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A PROTOTYPE PERIPHERAL VISION AIRCRAFT ATTITUDE DISPLAY

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FOREWORD

This report was prepared by Link Division, General Precision, Inc. for the Air Force on Contract Number AF 33(615)2895, Project 6190, "The Air Force Control-Display Program," for which Mr. John H. Kearns III served as Project Engineer. The effort was administrated under the direction of the Flight Control Division, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, as a part of Task Number 619004, "Control-Display Evaluation". Mr. Robert R. Davis served as Technical Monitor. The contractor's assigned job number for this study is 64-132.

The System was designed and constructed by Mr. Wolfred Greenberg and Mr. H.G. Ledbetter. This report was prepared during April 1965 by Mr. W. R. Williamson, Senior Engineer, General Precision, Inc., Link Division.

This is one of a succession of reports presenting results achieved in a continuing heuristic investigation in the area of control-display being conducted under Project 6190.

Manuscript released by the author June 1966 for publication as an RTD Technical Report.

This technical report has been reviewed and is approved.

Loren A. Anderson

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ABSTRACT

An instrument is described for presenting attitude information to the pilot in such a manner that he may maintain an awareness of his attitude through Peripheral Vision without the necessity for looking directly at a specific instrument. The system does this by projecting a line of light on the aircraft instrument panel and moving it in a manner similar to the motion of the real horizon. A design criteria and a detailed engineering description of the working model are also presented.

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SECTION I

INTRODUCTION

Often during instrument flight, the pilot must look away from the instrument panel for short periods. Not infrequently the attitude of the aircraft changes gradually without the pilot's cognizance while his attention is diverted. Under contract conditions, the pilot can normally detect attitude changes through peripheral vision motion cues even if his attention is directed into the cockpit.

Early in 1960, this Laboratory began its first effort to extend peripheral vision motion cues into instrument flight. A system was designed and built which projects attitude information in the form of a movable light line on the aircraft instrument panel. The purpose of the light line was to extend the horizon line of the attitude director indicator (ADI). The movement of the light line in pitch and roll was made to coincide with that of the ADI horizon line. Although the feasibility of using a project light line to present peripheral vision motion cues was demonstrated, this early system had three severe shortcomings. First, the light source, a mercury vapor lamp, generated excessive heat. Second, the equipment, as originally conceived and built, was not sufficiently sophisticated to determine the optimum light line dimensions. Finally, the motion cues were restricted to changes about the roll and pitch axis with no provision for the changes in yaw.

Encouraged by the feasibility demonstrated in the early effort, Control Systems Research Branch, Air Force Flight Dynamics Laboratory, began the development work described in this Technical Report. The result of this new work was a functional prototype Peripheral Vision Attitude Display. This display retained the pitch and roll presentations of the earlier system but added light line modulation to provide yaw motion cues.

Because the Simulation Facility is frequently visited by military and commercial pilots of friendly nations, a good cross section of pilot opinion about the value of this type presentation was obtained informally. Initial breadboard exploratory simulation efforts produced encouraging results. Consequently, a fully functional prototype was built and installed in a simulator. This was the system used to obtain subjective reactions of pilots concerning the desirability and requirements for such a device.

SECTION II

TECHNICAL DESCRIPTION

The optical portion of the Peripheral Vision Display was based upon a slide projector kit. The parts from this kit, and a servo-motor-driven mirror assembly, comprise the light beam projection and pitch motion portions of the display. The rest of the system was designed at the Simulation Facility.

Referring to the Block Diagram, Figure 1; the output of the light source is condensed into a beam which passes through a cylindrical lens forming a narrow line of light. This beam is further narrowed by passing it through a slit mask and another condensing lens. It then passes through the focusing projection lens to a mirror and is reflected onto the aircraft instrument panel. The line is rolled about a fixed point by rolling the cylindrical lens and slotted mask. Pitching motion is accomplished by rotating the mirror around an offset axis. The modulated horizontal lines are achieved by rotating a spoked wheel through the light at its source. The spoked wheel drive mechanism "rides" on the rotating cylindrical lens disc so that the modulated lines always appear to move along the projected light line regardless of its orientation.

