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This document contains _19_ pages

Analysis of Photographic Image

to Evaluate System Performance

Mission 1018-1

19 April 1965

# Analysis of Photographic Image to Evaluate System Performance

## TABLE OF CONTENTS

### Mission 1018-1

19 April 1965

TITLE:

Summary of Microdensitometer Derived Image Quality Data Collected from Mission 1018-1.

SECTION I:   INTRODUCTION

The normal quality evaluation of a photographic reconnaissance mission is based on a subjective judgment of the ground detail resolved on the film.   In an attempt to find an objective measurement technique for image evaluation, the microdensitometer has been used to scan sharp scene edges present on the film.   An illustration showing the conversion of a scene edge to M. T. F. and spread function is presented in Section IA.

Edges suitable for use in microdensitometer edge tracing should fulfill the criteria of the mathematical unit step function.   In practice, the following restrictions are placed on the edges selected for tracing.

(1)  The edge should appear sharp visually at 100X magnification.   Additionally, the two density levels extending away from the edge should be uniform for several resolution widths (15 or more microns on each side of the edge).

The minimum length of an edge is 150 $\mu$.   The most common type of scene edge having these characteristics is found in the image of the roof of a large industrial building; ventilators. etc. must be avoided.

(2)  The contrast of the edge must be high enough so that the edge can be readily aligned in the microdensitometer and yet not be of such high contrast that bleeding or halation is present.

(3)  The subject must be free of cloud cover and cloud shadows and have a minimum amount of haze.

(4)  The first 5 frames after each camera start up and the last 5 frames before shut down are avoided.

(5)  Two inches from each end of the frame are not used.

(6)  Subjects which occur in areas of soft spots or minus density are not used

(7)  Within acceptable portions of the frame there are no limitations nor restrictions on the location or orientation of the edge.

Three or more separate random sections of each edge are traced.   Multiple tracings are made without changing focus or edge alignment.

In this report, the evaluation data is presented as spread function width in microns and resolving power in lines per millimeter. A statistical summary of the edge data for this mission is presented in Section II, giving the arithmetic mean, standard deviation, coefficient of dispersion, and number of edges. Section IIA is included to show a statistical breakdown of the forward and aft camera quality.

Section III is a summary of all C/M/J Missions that have been recomputed with the new SWRDR computer program. Image Quality Ranking of all C/M/J Missions is listed in Section IIIA. A summary of the P.I. rating and the computed values for the M.I.P. frame is listed in Section IIIB. Frequency plots of the spread function and resolving power data are presented as Section IV to show the distribution of values. A tabulation of the location, description and image quality data for each edge is presented as Section V

Appendix A is included to show the edge orientation reference system and edge location grid In use, the film is placed on an illuminator with the titling correct reading (i.e. emulsion down) with the camera take-up end at the right and the supply at the left. The orientation of an edge is described as 000 for longitudinal and 090 for transverse edges; the numbering system runs in a clockwise direction. The coordinate locator grid consists of centimeter squares numbered such that the center of the frame is given as X46.0, Y12.0. X numbers increase toward the take-up and Y numbers increase toward the title.

The image quality data was obtained from sharp scene edges in the original negative by scanning with a Kodak Model 5 microdensitometer. A 1 x 80 micron slit was used. The data reduction consisted of the following steps:

(a) hand smoothing of the microdensitometer strip chart recording,

(b) key punching of chart (density) values at sample distance increments of 0.420 microns.

(c) I.B.M. 7044 computer conversion of chart values to relative exposure values, and transfer function by numerical methods.

The edge resolving power was predicted graphically as the intersection of the MTF curve and the aerial image modulation curve for 4404 film at a test object contrast of 2:1. The spread function width was calculated from the first differences of relative exposure as the width at which the gradient became 50% of the maximum gradient.

Each edge was traced three to five times on the microdensitometer. The computed spread function widths and resolutions of the individual tracings and the averaged values for each edge are presented in Section V.

