~~TOP SECRET~~

Handle Via TALENT - KEYHOLE Control Only

TCS-20292/70
Copy 159
29 pages

18.1

NRO
National Reconnaissance Office
DATA
BOOK

THE KH-8B CAMERA SYSTEM

THIRD EDITION

PUBLISHED BY
NATIONAL PHOTOGRAPHIC INTERPRETATION CENTER
OCTOBER 1970

Group I Excluded from Automatic
Downgrading and Declassification

~~TOP SECRET~~

Handle Via TALENT - KEYHOLE Control Only

PREFACE

This data book has been prepared by the National Reconnaissance Office with the assistance of the National Photographic Interpretation Center to facilitate the use of the photography from the KH-8B camera system. This book revises and updates previous releases concerning this system.

Third Edition

October 1970

TABLE OF CONTENTS

Page

LIST OF ILLUSTRATIONS

INTRODUCTION

The KH-8B camera system (Figure 1) consists of four cameras and two recovery buckets. Various improvements are designed to increase the primary camera resolution by about 30% and increase the lifetime of the vehicle by an additional 6 days over the next 10 missions (starting with 27). The Primary camera is designed to produce high-resolution, large-scale photography of selected target areas.

A separate unit, the Astro-Position Terrain Camera (APTC), contains the other 3 cameras, one 75mm focal length terrain frame camera and dual 90mm focal length stellar cameras. The terrain camera is designed to point in the direction of the principal ray of the main camera. It provides mapping coverage and images for relative orientation. The stellar cameras are pointed 180 degrees apart, one to the port (left) side of the vehicle and one to the starboard (right) side. These provide at least one reduceable stellar frame with each main camera frame. The APTC will also be improved by providing a larger film load.

MAIN CAMERA

Strip Cameras

A strip camera is a device which stabilizes an image in the focal plane of the camera by moving film past a stationary slit at the same speed that the image is moving past the slit. When these two motions are synchronized, an unsmeared image is recorded on the film.

If these motions are not synchronized, the images are distorted by either compression or elongation in the direction of film movement.

Mensuration techniques allow for these variations in film speed and permit determination of changes in film speed with a high degree of accuracy.

When the camera is operating normally, the film speed should be within 0.6 mm/sec of the speed desired, except during looper action and start up transients. Image distortion will also occur if the film speed drive malfunctions or is commanded to operate at the wrong speed. However, this compression or elongation will not be discernible to the photointerpreter, and proper mensuration techniques still permit accurate mensuration of images on the film.

Optics

The optical part of the main camera consists of a flat stereo mirror, an aspheric mirror used as a converging lens, a corrector lens assembly, a slit, and a platen.

Film Drive

The film-drive mechanism is designed to maintain highly accurate and consistent film speeds throughout camera operation and through the following range of possible image motion: altitude from 65 to 135 nautical miles (nm) and obliquity angles from 0 to 45 degrees.

The film load can be either 10,000 feet of black and white 1414 ultra-thin-base (UTB) film; 7,500 feet of SO-242 UTB color film; or a combination of both film types which results in a variable film load. The film-drive mechanism prevents motion, except rotation of the platen, during normal exposure.

Accurate determinations of film speed can be made by measuring the time-track recordings on the edge of the film. These aid greatly in determining the mensuration capability for missions (See Recorded Data, p. 9).

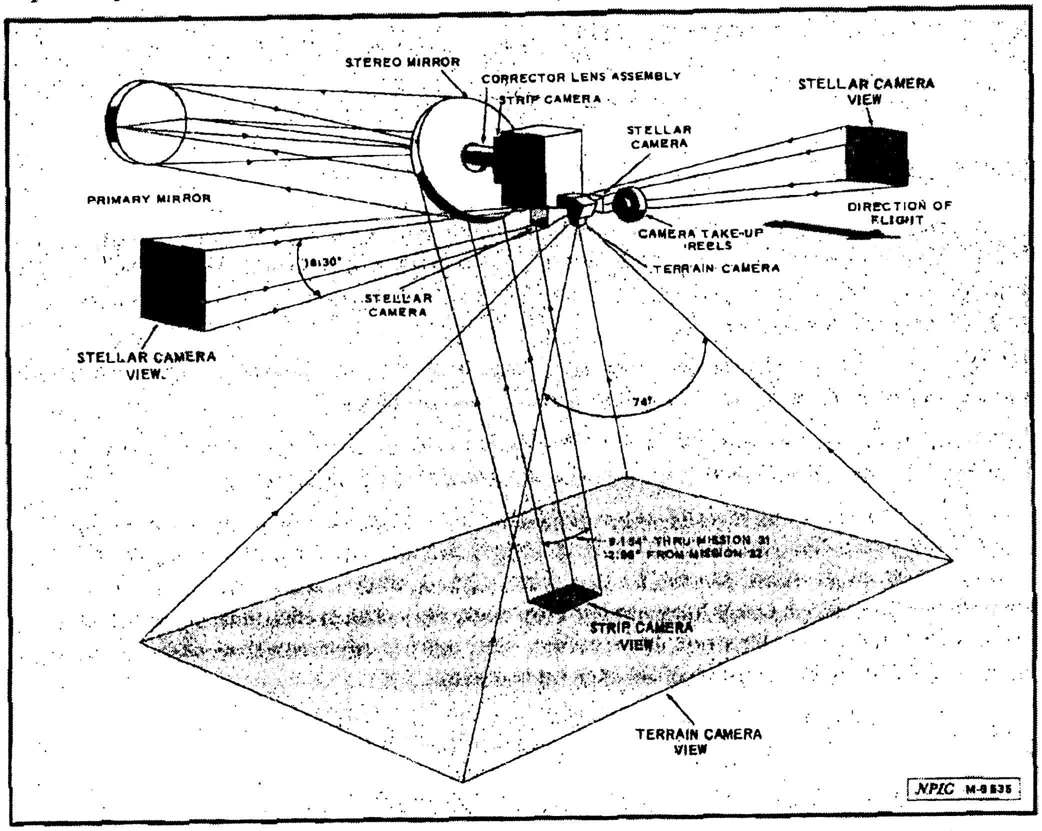


FIGURE 1. KH-8B CAMERA SYSTEM

Exposure

Film speed, slit size, and sun angle determine the exposure of images on the film. Since the film speed is determined by the speed of images in the focal plane, variation in film speed cannot be used for exposure control. Several slits have been supplied so that exposure can be controlled from sun angles of from 2 to 90 degrees and throughout the range of film speeds available (Figure 3).

Faster film speeds shorten and wider slits lengthen the exposure time. The film speed is determined by the image speed, and then the sun angle (and predicted snow cover) are viewed to find the best possible exposure. With these two parameters determined, the slit with the nearest exposure time for this combination can then be programmed.

Exposure may be determined by this formula:

$$T = W/VF$$

Where:

T = Exposure time in seconds

W = Slit width in inches

VF = Film velocity in inches per second

Unpredicted snow cover, desert scenes, and heavily wooded areas present special exposure problems. Consequently, some frames on each mission will not have the best possible exposure. These individual frames can be enhanced through printing techniques.

Control

The vehicle control system is designed to allow accurate pointing of a main camera system to the area of interest. The stereo mirror is rotated in the pitch plane of the vehicle to give the necessary angular relationship for stereoscopic coverage. The mirror can be stopped in any one of 3 positions. The effective lines of sight are 8.65 degrees forward from the vertical, vertical, and 8.65 degrees aft. Normal stereo is obtained in the forward and aft positions, but may be acquired in other modes.

