APOLLO SIM BAY PHOTOGRAPHIC

EQUIPMENT AND MISSION SUMMARY

APOLLO 17 SUPPLEMENT

PREPARED BY
MAPPING SCIENCES BRANCH
National Aeronautics and Space Administration
LYNDON B. JOHNSON SPACE CENTER
Houston, Texas

June 1973

S U M M A R Y

The final Apollo mission, Apollo 17 was launched from the Kennedy Space Center at 12:33:00 a.m. E.S.T., December 7, 1972. The launch was delayed for 2 hours and 40 minutes because of a failure in the launch vehicle ground support equipment. Translunar coast was shortened by this same amount of time and the spacecraft arrived at translunar injection at the preflight mission plan time. The mission timer was reset and the mission events coincided with the flight plan times.

The purpose of this Supplement is to present a summary of the SIM Bay Photographic experiments and premission calibrations for the Apollo 17 mission. All three experiments, the mapping camera, the laser altimeter and the panoramic cameras operated satisfactorily. With minor exceptions all planned photography was accomplished along with ten additional hours of laser altimeter accomplished during a sleep period late in the mission.

4.0 OPTICAL BAR PANORAMIC CAMERA (PC)

Pan camera operation was satisfactory and all photography was accomplished as planned with one minor exception. Approximately 8 minutes before termination of the final pass on revolution 74, the stereo drive motor failed resulting in the loss of stereophotography and a slight degradation of the resultant monographic coverage.

Early in the mission the velocity/altitude sensor telemetry indicated signs of erratic operation. To forestall possible degradation of the photography the sensor was switched to the manual mode except for resolution 15 and 28. This mode of operation should have no effect on the photography. The manual mode selected was for a 60-nautical mile orbit with a V/H of 13.67 milliradians per second.

The CTE time for the center of each exposure was read and is tabulated in Table 4.1. As with the MCS the CTE time can be related to UTC (USNO) using Table 6.1 or to Flight Plan time (GET) by adding 2 hours 40 minutes.

The panoramic photography will be transformed (rectified) by the Defense Mapping Agency Topographic Center (DMATC) using the Apollo transforming printer set up with the orbital support data. One set of rectified first generation master negatives will be generated from second generation positives provided by the Johnson Space Center (JSC). The required sets of products for the users will then be made at JSC and will be referred to as rectified second generation negatives/positives. Definitions of the products are as follows:

1. <u>Second Generation Master Positive</u> - The film produced by JSC directly from the flight film.

2. <u>Rectified First Generation Master Negative</u> - The rectified negative made by DMATC in the transforming printer from the second generation positive.

3. <u>Rectified Second Generation Negative/Positive</u> - Film produced by JSC from the rectified first generation master negative.

5.0 APOLLO ORBITAL SUPPORT DATA (PHOTOGRAPHIC EPHEMERIS)

The Apollo Photographic Evaluation (APE) orbital support data output is a listing of single page tabulations of computed spacecraft state vector, camera orientation, photograph position and lighting data. Each page, corresponding in number to the mapping camera frame number, presents the computation results for the exposure times as read from the data block. The times listed in the panoramic camera support data represent the center of scan time.

The mapping camera support data also includes a star pattern near the beginning and ending of each sequence. The page number listed corresponds to the mapping camera frame, not the stellar frame number (see 2.0 Mapping Camera Subsystem for correlation of mapping camera and stellar frame numbers).

The right ascension (RA) and declination (δ) are defined in radians on the star pattern pages. In addition the RA and δ of the stellar camera principal point are tabulated for each page of support data in hours and degrees respectfully. Note that the RA is a negative value and must be subtracted from 360° (when the given radian value is converted to degrees) or from 24 hours (when given in hours).

Where downlink gimbal data for spacecraft attitude were missing only the time and state vectors were computed. For these entries the state vector is expressed in Earth Radii (er) for X, Y, and Z for both the 1950.0 and the selenographic. To convert to the APE units, i.e., kilometers, multiply by 6378.16. The selenographic $\dot{x}$, $\dot{y}$ and $\dot{z}$ are expressed in Km/sec, the same as the other support data; however, the

1950.0 values are in er/min. To convert to Km/sec multiply by 106.3026667.

A page of the pan camera data is shown in Figure 5.1. Figure 5.2 is a page where downlink gimbal data were missing. Likewise, Figures 5.3 and 5.4 are similar pages of the mapping camera support data. Figure is an example of the stellar camera star field. A definition of the line entries for the orbital support data can be found in Table 5.1.

The orbital support data output is recorded on 16mm microfilm. It can be made available through either the Goddard Space Flight Center (GSFC), NSSDC Code 601, Greenbelt, Maryland 20771, or TF51/Chief, Mapping Sciences Branch, NASA Lyndon B. Johnson Space Center, Houston, Texas 77058.

NOTE: Several discrepancies were discovered in the orbital support data after the data were microfilmed. Incorrect support data are as listed below.

1. Panoramic Camera

a. Rev 15, frames 2355-2364. The fore-aft attitudes of these frames at the end of Rev 15 were inadvertently reversed, thus all data referenced to the principal point and camera attitude are invalid.

2. Rev 74, frames 3080-3151. This is the area where the stereo drive motor failed as mentioned in section 4.0. The data block continued to indicate the camera was oscillating fore and aft; however, it was actually in one position. The position in which the camera froze

was not determined. As with the Rev 15 problem all data referenced to the principal point and camera attitude are invalid during this series of photographs.

EXPLANATION OF DATA

GMT - Sidereal time of film exposure (year, month, day, hour, minute, second) - (UT1 - USNO).

CTE - Central clock time of film exposure which is recorded on the film (hour, minute, second).

1950 state vector - Mean of 1950 moon centered, inertial, cartesian coordinates of the spacecraft position (km) and velocity (km/sec).

Selenographic state vector - Selenographic, instantaneous inertial cartesian coordinates of vehicle position (km) and velocity (km/sec).

Nadir Point (Longitude, Latitude) - Intersection with the mean lunar surface, of the vector from the moon's center of mass to be spacecraft.

Camera Axis Intersect (Longitude, Latitude) - Position of principal intersection point - Intersection of camera optical axis direction with mean lunar surface.

Spacecraft radius - Vector from moon center of mass to spacecraft.

Spacecraft altitude - Height of spacecraft above mean lunar surface.

Scale Factor - Proportionality constant relating dimensions on the film to dimensions on the mean lunar surface.

Azimuth of Velocity Vector - Angle, measured positive clockwise in the local horizontal plane at nadir, between North and the projection of the vehicle velocity vector onto the local horizontal plane.

Mean altitude rate - Rate of change in spacecraft altitude above the mean lunar surface.

Horizontal velocity - Component of spacecraft velocity parallel to the lunar local horizontal plane at the nadir point.

Tilt azimuth - Angle, measured positive clockwise in the local horizontal plane at the principal intersection point, between North and the projection of a vector along the camera optical axis onto that local horizontal plane.

Table 5.1. Definition of Orbital Support Data Terms.

