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NPIC/TP-18/63
July 1963

TECHNICAL PUBLICATION



# KH-7 CAMERA SYSTEM

# PART I

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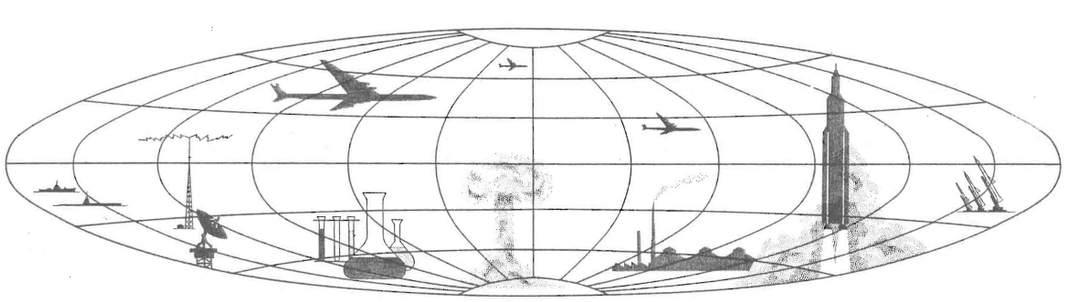

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# KH-7 CAMERA SYSTEM

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## PREFACE

This publication presents general technical information for the early exploitation of photography obtained by the KH-7 camera system. The scales, tables, charts, and graphs presented are for the photo-interpreter's use in determining approximate sizes, scales, and relative orientation of objects or images and is not meant to take the place of the more precise mensuration parameters.

Technical information with complete mathematical analysis for reduction of quantitative data will be published as Part II of this manual.

The following data will be made available for each mission on a timely basis:

1. Camera Data: Operational focal length, lens distortions, ramp informations, film velocity, image motion data, film type, filters, exposures, slit width, and expected resolution.
2. Stellar/Index Unit Data: Calibrated focal lengths, distortions, grid intersections, exposures, etc.
3. Orbital Data: A one second orbital ephemeris for each second of camera operation, including velocity, altitude, geographic position, time of operation, etc.
4. Vehicle Attitude: Pitch, roll, and yaw, and rates of each when available.

## INTRODUCTION

The KH-7 camera system consists of a single strip camera, a stellar camera, and an index camera.

The strip camera utilized in the KH-7 system will provide relatively large-scale, high-acuity photography of selected target areas in either monoscopic or stereo modes. It is designed to provide the photo-interpreter with an image considerably larger and with better ground resolution than that provided by the present KH-4 surveillance system. The strip camera can roll about its longitudinal axis to either side of the ground track in increments of 0.709 degrees to a maximum of plus or minus 44 degrees 40 minutes. This allows centering of the target area in the format of the strip frame. Also the camera is yawed around its vertical axis to eliminate coriolis force.

The strip camera consists of a rotating mirror, a 77-inch focal length folded lens system, and a cylindrical platen. (See Figure 1 for details.) The camera system may be operated in several modes: monoscopic strip, stereoscopic superimposed strips, or lateral pairs of strips. Any of these modes are available in any of the roll positions. (See Table No 1.)

*Table No 1. Roll Positions Available In Degrees (Left or Right)*

| | | | |
|---|---|---|---|
| 0 Vertical | 11.344 | 22.688 | 34.032 |
| 0.709 | 12.053 | 23.397 | 34.741 |
| 1.418 | 12.762 | 24.106 | 35.450 |
| 2.127 | 13.471 | 24.815 | 36.159 |
| 2.836 | 14.180 | 25.524 | 36.868 |
| 3.545 | 14.889 | 26.233 | 37.577 |
| 4.254 | 15.598 | 26.942 | 38.286 |
| 4.963 | 16.307 | 27.651 | 38.995 |
| 5.672 | 17.016 | 28.361 | 39.704 |
| 6.381 | 17.725 | 29.069 | 40.413 |
| 7.090 | 18.434 | 29.778 | 41.122 |
| 7.799 | 19.143 | 30.487 | 41.831 |
| 8.508 | 19.852 | 31.196 | 42.540 |
| 9.217 | 20.561 | 31.905 | 43.249 |
| 9.926 | 21.270 | 32.614 | 43.958 |
| 10.635 | 21.979 | 33.323 | 44.667 |

The film width is 9.460 inches with variable length to each strip depending on operation parameters. This system will produce an image at a nominal scale of about 1:90,000, and the nominal strip will be about 12 nautical miles (nm) in width.

