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15 DECEMBER 1972

HEXAGON MAPPING CAMERA SYSTEM DESCRIPTION

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HEXAGON MAPPING CAMERA SYSTEM DESCRIPTION

DEMO

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LIST OF ABBREVIATIONS

A mode	Ascent mode
AWAR	Area weighted average resolution
B mode	Backup mode
C mode	Calibrate mode
C&S	Control and synchronization
DBS	Doppler beacon system
EDAP	Electrical distribution and power
FMC	Forward motion compensation
MCM	Mapping camera module
MISEA	Main instrument system electronics assembly
NEC	Northeast contractor
NSPC	Normal stored program command
PMS	Pressure makeup system
PSPC	Protected stored program command
RTC	Real time command
RTS	Remote tracking station
RV	Recovery vehicle
SBAC	Satellite basic assembly contractor
SCF	Satellite control facility
STC	Satellite test center
SV	Satellite vehicle
TRANET	Transit network (doppler beacon tracking)
VPL	Velocity position lock
VSPC	Variable stored program command

1. MAPPING CAMERA SYSTEM DESCRIPTION

The Hexagon Mapping Camera Subsystem is the key element in a program which promises to revolutionize the disciplines of mapping, charting, and geodesy in the United States. The camera is a precisely calibrated and controlled instrument which acquires terrain images from an orbiting satellite. These images are used together with auxiliary data to accurately locate terrain objects. The distance between ground control points may be determined with an accuracy of better than 20 feet in 10 miles, or ground points may be located with an absolute accuracy of better than 300 feet in the World Geodetic System by use of mapping camera data.

The camera has the ability to discriminate ground objects smaller than 50 feet from its nominal operating altitude of 92.5 nautical miles. This resolution is sufficient to satisfy most of the content requirements for direct compilation of 1:50,000-scale topographic maps, and also makes the photography useful for search and earth survey objectives.

Mapping camera operations are scheduled to begin in early 1973, with the ultimate objective of acquiring a data bank covering the entire world's dry land area of 56 million square miles. This coverage will be obtained at a rate of approximately 4 million square miles per mission.

The mapping camera subsystem, Mark V film recovery vehicle, and doppler beacon subsystem are integrated in the mapping camera module (MCM) which is located at the front end of the satellite vehicle, as shown in Fig. 1-1. The major interface characteristics of the camera are given in Table 1-1. The camera includes both a wide-angle terrain instrument and a pair of aft-looking stellar instruments, used to accurately orient the camera in the celestial sphere. The major assemblies of the mapping camera are located in Fig. 1-2. The resultant film path, depicted in Fig. 1-3, is contained in lighttight chutes which are vented to space vacuum. During operation, a small flow of gas is bled into the chutes from a pressure makeup system (PMS) to inhibit film marking by corona discharge.

In normal operation, the camera cycles with a frame period proportional to V/h (ratio of orbital velocity to altitude), such that three or more frames cover the same ground area. By viewing the common scene from two perspectives, a stereo model of the overlap zone is created in which vertical dimensions can be measured. The camera can operate in two stereo modes which provide triple or quadruple overlap (see Fig. 1-4) or in a 10 percent overlap mode which provides monoscopic coverage.

The various modes of operation of the camera are listed in Table 1-2. During ascent (A mode), the film path is tensioned and shutter doors are closed to prevent damage due to the launch environment. Normal mode provides full command flexibility of variable V/h, overlap, and terrain exposures of 3, 6, or 12 milliseconds. The calibrate mode (C mode) enables a time exposure of stellar or artificial objects with known angular locations to determine the internal geometry of the camera. All modes are designed for high reliability, including use of redundant electronics where practical. As further insurance of mission success, a backup mode (B mode)

Approved for Release: 2017/03/24 C05100685

of operation is available which causes the camera to cycle at a fixed rate corresponding to nominal conditions. In addition, failsafe functions are provided to allow the mission to continue in the event of malfunction of the external shutters.

The mapping camera is functionally divided into the subsystems indicated in Fig. 1-5. Commands and raw bus power from the SV are received by the control and synchronization and electrical power and distribution (EDAP) subsystems. Internal timing signals and regulated voltages are output from these to the remaining subsystems. A variety of sensing components (e.g., temperature monitors, potentiometers, limit switches) in the subsystems generate signals which are conditioned into standard SV telemetry voltage ranges in the instrumentation subsystem. The subsystems of the terrain and stellar cameras are discussed in detail in the following sections.

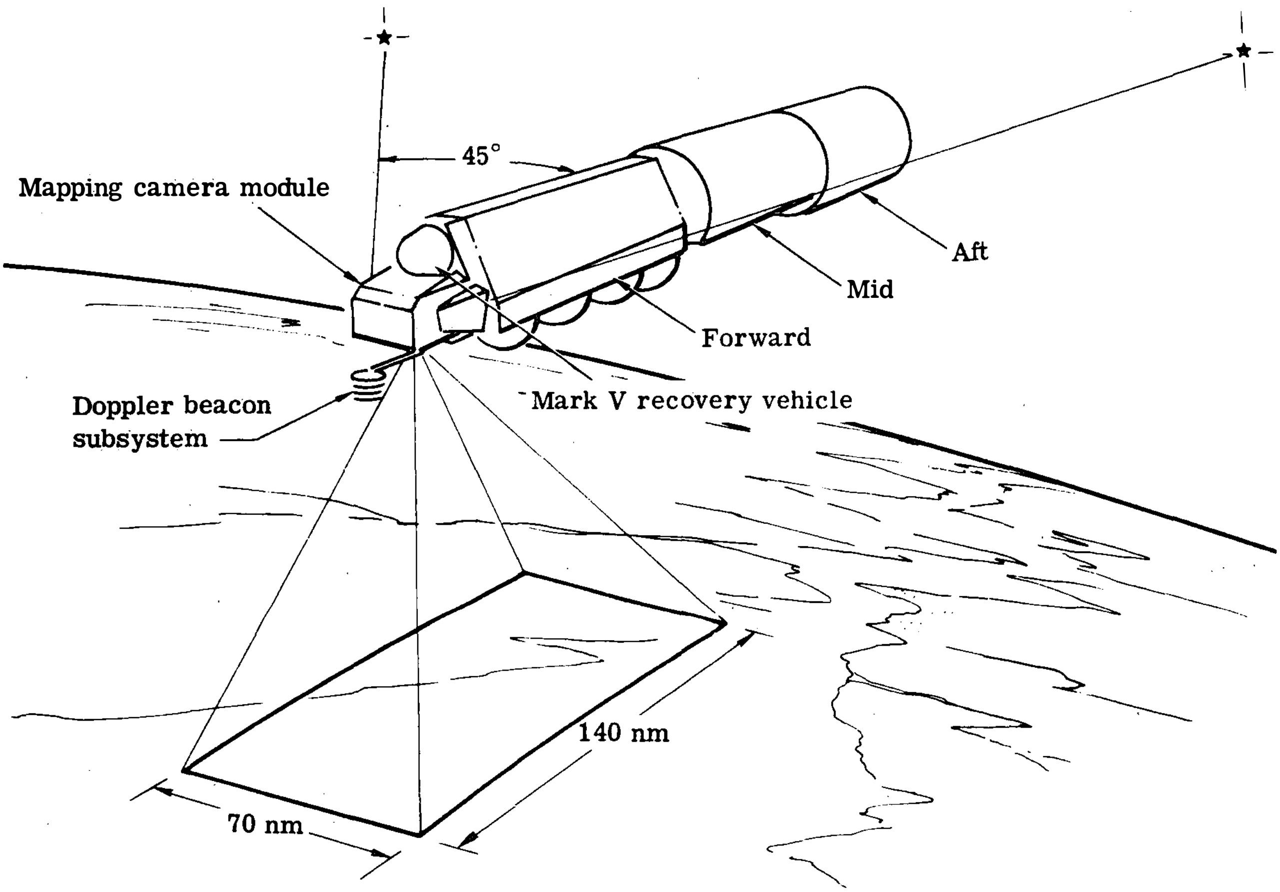


Fig. 1-1 — Hexagon satellite vehicle (92.5-n.mi. nominal altitude)

Table 1-1 — Mapping Camera System Characteristics

- Orbit during operation
  - 96.4 degrees inclination (nominal)
  - 80- to 240-n.mi. altitude southbound
  - Angle between orbit plane and sun 0 to 60 degrees
- Weight
  - Subsystem (dry) 756 pounds
  - Film load 72 pounds
  - Integrated mapping camera module 1,300 pounds, approximately
- Environmental control
  - 30 – 70 °F passive
  - 73 ± 1 °F active
- Power
  - 24-33 vdc unregulated
  - 30 amps peak
  - 30 watts max thermal
- Commands

• 2-variable stored program commands (4-bit and 12-bit variables)	1-real time command (loaded on pad only)	1-satellite vehicle time word (32 bits)
• 13-Normal stored program commands (switch function)	1-protected stored program command	1-500 pps (clock train)

