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DESCRIPTION AND PERFORMANCE OF THE LANGLEY VISUAL LANDING DISPLAY SYSTEM

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SUMMARY

The Langley Visual Landing Display System (VLDS) provides a means of generating a six-degree-of-freedom visual out-the-window scene for the pilot of a simulated aircraft. The system consists of a dual scaled terrain model, a lampbank to illuminate the model, a translation motion system, an optical/rotation motion system, and a color television system. The VLDS is driven by signals generated in an external computer which solves the equations of motion of the simulated aircraft. The VLDS provides television signals to an external cockpit window display device. The system was designed to accommodate simulation of a wide range of aircraft performance.

This report gives a detailed description of the hardware and its performance capability for meeting the visual requirements for a wide range of simulation studies. Appendix A of this report describes the VLDS software package which provides the necessary software interface between the outputs of a real-time aircraft simulation program and the required inputs to and outputs from

the VLDS hardware. Appendix B shows an example of how the software is implemented in a real-time program.

INTRODUCTION

The Langley Visual Landing Display System (VLDS) is the visual image generating equipment located in the simulation laboratory at Langley Research Center.

The VLDS is used in support of other Langley research facilities to generate a visual out-the-window scene which is displayed to the pilot in studies of the man/machine interface of aeronautical research. This paper describes and gives the perfomance of the equipment used to generate the video signal. The means by which the scene is displayed to the pilot on a cathode ray tube by either collimating or refractive type devices is considered the simulator cockpit display device and is not the subject of this paper. The VLDS, which became operational in the fall of 1975, can be interconnected to several different cockpits for a wide variety of simulation studies.

The VLDS consists of a dual scaled terrain model with two airports containing five runways and a heliport. The visual scene is viewed by a color television system mounted upon a translation system and mated to an optical/rotational system to give six degrees of freedom. The visual scene can represent either daytime, dusk, or nighttime conditions as well as maximum visibility conditions down to zero visibility conditions. The VLDS provides airport approach lighting systems including the requirements for

Category II operation. In addition, it provides both runway and identification lights and visual approach slope indicator lights.

The VLDS is used along with several simulator cockpits in research applications for simulation studies for several classes of aircraft. Studies for these type of aircraft may include landing approach studies, stability and control studies, takeoff/landings, ground handling studies, and simulation support of flight test programs. In addition, the VLDS will be used in studies contributing to the technical advancement of flight simulators, aeronautical research, and flight training. Because the VLDS will support a wide range of research projects, a wide range of performance was sought in the equipment. This paper describes the equipment and its desired performance. Also, the initial performance achieved is documented in this paper.

Appendix A of this report describes the VLDS software package which provides the necessary software interface between the outputs of a real-time aircraft simulation program and the required inputs to and outputs from the VLDS hardware. The first section of Appendix A describes the method and use of the software package while the second section gives storage and timing information. Appendix B shows an example of how it is implemented in a real-time program. Several figures are included to aid a user in coordination and geometry definitions, VLDS options, and variable definitions. The VLDS routines are coded in FORTRAN and COMPASS.

SIMULATOR DESCRIPTION

Basic System

The Visual Landing Display System (VLDS) is shown in an overall view as figure 1. The system consists of a terrain model, model lighting system, translation system, rotational/optical system, and closed circuit color television system. All control of these systems as well as interface with the remote central computer is provided in a control and test station located in the room with the system. Figure 2 presents the visual scene that would typically be seen by the simulator pilot. The necessary drive signals are generated externally to the VLDS on a central computer operating in real time at 32 iterations per second (typically).

Figure 3 shows the basic components that make up the system. The terrain model is 18.29 m (60 feet) long (X axis) and 7.32 m (24 feet) high (Y axis) while the track is 24.31 m (70 feet) and the tower allows for 6.10 m (20 feet) of vertical travel. Travel along the altitude drive (Z axis) is 1.22 m (4 feet).

The function of this system is to generate a television scene of the terrain model such that there are no objectionable distractions in the scene due to structural rigidity, system orthogonality, servo-dynamic response, or servo smoothness.

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Terrain Model

Model Dimensions.- The layout of the terrain model is shown in figure 4. The terrain model is a dual scaled, relief model consisting of two typical airports and the surrounding area. The overall dimensions of the model are 18.29 m (60 feet) long by 7.32 m (24 feet) wide. As may be noted in figure 4, the major portion of the model is at a scale factor of 1500/1 while a minor portion of the model is at a scale factor of 750/1. Terrain features are "faired-in" between the two differently scaled sections of the model so that there is no readily discernable change in model appearance. A dual scaled model is used so as to accommodate the landing of both large and small aircraft on the model because the minimum height of the "look-point" of the optical probe is limited to 0.178 cm (0.070 inch), which is 2.74 m (9 feet) at 1500/1 and 1.37 m (4.5 feet) at 750/1. The entire model is available regardless of the scale factor being used but the computer drive signals and the scene scale factors are only appropriate for the landing selected. The difference in scene scale factor is not distracting to the simulator pilot at the approach altitudes to either the 1500/1 or 750/1 airports. A reflective surface is mounted normal to the plane of the model and extending along the perimeter of the model so as to extend the apparent horizon in the televised display.

Model Terrain Content.- As can be seen in figure 4, about three quadrants of the overall model are typical of a rural area with cultivated fields, wooded areas, lakes, roads, railraod tracks, and scattered houses and buildings. About one quadrant of the model is typical of an urban area with tall buildings, industrial areas, tank farm, power plant, etc. The rural and urban areas both have lighting typical for dusk and night conditions conditions. The rural area lights and street lights are provided by small low voltage incandescent lamps mounted through the model surface. Illumination for the tall buildings in the urban area is provided by rear-mounted flood lamps which illuminate the transparent windows of the building models from the interior as the buildings models are open on the inside.

Model Construction.- The model is constructed of 2.44 m (8 feet) and 0.91 m (3 feet) modular panels (shown in fig. 4) which are mounted to a tubular steel framework. Each panel is constructed with a steel angle frame around its perimeter to which a flat sheet metal surface is applied. Art work was then applied to the panels to create the three-dimensional perspective for the features of the model. At installation the modular panels were assembled according to the layout of the model, the seams were "filled in" and the art work "touched up" so that the seams are not noticeably visible in the final display.

The 1500/1 airport and 750/1 airport are located on panels referred to as runway module inserts. Each runway insert is 3.66 m (12 feet) by 0.91 m (3 feet) in size and is constructed on a sheet of Melinex. This stretched sheet serves as the runway skin and upon it is painted the airfield detail. Prisms are mounted in accurately punched holes in the runway skin to represent the various lights on the airfield. Both runway module inserts are supported from the floor of the building independent of the rest of the model structure. Thus, the modules can be accurately aligned with respect to the translation drives and they will not be subjected to any vibrations that may be introduced to the main model structures. The seams between the stretched runway skin and adjacent model panels were disguised in a similar manner to that of the other modular panels in the model.

1500/1 Airport.- A representation of a metropolitan airport is contained in this portion of the model at a scale factor of 1500/1. This airport contains two runways for conventional takeoff and landing (CTOL) aircraft each of which is 3,505 m (11,500 feet) in length and 81 m (267 feet) in width. One of these runways is for instrument flight rules (IFR) operation and accurately simulates runway markings and lighting schemes for an approach lighting system with sequenced flashers for Category II (ALSF-2) operation as described in FAA Advisory Circular AC 150/5300-2B. This IFR runway contains active approach lights, sequenced flashers, centerline lights, touchdown zone lights, runway edge lights, taxiway lights, runway distance remaining lights, and end of runway lights. The second runway is for visual flight rules (VFR) and contains the same markings as the IFR runway but the lighting systems are dummy. The VFR runway does contain active runway end identification lights (REILS) and visual approach slope indicators (VASI).

This airport also contains a third runway for short takeoff and landing (STOL) aircraft which is 610 m (2,000 feet) in length and 41 m (133 feet) in width. The STOL runway contains appropriate markings and lighting for both VFR and IFR operation. The STOL runway contains active threshold lighting, runway edge lighting, runway distance remaining lights, and runway end lights. In addition, it contains REILS and a VASI system. The STOL lighting and marking system conforms to the requirements of FAA Advisory Circular AC 150/5300-8.

750/1 Airport.- A representation of a smaller airport is contained in this portion of the model at a scale factor of 750/1 as shown in figure 4. This airport contains one runway 1,524 m (5,000 feet) in length and 61 m (200 feet) in width with active lighting to meet the requirements for a Simplified Short Approach Lighting System with Runway Alignment Indicator Lights (SSALR) as defined in FAA Advisory Circular AC 150/5300-2B. This airport contains a runway 914 m (3,000 feet) in length and 41 m (133 feet) in width for VFR use which contains a dummy SSALR approach lighting system and runway markings. The VFR runway does contain active VASI and REILS. In addition, a heliport is provided with a landing and takeoff area typical of a Public Class III (large) heliport. The heliport contains lighting and markings for both VFR and IFR operation as given in FAA Advisory Circular AC 150/5390-1A.

Model Illumination

The model is evenly illuminated by a vertical bank of flourescent lamps located approximately 3.05 m (10 feet) from the model surface (see figs. 1 and 3). The optical probe/camera transport runs between the model and the lampbank, and to eliminate shadows on the model caused by them, an additional bank of flourescent tubes approximately 1.52 m (5 feet) wide and 7.32 m (24 feet) high is mounted on the camera transport (see fig. 5). In addition, six 150-watt quartz iodine lamps are mounted on the forward end of the Z carriage (see fig. 7).

For daytime operation, all of the lamps of the main lampbank are illuminated while 1/3 of the lamps are required for dusk operation and 1/6 for night operation.

Radiation measurements of the flourescent lampbank show that no hazard exists to the eyes of the VLDS operating personnel for ultraviolet nor near-infrared light based upon an 8-hour exposure period. Measurements also show that the radiation levels do not exceed the maximum permissible exposure for the skin based upon an 8-hour exposure period. However, measurements show the radiant flux levels within the visible bank are greater than the maximum permissible exposure based on an 8-hour exposure time. Thus, a person could receive the maximum permissible exposure for the eye by continuously looking at the lampbank for more than 27 minutes.

The lampbank has a luminance of 10,000 foot-candles, which is a brightness similar to the noon day sunlight incident on snow. This luminance level can cause "snow blindness" when one lets the unprotected eye become adapted to looking directly at this light level for extended periods.

Translational System

A camera carriage is provided which transports the optical/rotational system and the television camera to position the look point of the optics system with respect to the model. This camera is servo driven along horizontal parallel rails set in front of the model to provide the X translation motion. A tower mounted perpendicular to the X drive provides a vertical rail parallel to the model for the servo-driven Y motion of the camera carriage. The Z drive of the carriage is mounted on the Y drive normal to the model to servo drive the television camera toward and away from the model surface to provide changes in the height above the model surface. A nose cone switch is mounted on the optical probe which causes the Z drive to be retracted from the model if contact is made with the model surface.

The limits of travel in the three axes are

X, 17.07 m (56 feet) over the model area, plus approximately 3.35 m (11 feet) of over travel for positioning the camera carriage for maintenance purposes.

Y, ±3.05 m (±10 feet) from the model center.

Z, ±1.22 m (±4 feet) above the model. (Minimum height is 0.178 cm or 0.070 inch.)

Signals to drive these servos are generated in the real-time computer program for the particular study at hand. Analog-type output signals from the computer program provide velocity commands which are position error augmented as input signals to each translation servo. Input signals are scaled between -100 and +100 VDC. Each servo is driven by a d.c. torque motor. Each servo loop is closed in the hardware by velocity feedback from a precision tachometer. Fine and course feedback signals are provided from feedback potentiometers on each servo and are used for generating a position error term which is summed with the velocity command for each respective servo.

The structural rigidity of the carriage is designed such that no noticeable vibrations are introduced into the televised display scene during normal aircraft operating patterns. The orthogonality of the carriage axes is such that there is no noticeable coupling of any one axis due to motion of another axis for the system.

A cable payout system is provided to carry all cables to the camera carriage for the servo drives, television camera cables, power cables for the tower light system, and other auxiliary cables required for system operation. This payout system (see fig. 6) consists of a track, parallel to the track of the X drive, which supports a chain-drag mechanism through which the cables are attached. The cable handling system causes a constant loading on the X servo and does not degrade the required performance.

Optical/Rotational System

The optical/rotational system (optical probe) is mounted on the Z drive of the camera carriage (see fig. 7) and mates to the television camera. The optical probe is the "eye" of the VLDS and provides an angular field of view of 60° (±30 about a central line of sight). The optical probe uses independent servo systems to control each axis of motion (roll, pitch, and yaw) as well as servo drives for maintaining continuous focus and for "visibility" control through the skyplate drive.

The integral servo drives provide motion of the optics train to position the line of sight (optics axis) in an equivalent manner as a three-axis gimbal where yaw (ψ) is the outer gimbal, pitch (θ) is the middle gimbal, and roll (ϕ) is the inner gimbal. The position input signals to the optics system are generated on the central computer from a mathematical representation of the three-axis gimbal. The angular servo drives produce pure rotations about each axis both independently and simultaneously within the limits of operation of the optical probe.

The limits of travel about each axis are as follows:

Yaw (ψ)	continuous
Pitch (θ)	$^{+25}_{-45}$ degrees
Roll (ϕ)	continuous

where the (0,0,0) condition positions the line of sight normal to the local vertical for an airplane in level flight. Positive angles for pitch indicate nose-up, positive angles for roll indicate right wing down, and positive angles for yaw indicate nose right.

The optical probe provides a servo to maintain continuous control of focus of the displayed scene. The servo is a positional servo requiring a drive signal of 0 VDC for near focus and +100 VDC for infinite focus. The focus command is computed as a function of forward velocity, height, pitch angle, and visibility.

Limited visibility is provided for the system by means of an optical wedge or skyplate in the optical probe. The device consists of an optical wedge which is positioned by means of a servo in the optical path to create a sky above the terrain scene. The skyplate is illuminated by means of a small incandenscent lamp through a color filter to give the "sky" the desired brightness and color. The skyplate may also be positioned "in" and "out" of focus to provide a limited visibility cue ranging from maximum clear air conditions to zero visibility. In addition, the skyplate is positioned to prevent visibility of the area beyond the edge of the model when the maximum altitude is reached or when the optical probe is near the model edge. The drive signal for the visibility servo is generated in the central computer where a command signal of +100 volts d.c. represents maximum visibility and -100 d.c. represents zero visibility. The visibility drive command is computed from selected visibility, heading, and camera position on the model to give selected visibility where possible.

Television System

A closed circuit television system generates the video signal displayed to the pilot in each simulator by means of a CRT display device. A Norelco PCB 701 MOD 1 Camera System is used in the VLDS which utilizes 2.54 cm (1 inch) diameter Plumbicon image tubes for generating prime red, green, and blue colors simultaneously. The camera head and associated preamplifiers and hardware are mounted on the Z drive carriage. The camera is modular in construction using solid state circuitry. The scanning yokes are matched for optimal registration. A three-element color separating prism is used immediately in front of the Plumbicon tubes. The optical probe mounts in front of the color separating prism.

The camera control system shown in figure 9 and associated equipment are located at the test and control station as shown in figure 8. A "contours out-of-green" image enhancer is provided using horizontal and vertical contour techniques to give improved picture clarity and sharpness. A 35.6 cm (14 inch) monochrome picture monitor is provided along with a waveform monitor for monitoring picture content and waveforms, for setting up of synchronization, pedestal, registration, and color balance. A RGB 63.5 cm (25 inch) color monitor is provided for viewing the output scene, and as an aid to set up and maintenance to the system.

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System Control and Test Stations

The system control and test station is located at the end of the model adjacent to the extended section of the track. This station facilitates the maintenance and setting up of the visual system and provides system control and test capability. Figure 8 shows the layout of this station. The maintenance controls are grouped in four main areas.

