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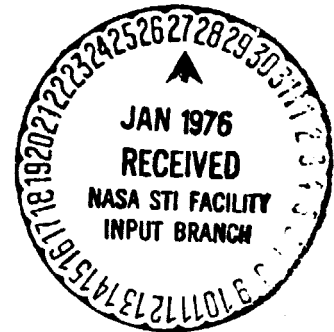
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**DESCRIPTION OF A LANDING SITE INDICATOR (LASI)
FOR LIGHT AIRCRAFT OPERATION**

Harry V. Fuller and Bruce K.E. Outlaw

January 1976



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16. Abstract An experimental cockpit mounted head-up type display system has been developed and evaluated by LaRC pilots during the landing phase of light aircraft operations. The Landing Site Indicator (LASI) system display consists of angle of attack, angle of sideslip, and indicated airspeed images superimposed on the pilot's view through the windshield. The information is made visible to the pilot by means of a partially reflective viewing screen which is suspended directly in front of the pilot's eyes. Synchro transmitters are operated by vanes, located at the left wing tip, which sense angle of attack and sideslip angle. Information is presented near the center of the display in the form of a moving index on a fixed grid. The airspeed is sensed by a pitot-static pressure transducer and is presented in numerical form at the top center of the display.					
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SUMMARY

An experimental cockpit mounted head-up type display system has been developed and evaluated by LaRC pilots during the landing phase of light aircraft operations.

The Landing Site Indicator (LASI) system display consists of angle of attack, angle of sideslip, and indicated airspeed images superimposed on the pilot's view through the windshield. The information is made visible to the pilot by means of a partially reflective viewing screen which is suspended directly in front of the pilot's eyes.

Synchro transmitters are operated by vanes, located at the left wing tip, which sense angle of attack and sideslip angle. Information is presented near the center of the display in the form of a moving index on a fixed grid. The airspeed is sensed by a pitot-static pressure transducer and is presented in numerical form at the top center of the display.

INTRODUCTION

The approach and landing phase is the most critical part of light aircraft operation. Statistics show (Ref. 1) that more accidents occur during this phase of flight operations than in any other.

In recent years, there has been considerable effort devoted to the development of head-up type displays to assist pilots during aircraft landings (Ref. 2-9). Activity has been centered in military

and commercial aviation, using cathode ray tube systems or precision servos and other equipment too expensive for the general aviation aircraft owner.

The Landing Site Indicator (LASI) is an experimental device for use in determining the feasibility of head-up displays for general aviation. Prior to construction of an experimental device, the LASI concept was investigated in an exploratory simulation study (Ref. 10) to establish concept feasibility. The experimental unit described uses a surplus Navy MK-18 reflex gunsight and a pair of servos, of the type used in the operation of radio controlled hobby aircraft models, along with the required sensors and electronics.

SYMBOLS

V	Indicated airspeed, miles per hour*
α	Angle of attack, degrees
β	Angle of sideslip, degrees
g	Gravitational constant, ft/sec ²
p	Dynamic pressure, lb/ft ²
ρ	Density of air at sea level, lb/ft ³

*The English system of units is used in this paper because the pilots' display is designed to present airspeed in these units as has been past practice in light aircraft.

SYSTEM DESCRIPTION

The LASI system consists of five basic components as shown in Figure 1. They include the control unit, the electronics unit, the display unit, the pressure transducer, and the alpha and beta vanes. Figure 2 shows the display unit and the control unit installed in a Cherokee 180 aircraft.

Operation - Figure 3 is the system block diagram. The pressure transducer signal is electronically digitized and then converted to a numerical display which passes through a lens for reduction. Along with the image of the fixed grid, the pressure transducer optical signal passes through a system of mirrors, through a collimating lens to the beam splitter, and finally to the pilot's eyes.

The alpha and beta signals control the rotation of the servo mirror which is mounted in a ball and socket pivot allowing for movement in two axes. The index image falls on the servo mirror and rotation by the alpha servo causes the image to move vertically, while rotation by the beta servo causes horizontal movement of the image.

The image is reflected through collimating lens No. 2 by the display mirror and then to the beam splitter, where the pilot observes it superimposed on the outside background.

Sensors - The airflow sensors are a pair of balsa vanes mounted on a boom attached to the left wing tip of the aircraft. In the horizontal plane, the vane measures angle of attack, while angle of sideslip is measured in the vertical plane. Each vane is coupled to a 400 cycle

synchro transmitter which drives a synchro receiver. The output of each receiver goes to a synchro converter whose output is a D.C. voltage proportional to vane rotation angle. The signal is then converted in the electronics unit to a pulse width modulated signal for operation of the display servos. The sensor ranges are -5 to +20 degrees for alpha, and -10 to +10 degrees for beta.

Airspeed is obtained from the output of a commercial differential pressure transducer. The transducer range is ± 0.5 PSID with a ± 5 volt output linear within $\pm 0.5\%$ of full scale. The displayed airspeed range is 0 to 199 miles per hour.

Display Unit - Figure 4 shows a simplified schematic of the display unit. The pilot observes the display through two separate lenses, one for each eye. Information to his left eye includes indicated airspeed and a background scale. The pilot's right eye sees only the moving index, but the two images mentally appear to be superimposed.

The display unit uses a Navy MK-18 reflex gunsight obtained as a surplus item. The gunsight was modified for this project by removing all of the original internal parts except the mirrors, lenses, and light sources. Two hobby-type miniature servos were installed with a pulley and cord system to pivot the movable mirror in two axes about its center. This mirror provides alpha and beta information to the pilot by reflecting the image of the index. Another mirror, fixed, provides airspeed and a reference scale for the index to the pilot.

