TECHNICAL PUBLICATION

PHOTOGRAPHIC EVALUATION REPORT

MISSION 1101

SPECIAL STUDY ON SLANT RANGE COMPUTATIONS RELATED TO UNIVERSAL GRID COORDINATES FOR THE KH-4B CAMERA SYSTEM

[redacted]

FEBRUARY 1968

COPY [redacted]

58 PAGES

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NATIONAL PHOTOGRAPHIC INTERPRETATION CENTER

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

GLOSSARY OF TERMS

ABSOLUTE HEIGHT	Vertical distance from the vehicle to the mean ground level of the area being photographed.
ACUITY	Sharpness - Edge definition.
ACUTANCE	Measure of the ability of a lens to reproduce sharp images.
AIR BASE	Ground distance between 2 exposure stations.
ALTITUDE	Vertical distance from the vehicle to the Hough Ellipsoid at the time of exposure.
AZIMUTH OF THE PRINCIPAL RAY	Horizontal clockwise angle, measured from true north to the camera principal ray.
BASE HEIGHT RATIO	Ratio between the air base and the absolute altitude of a stereoscopic pair of photographs.
CAMERA NADIR	Geodetic latitude and longitude of a point vertically beneath the perspective center of the camera lens on the Hough Ellipsoid.
CONE ANGLE	Angle between the principal ray and the vehicle nadir.
COPY GENERATION	Number of reproductive steps by which a negative or positive photographic copy is separated from the original, i.e. the original negative is copy 1, a positive made from the original negative is copy 2, etc.
DATE OF PHOTOGRAPHY	Indicates the day, month, and year (GMT) that the photography was acquired.

EXPOSURE*

Total quantity of light received per unit area on a sensitized plate or film.

EXPOSURE DURATION

Time during which a light-sensitive material is subjected to the influence of light. Expressed in this text in fractions of a second. Formula: Exposure Time (sec) = $\frac{\text{Slit Width (in)}}{\text{Scan Rate (radians per sec)}}$

EXPOSURE STATION

Position occupied by the camera lens at the moment of exposure.

FIDUCIAL MARK

A standard geometrical reference point imaged at the margin of a photograph. The intersection of the primary fiducial marks usually defines the principal point.

FOCAL LENGTH: CALIBRATED

Adjusted value of the equivalent focal length. Computed to distribute the effect of lens distortion over the entire field.

FOCAL LENGTH: EQUIVALENT

Distance measured along the lens axis from the rear nodal point to the plane of best average definition over the entire field. Points other than the rear nodal point may be used but must be specified for correct interpretation of data.

FOCAL PLANE

Plane perpendicular to the lens axis, in which images of points in the object field of the lens are focused.

FRAME

One of a series of full-format photographs comprising a roll of film.

[redacted]

GROUND RESOLUTION*	Resolved ground distance as determined from standard bar target resolution targets. A target is considered to be resolved when a grouping of 3 bars can be distinguished as 3 distinct lines. The lines need not have linear form.
HOLEY RAIL DOTS	Images of the rail holes associated with the pan geometry calibration of the camera.
IMC (Image Motion Compensation)	Correction for the forward motion of the vehicle while photographing the terrain.
ISODENSITOMETER	An instrument which is basically a microdensitometer with the capability of repeatedly scanning an image at pre-set intervals. Its output is in the form of a plot representing distance along 2 axes and density differences as code changes within each scan line.
LOCAL SUN TIME	Time of day computed from the position of the sun relative to the imaged terrain.
MICRODENSITOMETER	An instrument which measures the optical density of very small areas in an image. Its output is in the form of a continuous plot of density versus distance across an image. The microdensitometer used in NPIC can accurately measure distances as small as 1 micron and densities up to 5.0+.
NOD INDICATORS	A series of marks imaged in the border area of each frame for the purpose of defining the relative orientation of the optical axis and the ground scene.

[redacted]

NODAL TRACE	A continuous line imaged along the major axis of each frame to define the optical axis of the lens relative to any given instant of exposure.
PANORAMIC CAMERA	Photographs a partial or complete panorama of the terrain in a transverse direction through a scanning motion of the lens system.
PARALLAX	Apparent displacement of the position of an object in relation to a reference point, caused by a change in the point of observation.
PASS	Operational portion of an orbital revolution. A suffix D indicates the descending node and a suffix A indicates the ascending node. An additional suffix E indicates that the associated photography was generated for engineering purposes.
PITCH	Rotation of the camera about its transverse axis. Positive pitch indicates nose-up attitude.
PRINCIPAL RAY	That ray of light which emanates from a point in object space and passes undeviated through the lens to become imaged at the principal point of the camera system. It is co-incident with the optical axis of the lens.
PROCESSING LEVEL	Degree of development. Three levels of processing are currently employed: Primary, intermediate, and full.
RESOLUTION	Measure of the smallest array of point objects distinguishable as independent point images, expressed in lines/mm.
ROLL	Rotation of the camera about its longitudinal axis. Positive roll indicates left wing up attitude.

[redacted]

SHADOW FACTOR	A constant for each frame, used to calculate heights from shadow lengths.
SHRINKAGE MARKERS	Calibrated reference points used to calculate deformations of the photographic material.
SOLAR ELEVATION	Vertical angle measured from a plane (tangent to the surface of the earth at the point of intersection of the principal ray) to the sun, the vertex being at the center of the format.
STELLAR CAMERA	Used simultaneously with the index camera to photograph stars in order to determine vehicle attitude.
SYSTEM TIME LABEL	Binary presentation of the accumulative system time.
UNIVERSAL GRID	X, Y coordinate system used to locate images on photographic formats.
VEHICLE AZIMUTH	Clockwise horizontal angle measured from true north to the vehicle ground track.
VIGNETTING	Gradual reduction in density of parts of a photographic image due to the stopping of some of the rays entering the lens.
YAW	Rotation of the camera about its vertical axis. Positive yaw represents nose-left attitude, as viewed from the top of the camera.

*Defined differently than in the "Glossary of NPIC Terminology."

INDEX OF PHOTOGRAPHIC EVALUATION REPORTS AND SPECIAL STUDIES

PER	DOCUMENT NUMBER	SPECIAL STUDY
1033	[redacted]	None
1034		None
1036		None
1037		None
1038		None
1039		None
1040		None
1041		Slant Range Computations Related to Universal Grid Coordinates for the KH-4 Camera System
1042	[redacted]	None
1043		Scan Speed Deviation Analysis of the Forward Camera, Mission 1043
1101	[redacted]	Slant Range Computations Related to Universal Grid Coordinates for the KH-4B Camera System

[redacted]

SYNOPSIS

Mission 1101 provides the initial photography from the KH-4B camera system. The KH-4B camera system is an evolution of the KH-4A system and is based on the same fundamental design concepts. The most significant improvement is the constant rotating drum which houses the lens elements. This modification not only increases dynamic stability but also provides increased scan rate capability, permitting operation in orbits having a lower perigee. Other engineering modifications provide improved exposure through the use of a 4 position slit width capability and a 2 position filter changer. A slit width fail safe position is also provided. For photogrammetric purposes, the camera system incorporates the panoramic geometry modifications which have been used on some previous KH-4A missions.

To record terrain and stellar imagery, the DISIC (Dual Improved Stellar Index Cameras) subsystem was designed to replace the KH-4A stellar/index unit. The DISIC is comprised of 3 cameras: a 3 inch focal length terrain camera and two 3 inch focal length stellar cameras (one port-looking and one starboard-looking) whose axes are 10 degrees above horizontal. The DISIC subsystem will operate in conjunction with the panoramic cameras, or independently. Stellar-Index-Pan (SIP) correlation is obtained by interpolation of the binary time word from each film record.

Both panoramic cameras were operational throughout Mission 1101. The best photography was obtained from the fwd-looking camera and is equal to or better than the photography of any KH-4A mission. The aft camera imagery is out of focus throughout the mission. Several CORN and fixed resolution targets were covered. Readings of these targets are recorded in Part VI of this report.

The Mission Information Potential (MIP) rating for this mission is 95, the highest MIP rating to date. The MIP rev is 159D, frame 2.

The stellar cameras operated satisfactorily throughout the mission, producing a sufficient number of stars for attitude determination. However, due to software problems, attitude data reduction has not been accomplished to date.

The index camera functioned properly. The image quality is considered to be fair and the material is suitable for attitude determination, relative orientation, and auxiliary map making. An extensive analysis of the DISIC operation is being performed by NPIC. Results of the study are not available at this time.

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PART I. GENERAL SYSTEM INFORMATION

A. Camera Numbers

Forward-Looking Panoramic Camera	303
Aft-Looking Panoramic Camera	302
Stellar/Index Camera (Mission 1101-1)	3
Stellar/Index Camera (Mission 1101-2)	3

B. Launch and Recovery Dates

	(Mission 1101-1)	(Mission 1101-2)
Launch	1941Z/15 Sep 67	*
Recovery	2142Z/21 Sep 67	2005Z/28 Sep 67

C. Orbit Elements

Element	Planned	Actual Rev 45	Actual Rev 110	Photo Range
Period (min)	NA	89.844	89.866	*
Perigee (nm)	NA	84	84	84, rev 89
Apogee (nm)	NA	208	213	129, rev 8
Eccentricity	NA	0.01727	0.01794	*
Inclination (deg)	NA	80.08	80.08	*
Perigee Latitude	NA	10°N	22°N	*

NA - Not Available.
*Not Applicable.