Tilt - Angle between the camera optical axis direction and the lunar local vertical at the principal intersection point.

Sun Elevation at Prin Grnd Pnt - Angle between the vector from the sun to the pricipal intersection point and the lunar local horizontal plane at that point.

Sun Azimuth at Principal Grnd Pnt - Angle, measured positive clockwise in the lunar local horizontal plane, from North to the projection of the vector from the sun to the principal intersection point onto that plane.

Subsolar Point (Longitude, Latitude) - Intersection with the mean lunar surface, of a vector from the moon's center of mass to the sun's center.

Alpha - Angle between the camera optical axis and the projection of the lunar local vertical at the principal intersection point onto the plane of the phase angle (measure of surface tilt toward or away from the sun).

Swing - Angle between the camera Y axis and the projection of the line between the vehicle nadir and principal intersection point onto the camera X-Y plane.

Emission Angle - Angle between the camera optical axis and the lunar local vertical at the principal intersection point.

Phase Angle - Angle between the camera optical axis and the vector from the sun to the principal intersection point.

North Deviation Angle - Angle, measured positive clockwise in the camera X-Y plane, from the camera X axis to lunar North.

Phi, Kappa, Omega - Angles which rotate the camera axes coordinate system into the nadir point centered lunar local horizontal system, where:

- primary right-handed rotation about the camera Y-axis.
- secondary right-handed rotation about the intermediate X-axis.
- final right-handed rotation about the local vertical (local horizontal Z-axis).

X-tilt - (Lateral tilt) Angle from the local horizontal plane at the nadir point to the camera Y-axis.

Y-tilt - (Longitudinal tilt) Angle from the local horizontal plane at the nadir point to the camera X-axis.

Heading - Angle, measured positive clockwise in the lunar local horizontal plane at the nadir point, from North to the projection of the camera X-axis onto that plane.

Laser slant range - Telemetered laser altimeter readout.

Spacecraft altitude (Laser) - Vertical component of laser altimeter slant range based on the assumption that the laser altimeter was aligned along the 3-inch mapping camera optical axis.

Selenographic direction Cosines - Direction definition of vector from the spacecraft to the principal intersection point in the instantaneous inertial selenographic coordinate system.

Coordinate Transformation Matrices - Selenocentric coordinate system to camera axes coordinate system and local horizontal coordinate system to the camera axes coordinate system.

Photograph Footprint - Latitudes and Longitudes of field of view corner point projections onto the lunar surface (full field of view only for mapping camera, full field of view and inner field of view for panoramic camera).

Sigmas - First order uncertainties in selected camera aiming parameters arising from uncertainties in camera mounting angles, vehicle attitude measurements and film exposure times.

NOTE: In the event telemetered vehicle attitude data are not available for the APE computations the printout for those frames affected will contain only the following entries.

Page Number - number which corresponds to the mapping camer frame number.

GMT - Siderial time of film exposure (year, month, day, hour, minute, second) - UTC (USNO).

CTE - Central clock time of film exposure which is recorded on the film (hour, minute, second).

1950 state vector - Mean of 1950 moon centered, inertial, cortesian coordinates of spacecraft position (earth radii-er) and velocity (er/min).

Selenographic state vector - Selenographic, instantaneous inertial cortesian coordinates of spacecraft position (er) and velocity (er/min).

NOTE: 6378,16 Km/er should be used for conversion of these state vectors to the standard APE units of Km and Km/sec.

APOLLO 17 REV 2 PAN 4/73F PAGE - F 1590

	YEAR	MONTH	DAY	HOUR	MINUTE	SECOND
GMT	1972	12	10	21	44	1.448
CTE			3	16	11	1.140

STATE VECTOR	X (KM)	Y (KM)	Z (KM)	XDOT (KM/S)	YDOT (KM/S)	ZDOT (KM/S)
1950.0	1698.3344288	-102.3525543	-760.2876081	-.3716031	-1.5431120	-.9641320
SELENOGRAPHIC	-1578.3159430	-775.2632047	-617.0404117	-.7158835	1.4815954	.1645840

LONGITUDE OF NADIR POINT	-153.8398914 DEG		LATITUDE OF NADIR POINT	-19.3360739 DEG
	-153 DEG, 50 MIN, 23.6091614 SEC			-19 DEG, 20 MIN, 9.8659515 SEC
LONG OF CAMERA AXIS INTERSECT	-154.8864422 DEG		LATI OF CAMERA AXIS INTERSECT	-19.2638586 DEG
	-154 DEG, 53 MIN, 11.1918640 SEC			-19 DEG, 15 MIN, 49.8908043 SEC
SPACECRAFT RADIUS	1863.5592624 KM		SPACECRAFT ALTITUDE	125.4692661 KM
SCALE FACTOR	.0047378 M/KM		AZIMUTH OF VELOCITY VECTOR	275.2699184 DEG
MEAN ALTITUDE RATE	-.0645485 KM/SEC		HORIZONTAL VELOCITY	1.6524031 KM/SEC
TILT AZIMUTH	274.0085030 DEG		TILT ANGLE	13.4374923 DEG
SIGMA TILT AZIMUTH	.0008608 DEG		SIGMA TILT ANGLE	.0002000 DEG
SUN ELEVATION AT PRIN GRND PNT	2.5184326 DEG		SUN AZIMUTH AT PRINCIPAL GRND PNT	270.0456666 DEG
LONGITUDE OF SUBSOLAR POINT	117.5061552 DEG		LATITUDE OF SUBSOLAR POINT	-.7876608 DEG
	117 DEG, 30 MIN, 22.1587801 SEC			0 DEG, 47 MIN, 15.5789280 SEC
ALPHA	-14.3871144 DEG		SWING ANGLE	268.6212289 DEG
EMISSION ANGLE	14.4278490 DEG		SIGMA SWING ANGLE	.0008608 DEG
PHASE ANGLE	101.8682222 DEG		NORTH DEVIATION ANGLE	179.7221195 DEG
PHI	13.4337306 DEG		X-TILT	-.3203754 DEG
SIGMA PHI	.0002000 DEG		SIGMA X-TILT	.0002000 DEG
KAPPA	-174.6504593 DEG		Y-TILT	-13.4335160 DEG
SIGMA KAPPA	.0002000 DEG		SIGMA Y-TILT	.0002000 DEG
OMEGA	-.3203754 DEG		HEADING	-84.5739342 DEG
SIGMA OMEGA	.0002000 DEG		SIGMA HEADING	.0002056 DEG
SPACECRAFT ALTITUDE (LASER)	.0000000 KM		LASER SLANT RANGE	.0000000 KM

SELENOGRAPHIC DIRECTION COSINES	X	Y	Z	MAGNITUDE (KM)
OF CAMERA AXIS	.71671969	.61032177	.33737254	129.267700

TRANSFORMATION MATRIX FROM SELENOCENTRIC TO CAMERA

.28820202-01	-.92405104+00	-.38118106+00
-.36071313+00	.34603015+00	-.86611151+00
.93223137+00	.16245851+00	-.32334470+00

