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15 Pages

February 1963

TECHNICAL PUBLICATION

KH-6 CAMERA SYSTEM

ARMY NAVY AIR FORCE CIA

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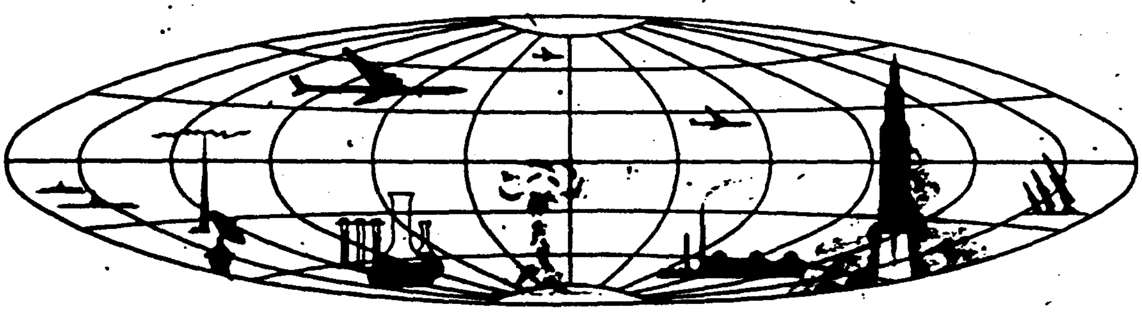

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TECHNICAL PUBLICATION

KH-6 CAMERA SYSTEM

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PREFACE

This publication presents general technical information necessary for the reduction of quantitative data from photography obtained by the KH-6 camera system.

Specific mission and camera data will be published separately for each KH-6 mission. The following data will be prepared for each mission:

1. Camera data - operational focal length, lens distortion, image motion compensation data, scan rate, type of film, filter, exposure, resolution capability, etc.
2. Stellar/Index calibration data - knee angle, calibrated focal length, distortion, calibrated grid intersections, etc.
3. Preliminary frame ephemeris - mirror position, roll-steering position, time, altitude, velocity, latitude, longitude, sun angle, pitch and roll obtained from data block, etc. for each frame. The preliminary ephemeris will be generated within a strict time schedule based upon accurate (though not final) orbital data and initial, uncorrected time readout.
4. Final frame ephemeris - will include the items listed under 3 above, with refined pitch, roll and yaw data from the Stellar/Index readout.

KH-6 CAMERA CONFIGURATION

The KH-6 camera system consists of a single panoramic camera, a stellar camera, and an index (framing) camera.

Panoramic Camera

The KH-6 panoramic camera provides relatively large-scale, high acuity monoscopic or stereoscopic photography of selected target areas. Both vertical (monoscopic) and convergent (stereoscopic) photography are accomplished by a single panoramic camera receiving its image via a mirror. The mirror, which is held stationary during a panoramic scan, may be tilted so that the camera scans vertically, 15 degrees forward, or 15 degrees aft (Figure 1).

The camera operates in units of 16 "bursts" each. The monoscopic mode will provide vertical photographic coverage either in a pulse mode (one 16-frame burst) or a continuous mode (a series of 16-frame bursts). In the stereo mode, eight frames are exposed with the camera looking forward 15 degrees; the mirror is then tilted so that the camera is looking aft 15 degrees, and eight additional frames are exposed covering the same ground area photographed by the first eight frames (Figure 2). This series of 16 convergent exposures may be repeated as many times as desired. However, a gap in ground coverage will occur between each 16 exposure series of stereo photographs. This gap will be approximately equal to the ground distance covered by one stereo burst (Figure 3).

The entire camera system may be rolled as much as plus or minus 30 degrees for selective coverage of targets not directly under the flight path. The roll-steering is accomplished in five discrete angles of plus 30 degrees, plus 15 degrees, zero degrees, minus 15 degrees, and minus 30 degrees (plus when the camera is looking to the starboard, minus when the camera is looking to the port side). Figures 2 and 4 illustrate the effect of camera mode upon ground coverage.

Stellar/Index Cameras

The KH-6 camera system will employ the same stellar/index (S/I) cameras utilized in the most recent KH-4 missions. These cameras may be operated either slaved to the panoramic camera or independently to provide attitude, position, and cartographic information.

When operated slaved to the pan camera, the S/I cameras will fire three times for each single pan burst of 16 frames at a 10 to 1 ratio, the third frame firing after completion of the pan burst at a time interval equivalent to 10 pan frames after the previous S/I firing. When the pan camera is fired several consecutive bursts the 10 to 1 ratio holds through all bursts except the final one when the stellar/index camera will fire three times as explained above.

Limited film capacity (75 feet for the stellar camera and 125 feet for the index camera) on early missions employing the KH-6 system will preclude independent operation of the S/I cameras. However, an increased film capacity on later missions (250 feet for the stellar camera and 500 feet for the index camera) will permit continuous independent operation of the S/I cameras on each photographic pass.

KH-6 CAMERA FEATURES

Panoramic Camera

Lens: diffraction limited, 6 element, f/5

Focal length: 66 inches (1,676 mm)

Scan Angle: 22 degrees

Shutter: focal plane

Shutter speeds: 10 interchangeable slit widths for exposures of 1/75 to 1/1,500 second.

Filter: Wratten 12 or Wratten 21

Film load: 5 inch x 8,000 feet (3-mil Estar film)

