[redacted]

THE KH-4B CAMERA SYSTEM

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LIST OF ILLUSTRATIONS AND TABLES

- PREFACE -

This data book has been prepared by the National Reconnaissance Office with the assistance of the National Photographic Reconnaissance Center to provide general technical information pertinent to the reduction of data obtained by the KH-4B camera system.

The KH-4B camera system is expected to be operational in the fall of 1967. This photographic system is a continuation of the KH-4 series with modifications to provide adjustable exposure control, selectable filters, and a change in the mechanism which provides image motion compensation as well as a larger 3 inch focal length terrain camera.

INTRODUCTION

This data book incorporates the latest modification to the basic KH-4 camera system. The KH-4B camera system consists of 2 main panoramic cameras, a stellar/index camera and 4 horizon cameras (Fig 1). The payload consists of 2 recoverable sub-systems, each containing approximately 16,000 ft of film (8,000 ft 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. The camera (Fig 1) is oriented so that the forward camera in the vehicle is the aft looking, and the aft camera is the forward looking.

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 so designated because of its primary control function over certain other system operations such as the firing of the stellar/index unit.

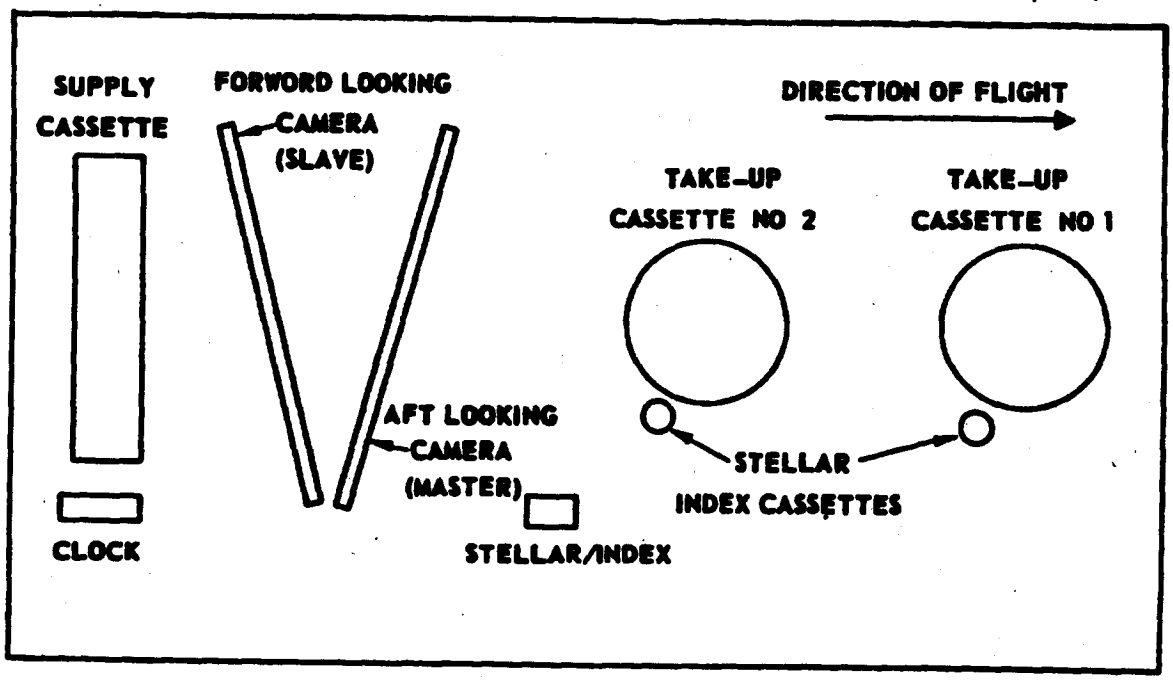


FIGURE 1. CAMERA SYSTEM CONFIGURATION.

PANORAMIC CAMERA DATA

Table 1. Panoramic Camera Data

Lens	Petzval f/3.5 T/3.8
Focal Length	609.602mm (24.0 in)
Scan Angle	70 deg (± 35 deg from track)
Field of View	5.12 deg (along track)
Usable Format	29.323" X 2.147"
Shutter	Focal Plane
Slit Widths	Variable--from 0.17 in to 0.30 in
Film Load	1. 70mm 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)
End Lap	7.6%
Image Motion Compensation (IMC)	Camera rate proportional to velocity/height (V/H) ratio
Filter	Variable -2 position commandable
Film Type	3404, Estar Base

Binary Values in Milliseconds

Least Significant Bit Nearest the Supply end of the format.	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 Nearest the Takeup end of the format.	268435456

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. 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.

2. Binary Time Word -- A recording of vehicle clock time to the nearest millisecond. The time word contains 29 bits plus a parity bit. There are six columns of 32 bits available, but only three columns of 30 binary bits are presently used as shown in Figure 3. The columns are parallel to the edge of the film and are read from left to right as seen from the side of the film away from the emulsion when the data block is on the edge of the film nearest the viewer. The column furthest from the film edge is column number one, and all 30 bits are illuminated to provide a registration for mechanical readout. Column two presents the time work in rows 1 through 29 with the 30th being the parity bit. Column three presents reciprocated time, again with the 30th bit being the parity bit. The data block is located on the takeup side of the platten area. This means that any time readout, as seen on the film, is associated with the following (next higher number) frame, or conversely, when ascertaining the time a particular frame was taken, it is necessary to look at the data block on the previous or lower numbered frame.

3. 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.

