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APPENDIX A

MURAL SYSTEM PERFORMANCE EVALUATION

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APPENDIX A

MURAL SYSTEM PERFORMANCE EVALUATION

1. INTRODUCTION

ACIC participation on the PET Evaluation Team was to evaluate the potential of the photographic materials obtained from the Mural System to satisfy cartographic objectives. This potential is dependent upon the following factors:

a. scale
b. mensurability of the photographic image
c. photographic geometry
d. auxiliary data
e. desirable cartographic products

Item (a) specifies the size of images detected in a photograph.

Item (b) is the result of a combination of all those factors which affect photographic image quality. Anything which tends to degrade the information content of a photograph as regards textures, tone contrasts, acuity, etc. will generally affect adversely the mensurability of a photographic image using either monoscopic or stereoscopic methods.

Under Item (c), unless a camera system can be used to recover the spatial geometry of the object imaged with respect to a given coordinate reference frame, it is little more than a detection and qualitative interpretation device and as such has little potential for mapping.

Item (d) is that information which is used to relate the camera frame of reference to terrain and consists of such things as time, camera station position, system relationships, camera calibration, etc.

Item (e) are those products which are derived using the materials developed by the acquisition system which meet the requirements of a user. A sampling of such products are:

a. enlargements and rectification
b. photomaps
c. maps
d. point bases
e. target relationships, etc.

Primary evaluation of the Mural System was based on the performance of Mission 1002-1. Where data was lacking from this mission, data from

other missions was selected to support the primary evaluation.

2. SCOPE

The information presented in this paper is directed towards the evaluation of the performance of frame and stellar cameras. Panoramic camera performance will only be considered as it affects exploitation of the Mural System in mapping activitites and in its relation to the operation of the frame stellar cameras.

3. INDEX FRAME CAMERA EVALUATION

Three lines of inquiry were followed to evaluate the index frame camera for Mission 1002-1:

a. camera malfunction and format titling
b. camera calibration
c. image mensurability

3.1 Camera Malfunctions and Format Titling

Camera malfunctions are listed as follows:

a. Exposure correlation: The number of frame prints and the number of frame triggers indicated in the master panoramic photographs were not in agreement. 392 frame triggers were indicated vs 363 frame exposures plus 19 frame slips that were not numbered.

b. Uneven frame vs panoramic exposure interval: The master panoramic camera usually triggered the frame camera every 7th exposure. Starting with revolution 21D, exposure 130, this sequence of operation was interrupted resulting in reduced forward lap or none at all. The repetitive triggering of the frame camera as shown on the panoramic makes it extremely difficult if not impossible to determine the actual time of index stellar exposure. These difficulties showed up also in revolution 24D, 25D, 31A, 36D, 37D and 38D. Operation after 38D appeared satisfactory. Table I below is an extract for Pass 24D to indicate the nature of the problem. This is believed to be due to malfunction of the stellar index camera programmer or center of format switch. The latter is not as probably as the former as time word read-out also controlled by the center of format switch is normal on the master panoramic camera.

TABLE I

Frame/Pan Trigger Correlation for Pass 24D

Frame Exposure Number	Pan Photo Showing Indicated Frame Trigger	Forward Overlap	Pan Photo Interval	System Time (seconds)
216	13			40289
	14			
	15			
217	35	0°/°	22	40345
	36			
218	53	0°/°	17	40389
219	72	0°/°	19	
	73			
	74			
	75			
220	87	9°/°	15	40470
	88			
221	108	0°/°	21	40519
	109			
222	128	0°/°	20	40565
	129			
	130			
223	146	0°/°	18	40607
	147			
224	168	0°/°	22	40656
	169			
	170			

c. Double Exposure:

Double exposures were contained in photos 250, 251 and 253 which occurred in revolution 37D. Panoramic photos 61 thru 138 were exposed during this time. This attributed to malfunction of the metering solenoid and may be related to the programmer failure.

d. Time Correlation:

In several instances frame exposure time could not be determined from the corresponding pan exposure due to edge fog on the pan (43 times), obscuration by the Kodak trade name in the film (10 times) and scratch marks (6 times). Data block index lamp and camera number on the AFT camera did not operate after revolution 24D exposure 35. This is due to lamp burn-out.

