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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 15 SIM BAY PHOTOGRAPHIC EQUIPMENT AND MISSION SUMMARY

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

PREPARED BY
MAPPING SCIENCES BRANCH
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SUMMARY

The Apollo 15 mission will provide the first mapping quality photographic products of the lunar surface. This will be accomplished using a Fairchild 3-inch metric mapping camera with associated stellar camera, and ITEK optical-bar 24-inch panoramic camera and an RCA ruby laser altimeter. The purpose of this document is to present selected pertinent data concerning the photographic experiments in the Scientific Instrument Module (SIM) bay. Included is a brief description of each experiment with available calibration data, an explanation of the photographic orbital support data and the mission photographic profile of planned/accomplished objectives.

This mission summary is intended to provide overall knowledge of the experiments and a quick reference to the planned and accomplished Apollo 15 SIM bay photographic objectives. This document will be supplemented by publication of the Apollo 15 Photographic Index and 16mm microfilm of the orbital support data. These additional data will not be available for several months after the mission.

CONTENTS

1.0 INTRODUCTION

The three photographic experiments discussed in this document, the Fairchild three-inch metric camera, ITEK 24-inch optical bar panoramic camera, and the RCA ruby laser altimeter, are located in the Scientific Instrument Module (SIM) located in bay 1 of the Service Module (Fig. 1-1). The SIM bay also contains the spectrometer experiments.

During blastoff and translunar coast, the SIM bay is covered by the SIM bay door. This door is to be jettisoned approximately 4 1/2 hours before lunar orbit insertion (LOI). After door jettison, the spacecraft attitude must be controlled to prevent impingement of direct sun rays within the look-angle envelope of the optics of each sun sensitive instrument. This includes both the mapping and panoramic cameras as well as certain of the spectrometers.

Operation of the SIM bay experiments is controlled by an astronaut using three control panels 181, 278, and 230 (Figs. 1-2 and 1-2a) located on the right hand side of the spacecraft. Explanation of specific switches that affect equipment operation are explained in the text of the individual experiments. Further explanation of the control panels is not germane to the purpose of this document and would not add substantially to knowledge of the experiments.

Also, for real time monitoring of the experiments, certain telemetered data are displayed on the closed circuit TV in the Mission Operations Center, Bldg. 30, MSC (Fig. 1-3). Recommended operational limitations for the data are also given. The limitations are those valid at the printing of this summary and may be subject to change. At times the experiments may be operated outside these limitations due to mission considerations, with an

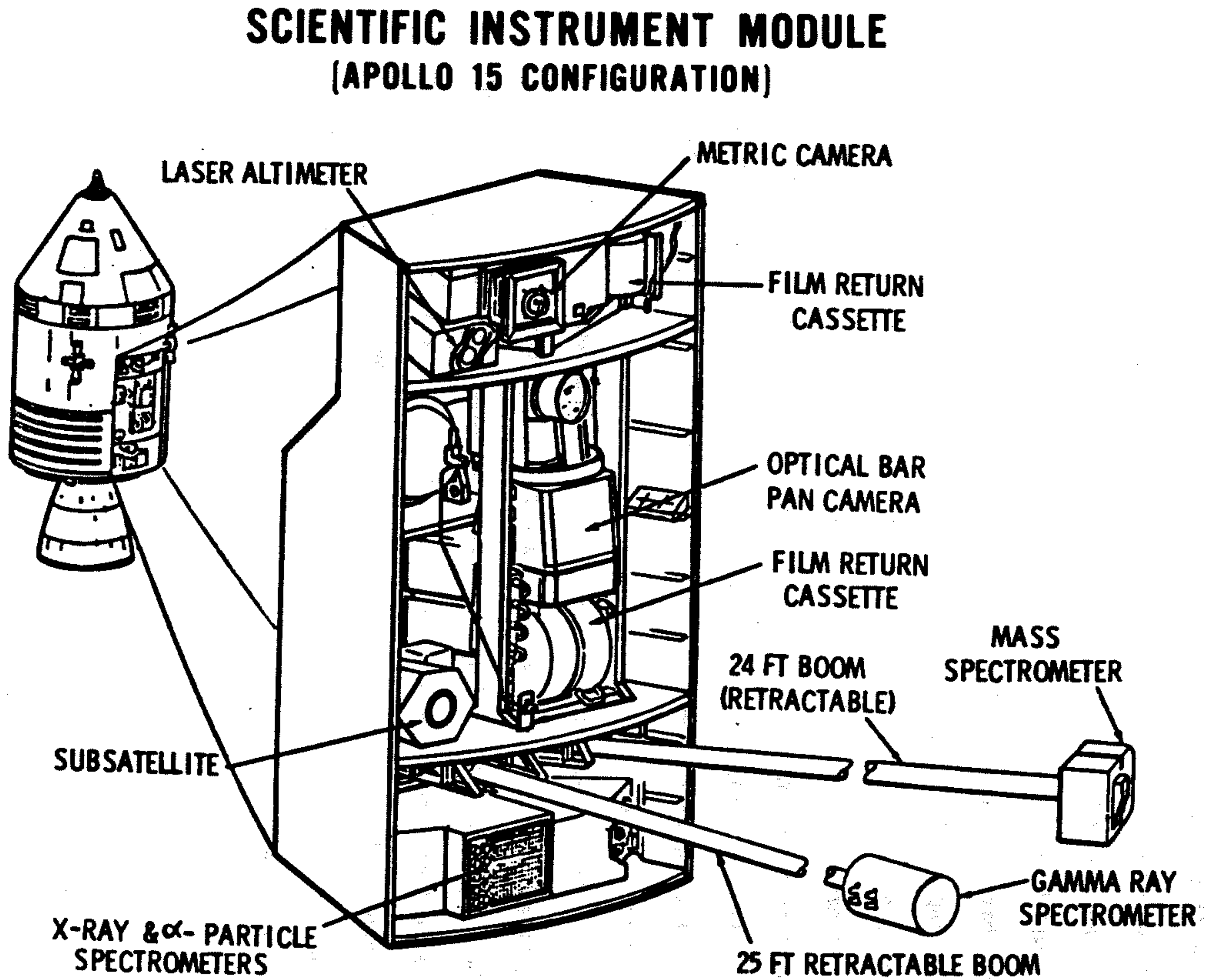
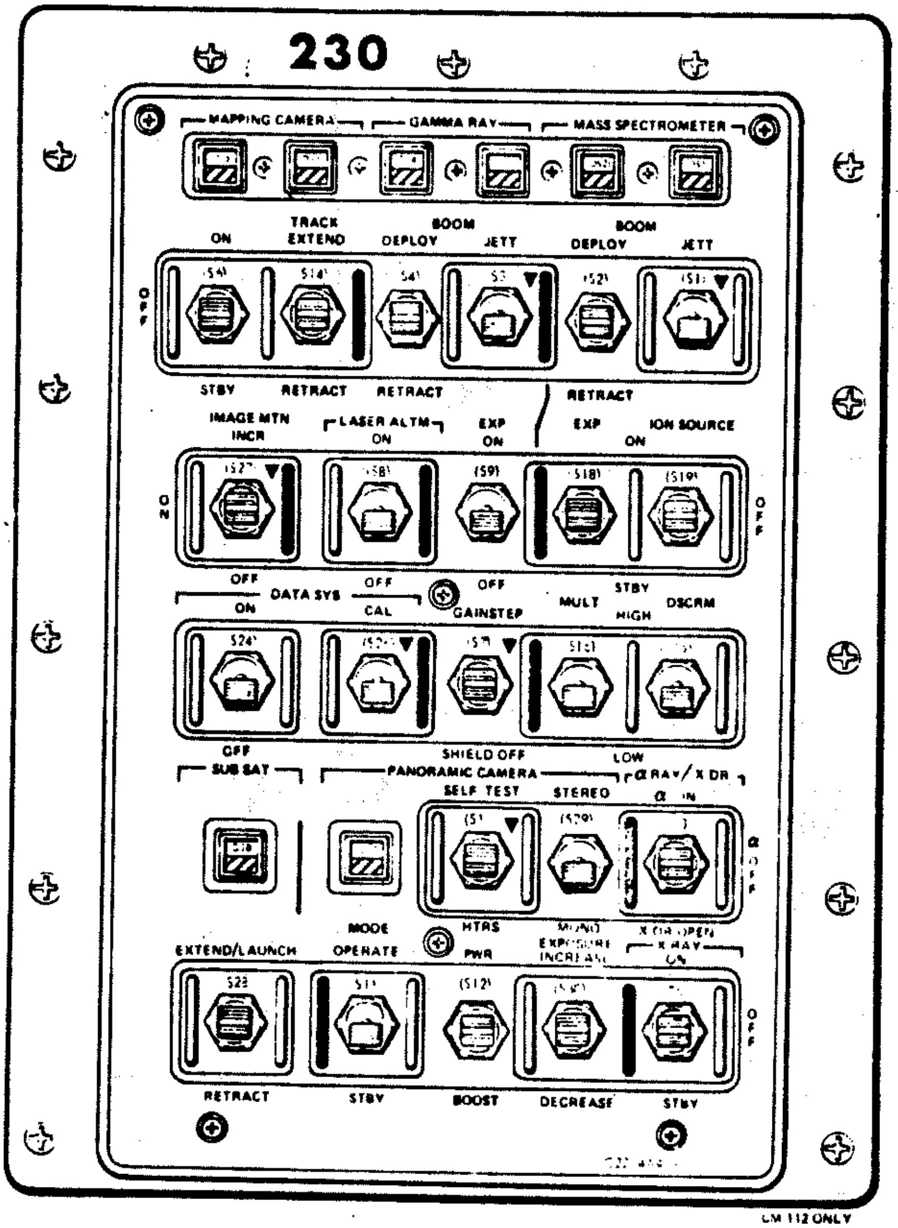


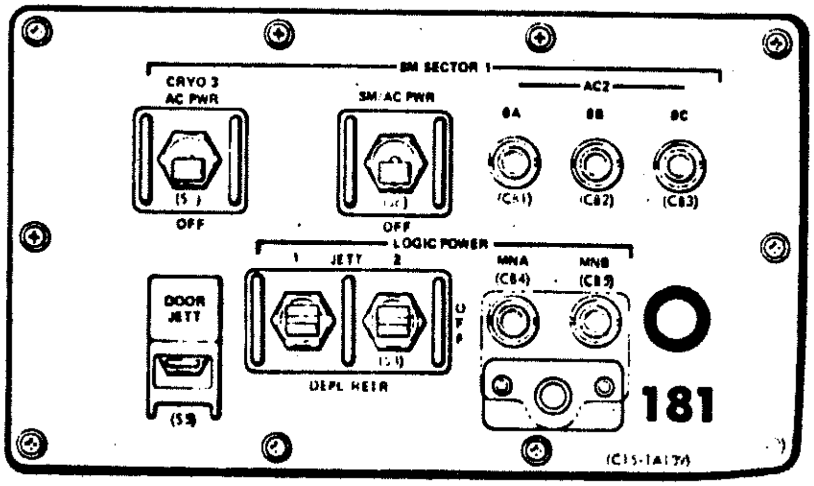
Fig. 1-1 Scientific Instrument Module Configuration

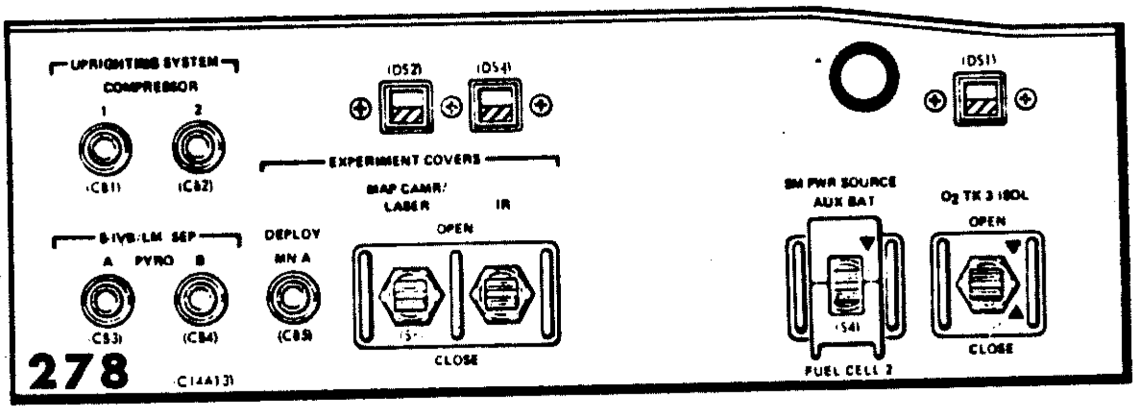
Fig. 1-1



CONTROL PANEL

Fig. 1-2





CONTROL PANELS

Fig. 1-2a

PHOTO/LASER

PANORAMIC CAMERA

SL1030V V/h CMD V	10.1 to 20 MRAD/Sec
SL1031X Air Sol	Event only: Open-close
SL1032T Elect Temp	86° to 110°F
SL1033M FR Roll Pos	0 to 47 inches
SL1034M Shuttle Pos	0 to 14.38 inches
SL1035C Lens Torq I	0-10 amps
SL1036X Cap Sht Pos	Event only: Open-close
SL1037V FMC Tach V	0-20 MRAD/Sec
SL1038H Expo CMD	0-2000 FL
SL1039T Lens Bar T	
SL1040T Fwd Lens T	88° ± 2°F
SL1041T Aft Lens T	
SL1042T Mech T	86° to 94°F
SL1044HSlit-Width	.015 to .300 inches

MAPPING CAMERA

SL1160T MC Fwd Len T	
SL1161T MC Len Bar T	
SL1162T SC Fwd Len T	70° ± 10°F
SL1163T SC Len Bar T	
SL1164T Cassette T	
SL1165X Image Mot	Event only: 0 or 5V
SL1166A Shut Speed	80 to 1280 RPM
SL1166X Deploy/Cut	Event only: deploy 3.IV, 1500 to 0 ft/cut 1.0V
SL1176Q Film RMG	
SL1181V V/h Inc LVL	12.1, 13.1, 14.1, 15.1, or 16.1 MRAD/Sec

LASER ALTIMETER

Reg +5V Ang Overflow Laser Output Q-SW Mtr Sta Krytron Trig MC Data Req	Event only: Condition "1" Operational Condition "0" non-opera.
SL1122K Altitude	xxxxxx meters
SL1091V - 5V Reg	Event only: 0v or 5V
SL1092V Photomult. V	
SL1093V PRN V	
SL1094T Cavity T	

FIG. 1-3 Photo/Laser Real Time Telemetry Display and Operational Values

accepted loss of accuracy in the resulting data.

The orientation of the experiments with respect to the lunar surface is determined from the spacecraft trajectory and onboard gimbal angles. These parameters have certain inherent errors that must be recognized. These errors, as well as others that may not be listed, affect the capability of recovering the experiment attitudes computed in the orbital support data. An explanation of attitude pointing terminology and errors is explained in Table 1-1. The orbital support data is discussed in paragraph 5.

The information in the Photographic Mission Summary has been kept brief because of the planned publication of a Photographic Data Utilization Manual for the SIM bay photographic experiments. This Manual is being compiled at the Manned Spacecraft Center and publication is planned prior to Apollo 16. If additional information related to this summary is desired please contact the Mapping Sciences Branch TF5, Manned Spacecraft Center, Houston.

DEFINITION OF TERMS

Two major types of attitude pointing requirements are specified for each experiment's pointing accuracy and pointing knowledge. These terms are defined as follows:

1. Pointing Accuracy Requirement/Capability - The real-time accuracy to which a given instrument must/can be pointed relative to the desired direction.

2. Pointing Knowledge Requirement/Capability - The accuracy to which a given instrument pointing history must/can be derived from post-flight data reduction.

The only significant quantitative difference between pointing accuracy capability and pointing knowledge capability is the magnitude of the attitude hold deadband maintained in lunar orbit. The instantaneous position in the control deadband can be determined from the telemetered IMU gimbal angles, thus providing a more accurate post-flight pointing knowledge.

SPECIAL TERMS FOR BOOM-MOUNTED INSTRUMENTS

Each boom-mounted experiment presents a special pointing accuracy problem due to the additional sources of attitude uncertainty associated with the deployment mechanism and the boom itself. Hence, for the sake of convenience on these experiments, two types of pointing accuracy terms are frequently used:

1. Sensor Pointing Accuracy - Pointing accuracy related to the boom-mounted sensor, including uncertainties due to the extended boom and deployment mechanism.

2. SIM Pointing Accuracy - Pointing accuracy related to the interface of the SIM shelf and the deployment mechanism, excluding uncertainties due to the extended boom and deployment mechanism.

In that the angular uncertainties associated with the boom deployment or jettison mechanism are an order of magnitude larger than the control deadband, knowledge of the CSM attitude in the deadband is of negligible significance. Thus, for boom-mounted instruments, post-flight pointing knowledge is effectively the same as in-flight pointing accuracy.

SOURCES OF ATTITUDE UNCERTAINTIES

The following items constitute the various sources of attitude uncertainties which contribute to the total pointing knowledge capability of all non-boom-mounted experiments:

	Attitude Uncertainty (degrees)
Alignment in the instrument*	±0.50
SIM structural tolerances	±0.50
Instrument mounting	±0.20
SIM installation tolerance	±0.23
SIM- G&N navigation base boresighting	±0.05
Deviation from one g to zero g	±1.00
Thermal-induced variations	±0.33
IMU alignment accuracy	±0.03
IMU drift (assuming six hours)	±0.54
CMC local vertical program	±0.25
Root sum of squares (RSS) of random tolerances of these 10 items	±1.44

*Deviations to this 0.50-degree instrument design requirement may be granted for individual experiments and will be specified in the appropriate ICD's.

For non-boom-mounted experiments, the pointing accuracy capability is the 1.44 degrees plus the attitude control deadband (nominally ±0.5 degrees), or ±1.94 degrees. For the boom-mounted instruments, both pointing

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knowledge and pointing accuracy are further degraded by uncertainties in the deployment mechanism and the boom itself.

OPERATIONAL CONSIDERATIONS

Only one planning tool is available that significantly affects pointing accuracy capability, i.e., the selection of control deadband width. For those experiments that require a total pointing accuracy of ±2 degrees, a control deadband of ±0.5 degrees must be selected. During those experiment periods limited to operation of instruments that require a total pointing accuracy of ±5.0 degrees, the control deadband can be opened up to ±3.5 degrees if desired.

2.0 MAPPING CAMERA SUBSYSTEM (MCS)

The Mapping Camera Subsystem (MCS) consists of a 3-inch mapping camera utilizing 5-inch film, a 3-inch stellar camera using 35mm film, detachable supply and takeup cassettes, lens glare shields, a laser altimeter and a deployment mechanism. The interlock angle between the cameras is 96° ±30' with their angular relationship defined in terms of tilt, swing, and azimuth. (Fig. 2-1, and Table 2-1).

The MCS and its deployment mechanism are mounted on the forward side of the SIM shelf parallel to the centerline. When deployed for operational photography the parallel relationship between the mapping camera optical axis and the SIM centerline is maintained. In the event the system fails to extend, mapping photography can be accomplished, however, stellar photography cannot.

Basic camera parameters are given in Table 2-2. Additional information related to the MCS is listed below.

- The subsystem is 8 x 22 x 51 inches and weighs 280 pounds including film, record container, laser altimeter and deployment mechanism. The film record container is 11 inches in diameter by 9 inches wide and weighs 23 pounds when it contains all of the exposed film.
- The deployment mechanism is an electro-mechanical device used to extend the MCS from the SIM during lunar orbit. The stellar lens glare shield is mechanically linked to the deployment mechanism and is extended during the deployment process. Deployment, as well as retraction, requires a maximum of four minutes.

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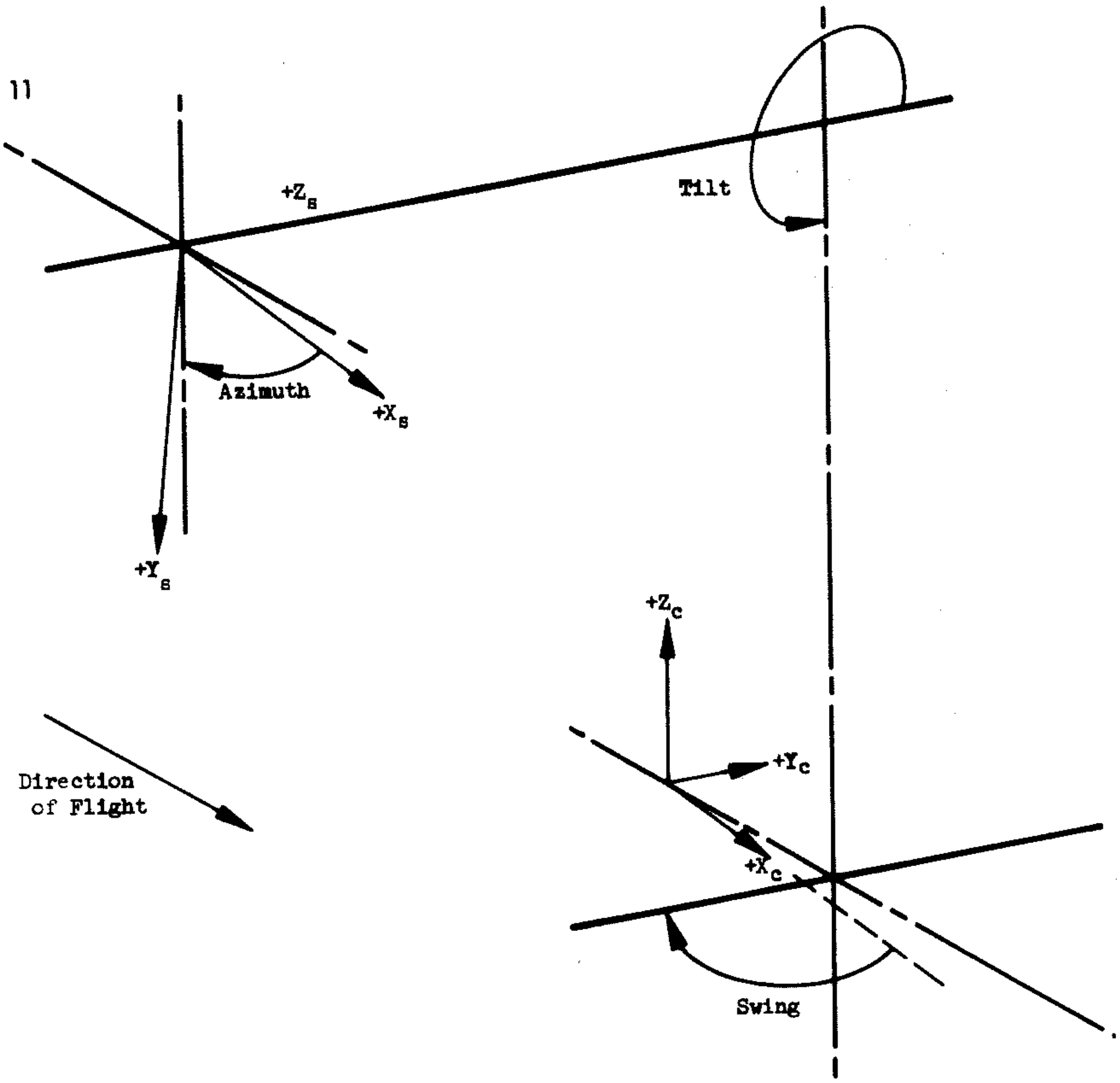


NOTES: (a) Carto Camera Coordinate System Rotated Slightly About Z_c Axis for Clarity

(b) Stellar Camera Coordinate System Rotated Slightly About Z_s Axis for Clarity

Figure 2-1 - MSC Interlock Angle Geometry

DEFINITION OF MCS INTERLOCK ANGLE GEOMETRY

The positive X axis of the cartographic camera shall be defined as being approximately in the direction of the vehicle velocity vector. The Z axis shall be perpendicular to the X-Y plane and positive in the direction of the terrain to vehicle radius vector. The cartographic camera Y axis shall be approximately perpendicular to the orbit plane and positive in such a direction as to conform to a right hand Cartesian Coordinate System. The positive X axis of the Stellar Camera shall be approximately in the direction of the vehicle velocity vector. The negative Y axis shall be in the approximate direction of the terrain to vehicle radius vector. The Z axis of the Stellar Camera shall be perpendicular to the X-Y plane and positive in such a direction as to conform to a right hand Cartesian Coordinate System.

Within each focal plane, the X and Y axes shall be defined as follows:

> The Y axis shall be defined as the line determined by the two fiducial marks which are approximately perpendicular to the vehicle velocity vector. The X Axis shall be defined as a line which is perpendicular to the Y axis, but passes through the indicated principal point. The Z axis is then defined as being perpendicular to the intersection of X and Y.

The principal plane shall be defined as that plane which contains Z_S and is parallel to Zc.

The three angles defining the system geometry are defined as follows:

TILT	The clockwise angle measured from Z_S to the projection of Zc on the principal plane (looking in the direction of flight). This angle shall be 264° ±30 minutes.
SWING	The angle measured from $+X_C$ to the trace of the principal plane in the -Y direction on the cartographic camera focal plane. This angle shall be 90° ±30 minutes.
AZIMUTH	The angle measured in the clockwise direction from $+X_S$ to the trace of the principal plane (looking in the $-Z_S$ direction). This angle shall be 90° ±30 minutes.

TABLE 2-1 MSC Interlock Geometry

MAPPING CAMERA CHARACTERISTICS

Type	Stationary film, mapping
Mode of Operation	Autocycle
Lens and Aperture	
Stellar	3 in. f/2.8 (fixed)
Mapping	3 in. f/4.5 (fixed)
Format	
Stellar	1.25 in. diameter with 0.96 in. flats
Mapping	4-1/2 x 4-1/2 in.
Coverage (Mapping)	74° x 74°
Film	
Stellar	35mm 2.5 mil base non-perforated
Mapping	5 in., 2.5 mil base non-perforated
Altitude	
Lunar	30 to 80 nautical miles — 60 nm.
Film Capacity	
Stellar	510 feet
Mapping	1500 feet
Cycle Time	
Stellar	8.25 to 33.0 sec/cycle
Mapping	8.25 to 33.0 sec/cycle
Exposure Time	
Stellar	1.5 sec (fixed)
Mapping	1/15 to 1/250 sec
Exposure Control (Mapping Only)	Automatic between lens shutter
Forward Motion Compensation (Mapping Only)	12.1 to 16.1 milliradian/second (in five discrete steps: 12.1, 13.1, 14.1, 15.1 and 16.1 milliradians/second)

TABLE 2-2 Mapping Camera Characteristics

Resolution	
Stellar	80 lines/mm AWAR, 1000:1 contrast target, EK 3400 film
Mapping	90 lines/mm AWAR, 2:1 contrast target, EK 3404 film
Distortion	
Stellar	±10 microns radial, 5 microns max tangential
Mapping	±50 microns radial, 5 microns max tangential
Overlap	
(Mapping Only)	78 pct (nominal) 67 pct, or 58 pct, adjustable only prior to installation in spacecraft
Camera Generated Recorded Data (see Fig. 2-2)	
Fixed Data	
Stellar	Reseau
	Fiducial
	Lens serial number
Mapping	Reseau
	Fiducial
	Camera serial number
Auxiliary Data	
Stellar	Index
	Coded Time
	Altitude
Mapping	Index
	Coded Time
	Altitude
	Shutter Speed
	FMC on/off
Power	28 VDC, Operating wattage 100 W min. to 150W max.

