving in weight of 12 pounds per system and a fabrication cost saving of $16,000.00. Mercury switches were recognized to be poorer than the accelerometers since they would not provide compensation for Coriolis acceleration error. This error would persist only if the aircraft were flying in the neighborhood of Mach 2. It was felt that the additional 0.5° error resulting would not appreciably compromise the overall performance of the system. Figure 2A shows the system using accelerometers. Figure 2B shows the system with the mercury switches.

2.4.2 Maps and Torquing Equations

Derivation of Azimuth torquing equations is a pre-requisite to developing a mechanization satisfying navigation requirements and to conducting an evaluation of system errors. For the Arrow aircraft these requirements involved navigation with respect to a grid overlay on a map or chart. The direction of grid north depends upon the type of map or chart used for representing the surface of the earth. In general, each type of map or chart requires a different Azimuth torquing equation.

The first Azimuth torquing equations for furnishing grid-north were derived for the Lambert Conformal chart. It was later determined that the Azimuthal Equidistant chart would be used. This required the derivation of a new set of torquing equations.

The mechanization for Azimuthal Equidistant chart proved to be very simple. A study showed that the torquing term due to eastward velocity was equal to zero. Thus the Azimuth torquing equation contained only the earth rate term.

In order to maintain a platform at local vertical as the aircraft traverses the earth's surface, the vertical gyros must be torqued in proportion to aircraft velocity components. This torquing provides what is called "de-drooping" of the erection system. Reference is made to Figure 3 where the Azimuth and vertical torquing equations are given.

2.4.3 Heading Alignment

Heading alignment of the Heading gimbal of the platform provided a very serious problem. It was obvious that, since the aircraft required alignment of the platform to grid north prior to each flight, a simple and quick method was necessary.

Originally, it was proposed to use the pendulous flux valve available in the aircraft. Using the appropriate grid and magnetic corrections it would then have been a simple matter to slave the platform Azimuth gimbal to the flux valve to indicate grid north. It was understood at the time that this was to be done in the ready hangar. Actual field measurements, however, indicated that the magnetic field distortion inside the hangar would have been of the order of 1 to 3 degrees; roughly an order of magnitude too large. Slaving to the flux valve during take-off was considered, but was ruled out due to the errors caused by the pendulosity of the flux valve under acceleration.

Numerous geometric methods using terrestrial references were considered. These involved using transits located on the ground or on the aircraft, and were discarded due to operational complexity. Another method involving plumb-bobs hanging from the aircraft to a grid painted on the hangar floor under the aircraft was discarded for the same reason. Still another method, involving the connection of the platform in a gyro compass connection was considered but was proven to be unsatisfactory due to the stringent requirements on gyro drift rate.

A method involving slaving the platform to the radar azimuth servo while it was sighted on a target appeared attractive. It would have been essentially automatic, and would have had all the advantages of the flux valve with none of the disadvantages. This method, however, did not meet the accuracy requirements, and proved to require considerable additional complexity and was, therefore, rejected.

The method finally chosen used a portable directional gyro or so called Heading Alignment Unit (HAU). In operation, the Heading Alignment Unit was placed and caged on a reference plate or fixture located near the aircraft. The unit was then wheeled out to the aircraft, removed from its carriage and placed on a reference plate located on the aircraft. By suitable interconnection, it was therefore possible to transfer the Heading Reference from the HAU to the platform. In fact, it was arranged so that the Heading information could be stored in a separate Heading Alignment Servo within the platform electronics assembly, without energizing the whole system. Thus, the Heading Alignment Unit could be removed from the aircraft and used again for alignment of other aircraft. This system thus had the advantage that the aircraft heading reference was stored within the aircraft and was available (providing the aircraft was not moved) to be stored within the platform upon energizing of the system.

2.4.4 Gyro Drift Compensation

A gyro drift has two components, a fixed drift and a variable or random drift. The fixed drift is usually a constant under steady operating conditions. However, temperature cycling which would naturally occur as the system was turned on and shut down periodically, may cause the level of such drift to vary. This change in level may or may not be significant, depending upon the application. For example, the change in level associated with the X and Y platform gyros was not extreme. In this case, a factory adjusted compensation was used. This involved simply supplying a DC current via the summing amplifier to the gyro torquer which would produce a rate equal and opposite to the fixed drift.

In the case of the heading gyro, however, the variation in the level of the fixed drift between temperature cycles was considered too high. It was, therefore, necessary to provide automatic drift compensation for the heading gyro. This was done by a small drift-trim servo within the platform amplifier assembly which before each flight, would sense and correct for the heading gyro fixed-drift rate.

Random drift is not as easily compensated for and depends almost entirely on good gyro design.

2.4.5 Erection Sequence

This was one of the areas which remained rather nebulous until the latter stages of the design. It was dependent upon decisions made in the foregoing four sections and in addition such considerations as warm-up. After storage of heading information the following four modes comprised the Erection Sequence:

1. Warm-up
2. Fast Erection
3. Drift Trim
4. Normal

These modes will be described in more detail in a later section.

4 DESCRIPTION OF UNIT

4.1 General Description

4.1.1 Mechanical

The VHRS finally evolved into three major components plus the Heading Alignment Unit. These were the Miniature Stable Platform itself, the Platform Amplifier Assembly and the Three Axis Repeater. An additional component called the Platform Computer was originally proposed, but was later scrapped when the platform heading resolver and elevation secant pot were placed on the gimbals. The Platform Computer had comprised the Two Axis Repeater plus the three summing amplifiers and the summing resistor unit. Since the Two Axis Repeater was no longer required for the stabilization of the platform, the three summing amplifiers and the summing resistor unit were removed and placed in the Platform Amplifier assembly. This was done quite easily since the space originally occupied by the accelerometer amplifiers and filter-limiter amplifier in the platform amplifier assembly was available when the switch was made from accelerometer erection to mercury switch erection. Reference is made to Figure 4 where the VHRS components are shown. The interruption in the line between the HAU and the Platform Amplifier Assembly indicates the connection made when the HAU is connected to the aircraft for initial heading alignment.

In Figure 5 the location of the various VHRS components are shown in their respective places within the Arrow Aircraft.

The platform was mounted in the duct bay on a rack or jig, which was permanently fixed to the aircraft, with an accuracy of ± 10 minutes with respect to the aircraft centre line. This rack provided means whereby the platform when installed was aligned within the above tolerance. Thus, no alignment procedure was required when changing platforms. The platform electronics assembly was mounted almost directly below the platform on the duct bay door.