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e. Light Streaks:

A great many photos were affected by light streaks. While the streaks affect only a small percent of overall coverage, because of the small scale of the photography, they result in obscuring detail over an area up to 600 km^2 on each frame photograph affected. This is caused by reflection of light coming around the edge of the reseau as it sits prior to transport and exposure by painting reseau edges.

f. Film Titling:

Security classification and frame numbers fall in the image area on 20 frames. Frame numbers themselves were assigned in consecutive order on exposures having images recorded. Where an exposure was made but no image recorded, no frame number was assigned. All stellar exposures were numbered consecutively regardless of image content. As a result of this difference in numbering on frame and stellar exposures, there is no consecutive one for one correlation between frame and stellar photo throughout a mission. This makes correlation between frame and stellar photographs difficult.

3.2 Camera Calibration

Frame camera calibration is tied to the frame reseau which is in turn correlated to the stellar reseau through an orientation matrix. Frame reseau calibration is accomplished by stellar means which have not proved satisfactory to tie down lens distortion in the extreme corners of the photograph. Recent test results indicate this deficiency can be corrected using the materials obtained from a mission. Procedures are now being instituted to determine future lens calibration using goniometer methods and by control in the manufacturing process.

Evaluation of the frame reseau was based on the following criteria :

a. control of line weight
b. completeness of the reseau
c. distortion of the reseau in photographic imagery

The reseau in Mission 1002-1 and these in other recent missions have had consistent line weight throughout with a maximum of 10μ and could be seen on all reproductions against various backgrounds and densities. It would be desirable if this line weight could be reduced to 5μ in order to improve coordinate mensuration on enlarged frame copies. The reseau

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is reasonably complete in that it is nearly continuous throughout. Occasional breaks in lines occur as shown in Figure (1) for exposure No. 5 of Mission 1002-1 but these have no influence on exploitation. In Mission 1002-1 the reseau was not placed to cover the entire film area shown in Figure 2.

Tests were made to determine any appreciable distortion between the reseau in Mission 1002-1 photos and the calibrated reseau. No significant distortions were detected. This is in contrast to previous missions such as 9045 where lack of complete contact of the film with the platen occurred, resulting in considerable distortion in the corner area. In Mission 1002-1, this deficiency was corrected so that no extreme local distortion effects were noted when comparing the original reseau with its exposure on original negatives and the duplicate positives.

3.3 Image Mensurability

Image mensurability was determined using three approaches. The first method was based upon the application of past experience and judgement obtained using photographic materials of different quality in stereophotographic instruments. In this method an index factor of 10 is assigned to a clear, sharp, and well defined photograph held 14" away from the eyes. Using experience as a guide, other prints are compared to this ideal and assigned index values up to ten. If the print is enlarged from the original using high resolution reproduction processes, the estimated index number is multiplied by the magnification to obtain the index number at original photo scale.

This method was applied against the Mural frame materials after being enlarged 10x, 20x and 40x. Using the method outlined above, starting from the enlarged prints, it was estimated the original negatives at contact scale had an index value of 60 to 80 at the center out to about 25 mm which then degraded to 6 to 8 in the corners.

A second method employed the photometer to measure the degradation of edge sharpness and contrast for the same type of detail image selected at 25 uniformly spaced locations in the photograph. All measurements were made on chips blown up 10x and processed uniformly. Photometer slit width was 10μ. Results of this test showed the transmittance range between minimum and maximum density portions of the selected image was reduced 50°/° and edge blur increased 6x in the corners of the photograph compared to values measured at the center of the print.

Based upon the above results, it is estimated that parallax measurements could be made to a standard error of 1/2μ at the center degrading to about 5μ in the corners.