1. Model Control Panel
2. Camera Control System
3. Manual Control Unit
4. Servo Input/Output Patch Panel

Model Control Panel.- The model control panel, as shown in figure 10, contains power ON and OFF switches for both local and TV power. The MAINTENANCE CONTROL/COMPUTER CONTROL switch is located here as well as a switch/indicator for resetting the camera position once it has become unlatched due to activation of the nose cone switch. Other switches on this panel enable the operator to select day, dusk, or night conditions; to select airport and approach lighting; strobe lights; VASI lights; REIL's; and aircraft landing lights.

Camera Control System.- This control system, as shown in figure 9, consists of the Electronics, Operation, and Registration Units. It supplies all operating voltages and pulses to the camera head and receives video from the camera head. All processing of the video signals and all operation and registration adjustments are made at the respective unit panels. All three units are mounted in a 48.3 cm (19 inch) rack.

The Electronics Unit consists of three drawers of individual plug-in modules which are used for video processing circuitry and for power supplies. Waveform and voltage test points and setup controls are provided on the front plate of individual modules.

The Operation Unit contains the controls and switches required for system operation. One series of push-button switches is provided for turning system power ON and OFF and transferring control to REMOTE operation. Controls are also provided for adjusting the GAIN and BLACK LEVEL of each channel individually and simultaneously.

The Registration Unit houses all the controls necessary for the proper geometric registration of the video signals plus beam and focus controls for the individual Plumbicons. The local PXM switches enable the operator to select, for display on the picture monitor, the red, green, and blue signals (singularly, or in any combination) as well as a linearity test pattern.

Manual Control Unit.- This unit is shown in figure 11 and is portable to allow manual control of the VLDS servos by the operator from any position along the entire length of the model. By means of switch/indicators on this unit, manual control may be acquired for all three degrees of rotation, all three degrees of translation, as well as for visibility and focus. Manual control potentiometers enable the operator to command position inputs for roll, pitch, yaw visibility, and focus while toggle switches enable rate commands for longitudinal, lateral, and altitude drives.

Servo Input/Output Patch Panel.- This panel is shown in figure 12 and provides test jacks for commanding inputs to the system and for monitoring certain feedback signals from the servos. To facilitate tests from this panel, two separate input voltage adjustment potentiometers with terminals brought out to the test jacks are provided along with input voltage reversal switches. Input jacks are provided for drive signals for all system servos including the VASI drives. Test jacks are provided for input commands to dimmer controls for the runway lights, VASI's REIL's, and strobes. Jacks are provided for monitoring position feedback for the rotational and translational servos and velocity feedback for the translation servos only. Also various test voltages are available from jacks for use as command voltages.

HARDWARE -- SYSTEMS PERFORMANCE

The function of the VLDS is to give the pilot an accurate visual out-the-window view of the terrain scene. Of very high importance in achieving an accurate representation of the external visual scene is performance of the translation and rotational servos used to generate the visual scene. This requires that the servos have high dynamic response as well as a high degree of smoothness of movement within the servo operating envelope. The servos must also be capable of providing high rates and accelerations. To meet the performance requirements for the VLDS servos, it was necessary that they be designed such as to minimize the effects of the transient response as well as the steady state time lags.

Also of high importance in achieving an accurate representation of the external visual scene is the performance of the television system used to view the terrain model and generate a video signal for the cockpit display device.

The maximum speed availability in user parameters for the translational servos are given as follows:

Servo Drive	1500/1 Scaling	750/1 Scaling
Longitudinal	152 m/sec -- original (296 knots)	76 m/sec -- original (148 knots)
	229 m/sec -- modified (444 knots)	114 m/sec -- modified (222 knots)
Lateral	152 m/sec -- original (296 knots)	76 m/sec -- original (148 knots)
	229 m/sec -- modified (444 knots)	114 m/sec -- modified (222 knots)
Altitude	152 m/sec (30,000 ft/min)	76 m/sec (15,000 ft/min)

Translational Servo Performance

To meet the overall goals of the VLDS, requirements were determined for the translation servos expressed in terms of static and dynamic performance requirements. Static performance is dependent upon the range of travel desired, accuracy (linearity) of the servos in positioning to a command position, and repeatibility of the servo to return accurately to a previously commanded position. The translational servos are driven by velocity command signals. The velocity command signal is augmented by a position error signal formed in the central computer by comparison of the translational drive position feedback signal with the computed position signal. The positioning accuracy requirement for the translation servos is 0.05 percent of full-scale travel with the actual values given in Tables I, II, and III for the X, Y, and Z servos, respectively. The required repeatibility for the X, Y, and Z servos is also given in the same table.

The servo dynamic performance was measured with the system interconnected to the central computer for command signals. As stated under the performance goals for the system, it is necessary that the servos meet the acceleration, velocity, dynamic tracking error, and smoothness requirements as well as to minimize the effects of the transient response and the steady state time lags. It was desired that these servos have a response characteristic typical of that provided by a second-order system. When driven by a constant velocity command, the steady state time lag is to be less than 0.1 second and the transient response such that this steady state lag is achieved within 1 second after the discontinuity. Table IV shows a comparison of the desired values of acceleration, slew velocity, constant velocity, and smoothness with the measured test result. Table V shows the frequency response characteristic measured by commanding the servo under test through a range of frequencies from the computer. A computer program was used to compare the servo position feedback with the commanded position to give the servo amplitude ratio and phase angle using a fast fourier transform technique. Table VI gives the approximate second-order transfer function parameters which were determined from the data given in Table V. The time-delay constant ($2\ \zeta/\omega_n$) for the translation servos is shown to be 0.010, 0.015, and 0.009 second for the longitudinal, lateral, and altitude servos, respectively.

In an early landing approach study to a runway diagonal to the longitudinal and lateral servo drives, it was noted that there was a steady-state positional lag in each translational servo. This has been corrected by modifying the software to allow for an adaptive forward loop gain which eliminated the problem (ref. 2).

Rotational Servo Performance

In a similar manner as that done for the translational servos, the requirements for the rotational servos were expressed in terms of static and dynamic performance requirements. The rotational servos, however, are driven by position command signals from the central computer. The position feedback loop for the rotational drive is closed within each servo. The static positioning accuracy requirement is that the line of sight shall be positioned to within plus or minus 0.1° of the commanded input, to within plus or minus 5° of the (0,0,0) condition, and to within plus or minus 0.3°

throughout the remainder of the travel. The static test results for the rotational servos are given in Tables VII, VIII, and IX.

Rotational servo dynamic performance was checked with the system interconnected to the central computer, to compare desired acceleration, velocity, tracking error, smoothness, and the steady state time lag with actual performance of the system. The desired response for the rotational servos is also that of a second-order servo with the steady state time lag to be less than 0.1 second when commanded by a constant velocity signal. Table X gives the dynamic performance measured for these servos while Table XI shows the frequency response characteristics measured in the same manner as for the translational servos. It should be noted in Table X that the measured acceleration was approximately a magnitude greater than required. The approximate second-order transfer function parameters determined from the data of Table XI are given in Table VI. The time-delay constant ($2\zeta/\omega_n$) for the rotational servos is shown to be 0.022, 0.022, 0.021 for the roll, pitch, and yaw servos, respectively.

Television System Performance

To insure that the television system would produce a high quality color picture at the output of the VLDS, it was necessary that the system meet certain requirements. These requirements were expressed in terms of peak signal-to-noise ratio, registration requirements, linearity and geometric distortion requirements, resolution requirements, and depth-of-field requirements. It was also required that the picture not display any microphonic noise for any maximum acceleration of the translational or rotational servos. The picture was not to show any evidence of fixed pattern noise, moiré, target grain, nor video shading.

Table XII gives the results of checks that were made on the system using appropriate test charts. The television system had a signal-to-noise ratio of 39.5 db when checked on a Rohde and Schwarz signal-to-noise meter set to wideband. However, with the meter set to 5 MHz bandwidth, the result was 42 db comparing with the requirement of 40 db.

CONCLUDING REMARKS

The Visual Landing Display Simulator provides a means of generating a realistic and accurate visual scene to support the flight simulation research for a variety of studies at the Langley Research Center. The dynamic performance of the VLDS is superior to that of similar TV model board systems normally found in the field. Also, the physical size, dual model scale factors and various landing sites available give it a great amount of versatility as a research support device.

The major limitation to the VLDS is that the field of view of the visual display (48° horizontal by 36° vertical) limits the capability for conducting full 360° traffic-pattern approaches as do most all visual scene generators in use today. Also there is a lack of true three-dimensional fidelity as exists in any presentation of this type.

From one study (ref. 2) conducted in a motion simulator, indications are that the VLDS appears to lower the subjective pilot workload and improve statistical consistency among pilots during landing approaches through touchdown when compared to an older model board with poorer performance. Yet, touchdown performance in the simulator does not approach that of actual flight and the visual problems of pitch attitude reference, and altitude and sink rate estimation are cited as the deficiencies responsible for this degradation.

An improvement under consideration is the replacement of the electro-mechanical optical sky generator with an electronic special effects unit which will allow flight above the cloud tops, flight into and from the clouds, flight below the cloud base, and generation of ground fog profiles.

The VLDS has been operational since the fall of 1975, supporting research for a number of studies with no serious performance deficiencies noted.

APPENDIX A

VLDS SOFTWARE PACKAGE

by

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METHOD AND USE

Method

The VLDS software program requires 28 real variables, 9 logical control variables, 2 logical discretes from the VLDS, and 11 analog signals from the VLDS. The program uses these inputs to calculate 19 analog signals to be sent to the hardware. Five logical outputs are also generated, which, along with 2 of the logical control inputs, are transmitted to the hardware as logical discretes. One common block is used to link the real-time application program to the VLDS subprograms. The DAC/ADC channels, input/output analog trunking groups and input/output discrete groups, are to be determined by the user.

Use

VLDS Common Block.- The common block VLDSC3 must be contained in the calling program to transfer information to and from the VLDS subprograms. The block is coded as follows:

```
      COMMON/VLDSC3/
     1         VLDSVAR(28)
     2         VLDSADC(11)
     3         VLDSDAC(19)
     4         VLDSLOG( 9)
     5         VLDSLI ( 2)
     6         VLDSLO ( 5)
      LOGICAL VLDSLOG, VLDSLI, VLDSLO
```

Input of Real Variables.- Twenty-eight real variables are required by the software package. They must be scaled and entered into the storage locations VLDSVAR.

1. XRNWAY - Aircraft c.g. to touchdown distance along the X-axis of the runway centered axis system (feet).

2. YRNWAY - Aircraft c.g. to touchdown distance along th- Y-axis of the runway centered axis system (feet).

3. HRNWAY - Height of the aircraft c.g. above the runway (feet).

4. UE - Aircraft north velocity relative to Quaternion North (ft/sec).

5. VE - Aircraft east velocity relative to Quaternion North (ft/sec).

6. WE - Aircraft vertical speed (positive WE for velocity downward), (ft/sec).

7. VG - Magnitude of the ground track velocity (ft/sec).

8. PA - Aircraft roll rate (rad/sec).

9. QA - Aircraft pitch rate (rad/sec).

10. RA - Aircraft yaw rate (rad/sec).

11. PHI - Aircraft Euler roll angle (deg/180).

12. THETA - Aircraft Euler pitch angle (deg/180).

13. PSI - Aircraft Euler yaw angle (deg/180).

14. SINTH - Sine Euler pitch angle (ND).

15. SINPHI - Sine Euler roll angle (ND).

16. COSTH - Cosine Euler pitch angle (ND).

17. COSPHI - Cosine Euler roll angle (ND).

18. PSIRN - Runway heading relative to True North (deg/180).

19. PSIBIAS - Quaternion North relative to True North (deg/180).

20. D1 - Pilot eye distance ahead of aircraft c.g. (ft).

21. D3 - Pilot eye distance to the right of aircraft c.g. (ft).

22. D2 - Pilot eye distance below aircraft c.g. (ft).

23. HCB - Selected cloud base height (ft).

24. RS - Selected visual slant range (ft).

25. RWS - Selected runway brightness constant (ND).

26. SS - Selected runway strobe brightness constant (ND).

27. GAMMA - Selected runway glide slope angle for use in V.A.S.I. drive equations (rad).

28. XKKC - Maximum selected visibility range (ft).

Input of Logical Control Variables.-

1. RWMOD - True for 750:1 scaling; false for 1500:1 scaling.

2. LEFTRW - True when leftmost runway is selected; otherwise false.

3. RIGHTRW - True when rightmost runway is selected; otherwise false.

4. STOLRW - True when STOL runway for 1500:1 scaling or diagonal runway for 750:1 scaling is selected; otherwise false.

5. SMR - True for the simulator reset mode (RESET, OR, HOLD, OR (AUTOMATIC HOLD)); otherwise false.

6. FLTF - True for flight freeze; else false.

7. TOTF - True for total freeze; else false.

8. POSF - True for X, Y, position freeze; else false.

9. LLIGHTS - True for landing lights; else false.

These logical control variables must be entered in the storage locations VLDSLOG.

Transfer of Analog Signals From the Simulator.- The 11 analog trunks from the simulator must be inverted and transferred into the storage locations VLDSLOG.

(Example: If trunks 21-40 are to be used,

```
VLDSADC(1)  =  -ADC(21)
VLDSADC(2)  =  -ADC(22)
   :              :
VLDSADC(11) =  -ADC(31))
```

Transfer of Discrete Signals From the Simulator.- Two discrete signals will come from the VLDS hardware and must be transferred to the VLDS software via the storage locations VLDSLI(2).

(Example: If discrete trunks 50-60 are used,

```
VLDSLI(1) = LDISI( 99)
VLDSLI(2) = LDISI(100))
```

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Transfer of Analog Signals From the Software to the Hardware.- Nineteen DAC channels must be chosen to transfer analog signals to the trunks to the VLDS. The signals must be inverted and are found in the storage locations VLDSDAC.

(Example: If DAC's 61-79 are used,

```
DAC(61) = -VLDSDAC( 1)
DAC(62) = -VLDSDAC( 2)
   :          :
DAC(79) = -VLDSDAC(19))
```

Transfer of Discrete Signals From the Software to the Hardware.- Seven discrete signals must be transferred to the hardware. Five of these signals come from the array VLDSLO and two signals are inputs from the control input array VLDSLOG.

(Example: If trunks 21-40 are used as trunks to the VLDS simulator,

```
LIDSO(21) = VLDSLO(1)
LDISO(22) = VLDSLO(2)
LDISO(23) = VLDSLO(3)
LDISO(24) - VLDSLO(4)
LDISO(25) = VLDSLO(5)
LDISO(26) = VLDSLOG(1)
LDISO(27) = VLDSLOG(9)
```

VLDS Software Calling Sequence

A. CALL VLDSIC.- This initialization call should be included in the reset loop.

B. The following sequence should be contained in the one-pass portion of the operate loop (i.e., if INT $\geq$ 1, bypass).

1. Input of real variables (Sec. II)

2. Input of logical control variables (Sec. III)

3. Transfer of analog signals from the VLDS (Sec. IV)

4. Transfer of discrete signals from the VLDS (Sec. V)

5. CALL VLDS1

6. Transfer of analog signals from the software to the VLDS hardware (Sec. VI)

7. Transfer of discrete signals from the software to the VLDS hardware (Sec. VII)

VLDS Options

A. Control of runway brightness. The real input variable VLDSVAR(25) controls the runway brightness. Its values are

1.0 100 percent brightness

0.6 standard

0.2 dim

-0.4 0 percent brightness

B. Control of strobe brightness. The real input variable VLDSVAR(26) controls the strobe brightness. Possible values are

1.0 100 percent brightness

0.75 75 percent brightness

0.5 50 percent brightness

0.25 25 percent brightness

0.0 0 percent brightness

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C. Visibility Control

1. Selected cloud base height. The real input variable VLDSVAR(23) controls the cloud base height in feet. The visibility goes to zero when the aircraft altitude equals the selected cloud base height. This input should be set less than or equal to the maximum simulator altitude of 1,829 m (6,000 ft) at 1500:1 and 914 m (3,000 ft) at 750:1.