As shown in Figure 4, airspeed is provided by three 7-segment incandescent readout units. When the airspeed readout image is pro-

jected through the reducing lens, it falls on a wedge-shaped mirror mounted on the front surface of the grid mask. The collimating lens focuses the images at infinity so that the pilot can see both the display and the outside world without having to refocus his eyes.

The index follows a similar optical path to the movable mirror. The mirror, mounted on the ball joint, has control cords attached to its sides and top and bottom. Figure 5 is a schematic side view of the display unit in which the optical path of the index can be seen.

The display, as seen by a pilot during a typical landing approach, is shown in Figure 6. The index position is a measure of direction of the aircraft velocity vector relative to the air, and the airspeed readout indicates the vector magnitude. During a landing approach, the pilot's objective is to adjust the aircrafts' airspeed and attitude such that the display index points to an imaginary contact point near the end of the runway. The aircraft does not actually touch the ground at this contact point, but instead initiates a flare at some altitude shortly before arriving at the point. This contact point, denoted as "landing point grid" in Figure 6, has two positions depending on whether or not the aircrafts' flaps are extended.

The display unit is aligned and calibrated in the cockpit so that the position of the display grid remains fixed relative to the aircraft axes. By observing the display during landing, the pilot is thus able to adjust the airspeed and flightpath of the aircraft to land at the proper approach speed and angle.

Electronics Unit - The electronics unit has three primary functions.

First, A.C. signals from the alpha and beta vanes are converted to pulse-width modulated signals which drive the display servos. Second, a D.C. analog signal proportional to dynamic pressure is converted to a digital coded signal proportional to indicated airspeed. Signal filtering is done in the electronics unit to minimize index and air-speed indicator fluctuations due to air turbulence.

A schematic diagram of the electronics unit is shown in Figure 7. The alpha and beta signals are buffered, amplified, and then fed to linear voltage-controlled pulse width modulators. The modulators maintain a constant output frequency of 50 Hertz with pulse width variations from one to two milliseconds. The pulse width modulated signals drive the alpha and beta servos in the display unit. Figure 8 shows the type of servo used.

The electronics unit also contains a square root circuit which converts the pressure transducer output to a signal proportional to airspeed. This signal is then digitized and displayed to the pilot. The relationship between pressure and indicated airspeed is obtained Bernoulli's equation as:

$$V = \left[\frac{0.93qP}{\rho_{SL}} \right]^{\frac{1}{2}}$$

The constant, 0.93 contains conversion factors required to give airspeed in miles per hour.

The analog-to-digital converter used to digitize the airspeed system has a nine-bit binary coded decimal (BCD) output with 100% over-range. The output goes to three 7-segment incandescent readouts via a

BCD to seven-segment decoder/driver.

Control Unit - The control unit, mounted on the instrument panel of the aircraft, contains the system power switch, potentiometers for controlling the light intensity of the airspeed and alpha-beta displays, and potentiometers for zero adjustment of the index. The alpha and beta index potentiometers provide zero adjustment of the index during calibration of the system.

ENVIRONMENTAL TESTS AND CALIBRATION

Vibration and temperature tests were performed on the LASI system to insure reliable performance in the aircraft environment. Vibration tests were conducted on all parts of the system except the sensors, which were already mounted on the aircraft from previous experiments. Temperature tests were performed on the electronics unit only, since the display unit and the control unit were mounted in the temperature controlled passenger compartment of the aircraft.

The electronics unit was temperature cycled from 0°C to 50°C and back to 0°C. No failures were encountered and temperature compensation was not necessary.

The LASI system was subjected to 5 to 500 Hertz vibration in three axes with a sweep rate of 2 octaves per minute at a maximum acceleration of 1.5G's. No failures were experienced.

Calibration was accomplished using D.C. voltage levels to simulate inputs from the airspeed, alpha and beta sensors. A wall mounted chart, marked off in degrees horizontally and vertically, was used to calibrate the index servos. Gains were adjusted with amplifiers in the alpha and beta electronics and the zeroes were set with the adjustment potentiometers in the control unit.

Figure 9 is a logarithmic plot showing the results of calibration of the indicated airspeed. The plot is linear, has the correct slope of 2 corresponding to the second-order airspeed equation, and has a random scatter of $\pm 0.5\%$ of full scale. Figures 10(A) and 10(B) show

the results of the alpha and beta calibration. Both graphs indicate a linear output with random vibrations within $\pm 3\%$ of full scale.

TEST RESULTS

Thirty flight hours were accumulated with the system. One hundred landings by four individual pilots were accomplished during this period, including one night landing.

After some initial erratic behavior, due to system grounding problems, the unit performed satisfactorily, with the exception of some index jitter due to air turbulence. In addition, the display did not seem bright enough due to high illumination levels in the cockpit.

The LASI Flight Test Program was designed to establish feasibility and determine pilot acceptance of a head-up type display. Pilot performance data is being reduced to determine feasibility.

Pilot acceptance was varied among the test pilots. Some veteran pilots preferred their normal visual cues in performance landings. Others felt that the head-up display concept would be very helpful for night flying or as a pilot training aid, although the angle of side-slip display was considered to be of limited value.

CONCLUDING REMARKS

A system (LASI) to provide the pilot with a head-up display of airspeed, angle of attack and sideslip angle has been designed, fabricated, and flight tested.