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RESEAU GRID

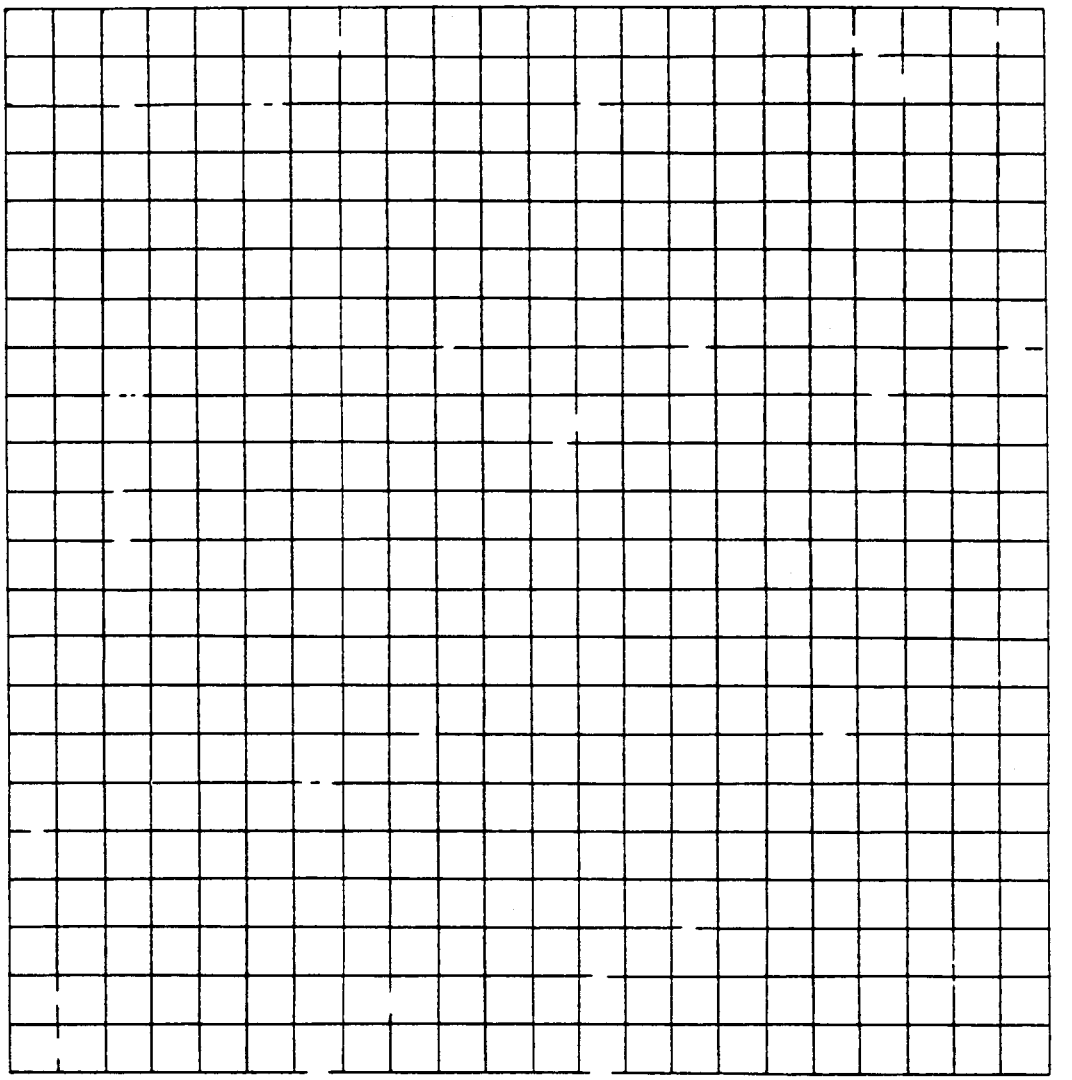

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Figure 1. Frame Camera reseau used in Mission 1002-1

