Air National Guard

MCDONNELL DOUGLAS CORPORATION

RF-101G/H

PHOTOGRAPHIC RECONNAISSANCE SYSTEMS

P.S.472
15 APR 68

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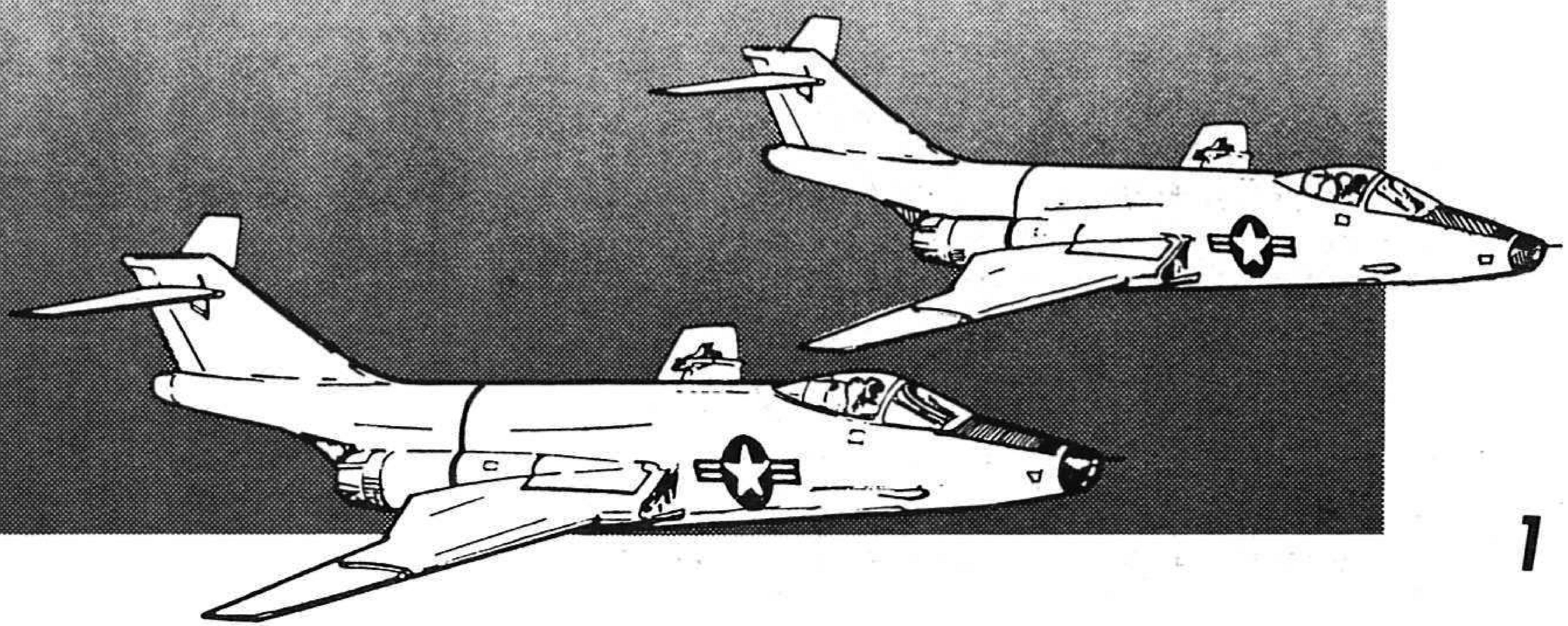
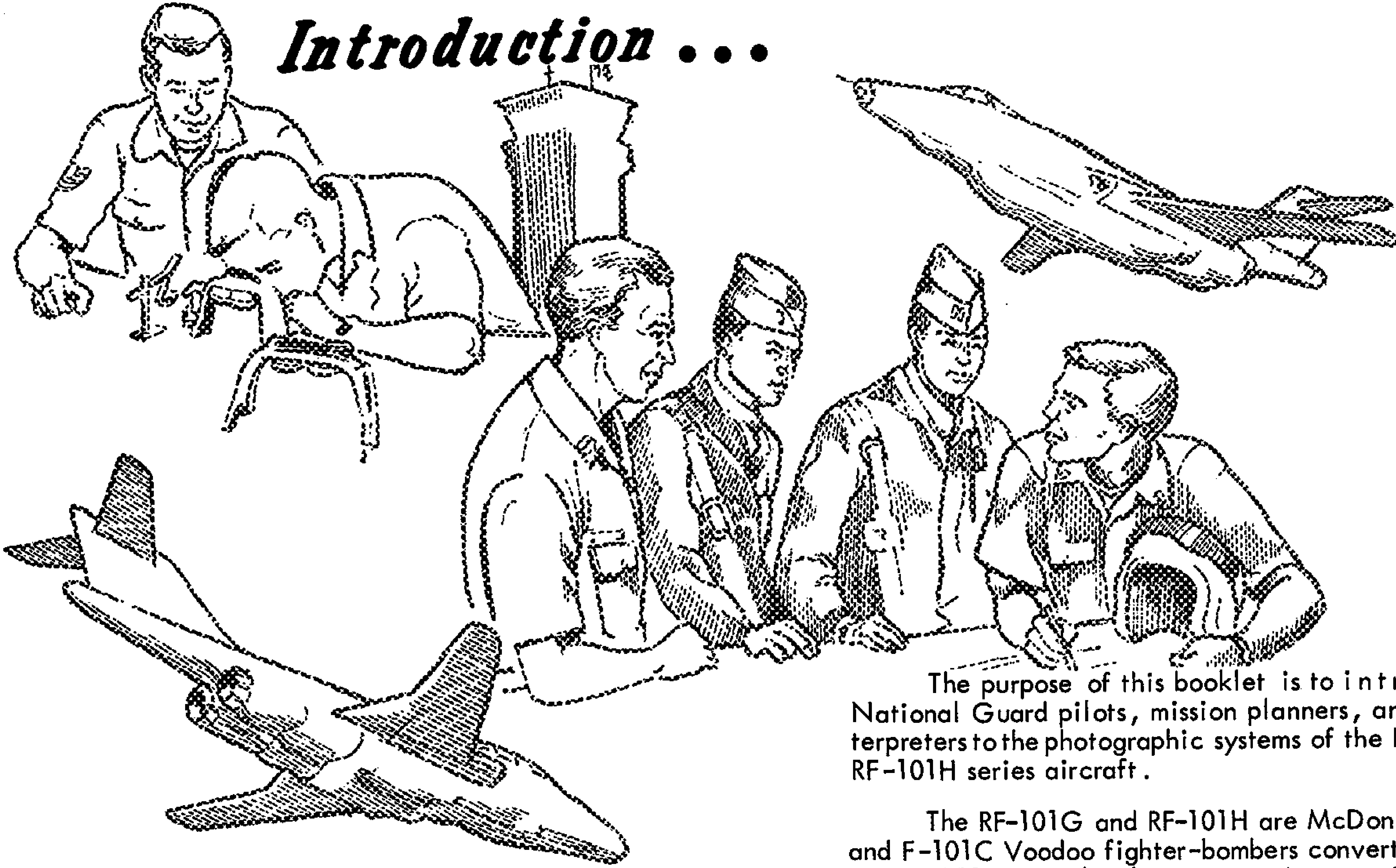


Introduction . . .



The purpose of this booklet is to introduce Air National Guard pilots, mission planners, and image interpreters to the photographic systems of the RF-101G and RF-101H series aircraft.

The RF-101G and RF-101H are McDonnell F-101A and F-101C Voodoo fighter-bombers converted by T.O. 1F-101-1112 to single-place reconnaissance aircraft capable of long-range, supersonic, daytime photographic missions.

For detailed information on the RF-101G/H photographic systems, refer to T. O. 1F-101(R)G-2-14.

RF-101GH Camera System

The optical sensors in the RF-101G/H aircraft are:

- Three KS-87 Framing Cameras
- One KA-56 Low-Altitude Panoramic Camera

The cameras are mounted forward of the cockpit in three separate stations:

- Forward
- Vertical
- Split Vertical

The three camera stations (shown in Figure 1) are accessible through doors 3L and 3R. In addition, the nose cone can be extended on rails to permit access to the Forward Station.

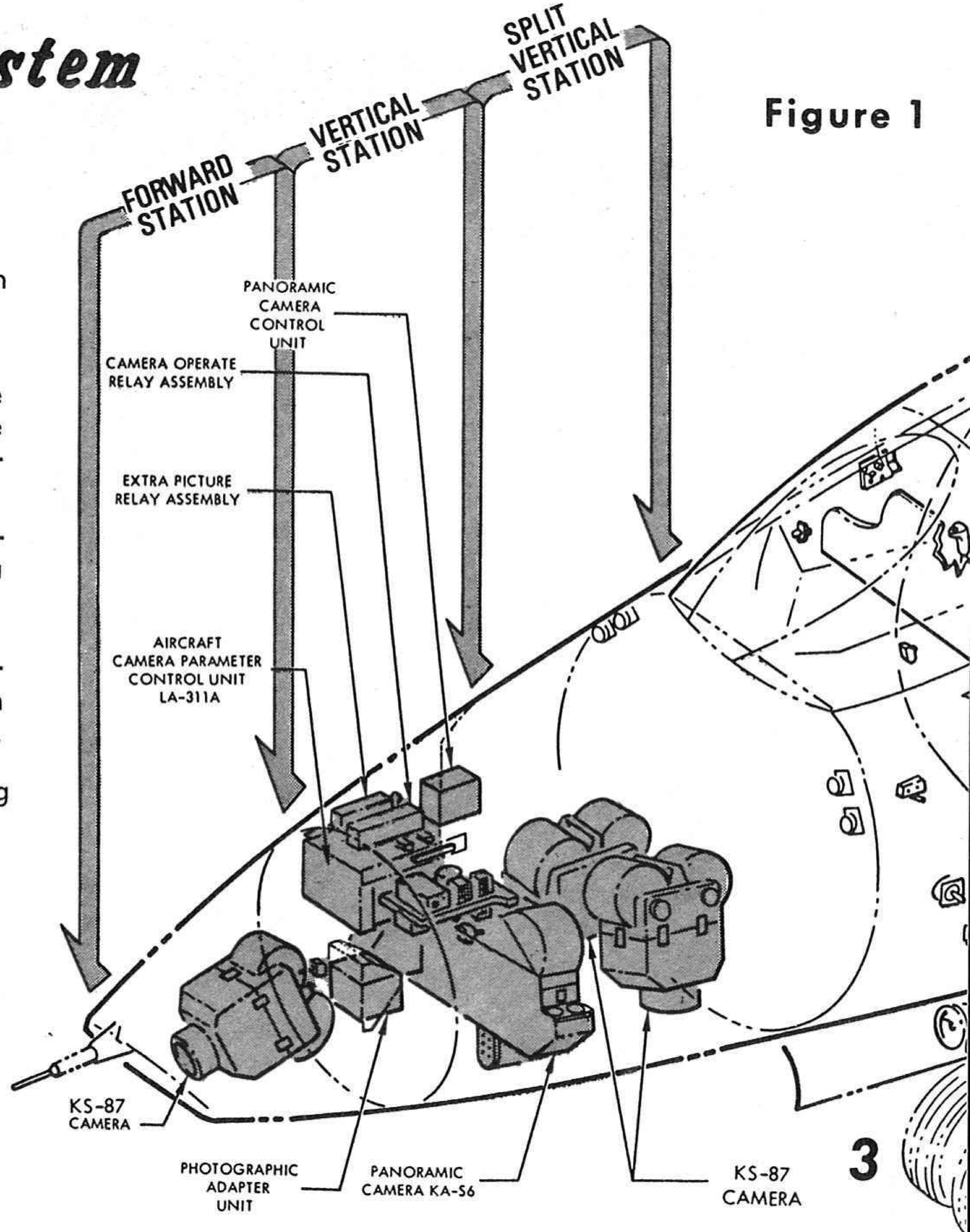
The Forward Station may be configured with a 6-inch focal length KS-87 camera depressed 15° or with a 12-inch focal length KS-87 camera depressed 10°.

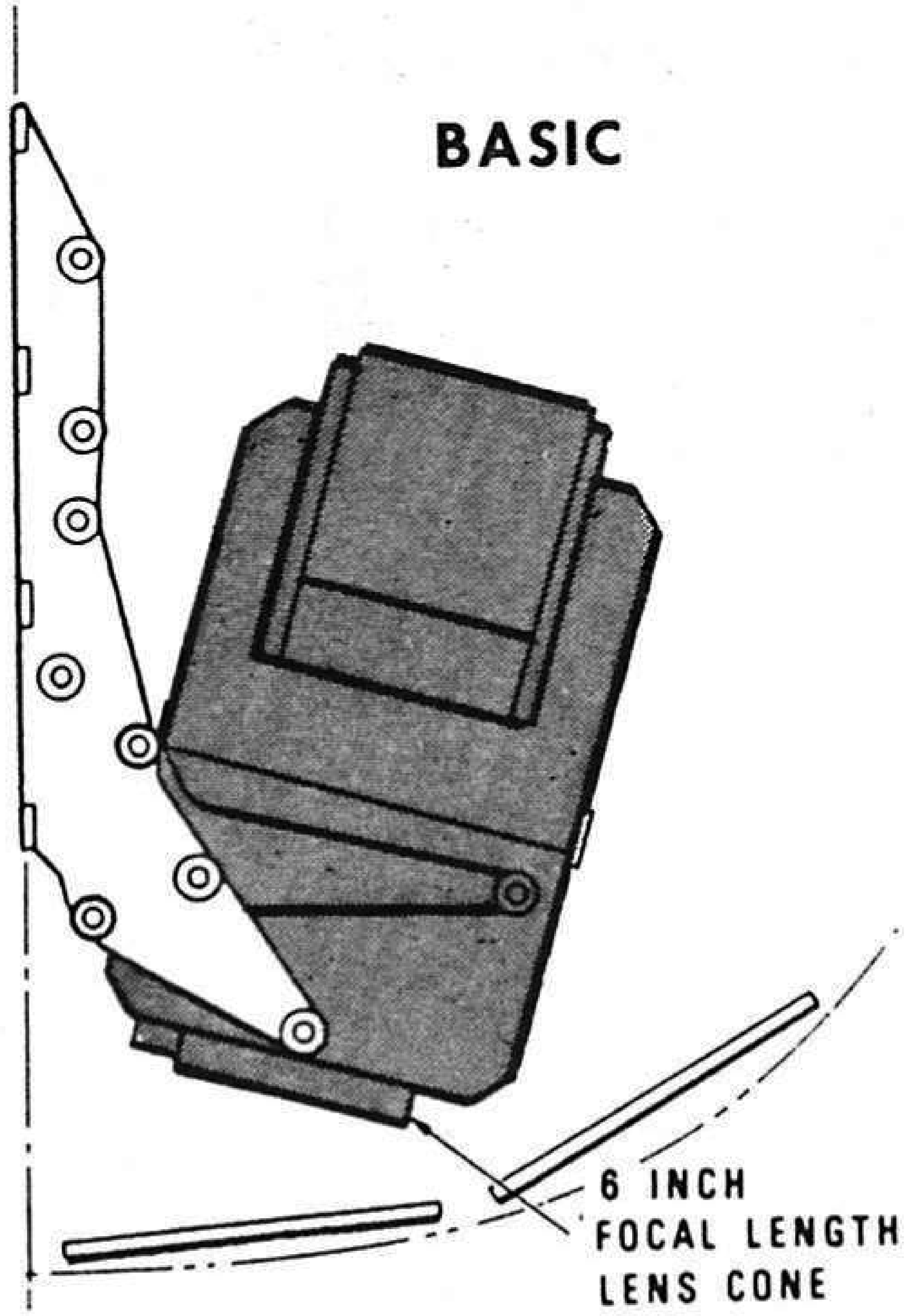
The Vertical Station contains the KA-56 Low-Altitude Panoramic Camera. This is a 3-inch focal length camera which scans the terrain from horizon to horizon.