- Telemetry
  - 43 discretes
  - 67 analog

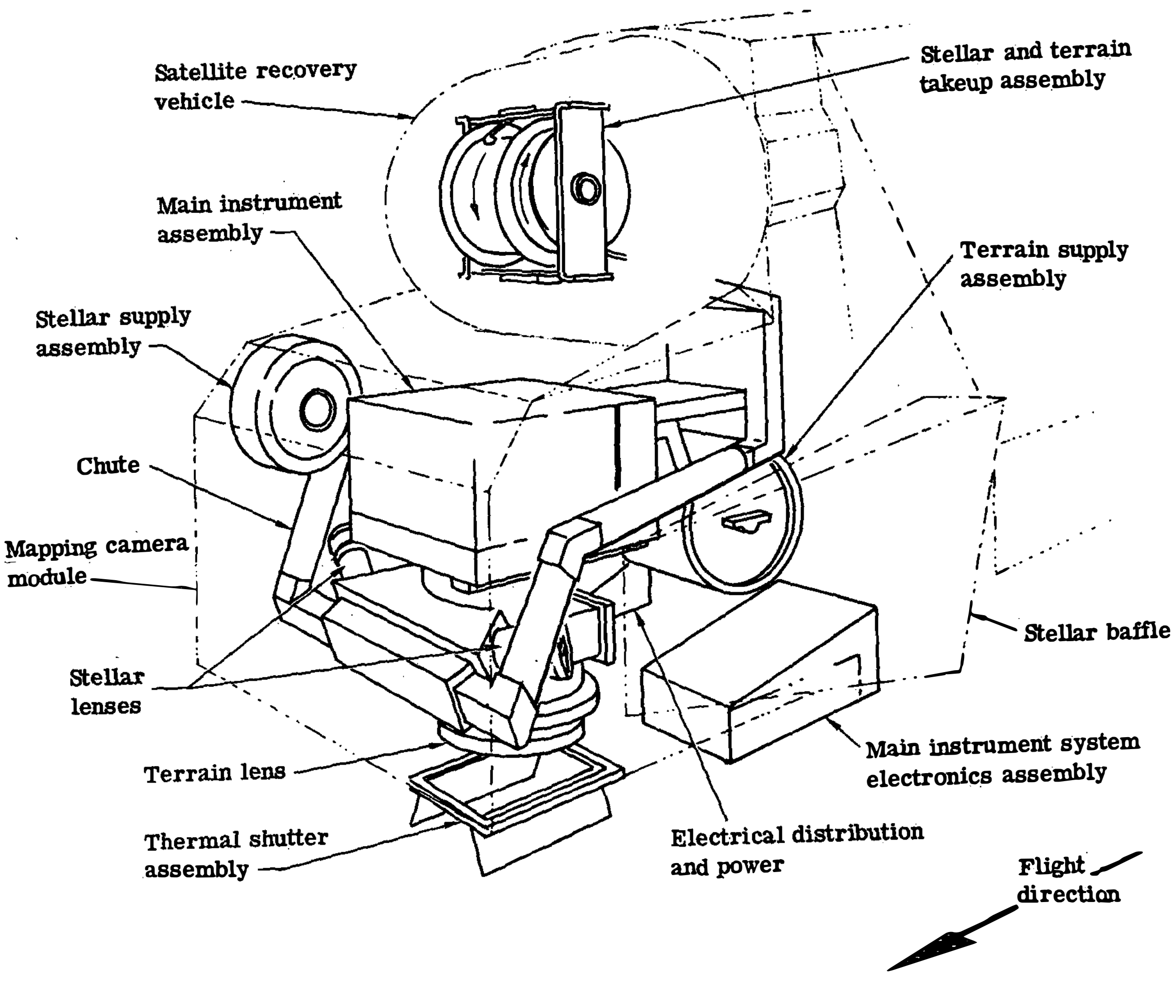


Fig. 1-2 — Mapping camera system

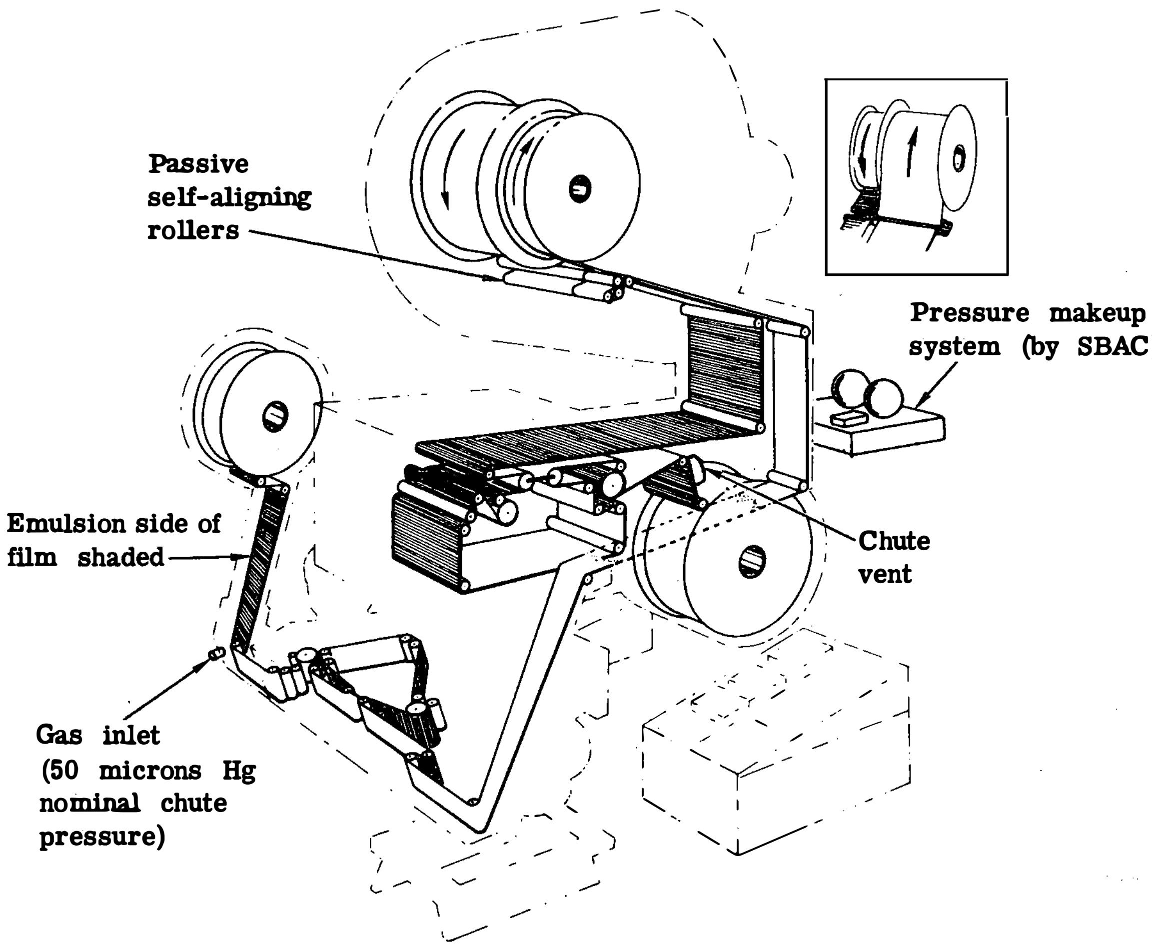
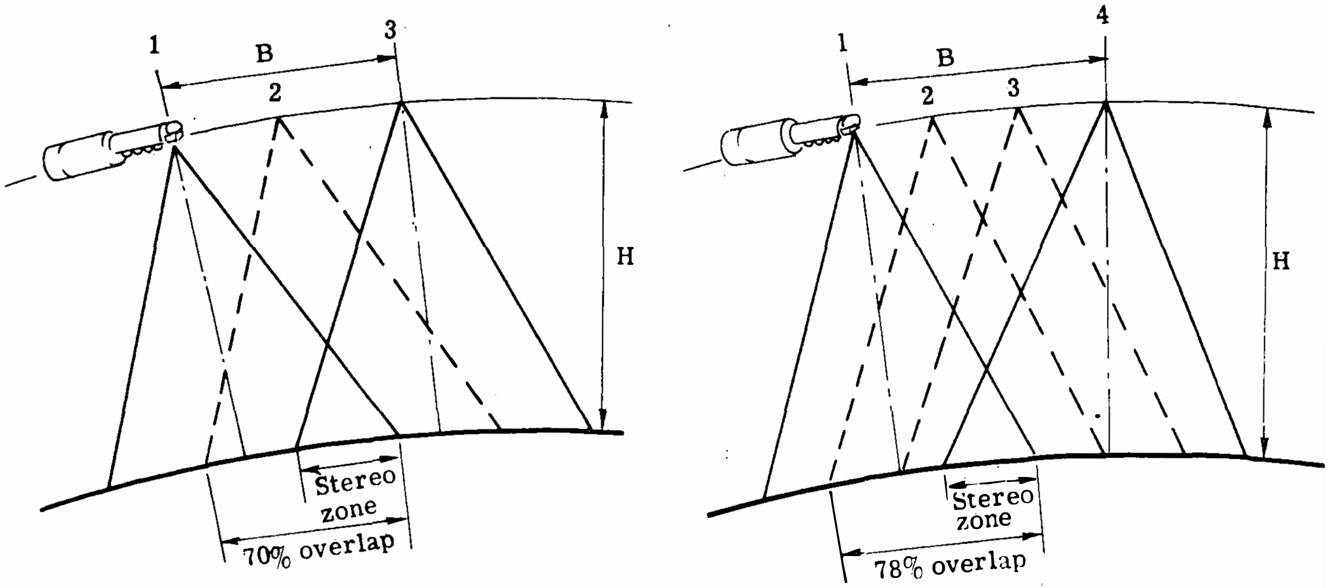


Fig. 1-3 — Mapping camera film path



Triple overlap; B/H = 0.9

(80 < H < 240 nm)

Quadruple overlap; B/H = 1.0

(100 < H < 240 nm)

Fig. 1-4 — Mapping camera stereo modes

Table 1-2 — Modes of Operation

- Standby
  - Heaters powered only

- Ascent mode
  - Film path tensioned
  - Stellar and thermal shutters closed (ascent condition)

- Normal mode
  - Primary photographic mission
  - $0.0165 < V/h < 0.0565$
  - Terrain exposure: 3, 6, 12 milliseconds
  - Overlap: 78%, 70%, 10%

- Backup mode
  - Backup operating mode in the event of an electrical malfunction in the normal mode
  - Terrain exposure: 6.2 ms } Fixed rate
  - FMC correct for nominal V/h = 0.046 } Fixed rate
  - Frame rate: 8.9 seconds } Fixed rate
  - 70 percent or greater overlap

- Calibrate mode
  - Calibration condition
  - Frame time: 20 seconds
  - Exposure: 2 seconds
  - FMC inhibited

- Redundant modes
  - Command selection of parallel control circuits for terrain capping shutter, thermal shutter, stellar platen press, stellar transport

- Fail safe modes
  - Ejection of terrain thermal shutter (shutter closed condition)
  - Capping of either stellar shutter (shutter open condition)