At the conclusion of the present phase of the LASI Project, some areas for improvement are suggested. A better compromise between noise filtering and response time would be desirable to reduce the influence of turbulence on angle-of-attack. Angle-of-sideslip could be eliminated from the display since most of the pilots felt that the normal visual cues were adequate. Due to the high illumination levels normally encountered in the cockpit on bright days, more display brightness would also be a desirable improvement.

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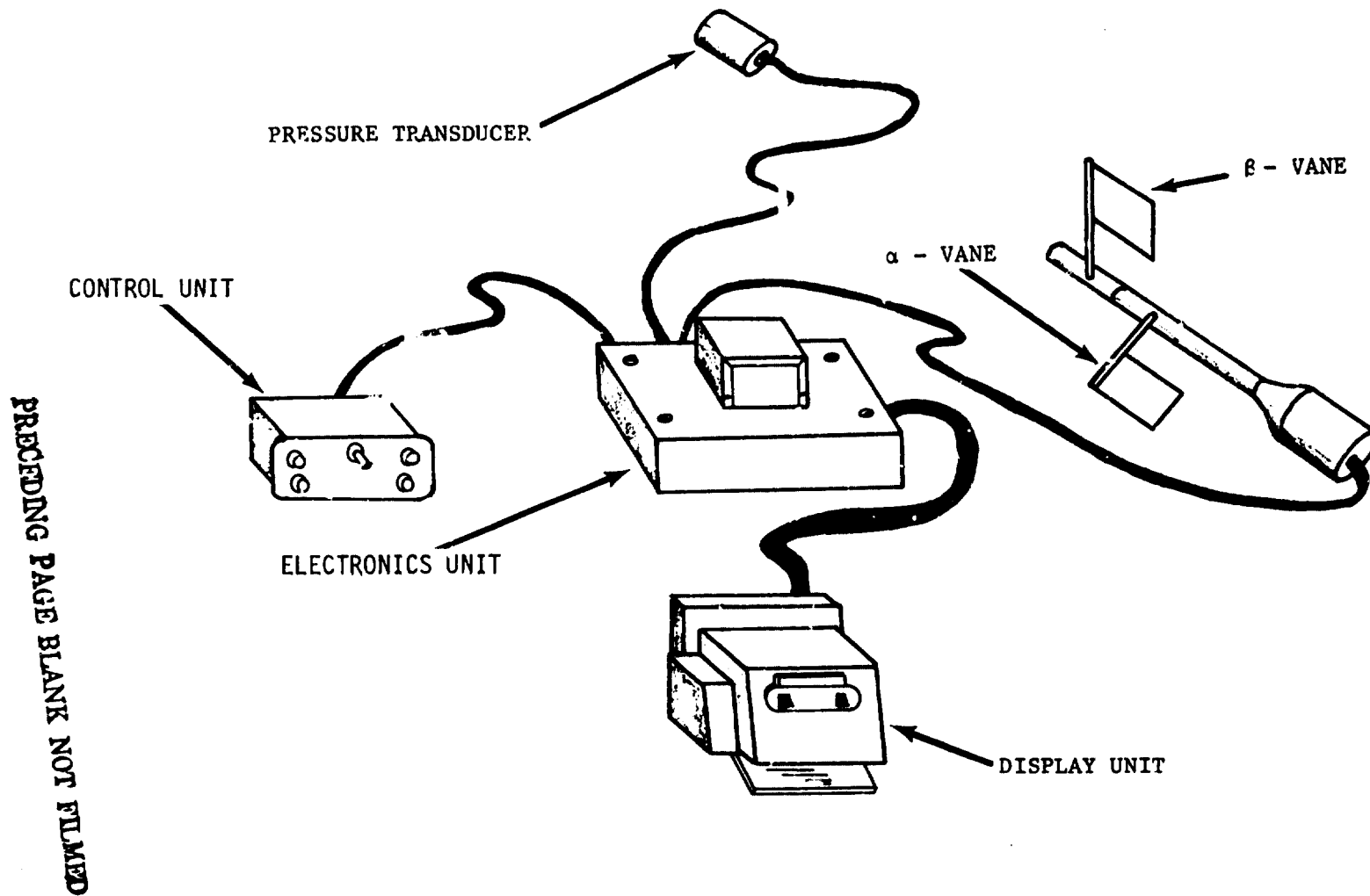