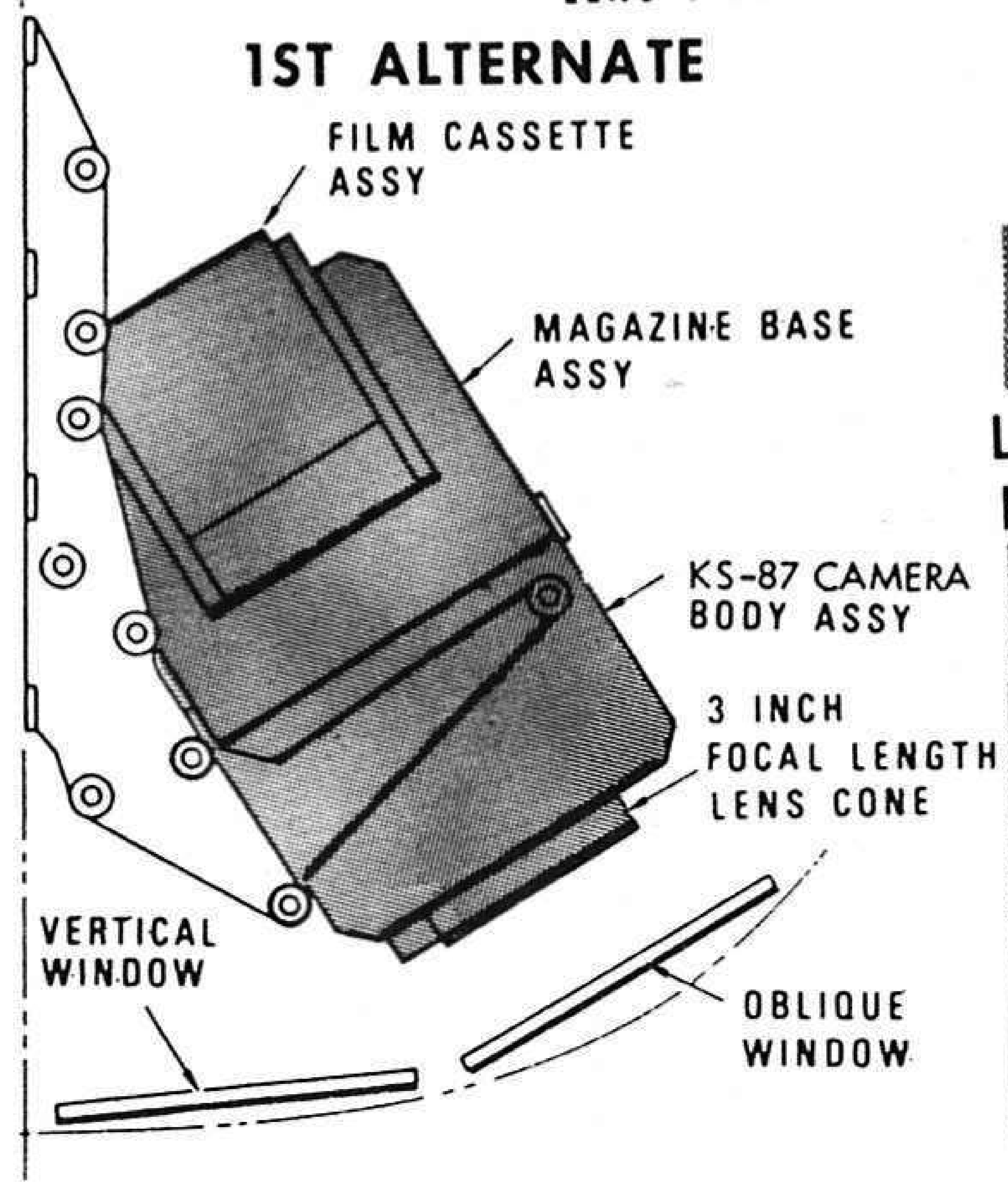
The Split Vertical Station will accept the following camera configurations:

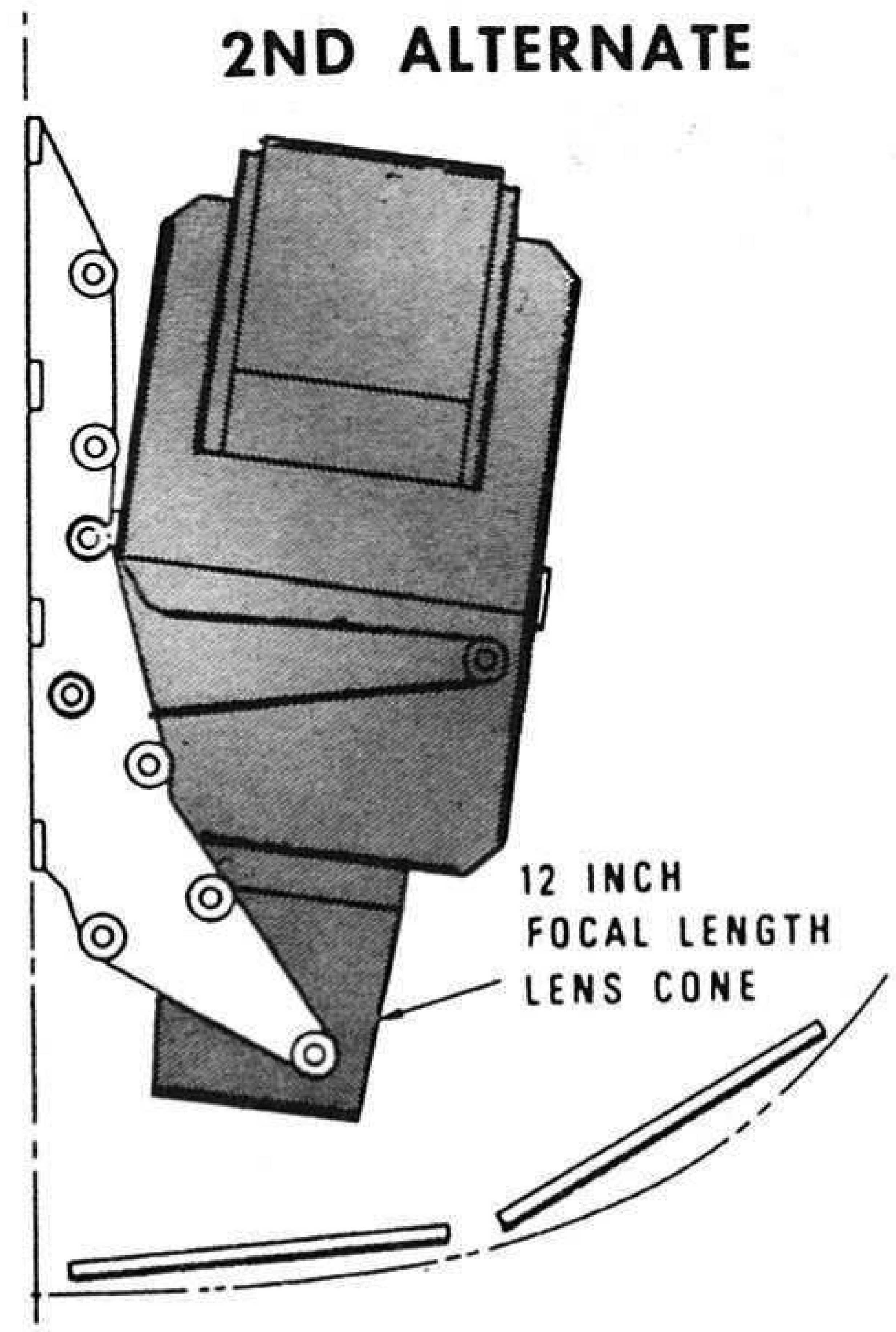
- Two 6-inch focal length Split Vertical Framing Cameras depressed 71°36'
  or
- Two 12-inch focal length Split Vertical Framing Cameras depressed 80°33'
  or
- Two 18-inch focal length Split Vertical Framing Cameras depressed 83°40'
  or
- Two 3-inch focal length Side Oblique Framing Cameras depressed 30°

Figure 1









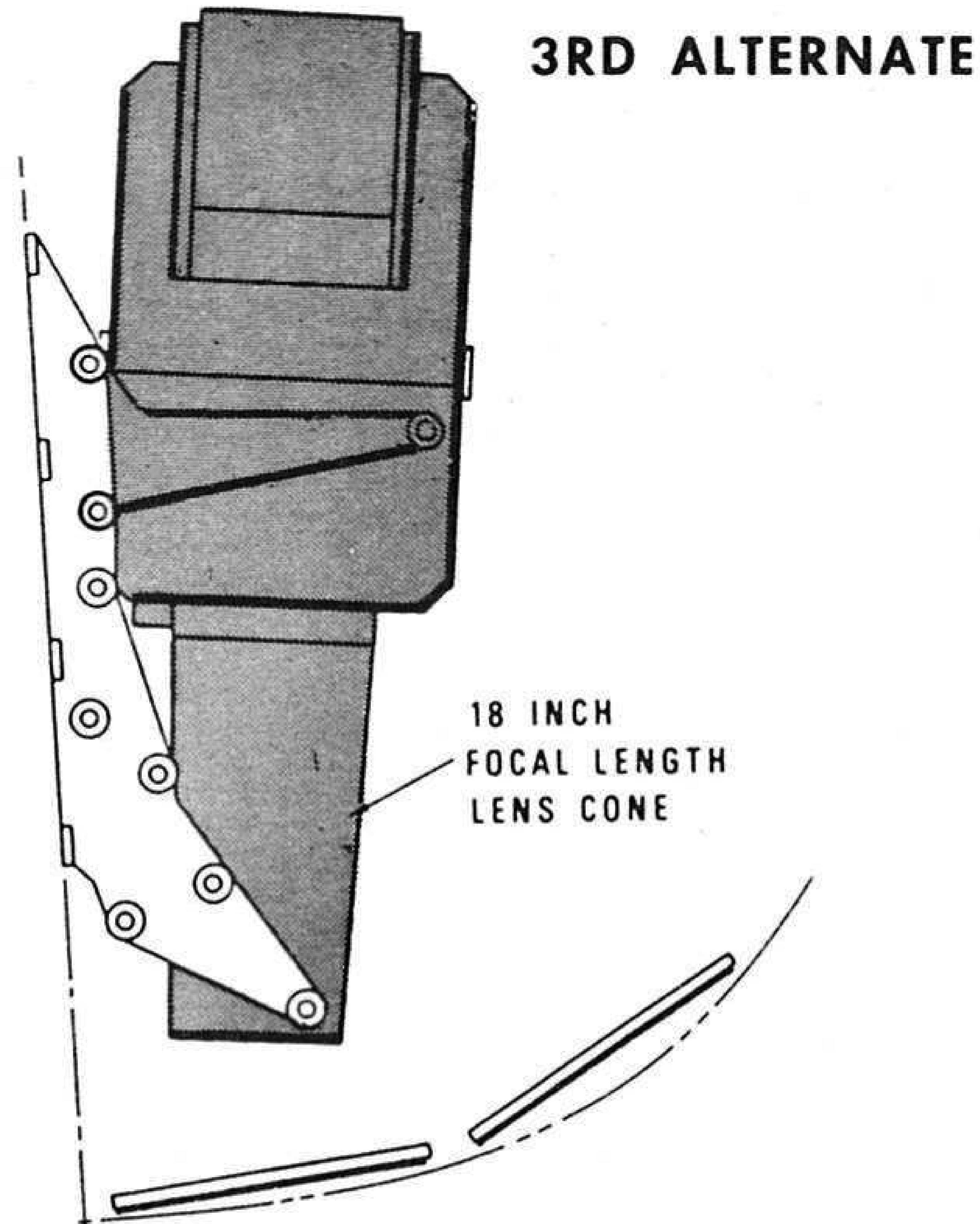


Figure 2 SPLIT VERTICAL STATION

LOOKING AFT AT F.S. 180 SHOWING LEFT HAND KS-87 CAMERA IN EACH OF FOUR CONFIGURATIONS.

Figure 2 shows the unique mounting features of the cameras in the Split Vertical Station.

Figure 3 is a Configuration Chart which describes possible camera configurations of the three stations.

Figure 3 CONFIGURATIONS

FORWARD STATION

CONFIGURATIONS	BASIC	ALTERNATE
CAMERA	KS-87	KS-87
FOCAL LENGTH	12 Inches	6 Inches
ATTITUDE	Forward Oblique	Forward Oblique
DEPRESSION ANGLE	10°	15°
NUMBER REQUIRED	1	1

VERTICAL STATION

CONFIGURATIONS	
CAMERA	KA-56
FOCAL LENGTH	3 Inches
ATTITUDE	Vertical
DEPRESSION ANGLE	90°
NUMBER REQUIRED	1

LEFT AND RIGHT STATION

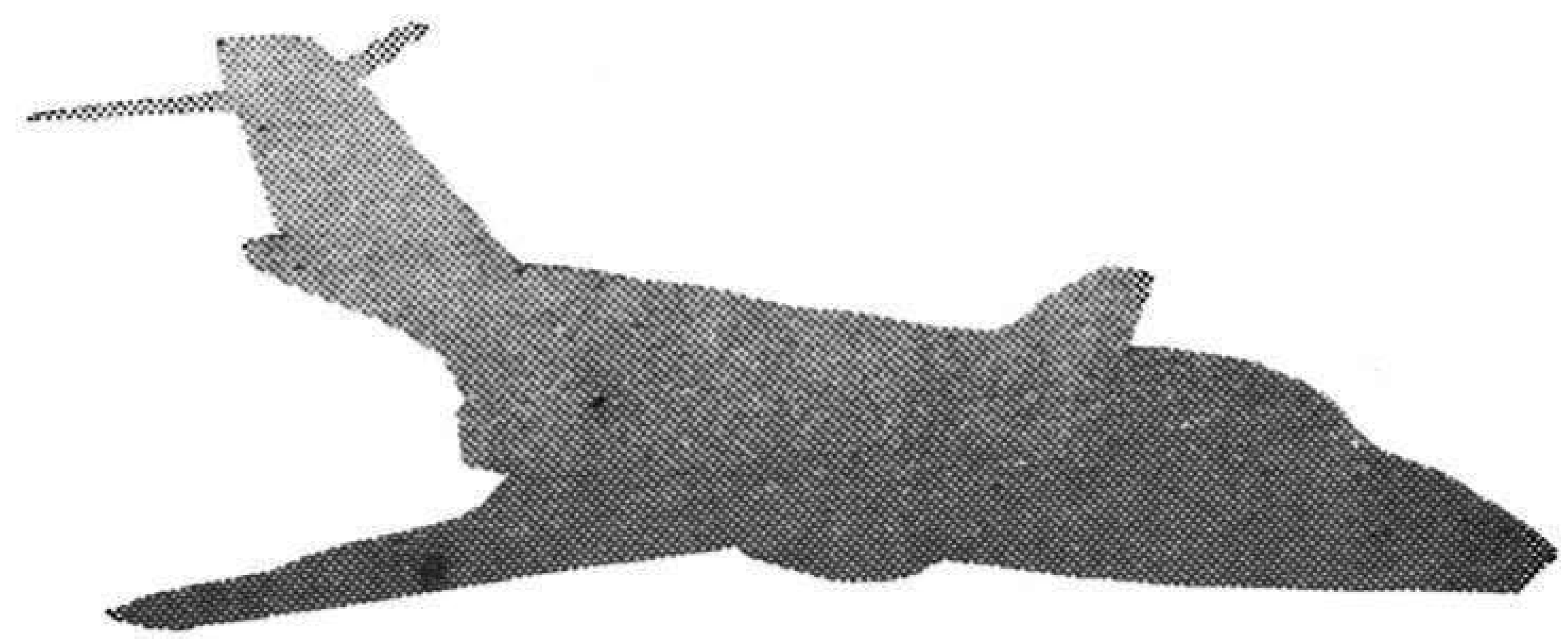
CONFIGURATIONS	BASIC	ALTERNATE	ALTERNATE	ALTERNATE
CAMERA	KS-87	KS-87	KS-87	KS-87
FOCAL LENGTH	6 Inches	3 Inches	12 Inches	18 Inches
ATTITUDE	Split Vertical	Split Vertical	Split Vertical	Split Vertical
DEPRESSION ANGLE	71° 36'	56° 30'	80° 33'	83° 40'
NUMBER REQUIRED	2	2	2	2

FORWARD STATION

CONFIGURATIONS		BASIC	ALTERNATE
CAMERA INSTALLATION	TYPE	KS-87	KS-87
	NUMBER REQUIRED	1	1
	FOCAL LENGTH	6 Inches	12 Inches
	ATTITUDE	Forward Oblique	Forward Oblique
	DEPRESSION ANGLE	15°	10°
REQUIRED GROUND SETTINGS ON AIRCRAFT CAMERA PARAMETER CONTROL, LA-311A	FWD FOCAL LENGTH	12"	18"
	FWD DEPR ANGLE	15°	10°

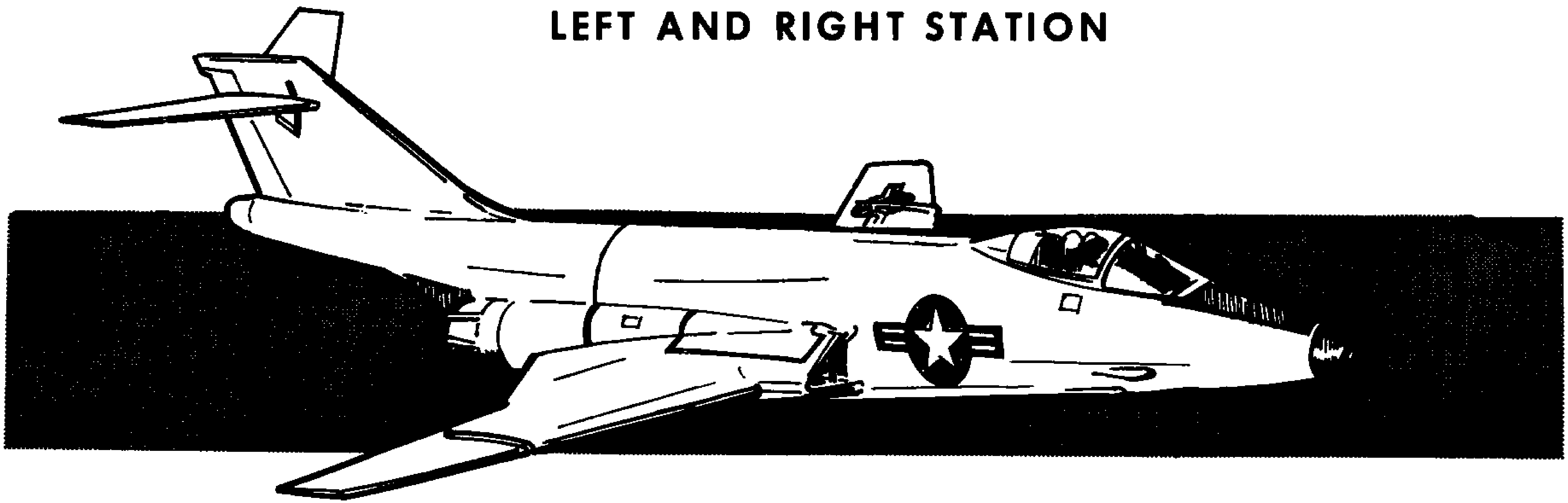
VERTICAL STATION

CONFIGURATIONS	
CAMERA	KA-56
FOCAL LENGTH	3 Inches
ATTITUDE	Vertical
DEPRESSION ANGLE	90°
NUMBER REQUIRED	1



CONFIGURATIONS		BASIC	1ST ALT	2ND ALT	3RD ALT
CAMERA INSTALLATION	TYPE	KS-87	KS-87	KS-87	KS-87
	NUMBER REQUIRED	2	2	2	2
	FOCAL LENGTH	6 Inch	3 Inch	12 Inch	18 Inch
	ATTITUDE	Split Vertical	Oblique	Split Vertical	Split Vertical
REQUIRED GROUND SETTINGS ON AIRCRAFT CAMERA PARAMETER CONTROL, LA-311A	ACPC CHANNEL	HI-ALT	RIGHT	HI-ALT	HI-ALT
	FOCAL LENGTH	6"	3"	12"	18"
	DEPR ANGLE	71.6°	30°	80.5°	83.7°
	FORMAT	4.5"			4.5"