TABLE 2-2 CONT'D

- The Aerial Exposure Control (AEC) photocell is pointed in the same direction as the metric lens and "sees" approximately the same surface coverage as the metric camera.

- The Forward Motion Compensation (FMC) drive mechanism provides rectilinear motion of the platen and film in the camera focal plane during exposure to compensate for image motion. The V/h signal can be manually set by the astronaut to five positions by pulsing the Image Motion switch momentarily to the INCR (increase) position (Fig. 1-2). The different V/h rates, accurate to within 3 percent, are: 12.1, 13.1, 14.1, 15.1, and 16.1 milliradians per second. The five step positions and their corresponding altitude ranges are: Step 0, 57-61n.m.; Step 1, 54-57n.m.; Step 2, 54n.m.; Step 3, 65-125 n.m.; Step 4, 61-65 n.m. FMC is disengaged if the switch is in the off position.

- The camera system must be in the STANDBY mode during launch, trans-lunar injection and all other SPS powered flight phases to prevent slack loops in the film.

- The cameras must be cycled once every 24± 6 hours following film loading to prevent film set. No warmup period is required.

- The system must be turned to the STANDBY mode for warmup 25 hours prior to use for operational photography.

- The nominal lunar altitude is 60 n.m. with an operating range between 40 and 80n.m.

- The cameras are directional and sun sensitive.

- Film flattening in each camera is accomplished by means of a glass focal plane platen and a moveable pressure plate. The emulsion side of the film is in contact with the focal plane platen.

- The laser altimeter is hard mounted to and boresighted with the mapping camera subsystem.

- Both cameras require a supply of gaseous nitrogen (GN2) to provide an inert and pressurized atmosphere to minimize potential static electrical corona discharge which could cause exposed areas on the film. The nitrogen supply is shared with the panoramic camera.

- The exposed film from both cameras is contained in a single recoverable record container that is retrieved via EVA during transearth coast.

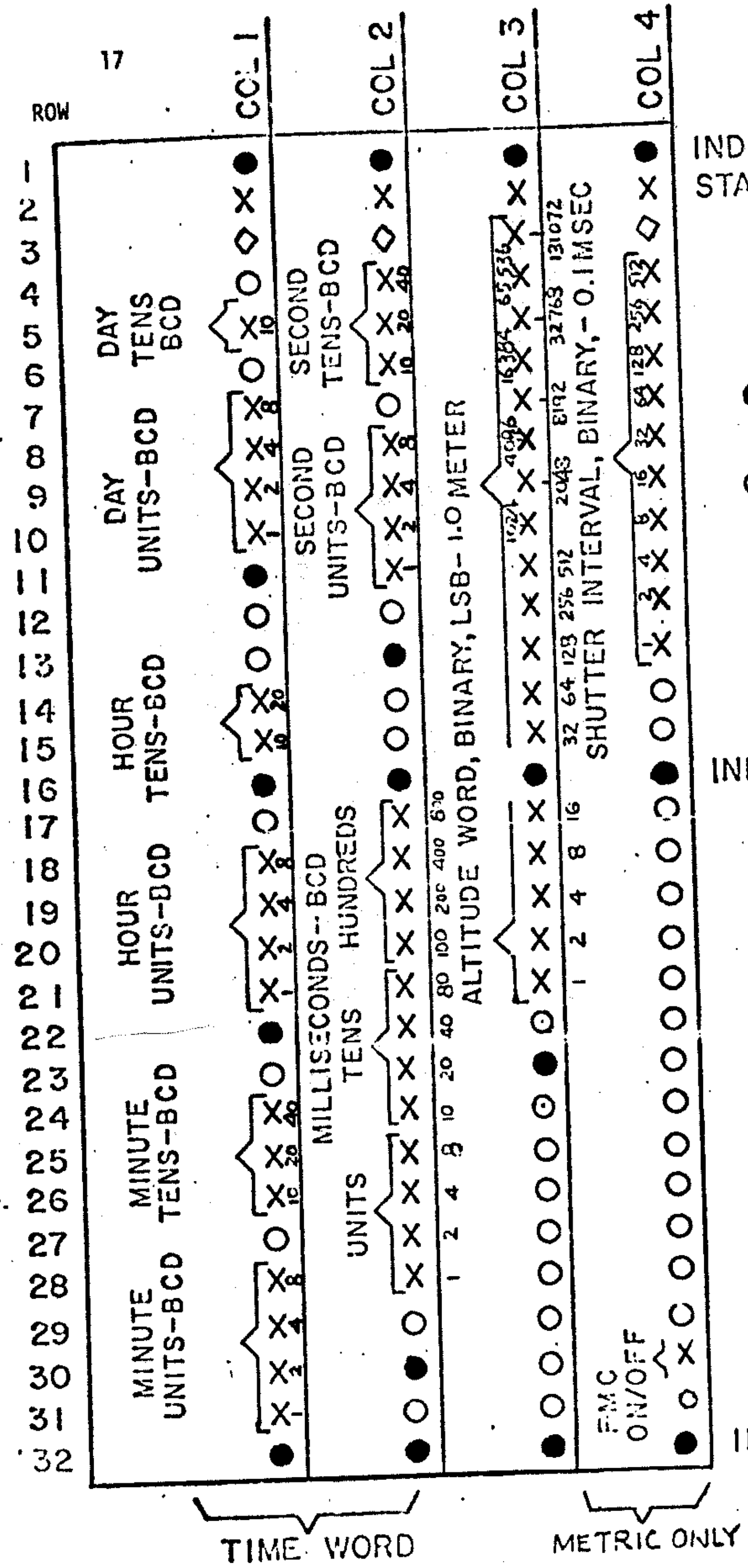
- The center of exposure pulse from the mapping camera is used to sychronize the stellar camera (within 20 milliseconds) and laser altimeter (within 10 milliseconds) of the mapping exposure.

- Overlap of the mapping coverage is nominally 78%. This can be adjusted prior to spacecraft installation at discrete steps of 56%, 67%, and 78%.

- The mapping film has fixed data recording including a square array of 121 reseau points, eight fiducial dots and the camera serial number. Auxiliary data recording displays, in binary word form include time, altitude, shutter speed and FMC on/off information (Figs. 2-2 and 2-3). These data are recorded simultaneously with the imagery.

- The stellar film has fixed data recording including a square array of 25 reseau crosses, four edge fiducials and the lens serial number. Auxiliary data, time and altitude are recorded in binary word form at center of exposure time. (Figs. 2-2 and 2-4).

3 February 1971
Revised Date:
23 July 1971



LEGEND

- ● DOT EVERYTIME BINARY ONE
- ○ BLANK EVERYTIME BINARY ZERO
- X DATA POSITION ONE OR ZERO
- ◇ DON'T CARE POS'N ONE OR ZERO

MCS ADR

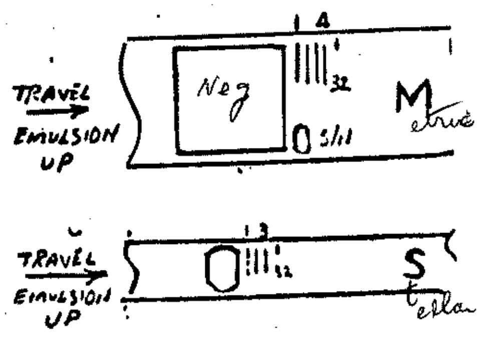


Fig. 2-2
Auxiliary Data Recording Format

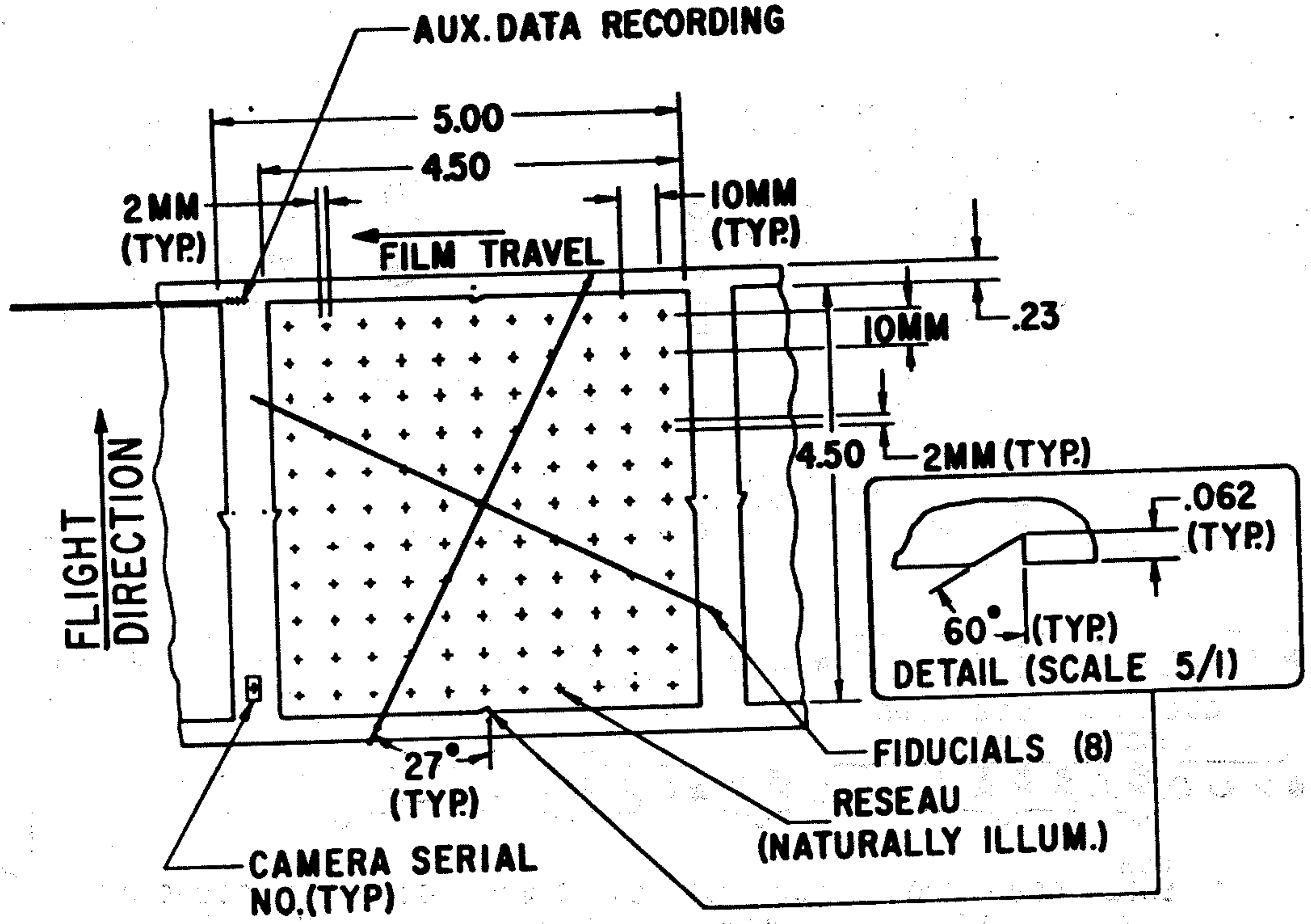


Fig. 2-3 Mapping Camera Film Format

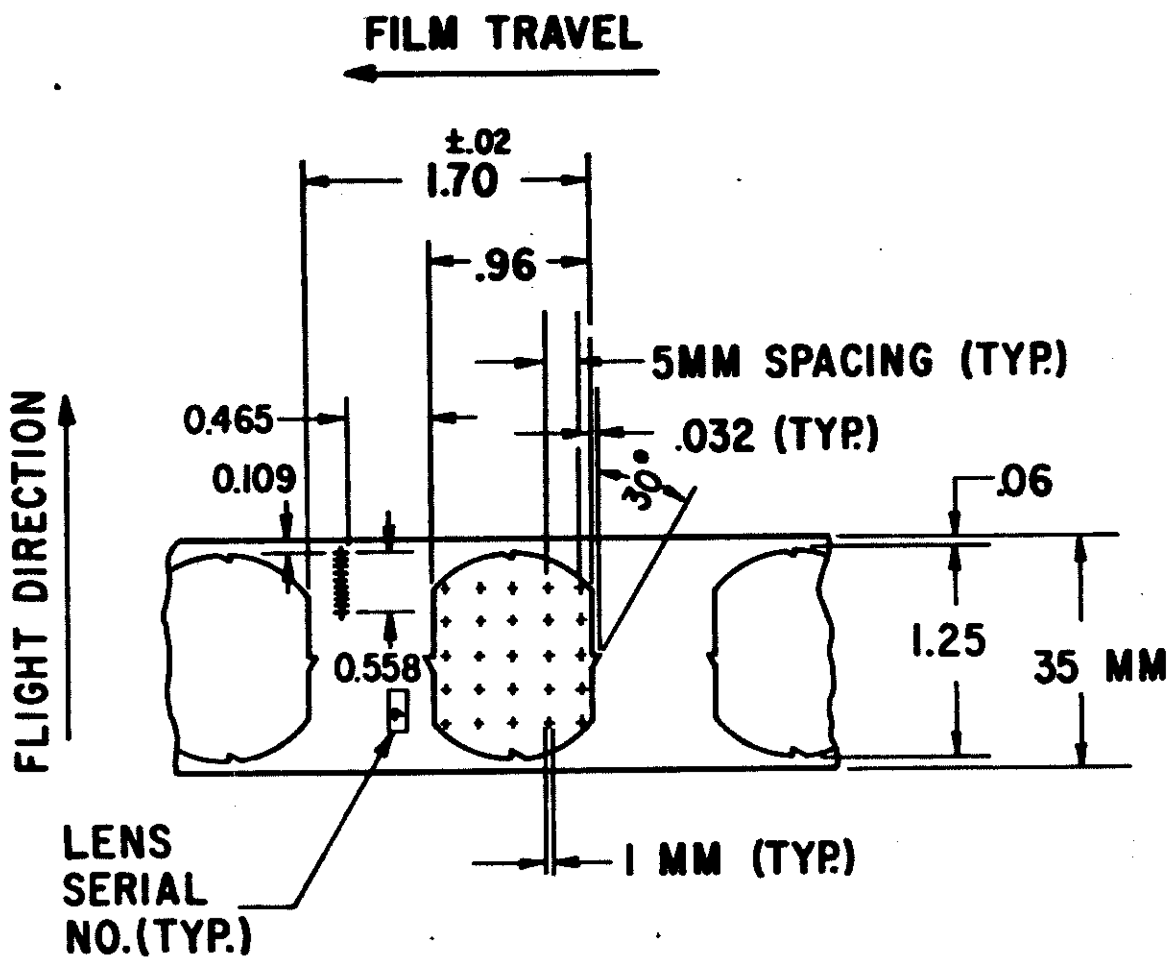


FIG. 2-4 Stellar Camera Film Format

• The mapping camera exposure times are determined by a rotating shutter. Shutter speeds vs. exposure times are as follows:

Shutter Speed (rpm)	Exposure time (sec)
1280	1/250
800	1/156
520	1/101
320	1/62.5
200	1/39
100	1/23.4
80	1/15.6

3.0 LASER ALTIMETER

The laser altimeter is an altitude measuring device utilizing a ruby laser and associated optics. The altimeter is hard mounted to the Mapping Camera Subsystem (MCS) and is bore sighted to the mapping camera. It has two modes of operation, Camera and Automatic. In the camera mode, the MCS commands the laser to range with each exposure of the mapping camera. In Automatic the laser automatically ranges once every 20 seconds. For the most part, the altimeter is used in the Camera mode in conjunction with the MCS which provides positional and attitude data. In this mode the altitude is recorded on both the metric and stellar exposures in addition to being telemetered .

During operation the ruby laser and associated optics transmits an intense, short duration, light (laser) pulse to the lunar surface. This pulse is reflected from the surface and is received and detected by the receiving telescope and photomultiplier tube in the altimeter. As the speed of the pulse is known the elapsed time difference between the transmitted and received pulse is easily converted to range by the electronic circuitry.

The output of the ruby laser at the resonnant reflector has a diameter of 0.250 inch and a beam width of 4.8 milliradians. A 16-power Galilean telescope expands the transmitted beam to a four-inch diameter with a 0.3 milliradian beamwidth. During the time interval between transmission and reception, the range counter performs the range measurement by counting increments of 6.67 nanoseconds (1 meter) supplied by a master crystal oscillator (149.8962 MHz). The range measurement is then clocked out as a serial word to the spacecraft data system (SDS).

In addition to altitude data, the laser altimeter provides digital and analog equipment status information for telemetering purposes. The digital data consists of 18 bits of range (altitude) data and six bits of equipment status: regulated +5vdc, range overflow, laser output, Q-switch motor status Krytron trigger, and MC data request (Fig. 1-3). The analog data consists of additional equipment status information and includes regulated -5 vdc, photomultiplier voltage, pulse forming network voltage and laser cavity temperature. The operational limits of these are shown in Fig. 1-3

4.0 OPTICAL BAR PANORAMIC CAMERA

The optical bar panoramic camera is configured as a single, self-contained unit with no separately housed components. The camera structure consists of three major assemblies; the roll frame assembly, the gimbal assembly, and the main frame assembly. (Fig. 4-1). The roll frame assembly, which rotates in the scan direction (crosstrack) during camera operation, supports the lens assembly roller cage and variable slit assembly. The roll frame, as well as the light sensor, lens drive, frame roller, and framing roller drive, is supported by the gimbal assembly which tilts fore and aft for stereo coverage and forward motion compensation. The gimbal structure is pivoted on bearings on the main frame along with the gimbal torque motor, V/h sensor, supply and takeup cassettes, film shuttle and the control electronics. The main frame is mounted on rails that are attached to shelves in the SIM with the centerline of the camera displaced 8.25 inches from the centerline of the SIM toward the positive Y coordinate. The optical axis (at center of format) is parallel to the SIM centerline. Basic camera parameters are listed in Table 4-1. Other pertinent facts related to camera installation and operation are listed below.

- The camera assembly envelope is 25 x 29 x 60 inches and weighs 335 pounds including film and cassettes. The film cassette weighs 72 pounds and is 19 inches in diameter and 7 inches wide.

- Since thermal stabilization is variable and dependent upon the SIM thermal environment, a warmup period is required prior to operation for the camera to stabilize at the specified operating temperature (88° ±2°F)

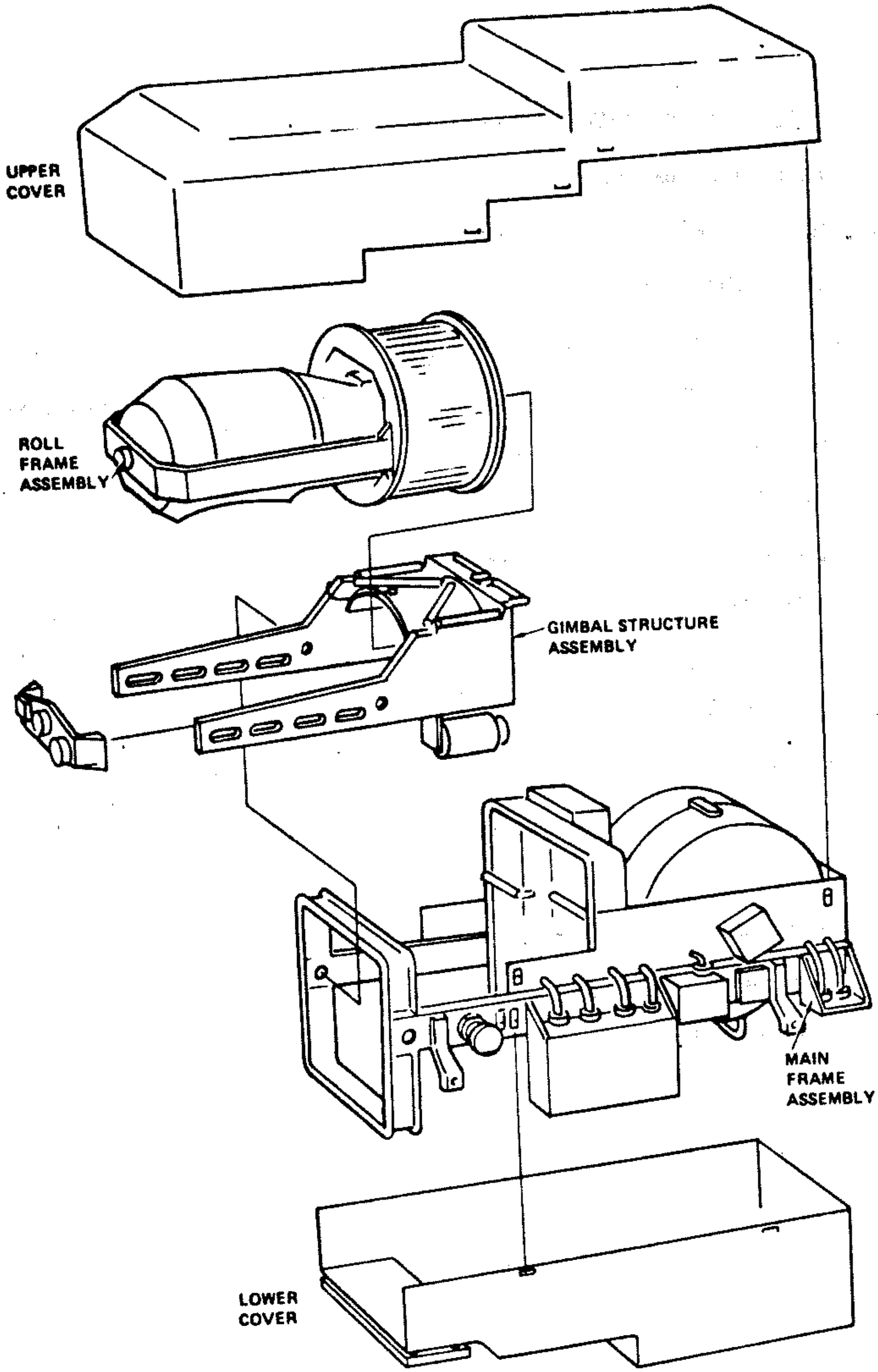


Fig. 4-1 Major Panoramic Camera Assemblies

CHARACTERISTICS OF THE APOLLO PANORAMIC CAMERA

Camera	Optical Bar
Lens	
Type	Petzval
Focal Length	24 inches (610 millimeters)
Relative Aperture	f/3.5
Resolution	135 lines per millimeter, 80 percent of targets, no targets less than 108 lines per millimeter, using 2:1 contrast, standard Air Force three-bar targets, 0.002-second exposure with 3404 film, Wratten 23A filter
Field of View	
Along Track	10 degrees, 46 minutes (11.7 nautical miles at 60-nautical-mile altitude) (Fig. 4-5)
Crosstrack scan	108 degrees (183 nautical miles at 60-nautical-mile altitude) (Fig. 4-5)
Overlap	Consecutive forward frames and consecutive aft frames overlap 10 percent; stereo pairs overlap 10 percent.
Shutter	
Type	Scanning slit
Slit Width	0.015 to 0.300 inch
Film	
Type	EK 3414 (6,500 feet; total of 1,650 exposures)
Width	5 inches
Thickness	0.0025 inch
Format	45.24 by 4.5 inches (47.24 inches including data block)
Data (See Fig. 2-5)	Data block for each image frame contains the following information: time (GMT or launch site), data card (shows mission particulars) V/h, frame number, camera pointing attitude (forward, vertical, aft), reference arrows (vertical arrow indicates FMC direction and camera line of flight -- direction of camera line of flight is directly opposite to FMC direction; horizontal arrow points to applicable image frame); fiducial marks are printed on both edges of the film and IRIG B time code is printed on the forward edge of the film.
Exposure Control	Automatic with variable slit
Slit Width Range	0.015 to 0.300 inch
V/h Range	0.010 to 0.019 radian per second mrad
Installation	Parallel to vehicle roll axis

TABLE 4-1 Characteristics of the Apollo Panoramic Camera

CHARACTERISTICS OF THE APOLLO PANORAMIC CAMERA

26	
Operating Modes	25-degree convergent stereo at autocycle of 4.7 to 8.9 seconds per cycle; monographic at autocycle of 8.9 to 16.9 seconds per cycle.
Lens Transmission	56%
Telemetry Circuits (See Fig. 1-3)	E (V/h) Exposure Command Slit width Capping Shutter Position Framing roll position Air Solenoid Shuttle position Lens torque current Camera Mechanical Temperature Electronic enclosure temperature Lens (forward) temperature Lens (aft) temperature Lens barrel temperature FMC tachometer

TABLE 4-1 (CONT'D)

- The V/h sensor governs the rotation rate of the roll frame assembly, and FMC rate thus assuring a controlled sequence of imagery related to changes in spacecraft velocity and altitude. Input from the V/h sensor, combined with AEC sensor input, also controls the aperture slit width for correct exposure.

- During camera "operate" or "standby" mode, 14 functional signals can be monitored at ground stations via the vehicle PCM telemetry circuits (Table 4-1).

- The camera must be cycled once every 25 hours ±6 hours following flight film loading to prevent film set. This automatically advanced 5 frames, no warmup required.

- The nominal mean lunar altitude of the V/h sensor is set for 60 n.m., thus limiting operation altitude capability between 45 and 80 n.m. to achieve specification quality photography. When operating outside this altitude band, or when the V/h signal is lost, the V/h sensor backup signal commands a nominal V/h value set for a 60n.m. lunar altitude, or 13.6 milliradians per second.

- The pan camera is a directional sensitive instrument (because of FMC) requiring the CSM positive X-axis to be in the direction of the velocity vector during camera operation. The camera is also sun sensitive.

