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CAMERA MANUAL

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PRELIMINARY KH-9 CAMERA MANUAL

PUBLISHED BY
NATIONAL PHOTOGRAPHIC INTERPRETATION CENTER
APRIL 1969

Group 1 Excluded from Automatic Downgrading and Declassification

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WARNING

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NATIONAL RECONNAISSANCE OFFICE
WASHINGTON, D.C.

TCS-20055/69

April 16, 1969

MEMORANDUM FOR: RECIPIENT

SUBJECT: KH-9 Camera Manual

This data book, "Preliminary KH-9 Camera Manual," has been prepared as technical information on the KH-9 system for advanced planning within the exploitation community. This information may be disseminated to persons having (1) a TALENT-KEYHOLE clearance and (2) a clearly specified need-to-know.

A final version of this data book will be published at least six months prior to first flight of the KH-9 system.

R. A. Berg

RUSSELL A. BERG
Brigadier General, USAF
Director
NRO Staff

PREFACE

This manual has been prepared by the National Photographic Interpretation Center with the Coordination of the National Reconnaissance Office to provide preliminary information for use in planning and exploitation of the products of this system.

Information is current as of the date of publication. Some changes may occur in the data presented when engineering or operational philosophy requires a redesign or modification.

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INTRODUCTION

The KH-9 Camera System consists of dual pan-strip cameras designed to provide high resolution convergent stereo coverage of major portions of the world for search and surveillance requirements. In addition to the dual cameras, the system will contain a stellar/terrain camera sub-system consisting of dual stellar cameras and a vertical terrain camera. These additional cameras have been designed to provide the mapping, charting, and geodetic community with a data base commensurate with its requirements.

I. MAIN CAMERA SYSTEM

Configuration

The main camera system consists of dual pan-strip cameras mounted side by side (Figure 1). The port camera unit looks forward 10° from vertical, and the starboard looks aft 10°, forming a 20° stereo convergence angle. Both units simultaneously scan across track in opposite directions -- the forward camera scans the ground from right to left, the aft unit from left to right.

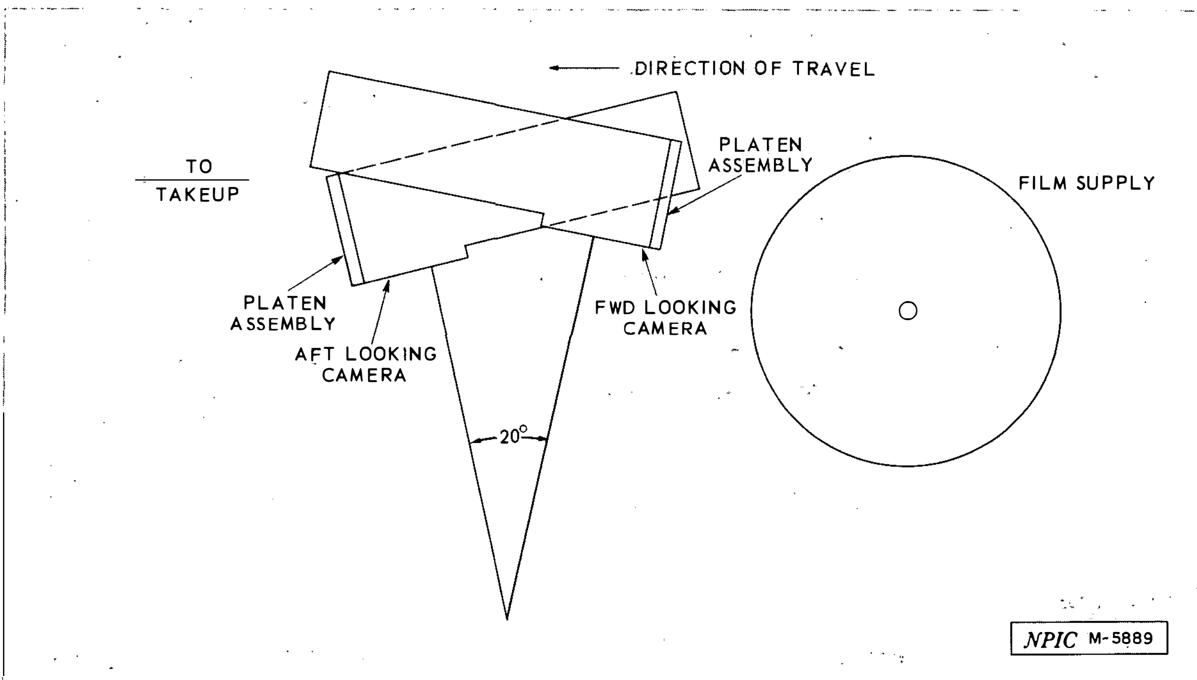


FIGURE 1. MAIN CAMERA ASSEMBLY.

Optics

The optical train is a catadioptric system consisting of an aspheric corrector plate, a primary spherical mirror, a folding mirror, and a field corrector group (Figure 2).

