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Overall Evaluation of Skylab (EREP) Images for Cartographic Application

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EREP Investigation No. 500

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a. Overall Status

Although SL-2 and SL-3 imagery has been received by cartographic investigators within USGS an evaluation of SL-4 is considered desirable before other than limited experimentation is undertaken. The IAGS report on EREP experiment No. 496B for the period Aug. 1, 1973 through Feb. 28, 1974 has been received and is being evaluated. Reports EC-1 Skylab (previous period but not reported) and EC-2 Skylab have been prepared and are attached.

b. Actions Required or Recommended

A comprehensive evaluation of all Skylab imagery should be made by appropriate investigators at JSC upon availability of SL-4 data. A specific plan must also be developed to allow selected investigators to evaluate imagery made directly from the original film.

c. Expected Accomplishments During Next Reporting Period

Evaluation of SL-4, reselection of optimum areas and initiation of specific experiments are expected during the next three months. Further evaluation of image quality is also anticipated, particularly with respect to high resolution color IR film (SO131) exposed by ETC on SL-4.

d. Significant Results

Results reported by IAGS (see a.) are evaluated as follows:

- The importance of photomap products derived from Skylab type imagery for portrayal of previously unmapped (or poorly mapped) areas is recognized as truly significant.

- Updating of maps of any scale from Skylab type imaging can only be accomplished on a selective basis. Relative positional accuracy commensurate with 1:100,000 scale (S190A) or even 1:50,000 (S190B) is considered correct. However, many features required on such maps cannot be properly identified or classified from such imagery. The comprehensive updating of larger scale maps requires supplementary photography or ground truth.

e. Summary Outlook for Remaining Effort

See b.

f. Travel Summary and Plans

See b.

United States Department of the Interior

GEOLOGICAL SURVEY

November 14, 1973

Memorandum for the Record (EC-1-Skylab)

By: Chief, Remote Sensors Section RT-P , Topo. Div.
Thru: EROS Cartography Coordinator

Subject: Image quality - S190A and S190B

The enclosed memo from Dr. Welch describes the results of his preliminary analysis of second generation (contact) Skylab 2 photographs obtained with the S190A and S190B cameras.

The resolution is very close to predicted values except for two conditions. The first is the degradation introduced by the loss of platen vacuum on the S190B camera during the use of 3414 film. The second condition is the reduction of the predicted 60-70 lp/mm resolution of the original SO-242 and SO-356 color films to about 35 lp/mm through contact printing on lower resolution SO-360 second-generation film. This could be largely corrected by direct enlargement from the original film.

The relationship between film and ground resolution for an orbital altitude of 435 km is as follows:

Camera System	Film Resolution lp/mm (line pairs per mm)	Ground Resolution m/lp (meters per line pair)
S190A		
focal length = 6" or (152 mm)	70	41
	60	48
	35	82
scale: 1:2,862,000		
S190B		
focal length = 18" or (460 mm)	70	14
	60	16
	35	27
scale: 1:946,000		

Robert B. McEwen

Enclosure

Memo to: Dr. Robert B. McEwen
From: R. Welch
Subject: SKYLAB Image Evaluation (Ref. Memo of 9-6-73)

Modulation transfer functions (MTF's) have been determined for second generation S190 A images of the Salton Sea, California and Rapid City, South Dakota areas, and for S190 B images of Rapid City, coastal Brazil, & Montana. This report summarizes the results of these MTF analyses.

The scenes selected for analysis were those which contained sharp natural boundaries such as coastlines or cultivated field patterns and for which representative good quality photographs had been obtained. Using these images, microdensitometer edge traces were made across the boundaries. MTF's were then calculated from the edge traces using a graphical-digital technique.[1] Sensitometric data for both the original and duplicating films was provided by NASA.[2]

With reference to the S190 A system, the minor differences in quality noted between spectral bands utilizing the same film permitted the MTF's to be classified according to the following original-duplicating film combinations.