- During pan camera operation the gamma-ray spectrometer boom and mass spectrometer boom must be retracted so as not to be in the optical field-of-view of the camera.

- The exposure can be biased by the astronaut through the Exposure Increase/Decrease switch (Figure 1-2). Placing the switch in Increase, biases the AEC command to increase exposure by 1/2 f stop. This is accomplished by increasing the size of the slit opening. In the Decrease position the AEC command is biased by 1 f stop by decreasing the slit width.

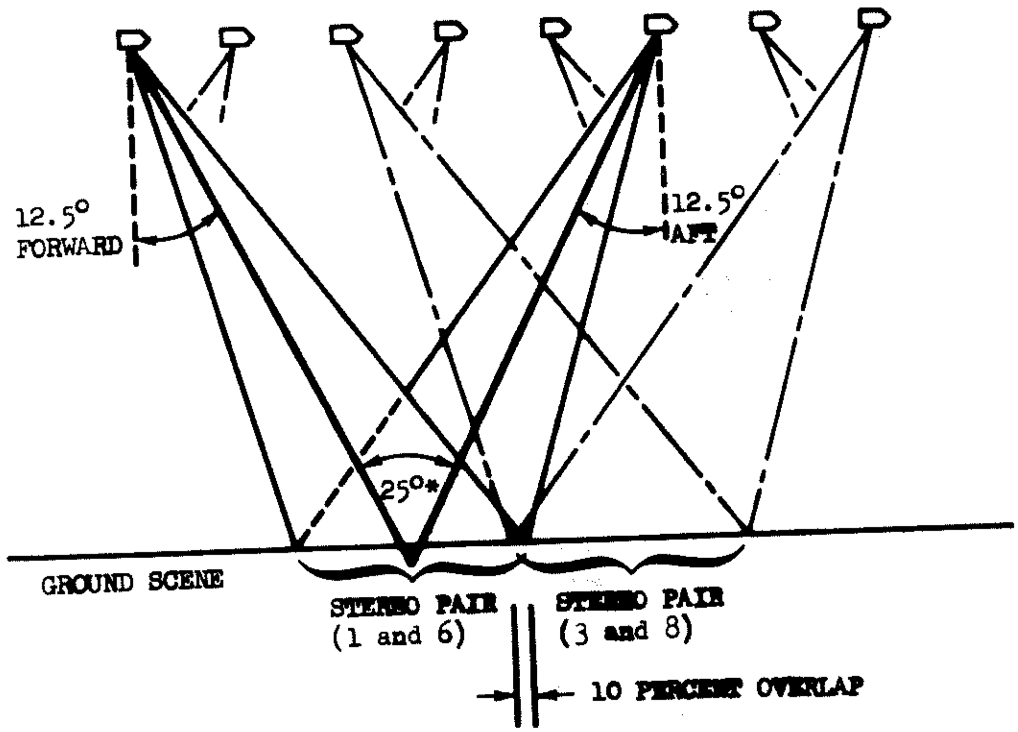
- Stereographic photography is achieved by alternately tilting the gimbal assembly 12.5° forward and 12.5° aft prior to exposure of each frame. Cycling rate is controlled to insure image overlap between stereo pairs of 10 percent. The stereo-mate to frame number N will be N+5 when frame number N is a forward exposure or N-5 when N is an aft exposure (Fig. 4-2).

- Scan angle "fiducial" marks are generated along both sides of the photography at 2.5° intervals. The relative angular position of the imaged marks is known to about 5 minutes of arc and the marks are referenced to the center of scan mark at the centerline of the camera (Fig. 4-3).

- IRIG B coded time from the vehicle central timing equipment (CTE) is recorded on the edge of the film. The complete time word is recorded every second in seconds, minutes, hours and days for the instant of exposure of the reference mark. Timing marks are provided continuously in 10 millisecond increments between successive time words (Figs. 4-3 and 4-4). Spacing between timing marks as recorded on the film will vary directly with the cycle rate (V/h rate) of the camera.

- Operating time is limited to 30 minutes per pass to prevent overheating of the camera.

- The post-flight pointing knowledge requirement of the pan camera is ±2° (three axes) thus requiring a spacecraft control deadband of ±0.5° during operation. The root sum square (RSS) of the altitude uncertainty is ±1.44°.



*CONVERGENCE ANGLE

Fig. 4-2 - Stereo coverage and overlap (25-degree convergence angle)

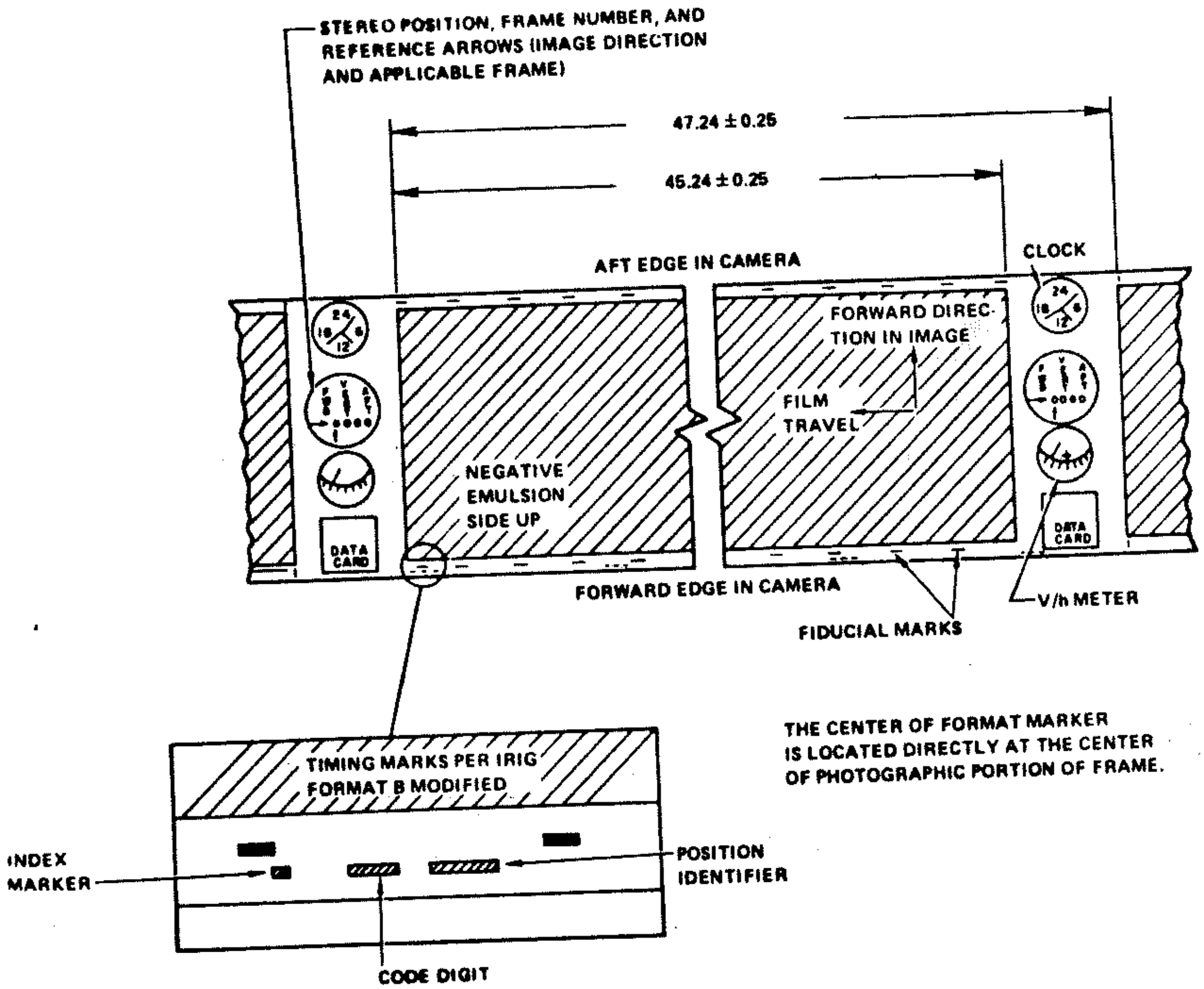
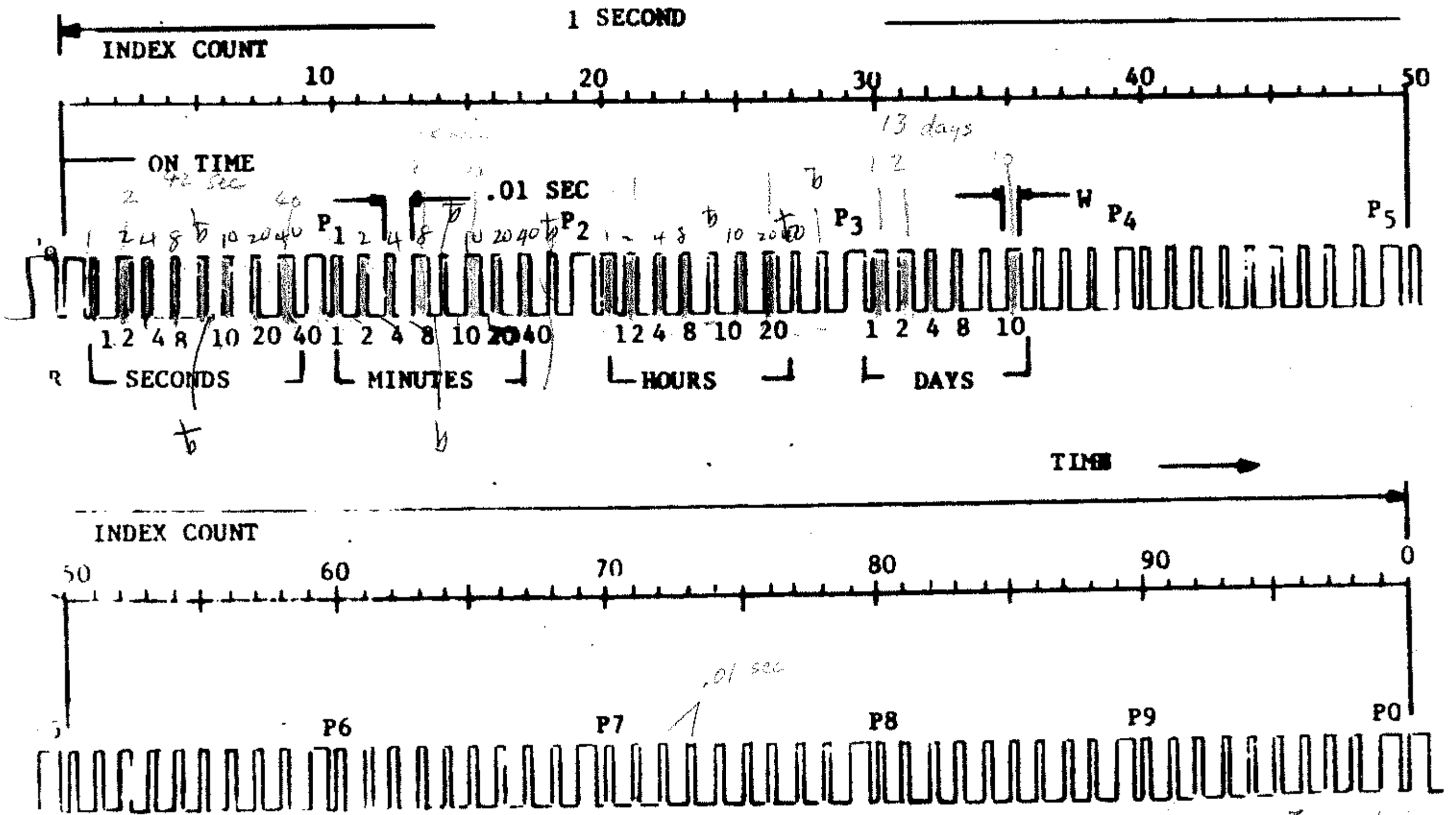


Fig. 4-3 Panoramic Camera Film Format



R = 1 sec reference marker
P = Position identifier, 8 ms duration
W = Weighted code digit, 5 ms duration
Duration of index markers = 2 ms

Sample time shown is
13 days, 12 hours, 18 minutes, 42 seconds
(Balance of frame is unmodulated)

Fig 4-4 100 PPS Code - Modified IRIG Standard Format B

- An astronaut will retrieve the film cassette via EVA during transearth coast.
- This experiment does not require concurrent performance of any other experiment; however, it is desirable the mapping camera be operated during panoramic camera operation.

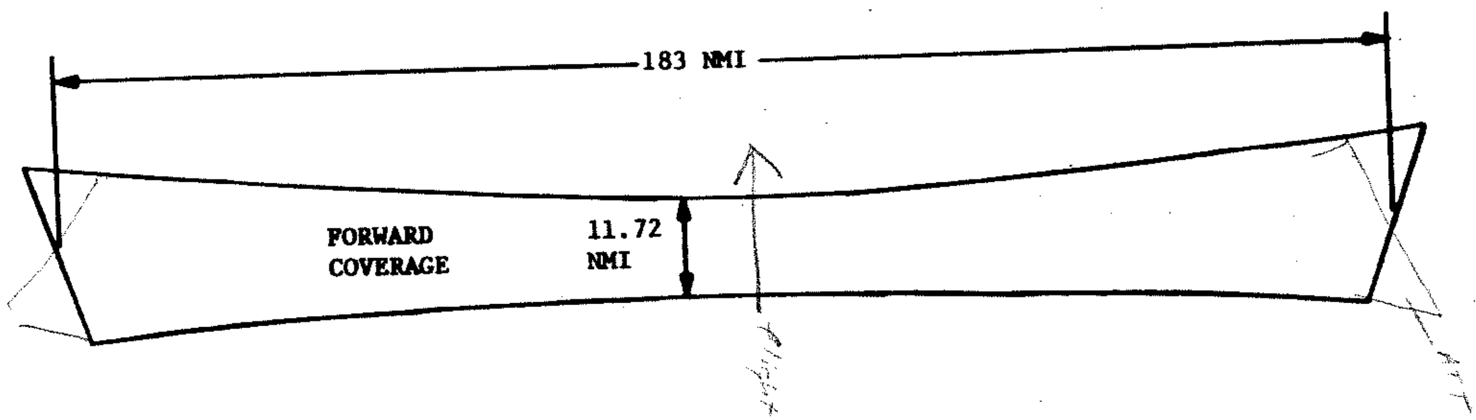


Fig. 4-5 LUNAR SURFACE FOOTPRINT FOR 60 NMI ORBIT

5.0 APOLLO ORBITAL SUPPORT DATA (PHOTOGRAPHIC EPHEMERIS)

The Apollo Photograph Evaluation (APE) program is a UNIVAC 1108 computer program developed with the primary function to generate camera position, orientation and evaluation data for use in the photographic phases of Apollo missions. The APE program links together a spacecraft attitude history and camera attitude history to form a data base for its computations. APE operates on these data by way of a generalized camera model to:

1. Define the camera orientation
2. Define the aiming direction of the camera optical axis.
3. Locate on the surface of the central body
   a. the spacecraft nadir
   b. the principal intersection point (intersection of the camera optical axis direction with the central body surface)
   c. points along the boundary of the photograph footprint on the central body surface.
4. Define geometrical relationships between the local vertical to the central body surface and the camera axes coordinate system.
5. Define lighting parameters at the principal point of intersection.
6. Define first-order uncertainties in selected location and camera orientation parameters.

The APE program is configured to operate on the following input data combination.

1. A Houston Operations Predictor/Estimator (HOPE) generated moon-centered, CSM trajectory with state vectors and a covariance matrix defined

at times coinciding with actual camera shutter times (Downlinked camera shutter times are input to HOPE through APE). (Tape Input)

2. Actual telemetered histories of the spacecraft gimbal angles. (Tape Input).

3. Histories of the camera positioning angles, input via cards, except for those for the sextant camera (shaft and trunnion angles) which are input along with the vehicle gimbal angles on the input telemetered data tape.

4. The JPL DE19 planetary ephemeris for stellar camera only. (Tape input).

5. The SAO star catalog for stellar camera only (Tape Input).

Operating on the above combination of inputs, APE computes for all except the stellar camera:

1. The rotation angles (ϕ,ω,κ) which reference the camera axis coordinate system to the local horizontal system.

2. The camera optical axis tilt (t). The angle between the local vertical and the camera optical axis.

3. Tilt azimuth (α). The angle between north and the projection of the camera optical axis on the local horizontal plane.

4. X-tilt (t_x) and y-tilt (t_y). The angles between the local horizontal plane and the camera x and y axes respectively.

5. Heading (H). The angle between north and the projection of the camera x-axis on the local horizontal plane.

6. Swing (S). The angle at the principal point of intersection between the positive camera y-axis and the nadir point.

7. The latitude (Δ) and longitude (λ) of nadir taken directly from the input trajectory.

8. The latitude (δ) and longitude (η) of the principal point of intersection.

9. At the principal point of intersection, the sun elevation (μ) azimuth (σ) and phase (ρ) angles.

10. The latitude and longitude of points along the boundaries of the photo footprint on the lunar surface.

Employment of APE in the star pattern prediction mode will allow for the following operations:

1. Computation of the direction cosine matrix relating to the stellar camera diapositive coordinate system to the geocentric mean of 1950 coordinate system.

2. Definition of the stellar camera optical axis aiming direction in terms of mean of 1950 right ascension (α) and declination (δ).

Specifically, the basis for all APE camera orientation and related definitions is the APE-constructed generalized direction cosine matrix [M]. This is the product of transformation matrices which defines the relationship between the camera axes coordinate system and the local horizontal coordinate system. This matrix derives its generality with regards to various camera systems through its structure of the matrix component which expresses the transformation from the spacecraft body axes coordinate system to the camera axes coordinate system. It derives its generality with regards to various central bodies through its matrix component which expresses the transformation from the local horizontal system to the mean of nearest Besselian year coordinate system.

The direction cosine matrix employed for processing CSM lunar orbital photography is:

$$[M] = [A]\,[B]\,[C]\,[D] \qquad (1)$$

where

$$[A] = [\rho]_z[3\pi/2 + \gamma]_y[\delta]_z; \; (\rho,\ \gamma,\ \delta = \text{camera mounting angles}) \qquad (2)$$

= Transformation matrix from the spacecraft body axes coordinate system to the camera axes coordinate system.

$$[B] = [\psi]_x[\theta]_z[\beta]_y \quad (\psi,\ \theta,\ \beta = \text{spacecraft gimbal angles} \qquad (3)$$

= Transformation matrix from the spacecraft platform (IMU) coordinate system to the spacecraft body axes coordinate system

[C] = [REFSMMAT]

= Transformation from the mean of nearest Besselian year (NBY) coordinate system to the spacecraft platform coordinate system

= [E] [F]; in which,

[E] = Transformation matrix from the selenographic coordinate system to the mean of nearest Besselian year coordinate system.

[F] = Transformation matrix from the local horizontal coordinate system to the selenographic coordinate system.

The characteristics of these matrix elements of [M] are as follows:

- [A]

As a triple rotation, [A] is adaptable to any spacecraft-mounted experiment. Its utility is realized by assigning proper values to ρ, γ and δ as determined from the decomposition of the various spacecraft body axes to the camera axes transformations into ρ, γ and δequivalents. The assigned mounting angles are preflight determined and are input to APE via cards.

- [B]

The spacecraft gimbal angle values necessary for the construction of this matrix are provided to APE by the input telemetered data tape. The values employed by APE are interpolated values determined by a two parabola averaging technique.

- [C]

This matrix [REFSMMAT] is a card input to APE, whose values are determined in the RTCC.

- [E]

This matrix is determined by way of the standard TRW rotation routine ROTAT which is employed in all Houston Operations trajectory programs.

- [F]

This transformation matrix is developed in APE via a set of vector equations. The values of its elements are determined from the input (trajectory tape) spacecraft coordinates expressed in the body-centered inertial coordinates of the central body (selenographic for the moon) and the card input central body mean radius values.

When APE is operating under the star pattern prediction for the stellar camera it is used to:

1. Define the orientation of the camera axes coordinate system relative to the mean of 1950 coordinate system.

2. Define the camera optical axis aiming direction in terms of the star catalog star location parameters (mean of 1950 right ascension and declination).

3. Define the stellar camera field of view bounds in terms of these same parameters

4. Select from the input star catalog all stars within a specified brightness range which lie within these bounds.

5. Select all planets from the input planetary ephemeris that lie within the field of view bounds.

6. Correct the star catalog positions of the selected stars for proper motion and aberration.

7. Correct the positions of the selected planets for aberrations.

8. Compute and plot the rectangular coordinates of the projections of selected star and planet positions onto the stellar camera diapositive.

When serving this purpose APE defines camera axes orientations via an [M] relating the stellar camera diapositive coordinate system to the mean of nearest Besselian year coordinate system. Computations for definition of stellar camera field of view boundaries and of stellar camera diapositive star coordinates are substituted for the normal surface location computations and star catalog search and select logic is added.

Sample printouts of the ephemeris for the mapping and panoramic cameras are shown in Figures 5-1,5-2.The laser altimeter altitude for each mapping camera exposure is included in the mapping camera ephemeris. Those familiar with the Lunar Orbiter experiment will note that the format is similar in composition and content. As stated earlier the 16mm microfilm of the orbital support data will not be available for several months after the mission.

APOLLO 12 R40,41 SS2 METRIC9/70 FIN FRAME - 1

	YEAR	MONTH	DAY	HOUR	MINUTE	SECOND
GMT	69	11	21	9	56	30.000
GET			6	17	34	30.000

STATE VECTOR	X	Y	Z	X DOT	Y DOT	Z DOT
1950.0	-1468.967697	-902.6637192	-647.3101807	-.9871831	1.1099243	.6822385
SELENOGRAPHIC	1771.4119415	423.5657768	-272.7088356	.4111990	-1.5678300	.2115187
SIGMA(SELENO)	.00	.00	.00	.000	.000	.000

LONGITUDE OF NADIR POINT	13.4476075 DEG	LATITUDE OF NADIR POINT	-8.5155866 DEG
SIGMA NADIR LONGITUDE	.0000000 DEG	SIGMA NADIR LATITUDE	.0000000 DEG
LONG OF CAMERA AXIS INTERSECT	14.1854523 DEG	LATI OF CAMERA AXIS INTERSECT	-8.5280169 DEG
SPACECRAFT RADIUS	1841.6509552 KM	SPACECRAFT ALTITUDE	103.5609283 KM
SIGMA SPACECRAFT RADIUS	.0000000 KM	AZIMUTH OF VELOCITY VECTOR	277.5374146 DEG
MEAN ALTITUDE RATE	.0036009 KM/SEC	HORIZONTAL VELOCITY	1.6345675 KM/SE
TILT AZIMUTH	91.0305700 DEG	TILT ANGLE	12.0506202 DEG
SIGMA TILT AZIMUTH	5.4383475 DEG	SIGMA TILT ANGLE	4.3532313 DEG
SUN ELEVATION AT PRIN GRND PNT	67.4664011 DEG	SUN AZIMUTH AT PRINCIPAL GRND PNT	72.9538736 DEG
LONGITUDE OF SUBSOLAR POINT	35.6861515 DEG	LATITUDE OF SUBSOLAR POINT	-1.4826630 DEG
ALPHA	-12.5134517 DEG	SWING ANGLE	82.6532001 DEG
EMISSION ANGLE	12.7804228 DEG	SIGMA SWING ANGLE	2.1758550 DEG
PHASE ANGLE	34.9021535 DEG	NORTH DEVIATION ANGLE	171.7547817 DEG
PHI	-11.9545481 DEG	X-TILT	1.5298157 DEG
SIGMA PHI	.7330002 DEG	SIGMA X-TILT	.5311160 DEG
KAPPA	-171.7828197 DEG	Y-TILT	11.9502243 DEG
SIGMA KAPPA	.2274052 DEG	SIGMA Y-TILT	.7145555 DEG
OMEGA	1.5298157 DEG	HEADING	-81.4589548 DEG
SIGMA OMEGA	.5311160 DEG	SIGMA HEADING	.7807548 DEG
SCALE FACTOR	.0007544 M/KM	LASER SLANT RANGE	109.0000000 KM
SPACECRAFT ALTITUDE(LASER)	103.0000000 KM	ALTITUDE DIFFERENCE	-.5609283 KM

FIG. 5-1 Metric Orbital Support Data

SELENOGRAPHIC DIRECTION COSINES OF CAMERA AXIS

	X	Y	Z	MAGNITUDE (KM)
	-.98974986	-.02203455	.14110170	106.038651

FRAME CORNER POSITIONS

LONG 12.8303 DEG	LONG 13.1993 DEG
LATI -9.4662 DEG	LATI -7.2419 DEG
(1)	(2)

(1)–(2): 68.14852 KM

(1)–(4): 75.23465 KM

(2)–(3): 76.88946 KM

(4)–(3): 79.78872 KM

(4)	(3)
LONG 15.3378 DEG	LONG 15.7499 DEG
LATI -10.0003 DEG	LATI -7.4015 DEG

TRANSFORMATION MATRIX FROM LOCAL HORIZONTAL TO CAMERA

-.96747792+00	.14529921+00	-.20706184+00
-.14287485+00	-.98938063+00	-.26697149-01
-.20874205+00	.37550271-02	.97796351+00

TRANSFORMATION MATRIX FROM SELENOCENTRIC TO CAMERA

-.42445775+00	.75740624+00	.49615661+00
.48231946-01	.56610373+00	-.82292177+00
-.90416220+00	-.32536492+00	-.27681829+00

FIG. 5-1 (CONT'D)

APOLLO 12 R40 PAN 9/70 FIN FRAME - 201, RELATED FRAME(206)

	YEAR	MONTH	DAY	HOUR	MINUTE	SECOND
GMT	69	11	21	9	56	30.000
GET			6	17	34	30.000

STATE VECTOR	X	Y	Z	X DOT	Y DOT	Z DOT
1950.0	-1468.9676971	-902.6637192	-647.3101807	-.9871831	1.1099243	.6822385
SELENOGRAPHIC	1771.4119415	423.5657768	-272.7088356	.4111940	-1.5678300	.2115167
SIGMA(SELENO)	1924.39	7337.44	989.91	6.509	1.557	1.002

LONGITUDE OF NADIR POINT	13.4476075 DEG	LATITUDE OF NADIR POINT	-6.5155866 DEG
SIGMA NADIR LONGITUDE	4.1636403 DEG	SIGMA NADIR LATITUDE	.5445728 DEG
LONG OF CAMERA AXIS INTERSECT	12.7193147 DEG	LATI OF CAMERA AXIS INTERSECT	-8.3492838 DEG
SPACECRAFT RADIUS	1841.6509552 KM	SPACECRAFT ALTITUDE	103.5609283 KM
SIGMA SPACECRAFT RADIUS	.0026422 KM	AZIMUTH OF VELOCITY VECTOR	277.5374146 DEG
MEAN ALTITUDE RATE	.0036009 KM/SEC	HORIZONTAL VELOCITY	1.6345675 KM/S.
TILT AZIMUTH	282.9449196 DEG	TILT ANGLE	12.2033944 DEG
SIGMA TILT AZIMUTH	.0000000 DEG	SIGMA TILT ANGLE	.0000000 DEG
SUN ELEVATION AT PRIN GRND PNT	66.1241274 DEG	SUN AZIMUTH AT PRINCIPAL GRND PNT	74.5168362 DEG
LONGITUDE OF SUBSOLAR POINT	35.6861515 DEG	LATITUDE OF SUBSOLAR POINT	-1.4826630 DEG
ALPHA	7.7377850 DEG	SWING ANGLE	275.1298065 DEG
EMISSION ANGLE	12.9427638 DEG	SIGMA SWING ANGLE	.0000000 DEG
PHASE ANGLE	13.8712469 DEG	NORTH DEVIATION ANGLE	172.3967255 DEG
PHI	12.1559746 DEG	X-TILT	1.0829695 DEG
SIGMA PHI	.0000000 DEG	SIGMA X-TILT	.0000000 DEG
KAPPA	-172.0695686 DEG	Y-TILT	-12.1537701 DEG
SIGMA KAPPA	.0000000 DEG	SIGMA Y-TILT	.0000000 DEG
OMEGA	1.0829695 DEG	HEADING	-82.3028259 DEG
SIGMA OMEGA	.0000000 DEG	SIGMA HEADING	.0000000 DEG
SCALE FACTOR	.0007540 M/KM		

FIG. 5-2 Panoramic Orbital Support Data

	X	Y	Z	MAGNITUDE (KM)
SELENOGRAPHIC DIRECTION COSINES OF CAMERA AXIS	-.98974986	-.02203455	.14110170	106.038651

FRAME CORNER POSITIONS

LONG 12.8303 DEG
LATI -9.4562 DEG

LONG 13.1993 DEG
LATI -7.2419 DEG

(1) • 68.14852 KM • (2)

75.23465 KM

76.88946 KM

(4) • 79.78872 KM • (3)

LONG 15.3378 DEG
LATI -10.0003 DEG

LONG 15.7499 DEG
LATI -7.4015 DEG

TRANSFORMATION MATRIX FROM
LOCAL HORIZONTAL TO CAMERA

-.96747792+00	.14529921+00	-.20706184+00
-.14287485+00	-.98938063+00	-.26697149-01
-.20874205+00	.37550271-02	.97796351+00

TRANSFORMATION MATRIX FROM
SELENOCENTRIC TO CAMERA

-.42445775+00	.75740624+00	.49615661+00
.48231946-01	.56610373+00	-.82292177+00
-.90416220+00	-.32536492+00	-.27681829+00

FIG. 5-2 (Con'td)

6.0 CAMERA CALIBRATION DATA

Calibration of the Apollo 15 SIM bay cameras was provided by the equipment manufacturers. Copies of the original calibration reports are presented in this section. Although portions of the data may be difficult to read, it seemed more appropriate to include the original reports than to have them retyped. No additional calibration was accomplished by NASA/MSC.