The lens film resolution will be approximately 2.5 feet with proper camera operation.

Two time tracks are recorded on the film with a binary time word recorded on each track every .8 second.

Yaw slits are exposed on both sides of the film as an aid in attitude analysis.

## THE STRIP CAMERA

### DESCRIPTION OF THE STRIP CAMERA

The strip camera is a 77-inch focal length folded lens system consisting of a primary rotating mirror, a meniscus lens, a stationary primary mirror, a diagonal mirror, field flatteners, a slit plate, and a rotating platen.

The rotating mirror moves to forward and aft positions to produce 30 degree convergent photography for the stereo and lateral pair operating modes. In the mono strip mode the mirror is stationary at 45 degrees from the axis of the lens system. This is a narrow angle lens system since the angle of coverage is only 6.4 degrees with a half angle of 3.2 degrees across ground track. The primary mirror and diagonal mirror focus the image through the slit onto the rotating platen.

*Table No 2. Lengths of Film Strips in Inches With Varying Film Speeds and Lengths of Operations*

| Film Speed Inches Per Second | Length of Operation in Seconds | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2.0 | 3.0 | 4.0 | 5.0 | 6.6 | 9.0 | 12.3 | 25.0 | 50.0 | 102.4 |
| 2.022 | 4.04 | 6.07 | 8.09 | 10.11 | 13.35 | 18.20 | 24.87 | 50.55 | 101.10 | 207.05 |
| 2.132 | 4.26 | 6.40 | 8.52 | 10.66 | 14.07 | 19.19 | 26.22 | 53.30 | 106.60 | 218.32 |
| 2.242 | 4.48 | 6.73 | 8.97 | 11.21 | 14.80 | 20.18 | 27.58 | 56.05 | 112.10 | 229.58 |
| 2.352 | 4.70 | 7.06 | 9.41 | 11.76 | 15.52 | 21.17 | 28.93 | 58.80 | 117.60 | 240.85 |
| 2.462 | 4.92 | 7.39 | 9.85 | 12.31 | 16.25 | 22.16 | 30.29 | 61.55 | 123.10 | 252.11 |
| 2.572 | 5.14 | 7.72 | 10.29 | 12.86 | 16.98 | 23.15 | 31.64 | 64.30 | 128.60 | 263.38 |
| 2.682 | 5.36 | 8.05 | 10.73 | 13.41 | 17.70 | 24.14 | 33.00 | 67.05 | 134.10 | 274.64 |
| 2.793 | 5.59 | 8.38 | 11.17 | 13.97 | 18.43 | 25.13 | 34.35 | 69.83 | 139.65 | 286.00 |
| 2.903 | 5.81 | 8.71 | 11.61 | 14.52 | 19.15 | 26.12 | 35.70 | 72.58 | 145.15 | 297.27 |
| 3.013 | 6.03 | 9.04 | 12.05 | 15.07 | 19.88 | 27.11 | 37.06 | 75.33 | 150.65 | 308.53 |
| 3.123 | 6.25 | 9.37 | 12.49 | 15.62 | 20.61 | 28.10 | 38.41 | 78.08 | 156.15 | 319.80 |
| 3.233 | 6.47 | 9.70 | 12.93 | 16.17 | 21.33 | 29.09 | 39.76 | 80.83 | 161.65 | 331.06 |
| 3.343 | 6.69 | 10.03 | 13.37 | 16.72 | 22.06 | 30.08 | 41.12 | 83.58 | 167.15 | 342.22 |
| 3.453 | 6.91 | 10.36 | 13.82 | 17.27 | 22.79 | 31.08 | 42.48 | 86.33 | 172.65 | 353.59 |
| 3.564 | 7.13 | 10.69 | 14.26 | 17.82 | 23.52 | 32.07 | 43.83 | 89.10 | 178.15 | 364.95 |
| 3.674 | 7.35 | 11.02 | 14.70 | 18.37 | 24.25 | 33.06 | 45.19 | 91.85 | 183.70 | 376.22 |
| 3.784 | 7.57 | 11.35 | 15.14 | 18.92 | 24.98 | 34.06 | 46.54 | 94.60 | 189.20 | 387.48 |

lines, there will be four yaw slits, two on each edge of the film. Each pair of slits is offset from the image slit, one on either side, so that the same image is exposed at two different times. By analyzing the image displacement from slit to slit, roll and yaw can be determined.