EK Film/Duplicating Film Combination	Band
2424/2420	Infrared
2443/SO-360	Color Infrared
SO-356/SO-360	Color
SO-22/2430	Green, Red

The average measured MTF for each combination is shown in the attached figure ("S190 A Measured MTF's"). In addition to the average measured MTF's, predicted MTF's were produced for the S190 A system by cascading the component lens, original film and duplicating film MTF's obtained from manufacturers' data.[3,4] These predicted curves are shown in a separate figure ("S190 A Predicted MTF's") and although giving slightly higher response values, generally correspond to within 10 percent of the measured values. This agreement is very good, (particularly when differences between the manufacturer's and user conditions, and the variabilities of the photographic process are considered) and confirms that system performance in terms of both MTF's and resolution is about as predicted.[3,5]

Average MTF's were also calculated for the S190 B 3414/2430 and SO-242/SO-360 combinations. These MTF's are plotted in a separate figure ("S190 B Measured MTF's"). The SO-242/SO-360 MTF's, closely approximate the corresponding SO-356/SO-360 curves for the S190 A system, indicating comparable performance. By contrast, the greatly reduced MTF for the 3414/2430 combination reflects the degradation introduced by the reported vacuum system problems and is not representative of expected S190 B system performance.

The SKYLAB photographs, with the exception of the high-resolution color originals (SO-242 and SO-356), have been reproduced on duplicating films with imaging characteristics superior to those of the films utilized in the cameras. Consequently, only the color duplicates produced on SO-360 film appear to have suffered a significant loss of resolution. Analytical techniques indicate that low contrast (1.6:1) resolution values of approximately 35 lpr/mm are appropriate for the SO-242/SO-360 and SO-356/SO-360 combinations, as compared to the predicted 60 to 70 lpr/mm for the original photos.

Roy Welch

October 19, 1973

REFERENCES

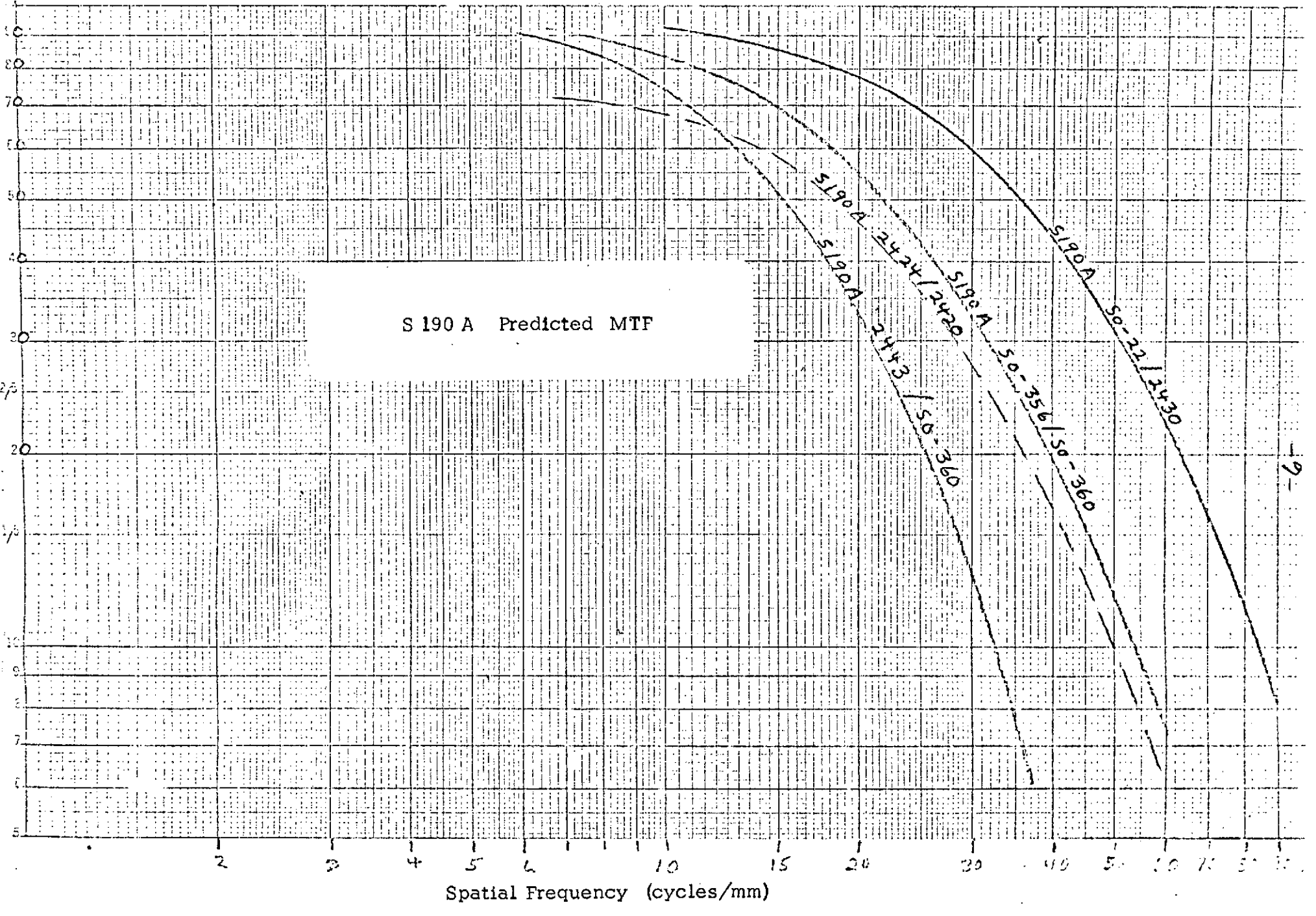
1. Welch, R., 1971, "Modulation Transfer Functions," Photogrammetric Engineering, Vol. XXXVII, No. 3, pp. 247-259.