FIGURE 1 - PICTORIAL DIAGRAM OF LASI SYSTEM

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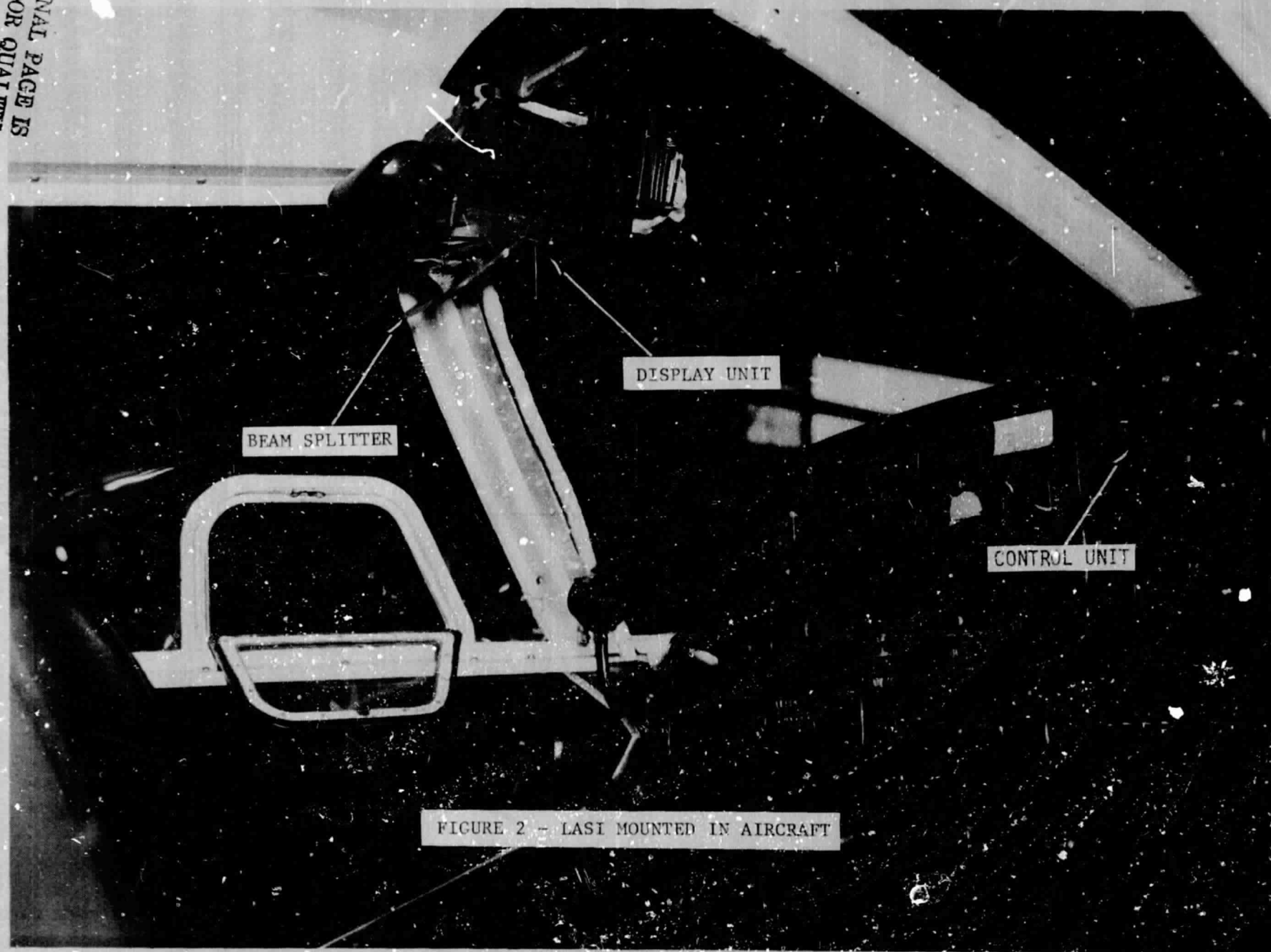