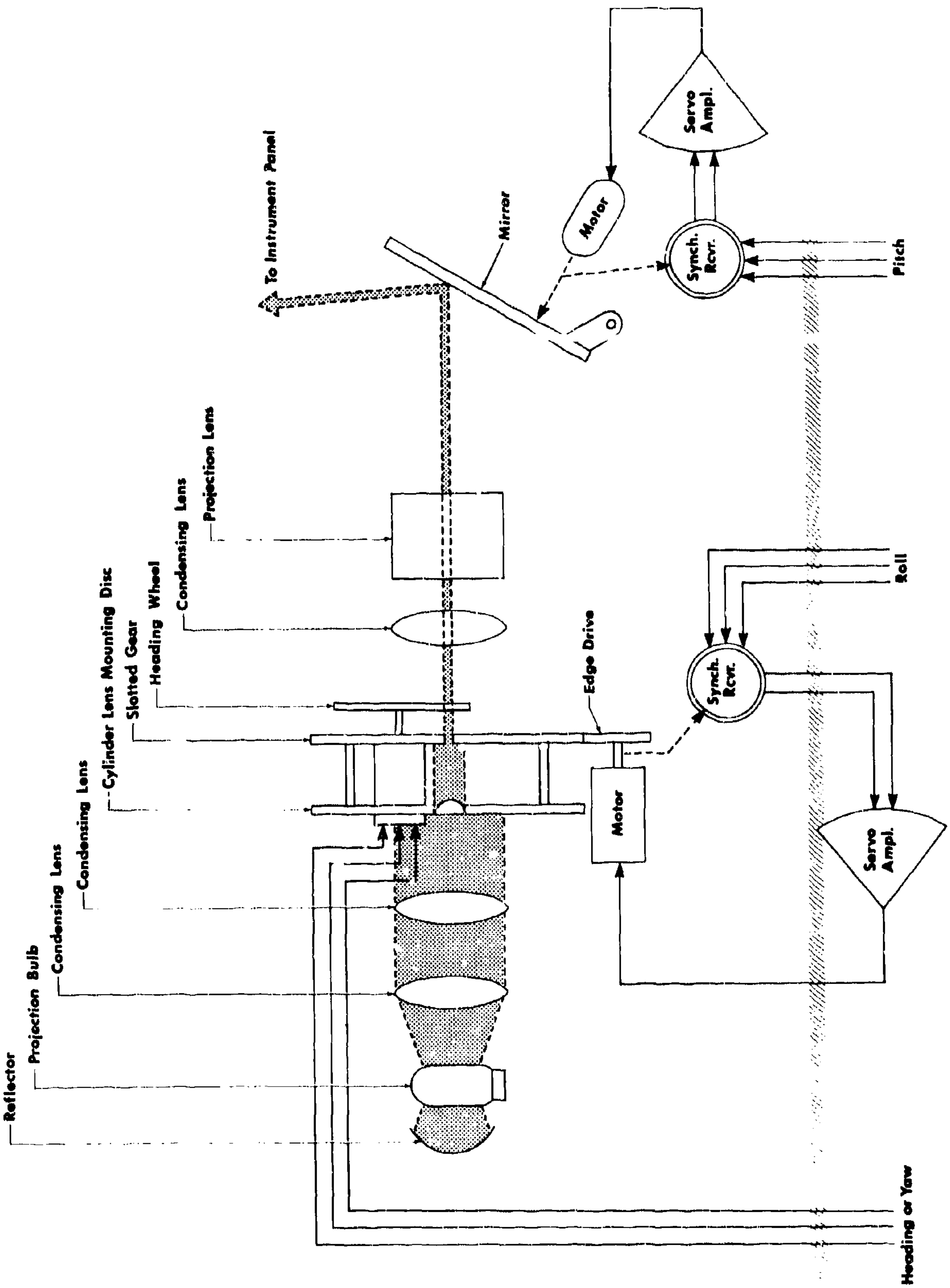
The light source and beam forming apparatus is comprised of a 100-watt projection bulb, reflector, and two condensing lenses, all from the projection kit.

The line forming cylindrical lens and slotted mask are mounted on an edge driven unit consisting of a 4-in. gear and ring assembly and an offset 4-in. disc, (Figure 2). The lens is mounted on the disc and the slotted mask is mounted on the gear. The gear and ring are staked together, and the cylindrical lens mounting disc is attached by four bolted spacers, thus forming a rigid unit. The device was first attempted with just the gear and lens mounting disc, with small free rotating gears instead of rollers for support. This resulted in an excessive friction load for the roll motor drive unit. Later, when the ring and pulley support rollers were added, satisfactory results were achieved.

The heading synchro-receiver is mounted directly on the roll gear and extends back through a hole in the lens mounting disc. The synchro-receiver provides enough torque to drive the heading spoked wheel directly without a servo-motor. No brush and ring assembly is needed since it is seldom necessary to consider a roll requirement greater than 90 degrees either side of center. Wiring to the heading synchro has enough flexibility (extra length) to permit several continuous 360-degree roll-over maneuvers without winding up to the extent that it applies a load to the mechanism. This is a very unlikely occurrence in simulation equipment.