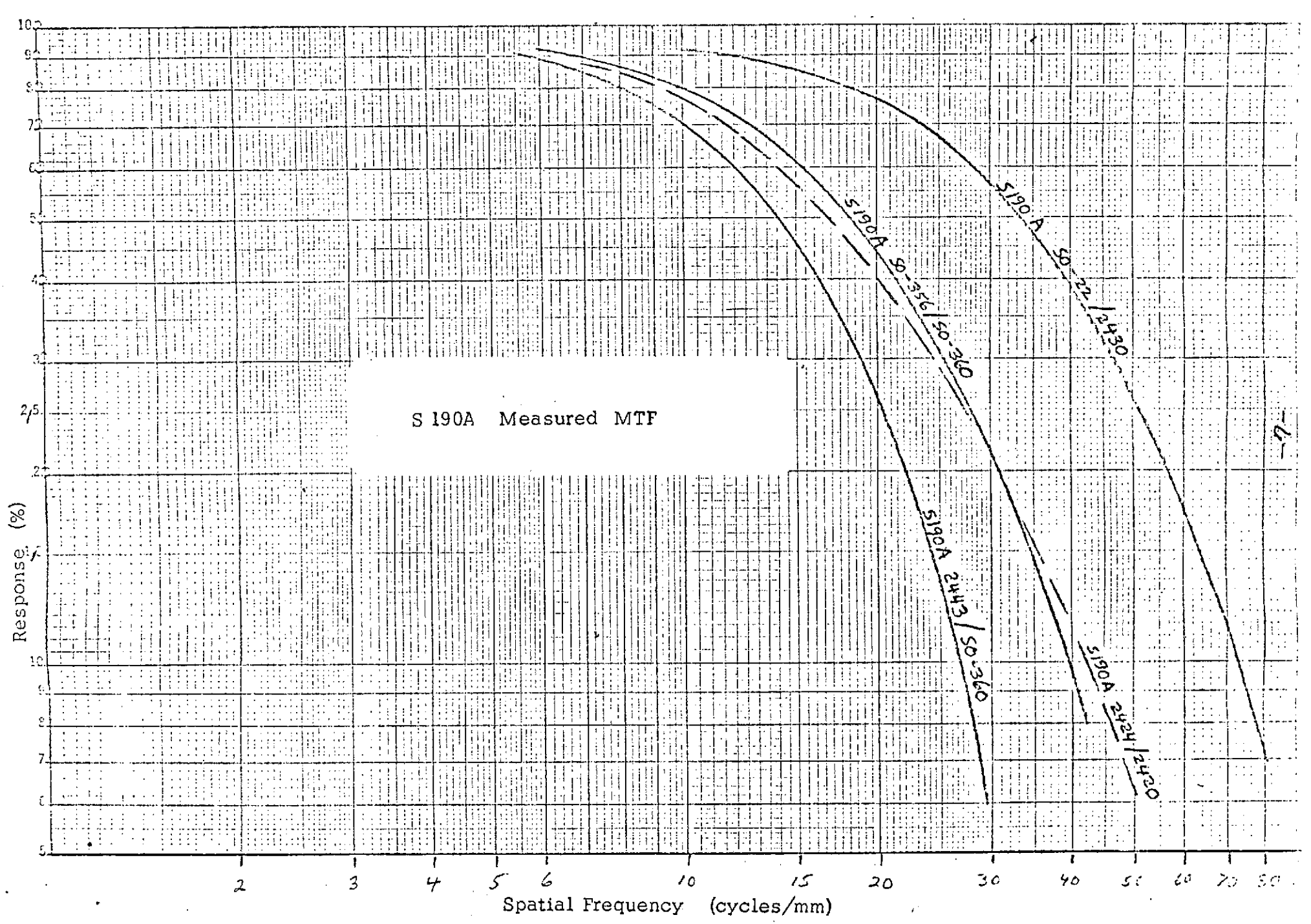
2. NASA, 1973, SL/2 Sensitometric Data Package, July, 490 pages.