### STRIP CAMERA FEATURES

Lens: Meniscus Maksutov, Concave-Convex Type.

Rotating Mirror: Plano Surface Mirror 33 Inch Diameter.

Focal Length: 77 Inches.

Slit Plate: Three Slit Widths Available (not changeable during operation).

Primary Mirror: 1st Surface Spherical Mirror (focusing mirror).

Diagonal Mirror: Rectangular Flat Mirror.

Field Flattener: Two Lens Elements (Chromatic Aberration Corrector).

Film Load: 3,000 Feet, 9.460 Inch Width.

Format Size: 8.718 Inches (variable length).

### DISCUSSION OF STRIP CAMERA

A strip camera is primarily a motion recording device which stabilizes an image in the focal plane by moving the film past a stationary slit at the same speed as the image moves past the slit. When these two motions are in synchronization, a high resolution image is recorded on the film. Since the film speed and image speed are difficult to establish in an orbiting vehicle, a discussion of variations caused by changes in speed is necessary.

Assuming a stable vehicle, the camera can be operated at near the proper speed, and images formed are very close to precise scale; however, as the speed of the film image combination varies away from the synchronous position, distortion will occur along the line of flight. This distortion or smearing of images is a direct result of film-image speeds, and with the speed available in the KH-7 camera system, smear of 130% is possible along the flight path.

Smear is not the only type distortion apparent in strip photography since a mismatch