Format size: 4.5 inches x 25 inches

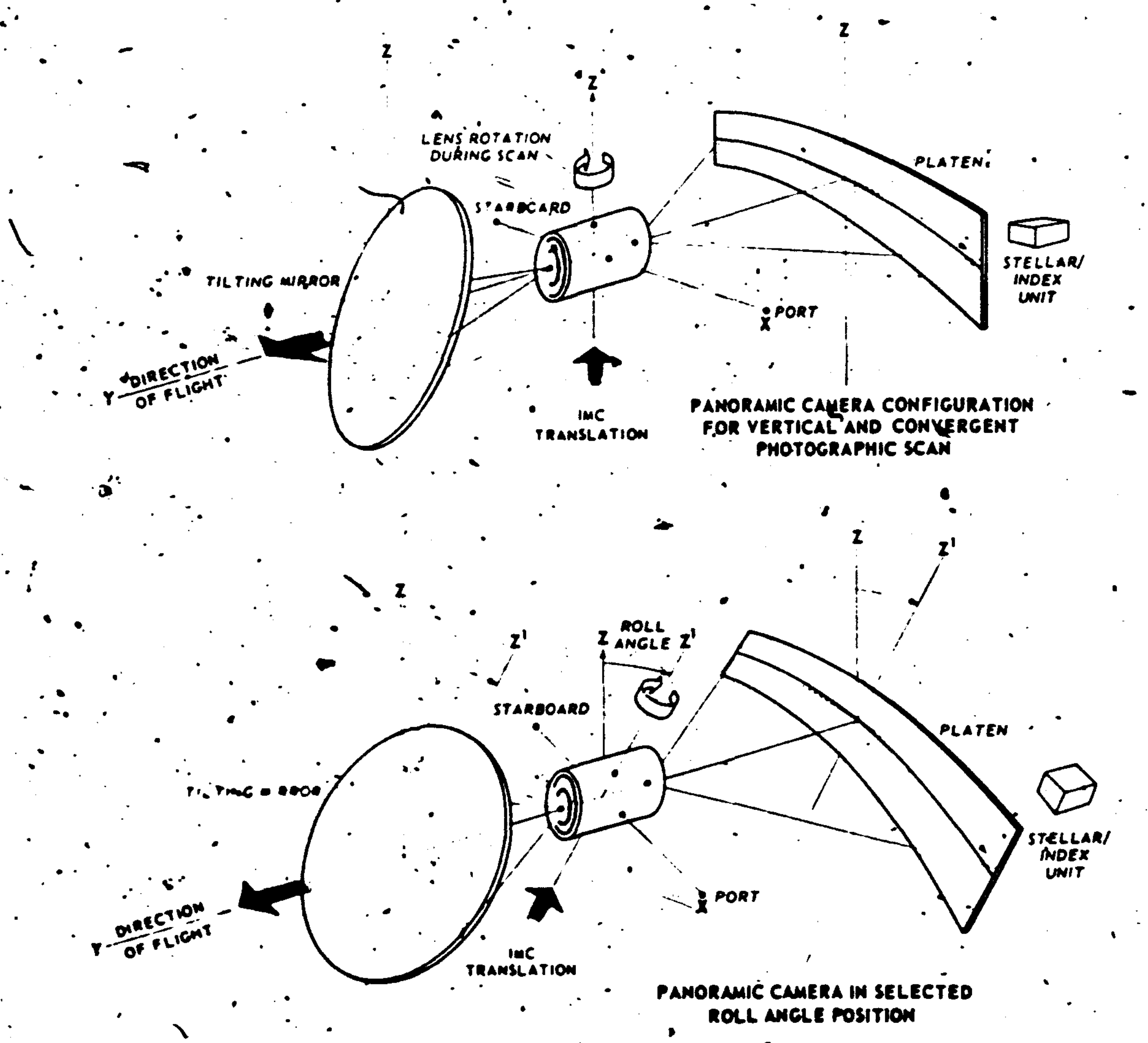

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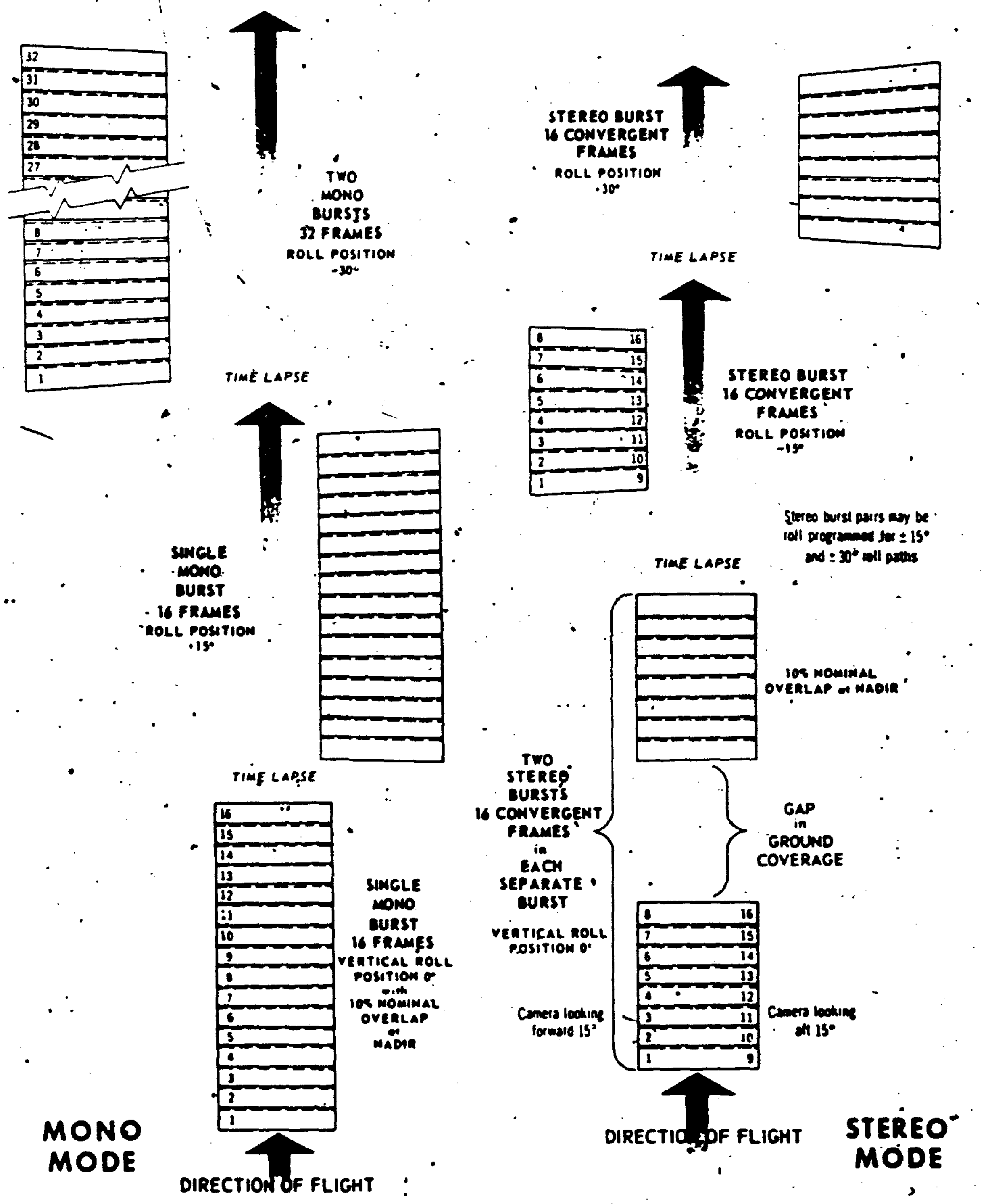
FIGURE 1. KH-6 CAMERA CONFIGURATION AND ROLL DIAGRAM.