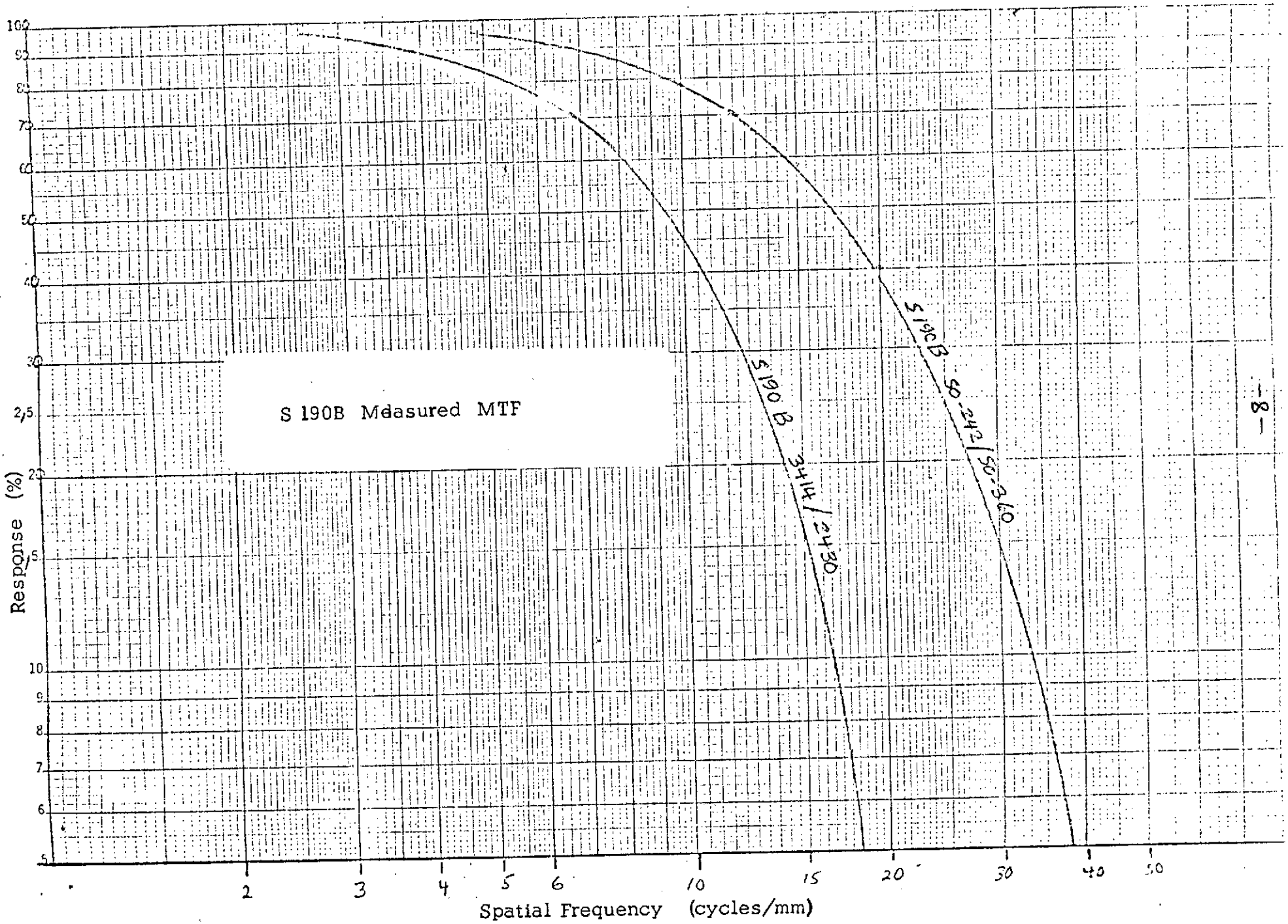
3. Forkey, R. E. and Womble, D. A., 1972, "Unique Lens Design for Multi-spectral Photographic Cameras," Presented Paper, International Society of Photogrammetry, XII Congress, Ottawa, Canada.