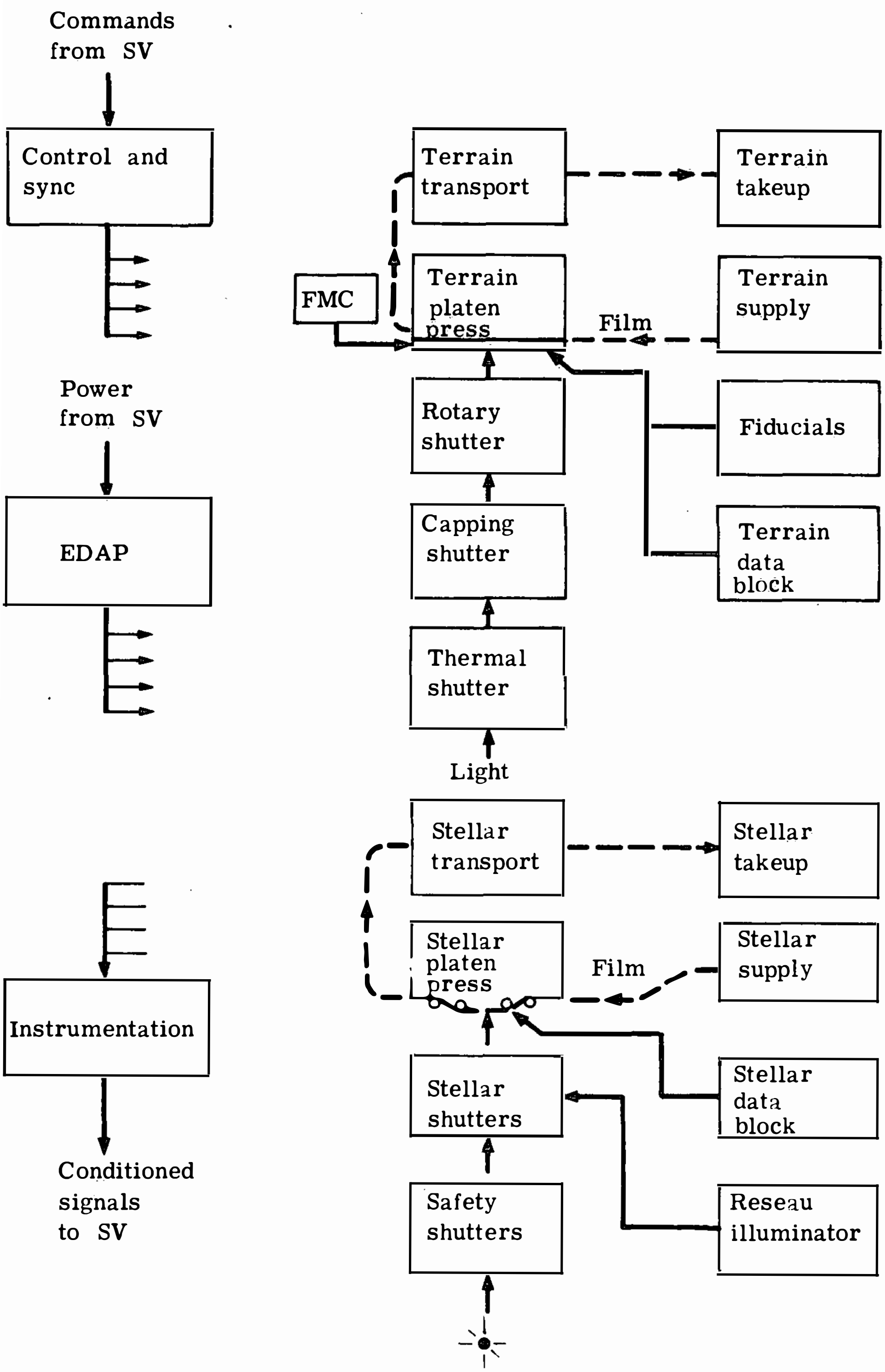


Fig. 1-5 — Mapping camera simplified block diagram

2. TERRAIN CAMERA DESCRIPTION

The terrain camera obtains high resolution, wide field imagery of the ground scene through the terrain lens shown in Fig. 2-1. The lens is optimized for vacuum operation and photography with black and white type 3400 (Pan-X) film.

The terrain image format (Fig. 2-2) has a usable area of 9 by 18 inches and contains a calibrated reseau grid of microlines which shadow the ground scene at one-centimeter intervals to permit compensation for film distortion. The entire format is flexure supported from the lens cell, and is moved in the x direction to compensate for image motion produced by satellite forward velocity. Fiducial images are exposed near the four corners of the format at midexposure to accurately locate the format with respect to the camera body. Dense marks are exposed near the top center of the format; these are sensed during film processing and locate title information which is exposed in the margin at that time. The data block in the lower left corner of the format is an array of illuminated dots which convey time information in a binary code.

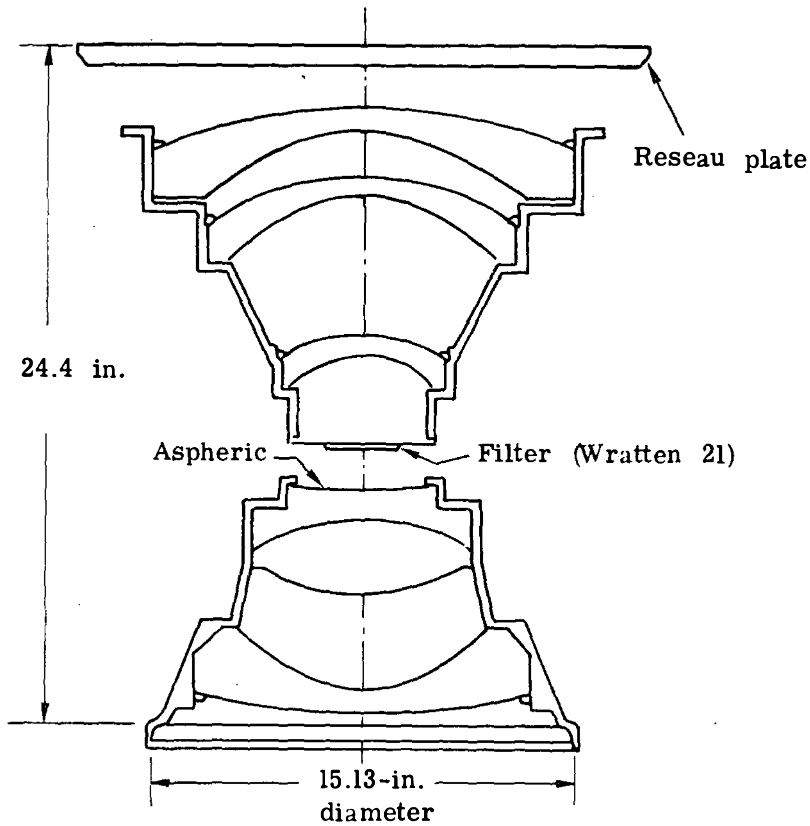
The lens body is machined from solid beryllium billets for extreme stability, and forms the mounting structure for most of the camera subassemblies. A temperature controlled oven is installed around the camera body, and the entire assembly is supported such that distortions of the MCM structure will not strain the camera.

The other subsystems of the terrain camera have the characteristics tabulated in Table 2-1 and are located in the mechanical arrangement shown in Fig. 2-3. The transport, forward motion compensation (FMC), and rotary shutter drives rotate continuously when the camera is operating to minimize dynamic disturbances. To maintain synchronism at the time of exposure, these drives must rotate with periods which are integral multiples of each other, as indicated in Fig. 2-4. The FMC period is related directly to V/h; the transport period, or frame time, is a multiple of the FMC period determined by the overlap command; and the rotary shutter period is a fraction of the FMC period determined by the exposure command. The precise timing relationships and wide dynamic ranges required of mapping camera operations are achieved by driving each of the servo subsystems in response to highly stable signals derived digitally in the C&S subsystem.

At system startup in the normal mode, the FMC and rotary shutter are accelerated to speeds which produce synchronism between velocity sync pulses output by high density tracks on the encoders of these mechanisms and corresponding C&S output pulse trains, as shown in Fig. 2-5. When velocity synchronism is reached, error signals are generated which define the phase difference between position signals derived from 1-pulse-per-rev outputs of the encoders and the C&S (see Fig. 2-6). The servos undergo a series of acceleration/deceleration position corrections, as shown in Fig. 2-7, until both velocity and position outputs of the encoders are synchronized with the C&S. After a fixed delay, the terrain transport starts and reaches synchronism by a similar process. Synchronism of the velocity/position locks (VPL's) and C&S are checked and updated over each camera cycle thereafter. Other timing relationships in the normal mode are shown in Fig. 2-8 and are derived by digital countdown in the C&S.

In the backup mode (B mode) the transports, shutters, and FMC are synchronized by a multitrack potentiometer on the terrain transport. The transport operates at a constant speed and outputs signals varying as sine and cosine functions with frequency multiples corresponding to the desired speed ratios for the FMC and rotary shutter. The opening command for the stellar shutters is derived from a special track on the same potentiometer, gated by a switch which also initiates discrete functions such as capping and thermal shutter opening.

In the calibrate mode (C mode), the FMC and rotary shutter are driven to the zero crossing of the potentiometer used for backup mode (B mode) synchronism. The transports operate at a fixed rate, and switches on the terrain transport initiate the required discrete functions.



Focal length: 12.0 in.
f/6, T/14
Distortion: 100 microns max radial
20 microns max tangential
Stability: 2 microns in operation
Resolution: 50 l/mm AWAR (2:1 contrast on 3400 film)
38 l/mm min
Field of view: 38 by 72 degrees

Fig. 2-1 — Terrain lens

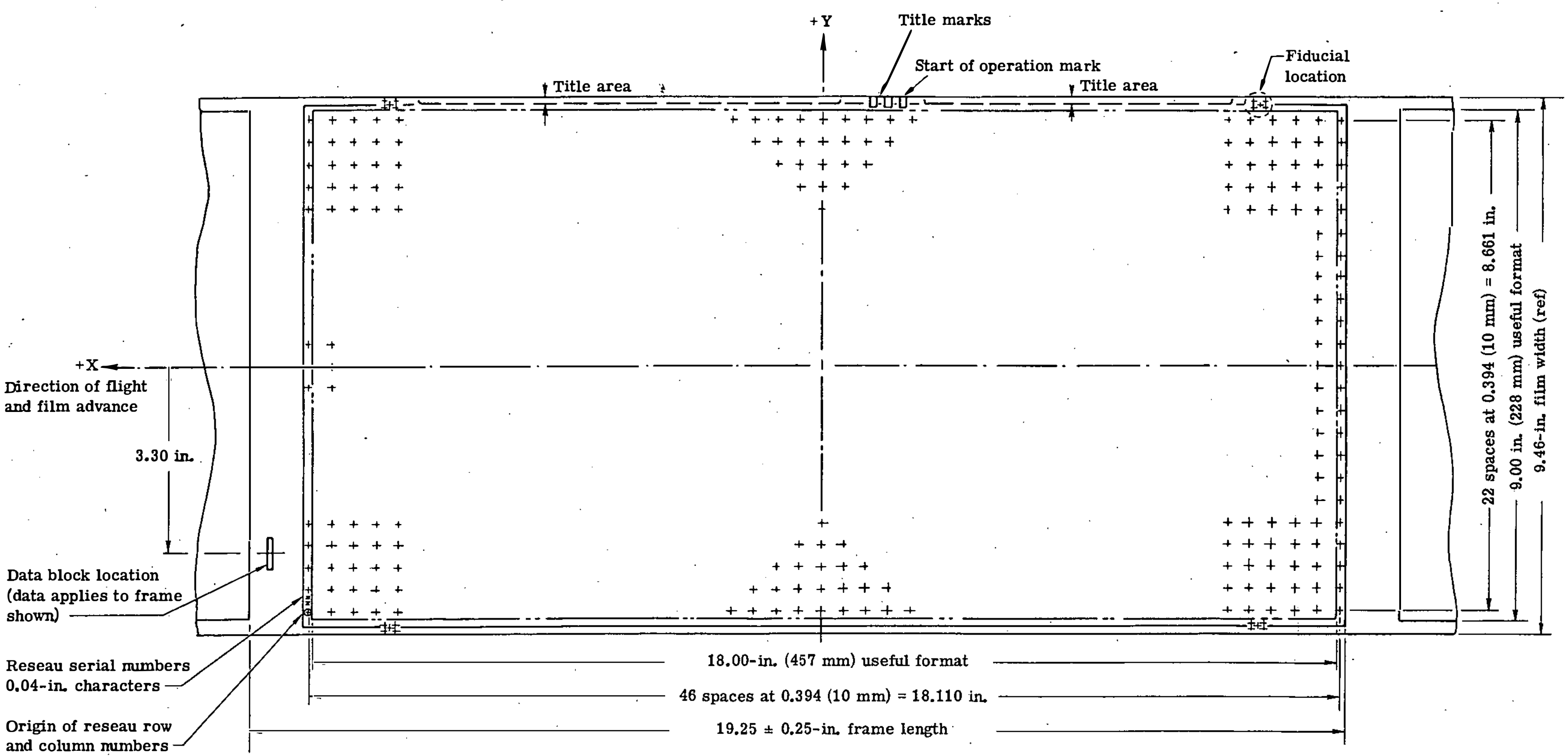


Fig. 2-2 — Terrain camera format (original negative emulsion down)