The mirror is crabbed in the roll plane to compensate for the Earth's rotation.

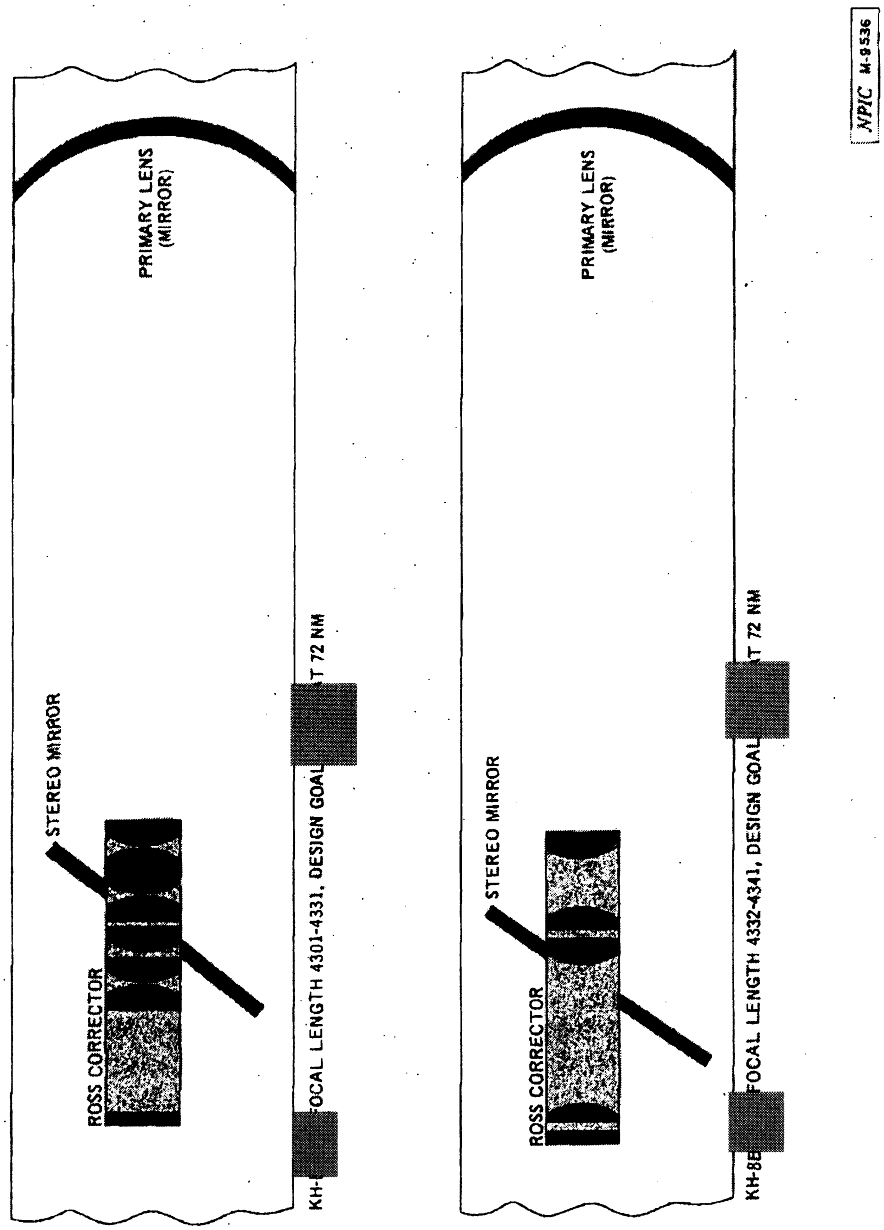


FIGURE 2. KH-8B LENS IMPROVEMENT PROGRAM

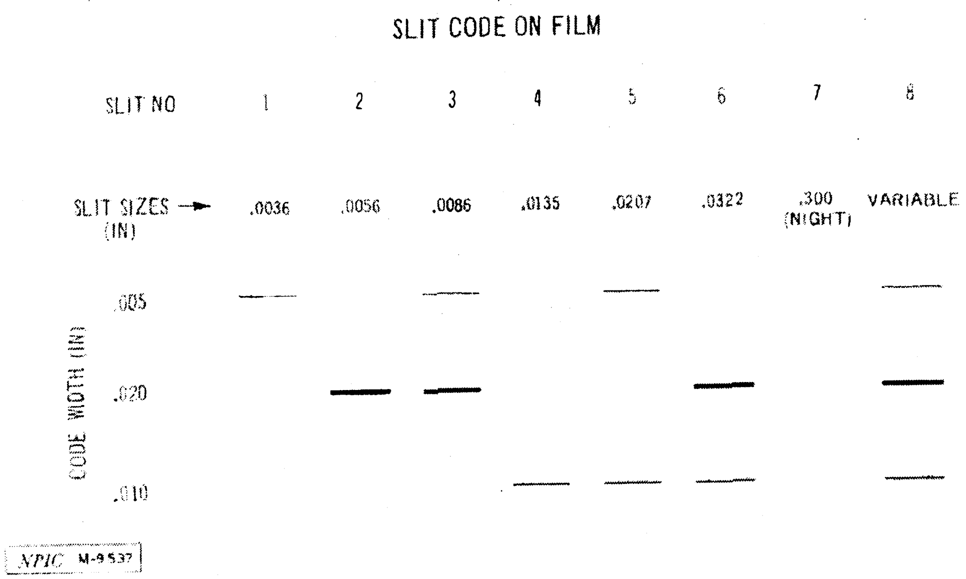


FIGURE 3. SLIT CODE ON FILM

Modes of Operation

The main camera can be used in various ways to provide the best views and selection of targets. These include:

Stereo: Fwd-aft, fwd-vertical, vertical-aft, fwd-vertical with aft mono, fwd-aft with vertical mono, fwd mono with vertical-aft.

Stereo: Double stereo fwd-aft of target with fwd-aft of second target interspersed.

Mono: Forward, vertical, aft, lateral pair, lateral triplet, end to end, and strip.