TRANSFORMATION MATRIX FROM LOCAL HORIZONTAL TO CAMERA

-.96828176+00	.91974033-01	.23231690+00
-.93230040-01	-.99562888+00	.55915756-02
.23181568+00	-.16244704-01	.97262402+00

PHOTOGRAPH FOOTPRINT

LATITUDE	LONGITUDE	LATITUDE	LONGITUDE
-13.183	-153.896	-16.360	-154.171
-25.537	-155.194	-22.271	-154.787
-25.821	-156.258	-22.340	-155.721
-12.734	-154.782	-16.125	-155.031

Figure 5.1 Panoramic Camera Orbital Support Data

IFRAME = 1882

	YEAR	MONTH	DAY	HOUR	MINUTE	SECOND
GMT	1972	12	11	20	56	.364+002
CTE			4	15	23	38.053

STATE VECTOR	X	Y	Z	X DOT	Y DOT	Z DOT
1950.0	.1645965+004	-.2835558+003	-.8043529+003	-.4431479+000	-.1509780+001	-.4048601+000
SELENOGRAPHIC	-.1745339+004	-.2096859+003	-.5885675+003	-.2736827+000	.1588422+001	.2043067+000

Figure 5.2 Panoramic Camera Orbital Support Data, No Gimbal Data

APOLLO 17 REV 1/2 MAP 4/73F PAGE = 175

	YEAR	MONTH	DAY	HOUR	MINUTE	SECOND
GMT	1972	12	10	21	46	20.388
CTE			3	16	13	20.080

STATE VECTOR	X (KM)	Y (KM)	Z (KM)	XDOT (KM/S)	YDOT (KM/S)	ZDOT (KM/S)
1950.0	1634.3665286	-315.4772305	-819.0323257	-.5484668	-1.5209373	-.3802523
SELENOGRAPHIC	-1666.1621510	-563.6092217	-589.6966299	-.5431205	1.5528621	.2286857

LONGITUDE OF NADIR POINT	-161.3109703 DEG	LATITUDE OF NADIR POINT	-18.5344083 DEG
	-161 DEG, 18 MIN, 39.4931030 SEC		-18 DEG, 32 MIN, 3.8699913 SEC
LONG OF CAMERA AXIS INTERSECT	-161.3711987 DEG	LATI OF CAMERA AXIS INTERSECT	-18.5220532 DEG
	-161 DEG, 22 MIN, 16.3151550 SEC		-18 DEG, 31 MIN, 19.3914702 SEC
SPACECRAFT RADIUS	1855.1263524 KM	SPACECRAFT ALTITUDE	117.0363561 KM
SCALE FACTOR	.0006401 M/KM	AZIMUTH OF VELOCITY VECTOR	277.6924984 DEG
MEAN ALTITUDE RATE	-.0566726 KM/SEC	HORIZONTAL VELOCITY	1.6599234 KM/SEC
TILT AZIMUTH	282.1983032 DEG	TILT ANGLE	.8677476 DEG
SIGMA TILT AZIMUTH	.0132043 DEG	SIGMA TILT ANGLE	.0002000 DEG
SUN ELEVATION AT PRIN GRND PNT	8.6477375 DEG	SUN AZIMUTH AT PRINCIPAL GRND PNT	272.0796776 DEG
LONGITUDE OF SUBSOLAR POINT	117.4865743 DEG	LATITUDE OF SUBSOLAR POINT	-.7876198 DEG
	117 DEG, 29 MIN, 11.6673374 SEC		0 DEG, 47 MIN, 15.4311848 SEC
ALPHA	-.9116037 DEG	SWING ANGLE	274.3451811 DEG
EMISSION ANGLE	.9259919 DEG	SIGMA SWING ANGLE	.0132042 DEG
PHASE ANGLE	82.2638311 DEG	NORTH DEVIATION ANGLE	172.1682361 DEG
PHI	.8650495 DEG	X-TILT	.0660306 DEG
SIGMA PHI	.0002000 DEG	SIGMA X-TILT	.0002000 DEG
KAPPA	-172.1663818 DEG	Y-TILT	-.8650489 DEG
SIGMA KAPPA	.0002000 DEG	SIGMA Y-TILT	.0002000 DEG
OMEGA	.0660306 DEG	HEADING	-82.1673779 DEG
SIGMA OMEGA	.0002000 DEG	SIGMA HEADING	.0002000 DEG
SPACECRAFT ALTITUDE (LASER)	116.9365873 KM	LASER SLANT RANGE	116.9499998 KM

SELENOGRAPHIC DIRECTION COSINES	X	Y	Z	MAGNITUDE (KM)
OF CAMERA AXIS	.89233094	.31747014	.32087102	117.050678

TRANSFORMATION MATRIX FROM SELENOCENTRIC TO CAMERA

-.28587964+00	-.92543033+00	-.24869952+00
-.36731423+00	.34553391+00	-.86353144+00
.88507230+00	-.15551521+00	-.43870485+00

TRANSFORMATION MATRIX FROM LOCAL HORIZONTAL TO CAMERA

-.99055746+00	.13626411+00	.15097378-01
-.13629675+00	-.99066737+00	-.11524513-02
.14799417-01	-.31992884-02	.99988532+00

PHOTOGRAPH FOOTPRINT

LATITUDE	LONGITUDE
-15.933	-157.864
-21.870	-158.624
-21.105	-165.082
-15.036	-164.092

DIRECTION TO STELLAR PHOTO CENTER

RIGHT ASCENSION -2 HR, 33 MIN, 3.7 SEC DECLINATION 54 DEG, 26 MIN, 27.8 SEC

Figure 5.3 Mapping Camera Orbital Support Data

IFRAME = 324

	YEAR	MONTH	DAY	HOUR	MINUTE	SECOND
GMT	1972	12	11	20	53	.210+002
CTE			9	15	20	22.726

STATE VECTOR	X	Y	Z	X DOT	Y DOT	Z DOT
1950.0	.1707956+004	.1905571+002	-.7136535+003	-.1898574+000	-.1530081+001	-.5195922+000
SELENOGRAPHIC	-.1566274+004	-.5162188+003	-.6196394+003	-.5321419+000	.1533373+001	.1129718+000