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## SECTION IA

### Conversion of Scene Edge to MTF and Spread Function

OBJECT

CAMERA LENS

IMAGE

MICRODENSITOMETER AND DATA REDUCTION

SPREAD FUNCTION

50% AMPLITUDE
WIDTH

MTF

REPORT
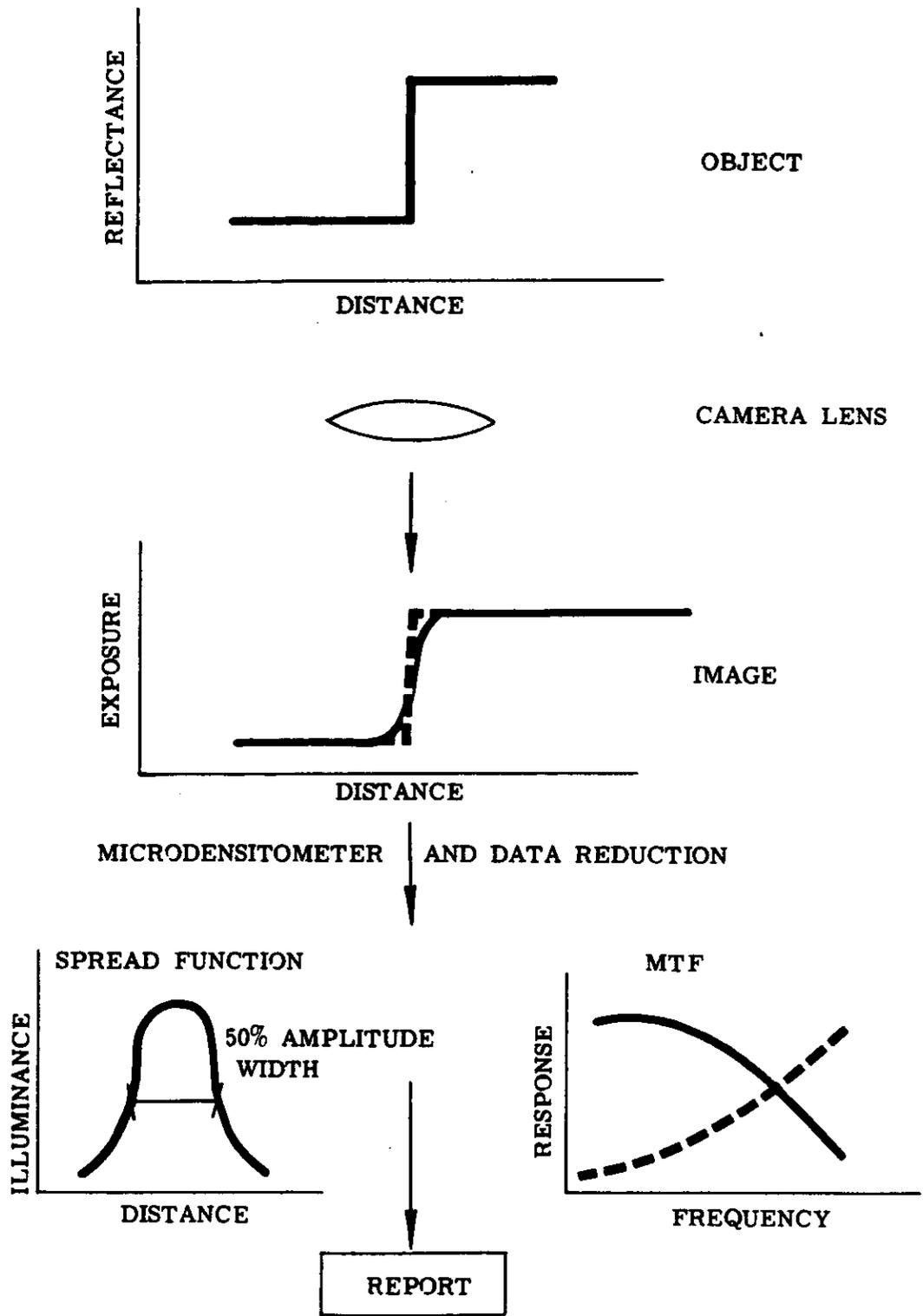
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## SECTION II SUMMARY SHEET

### Mission 1018-1

Resolution in lines/mm based on the aerial image modulation - 4404 curve from edge trace data reduced by computer techniques.

| | |
|---|---|
| Arithmetic Mean | 88.7 1/mm |
| Standard Deviation | 18.3 1/mm |
| Coefficient of Dispersion | 21% |
| Number of Edges | 34 |
| M.I.P. Frame | 78 1/mm |