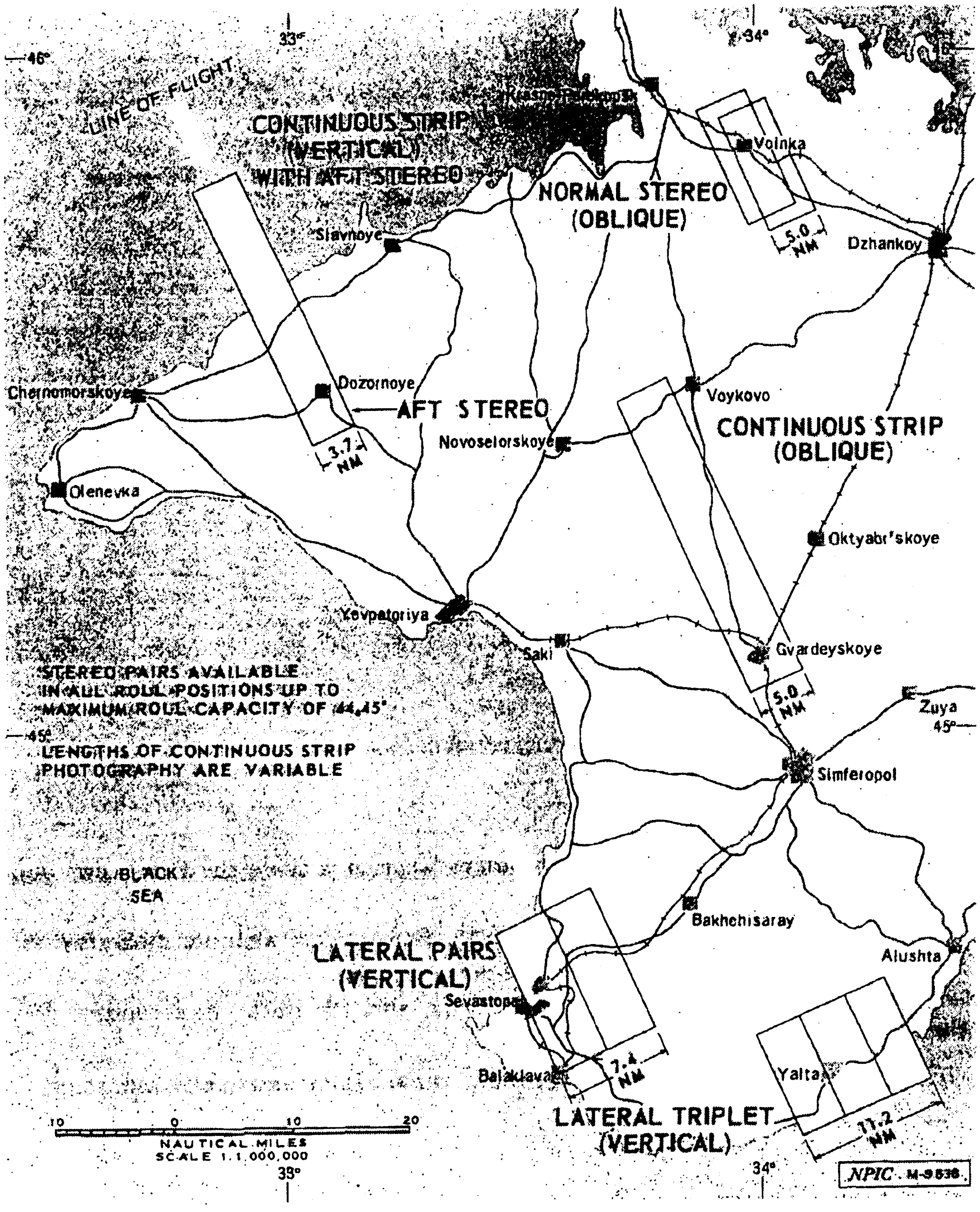


FIGURE 4. FRAME COVERAGE WITH 160" FOCAL LENGTH LENS

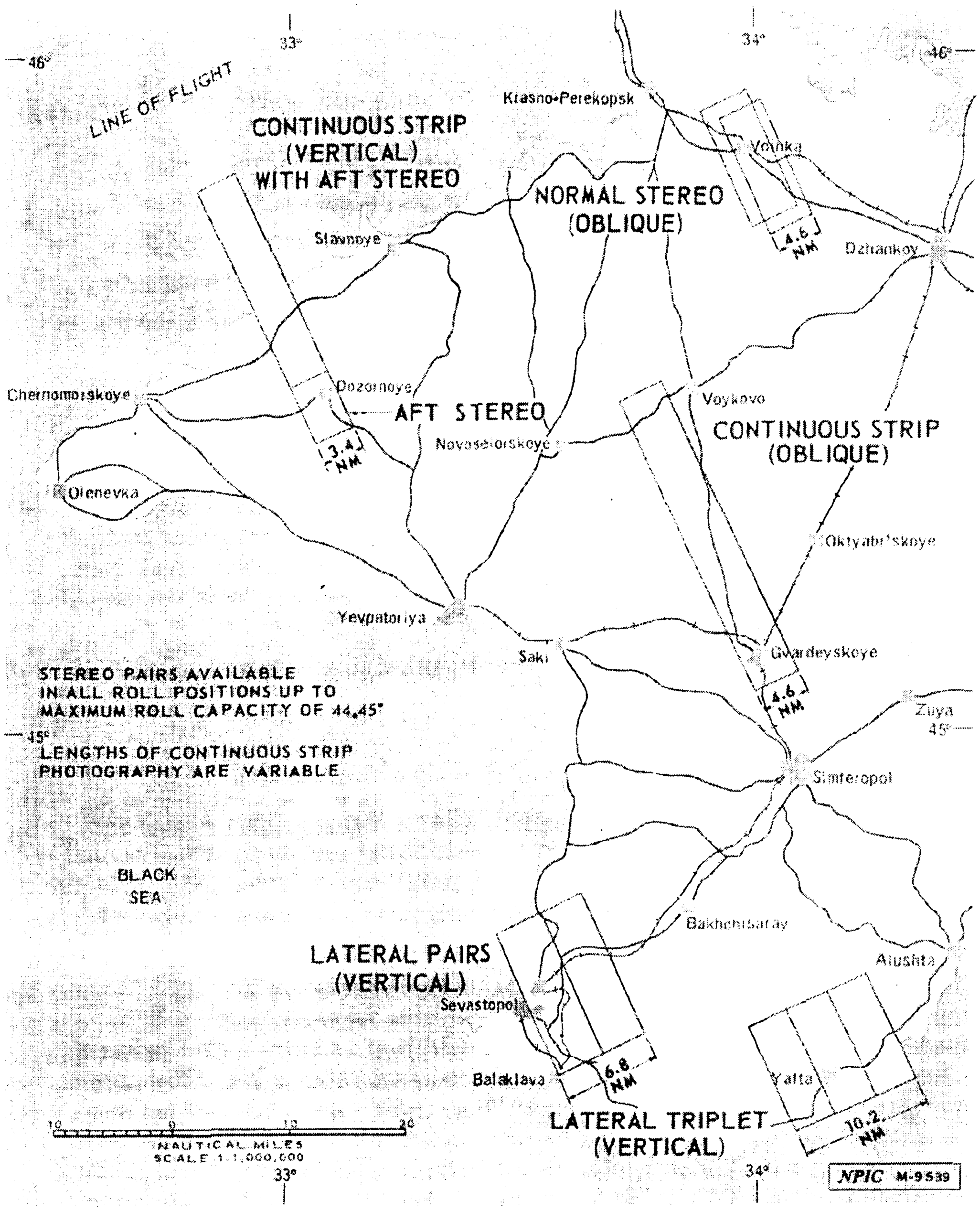


FIGURE 5. FRAME COVERAGE WITH 175.6" FOCAL LENGTH LENS

Table 1. Main Camera Improvements

Mission	Improvement
27	Low coefficient stereo mirror
29-31 (only)	Minus red filter coated on [redacted]
32	Focal length increase fro[redacted]
32	Flatter field & color corrected lens
26-32	Approach lower end of altitude range

Start-up Times and Film Coast

This system utilizes film moving on the platen face to record imagery; and, since this is a dynamic motion, a 0.25-second start-up transient time is necessary for the film to gain the proper speed. Also, when the command to stop is received, the platen and film coast to a stationary position. This coasting distance varies with the speed of the platen, but it is between 0.3 and 1.35 inches.

These two areas of the film may record some degraded imagery which should not be used for interpretation mensuration.

Format

The main camera records the image and all data on a film roll 9.5 inches wide (Figures 6 and 7). The image area is 8.810 inches wide with a yaw slit 0.100 inch wide on both sides of the film. The yaw slits record images at the ends of the main slit and provide some checks on vehicle motion (see Figure 6). Two data tracks are recorded outside the yaw slit on one side of the film.