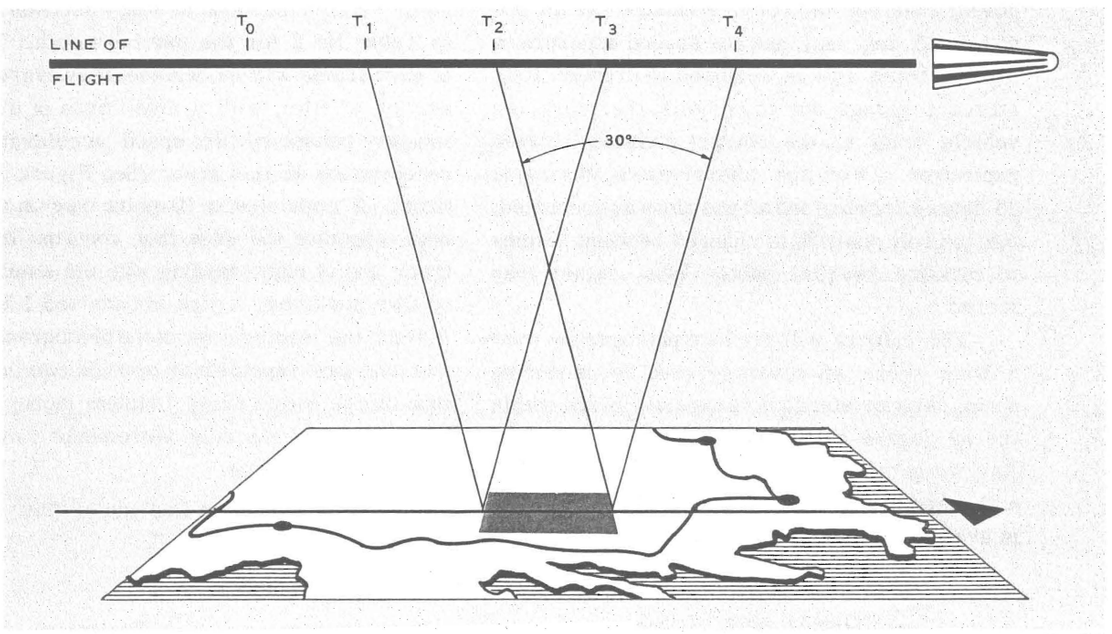


*FIGURE 2. STEREO OPERATION SCHEMATIC.*

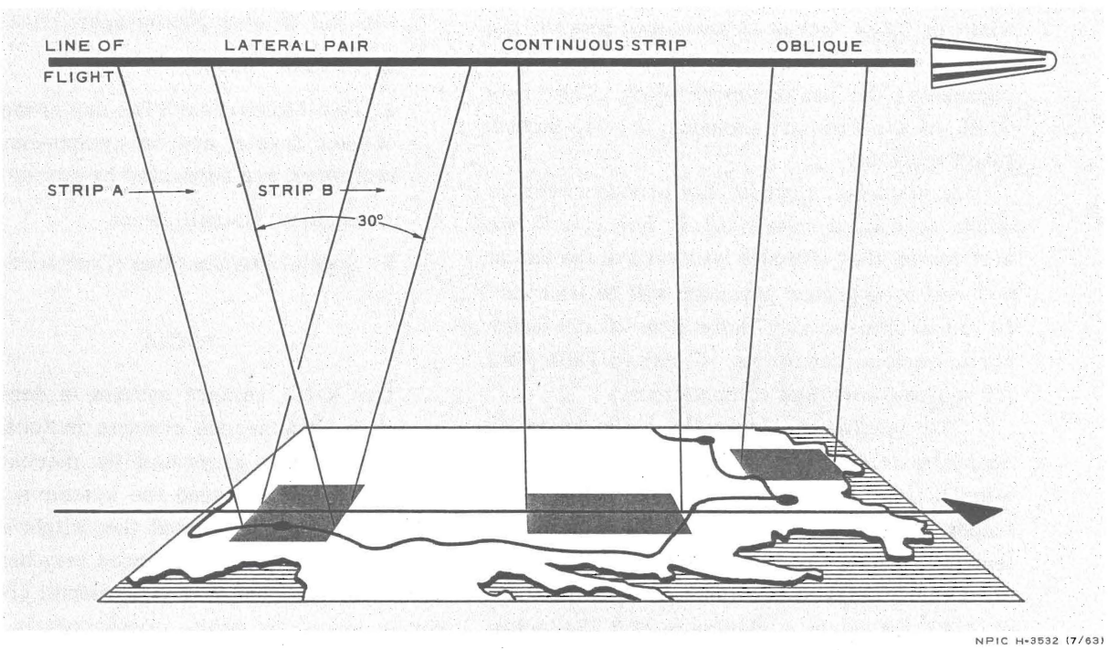


*FIGURE 3. OPERATING MODES KH-7 CAMERA SYSTEM.*