NPIC H-1217 (2-63)

FIGURE 2. GROUND COVERAGE PATTERNS IN MONOSCOPIC AND STEREOSCOPIC MODES.

Scale: approximately 1:100,000

Image motion compensation (IMC): proportional to velocity/height (V/h) ratio. 11 ramps available.

Stellar Camera

Lens: Cannon f/1.9

Focal length: 85 mm

Cone angle: 16 degrees

Shutter speed: 1/2 second to 6 seconds

Filter: none

Film load: 35 mm x 250 feet

Format size: 0.9375-inch diameter

Reseau: 2.5 mm reseau for calibration purposes, not visible on exposures.

Index Camera

Lens: Zeiss Biogon f/4.5

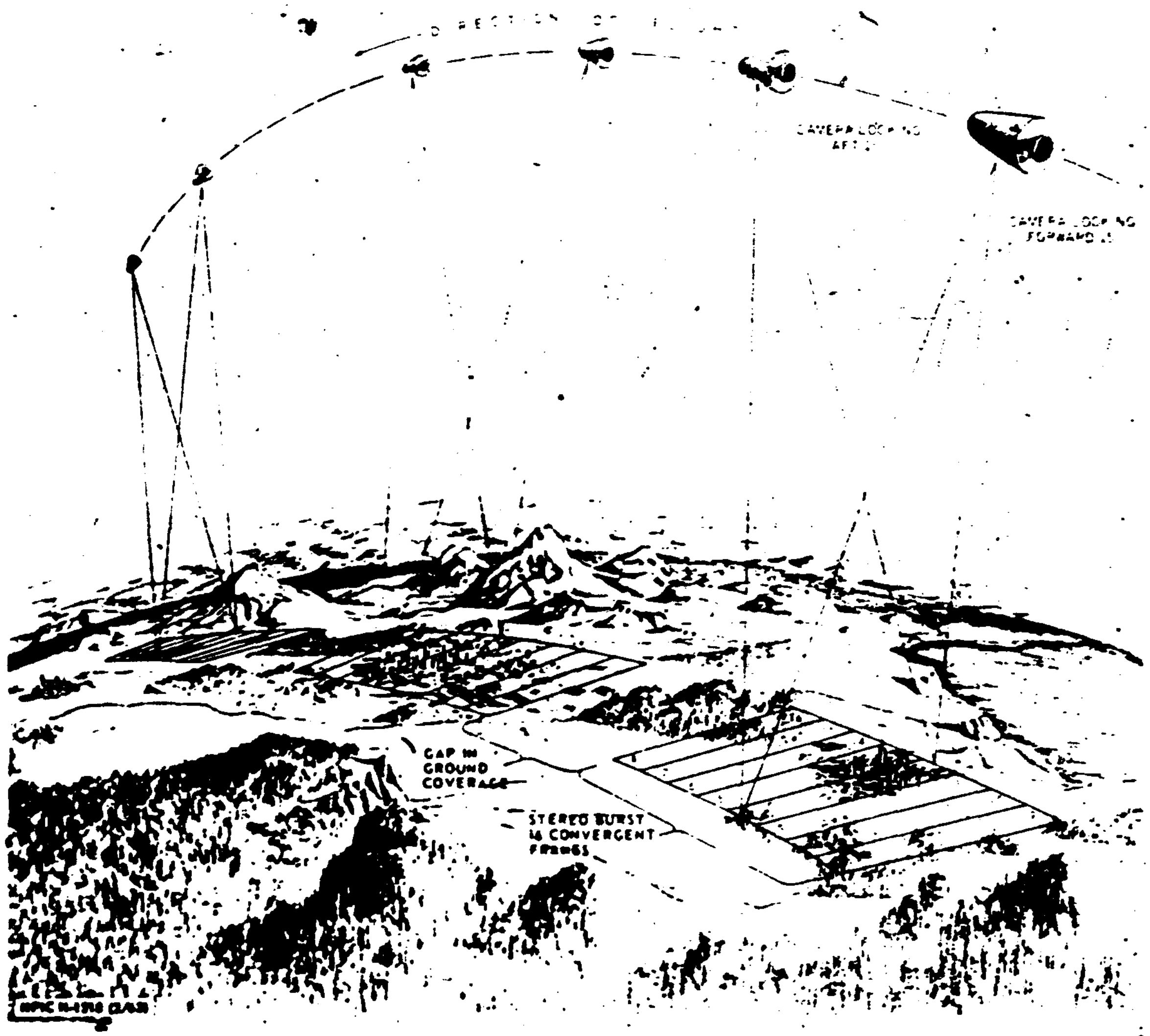


FIGURE 3. SCHEMATIC DRAWING SHOWING STEREO MODE PROGRAMMING SEQUENCE.