The end-of-frame markers are recorded on the opposite edge of the film. At the beginning of each exposure or frame, the film will have remained stationary for a period far in excess of any normal exposure time, resulting in a burn-in area or burn-in line. A pair of frame-line position marks are centered about a line 2.25 inches preceding the burn-in area or burn-in line. These marks are produced by lamp exposure in the area normally reserved for labeling on the edge opposite the data tracks. The location and dimension of these marks is given in Figure 4. These marks are simultaneously flashed 700 $\pm$ 50 milliseconds after the camera is commanded off.

Titling Information

Titling information is on the base side of the original negative along the edge opposite the time track. It includes:

	SAMPLE
a. Revolution number (Pass)	196
b. Frame number	27
c. Mission - bucket number.	4332-2
d. Date of actual photography	Jan 4, 1970
e. Classification	TOP SECRET RUFF
f. Index number	+33

This information is repeated on long frames within each 18 inches of film. The frame numbers remain constant within each frame, but the index numbers advance sequentially with each title. Frames are numbered sequentially within each pass, beginning with 001. Index numbers on each pass also begin with 001.

Recorded Data

The data tracks are located near the left-hand edge of the primary film (see Figure 6). These data tracks record as photographic code marks such pertinent data as vehicle time, time of terrain camera shutter actuation and roll position.

A time label is recorded on data track A at 200 millisecond intervals. Each positive bit in the time code causes a lamp to produce a 1-millisecond exposure. The first bit in the code is always positive (binary one) and serves as synchronization pulse. The synchronization pulse is followed by a 22 bit time word with least significant bit first. For example, Figure 8 reads:

binary	1	010	010	111	111	111	100	100	10
octal		2	2	7	7	7	1	0	1

or, reading from most to least significant bit, 10177722.

A slit identifier code is also recorded on the same edge of the frame as the time track. This recording identifies the slit that is being used by continuously recording a code in three channels on the film edge (Figure 3).

Data track B is a 500 pulse-per-second timing signal containing the complement time label of data track A and the terrain camera shutter actuation indicator.

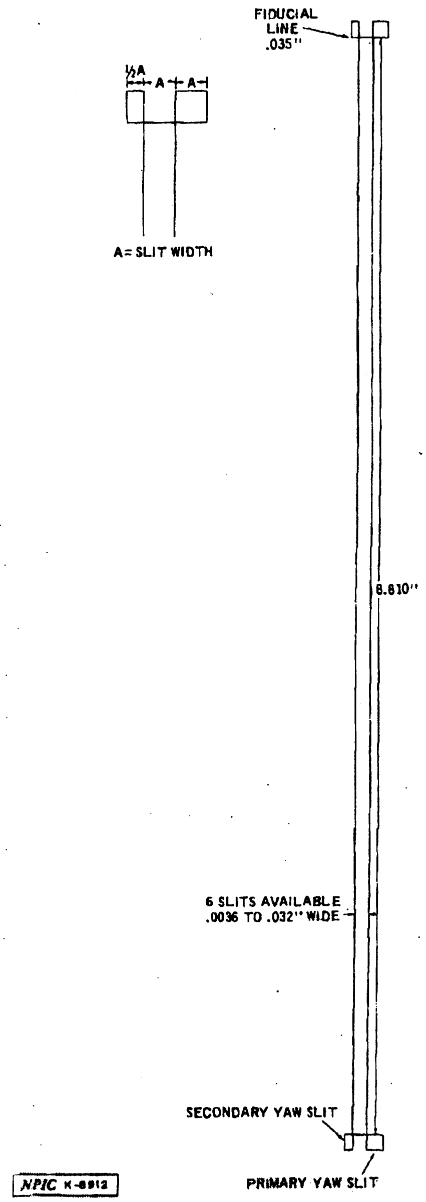


FIGURE 6. PRIMARY CAMERA SLIT

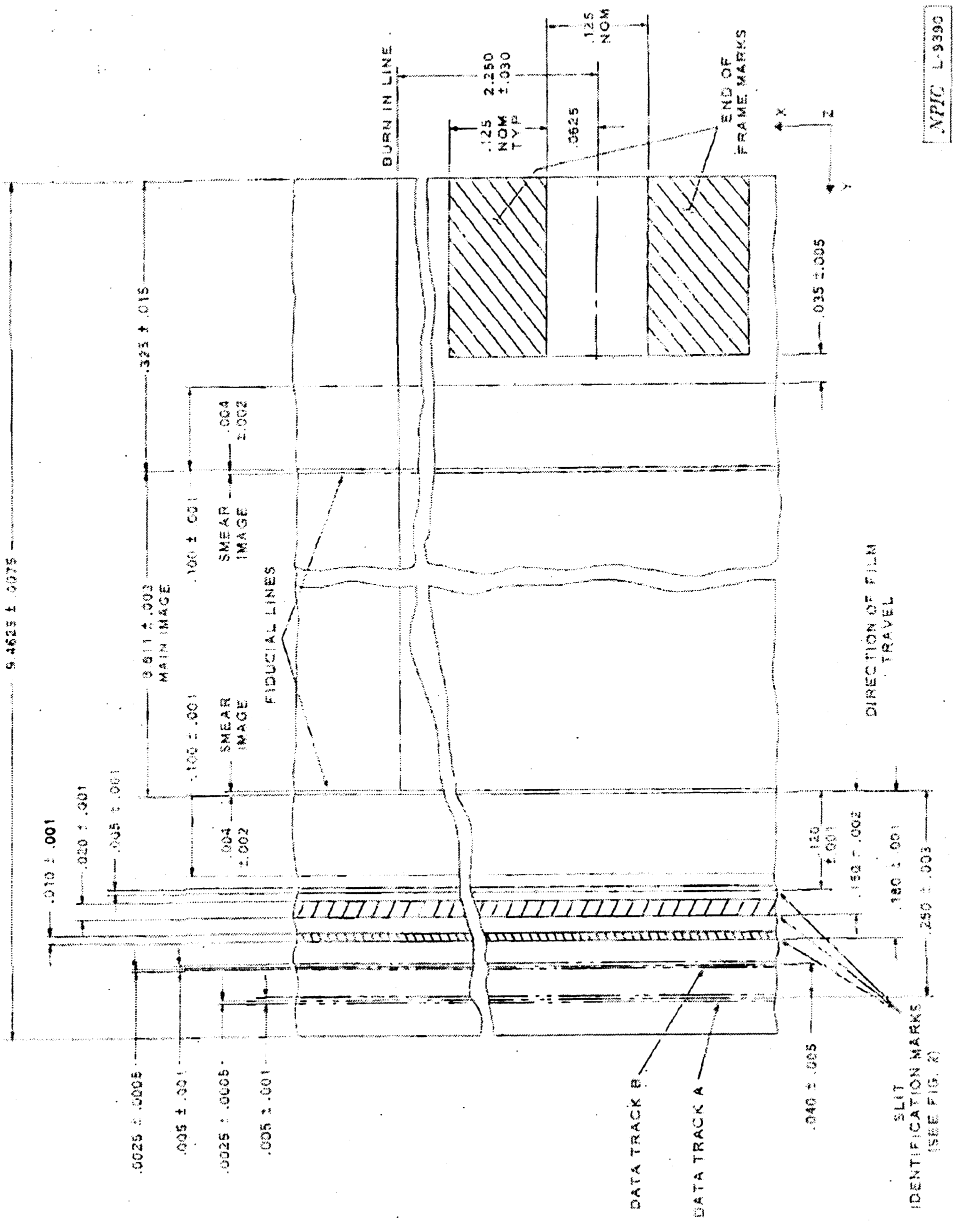


FIGURE 7. PRIMARY CAMERA FILM FORMAT, FILM NEGATIVE EMULSION SIDE DOWN

In addition to the data recorded in the camera system, there are other sources of information available such as telemetry, command lists, calibration manuals, computer sources, and the mission correlation data (MCD), an outline of which is given below.