Table 2-1 — Terrain Camera Characteristics

- Structure
  - Machined beryllium
  - Kinematically supported
- Shutter
  - 3, 6, 12-millisecond exposure
  - Rotary disc speed: 2,000 rpm max
  - Capper actuation 100 milliseconds
- FMC
  - Continuous running
  - ± 0.06-inch stroke
  - 2% overall accuracy
- Transport
  - Continuous metering
  - Film load: 3,300 feet of type 3400
  - Frame period: 7.8 - 80 sec
- Timing
  - Fiducial/midexposure: 1 millisecond
  - SV time recording: 1 millisecond
  - Inter-frame time recording: 0.1 millisecond

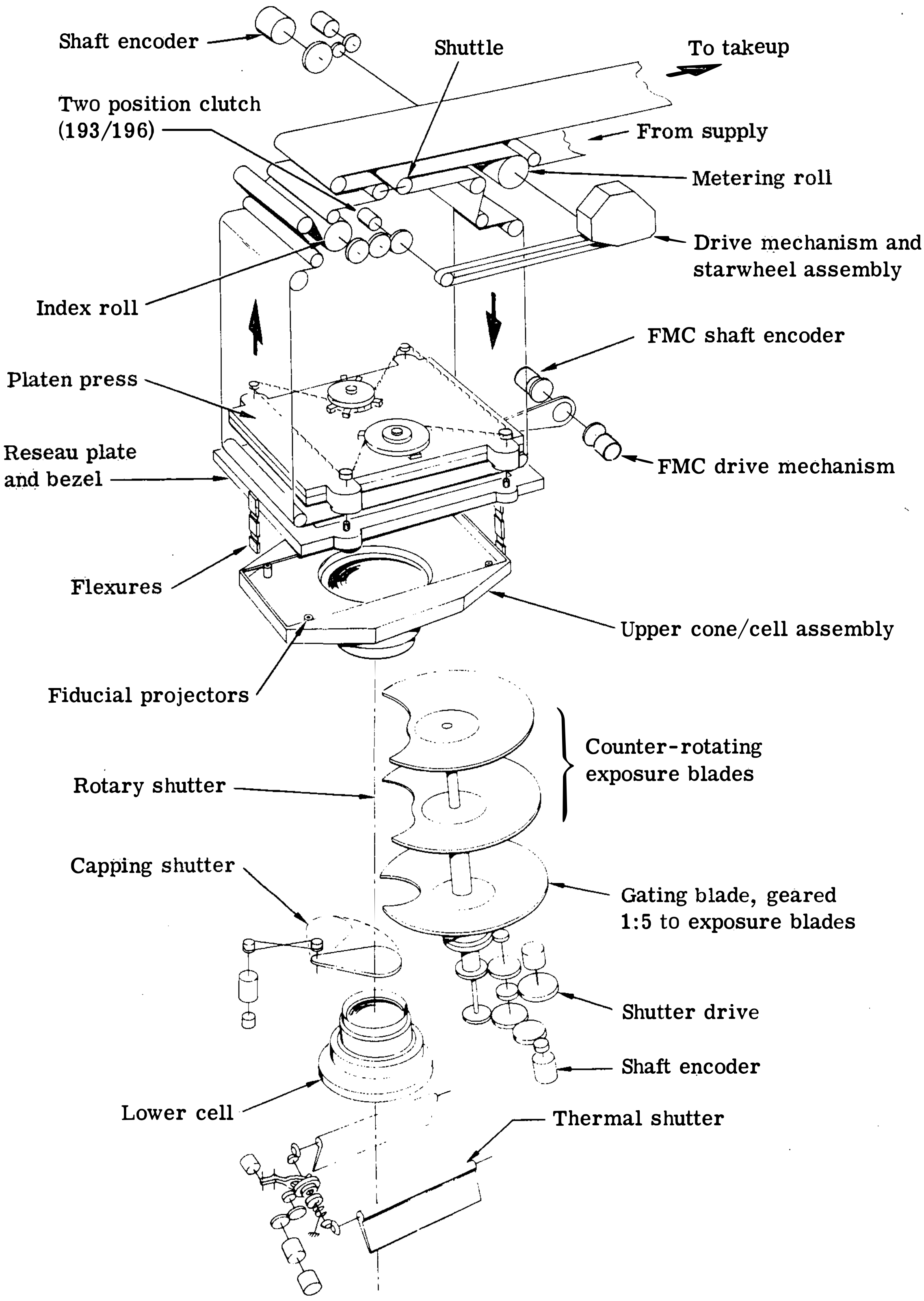


Fig. 2-3 — Terrain camera—mechanical arrangement

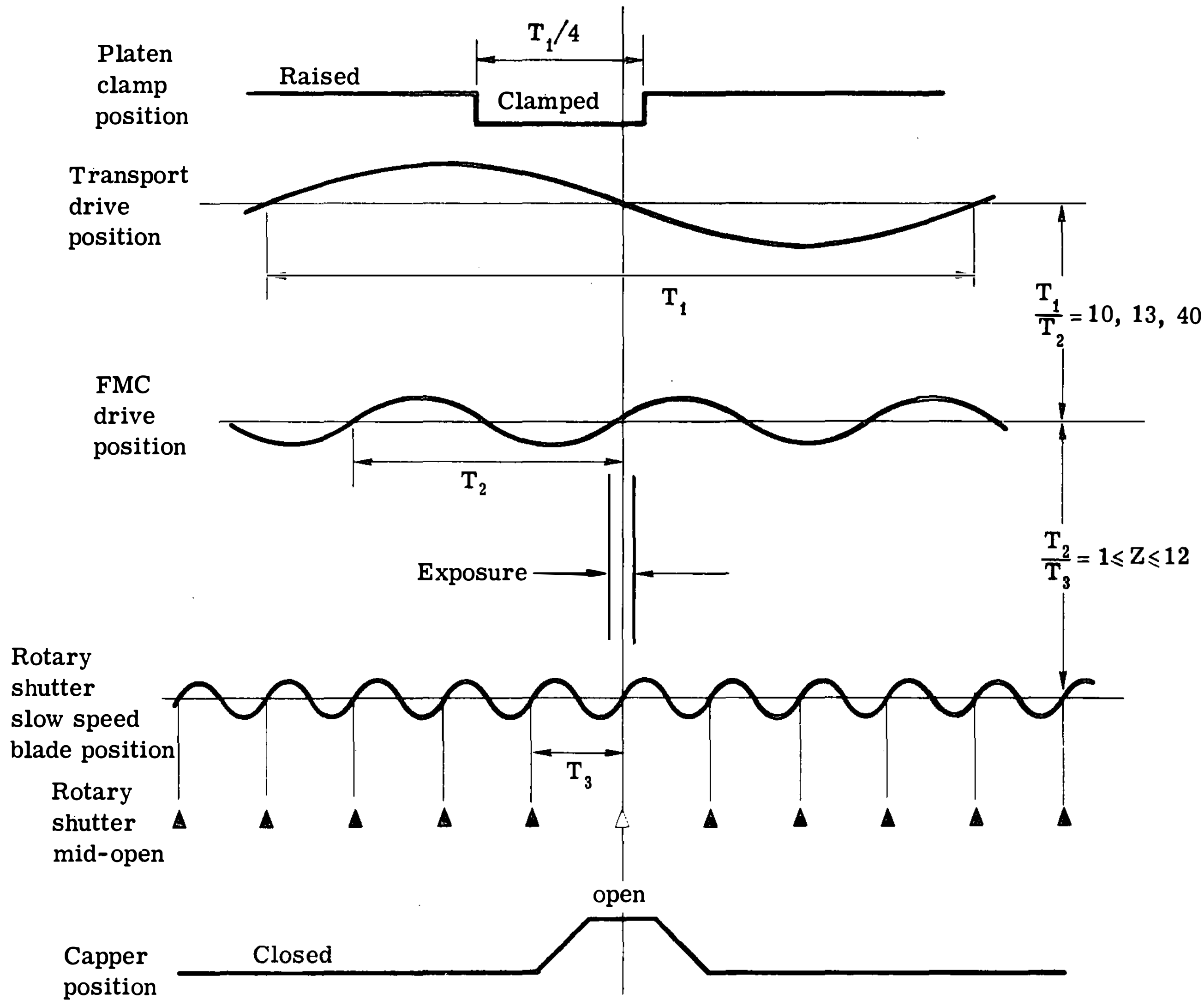
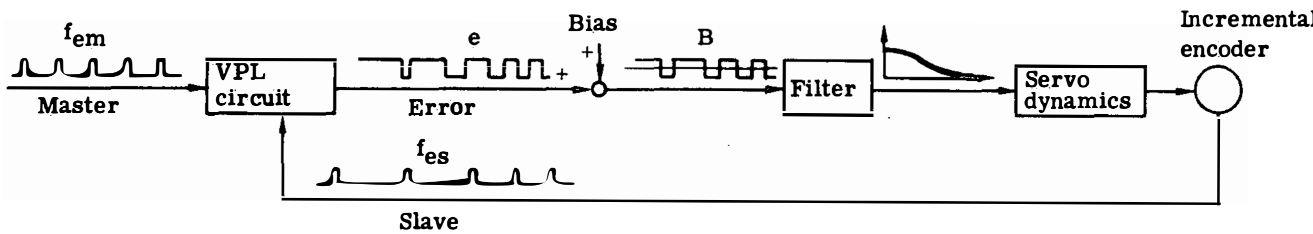