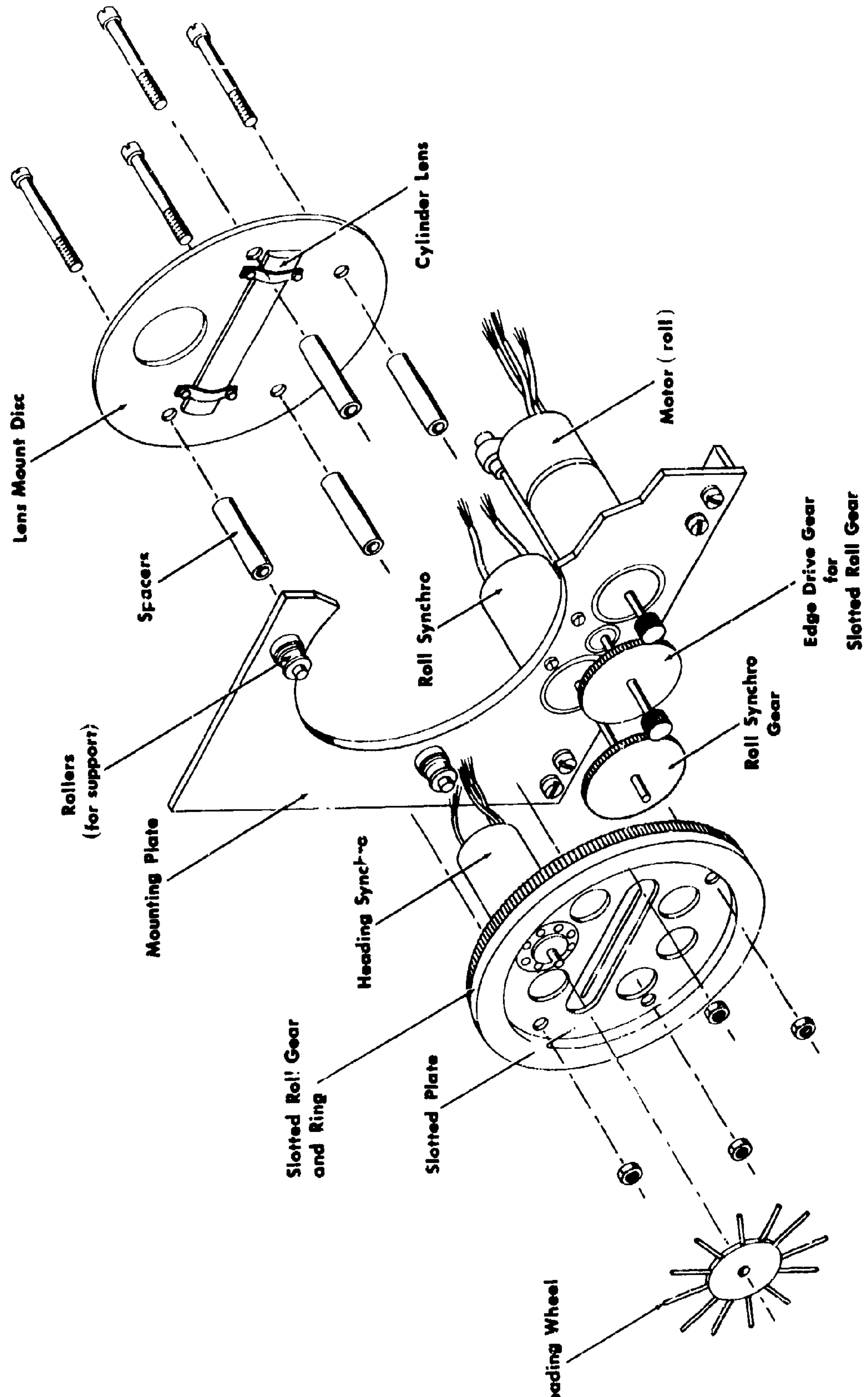
The edge drive for the roll mechanism is provided by a synchro-receiver servo-motor. The gearing from the motor output shaft to the edge drive gear is a 4:1 step down. The ratio from the edge drive gear to the roll gear is also 4:1 as is the ratio from the edge drive shaft to the roll synchro gear. This results in synchronous rotation of the roll gear and synchro gear. The servo amplifier for the roll system is built into the Universal Flight Trainer computer cabinet and consists of a d.c. operational amplifier, a general purpose 400 cps demodulator, a 3.5-watt magnetic amplifier, and a matching transformer.