Spread function width at 50% amplitude in microns from edge trace data reduced by computer techniques.

| | |
|---|---|
| Arithmetic Mean | 9.6 $\mu$ |
| Standard Deviation | 2.5 $\mu$ |
| Coefficient of Dispersion | 26% |
| Number of Edges | 34 |
| M.I.P. Frame | 9.9 $\mu$ |

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SECTION IIA SUMMARY SHEET

Mission 1018-1

Resolution in lines/mm based on the aerial image modulation - 4404 curve from edge trace data reduced by computer techniques.

|  | FWD Camera | AFT Camera |
|---|---|---|
| Arithmetic Mean | 81.3 l/mm | 96.1 l/mm |
| Standard Deviation | 15.5 l/mm | 18.2 l/mm |
| Coefficient of Dispersion | 19% | 19% |
| Number of Edges | 17 | 17 |

Spread function width at 50% amplitude in microns from edge trace data reduced by computer techniques.

|  | FWD Camera | AFT Camera |
|---|---|---|
| Arithmetic Mean | 10.3 $\mu$ | 8.8 $\mu$ |
| Standard Deviation | 2.3 $\mu$ | 2.5 $\mu$ |
| Coefficient of Dispersion | 22% | 29% |
| Number of Edges | 17 | 17 |

Analysis of Photographic Image to Evaluate System Performance

## SECTION III - MISSION 1018-1

### Summary of all C/M/J Missions Traced and Computed
### With the New SWRDR Computer Program

| Mission Number | Number of Edges | Spread Function Width at 50% Amplitude in Microns, Computer Calculations | | | Resolution in lines/mm from A.I.M 4404 Curve, Computer Calculations | | |
|---|---|---|---|---|---|---|---|
| | | Arithmetic Mean | Standard Deviation | Coefficient of Dispersion | Arithmetic Mean | Standard Deviation | Coefficient of Dispersion |
| 1007-2* | 106 | 12.2 | 3.9 | 32% | 71.0 | 18.0 | 25% |
| 1008-1* | 103 | 10.6 | 3.2 | 30% | 83.0 | 21.1 | 25% |
| 1008-2* | 123 | 10.2 | 3.9 | 38% | 84.3 | 21.0 | 25% |
| 1009-1 | 80 | 11.7 | 4.2 | 36% | 75.3 | 19.9 | 26% |
| 1009-2 | 110 | 13.0 | 5.0 | 39% | 74.1 | 21.7 | 29% |
| 1010-1 | 119 | 9.8 | 3.3 | 33% | 89.4 | 22.7 | 25% |
| 1010-2 | 110 | 9.8 | 3.2 | 32% | 84.3 | 21.4 | 25% |
| 1011-1 | 115 | 10.9 | 3.8 | 35% | 80.5 | 21.6 | 27% |
| 1012-1 | 94 | 10.1 | 3.7 | 36% | 86.1 | 20.4 | 24% |
| 1012-2 | 100 | 10.2 | 3.1 | 31% | 84.0 | 21.4 | 26% |
| 1013-1 | 49 | 10.8 | 4.1 | 38% | 83.3 | 27.3 | 33% |
| 1014-1 | 92 | 10.8 | 4.5 | 41% | 83.0 | 24.7 | 30% |
| 1014-2 | 90 | 11.7 | 3.9 | 34% | 74.2 | 20.1 | 27% |
| 1015-1 | 35** | 8.8 | 2.3 | 26% | 93.1 | 16.5 | 18% |
| 1015-2 | 40** | 9.2 | 2.3 | 25% | 89.7 | 17.8 | 20% |
| 1016-1 | 31** | 9.7 | 2.3 | 24% | 88.0 | 18.6 | 21% |
| 1016-2 | 33** | 9.8 | 3.2 | 32% | 91.5 | 16.1 | 18% |
| 1017-1 | 42** | 10.2 | 3.5 | 34% | 86.6 | 18.8 | 22% |
| 1017-2 | 45** | 11.4 | 3.6 | 31% | 82.2 | 17.8 | 22% |
| 1018-1 | 34** | 9.6 | 2.5 | 26% | 88.7 | 18.3 | 21% |