Figure 5.4 Mapping Camera Orbital Support Data, No Gimbal Data

REV 1/2 MAP 4/73F FRAME NUMBER = 175

RT ASCENTION = -.63000496568144229 9+000 GMT

DECLINATION = .95985405818954971 6+000 GET

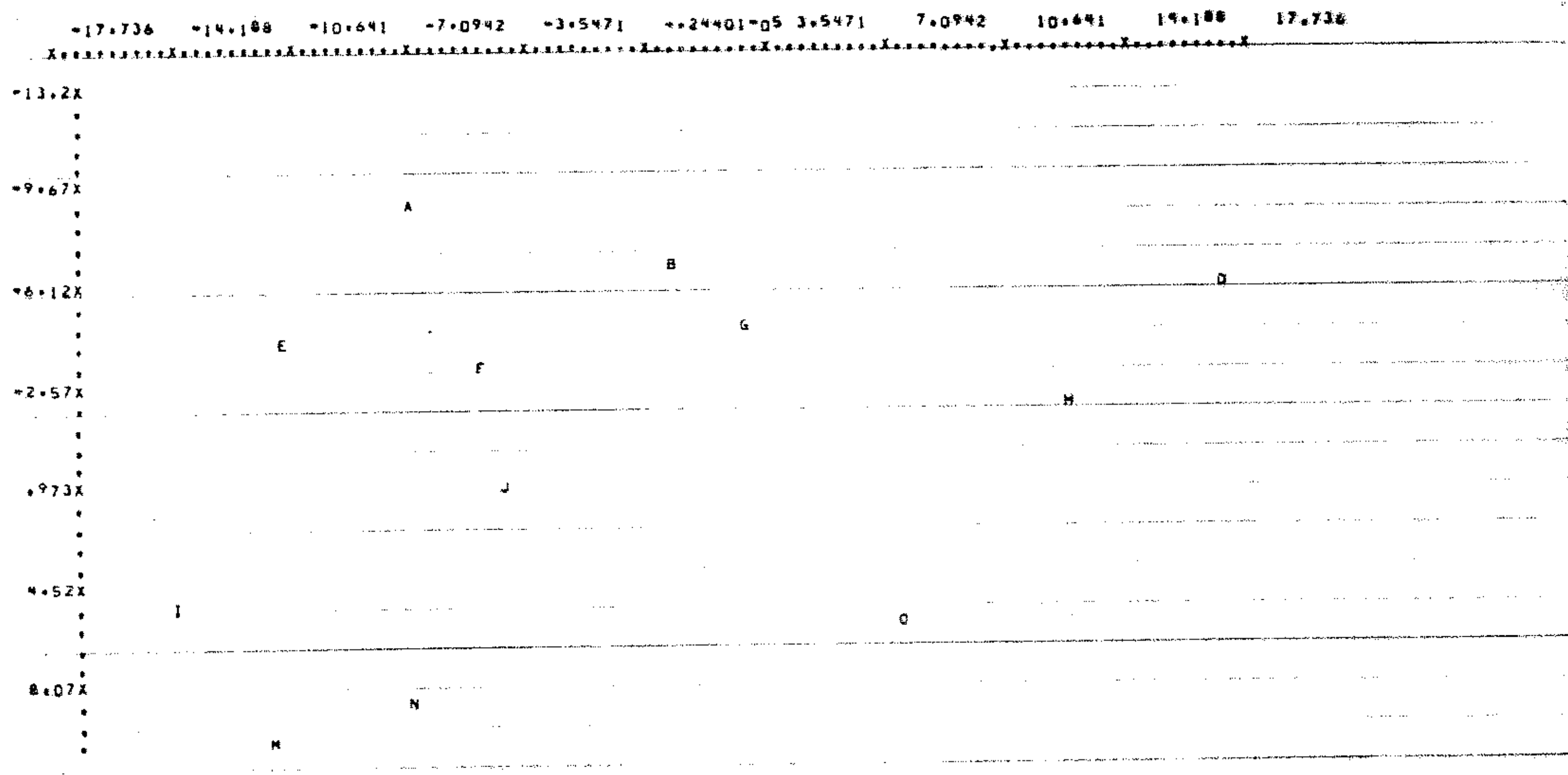
YEAR MONTH DAY HOUR MINUTE SECOND

3 16 13 20.080

FRAME CORNERS

-.20306287639838924 9+000 .11023455940307618 9+001 -.30649313851383168 8+000 .80059973127801723 8+000

-.89171584000286653 4+000 .76322762684292426 3+000 -.10882282960559353 4+001 .10467283117724989 3+001



STAR	Y DIAPOS	X DIAPOS	SAO NO.	BOSS NO.
A	-9.0583	-8.2955	18979.0	28832.0
B	-7.0322	-.1981	19466.0	30150.0
C	-9.0446	1.1782	19541.0	30302.0
D	-6.3061	15.8900	35147.0	32197.0
E	-4.1121	-12.1144	32627.0	28531.0
F	-3.0535	-6.0623	33078.0	29393.0
G	-4.5650	1.6268	33693.0	30440.0
H	-2.0060	11.4390	34651.0	31615.0
I	4.9193	-15.3963	49712.0	26537.0
J	1.3142	-5.4951	33185.0	29608.0
K	5.4252	.3788	33665.0	30391.0
L	5.0239	11.9079	34628.0	31586.0
M	9.9011	-12.4841	50099.0	29036.0
N	8.8702	-7.9870	50456.0	29519.0
O	6.2269	6.4318	34143.0	31046.0
P	10.3232	10.4290	52055.0	31424.0

Figure 5.5 MCS Stellar Camera Star Field

8.0 CALIBRATION DATA

Calibrations of the Apollo 17 SIM Bay cameras and the laser altimeter were 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 .

8.1 Mapping Camera Subsystem

APOLLO 17

MAPPING CAMERA SUBSYSTEM CALIBRATION DATA

TR-71-3404-3

CAMERA CALIBRATION REPORT

CAMERA UNIT SN-004

AUGUST 1971

Prepared by

Autometric Operation
Equipment Division
Raytheon Company

400 Army Navy Drive
IDA Building, Room 3-D 18
Arlington, Virginia 22202

Prepared for

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

CAMERA CALIBRATION RESULTS

Lunar Mapping Camera SN 004 Stellar Calibration

Terrain Lens (203) Constants of Internal Geometry

EFL = 75.816 mm.	S.D. = 0.003 mm.
CFL = 75.842 mm.	S.D. = 0.003 mm.

Principal Point With Respect to Indicated Principal Point

(Indicated principal point x_{ipp} = 0.0 mm., y_{ipp} = 0.0mm.),

x_p = −0.005 mm.	S.D. = 0.001 mm.
y_p = −0.007 mm.	S.D. = 0.001 mm.

Radial Distortion Parameters

$K_1 = -0.13002628 \times 10^{-5}$	S.D. = $0.41435692 \times 10^{-7}$
$K_2 = 0.53903721 \times 10^{-9}$	S.D. = $0.14760380 \times 10^{-10}$
$K_3 = -0.54031164 \times 10^{-13}$	S.D. = $0.15759510 \times 10^{-14}$

Lens Decentration Distortion Parameters

$J_1 = 0.85729357 \times 10^{-6}$	S.D. = $0.54354565 \times 10^{-6}$
$J_2 = -0.17887586 \times 10^{-9}$	S.D. = $0.11295716 \times 10^{-9}$
ϕ_0 = 3.1067218 radians	S.D. = 0.26246993

Stellar Lens (102) Constants of Internal Geometry

EFL = 75.744 mm. S.D. = 0.017 mm.
CFL = 75.854 mm. S.D. = 0.017 mm.

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

x_p = -0.022 mm. S.D. = 0.026 mm.

y_p = -0.110 mm. S.D. = 0.025 mm.