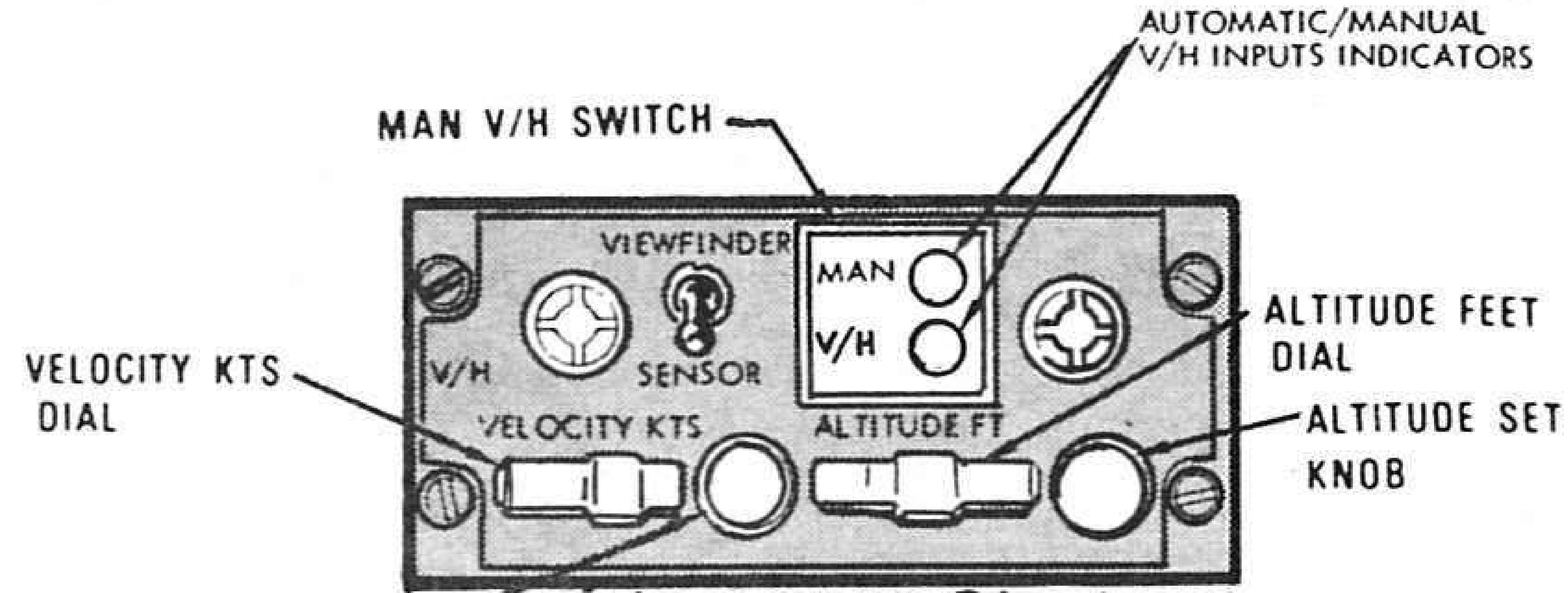
LEFT AND RIGHT STATION



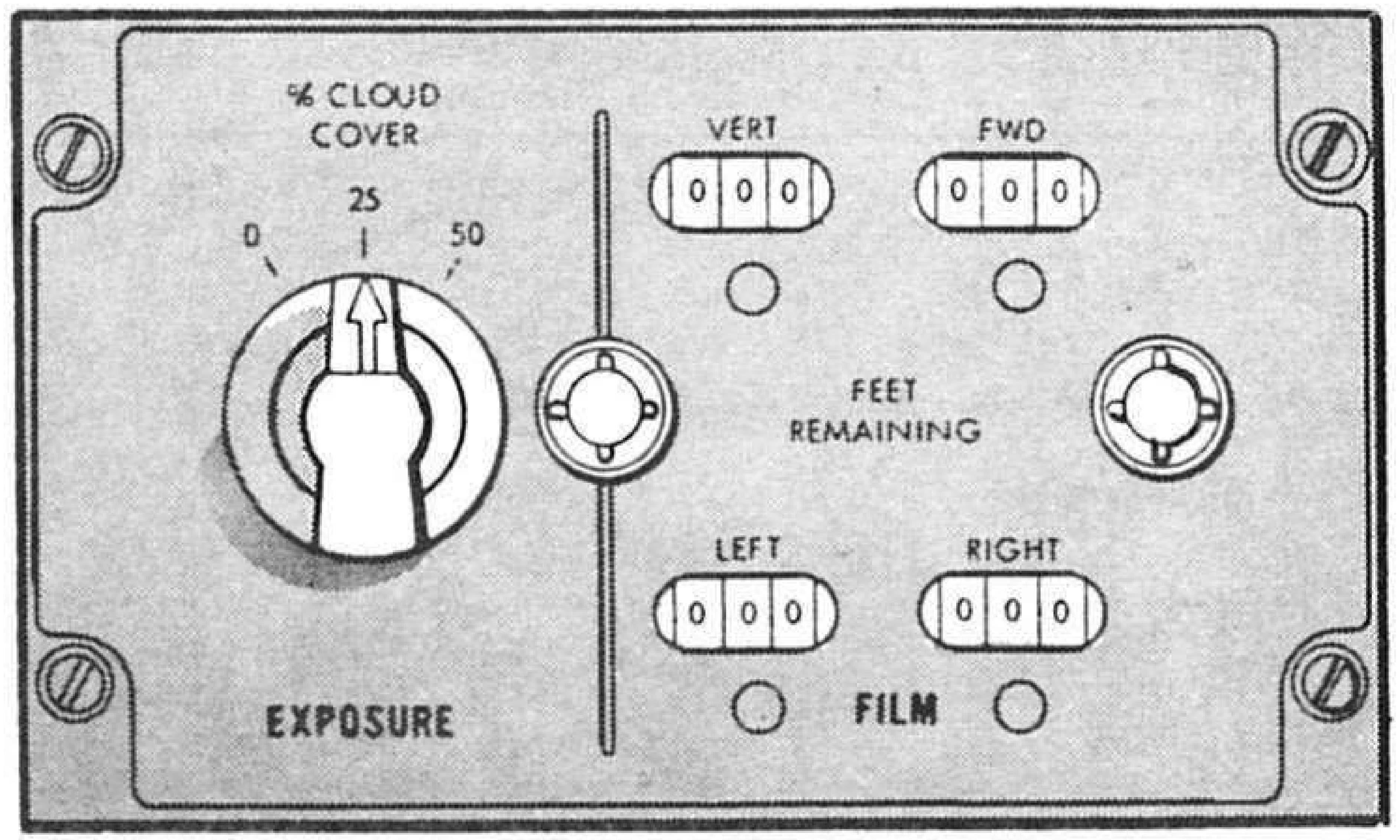
Camera System Operation

Operation of the RF-101G/H camera system is controlled and monitored by the pilot from the aircraft cockpit. The control equipment and indicators, shown in Figure 4, are the Sensor Control Panel, V/H Control Panel, Exposure-Film Panel, Camera Operate Light, Camera Fail Light, and the Camera Operate Switch and Extra Picture Switch on the control stick. Also shown is the Aircraft Camera Parameter Control in the camera compartment which contains selector switches ground set by maintenance personnel.

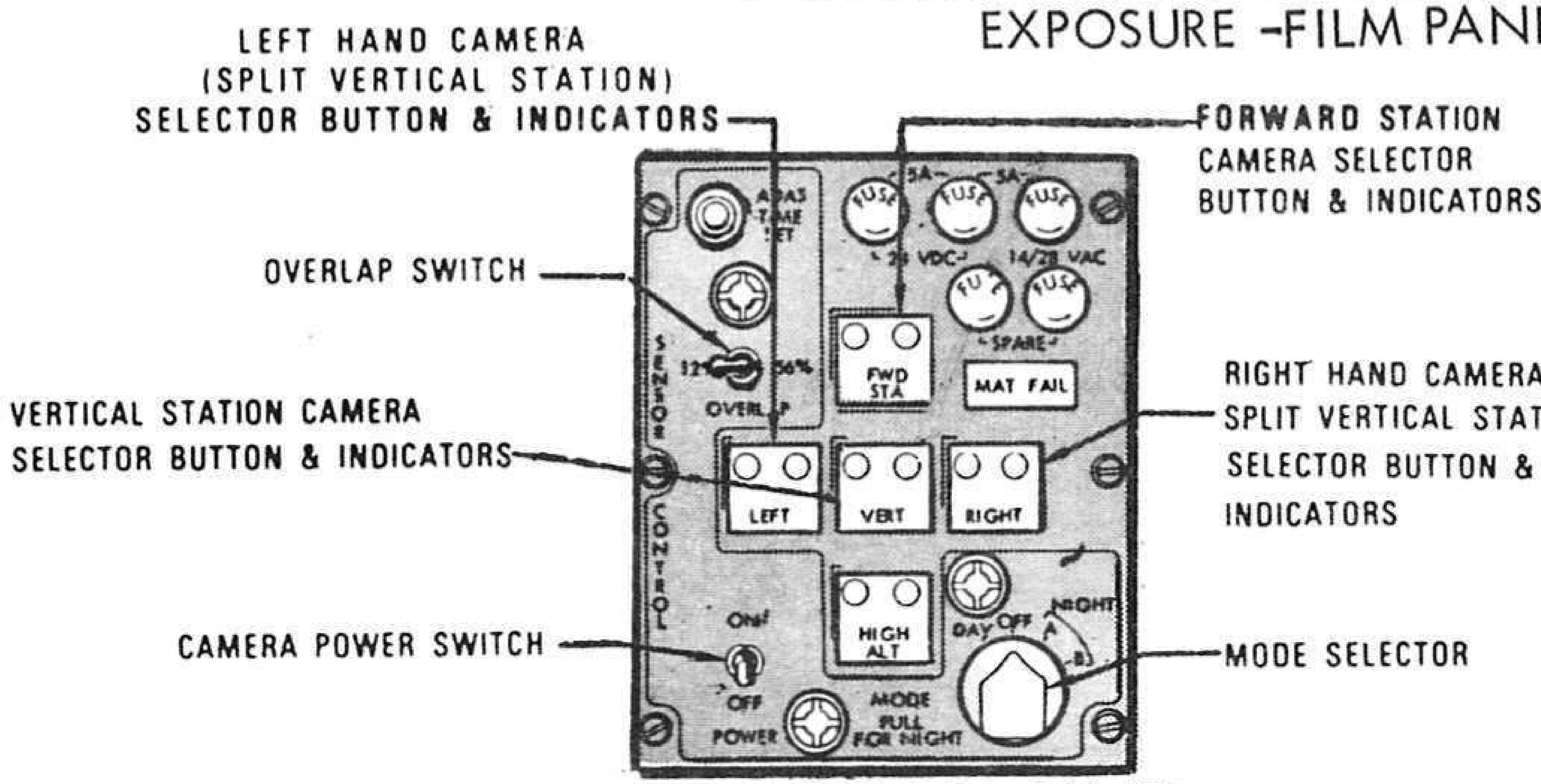
The RF-101G/H camera system was designed for high-resolution photographs during high-level or low-level, high-speed, tactical day reconnaissance missions. To achieve low-level, high-speed aerial photography, the camera must move the film forward at a rate relative to ground motion while exposing the film. This rate of film movement, known as Forward Motion Compensation (FMC), is a function of aircraft altitude, aircraft ground speed, camera focal length, and camera depression angle. The camera also must operate at a high pulse rate to obtain successive photographs with the desired forward overlap. The proper pulse rate and FMC commands are supplied by the Integrated Camera Control System.