The modulated light line is passed through a condensing lens and fast f/1.9 projection lens (both part of the slide projector kit) to the servo driven mirror. The mirror unit consists of a servo motor which drives a mirror tilt platform through a precision worm and wheel gear assembly. The mirror which is mounted approximately 4 feet from the instrument panel, may be positioned through an arc of approximately 45 degrees. Such angular displacement is adequate for normal pitch representation. The axis of rotation of the mirror is offset from the point of light line incidence. The purpose of the offset is to reduce distortion when the line is tilted in the roll plane. Thus, the focal distances of the ends of the tilted line are as equal as possible, consistent, with the



UNIVERSAL FLIGHT TRAINER COMPUTER CABINET

Figure 1. Peripheral Vision Display Block Diagram


Lens Mount Disc
Cylinder Lens
Spacers
Motor (roll)
Roll Synchro
Edge Drive Gear for Slotted Roll Gear
Rollers (for support)
Roll Synchro Gear
Mounting Plate
Heading Synchro
Slotted Roll Gear and Ring
Slotted Plate
Heading Wheel

physical length of the projector. Ideally, the mirror would be an "infinite" distance from the projector.

The mirror drive, also a synchro servomechanism, accepts pitch information from the Universal Flight Trainer in 3-wire synchro form and produces a single phase error signal. A transistorized servo-amplifier is an integral part of the projector in the pitch system.

The overall Peripheral Vision Display is 8 in. wide, 6-1/4 in. high, and 19 in. long. It projects a line approximately two feet wide onto a flat black surface up to five feet away. Pitch movement, as set up in the Universal Flight Trainer, is scaled so that five degrees is approximately equal to three inches vertical movement of the light line. Power requirements are 115 vac for the Display at 400 cps, 115 vac at 60 cps, and -28 vdc. Power requirements could be reduced somewhat since the 60-cycle power is used only for the projection light bulb and the 400-cycle power for the cooling fan and the servo control. The -28 vdc is for the pitch servo amplifier. Input requirements are for roll, pitch and heading signals. These three signals are in 11.8 vac, 400 cps, 3-wire synchro form. Two switches are used to turn the system on and off; one is for the projector, including heading and roll, and one is for the pitch system, which is external to the projector.

SECTION III

DESIGN DETAILS

PITCH SYSTEM

The servo-motor-driven mirror assembly unit (Figure 3) consists of a 400 cps servo motor, size 18, 115-volt fixed phase, 115/57.5 volt control phase, driving a mirror tilt platform through a precision worm-and-wheel gear assembly. The wheel shaft is fitted with three adjustable cams which operate limit switches. These were not used.

The optically flat mirror (Figure 3) is 3 in. wide, 3-3/4 in. high, and 3/8 in. thick. It may be positioned through an arc of approximately 45 degrees. Overall dimensions are 4-1/2 in. in width, 6 in. in length, and 6 in. in height when the mirror is at the highest point.

A synchro transmitter, size 8, single phase 26-volt rotor, three phase 11.8-volt stator, 400 cps, is used as a synchro control transformer in the mirror-drive servo loop (Figure 3). It accepts the three-wire pitch information from the Universal Flight Trainer. The trainer is a simplified aircraft simulator located in the Flight Dynamics Laboratory Simulation Facility. It is specifically intended for projects of this nature. The synchro transmitter develops an error signal for the motor-driven mirror assembly.

The transistorized servo amplifier, shown in Figure 1, was developed by the Link Group at the Flight Dynamics Laboratory (Reference 2).

ROLL SYSTEM

A 400 cps, servo motor, size 10, 115-volt fixed phase, 60-volt control phase, drives the roll optics disc mechanism (Figures 2 and 4). This servo motor has a gear head as an integral attachment.

A 400 cps, Torque receiver, size 10, single phase 26 volt rotor, three-phase 11.8-volt stator, is used as the control transformer in the roll servo loop. It accepts the 3-wire roll information from the Universal Flight Trainer and provides the error signal for the roll optics mechanism (Figure 4).

The servo amplifier is composed of spare units existing in the Universal Flight Trainer; a d.c. operational amplifier, a general purpose 400 cps demodulator (Reference 1), a 115-volt, 3.5-watt, 400 cps magnetic amplifier, and a speaker matching transformer for impedance match of the motor (Figure 4).

HEADING SYSTEM

The heading system consists of a spoked wheel (shown in Figure 2 and also laying on top of black box in top view photo Figure 4.) driven by an Autosyn synchro receiver, 400 cps, 26-volt single phase, 11.8-volt 3-phase. There is no servomechanism; the synchro receiver produces enough torque to drive the wheel as a function of the 3-wire heading (or yaw) information from the Universal Flight Trainer.