Radial Distortion Parameters

$K_1 = -0.99537549 \times 10^{-5}$ S.D. $= 0.60376701 \times 10^{-5}$

$K_2 = 0.63007711 \times 10^{-7}$ S.D. $= 0.48277546 \times 10^{-7}$

$K_3 = -0.99410657 \times 10^{-10}$ S.D. $= 0.11570656 \times 10^{-9}$

Lens Decentration Distortion Parameters

$J_1 = 0.63320333 \times 10^{-4}$ S.D. $= 0.15004343 \times 10^{-4}$

$J_2 = 0.26811998 \times 10^{-6}$ S.D. $= 0.61419662 \times 10^{-7}$

ϕ_0 = 1.5424244 radians S.D. = 0.23214470

Results of Lock-Angle Calibration

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

0.999999863	0.000408516	-0.000326047
-0.000282131	-0.103236695	-0.994656778
-0.000439993	0.994656734	-0.103236565

Relative Orientation Angles (Degrees, Minutes, Seconds)

OMEGA =	-95	55	32.079
PHI =	- 0	1	30.755
KAPPA =	0	0	58.194

Covariance Matric

0.17515×10^{-10}	-0.29235×10^{-12}	-0.16162×10^{-11}
-0.29235×10^{-12}	0.33749×10^{-10}	-0.12441×10^{-11}
-0.16162×10^{-11}	-0.12441×10^{-11}	0.68412×10^{-9}

Standard Deviation of Orientation Angles (Arc-seconds)

S.D. OMEGA = 0.86
S.D. PHI = 1.20
S.D. KAPPA = 5.40

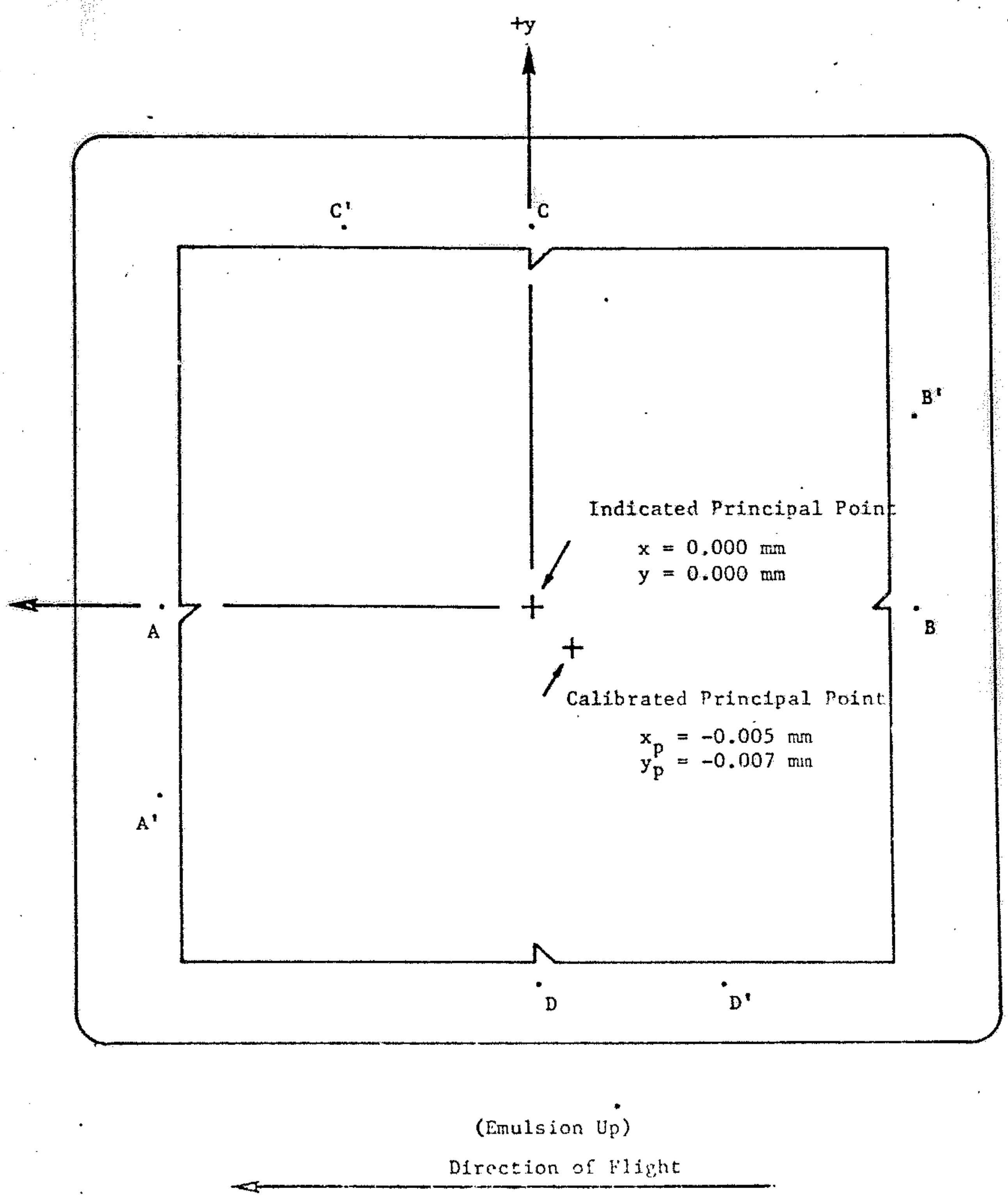
Statistical Data From Simultaneous Solution

Weighted Sum of Squares = 0.047260

Degrees of Freedom = 1850

Standard Deviation of Unit Weight = 0.005 mm.