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7-14

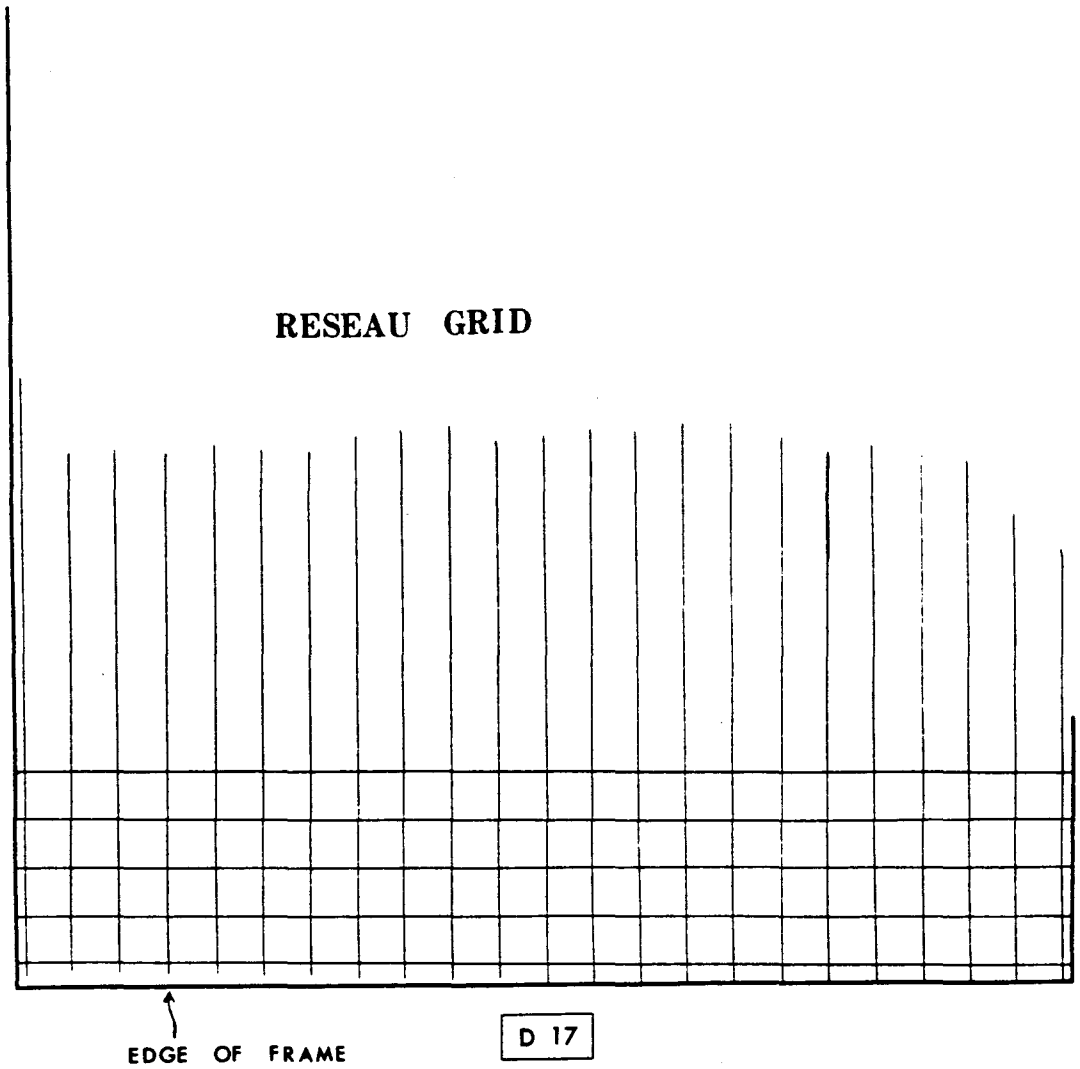

Figure 2. Placement of reseau with respect to frame camera format of Mission 1002-1

4. STELLAR CAMERA EVALUATION

In the same manner as for the frame, evaluation of the stellar camera was based upon:

a. camera malfunction and titling
b. camera calibration
c. image mensurability

Comments relating to stellar camera operation covered already in the frame camera evaluation will not be considered further in this section.