OPTICAL SYSTEM

The optics in the Peripheral Vision Display (Figures 1 and 2) are composed of a Slide Projector Kit and a cylinder lens. A complete set of instructions for building the projector accompanies the kit.

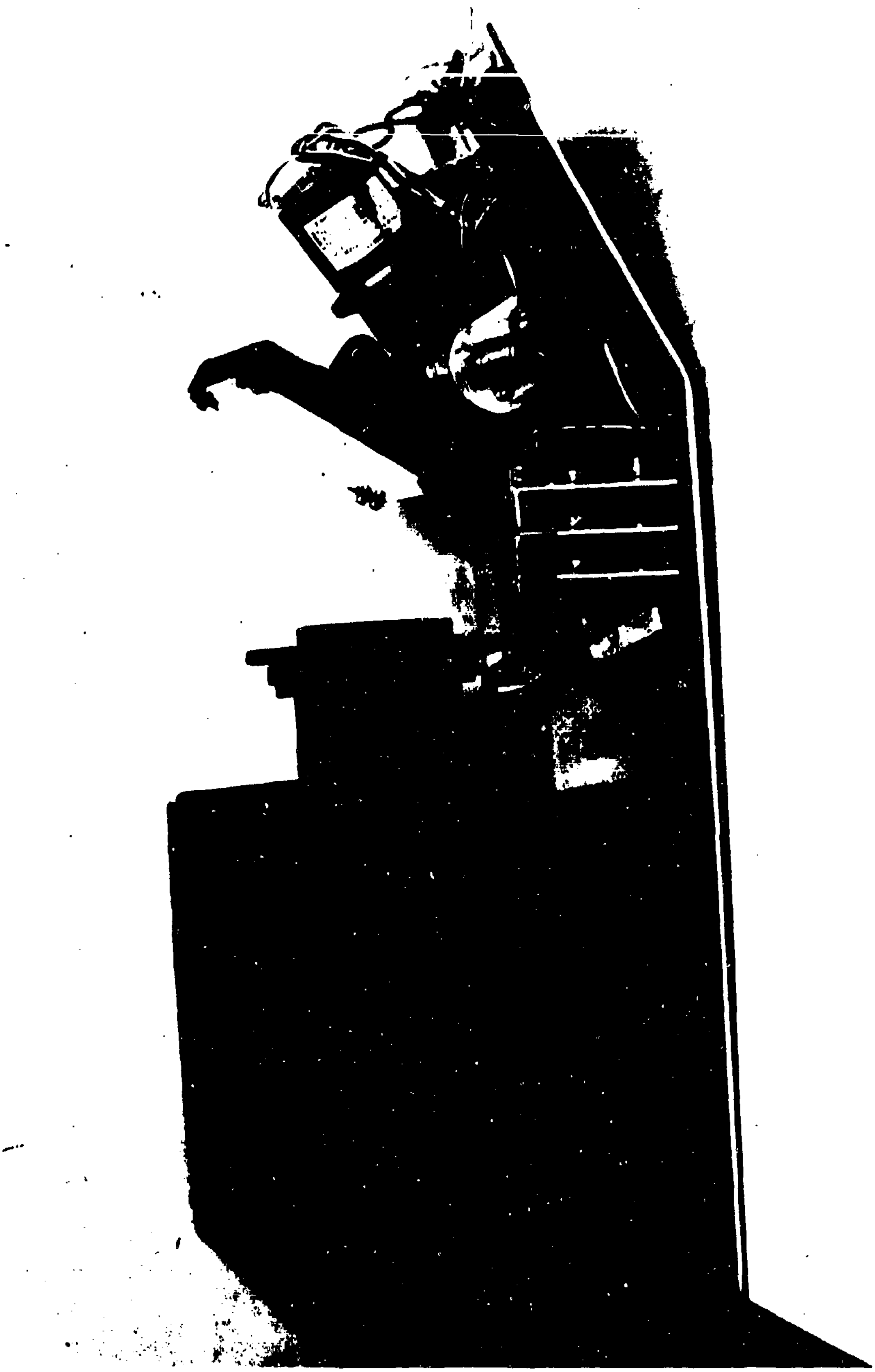


Figure 3. Side View of Projector Assembly

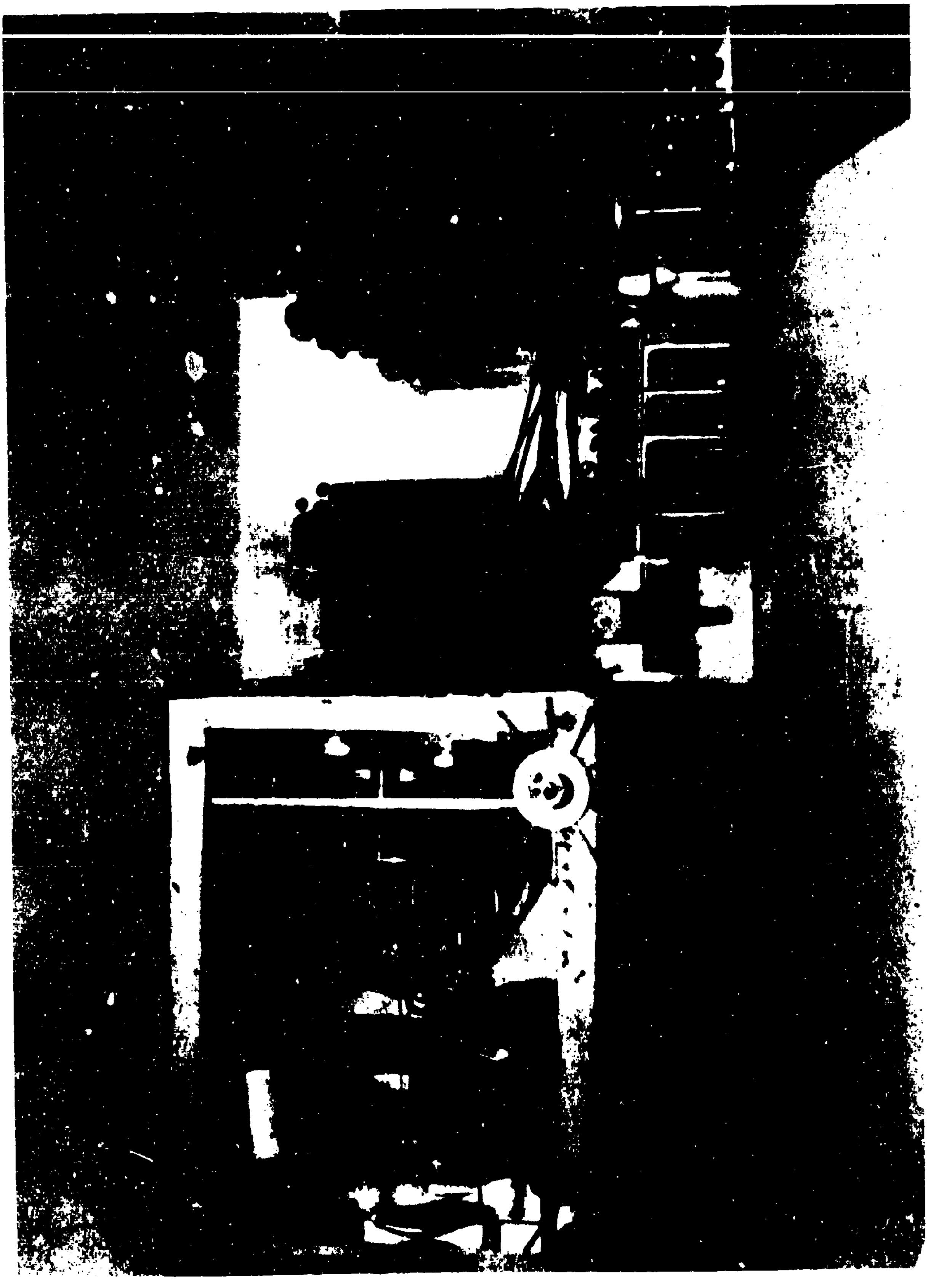


Figure 4. Top View of Projector Assembly

SECTION IV

SUMMARY AND CONCLUSIONS

SUMMARY

During instrument flight conditions, an aircraft's attitude can gradually change because the pilot's attention is diverted to operate a radio or navigation equipment. Under these conditions, the pilot, through his peripheral vision, is aware of these attitude changes even though his attention is directed away from the flight instruments. The concept of this project was to develop a prototype device which would present visual information to the pilot and make use of his peripheral vision.

Initial breadboard exploratory efforts were conducted to project a line of light across the instrument panel of a simulator. The light beam moved in the pitch and roll axis and was modulated to give the illusion of heading or yaw motion. A prototype instrument was developed which utilized a slide projection kit for the optical portion of the display. A light source was condensed into a beam and passed through a cylindrical lens. The light beam was reflected from a mirror assembly on to the instrument panel. Pitch and roll movement was accomplished by rotating the mirror assembly for the pitch axis, and rotating the cylindrical lens in the roll axis. The modulated horizontal lines were achieved by rotating a spoked wheel through the light line.