The Three Axis Repeater was mounted on its rack in the electronics bay. The Heading Alignment Unit (HAU) reference plate was located with the necessary connector, in the nosewheel well as shown.

The Miniature Stable Platform finally evolved as a cylinder 10" in diameter by 16 1/2" long and 33.2 pounds in weight. The corresponding rack was

10" x 4" x 15" and weighed 5.8 pounds. The platform amplifier assembly was approximately 9" x 9-1/2" x 15" and weighed 30-1/2 pounds. Its rack was about 10" x 2.4" x 15.6" and weighed about 3-1/2 pounds.

4.1.2 Electrical

The functional schematic diagram of the VHRS is shown in Figure 6.

The Navigation Computer is shown as supply inputs to the VHRS on the far left side of Figure 6. The velocity input shown was provided by doppler radar. The earth rate potentiometers are shown located in the navigation computer and were available so that different values of base latitude could be set in, corresponding to different bases.

Below this is shown the Heading Alignment Unit with the cageable directional gyro. This is shown feeding into the heading alignment servo within the platform amplifier assembly.

Within the navigation computer wind display there was an emergency alignment switch which could be used by the pilot to slew the platform in heading under emergency conditions.

The thermostat and heaters associated with platform warm-up are shown at the lower right.

Signals designated S_1 and S_0 were those associated with first line testing of the platform and have no significance in the present discussion. First and second line maintenance testing of the VHRS is described in Honeywell Document CR-ED 1048, "Termination Report on the Ground Test Equipment for the Flight Control System of the CF-105 Arrow Aircraft."

4.2 Component Parts

4.2.1 Platform

The following are the component parts of the miniature stable platform according to gimbal:

a) Heading Gimbal Components:
Three Miniature Integrating gyros, MH Type GG49
2 Sets of mercury switches
One direct drive DC servo motor
One direct drive synchro transmitter
Two cartridge type heaters embedded in gimbal casing;
So-called platform heaters;
One temperature control sensing bridge.

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b) Inner roll gimbal components:
One direct drive DC servo motor;
One direct drive synchro transmitter.

c) Elevation gimbal components:
One direct drive DC servo motor,
One direct drive synchro transmitter.

d) Outer roll gimbal components:
One direct drive DC servo motor,
One direct drive synchro transmitter.

e) Outer case components:
Two blowers to circulate atmosphere in case.
Case heaters and thermostats.
Two connectors for power and signals.

4.2.2 Platform Amplifier Assembly

The following are the component parts of the platform amplifier assembly; Four power amplifiers to drive gimbal servo motors; one frequency sensitive AC to DC converter to provide pattern field excitation for gyro torquers; one isolation transformer to provide 26 volt three-phase 400 cycle power to gyro spin motors; one combination 30 - 65 volt DC power supply for transistor amplifiers; one 8 volt power supply for excitation of potentiometers in navigation computer; three gyro summing amplifiers; one temperature control amplifier; eight synchro signal amplifiers; four double lead stabilization networks for gimbal loop stabilization; one drift-trim servo for heading gyro; one heading alignment servo for heading storage and alignment.

4.2.3 Three-Axis Repeater

The Three Axis Repeater comprised three servo repeater modules, each containing; one size 15 inertial damped servo motor, one transistor pre-amplifier; one transistor power amplifier; one synchro control transformer; provision for 13 size 11 output devices.

4.2.4 Heading Alignment Unit

The configuration of a Heading Alignment Unit was not firm at the time of cut-off. However, the following are the basic components of which it was comprised; one cageable directional gyro, one synchro control transmitter, one carriage on which the directional gyro could be mounted.

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4.3 Description of Erection Sequence

4.3.1 Initial Heading Alignment

Reference is made to Figure 7, where the Heading Alignment Unit is shown. It was located in the nose-wheel well of the aircraft, mounted on its reference plate and connected to the Heading Alignment Servo in the platform amplifier assembly. When the initial external alignment switch in the HAU was depressed, the initial alignment relay within the platform amplifier assembly was excited. Simultaneously, power was applied from the HAU to the heading alignment servo amplifier and motor. The heading alignment servo was thus slewed until the aircraft heading angle was stored within the heading alignment servo control transformer, CTA. A time delay relay located in the HAU allowed one minute for this operation.

The Heading Alignment Unit (HAU) was then removed from the aircraft and the heading alignment servo de-energized; thus aircraft heading was locked into CTA and was available providing the aircraft was not moved. Note that only the heading alignment servo was energized during the initial heading alignment operation.

4.3.2 Warm-Up

Warm-up was mode 1 of the erection sequence and started when the Arrow Electronic System was energized. The simplified circuitry shown in Figure 8 will serve to illustrate the warm-up operation.

Initially, power was applied to the case heaters, the platform heater, and the gyro flex-lead heaters. When the temperature of the case reached 140°F, the case heater thermostat opened and de-energized the case heaters. When the temperature climbed to 160°F., the platform thermostat closed and energized the warm-up relay K-3. This cut out power to the gyro flex-lead heaters and placed the platform heater under the control of the temperature control amplifier and temperature sensing bridge. The platform continued to operate in this way unless the temperature rose to 195°F., the overheat condition, in which case the overheat relay K-1 removed all power from the system.

4.3.3 Fast Erection

The inter-connections necessary for fast erection or mode 2 are shown in Figure 9.

The system went into mode 2 for fast erection immediately upon completion of the warm-up mode.

When in this mode, the heading alignment servo was de-energized, but it will be noted that the heading alignment servo CTA was connected to the azimuth gimbal control transformer. The rotor of the CTA was connected by the secondary of a transformer to the azimuth alignment amplifiers. The azimuth stabilization loop would quickly drive to give an output equal to the stored heading within the CTA. This would cause the Z gyro to come up against its stops which are ± 3 degrees from null. This 3 degrees corresponds to 1/2° when the loop is under gyro control. The transformer was provided so that the signal from the gyro corresponding to its being on its stop, was put in as a bias on the azimuth gimbal. However, at the end of the fast erection mode, which lasted fifteen seconds, the loop would have an equal and opposite angle put into the system as the gyro moved off its stop to its null position.

In the lower part of Figure 9, the mercury switches are shown connected to the gyros, these to the heading resolver, and thus on to the alignment amplifiers and torquers. Originally it was proposed to connect the mercury switches directly into the stabilization loops at the heading resolver, however, undesired oscillation due to the mercury switch dead zone was observed. In any event, it will be seen that the system would quickly erect to vertical as shown.