4.1 Camera Malfunction and Titling

Camera malfunctions of the stellar camera were noted as follows:

a. Film metering:

Seventeen sets of fiducials and/or correlation light exposures were made on the film preceding the first exposure on Mission 1002-1. These were expended during loading and pre-flight engineering operations. After satellite operation was started, film metering malfunctions occurred between exposures 222-223, 226-227, 229-230, 231-232 and 233-234.

b. Image Quality:

Twenty exposures are 90°/o blank. (example: Figure 3 and exposures 88, 89, 109, 142, 167-169, 122, 124, 225, 231, 233, 237, 238, and 240). Twenty exposures are totally blank (275, 281, 283, 295, 309, 335-340, 345, 346, 358-363). The third exposure from the last of each pass contains a blank area on the left edge of each exposure which is attributed to corona discharge and which also affects the image of the following exposure (Figure 4, exposures 63, 64). All exposures had a light streak about 2.5 mm in width across the lower field of view. This is caused by reflection of light from the fairing striking the end of the ~~buffer~~ BAFFLE. It may or may not obscure stellar images depending upon its intensity. (See Figure 5) In spite of these problems, a considerable number of stars can be seen on remaining exposures (Figure 5, exposures 234, 235).

c. Fiducial Quality:

Only ten exposures had fiducials of even fair readability. In nearly every case, the fiducial in the upper left corner was blurred. Circuitry and pre-flight check-out of the fiducials are being investigated to correct this problem.

