TECHNICAL PUB TION

NATIONAL PHOTOGRAPHIC INTERPRETATION CENTER

CAMERA SYSTEM

MARCH 1967

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TECHNICAL PUBLICATION

THE KH-4A CAMERA SYSTEM

MARCH 1967

NATIONAL PHOTOGRAPHIC INTERPRETATION CENTER

PREFACE

This publication presents general technical information pertinent to the reduction of quantitative data obtained by the KH-4A camera system.

This photographic system, in effect, produces 2 consecutive missions from a single vehicle launching. The recent addition of certain geometric features to the panoramic camera is an effort to improve the metric capability for both mapping and mensuration.

This manual encompasses modifications to the KH-4A camera system and supersedes corresponding data contained in [redacted]

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LIST OF ILLUSTRATIONS

INTRODUCTION

This data book incorporates the latest minor modification to the basic KH-4A camera system. The KH-4A camera system consists of 2 main panoramic cameras, 2 stellar/index units (one unit per recoverable sub-system), and 4 horizon cameras (Figure 1). The payload consists of 2 recoverable sub-systems, each containing approximately 16,000 feet of film (8,000 feet of film per camera). The 2 recoverable sub-systems are designated mission part 1 and mission part 2. The system may be used to meet either reconnaissance or cartographic objectives. When used on a reconnaissance mission, the camera configuration (Figure 1) is oriented so that arrow A points in the direction of vehicle movement. When used on a cartographic mission, the camera configuration is oriented so that arrow B points in the direction of movement. The text and figures in this manual conform to the reconnaissance application.

PANORAMIC CAMERAS

Each panoramic camera is mounted in the photographic vehicle at a 15 degree angle from the vertical, thus forming a 30 degree convergence angle. The cameras are designated as follows: The forward-looking camera is the forward camera and the aft-looking camera is the aft camera. The designations master and slave are used sometimes. The master camera is indicated by an even serial number and the slave by an odd serial number. The master camera is the forward on a reconnaissance mission but may be the aft on a cartographic mission. The master camera is so designated because of its primary control function over certain other system operations such as the firing of the stellar/index unit.

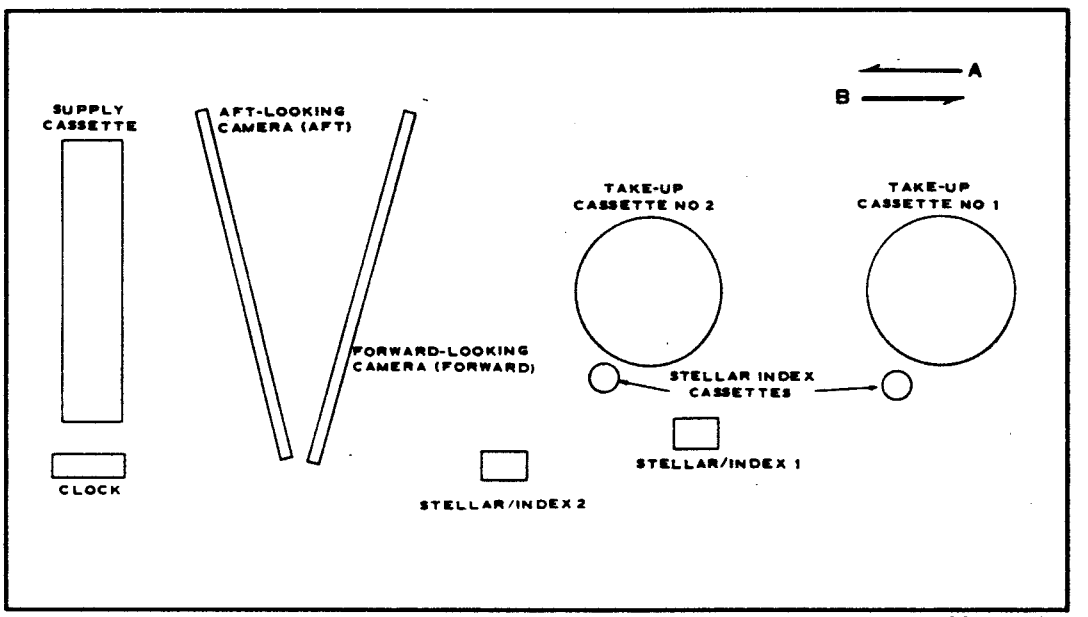

FIGURE 1. CAMERA SYSTEM CONFIGURATION.