Fig. 2-4 — Terrain camera synchronizing



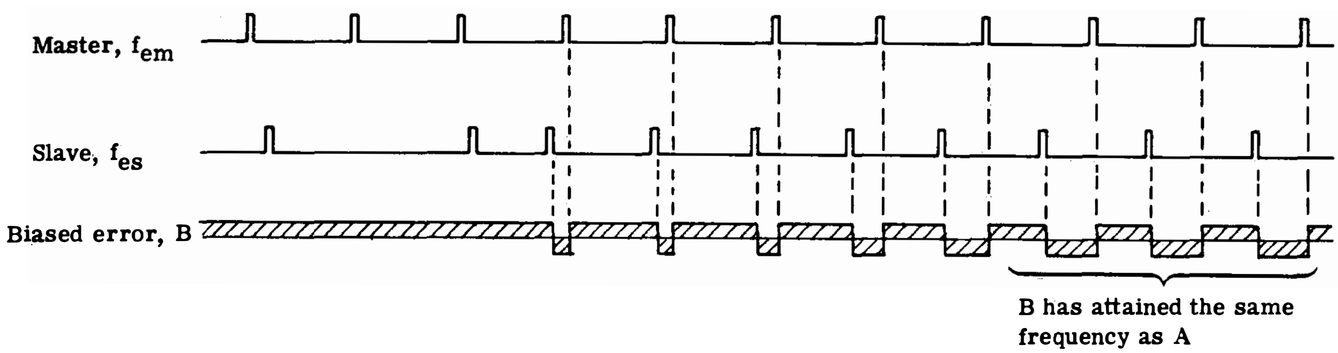


Fig. 2-5 — Illustration of velocity locking a servo

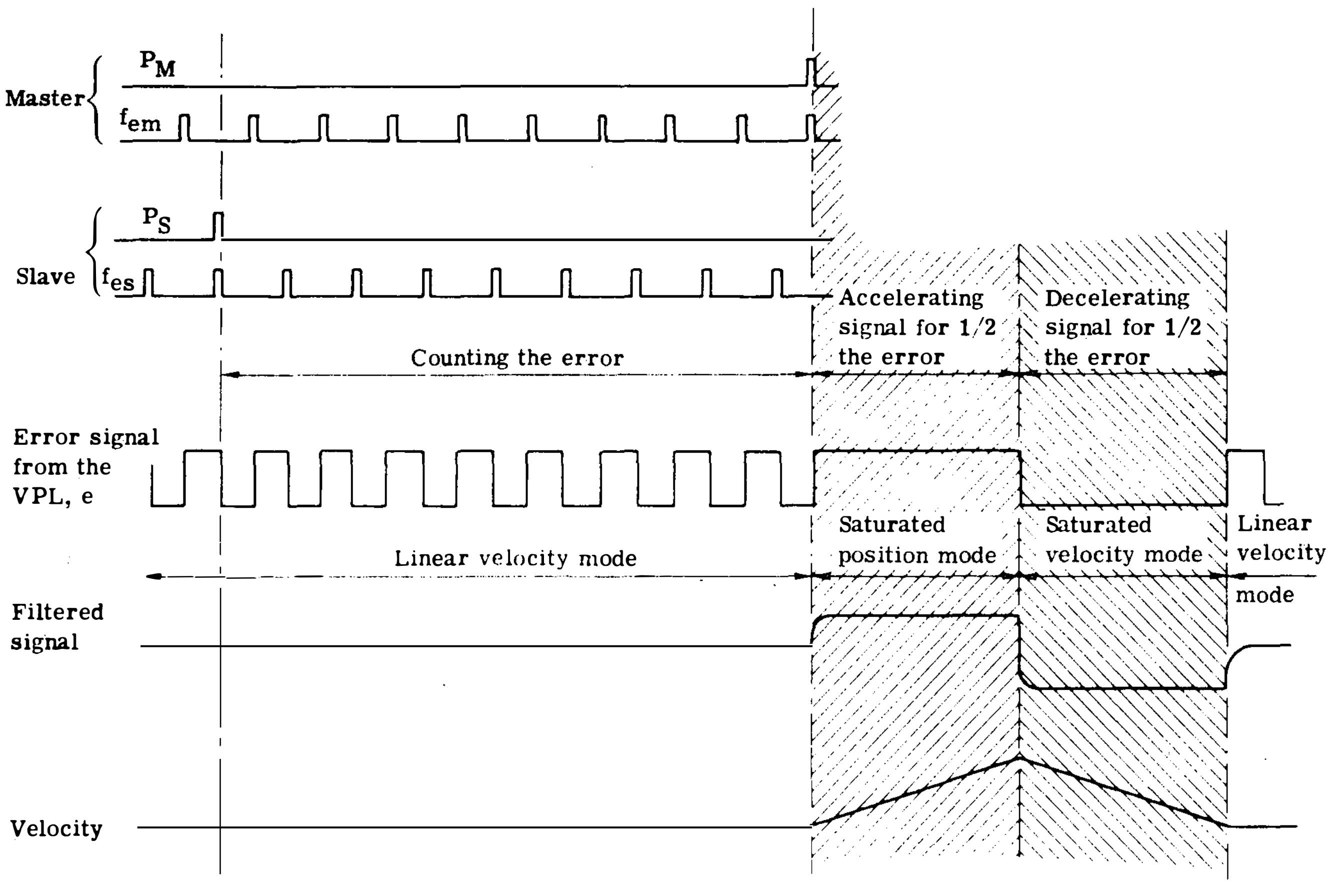


Fig. 2-6 — Illustration of position locking

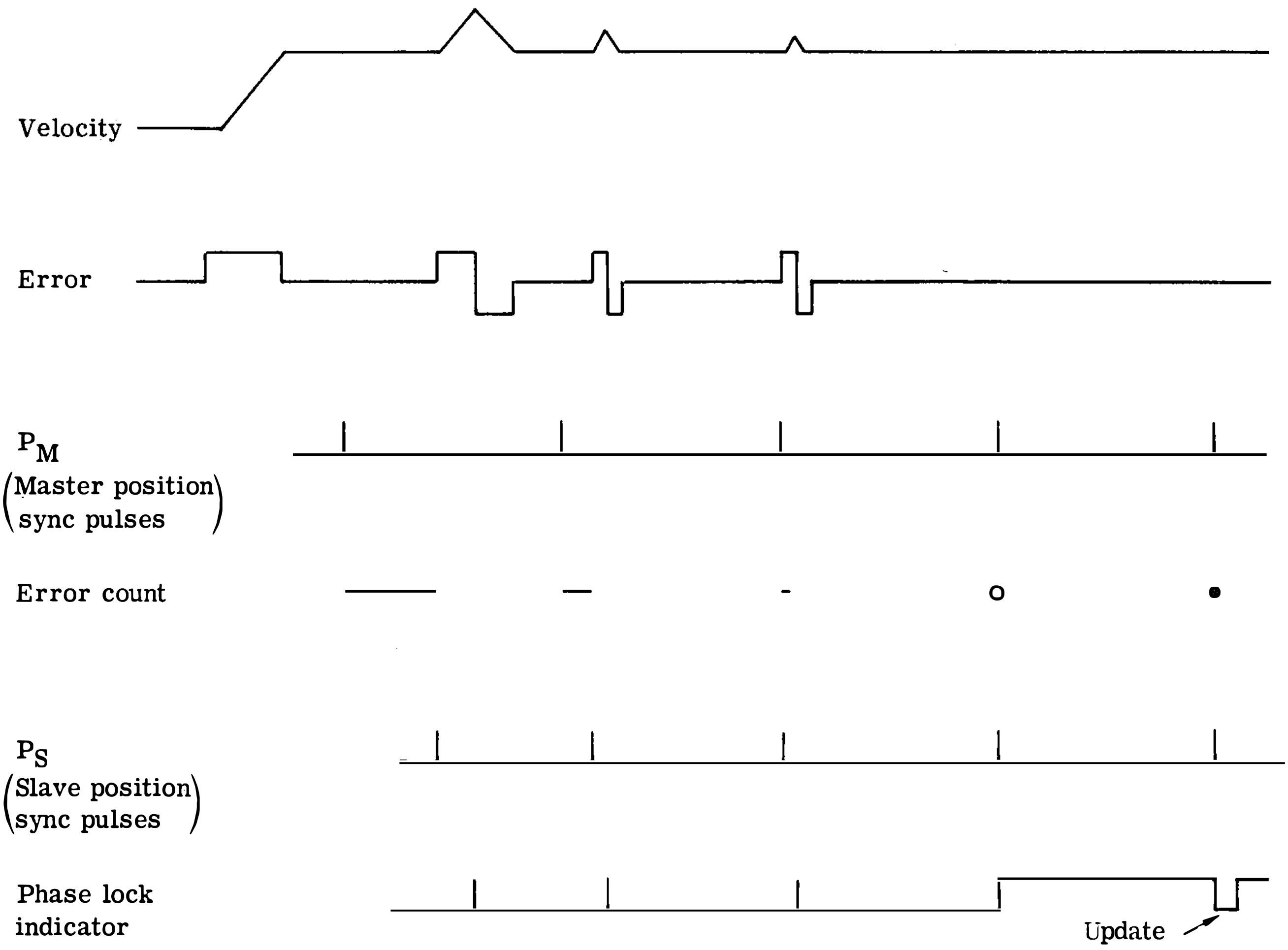


Fig. 2-7 — Typical phase lock loop position corrections

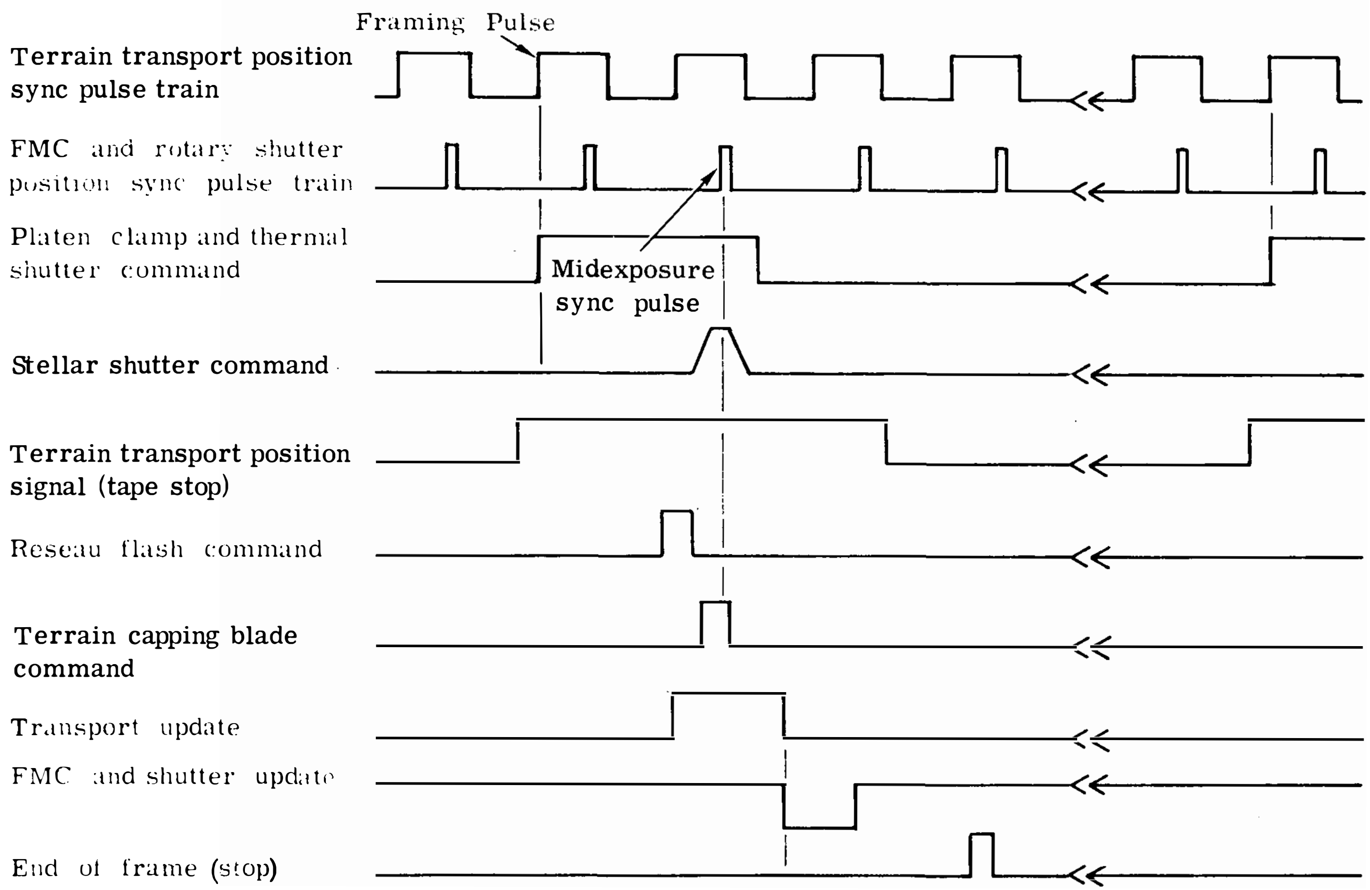


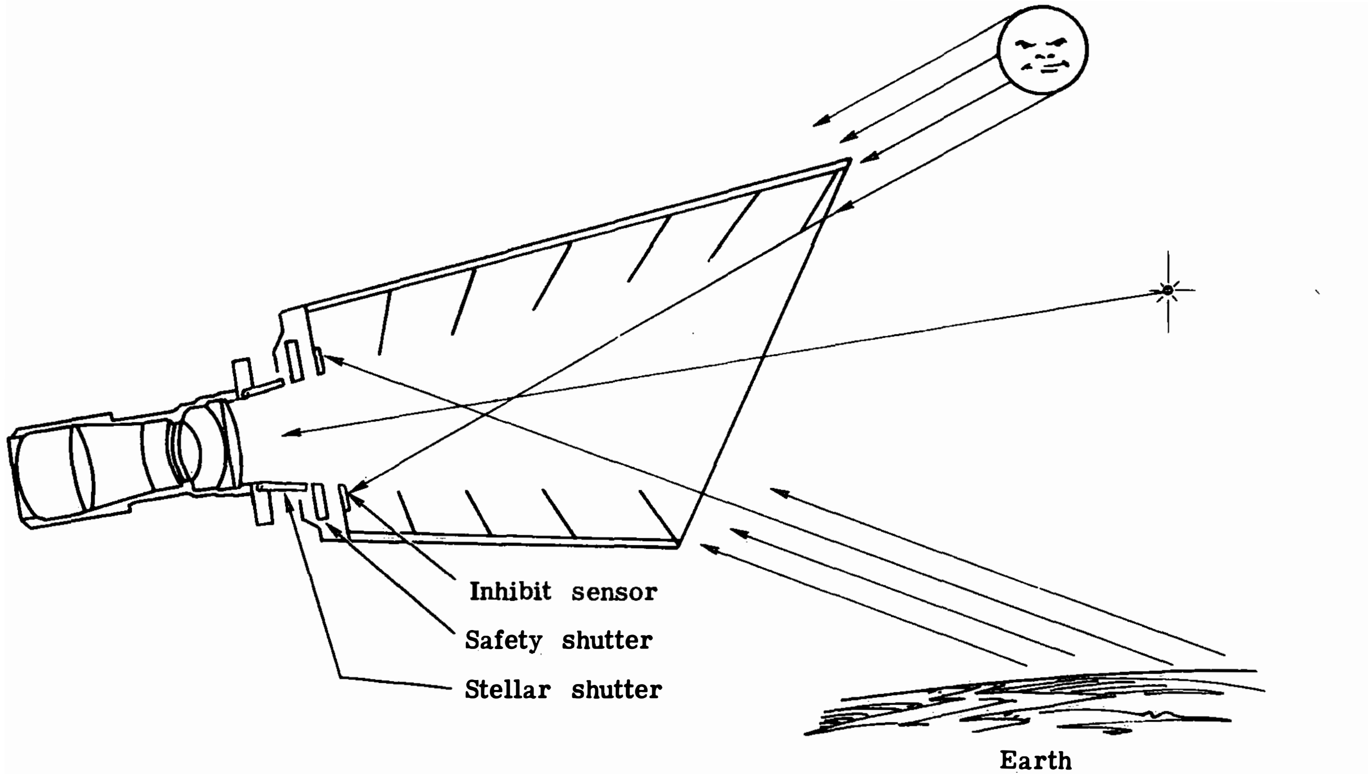
Fig. 2-8 — Normal mode C&S timing

3. STELLAR CAMERA DESCRIPTION

The stellar lenses are rigidly attached to the camera body and point aft ±45 degrees to the flight path and in a plane 10 degrees above horizontal. A large baffle is mounted to the MCM structure outboard of each stellar lens, as shown in Fig. 3-1. The function of the baffle is to prevent stray light from reaching the lens aperture, either from the earth's horizon or the sun (when outside the field of view by 15 degrees, or more). Under some orbital conditions (high latitudes in the southern hemisphere) the sun will enter the field of one or the other lens. To prevent damage to the camera and allow use of the data from the other half of the format, light sensors and circuitry sense the approach of the sun to the field and inhibit operation of the affected shutter.

The lens reseau plates are adjacent to each other such that a single stellar camera format (Fig. 3-2) contains both images of a frame with data block and process marks between them. The functions of the data block, process marks, and reseaux are identical to those for the terrain camera. Since insufficient background illumination is available in the star field to reliably shadow the reseaux, light sources are placed inside the shutters and are flashed before the shutters open.