6.1 CALIBRATION DATA FOR THE MAPPING CAMERA SUBSYSTEM (MCS)

The stellar calibration report was prepared by Raytheon/Autometric under contract to Fairchild Space and Defense System. In addition to the camera calibrations the report includes calibrated values of the reseaus and the relative orientation angle between the connected lens cones. Fairchild data concerning relative illumination and resolving power of the cameras are included.

TR-71-3404-2R

FINAL

CAMERA CALIBRATION REPORT

CAMERA UNIT SN-003

JULY 1971

Prepared by

Autometric Operation
Equipment Division
Raytheon Company

4217 Wheeler Avenua
Alexandria, Virginia 22304

Prepared for

Fairchild Space and Defense Systems
300 Robbins Lane
Syosset, L.I., New York 11791

FOREWARD

This final stellar calibration report is submitted to NASA Manned Spacecraft Center, Houston, Texas, by Fairchild Space and Defense Systems (FSDS), A Division of Fairchild Camera and Instrument Corporation under NASA Contract No. NAS 9-10457. This report was prepared by Raytheon/Autometric, Alexandria, Virginia, under separate contract to FSDS. It supersedes the preliminary version which was previously submitted in May 1971.

This report summarizes the results of the stellar calibration of Mapping Camera Subsystem (MCS) Serial Number 003. The actual stellar field calibration was performed at the NASA White Sands Test Facility (WSTF), Las Cruces, New Mexico, during the period 25-26 March 1971. The resulting stellar imagery was subsequently reduced by Raytheon/Autometric and computer processed and outputted into the form presented herein. It should be emphasized that the calibration values shown for the individual terrain lens/stellar lens internal geometry parameters and relative orientation between connected lens cones are indicative of the capabilities of MCS 003, as derived by stellar methods. Also included in this report are the calibrated values of the terrain and stellar reseau coordinate intersections.

All calibration values presented herein should be utilized in the subsequent post-flight data reductions of MCS 003 terrain and stellar imagery.

A. D. Beccasio
Senior Staff Engineer

Approved by: A. G. Hutchins
MCS Program Manager

12 July 1971
Fairchild Space & Defense Systems
300 Robbins Lane
Syosset, New York 11791

CAMERA CALIBRATION RESULTS

Lunar Mapping Camera SN-003 Stellar Calibration

Terrain Lens (202) Constants of Internal Geometry

EFL = 76.054 mm.	S.D. = 0.002 mm.
CFL = 76.080 mm.	S.D. = 0.002 mm.

Principal Point With Respect to Indicated Principal Point
(Indicated principal point x_{ipp} = 0.0 mm., y_{ipp} = 0.0mm.),

x_p = -0.006 mm.	S.D. = 0.001 mm.
y_p = -0.002 mm.	S.D. = 0.001 mm.

Radial Distortion Parameters

$K_1 = -0.13361854 \times 10^{-5}$	S.D. = $0.39272852 \times 10^{-7}$
$K_2 = 0.52261757 \times 10^{-9}$	S.D. = $0.15933971 \times 10^{-10}$
$K_3 = -0.50728336 \times 10^{-13}$	S.D. = $0.19335059 \times 10^{-14}$

Lens Decentration Distortion Parameters

$J_1 = -0.54958195 \times 10^{-6}$	S.D. = $0.48922291 \times 10^{-6}$
$J_2 = -0.46089420 \times 10^{-10}$	S.D. = $0.11215963 \times 10^{-9}$
ϕ_0 = 2.9659070 radians	S.D. = 0.23946572

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Stellar Lens (104) Constants of Internal Geometry

EFL = 75.713 mm.	S.D. = 0.011 mm.
CFL = 75.735 mm.	S.D. = 0.011 mm.

Principal Point With Respect to Indicated Principal Point
(Indicated principal point x_{ipp} = 0.0 mm., y_{ipp} = 0.0 mm.),

x_p = 0.042 mm.	S.D. = 0.019 mm.
y_p = -0.003 mm.	S.D. = 0.018 mm.

Radial Distortion Parameters

$K_1 = -0.92376425 \times 10^{-5}$	S.D. = $0.40956407 \times 10^{-5}$
$K_2 = 0.53810549 \times 10^{-7}$	S.D. = $0.33179901 \times 10^{-7}$
$K_3 = -0.70032005 \times 10^{-10}$	S.D. = $0.80049661 \times 10^{-10}$

Lens Decentration Distortion Parameters

$J_1 = 0.81424290 \times 10^{-6}$	S.D. = $0.10033483 \times 10^{-4}$
$J_2 = -0.20686782 \times 10^{-7}$	S.D. = $0.42974779 \times 10^{-7}$
ϕ_0 = 1.2355515 radians	S.D. = 0.75665362

Results of Lock-Angle Calibration

Relative Orientation Matrix Defining a Transformation from the Terrain Camera to the Stellar Camera

0.999999850	-0.000517921	0.000180754
0.000125645	-0.104494099	-0.994525499
0.000533973	0.994525372	-0.104494018

Relative Orientation Angles (Degrees, Minutes, Seconds)

OMEGA	=	-95	59	52.859
PHI	=	0	1	50.140
KAPPA	=	- 0	0	25.916

Covariance Matrix

0.98562×10^{-11}	-0.33758×10^{-12}	0.88273×10^{-12}
-0.33758×10^{-12}	0.22323×10^{-10}	0.34486×10^{-12}
0.88273×10^{-12}	0.34486×10^{-12}	0.35148×10^{-9}

Standard Deviation of Orientation Angles (Arc-seconds)

S.D. OMEGA = 0.65
S.D. PHI = 0.98
S.D. KAPPA = 3.87

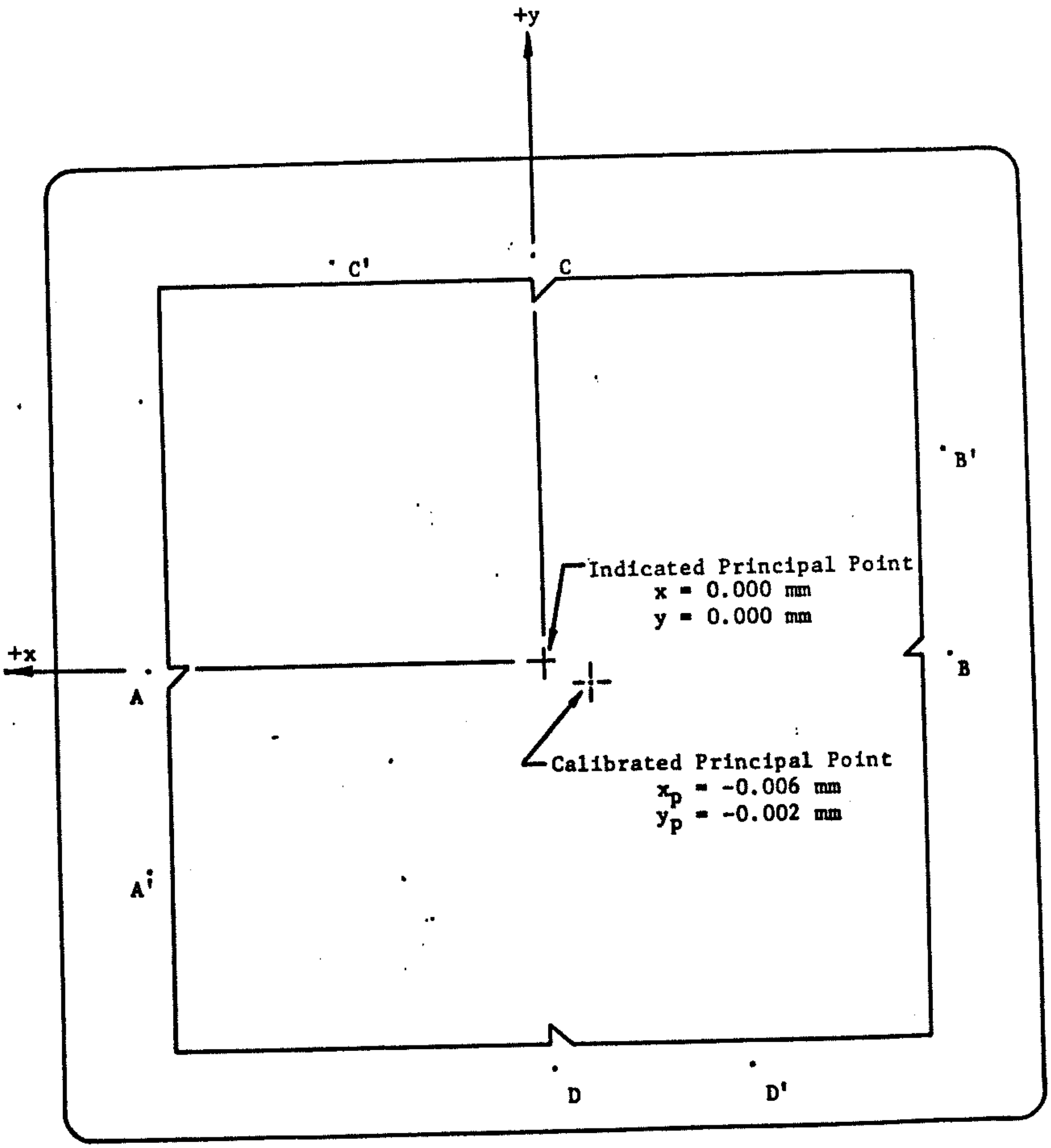
Statistical Data From Simultaneous Solution

Weighted Sum of Squares = 0.031920

Degrees of Freedom = 1996

Standard Deviation of Unit Weight = 0.004 mm.

PRINCIPAL POINT LOCATION FOR TERRAIN CAMERA, LENS NO. 202



(Emulsion Up)

Direction of Flight

Figure 1.

<u>Master Fiducial Coordinate List for Terrain Camera</u>

(Data provided by Fairchild Company)

Note: All coordinates in millimeters. Refer to Figure 1.

A_x = 60.236

A_y = 0.000

A'_x = 60.262

A'_y = -30.778

B_x = -60.324

B_y = 0.000

B'_x = -60.384

B'_y = 30.843

C_x = 0.003

C_y = 60.450

C'_x = 30.887

C'_y = 60.526

D_x = - 0.003

D_y = -60.305

D'_x = -30.781

D'_y = -60.311

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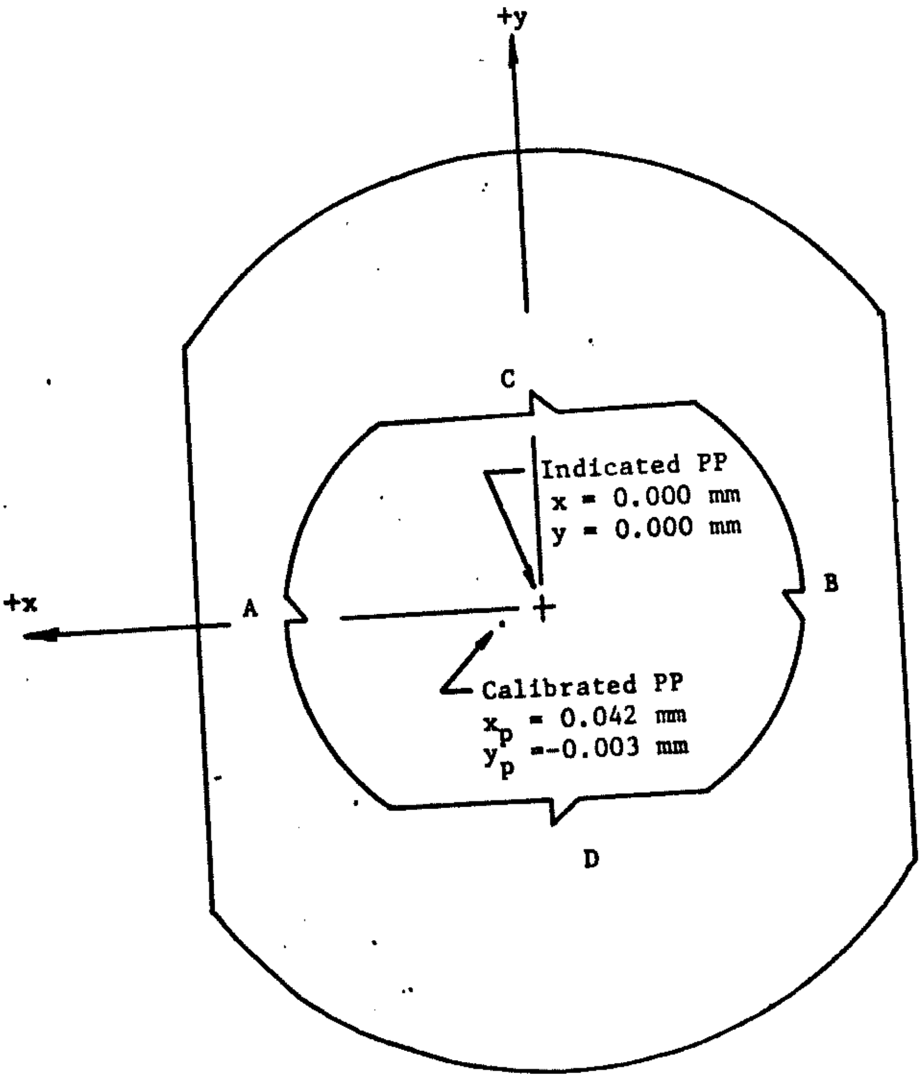
PRINCIPAL POINT LOCATION FOR STELLAR CAMERA, LENS NO. 104



(Emulsion up)

Direction of Flight

Figure 2.

EXPLANATORY NOTES - Calibration of Unit SN-003

1. General

All mensuration by Autometric utilized the original negative film stellar exposures.

2. Distortion Function

Radial distortion, Δr, is represented by an odd-power polynomial in r, the radial distance from the principal point.

$$\Delta r = K_1 r^3 + K_2 r^5 + K_3 r^7$$

The x and y components of r are

$$\Delta x_r = \frac{\Delta r}{r} (x') = (K_1 r^2 + K_2 r^4 + K_3 r^6) (x')$$

$$\Delta y_r = \frac{\Delta r}{r} (y') = (K_1 r^2 + K_2 r^4 + K_3 r^6) (y')$$

where x' and y' are measured image coordinates, relative to principal point origin.

Tangential distortion, Δt, is represented by an even-power polynomial in r.

$$\Delta t = J_1 r^2 + J_2 r^4$$

The x and y components of Δt are

$$\Delta x_t = -\Delta t \sin \phi_0 = -(J_1 r^2 + J_2 r^4) \sin \phi_0$$

$$\Delta y_t = \Delta t \cos \phi_0 = (J_1 r^2 + J_2 r^4) \cos \phi_0$$

where ϕ_0 is the angle the axis of maximum tangential distortion makes with the x axis.

x' and y' image coordinates can be corrected for radial and tangential lens distortion by the functions

$$x = (1 + K_1r^2 + K_2r^4 + K_3r^6)x' - (J_1r^2 + J_2r^4)\sin \phi_0$$

$$y = (1 + K_1r^2 + K_2r^4 + K_3r^6)y' + (J_1r^2 + J_2r^4)\cos \phi_0$$

where x and y are corrected image coordinates, and K_1, K_2, K_3, J_1, J_2, ϕ_0 are the distortion parameters given by the calibration.

Radial distortion curves for terrain camera lens 202 are presented in Figure 3. The figure gives the EFL radial distortion curve from the stellar calibration and compares the corresponding CFL curve with the Fairchild CFL curve, as determined by laboratory methods. Both CFL curves represent radial distortion characteristics under vacuum conditions, balanced for equal positive and negative distortion values.

Studies made by Fairchild indicate that a negligible change in distortion occurs when the camera is operated under vacuum conditions, rather than the atmospheric conditions under which the stellar calibration was performed. As a result of the supporting Fairchild data given below, no adjustment is made for the change in operating medium from 5000 feet altitude (610 mm. Hg.) to vacuum (0.0001 mm. Hg.).

Field Angle (Degrees)	Distortion Change (Micrometers)
11.25	-0.05
22.50	-0.14
33.75	-0.25
45.00	-1.10

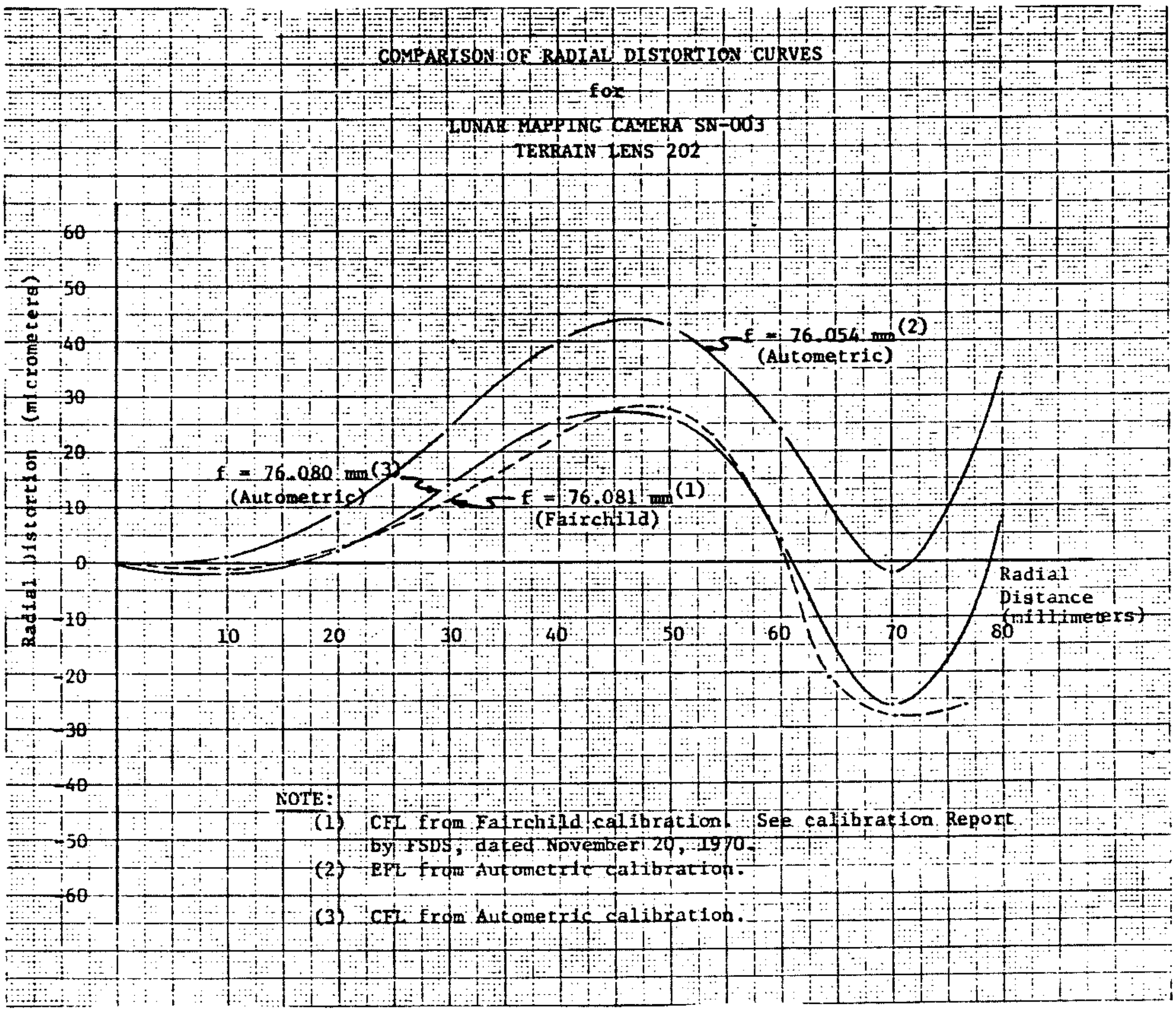

COMPARISON OF RADIAL DISTORTION CURVES
for
LUNAR MAPPING CAMERA SN-003
TERRAIN LENS 202
f = 76.054 mm (2)
(Autometric)
f = 76.080 mm (3)
(Autometric)
f = 76.081 mm (1)
(Fairchild)
Radial Distortion (micrometers)
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
10
20
30
40
50
60
70
80
Radial
Distance
(millimeters)
NOTE:
(1) CFL from Fairchild calibration. See calibration Report
by FSDS, dated November 20, 1970.
(2) EFL from Autometric calibration.
(3) CFL from Autometric calibration.

Figure 3.

3. Relative Orientation System:

The relative orientation matrix

$$M = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix}$$

gives the angular orientation of the stellar camera coordinate system with respect to the terrain camera coordinate system. The orientation matrix can be factored into three orthogonal matrices each representing a simple rotation of the stellar camera coordinate system about a particular stellar axis. The sequence of the three rotations must be specified, because different angular orientations result from different sequences. The orientation of x_s, y_s, z_s with respect to X_T, Y_T, Z_T can be developed as follows.

Consider a stellar camera coordinate system x, y, z initially coincident with the terrain camera coordinate system X_T, Y_T, Z_T (refer to Figure 4). The three rotations ω, ϕ, κ are applied to the stellar camera coordinate axes in the given sequence to place the system into its final position, x_s, y_s, z_s.

ω (roll) - Rotation about the x axis. Positive ω takes the +y axis toward the +z axis, resulting in x', y', z' in Figure 4.

ϕ (pitch) - Rotation about the y' axis. Positive ϕ takes the +z' axis toward the +x' axis, resulting in x'', y'', z'' in Figure 4.

κ (yaw) - Rotation about the z'' axis. Positive κ takes the +x'' axis toward the +y'' axis, resulting in the final position of the stellar camera coordinate system x_s, y_s, z_s in Figure 4.

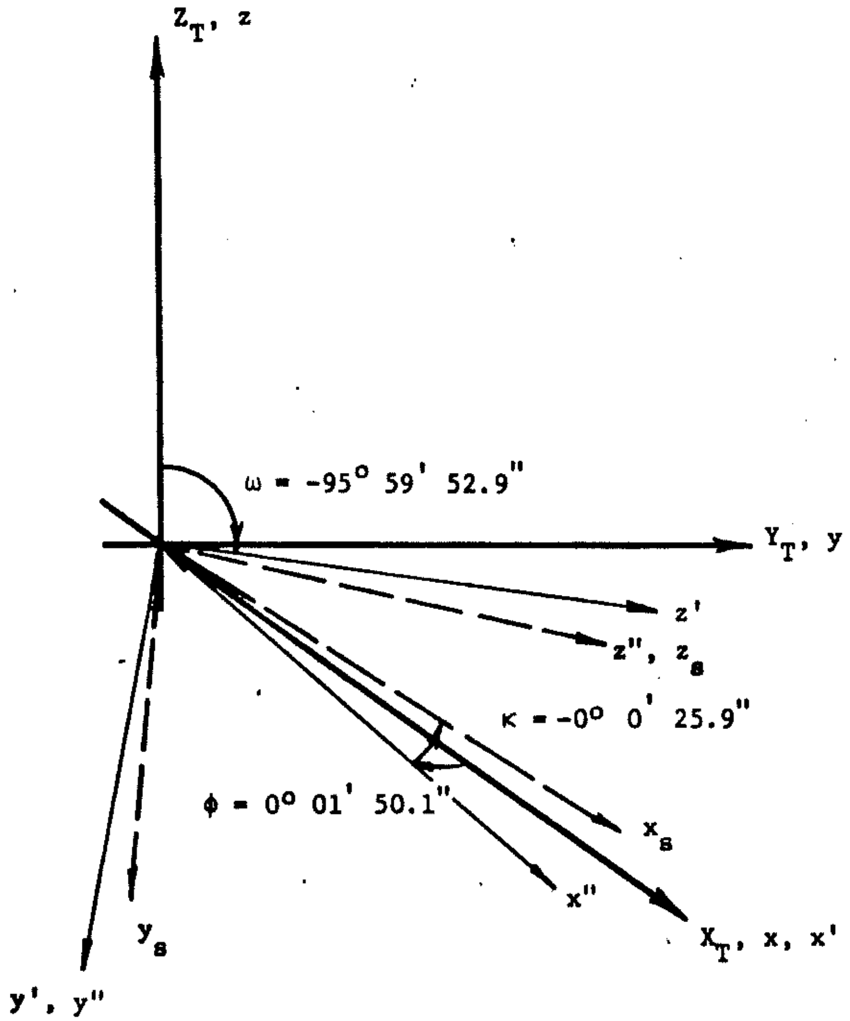


Figure 4. Orientation of Stellar Camera Coordinate System With Respect to Terrain Camera Coordinate System.