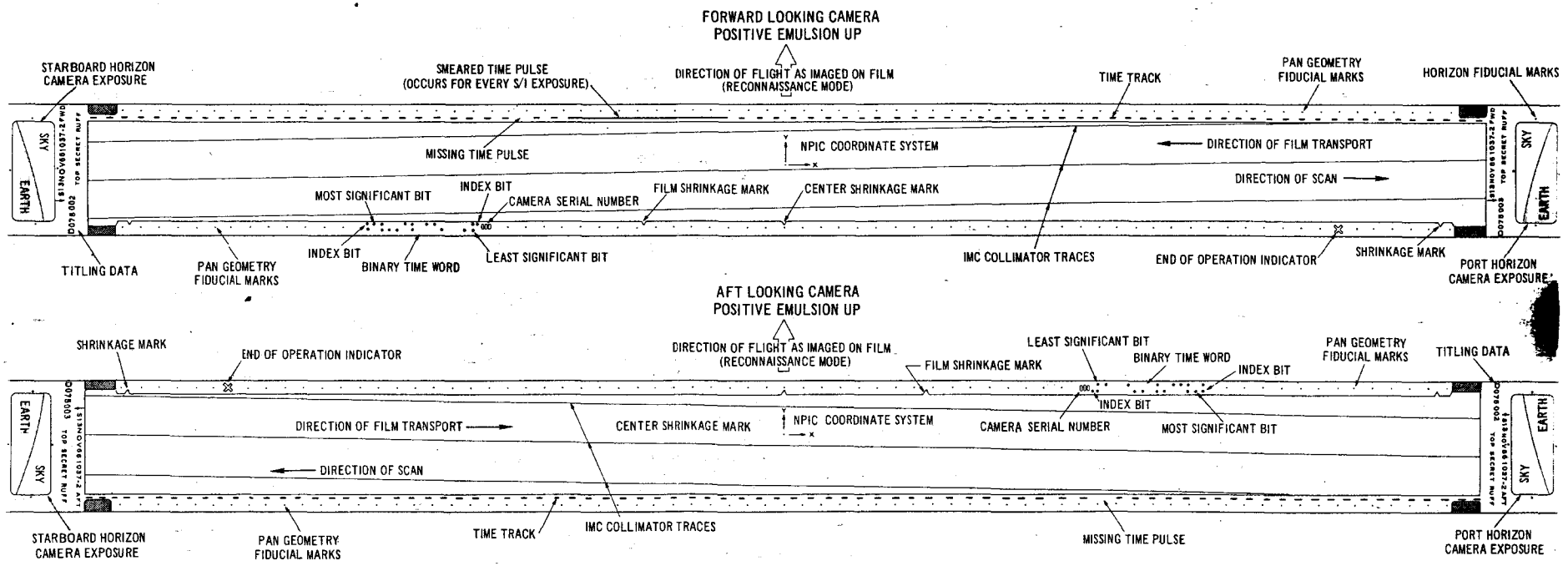

FIGURE 2. PANORAMIC CAMERA FORMAT.

Panoramic Camera Data

Table 1. Panoramic Camera Data

Lens	Petzval f/3.5
Focal Length	609.602 mm (24.0 in)
Scan Angle	70 deg (±35 deg from track)
Field of View	5 deg (along track)
Shutter	Focal Plane
Slit Widths	Variable -- from 0.17 in to 0.30 in
Film Load	1. 70 mm wide 2. 8,000 ft per recoverable subsystem (part 1 or 2 of a mission) for each camera 3. 16,000 ft per recoverable subsystem 4. 16,000 ft per camera per mission 5. 32,000 ft total load for both cameras for a mission (parts 1 and 2)
Image Motion Compensation (IMC)	Lens translation proportional to velocity height (V/H) ratio
Filter	Wratten 21, 23, or 25
Film Type	3404, Estar Base

Format Characteristics

Figure 2 is a complete record of the format for the forward and aft main panoramic cameras. The following is a description of the various items on the film.