4.3.4 Drift Trim Mode

The interconnection necessary for the Drift-Trim Mode or mode 3 is illustrated in Figure 10.

In this mode, the drift-trim servo is energized. It will be noted that the output of the azimuth alignment amplifier is connected directly back to the Z summing amplifier and also to the drift-trim servo input. As the Z gyro drifts, a signal would appear at the output of the azimuth alignment amplifier. This signal would cause an output from the Z summing amplifier sufficient to develop a rate equal and opposite to the drift-rate. It would also cause the drift-trim servo to slew so that the voltage appearing on the DC excited potentiometer at the output would memorize the voltage required at the input of the summing amplifier, which would null out the drift. N movement of the azimuth gimbal would be observed since the signal from the azimuth alignment amplifier would remain below the threshold or stiction level of the azimuth torquer.

In the lower part of Figure 10 is shown the vertical channels now under control of the gyros. The factory adjusted drift-trim compensation is applied via the summing amplifiers to the vertical gyros to null out their fixed drift rate.

It will be noted that the azimuth gimbal control transformer was connected during the drift-trim mode to the heading alignment servo, CTA. This arrangement permitted automatic termination of the drift-trim mode when the aircraft heading was changed in preparation for take-off. Since aircraft heading was still stored within the CTA, any change of aircraft heading as indicated on the azimuth gimbal CX would produce a signal which when fed through the heading alignment servo amplifier, would activate the drift-trim cut-out relay. The system was then in the normal mode.

4.3.5 Normal Mode

The configuration of the system in the normal mode, or mode 4, is shown in Figure 6.

4.3.6 Emergency Alignment Mode

In this mode, a signal was applied from the navigation computer wind display which caused the heading alignment servo to be actuated and slewed. When the desired change in heading had been achieved, the system proceeded to the fast erection mode and continued in the normal fashion until the normal mode.

5 STATUS AT CUT-OFF

a) A complete platform and amplifier assembly were undergoing system test. They were about one month away from being flight tested.

b) Platform #2 was ready to be tied to an amplifier, as all of the open loop tests had been completed.

c) Amplifier #2 was being tested.

d) A CF-100 was ready to accomodate a platform amplifier and three axis repeater to conduct formal flight tests.

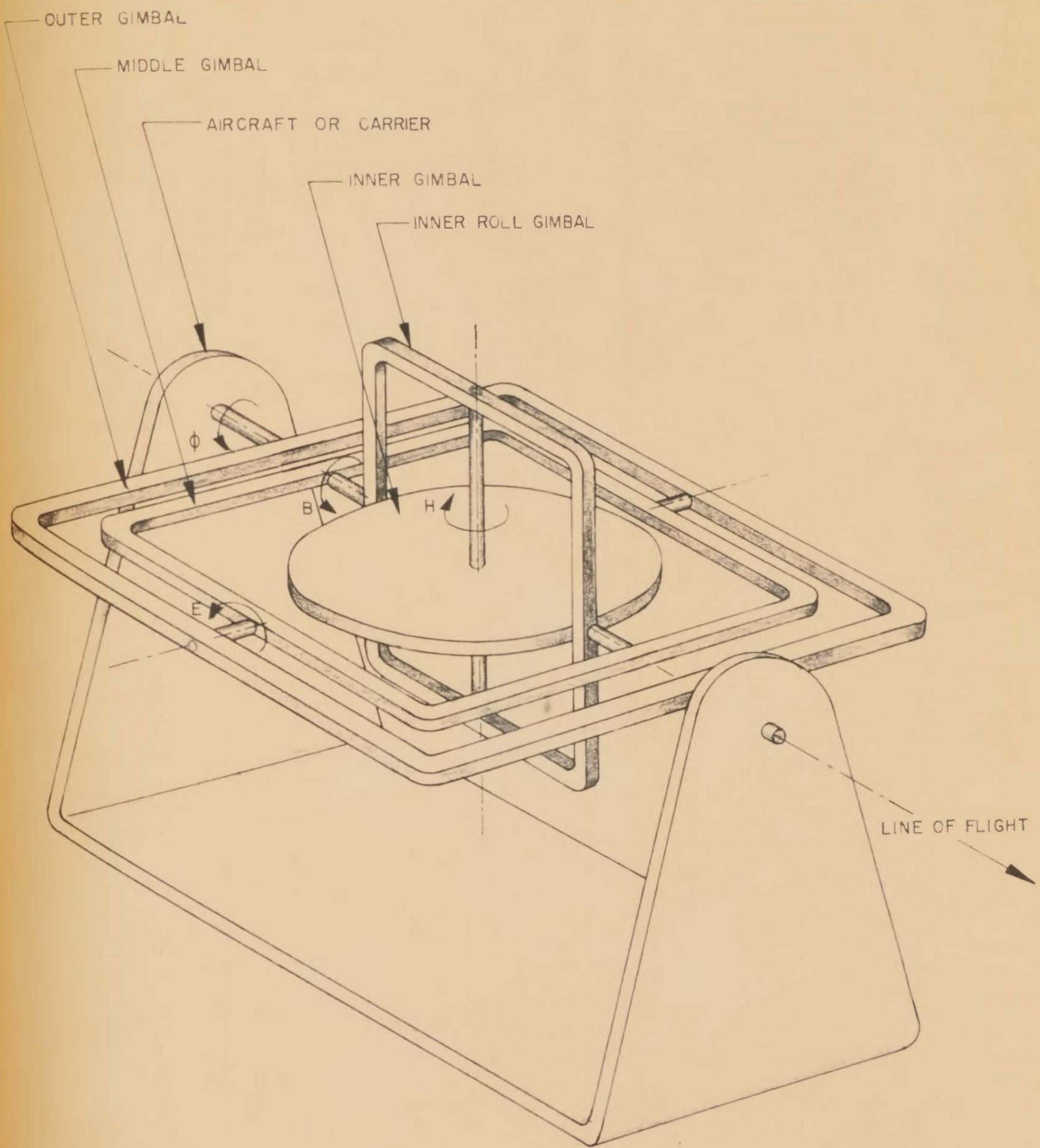
6 PROPOSED FUTURE PROGRAMS

Studies were being performed to determine the feasibility of deriving velocity information from the system. This would mean replacing the mercury switches by the accelerometers and providing two high-quality integrators. The obvious advantage of this was that the doppler radar would be no longer required.