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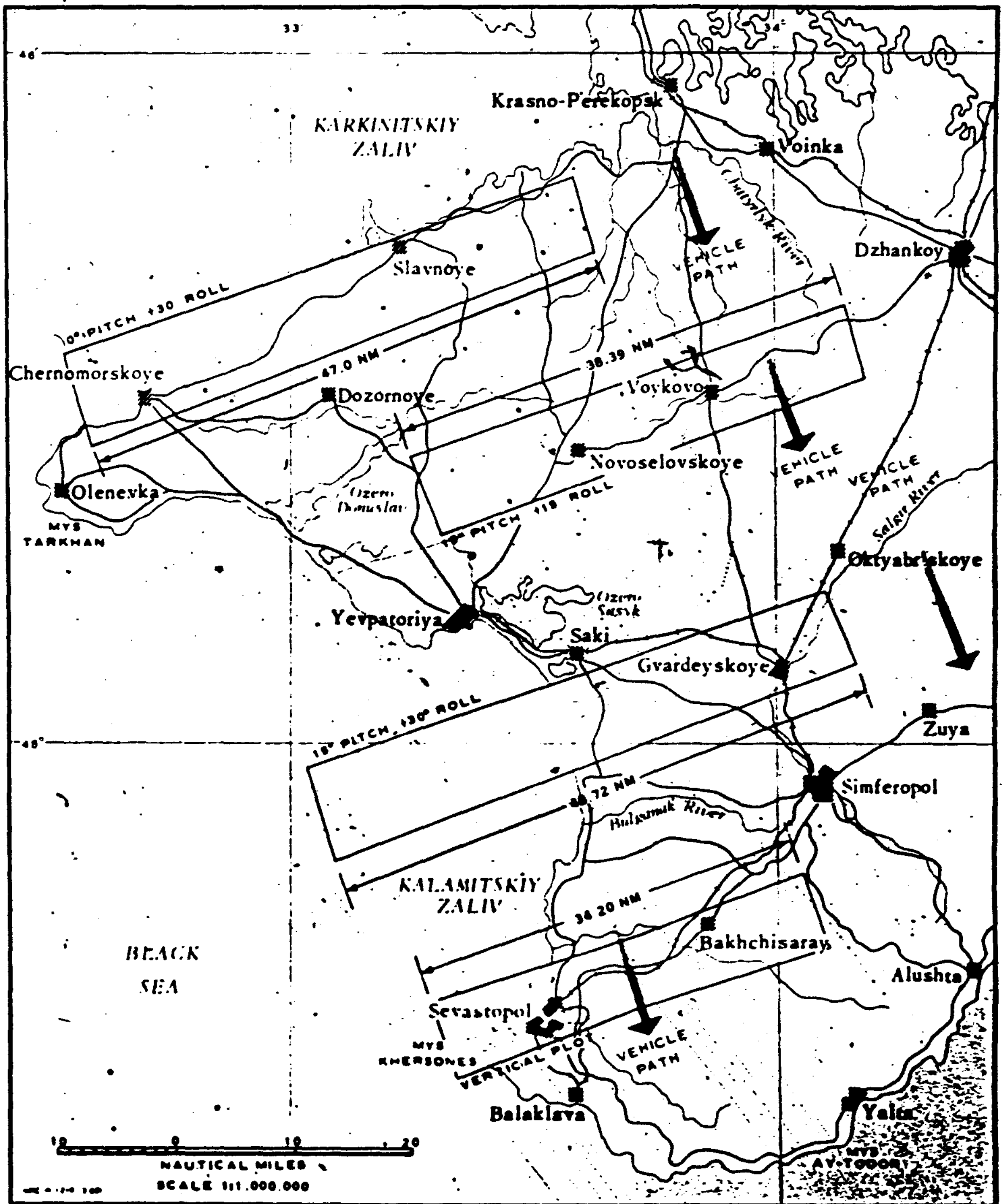


FIGURE 4. TYPICAL EXAMPLES OF SINGLE-FRAME RELATIVE GROUND COVERAGE AREAS AT NOMINAL 90 NM ALTITUDE.

Focal length: 38 mm

Field Angle: 72 degrees x 72 degrees

Shutter speeds: 1/125 second, 1/250 second, and 1/500 second

Filter: Wratten 21

Film load: 70 mm x 500 feet

Format size: 2.25 inches x 2.25 inches with 1/8 inch separation between frames

Reseau: the lens-camera system is equipped with a reseau made of evaporated nickel chromium on a one-millimeter borosilicate glass plate. The reseau interval is 2.5 mm over the entire format.

Scale: approximately 1:4,400,000

FORMAT AND TITLING

Panoramic Camera

The KH-6 panoramic camera format is 4.5 x 25 inches with indefinite demarcation of the ends of the frame (Figure 5). Vertical ground coverage at 90 nautical miles (nm) altitude is 6.3 x 34.2 nm, with approximately 700,000 square nm of coverage for a mission of 3,600 frames. Overlap is 10 percent nominal at the nadir, and is maintained for the entire V/h range.

Viewed through the base of a film positive, the titling will appear on the leading edge (direction-of-flight) of the frame and will contain the following information:

1. Pass designator ("A" for ascending; "D" for descending; "M" for a continuous pass, both ascending and descending).
2. Pass number (two digits)
3. Frame number (three digits)
4. Mission number
5. Date of mission
6. Classification and codeword

Frames will be numbered consecutively for each pass.

A data block will appear between frames. It should be noted that the data block is one frame removed from the frame to which it applies; for example, the data block for frame 113 is located between frames 114 and 115 (Figure 5). The data block will include a 29-bit binary time word, roll-steering position indicator (plus 30 degrees, plus 15 degrees, zero degrees, minus 15 degrees, minus 30 degrees), mirror position indicator (forward, vertical, aft), scan rate error indicator, and vehicle pitch and roll data* acquired from the vehicle guidance system (Figure 6). Pitch and roll will be recorded to a least REF [redacted] SUPPLEMENT significant value of 10 minutes over a range of plus or minus five degrees from nominal. Pitch will be recorded for every other frame and roll for the alternate frames.