59

This Final Report was prepared for Fairchild Space and Defense Systems by Raytheon Company, Autometric Operation, under Contract N-0234.

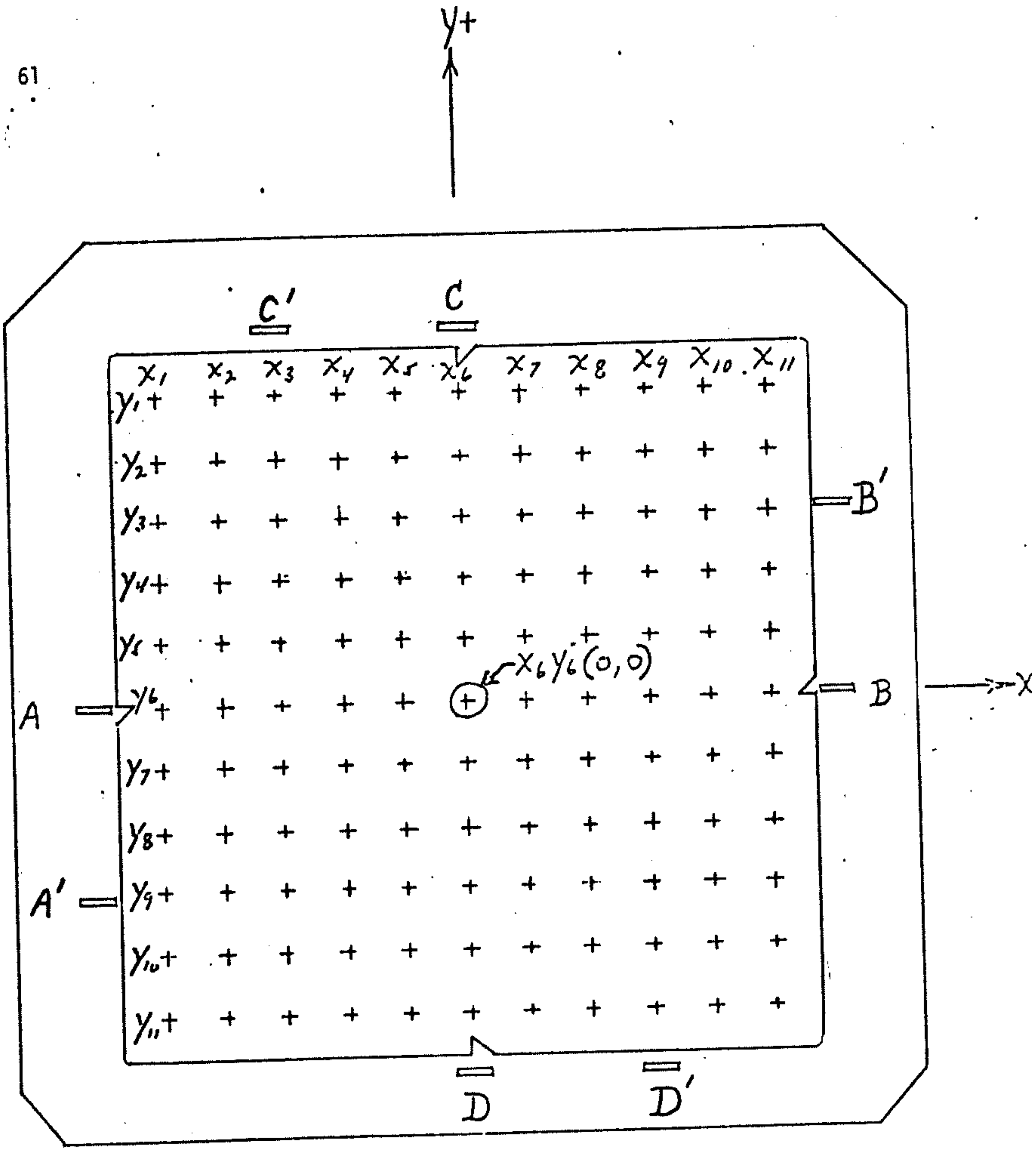
Ronald K. Brewer
Senior Scientist/Photogrammetry
Program Manager

STELLAR CALIBRATION REPORT SUPPLEMENT

Calibrated Ikogon (Mapping)
and
Ikotar (Stellar)
Reseau Coordinate Intersections

IKOGON B GRID PLATE LAYOUT

61



{EMULSION UP}

LINE OF FLIGHT

IKOGON B MASTER GRID PLATE
CALIBRATION DATA
(COORDINATES IN MILLIMETERS)

CROSS	COORDINATES X-	Y-	CROSS	COORDINATES X-	Y-
X1, Y1	-50.0014	+50.0019	X1, Y4	-50.0014	+20.0015
X2, Y1	-39.9997	+50.0019	X2, Y4	-39.9997	+20.0015
X3, Y1	-29.9977	+50.0019	X3, Y4	-29.9977	+20.0015
X4, Y1	-19.9974	+50.0019	X4, Y4	-19.9974	+20.0015
X5, Y1	- 9.9990	+50.0019	X5, Y4	- 9.9990	+20.0015
X6, Y1	0.0000	+50.0019	X6, Y4	0.0000	+20.0015
X7, Y1	+ 9.9992	+50.0019	X7, Y4	+ 9.9992	+20.0015
X8, Y1	+19.9995	+50.0019	X8, Y4	+19.9995	+20.0015
X9, Y1	+29.9994	+50.0019	X9, Y4	+29.9994	+20.0015
X10, Y1	+40.0019	+50.0019	X10, Y4	+40.0019	+20.0015
X11, Y1	+50.0029	+50.0019	X11, Y4	+50.0029	+20.0015
X1, Y2	-50.0014	+40.0022	X1, Y5	-50.0014	+10.0013
X2, Y2	-39.9997	+40.0022	X2, Y5	-39.9997	+10.0013
X3, Y2	-29.9977	+40.0022	X3, Y5	-29.9977	+10.0013
X4, Y2	-19.9974	+40.0022	X4, Y5	-19.9974	+10.0013
X5, Y2	- 9.9990	+40.0022	X5, Y5	- 9.9990	+10.0013
X6, Y2	0.0000	+40.0022	X6, Y5	0.0000	+10.0013
X7, Y2	+ 9.9992	+40.0022	X7, Y5	+ 9.9992	+10.0013
X8, Y2	+19.9995	+40.0022	X8, Y5	+19.9995	+10.0013
X9, Y2	+29.9994	+40.0022	X9, Y5	+29.9994	+10.0013
X10, Y2	+40.0019	+40.0022	X10, Y5	+40.0019	+10.0013
X11, Y2	+50.0029	+40.0022	X11, Y5	+50.0029	+10.0013
X1, Y3	-50.0014	+30.0030	X1, Y6	-50.0014	0.0000
X2, Y3	-39.9997	+30.0030	X2, Y6	-39.9997	0.0000
X3, Y3	-29.9977	+30.0030	X3, Y6	-29.9977	0.0000
X4, Y3	-19.9974	+30.0030	X4, Y6	-19.9974	0.0000
X5, Y3	- 9.9990	+30.0030	X5, Y6	- 9.9990	0.0000
X6, Y3	0.0000	+30.0030	X6, Y6	0.0000	0.0000
X7, Y3	+ 9.9992	+30.0030	X7, Y6	+ 9.9992	0.0000
X8, Y3	+19.9995	+30.0030	X8, Y6	+19.9995	0.0000
X9, Y3	+29.9994	+30.0030	X9, Y6	+29.9994	0.0000
X10, Y3	+40.0019	+30.0030	X10, Y6	+40.0019	0.0000
X11, Y3	+50.0029	+30.0030	X11, Y6	+50.0029	0.0000

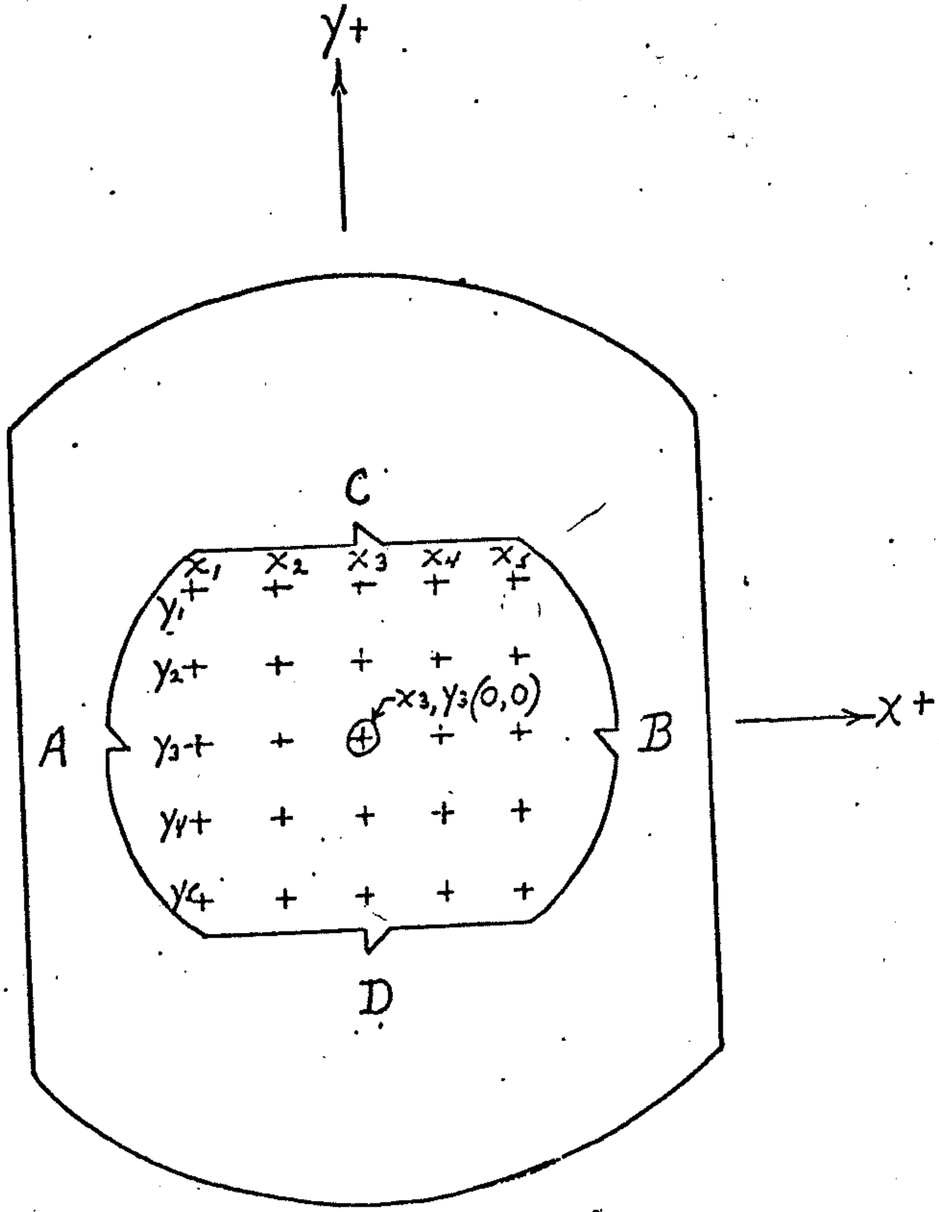
IKOGON B MASTER GRID PLATE
CALIBRATION DATA -----(COORDINATES IN MILLIMETERS)

CROSS	COORDINATES X-	COORDINATES Y-
X1, Y7	-50.0014	-10.0000
X2, Y7	-39.9997	-10.0000
X3, Y7	-29.9977	-10.0000
X4, Y7	-19.9974	-10.0000
X5, Y7	- 9.9990	-10.0000
X6, Y7	0.0000	-10.0000
X7, Y7	+ 9.9992	-10.0000
X8, Y7	+19.9995	-10.0000
X9, Y7	+29.9994	-10.0000
X10, Y7	+40.0019	-10.0000
X11, Y7	+50.0029	-10.0000
X1, Y8	-50.0014	-19.9992
X2, Y8	-39.9997	-19.9992
X3, Y8	-29.9977	-19.9992
X4, Y8	-19.9974	-19.9992
X5, Y8	- 9.9990	-19.9992
X6, Y8	0.0000	-19.9992
X7, Y8	+ 9.9992	-19.9992
X8, Y8	+19.9995	-19.9992
X9, Y8	+29.9994	-19.9992
X10, Y8	+40.0019	-19.9992
X11, Y8	+50.0029	-19.9992
X1, Y9	-50.0014	-29.9987
X2, Y9	-39.9997	-29.9987
X3, Y9	-29.9977	-29.9987
X4, Y9	-19.9974	-29.9987
X5, Y9	- 9.9990	-29.9987
X6, Y9	0.0000	-29.9987
X7, Y9	+ 9.9992	-29.9987
X8, Y9	+19.9995	-29.9987
X9, Y9	+29.9994	-29.9987
X10, Y9	+40.0019	-29.9987
X11, Y9	+50.0029	-29.9987
X1, Y10	-50.0014	-39.9974
X2, Y10	-39.9997	-39.9974
X3, Y10	-29.9977	-39.9974
X4, Y10	-19.9974	-39.9974
X5, Y10	- 9.9990	-39.9974
X6, Y10	0.0000	-39.9974
X7, Y10	+ 9.9992	-39.9974
X8, Y10	+19.9995	-39.9974
X9, Y10	+29.9994	-39.9974
X10, Y10	+40.0019	-39.9974
X11, Y10	+50.0029	-39.9974
X1, Y11	-50.0014	-49.9969
X2, Y11	-39.9997	-49.9969
X3, Y11	-29.9977	-49.9969
X4, Y11	-19.9974	-49.9969
X5, Y11	- 9.9990	-49.9969
X6, Y11	0.0000	-49.9969
X7, Y11	+ 9.9992	-49.9969
X8, Y11	+19.9995	-49.9969
X9, Y11	+29.9994	-49.9969
X10, Y11	+40.0019	-49.9969
X11, Y11	+50.0029	-49.9969

CERTIFICATION

Signed ____________

IKOTAR B GRID PLATE LAYOUT



{EMULSION UP}

LINE OF FLIGHT

IKOTAR B MASTER GRID PLATE CALIBRATION DATA (COORDINATES IN MILLIMETERS)

CROSS	COORDINATES X-	COORDINATES Y-	CROSS	COORDINATES X-	COORDINATES Y-
X1, Y1	-10.0015	+10.0003	X1, Y4	-10.0015	-5.0002
X2, Y1	-5.0004	+10.0005	X2, Y4	-5.0008	-5.0005
X3, Y1	-0.0003	+10.0000	X3, Y4	-0.0005	-5.0004
X4, Y1	+4.9996	+10.0000	X4, Y4	+4.9995	-5.0000
X5, Y1	+9.9996	+10.0000	X5, Y4	+9.9996	-5.0002
X1, Y2	-10.0015	+5.0011	X1, Y5	-10.0015	-10.0015
X2, Y2	-5.0004	+5.0001	X2, Y5	-5.0010	-10.0015
X3, Y2	0.0000	+5.0000	X3, Y5	-0.0005	-10.0015
X4, Y2	+4.9996	+5.0006	X4, Y5	+4.9992	-10.0015
X5, Y2	+9.9992	+5.0004	X5, Y5	+9.9992	-10.0015
X1, Y3	-10.0015	+0.0006			
X2, Y3	-5.0009	+0.0002			
X3, Y3	0.0000	+0.0000			
X4, Y3	+4.9993	+0.0006			
X5, Y3	+9.9992	+0.0004			

FAIRCHILD SPACE AND DEFENSE SYSTEMS
A DIVISION OF FAIRCHILD CAMERA AND INSTRUMENT CORPORATION

66

Lens Type IKOGON "B" Date 12 Oct 70

Serial Number 202

Relative Illumination

Axis	5°	10°	15°	20°	25°	30°	35°	40°	45°
98%	98%	100%	99%	98%	96%	91%	78%	66%	45%

Σ = 84.9%

Lens Transmittance = 43.9%

Lens T# $= \frac{4.5}{\sqrt{.439}} = \frac{4.5}{663} = 6.787$

Awat $= \frac{6.787}{\sqrt{.849}} = \frac{6.787}{.922}$

Awat = 7.36

Relative Aperture

$\frac{\text{EFL}}{\text{EFFECTIVE APERTURE}} = \frac{2.9[illegible]35''}{.690''} = 4.35$

RESOLUTION Date: Nov 20, 1970

3.1 **Average Resolving Power** - Contrast 1000:1

FILM TYPE: 3404

	Axis	7.5°	15°	22.5°	27.5°	30°	32.5°	35°	37.5°	40°	42.5°	45°
ngential	144	150	126	124	105	126	134	134	129	106	55	61
dial	162	148	144	162	162	162	162	135	162	158	119	102

3.2 AWAR = 135.5 L/MM

FAIRCHILD SPACE AND DEFENSE SYSTEMS
A Division of Fairchild Camera and Instrument Corporation
El Segundo, California

67

LENS TYPE IKOTAR "B" DATE 6 Oct. 1970

SERIAL NUMBER 104

II. RESOLVING POWER

FILM 3400

PROCESSING Mx641 1 min @ 69° DIAG. #1 AWAR 84.4

TARGET CONTRAST 1000:1 DIAG. #2 AWAR 84.6

DIAG. #1	0°	2½°	5°	7½°	10°							
RADIAL	90	90	89	84	85							
TANGENTIAL	90	95	89	79	75							

DIAG. #2	0°	2½°	5°	7½°	10°							
RADIAL	90	95	95	84	75							
TANGENTIAL	90	95	85	79	79							

FAIRCHILD SPACE AND DEFENSE SYSTEMS
A DIVISION OF FAIRCHILD CAMERA & INSTRUMENT CORPORATION
EL SEGUNDO, CALIFORNIA

Lens Type IKOTAR "B"

Date 6 Oct. 1970

Serial Number 104

Relative Illumination

10°	7½°	5°	2½°	Axis	2½°	5°	7½°	10°
90	96	99	100	100	100	97	94	88

Transmission

93%

Relative Aperture

f/2.75

6.2 CALIBRATION DATA FOR THE OPTICAL BAR PANORAMIC CAMERA

The ITEK calibration reports include relative illumination, spectral transmittance, veiling glare, calibrated focal length and system resolution.

Test Procedure No. TP125 No. of Pages 8

70

TEST PROCEDURE

FOR

PROJECT 9446
RELATIVE ILLUMINATION
MEASUREMENTS
PANORAMIC CAMERA
FOR SCIENTIFIC INSTRUMENT
MODULE

EXPERIMENT S-163

Itek

ITEK CORPORATION

Lexington 73, Massachusetts

Date 9-15-70

Lens S/N N-54

	PREPARED	PROJECT APPROVAL	QUALITY ASSURANCE APPROVAL
By	R. SHERLOCK	C. BACKE	R. WESPISER
Signed	R. Sherlock	C. Backe	R. Wespiser
Date	9/17/70	9/21/70	9/18/70

CUST./GOV'T. REP. ______________ Date ______________
Reviewed

Q199-1 11/65

5.3.1.3 Itek Test Data Sheet

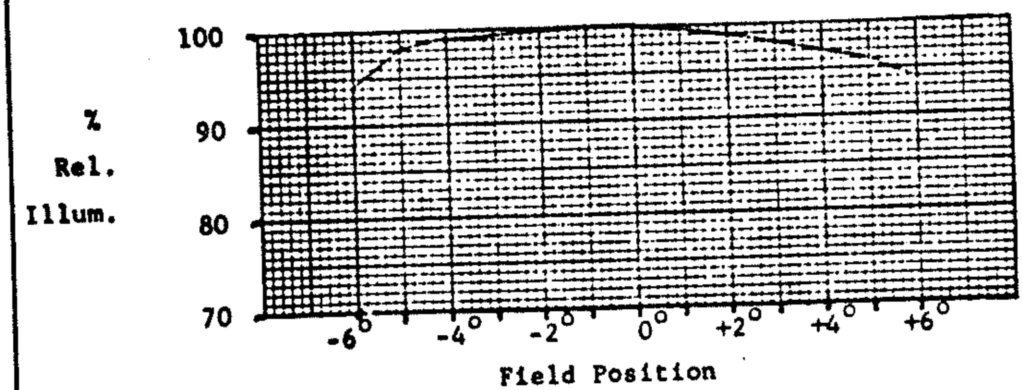
RELATIVE ILLUMINATION MEASUREMENT

Panoramic Camera Lens, P/N 105150, Serial No. N-54

	Field Position	Radiometer Readings vdc	Relative Illumination %
B	-6°	76.0	93.8
	-5°	79.5	98.1
	-4°	80.0	98.8
	-3°	80.5	99.4
	-2°	80.8	99.8
	-1°	81.0	100.0
A	0°	81.0	100.0
B	+1°	80.5	99.4
	+2°	80.0	98.8
	+3°	79.5	98.1
	+4°	78.5	96.9
	+5°	77.5	95.7
	+6°	76.0	93.8

Meter Scale for Radiometer Readings: 100

% Relative Illumination = $\frac{B}{A} \times 100$



Data Recorded By: [signature] Date: 10/12/70

QA Monitor: A.C. Delley 10-15-70

Project Approval: [signature] 10-19-70

Test Procedure No. TP125 Page 8

Test Procedure No. TP123 | No. of Pages 9

TEST PROCEDURE

FOR

PROJECT 9446
SPECTRAL TRANSMITTANCE
MEASUREMENTS
PANORAMIC CAMERA
FOR SCIENTIFIC INSTRUMENT
MODULE

EXPERIMENT S-163

Itek

ITEK CORPORATION

Lexington 73, Massachusetts

Date 9-15-70

Lens S/N N-54

	PREPARED	PROJECT APPROVAL	QUALITY ASSURANCE APPROVAL
By	R. SHERLOCK	C. BACKE	R. WESPISER
Signed	R. Sherlock	C. Backe	R. J. Wespiser
Date	9/17/70	9/21/70	9/17/70

CUST./GOV'T. REP. ______________ Date ______________
Reviewed

Q199-1 11/65

6.3.1.3 Itek Test Data Sheet

SPECTRAL TRANSMITTANCE MEASUREMENT

Panoramic Camera Lens, P/N 105150, Serial No. N-54

Wavelength nm	Radiometer Readings A	A_1	B	B_1	% Transmittance
400	9.2	2.65	2.0	.13	22.6
420	25.8	6.6	5.4	.55	39.8
440	46.0	12.2	9.5	1.3	51.6
480	100.0	27.0	21.0	3.8	67.0
520	144.9	41.0	32.5	6.6	71.8
560	160.0	44.5	36.0	7.4	73.9
601	145.0	39.5	33.0	6.2	69.0
640	125.0	35.0	21.5	4.8	63.8
680	106.0	25.7	24.0	3.3	56.7
720	80.0	18.0	13.0	2.0	49.4

Legend:

A = Brightness of the calibrated standard Lambertian source using the radiometer telescope.

A_1 = Brightness of the collimator target as seen from the lens test position using the radiometer telescope.

B = Brightness of the calibrated standard Lambertian source using the radiometer microscope.

B_1 = Brightness of the collimator target aerial image at the image plane (lens in place) using the radiometer microscope.

% Transmittance = $\left[(B_1/B) \div (A_1/A)\right] \times 100.$

Data Recorded By: [signature] Date: 10/12/70

QA Monitor: [signature] 10-15-70

Project Approval: [signature] 10-19-70

Test Procedure No. TP123

6.3.1.3 Itek Test Data Sheet

T STOP CALCULATION

Panoramic Camera Lens, P/N 105150, Serial No. N-54

Wavelength nm	% Transmittance	T STOP
400	22.6	7.4
420	39.8	5.5
440	51.6	4.9
480	67.0	4.3
520	71.8	4.1
560	73.9	4.1
601	69.0	4.2
640	63.8	4.4
680	56.7	4.6
720	49.4	5.0

Legend:

$$T\ STOP = \frac{f/number}{\sqrt{t}}$$ where f/number is 3.5 and t is transmittance.

Data Recorded By: [signature] Date: Oct 12 1970

QA Monitor: A.C. [signature] 10-15-70

Project Approval: [signature] 10-19-70

Test Procedure No. TP123

Q199-5 11/65

ITEK CORPORATION
Lexington 73, Massachusetts

Test Procedure No. TP121 No. of Pages 8

TEST PROCEDURE

FOR

PROJECT 9446
VEILING GLARE MEASUREMENTS
PANORAMIC CAMERA
FOR SCIENTIFIC INSTRUMENT
MODULE

EXPERIMENT S-163

Itek

ITEK CORPORATION

Lexington 73, Massachusetts

Date 9-15-70

Lens S/N N-54

	PREPARED	PROJECT APPROVAL	QUALITY ASSURANCE APPROVAL
By	R. SHERLOCK	C. BACKE	R. WESPISER
Signed	[signature]	C. Backe	R. Wespiser
Date	9/17/70	9/21/70	9/18/70

CUST./GOV'T. REP. ______________ Date ______________
Reviewed

6.3.1.3 Itek Test Data Sheet

VEILING GLARE MEASUREMENT

Panoramic Camera Lens, P/N 105150, Serial No. N-54

Step No.	1	2	3	4	5	6	7	Black Dot	% Veiling Glare
	Step Wedge								
* Calibrated Value	1.22	1.07	.92	.78	.65	.50	.36		
Field Position	* Measured Test Values								
-6°	.24	.34	.51	.80	1.14	1.44	1.79	.55	12.6
-4°	.22	.30	.43	65	.94	126	162	.44	12.3
-2°	.60	.93	1.30	1.62	1.88	2.04	2.24	1.34	12.7
0°	.24	.32	.50	.80	1.13	1.44	1.74	.54	13.2
+2°	.26	.36	.55	.84	1.11	1.40	1.77	.82	16.2
+4°	.25	.37	.56	.86	1.14	1.45	1.83	.84	16.2
+6°	.22	.30	.46	.71	1.05	1.36	1.70	.64	15.1

Legend: * Density values are logarithmic as read on the Macbeth Densitometer.