Mission Correlation Data

A. <u>Data Output at Beginning of each Run</u>

1. Earth constants
2. Vehicle Payload Constants:

a. Primary:

(1) Slit calibrations
(2) Focal length
(3) Field angles
(4) Mirror pitch angles (calibrated)
(5) Skew angle

b. APTC:

(1) Focal lengths (3 cameras)
(2) Field angles (3 cameras)
(3) Calibration angles (3 cameras)

B. <u>Data Output at the Beginning of Each Rev Which Has Camera Operations</u>

1. Start of new rev indicators:

a. Rev & mission number
b. GMT date of new rev
c. GMT time & longitude of ascending node

2. Ephemeris Data:

a. Vehicle inertial position (X, Y, Z)
b. Vehicle inertial velocity (XD, YD, ZD)
c. Vehicle inertial acceleration (XDD, YDD, ZDD)

C. <u>Data Output for Primary Camera Operations</u>

1. Event data:

a. Rev number
b. Frame number
c. Duration of event (camera exposure time)
d. Mode:

(1) One-half of a stereo pair
(2) Strip
(3) One-half of a lateral pair
(4) F = mirror fwd
(5) V = mirror vertical
(6) A = mirror aft

e. Aperture designator (slit size)
f. Cone angle (angle between nadir and principal ray)
g. Camera roll
h. Film velocity (theoretical & commanded) in inches/second
i. Camera crab angle
j. Effective shutter speed
k. Intrack-crosstrack scale
l. Frame altitude
m. Skew angle
n. Frame length in inches

2. Target Data:

a. Programmed (Target ID)
b. Actual target ID, priority and X and Y coordinates on frame for target location
c. Marginal targets
d. Frame corners latitude and longitude

3. Ephemeris and Positioning Data:

a. System time referenced to GMT
b. Geodetic position of vehicle nadir
c. Geodetic position of intersection of camera principal ray with the earth.
d. Vehicle altitude
e. Inertial velocity & azimuth of vehicle
f. Flight path angle of vehicle
g. Sun elevation & azimuth
h. V/H (Velocity/Height) ratio in radians/second
i. Payload clock time (OCTAL)

4. Programmed blank frame event & corresponding data:

D. <u>APTC Camera Data</u>

1. Dependent operation
2. Independent operation

3. Frame number
4. Time of exposure GMT & OCTAL
5. Shutter speed
6. Geodetic Latitude & Longitude of Principal Ray
7. Altitude & radial distance
8. Inertial velocity & azimuth
9. Right ascension
10. Camera roll
11. Velocity/height ratio
12. Right ascension & declination
13. Solar azimuth & elevation
14. Flight path angle
15. Swing angle

E. <u>Film Summary Data</u>

1. Primary Camera Data:

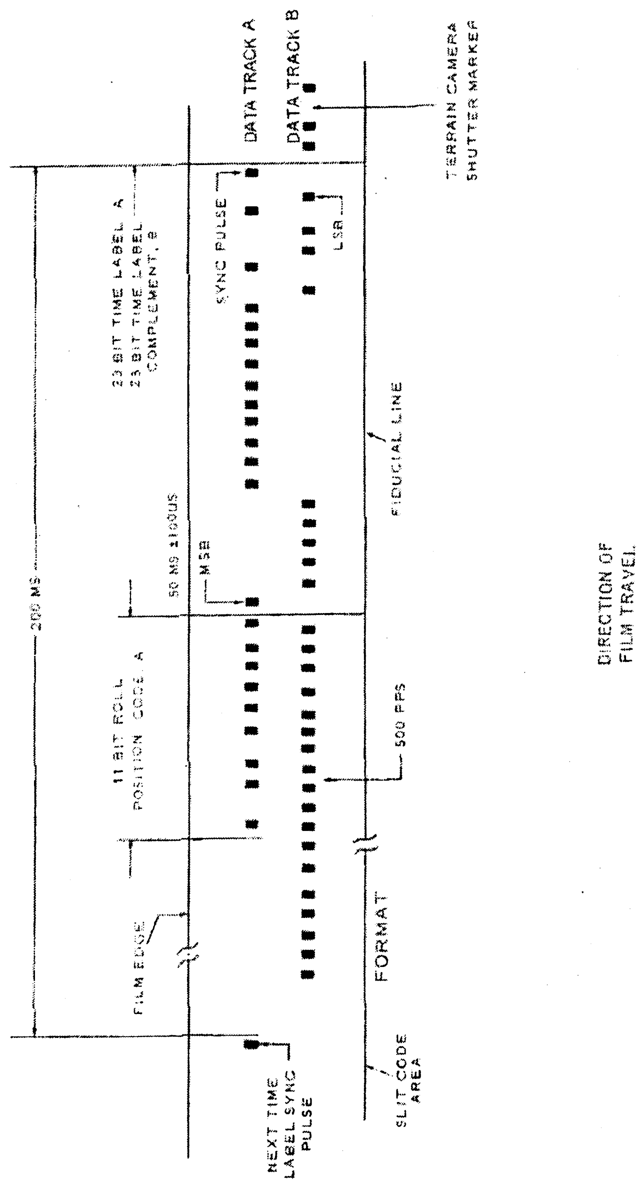
(a) Rev number
(b) Exposed frames & footage
(c) Unexposed frames & footage
(d) R&D exposed frames & footage
(e) Total footage for rev
(f) Total footage for mission

2. APTC:

a. Independent & dependent frames
b. Blank frames
c. Rev and mission total footages

ASTRO-POSITION TERRAIN CAMERA

The Astro-Position Terrain Camera (APTC) system is used to produce: 1) terrain photographs for image correlation, mapping, geodetic, and relative orientation purposes, and 2) stellar photographs for attitude determinations and rate computations (Figures 9, 10, and 11).