2. Maximum selected visibility range. The real input variable VLDSVAR(28) is set to the nominal value of 17,374 m (57,001 ft).

3. Selected visual slant range. The real input variable VLDSVAR(24) is set to the desired distance of visibility. A visibility of around 16,093 m (52,800 ft) is usually a good value. For maximum visibility, set the variable to 17,374 m (57,001 ft) (greater than the maximum visibility range).

4. To have the skyplate up during the simulator reset mode, select OPT1*=.T.

5. To prevent the skyplate from falling and causing zero visibility when an out-of sync mode is detected, select OPT2*-.T.

D. Selecting the slideslope for the V.A.S.I. systems. The real input variable VLDSVAR(27) is set to the desired glideslope angle in radians. Usually for the STOL runway of the 1500:1 scale, a glideslope angle of 7.5° (0.1309 radian) is used. For the diagonal runway of the 750:1 scale, usually a 3° approach (0.0524 radian) is used.

E. If the heading or roll feedback systems are out of order, set OPT3*=.T. to disable the roll or yaw out-of-sync modes.

*The COMMON BLOCK

```
COMMON/VLDSOPT/OPT1, OPT2, OPT3, OPT4, OPT5
LOGICAL OPT1, OPT2, OPT3, OPT4, OPT5
```

must be included to use these options.

Example of Usage.- The listing in Appendix B is from the tie in with the 737 aircraft simulation. An index of the VLDS interface code is provided.

A. VLDS common blocks . . . . p. 36

Only the block VLDSC3 (and for added options the block VLDSOPT) is necessary. The other blocks are used for display only.

B. VLDS variable display (optional) . . . . . p. 37

C. VLDS initialization . . . . p. 37

D. Operate loop VLDS interface . . . . p. 37-39

E. Examples of starting conditions are given in Figures 16-19.

Attaching the VLDS software package.- The VLDS subroutines are available in card from or may be attached to ones program by ALTLIBing with the VLDS library file.

(Example: Assume a normal setup to produce the binary file LGO,

```
FETCH, DC021,, DATA,,, OLDPLV.
COPYBR, OLDPLV, DUMY.
COPYBF, OLDPLV, VLDS.


RUN, S,,, SOURCE.
ALTLIB, LGO, RTSLIB, LGO.
ALTLIB, LGO, VLDS, LGO.
SETINDF.
LGO.
```

STORAGE AND TIMING REQUIREMENTS

Storage

COMMON	265
CALLING CODE	177
VDIMDR	72
VEYEDV	274
VFEEDBK	177
VFOCVDR	457
VFUNC1	12
VHTDRV	131
VLDSIC	317
VLDS1	23
VL1M6	7
VOUTPUT	53

VPBHDRV	254
VRSET	110
VVASI2	132
VVASI3	166
VXYDRV	316
	3,721

Timing

Approximately 1.75 msec/iteration
(Using a CDC 6600 Computer)

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APPENDIX B

TCV 737 APPLICATIONS PROGRAM

by

Dennis J. Martin, Jr.
Sperry Rand Corporation

```
      OVERLAY(TCVFILE,4,4)
      PROGRAM AC737
C
C
C     THIS PROGRAM PROVIDES THE CONTROL FOR THE AIRCRAFT
C     DYNAMICS AND THE WASHOUT INTERFACE
C
      .
      .
      .
      737 STORAGE AND DECLARATION STATEMENTS
      .
      .
      .
C
C     VLDS COMMON BLOCKS
C
      COMMON / VLDSC1 /
     1                  VLDSKK(54)
      COMMON / VLDSC1 /
     1                  VLDSXX(35)
      COMMON / VLDSC3 /
     X                  VLDSVAR(28),VLDSADC(11),VLDSDAC(19),
     X                  VLDSLOG(9),VLDSLI(2),VLDSLO(5)
      COMMON / VLDSC4 /
     1                  VLDSLL(13)
      COMMON / VLDSOPT /
     1                  OPT1,OPT2,OPT3,OPT4,OPT5
      LOGICAL           OPT1,OPT2,OPT3,OPT4,OPT5
      LOGICAL VLDSLL,VLDSLOG,VLDSLI,VLDSLO
C
      CALL LOSTIME(99999S)
      CALL CYCLE(90006S)
      .
      .
      ASSIGN STATEMENTS
      .
      .
      .
      CALL READY
90003 CONTINUE
      .
      .
      RESET LOOP
      .
      .
      IF(LOGIC(21)) GO TO 2343
      .
      .
2343  CONTINUE
```

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```
C     CALL TO EASILY DISPLAY VLDS VARIABLES
C     NORMAL PROGRAMS MUST USE THIS CALL IN A NON-REALTIME STATUS
      CALL DATABLX(VLDSKK,155,INTEG,20,VLDSLOG,34,ADC,40,DAG,96,LDISI,
     X99,LDISO,180)
 2343 CONTINUE
      .
      .
      .
      CALL MBRESET
C
C     VLDS INITIALIZATION(RESET LOOP)
C
      CALL VLDSIC
      .
90002 CONTINUE
      .
      .
90006 CONTINUE
      .
      .
      .
C
C     INTERFACE WITH VLDS SOFTWARE
C
C     VLDS CALLS ARE TO BE MADE ONE PASS PER TIME FRAME
      IF(INT.GE.1) GO TO 2598
90046 CONTINUE
      DATA PI / 3.1415926536 /
C     INPUT OF REAL VARIABLES
      VLDSVAR(01) = XRNWAY
      VLDSVAR(02) = YRNWAY
      VLDSVAR(03) = ALT
      VLDSVAR(04) = SXEDOT
      VLDSVAR(05) = SYEDOT
      VLDSVAR(06) = -HDOT
      VLDSVAR(07) = SQRT(SXEDOT*SXEDOT+SYEDOT*SYEDOT)
      VLDSVAR(08) = PB
      VLDSVAR(09) = QB
      VLDSVAR(10) - RB
      DATA PII / 0.3183098861 /
      VLDSVAR(11) = PHI  *PII
      VLDSVAR(12) = THETA*PII
      VLDSVAR(13) = PSI  *PII
      VLDSVAR(14) = SINTHE
      VLDSVAR(15) = SINPHI
      VLDSVAR(16) = COSTHE
      VLDSVAR(17) = COSPHI
      VLDSVAR(18) = PSILS * PII
C     IF VLDSVAR 19-28 ARE NOT SPECIFIED, STANDARD VALUES WILL BE USED
      VLDSVAR(20) = XP
      VLDSVAR(21) = YP
      VLDSVAR(22) = ZP
```

```
C     VLDSVAR(23) = SELECTED CLOUDBASE HEIGHT
C     VLDSVAR(24) = SELECTED SLANT VISUAL RANGE
C     VLDSVAR(25) = SELECTED RUNWAY BRIGHTNESS CONSTANT
C     VLDSVAR(26) = SELECTED RUNWAY STROBE BRIGHTNESS CONSTANT
C     VLDSVAR(27) = SELECTED RUNWAY GLIDESLOPE ANGLE
C     VLDSVAR(28) = MAXIMUM SELECTED VISIBILITY RANGE
C     INPUT OF LOGICAL CONTROL VARIABLES
      VLDSLOG(1) = LOGIC(22)
      VLDSLOG(2) = LOGIC(23)
      VLDSLOG(3) = LOGIC(24)
      VLDSLOG(4) = LOGIC(25)
C     LOGIC(7) IS A LOGICAL TO SIGNIFY AUTOMATIC HOLD
      VLDSLOG(5) = LDISI(18).OR.LDISI(19).OR.LOGIC(7)
      VLDSLOG(6) = LOGIC(26)
      VLDSLOG(7) = LOGIC(27)
      VLDSLOG(8) = LOGIC(28)
      VLDSLOG(9) = LOGIC(29)
C     INPUT OF ANALOG SIGNALS FROM VLDS HARDWARE
C     ANALOG TRUNKS 21-40 FROM SIMULATOR ARE USED FOR VLDS SIGNALS
      VLDSADC(01) = -ADC(21)
      VLDSADC(02) = -ADC(22)
      VLDSADC(03) = -ADC(23)
      VLDSADC(04) = -ADC(24)
      VLDSADC(05) = -ADC(25)
      VLDSADC(06) = -ADC(26)
      VLDSADC(07) = -ADC(27)
      VLDSADC(08) = -ADC(28)
      VLDSADC(09) = -ADC(29)
      VLDSADC(10) = -ADC(30)
      VLDSADC(11) = -ADC(31)
C     INPUT OF LOGICAL DISCRETES FROM VLDS HARDWARE
C     DISCRETE TRUNKS 41-60 FROM SIMULATOR ARE USED FOR VLDS SIGNALS
      VLDSLI(1) = LDISI(99)
      VLDSLI(2) = LDISI(100)
C
C     CALL TO VLDS MAIN LOOP SOFTWARE
C
      CALL VLDS1
C
C     OUTPUT OF LOGICAL DISCRETE SIGNALS TO VLDS HARDWARE
C     DISCRETE TRUNKS 21-40 TO SIMULATOR ARE USED FOR VLDS SIGNALS
      LDISO(21) = VLDSLO(1)
      LDISO(22) = VLDSLO(2)
      LDISO(23) = VLDSLO(3)
      LDISO(24) = VLDSLO(4)
      LDISO(25) = VLDSLO(5)
      LDISO(26) = VLDSLOG(1)
      LDISO(27) = VLDSLOG(9)
C     OUTPUT OF ANALOG SIGNALS TO VLDS HARDWARE
C     DACS 81-96 ARE USED FOR VLDS TO SIMULATOR TRUNKS 1-16
C     DACS 1-3 ARE USED FOR DACS TO SIMULATOR TRUNKS 17-19
      DAC(81) = -VLDSDAC(01)
      DAC(82) = -VLDSDAC(02)
      DAC(83) = -VLDSDAC(03)
      DAC(84) = -VLDSDAC(04)
```