CONCLUSION

The first operational model of the Peripheral Vision Display was installed in the Universal Flight Trainer. The display operates satisfactorily and the light line is clear and bright, moves as desired, and optical distortion is low. The display was demonstrated, on an informal basis to approximately fifty people over a period of a few months. Based on the work conducted on the Peripheral Vision Display, and the comments received, the following conclusions were made:

1. Senior individuals in air line companies indicated that such a device is needed, and that this approach to presenting information would be a real aid to pilots.

2. The curved cowling in modern cockpit configurations no longer adequate for pilots to line up the horizon with the top of the instrument panel.

3. An artificial horizon line projected on the instrument panel reduces pilot fatigue, by reducing the quantitative instrument readings that are required.

4. Pitch and roll changes are shown immediately, even though the pilot's attention is directed away from the flight instruments.

5. A light line provides the transition from the instruments to the outside world, under contact conditions. This transition has long been lost due to the present design of cockpit windows.

6. The pitch display unit is permanently attached to the Universal Flight Simulator. On the basis of the favorable comments, the package should be redesigned and universalized so that it can be used on all simulators, or manually operated for demonstrations.

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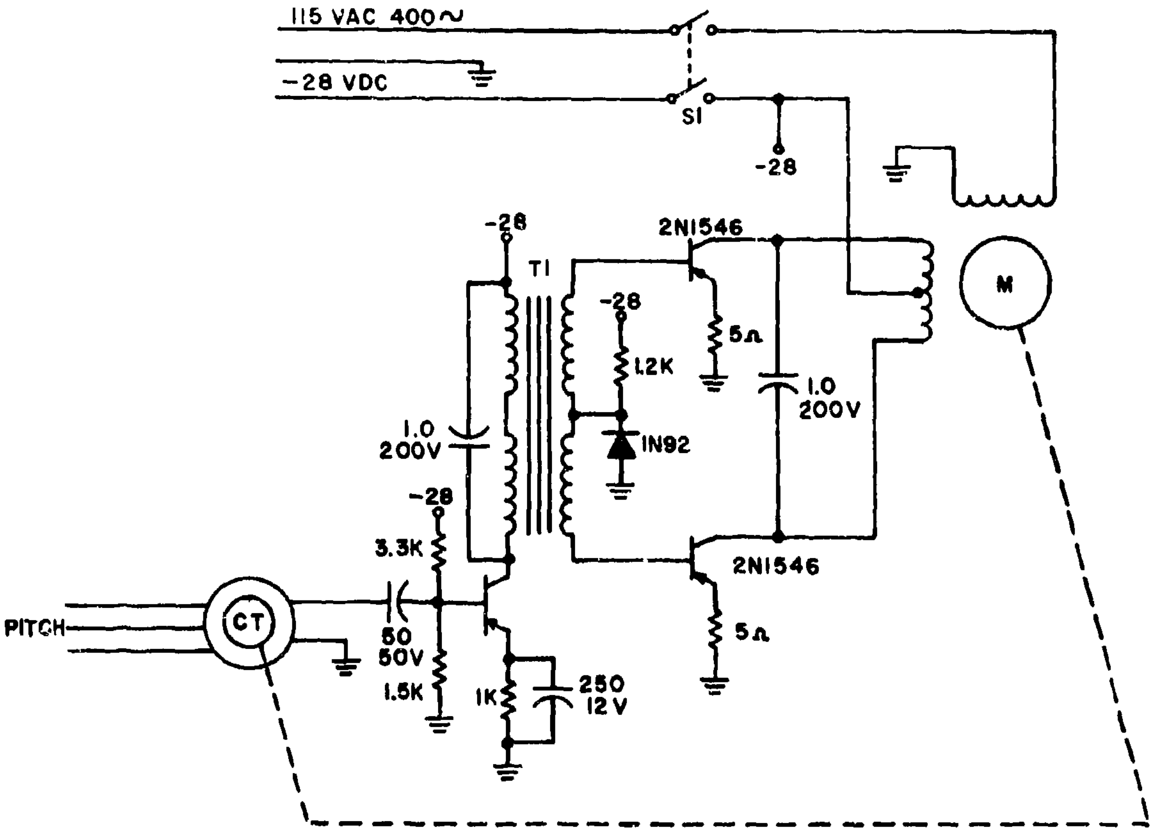
1. W. Greenberg, Demodulator, 400 Cycle - General Purpose. Dayton Laboratory Tech. Memo. #3, Link Group/Systems Division, General Precision, Inc., 20 December, 1963.