[redacted]

[redacted]

D. Photographic Operations

1. Panoramic Cameras

Type	Mission 1101-1 Revs	Mission 1101-1 Frames	Mission 1101-2 Revs	Mission 1101-2 Frames	Total Revs	Total Frames
Operational						
Fwd	36	2,732	48	2,711	84	5,443
Aft	36	2,743	48	2,703	84	5,446
Operational/Domestic						
Fwd	0	0	0	0	0	0
Aft	0	0	0	0	0	0
Domestic						
Fwd	3	74	8	326	11	400
Aft	3	75	8	326	11	401
Engineering (no imagery)						
Fwd	2	30	1	5	3	35
Aft	2	30	1	5	3	35
Totals						
Fwd	41	2,836	57	3,042	98	5,878
Aft	41	2,848	57	3,034	98	5,882

2. Secondary Cameras

Camera	Frames
Stellar (Mission 1101-1)	3,578 starboard, 3,572 port
Index (Mission 1101-1)	2,128
Stellar (Mission 1101-2)	3,805 starboard, 3,800 port
Index (Mission 1101-2)	2,446

[redacted]

E. Film Usage

	Film Load (Total, ft)	Pre-Flight Footage	Processed Footage
Fwd-Looking (Mission 1101-1)	16,000*	464	7,487
Aft-Looking (Mission 1101-1)	16,000*	474	7,519
Fwd-Looking (Mission 1101-2)	NA	NA	8,031
Aft-Looking (Mission 1101-2)	NA	NA	8,006
Stellar (Mission 1101-1)	1,000	84.66	1,085
Stellar (Mission 1101-2)	1,000	NA	965
Index (Mission 1101-1)	1,000	63.75	1,016
Index (Mission 1101-2)	1,000	NA	1,023

*Total Load for Both Buckets.
NA - Not Applicable.

PART II. IMAGE ANALYSIS

A. Fwd-Looking Panoramic Camera

1. Density: The density of the original negative of Mission 1101 is generally medium. The use of 4 slit widths varied the exposure in areas where exposure changes were necessary because of terrain conditions and/or solar elevation. The multi-slit capability was also used to generate the through exposure test as described in Part VIII of this report.

2. Contrast: In general, the fwd-looking camera produced medium contrast imagery.

3. Acuity: The edge sharpness of the imagery of Mission 1101 is good and compares favorably with the better quality imagery obtained from the KH-4A missions. There is, however, a band of smeared imagery at the take-up end of each frame (as described in Part II, sec B, para 4).

4. Imaged Degradations

a. Light Leaks: Very minor fog patterns are present on the first frame and next-to-last frame of approximately 30 percent of all camera operations (See Graphic 1).

b. Static: None noted.

c. Other: None noted.

5. Physical Degradations: Rail scratches are continuous along both film edges throughout the mission.

6. Product Quality: The overall quality of the fwd-looking camera record is good.

B. Aft-Looking Panoramic Camera

1. Density: Same as reported for the fwd-looking camera.

2. Contrast: Same as reported for the fwd-looking camera.

3. Acuity: The edge sharpness of the imagery on the aft-looking camera record is poor. The imagery is out of focus throughout the mission. Analysis of lens fabrication data showed a back focus shift of one-thousandth of an inch less than anticipated. In addition, an ambient versus altitude test has indicated an added shift of approximately one-half of a thousandth of an inch at the focal plane. The forward camera was focused in a position that permitted the above changes without going out of focus. On both main camera records, there is a one quarter inch wide band of smeared imagery near the take-up end of each frame. This anomaly is caused by the scan head roller assembly which disturbs the film as it enters the format. This condition was probably aggravated by the lower temperatures encountered on this flight.

4. Imaged Degradations:

a. Light Leaks: Very minor fog patterns are present on frames 1 and 2 and the next-to-last frame of approximately 30 percent of all camera operations (See Graphic 2).

b. Static: None noted.

c. Other: None noted.

5. Physical Degradations: Rail scratches are continuous on both film edges throughout the mission. Numerous emulsion scratches, near the format center, appear intermittently throughout the mission.

6. Product Quality: The physical quality of the aft camera record is good. However, the image quality is only fair to poor due to the out-of-focus condition.

C. Stellar Camera (Mission 1101-1)

1. Density: The density of the stellar record is generally medium. However, the port-looking camera frames display heavier densities than those obtained from the starboard-looking camera. In some instances, these heavier densities preclude detection of stellar images.

2. Contrast: In general, the contrast of the stellar camera record is medium and adequate for the detection of stellar images.

3. Image Shape: Generally point type to slightly elongated.

4. Images Per Frame: A total of 25 to 50 star images can be detected in the frames of the starboard-looking camera. The port-looking camera produced significantly fewer images, ranging from a minimum of zero to a maximum of 10 with many frames having no images at all.

5. Flare Level: Most stellar formats are affected by general fogging, which is often heavier in one area of the format and usually heavier on the port than on the starboard frames. Significantly heavier densities were recorded on the second half of the mission. Degradation ranges from minor to severe. A loss of star images is evident on the more heavily fogged frames. The primary cause of this degradation is light reflected into the lens from baffle surfaces. Abrupt changes in flare density are apparently caused by slight changes in vehicle attitude at the time of pan camera start up or shut down.

6. Imaged Degradations:

a. Light Leaks: Light leak induced fog degrades approximately 4 to 6 frames at all camera off periods. The affected frames are those that fall between the port and starboard cameras during nonoperative periods. Degradation is minor to severe, depending on the duration of the sit period. This light leak is the result of a loose seal between the DISIC cover and terrain camera lens.

b. Static: Dendritic type fog patterns caused by static discharges are present intermittently throughout the stellar record. They vary in size and intensity and in most cases enter the active format area. Approximately 40 to 50 frames near the center of the mission are degraded by corona static fogging. The first port-looking camera frame of most stellar camera operations is degraded by a heavy plus density waffle pattern which appears to be a mechanical and/or electrostatic marking caused by the coarse texture of the platen pressure pads and heavy platen pressure.

c. Other: A repetitive pattern of small minus density spots is present in both formats intermittently throughout the mission. The repetition of the pattern is dependent on metering and therefore is not caused by dirt on the reseau plate. The port camera grid contains obstructions which cause 2 small minus density spots in the corner of all port camera frames. A pattern of plus density streaks is present in the border along both film edges throughout the mission. The pattern is repetitive and is more dense on the binary edge than on the opposite edge and less severe at the beginning of the mission than at the end. These marks are caused by pressure of the skew bead rollers in the DISIC exit box.

7. Physical Degradations: None noted except those associated with film cut.

8. Product Quality: The overall quality of the stellar record is good and is adequate for attitude determination throughout the mission.

D. Stellar Camera (Mission 1101-2)

1. Density: The densities of the stellar record of Mission 1101-2 are generally heavier than those of Mission 1101-1. In many instances, these heavier densities caused a loss of star images.

2. Contrast: The contrast is generally medium. However, due to the heavier densities many frames are of low contrast.

3. Image Shape: Same as reported for Mission 1101-1.

4. Images Per Frame: Significantly fewer images were recorded on Mission 1101-2. However, the range of star images per frame is the same as reported for Mission 1101-1.

5. Flare Level: Same as reported for Mission 1101-1.

6. Image Degradations:

a. Light Leaks: Same as reported for Mission 1101-1.

b. Static: Same as reported for Mission 1101-1.

c. Other: Same as reported for Mission 1101-1.

7. Physical Degradations: Same as reported for Mission 1101-1.

8. Product Quality: Same as reported for Mission 1101-1.

E. Index Camera (Mission 1101-1)

1. Density: The density of the index camera record is generally medium to heavy. The heavier density was caused by the failure of the exposure control command to switch to the 1/500 of a second position at the predicted times. A review of the tape recorded data and flight requirements list confirmed that the timer which controls the index camera exposure was improperly set prior to launch.

2. Contrast: The contrast of the imagery on the index camera record is predominantly low. Overexposure and a low gamma processing were the major contributors to the very flat appearance of most index photography.

3. Acuity: The edge sharpness of the imagery on the index camera record is poor. The imagery may have been affected in part by increased smear due to the intermittent, slower-than-programmed shutter speed.

4. Imaged Degradations:

a. Light Leaks: None noted.

b. Static: Electrostatic markings of the corona and dendritic types are present intermittently throughout the mission. Image degradation associated with these markings is considered minor.

c. Other: Numerous small minus density spots are present in the same location in all index camera frames throughout the mission. The probable causes of these marks are flaked paint and dust on the back reseau surface and dirt/emulsion particle build up by the metering roller.

5. Physical Degradations: None noted.

6. Product Quality: The physical quality of the index record is good. However, the image quality is only fair. There is a definite lack of sharpness, which is probably the combined result of the exposure control problem, the film processing conditions, and the low vehicle temperatures experienced throughout the mission.

F. Index Camera (Mission 1101-2)

1. Density: Generally medium.

2. Contrast: Medium to low.

3. Acuity: Same as reported for Mission 1101-1.

4. Imaged Degradations:

a. Light Leaks: None noted.

b. Static: Same as reported for Mission 1101-1.

c. Other: Same as reported for Mission 1101-1.

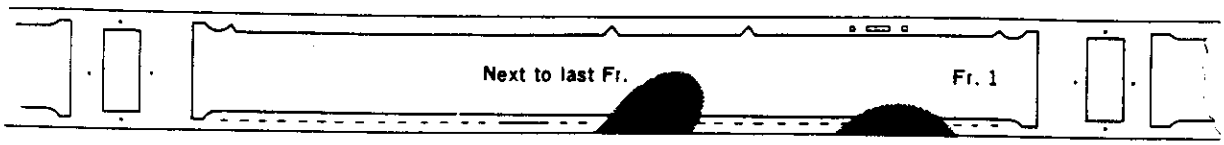
5. Physical Degradation: None noted.