*A 1 x 320 micron slit was used

**Each edge was traced three or more times on the microdensitometer

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SECTION IIIA. - MISSION 1018-1

Image Quality Ranking of C/M/J Missions

| Mission Number | Average Resolution in lines/mm for A.I.M. 4404 Curve |
|---|---|
| 1015-1 | 93.1 l/mm |
| 1016-2 | 91.5 l/mm |
| 1015-2 | 89.7 l/mm |
| 1010-1 | 89.4 l/mm |
| 1018-1 | 88.7 l/mm |
| 1016-1 | 88.0 l/mm |
| 1017-1 | 86.6 l/mm |
| 1012-1 | 86.1 l/mm |
| 1008-2 | 84.3 l/mm |
| 1010-2 | 84.3 l/mm |
| 1012-2 | 84.0 l/mm |
| 1013-1 | 83.3 l/mm |
| 1008-1 | 83.0 l/mm |
| 1014-1 | 83.0 l/mm |
| 1017-2 | 82.2 l/mm |
| 1011-1 | 80.5 l/mm |
| 1009-1 | 75.3 l/mm |
| 1014-2 | 74.2 l/mm |
| 1009-2 | 74.1 l/mm |
| 1007-2 | 71.0 l/mm |

NOTE: Since this is a research and development effort, modifications and improvements are continually being made in the methods of collecting edge data and in the computer data reduction. Caution is advised in making system comparisons based on lines per millimeter resolution or spread function width until better methods become available for calibration of the edge tracing technique.

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## SECTION IIIB M.I.P. SUMMARY SHEET
### Mission 1018-1

| Mission Number | PI M.I.P. Rating | Resolution in lines/mm | Spread Function |
|---|---|---|---|
| 1009-1 | 85 | 112 l/mm | 7.3 $\mu$ |
| 1009-2 | 85 | --- | --- |
| 1010-1 | 85 | 134 l/mm | 5.3 $\mu$ |
| 1010-2 | 85 | 136 l/mm | 5.0 $\mu$ |
| 1011-1 | 85 | 113 l/mm | 6.3 $\mu$ |
| 1012-1 | 85 | 120 l/mm | 6.7 $\mu$ |
| 1012-2 | 85 | 117 l/mm | 5.0 $\mu$ |
| 1013-1 | 85 | 95 l/mm | 9.2 $\mu$ |
| 1014-1 | 80 | 109 l/mm | 5.6 $\mu$ |
| 1014-2 | 80 | --- | --- |
| 1015-1 | 85 | 92 l/mm | 8.6 $\mu$ |
| 1015-2 | 85 | 86 l/mm | 8.4 $\mu$ |
| 1016-1 | 85 | 114 l/mm | 6.0 $\mu$ |
| 1016-2 | 85 | 106 l/mm | 7.6 $\mu$ |
| 1017-1 | --- | 112 l/mm | 7.6 $\mu$ |
| 1017-2 | --- | 97 l/mm | 8.6 $\mu$ |
| 1018-1 | 85 | 78 l/mm | 9.9 $\mu$ |