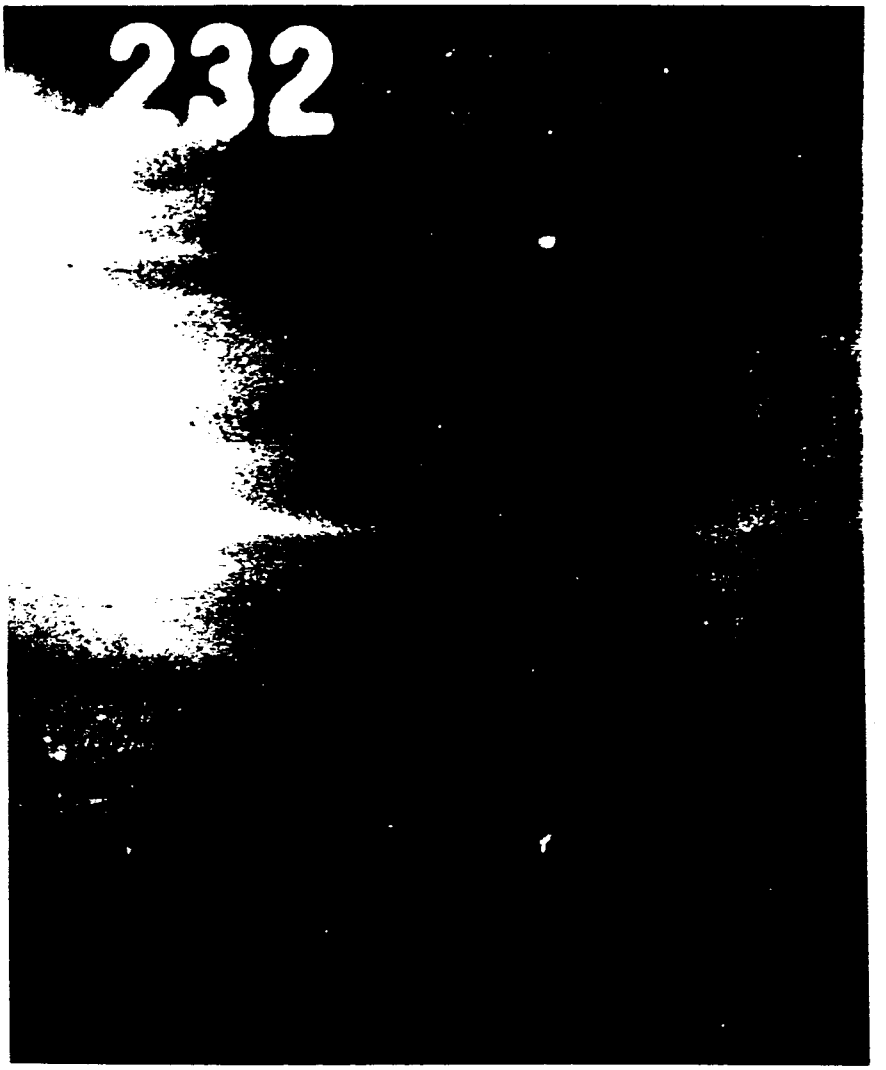

Figure 3. Example of blank stellar exposure for Mission 1002-1

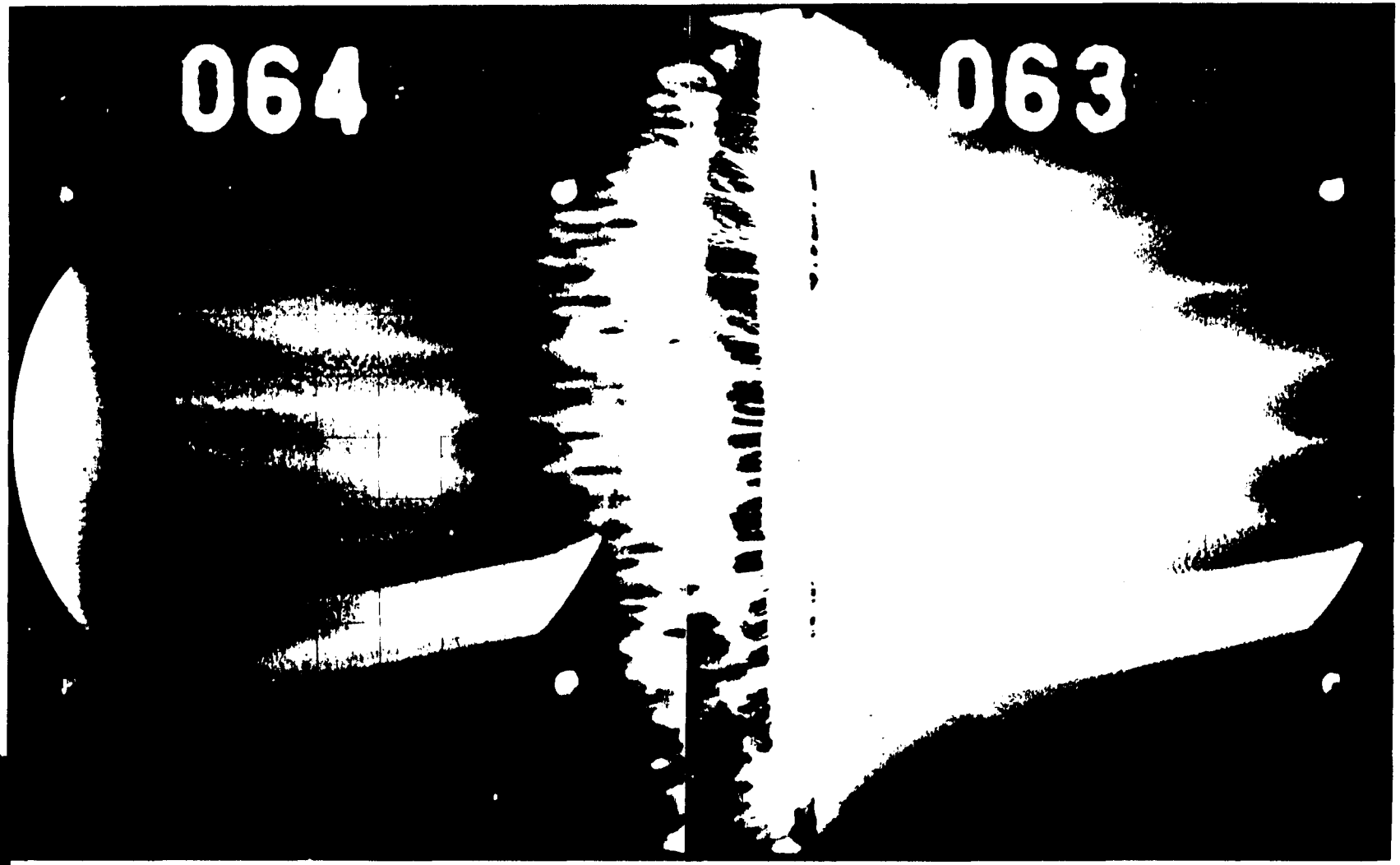