1. Film Shrinkage Marks -- Images of arrowhead-shaped cut-outs on the film guide rails. The actual distance between film shrinkage marks on the guide rails is available from the calibration data report. The measured distances on the film may be used to determine film shrinkage.

2. Camera Serial Number -- An imaged record of the camera manufacturer's serial number. An even number indicates the master camera. An odd number indicates the slave camera.

3. Binary Time Word -- A recording of vehicle clock time to the nearest millisecond. The time word contains 29 bits plus 2 index marks.

Binary Values In Milliseconds

Least Significant Bit	1
	2
	4
	8
	16
	32
	64
	128
	256
	512
	1024
	2048
	4096
	8192
	16384
	32768
	65536
	131072
	262144
	524288
	1048576
	2097152
	4194304
	8388608
	16777216
	33554432
	67108864
	134217728
Most Significant Bit	268435456

4. Titling Data -- The title is affixed crossway on the film between frames and consists of a pass number, frame number, an arrow (indicates frame to which title applies), mode (S for stereo, M for mono, or MS for mixed), date, mission number, camera (fwd- or aft-looking), and classification. The letters D, A, M, and E preceding the pass number have the following meanings:

a. D -- The pass is descending from north to south.

b. A -- The pass is ascending from south to north.

c. M -- The pass is mixed; ascending and descending.

d. E -- Engineering pass.

5. IMC Collimator Traces -- An imaged record of fixed angular separations on the camera scan head.

6. Pan Geometry Fiducial Marks -- An image of the 73 holes through the film guide rails. Each hole is approximately 40 microns in diameter spaced at 1 centimeter intervals.

7. Time Track -- An image of a 200 cycle per second light pulse which records the camera lens scan rate.

8. Missing Time Pulse -- Indicates scan arm position when clock was interrogated.

9. Smeared Time Pulse* -- A stretched pulse which normally is imaged every seventh frame on the forward camera format. It indicates a stellar index firing so that panoramic frames may be correlated to stellar index frames.

10. End-of-Operation Indicator -- A cross imaged on the last frame of a camera operation.

Coverage

Table 2 lists approximate lateral and forward ground coverage in nautical miles (nm) based on a flat earth and nominal attitude conditions. The indicated scale is valid only at the principal point in a direction normal to the flight line.

Total mission coverage in square nautical miles varies considerably but 3,800,000 square nautical miles per camera per recoverable subsystem is a fair approximation. Figure 3 shows typical coverage of a frame of photography.

*Under certain circumstances, the stretched time pulse may occur on the aft frame. This happens when control of the stellar index firing is switched from the forward camera to the aft camera just prior to the "on off" operation or at the end of a pass when the system is operating in a stereo suppress mode. The stereo suppress mode delays both the on and off time of the aft camera approximately 12 to 14 seconds. As a result, equally numbered frames on the forward and aft cameras image approximately the same ground area.

Table. 2. Ground Coverage Per Frame

Height (nm)	Height (ft)	Lateral Coverage (nm)	Forward Coverage (nm)	Scale
80	486.000	112	7.8	252.000
90	547.000	126	8.7	283.000
95	577.000	133	9.2	298.000
100	608.000	140	9.7	314.000
105	638.000	147	10.2	330.000
110	669.000	154	10.7	346.000
115	699.000	161	11.2	362.000
120	730.000	168	11.6	377.000
130	790.000	182	12.6	409.000

HORIZON CAMERAS

Two horizon cameras are associated with each panoramic camera. The imagery from the horizon cameras is used to determine the attitude (pitch and roll) of the main panoramic cameras. The paired horizon cameras will operate simultaneously on alternate panoramic frames. The horizon camera formats are exposed adjacent to the main panoramic frames (Figure 2).