```
      DAC(85) = -VLDSDAC(05)
      DAC(86) = -VLDSDAC(06)
      DAC(87) = -VLDSDAC(07)
      DAC(88) = -VLDSDAC(08)
      DAC(89) = -VLDSDAC(09)
      DAC(90) = -VLDSDAC(10)
      DAC(91) = -VLDSDAC(11)
      DAC(92) = -VLDSDAC(12)
      DAC(93) = -VLDSDAC(13)
      DAC(94) = -VLDSDAC(14)
      DAC(95) = -VLDSDAC(15)
      DAC(96) = -VLDSDAC(16)
      DAC(01) = -VLDSDAC(17)
      DAC(02) = -VLDSDAC(18)
      DAC(03) = -VLDSDAC(19)
      IF(.NOT. LDISI(25) ) GO TO 2598
C     STATIC CHECK VOLTAGES TO THE VLDS
      DAC(81)=-.01
      DAC(82)=-.02
      DAC(83)=-.03
      DAC(84)=-.04
      DAC(85)=-.05
      DAC(86)=-.06
      DAC(87)=-.07
      DAC(88)=-.08
      DAC(89)=-.09
      DAC(90)=-.10
      DAC(91)=-.11
      DAC(92)=-.12
      DAC(93)=-.13
      DAC(94)=-.14
      DAC(95)=-.15
      DAC(96)=-.16
      DAC(01)=-.17
      DAC(02)=-.18
      DAC(03)=-.19
      LDISO(21)=LDISO(22)=LDISO(23)=LDISO(24)=LDISO(25)=LDISO(26)=
     XLDISO(27)=.T.
 2598 CONTINUE
      .
      .
      .
      .
90050 CALL RTMODE
      .
      .
      .
      .
      END
```

REFERENCES

1. Ashworth, B. R.; and Kahlbaum, W. M., Jr.: Description and Performance of the Langley Differential Maneuvering Simulator. NASA TN D-7304, June 1973.
2. Parrish, R. V.; Rollins, J. D.; and Martin, D. J., Jr.: Visual Motion Simulation of CTOL Flare and Touchdown Comparing Data Obtained From Two Model Board Display Systems. Presented at the AIAA Visual Motion Simulation Conference (Dayton, Ohio), April 26-28, 1976.
3. Anon.: Simulators We Have Known and Loved and Hated. Human Factors Society Bulletin, Vol, 19, No. 6, June 1976, pp. 1-5.

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TABLE I

X Servo Static Test Results

Input Command		Test Position		Error		Repeatibility			
						Positive		Negative	
Meters	ft	Meters	ft	cm	in	cm	in	cm	in
-8.534	-28.000	-8.532	-27.995	.16	.06	0	0	0	0
-8.128	-26.667	-8.130	-26.675	.23	.09	0	0	0	0
-7.112	-23.333	-7.111	-23.331	.08	.03	0	0	0	0
-6.096	-20.000	-6.094	-19.992	.24	.09	0	0	0	0
-5.080	-16.667	-5.082	-16.672	.16	.06	0	0	0	0
-4.064	-13.333	-4.064	-13.333	0	0	0	0	0	0
-3.048	-10.000	-3.046	- 9.992	.24	.09	0	0	0	0
-2.032	-6.667	-5.082	- 6.672	.16	.06	0	0	0	0
-1.016	-3.333	-1.016	- 3.333	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
1.016	3.333	1.015	3.331	.08	.03	0	0	0	0
2.032	6.667	2.032	6.667	0	0	0	0	0	0
3.048	10.000	3.044	9.987	.40	.15	0	0	0	0
4.064	13.333	4.063	13.331	.08	.03	0	0	0	0
5.080	16.667	5.080	16.667	0	0	0	0	0	0
6.096	20.000	6.091	19.984	.48	.19	0	0	0	0
7.112	23.333	7.109	23.323	.32	.13	0	0	0	0
8.128	26.667	8.126	26.662	.16	.06	.08	.03	0	0
8.331	27.333	8.324	27.313	.64	.25	0	0	.08	.03
PERFORMANCE GOALS				±.85	±.34	±.16	±.06	±.16	±.06

TABLE II

Y Servo Static Test Results

Input Command		Test Position		Error		Repeatability Positive		Repeatability Negative	
Meters	Ft	Meters	Ft	cm	in	cm	in	cm	in
3.048	10.000	3.048	10.000	0	0	0	0	0	0
2.438	8.000	2.438	8.000	0	0	0	0	0	0
