The work done to date by [redacted] falls into two general areas: 25X1

1) <u>Investigation of the effective exposure hypothesis.</u> This work is important due to its fundamental relationship to system analysis and to such exploitation techniques as image processing. The use of linear system analysis techniques and the application of inverse filtration and other methods depend on the assumption of linearity. If this assumption is not good, then the whole fabric of these techniques is suspect. It is generally accepted that the photographic process is linear in terms of effective exposure as long as the spatial frequency is very low, say a few cycles per millimeter. At higher frequencies, one can show that the hypothesis cannot work at least in a qualitative sense. It is important to determine the degree of residual non-linearity so that a positive statement can be made about the result.

   In the past two contract periods, [redacted] has investigated the uniformity of the transfer function and the degree of residual non-linearity in terms of residual harmonic distortion. One vital question remains. The entire concept of linearity is important primarily because of the idea of additivity of stimuli. If the system is linear, then the response of the system to the sum of a set of stimuli is the sum of the responses of the system to each of the individual stimuli. In other words, the system responds to each stimulus as though the others were not present. This concept is essential to the use of frequency plane analysis for any purpose. In Fourier series analysis, for example, we break up the stimulus into its component frequencies and analyze the response of the system to each. If these frequencies look different to the system, depending on how many are present and what their amplitudes are, we are faced with a hopeless analytical situation. 25X1

   The critical experiment, therefore, in regard to this hypothesis is the additivity experiment. We measure the response of the system to each of several separate stimuli, in this case, sinusoids in intensity. We then subject the system to the

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sum of two or more stimuli and compare the result with that predicted by the linear theory.

2) <u>Mensuration Experimentation.</u>
The mensuration program attempts to define, in quantitative terms, the error to be expected in measuring the size of objects whose images are only a few resolution elements across. The program involves a mensuration target in both positive and negative form which is imaged with suitable reduction and at appropriate resolution levels. The size of circles, triangles and lines is measured by both conventional microcomparator methods and by microdensitometry. While a large number of test frames were involved, the test design was such that there were no replicates of any case with respect to the photographic variables. Since the errors found are potentially correctible, it is important that the statistics of these errors be known. In other words, any particular observation could possibly be an error. Additional testing will provide an assessment of the potential usefulness of the data gathered so far. In addition, the use of existing test materials can be exploited in another way. It is likely that mensuration will be the greatest benefactor of image processing. In many cases, images are degraded in such a way that complete knowledge of the effective transfer function is not readily attainable. It is very likely, however, that even a modest degree of image processing will produce a decrease in the variance of measurement and therefore contribute to higher confidence in the measurement of small objects.

Since [redacted] has available a sophisticated 25X1 image processing package, it is possible to treat a limited amount of the new, replicated, data with image manipulation methods. Measurement of object size from the computer output can then be accomplished and the result compared with that obtained from manual measurement.

One additional factor should be considered. All the [redacted] tests conducted earlier were 25X1 carried out at a single performance level, for all practical purposes. In this series of tests, one additional resolution level, achieved by stopping the lens, should be provided.

Suggested Program Outline

I. Additivity Experiment

The test materials should be unchanged. Exposures required are in the range of 10, 40 and 100 cycles per millimeter. Combinations to be used are:

10 and 40
10 and 100
40 and 100

Modulations employed should be low, about 0.3, for one set of experiments, and medium, about 0.6, for another. The ratio of lower to higher frequency modulation should be that conveniently available.

defer until later

The tests should be of the form A, B, A+B with the data analyzed for each input stimulus. The tests are of a critical nature and any inconsistencies must be resolved at the outset. Analysis will be along the lines used previously, i.e., spatial spectral analysis based on effective exposure from microdensitometric measurement. Results will be depicted graphically and compared with those expected from linear superposition of the results obtained from the individual stimuli. Adequate analysis and discussion must be supplied that the results can be interpreted.

II. Mensuration Data Verification

A selected set of photographs will be produced, following the general methods employed in the earlier tests. Approximately 40 negatives will be prepared at each of two aperture settings. The exact apertures used will depend on experimental conditions available but should be such that the bar target resolution is noticeably (20% or more) reduced in the stopped down case. The conditions of exposure should be

2 targets x 2 exposures ~~times~~ (perf levels) x 10 replicates = 40 negatives

all subjected to the same processing. It is not necessary that all replicates be used if sequential testing shows this to be unnecessary.

The cases selected for replicates of existing data must correspond to exisitng data insofar as targets, exposure times and processing. Since the stopped down cases are not replicates of anything, they may be taken under the same conditions as the replicates of earlier data, but with the aperture stopped appropriately.

The manual data will be produced as before, but sufficient statistical data will be provided that means, confidence limits and sources of variance can be identified. Final data will include a comparison of the mean of new data with that produced earlier, the variance at each measuring point and the 95% confidence limits of the mean.

A suitable minimum number of negatives will be subjected to treatment by image restoration on a digital computer. The results will be verified by replication , using the frames prepared for that purpose, and repeated at two resolution levels. The measurement of object size will be performed by scaling directly from the computer output, said scaling being performed enough times by different operators that the error contribution connected therewith is identified.

Upon completion of this series of experiments, results will be compared among the various cases and a suitable report prepared.

III. Specific Requirements

The following specific questions are to be answered:

1) Considering the results of this and the previous work, is there reason not to utilize the effective exposure concept in its usual context?

2) Explain the conclusion of (1) analytically, substantiating the conclusion by reference to experimental data.

3) Is the earlier mensuration data consistent with the results of the replicated tests?

4) Are the dispersions in results and the systematic errors involved such that it is worthwhile to consider making corrections in measured data? If so, how does one relate the corrections to real objects?

5) Does the use of digital image processing improve the precision and accuracy of mensuration of small objects? If so, what are the constraints with respect to processing methods, cost and time? Compare the results obtained with the manual data in the case where a comparison is possible. Compare results at the two resolution levels.

IV. Planning Requirements

The following steps shall be taken upon initiation of the program:

1) Prepare a program plan, showing the detailed steps to be taken, the person responsible and the time scale allowed.

2) Identify, on the project time scale, significant

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milestone points and specify the accomplishments to be made at each of these points. There shall be no fewer than four each such points for each of the two major portions of the program.

3) Provide an experimental design which shows the tasks to be performed, the plan of attack, and sufficient statistical analysis to defend the program.

4) If at any time results are obtained which indicate that the approach may be faulty or that experimental data is defective, such results shall be reported to the contract monitor without delay. It is understood that this instruction shall apply to items of major proportion.