Horizon Camera Data

Table 3. Horizon Camera Data

Focal Length	55mm
Depression Angle	15 deg
Filter	Wratten 25
Exposure	1/50 or 1/100 sec
Film Type	Same as main panoramic cameras
Angular Field of View	Approximately 51 deg 30 min by 23 deg 30 min
Aperture	f/6.8 or f/8.0 -- varies according to which cameras are primarily pointing toward or away from the sun

The horizon camera photographs have no specific scale associated with them, nor do they have an independent frame number. They are referred to as the port or starboard exposures associated with the forward or aft panoramic camera frame. Port is defined as the left side of the vehicle as the observer faces in the direction of flight and starboard is the right side.

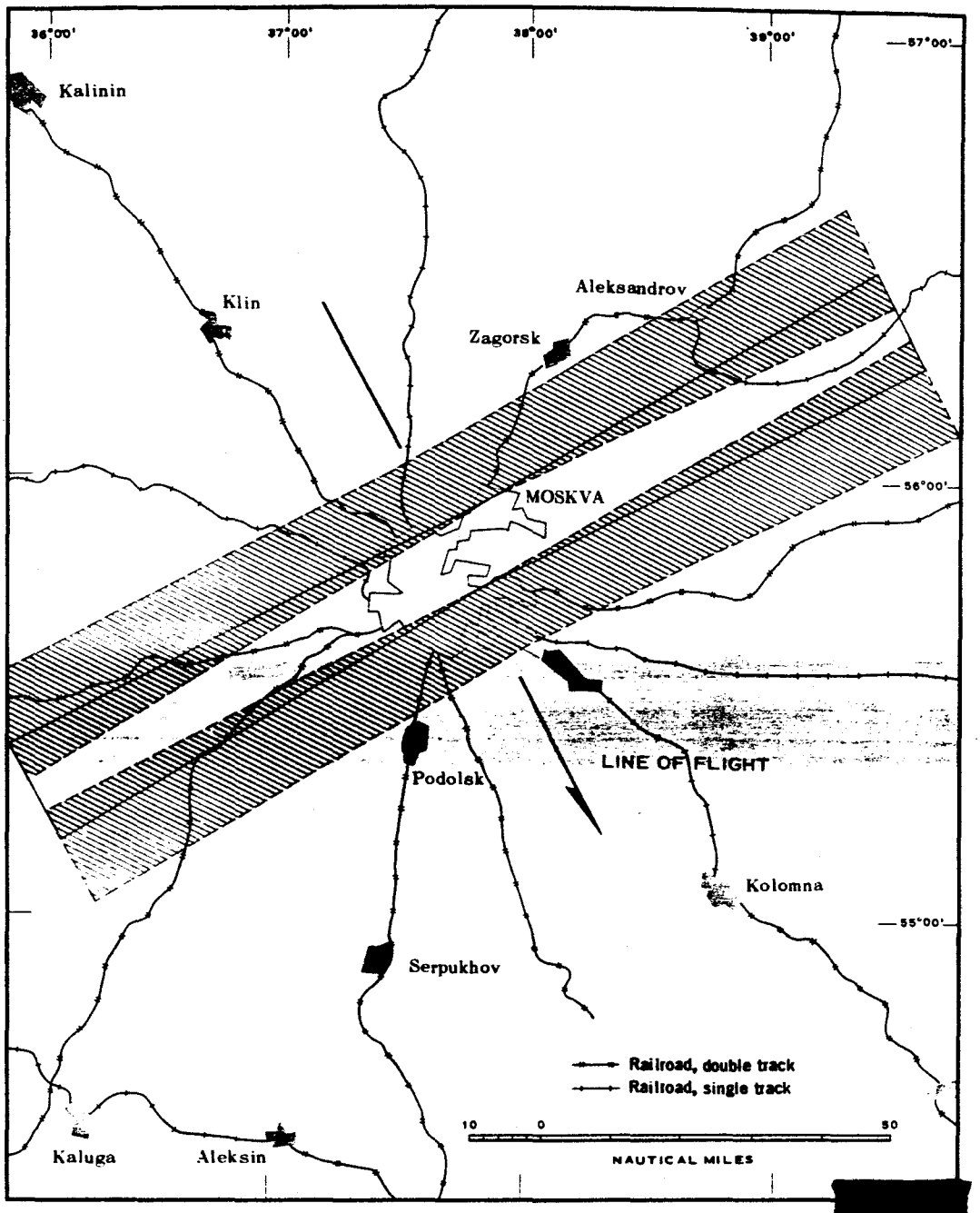

FIGURE 3. TYPICAL FRAME COVERAGE.