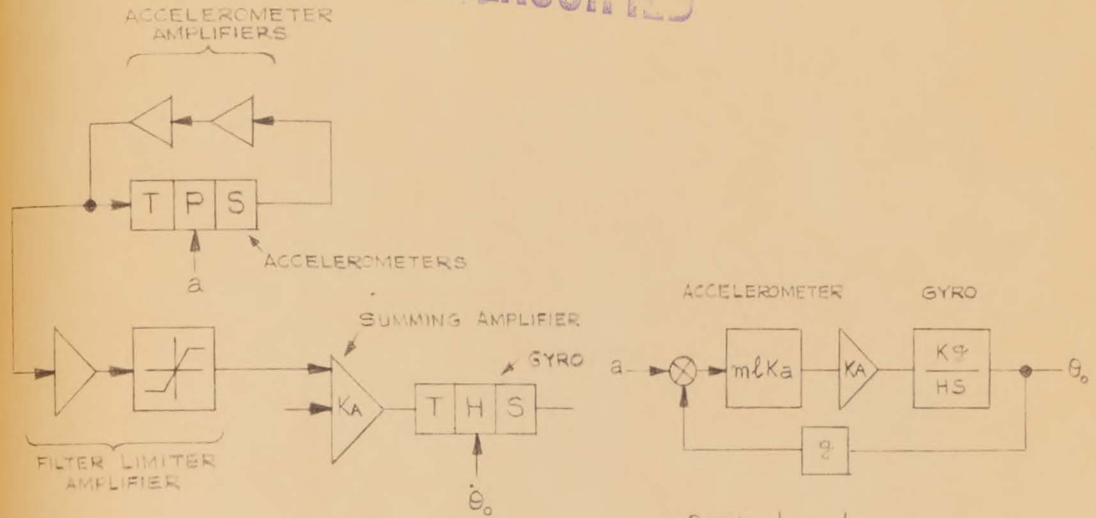
Random drift-rates of the MIG gyros are under 0.1 degree per hour, as indicated in recent tests. This is certainly opening the door to an all-inertial system. Recent developments in inertial quality integrators are also encouraging.

7 CONCLUSIONS

Much controversy developed during the development of the miniature stable platform. When the accelerometers on the platform were replaced with the mercury switches, it was argued that the system was no longer any better than current vertical and heading reference systems, even with its all-attitude capability. It is difficult at this time due to the early date of cut-off, to evaluate how well the system would have developed as time went on. As indicated in Section 7, the system had vast potential and might have more than made up for its initial complexity and problems.



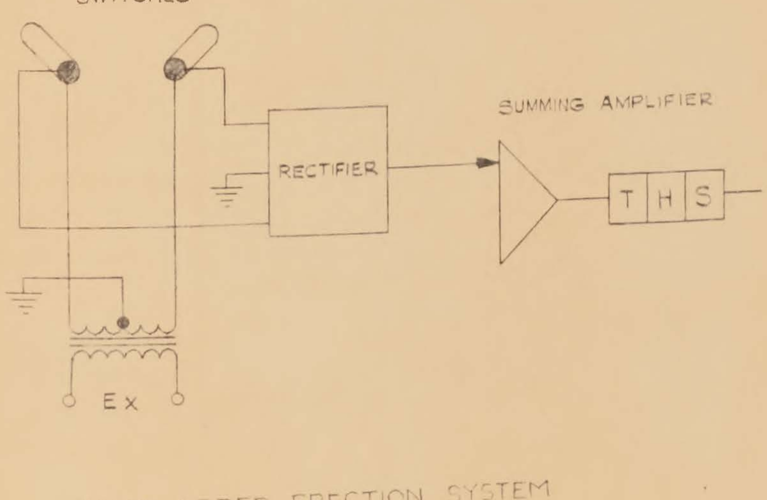
THREE-AXIS, FOUR-GIMBAL PLATFORM, PICTORIAL REPRESENTATION



$$\theta_o(S) = \frac{1}{g}\ \frac{1}{\tau S+1}$$

$$\dot{\theta}_o(t) = \frac{a}{g\tau} C^{-\frac{t}{\tau}}$$

FIRST ORDER ERECTION SYSTEM
WITH ACCELEROMETERS
FIG 2(a)



FIRST ORDER ERECTION SYSTEM
WITH MERCURY SWITCHES
FIG 2(b)

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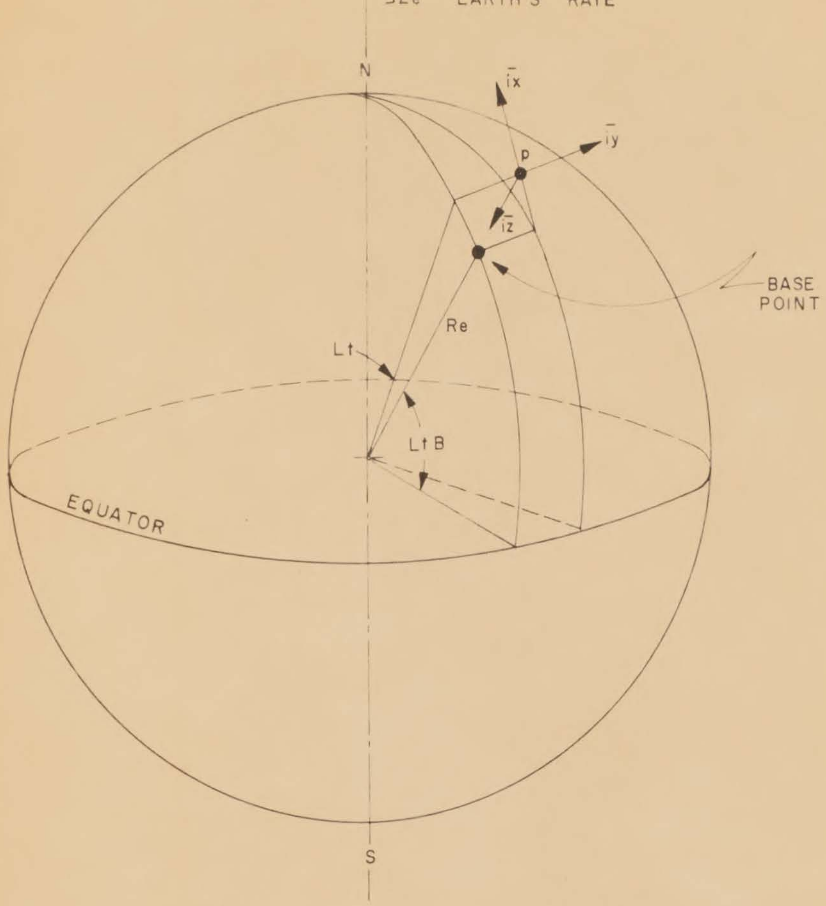