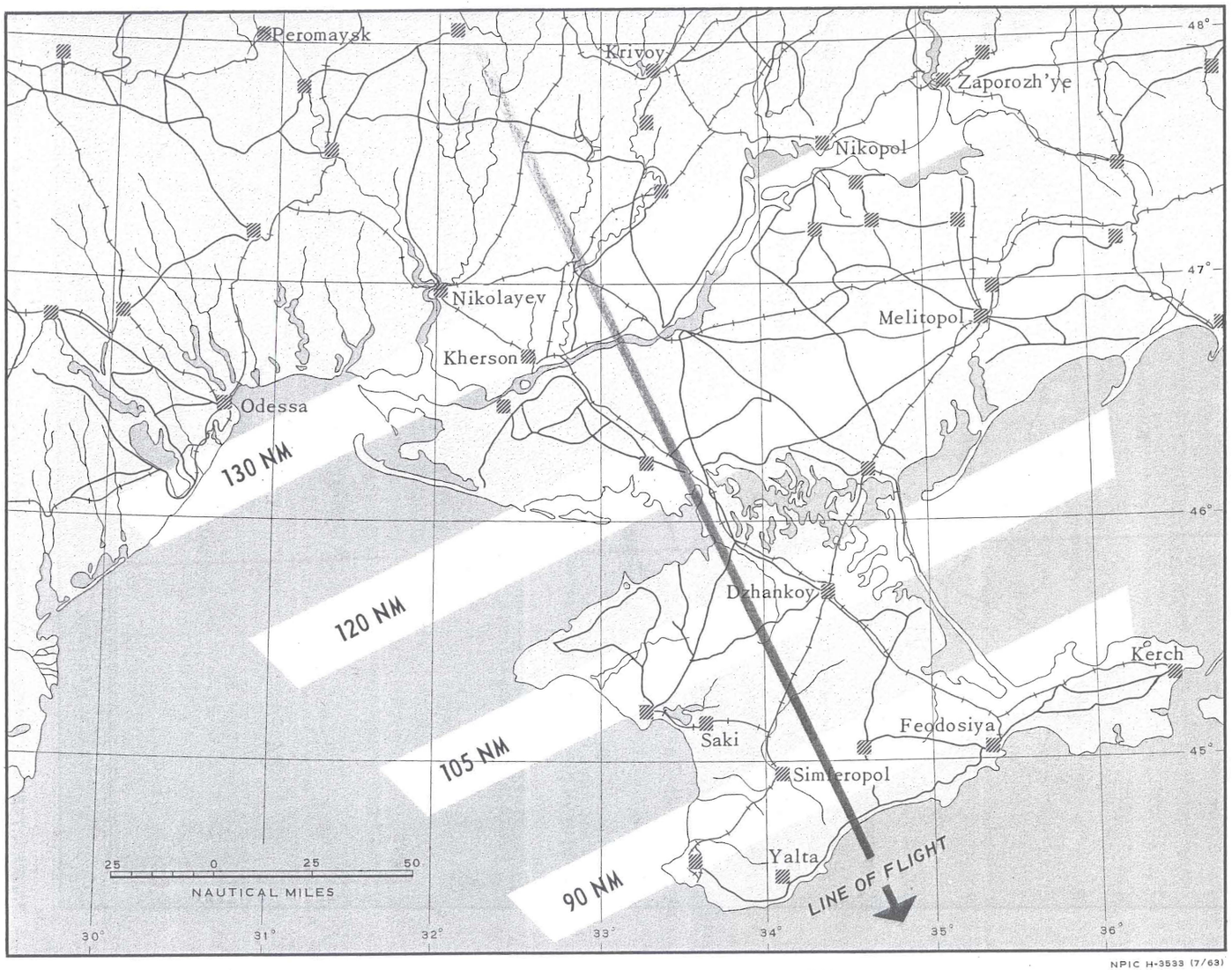


FIGURE 4. POSSIBLE SEARCH AREA FOR VARIOUS ALTITUDES OF KH-7 PROVIDED BY ROLL CAPABILITY.