NPIC M-9540

FIGURE 8. PRIMARY FILM DATA TRACKS, NEGATIVE EMULSION DOWN

NPIC M-9541

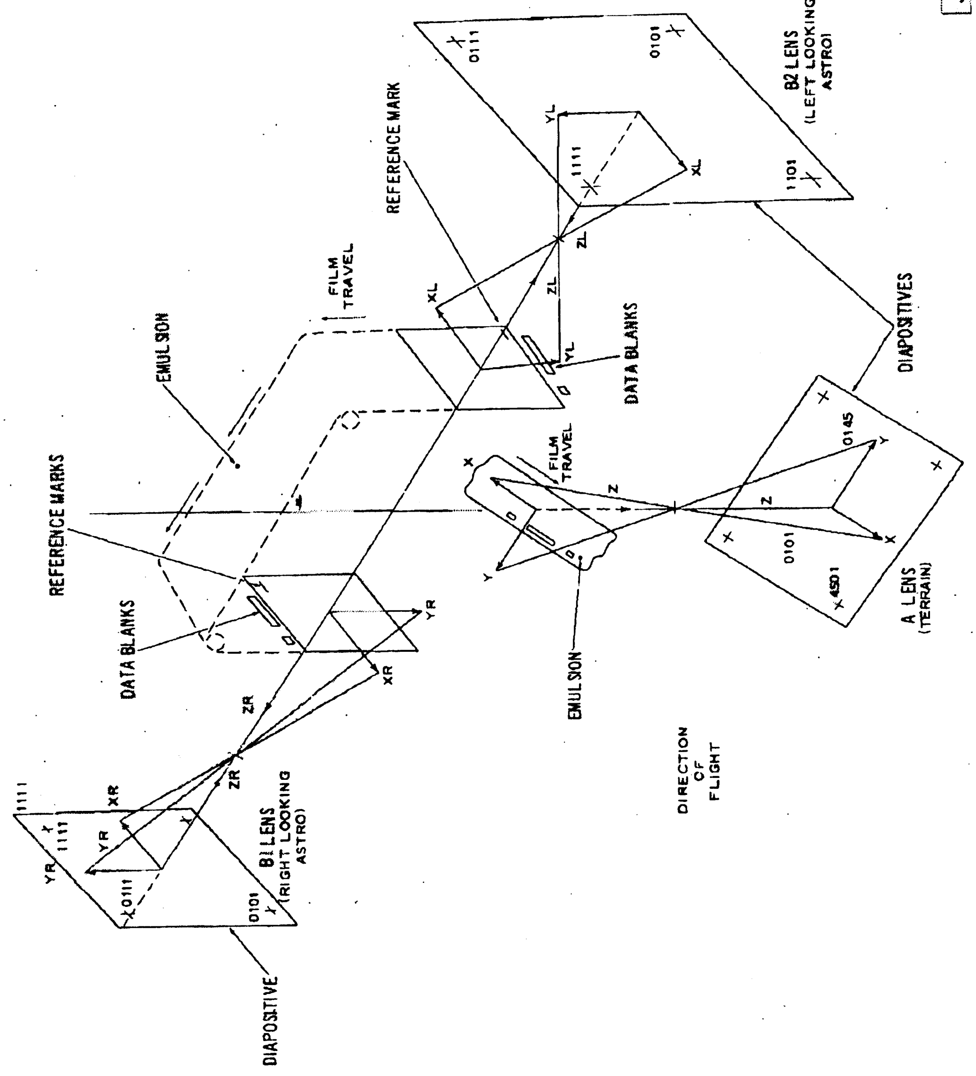
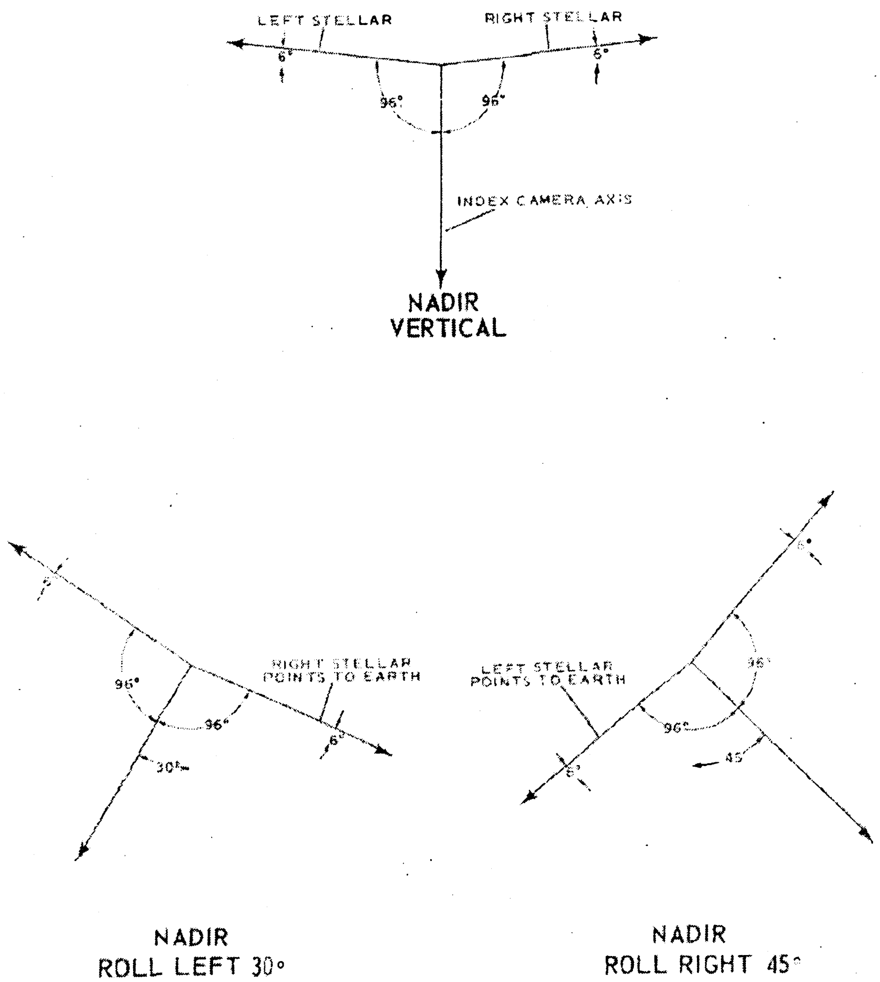


FIGURE 9. THE ASTRO-POSITION TERRAIN CAMERA COORDINATE SYSTEM



NPIC M-9542

FIGURE 10. APTC ORIENTATION

Terrain Camera

The terrain camera is an f/5.0 frame camera with a 75 mm focal length. The camera uses an Aptcagon lens with a 74-degree field angle and produces frames 4.5 x 4.5 inches on 5-inch film. The camera contains sufficient ultra-thin-base (UTB) 5-inch film to photograph approximately 3,190 frames per mission. The film load will be increased with Mission 4330 to match the new APC capacity of 4,150 frames per mission.

The primary purpose of the terrain camera is to provide input to relative orientation computations for an accurate determination of the attitudes of the main frame. The terrain camera and the stellar cameras are accurately calibrated. The terrain camera is also used independently for mapping and geodetic purposes to obtain photography of poorly mapped or controlled areas of the world.

Titling Information

The titling information for the terrain camera is placed on the base side of original negatives. The information is along the edge of the film, opposite the binary time word. It includes:

Pass number

Frame number

Mission number

Date of photography

Classification

Pass numbers are titled in the blank frame at the beginning and end of each pass. Frames are numbered sequentially throughout each pass, beginning with 001. The terrain format is shown in Figure 12.

Data

Table 3. Terrain Camera Data

Focal length	75mm
f number	5.0
Half field angle	47 deg diagonal
Full field angle	94 deg
Film format	4.5 x 4.5 in
Film type	1414
Exposure	1/200 sec, 1/300 sec, and 1/500 sec (changeable on orbit)
Film supply	3,190 to 4,150 frames
Reseau	2.5-mm grid

Stellar Camera

The stellar cameras, pointed out opposite sides of the vehicle, are used to match main camera frames with useable stellar frames. These cameras point with the main camera. Therefore when the main camera rolls the APTC rolls to the same place. Since high roll angles would cause a single stellar camera to be pointing at the ground half the time, two stellar cameras are required to get full coverage. They are mounted to point six degrees above the horizontal line through the vehicle to eliminate albedo light. Therefore, in the vertical and near vertical positions, two useable photographs will be taken.

The stellar cameras are f/2.0 cameras with a 90-mm focal length, a 25.6-degree field angle, and a 29 x 29mm square film format (Figure 13).

A 2.5-mm reseau grid superimposed on the format of both the stellar and terrain cameras aids in calibration and data reduction.

The stellar cameras produce two exposures with each index frame, and, since these two cameras are physically separated, the same left and right exposures are two frames apart on the film.