INDEX (TERRAIN) CAMERA

The index camera is a frame camera which provides vertical small-scale photography. It may be used for rapid correlation and indexing of main panoramic photography. The index camera also provides conjugate imagery for a relative orientation between the index and main panoramic cameras. This is necessary for eventual adjustment of attitude data (pitch, roll, and yaw) between the stellar and main panoramic cameras. The ratio of index camera exposures to main panoramic camera exposures is approximately 1 to 7.

Index Camera Data

Table 4. Index Camera Data

Lens	Biogon f 4.5
Focal Length	38.1 mm
Field Angle	72 deg
Shutter Speeds	1/125, 1/250, 1/500 sec
Reseau	Glass plate with 2.5 mm interval grid
Format Size	2¼ in by 2¼ in
Filter	Wratten 21
Film Load	70 mm by 135 ft
Overlap	55 to 60 percent
Film Type	3400
Scale	1/4,864,000 at 100 nm altitude
Coverage	22,500 sq/nm per frame at 100 nm altitude; 3,800,000 sq/nm per recoverable sub-system

Titling Data

Each index frame is numbered sequentially from 1 through n for each recoverable subsystem of a mission (Figure 4). Titling data consists of frame number, mission number, date, and classification. On the leader of the index film is a breakdown of the frames and their respective passes.

The frame correlation fiducial mark is an image of a lamp on both the index and stellar photography exposed simultaneously to aid in correlation. The lamp is not lit on every frame. Thus the correlation is accomplished by matching the lit/unlit patterns of the stellar and index photography.

The reseau grid forms a calibrated array of points on the photograph which may be used as an aid in correcting the effects of film shrinkage, lens distortion, and atmospheric refraction.

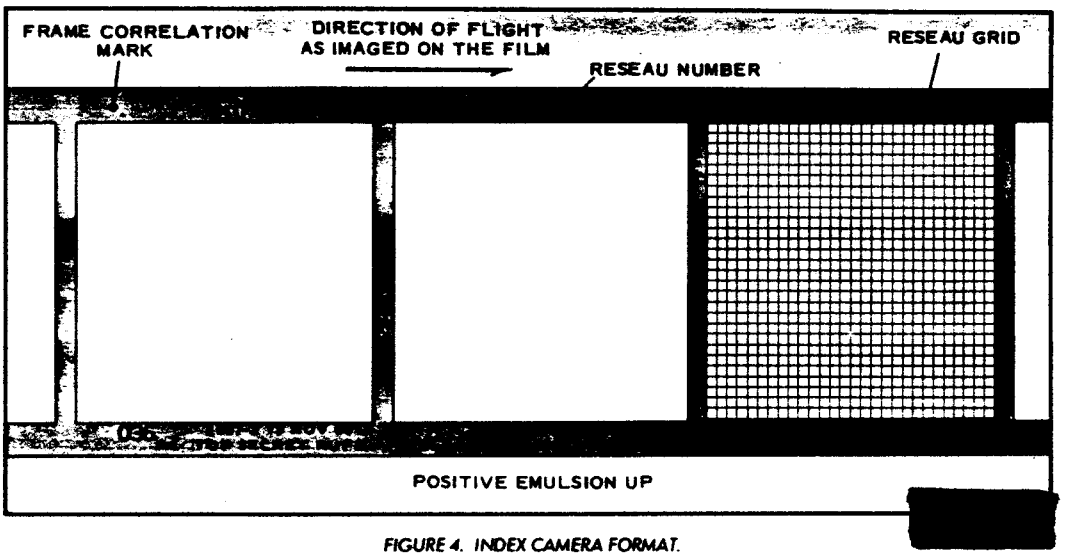

FIGURE 4. INDEX CAMERA FORMAT.

STELLAR CAMERA

Stellar photography provides a means for very accurate determination of pitch, roll, and yaw during operational cycles. One stellar photograph is generated simultaneously with each index camera exposure. A reseau is provided to correct for image distortion and to recover geometric orientation.