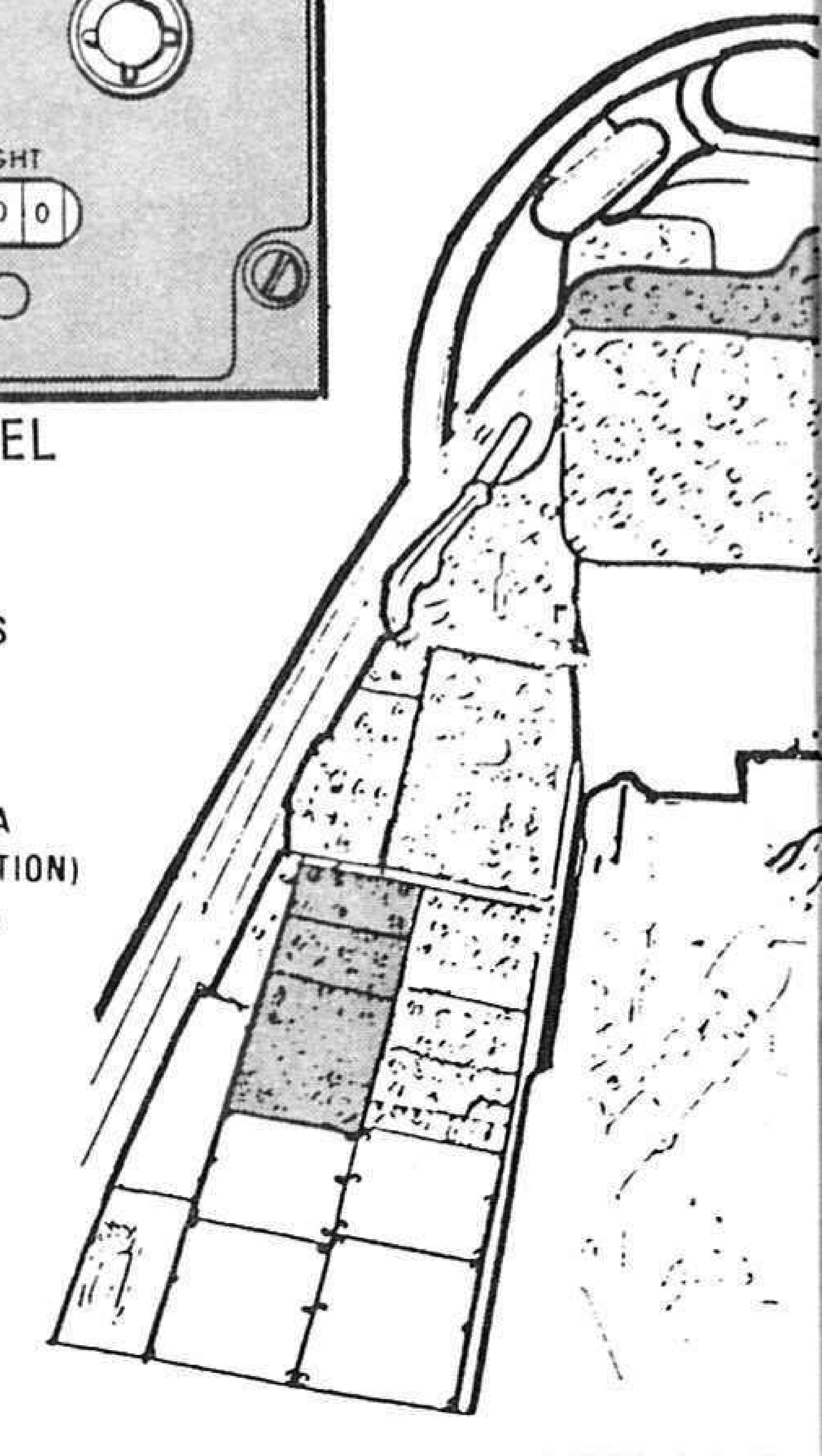
V/H CONTROL PANEL

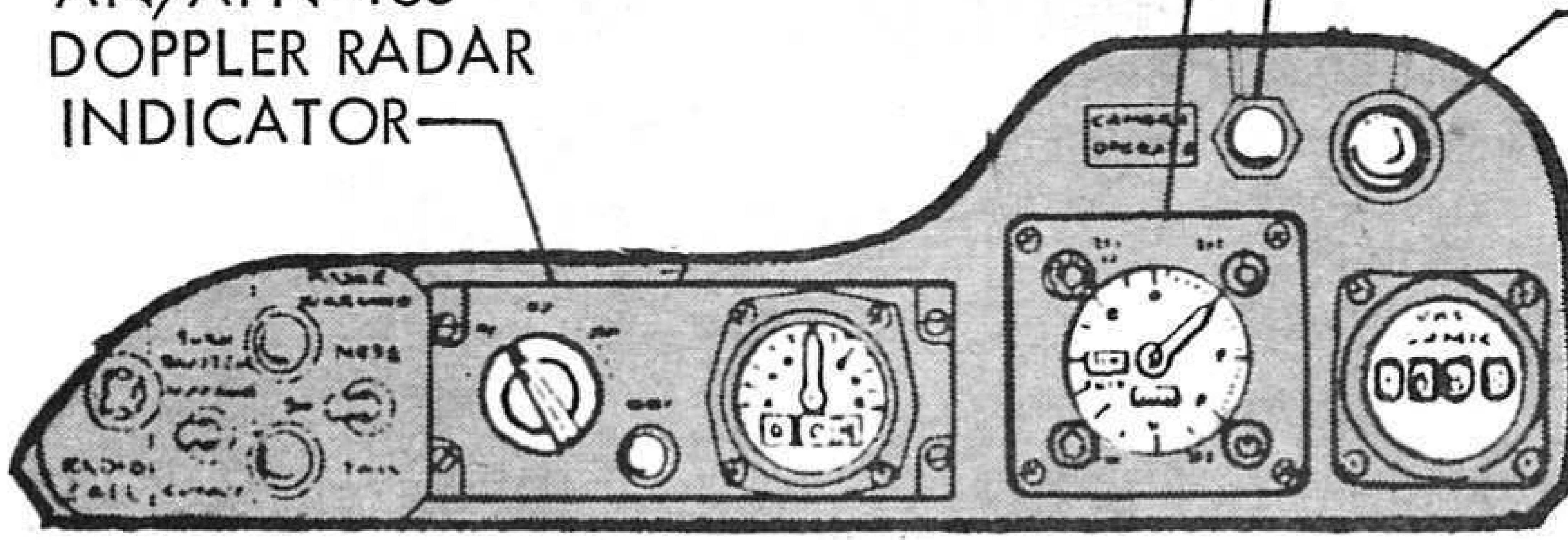


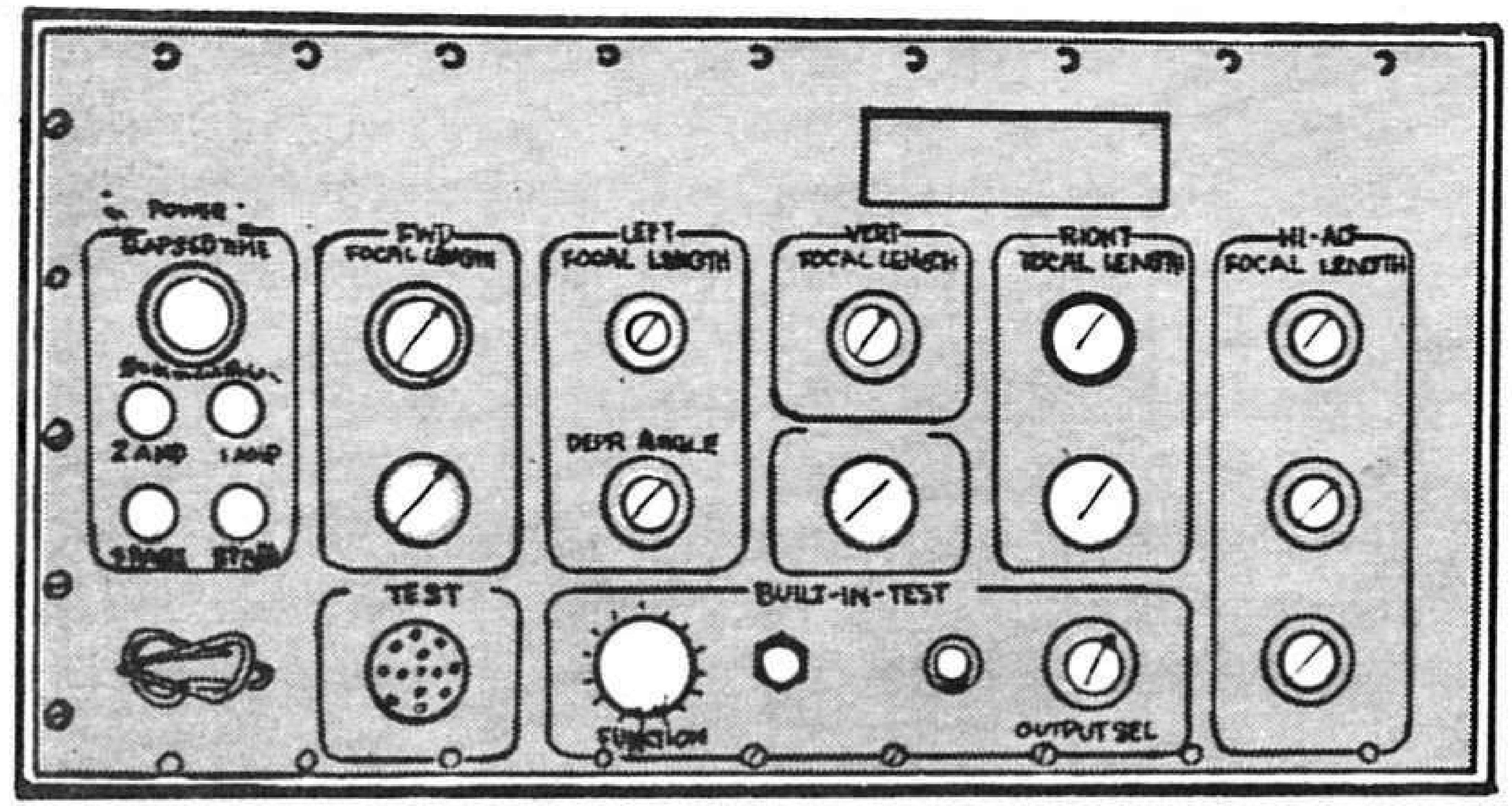
EXPOSURE -FILM PANEL



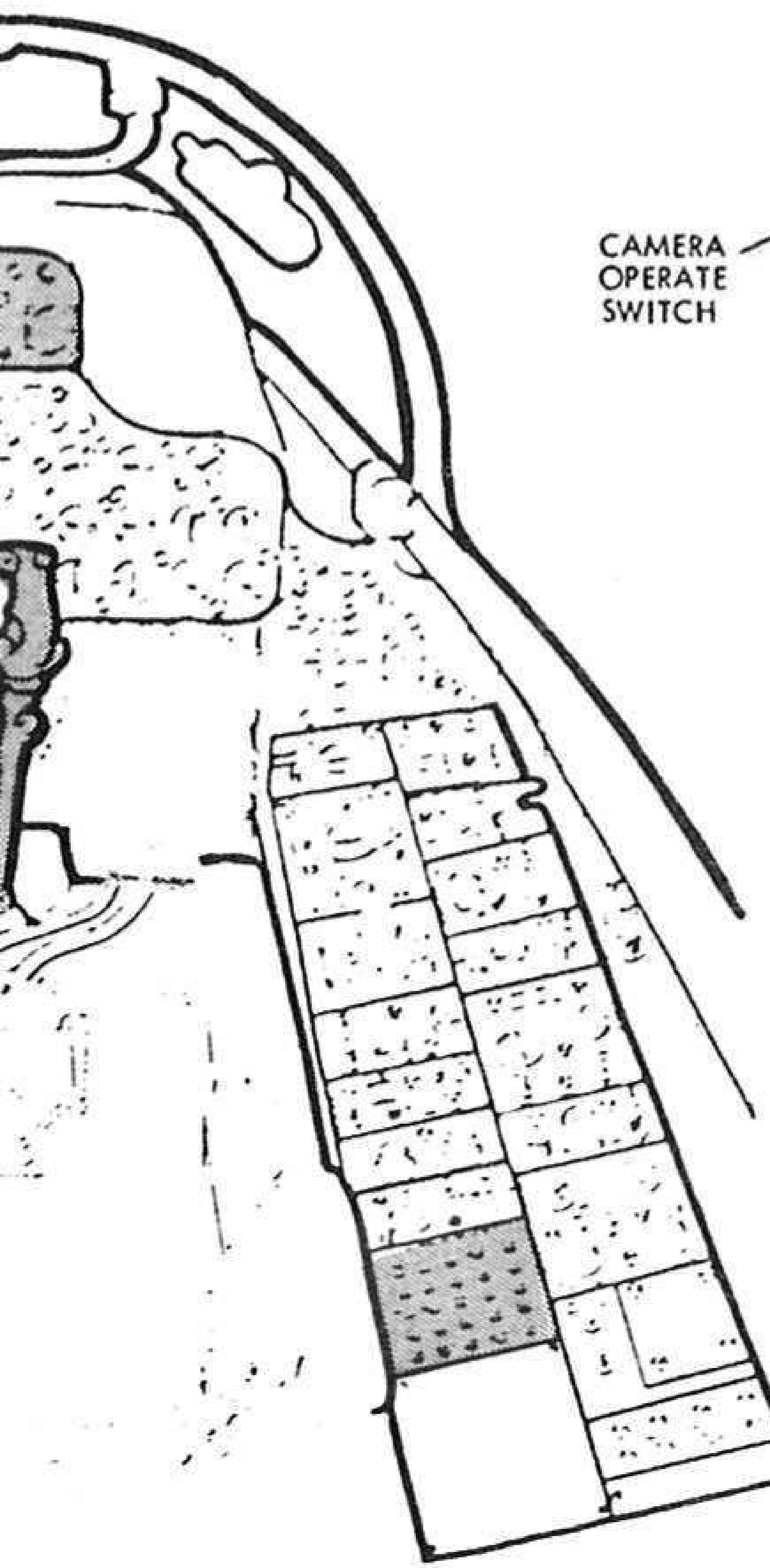
SENSOR CONTROL PANEL

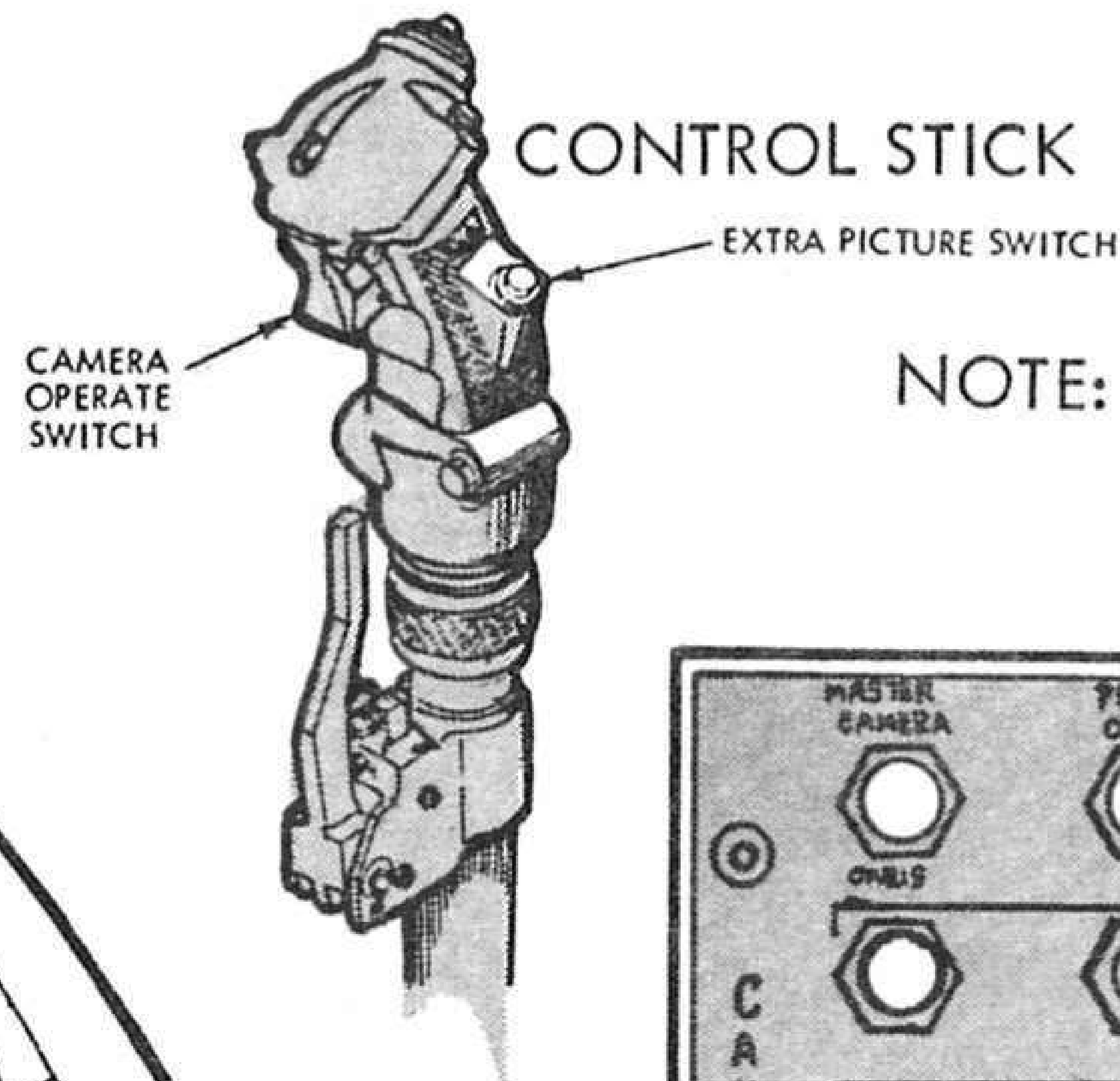




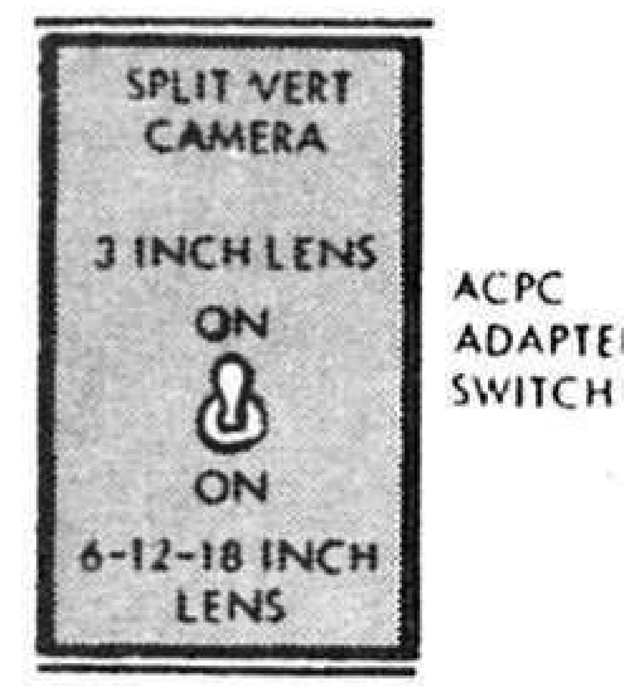


AIRCRAFT CAMERA PARAMETER CONTROL
(CAMERA COMPARTMENT IN NOSE)