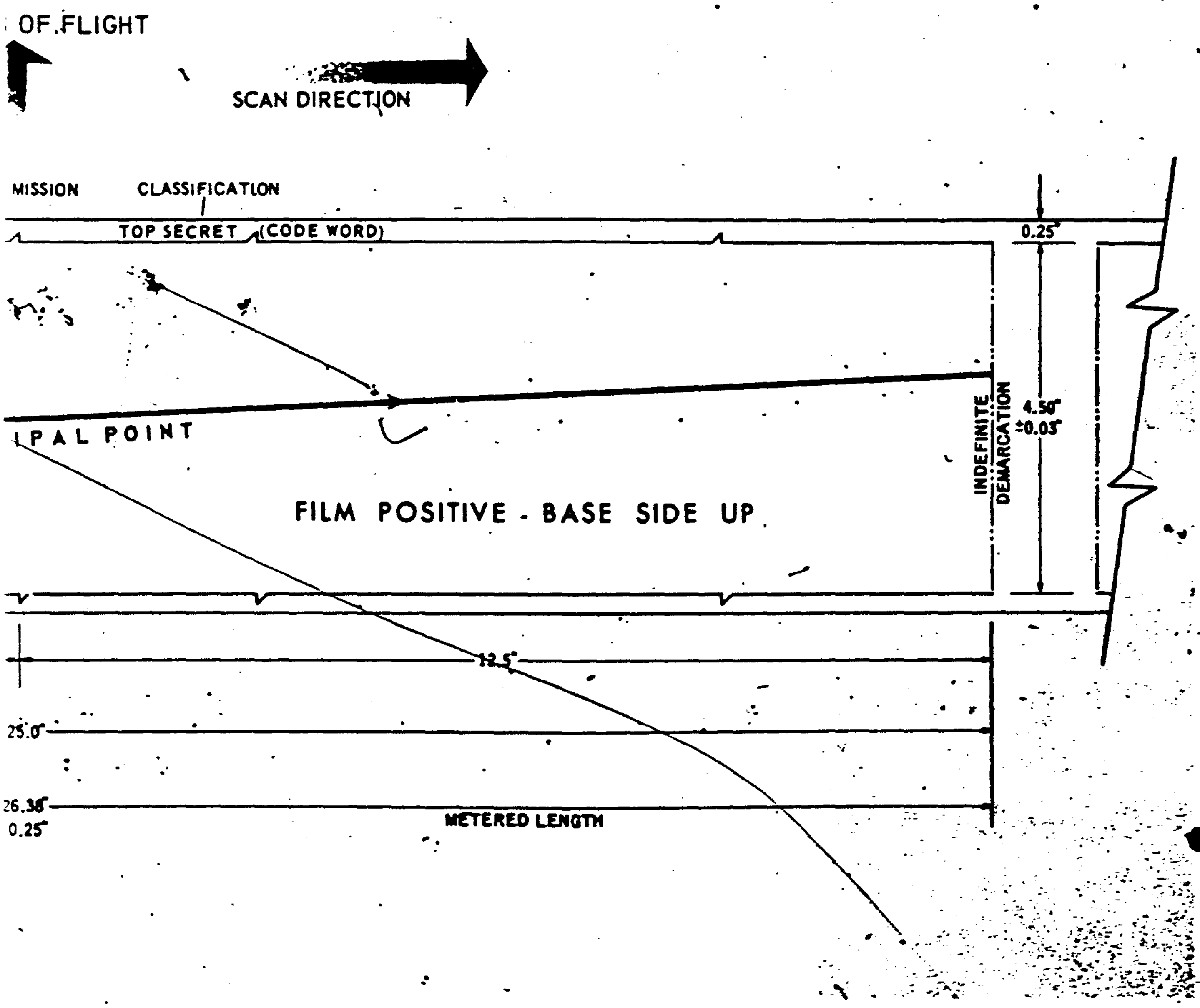
The KH-6 camera system utilizes the same clock as employed in the KH-4 system, with an accuracy of plus or minus five milliseconds. The time data is recorded by 29 bits and represents elapsed time; however, unlike the KH-4 system, no frequency marks are imaged on the format. Mirror position and roll-steering are indicated individually by a series of 3 bits. When scan rate error exceeds 10 percent it will be indicated by a lighted bit in the scan rate error block.

Stellar Camera

The stellar format is 0.9375 inches in diameter. A reseau will be installed for calibration

*Plus pitch is longitudinal axis of vehicle in direction of flight pointed up. Plus roll is starboard "wing" up.

[redacted]



MAT AND TITLING.