Stellar Camera Data

Table 5. Stellar Camera Data

Focal Length	84 mm
Field Angle	Approximately 16 deg 40 min
Aperture	f 1.8
Exposure Time	0.5 to 2.0 sec
Filter	None
Format Size	Approximately 24 mm in diameter
Film Type	3401
Film Load	35 mm by 75 ft
Reseau	Glass plate with 2.5 mm interval grid

Although the stellar imagery is originally produced on unperforated 35mm film, it is customarily reproduced on 70mm duplicate positives for ease of handling by specified users (Figure 5).

The stellar photography is not numbered on the original negative. Instead, each frame of the duplicate positive is numbered sequentially from 1 through n for each recoverable sub-system of a mission. A breakdown of the frames and their respective passes is on the leader of the stellar imagery.

The reseau calibration fiducials are shown outside of the format area and are to be correlated to calibrated data supplied for each unit.

CAMERA SYSTEM OPERATION

During operation, input metering rollers continuously pull film from the supply spool and meter it into the instrument at a rate consistent with the average flow through the system. Since the film in the platen area is stationary during exposure and film movement from the supply spool and from the instrument to cassette is continuous, a shuttle mechanism is provided to store and release the moving portions of the

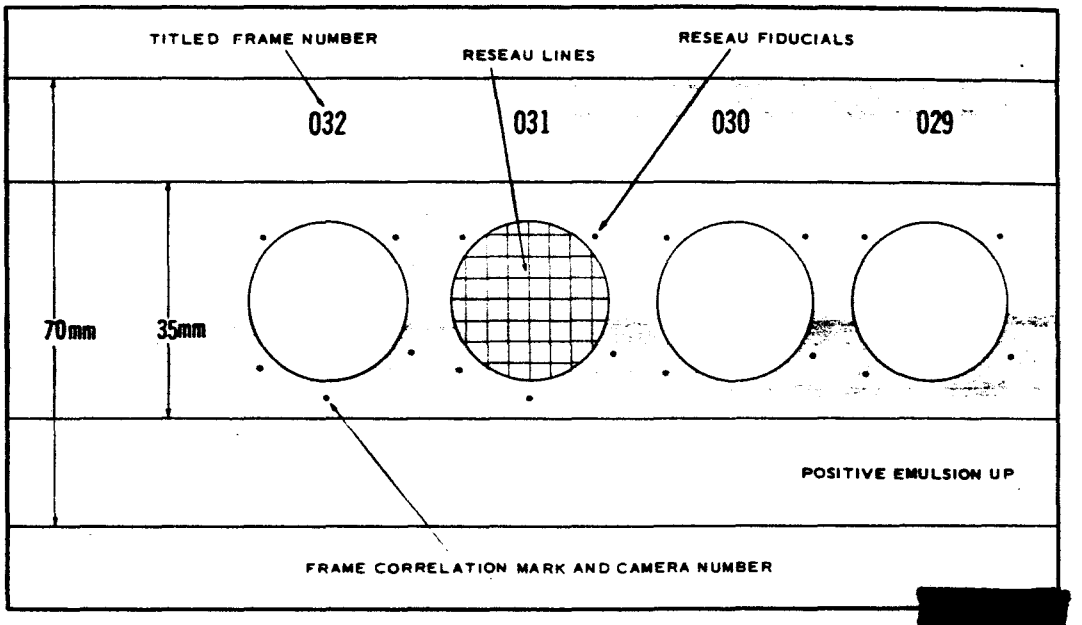

FIGURE 5. STELLAR CAMERA FORMAT.

film during the scan.

The lens barrel of each panoramic camera is rotating continuously while the scan arm moves back and forth across the format. During the scan portion of the cycle, the lens barrel and scan arm are locked together and their motion is synchronous during film exposure. While the scan arm is returning, metering rollers move the exposed film out of the platen area. At the same time, unexposed film is moved into the platen.

The V/H programmer provides camera speed control to match the achieved orbit parameters. IMC is achieved by moving the lens system opposite to the direction of flight. The rate of IMC is a function of operating speed, is variable, and is controlled by the V/H programmer.