The M.I.P. rating is an arbitrary figure assigned by the PI to indicate the quality of the best photography obtained in a particular mission. The pass and frame is selected by the PI and the target to be traced is selected by the Microdensitometer operator.
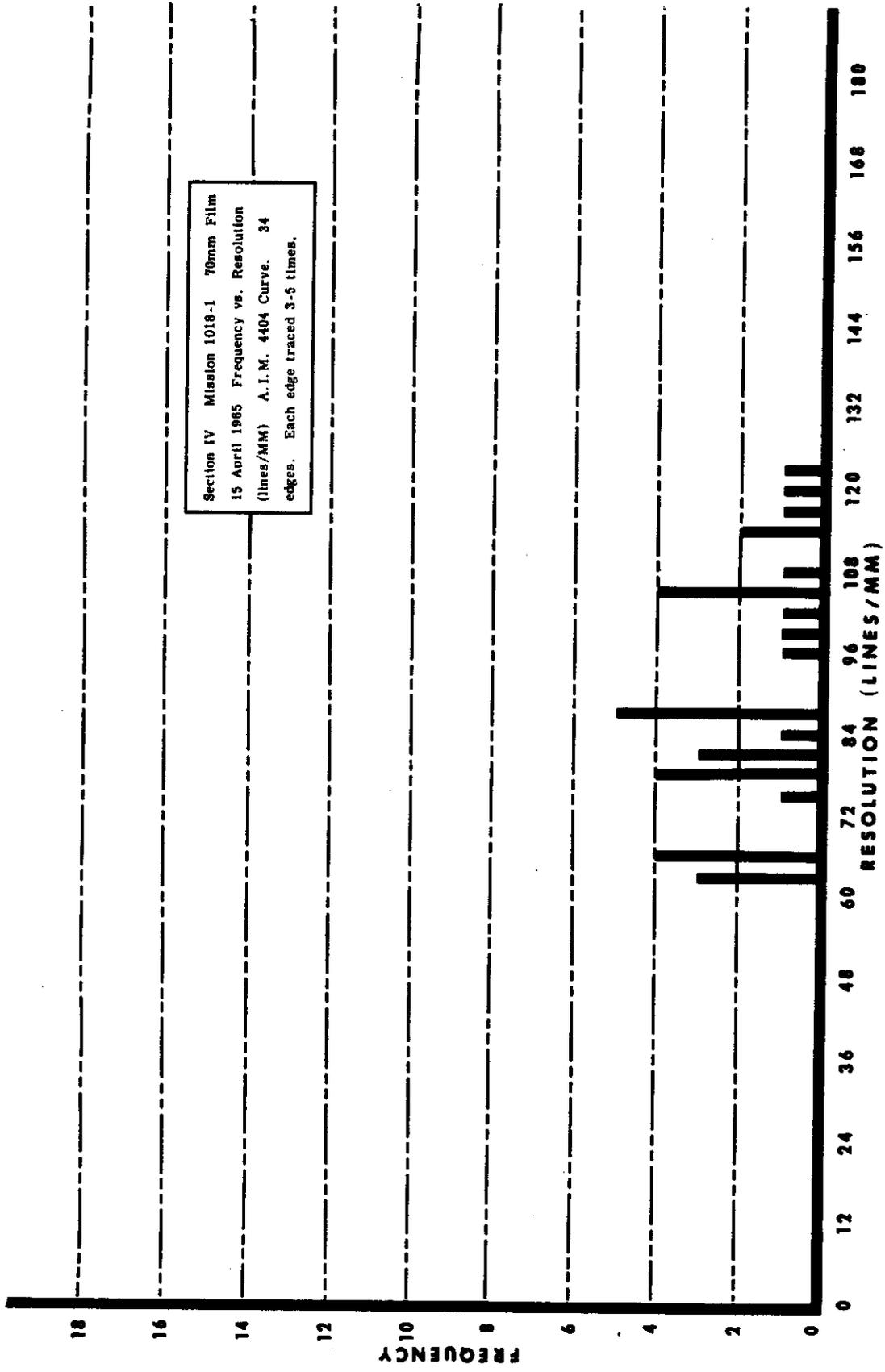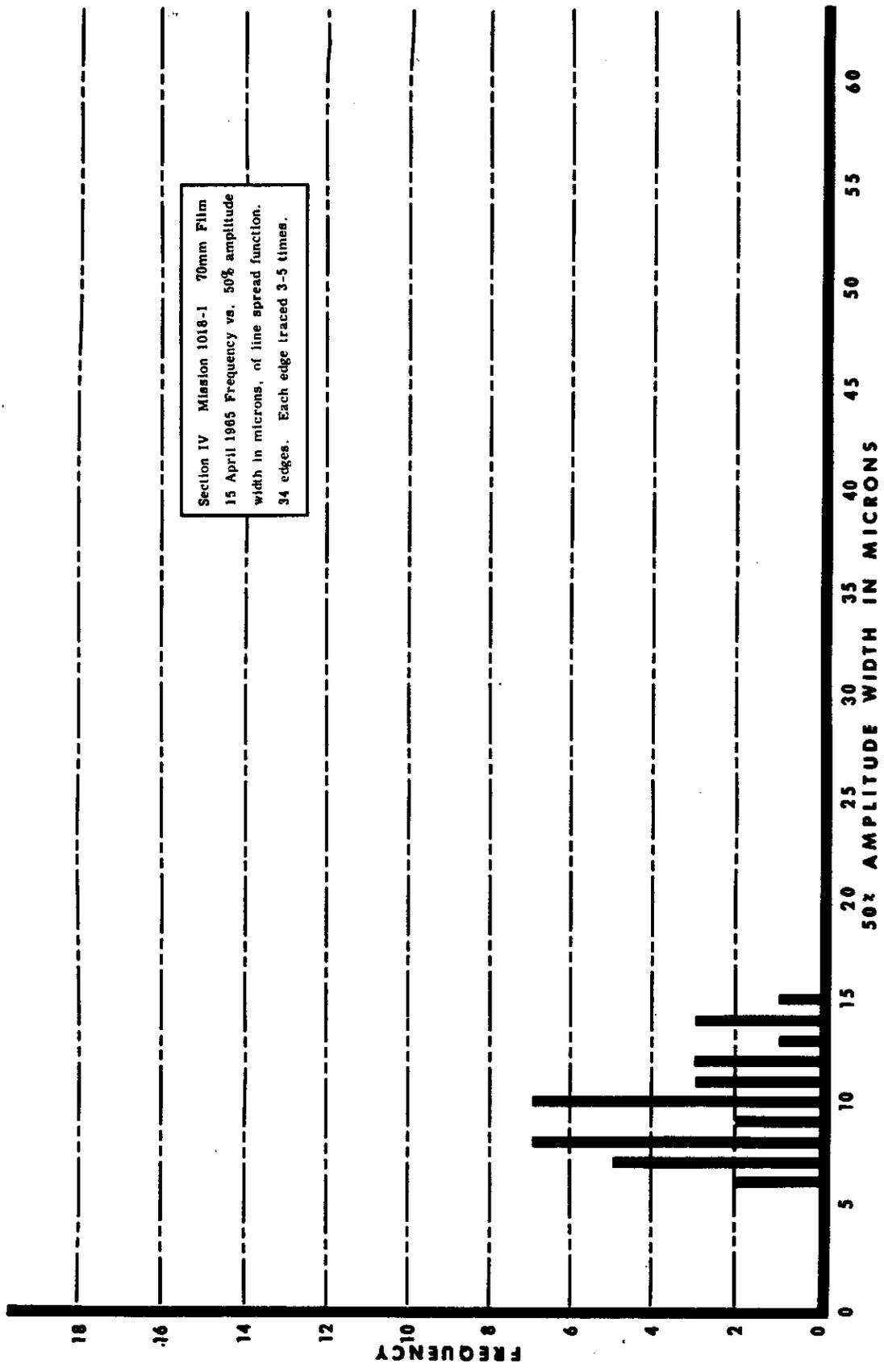
Section IV   Mission 1018-1   70mm Film