The characteristics of the stellar camera are listed in Table 3-1 and the subsystems of the camera are shown in the mechanical arrangement in Fig. 3-3. The stellar transport is slaved to the terrain transport and is mechanically similar. Outboard of the normal stellar shutters are safety shutters which may be permanently closed during the mission in the event of a malfunction which causes either stellar shutter to remain open; the mission may then continue without degradation of the other half-format.



Lens focal length = 10.0 inches
f/2.0
Sensitivity = 6th magnitude stars or brighter
Boresight stability = 2 arc-sec in operation
Field of view: 16 by 25 degrees

Fig. 3-1 — Stellar lens and baffle

H/SECRET HANDLE VIA BYEMAN CONTROL SYSTEM

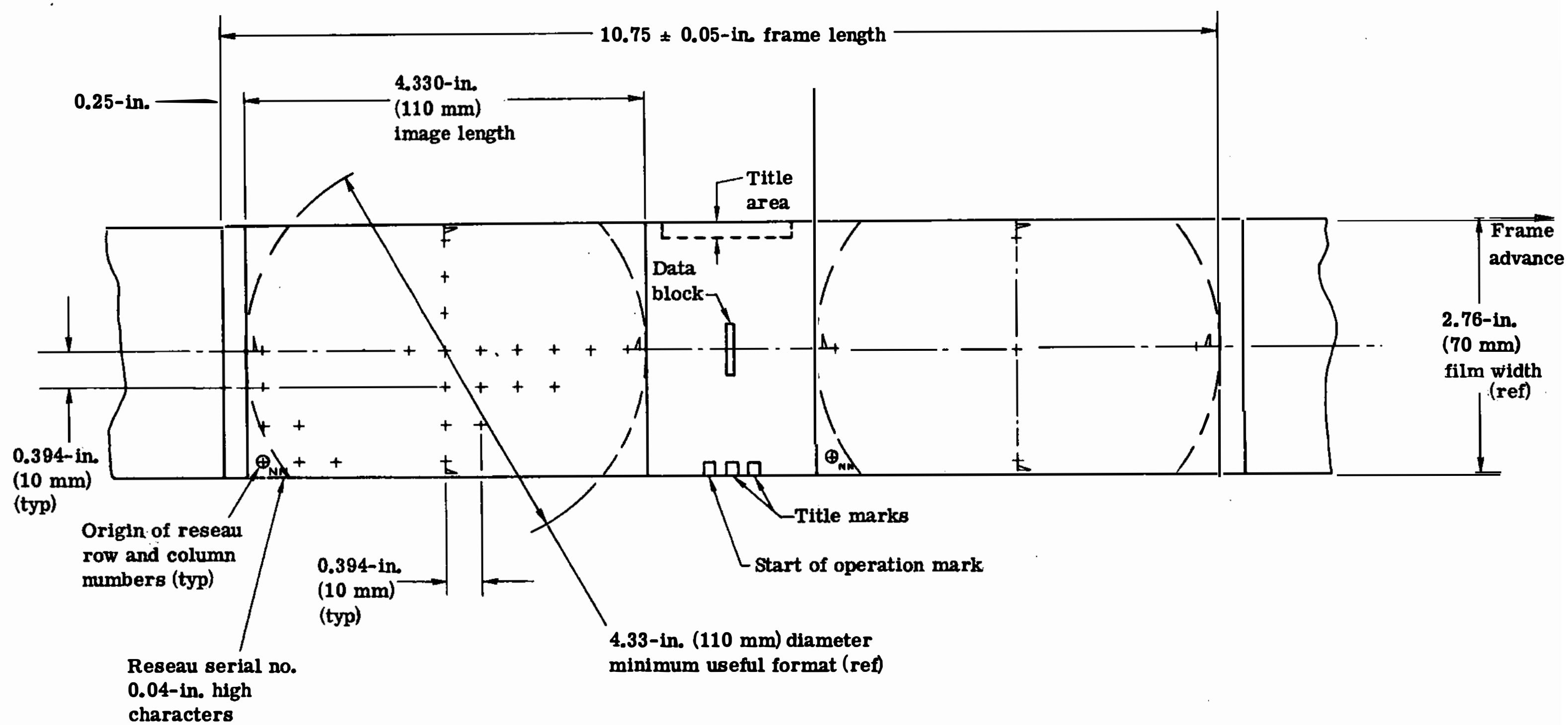


Fig. 3-2 — Stellar camera format (original negative emulsion down)

H/SECRET HANDLE VIA BYEMAN CONTROL SYSTEM

BIF-059W-5439-72A

Table 3-1 — Stellar Camera Characteristics

- Structure
  - Machined beryllium
  - Integrated with terrain cell
- Shutter
  - 200-millisecond exposure
  - Combined thermal/optical gate
- Transport
  - Synchronous with terrain
  - Film load: 2,000 feet of type 3401
- Timing
  - Midexposure coincidence: 4 milliseconds between stellar and terrain
  - Shutter half open/closed time recording: 10 milliseconds