PANORAMIC GEOMETRY FEATURE

The pan geometry feature is designed to aid in cartographic reduction by:

1. Defining the relationship between the scanning motion (cross track) of the camera and its IMC translation (along track) more precisely.
2. Providing a type of dynamic control in the form of pan geometry fiducial marks (holes through the rails) and IMC collimator traces to assist in the correction of film shrinkage, lens distortion, and atmospheric refraction.

A calibration report is prepared for each mission, available at time of receipt of photography. The calibration report will contain:

1. A sketch of the format including the point identification system and coordinate system.
2. Calibration statistics including average variance for the rail holes and for each of the traces.
3. Focal length and cam constant (+ or -) in microns.
4. A point-by-point plot of individual readings on each trace.
5. A listing of coordinates for all 73 holes on each rail and 73 points on each trace. Points on the traces are defined by the intersection of the traces and the lines connecting each pair of opposite holes.

Figures 6 and 7 describe the coordinate system and point identification key as they will be referenced in the calibration reports. The numbering system takes the form of a matrix of 5 rows and 73 columns with an irregular row numbering system. The first 2 digits are the row indicators. The last 2 digits are the column indicator. Note that +X is in the direction of flight. This is different than the NPIC convention of +Y in the direction of flight.

Figure 6 shows, for the forward-looking camera, the coordinate system and point identification key as they would appear on a positive emulsion side up.

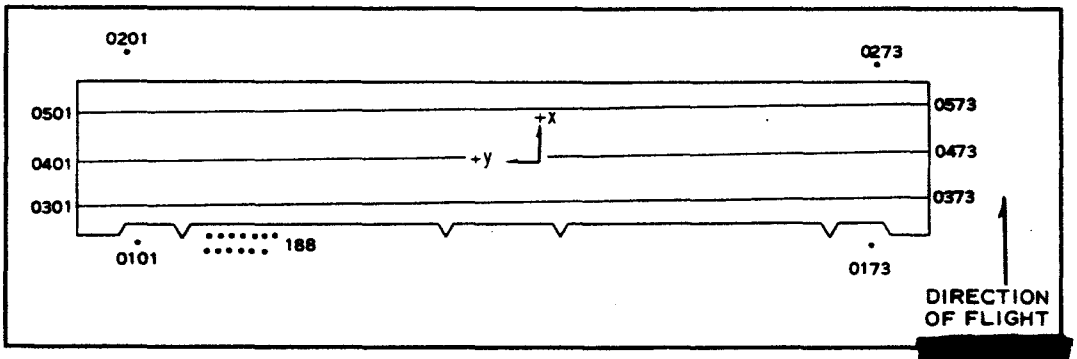

FIGURE 6. PANORAMIC GEOMETRY–FWD CAMERA.

Figure 7 shows, for the aft-looking camera, the coordinate system and point identification key as they would appear on a positive emulsion side up.

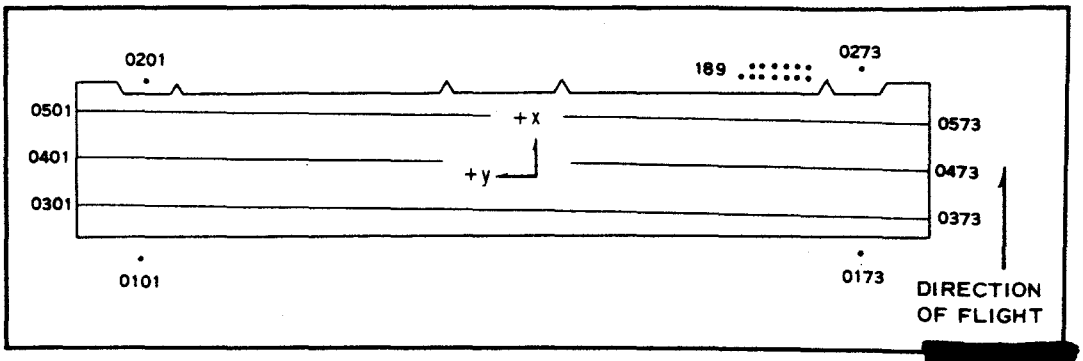

FIGURE 7. PANORAMIC GEOMETRY–AFT CAMERA.