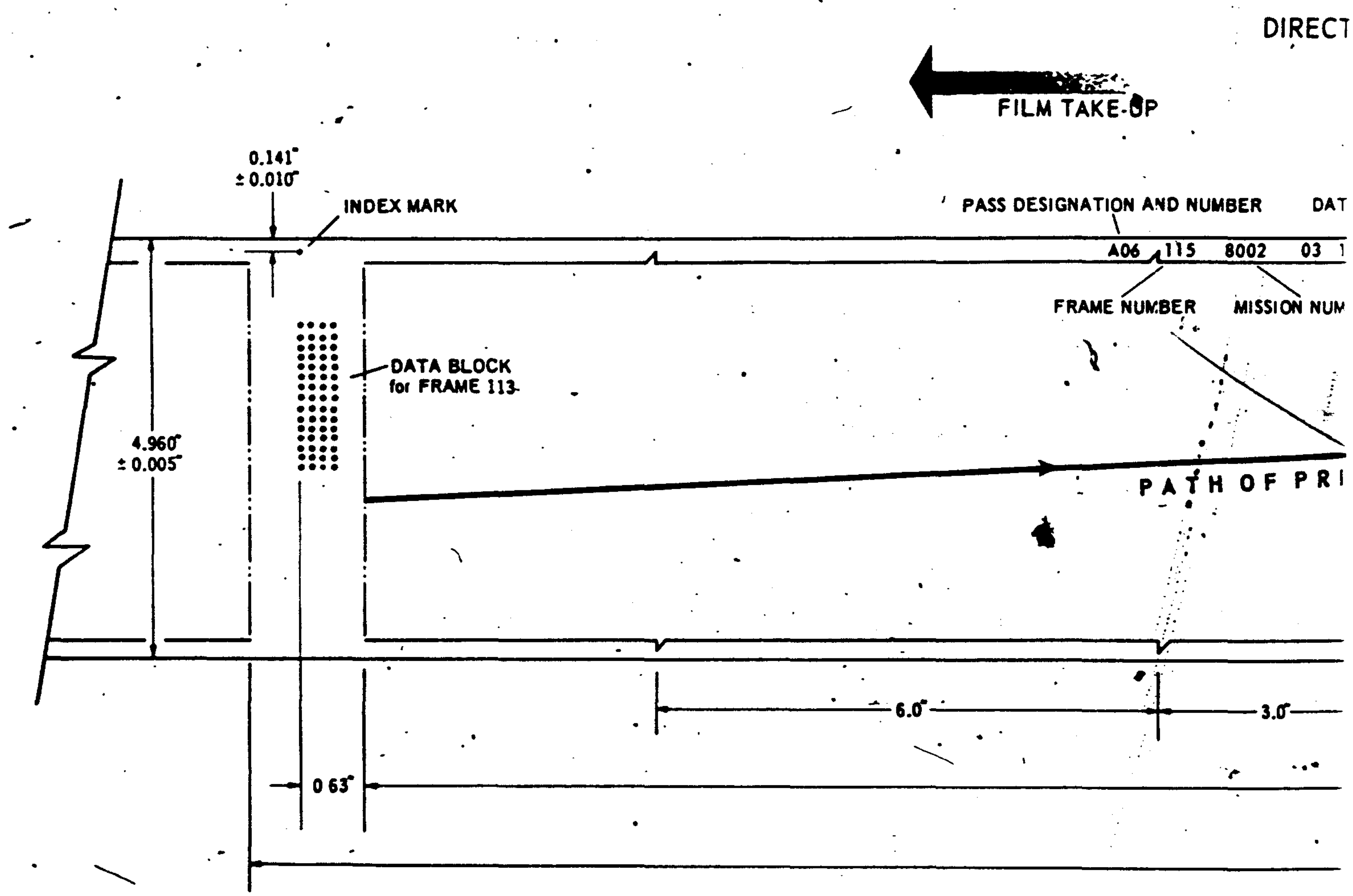


FIGURE 5. PANORAMIC CAMER

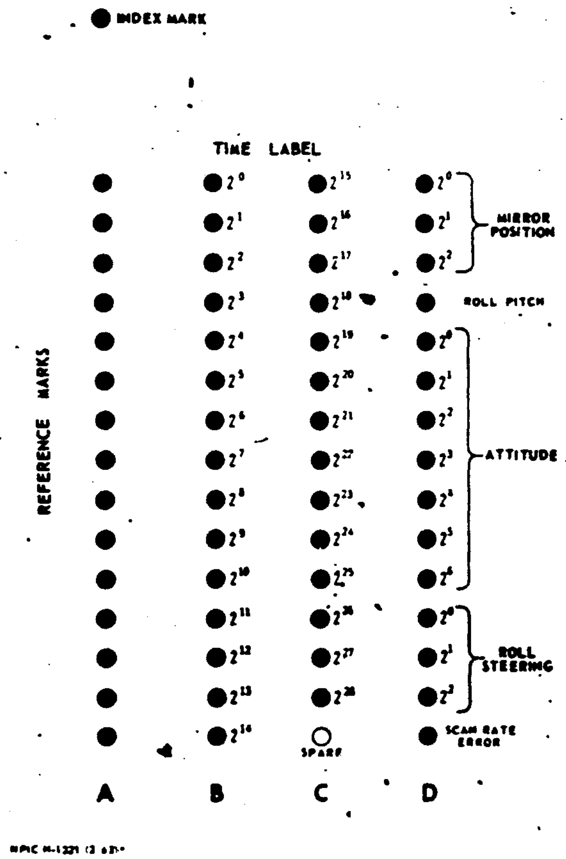


FIGURE 6. PANORAMIC CAMERA DATA BLOCK.

Table 1. Mirror Position

	2^2	2^1	2^0
Forward	1	0	0
Vertical	0	1	0
Aft	0	0	1

Table 2. Roll Steering

	30°	15°	Sign
	2^2	2^1	2^0
+30°	1	0	0
+15°	0	1	0
0°	0	0	0
-15°	0	1	1
-30°	1	0	1

Table 3. Roll Pitch Light

Roll	1
Pitch	0

Table 4. Roll/Pitch Indication Seven Bit Binary

-5°	0	0	0	0	0	0	0
0°	1	0	0	0	0	0	0
+4.9°	1	1	1	1	1	1	1

purposes, but will not show on the film. Instead, four reseau calibration points (intersections) will be exposed on the film in symmetrical arrangement outside the format. Their orientation may vary from one mission to another (Figure 7).

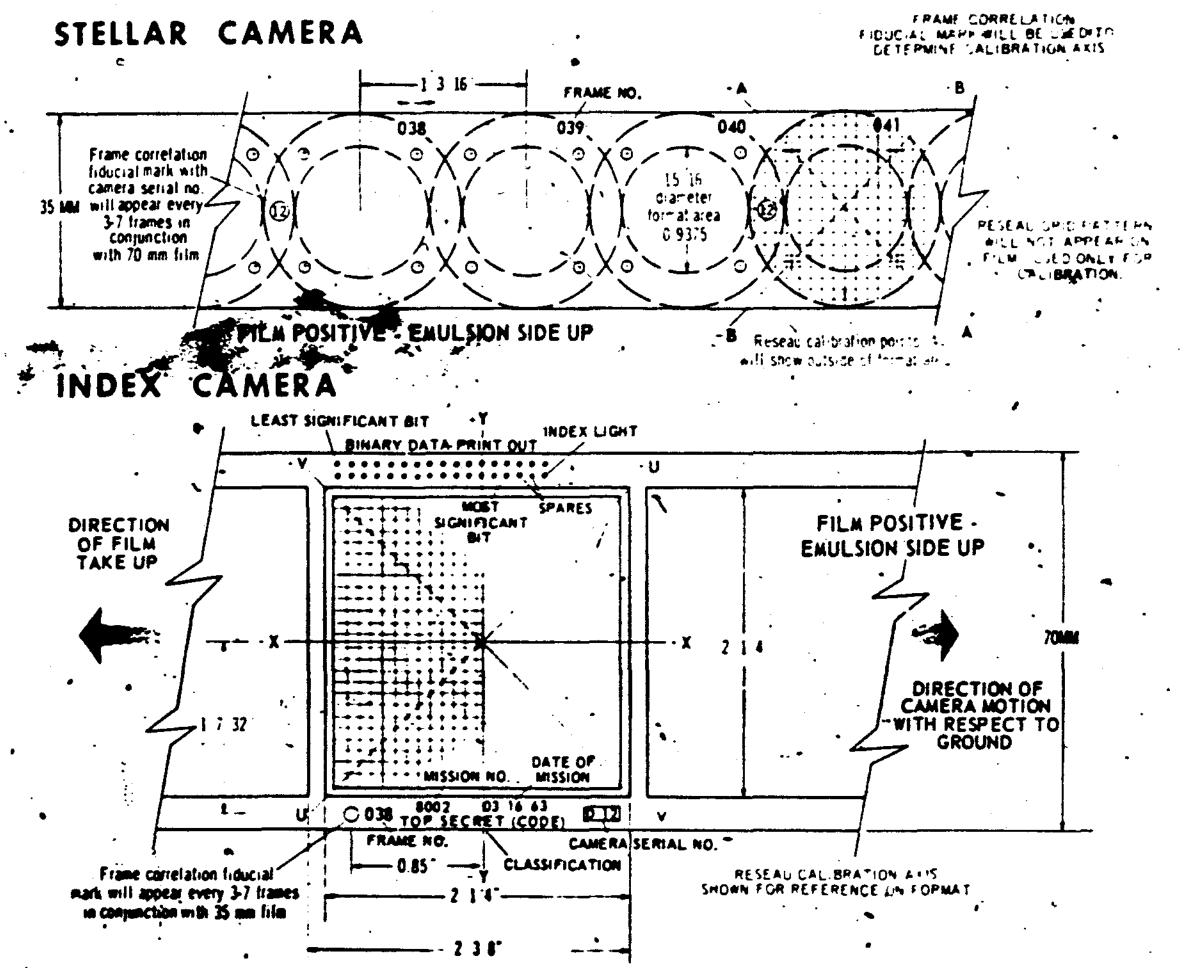
Calibration data will be provided for each camera. The camera serial number will be recorded on each frame and a frame correlation mark will appear on random frames, the latter for correlation of stellar frame to index frame.