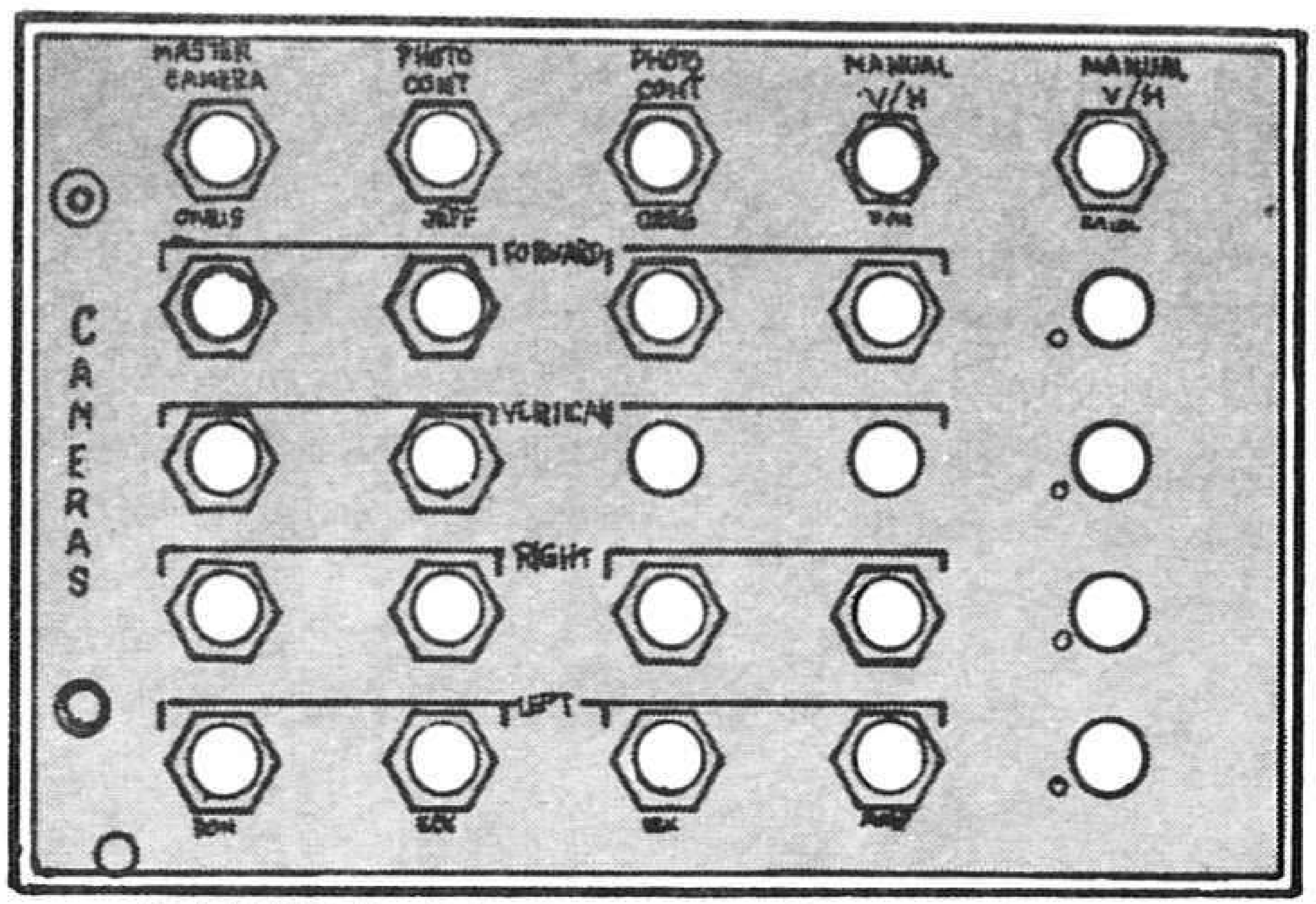




NOTE: T.O.IF-101-1112C INCORPORATED



ACPC ADAPTER SWITCH



CAMERA CIRCUIT BREAKER PANEL

Figure 4
COCKPIT CONTROLS
AND INDICATORS

RF-101G/H INTEGRATED CAMERA CONTROL SYSTEM DIAGRAM

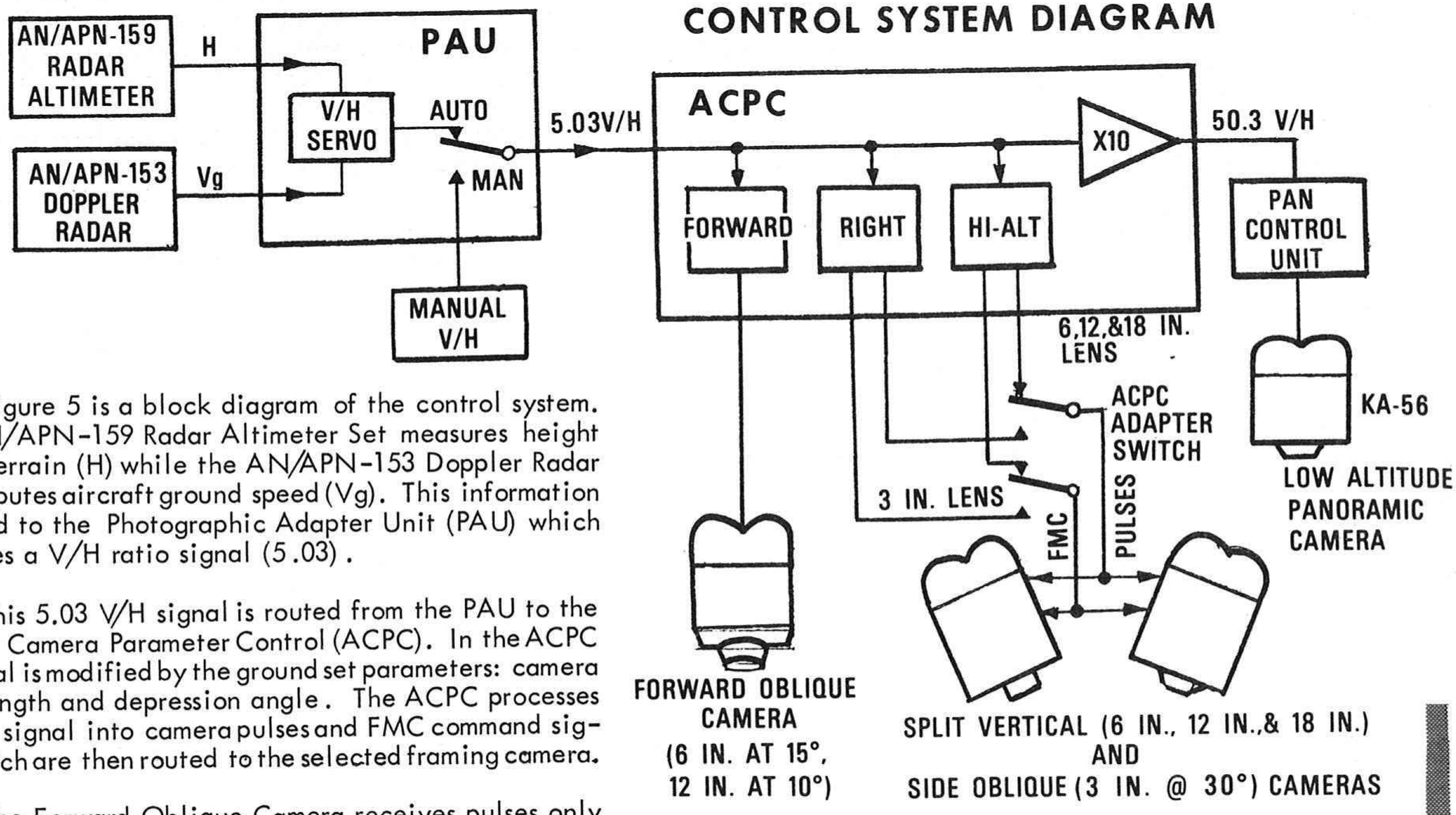


Figure 5

Figure 5 is a block diagram of the control system. The AN/APN-159 Radar Altimeter Set measures height above terrain (H) while the AN/APN-153 Doppler Radar Set computes aircraft ground speed (Vg). This information is routed to the Photographic Adapter Unit (PAU) which computes a V/H ratio signal (5.03).

This 5.03 V/H signal is routed from the PAU to the Aircraft Camera Parameter Control (ACPC). In the ACPC the signal is modified by the ground set parameters: camera focal length and depression angle. The ACPC processes the V/H signal into camera pulses and FMC command signals which are then routed to the selected framing camera.

The Forward Oblique Camera receives pulses only from the ACPC. FMC is not required in the forward oblique position.

The ACPC Adapter Switch in the camera compartment determines the channel of the ACPC which will furnish inputs to the framing cameras. If Split Vertical Cameras are being used, the switch should be in the 6-12-18 INCH LENS position. In this position the Split Vertical Cameras receive command signals from the HI-ALT channel of the ACPC. If 3-inch focal length Side Oblique Cameras are being used, the Adapter Switch must be in the 3-INCH LENS position. In this position the RIGHT channel of the ACPC generates command voltages to the two oblique cameras. Proper switch positioning is necessary to achieve proper camera operation. If the switch is in the wrong position, degraded imagery will result from erroneous FMC; and improper forward overlap will be evident from the erroneous pulse rate. This switch is ground set by maintenance personnel.

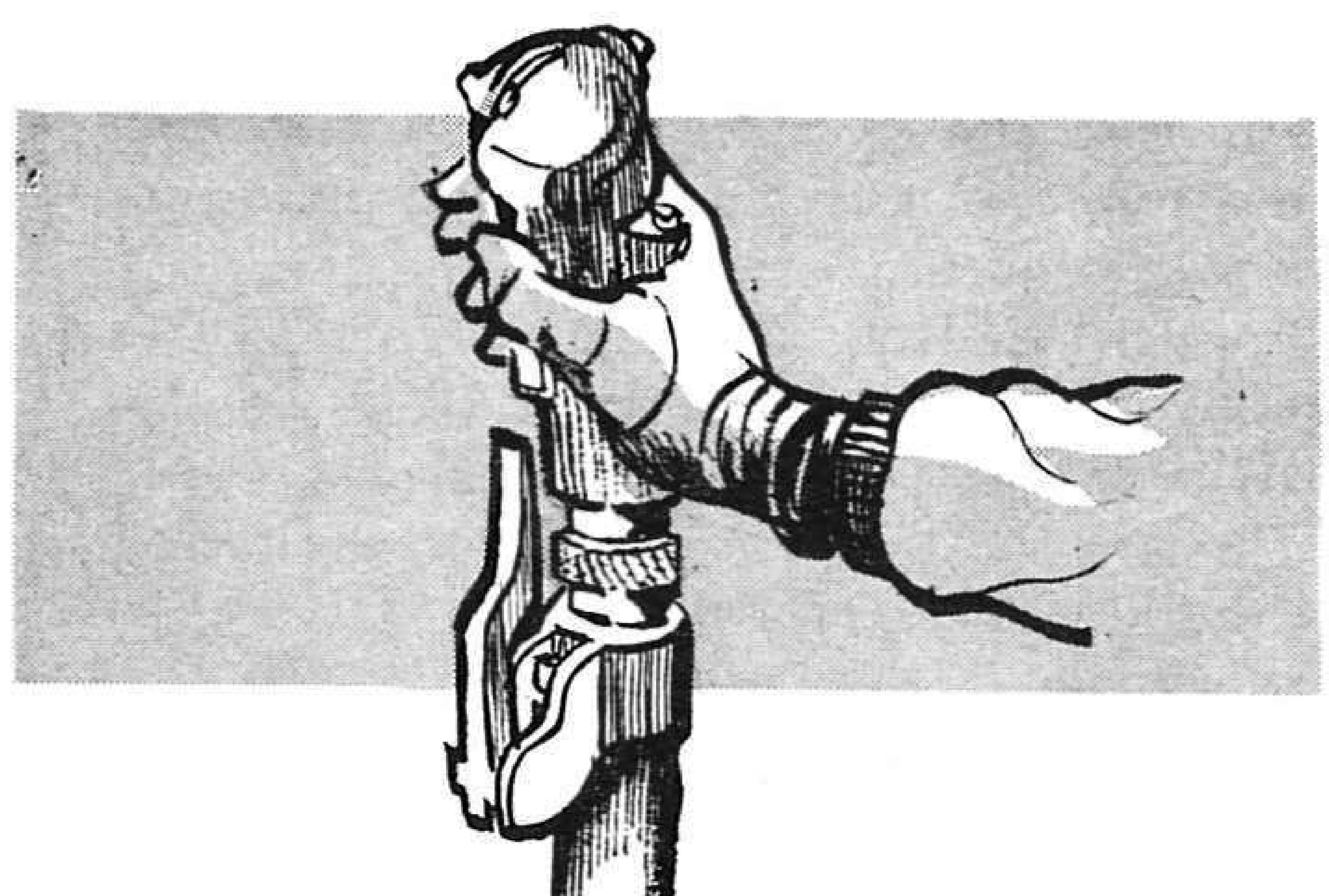
The 5.03 V/H signal entering the ACPC is also amplified by an amplifier with a gain of 10. The resulting 50.3 V/H signal is then routed to the KA-56 Panoramic Camera. This is an autocycling camera in which cycling rate is determined by the magnitude of the V/H voltage.

Two modes of V/H are used for the camera system: Automatic V/H as just described, and Manual V/H. The Manual V/H inputs are set on the V/H Control Panel in the cockpit by the pilot. If either the Radar Altimeter or Doppler Radar become unreliable, switching circuits within the PAU automatically select the Manual V/H signal. It is therefore important that the pilot maintain proper velocity and altitude settings on the V/H Control Panel.

The V/H Mode Selector (MAN V/H) button is a push-on/push-off type which indicates the mode by lights within the button. When Manual V/H is selected, a green light in the lower portion of the button is illuminated. However, if an amber light in the upper portion of the button is illuminated, it means Automatic V/H has been selected but (due to an unreliable signal from either the Radar Altimeter of Doppler Radar) the PAU has automatically switched to the Manual V/H signal. When the amber light is extinguished the system is in the Automatic mode of V/H operation. To repeat:

- Green light means Manual V/H selected.
- No light means reliable Automatic V/H.
- Amber light means return to Manual V/H because of unreliable Automatic V/H.

It is imperative that the VIEWFINDER-SENSOR Switch on the V/H Control Panel be in the SENSOR position for either the Automatic or Manual mode of operation. Because the VIEWFINDER position is not applicable to the RF-101G/H, this switch should be locked in the SENSOR position.



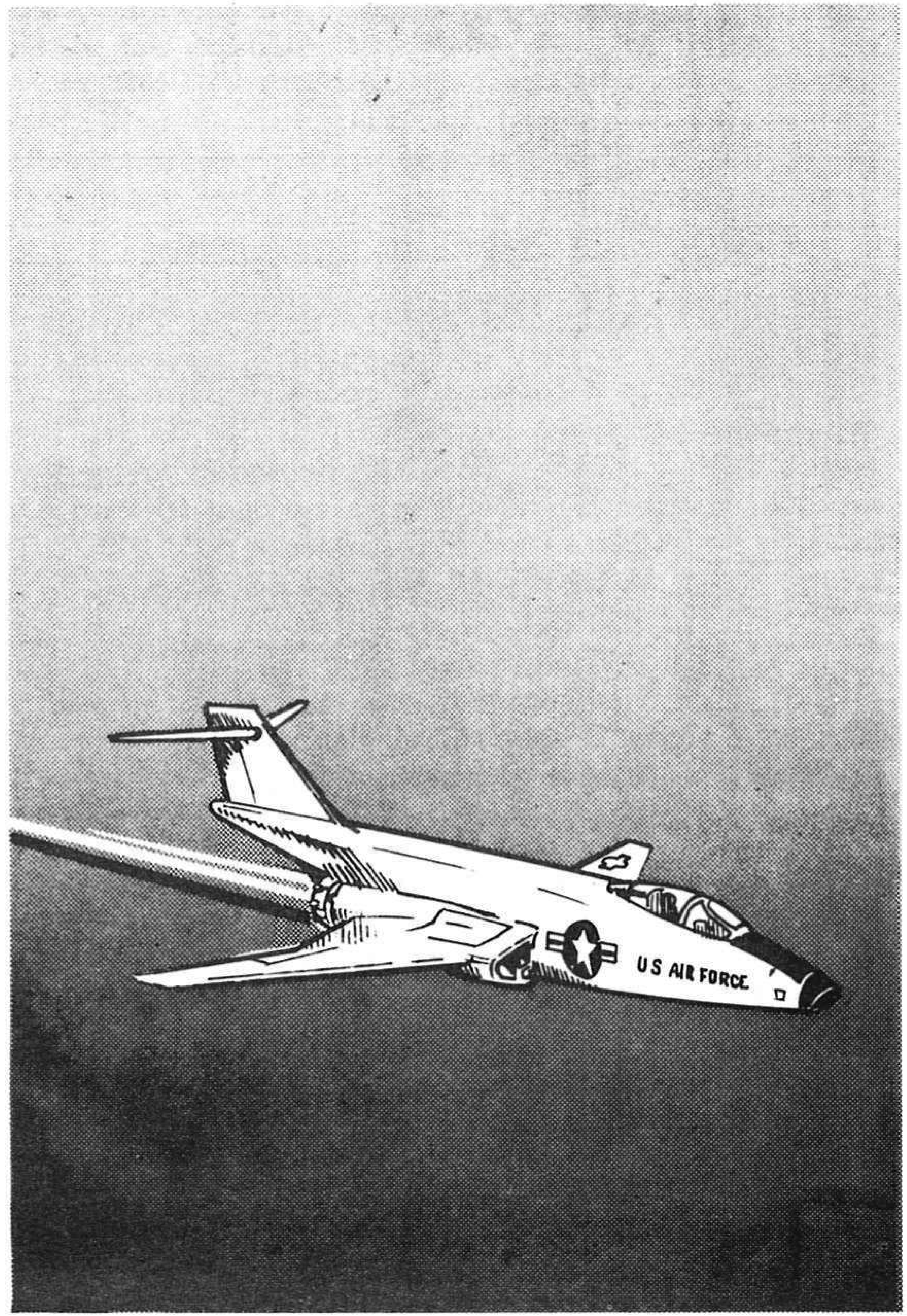
The cameras and control systems are put into the Ready-Operate position by placing the Camera Power Switch on the Sensor Control Panel to ON, setting the Mode Selector on this same panel to DAY, and then selecting the desired camera stations. It's a good idea to leave the Mode Selector in the DAY position to eliminate one step of operation.

The pilot controls camera operation by squeezing the Camera Operate Switch on the control stick grip. This switch is a squeeze-on/squeeze-off type. Actuation of the switch causes the selected cameras to be controlled by the ACPC command signals as computed from the V/H signal.