15 April 1965   Frequency vs. Resolution

(lines/MM)   A.I.M.  4404 Curve.   34

edges.   Each edge traced 3-5 times.

RESOLUTION (LINES/MM)

0   12   24   36   48   60   72   84   96   108   120   132   144   156   168   180

FREQUENCY

0   2   4   6   8   10   12   14   16   18

Section IV   Mission 1018-1    70mm Film

15 April 1965 Frequency vs. 50% amplitude width in microns, of line spread function.

34 edges.   Each edge traced 3-5 times.

50% AMPLITUDE WIDTH IN MICRONS

FREQUENCY

# Analysis of Photographic Image to Evaluate System Performance

## Mission 1018-1
### Section V

### Forward Camera

| Pass | Frame | Location | Orientation | Subject | 50% Amplitude Spread Function Width (Microns) | | A.I.M. Resolution | |
|------|-------|----------|-------------|---------|-----|------|-----|-----|
| D-08 | 097 | X29.6 Y13.3 | 120 | Buildings | 10.2 8.1 5.4 | 7.9 | 75 85 128 | 96 |
| D-24 | 084 | X78.9 Y10.4 | 170 | Buildings | 12.7 14.3 9.6 | 12.2 | 68 61 55 | 65 |
| D-24 | 087 | X41.9 Y11.6 | 020 | Buildings | 7.6 7.7 7.6 | 7.7 | 108 71 93 | 91 |
| D-24 | 088 | X63.3 Y13.3 | 035 | Buildings | 12.7 11.8 11.6 | 12.0 | 67 62 58 | 62 |
| D-24 | 093 | X51.0 Y11.5 | 070 | Dam | 17.3 14.6 9.5 | 13.8 | 70 50 76 | 65 |
| D-25 | 038 | X17.5 Y14.3 | 050 | Buildings | 12.4 11.7 11.0 | 11.7 | 64 64 71 | 66 |
| D-26 | 092 | X26.4 Y14.3 | 005 | Buildings | 7.6 7.5 7.8 | 7.6 | 106 110 95 | 104 |
| D-31 | 012 | X60.3 Y13.9 | 175 | Buildings | 9.2 9.3 7.9 | 8.8 | 96 98 106 | 100 |
| D-31 | 012 | X49.5 Y14.1 | 100 | Buildings | 7.7 8.1 6.8 | 7.5 | 92 107 113 | 104 |

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Forward Camera

| Pass | Frame | Location | Orientation | Subject | 50% Amplitude Spread Function Width (Microns) | | A. I. M Resolution | |
|------|-------|----------|-------------|---------|---|---|---|---|
| *D-31 | 013 | X53.7 Y10.2 | 125 | Airfield | 9.5 10.3 8.9 10.9 | 9.9 | 75 74 90 74 | 78 |
| D-31 | 015 | X33.3 Y13.5 | 165 | Buildings | 10.9 10.0 13.0 | 11.3 | 61 60 67 | 63 |
| D-31 | 019 | X54.8 Y12.0 | 010 ' | Buildings | 8.4 8.1 6.3 | 7.6 | 98 96 117 | 104 |
| D-31 | 023 | X44.8 Y11.0 | 180 | Buildings | 14.3 13.6 14.4 | 14.1 | 62 81 85 | 76 |
| D-59 | 041 | X20.0 Y11.2 | 140 | Buildings | 8.0 10.1 11.7 | 9.9 | 83 95 76 | 85 |
| D-59 | 041 | X23.3 Y 9.5 | 050 | Buildings | 10.1 10.1 10.5 | 10.2 | 99 69 71 | 80 |
| D-16E | 013 | X17.2 Y10.2 | 055 | Buildings | 16.1 14.0 11.1 | 13.7 | 70 58 71 | 66 |
| D-16E | 018 | X39.8 Y12.4 | 015 | Buildings | 8.6 10.1 10.5 | 9.7 | 88 89 83 | 87 |

*M. I. P. Frame

## Aft Camera

| Pass | Frame | Location | Orientation | Subject | 50% Amplitude Spread Function Width (Microns) | | A.I.M. Resolution | |
|------|-------|----------|-------------|---------|------|-----|------|-----|
| D-08 | 103 | X62.2 Y10.3 | 140 | Buildings | 5.8 / 9.1 / 11.4 | 8.8 | 99 / 90 / 69 | 86 |
| D-24 | 090 | X11.3 Y13.9 | 170 | Buildings | 6.3 / 6.6 / 7.5 | 6.8 | 116 / 120 / 109 | 115 |
| D-24 | 093 | X49.5 Y12.6 | 020 | Buildings | 5.5 / 7.8 / 6.8 | 6.7 | 123 / 108 / 111 | 114 |
| D-24 | 094 | X28.5 Y10.8 | 035 | Buildings | 7.2 / 4.5 / 9.4 | 7.0 | 107 / 132 / 80 | 106 |
| D-24 | 099 | X40.5 Y12.5 | 070 | Dam | 14.4 / 7.3 / 10.0 | 10.6 | 59 / 93 / 83 | 78 |
| D-25 | 044 | X73.9 Y10.8 | 035 | Buildings | 4.8 / 11.1 / 8.2 | 8.0 | 106 / 75 / 84 | 88 |
| D-26 | 097 | X64.7 Y13.0 | 087 | Buildings | 6.1 | 6.1 | 120 | 120 |
| D-31 | 021 | X58.7 Y11.5 | 170 | Buildings | 7.3 / 8.7 | 8.0 | 122 / 91 | 107 |
| D-31 | 025 | X36.8 Y14.0 | 180 | Buildings | 5.7 / 9.2 / 6.4 | 7.1 | 129 / 90 / 129 | 116 |
| D-31 | 025 | X36.8 Y13.2 | 015 | Buildings | 5.5 | 5.5 | 124 | 124 |