The exposure time selected for the stellar cameras is 0.4 seconds. However, if this should prove inadequate, it can be changed to .8, 1.2, 1.6, or 2.0 seconds as necessary on future missions.

Titling Information

The original negative on the stellar camera is not titled except for the beginning and end of each pass. The duplicate negatives are titled on the base side, the duplicate positives are titled on the emulsion side.

The information carried on the duplicate negatives and duplicate positives includes the frame number (in sequence) and the left or right designator. The sequence of photographs in each stellar pass is as follows: 1 left, blank, 2 left, 1 right, 3 left, 2 right, 4 left, 3 right, etc. The leader contains the mission number and classification. The stellar format is shown in Figure 13.

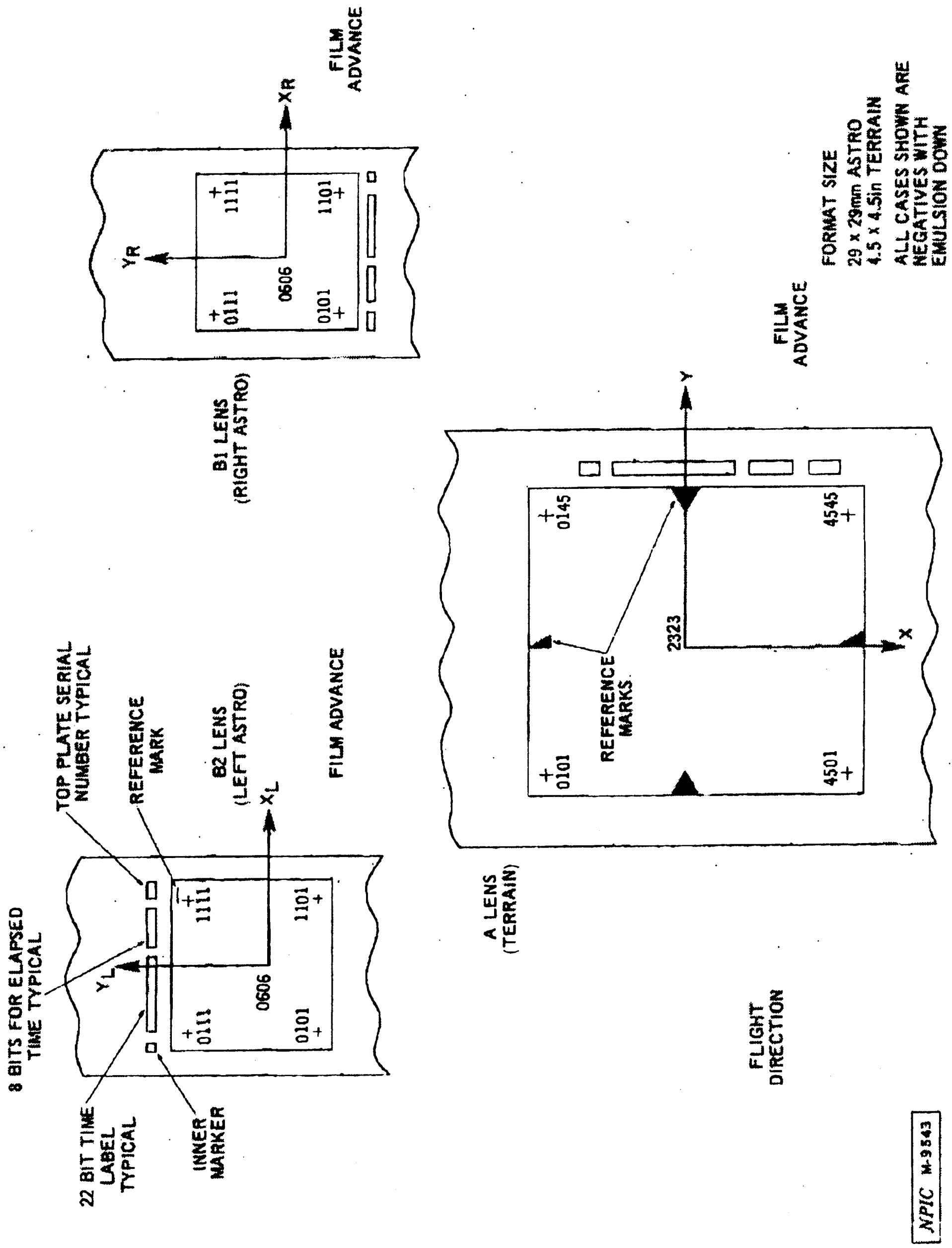


FIGURE 11. APTC FILM FORMAT AND IDENTIFICATION OF RESEAU INTERSECTIONS

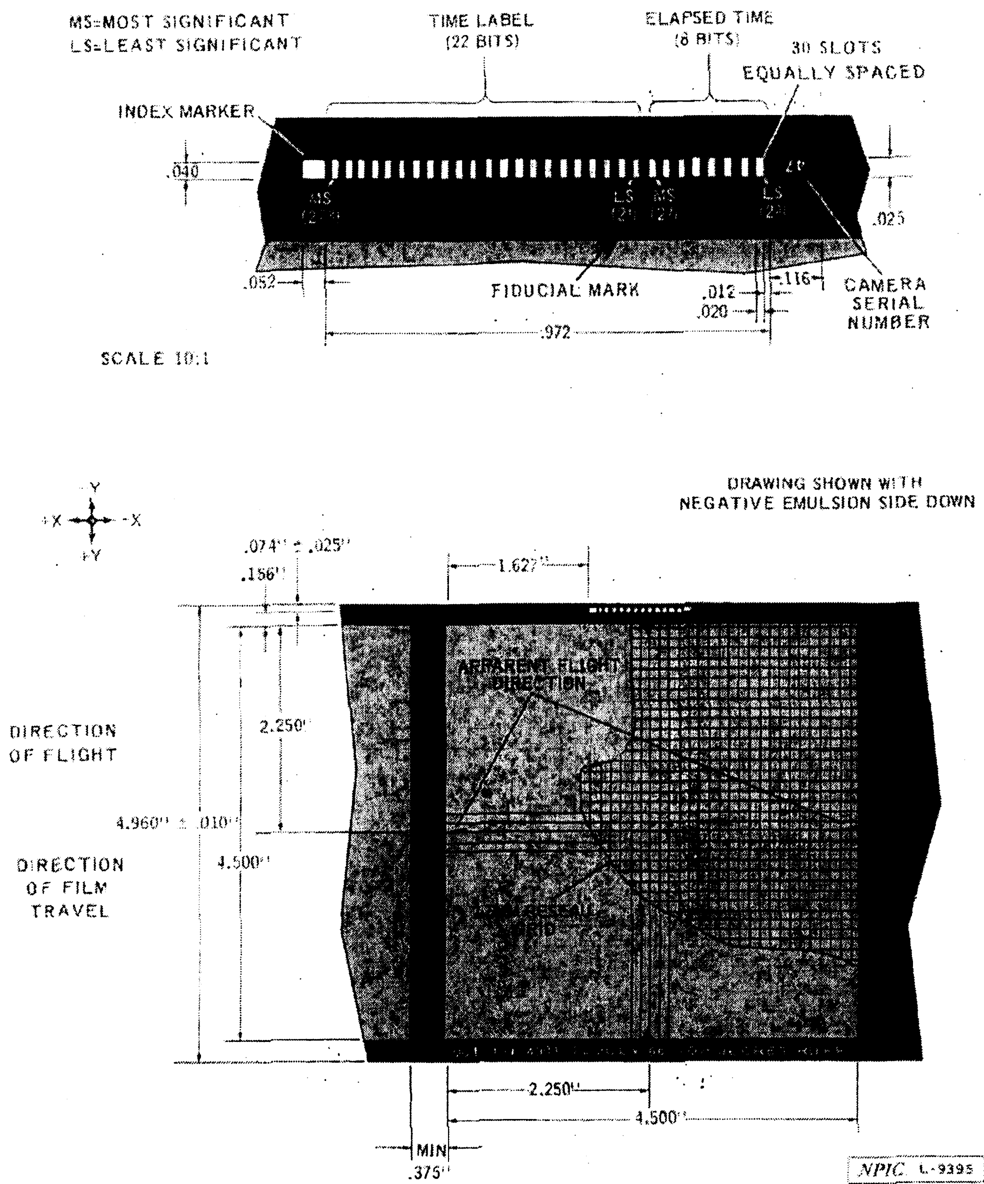


FIGURE 12. TERRAIN CAMERA FORMAT

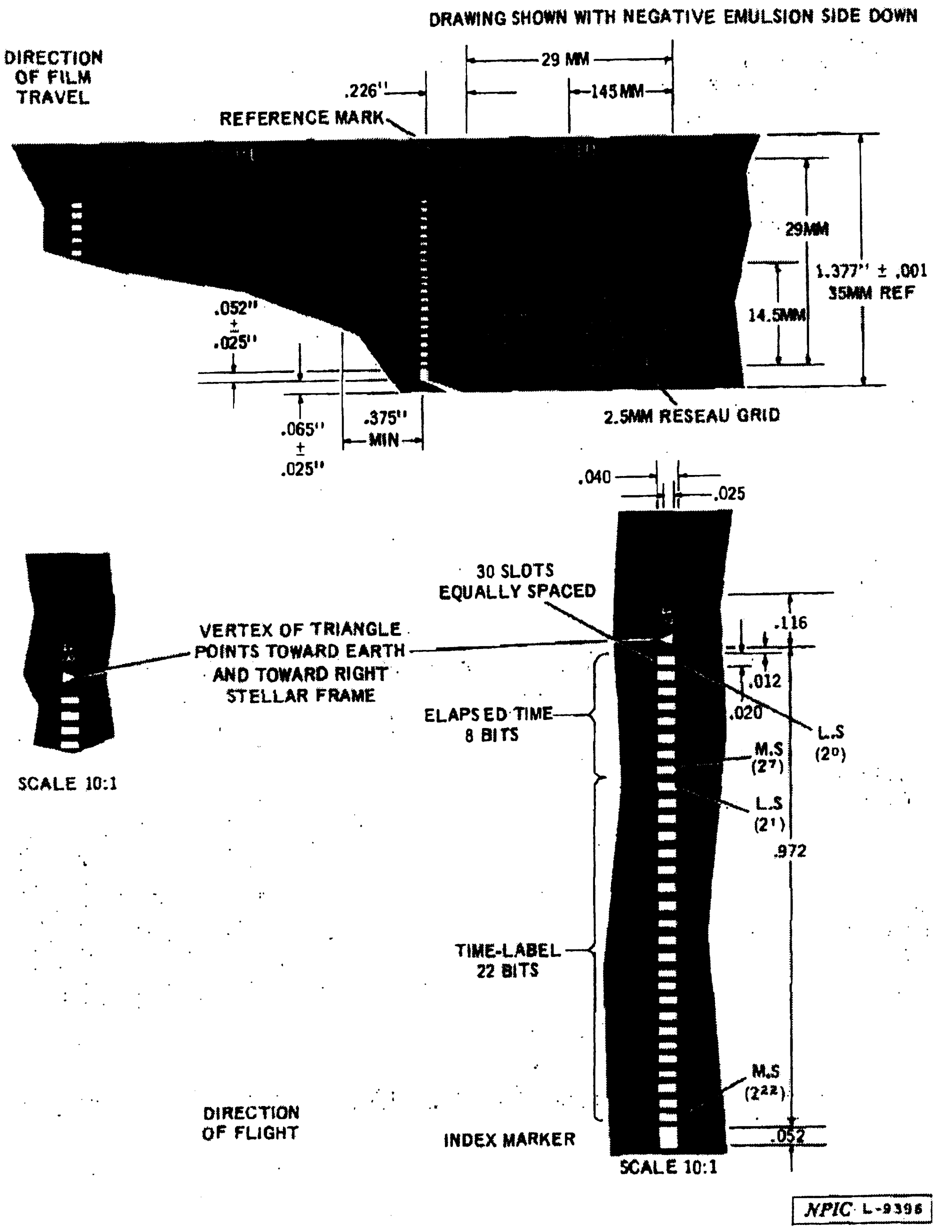


FIGURE 13. STELLAR CAMERA FORMAT

Data

Table 4. Stellar Camera Data

Focal length	90 mm
f number	2.0
Half angle	12.8 deg diagonal
Full angle	25.6 deg
Film format	29 x 29 mm
Film type	3401
Exposure	0.4 sec (standard), changeable at factory up to 2.0 sec
Film supply	3,190 and 4,150 frames
Reseau	2.5-mm grid

APTC Operation

The APTC can operate in either a dependent mode with the main camera or in an independent mode for mapping or geodetic purposes.

The independent mode is utilized exclusively for coverage of areas of the world that have inadequate maps or inadequate geodetic bases. The dependent mode is used to match the main camera frames with reduceable stellar frames. For strip photographs of long duration, one reduceable frame will be cycled each 10 seconds of operation.

Both the terrain camera and the stellar cameras record the time of exposure to an accuracy of .001 second in a 30-bit binary time word in the space outside the frame. The stellar cameras record the time word across the format and the terrain camera records along the format. Both units record a camera number or designator at the ends of the time words. The lower 8 bits are used to designate the milliseconds of elapsed time and the higher 22 bits record the actual clock time to .1 seconds.