FIGURE 2 - LASI MOUNTED IN AIRCRAFT

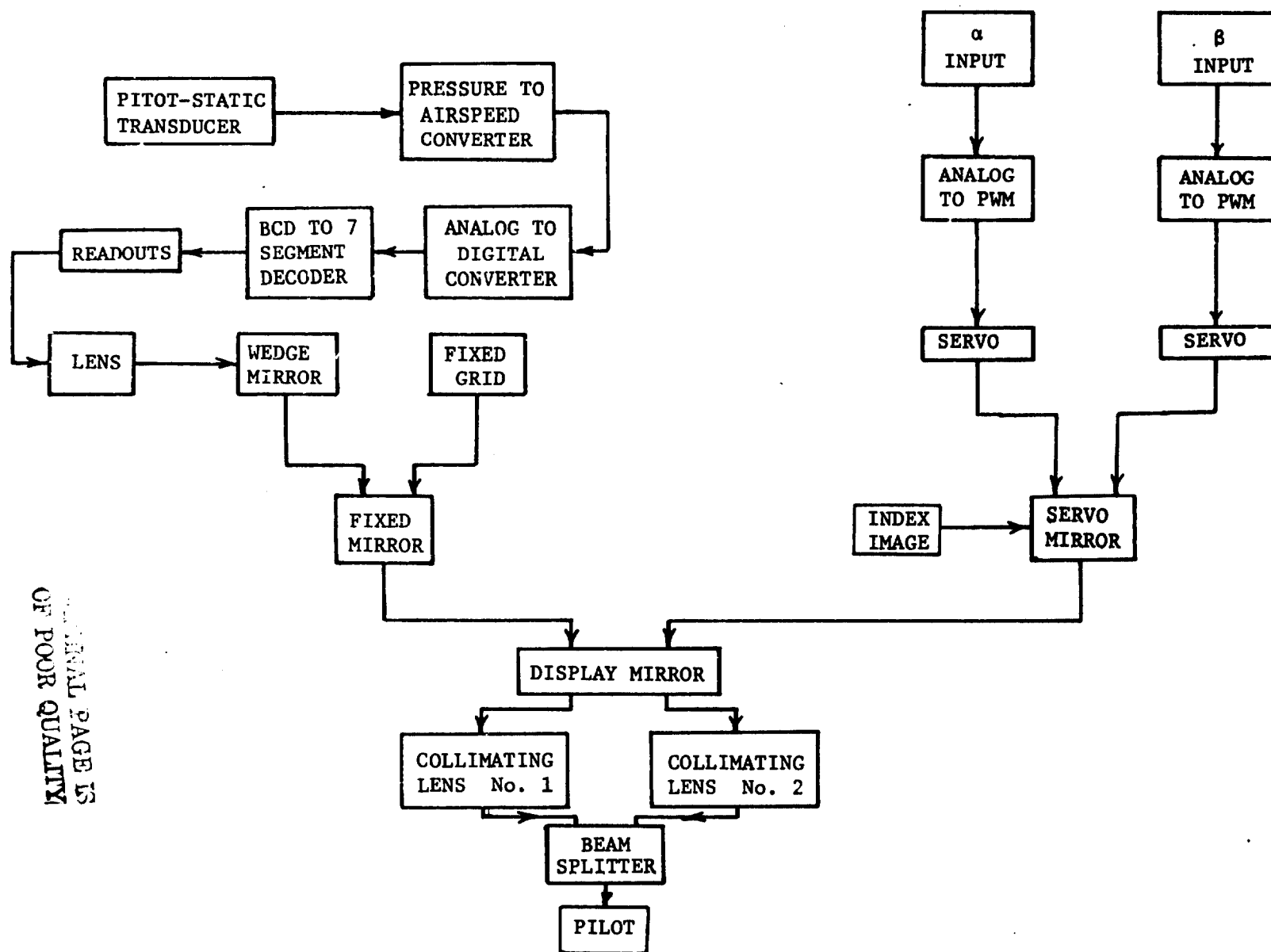


FIGURE 3 - BLOCK DIAGRAM OF THE LASI SYSTEM

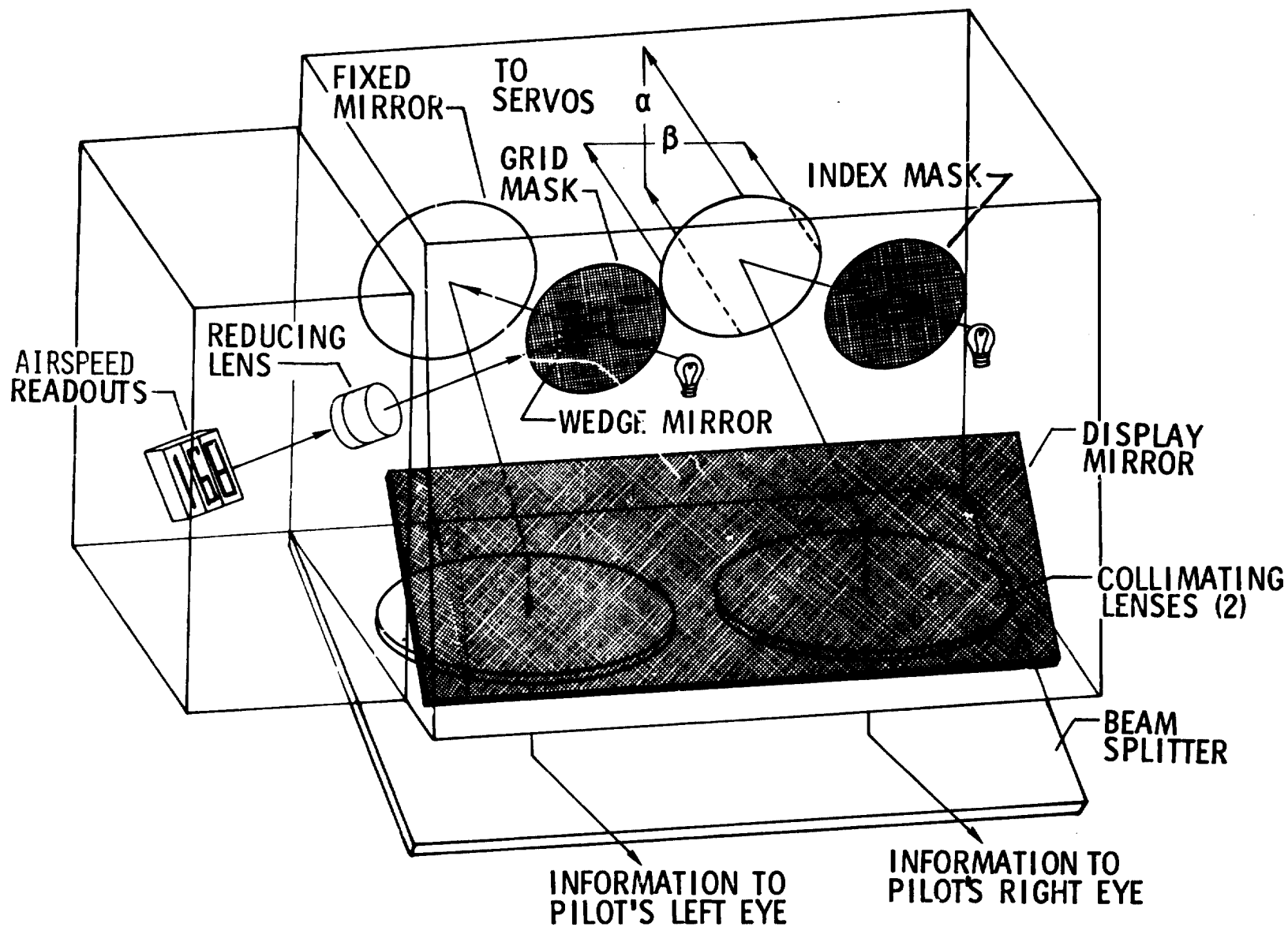


FIGURE 4 - SIMPLIFIED SCHEMATIC OF THE LASI DISPLAY UNIT