% Veiling Glare is computed from the black spot density plot (attached) for each field position.

Data Recorded By: [signature] Date: 10/13-70

QA Monitor: [signature] 10/16/70

Project Approval: [signature] 10/19/70

Test Procedure No. TP121

Page 8

Q199-5 11/65

ITEK CORPORATION
Lexington 73, Massachusetts

Test Procedure No. TP127 | No. of Pages 5

TEST PROCEDURE

FOR

PROJECT 9446

C.F.L./MEASUREMENTS
PANORAMIC CAMERA

FOR SCIENTIFIC INSTRUMENT
MODULE

EXPERIMENT S-163

Itek

ITEK CORPORATION

Lexington 73, Massachusetts

Date 9-15-70

	PREPARED	PROJECT APPROVAL	QUALITY ASSURANCE APPROVAL
By	R. SHERLOCK	C. BACKE	R. WESPISER
Signed	[signature]	C. Backe	[signature]
Date	9/17/70	9/21/70	9/21/70

CUST./GOV'T. REP. ____________ Date ____________
Reviewed

Q199-1 11/65

6.3.1.3 Test Data Summary

Lens - N-54

C.F.L. Calibration Summary

Filter	Field Position (degrees)	Mean C.F.L. (inches)	STD Deviation of of mean (C.F.L.)
23A	+6	24.0057	0.0004
	+4	24.0058	0.0003
	+2	24.0015	0.0006
	0 *	24.0052	0.0008
	-2	24.0073	0.0006
	-4	24.0057	0.0001
	-6	24.0C50	0.0003
12	+6	24.0063	0.0008
	+4	24.0080	0.0003
	+2	24.0086	0.0009
	0 *	24.0081	0.0004
	-2	24.0088	0.0006
	-4	24.0089	0.0004
	-6	24.0080	0.0001
8	+6	24.0076	0.0004
	+4	24.0096	0.0007
	+2	24.0106	0.0005
	0 *	24.0080	0.0007
	-2	24.0059	0.0003
	-4	24.0081	0.0015
	-6	24.0064	0.0009
2A	+6	24.0044	0.0003
	+4	24.0075	0.0006
	+2	24.0085	0.0008
	0 *	24.0062	0.0007
	-2	24.0047	0.0013
	-4	24.0055	0.0006
	-6	24.0066	0.0005
no filter	+6	24.0037	0.0003
	+4	24.0050	0.0004
	+2	24.0065	0.0006
	0 *	24.0045	0.0005
	-2	24.0032	0.0004
	-4	24.0048	0.0008
	-6	24.0037	0.0006

Avg: 24.0045 in = 609.717 mm

* Average of all field positions

Quality Assurance Review A. C. McHenry QA 32

Test Procedure No. TP-70-9446-42-4 B No. of Pages 47

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5/N003 1-27-71

ITEK APPROVED

TEST PROCEDURE

FOR

PHOTOGRAPHIC BASELINE (PBL)
(DYNAMIC TESTING WITH FORWARD MOTION COMPENSATION)
ACCEPTANCE OF THE PANORAMIC CAMERA
EXPERIMENT S-163

1053 234 Filter

Itek

ITEK CORPORATION

Lexington 73, Massachusetts

Date 9/3/70

	PREPARED	PROJECT APPROVAL	QUALITY ASSURANCE APPROVAL
By	A D Auk	[illegible]	W ZEDLEY
Signed	[illegible]	[illegible]	W. Zelley
Date	7/24/70	7-24-70	7/24/70

CUST./GOV'T. REP. ______________ Date ______________
Reviewed

Q199-1 11/65

NO FILTER 79
FLIGHT CONFIG.

DYNAMIC TESTING WITH FMC W/O FILTER

RUN 951'G.

DATA SHEET

∞

FORMAT POSITION - 4°

FRAME NO.	FP0 (.466) Collimator 3 Resolution III / ≡	Avg.	FP1 (.474) Collimator 3 Resolution III / ≡	Avg.	FP2 (.482) Collimator 3 Resolution III / ≡	Avg.	FP3 (.490) Collimator 3 Resolution III / ≡	Avg.	FP4 (.498) Collimator 3 Resolution III / ≡	Avg.
1	108/114	111	152/149	153	120/144	136	144/152	148	144/144	144
2	128/128	128	121/136	129	152/152	152	144/161	153	121/152	137
3	136/128	132	76/102	89	181/152	167	136/152	144	144/121	133
4	108/96	102	152/152	152	114/152	133	136/152	144	128/128	128
5	108/102	105	144/178	136	136/144	140	161/136	149	152/161	157
6	161/136	149	136/102	119	114/144	129	152/171	162	114/144	129
7	108/156	130	144/152	148	114/152	133	152/161	157	144/136	140
8	121/136	129	152/121	137	144/128	136	152/161	157	161/181	171
9	121/108	115	128/128	128	144/161	153	114/161	138	102/152	127
10	114/102	108	144/128	136	121/152	137	128/152	140	121/144	133
AVERAGES		121		132		142		149		140

FRAME NO.	FP5 (.506) Collimator 3 Resolution III / ≡	Avg.	FP6 (.514) Collimator 3 Resolution III / ≡	Avg.	FP7 (.522) Collimator 3 Resolution III / ≡	Avg.	FP8 (.530) Collimator 3 Resolution III / ≡	Avg.
1	108/144	126	108/102	105	64/76	70	64/72	68
2	108/121	115	81/108	95	54/64	59	60/64	62
3	96/128	112	64/76	70	54/76	65	64/57	61
4	121/121	125	68/102	85	54/76	65	45/60	53
5	121/128	125	96/102	99	54/81	68	48/57	53
6	121/136	[illegible]	102/76	89	64/60	62	60/57	52
7	114/128	121	76/76	76	54/68	61	64/76	70
8	108/152	130	76/68	72	72/72	72	60/51	56
9	114/108	111	91/81	86	54/76	65	64/60	62
10	108/128	118	96/91	94	54/81	68	68/72	70
AVERAGES		121		87		66		61

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DYNAMIC TESTING WITH FMC W/O FILTER

RUN 951 J

DATA SHEET

FORMAT POSITION +4°

FRAME NO.	F5 (466) COLLIMATOR 3 Resolution III	/ ≡	Avg.	F3 (474) COLLIMATOR 3 Resolution III	/ ≡	Avg.	F2 (482) COLLIMATOR 3 Resolution III	/ ≡	Avg.	F3 (490) COLLIMATOR 3 Resolution III	/ ≡	Avg.	F4 (498) COLLIMATOR 3 Resolution III	/ ≡	Avg.
1	128	128	128	121	152	144	128	162	140	171	154	182	108	171	140
2	121	108	115	161	152	157	152	144	148	121	152	137	114	152	133
3	144	152	148	147	136	140	102	128	115	131	152	151	121	171	146
4	144	114	129	144	144	144	125	144	136	[illegible]	[illegible]	144	[illegible]	[illegible]	123
5	144	114	129	161	136	149	152	144	148	121	[illegible]	136	91	152	122
6	121	136	129	152	144	148	161	171	166	144	152	148	114	152	133
7	128	144	136	121	144	133	121	152	[illegible]	144	144	144	114	152	133
8	136	108	121	144	171	158	102	126	119	114	161	138	102	161	132
9	161	152	157	128	137	128	151	152	149	152	181	167	[illegible]	[illegible]	[illegible]
10	128	152	140	152	152	152	152	152	152	121	161	141	128	152	140
AVERAGES			133			145			142			149			135

FRAME NO.	F5 (506) COLLIMATOR 3 Resolution III	/ ≡	Avg.	F6 (514) COLLIMATOR 3 Resolution III	/ ≡	Avg.	F7 (522) COLLIMATOR 3 Resolution III	/ ≡	Avg.	F2 (530) COLLIMATOR 3 Resolution III	/ ≡	Avg.
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
AVERAGES			*			*			*			*

* SEE DEV #3

R J Lapobiancir CA V13

Felix J Victor

Out of film – yet they plotted 6 points using +4°, 0°, –4°

93

7.0 PHOTOGRAPHIC MISSION OPERATIONS

Mission operation contingencies required rescheduling of some photography during the latter part of the mission; however, the photography accomplished generally covered the areas delineated in premission planning. Operation of the laser altimeter was curtailed because of a malfunction, thus all scheduled operations from Rev 50 on were accomplished on daylight side only. A complete girth of the moon with the laser was recorded on Rev 15/16 with sporadic data being recorded the remaining time in lunar orbit. No estimate of total operational laser data recorded can be made until postflight analysis is completed.

On the accompanying figures the times shown in the "accomplished" column are flight plan update times made during the mission. The longitudes opposite these times were determined from mission trajectories and are included merely as a reference as they are only approximate values. The time and position for each exposure will be listed in the orbital support data (APE) that is to be published.

Major deviations from the planned mission are listed below.

Metric Camera

Rev 35 - North oblique strip was flown with a spacecraft attitude that introduced yaw in the camera orientation and are not true north obliques as planned.

Rev 50 - Camera turned off early as spacecraft attitude had drifted beyond desired limits.

Rev 62 - Camera turned on late because of other activities. This is a reschedule of photography missed on Rev 58/59. Lightside pass only.

Rev 63 - Reduced to lightside pass only.

Rev 70 -Reschedule of Rev 69. Lightside pass only.

Rev 72 - Lightside pass only.

Panoramic Camera - Telemetry readouts received at MSC during the mission indicated the FMC was giving spurious readings at an erratic interval. Estimates were that approximately 80% of the time the unit was functioning correctly.

Rev 38 - Last part of first strip on this rev was switched to mono; however, time of this change not known.

Rev 58 - Not accomplished because of extended rest period.

Rev 60 - Partial reschedule of Rev 58. Second test cycle taken over LM impact area.

Rev 61 Additional photos over LM impact area to provide stereo photography with the Rev 60 photos.

Rev 63 - Partial reschedule of Rev 58.

SCHEDULED

REV	START GET(H:M:S)	START LONG(DEG)	STOP GET(H:M:S)	STOP LONG(DEG)	REMARKS
3/4	84:42:35	179.6W	84:54:15	142.5°E	
15	105:52:20	144.5E	106:17:20	74.0°E	
15/16	106:56:15	49.8W	108:54:40	50.8W	Full Rev
22/23	119:33:35	162.7E	121:32:02	161.7E	Full Rev
23	121:37:04	143.7E	122:31:28	18.8W	Forward Oblique
27	129:26:27	157.7E	130:26:00	22.8W	
33/34	141:16:34	151:6E	143:15:02	150.6E	Full Rev
34	143:15:02	150.6E	144:09:00	11.8W	BKWD Ob.
35	145:13:30	149.6E	146:12:55	30.8W	N Ob.
37/38	150:08:58	32.9W	152:08:20	33.9W	Full Rev
44	162:59:44	140.6E	163:59:10	39.9W	
50	174:50:06	134.6E	175:49:22	45.9W	
58/59	190:37:25	126.6E	192:35:51	125.6E	Full Rev
62/63	199:30:22	57.9W	201:28:11	58.9W	Full Rev
69	212:19:43	115.6E	214:18:10	114.6E	Full Rev
71	216:16:37	113.6E	217:15:47	66.9W	South Ob
71/72	217:20:00	82.9W	219:14:14	67.9W	

ACCOMPLISHED

REV	START GET(H:M:S)	START LONG(DEG)	STOP GET(H:M:S)	STOP LONG(DEG)	REMARKS
4	84:42:23	179.1W	84:54:14	142.5E	
15	105:52:58	144.4E	106:17:57	74.0E	
15/16	106:56:51	50.0W	108:55:19	50.6W	
22/23	119:34:53	161.3E	121:33:02	161.9E	
23	121:39:34	141.5E	122:32:43	18.9W	FWD Obl.
27	129:26:52	157.2E	130:26:30	22.8W	
33/34	141:17:26 143:14:00	150.8E	143:14:00 144:09:30	158.E 9.5W	AFT Obl.
35	145:14:16	149.6E	146:13:56	31.2W	AFT Obl.
38	151:09:22	146.6E	152:09:32	35.5W	
44	162:59:30	140.5E	163:59:11	40.4W	
50	174:50:04	134.4E	175:32:32	12.1E	
62	198:44:40	83.4E	199:31:56	56.8W	
63	200:30:56	120.0E	201:30:21	59.1W	
70	214:20:03	114.5E	215:19:49	66.8W	
71	216:18:30	113.4E	217:18:15	67.1W	S. Obl.
72	218:16:59	112.3E	219:16:44	68.2W	

FIG. 7-1 Apollo 15 Mapping Camera Photography

PANORAMIC CAMERA PHOTOGRAPHY

SCHEDULED

REV	START GET(H:M:S)	START LONG(DEG)	STOP GET(H:M:S)	STOP LONG(DEG)	MODE
3/4	84:42:35	179.6W (E TERM)	84:45:55	170.5E	Mono
	84:45:55	170.5E	84:54:15	142.5E	Stereo
15	105:52:20	144:5E	106:07:30	100E	Stereo
	106:07:50	100E	106:14:20	82E	Mono
	106:14:20	82E	106:17:20	74E	Stereo
16	108:14:40	76E	108:39:15	1.8W	Stereo
	108:39:15	1.8W	108:42:33	11.8W (WTerm)	Mono
27	130:16:45	5.7E	130:18:00	1.7E	Stereo
33	141:45:05	67.5E	142:00:20	23E	Stereo
38	151:12:40	134E	151:31:50	77.5E	Stereo
	151:31:50	77.5E	151:36:12	65.5E	Mono
	151:56:20	5.7E	151:57:05	1.7E	Stereo
50	175:34:07	5.7E	175:36:00	0.3W	Stereo
58	190:37:25	126.6E (E TERM)	190:40:45	116.6E	Mono
	190:40:45	116.6E	190:55:50	69.E	Stereo
	190:55:50	69.E	191:01:45	53.E	Mono
	191:01:45	53.E	191:08:20	36.5E	Stereo
59	193:05:25	38.5E	193;18;30	0	Stereo
	193:31:45	44.9W	193:35:05	54.9W (W TERM)	Mono
70	214:42:10	42E	214:50:12	20E	Stereo
72	218:48:30	22E	219:10:54	57.9W	Stereo
	219:10:54	57.9W	219:14:14	67.9W	Mono

** Rev 70 will be scheduled only if it is determined REAL TIME that film is available

ACCOMPLISHED

REV	START GET(H:M:S)	START LONG(DEG)	STOP GET(H:M:S)	STOP LONG(DEG)	MODE
3/4	84:42:23	179.1W	84:45:43	169.6E	Mono
	84:45:43	169.6E	84:54:14	142.5E	Stereo
15	105:52:58	144:4E	106:08:28	100.1E	Stereo
	106:08:28	100.1E	106:14:58	81.8E	Mono
	106:14:58	81.8E	106:17:57	74.0E	Stereo
16	108:15:27	75.9E	108:43:15	11.9W	Stereo
27	130:18:05	5.9E	130:19:16	1.1E	Stereo
33	141:46:11	67.5E	142:01:31	23.2E	Stereo
38	151:13:13	133.8E	151;37:01	65.4E	Stereo
	151:57;14	5.4E	151:59:05	0.1W	Stereo
50	175;34:38	4.9E	175:36:56	2.4W	Stereo
60	195:04;13	40.7E	195:14:30	12.0E	Stereo
	195;16:23	6.3E	Test cycle	5 frames	Mono
	195:18:23	0.1E	Test cycle	5 frames	Mono
61	197:16:23	0.2E	197:17;43	2.8W	Mono
	197;17:43	2.8W	197;18:23	4.3W	Stereo
63	200:33:29	121.1E	200:49:32	64.8E	Stereo
	200;49:32	64.8E	200:54:27	51.7E	Mono
	200:54:27	51.7E	200:59:22	38.0E	Stereo
72	218:52:55	9.2E	219:13;24	56.7W	Stereo
	219:13:24	56.7W	219:16:44	70.8W	Mono

FIG. 7-2

Apollo 15 Panoramic Photography

NASA — MSC — Coml., Houston, Texas

Apollo 15, ww 8/23/71
Mapping Camera

6.0 CAMERA CALIBRATION DATA

Calibration of the Apollo 15 SIM bay cameras was provided by the equipment manufacturers. Copies of the original calibration reports are presented in this section. Although portions of the data may be difficult to read, it seemed more appropriate to include the original reports than to have them retyped. No additional calibration was accomplished by NASA/MSC.

6.1 CALIBRATION DATA FOR THE MAPPING CAMERA SUBSYSTEM (MCS)

The stellar calibration report was prepared by Raytheon/Autometric under contract to Fairchild Space and Defense System. In addition to the camera calibrations the report includes calibrated values of the reseaus and the relative orientation angle between the connected lens cones. Fairchild data concerning relative illumination and resolving power of the cameras are included.

TR-71-3404-2R

FINAL

CAMERA CALIBRATION REPORT

CAMERA UNIT SN-003

JULY 1971

Prepared by

Autometric Operation
Equipment Division
Raytheon Company

4217 Wheeler Avenua
Alexandria, Virginia 22304

Prepared for

Fairchild Space and Defense Systems
300 Robbins Lane
Syosset, L.I., New York 11791

FOREWARD

This final stellar calibration report is submitted to NASA Manned Spacecraft Center, Houston, Texas, by Fairchild Space and Defense Systems (FSDS), A Division of Fairchild Camera and Instrument Corporation under NASA Contract No. NAS 9-10457. This report was prepared by Raytheon/Autometric, Alexandria, Virginia, under separate contract to FSDS. It supersedes the preliminary version which was previously submitted in May 1971.

This report summarizes the results of the stellar calibration of Mapping Camera Subsystem (MCS) Serial Number 003. The actual stellar field calibration was performed at the NASA White Sands Test Facility (WSTF), Las Cruces, New Mexico, during the period 25-26 March 1971. The resulting stellar imagery was subsequently reduced by Raytheon/Autometric and computer processed and outputted into the form presented herein. It should be emphasized that the calibration values shown for the individual terrain lens/stellar lens internal geometry parameters and relative orientation between connected lens cones are indicative of the capabilities of MCS 003, as derived by stellar methods. Also included in this report are the calibrated values of the terrain and stellar reseau coordinate intersections.

All calibration values presented herein should be utilized in the subsequent post-flight data reductions of MCS 003 terrain and stellar imagery.

A. D. Beccasio
Senior Staff Engineer

Approved by: A. G. Hutchins
A. G. Hutchins
MCS Program Manager

12 July 1971
Fairchild Space & Defense Systems
300 Robbins Lane
Syosset, New York 11791

CAMERA CALIBRATION RESULTS

Lunar Mapping Camera SN-003 Stellar Calibration

Terrain Lens (202) Constants of Internal Geometry

EFL = 76.054 mm.	S.D. = 0.002 mm.
CFL = 76.080 mm.	S.D. = 0.002 mm.

Principal Point With Respect to Indicated Principal Point
(Indicated principal point x_{ipp} = 0.0 mm., y_{ipp} = 0.0mm.),

x_p = -0.006 mm.	S.D. = 0.001 mm.
y_p = -0.002 mm.	S.D. = 0.001 mm.

Radial Distortion Parameters

$K_1 = -0.13361854 \times 10^{-5}$	S.D. = $0.39272852 \times 10^{-7}$
$K_2 = 0.52261757 \times 10^{-9}$	S.D. = $0.15933971 \times 10^{-10}$
$K_3 = -0.50728336 \times 10^{-13}$	S.D. = $0.19335059 \times 10^{-14}$

Lens Decentration Distortion Parameters

$J_1 = -0.54958195 \times 10^{-6}$	S.D. = $0.48922291 \times 10^{-6}$
$J_2 = -0.46089420 \times 10^{-10}$	S.D. = $0.11215963 \times 10^{-9}$
ϕ_0 = 2.9659070 radians	S.D. = 0.23946572

Stellar Lens (104) Constants of Internal Geometry

EFL = 75.713 mm. S.D. = 0.011 mm.
CFL = 75.735 mm. S.D. = 0.011 mm.

Principal Point With Respect to Indicated Principal Point
(Indicated principal point x_{ipp} = 0.0 mm., y_{ipp} = 0.0 mm.),

x_p = 0.042 mm. S.D. = 0.019 mm.

y_p = -0.003 mm. S.D. = 0.018 mm.

Radial Distortion Parameters

$K_1 = -0.92376425 \times 10^{-5}$ S.D. = $0.40956407 \times 10^{-5}$

$K_2 = 0.53810549 \times 10^{-7}$ S.D. = $0.33179901 \times 10^{-7}$

$K_3 = -0.70032005 \times 10^{-10}$ S.D. = $0.80049661 \times 10^{-10}$

Lens Decentration Distortion Parameters

$J_1 = 0.81424290 \times 10^{-6}$ S.D. = $0.10033483 \times 10^{-4}$

$J_2 = -0.20686782 \times 10^{-7}$ S.D. = $0.42974779 \times 10^{-7}$

ϕ_0 = 1.2355515 radians S.D. = 0.75665362

Results of Lock-Angle Calibration

Relative Orientation Matrix Defining a Transformation from the Terrain Camera to the Stellar Camera

0.999999850	-0.000517921	0.000180754
0.000125645	-0.104494099	-0.994525499
0.000533973	0.994525372	-0.104494018

Relative Orientation Angles (Degrees, Minutes, Seconds)

OMEGA	=	-95	59	52.859
PHI	=	0	1	50.140
KAPPA	=	- 0	0	25.916

Covariance Matrix

0.98562×10^{-11}	-0.33758×10^{-12}	0.88273×10^{-12}
-0.33758×10^{-12}	0.22323×10^{-10}	0.34486×10^{-12}
0.88273×10^{-12}	0.34486×10^{-12}	0.35148×10^{-9}

Standard Deviation of Orientation Angles (Arc-seconds)

S.D. OMEGA = 0.65
S.D. PHI = 0.98
S.D. KAPPA = 3.87

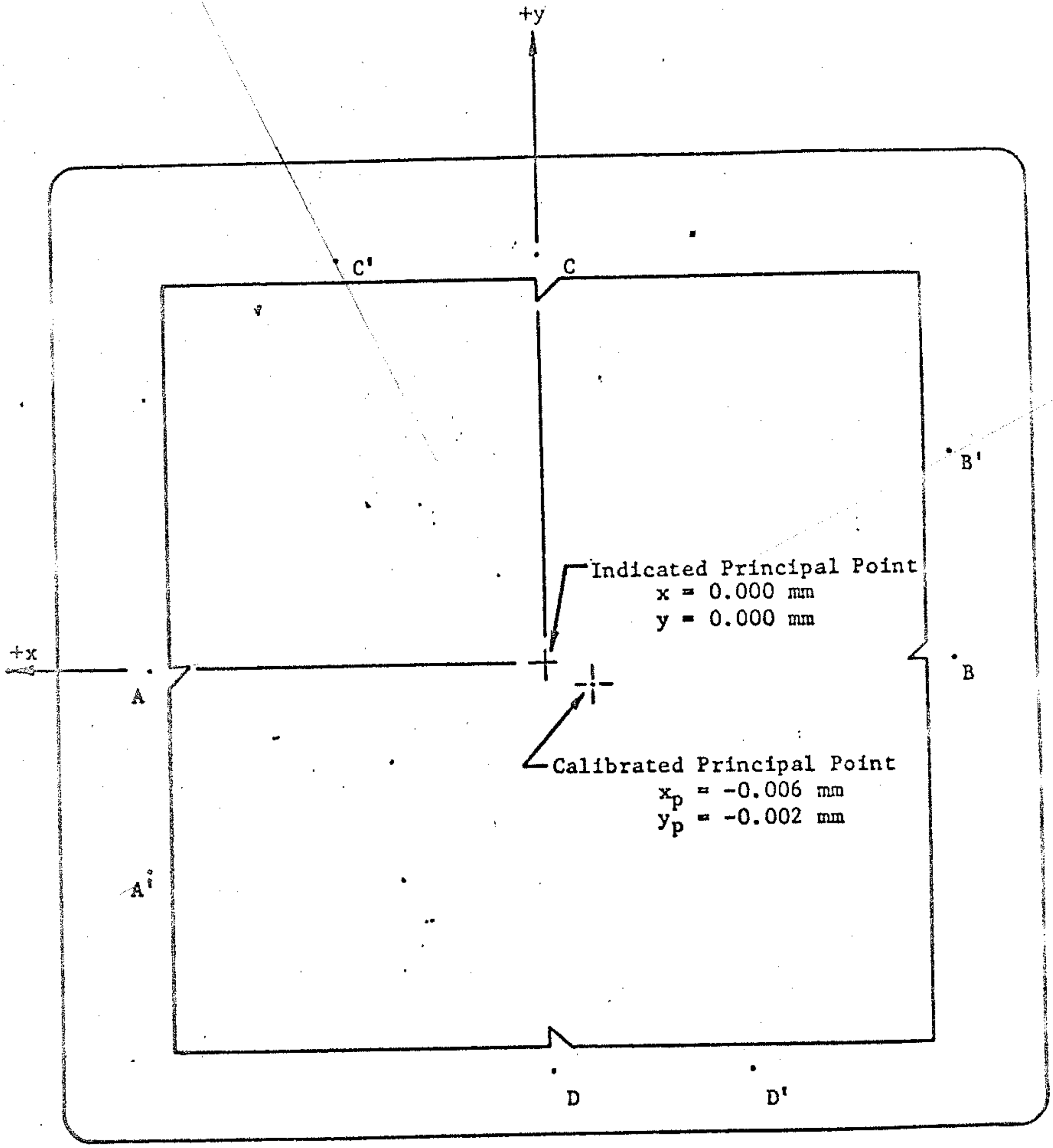
Statistical Data From Simultaneous Solution

Weighted Sum of Squares = 0.031920

Degrees of Freedom = 1996

Standard Deviation of Unit Weight = 0.004 mm.