PRINCIPAL POINT LOCATION FOR TERRAIN CAMERA, LENS NO. 203



(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 = 60.614

A_y = 0.000

A'_x = 60.555

A'_y = -30.796

B_x = -60.627

B_y = 0.000

B'_x = -60.475

B'_y = 30.754

C_x = -0.010

C_y = 60.482

C'_x = 30.662

C'_y = 60.566

D_x = 0.011

D_y = -60.439

D'_x = -30.678

D'_y = -60.580

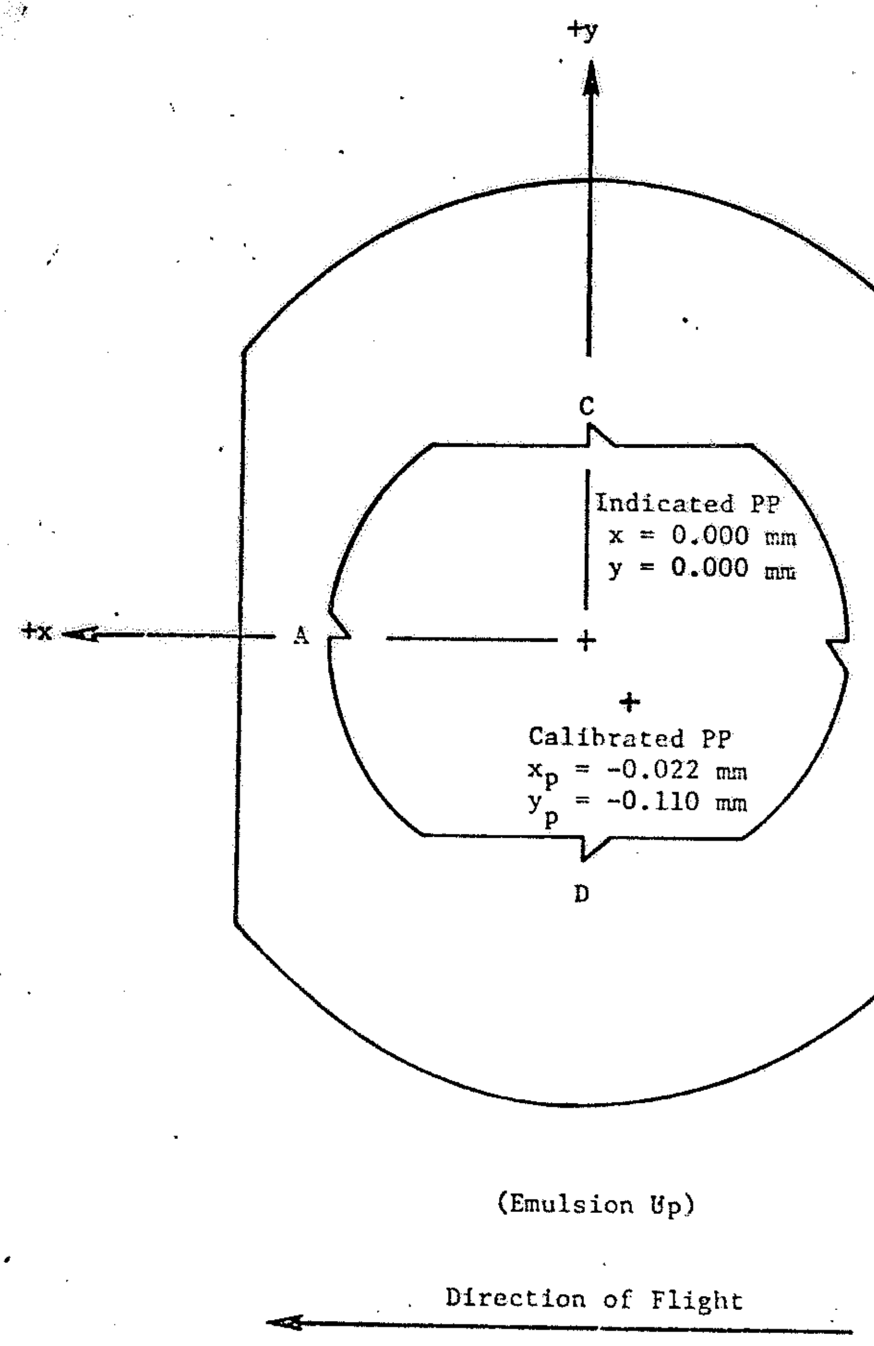

+y
C
Indicated PP
x = 0.000 mm
y = 0.000 mm
+x
A
B
Calibrated PP
x_p = -0.022 mm
y_p = -0.110 mm
D
(Emulsion Up)
Direction of Flight

Figure 2

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 128

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

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

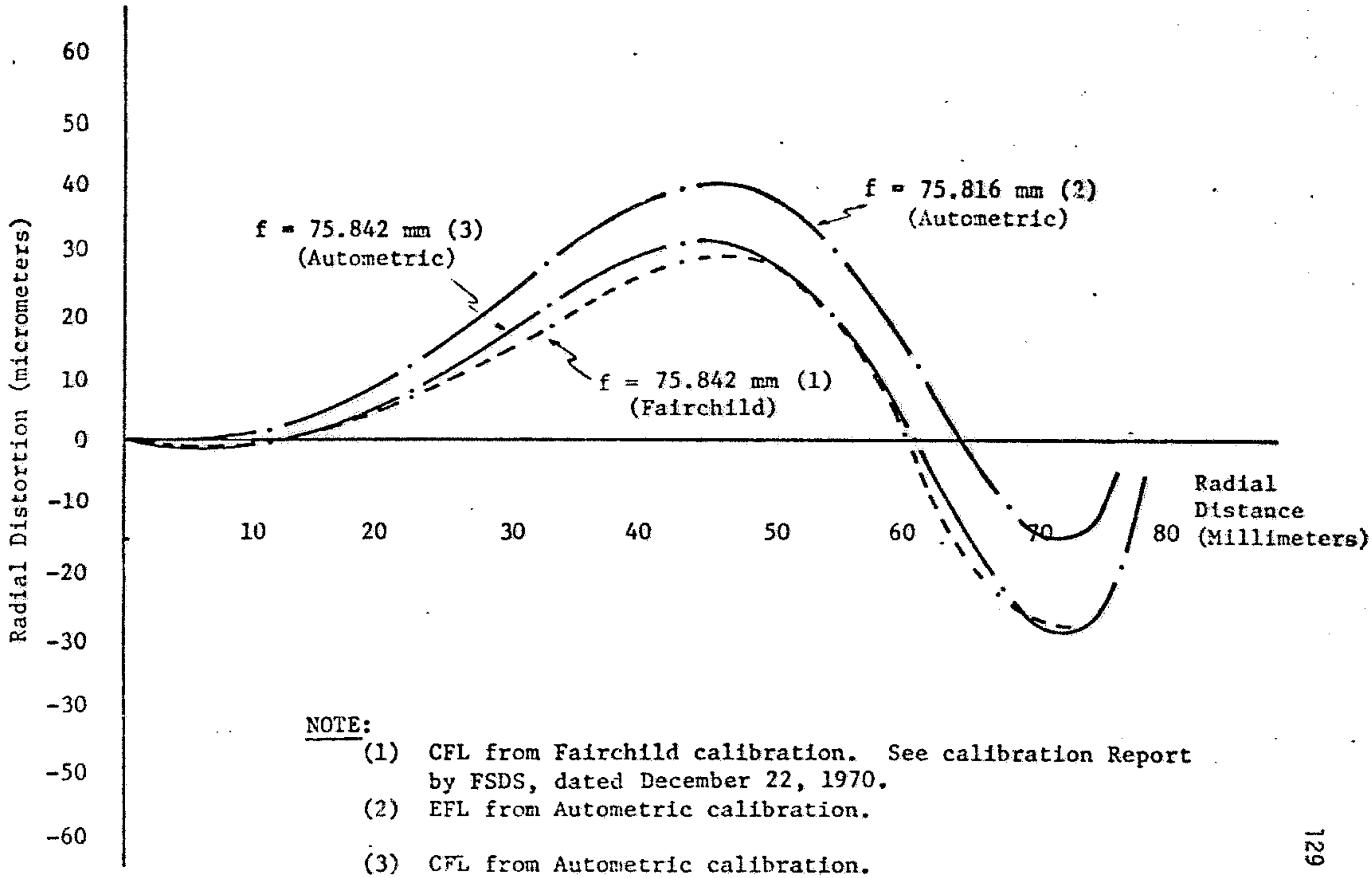
where x and y are corrected image coordinates, and K_1, K_2, K_3, J_1, J_2, ϕ_0 are the distortion parameters given by the calibration.