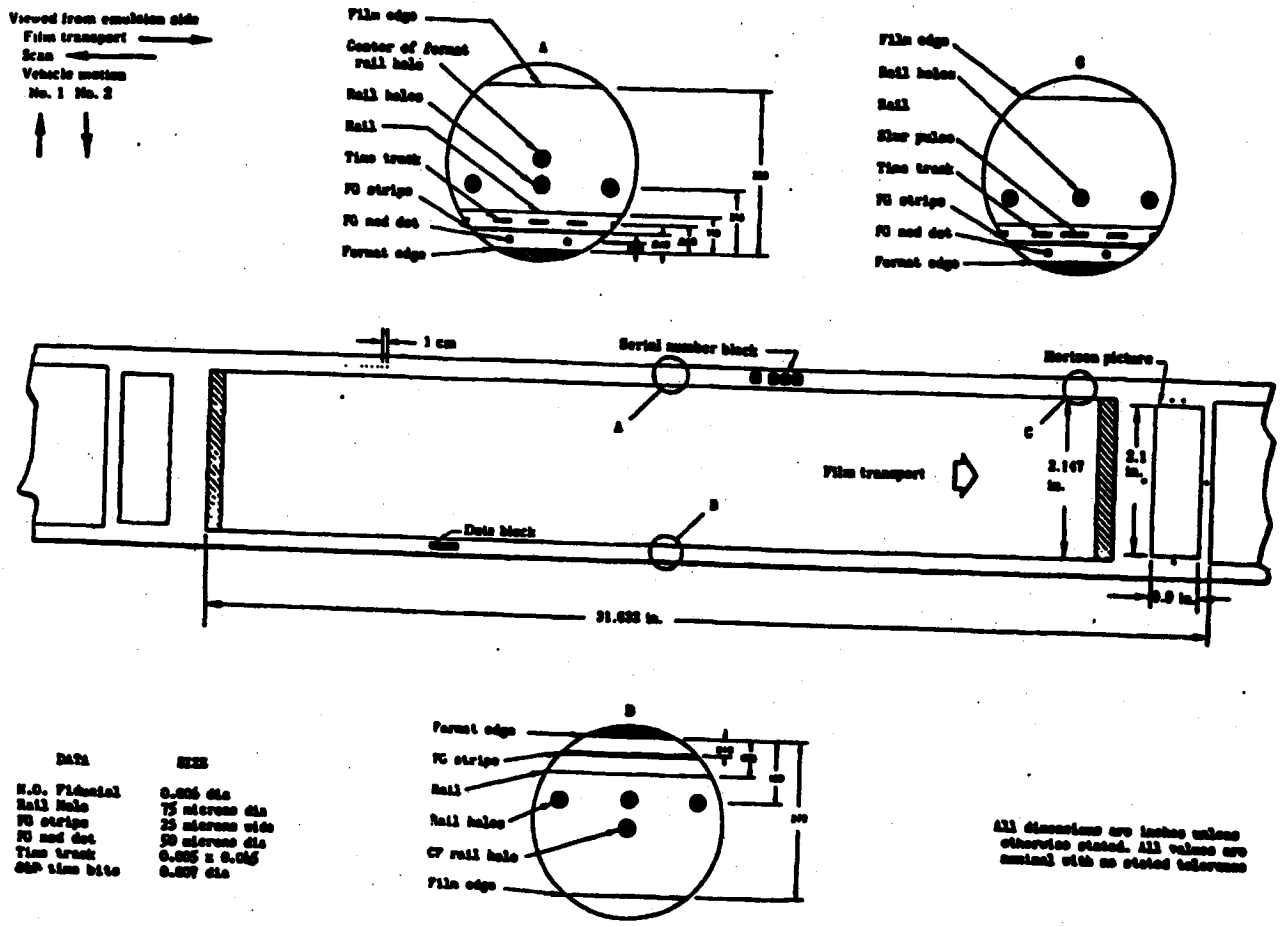
d. E -- Engineering pass.

4. Panoramic Geometry Traces -- lines on either side of the format which aid in determining the principle axis of the lens.

5. A nod angle calibration system which, by means of a xenon flash triggered by an optical encoder mounted on the mod axis, images a series of small dots along the edge of the format.

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 with a double hole at the center of format.

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

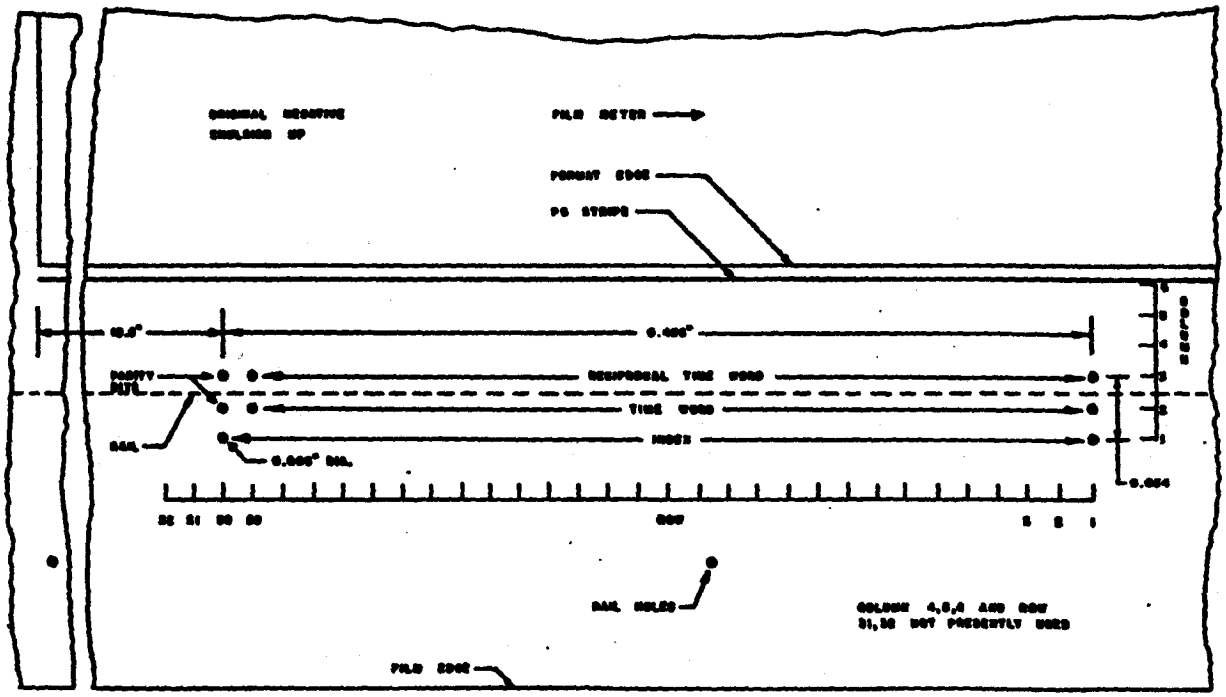


DATA	SIZE
H.O. Fiducial	0.005 dia
Roll Hole	75 microns dia
FG stripe	25 microns wide
FG mod dot	50 microns dia
Time track	0.005 x 0.015
ASP time bits	0.007 dia