6. Product Quality: Same as reported for Mission 1101-1.

[redacted]

G. Graphic Display (Mission 1101)

The patterns illustrated below are referenced in the text of this report.



NPIC M-1791

PART III. IMAGED AUXILIARY DATA

A. Fwd-Looking Panoramic Camera

1. Horizon Cameras

a. Starboard-Looking

(1) Imagery: In some cases, the horizon imagery was not as sharp as is normally expected. This was not caused by "veiling," as has happened in the past, nor did it appear to be an out-of-focus condition. A possible cause of this degradation is the timing of the shutter opening solenoid with the open position of the shutter. The shutter should be closed prior to the end of solenoid travel. All 4 horizon cameras produced vignetted imagery. The forward-looking port side and the aft-looking starboard side displayed similar vignetting. Likewise, the forward-looking starboard side and the aft-looking port side produced similar vignetting but different than the other 2 horizon cameras. The total extent of the horizon line that was obscured varies from 25 percent to about 40 percent. Attitude determination, using the horizon imagery, was accomplished on a few selected passes. However, the accuracy confidence is reduced due to the vignetting. The significance of the anomaly cannot be fully determined. Mission attitude is derived from the stellar camera photography.

(2) Fiducials: Sharp and well defined.

b. Port-Looking

(1) Imagery: Same as reported for the starboard-looking camera.

(2) Fiducials: Sharp and well defined.

2. Frequency Marks: Sharp and well defined.

3. Binary Time Word: The binary time word functioned properly throughout the mission. No problems were encountered with the binary reader. The tape recorder times correlate within 2 to 5 milliseconds of the main camera binary values.

4. Binary Index: Sharp and well defined.

5. Camera Number: Slightly bloomed but readable.

6. Pan Geometry Dots: In general, the rail hole image quality is good. The images are sharp and well defined. The major problem, as experienced on earlier KH-4A, PG systems, is the loss of many images on both main cameras due to emulsion filling the holes. Effective with Mission 1102, the rail holes are filled with a transparent substance. This innovation is expected to reduce the loss of rail hole images.

7. Nodal Traces: The scan trace imagery is present in the borders of both main camera records. In general, the traces are sharp and distinct. However, near the end of Mission 1101-1 and throughout Mission 1101-2 the trace on the binary edge of both main camera film records becomes broken. This anomaly is the direct result of emulsion build-up on the guide rails. Although highly polished rails have been introduced to reduce emulsion removal due to rail scratching, the condition has not been eliminated.

8. Nod Indicators: Not applicable.

B. Aft-Looking Panoramic Camera

1. Horizon Cameras

a. Starboard-Looking

(1) Imagery: Same as reported for the fwd-looking camera.

(2) Fiducials: Same as reported for the fwd-looking camera.

b. Port-Looking

(1) Imagery: Same as reported for the fwd-looking camera.

(2) Fiducials: Same as reported for the fwd-looking camera.

2. Frequency Marks: Same as reported for the fwd-looking camera.

3. Binary Time Word: Same as reported for the fwd-looking camera.

4. Binary Index: Sharp and well defined.

5. Camera Number: Same as reported for the fwd-looking camera.

6. Pan Geometry Dots: Same as reported for the fwd-looking camera.

7. Nodal Traces: Same as reported for the fwd-looking camera.

8. Nod Indicators: Not applicable.

C. Stellar Camera (Mission 1101-1)

1. Grid Image Quality: Sharp and distinct.

2. Correlation Lamp Image Quality: Not applicable.

3. Binary Time Word: The time word image quality is good. However, numerous software problems and reader-timer interface problems have delayed final reduction of the data.

4. Lens Serial Number Legibility: Good.

D. Stellar Camera (Mission 1101-2)

1. Grid Image Quality: Sharp and distinct.

2. Correlation Lamp Image Quality: Not applicable.

3. Binary Time Word: Same as reported for Mission 1101-1.

4. Lens Serial Number Legibility: Good.

E. Index Camera (Mission 1101-1)

1. Grid Image Quality: Sharp and well defined.

2. Correlation Lamp Image Quality: Not applicable.

3. Camera Number Legibility: The camera number image is weak but readable.

4. Binary Time Word: Same as reported for the stellar cameras.

F. Index Camera (Mission 1101-2)

1. Grid Image Quality: Sharp and distinct.

2. Correlation Lamp Image Quality: Not applicable.

3. Camera Number Legibility: Weak but readable.

4. Binary Time Word: Same as reported for the stellar cameras.

PART IV. MENSURATION QUALITY

A. Fwd-Looking Panoramic Camera

There were 36 requests for mensuration on Mission 1101, 24 on part 1 and 12 on part 2, involving 960 pointings. All mensuration was performed on the Mann 880 Real Time Mode.

The image quality is considered to be better than that obtained from the KH-4A system with respect to pointing accuracy. Those dimensions that could be compared with previous measurements showed a close correlation. The only problem encountered was the filling of the double rail hole which indicates center format. These images are used as the zero reference. When the hole images were obscured, the zero reference point had to be approximated.

B. Aft-Looking Panoramic Camera

Mensuration from the aft camera record was very limited due to the out-of-focus condition.

PART V. FILM PROCESSING

A. Processing Machines and Process Gamma

Film	Part: Entire Mission Machine	Gamma	Part: NA Machine	Gamma
Fwd (Mission 1101-1)	Trenton	2.23	NA	NA
Aft (Mission 1101-1)	Trenton	2.16	NA	NA
Fwd (Mission 1101-2)	Trenton	2.13	NA	NA
Aft (Mission 1101-2)	Trenton	2.12	NA	NA
Stellar (Mission 1101-1)	Trenton	2.29	NA	NA
Stellar (Mission 1101-2)	Trenton	2.43	NA	NA
Index (Mission 1101-1)	Drape	0.87	NA	NA
*Index (Mission 1101-2)	Drape	1.44 (type 3400)	Yardleigh	2.41 (SO-230)

*See para 2, item 6 of Part 5.
NA - Not Applicable.

B. Processing Levels

1. Panoramic Cameras

Film	Primary	Intermediate	Full	Transition	Processing Changes
Fwd (Mission 1101-1)	3%	3%	84%	10%	20
Aft (Mission 1101-1)	0%	8%	85%	7%	16
Fwd (Mission 1101-2)	3%	7%	82%	8%	20
Aft (Mission 1101-2)	3%	5%	82%	10%	26

2. Secondary Cameras

a. Stellar Camera: The stellar camera records were processed in a Trenton processor at a single level of development.

b. Index Cameras: The index camera record of Part I contained film type 3400. Part 2 contained 814 feet of film type 3400 and 209 feet of film type SO-230. The 3400 material was processed in a Drape processor and the SO-230 portion in a Yardleigh processor, both at a single level of development.

C. Film Handling Summary

1. Fwd-Looking Camera

a. Capsule De-Filming

(1) Mission 1101-1: All cameras were defilmed prior to the delivery of the film to the processing site. The film was prespooled, inspected, and processed without incident. The R-2 sample for the panoramic record was not received until after Mission 1101-2 was processed. Samples of film type 3404-292-8-7 (same batch as flight film) were used as a substitute for the R-2 sample. A later evaluation of the R-2 sample showed that it was essentially sensitometrically identical to the substitute film sample. Material from the pre-flight portion of Mission 1101-1 was removed from the aft camera spool for special testing of film resolution characteristics of post flight film. Results of this analysis are included in the processing contractor's evaluation report of Mission 1101.

(2) Mission 1101-2: No problems encountered.

b. Prespooling

(1) Mission 1101-1: No problems encountered.

(2) Mission 1101-2: Accomplished without incident.

c. Manufacturing Splices

(1) Mission 1101-1: Frame 106, pass 56D.

(2) Mission 1101-2: Frame 18, pass 111D.

d. Processing Splices

(1) Mission 1101-1: None other than those normal for mission handling.

(2) Mission 1101-2: None noted.

e. Manufacturing Defects

(1) Mission 1101-1: None noted.

(2) Mission 1101-2: None noted.

f. Processing Anomalies: None.

g. Breakdown: No problems encountered.

2. Aft-Looking Camera

a. Capsule De-Filming

(1) Mission 1101-1: Same as reported for the fwd camera.

(2) Mission 1101-2: Same as reported for the fwd camera.

b. Pre-Spooling

(1) Mission 1101-1: Same as reported for the fwd camera.

(2) Mission 1101-2: Same as reported for the fwd camera.

c. Manufacturing Splices

(1) Mission 1101-1: Frame 22, pass 35D.

(2) Mission 1101-2: Frame 28, pass 87D, frame 29, pass 168D.

d. Processing Splices

(1) Mission 1101-1: None.

(2) Mission 1101-2: None.

e. Manufacturing Defects

(1) Mission 1101-1: None noted.

(2) Mission 1101-2: None noted.

f. Processing Anomalies: None.

g. Breakdown: Accomplished without incident.

3. Index Camera

a. Capsule De-Filming

(1) Mission 1101-1: Some delay was encountered defilming the DISIC due to assembly changes.

(2) Mission 1101-2: No problems encountered.

b. Pre-Spooling

(1) Mission 1101-1: No problems encountered.

(2) Mission 1101-2: No problems encountered.

c. Manufacturing Splices

(1) Mission 1101-1: None noted.