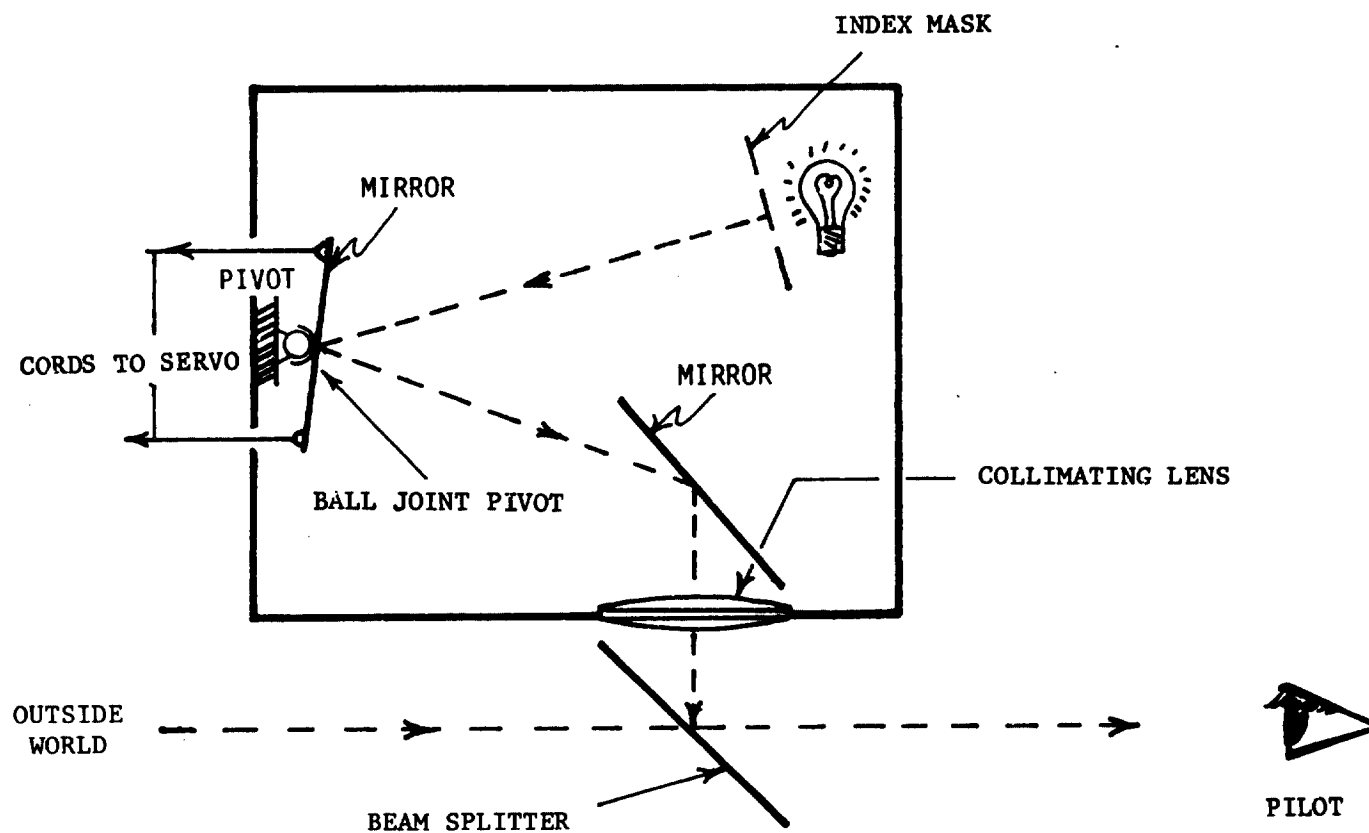


FIGURE 5 - SCHEMATIC OF ANGLE OF ATTACK INDICATION

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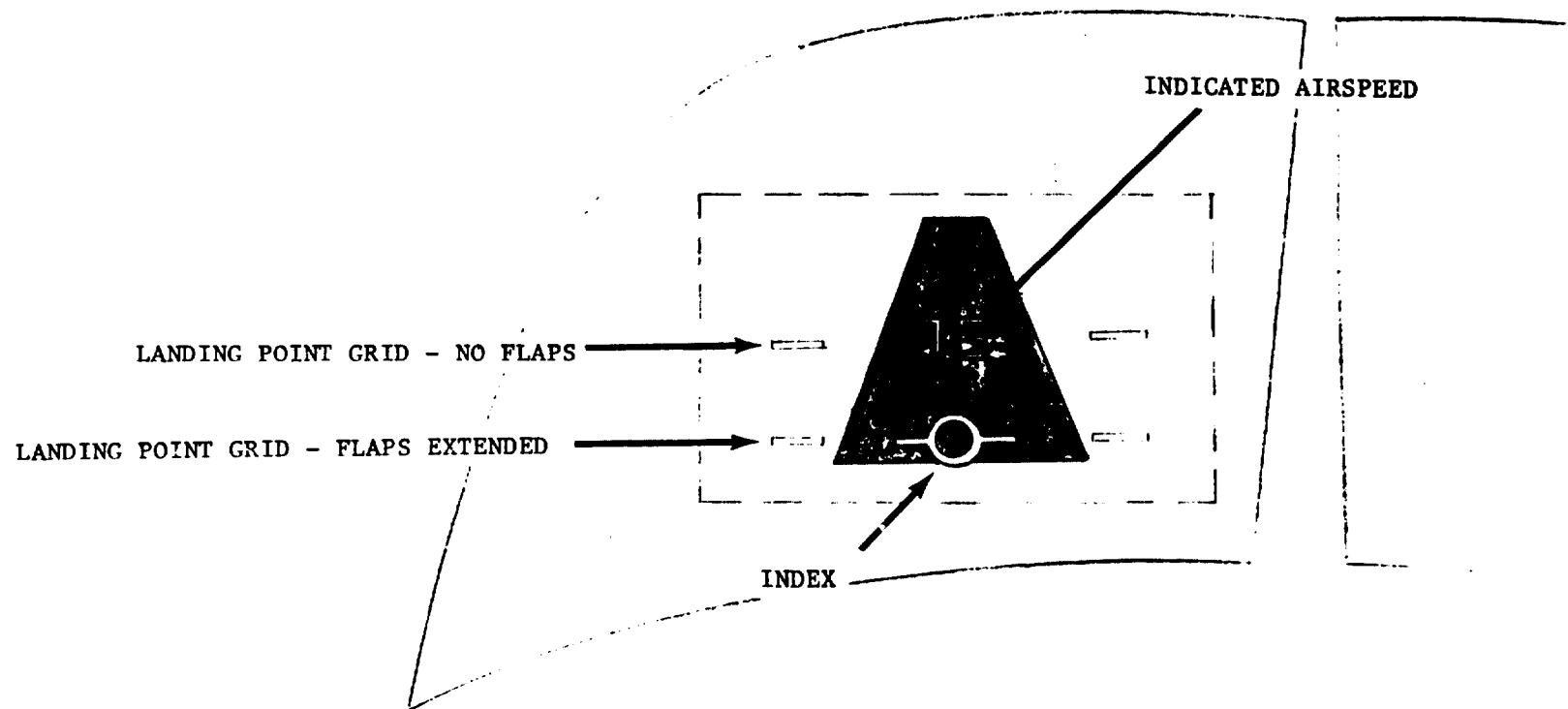