*Table No 3. Vertical Coverage Table*

| ALTITUDE NAUTICAL MILES | ALTITUDE FEET | WIDTH COVERAGE NAUTICAL MILES | SCALES | WIDTH COVERAGE IN FEET |
|---|---|---|---|---|
| 90 | 547,200 | 10.06 | 85,275 | 61,186 |
| 90.46 | 550,000 | 10.12 | 85,712 | 61,500 |
| 95 | 577,600 | 10.62 | 90,013 | 64,586 |
| 98.68 | 600,000 | 11.03 | 93,504 | 67,090 |
| 100 | 608,000 | 11.18 | 94,750 | 67,984 |
| 100.33 | 610,000 | 11.22 | 95,062 | 68,200 |
| 102.80 | 625,000 | 11.50 | 97,400 | 69,886 |
| 104.44 | 635,000 | 11.68 | 98,958 | 71,004 |
| 105 | 638,400 | 11.74 | 99,488 | 71,384 |
| 106.91 | 650,000 | 11.95 | 101,296 | 72,680 |
| 110 | 668,800 | 12.30 | 104,225 | 74,784 |
| 111.84 | 680,000 | 12.51 | 105,970 | 76,036 |
| 113.49 | 690,000 | 12.69 | 107,530 | 77,154 |
| 115 | 699,200 | 12.86 | 108,965 | 78,182 |
| 115.13 | 700,000 | 12.89 | 109,088 | 78,372 |
| 116.78 | 710,000 | 13.06 | 110,646 | 79,390 |
| 118.42 | 720,000 | 13.24 | 112,205 | 80,508 |
| 120 | 729,600 | 13.42 | 113,700 | 81,582 |
| 120.89 | 735,000 | 13.51 | 114,540 | 82,186 |
| 123.35 | 750,000 | 13.80 | 116,880 | 83,864 |
| 125 | 760,000 | 13.98 | 118,438 | 84,980 |
| 125.82 | 765,000 | 14.07 | 119,218 | 85,540 |
| 127.46 | 775,000 | 14.25 | 120,776 | 86,660 |
| 129.93 | 790,000 | 14.53 | 123,115 | 88,340 |
| 130 | 790,400 | 14.54 | 123,175 | 88,380 |
| 131.58 | 800,000 | 14.71 | 124,672 | 89,454 |
| 135 | 820,800 | 15.10 | 127,913 | 91,780 |
| 139.80 | 850,000 | 15.63 | 132,464 | 95,044 |
| 140 | 851,200 | 15.65 | 132,651 | 95,180 |
| 143.91 | 875,000 | 16.09 | 136,360 | 97,840 |
| 145 | 881,600 | 16.21 | 137,389 | 98,578 |
| 148.02 | 900,000 | 16.55 | 140,256 | 100,636 |
| 150 | 912,000 | 16.77 | 142,216 | 101,978 |
| 152.13 | 925,000 | 17.01 | 144,152 | 103,430 |
| 155 | 942,400 | 17.33 | 146,864 | 105,376 |
| 156.25 | 950,000 | 17.48 | 148,048 | 106,226 |
| 160 | 972,800 | 17.89 | 151,601 | 108,776 |
| 160.36 | 975,000 | 17.93 | 151,944 | 109,020 |
| 164.47 | 1,000,000 | 18.40 | 155,840 | 111,818 |
| 165 | 1,003,200 | 18.45 | 156,340 | 112,176 |
| 168.58 | 1,025,000 | 18.85 | 159,736 | 114,612 |
| 170 | 1,033,600 | 19.00 | 161,076 | 115,574 |
| 172.69 | 1,050,000 | 19.31 | 163,632 | 117,408 |
| 175 | 1,064,000 | 19.57 | 165,814 | 118,974 |
| 176.81 | 1,075,000 | 19.77 | 167,528 | 120,204 |
| 180 | 1,094,400 | 20.13 | 170,551 | 122,372 |
| 180.92 | 1,100,000 | 20.25 | 171,424 | 123,000 |

of the optimal lens-image plane--film-surface plane relationship. The range of focus adjustment is ± 0.010 inches.

In general terms, the focus control assembly evaluates the conditions of focus. When departure from the limits of best focus is detected, the focus output signals (generated by the detector) indicate that an adjustment of focus is required. The focus drive motor, upon command, then shifts the film platen a controlled distance, returning the plane of best focus to coincidence with the film surface plane.

### TIME MARKS

A time track will be exposed on the film from which correlative data may be extracted. This time track is composed of two separate time tracks, one operating at 10 cycles per second (cps) and one operating at 20 cps. Binary time is recorded in both time tracks for redundancy checks, with the index marks for each track appearing at different intervals (50 milliseconds apart for the 20 cps track and 100 milliseconds apart for the 10 cps track). (See Inset, Figure 6.)

The binary time word is recorded in 23 bits to an accuracy of .1 second and is repeated every .8 second.

The size and variability of this time word and time track precludes early and easy access to the information. The variability of the time track and time word are controlled by the speed of the film moving past the slit; since this is a variable speed, the recording of the time track is variable also. (See "Discussion of Strip Cameras".) The size of the time track is so small that it is difficult to distinguish individual data bits at less than 10-time magnification, and a 25- or 30-time magnification is necessary to adequately read the time track.

### STELLAR/INDEX CAMERA

The stellar/index camera system to be employed in the KH-7 system is the same one used in previous KH-4 and KH-6 systems. (See Figure 7.) These S/I units may be operated at varying intervals to produce adequate exposures for attitude determination during the main strip camera operation. A greater film supply than has been available in the KH-4 S/I units will allow more flexibility in the number of exposures and therefore attitude determination.

### STELLAR CAMERA

The stellar camera produces photography of the stellar field over a format area 0.9375 inches diameter. A reseau grid is superimposed on the image plane to produce four fiducial marks at certain intersections of the grid and also to produce a grid on the exposure. The orientation of the reseau grid will vary from mission to mission. Calibration data for the camera and its reseau grid will be supplied with other camera data for each mission.