(2) Mission 1101-2: None noted.

d. Processing Splices

(1) Mission 1101-1: None.

(2) Mission 1101-2: None.

e. Manufacturing Defects

(1) Mission 1101-1: None.

(2) Mission 1101-2: None.

f. Processing Anomalies: None.

g. Breakdown: Accomplished without incident.

4. Stellar Camera

a. Capsule De-Filming

(1) Missions 1101-1, 1101-2: Same as the index camera payload of this mission. There was some difficulty associated with defilming the stellar cameras because of the technicians unfamilarity with the configuration.

b. Pre-Spooling

(1) Mission 1101-1: No problems encountered.

(2) Mission 1101-2: No problems encountered.

c. Manufacturing Splices

(1) Mission 1101-1: None noted.

(2) Mission 1101-2: None noted.

d. Processing Splices

(1) Mission 1101-1: None.

(2) Mission 1101-2: None.

e. Manufacturing Defects

(1) Mission 1101-1: None.

(2) Mission 1101-2: None.

f. Processing Anomalies: None.

g. Breakdown: Accomplished without incident.

D. Timetable

Film	Recovered	Received at Processing Site	Priority 1A at NPIC Recd
Fwd (Mission 1101-1)	21 Sep 67/2142Z	22 Sep 67/2315 EST	25 Sep 67/0342 EST
Aft (Mission 1101-1)	"	22 Sep 67/1815 EST	"
Stellar (Mission 1101-1)	"	"	"
Index (Mission 1101-1)	"	"	"
Fwd (Mission 1101-2)	28 Sep 67/2005Z	28 Sep 67/1800 EST	3 Oct 67/0005 EST
Aft (Mission 1101-2)	"	"	"
Stellar (Mission 1101-2)	"	"	"
Index (Mission 1101-2)	"	"	"

No special shipment received at NPIC.

PART VI. PI SUITABILITY

A. Definition of Photographic Interpretation (PI) Suitability

The PI suitability is an assessment of the information content of photographic reconnaissance material and its interpretability. A number of interrelated factors are involved, such as the quality of the photography, the extent of target coverage, scale, and weather limitations. However, the fundamental criteria for assigning a PI suitability rating may be reduced to (a) the scope of the photographic coverage and (b) the degree to which a photographic interpreter may extract useful and reliable information from the material.

PI suitability ratings are categorized as Excellent, Good, Fair, Poor, and Unuseable. These ratings refer to the overall interpretive value of the photography obtained from a particular reconnaissance mission. Individual targets may also be assigned PI suitability ratings. The standards that determine assignment of the various ratings are:

Excellent: The photography is free of degradations by camera malfunctions or processing faults and the weather conditions are favorable throughout. The imagery contains sharp, well-defined edges and corners with no unusual distortions. Contrast is optimum and shadow details, as well as details in the highlight areas, are readily detectable. Observation of small objects and a high order of mensuration are made possible by the consistently good quality of the photography.

Good: The photography is relatively free of degradation or limiting atmospheric conditions. Edges and corners are well defined. No unusual distortions are present. Detection and accurate mensuration of small objects are feasible, but to a lesser degree than in material rated as "Excellent."

Fair: Degradation is present and the acuity of the photography is less than optimum. Edges and corners are not crisply defined and there is loss of detail in shadow and/or highlight areas. Detection and identification of small objects are possible, but accuracy of mensuration is reduced by the fall-off in image quality and the less-than-optimum contrast that prevails.

Poor: Camera-induced degradations and/or weather limitations severely reduce the effectiveness of the photography. Definition of edges and corners is not sharp. Only gross terrain features and culture may be detected or identified and distortion of form may exist. Accurate mensuration of even large objects is doubtful.

Unuseable: Degradation of photography completely precludes detection, identification, and mensuration of cultural details.

B. PI Statistics

1. Target Coverage

	Mission 1101-1	Mission 1101-2	Totals
Priority 1 Targets Programmed	Not available.		
Priority 1 Targets Covered	196	192	388

2. PI Quality Appraisal

Rating	Missiles	Nuclear Energy	Air Facilities	Ports	Elect Commo	Military Activity	Complex	B/C War
Good	15	-	15	9	-	8	2	2
Fair	87	2	48	9	1	46	22	7
Poor	60	5	27	2	-	11	8	2
Totals	162	7	90	20	1	65	32	11

3. Summary of PI Quality Ratings (Percentage)

Good	14
Fair	57
Poor	29

*A discrepancy exists between total number of targets covered and the total PI reports because some targets are covered more repeatedly.

C. PI Comments

1. Atmospheric attenuation: Listed below is the photointerpreter's report of weather conditions for the priority 1 targets covered on this mission:

a.	Clear	236	60%
b.	Scattered Clouds:	73	19%
c.	Heavy Clouds:	26	6%
d.	Haze:	28	7%
e.	Cloud Shadow:	31	8%

2. Terrain Conditions: The terrain conditions were considered good for interpretation purposes.

[redacted]

3. Product Interpretability: The interpretability of the fwd-looking camera record ranges from fair to good throughout the first half of the mission and is generally good throughout the second half of the mission. The aft camera record is considered to be poor to fair throughout the mission due to the existing out-of-focus condition. The improved information content of the second half of the mission is the direct result of the shift in perigee which produced larger scale photography over the prime target areas.

[redacted]

[redacted]

RESOLUTION TARGET DATA

4. Resolution Target Analysis

Target Designator	A		B	
Camera (Looking)	Fwd	Aft	Fwd	Aft
Pass	14D	14D	14D	14D
Frame	13	20	31	37
Date of Photography	16 Sep 67	16 Sep 67	16 Sep 67	16 Sep 67
Universal Grid Coordinates	64.3 - 01.8	10.9 - 00.5	48.1 - 04.4	27.4 - 02.3
Geographic Coordinates of Format Center	42-50N 079-50W	42-42N 079-50W	40-14N 079-10W	40-15N 079-13W
Altitude (ft)	614,641	609,650	601,721	597,916
Camera				
Pitch (deg)	NA	NA	NA	NA
Roll (deg)	NA	NA	NA	NA
Yaw (deg)	NA	NA	NA	NA
Local Sun Time	1120	1120	1121	1121
Solar Elevation (deg)	48°41'	48°49'	52°02'	51°21'
Solar Azimuth (deg)	165°	165°	164°	164°
Exposure (sec)	1/313	1/394	1/320	1/403
Processing Level	Full	Full	Full	Full
Vehicle Azimuth (deg)	168°51'	169°07'	169°31'	169°43'
Filter (Wratten)	23A	21	23A	21
Target Type	51/51 T-Bar	51/51 T-Bar	51/51 T-Bar	51/51 T-Bar
Target Contrast	Medium	Medium	Medium	Medium
Weather Conditions	Light Haze	Light Haze	Scattered Clouds	Scattered Clouds

GROUND RESOLUTION IN FEET AS DETERMINED FROM THE ORIGINAL NEGATIVE

	A				B				
	Along Track		Across Track			Along Track		Across Track	
	Fwd	Aft	Fwd	Aft		Fwd	Aft	Fwd	Aft
Observer 1	16	*	*	*	Observer 1	12	*	8	16
Observer 2	12	*	16	*	Observer 2	12	*	8	16
Observer 3	12	*	16	*	Observer 3	8	*	8	16

*No bars resolved.
NA - Not Available.

[redacted]

Target Designator	A		B	
Camera (Looking)	Fwd	Aft	Fwd	Aft
Pass	127D	127D	127D	127D
Frame	23	29	15	21
Date of Photography	23 Sep 67	23 Sep 67	23 Sep 67	23 Sep 67
Universal Grid Coordinates	41.8 - 04.1	33.6 - 02.5	24.1 - 01.6	51.0 - 02.3
Geographic Coordinates of				
Format Center	35-18N 116-11W	35-19N 116-14W	36-18N 116-23W	36-19N 116-26W
Altitude (ft)	517,146	516,441	518,250	517,466
Camera				
Pitch (deg)	NA	NA	NA	NA
Roll (deg)	NA	NA	NA	NA
Yaw (deg)	NA	NA	NA	NA
Local Sun Time	1015	1015	1015	1015
Solar Elevation (deg)	49°07'	49°06'	48°10'	48°09'
Solar Azimuth (deg)	141	141	141	141
Exposure (sec)	1/372	1/468	1/372	1/468
Processing Level	Full	Full	Full	Full
Vehicle Azimuth (deg)	168	168	168	168
Filter (Wratten)	23A	21	23A	21
Target Type	51/51 T-Bar	51/51 T-Bar	Pahrump	Pahrump
Target Contrast	Medium	Medium	High	High
Weather Conditions	Clear	Clear	Clear	Clear

GROUND RESOLUTION IN FEET AS DETERMINED FROM THE ORIGINAL NEGATIVE

	A				B				
	Along Track		Across Track			Along Track		Across Track	
	Fwd	Aft	Fwd	Aft		Fwd	Aft	Fwd	Aft
Observer 1	8	*	16	*	Observer 1	7'8"	8'7"	13'8"	10'10"
Observer 2	8	*	16	*	Observer 2	6'1"	8'7"	12'2"	8'7"
Observer 3	8	*	16	*	Observer 3	6'10"	7'8"	12'2"	8'7"

*No bars resolved.
NA - Not Available.