Figure 4. Effect of corona discharge on stellar photos in Mission 1002-1

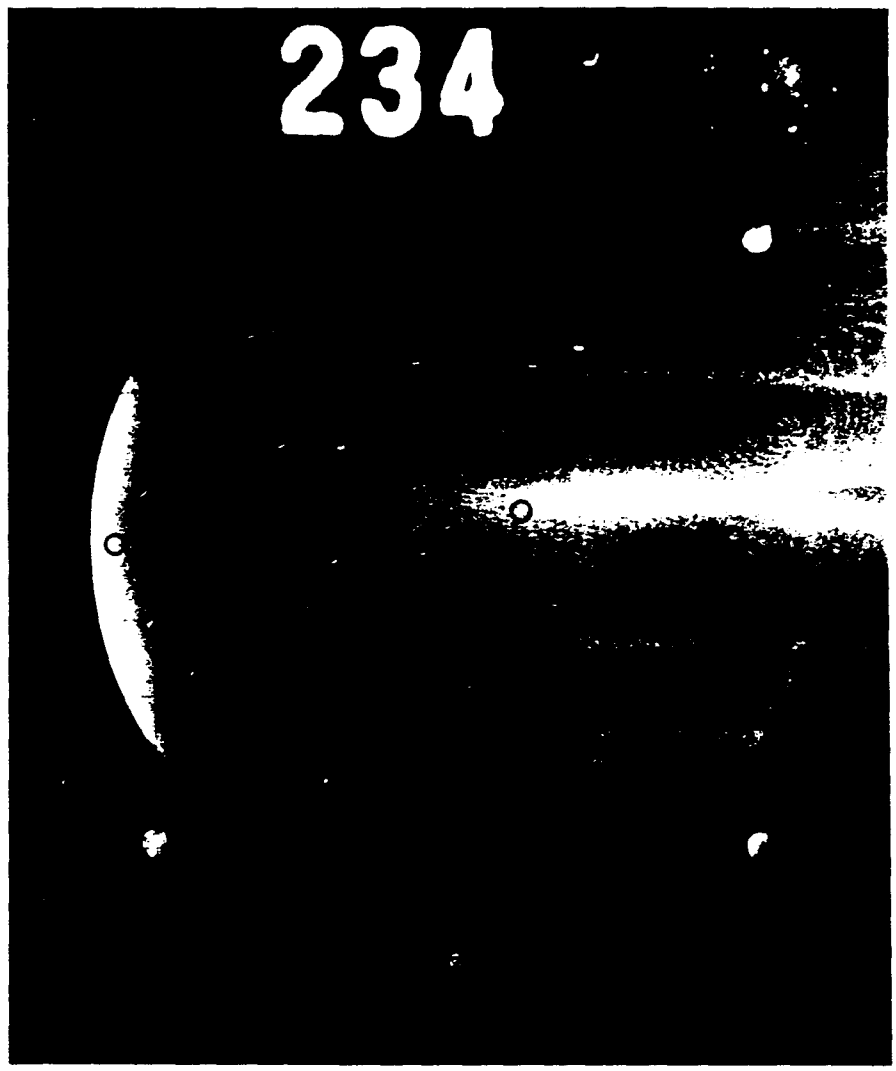

Figure 5. Star images detectable on successful stellar exposure of Mission 1002-1