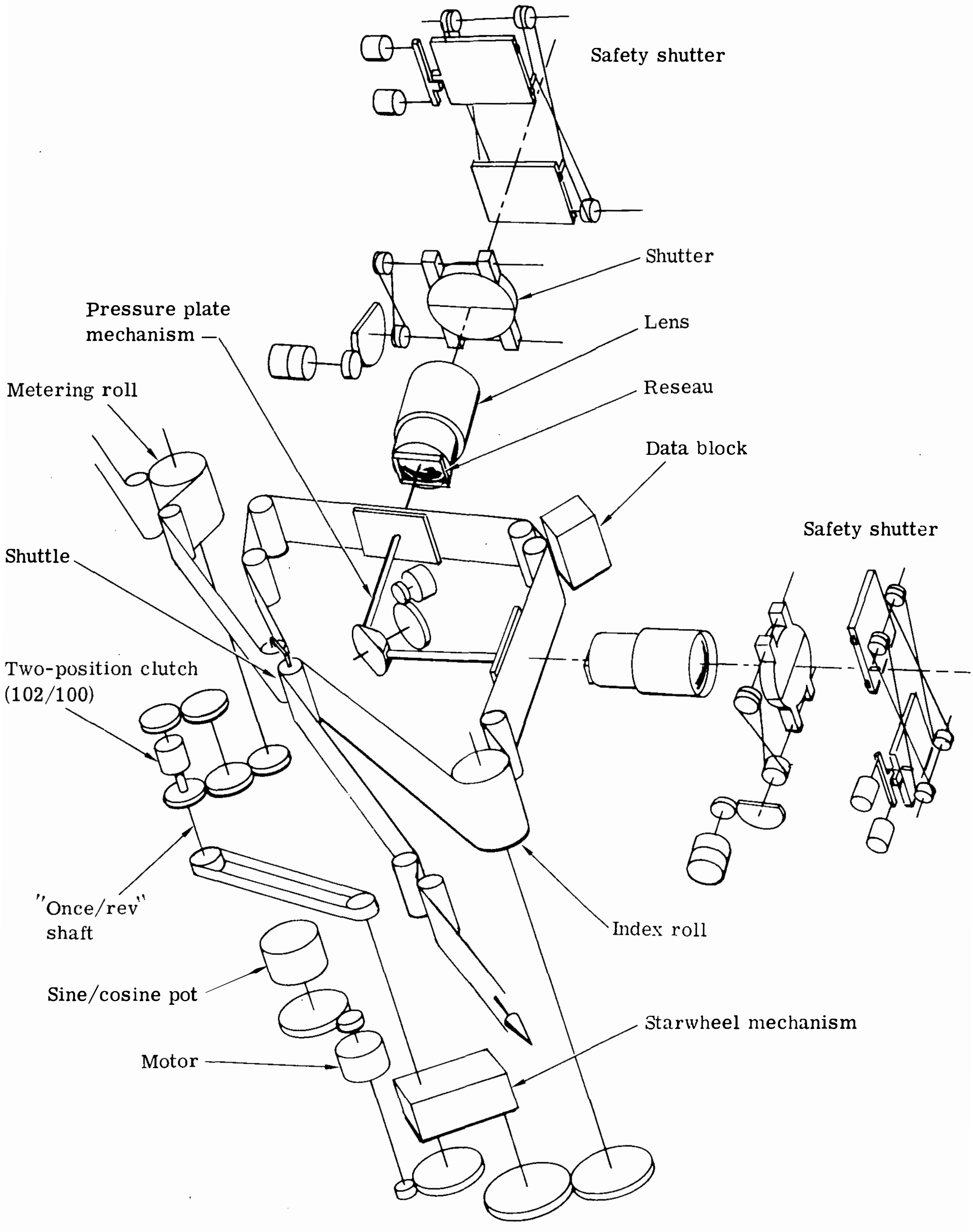


Fig. 3-3 — Stellar camera—mechanical arrangement

4. MAPPING CAMERA OPERATIONS

The sequence of operations from mapping camera buildup through orbital operation is shown in Fig. 4-1. Confirmations of system stability and resolution performance are obtained at NEC, and the prelaunch calibration signature of the camera is obtained at a Government facility in Cloudcroft, New Mexico. No photographic tests are conducted after arrival at SBAC, although basic functional parameters are reverified at stages throughout the factory flow.

The final film load is normally installed at the SBAC factory before shipment of the SV to VAFB. A limited number of frames are passed for checkout at the pad before launch. Normal launches will be into a near-polar, sun-synchronous orbit within 2 to 3 hours of local noon. The camera is commanded into the A mode during powered flight.

Orbital operations are controlled from the AF Satellite Test Center (STC), Sunnyvale, California (see Fig. 4-2). Land area acquisition priorities and camera parameters are stored in a data base in the STC computers. As the predicted spacecraft track crosses the land, the STC software continuously checks the acquisition priority of the area within the camera's field of view, determines if the predicted cloud cover over the area is below a preset threshold, and generates a command message which programs camera operations at times when the acquisition criteria are satisfied. The command message is relayed to the SV from one of several remote tracking stations (RTS) in the satellite control facility (SCF) network, and executed within a few revolutions of generation. During programmed camera operations, data from camera instrumentation is stored on an on-board tape recorder, played back during an RTS pass, preprocessed, and relayed to the STC. Telemetry data are analyzed at the STC for indication of malfunction, and alternate modes of operation will be commanded when appropriate, in accordance with a contingency plan.

The terrain film load contains a short segment of type 3401 (Plus X) film at its end, separated from the normal type 3400 film length by an opaque splice. The higher speed 3401 film is used for in-flight stellar calibration of the camera. When a detector in the camera is enabled, passage of the splice through the terrain transport causes the system to stop. On a succeeding revolution, the SV may be commanded into a pitched-down attitude (see Fig. 4-3) such that the terrain and both stellar fields view the celestial sphere, and 2-second time exposures are made to obtain star records. Alternatively, the camera may be calibrated in its normal mode of operation over a ground range containing control points whose relative spacing has been accurately measured. Such a range exists in the Arizona-New Mexico area; this range is equipped with geoceivers which allow accurate spacecraft position determination so that a calibration of the stellar/terrain lock angle can also be obtained.

Normal mission termination occurs when the film load has been depleted. A cut/seal device is actuated to sever any film remaining outside the RV and to close the capsule. The spacecraft is again commanded into a pitched-down attitude, the RV is ejected, and retrofire and other recovery events are initiated by the RV sequencer. The recovered capsule is returned intact for film processing.

Referring again to Fig. 4-2, the processed film is routed to the map production organizations. The time words are read from the data blocks and used, together with a refined ephemeris determined postflight from doppler beacon tracking data, to accurately locate the camera at the time of each exposure. Camera orientation for each exposure is determined by processing measured star image coordinates, stellar camera calibration parameters, and star catalog data. Ground control point locations are then established by imposing air station location, orientation, and terrain lens and reseau calibration data on measured terrain image point coordinates. The final step in production of a map manuscript involves completion of the scene detail and elevation contours in a format which is warped to fit the measured control points. This step is accomplished in either a visual plotting instrument or in available scene-correlating automatic compilers, using photography from the mapping camera or another system.

A portion of a typical 1:50,000-scale map and the detail provided in a blowup of a mapping camera image is shown in Fig. 4-4. It is expected that the Hexagon mapping camera imagery, augmented with panoramic camera imagery in some areas, will satisfy all current national objectives for completion of 1:50,000 class A topographic maps.