Optical System Parameters

Effective focal length	60 inches
Numerical aperture	f/3
Field coverage	2.83 degrees (half angle) 5.66 degrees (full field)
Filter	Wratten 12
Slit length	6.0 inches
Slit width	0.08 to 0.91 inches
T-number	3.5 maximum
Optical system	Folded Wright

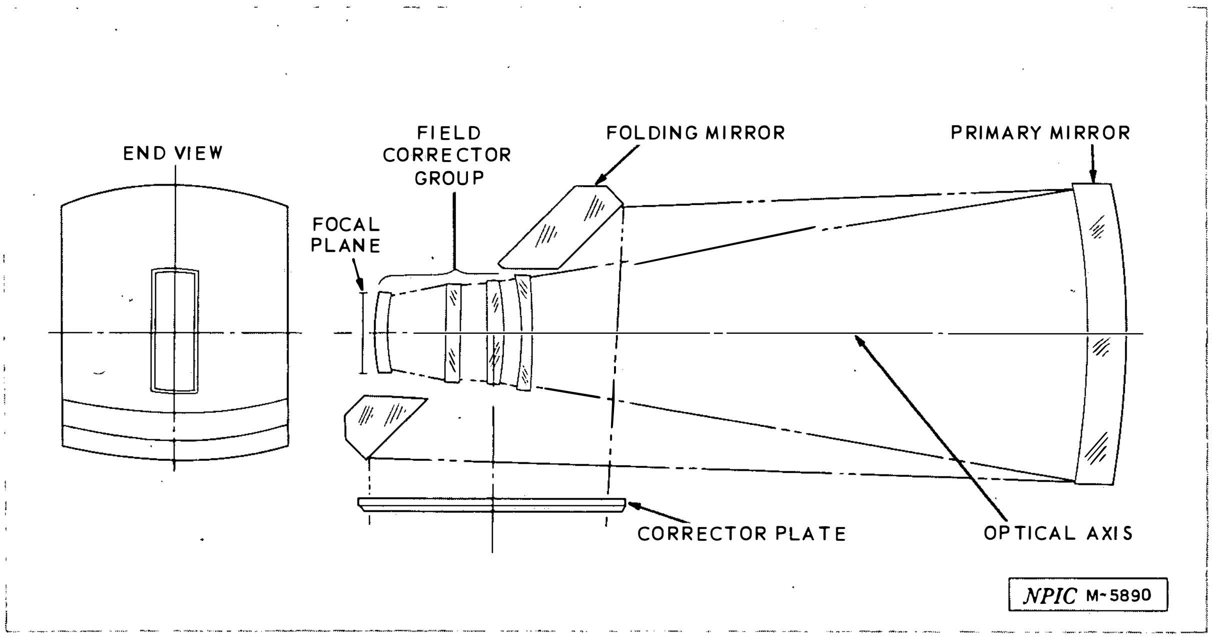


FIGURE 2. MAIN CAMERA OPTICS.

Coverage

The cameras' constant 20° convergence angle will result in a one-half frame overlap between the forward and aft cameras. Therefore, the first half frame of the forward camera and the last half frame of the aft camera will be monoscopic in every operation. All other imagery will be 20° convergent stereoscopic coverage.

An average mission will provide approximately 24 million square nautical miles of stereoscopic coverage. Other coverage statistics, as computed at an 82-nm altitude, are given below.

Lateral Ground Coverage in NM /Frame

		Scan Center			
		0°	±15°	±30°	±45°
	30°	44	48	61	99
Scan	60°	95	105	147	
Sector	90°	167	195		
	120°	294			