2. E. D. Vinson, Transistorized Servo Amplifier. Dayton Laboratory Tech. Memo #2, Link Group/Systems Division, General Precision, Inc., 2 December, 1963.



T1: ALLIED RADIO (KNIGHT) 64G165 DRIVER TRANSFORMER
PRIM. 500 T CT 36.5Ω
SEC. 200 T CT 15.5Ω

ALL CAPACITORS IN μf

Figure 5. Pitch System Schematic

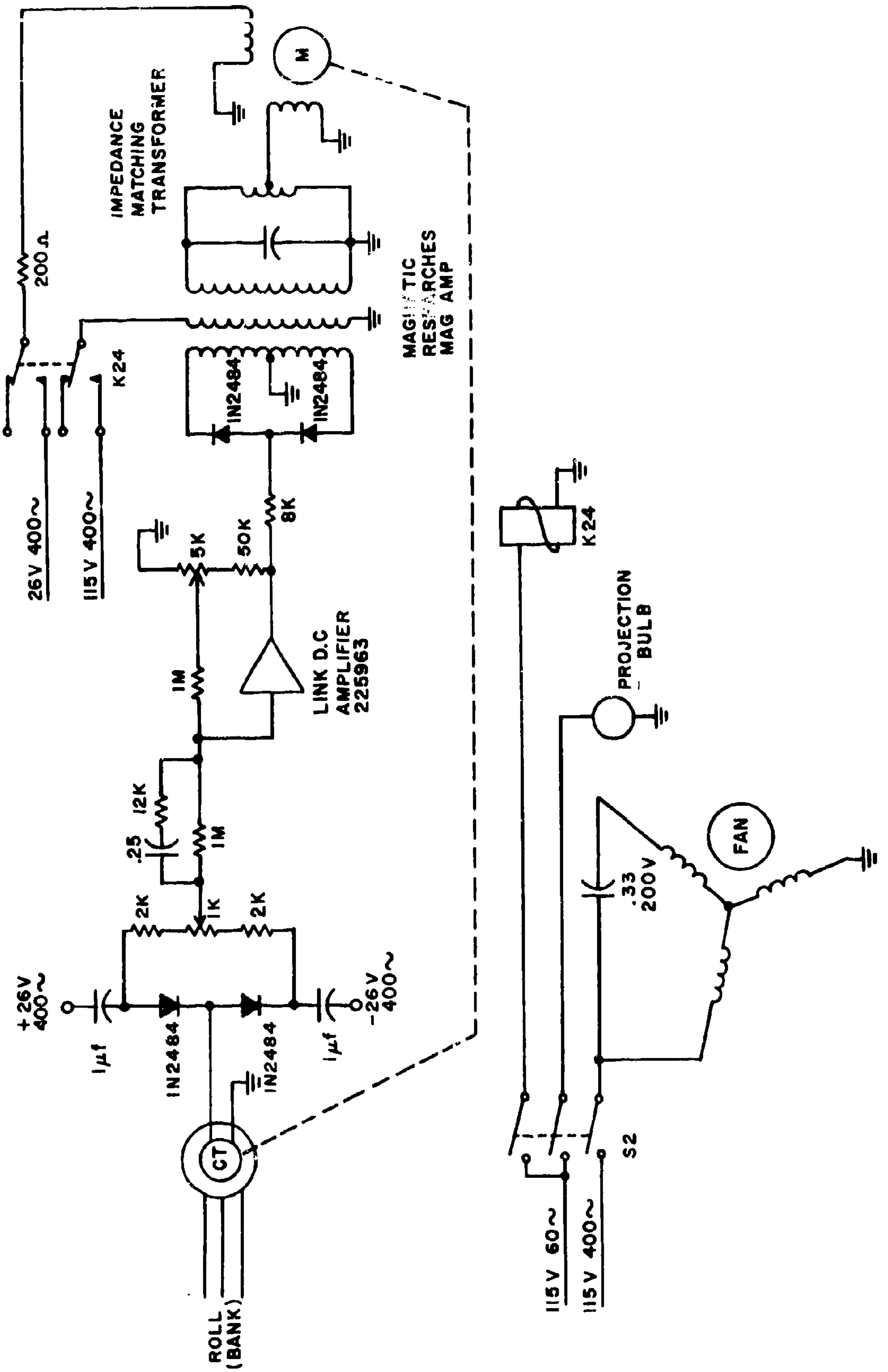


Figure 6. Roll System Schematic

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13. ABSTRACT

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