Frame correlation marks will appear on random frames for correlations of stellar frame and 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.

#### Stellar Camera Data

Lens: Cannon f/1.9.

Focal Length: 85 mm.

Cone Angle: 16 degrees.

Shutter Speed: 0.5 second to 6 seconds.

Filter: None.

Film Load: Variable 35 mm by 75 to 250 feet.

Format Size: 0.9375 inches diameter.

Reseau Grid: 2.5 mm calibrated grid.

In the roll positions available, the stellar camera will be photographing a changing star field since the entire package is rolled to these positions. In the case of a negative roll condition, the stellar unit will be pointing at or near the earth's surface; therefore, attitude may not always be available from this source.

Filter: Wratten 21.

Film Load: 70 mm by 125 to 500 feet.

Format Size: 2.25 inches square.

Reseau: 2.5 mm calibrated grid.

Scale: Approximately 1:4,400,000.

The index camera will photograph the portion of the earth directly in line with the roll position of the vehicle since the index camera will be rolled the same amount as the main camera system. This will preclude yaw analysis and stereo coverage between frames taken at different roll positions.

## GLOSSARY

The possible degradation of photography by image smearing is inherent in any aerial photographic system. (See Figures 8, 9, and 10.) Hence, one of the major requirements of a system is the capability of reducing or compensating for the various smear-inducing factors. The following are technical terms most commonly encountered with relation to this problem:

IMAGE SMEAR: The degradation or distortion of terrestrial images, usually evidenced by edge-smearing in a direction parallel to the line of flight or approximately perpendicular to it, depending on the factors involved. Elongation or compression of images results, and circular objects may be recorded as elliptical forms.

ALONG-TRACK SMEAR: Image smear parallel to the forward motion or flight path of the camera vehicle.

CROSS-TRACK SMEAR: Image smear perpendicular to the forward motion or flight path of the camera vehicle.

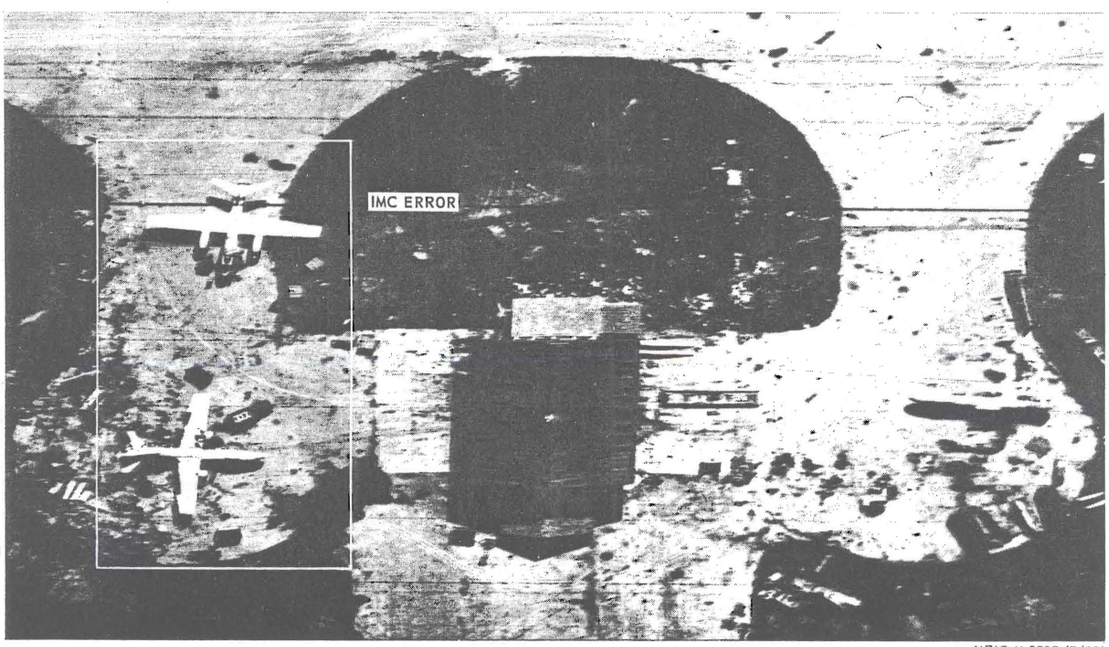


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*FIGURE 8. DISTORTION IN STRIP PHOTOGRAPHY.*