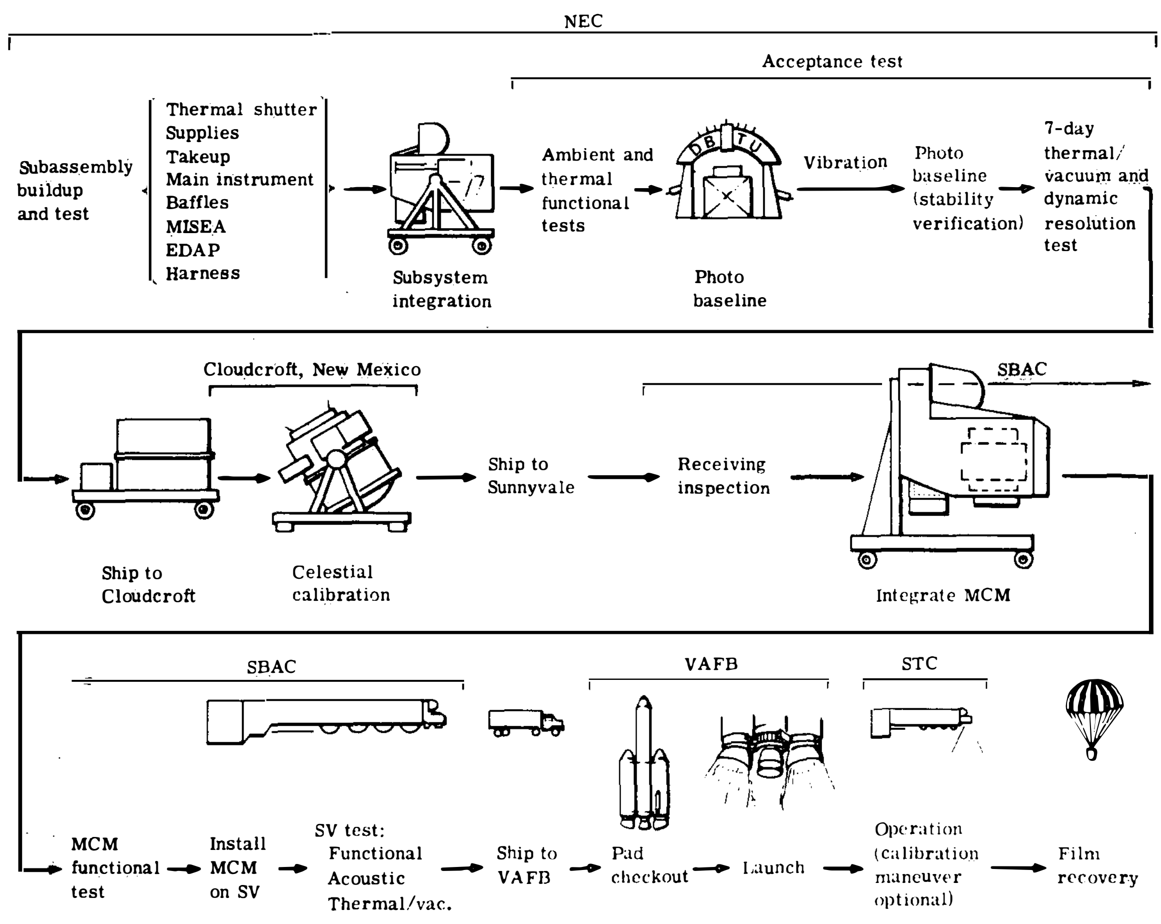


Fig. 4-1 — Mapping camera integration and operation flow

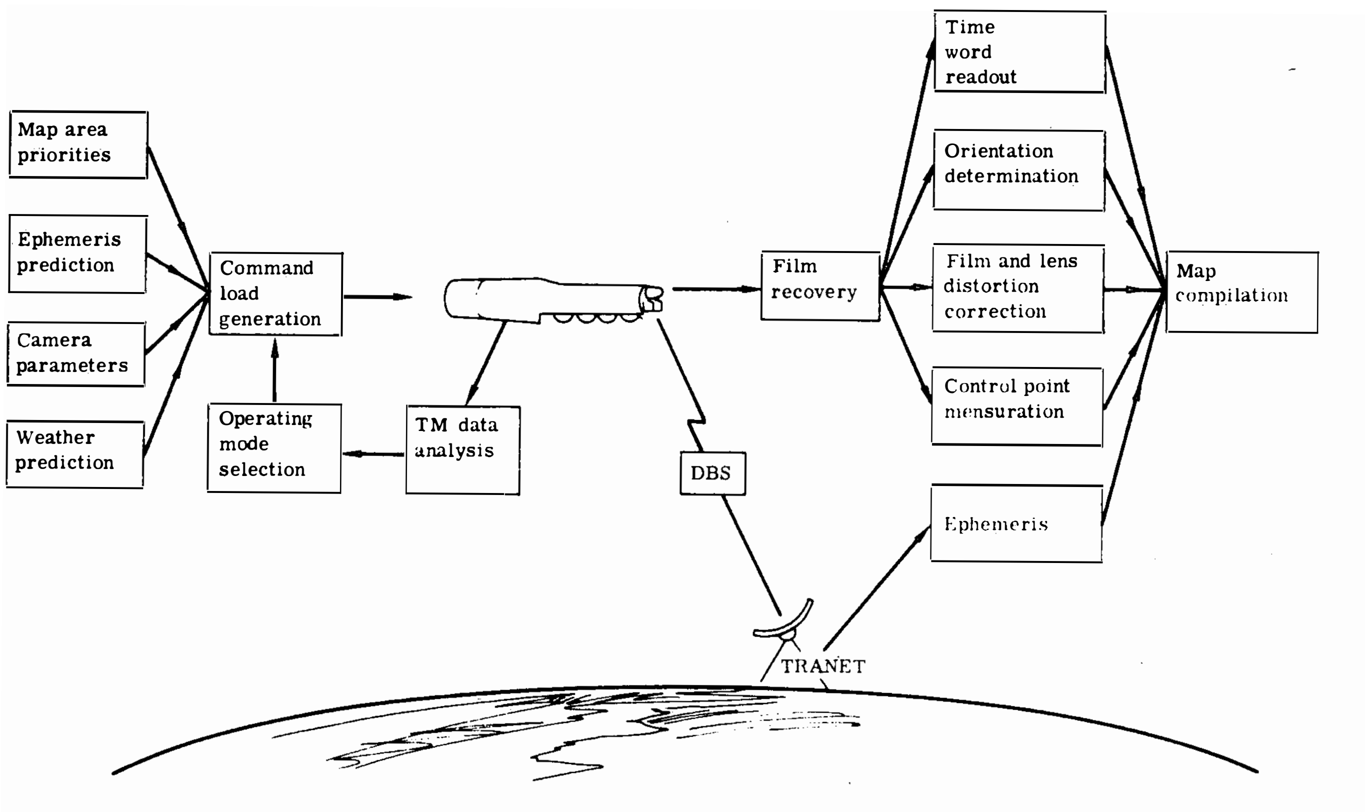


Fig. 4-2 — Mapping camera operational data flow

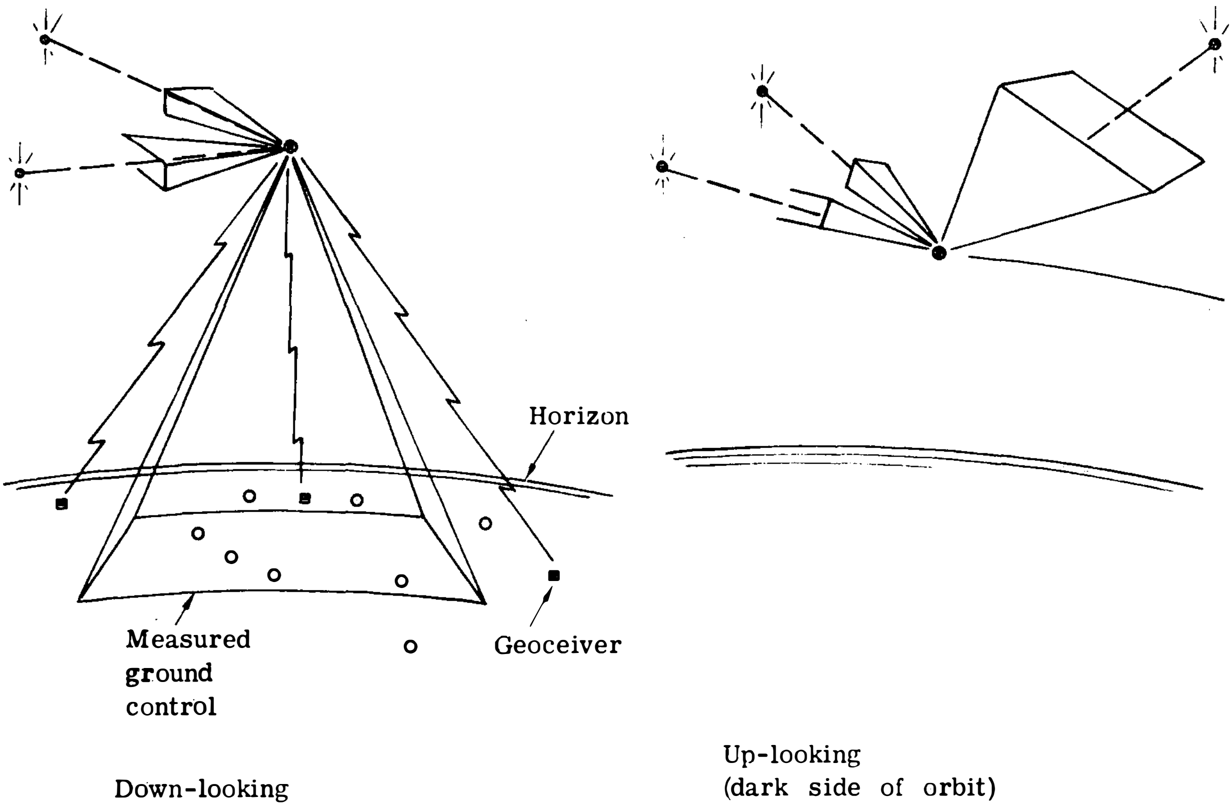


Fig. 4-3 — Mapping camera in-flight calibration

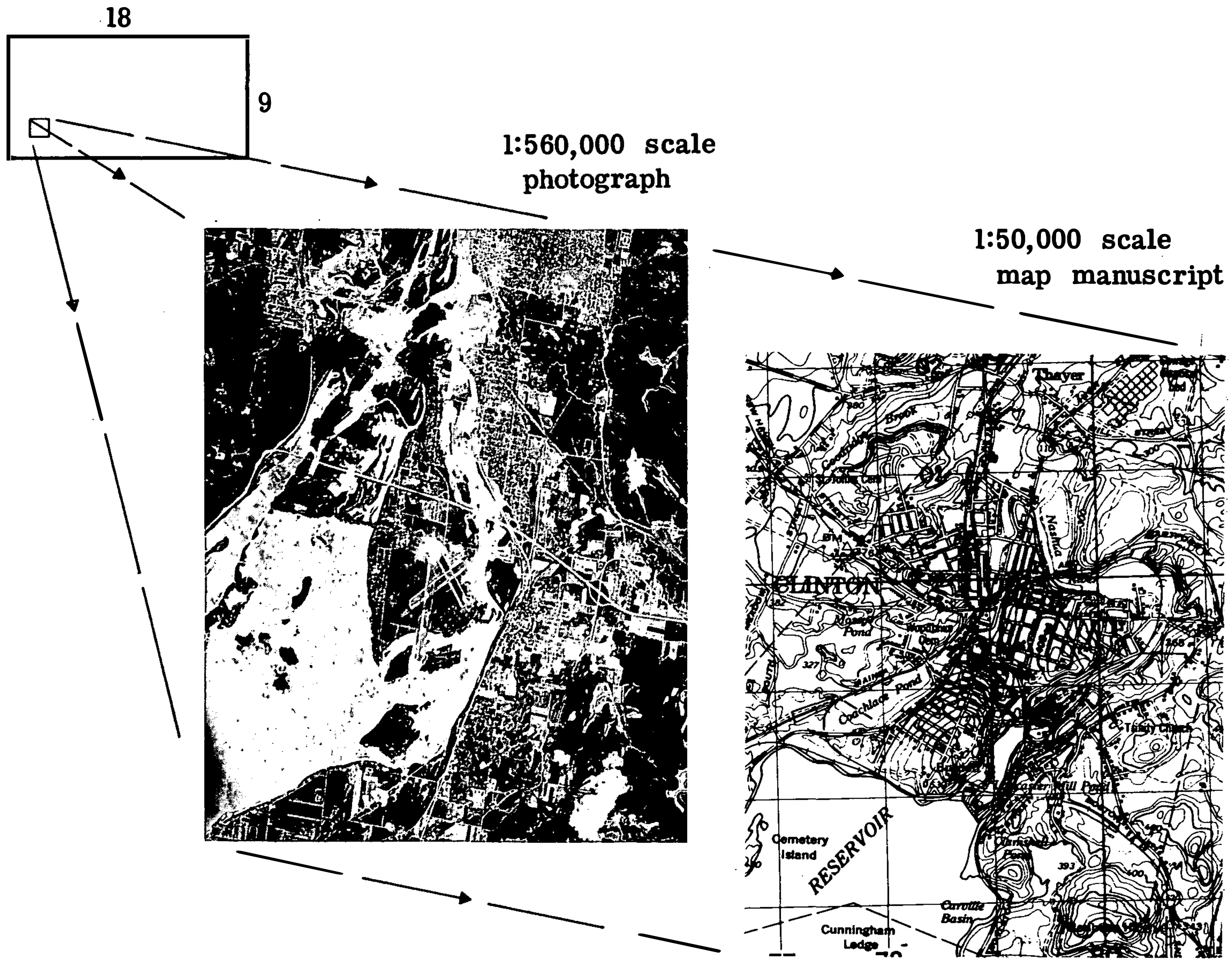


Fig. 4-4 — Example of mapping camera product

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