All dimensions are inches unless otherwise stated. All values are nominal with no stated tolerance

ORIGINAL NEGATIVE FORMAT DRAWING

FIGURE 2



DATA BLOCK FORMAT

FIGURE 3

TABLE 2

PANORAMIC CAMERA CALIBRATION

COMPONENT	PARAMETER	CALIBRATION
Main Lens	Equivalent Focal Length	25 Microns
Main Lens	Radial Distortion	1 Micron
Main Lenses	Convergence	60 ARC Seconds
Horizon Optics	Equivalent Focal Length	25 Microns
Horizon Optics	Principle Point to Fiducial Intersection	10 Microns
All Lenses	Allignment Horizon to Pan and Pan to Pan	60 ARC Seconds
P6 Nod dot encoder	Nod angle position	One dot every 14.79 ~~39.55~~ arc sec of nod shaft rotation

8. Slur Time Pulse -- A stretched pulse which occurs immediately after the clock is interrogated in order to show the relation between the time marks and the clock time. This should permit the determination of the time at which a point on the format was exposed with accuracy of 2.5 milliseconds (3 sigma).

9. Start of Operation Indicator -- A cross imaged near the camera serial number on the first frame of a camera operation.

COVERAGE

Figure 4 shows the angles covered by the several cameras. Figure 5 shows the typical terrain coverage expected and lists the coverage for various altitudes. Figure 6 is a conversion chart to determine photographic scale at different distances from the format center over the altitude range from 80 to 120 nautical miles.

CAMERA CALIBRATION

The panoramic camera lenses and horizon cameras are individually calibrated prior to being mounted on the panoramic camera. This individual calibration consists of determining the principal point of autocollimation and the equivalent focal length, and checking the lens distortion characteristics. Subsequent to this, each camera system is calibrated to determine the position of the horizontal cameras in relation to their respective panoramic camera lens. The accuracy of these calibrations is shown in Table 2.

HORIZON CAMERAS

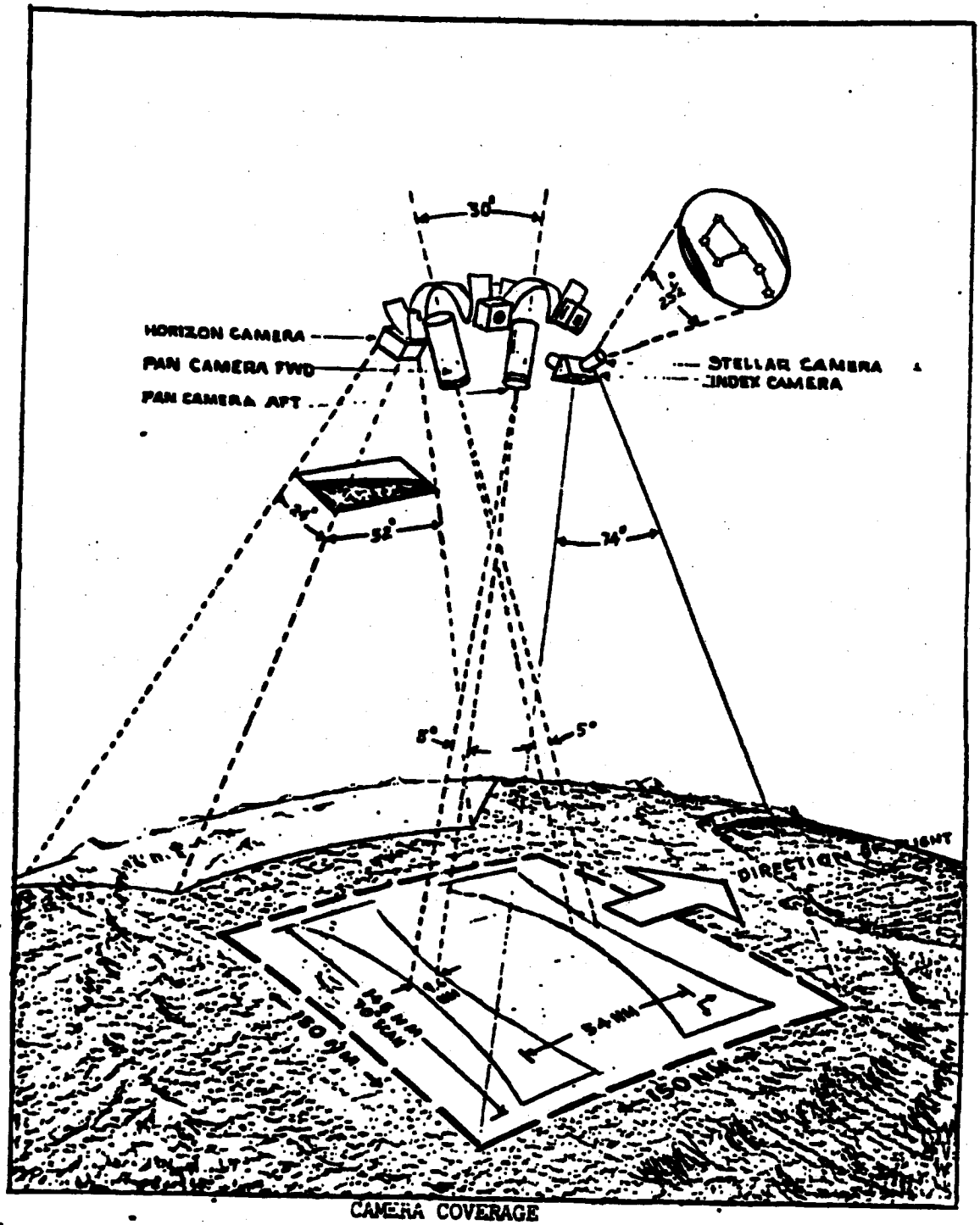
Two horizon cameras are associated with each panoramic camera. The imagery from the horizon cameras is used to determine the attitude (pitch and roll) of the main panoramic cameras. The paired horizon cameras will operate simultaneously on alternate panoramic frames. The horizon camera formats are exposed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