In Track Ground Coverage in NM /Frame

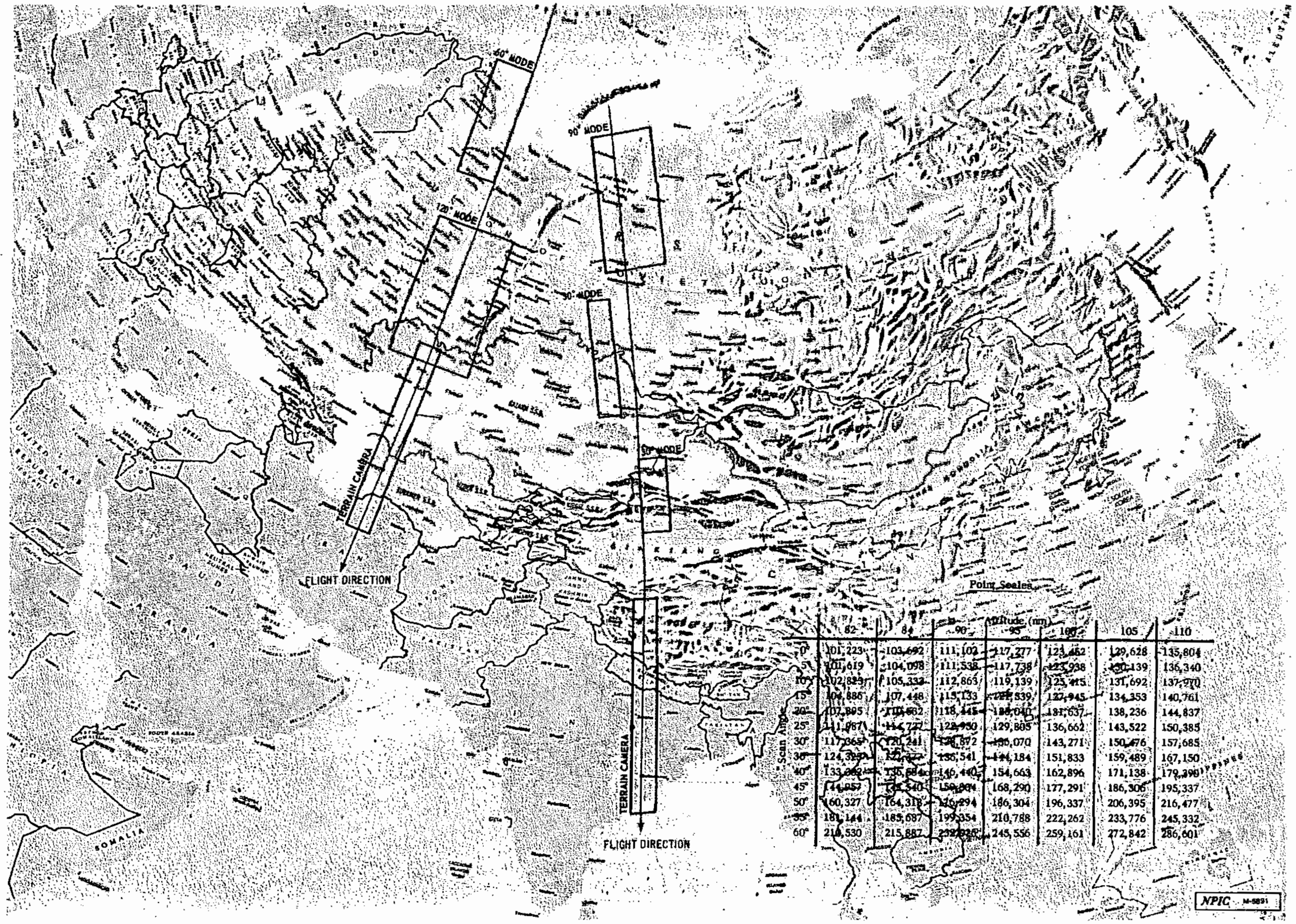
0°	8.4
±15°	8.8
±30°	9.8
±45°	12.3
±60°	18.5

Area Ground Coverage in NM^2/Frame

		Scan Center			
		0°	±15°	±30°	±45°
	30°	380	430	634	1362
Scan	60°	860	1014	1792	
Sector	90°	1648	2222		
	120°	3584			

Modes of Operation

The KH-9 camera will operate in any single commanded mode (scan center and swath width) throughout an operation. An operation is measured from the time the cameras are commanded on until they are commanded off. A 25- to 70-second delay is required to restart the cameras at a different scan center or swath width.



Point Scales

Scan Angle	Altitude (nm) 82	84	90	95	100	105	110
0°	101,223	103,692	111,102	117,277	123,462	129,628	135,804
5°	101,619	104,098	111,538	117,738	123,938	130,139	136,340
10°	102,823	105,332	112,863	119,139	125,415	131,692	137,970
15°	104,886	107,448	115,133	121,539	127,945	134,353	140,761
20°	107,895	110,532	118,445	125,040	131,637	138,236	144,837
25°	111,987	114,727	122,930	129,805	136,662	143,522	150,385
30°	117,365	120,241	128,872	136,070	143,271	150,476	157,685
35°	124,329	127,377	136,541	144,184	151,833	159,489	167,150
40°	133,382	136,684	146,440	154,663	162,896	171,138	179,390
45°	144,957	148,540	159,804	168,290	177,291	186,306	195,337
50°	160,327	164,318	176,294	186,304	196,337	206,395	216,477
55°	181,144	185,687	199,354	210,788	222,262	233,776	245,332
60°	210,530	215,887	232,026	245,556	259,161	272,842	286,601

FIGURE 3. COVERAGE DIAGRAM.

A scan sector of 30°, 60°, 90°, or 120° can be programmed for any one camera operation (Figure 3). The programmed scan sector can be centered at 0°, ±15°, ±30°, or ±45° across the flight track (Figure 4).

Scan Centers

Scan Length	45°L	30°L	15°L	0°	15°R	30°R	45°R
30°	X	X	X	X	X	X	X
60°		X	X	X	X	X	
90°			X	X	X		
120°				X			

ground track

Format

The format length is dependent on the particular scan sector being used, but the width is a constant 6.0 inches. Sizes range as follows.