4. Eastman Kodak, 1972, "Kodak Aerial Films and Photographic Plates," Publication No. M-61.

5. Welch, R., 1971, "Earth Satellite Camera Systems: Resolution Estimates and Mapping Applications," The Photogrammetric Record, Vol. VII, No. 38, pp. 237-246.


S 190 A Predicted MTF
S190A 50-22 / 2430
S190A 2424 / 2429
S190A 50-356 / 50-360
S190A 2423 / 50-360
Spatial Frequency (cycles/mm)


S 190A Measured MTF
Response (%)
Spatial Frequency (cycles/mm)
2
3
4
5
6
10
15
20
30
40
50
60
70
80
S190A 50-22/2430
S190A 50-356/50-360
S190A 2443/50-360
S190A 2424/2420


S 190B Measured MTF
S190B 50-242 / 50-360
S190B 3414 / 2430
Response (%)
Spatial Frequency (cycles/mm)
100
90
80
70
60
50
40
30
25
20
15
10
9
8
7
6
5
2
3
4
5
6
10
15
20
30
40
50

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VIRGINIA 22092

January 29, 1974

Memorandum for the Record (EC-2-Skylab)

By: Chief, Remote Sensors Section, RT-P, Topo Division
Thru: Cartography Coordinator, EROS Program
Chief, Branch of Photogrammetry

Subject: Image Quality - S190B

The enclosed memorandum from Dr. Roy Welch describes an image quality evaluation performed on a 9.5X enlargement from the original film of the S190B camera. The enlarged area is near the edge of the frame and covers St. Louis, Missouri. It is scheduled for printing on the cover of the February 1974 issue of Photogrammetric Engineering.

A previous memorandum (EC-1-Skylab) described the resolution loss when the original color or color IR film is contact printed on color duplicating film. The edge traces measured by a microdensitometer were about 60 μm in width and yielded a ground resolution of 27 meters/line pair.

The images enlarged from the original color film yielded a scaled microdensitometer trace of 42 μm. This closely approximates the estimated quality of the original film. The enlargement should have a resolution of about 5 lp/mm or 20 meters/line pair on the ground.

Dr. Welch recommends an enlargement of 3X or more when copying the original color or color IR film. This will avoid the resolution loss of duplicating film. Black and white, high-resolution film is expected to have higher resolution than the color film or color enlargements. When high-resolution duplicating film is properly used, only a minimal resolution loss is expected in the black and white contact processing.

Robert B. McEwen

Robert B. McEwen

Enclosure

Memo to: Dr. Robert B. McEwen
From: R. Welch
Date: January 3, 1974
Subject: Quality of St. Louis SKYLAB photos and recommended procedures for duplicating and evaluating SKYLAB photos. (Ref. Memo of 10-19-73)

In mid-December analyses of color contact film transparencies and 9.5X enlargements produced directly from the original S190B/SO-242 color photographs of St. Louis were analyzed to determine comparative image quality values. These analyses have been based on microdensitometer traces of corresponding edges on the enlargements and contact transparencies, supplemented by visual inspections of the images.