Target Designator	A		B	
Camera (Looking)	Fwd	Aft	Fwd	Aft
Pass	127D	127D	143D	143D
Frame	13	19	20	26
Date of Photography	23 Sep 67	23 Sep 67	24 Sep 67	24 Sep 67
Universal Grid Coordinates	68.2 - 03.6	07.1 - 02.8	42.0 - 02.6	32.2 - 03.8
Geographic Coordinates of Format Center	36-33N 116-26W	36-34N 116-29W	35-08N 118-33W	35-08N 118-35W
Altitude (ft)	518,553	517,721	514,026	513,641
Camera				
Pitch (deg)	NA	NA	NA	NA
Roll (deg)	NA	NA	NA	NA
Yaw (deg)	NA	NA	NA	NA
Local Sun Time	1015	1015	1015	1015
Solar Elevation (deg)	47056'	47055'	47046'	47045'
Solar Azimuth (deg)	141	141	142	142
Exposure (sec)	1/372	1/463	1/372	1/611
Processing Level	Full	Full	Full	Full
Vehicle Azimuth (deg)	168	168	167°40'	167°40'
Filter (Wratten)	23A	21	25	21
Target Type	Indian Springs	Indian Springs	51/51 T-Bar	51/51 T-Bar
Target Contrast	High	High	Medium	Medium
Weather Conditions	Scattered Clouds	Scattered Clouds	Clear	Clear

GROUND RESOLUTION IN FEET AS DETERMINED FROM THE ORIGINAL NEGATIVE

	A				B				
	Along Track		Across Track			Along Track		Across Track	
	Fwd	Aft	Fwd	Aft		Fwd	Aft	Fwd	Aft
Observer 1	8'7"	*	*	*	Observer 1	12	*	16	16
Observer 2	8'7"	*	*	*	Observer 2	12	*	16	12
Observer 3	8'7"	*	*	*	Observer 3	12	*	16	12

*No bars resolved.
NA - Not Available.

Target Designator	A		B	
Camera (Looking)	Fwd	Aft	Fwd	Aft
Pass	157D	157D	173D	173D
Frame	9	16	19	25
Date of Photography	25 Sep 67	25 Sep 67	26 Sep 67	26 Sep 67
Universal Grid Coordinates	32.2 - 01.2	43.2 - 01.0	40.8 - 04.0	34.6 - 02.9
Geographic Coordinates of				
Format Center	41-19N 076-45W	41-13N 076-46W	41-09N 078-58W	41-10N 079-01W
Altitude (ft)	515,579	514,762	514,693	514,293
Camera				
Pitch (deg)	NA	NA	NA	NA
Roll (deg)	NA	NA	NA	NA
Yaw (deg)	NA	NA	NA	NA
Local Sun Time	0950	0950	0949	0949
Solar Elevation (deg)	40°45'	40°50'	39°24'	39°23'
Solar Azimuth (deg)	137	137	137	137
Exposure (sec)	1/303	1/371	1/304	1/370
Processing Level	Full	Full	Full	Full
Vehicle Azimuth (deg)	166°40'	166°40'	166°30'	166°30'
Filter (Wratten)	23A	21	25	23A
Target Type	51/51 T-Bar	51/51 T-Bar	51/51 T-Bar	51/51 T-Bar
Target Contrast	Medium	Medium	Medium	Medium
Weather Conditions	Clear	Clear	Clear	Clear

GROUND RESOLUTION IN FEET AS DETERMINED FROM THE ORIGINAL NEGATIVE

	A					B			
	Along Track		Across Track			Along Track		Across Track	
	Fwd	Aft	Fwd	Aft		Fwd	Aft	Fwd	Aft
Observer 1	6'4"	*	8	*	Observer 1	12	*	12	16
Observer 2	6'4"	16	12	*	Observer 2	12	*	12	16
Observer 3	6'4"	16	8	*	Observer 3	12	16	12	16

*No bars resolved.
NA - Not Available.

PART VII. MISSION DATA

	Pan	Master Take-up Horizon	Master Supply Horizon	Slave Pan	Slave Take-up Horizon	Slave Supply Horizon	Mission 1101 Stellar		Mission 1101 Index
							Port	Stbd	
Camera Number	303	*	*	302	*	*	3		3
Reseau Number	NA	NA	NA	NA	NA	NA	1P	1	102
Lens Serial Number	I-172	E23764	E23784	I-167	E23806	E23788	1P	1	102
Slit Width	.150 .171 .218 .272 .250	NA	NA	.134 .134 .175 .225 .200	NA	NA	NA	NA	NA
Aperture	NA	F/8.0	F/6.3	NA	F/6.3	F/6.3	F/2.8	F/2.8	F/4.5
Exposure Time (sec)	NA	1/100	1/100	NA	1/100	1/100	1.5	1.5	1/250, 1/500
Filter (Wratten)	23A 25	25	25	21 23A	25	25	NA	NA	12
Focal Length (mm)	609.625	54.652	54.772	609.600	54.599	54.648	75.811	75.698	76.901
Film Length (ft)	16,000	NA	NA	16,000	NA	NA	2,000		1,800/200
Splices	5	NA	NA	5	NA	NA	0		1
Emulsion	284-3-6-7	NA	NA	284-3-7-6-7	NA	NA	231-9-7-7		156-9-8-7
Film Type	3404	3404	3404	3404	3404	3404	3401		SO-230-6-1 3400/SO230
Resolution Data (L/mm)									
Static									
High Contrast	*	NA	NA	263	NA	NA	NA	NA	79
Low Contrast	145	NA	NA	150	NA	NA	NA	NA	74
Dynamic									
I High Contrast	209	NA	NA	195	NA	NA	NA	NA	*
I Low Contrast	130	NA	NA	122	NA	NA	NA	NA	*
P High Contrast	213	NA	NA	207	NA	NA	NA	NA	*
P Low Contrast	118	NA	NA	118	NA	NA	NA	NA	*

NA - Not applicable.
*Not available.

PART VIII. ENGINEERING EXPERIMENTS

A. Mission 1101 Experiments

A "during operation filter change" and a "through exposure test" were accomplished on Mission 1101. The filter experiment occurred on pass 143D. The first 36 frames of the fwd-looking camera record were exposed using a Wratten 25 filter and the remaining 17 frames using a Wratten 23A filter. On the aft camera record, the first 16 frames were exposed using a Wratten 23A filter and the remaining 37 frames using a Wratten 21 filter.

The through exposure test occurred on pass 159D. The various slit widths used during the operation are correlated with the applicable frames below:

Frame Number	Fwd-Looking Slit Width	Aft-Looking Slit Width
1-11	0.218	0.175
12-13	0.150	0.134
14-16	0.171	0.134
17-19	0.218	0.175
20-21	0.272	0.225
22-24	0.218	0.200
25-27	0.250	0.175
28-30	0.250	0.200
31-50	0.218	0.175

B. Analysis of Experiments: An analysis of these experiments is being conducted by the camera contractor. The original negative is not available at the NPIC for a detailed PI analysis at this time.

C. Schedule of Future Experiments

Mission		
1102	Bi-spectral	Wratten 25 and a SF 05 (Green Filter)
	Polarizer	Polocoat, 20° Angle
	SO-230	"Faster," 3404 type film
1103	Bi-spectral	Wratten 25 and SF 05 (Green Filter), Operational
	Wide Band Filter	Wratten 12
	SO-380	Ultra Thin Base Film
1104	SO-180	Color Infrared Film
	Night	SO-340 (Tri X Type emulsion)

Tentative Experiments

1105	Kodachrome II	High Resolution Color Film
1106 & 1107	Polarizer Through Focus	Winter, Proper Azimuth Stepped Glass Filter

FIGURE 1. BEST IMAGE QUALITY

NPIC L-4800

Image quality comparable to the best of this mission. MIP-95.

FIGURE 2. CORRESPONDING COVERAGE

NPIC L-4801

Corresponding coverage as imaged by the aft camera. Out-of-focus condition.

[redacted]

	FIGURE 1	FIGURE 2
Camera	303	302
Pass	159D	159D
Frame	2	9
Date of Photography (GMT)	25 Sep 67	25 Sep 67
Universal Grid Coordinates	39.0 - 01.5	36.2 - 00.8
Enlargement Factor	20X	20X
Geographic Coordinates	38-36N 121-21W	36-40N 120-51W
Altitude (ft)	513,762	510,043
Camera Attitude:		
Pitch (deg)	NA	NA
Roll (deg)	NA	NA
Yaw (deg)	NA	NA
Local Sun Time	0954	0954
Solar Elevation (deg)	43°04'	43°04'
Solar Azimuth (deg)	141°	141°
Exposure (sec)	1/333	1/477
Vehicle Azimuth (deg)	170°32'	170°32'
Processing Level	Full	Full

NA - Not Available.