FIGURE 6 - PILOTS' VIEW OF LASI DISPLAY DURING LANDING APPROACH WITH FLAPS DOWN

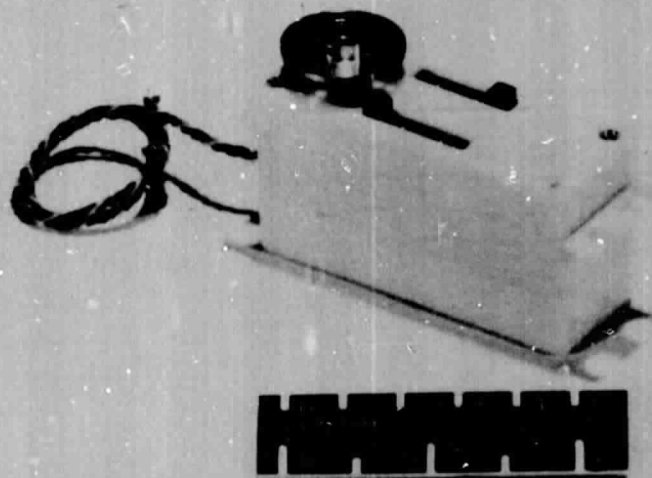


FIGURE 8 - TYPICAL SERVO USED TO ROTATE THE α - β MIRROR

PRESSURE INPUT, PSID

1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1

60 80 100 200

INDICATED AIRSPEED, MPH

FIGURE 9 - INDICATED AIRSPEED AS A FUNCTION OF DYNAMIC PRESSURE

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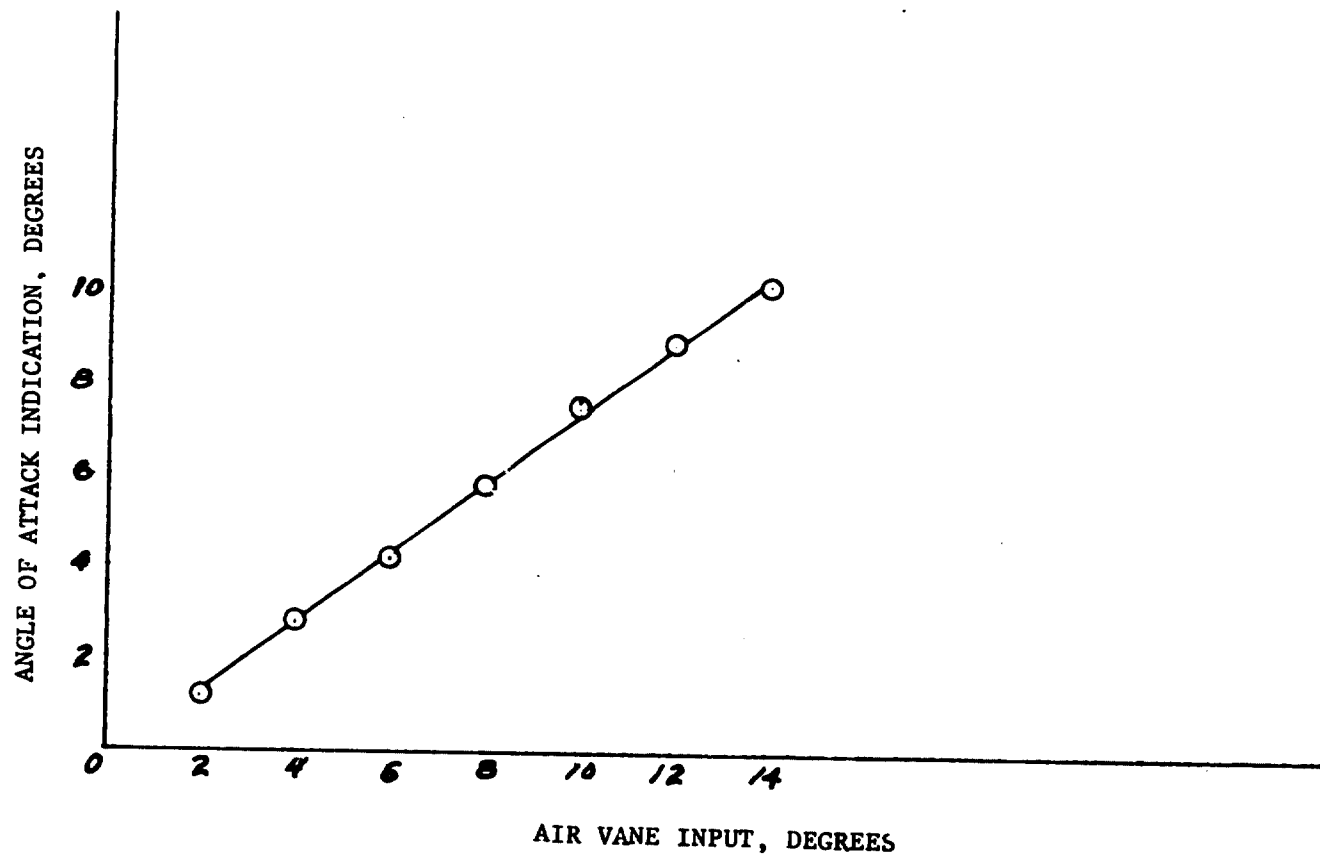