Only the frame number will be titled on each frame. Frames will be numbered consecutively throughout the mission. Titling information consisting of mission number, date, classification, codeword and a chart correlating frames to passes will be affixed to the head leader.

Index Camera

The index format is 2.25 x 2.25 inches and will have a 2.5 mm reseau superimposed on the image. Calibration will be provided for each camera, and the camera serial number will be recorded on each frame. A frame correlation mark, on a random frame basis for correlation of index frame to stellar frame, will appear on one edge of the frame. A 29-bit binary time word will be imaged on the opposite edge. Time data will be recorded by the standard 29-bit binary word, with interrogation being made of the same clock that supplies time to the panoramic data block (Figure 7).

Titling data will be in a double line consisting of frame number, mission number, date,



NPIC H-1222 (2/63)

FIGURE 7. STELLAR AND INDEX CAMERA FORMAT AND TITLING.

classification and codeword. Frames will be numbered consecutively throughout the mission. A chart correlating frames to passes will be affixed to the head leader.

IMAGE MOTION COMPENSATION

Image motion compensation (IMC) is accomplished by translating the lens along its axis of rotation while the film is being scanned, and is variable proportional to V/h with an accuracy to within one-half of one percent of the programed value. Eleven V/h ramps provide for a range in IMC to match cycle periods from a minimum of 1.3 seconds to a maximum of 2.6 seconds, corresponding to a scan velocity range of 1.1164 radians/second to 0.5582 radians/second.

The equation of the path of the principal point on the format, with the Y axis paralled to the direction of vehicle motion, is given by

$$Y = 2.908 \sin \theta$$

where Y is in inches, and θ is the scan angle measured from the center of the format.

Due to the absence of timing pips, scan rate will be provided with camera data on each mission.

A variable vehicle yaw to compensate for Coriolis force is incorporated in the system design. Consequently, the long axis of the frame should be perpendicular to the ground track of the vehicle.

Derivation of IMC

Given:

- I - Pitch inertia of vehicle - 12,590 lb-ft-sec^2
- M - Mass of lens - 6 slugs - 192 lbs
- L - Distance from lens to vehicle center of gravity (without lens) - 88 in
- f - Focal length - 66 in
- θ - Scan angle from center of format
- W_s - Scan rate in rad/sec
- t - Time in sec
- h - altitude in ft above Hough ellipsoid
- V_G - ground velocity in ft sec

V_{IMC} - Velocity of lens

$$V_{IMC} = \left(\frac{V_G}{h}\right) f \left(\frac{I + ML^2}{I + ML^2 - fML}\right) \cos \theta$$

$$\frac{I + ML^2}{I + ML^2 - fML} = 1.019$$

thus,

$$V_{IMC} = 1.019 \left(\frac{V_G}{h}\right) f \cos \theta$$

$$\theta = W_s t$$

Integrating the V_{IMC} with respect to t yields Y_{IMC} or the path of the principal point.

$$Y_{IMC} = 1.019 \left(\frac{V_G}{h}\right)\left(\frac{f}{W_s}\right) \sin \theta = Y_o \sin \theta$$

$Y_o = (1.019)(0.3422)\left(\frac{66}{0.?96}\right) = 2.908$ in.

$100\% \ \frac{V_G}{h} = 0.3422$

$100\% \ W_s =$ 0.[illegible]96

Y_{IMC} (in inches) $= 2.908 \sin \theta$

Note:

$$\int \cos \theta \, dt = \int \cos W_s t \, dt = \frac{1}{W_s}$$

$$(\sin W_s) \ t = \left(\frac{1}{W_s}\right) \sin \theta$$

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Supplement
April 1963

TECHNICAL PUBLICATION

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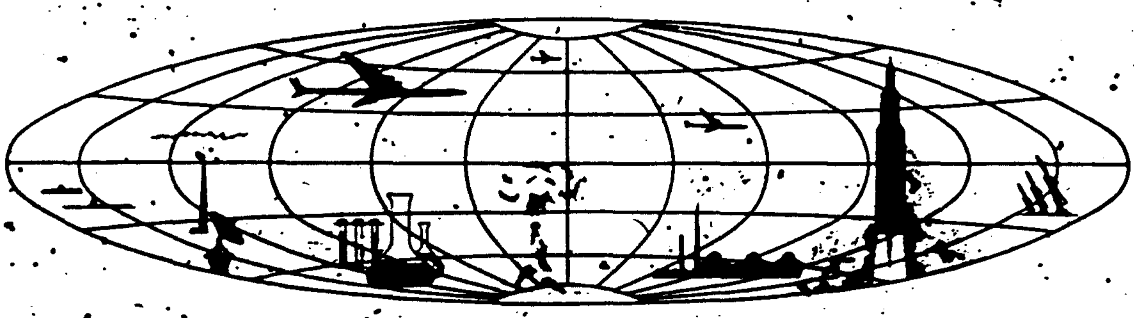

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KH-6 CAMERA SYSTEM

This supplement has been prepared to answer several questions which have arisen on [redacted] KH-6 Camera System, dated February 1963. The following changes and elaborations should be made in [redacted].