30° scan	2.62′ x 6″
60° scan	5.24′ x 6″
90° scan	7.86′ x 6″
120° scan	10.48′ x 6″

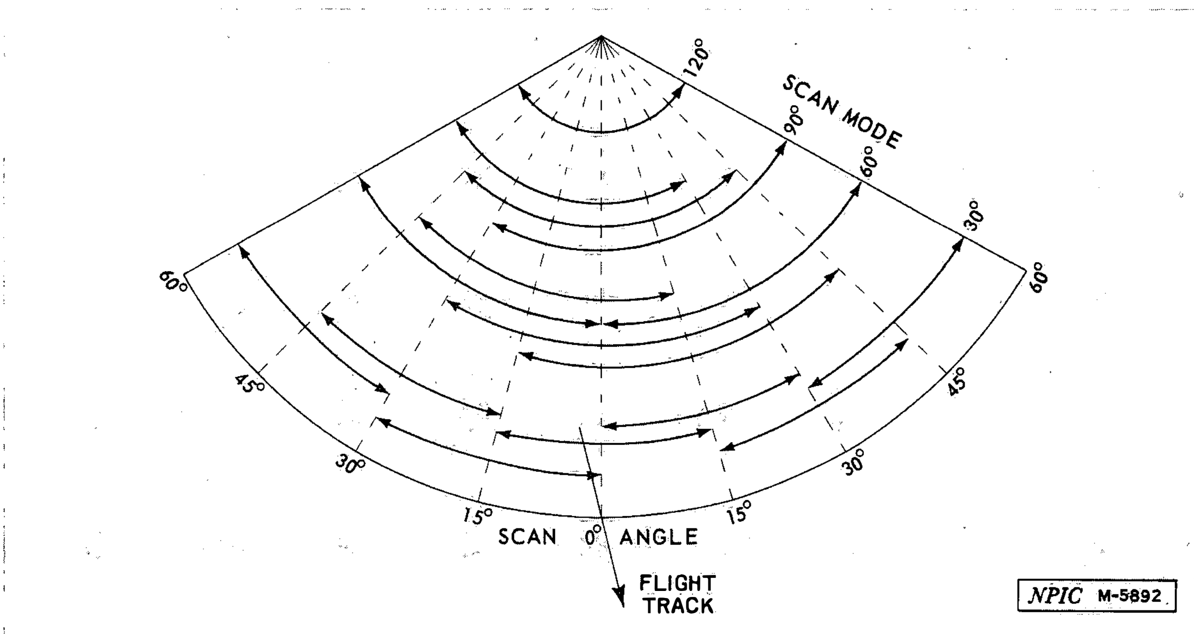


FIGURE 4. MODES AND SCAN ANGLES.

Film

Film Data

The film supply capacity for each camera is 104,000 feet of ultra thin base (UTB) SO-380 film 6.6 inches wide. Data for SO-380 film are as follows.

	Each Main Camera Fwd and Aft	Main Camera System Total
Film Load	104,000 feet	208,000 feet
Frames		
Minimum	8,000	16,000
Maximum	32,000	64,000
Average	18,360	36,720

The exposed film will be retrieved in four buckets, each containing approximately 52,000 feet of material. The buckets will contain nearly equal footage but recovery sequences will not have equal time spans.

Approximately 15.6 percent of the film will be used for interframe and interoperation spacing. This will vary according to the philosophy of operation and can be as low as eight percent or as high as 18 percent.

Average Useful Film Load Per Camera and Mission

Scan Sector	Useful Film Load	Film Length Expended (ft)	Number of Frames
30°	30%	26,320	10,000
60°	20%	17,550	3,340
90°	20%	17,550	2,230
120°	30%	26,320	2,500
	TOTALS	87,740 (Camera)	18,070 (Camera)
		175,480 (Mission)	36,140 (Mission)