PLATFORM ERECTED AT BASE POINT

AIRCRAFT VELOCITY $\bar{V} = V_x \bar{i}x + V_y \bar{i}y + V_z \bar{i}z$

TO KEEP PLATFORM VERTICAL IN PRESENCE OF $\bar{V}$ AND $\bar{\Omega}e$, MUST TORQUE

X-GYRO AT $W_x = \frac{V_y}{Re} + \Omega e \text{ Cos LtB}$ °/HR;

AND Y-GYRO AT $W_y = -\frac{V_x}{Re}$

TO KEEP GRID NORTH HEADING REFERENCE ON AZIMUTHAL EQUIDISTANT PROJECTION, MUST TORQUE Z-GYRO AT $W_Z = -\Omega e \text{ Sin}(LtB + Lt) =$

$-\Omega e \text{ Sin LtB} + \Omega e \frac{X}{Re} \text{ Cos LtB}$ °/HR

TORQUING EQUATIONS

FIG. 3

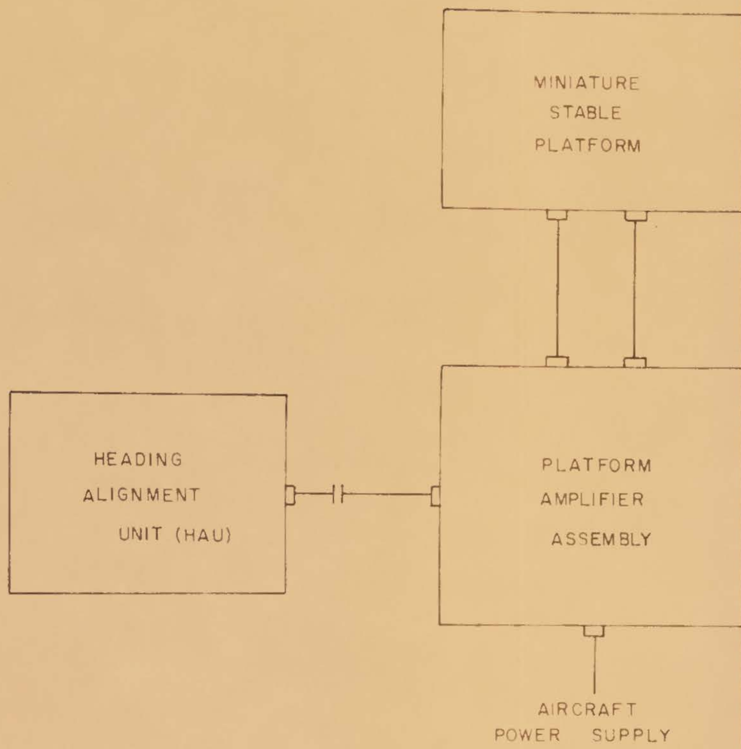

FIG. 4 VHRS COMPONENTS

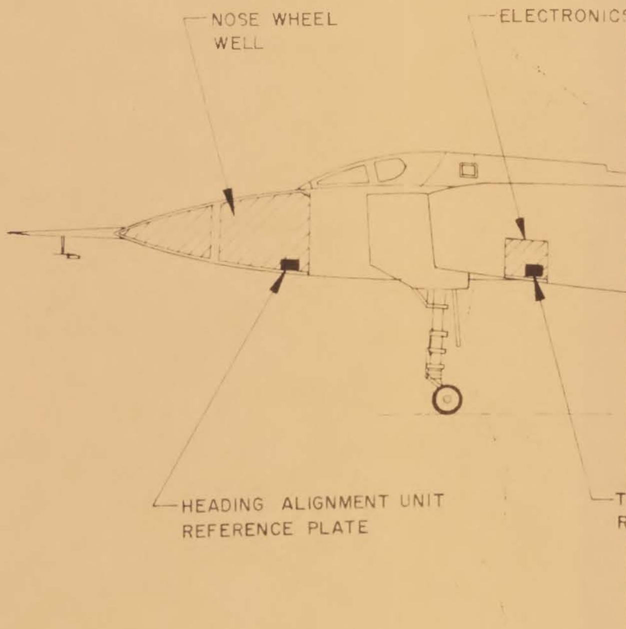

FIG 5 LOCATION OF VHRS I

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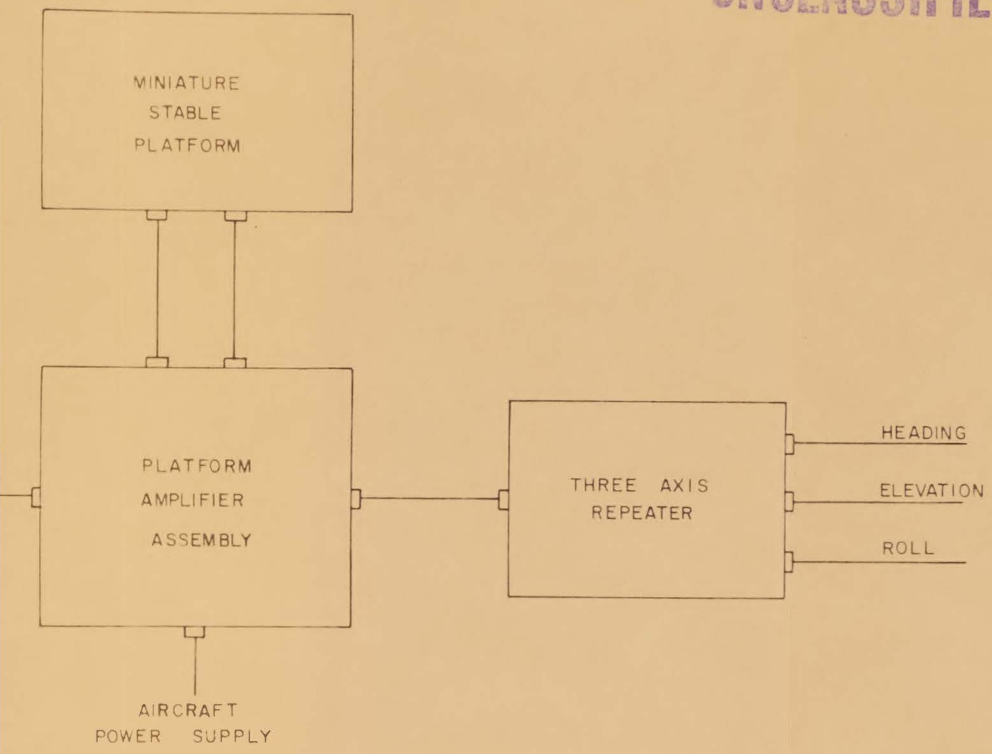
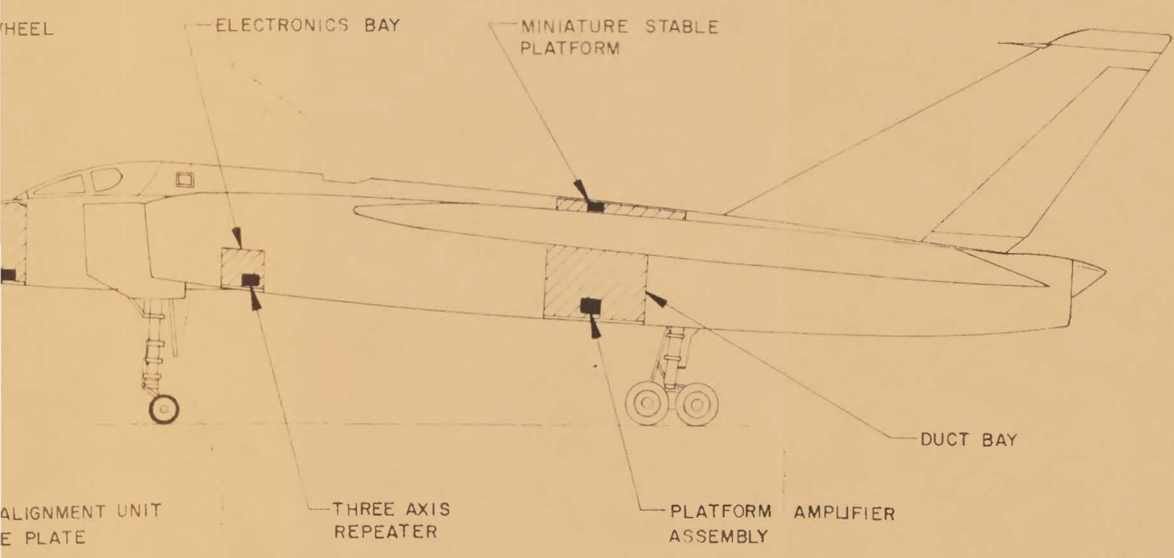


G. 4 VHRS COMPONENTS



5 LOCATION OF VHRS IN AIRCRAFT

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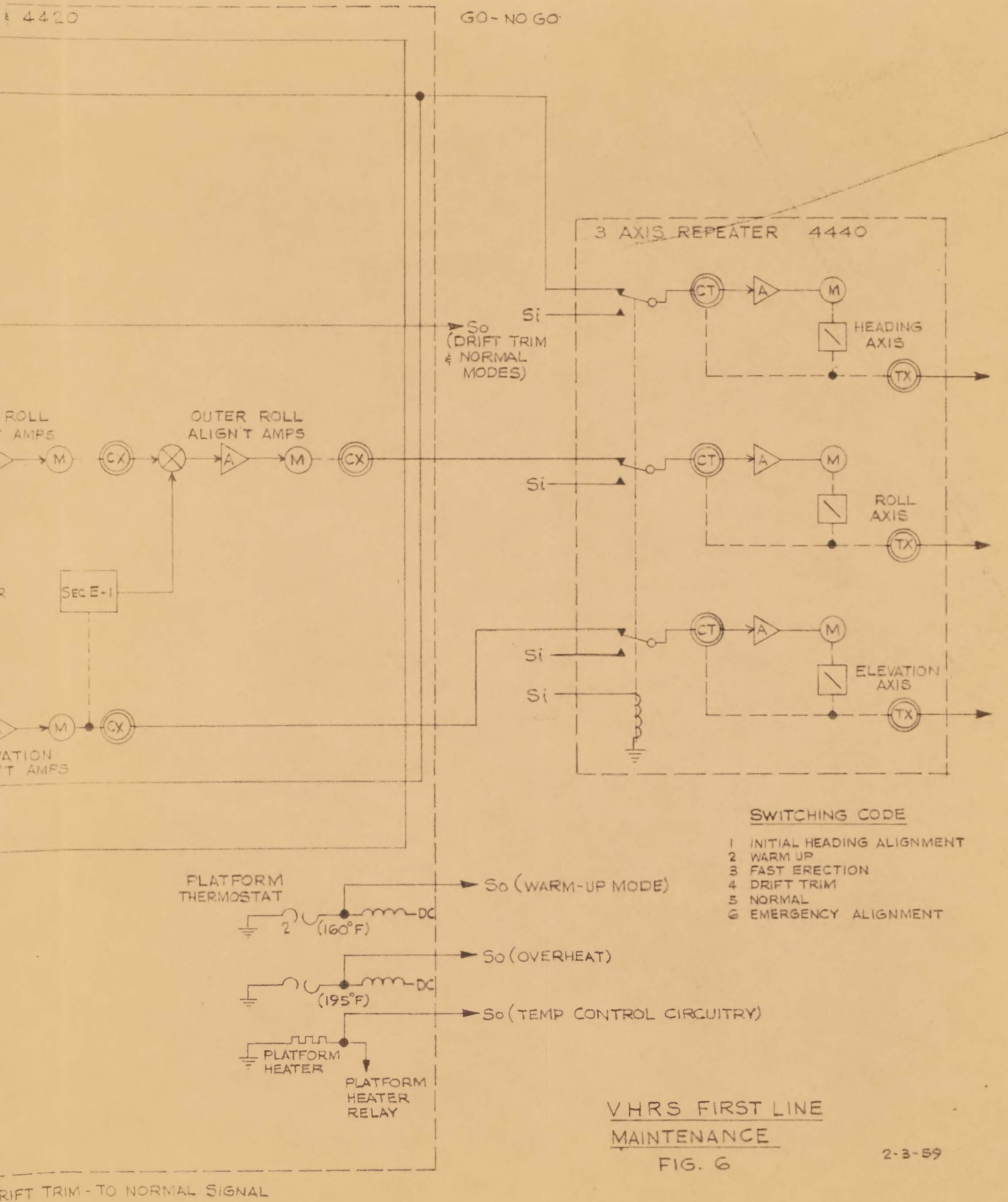
1-29-59