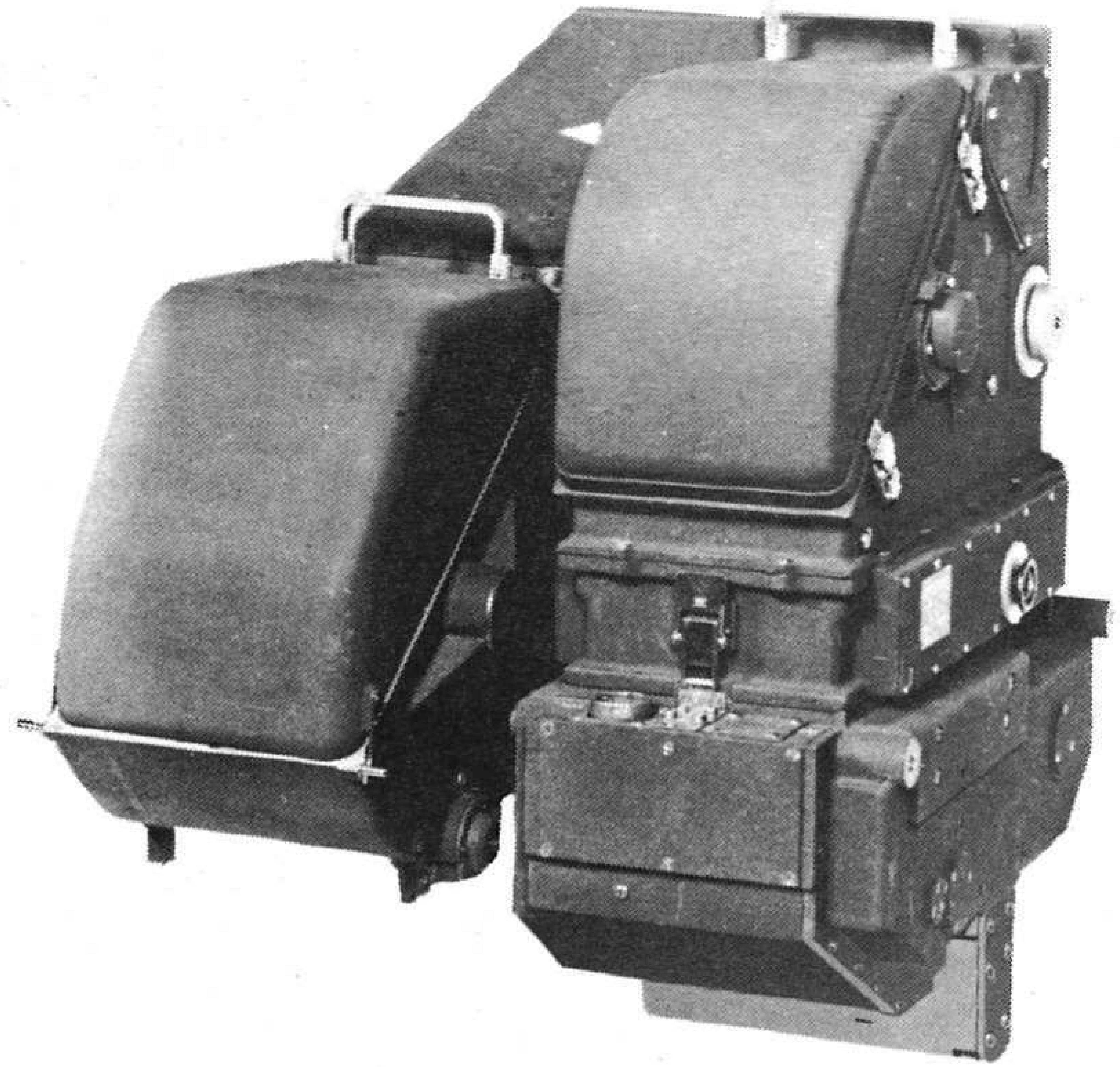
The framing cameras may be pulsed once with each actuation of the Extra Picture Switch on the stick grip. This switch does not control the KA-56 Panoramic Camera.

The pilot also has an exposure override control on the Exposure-Film Panel in the cockpit. This control is the three-position % CLOUD COVER selector, which allows the pilot to open up the camera exposure control when high reflective cloud cover exists beneath the aircraft. The 25% position represents one f stop and 50% represents two f stops. This switch controls all cameras.

The Forward Oblique Camera is selected by actuating the FWD STA button/indicator on the Sensor Control Panel. The Split Vertical Cameras or Oblique Cameras are selected by actuating the LEFT or RIGHT button/indicator. The VERT button/indicator selects the KA-56 Panoramic Camera. (The HIGH ALT button/indicator is not used in the RF-101G/H.)



KA-56 Panoramic Camera



The KA-56 Panoramic Camera is an autocycling camera which uses a 3-inch focal length, f4.5 lens. The camera scans the terrain laterally from horizon to horizon by rotating a double Dove prism in front of the lens. Rotating at proper V/H speed, the prism directs the terrain image to the lens where it is focused through a variable focal plane slit onto the film. Because the film is pulled across the slit at a speed synchronized with prism rotation, the imagery in effect is painted on the film.

The camera has Automatic Exposure Control (AEC). A photoelectric cell mounted in the camera body senses terrain brightness. Width of the variable slits is controlled by both the AEC command and the V/H signal. As terrain brightness increases, the slit width decreases; but as V/H increases, the slit width increases. This arrangement permits the camera to maintain proper film exposure under conditions of varying speed, altitude and light intensity.

The KA-56 camera was designed for tactical day reconnaissance during high-speed, low-level missions. Successive pictures have a fixed 56% forward overlap. Maximum cycling rate is 6 CPS and minimum cycling rate is 1 CPS. The maximum cycling rate is achieved at a V/H ratio of 2.4 (600 knots/250 feet). The minimum cycling rate occurs at a V/H ratio of 0.38 (310 knots/800 feet). Decreasing the V/H ratio beyond 0.38 (increased altitude, decreased speed) causes the camera to have greater than 56% forward overlap. The KA-56 camera is not affected by the OVERLAP Switch position.

The camera maintains Forward Motion Compensation across the film format over a V/H range of 0.1 to 2.4. FMC is accomplished by displacing the lens in the longitudinal axis as the film is exposed. Lens movement is zero at the horizon, increases as the prism rotates to the nadir (maximum FMC), and then decreases as the prism sweeps out to the horizon on the other side of the aircraft. The lens then resets; and another sweep start for the next exposure.

Figure 6

KA-56 LOW-ALTITUDE PANORAMIC CAMERA PERCENT OVERLAP ENVELOPE

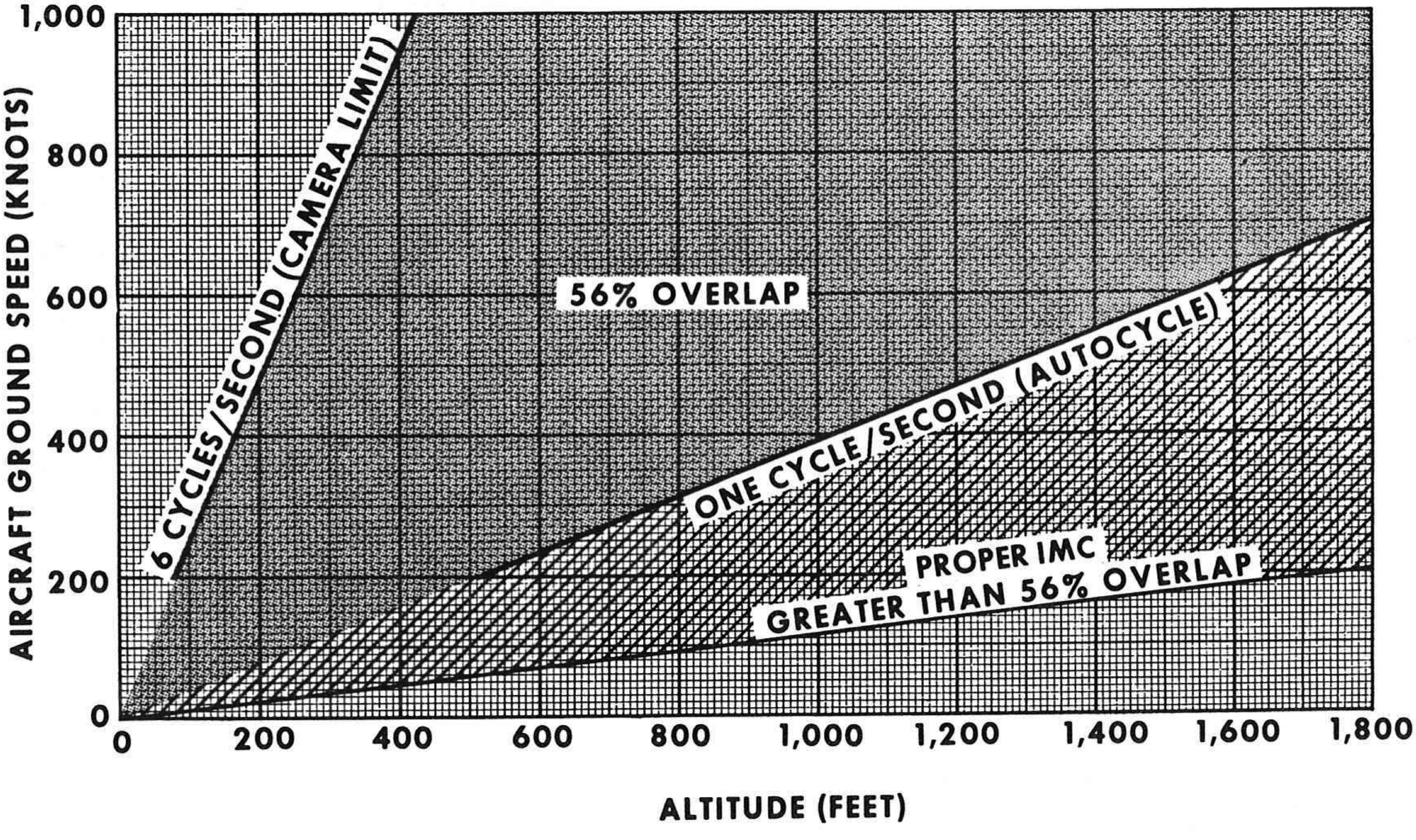


Figure 6 is a graph covering the cycling parameters of the KA-56 camera. It can be seen that proper FMC (but with excessive overlap) will exist between lines 1 and 2. Between lines 2 and 3, proper FMC and proper forward overlap of 56% will exist. The relationships, of course, are predicated on proper V/H information.

Advantages

Advantages of the KA-56 Panoramic Camera are:

- Wide coverage (permitting greater latitude in flight line navigation)
- High cycling rate (permitting low-level, high-speed profiles)
- Proper FMC across entire film format

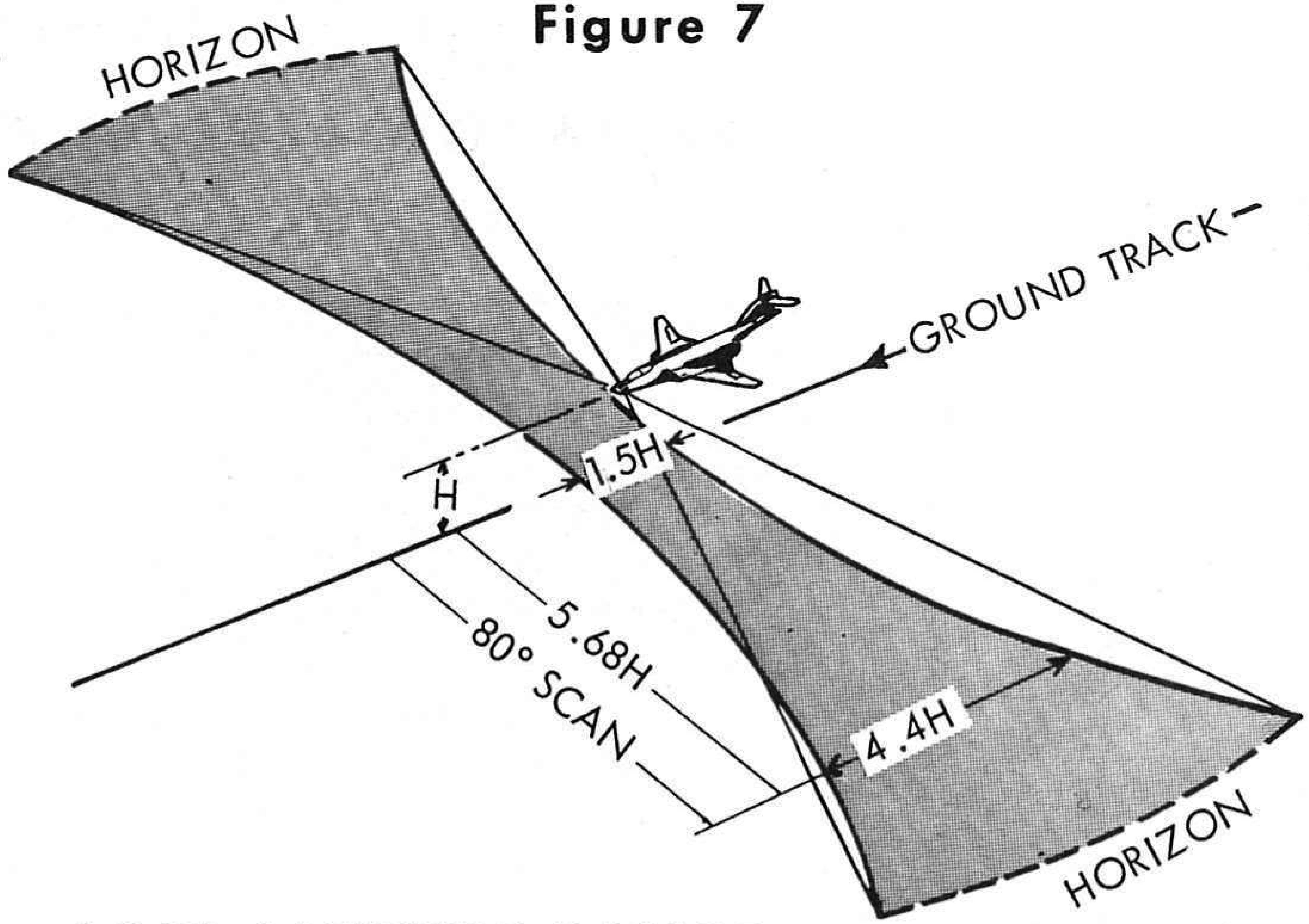
The panoramic camera gives horizon-to-horizon coverage on one strip of film. It would take three framing cameras in a tri-net configuration to give equal coverage, and three strips of film would have to be processed and evaluated.

Disadvantages

Disadvantages of the KA-56 Panoramic Camera are:

- Day photography only (whereas framing cameras may be used both day and night)
- Photo scale varies throughout format (mensuration is more difficult)

Figure 7



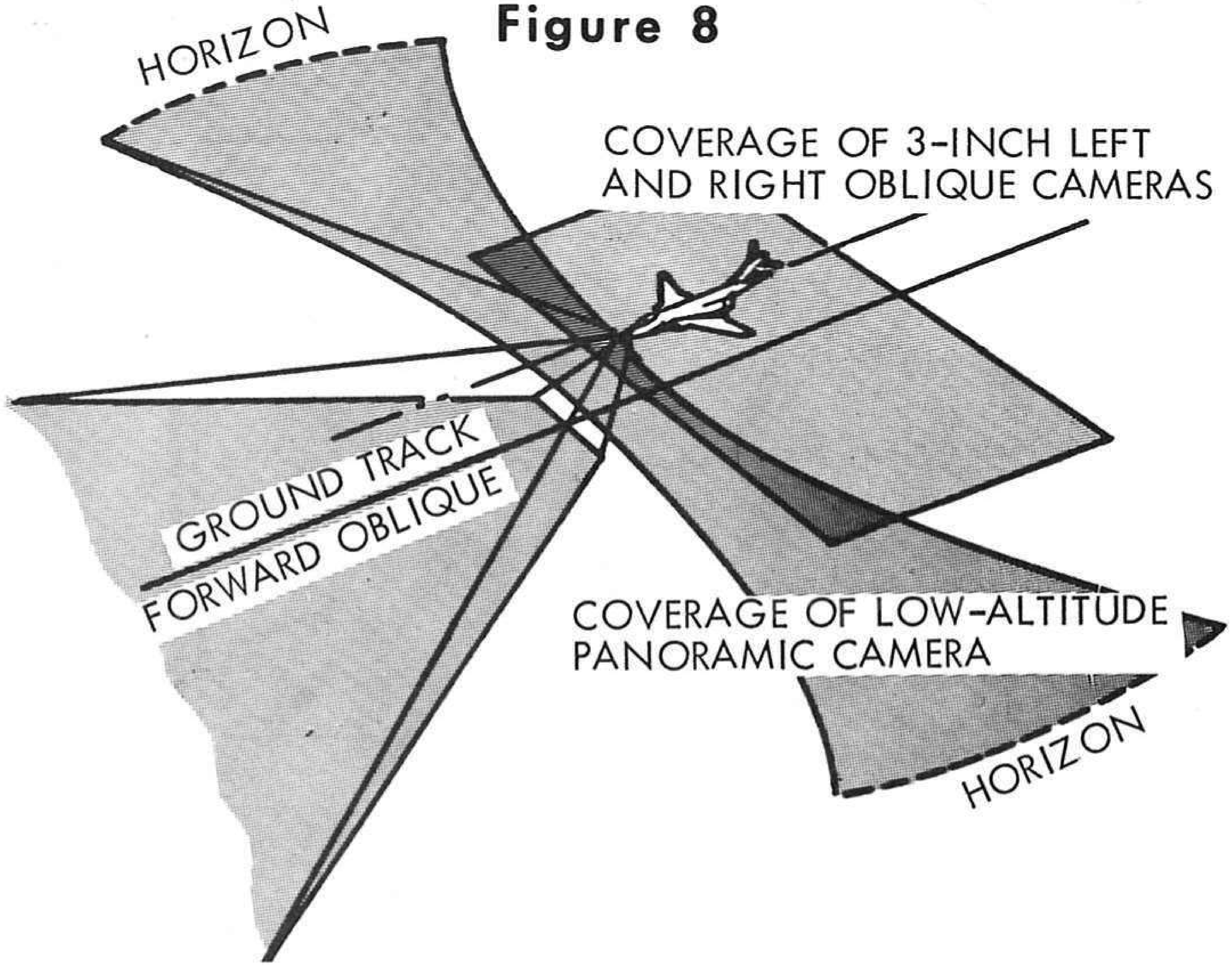
LOW-ALTITUDE PANORAMIC CAMERA COVERAGE 3inch, 180° scan

Pilot Responsibility

It is the responsibility of the RF-101G/H pilot to maintain proper V/H signals to the camera system. It is wise to operate in the Automatic Mode of V/H while maintaining proper Manual V/H backup settings.