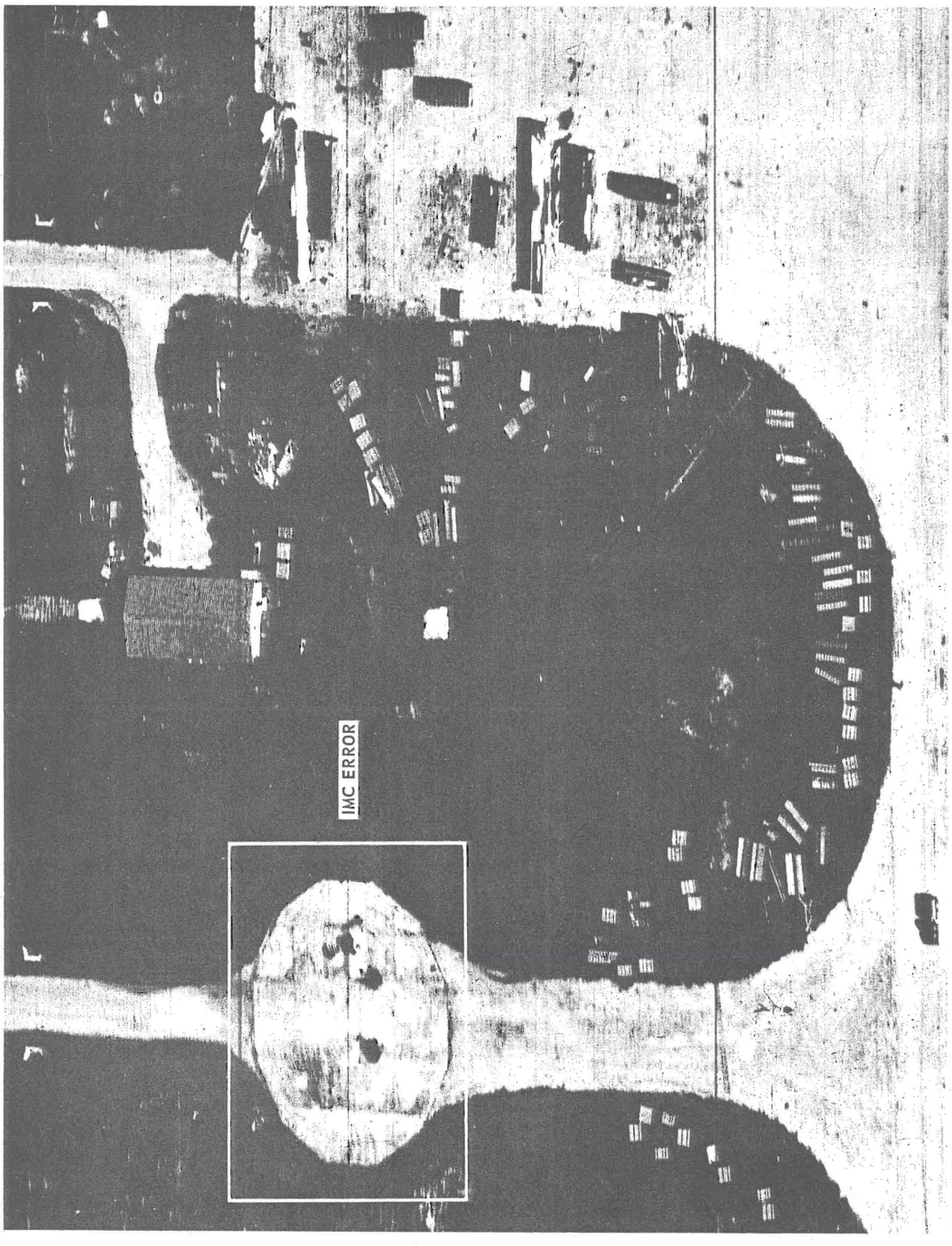


FIGURE 10. DISTORTION IN STRIP PHOTOGRAPHY.