[redacted]

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Control System Only

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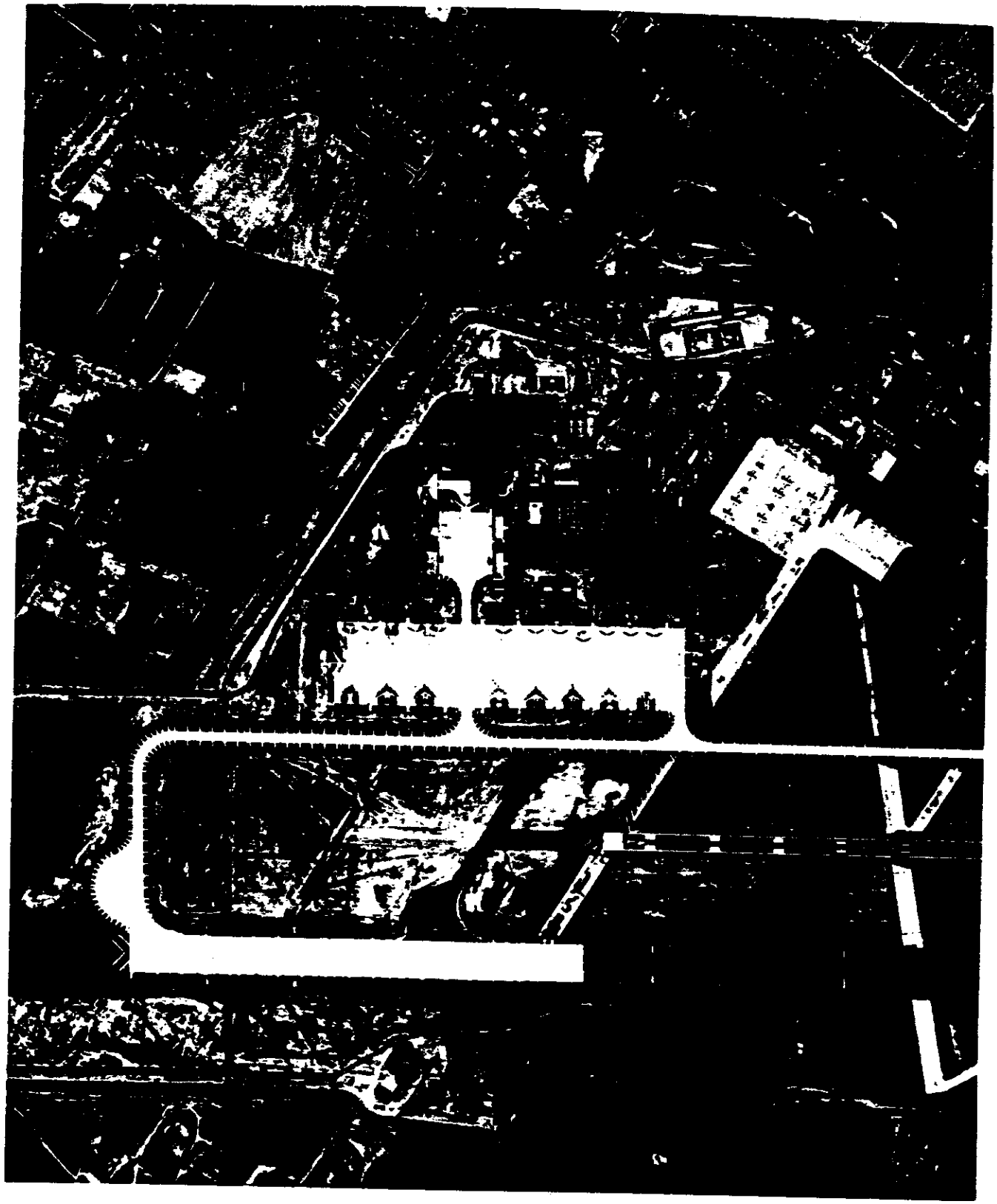

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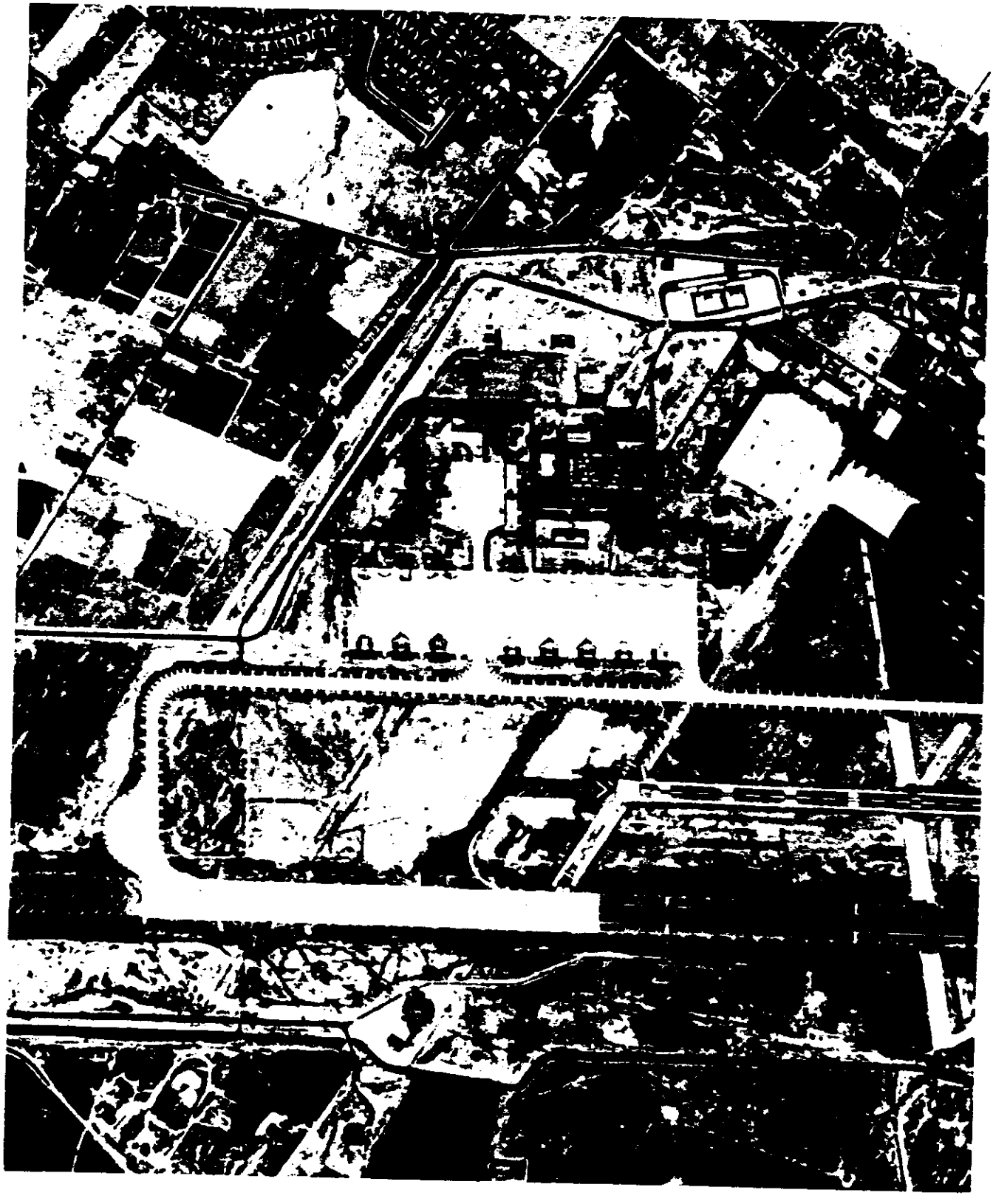

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FIGURE 3. STELLAR FORMAT (MISSION 1101-1)

NPIC L-4802

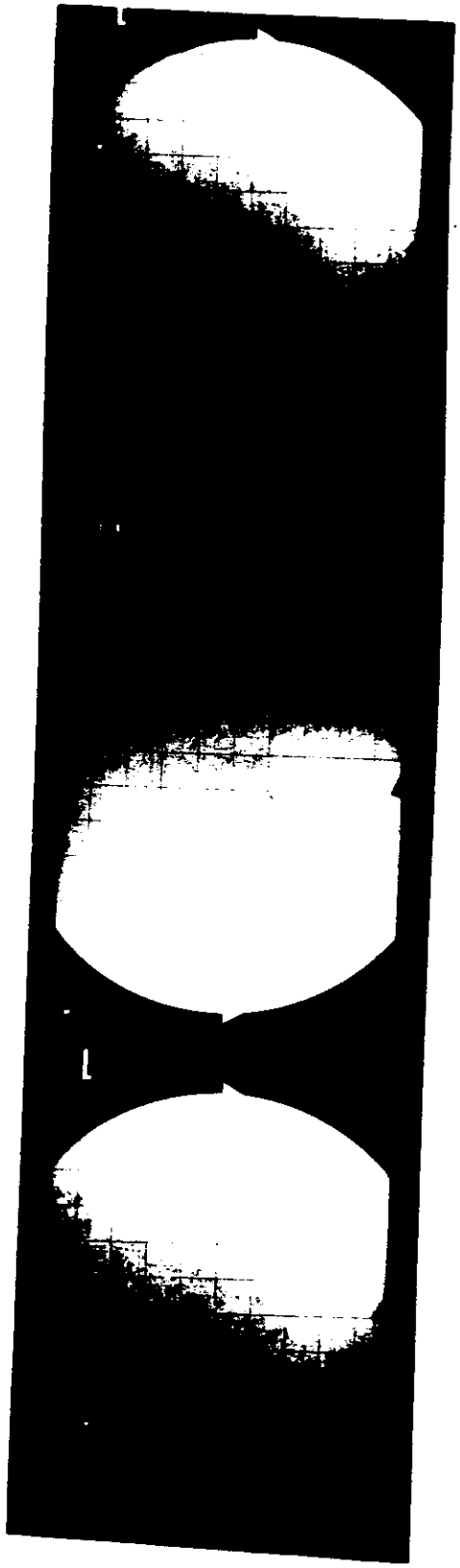
FIGURE 4. STELLAR FORMAT (MISSION 1101-2)

NPIC L-4803

Flare pattern typical throughout the mission.