2.032	6.667	2.032	6.667	0	0	0	0	0	0
1.626	5.333	1.627	5.339	.18	.07	0	0	0	0
1.219	4.000	1.219	4.000	0	0	.15	.06	0	0
.813	2.667	.811	2.661	.18	.07	0	0	0	0
.406	1.33	.405	1.328	.15	.06	0	0	0	0
0	0	0	0	0	0	0	0	0	0
-.406	-1.333	.408	-1.339	.18	.07	0	0	0	0
-.813	-2.667	.813	-2.672	.15	.06	.15	.06	.15	.06
-1.219	-4.000	1.221	-4.005	.15	.06	0	0	0	0
-1.626	-5.333	1.626	-5.333	0	0	0	0	0	0
-2.032	-6.667	2.035	-6.677	.30	.12	0	0	0	0
-2.438	-8.000	2.441	-8.010	.30	.12	0	0	0	0
-3.048	-10.000	3.051	-10.010	.30	.12	0	0	.30	.12
PERFORMANCE GOALS				±.30	±.12	±.16	±.06	±.16	±.06

TABLE III

Z Servo Static Test Results

Input Command		Test Position		Error		Repeatability Positive		Repeatability Negative	
cm	in	cm	in	cm	in	cm	in	cm	in
.000	.000	Reference		--	--	+.040	+.016	+.040	+.016
1.016	.400	.992	.391	-.024	-.009	0	0	0	0
2.032	.800	1.985	.781	-.048	-.019	0	0	0	0
3.048	1.200	2.977	1.172	-.071	-.028	-.040	-.016	0	0
4.064	1.600	4.048	1.594	-.016	-.006	0	0	+.040	+.016
5.080	2.000	5.008	1.969	-.079	-.031	0	0	0	0
10.160	4.000	10.041	3.953	-.119	-.047	-.040	-.016	-.040	-.016
15.240	6.000	15.200	5.984	-.040	-.016	0	0	0	0
20.320	8.000	20.281	7.984	-.040	-.016	0	0	0	0
40.640	16.000	40.561	15.969	-.080	-.031	-.040	-.016	0	0
60.960	24.000	60.841	23.953	-.119	-.047	-.040	-.016	0	0
81.280	32.000	81.161	31.953	-.119	-.047	-.040	-.016	0	0
101.600	40.000	101.521	39.969	-.079	-.031	0	0	0	0
121.920	48.000	121.880	47.984	-.040	-.016	0	0	+.040	+.016
PERFORMANCE GOALS				±.061	±.024	±.040	±.016	±.040	±.016

TABLE IV

Translation Servo Dynamic Performance Summary

	Longitudinal (X)				Lateral (Y)				Altitude (Z)			
	Desired		Actual		Desired		Actual		Desired		Actual	
Acceleration	20.33 cm/sec^2	8 in/sec^2	30.63 35.94 cm/sec^2	12.06 14.15 in/sec^2	20.33 cm/sec^2	8 in/sec^2	56.39 41.91 cm/sec^2	22.20 16.50 in/sec^2	30.48 cm/sec^2	12.00 in/sec^2	48.25 68.58 cm/sec^2	19.00 27.00 in/sec^2
Slew Velocity	25.40 cm/sec	10.0 in/sec	26.43 cm/sec	10.40 in/sec	25.40 cm/sec	10.0 in/sec	32.25 cm/sec	12.70 in/sec	25.40 cm/sec	10.0 in/sec	33.77 cm/sec	13.3 in/sec
Constant Velocity Commanded (V_c)	10.16 .0052 cm/sec	4.0 .002 in/sec	10.16 10.147 .0050 .0048 cm/sec	4.0 3.995 .00197 .0019 in/sec	10.16 .0052 cm/sec	4.0 .002 .002 in/sec	10.21 10.26 .0052 .0052 cm/sec	4.02 4.04 .002 .002 in/sec	10.16 .0052 cm/sec	4.0 .002 in/sec	10.74 .0046 cm/sec	4.23 .0018 in/sec
Smoothness	$\Delta V < \pm .1 V_c$		Within Limits		$\Delta V < \pm .1 V_c$		Within Limits		$\Delta V < \pm .1 V_c$		Within Limits	

TABLE V

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Translational Servos Frequency Response

Frequency rad/sec	Longitudinal (X)		Lateral (Y)		Altitude (Z)	
	Amp Ratio	Phase (Deg)	Amp Ratio	Phase (Deg)	Amp Ratio	Phase (Deg)
.196	1.022	- .912	1.014	- .578	1.011	-0.780
.785	1.031	- .343	1.017	.934	1.031	0.730
1.571	1.041	0.687	1.032	1.476	1.025	0.473
2.356	1.044	1.147	1.021	2.971	1.029	1.075
3.142	1.047	1.900	1.026	3.250	1.022	0.303