PRINCIPAL POINT LOCATION FOR TERRAIN CAMERA, LENS NO. 202



(Emulsion Up)

Direction of Flight

Figure 1.

Master Fiducial Coordinate List for Terrain Camera

(Data provided by Fairchild Company)

Note: All coordinates in millimeters. Refer to Figure 1.

A_x = 60.236

A_y = 0.000

A'_x = 60.262

A'_y = -30.778

B_x = -60.324

B_y = 0.000

B'_x = -60.384

B'_y = 30.843

C_x = 0.003

C_y = 60.450

C'_x = 30.887

C'_y = 60.526

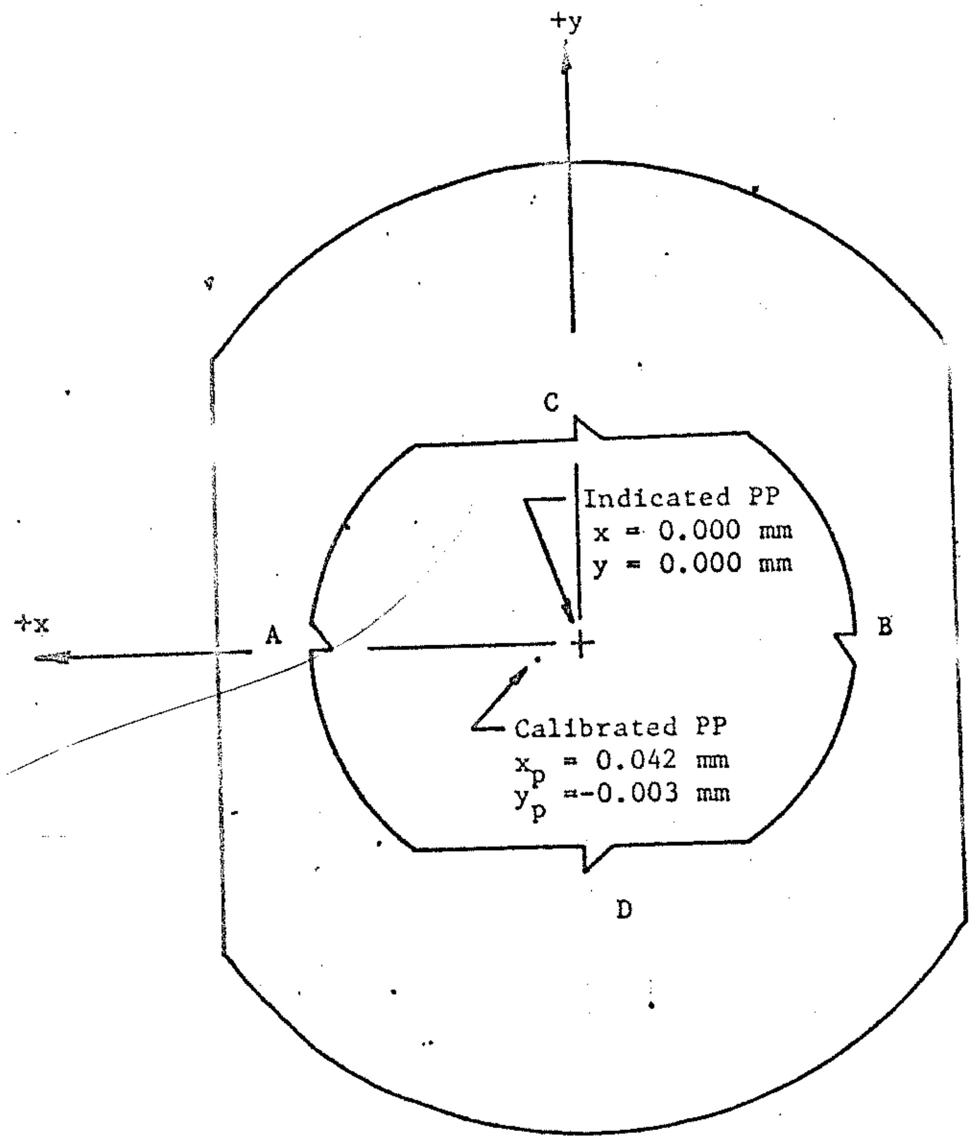
D_x = - 0.003

D_y = -60.305

D'_x = -30.781

D'_y = -60.311

PRINCIPAL POINT LOCATION FOR STELLAR CAMERA, LENS NO. 104



(Emulsion up)

Direction of Flight

Figure 2.

EXPLANATORY NOTES - Calibration of Unit SN-003'

1. General

All mensuration by Autometric utilized the original negative film stellar exposures.

2. Distortion Function

Radial distortion, Δr, is represented by an odd-power polynomial in r, the radial distance from the principal point.

$$\Delta r = K_1 r^3 + K_2 r^5 + K_3 r^7$$

The x and y components of r are

$$\Delta x_r = \frac{\Delta r}{r}(x') = (K_1 r^2 + K_2 r^4 + K_3 r^6)\ (x')$$

$$\Delta y_r = \frac{\Delta r}{r}(y') = (K_1 r^2 + K_2 r^4 + K_3 r^6)\ (y')$$

where x' and y' are measured image coordinates, relative to principal point origin.

Tangential distortion, Δt, is represented by an even-power polynomial in r.

$$\Delta t = J_1 r^2 + J_2 r^4$$

The x and y components of Δt are

$$\Delta x_t = -\Delta t \sin \phi_0 = -(J_1 r^2 + J_2 r^4) \sin \phi_0$$

$$\Delta y_t = \Delta t \cos \phi_0 = (J_1 r^2 + J_2 r^4) \cos \phi_0$$

where ϕ_0 is the angle the axis of maximum tangential distortion makes with the x axis.

x' and y' image coordinates can be corrected for radial and tangential lens distortion by the functions

$$x = (1 + K_1r^2 + K_2r^4 + K_3r^6)x' - (J_1r^2 + J_2r^4)\sin \phi_0$$

$$y = (1 + K_1r^2 + K_2r^4 + K_3r^6)y' + (J_1r^2 + J_2r^4)\cos \phi_0$$

where x and y are corrected image coordinates, and K_1, K_2, K_3, J_1, J_2, ϕ_0 are the distortion parameters given by the calibration.

Radial distortion curves for terrain camera lens 202 are presented in Figure 3. The figure gives the EFL radial distortion curve from the stellar calibration and compares the corresponding CFL curve with the Fairchild CFL curve, as determined by laboratory methods. Both CFL curves represent radial distortion characteristics under vacuum conditions, balanced for equal positive and negative distortion values.

Studies made by Fairchild indicate that a negligible change in distortion occurs when the camera is operated under vacuum conditions, rather than the atmospheric conditions under which the stellar calibration was performed. As a result of the supporting Fairchild data given below, no adjustment is made for the change in operating medium from 5000 feet altitude (610 mm. Hg.) to vacuum (0.0001 mm. Hg.).

Field Angle (Degrees)	Distortion Change (Micrometers)
11.25	-0.05
22.50	-0.14
33.75	-0.25
45.00	-1.10

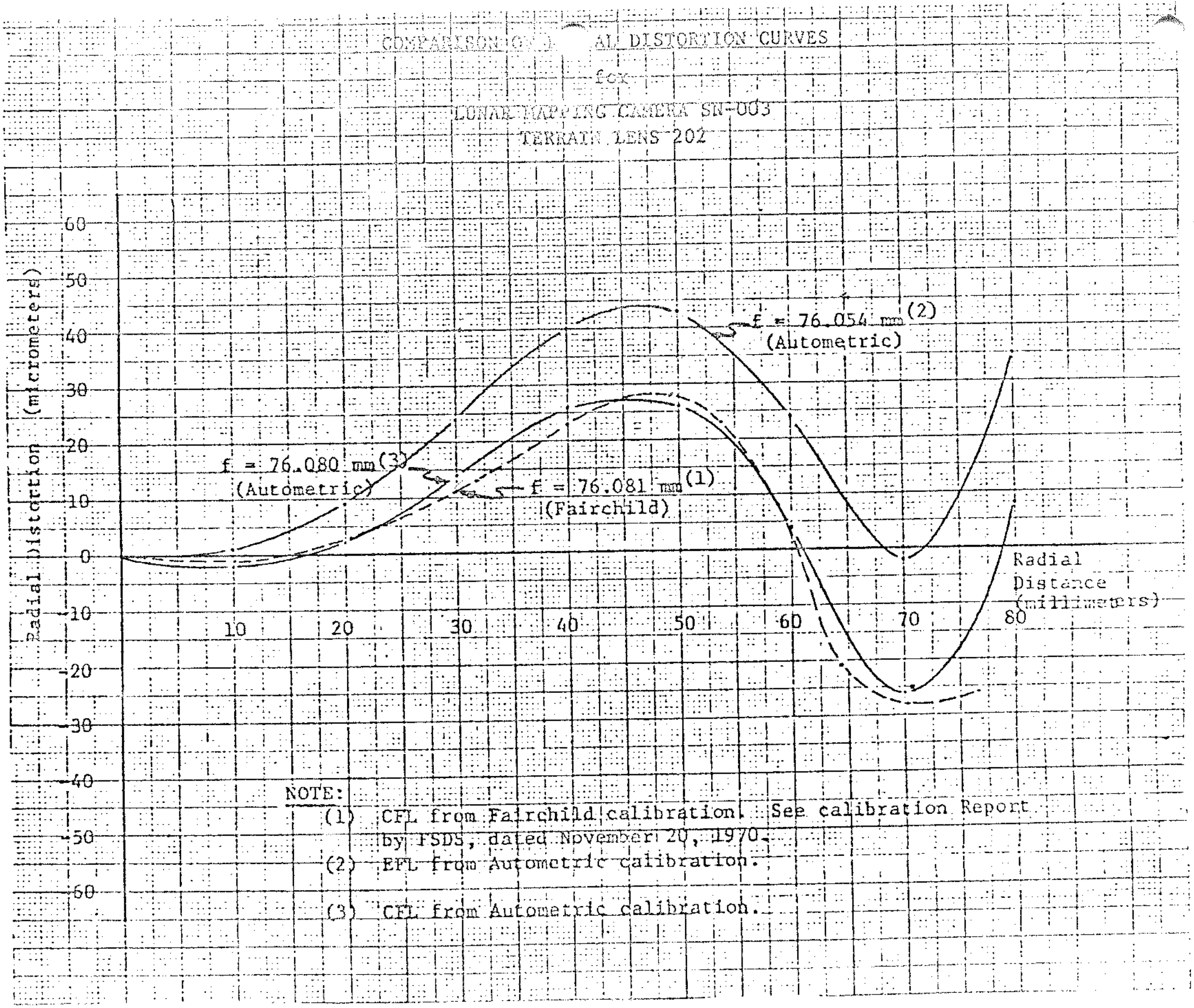

COMPARISON OF ... AL DISTORTION CURVES
for
LUNAR MAPPING CAMERA SN-003
TERRAIN LENS 202
Radial Distortion (micrometers)
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
10
20
30
40
50
60
70
80
Radial Distance (millimeters)
f = 76.054 mm (2) (Autometric)
f = 76.080 mm (3) (Autometric)
f = 76.081 mm (1) (Fairchild)
NOTE:
(1) CFL from Fairchild calibration. See calibration Report by FSDS, dated November 20, 1970.
(2) EFL from Autometric calibration.
(3) CFL from Autometric calibration.

Figure 3.

3. <u>Relative Orientation System:</u>

The relative orientation matrix

$$M = \begin{bmatrix} m_{1\,1} & m_{1\,2} & m_{1\,3} \\ m_{2\,1} & m_{2\,2} & m_{2\,3} \\ m_{3\,1} & m_{3\,2} & m_{3\,3} \end{bmatrix}$$

gives the angular orientation of the stellar camera coordinate system with respect to the terrain camera coordinate system. The orientation matrix can be factored into three orthogonal matrices each representing a simple rotation of the stellar camera coordinate system about a particular stellar axis. The sequence of the three rotations must be specified, because different angular orientations result from different sequences. The orientation of x_s, y_s, z_s with respect to X_T, Y_T, Z_T can be developed as follows.

Consider a stellar camera coordinate system x, y, z initially coincident with the terrain camera coordinate system X_T, Y_T, Z_T (refer to Figure 4). The three rotations ω, ϕ, κ are applied to the stellar camera coordinate axes in the given sequence to place the system into its final position, x_s, y_s, z_s.

ω (roll)	- Rotation about the x axis. Positive ω takes the +y axis toward the +z axis, resulting in x', y', z' in Figure 4.
ϕ (pitch)	- Rotation about the y' axis. Positive ϕ takes the +z' axis toward the +x' axis, resulting in x'', y'', z'' in Figure 4.
κ (yaw)	- Rotation about the z'' axis. Positive κ takes the +x'' axis toward the +y'' axis, resulting in the final position of the stellar camera coordinate system x_s, y_s, z_s in Figure 4.

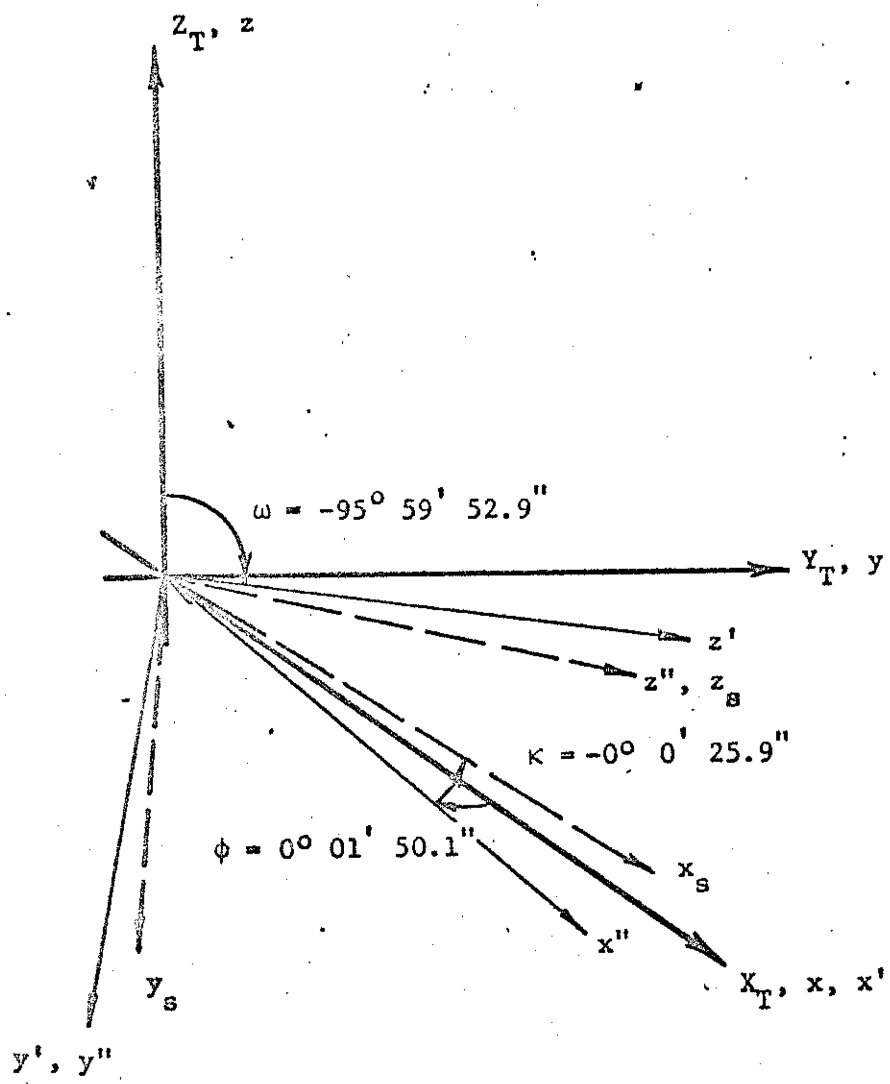


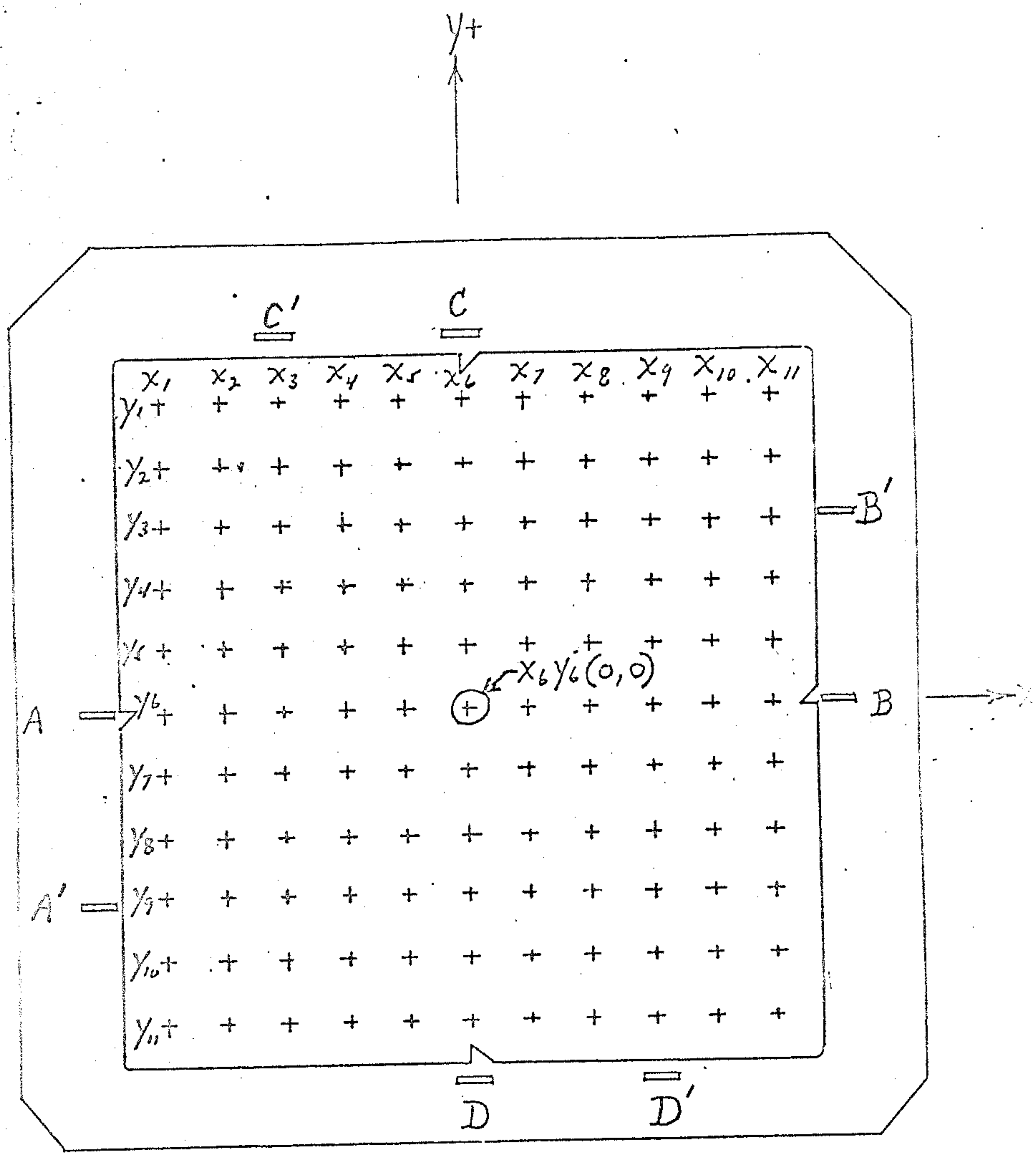
Figure 4. Orientation of Stellar Camera Coordinate System With Respect to Terrain Camera Coordinate System.

This Final Report was prepared for Fairchild Space and Defense Systems by Raytheon Company, Autometric Operation, under Contract N-0234.

Ronald K. Brewer
Senior Scientist/Photogrammetry
Program Manager

STELLAR CALIBRATION REPORT SUPPLEMENT

Calibrated Ikogon (Mapping)
and
Ikotar (Stellar)
Reseaù Coordinate Intersections



{EMULSION UP}

11 x 11
reseaux matrix

LINE OF FLIGHT

negative?

IKOGON B MASTER GRID PLATE
CALIBRATION DATA
(COORDINATES IN MILLIMETERS)

CROSS	COORDINATES		CROSS	COORDINATES	
	X-	Y-		X-	Y-
X1, Y1	-50.0014	+50.0019	X1, Y4	-50.0014	+20.0015
X2, Y1	-39.9997	+50.0019	X2, Y4	-39.9997	+20.0015
X3, Y1	-29.9977	+50.0019	X3, Y4	-29.9977	+20.0015
X4, Y1	-19.9974	+50.0019	X4, Y4	-19.9974	+20.0015
X5, Y1	- 9.9990	+50.0019	X5, Y4	- 9.9990	+20.0015
X6, Y1	0.0000	+50.0019	X6, Y4	0.0000	+20.0015
X7, Y1	+ 9.9992	+50.0019	X7, Y4	+ 9.9992	+20.0015
X8, Y1	+19.9995	+50.0019	X8, Y4	+19.9995	+20.0015
X9, Y1	+29.9994	+50.0019	X9, Y4	+29.9994	+20.0015
X10, Y1	+40.0019	+50.0019	X10, Y4	+40.0019	+20.0015
X11, Y1	+50.0029	+50.0019	X11, Y4	+50.0029	+20.0015
X1, Y2	-50.0014	+40.0022	X1, Y5	-50.0014	+10.0013
X2, Y2	-39.9997	+40.0022	X2, Y5	-39.9997	+10.0013
X3, Y2	-29.9977	+40.0022	X3, Y5	-29.9977	+10.0013
X4, Y2	-19.9974	+40.0022	X4, Y5	-19.9974	+10.0013
X5, Y2	- 9.9990	+40.0022	X5, Y5	- 9.9990	+10.0013
X6, Y2	0.0000	+40.0022	X6, Y5	0.0000	+10.0013
X7, Y2	+ 9.9992	+40.0022	X7, Y5	+ 9.9992	+10.0013
X8, Y2	+19.9995	+40.0022	X8, Y5	+19.9995	+10.0013
X9, Y2	+29.9994	+40.0022	X9, Y5	+29.9994	+10.0013
X10, Y2	+40.0019	+40.0022	X10, Y5	+40.0019	+10.0013
X11, Y2	+50.0029	+40.0022	X11, Y5	+50.0029	+10.0013
X1, Y3	-50.0014	+30.0030	X1, Y6	-50.0014	0.0000
X2, Y3	-39.9997	+30.0030	X2, Y6	-39.9997	0.0000
X3, Y3	-29.9977	+30.0030	X3, Y6	-29.9977	0.0000
X4, Y3	-19.9974	+30.0030	X4, Y6	-19.9974	0.0000
X5, Y3	- 9.9990	+30.0030	X5, Y6	- 9.9990	0.0000
X6, Y3	0.0000	+30.0030	X6, Y6	0.0000	0.0000
X7, Y3	+ 9.9992	+30.0030	X7, Y6	+ 9.9992	0.0000
X8, Y3	+19.9995	+30.0030	X8, Y6	+19.9995	0.0000
X9, Y3	+29.9994	+30.0030	X9, Y6	+29.9994	0.0000
X10, Y3	+40.0019	+30.0030	X10, Y6	+40.0019	0.0000
X11, Y3	+50.0029	+30.0030	X11, Y6	+50.0029	0.0000

IKOGON B MASTER GRID PLATE

CALIBRATION DATA -----(COORDINATES IN MILLIMETERS)

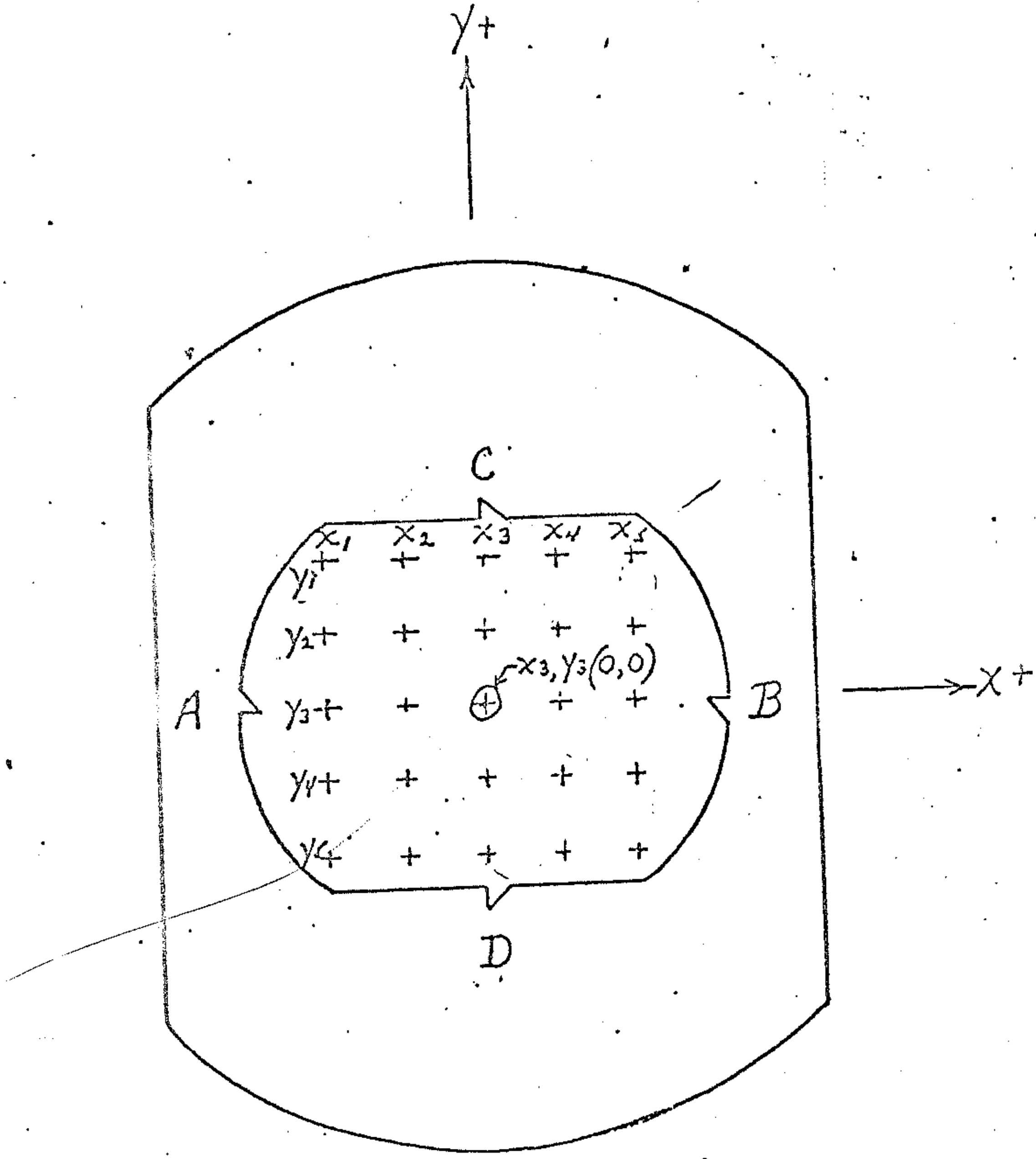
CROSS	COORDINATES X-	COORDINATES Y-
X1, Y7	-50.0014	-10.0000
X2, Y7	-39.9997	-10.0000
X3, Y7	-29.9977	-10.0000
X4, Y7	-19.9974	-10.0000
X5, Y7	- 9.9990	-10.0000
X6, Y7	0.0000	-10.0000
X7, Y7	+ 9.9992	-10.0000
X8, Y7	+19.9995	-10.0000
X9, Y7	+29.9994	-10.0000
X10, Y7	+40.0019	-10.0000
X11, Y7	+50.0029	-10.0000
X1, Y8	-50.0014	-19.9992
X2, Y8	-39.9997	-19.9992
X3, Y8	-29.9977	-19.9992
X4, Y8	-19.9974	-19.9992
X5, Y8	- 9.9990	-19.9992
X6, Y8	0.0000	-19.9992
X7, Y8	+ 9.9992	-19.9992
X8, Y8	+19.9995	-19.9992
X9, Y8	+29.9994	-19.9992
X10, Y8	+40.0019	-19.9992
X11, Y8	+50.0029	-19.9992
X1, Y9	-50.0014	-29.9987
X2, Y9	-39.9997	-29.9987
X3, Y9	-29.9977	-29.9987
X4, Y9	-19.9974	-29.9987
X5, Y9	- 9.9990	-29.9987
X6, Y9	0.0000	-29.9987
X7, Y9	+ 9.9992	-29.9987
X8, Y9	+19.9995	-29.9987
X9, Y9	+29.9994	-29.9987
X10, Y9	+40.0019	-29.9987
X11, Y9	+50.0029	-29.9987