Radial distortion curves for terrain camera lens 203 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-004
TERRAIN LENS 203



NOTE:
(1) CFL from Fairchild calibration. See calibration Report by FSDS, dated December 22, 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.

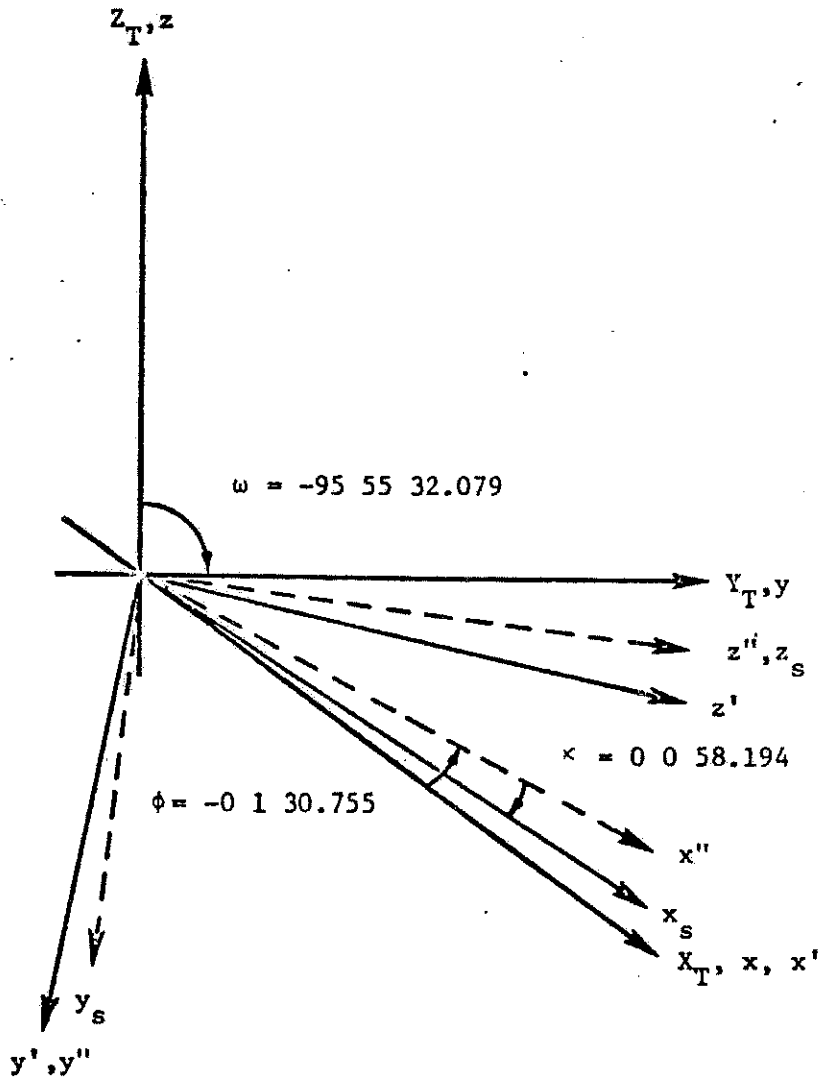


Figure 4. Orientation of Stellar Camera Coordinate System With Respect to Terrain Camera Coordinate System.

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

Eldon D. Sewell

8.2 Laser Altimeter

APOLLO 17

LASER ALTIMETER CALIBRATION DATA

DATA SHEET NO. 7

NASA MAPPER CAMERA NO. 71-004 LENS NO. 203

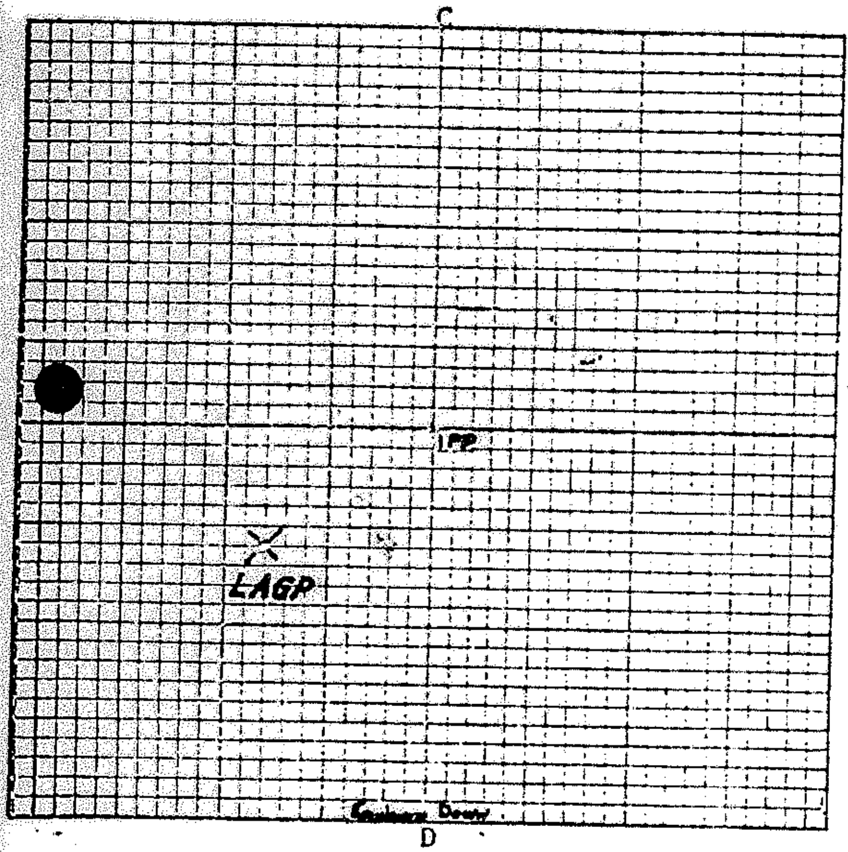
LASER ALTIMETER NO. 0006

LASER ALTIMETER GROUND MEASUREMENT POINT

The positions of all points are referenced to the Indicated Principal Point (IPP) as origin with the straight line drawn between the A and B fiducials being coincident with the X- axis. The CD line goes through the origin but is not generally coincident with the Y- axis.

Scale 1 Box = 0.001 MM

Note: Emulsion Down



(+)	X_{LAGP} =	− 0.008	mm
(−)	X_{LAGP} =	− 0.008	mm
AVG	X_{LAGP} =	− 0.008	mm
(+)	Y_{LAGP} =	− 0.006	mm
(−)	Y_{LAGP} =	− 0.006	mm
AVG	Y_{LAGP} =	− 0.006	mm

A

NOTE: SIGNS ARE CORRECT FOR EMULSION DOWN MEASUREMENT.