[redacted]

	FIGURE 3	FIGURE 4
Mission Number	1101-1	1101-2
Stellar Frame Numbers	465S, 460P, 466S	943S, 938P, 944S
Pass	14D	111D
Date of Photography	16 Sep 67	22 Sep 67
Enlargement Factor	2.5	2.5
Exposure (sec)	1.5	1.5



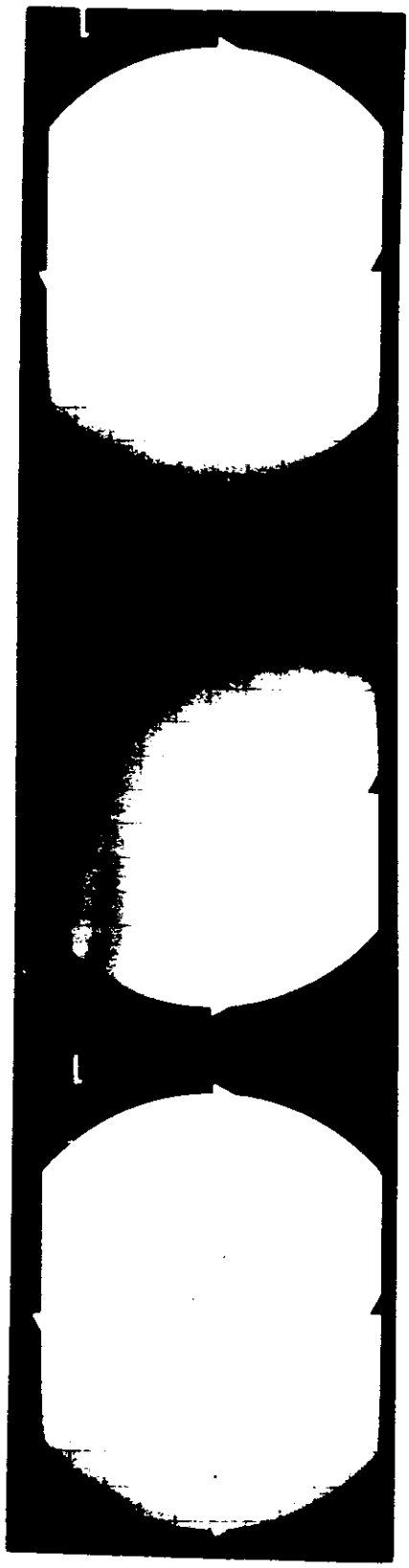


FIGURE 5. INDEX FORMAT (MISSION 1101-1)

NPIC L-4804

Best of mission.

FIGURE 5

Mission Number	1101-1
Pass Number	56D
Frame Number	45
Date of Photography	19 Sep 67
Enlargement Factor	Contact
Exposure (sec)	1/250

[redacted]

[redacted]

Special Study: Slant Range Computations Related to Universal Grid Coordinates for the KH-4B Camera System

This special study develops 3 equations for computing the slant range of a target related to the universal grid coordinates on KH-4B photography. This study also shows the accuracy that can be expected when the slant range is computed from 2 of these equations.

Equation (1) $S = H \text{ Sec } w \text{ Sec } \phi$

where
- S = Slant Range
- H = Vehicle Height
- w = Pitch
- ϕ = Scan Angle

Equation (1) represents a slant range based on a flat earth (tangent plane). It has an inherent error due to earth curvature. The maximum difference in equation (1), due to earth curvature, at universal coordinate (0, 5) is 1.24 nautical miles (nm) or 0.955 percent.

Table 1, developed from equation (1), using a 15° nominal pitch angle at the center of format, provides a scale factor of F = Sec w Sec ϕ for each coordinate of the universal grid. Thus, the slant range of a universal grid coordinate can be quickly computed from the product (H)(F). When the slant range is computed from the product (H)(F) no allowance can be made for changes in vehicle attitude or earth curvature.

To allow approximate corrections for earth curvature, equation (2), was developed:

Equation (2) $S = (H)(F) + F\left[\sqrt{R^2 + H^2(F^2-1)} - R\right]$

where
- S = Slant Range
- H = Vehicle Height
- F = Scale Factor = Sec w Sec ϕ
- R = Radius of Earth = 3,437 nm can be used.

Equation (2) is an approximation formula with a maximum slant range difference, at universal grid coordinate (0, 5), of 0.02 nm or 0.015 percent.

The development of equation (2) is as follows:

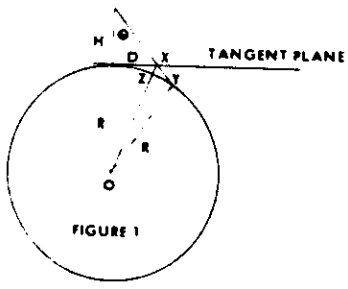


FIGURE 1

$\text{Cos } \Theta = \dfrac{H}{H \text{ sec } w \text{ sec } \phi}$

$= \cos w \cos \phi$ $\quad \Theta$ = Cone Angle

$D = H \tan \Theta$

where D is the ground distance from the nadir to the point where the principal ray would intersect the flat earth (tangent plane).

In right triangle x, y, z of Figure 1,

$$\text{side } (xz) = B = \sqrt{R^2 + D^2} - R$$

$$= B = \sqrt{R^2 + H^2 \tan^2 \theta} - R$$

$$= B = \sqrt{R^2 + H^2 (\sec^2 \theta - 1)} - R$$

$$= B = \sqrt{R^2 + H^2 \left[(\sec w \sec \phi)^2 - 1\right]} - R$$

$\therefore$ side $(xy) \approx A = B \sec \xi$ where A is the correction for earth curvature

$\approx A \approx B \sec w \sec \phi$ assuming angle $(zxy) =$ is approximately equal to θ

$$\approx A \approx (\sec w \sec \phi) \left[\sqrt{R^2 + H^2 \left[(\sec w \sec \phi)^2 - 1\right]} - R\right]$$

$$\therefore S \approx H \sec w \sec \phi \left[\sqrt{R^2 + H^2 (\sec^2 w \sec^2 \phi - 1)} - R\right]$$

Using the scale factor $F = (\sec w \sec \phi)$ the slant range is

Equation (2) $\quad S \approx (H)(F) + F\left[\sqrt{R^2 + H^2 \left[F^2 - 1\right]} - R\right]$

When it is necessary to compute the slant range more accurately than can be given by either the product (H)(F), as developed from equation (1) or equation (2) then by applying the law of sines (Figure 2) we have:

$$\frac{\text{Sin } A}{R} = \frac{\text{Sin } B}{R + H} \quad \text{where the cone angle } \theta = A = \text{Cos}^{-1}\left[\cos w \cos \phi\right]$$

$$\sin B = \frac{(R+H) \sin A}{R}$$

$A+B+C = 180$ and $C = 180-A-B$ $\qquad 90^\circ \leq B \leq 180^\circ$

$$\frac{\sin C}{S} = \frac{\sin A}{R}$$

Equation (3) $\quad S = \dfrac{R \sin (180-A-B)}{\sin A}$

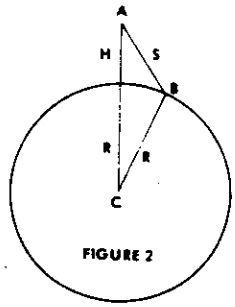


FIGURE 2

When H = 100 nm, the slant range for the universal grid coordinate (0, 5), when computed with equation (1), is 128.60 nm (assuming no errors). The value of S computed from equation (3) is 129.84 nm. Therefore, the maximum difference in slant range between equations (1) and (3) is 1.24 nm or 0.955 percent. Using equation (2), the slant range is computed to be 129.82 nm. Therefore, the maximum difference in slant range between equations (2) and (3) is 0.02 nm or 0.015 percent.

Conclusion: Equation 3 is the best formula for determining slant range but it is still an approximation since the true shape of the earth is not taken into account. When the Hough Ellipsoid radius is used for R, this equation provides the best available answer.

Of the 3 equations above, equation (1), i.e., the product (H)(F), is the one which is most useful when nominal accuracy is acceptable. In equation (2) and (3), allowances for earth curvature and changes in vehicle attitude can be made. Grid placement and line weights of the universal grid will contribute to the accuracy of the slant range values produced, but these errors have not been considered in this study.

The expected standard deviation of the slant range (σS) related to equation (1), when there are errors in the scan angle, pitch angle, or altitude, was developed using the law of propagation of errors as expressed by equation (P):

$$\text{Equation (P)} \quad (\sigma s)^2 = \begin{bmatrix} \frac{\partial s}{\partial H} & \frac{\partial s}{\partial \omega} & \frac{\partial s}{\partial \phi} \end{bmatrix} \begin{bmatrix} (\sigma H)^2 & 0 & 0 \\ 0 & (\sigma \omega)^2 & 0 \\ 0 & 0 & (\sigma \phi)^2 \end{bmatrix} \begin{bmatrix} \frac{\partial s}{\partial H} \\ \frac{\partial}{\partial \omega} \\ \frac{\partial s}{\partial \phi} \end{bmatrix}$$

From equation (1) $S = H \text{ Sec } w \text{ Sec } \phi$ and the partial derivatives of S with respect to H, w, and ϕ are:

$$\partial s/\partial H = F$$
$$\partial s/\partial \omega = s \text{ Tan } \omega$$
$$\partial s/\partial \phi = s \text{ Tan } \phi$$

Substitution into equation (P) yields

$$(\sigma s)^2 = \begin{bmatrix} F & s \text{ Tan } \omega & s \text{ Tan } \phi \end{bmatrix} \begin{bmatrix} (\sigma H)^2 & 0 & 0 \\ 0 & (\sigma \omega)^2 & 0 \\ 0 & 0 & \sigma \phi)^2 \end{bmatrix} \begin{bmatrix} F \\ S \text{ Tan } \omega \\ S \text{ Tan } \phi \end{bmatrix}$$

Considering a maximum case, we put H = 100 nm, choose grid coordinates (0, 5) = (Ø, w) = (35°31'40", 17°09'43") and set the standard deviations* of H, w, and Ø such that $(\sigma H)^2 = 0.0049$ and $(\sigma w)^2 = (\sigma \phi)^2 = 0.00004874$ and substitute these values into equation (P). The result is then σS = 0.70 nm.