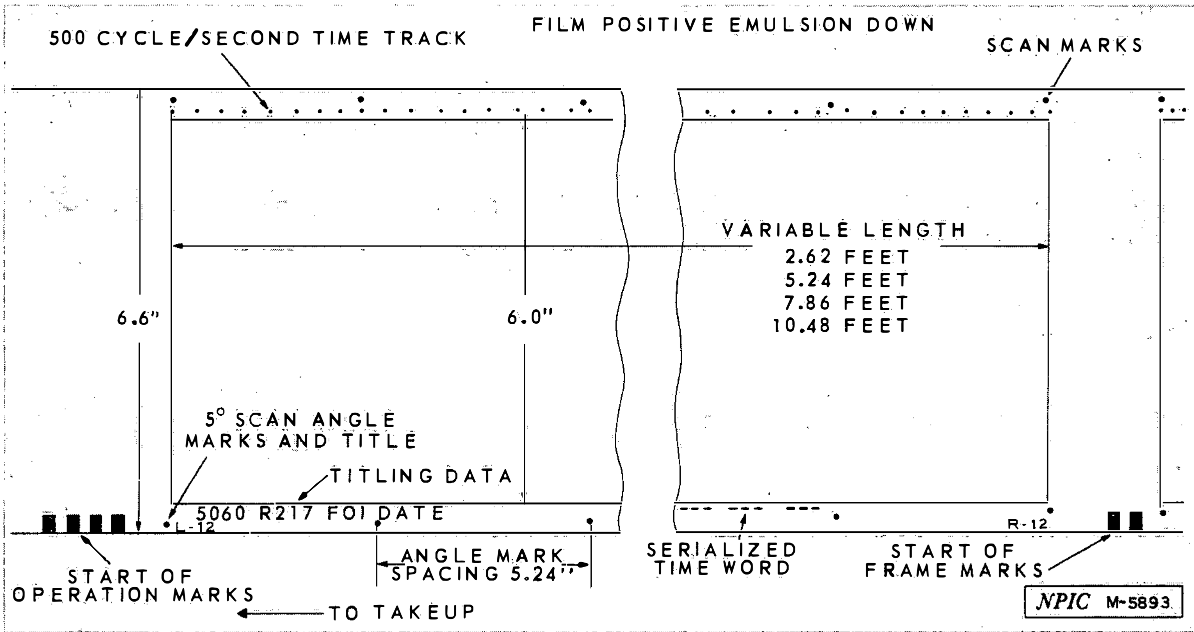


FIGURE 5. MAIN CAMERA FORMAT DIAGRAM.

<u>Film Exposure</u>

Film exposure ranges from 1.4 to 5.1 milliseconds. It is controlled by the slit width, which varies from 0.080 to 0.91 inch. The slit can be adjusted in 0.03-inch increments, with only one increment adjustment during the transport recycle between frames. The slit width will be independently controlled for each camera.

Recorded Data

The main camera will contain several items of recorded data which are of importance to the exploitation system (Figure 5). These items include scan angle marks, time track recording, and start of frame and start of operation marks.

1) <u>Scan Angle Marks</u>. These are 12-micrometer (micron) diameter dots spaced at 5.24-inch intervals along the format edges to reference universal grid orientation and reporting. They are optically recorded during exposure at 5° intervals along both edges of the film.

2) <u>Time Recording</u>. The one millisecond time recording will occur on only one edge of the film and will be a continuous recording of a 500 cycle pulse. In addition, there will be a serialized time word recorded on the titling edge of the film starting at the center of format on each frame. This time word will be used as a backup system if the ephemeris data are not available. The time track and the serialized time word will be variable in spacing since they are recorded at different film speeds on each frame. The vehicle clock is interrogated five

degrees from scan start, but the time is serially imaged on the format immediately after the scan center.

3) Start of Frame Indicator. The beginning of each frame will be indicated by two marks (0.25 x 0.30 inches) imaged on the film edge in the space preceding the frame.

4) Start of Operation Indicator. The beginning of an operation will be signified by four marks preceding the first frame of the operation.

Titling Data

The following data will be optically titled on the original negative (Figure 5): mission, revolution, operation, frame, and camera numbers; camera unit; date of photography; security classification; scan center; and scan width. In addition, the scan marks will be optically titled alphanumerically for identification and reporting ease.

Ephemeris Information

There will be a complete ephemeris on the KH-9 System provided on a daily basis. This will be available within NPIC several days prior to the arrival of the film and will provide the data for the mensuration data base as well as the target information necessary for exploitation.

This ephemeris will be as accurate as the tracking system used in developing the orbital parameters and will include the data listed below.

Data	Frequency
1. Mission Number & Bucket Number	Report
2. Operation Number	Frame
3. Rev Number	Frame
4. Frame Number	Frame
5. Camera Number & Designator	Report
6. Classification	Page
7. Lat of Nadir at Time Word	Frame
8. Long of Nadir at Time Word	Frame
9. Lat of Photo at Time Word	Frame
10. Long of Photo at Time Word	Frame
11. Photography Date	Operation

	Data	Frequency
12.	Swath Indicator	Operation
13.	Swath Center Angle	Operation
14.	Frame Time	Frame
15.	Ephemeris Time	Frame
16.	Solar Elevation & Azimuth	Frame
17.	Slit Value	Frame
18.	Altitude	Frame
19.	Inertial Velocity	Frame
20.	Vehicle Azimuth	Frame
21.	Ground Track Velocity	Frame
22.	Ground Track Azimuth	Frame
23.	IMC Rate (computed)	Frame
24.	Time Correlation Parameters	Report
25.	All Target IDs Covered	Frame
26.	Marginal Targets	Frame
27.	Target Lat & Long	Frame
28.	Target Alt	Frame
29.	Target X-Y Coordinates on Film	Frame
30.	Inter-Operation Film Usage	Operation
31.	Film Usage per Operation	Operation
32.	Attitude	
	a. Pitch & Rates	Frame
	b. Roll & Rates	Frame
	c. Yaw & Rates	Frame
33.	Scale Factor for Each Target	Frame
34.	A 20 pt Ephemeris XYZ, XD YD ZD, XDD YDD ZDD	Revolution
35.	Lat & Long of 4 Corners of Each Operation	Operation
36.	Command Vx/H & Vy/H	Frame
37.	Flight Path Angle	Frame
38.	Orbit Adjust Maneuvers	Event
39.	Special Events	Report
40.	Filter	Report
41.	Film Type	Report
42.	Film Speed (computed)	Frame

Image Motion Compensation

Compensation for image motion is accomplished by a combination of film movement and platen rotation. To compensate for the motion caused by the scanning optics, the film is moved laterally at a velocity proportional to the optical bar scan rate. To compensate for the forward motion of the vehicle, the angle of film movement in the lateral plane is continually changed. This skew angle is varied by platen rotation as a function of scan angle and conforms to the cosine form of the image motion.