The stellars are presently inhibited in the near-vertical positions since attitude is not necessary in the lower roll positions. The inhibited portion of the flight is at approximately 16 degrees obliquity.

GLOSSARY

The possible degradation of photography by image smearing is inherent in any aerial photographic system. 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 either parallel to the line of flight or approximately perpendicular to it, depending upon 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 vehicle.

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

FILM SPEED: The rate at which the film is advanced in the camera as a means of compensation for the relative motion between terrestrial images and the camera. If the film is too slow, images of ground objects will be compressed; if it is too fast, images will be elongated.

PITCH: Rotation of the vehicle about its lateral axis. Pitch deviations may be negative or positive with relation to the nominal reference angle, and may alter the camera's effective attitude over ground objects.

PITCH RATE: Motion about the lateral axis--not to be confused with pitch, per se. Pitch rate causes along-track image smearing.

ROLL: Rotation of the vehicle about its longitudinal axis. This results in a change in attitude that alters the slant range of the camera to ground images; hence, it is an along-track error. However, note carefully the distinction between roll and roll rate with relation to image-smear effect.

ROLL RATE:	Motion about the longitudinal axis. Since roll change is perpendicular to the line of flight, it is so recorded by film, resulting in across-track image smears.
YAW:	Rotation from the line of flight of the longitudinal axis of the vehicle about its vertical axis. The resultant displacement of ground imagery is solely in a lateral direction and induces cross-track smearing.
YAW RATE:	Motion about the verticle axis. Smearing caused by yaw rate is negligible.