HORIZON CAMERA DATA

Table 3. Horizon Camera Data

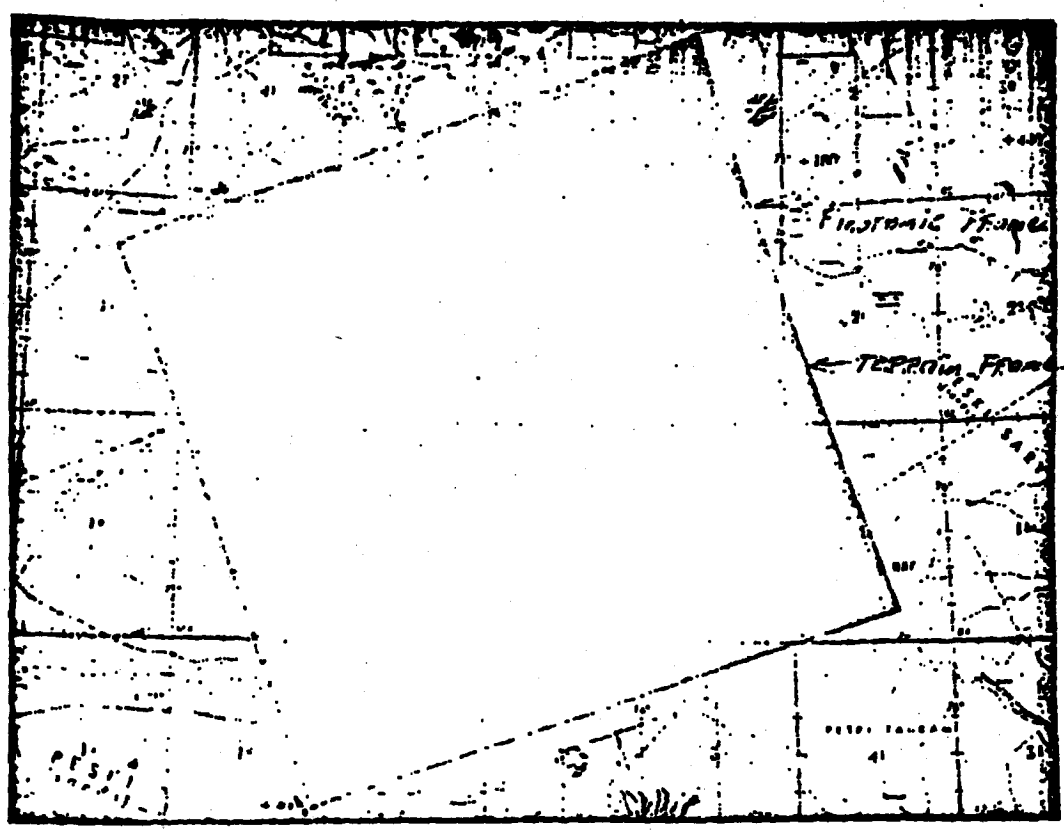
Focal Length	55mm
Depression Angle	15 deg
Filter	Wratten 25 plus Commandable A Henuator
Exposure	1/100 sec
Film Type	Same as main panoramic cameras
Angular Field or View	Approximately 51 deg 30 min by 23 deg 30 min
Usable Format	2.1" X .9"
Aperture	f/6.8 or f/8.0 -- varies according to which cameras 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 vhiecle as the observer faces in the direction of flight and starboard is the right side.



CAMERA COVERAGE

FIGURE 4



PANORAMIC CAMERA SYSTEM COVERAGE (3.0 MIL.BASE FILM)

ALTITUDE (N.M.)	80	85	90	95	100	105	110	115	120
FRAME FORWARD COVER(N.M.)	7.7	8.2	8.6	9.1	9.6	10.1	10.6	11.0	11.5
FRAME WIDTH COVER(N.M.)	116.0	123.2	130.5	137.7	145.0	152.2	159.5	166.7	174.0
AREA PR. FR. (SQ.N.M. X 10^2)	8.9	10.0	11.3	12.5	13.9	15.3	16.8	18.4	20.0
MISSION STEREO COVER (SQ.N.M. X 10^5)	4.9	5.6	6.2	7.0	7.7	8.5	9.3	10.2	11.1

TERRAIN CAMERA COVERAGE

A listing of the coverage and overlap of the terrain camera is shown below for selected altitudes between 80 N.M. and 120 N.M.