Film Velocity

The film velocity is programmed as a function of the Velocity/Height ratio and is directly tied to the optical bar rotation with a maximum velocity of 204 inches per second. The film velocity past the slit is synchronous with the angular scan rate and is accurate within plus or minus 0.03 percent. The film velocity is modulated by 0.25 percent to correct for cross-track components of image motion.

Attitude Control Device

The addition of an accurate attitude device to augment the normal attitude control devices used to keep the cameras pointing down is presently under study. (This would not be applicable to the stellar/terrain subsystem due to the distance of approximately 28 feet between units.)

II. STELLAR/TERRAIN CAMERA SUBSYSTEM

The stellar/terrain camera subsystem (STCS) will satisfy mapping, charting, and geodetic (MC&G) requirements, which will probably vary from mission to mission. The STCS is operated separately from the main camera system, whose search and surveillance requirements should remain relatively stable.

It is expected that a maximum of 50 percent of the index material will cover the same imagery as the main camera and that a minimum of 20 percent of the coverage will be similar. According to operational philosophy, however, it is entirely possible that there will be 100 percent conjugate imagery or no conjugate imagery.

The stellar/terrain camera subsystem will provide accurate ephemeris information for horizontal and vertical control to the MC&G community.

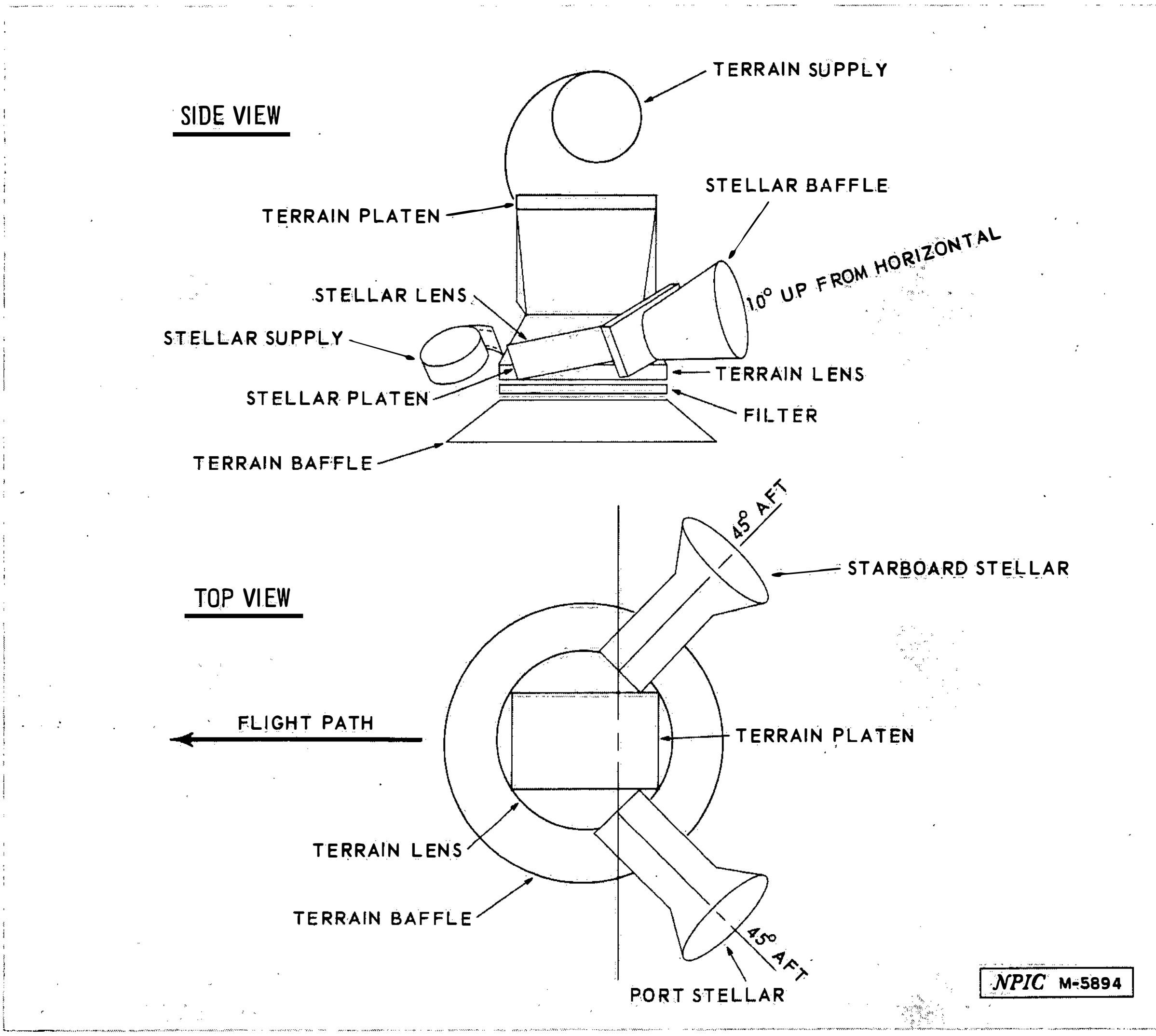


FIGURE 6. STELLAR/TERRAIN CAMERA ASSEMBLY.

Configuration

The stellar/terrain camera subsystem (Figure 6) is composed of a vertical terrain camera with a 12-inch focal length lens and twin stellar cameras with 10-inch focal length lenses.

The stellars are pointed 45° aft and 10° up from the horizontal to increase the accuracy of pitch determination and to eliminate sun and albedo problems in recording stars. The two stellars will operate as a unit, recording both a left and right exposure of a portion of the stellar field at each shutter open command. They will be synchronous with the terrain camera, the terrain camera shutter opening at the center of each stellar shutter opening.

The terrain camera will provide best resolutions of 28 feet on axis and will cover terrain that is not normally covered by the main camera.

Stellar Camera

The stellar cameras will contain 2,400 feet of film. The format will be 108mm rectangular frames superimposed on a 70mm web of film to provide 2,670 stellar pairs per mission, one stellar pair per terrain photograph.