4.712	1.064	2.674	1.023	4.992	1.027	2.778
6.283	1.082	3.212	1.021	7.560	1.021	2.872
9.425	1.137	5.546	1.057	8.338	1.015	5.822
12.566	1.219	8.361	1.074	11.609	1.046	6.505
15.708	1.216	10.916	1.108	15.097	1.036	8.105

TABLE VI

Translational and Rotational Second-Order Transfer Function Parameters

@ ω = 12.866 rad/sec

Drive	ω_n (rad/sec)	ζ	$2\zeta/\omega_n$ (sec)
Longitudinal	30.409	.147	.010
Lateral	45.801	.346	.015
Altitude	63.142	.275	.009
Roll	59.298	.643	.022
Pitch	59.396	.662	.022
Yaw	52.961	.545	.021

TABLE VII

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Roll Servo Static Test Results

Input (Degrees)	Reading (Degrees)	Error (Degrees)
0	REF.	0.0
1	1.0	0.0
2	2.0	0.0
3	3.0	0.0
4	4.0	0.0
5	5.0	0.0
10	10.0	0.0
20	20.0	0.0
40	39.8	-0.2
60	59.7	-0.3
80	79.9	-0.1
100	100.0	0.0
120	120.0	0.0
140	140.2	+0.2
160	160.2	+0.2
180	179.9	-0.1
200	199.8	-0.2
220	219.7	-0.3
240	239.6	-0.4
260	259.9	-0.1
280	279.8	-0.2
300	299.7	-0.3
320	320.2	+0.2
340	340.1	+0.1
350	350.0	0.0
355	354.8	-0.2
356	355.9	-0.1
357	357.0	0.0
358	358.1	+0.1
359	358.9	-0.1
360	360.1	+0.1
PERFORMANCE GOALS	$-5^{\circ} \leq \phi \leq 5^{\circ}$ $\pm 0.1^{\circ}$ $-5^{\circ} > \phi > 5^{\circ}$ $\pm 0.3^{\circ}$	

TABLE VIII

Pitch Servo Static Test Results

Pitch Angle (Deg)	Maximum Error (Deg)	Pitch Angle (Deg)	Maximum Error (Deg)
0.00	+0.13	-1.00	-0.10
+1.00	+0.04	-2.00	-0.16
+2.00	+0.06	-3.00	-0.12
+3.00	+0.12	-4.00	-0.10
+4.00	+0.22	-5.00	-0.01
+5.00	+0.17	-10.00	-0.40
+10.00	-0.14	-15.00	+0.17
+15.00	+0.04	-20.00	+0.07
+20.00	+0.26	-25.00	+0.01
+24.00	+0.30	-30.00	+0.07
+20.00	-0.07	-35.00	+0.47
+15.00	-0.30	-40.00	+0.38
+10.00	-0.40	-45.00	+0.15
+5.00	-0.03	-49.90	-0.04
+4.00	+0.05	-45.00	-0.17
+3.00	-0.08	-40.00	+0.09
+2.00	-0.13	-35.00	+0.19
+1.00	-0.12	-30.00	-0.08
0.00	-0.09	-25.00	-0.12
		-20.00	-0.25
		-15.00	-0.09
		-10.00	-0.12
		-5.00	+0.21
		-4.00	+0.15
		-3.00	+0.12
		-2.00	+0.07
		-1.00	+0.08
		0.00	+0.14
PERFORMANCE GOALS		$-5^{\circ} \leq \theta \leq 5^{\circ}$ $\pm 0.1^{\circ}$ $-5^{\circ} > \theta > 5^{\circ}$ $\pm 0.3^{\circ}$	

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TABLE IX

Yaw Servo Static Test Results

Input (Degrees)	Reading (Degrees)	Error (Degrees)
0	REF.	REF.
1	1.1	+0.1
2	2.0	0.0
3	3.0	0.0
4	4.0	0.0
5	5.0	0.0
10	10.0	0.0
30	30.0	0.0
50	50.0	0.0
70	70.0	0.0
90	90.2	+0.2
110	110.2	+0.2
130	130.3	+0.3
150	150.1	+0.1
170	170.2	+0.2
190	190.2	+0.2
210	210.2	+0.2
230	230.4	+0.4
250	250.4	+0.4
270	270.4	+0.4
290	290.2	+0.2
310	310.2	+0.2
330	330.2	+0.2
350	350.2	+0.2
355	355.1	+0.1
356	356.2	+0.2
357	357.1	+0.1
358	358.2	+0.2
359	359.1	+0.1
360	360.1	+0.1
PERFORMANCE GOALS	$-5^\circ \leq \psi \leq 5^\circ$ $\pm 0.1^\circ$ $-5^\circ > \psi > 5^\circ$ $\pm 0.3^\circ$	

TABLE X

Rotational Servo Dynamic Performance Summary

	Roll		Pitch		Yaw	
	Desired	Actual	Desired	Actual	Desired	Actual
Allowable Dynamic Error	1° max @ 20°/sec	$.22^{\circ}$ max	1° max @ 20°/sec	$.34^{\circ}$ max	1° max @ 20°/sec	$.27^{\circ}$ max