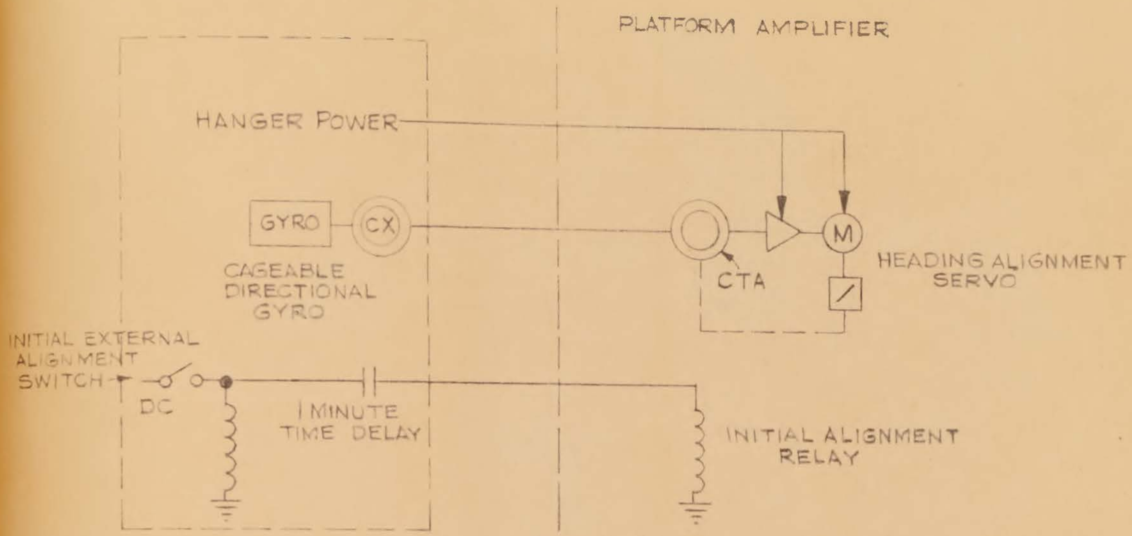
SWITCHING CODE

1 INITIAL HEADING ALIGNMENT
2 WARM UP
3 FAST ERECTION
4 DRIFT TRIM
5 NORMAL
6 EMERGENCY ALIGNMENT

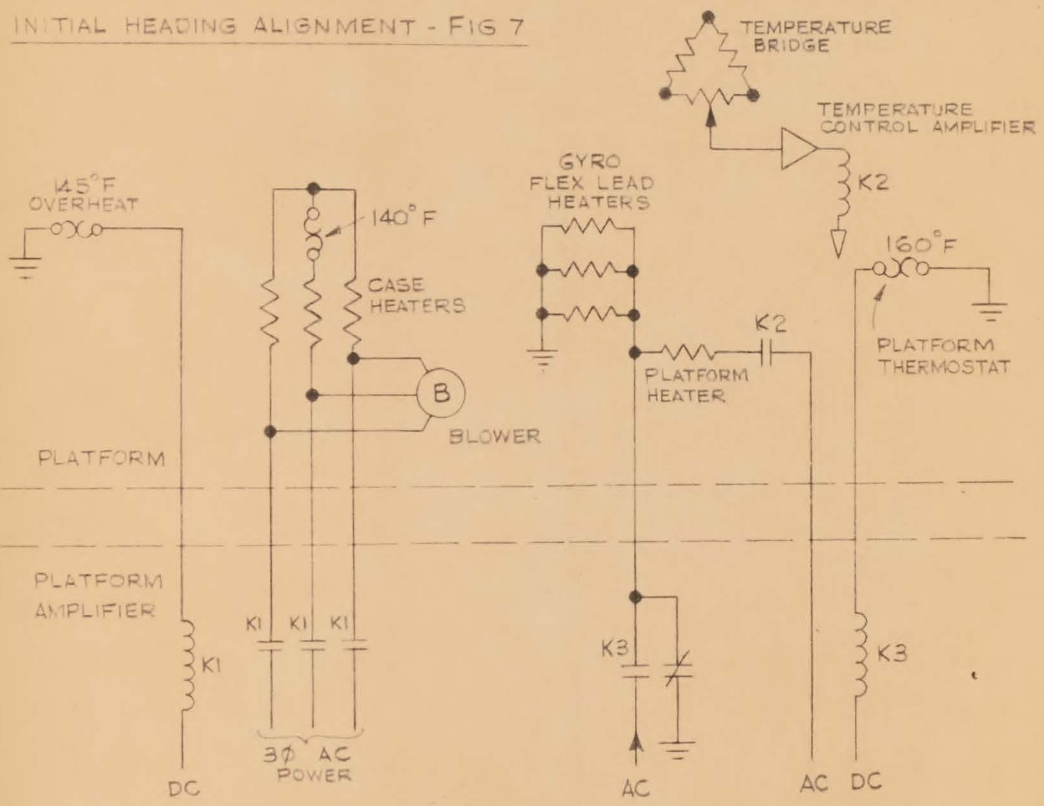
VHRS FIRST LINE MAINTENANCE

FIG. 6

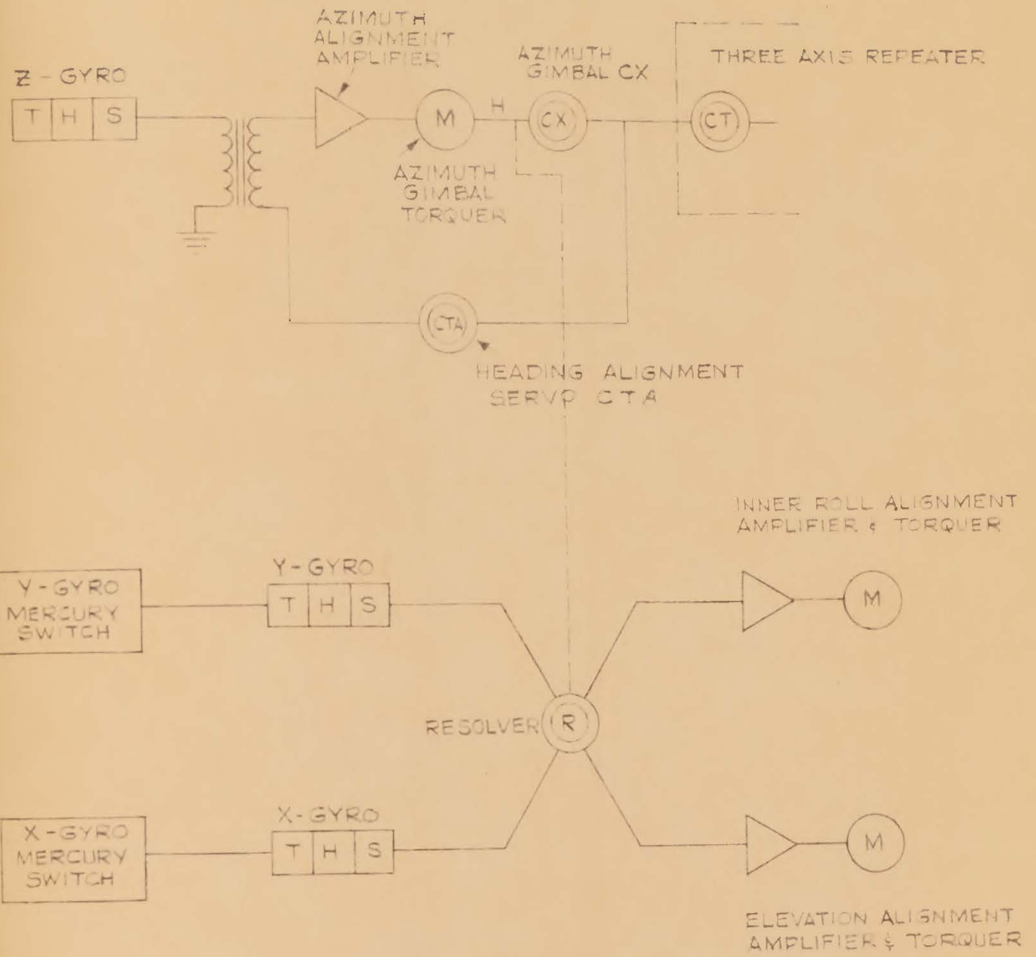