*The standard deviations for H, w, and Ø are:

$\sigma H = \pm 0.07$ nm = ± 425 ft.
$\sigma w = \pm 0.4^{o}$
$\sigma \phi = \pm 0.4^{o}$

These values were arrived at by an analysis of previous KH-4A missions and may not hold for the KH-4B camera system.

List of Symbols

S = Slant Range
ϕ = Scan Angle
w = Pitch
H = Vehicle Height
R = Radius of Earth = 3437 nautical miles
F = Scale Factor
θ = Cone Angle
Γ = Ground Distance
$\approx$ Means Approximately Equal To
σ = Standard Deviation
∂ = Partial Derivative
ξ Is an angle approximately equal to the cone angle
$\therefore$ = Therefore

Instructions for use of the Universal Grid KH-4B.

Place the film with the title readable and the data block along the top edge away from the viewer. The camera number (on the near edge) will not be readable. Place the grid over the film with the lettering upright and readable.

Align X-0 along the left edge of the format.
Align Y-0 along the bottom edge of the format.

The camera number will be between X-55 and X-56 below Y-0.
The data block will be at X-28, Y-6.

Example: X-37.0/Y2.8 indicates the center of format.

Table 1.

Y	0	1	2	3	4	5
Pitch Angle	12°27'49"	13°24'07"	14°20'31"	15°17'00"	16°13'20"	17°09'43"
X Scan Angle Deg-Min-Sec						
0 (35-31-40)	1.258400	1.263150	1.268278	1.273901	1.279703	1.286012
1 (34-35-16)	1.243996	1.248691	1.253761	1.259220	1.265054	1.271292
2 (33-38-53)	1.230249	1.234892	1.239906	1.245305	1.251075	1.257243
3 (32-42-29)	1.217122	1.221716	1.226676	1.232018	1.237726	1.243828
4 (31-46-06)	1.204597	1.209144	1.214053	1.219339	1.224989	1.231028
5 (30-49-42)	1.192641	1.197143	1.202003	1.207237	1.212830	1.218810
6 (29-53-18)	1.181235	1.185694	1.190508	1.195692	1.201231	1.207154
7 (28-56-55)	1.170361	1.174778	1.179547	1.184684	1.190173	1.196041
8 (28-00-31)	1.159990	1.164356	1.169083	1.174187	1.179627	1.185448
9 (27-04-08)	1.150112	1.154453	1.159140	1.164188	1.169581	1.175348
10 (26-07-44)	1.140702	1.145008	1.149656	1.154662	1.160012	1.165732
11 (25-11-20)	1.131747	1.136019	1.140631	1.145598	1.150906	1.156580
12 (24-14-57)	1.123234	1.127474	1.132051	1.136980	1.142248	1.147880
13 (23-18-33)	1.115144	1.119352	1.123897	1.128791	1.134020	1.139612
14 (22-22-10)	1.107467	1.111647	1.116160	1.121020	1.126214	1.131767
15 (21-25-46)	1.100187	1.104339	1.108823	1.1136512	1.118811	1.124327
16 (20-29-22)	1.093292	1.097421	1.101876	1.1066743	1.111802	1.117283
17 (19-32-59)	1.086780	1.090882	1.095311	1.1000805	1.105177	1.110626
18 (18-36-35)	1.080630	1.084678	1.089113	1.0938555	1.098923	1.104342
19 (17-40-12)	1.074839	1.078896	1.083276	1.0879934	1.093034	1.098423
20 (16-43-48)	1.069394	1.073431	1.077789	1.0824819	1.087497	1.092859
21 (15-47-24)	1.064289	1.068306	1.072644	1.0773144	1.082306	1.087642
22 (14-51-01)	1.059518	1.063517	1.067835	1.0724847	1.077454	1.082766
23 (13-54-37)	1.055071	1.059053	1.063352	1.067983	1.072931	1.078221
24 (12-58-14)	1.050943	1.054910	1.059193	1.063805	1.068734	1.074003
25 (12-01-50)	1.047127	1.051080	1.055347	1.059942	1.064853	1.070104
26 (11-05-26)	1.043619	1.047558	1.051811	1.056391	1.061286	1.066518
27 (10-09-03)	1.040414	1.044341	1.048581	1.053147	1.058027	1.063243
28 (9-12-39)	1.037506	1.041422	1.045650	1.050204	1.055070	1.060271
29 (8-16-16)	1.034893	1.038800	1.043017	1.047559	1.052412	1.057601
30 (7-19-52)	1.032570	1.036467	1.040675	1.045207	1.050049	1.055226
31 (6-23-28)	1.030534	1.034423	1.038623	1.043145	1.047978	1.053145
32 (5-27-05)	1.028782	1.032665	1.036857	1.041372	1.046197	1.051356
33 (4-30-41)	1.027312	1.031189	1.035376	1.039884	1.044702	1.049853
34 (3-34-18)	1.026122	1.029995	1.034177	1.038680	1.043492	1.048637
35 (2-37-54)	1.025210	1.029080	1.033258	1.037757	1.042565	1.047705
36 (1-41-30)	1.024576	1.028443	1.032618	1.037114	1.041919	1.047057
37 (00-45-07)	1.024217	1.028093	1.032257	1.036752	1.041555	1.046690
38 (00-11-17)	1.024135	1.028000	1.032173	1.036668	1.041471	1.046606

[redacted]

	0 12°27'43"	1 [illegible]°24'07"	2 14°20'31"	3 15°17'00"	4 16°13'20"	5 17°09'43"
39 ([illegible])	1.024327	1.028193	1.032368	1.036863	1.041667	1.046803
([illegible]-04-04)	1.024796	1.028664	1.032840	1.037338	1.042144	1.047282
(3-00-07)	1.025542	1.029413	1.033592	1.038093	1.042903	1.048044
([illegible]-56-5[illegible])	1.026564	[illegible]0439	1.034622	1.039127	1.043942	1.049089
([illegible]-14)	1.027866	[illegible]1745	1.035934	1.040445	1.0[illegible]5266	1.050419
([illegible])	[illegible]	[illegible]334	1.037529	1.04[illegible]	1.0[illegible]6875	1.052037
([illegible])	[illegible]	[illegible]5200	1.039409	1.04[illegible]935	1.048772	1.053942
([illegible]-25)	[illegible]	[illegible]7364	1.0415764	1.0461120	1.0509588	1.0561404
([illegible])	[illegible]	[illegible]8133	1.0440348	1.0485811	1.0534394	1.0586332
([illegible]5-12)	[illegible]	[illegible]3537	1.0467864	1.0513446	1.0562157	1.0614232
([illegible]-31-3[illegible])	1.041[illegible]	[illegible]5591	1.0498366	1.054408	1.059293	1.064516
([illegible])	[illegible]	[illegible]8929	1.053187	1.057774	1.062674	1.067914
([illegible])	[illegible]	[illegible]2573	1.056847	1.061449	1.0[illegible]6366	1.071624
([illegible])	1.05255[illegible]	[illegible]28	1.060818	1.065437	1.070373	1.075651
([illegible]-10)	1.056[illegible]10	[illegible]0798	1.065105	1.069743	1.0[illegible]4699	[illegible]
([illegible])	[illegible]	[illegible]391	1.069716	1.074374	[illegible]	[illegible]
([illegible])	[illegible]290	[illegible]	1.074660	[illegible]	[illegible]	[illegible]
([illegible]-0[illegible]-2[illegible])	[illegible]	[illegible]5574	1.079941	[illegible]	[illegible]	[illegible]
([illegible]-02-45)	[illegible]	[illegible]1178	1.085567	1.090294	1.095346	1.100747
([illegible]-59-[illegible])	[illegible]	[illegible]133	1.091547	1.096300	1.10379	1.106810
([illegible])	[illegible]341	[illegible]452	1.097892	1.102672	[illegible]	[illegible]
([illegible])	[illegible]	[illegible]141	1.104607	1.109417	1.114557	1.120052
([illegible]-45-[illegible])	1.103050	1.107213	1.111708	1.116549	1.121722	1.127253
(22-[illegible])	[illegible]	[illegible]	1.119223	1.124097	1.129305	1.134873
([illegible]-1-0[illegible])	[illegible]	[illegible]	1.127106	1.132014	1.137259	[illegible]
([illegible]-30)	[illegible]	[illegible]	1.135430	1.140374	1.145658	[illegible]
([illegible]-33-5[illegible])	1.135274	[illegible]558	1.144185	1.149167	[illegible]	[illegible]
([illegible]-30-17)	[illegible]	[illegible]8728	1.153392	1.158414	[illegible]	[illegible]
([illegible])	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
([illegible])	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]782	[illegible]
([illegible])	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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([illegible]-02)	[illegible]	[illegible]214	[illegible]	[illegible]	[illegible]	[illegible]
([illegible]-20)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
([illegible]4-[illegible]-[illegible]9)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]