The actual coverage of the KA-56 camera has a "bow tie" shape for any individual frame. Figure 7 expresses the coverage of the camera as a function of aircraft altitude (H) and shows the bow tie effect.

Figure 8



MULTI-CAMERA COVERAGE

The KA-56 Panoramic Camera is an excellent choice for any low-level day reconnaissance mission. Figure 8 shows the coverage of this camera in combination with the framing cameras. This multi-camera coverage is an excellent choice for flying missions directly over the target. If an offset course must be flown with respect to the target, left and/or right oblique cameras should be selected.

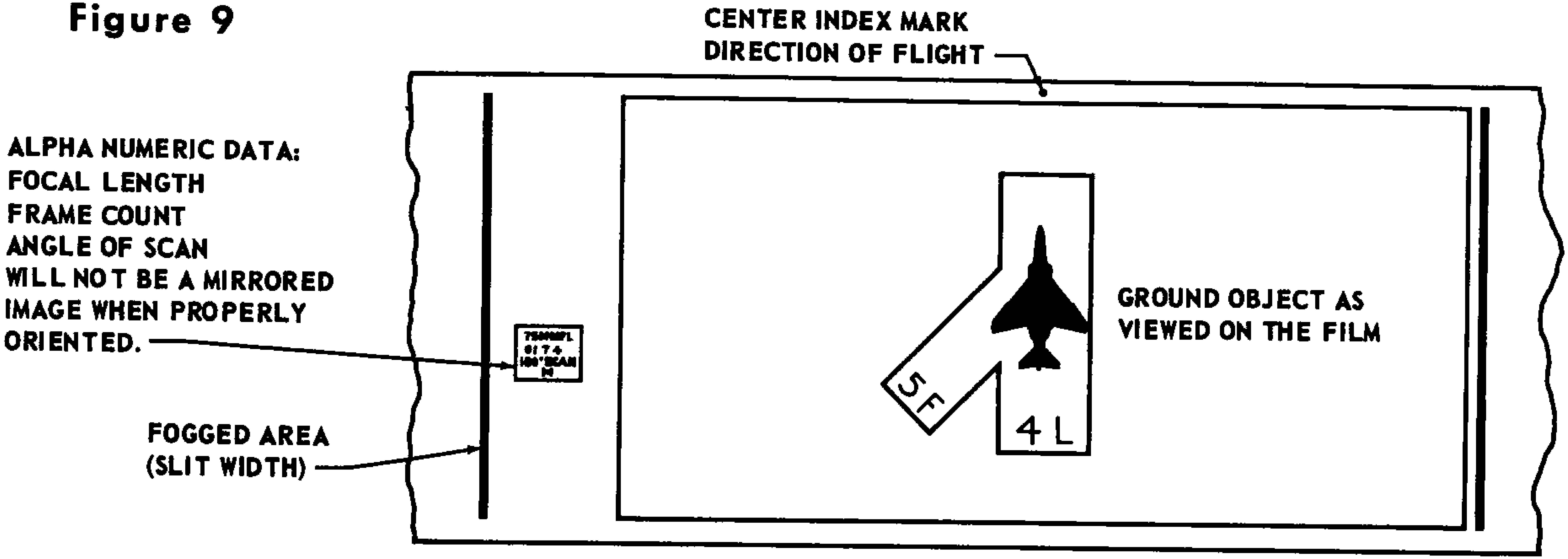
Image Interpretation

Interpretation of KA-56 imagery is best accomplished by placing the film on a light table with the emulsion side up. (See Figure 9.) If the interpreter positions himself at the light table so the index mark at the center of each image is at the top of the film, proper orientation of imagery with respect to aircraft position will be maintained. The center index mark indicates ground track and direction of flight. With the film so positioned, objects to the left of the index mark lie to the left of the actual ground track, and objects right of the index mark are to the right of the actual ground track.

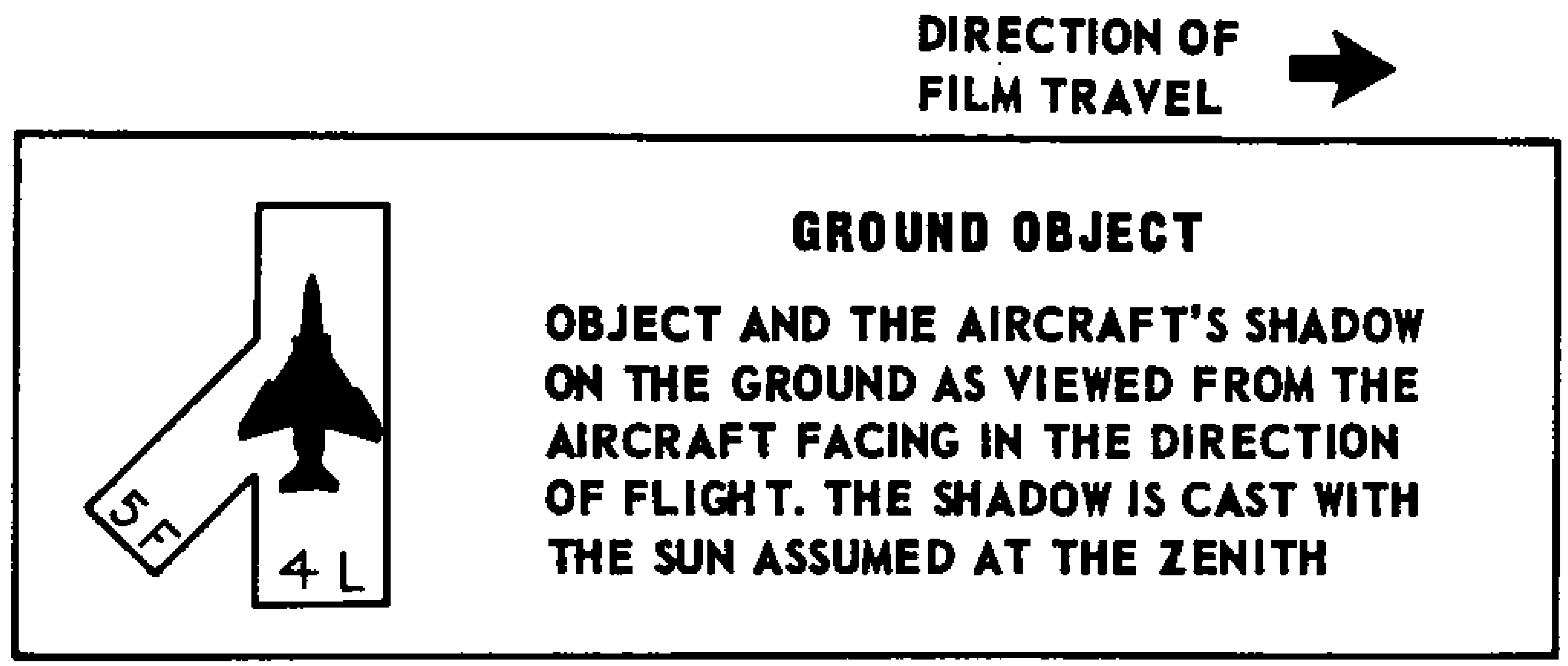
The dark, over-exposed strip on the left-hand edge of the film indicates the width of the variable slit. A wide slit (0.25-inch maximum opening) indicates a slow shutter speed, while a narrow slit means a faster shutter speed.

Mensuration is fairly easily accomplished by using the proper grid overlay on the film format. (See Figure 10.) Align the center index mark with the grid center axis, and align the end of the grid with the end of the negative. The image coordinates are now obtained by multiplying the altitude scale factor by the grid coordinates. The altitude scale factor is obtained by dividing the aircraft altitude above the terrain by 100. The altitude is readily obtained from the radar altitude section of the data annotation block. The grid is read as a conventional XY coordinate system. The direction of flight is the X axis; and the Y axis is 90° to the X axis. The center of the grid is the nadir (here X=0, Y=0). The grid is divided into the four conventional quadrants. Y is positive (+) to right of center and negative (-) to left of

Figure 9



EMULSION SIDE UP



center. X is positive (+) forward of nadir and negative (-) aft of nadir.

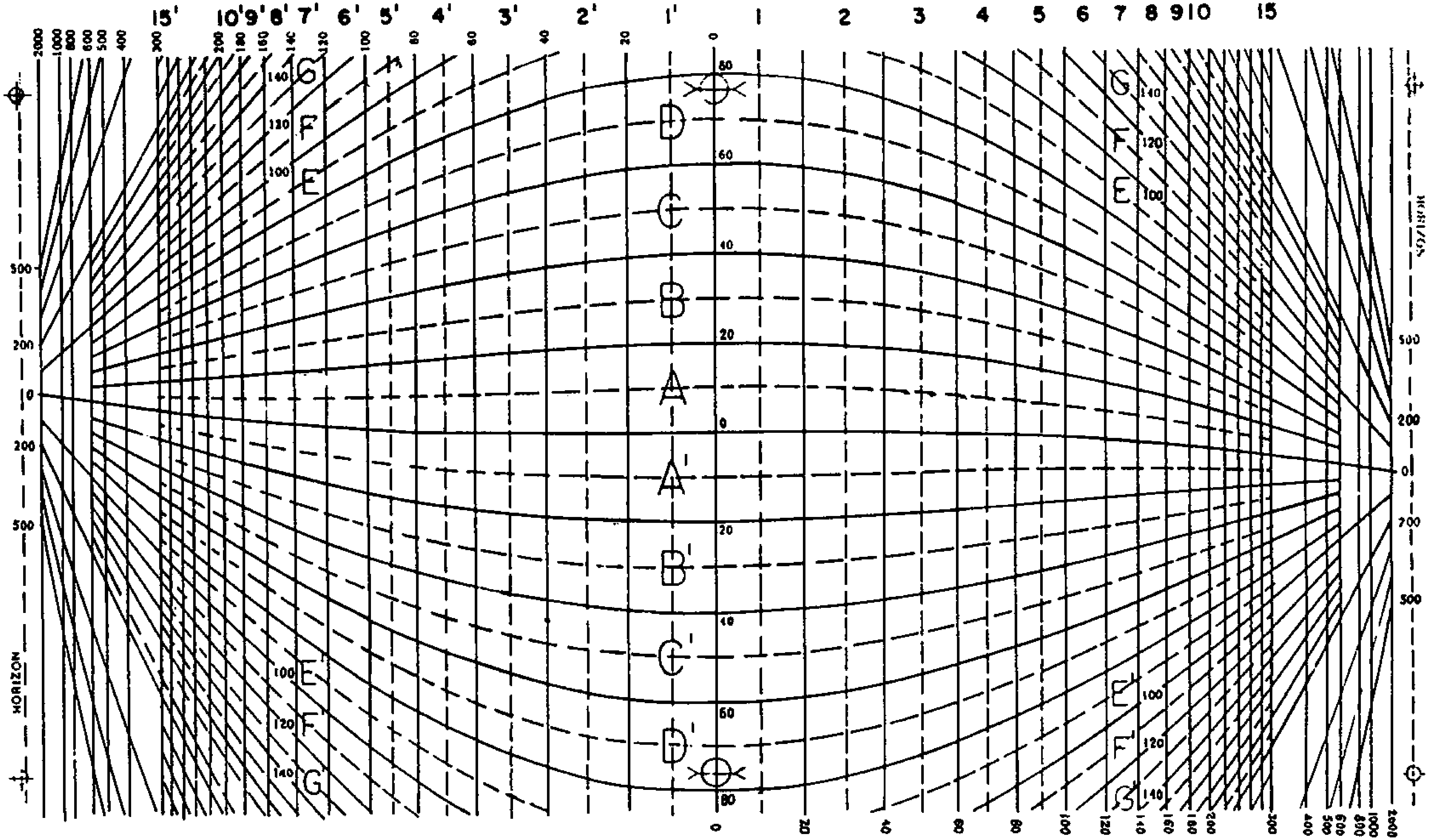
Using this method, a point may then be established with respect to the nadir. The length of a line may be computed by establishing both ends by this method and treating the line as the hypotenuse of a right triangle. Using the Pythagorean Theorem, the length of the line is:

$$\text{Length} = \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2}$$

The forward overlap of the KA-56 camera is estimated down the center line of the negative. The overlap should always be 56% if the V/H is correct and the V/H ratio is greater than 0.38. To exhibit the proper 56% overlap, an image entering the format at the center of one frame should move 44% into the format on the second frame and 88% into the format of the third frame. As a rough estimate, overlap is proper if an image appears down the center of two consecutive frames and in not more than three frames.

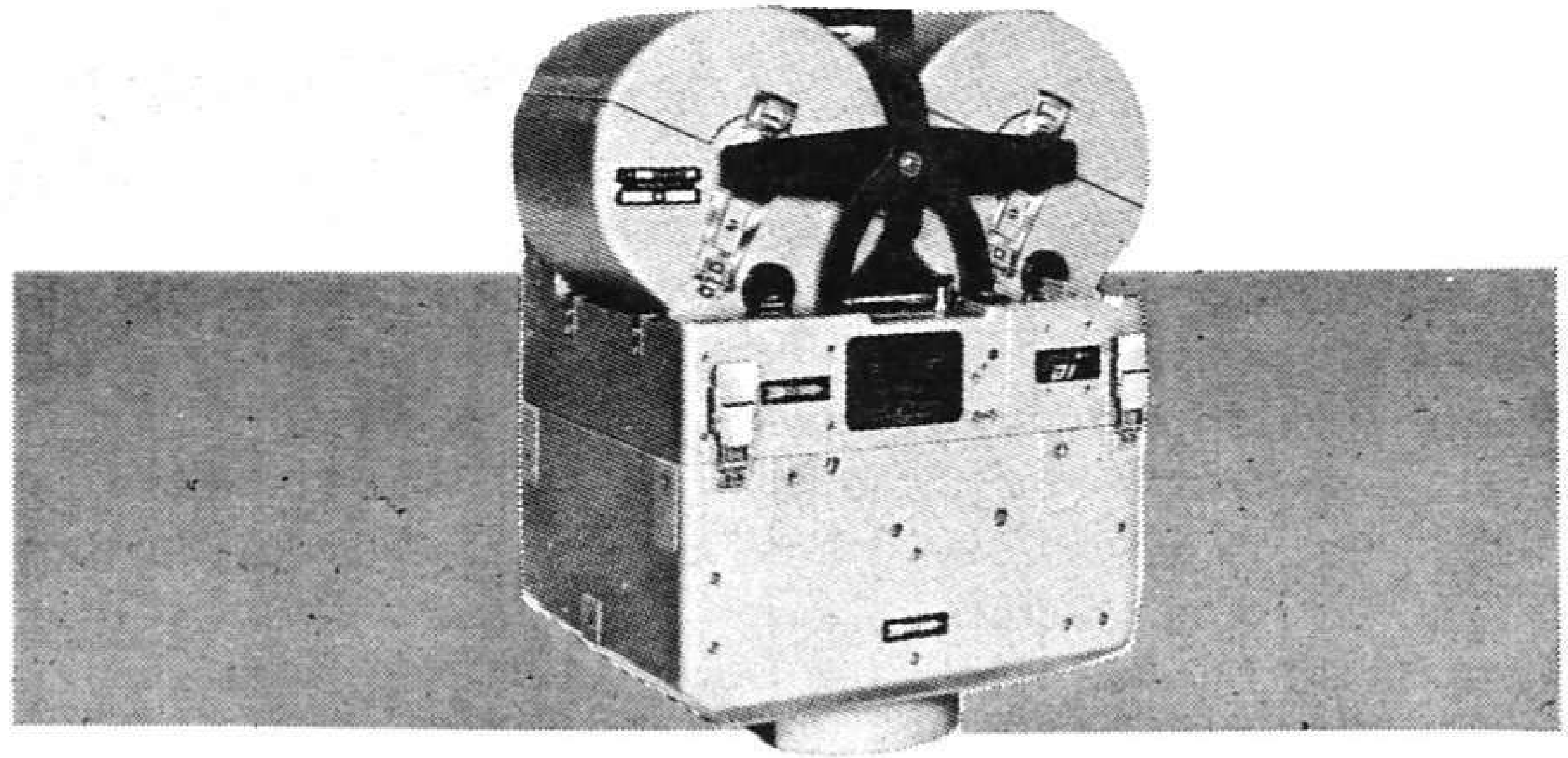
KA-56 PANORAMIC PHOTOGRAPHY COORDINATE GRID

Figure 10



1. VIEW NEGATIVE EMULSION SIDE UP (FRAME COUNTER NUMBERS NORMAL)
   OR
   VIEW POSITIVE TRANSPARENCY EMULSION SIDE DOWN (FRAME COUNTER NUMBERS NORMAL)
2. ALIGN NEGATIVE WITH CENTERING MARKS ON CENTER VERTICAL AXIS AND END MARK ALONG EDGE OF GRID
3. MULTIPLY GRID COORDINATES BY CAMERA ALTITUDE IN HUNDREDS OF FEET TO GET GROUND COORDINATES IN FEET

KS-87 Framing Camera



The KS-87 Framing Camera uses a 4.5 x 4.5-inch format. It is pulse operated and has day-night photo capability. The camera will accept four interchangeable lens cones with focal lengths of 3, 6, 12, and 18 inches. The 6-inch lens cone is the only one capable of night photoflash imagery. The camera has a maximum day cycling rate of 6 CPS and Forward Motion Compensation capability of 12 inches/second. These parameters permit photography with a 3-inch focal length lens cone up to a V/H ratio of 2.4 (600 knots at 250 feet altitude). The FMC limit of 12 inches/second is reached at this V/H on a vertically mounted KS-87 camera.