2-3-59



INITIAL HEADING ALIGNMENT - FIG 7

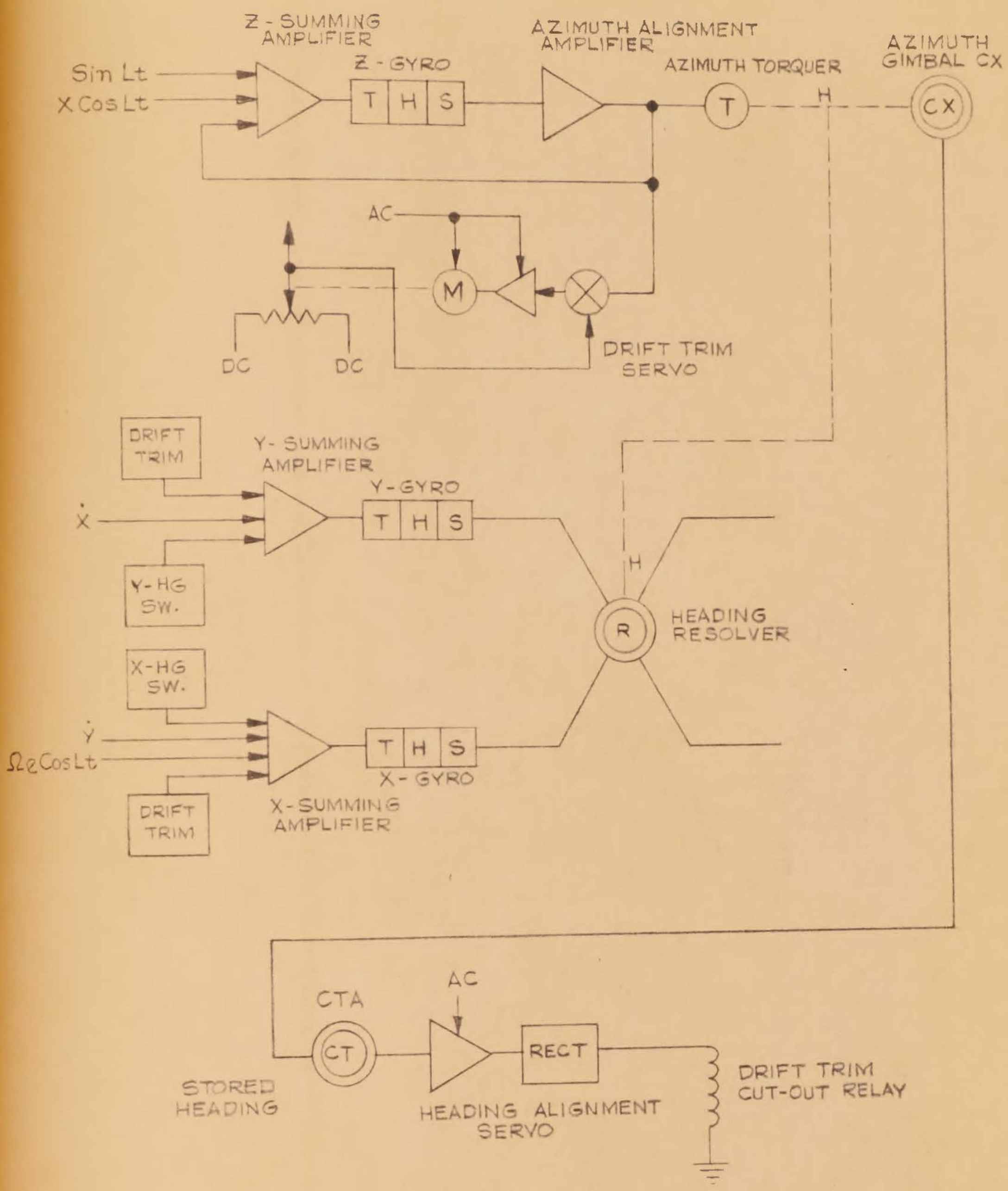


WARM UP - MODE 1 FIG 8



FAST ERECTION - MODE 2 FIG 9

JAN 30 - 59



DRIFT TRIM - FIG 10

CONFID

12

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