1. On page 6, in the fourth paragraph under the heading "Format and Titling," the penultimate sentence should read as follows: "Pitch and roll will be recorded in increments of approximately 4.7 minutes over a range of plus or minus five degrees from nominal."

2. The following pitch and roll conversion table illustrates this system of recording:

PITCH & ROLL CONVERSION TABLE KH-6 SYSTEM

BINARY	DEGREES	MIN	BINARY	DEGREES	MIN	BINARY	DEGREES	MIN
0000000	−5		0101011	−1	38.4	1010110	+1	43.1
0000001	−4	55.3	0101100	−1	33.7	1010111	+1	47.8
0000010	−4	50.6	0101101	−1	29.1	1011000	+1	52.5
0000011	−4	45.9	0101110	−1	24.4	1011001	+1	57.2
0000100	−4	41.2	0101111	−1	19.7	1011010	+2	01.9
0000101	−4	36.6	0110000	−1	15.0	1011011	+2	06.5
0000110	−4	31.9	0110001	−1	10.3	1011100	+2	11.2
0000111	−4	27.2	0110010	−1	05.6	1011101	+2	15.9
0001000	−4	22.5	0110011	−1	00.9	1011110	+2	20.6
0001001	−4	17.8	0110100	−0	56.2	1011111	+2	25.3
0001010	−4	13.1	0110101	−0	51.6	1100000	+2	30.0
0001011	−4	08.4	0110110	−0	46.9	1100001	+2	34.7
0001100	−4	03.7	0110111	−0	42.2	1100010	+2	39.4
0001101	−3	59.1	0111000	−0	37.5	1100011	+2	44.1
0001110	−3	54.4	0111001	−0	32.8	1100100	+2	48.7
0001111	−3	49.7	0111010	−0	28.1	1100101	+2	53.4
0010000	−3	45.0	0111011	−0	23.4	1100110	+2	58.1
0010001	−3	40.3	0111100	−0	18.7	1100111	+3	02.8
0010010	−3	35.6	0111101	−0	14.1	1101000	+3	07.5
0010011	−3	30.9	0111110	−0	09.4	1101001	+3	12.2
0010100	−3	26.2	0111111	−0	04.7	1101010	+3	16.9
0010101	−3	21.6	1000000	+0	00.0	1101011	+3	21.6
0010110	−3	16.9	1000001	+0	04.7	1101100	+3	26.3
0010111	−3	12.2	1000010	+0	09.4	1101101	+3	30.9
0011000	−3	07.5	1000011	+0	14.1	1101110	+3	35.6
0011001	−3	02.8	1000100	+0	18.7	1101111	+3	40.3
0011010	−2	58.1	1000101	+0	23.4	1110100	+3	45.0
0011011	−2	53.4	1000110	+0	28.1	1110001	+3	49.7
0011100	−2	48.7	1000111	+0	32.8	1110010	+3	54.4
0011101	−2	44.1	1001000	+0	37.5	1110011	+3	59.1
0011110	−2	39.4	1001001	+0	42.2	1110100	+4	03.7
0011111	−2	34.7	1001010	+0	46.9	1110101	+4	08.4
0100000	−2	30.0	1001011	+0	51.6	1110110	+4	13.1
0100001	−2	25.3	1001100	+0	56.2	1110111	+4	17.8
0100010	−2	20.6	1001101	+1	00.9	1111000	+4	22.5
0100011	−2	15.9	1001110	+1	05.6	1111001	+4	27.2
0100100	−2	11.2	1001111	+1	10.3	1111010	+4	31.9
0100101	−2	06.5	1010000	+1	15.0	1111011	+4	36.6
0100110	−2	01.9	1010001	+1	19.7	1111100	+4	41.2
0100111	−1	57.2	1010010	+1	24.3	1111101	+4	45.9
0101000	−1	52.5	1010011	+1	29.1	1111110	+4	50.6
0101001	−1	47.8	1010100	+1	33.8	1111111	+4	55.3
0101010	−1	43.1	1010101	+1	38.4			

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Supplement

3. Page 11, second paragraph, gives the equation $Y = 2.908 \sin \theta$. This equation is applicable in all roll steering positions, since the variables $\frac{V_G}{h}$ and W_s in the formula are set so that the principle point path always goes through the center of the format. As the ramps change for different operating positions the $\frac{V_G}{h}$ and W_s rates change accordingly to a different position on the ramp and the 2.908 sin θ figure remains unchanged.

4. Also on page 11, the formula in the final paragraph should be changed as follows (the red underlining signifies the changes):

Integrating the V_{IMC} with respect to t yields Y_{IMC} or the path of the principal point.

$$Y_{IMC} = 1.019 \left(\frac{V_G}{h}\right)\left(\frac{f}{W_s}\right) \sin \theta = Y_o \sin \theta$$

$$Y_o = (1.019)\ \underline{(0.03442)} \left(\frac{66}{0.796}\right) = 2.908 \text{ in.}$$

$$100\% \frac{V_G}{h} = \underline{(0.03442)}$$

$$100\%\ W_s = 0.796$$

$$Y_{IMC} \text{ (in inches)} = 2.908 \sin \theta$$

Note:

$$\int \cos \theta \, dt = \int \cos W_s \; t dt = \frac{1}{W_s}$$

$$\left(\sin W_s\right) t = \left(\frac{1}{W_s}\right) \sin \theta$$

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