There will be four fiducials on the format for alignment and the data block will be positioned between frames (Figure 7). A 10mm grid will be superimposed on the format for calibration and mensuration purposes. This grid will be intersections only and will be postflashed for maximum recording accuracy.

Terrain Camera

The terrain camera will contain 4,200 feet of film 9.5 inches wide with a 19-inch cycle spacing. This will provide a maximum of 2,670 9.0- by 18-inch frames per mission that will cover the vertical area along the flight line.

The camera can operate in 10, 70, or 78 percent overlap cycles and will provide the following coverage.

10% overlap	20,000,000 nm^2
70% overlap	8,000,000 nm^2
78% overlap	6,400,000 nm^2

With 70 percent overlap the camera will cover 9,112 nm^2 at a 90-nm altitude with each frame. The 10 and 78 percent overlap will be used for higher altitudes or monoscopic coverage.

The camera will have a minimum six-second cycle with two percent step increases to satisfy the changing altitudes between 80 and 240 nautical miles.

The terrain format will contain a 10mm spaced reseau and six fiducials as shown in Figure 8. The reseau will be 8 to 12 micrometer- (micron-) wide lines 2.5mm long at each intersection over the entire format.

The terrain camera will have image motion compensation (IMC) for all Velocity/Height ratios between 0.0525 to 0.0175 radians per second. This will provide smear-free photography within the altitude envelope (80 to 240 nm).

Stellar/Terrain Camera Data

	Terrain	Stellars
Focal length	12''	10''
Aperture	f-6 (2.0'')	f-1.8 (138mm)
Points	Vertical	10° above horizon Port -- left 45° aft Starboard -- right 45° aft
Film load	9.5'' x 4,200'	70mm x 2,400' (Single web)
Film type	3404	3401
Resolution	28' on axis	6th and 7th order stars
Frames	2,670	2,670 pairs
Format size	9'' x 18'' rectangle	70mm x 110mm rectangle
IMC	Moving platen (V/H control)	None
Coverage	8,000,000 nm^2	Star fields
Filter	Wratten 25	None
Reseau	10mm	10mm
Fiducials	6	4
Exposure	1.5 to 12 milliseconds	200 milliseconds

Recorded Data

The stellar data block will provide the following information:

- Vehicle time at midexposure
- Time of stellar shutter opening
- Time of stellar shutter closing
- Frame number
- Serial numbers
- Parity check

The terrain data block will contain the following information:

- Vehicle time at midexposure to 1 millisecond accuracy
- Time interval between exposures to 0.1 millisecond
- Velocity height ratio (V/H)
- Terrain exposure
- Frame number

Camera serial number
Commanded overlap
Parity check

These data blocks will be standard DOD data diode array recordings.

Ephemeris Information

There will be either a daily or mission ephemeris developed for the stellar/ terrain camera system. This will contain all the data necessary for exploitation except the targeting information.