Smoothness for Constant Vel. Cmd. (V_c)	$\Delta V < \pm .1V_c$	Within Limits	$\Delta V < \pm .1V_c$	Within Limits	$\Delta V < \pm .1V_c$	Within Limits
Max Velocity	300 deg/sec	300 + 311 − deg/sec	120 deg/sec	259 + 243 − deg/sec	200 deg/sec	219 + 231 deg/sec
Max Acceleration	500 deg/sec^2	5780 + 6600 − deg/sec^2	300 deg/sec^2	3760 + 3220 − deg/sec^2	500°/sec^2	3460 + 3990 − deg/sec^2

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TABLE XI

Rotational Servos
Frequency Response

Frequency (Rad/Sec)	Roll (ϕ)		Pitch (θ)		Yaw (ψ)	
	Amp Ratio	Phase (Deg)	Amp Ratio	Phase (Deg)	Amp Ratio	Phase (Deg)
0.196	1.011	.250	1.001	0.247	1.037	0.317
0.785	1.009	1.268	1.001	1.006	1.037	0.722
1.571	1.012	1.797	1.001	1.916	1.037	2.000
2.356	1.012	3.394	1.010	3.056	1.037	2.242
3.142	1.007	4.603	1.001	4.070	1.036	3.308
4.712	1.007	7.077	1.001	6.099	1.034	4.608
6.283	1.004	9.303	1.001	8.206	1.050	7.514
9.425	1.003	12.600	1.003	12.159	1.046	10.315
12.566	1.018	15.936	1.005	16.347	1.059	15.326
15.708	1.001	20.987	1.010	20.619	1.058	17.952
18.850	1.008	23.549	1.015	25.093	1.083	23.518
21.991	1.034	28.572	1.017	29.029	1.055	26.300
25.133	0.966	33.086	0.890	43.732	1.132	30.219

Television System Performance

Zone 1 - Circle of diameter 80% of picture height, located at picture center. Zone 2 - Area between Zone 1 and circumference of circle whose diameter is equal to picture width. Zone 3 - Area outside Zone 2.		
Registration Errors	<u>Design Standard</u> Zone 1 - less than 0.1% of picture height or width.	<u>Measured Values</u> 0.1% vertically and horizontally
	Zone 2 - less than 0.2% of picture height or width.	< .2% vertically < .015% horizontally
	Zone 3 - less than 0.5% of picture height or width.	< .4% vertically < .3% horizontally
Linearity and Geometry	<u>Design Standard</u> Zone 1 - less than 0.5% of picture height or width.	<u>Measured Values</u> < .5% vertically < .5% horizontally
	Zone 2 - less than 1% of picture height or width.	< 1% vertically and horizontally
	Zone 3 - less than 2% of picture height or width.	< 1.5% vertically and horizontally
Resolution (Horizontally)	<u>Design Standard</u> Zone 1 - not less than 550 lines Zone 2 - not less than 400 lines Zone 3 - not less than 300 lines	<u>Results</u> 500 to 550 400 350 to 400
Diagonal Field of View	Design Standard 60°	Measured 59.3-

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TABLE XII - Concluded.

Signal-to-Noise Ratio		Design Standard 40 db peak signal-to-RMS noise ratio	39.5 db wideband 42 db with 3.5 to 5 MHz filter
Depth of Field		Design Standard	Results
Probe height (in)	Range (in)	TV lines per degree	TV lines per degree
0.2	2.4	8	8
0.2	3.0	8	8
0.2	4.5	10	8
0.2	6.0	10	10
0.2	9.0	10	12
0.2	12.0	12	12
0.2	15.0	12	12
0.2	18.0	12	No Chart
0.7	2.4	10	10
0.7	3.0	10	10
0.7	4.5	12	10
0.7	6.0	12	12
0.7	9.0	12	12
0.7	12.0	12	12
0.7	15.0	12	12
0.7	18.0	12	12
2.5	6.0	10	10
2.5	9.0	10	10
2.5	12.0	12	12
2.5	15.0	12	12