ALTITUDE - N.M.	80	90	100	110	120
SIDE DIMENSION OF GROUND PATTERN-N.M.	120.6	135.6	150.7	165.8	180.8
AREA COVERAGE PR. FRAME - SQ. N.M. X 10^4	1.45	1.84	2.27	2.75	3.27
OVERLAP-% 9.378 sec/cycle	69.0	71.6	74.4	76.7	78.7
12.5 sec/cycle	57.4	62.1	66.9	69.0	71.6

PANORAMIC AND TERRAIN CAMERA COVERAGE

FIGURE 5

SCALE CONVERSION

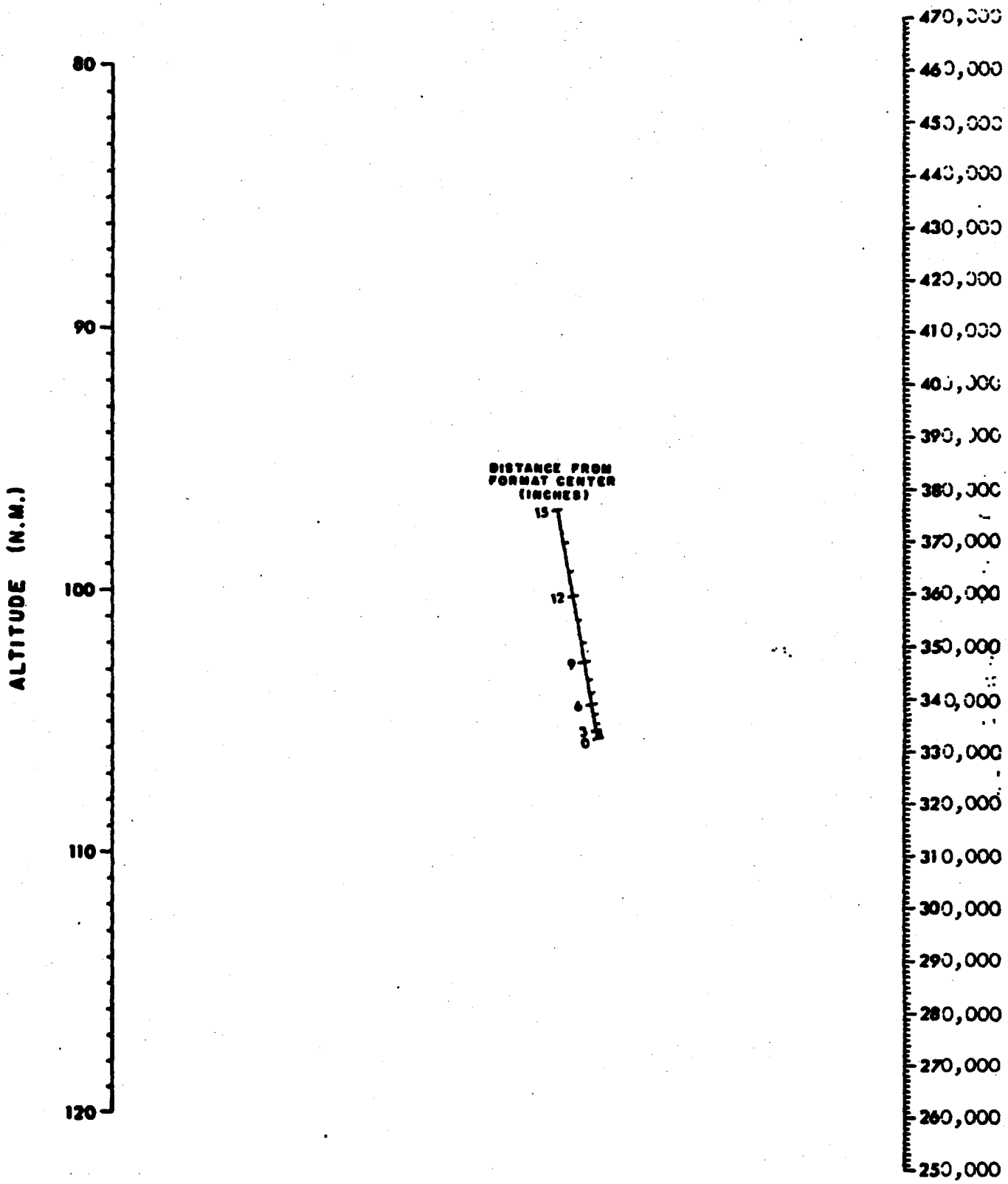


FIGURE 6

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 index camera is preset to operate at 9.375, 12.5, 15.625, or 18.75 seconds per cycle; based on the planned camera altitude, it can be programmed to operate independently from the panoramic cameras.

The terrain format is shown in Figure 7. Figure 8 shows the data block details and the start of pass marks.