FIGURE 10 (A) - ANGLE OF ATTACK READOUT VERSUS CALIBRATED AIR VANE INPUT

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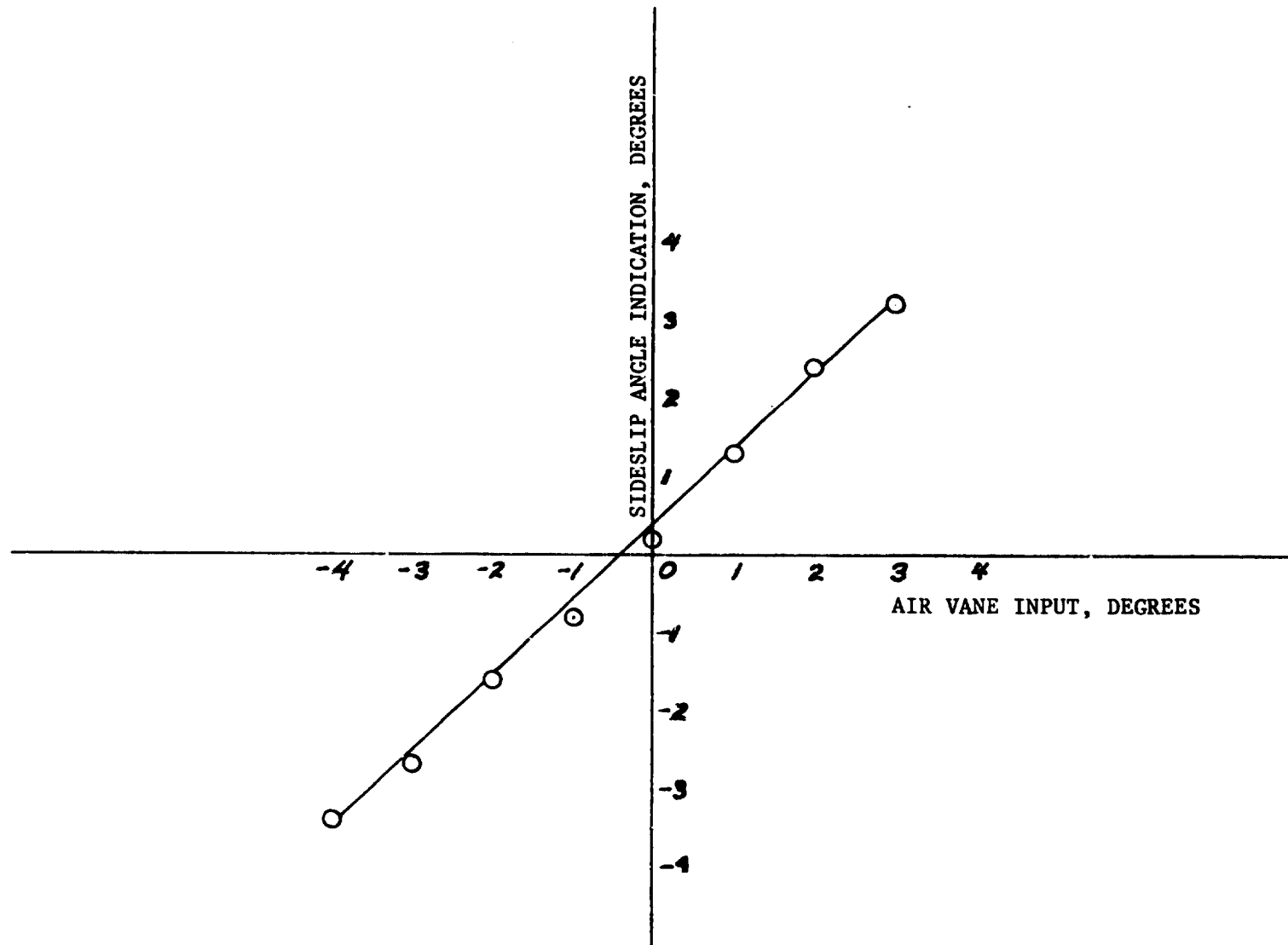


FIGURE 10(B) - SIDESLIP ANGLE READOUT VERSUS CALIBRATED AIR VANE INPUT