11-4-72

X_{LAGP} - Location on X - coordinate of Laser Altimeter Ground Measurement Point

Y_{LAGP} - Location on Y - coordinate of Laser Altimeter Ground Measurement Point

(+) - "+g" mode

(−) - "-g" mode

8.3 Optical Bar Panoramic Camera

APOLLO 17

PANORAMIC CAMERA CALIBRATION DATA

Test Procedure No. TP121 No. of Pages 8

APOLLO 17

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

	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 1 /65

6.3.1.3 Itek Test Data Sheet

VEILING GLARE MEASUREMENT

Panoramic Camera Lens, P/N 105150, Serial No. N-53

	Step Wedge							Black Dot	% Veiling Glare
Step No.	1	2	3	4	5	6	7		
	* Calibrated Value								
	1.22	1.07	.92	.78	.65	.50	.36		
Field Position	*Measured Test Values								
-6°	.18	.26	.38	.58	.79	1.14	1.58	.46	13.8
-4°	.20	.28	.42	.66	.92	1.24	1.58	.51	13.8
-2°	.20	.27	.42	.66	.92	1.24	1.58	.50	13.3
0°	.20	.26	.37	.58	.82	1.10	1.45	.46	14.1
+2°	.20	.25	.36	.57	.86	1.08	1.49	.64	17.8
+4°	.20	.28	.44	.71	.88	1.36	1.57	.70	16.2
+6°	.22	.30	.46	.70	.99	1.27	1.58	.78	17.9

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: 9/23/70

QA Monitor: [signature] 9-25-70

Project Approval: [signature] 9-25-70

Test Procedure No. TP121

Q199-5 11/65

ITEK CORPORATION
Lexington 73, Massachusetts

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

	PREPARED	PROJECT APPROVAL	QUALITY ASSURANCE APPROVAL
By	R. SHERLOCK	C. BACKE	R. WESPISER
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Date	9/17/70	9/21/70	9/17/70

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6.3.1.3 Itek Test Data Sheet

SPECTRAL TRANSMITTANCE MEASUREMENT

Panoramic Camera Lens, P/N 105150, Serial No. N-53

Wavelength nm	Radiometer Readings A	A_1	B	B_1	% Transmittance
400	5.7	2.0	1.2	.2	47.5
420	18.3	6.7	3.4	.6	48.2
440	35.5	13.5	6.3	1.3	54.3
480	83.0	33.0	15.0	3.9	65.4
520	128.0	52.0	23.3	6.8	71.8
560	143.0	58.0	26.0	7.6	72.1
601	133.0	53.0	23.7	6.5	68.8
640	118.0	43.0	20.7	4.8	63.6
680	97.5	34.5	17.3	3.4	55.5
720	51.5	23.5	12.7	2.1	36.2

Legend:

A = Brightness of the calibrated standars 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: 9/23/70

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Test Procedure No. TP123

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6.3.1.3 Itek Test Data Sheet

T STOP CALCULATION

Panoramic Camera Lens, P/N 105150, Serial No. N-53

Wavelength nm	% Transmittance	T STOP
400	47.5	5.08
420	48.2	5.04
440	54.3	4.81
480	65.4	4.33
520	71.8	4.14
560	72.1	4.12
601	68.8	4.22
640	63.6	4.39
680	55.5	4.69
720	36.2	5.83

Legend:

$$\text{T STOP} = \frac{f/\text{number}}{\sqrt{t}}$$

where f/number is 3.5 and t is transmittance.

Data Recorded By: [signature] Date: 9/25/70

QA Monitor: [signature] 9-25-70

Project Approval: [signature] 9/25/70

Test Procedure No. TP123

Test Procedure No. TP125 No. of Pages 8

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

	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

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5.3.1.3 Itek Test Data Sheet

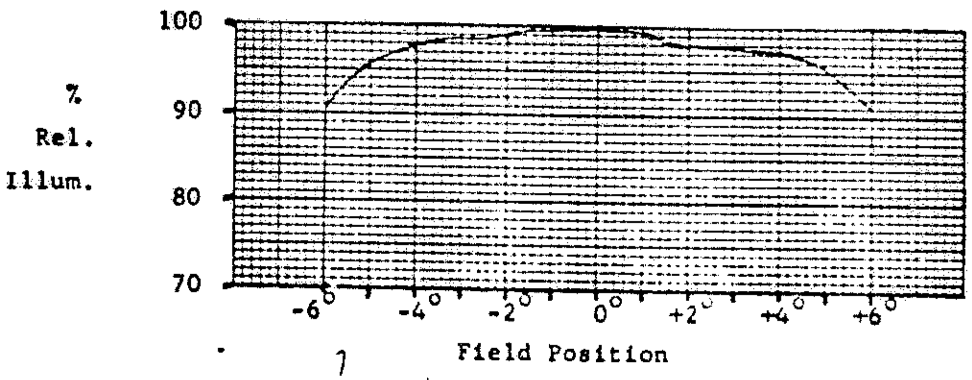
RELATIVE ILLUMINATION MEASUREMENT

Panoramic Camera Lens, P/N 105150, Serial No. N-53

	Field Position	Radiometer Readings vdc	Relative Illumination %
B	-6°	66	90.4
B	-5°	70	95.9
B	-4°	71	97.3
B	-3°	72	98.6
B	-2°	72	98.6
B	-1°	72.5	99.3
A	0°	73	100.0
B	+1°	72.5	99.3
B	+2°	71.5	97.9
B	+3°	71.5	97.9
B	+4°	71	97.3
B	+5°	69.5	95.2
B	+6°	66.5	91.1

Meter Scale for Radiometer Readings: 1K

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



Data Recorded By: [illegible] Date: [illegible]

QA Monitor: H R McBride 9-25-70

Project Approval: [illegible] 9-25-70

Test Procedure No. TP125

17

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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

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Lens N- 53

C.F.L. Calibration Summary

Filter	Field Position (degrees)	Mean C.F. L. (inches)	STD Deviation of mean CFL (inches)
23A	+6	23.9991	0.0002
	+4	24.0002	0.0007
	+2	24.0026	0.0009
	0 *	24.0008	0.0005
	-2	24.0008	0.0010
	-4	24.0018	0.0003
	-6	24.0003	0.0003
12	+6	24.0030	0.0012
	+4	24.0053	0.0010
	+2	24.0045	0.0019
	0 *	24.0029	0.0007
	-2	24.0009	0.0014
	-4	24.0028	0.0009
	-6	24.0009	0.0006
8	+6	24.0040	0.0002
	+4	24.0070	0.0008
	+2	24.0069	0.0003
	0 *	24.0052	0.0006
	-2	24.0048	0.0016
	-4	24.0045	0.0004
	-6	24.0041	0.0012
2A	+6	24.0033	0.0003
	+4	24.0059	0.0004
	+2	24.0056	0.0008
	0 *	24.0040	0.0006
	-2	24.0030	0.0007
	-4	24.0036	0.0002
	-6	24.0023	0.0008
no filter	+6	24.0036	0.0004
	+4	24.0052	0.0008
	+2	24.0067	0.0015
	0 *	24.0031	0.0010
	-2	23.9998	0.0010
	-4	24.0023	0.0007
	-6	24.0011	$<$ 0.0001

* Average of all field positions

Quality Assurance Review H R McBride

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