INDEX CAMERA DATA

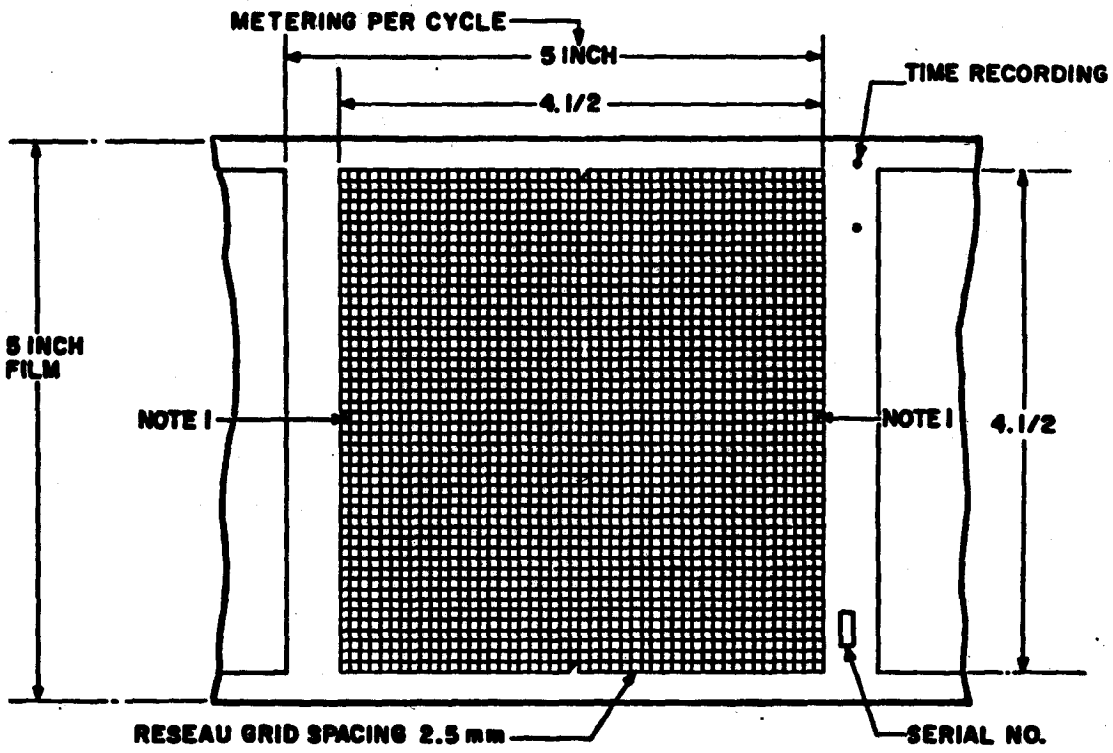
Table 4. Index Camera Data

Lens	f/4.5 T/6.75
Focal Length	3 inches
Field Angle	74 deg
Shutter Speeds	1/250, 1/500 sec
Shutter Type	Rotary
Reseau	Glass plate with 2.5mm interval grid
Format Size	4½ by 4½ inch
Filter	Wratten 21
Film Load	5 in by 2,000 ft
Overlap	55 to 60 percent
Cycle Period	9.375 sec/cycle 12.5 sec/cycle 15.625 sec/cycle or 18.75 sec/cycle
Scale	1/2,432,000 at 100nm altitude
Coverage	22,700 sq/nm per frame at 100nm altitude; 30 X 10^6 sq/nm per mission

TITLING DATA

Each index frame is numbered sequentially from 1 through n for each recoverable subsystem of a mission (Figure 7). 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 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.



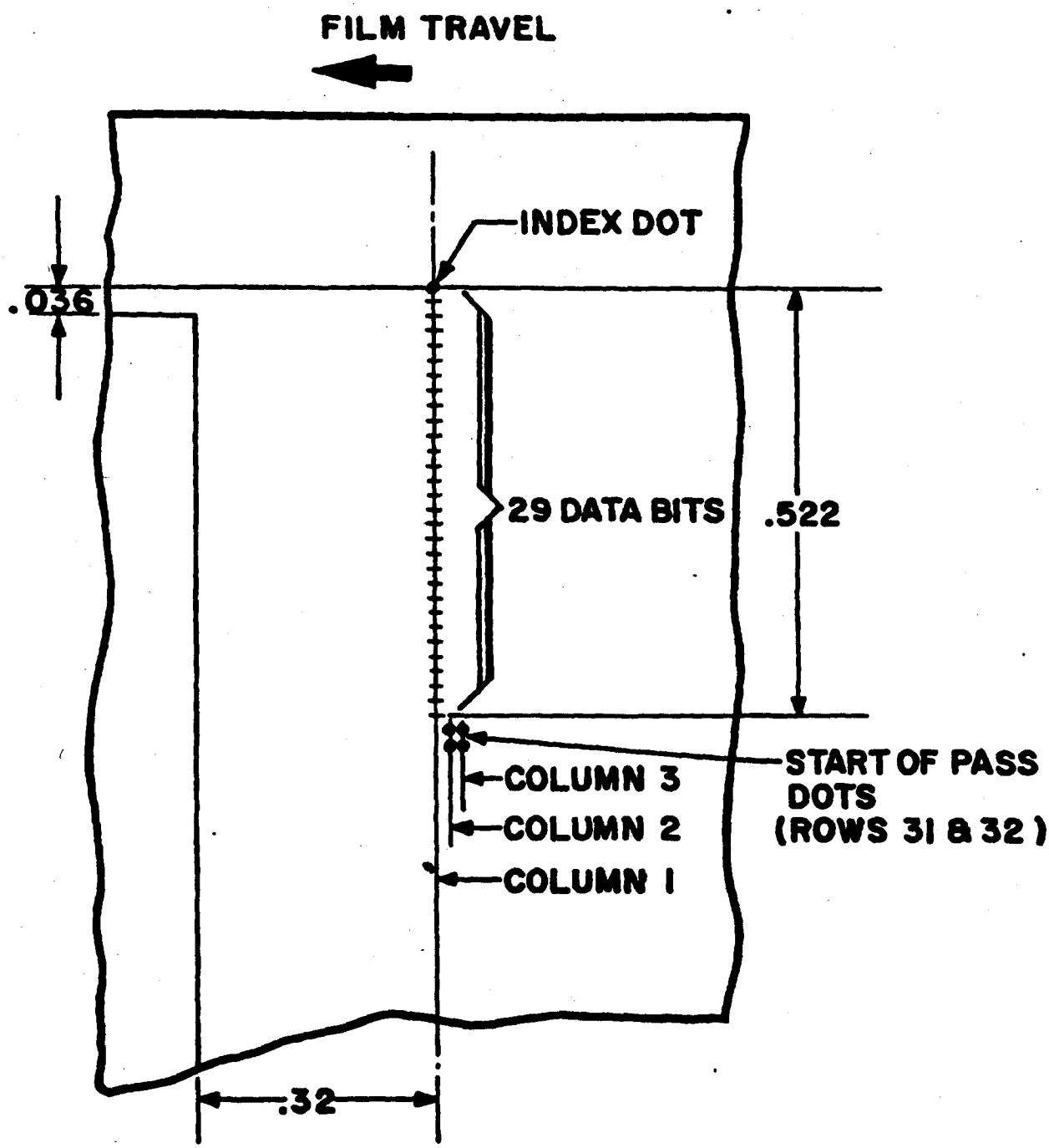
VIEW FROM EMULSION SIDE

NOTE:

1. THESE FIDUCIALS INDICATE DIRECTION OF FLIGHT WITH RESPECT TO TERRAIN CAMERA CONFIGURATION

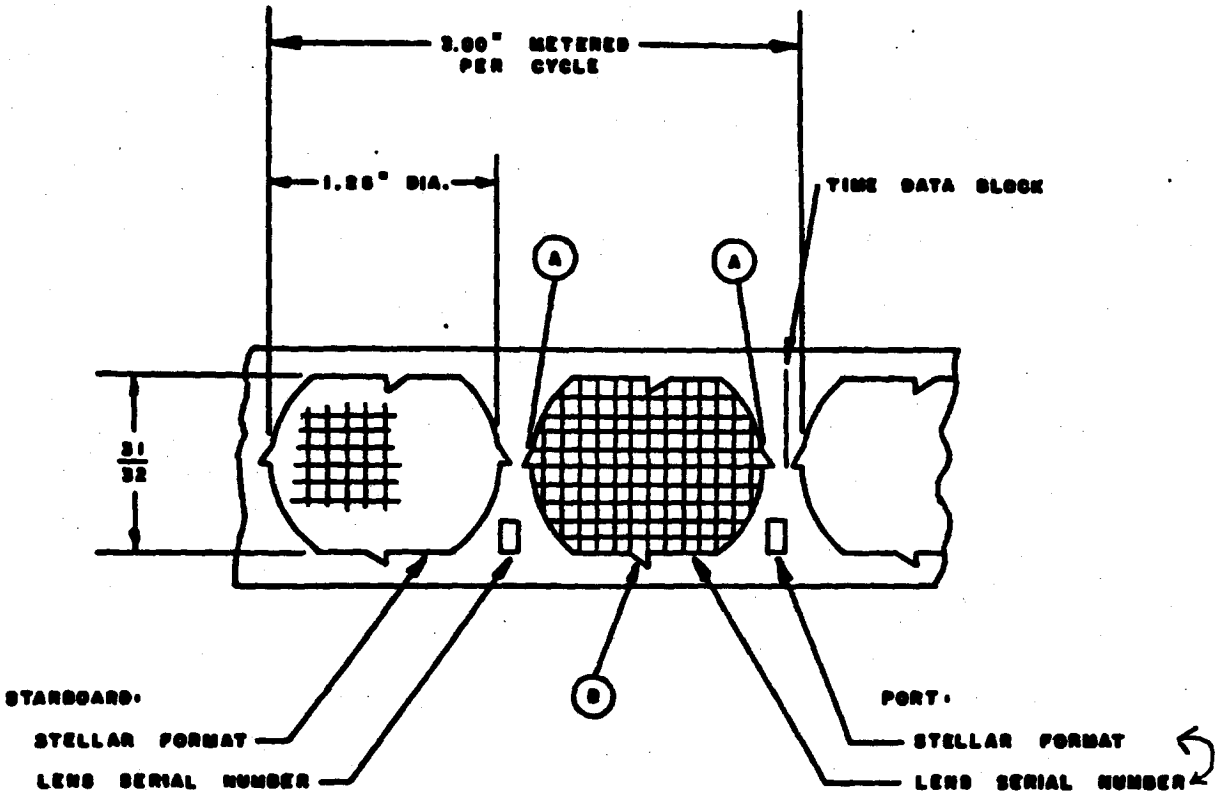
TERRAIN FORMAT

FIGURE 7



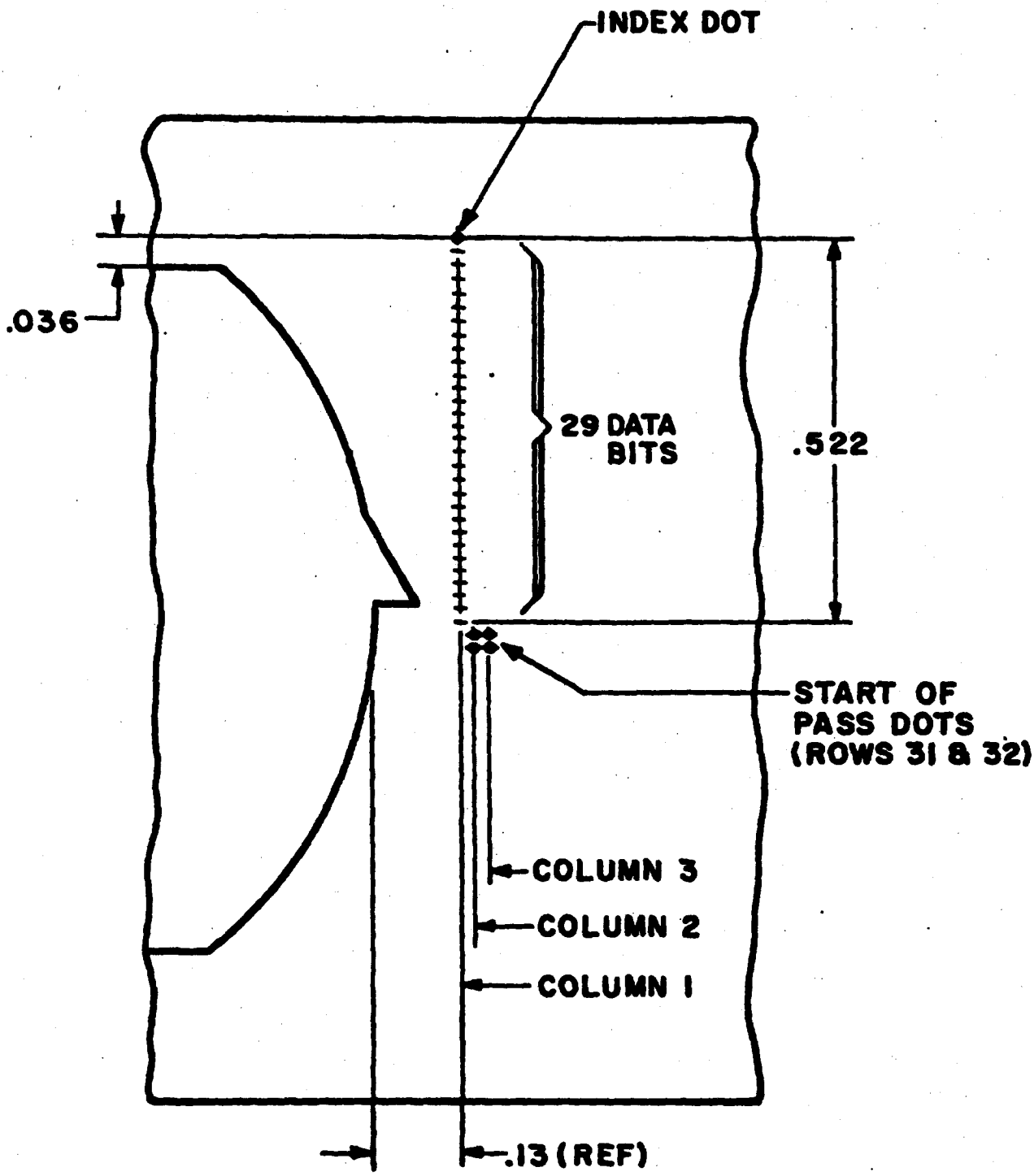
TERRAIN FORMAT

FIGURE 8



STELLAR CAMERA FORMAT

FIGURE 9



STELLAR FORMAT

FIGURE 10

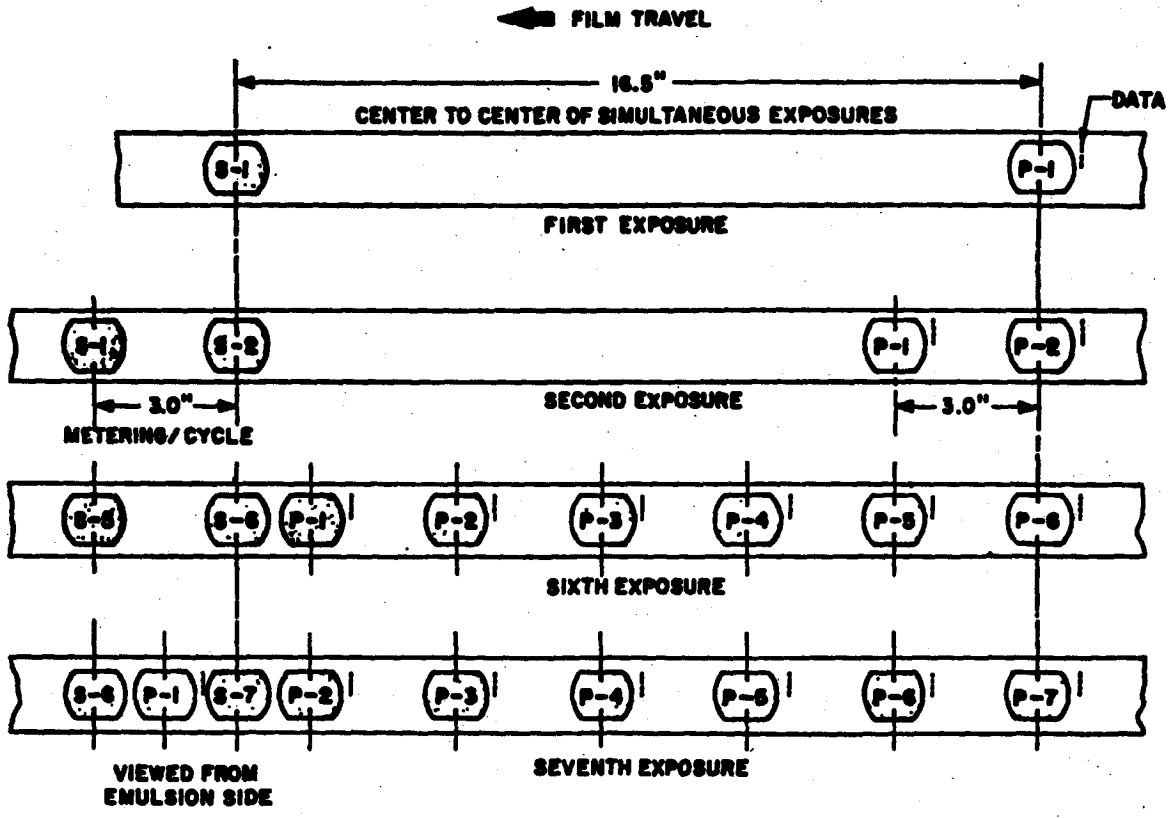


FIGURE 11

STELLAR 35MM FILM FORMAT

STELLAR CAMERA

Stellar photography provides a means for very accurate determination of pitch, roll, and yaw during operational cycles. One stellar photograph is pointed out either side with the axis 10° above the horizontal. A reseau is provided to correct for image distortion and to recover geometric orientation.

STELLAR CAMERA DATA

Table 5
Stellar Camera Data

Focal length	3 inches
Field Angle	Approximately 23½°
Aperture	f/2.8 T/3.1
Exposure Time	1.5 sec
Filter	None
Format Size	1.25 sec with flats diameter
Film Type	3401
Film Load	35mm by 2000 feet
Reseau Gl	Glass plate with 2.5 mm interval grid
Shuller	Rotary
Knee Angle	100°
Max Distortion	15 microns (R) 5 microns (T)

Either of the stellar cameras can be capped if sunlight (which could degrade the imagery from the other camera) shines directly into the lens.

The stellar camera cycle period is 3.125 seconds, while the terrain camera is operating as a slave to the panoramic camera. When the terrain camera is operating independently, the stellar camera operates once for each terrain exposure. The lens serial number for each stellar camera is exposed on the format (see Figure 9). The time word is exposed adjacent to the port serial number. The port serial number is further identified by a "P" after the number. Start of pass marks is exposed adjacent to the time word as shown in Figure 10. The format sequencing is shown in Figure 11.

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 as shown in Figure 9.

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 subsystem 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 film during the scan.

The lens barrel of each panoramic camera is rotating continuously during camera operations.

IMC is achieved by tilting or nodding the camera. The rate of IMC is a function of operating speed, is variable, and is controlled by a V/H programmer.