Contact Transparencies

Second generation S190B contact color transparencies produced on SO-360 film have an estimated resolution of 35 lpr/mm for a 1.6:1 contrast target and produce the MTF (S190B/SO-242/SO-360) shown in Figure 1 (Ref EC-1-SKYLAB, 14 November 1973). The ΔX distance of an edge trace for these transparencies averages about 60 μm.

9.5x Color Enlargement

The second generation 9.5x color enlargements were produced from the original S190B color photos by NASA/Houston using a Durst Enlarger and EK 6120 film. However, since sensitometric data were not recorded for the enlargements, MTF's cannot be computed. Consequently, comparisons of image quality between the enlargements and contact transparencies must be based on the raw microdensitometer edge traces. On these enlargements the ΔX value for edge traces averaged 400 μm, which equates to about 42 μm at the contact scale. A comparison of this value with the 60 μm edge for the contact film transparencies indicates that, as expected, the enlargement more nearly retains the quality of the original photos. Although the maximum resolution of the enlargement is estimated to be on the order of 3 to 5 lpr/mm, it must be emphasized that this is simply a "best guess." Lack of data on sensitometry, enlarger lens and duplicating film characteristics and the absence of "good" edges in the small-scale St. Louis photo do not permit definitive analyses.

A visual inspection of the St. Louis enlargement revealed blurred image detail along one border. Since the enlargement was produced from a marginal (format edge) portion of the original photo and the area of blurred detail generally coincides with a slightly blurred area on the second generation contact transparency, it is assumed that the quality of the original photo at the format edge, rather than focus or instrument errors in the enlarging process, is responsible for the local degradation in the enlargement. Generally, the enlargement appears to be fairly representative of the quality that can be expected for 10X reproductions of original Skylab color photos.

Recommendations for Duplicating and Analyzing SKYLAB Photos

To achieve the objective of producing duplicates from the color (or black-and-white) Skylab photos which retain the image quality values of the original photos, the following steps are suggested for consideration.

1. Produce enlargements (instead of contact prints) directly from the original Skylab images. The enlargement factor should be regulated by the quality of the original photo, enlarger design considerations, duplicating film characteristics and reproducible format size. For example, enlargement factors for the original color photos can be reasonably estimated from the MTF's in Figure 1 using the methods described by Welch (1972). Note: the enlargement factor should be sufficient to nullify any degrading effects of the duplicating film and process. For the Skylab color photos a factor of about 3 or 4 should prove adequate.

2. In order to directly analyze the quality of contact prints and/or enlargements and indirectly determine the quality of the original photos, the following materials should be obtained:

   a. Second generation photos for selected scenes containing edge images which can be subjected to edge analysis techniques.

   b. Supplementary data:

      1. Camera system including information on exposure.

      2. Duplicating instrumentation.

      3. Sensitometry--for original and duplicating films.

      4. MTF's of camera lenses, films, enlarger lenses, etc.

      5. Resolution values for camera systems, enlarging systems, films, etc.

      6. Film TM curves.

3. Subject the photos to edge analysis techniques, supported by visual evaluations of quality. System MTF's determined from measurements on the photos can then be compared to predicted MTF's obtained by cascading the MTF's of the appropriate components. These MTF's can also be used to produce resolution estimates.

Roy Welch

s/Roy Welch 1/

Ref.

Welch, R., 1972, "Photomap Image Quality," The Cartographic Journal, Vol. 9, No. 2., pp. 87-92.