2.5	18.0	12	12
2.5			

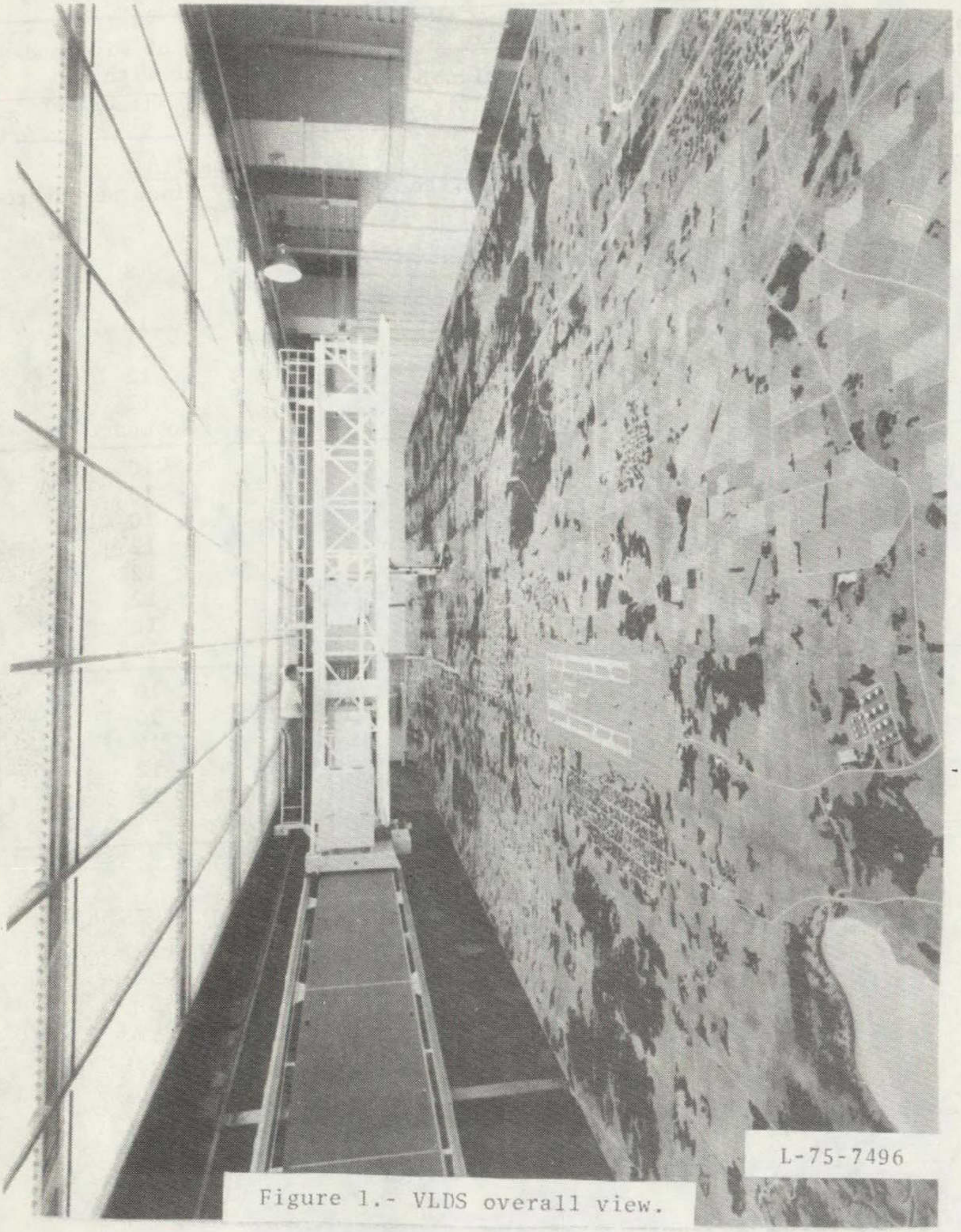

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Figure 1.- VLDS overall view.

Figure 2.- Landing approach scene.

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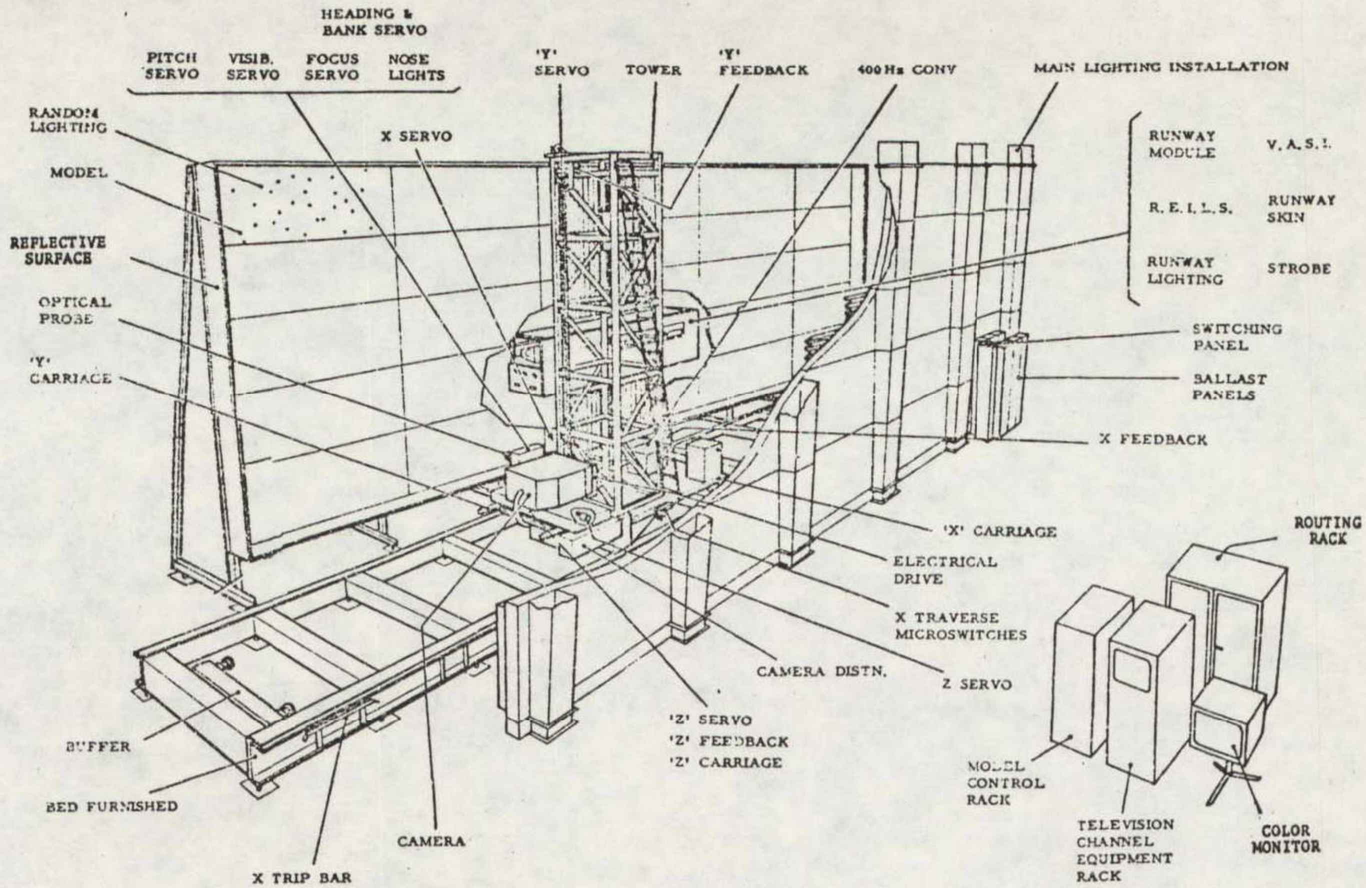

Figure 3.- VLDS system components.

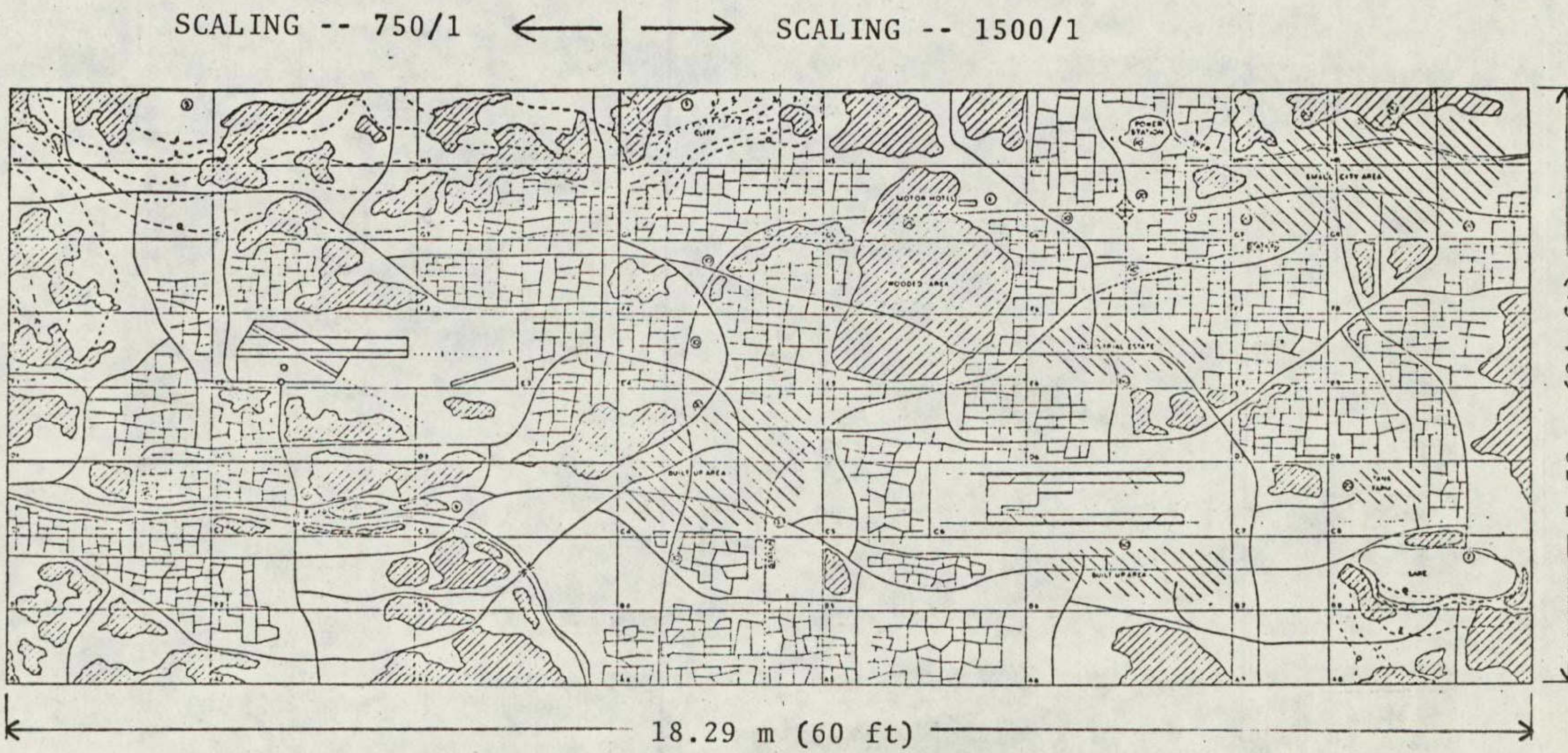

Figure 4.- Dual-scaled model board layout.

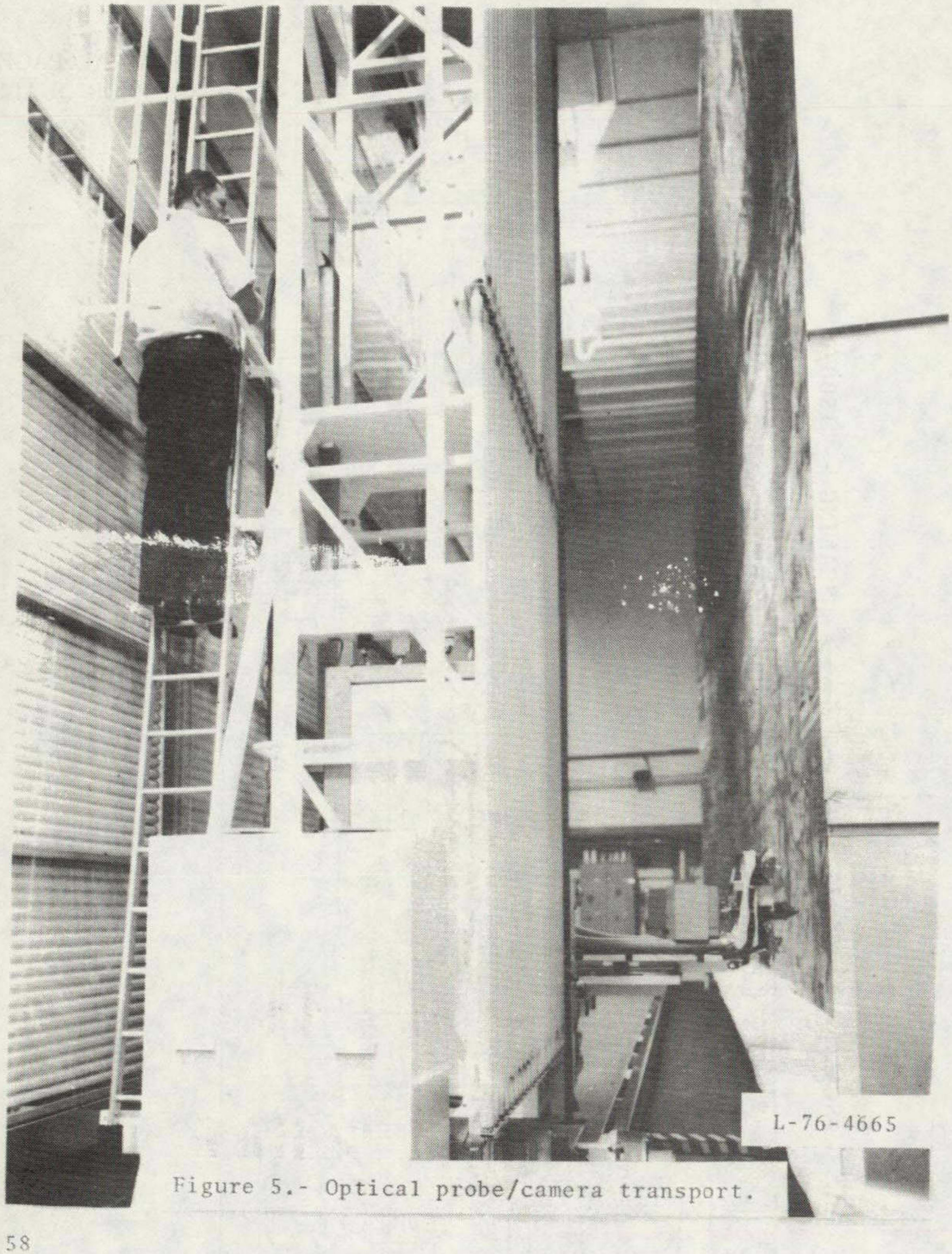

Figure 5.- Optical probe/camera transport.

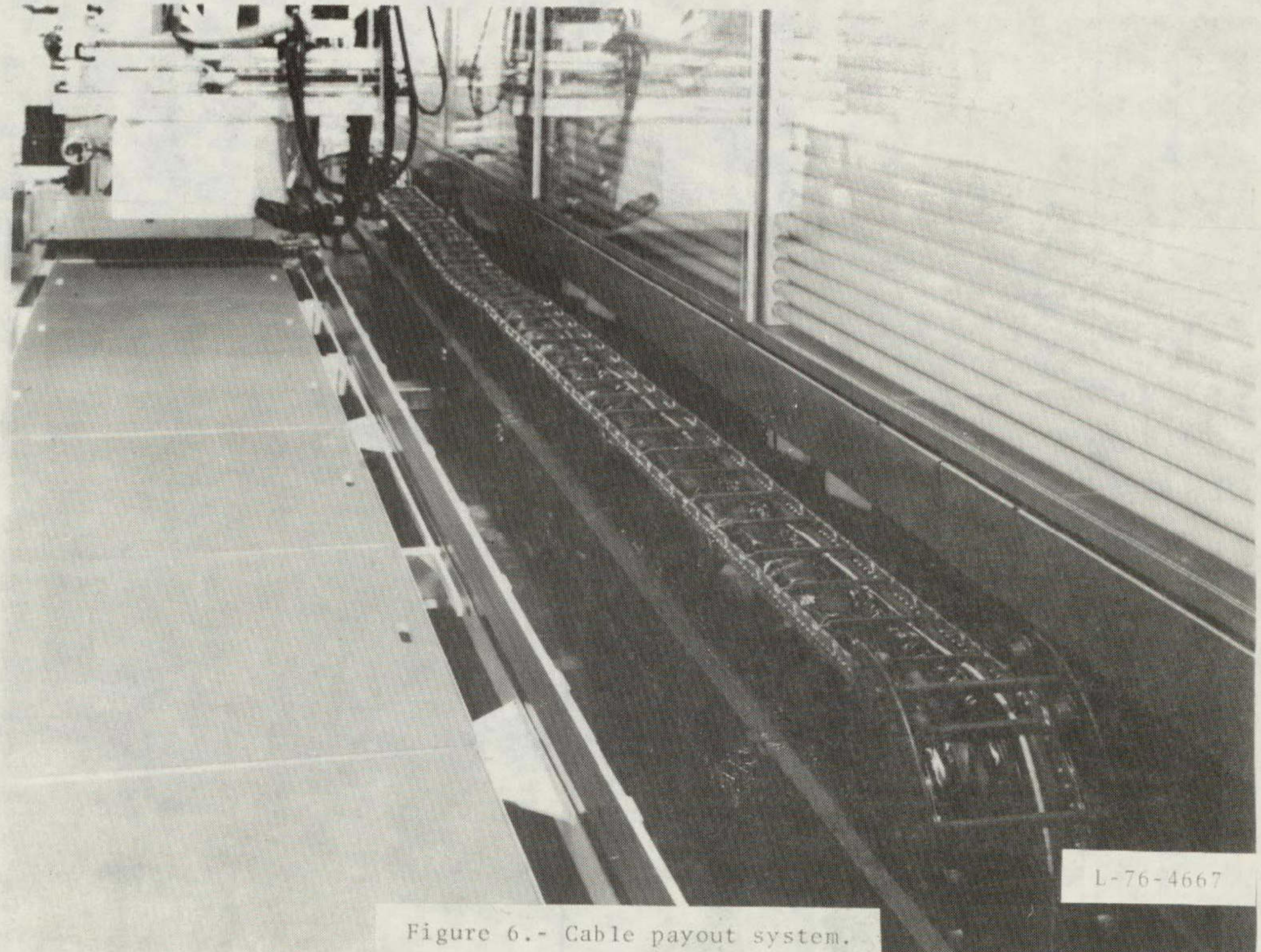

Figure 6.- Cable payout system.

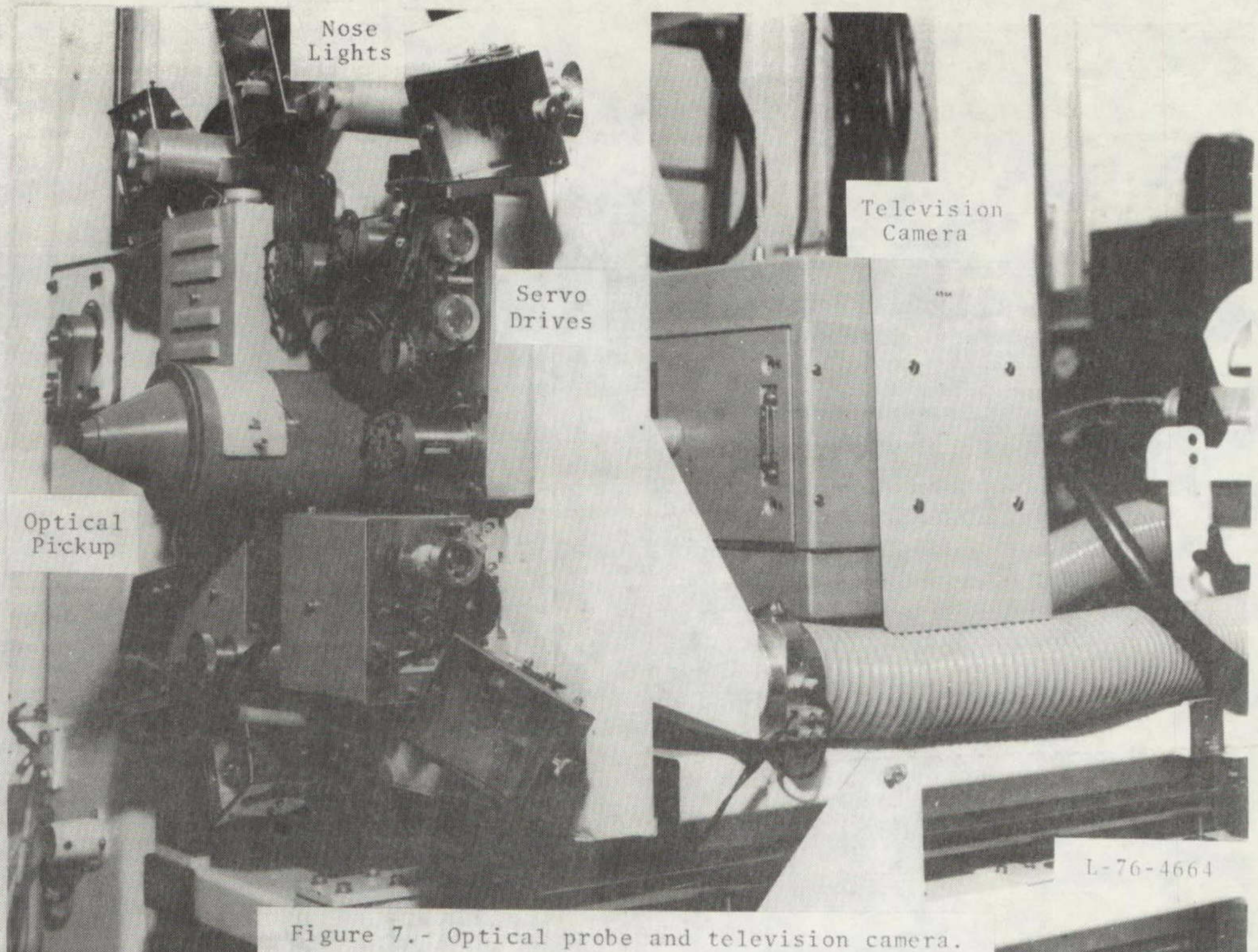

Figure 7.- Optical probe and television camera.

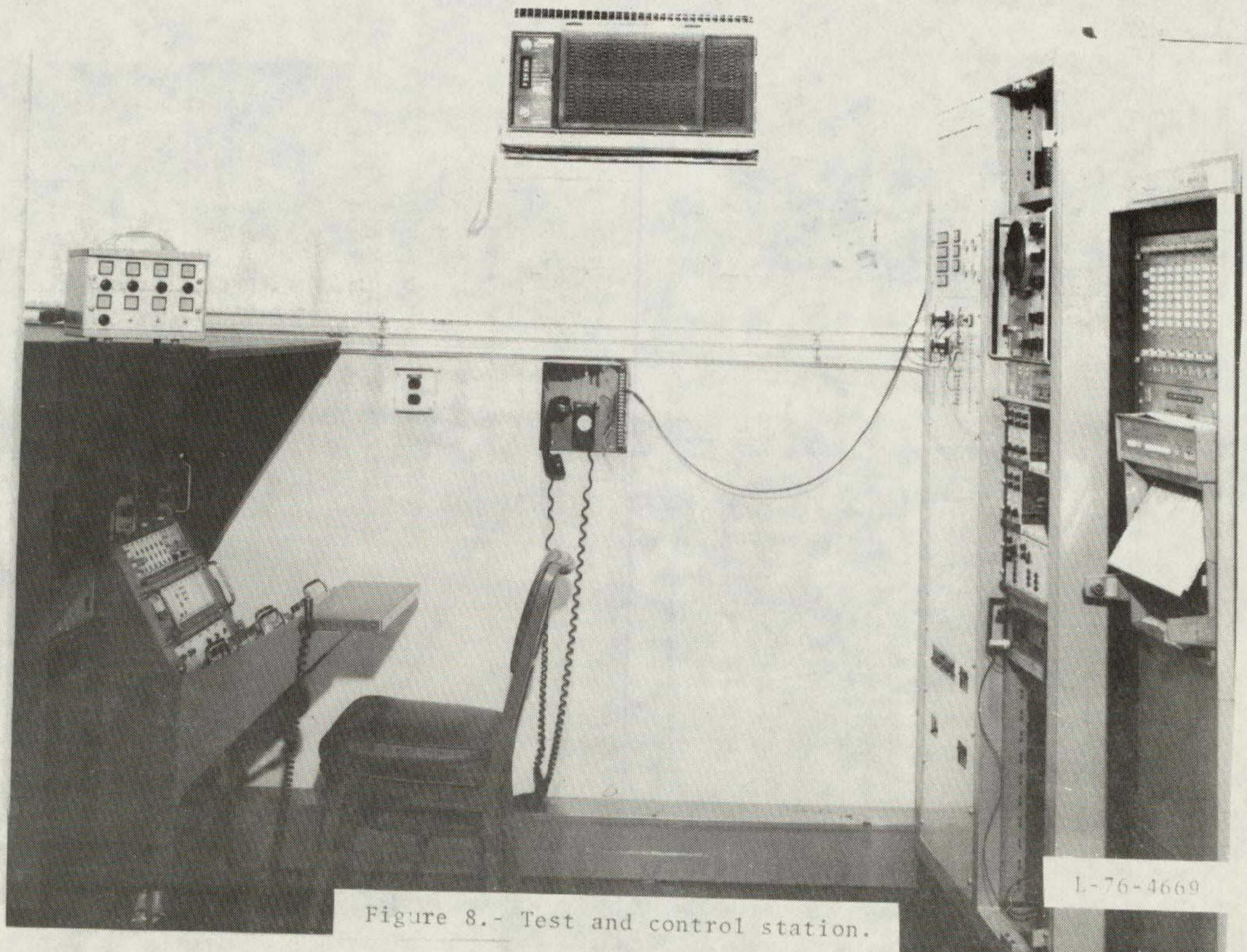

Figure 8.- Test and control station.

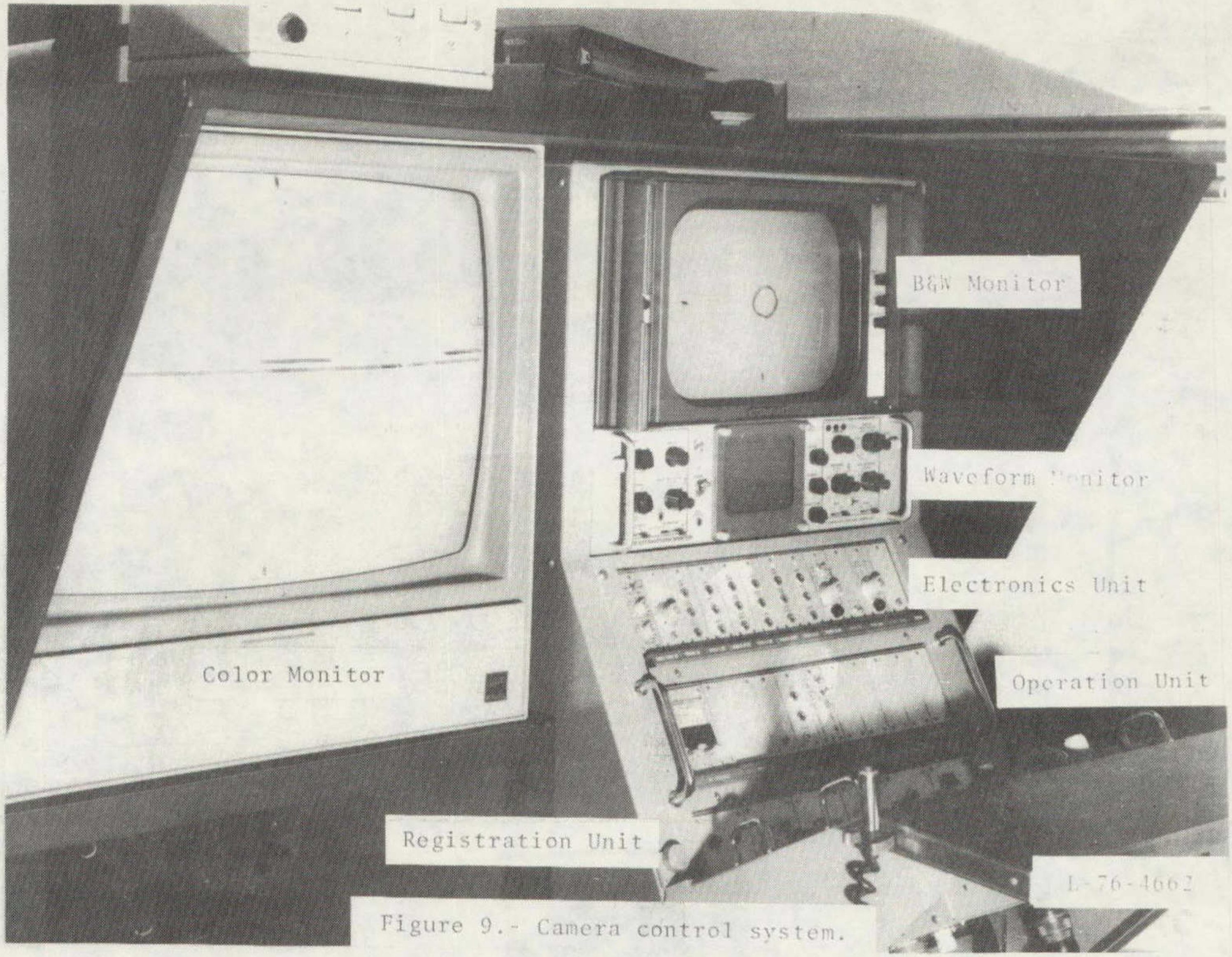

Figure 9.- Camera control system.

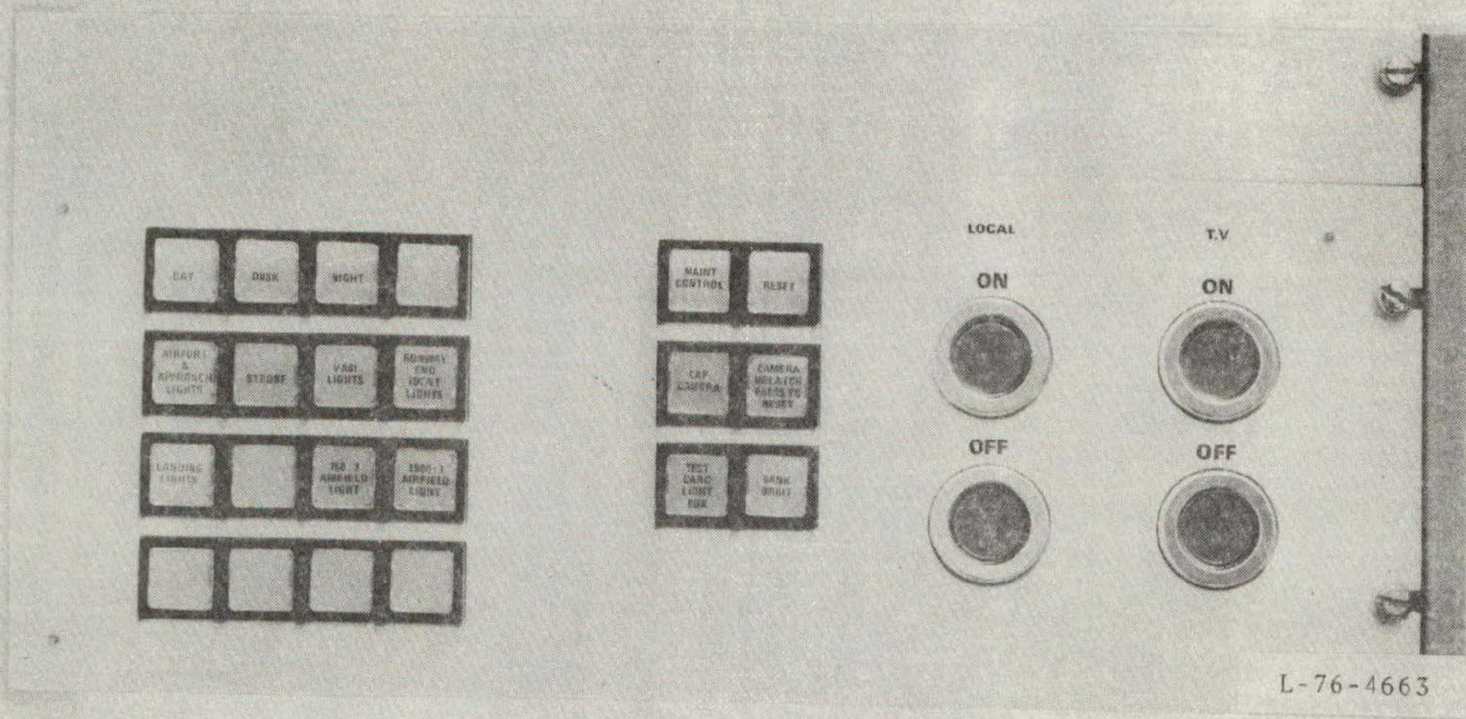

Figure 10.- Model control panel.

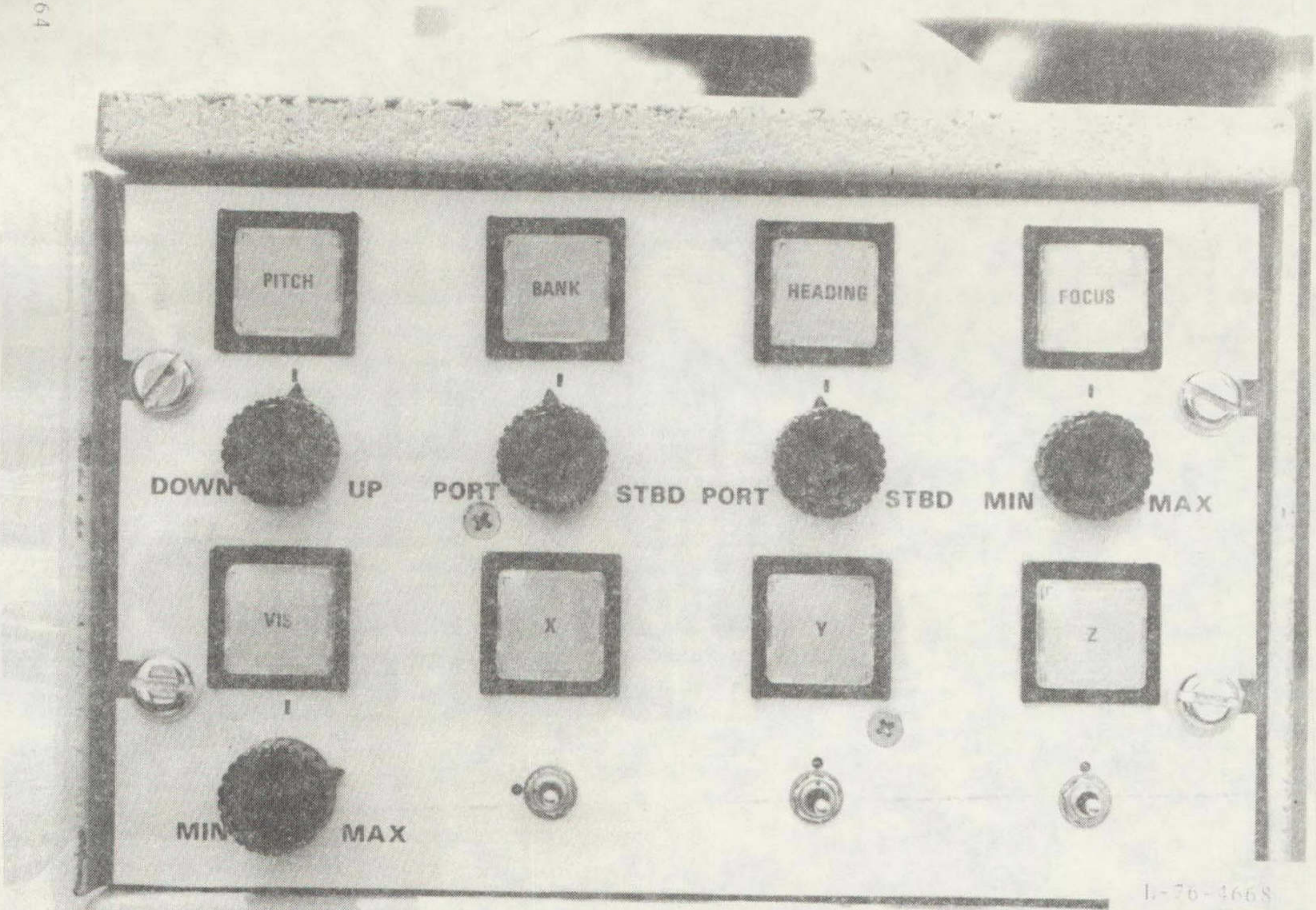

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Figure 11.- Manual control unit.

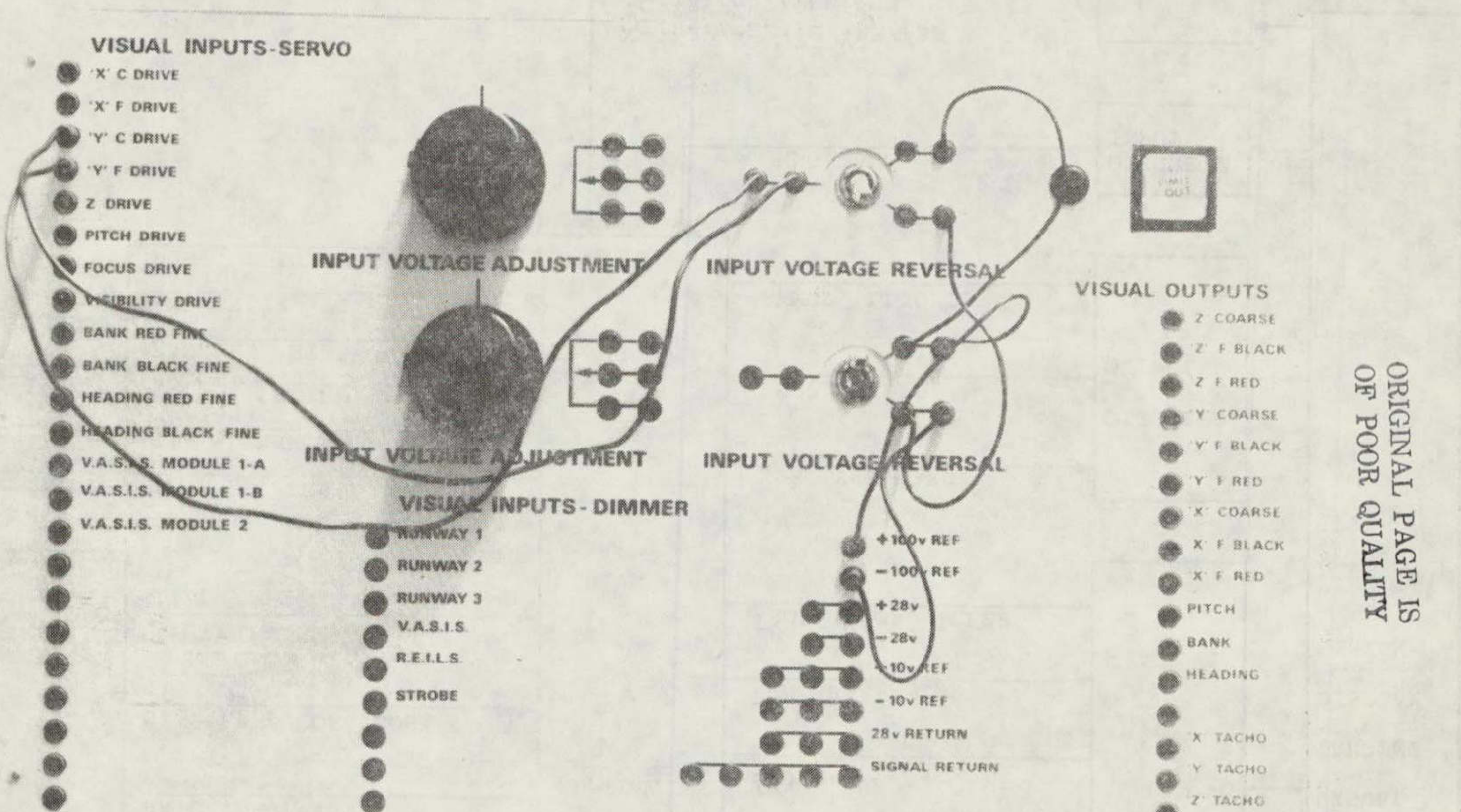

Figure 12. Servo input/output patch panel.

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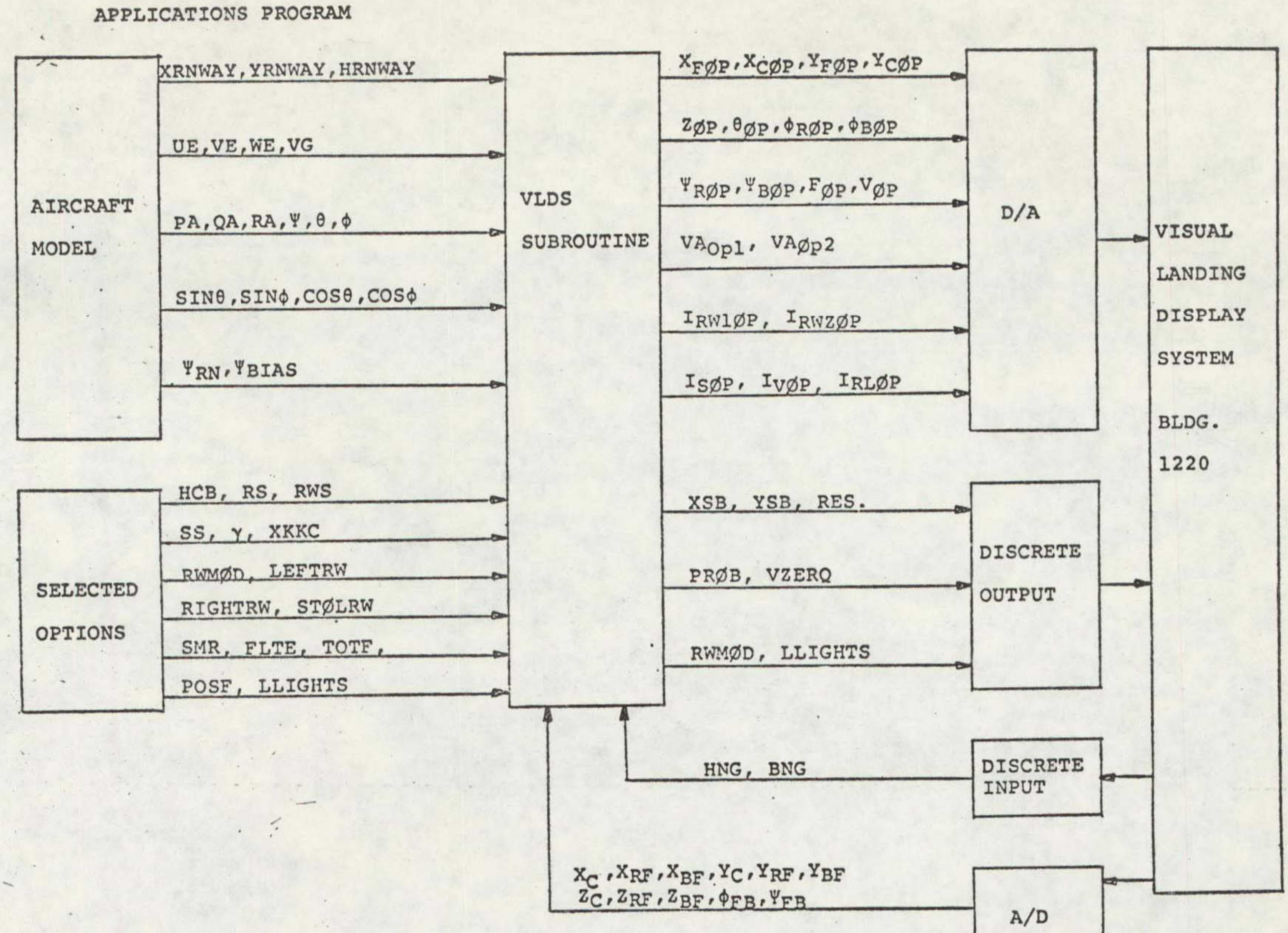

Figure 13.- Basic block diagram.

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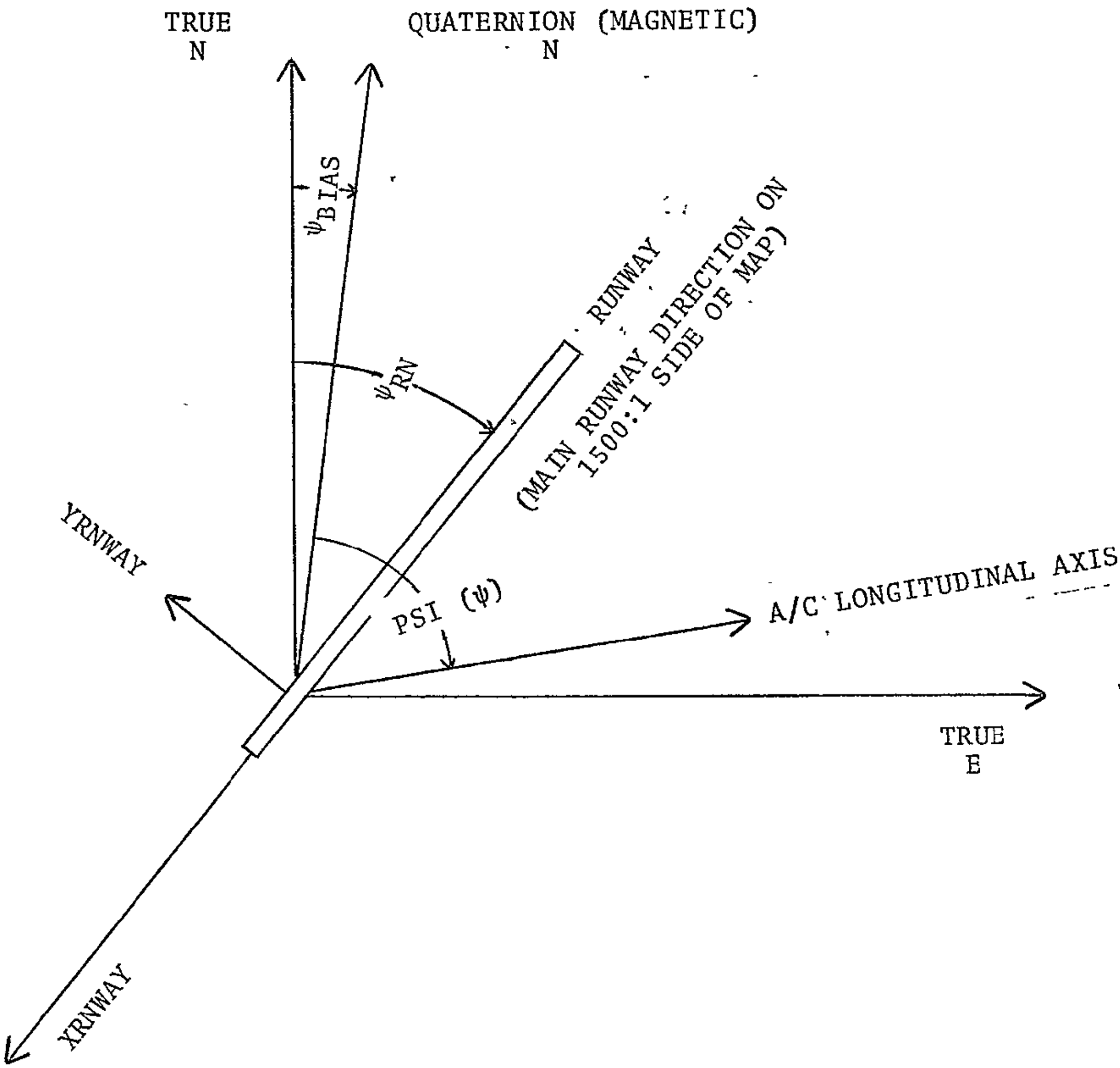

Figure 14.- Coordinate definitions.

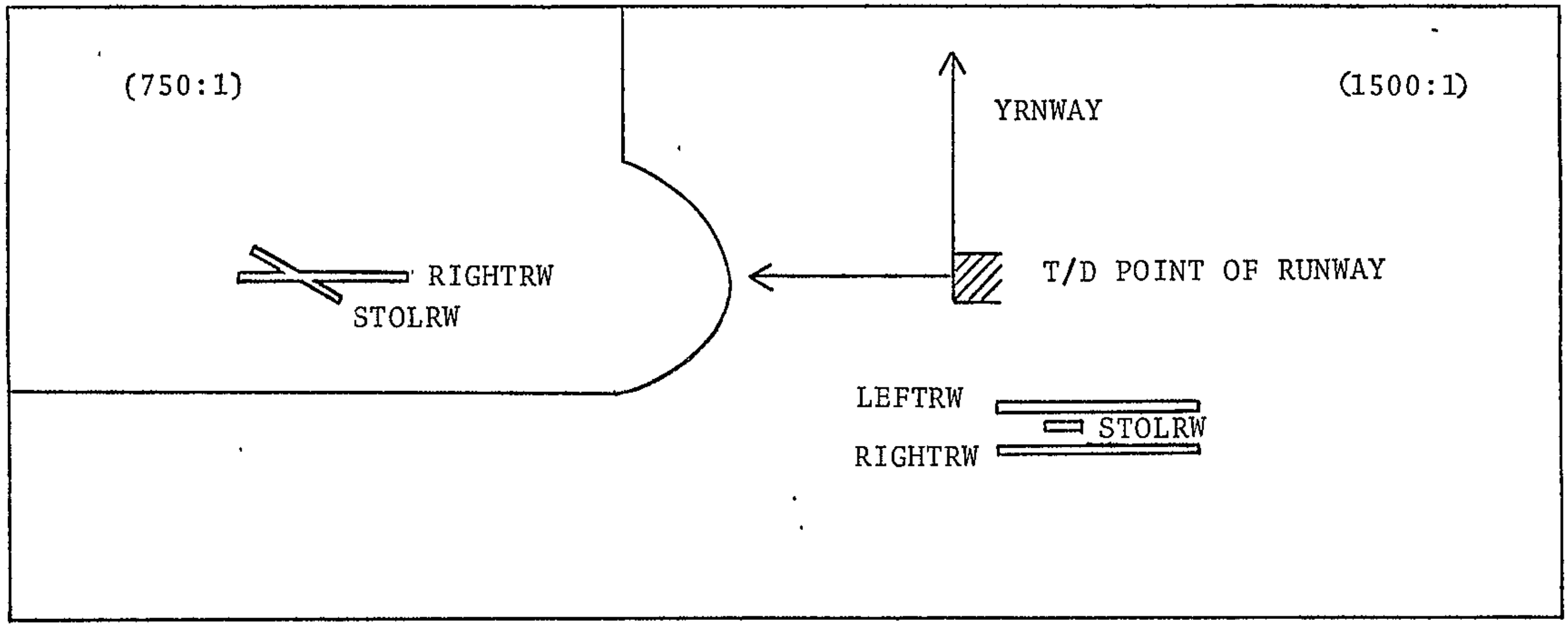

Figure 15.- Runway configurations.

EXAMPLE: RWMOD = .F.
LEFTRW = .T.
PSIBIAS = -10°/180
PSIRN = 45°/180
PSI = 55°/180
XRNWAY = 6,096 m (20,000 ft)
YRNWAY = -2,134 m (-7,000 ft)

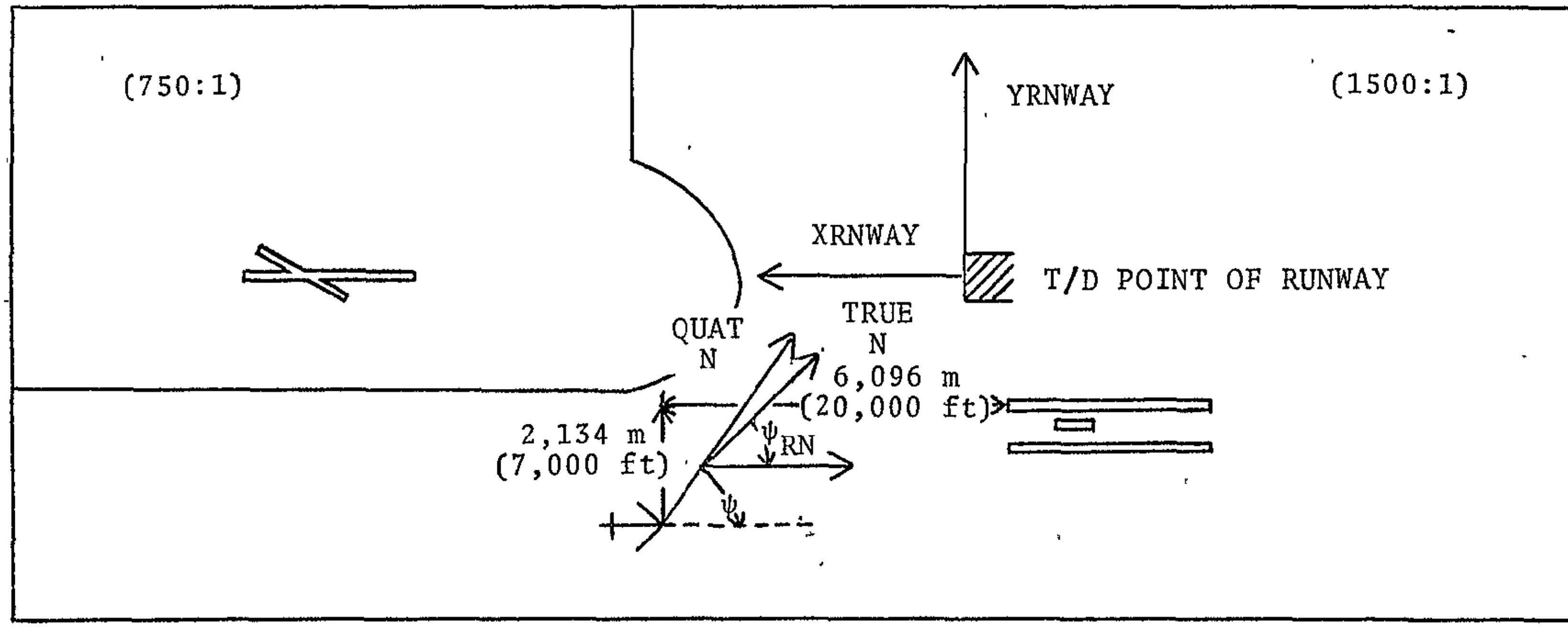

Figure 16.- Example one.

EXAMPLE: RWMØD = .F.
STOLRW = .T.
PSIBIAS = 0
PSIRN = 90°/180
PSI = 270°/180
XRNWAY = -6,401 m (-21,000 ft)
YRNWAY = 1,067 m (3,500 ft)

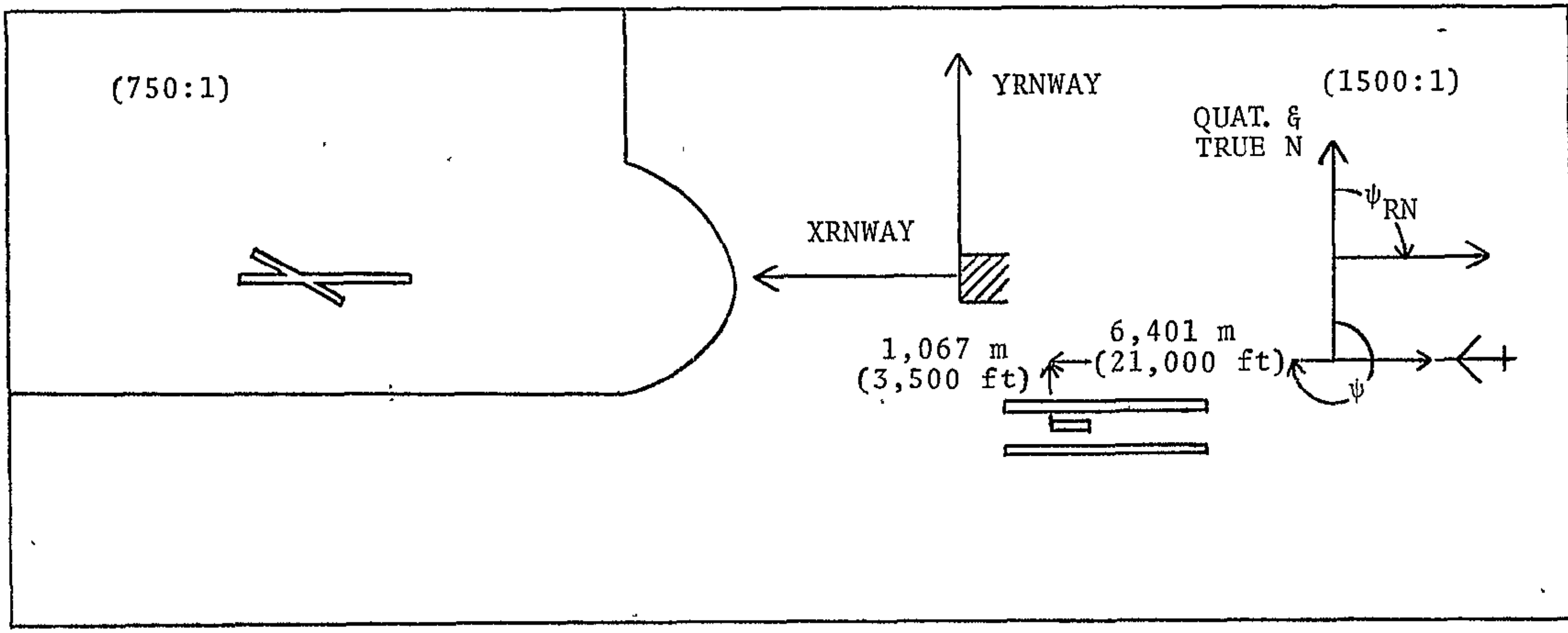

Figure 17.- Example two.

EXAMPLE: RWMOD = .T.
STOLRW = .T.
PSIBIAS = 0
PSIRN = 180°/180
PSI = 30°/180
XRNWAY = -2,896m (-9,500 ft)
RYNWAY = 1,767 m (5,500 ft)

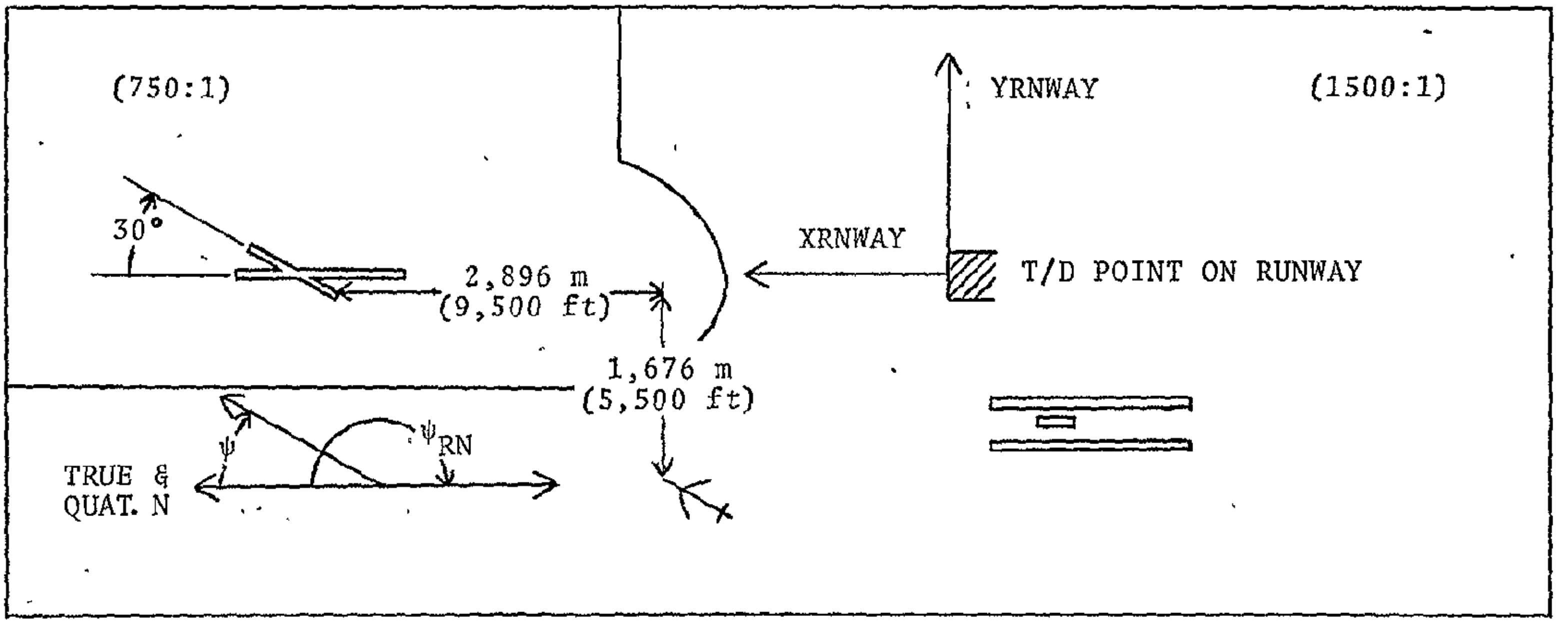

Figure 18.- Example three.

EXAMPLE:	RWMOD	=	.T.	
	RIGHTRW	=	.T.	
	PSIBIAS	=	5°/180	
	PSIRN	=	0	
	PSI	=	175°/180	
	XRNWAY	=	-2,286 m	(-7,500 ft)
	YRNWAY	=	-1,524 m	(-5,000 ft)

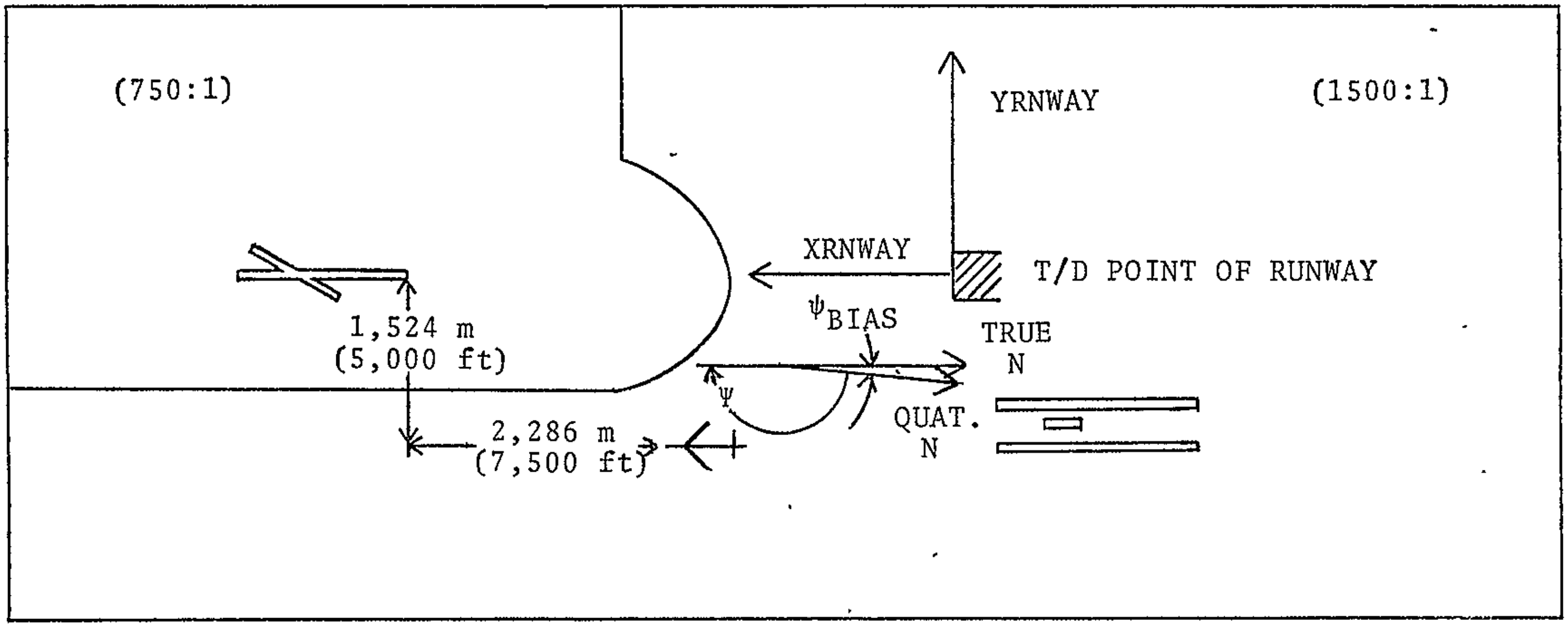

Figure 19.- Example four.

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16 Abstract

The Langley Visual Landing Display System is a television/model board system which provides a means of generating a six-degree-of-freedom visual out-the-window scene for the pilot of a simulated aircraft.

This report gives a detailed description of the hardware and its performance capability for meeting the visual requirements for a wide range of simulation studies. This report also includes a description of the computer software required for the system and gives an example of how the software is implemented in a real-time computer program.

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