The camera uses a focal plane shutter for day operation. The shutter speed varies from 1/60 second to 1/3000 second depending on terrain light conditions. The shutter is a variable slit width curtain which moves fore and aft across the format. Film is exposed in one direction only; then the shutter caps and reverses direction before starting the next exposure. The 6-inch lens uses an intra-lens shutter for night photography. In day operation the intra-lens shutter is held open and the focal plane shutter exposes the film. In night operation the curtains of the focal plane shutter are driven open and exposure is controlled by the intra-lens shutter.

Each camera has Automatic Exposure Control (AEC). Using a photo cell which monitors terrain light conditions, the exposure control is designed so the camera will operate at faster shutter speed as light conditions deteriorate, until the iris is fully opened. If more exposure time is required when the iris is fully opened, the focal plane shutter slit will begin opening. The 6-inch lens cone is the only lens with the variable apertures so that only slit width is controlled by the AEC. The AEC is referenced to the type of film and filter by the S/C dial on the lens cone assembly. On this control, S is the exposure index of the film and C is the filter factor of the filter. For example, if Aerecon Plus X film (exposure index:80) is used and a yellow filter (factor:2) is installed, the S/C setting therefore is 80/2.

Forward Motion Compensation is employed in all positions of the framing cameras except the forward oblique. FMC is accomplished by moving the film forward during exposure at a rate determined by the ground speed and altitude of the aircraft. FMC becomes quite critical in limited light conditions (slow shutter speed) or when a high V/H ratio exists. Since FMC control is a direct function of V/H it follows that proper V/H inputs are important for quality imagery. The FMC range is from .1 inch/second to 12 inches/second of film movement. The 12 inches/second limit is reached at a V/H ratio of 2.4 on a vertically mounted 3-inch focal length camera.

The KS-87 camera may be pulsed at either 56% or 12% forward overlap as desired by selection of the OVERLAP switch on the Sensor Control Panel in the Cockpit. Forward overlap is computed by the ACPC parameters. Forward overlap of 56% is properly depicted if an image which has just moved into the format of one frame then moves 44% into the format of the succeeding frame. This same image would now move another 44% into the third frame. Proper overlap of 12% is evident when the image moves 88% into the second frame. It is therefore evident that 12% overlap is half the rate of 56%.

Forward overlap is determined by the pulse rate from the Aircraft Camera Parameter Control. The ACPC derives the pulse rate from the following equation:

$$R = 1.69\,\frac{V}{H} \times \frac{F}{P} \times \left(\frac{1}{1-.01L}\right) \times \sin\theta$$

Where: R = Pulse rate = 1/interval

F = Focal length (in inches)

P = Format dimension in direction of flight

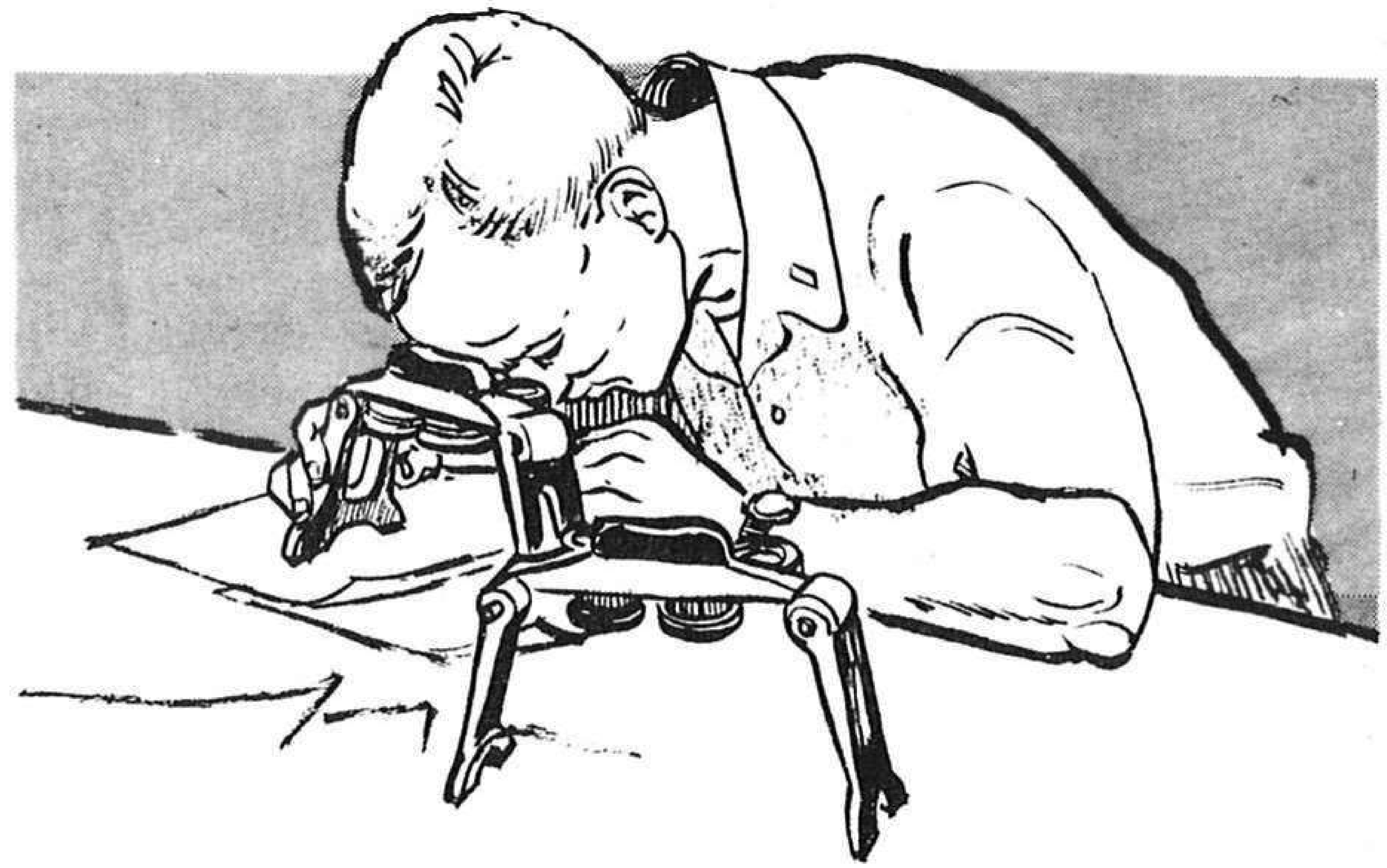
L = % overlap

θ = Depression angle

V = Knots (ground speed)

H = Altitude above terrain (in feet)

The pulse rate for any camera configuration may then be expressed as a function of V/H as all other parameters become constants. Combining all factors peculiar to a camera configuration, the pulse rate may be expressed as shown on page 21. (Note that the pulse rate for 12% overlap is one-half the rate for 56% overlap.)



Using the pulse rate equation and comparing calculations against actual results, the maintenance technician or pilot can quickly determine if the camera system is operating properly. First he dials in a given amount of manual V/H on the VELOCITY KTS and ALTITUDE FT dials on the V/H Control Panel (for example: 500 knots and 500 feet, which gives a convenient V/H of 1). Then, while monitoring the FEET REMAINING counter on the Exposure-Film Panel, and using a timer, he operates the camera system for a specific time interval (say 10 or 15 seconds) and determines the footage used.

Since every pulse of the framing camera represents 5 inches of film, the camera operator now can estimate 10 pulses for approximately every 4 feet of film. Knowing the time and number of pulses, he also knows the pulse rate and can compare it with the rate calculated from the equation. A tolerance of ±1 pulse is acceptable.

This double-checking method verifies that the manual V/H inputs are correct, that the ACPC has computed the proper pulse rate, that the camera has properly transported the correct amount of film, and that the FEET REMAINING counter has properly displayed the amount of film used.

Ground Coverage Patterns

Figures 11 through 16 show the ground coverage patterns of the KS-87 camera installation and express the ground coverage dimension as a function of aircraft altitude (H). These drawings are handy guides for determining desired flight altitude to obtain a given coverage.

CAMERA CONFIGURATION	ACPC SETTING	PULSE RATE (56% OVERLAP)	(12% OVERLAP)
3-inch Oblique at 56.5°	3" FOCAL LENGTH, 30° DEPR ANGLE	R = 1.28 V/H	R = .64 V/H
6-inch Split Vertical at 71.6°	6" FOCAL LENGTH, 71.6° DEPR ANGLE	R = 4.84 V/H	R = 2.42 V/H
12-inch Split Vertical at 80.5°	12" FOCAL LENGTH, 80.5° DEPR ANGLE	R = 10.2 V/H	R = 5.1 V/H
18-inch Split Vertical at 83.7°	18" FOCAL LENGTH, 83.7° DEPR ANGLE	R = 15.2 V/H	R = 7.6 V/H
3-inch Low Altitude Panoramic KA-56	Not Applicable	R = 2.56 V/H	R = 1.28 V/H

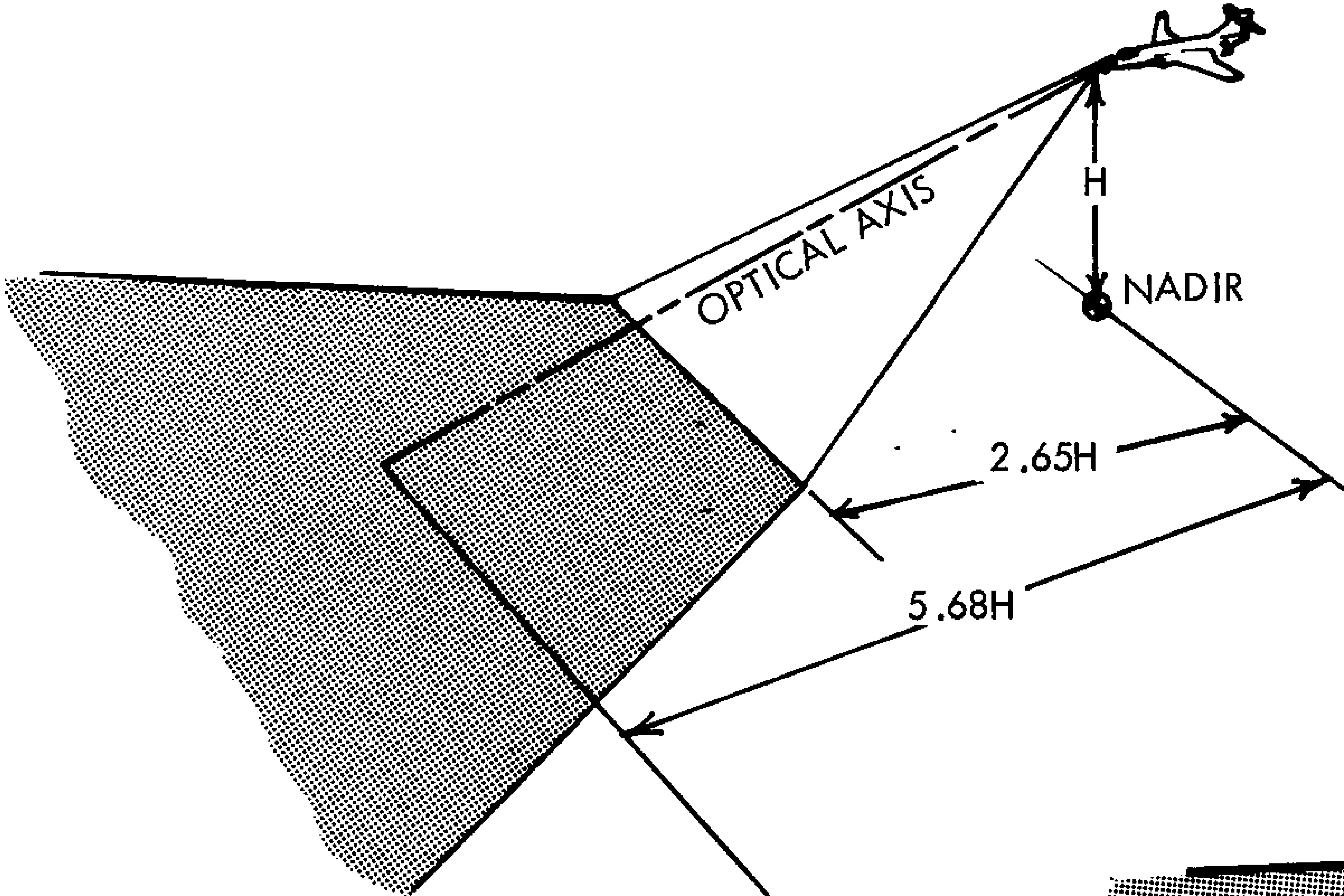


Figure 15

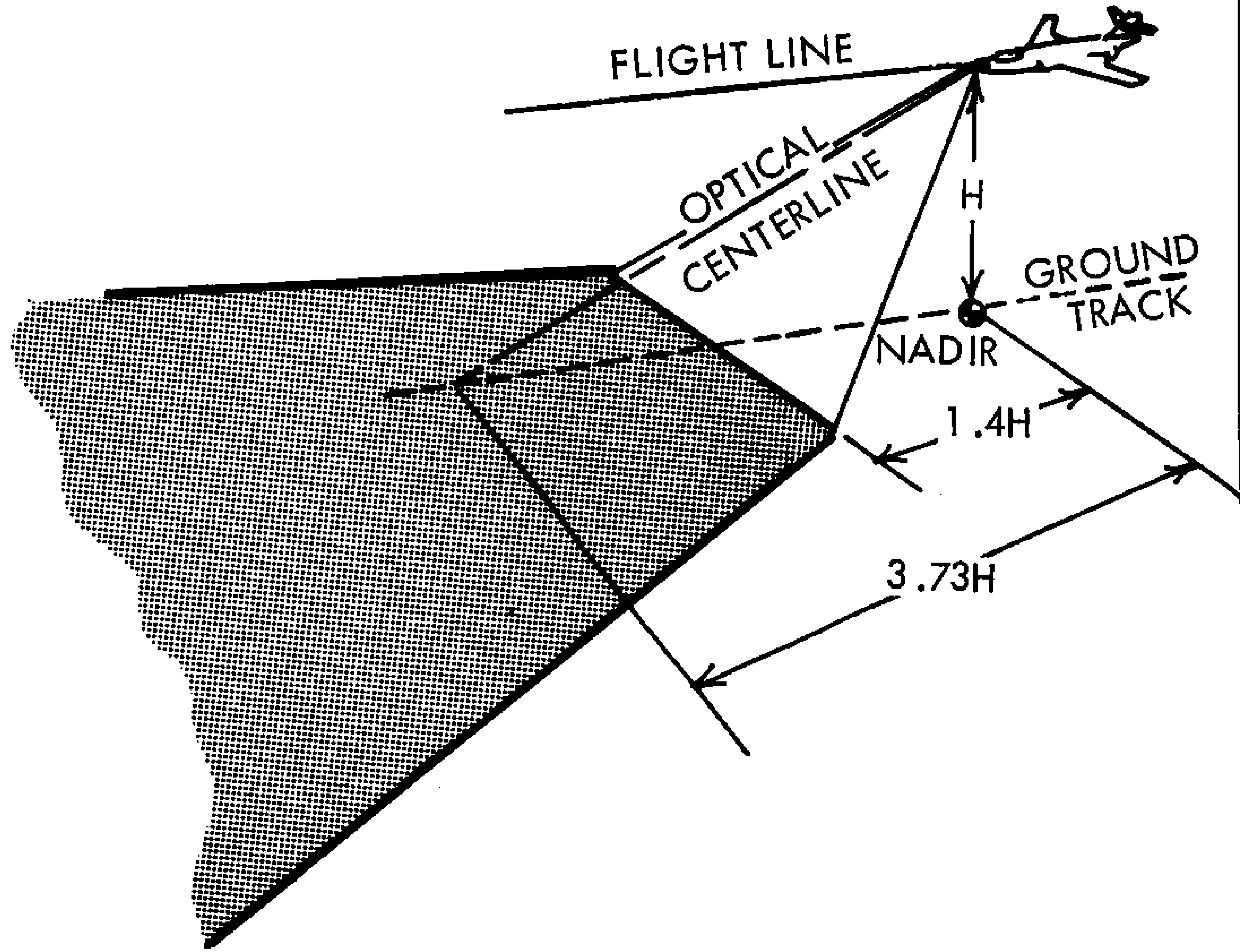
FORWARD OBLIQUE COVERAGE

12 INCH FOCAL LENGTH AT 10°

Figure 16

FORWARD OBLIQUE COVERAGE

6-INCH FOCAL LENGTH AT 15°



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