CROSS	COORDINATES X-	COORDINATES Y-
X1, Y10	-50.0014	-39.9974
X2, Y10	-39.9997	-39.9974
X3, Y10	-29.9977	-39.9974
X4, Y10	-19.9974	-39.9974
X5, Y10	- 9.9990	-39.9974
X6, Y10	0.0000	-39.9974
X7, Y10	+ 9.9992	-39.9974
X8, Y10	+19.9995	-39.9974
X9, Y10	+29.9994	-39.9974
X10, Y10	+40.0019	-39.9974
X11, Y10	+50.0029	-39.9974
X1, Y11	-50.0014	-49.9969
X2, Y11	-39.9997	-49.9969
X3, Y11	-29.9977	-49.9969
X4, Y11	-19.9974	-49.9969
X5, Y11	- 9.9990	-49.9969
X6, Y11	0.0000	-49.9969
X7, Y11	+ 9.9992	-49.9969
X8, Y11	+19.9995	-49.9969
X9, Y11	+29.9994	-49.9969
X10, Y11	+40.0019	-49.99[illegible]
X11, Y11	+50.0029	-49.996[illegible]

CERTIFICATION

Signed ____

IKOTAR B GRID PLATE LAYOUT



{EMULSION UP}

LINE OF FLIGHT

IKOTAR B MASTER GRID PLATE
CALIBRATION DATA
(COORDINATES IN MILLIMETERS)

CROSS	COORDINATES X-	COORDINATES Y-	CROSS	COORDINATES X-	COORDINATES Y-
X1, Y1	-10.0015	+10.0003	X1, Y4	-10.0015	-5.0002
X2, Y1	-5.0004	+10.0005	X2, Y4	-5.0008	-5.0005
X3, Y1	-0.0003	+10.0000	X3, Y4	-0.0005	-5.0004
X4, Y1	+4.9996	+10.0000	X4, Y4	+4.9995	-5.0000
X5, Y1	+9.9996	+10.0000	X5, Y4	+9.9996	-5.0002
X1, Y2	-10.0015	+5.0011	X1, Y5	-10.0015	-10.0015
X2, Y2	-5.0004	+5.0001	X2, Y5	-5.0010	-10.0015
X3, Y2	0.0000	+5.0000	X3, Y5	-0.0005	-10.0015
X4, Y2	+4.9996	+5.0006	X4, Y5	+4.9992	-10.0015
X5, Y2	+9.9992	+5.0004	X5, Y5	+9.9992	-10.0015
X1, Y3	-10.0015	+0.0006			
X2, Y3	-5.0009	+0.0002			
X3, Y3	0.0000	+0.0000			
X4, Y3	+4.9993	+0.0006			
X5, Y3	+9.9992	+0.0004			

FAIRCHILD SPACE AND DEFENSE SYSTEMS
A Division of Fairchild Camera and Instrument Corporation
El Segundo, California

LENS TYPE IMOTAR "B"

DATE 6 Oct. 1970

SERIAL NUMBER 104

II. RESOLVING POWER

FILM 3400

PROCESSING MX641 1 min @ 69° DIAG. #1 AWAR 84.4

TARGET CONTRAST 1000:1 DIAG. #2 AWAR 84.6

DIAG. #1	0°	2½°	5°	7½°	10°							
RADIAL	90	90	89	84	85							
TANGENTIAL	90	95	89	79	75							

DIAG. #2	0°	2½°	5°	7½°	10°							
RADIAL	90	75	95	84	75							
TANGENTIAL	90	95	85	79	73							

Lens Type IKOGON "8"

Date 12 Oct 70

Serial Number 202

Relative Illumination

Axis	5°	10°	15°	20°	25°	30°	35°	40°	45°
99%	98%	100%	99%	98%	96%	91%	78%	66%	45%

Σ = 84.9%

Lens Transmittance = 43.9%

Lens T/# = $\frac{4.5}{\sqrt{.439}}$ = $\frac{4.5}{663}$ = 6.787

[illegible] = $\frac{6.737}{\sqrt{.849}}$ = $\frac{6.737}{.922}$

[illegible] = 7.36

Relative Aperture

$\frac{\text{EFL}}{\text{EFFECTIVE APERTURE}}$ = $\frac{2.[illegible]"}{.690"}$ = 4.35

[illegible]UTION

Date: Nov 20, 1970

3.1 [illegible] Resolving Power - Contrast 1000:1

[illegible] 3404

[illegible]	[illegible]	[illegible]	[illegible]	22.5°	27.5°	30°	32.5°	35°	37.5°	40°	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	124	105	126	134	134	129	106	55	61
	162	[illegible]	[illegible]	162	162	162	162	135	162	159	[illegible]	[illegible]

3.2 [illegible] = 135.5 L/MM

A DIVISION OF FAIRCHILD CAMERA & INSTRUMENT CORPORATION

EL SEGUNDO, CALIFORNIA

Lens Type IKOTAR "B"　　　　Date 6 Oct. 1970

Serial Number 104

Relative Illumination

10°	7½°	5°	2½°	Axis	2½°	5°	7½°	10°
90	96	99	100	100	100	97	94	88

Transmission

93%

Relative Aperture

f/2.75

6.2 CALIBRATION DATA FOR THE OPTICAL BAR PANORAMIC CAMERA

The ITEK calibration reports include relative illumination, spectral transmittance, veiling glare, calibrated focal length and system resolution.

TEST PROCEDURE

FOR

PROJECT 9446
RELATIVE ILLUMINATION
MEASUREMENTS
PANORAMIC CAMERA
FOR SCIENTIFIC INSTRUMENT
MODULE

EXPERIMENT S-163

Itek

ITEK CORPORATION

Lexington 73, Massachusetts

Date 9-15-70

Lens S/N N-54

	PREPARED	PROJECT APPROVAL	QUALITY ASSURANCE APPROVAL
By	R. SHERLOCK	C. BACKE	R. WESPISER
Signed	R Sherlock	C. Backe	R Wespiser QA 6
Date	9/17/70	9/21/70	9/18/70

CUST./GOV'T. REP. ______________ Date ______________
Reviewed

Q199-1 11/65

5.3.1.3 Itek Test Data Sheet

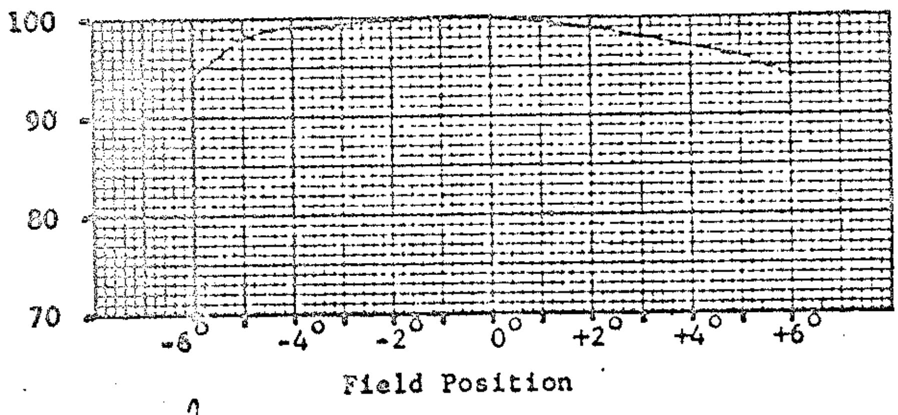
RELATIVE ILLUMINATION MEASUREMENT

Panoramic Camera Lens, P/N 105150, Serial No. N-54

	Field Position	Radiometer Readings vdc	Relative Illumination %
B	-6°	76.0	93.8
	-5°	79.5	98.1
	-4°	80.0	98.8
	-3°	80.5	99.4
	-2°	80.8	99.8
	-1°	81.0	100.0
A	0°	81.0	100.0
B	$+1^{\circ}$	80.5	99.4
	$+2^{\circ}$	80.0	98.8
	$+3^{\circ}$	79.5	98.1
	$+4^{\circ}$	78.5	96.9
	$+5^{\circ}$	77.5	95.7
	$+6^{\circ}$	76.0	93.8

Meter Scale for Radiometer Readings: 100

% Relative Illumination $= \frac{B}{A} \times 100$



Data Recorded By: [illegible] Date: 10/12/70

QA Monitor: [illegible] 10.15.70

Project Approval: [illegible] 10-19-70

Test Procedure No. TP125 Page 8

Test Procedure No. TP123 No. of Pages 9

TEST PROCEDURE

FOR

PROJECT 9446
SPECTRAL TRANSMITTANCE
MEASUREMENTS
PANORAMIC CAMERA
FOR SCIENTIFIC INSTRUMENT
MODULE

EXPERIMENT S-163

Itek

ITEK CORPORATION

Lexington 73, Massachusetts

Date 9-15-70

Lens S/N N-54

	PREPARED	PROJECT APPROVAL	QUALITY ASSURANCE APPROVAL
By	R. SHERLOCK	C. BACKE	R. WESPISER
Signed	[signature]	C. Backe	[signature]
Date	9/17/70	9/21/70	9/17/70

CUST./GOV'T. REP. ____________ Date ________
Reviewed

Q199-1 11/65

6.3.1.3 Itek Test Data Sheet

SPECTRAL TRANSMITTANCE MEASUREMENT

Panoramic Camera Lens, P/N 105150, Serial No. N-54

Wavelength nm	Radiometer Readings A	A_1	B	B_1	% Transmittance
400	9.2	2.65	2.0	.13	22.6
420	25.8	6.6	5.4	.55	39.8
440	46.0	12.2	9.5	1.3	51.6
480	100.0	27.0	21.0	3.8	67.0
520	144.9	41.0	32.5	6.6	71.8
560	160.0	44.5	36.0	7.4	73.9
601	145.0	39.5	33.0	6.2	69.0
640	125.0	33.0	21.5	4.8	63.8
680	106.0	25.7	19.0	3.3	56.7
720	80.0	18.0	13.0	2.0	49.4

Legend:

A = Brightness of the calibrated standard Lambertian source using the radiometer telescope.

A_1 = Brightness of the collimator target as seen from the lens test position using the radiometer telescope.

B = Brightness of the calibrated standard Lambertian source using the radiometer microscope.

B_1 = Brightness of the collimator target aerial image at the image plane (lens in place) using the radiometer microscope.

% Transmittance = $\left[(B_1/B) \div (A_1/A)\right] \times 100.$

Data Recorded By: [illegible] Date: 10/12-70

QA Monitor: [illegible] 10-15-70

Project Approval: [illegible] 10-18-70

Test Procedure No. TP123

Q199-5 11/65

ITEK CORPORATION
Lexington 73, Massachusetts

6.3.1.3 Itek Test Data Sheet

T STOP CALCULATION

Panoramic Camera Lens, P/N 105150, Serial No. N-54

Wavelength nm	% Transmittance	T STOP
400	22.6	7.4
420	39.8	5.5
440	51.6	4.9
480	67.0	4.3
520	71.8	4.1
560	73.9	4.1
601	69.0	4.2
640	63.8	4.4
680	56.7	4.6
720	49.4	5.0

Legend:

$$T\ STOP = \frac{f/number}{\sqrt{t}}$$ where f/number is 3.5 and t is transmittance.

Data Recorded By: [signature] Date: Oct 12 1970

QA Monitor: R.C. [signature] 10-15-70

Project Approval: [signature] 10-19-70

Test Procedure No. TP123

Test Procedure No. TP121 No. of Pages 8

TEST PROCEDURE

FOR

PROJECT 9446
VEILING GLARE MEASUREMENTS
PANORAMIC CAMERA
FOR SCIENTIFIC INSTRUMENT
MODULE

EXPERIMENT S-163

Itek

ITEK CORPORATION

Lexington 73, Massachusetts

Date 9-15-70

Lens S/N N-54

	PREPARED	PROJECT APPROVAL	QUALITY ASSURANCE APPROVAL
By	R. SHERLOCK	C. BACKE	R. WESPISER
Signed	[signature]	C. Backe	R. Wespiser
Date	9/17/70	9/21/70	9/18/70

CUST./GOV'T. REP. ____________ Date ____________
Reviewed

6.3.1.3 Itek Test Data Sheet

VEILING GLARE MEASUREMENT

Panoramic Camera Lens, P/N 105150, Serial No. N-54

Field Position	Step Wedge 1	2	3	4	5	6	7	Black Dot	% Veiling Glare
Step No.	1	2	3	4	5	6	7	X	
* Calibrated Value	1.22	1.07	.92	.78	.65	.50	.36	X	
*Measured Test Values									
-6°	.24	.34	.51	.80	1.14	1.44	1.77	.55	12.6
-4°	.22	.30	.43	.65	.94	1.26	1.62	.44	12.3
-2°	.60	.93	1.30	1.62	1.88	2.04	2.24	1.34	12.7
0°	.24	.32	.50	.80	1.13	1.44	1.74	.54	13.2
+2°	.26	.36	.55	.84	1.11	1.40	1.77	.82	16.2
+4°	.25	.37	.56	.86	1.14	1.45	1.83	.84	16.2
+6°	.22	.30	.46	.71	1.05	1.36	1.70	.64	15.1

Legend: * Density values are logarithmic as read on the Macbeth Densitometer.

% Veiling Glare is computed from the black spot density plot (attached) for each field position.

Data Recorded By: [illegible] Date: 10/12/70

QA Monitor: [illegible] 10/16/70

Project Approval: [illegible] 10/19/70

Test Procedure No. TP127 No. of Pages 5

TEST PROCEDURE

FOR

PROJECT 9446

C.F.L./MEASUREMENTS
PANORAMIC CAMERA

FOR SCIENTIFIC INSTRUMENT
MODULE

EXPERIMENT S-163

Itek

ITEK CORPORATION

Lexington 73, Massachusetts

Date 9-15-70

	PREPARED	PROJECT APPROVAL	QUALITY ASSURANCE APPROVAL
By	R. SHERLOCK	C. BACKE	R. WESPISER
Signed	[signature]	C. Backe	[signature]
Date	9/17/70	9/21/70	9/21/70

CUST./GOV'T. REP. ______________ Date ____________
Reviewed

Q199-1 11/65

3

6.3.1.3 Test Data Summary

Lens - N-54

C.F.L. Calibration Summary

Filter	Field Position (degrees)	Mean C.F.L. (inches)	STD Deviation of of mean (C.F.L.)
23A	+6	24.0057	0.0004
	+4	24.0058	0.0003
	+2	24.0015	0.0006
	0 *	24.0052	0.0008
	-2	24.0073	0.0006
	-4	24.0057	0.0001
	-6	24.0C50	0.0003
12	+6	24.0063	0.0008
	+4	24.0080	0.0003
	+2	24.0086	0.0009
	0 *	24.0081	0.0004
	-2	24.0088	0.0006
	-4	24.0089	0.0004
	-6	24.0080	0.0001
8	+6	24.0076	0.0004
	+4	24.0096	0.0007
	+2	24.0106	0.0005
	0 *	24.0080	0.0007
	-2	24.0059	0.0003
	-4	24.0081	0.0015
	-6	24.0064	0.0009
2A	+6	24.0044	0.0003
	+4	24.0075	0.0006
	+2	24.0085	0.0008
	0 *	24.0062	0.0007
	-2	24.0047	0.0013
	-4	24.0055	0.0006
	-6	24.0066	0.0005
no filter	+6	24.0037	0.0003
	+4	24.0050	0.0004
	+2	24.0065	0.0006
	0 *	24.0045	0.0005
	-2	24.0032	0.0004
	-4	24.0048	0.0008
	-6	24.0037	0.0006

* Average of all field positions

Quality Assurance Review ________________ QA 32

Test Procedure No. TP-70-9446-42-4 ⊖ No. of Pages 47

3/N003 1-27-71

ITEK APPROVED

TEST PROCEDURE

FOR

PHOTOGRAPHIC BASELINE (PBL)
(DYNAMIC TESTING WITH FORWARD MOTION COMPENSATION)
ACCEPTANCE OF THE PANORAMIC CAMERA
EXPERIMENT S-163

Loss 23A Filter

Itek

ITEK CORPORATION
Lexington 73, Massachusetts

Date 9/3/70

	PREPARED	PROJECT APPROVAL	QUALITY ASSURANCE APPROVAL
By	A D Aure	[illegible]	W ZEBLEY
Signed	[signature]	[signature]	W. Zebley
Date	7/24/70	7-24-70	7/24/70

CUST./GOV'T. REP. ________________ Date ____________
Reviewed

Q199-1 11/65

NO FILTER
FLIGHT CONFIG.

79

DYNAMIC TESTING WITH FMC w/o Filter

DATA SHEET

FORMAT POSITION 0° ∞ RUN 961-A

FRAME NO.	FP0 (.466) Collimator 3 Resolution III / ≡	Avg.	FP1 (.474) Collimator 3 Resolution III / ≡	Avg.	FP2 (.482) Collimator 3 Resolution III / ≡	Avg.
1	114 / 113	114	108 / 128	118	102 / 119	102
2	136 / 100	121	128 / 171	150	128 / 152	140
3	144 / 161	153	144 / 128	136	121 / 150	137
4	152 / 144	148	144 / 181	163	119 / 128	121
5	123 / 144	136	152 / 161	157	171 / 171	171
6	136 / 121	129	121 / 121	121	128 / 136	132
7	181 / 161	171	152 / 136	144	108 / 136	121
8	144 / 121	133	161 / 171	166	108 / 152	130
9	114 / 128	121	181 / 171	176	161 / 136	149
10	144 / 136	140	161 / 181	171	108 / 136	121
AVERAGES		137		150		133

FRAME NO.	FP3 (.490) Collimator 3 Resolution III / ≡	Avg.	FP4 (.498) Collimator 3 Resolution III / ≡	Avg.	FP5 (.506) Collimator 3 Resolution III / ≡	Avg.
1	136 / 171	154	144 / 128	136	152 / 152	152
2	152 / 136	144	121 / 152	137	91 / 136	114
3	161 / 152	157	152 / 144	148	108 / 171	140
4	152 / 171	162	128 / 152	140	114 / 121	118
5	152 / 192	172	128 / 171	150	108 / 161	135
6	136 / 161	149	128 / 152	140	114 / 132	123
7	152 / 161	157	144 / 161	153	114 / 121	118
8	152 / 192	172	136 / 144	140	108 / 121	115
9	144 / 161	153	144 / 171	158	144 / 128	136
10	136 / 152	144	181 / 152	167	108 / 114	111
AVERAGES		156		147		125

FRAME NO.	FP6 (.514) Collimator 3 Resolution III / ≡	Avg.	FP7 (.522) Collimator 3 Resolution III / ≡	Avg.	FP8 (.530) Collimator 3 Resolution III / ≡	Avg.
1	72 / 76	74	81 / 64	73	51 / 76	64
2	54 / 81	68	72 / 76	74	57 / 96	77
3	76 / 91	83	68 / 76	72	64 / 68	66
4	76 / 76	76	68 / 72	70	54 / 72	63
5	76 / 108	92	60 / 64	62	48 / 76	62
6	60 / 81	71	72 / 81	79	64 / 81	73
7	81 / 76	79	68 / 60	64	60 / 68	64
8	91 / 114	102	51 / 64	58	54 / 76	65
9	65 / 108	87	76 / 91	83	51 / 68	60
10	76 / 108	92	81 / 102	92	54 / 60	57
AVERAGES		84		73		65

[illegible]

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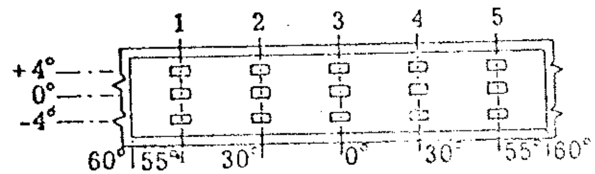
Collimator positions



Nadir Format

DYNAMIC TESTING WITH FMC w/o Ferr...

RUN 95/6.

DATA SHEET

∞

FORMAT POSITION – 4°

FRAME NO.	FP0 (.466) Collimator 3 Resolution III / ≡	FP0 Avg.	FP1 (.474) Collimator 3 Resolution III / ≡	FP1 Avg.	FP2 (.482) Collimator 3 Resolution III / ≡	FP2 Avg.
1	108/119	111	152/149	148	120/152	136
2	128/128	128	121/136	129	152/152	152
3	136/128	132	76/102	89	181/152	167
4	108/96	102	152/152	152	114/152	133
5	108/102	105	144/128	136	136/144	140
6	161/136	149	136/102	119	114/144	129
7	108/156	130	144/152	148	114/152	133
8	121/136	129	152/121	137	144/[illegible]	136
9	121/108	11.5	128/128	128	144/161	153
10	114/102	108	144/128	136	121/152	137
AVERAGES		121		132		142

FRAME NO.	FP3 (.490) Collimator 3 Resolution III / ≡	FP3 Avg.	FP4 (.498) Collimator 3 Resolution III / ≡	FP4 Avg.	FP5 (.506) Collimator 3 Resolution III / ≡	FP5 Avg.
1	144/152	148	144/144	144	108/144	126
2	144/161	153	121/152	137	108/121	115
3	136/152	144	144/121	133	96/128	112
4	136/152	144	128/128	128	121/121	125
5	161/136	149	152/161	157	121/128	125
6	152/171	162	114/144	129	121/136	129
7	152/161	157	144/136	140	114/128	121
8	152/161	157	161/181	171	108/152	130
9	114/161	138	102/152	127	114/108	111
10	128/152	140	121/144	133	108/128	118
AVERAGES		149		140		121

FRAME NO.	FP6 (.514) Collimator 3 Resolution III / ≡	FP6 Avg.	FP7 (.522) Collimator 3 Resolution III / ≡	FP7 Avg.	FP8 (.530) Collimator 3 Resolution III / ≡	FP8 Avg.
1	108/102	105	64/76	70	64/72	68
2	81/108	95	54/64	59	60/64	62
3	64/76	70	54/76	65	64/57	61
4	68/102	85	54/76	65	45/60	53
5	96/102	99	54/81	68	48/57	53
6	102/76	89	64/60	62	60/57	52
7	76/76	76	54/68	61	64/76	70
8	76/68	72	72/72	72	60/51	56
9	91/81	86	54/76	65	64/60	62
10	96/91	94	54/81	68	68/72	70
AVERAGES		87		66		61

[signature]

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DYNAMIC TESTING WITH FMC w/o filter

RUN 251 J

DATA SHEET

Focus position +4°

FRAME NO.	F3 (466) COLLIMATOR 3 Resolution III / ☰		Avg.	F4 (474) COLLIMATOR 3 Resolution III / ☰		Avg.	F5 (482) COLLIMATOR 3 Resolution III / ☰		Avg.	F5 (490) COLLIMATOR 3 Resolution III / ☰		Avg.	F6 (498) COLLIMATOR 3 Resolution III / ☰		Avg.	F6 (506) COLLIMATOR 3 Resolution III / ☰		Avg.	F7 (514) COLLIMATOR 3 Resolution III / ☰		Avg.	F7 (522) COLLIMATOR 3 Resolution III / ☰		Avg.	F8 (530) COLLIMATOR 3 Resolution III / ☰		Avg.
1	128	128	128	121	152	134	128	152	140	171	136	152	108	171	140												
2	121	108	115	161	152	157	152	108	128	121	152	137	114	152	133												
3	144	152	149	144	138	140	102	128	115	161	152	157	121	171	146												
4	144	114	129	144	144	144	128	144	136	144	144	144	92	152	123												
5	144	114	129	161	136	149	152	144	148	121	152	136	91	152	122												
6	121	136	129	152	144	148	161	171	166	144	152	149	114	152	133												
7	128	144	136	121	144	133	121	152	136	144	144	144	114	152	133												
8	136	108	121	144	171	158	102	136	119	114	151	133	102	141	122												
9	161	152	157	128	138	128	161	136	149	152	181	167	144	151	149												
10	128	152	140	152	152	152	152	152	152	121	161	141	128	152	140												
AVERAGES			133			145			142			149			135			*			*			*			*

See Dev #3

R J Lapobrancis CA V13

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Out of film – yet they plotted 6 points using +4°, 0°, −4°

93

REQUEST NUMBER: RK1289

A C K N O W L E D G E M E N T S

When using the data in any reports, publications, or presentations, please acknowledge the National Space Science Data Center and the following individuals or groups:

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