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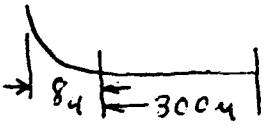
d. Frame Camera Correlation:

Index light correlation was satisfactory between frame and stellar camera exposures.

e. Star Image Quality:

Almost all stellar exposures have spot images of stars except exposures 226, 227, 234, 235, 280 and 326. In photo 234 image traces were a maximum of 300μ at the edge of the print and 100μ at the bottom. Assuming 5 second exposure time, these traces indicate rotation rates of 47 to 140 arc seconds per second about vehicle roll and crab axis. The traces seem to have an up turn of a few microns about 8μ from the edge of a trace indicating a change in rotation rate of the vehicle. Here is an exaggerated diagram of the image observed:



f. Star Density:

As seen in Figure 5 and on other successful exposures, stars were well distributed on most exposures and of sufficient density with respect to background density to be measured easily. Based upon limited tests, an average of 25 stars could be identified and measured with errors less than 3 - 10μ.

g. Double Exposures:

Stellar print 251 was double exposed. Double exposure of the stellar print did not correlate with frame double exposures. Frame materials showed exposures 250, 251 and 253 so affected while their corresponding stellar exposures were not.

h. Stellar Reseau:

The stellar reseau was visable on 95°/o of all exposures having stellar images. Upon visual examination, the stellar fiducials appeared poor but when measured and adjusted were as accurate as the internal reseau and were not affected by their appearance.

4.2 Reseau Calibration of Stellar Camera

Stellar calibration was more accurate and consistent than the frame camera owing to its narrow field angle and overall better illumination

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throughout the photographic area. Calibration was done using stellar techniques although in the future calibration will be done using the goniometer procedure.

Reseau line weight was 6μ on the original negatives which was increased to 10μ in the dup positives and all subsequent reproductions.

The relationship of the reseau of the stellar camera to that of the frame camera was determined by means of simultaneous stellar exposures. The time relationship between the frame and stellar exposures to each other and to that shown on the master pan was not given in the calibration reports. Assuming a 50 millisecond uncertainty, this lack of information could result in an orientation error up to 10 seconds of arc between the stellar and frame camera systems.

4.3 Mensurability of Stellar Camera

Based upon image evaluation studies and reseau quality, it is estimated measurement of stellar images were reliable to a standard error of 3μ. At the time denoted by the average center of gravity of a stellar trace, it is estimated camera attitude could be determined with a standard error of about 10 arc seconds.

5. EVALUATION OF PANORAMIC MATERIALS

Very little work was performed by ACIC in evaluating the Mural Pan Camera System except as it pertained to the operation of the frame camera and the developing of various cartographic products.

The first tests were concerned with determining index values of the pan materials as they affected mensuration and derived photographic products. Using the first method given in paragraph 3.3, index values ranged from 90 to 160. Such a range of index values requires minimum high resolution enlargements of 10x to 20x to allow maximum exploitation of these materials.

6. PROGRAM PLANNING OF "M" SYSTEM MISSION 1002-1

For cartographic exploitation, 50 - 60 °/o forward lap is needed. In Mission 1002-1, 311 potential stereo models should have resulted from the frame photography obtained. Of this total, 14 models had between 13°/o and 45°/o forward lap making them unsuitable, there were 17 breaks between successive photographs, fourteen frames were blank due to poor lighting and there were 3 double exposures. A total of 36 models were lost due to camera malfunctions resulting in an approximate total ground coverage loss of 370, 000 square miles - an area equivalent to that contained by all the states on the eastern Seaboard of the United States.

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