Mission 1018-1

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Aft Camera

| Pass | Frame | Location | Orientation | Subject | 50% Amplitude Spread Function Width (Microns) | | A. I. M. Resolution | |
|------|-------|----------|-------------|---------|----------|------|------|------|
| D-31 | 028 | X53.4 Y11.0 | 088 | Buildings | 4.8 24.4 10.4 | 13.2 | 131 54 80 | 88 |
| D-31 | 029 | X46.8 Y14.2 | 178 | Buildings | 18.5 14.3 11.9 | 14.9 | 62 57 67 | 62 |
| D-59 | 005 | X58.6 Y11.7 | 178 | Buildings | 7.4 6.9 7.7 | 7.3 | 107 114 88 | 103 |
| D-59 | 006 | X63.3 Y13.3 | 170 | Buildings | 8.8 10.1 9.7 | 9.5 | 91 76 79 | 82 |
| D-59 | 008 | X66.0 Y10.3 | 150 | Buildings | 10.9 8.6 11.6 | 10.4 | 68 96 74 | 79 |
| D-16E | 019 | X75.5 Y14.6 | 075 | Buildings | 11.5 10.9 6.1 | 9.5 | 84 65 115 | 88 |
| D-16E | 021 | X46.6 Y14.2 | 088 | Buildings | 11.5 11.8 8.9 | 10.7 | 78 69 83 | 77 |

# APPENDIX "A"

Reference System For Orientation Of  C/M/J  Mission Edges
original negative — emulsion down

**SUPPLY**                    **TITLE AREA**                    **TAKE-UP**

```
180 ── 000
165 ── 015
150 ── 030
135 ── 045
120 ── 060
105 ── 075
      090
```
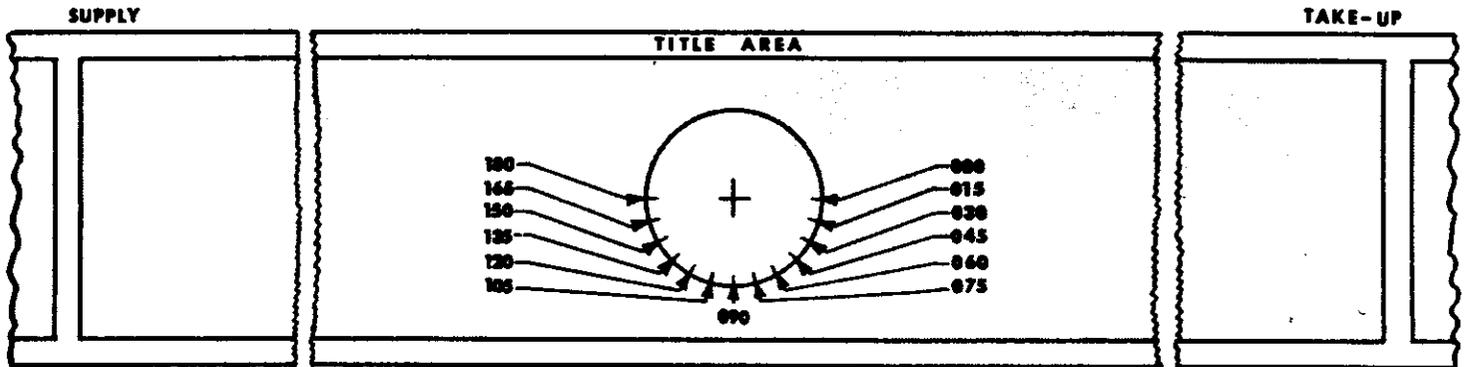
Coordinate Locator Grid For   C/M/J  Mission Edges
original negative — emulsion down

**SUPPLY**          **TITLE AREA**          15          **TAKE-UP**

```
                                              14
                                              13
9  10  11  12    38 39 40 41 42 43 44 45 46  47 48 49 50 51 52 53 54    60 61 62 63
                                              12
                                              11
                                              10
                                               9
```

ONE  CENTIMETER  SQUARES                    IMAGE AREA  [        ]

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