	Data	Frequency
1.	Nadir Lat & Long	Frame
2.	Time at Center of Format	Frame
3.	Rev Number	Frame
4.	Frame Number	Frame
5.	Camera ID	Frame
6.	Date	Frame
7.	Solar Elevation	Frame
8.	Altitude	Frame
9.	Inertial Velocity	Frame
10.	Ground Track Azimuth	Frame
11.	IMC Rate	Frame
12.	Time Correlation Parameters	Report
13.	Focal Length	Report
14.	Right Ascension & Declination of each Stellar Axis	Frame
15.	A 20 Point Ephemeris XYZ, XD YD ZD, XDD YDD ZDD	Revolution
16.	Lat & Long of 4 Corners of Each Camera Operation	Operation
17.	Filter	Report
18.	Film	Report
19.	DMU Firings and Special Events	Event

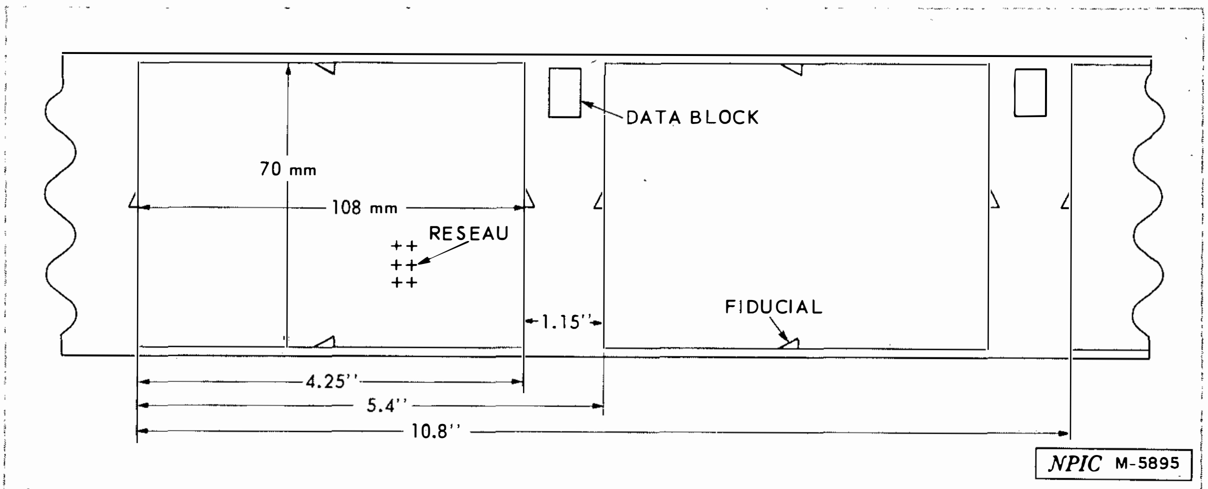


FIGURE 7. STELLAR CAMERA FORMAT.

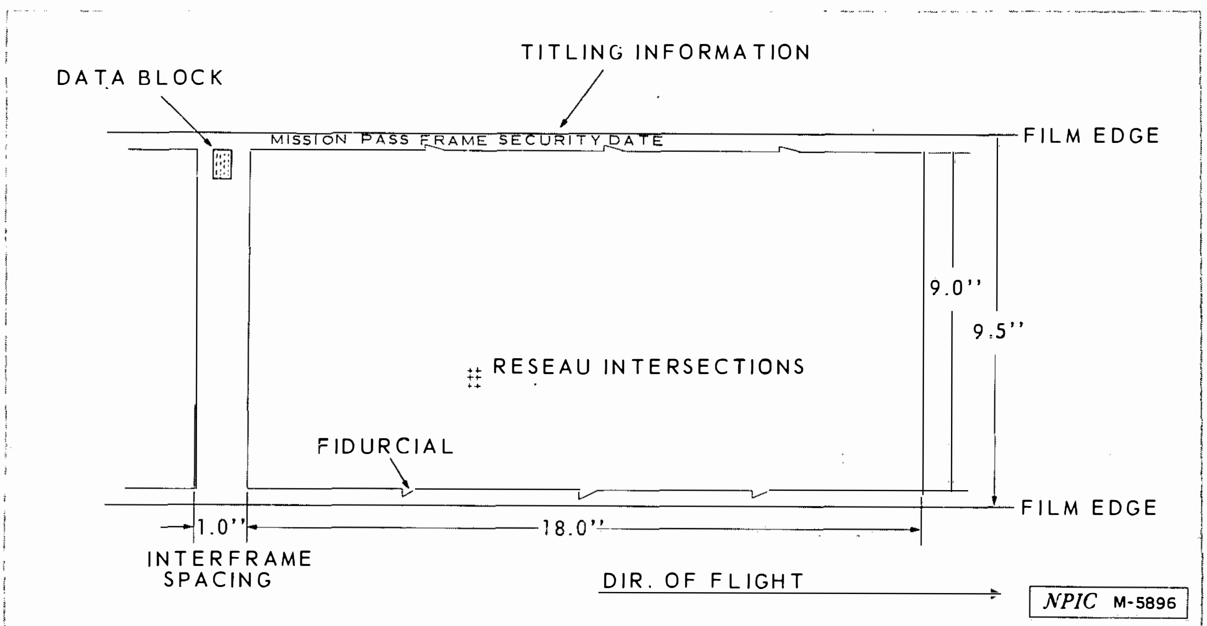


FIGURE 8. TERRAIN CAMERA FORMAT.