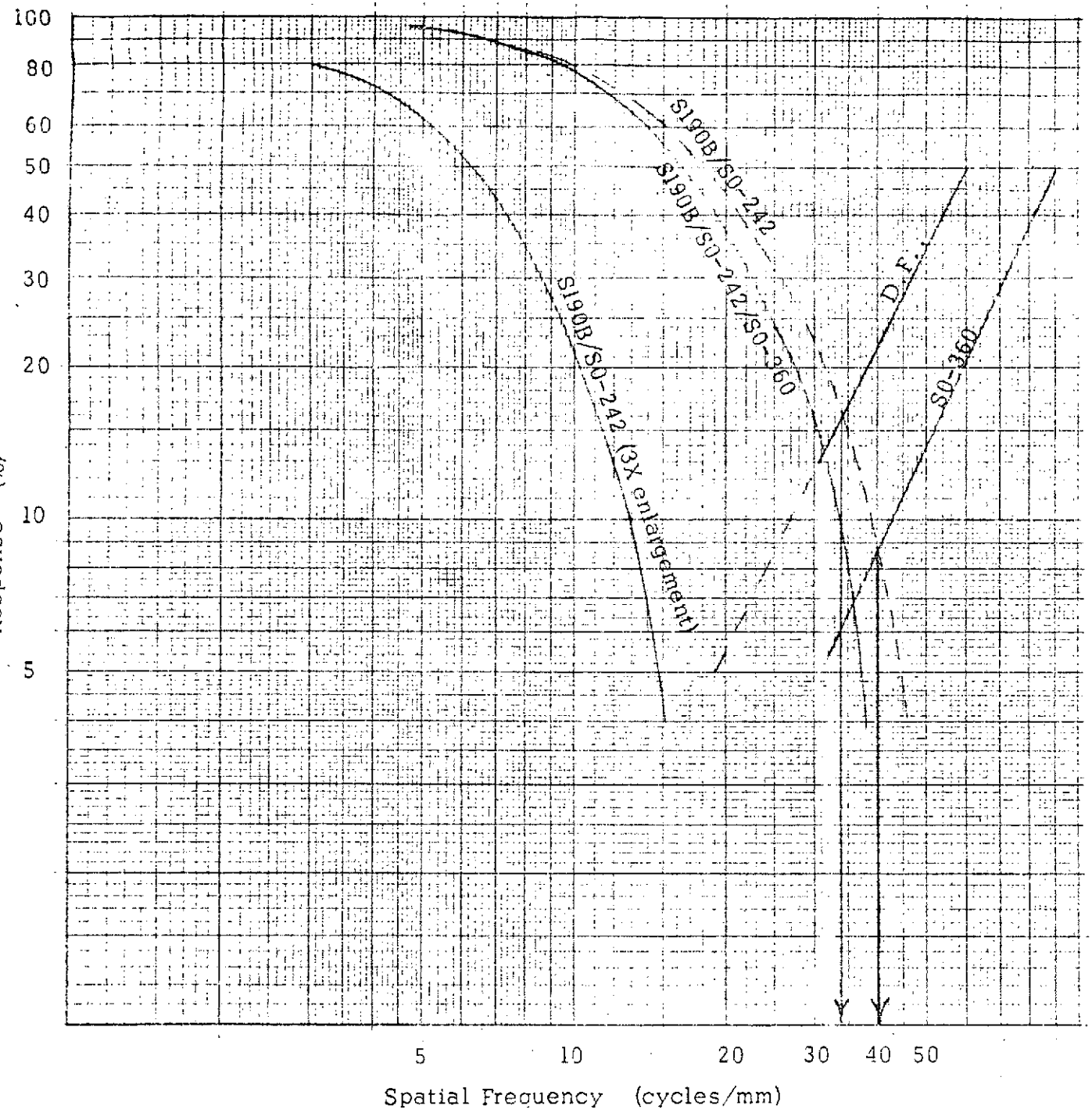


Figure 1.--S190 B Modulation Transfer Functions.

The MTF of second generation contact color film transparencies is given by curve S190B/SO-242/SO-360. (The label indicates camera/original film/duplicating film.) Similarly, curve S190B/SO-242 is representative of the MTF for the original photo, and curve S190B SO-242(3X) for the original photo enlarged three times. The straight lines labeled SO-360 and D.F. approximate the threshold modulation curves for SO-360 and a duplicating film of lesser capability. Contact printing the S190B/SO242 photos on SO-360 and the D.F. would result in high contrast resolution values of about 40 and 34 cycles/mm respectively. Both reproduction films reduce image quality. If the original photo is enlarged by a factor of 3X or greater before printing, the duplicating films do not limit resolution.