To: R. Buchanan

Subject: Optical Evaluation Procedures Date: October 10, 1967

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1. Attachment #1 is the generalized Test Plan which will be used for the evaluation of the MDS ATS optics breadboard. Besides allowing for qualitative and quantitative visual inspection (i.e., tribar targets), it will generate sufficient optical performance data (i.e., point spread functions, contrast transmittance, etc.) to allow the Visibility Laboratory to produce realistic image photographs. This will enable the following to be done:

   a. Allow for comparisons to be made of similarly produced images using the predicted ATS AVE optical characteristics, thereby assuring a more complete understanding of image simulation requirements.

   b. Determine whether the proposed substitution of an "AVE like" ATS eyepiece into the MDS at a later date will actually produce a more appropriate image. If not, suggested modifications to its design can be made sufficiently early.

   c. Assess the possibility of using the MDS design for the MMSE.

   d. Develop confidence in the GE/ITEK capability to develop proper optics for simulator use.

   e. Develop tests procedures for use in acceptance testing of the AVE ATS optics.

2. Attachment #2 gives more complete details of how we plan to use the quantitative optical performance data at the Visibility Laboratory. For this present effort, we will rely upon photographs produced using the predicted characteristics of the AVE ATS as a diffraction limited system (perfect optics) and the MDS actual optical performance photographic images in a comparative manner. Appropriate objects have already been selected, i.e., fighter on runup pad, various types of trucks in a parking lot, helicopters and a variety of aircraft on a ramp. J. Harris has already incorporated these images in his computer programs along with scale size to produce 127 X magnification, contrast degradation appropriate to presently conceived atmospheric models, etc. When the MDS Bench Data are therefore available, J. Harris, in a very short order will be able to produce the appropriate photographs to be used in our evaluations.

3. Page 3 and 4 of Attachment #2 detail work that we hope to accomplish in

the future. This will give further information as to the visual performance capacity to detect and hopefully rapidly assess objects as seen in the HPA task. Ranges of size and form complexity can therefore be developed to help further identify the general categories to be used as activity indicators.

F. Doppelt

L. Thomas

2 Atchs:

(1) Ltr, Aug 31, 1967, WHS-434, Subj: Generalized Test Plan for Evaluation of the [illegible] Breadboard for the MDS (Composed of Optical Elements and Mirrors), 4 Pages

(2) Memo, 13 Sep 1967, Subj: Simulation and Analysis of Imagery for Visual Optical Instruments, 4 Pages, UNCLASSIFIED

Cys to:

H. Bernstein
F. Doppelt
C. Gandy
L. Thomas
D. Truly

WHS-434
Copy 2E of
Pages: Four (4)

To: R. A. Marott

Subject: Generalized Test Plan for Evaluation of the ATS Breadboard for the MDS (Composed of Optical Elements and Mirrors)

Date: August 31, 1967

The test program is to be divided into two general inspection categories. The first to be a qualitative inspection, the purpose of which is to obtain a general feeling for the quality of the device and to assist in defining some of the specific parameters to be measured in the second category. This second category is a quantitative inspection and will additionally serve to generate data which can be input to computer programs whose function is to determine the fitness of the system. All tests should be run at 150-200 ft. Lamberts equivalent at eyepiece exit pupil.

The qualitative inspection will be done by observing at the simulator reticle plane the images of various objects. This inspection will be done without an eyepiece but using a traveling microscope of suitable power, with and without the presence of the anamorphic lens system. The objects to be used are:

1. Bar target resolution chart
   a. low about (2.0:1) contrast - standard Itek supplied chart of known tested contrast.
   b. high contrast (MIL-STD 150A)
2. Point source (artificial star) generated by Itek.
3. Color bar targets (TBD re: Discussion between Gehrke and Shannon).

Images of these objects will be viewed on axis and off-axis (in many azimuths sufficient to delineate the points where maximum image change occurs) at various settings throughout the zoom range (with and without the flip lens) and at various representative settings of the anamorphic lenses (0°, 30°, 60° and 90° angles between the anamorphic axes). Red, green and blue narrow band filters will be used as well as white light illumination. The

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A/C ...

The purpose of this examination will be to observe:

1. General quality
2. Apparent resolving power
3. Visual contrast rendition
4. Field curvature
5. Degree of correction of off-axis aberrations (coma, astigmatism, etc.)
6. Chromatic aberrations
7. Visual effect of system spectral transmission

In addition, appropriate scene material, supplied by Itek at 2:1, 10:1 and 30:1 contrast levels at 100 line pairs, will be viewed as a further check on overall quality. This material will be viewed with a typical eyepiece instead of the microscope and should be of proper scale. The effect of anamorphic and other distortions will be observed as well as the general appearance of the image.

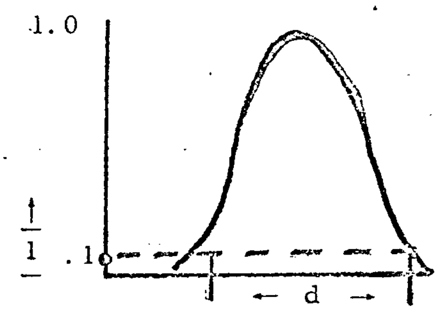
The quantitative inspection will be made at the reticle plane for all tests and through an eyepiece for resolution tests as well. The quantitative tests will consist of:

1. Bar chart resolution
   a. low contrast (same as used for qualitative tests)
   b. high contrast (MIL-STD 150A). This test will be to determine compliance with resolution specs. These tests are to be made on axis and at off-axis points as established in the qualitative inspection and at various zoom and anamorphic settings.
2. System transmission
   a. The percentage transmission of the system to a uniformly illuminated source will be measured.
   b. The contrast transmittance for small objects will be measured. This will be measured by scanning the image of a relatively small opaque object with a microphotometer which will have photometric precision of 10% or better. If N_B is the background brightness, N* is the minimum brightness of the image

of the opaque object and T is the system transmittance, the contrast transmittance is defined as:

$$\frac{C}{Co} = \frac{1}{1 + \frac{N^*}{N_B} \times \frac{1}{T}}$$

3. Point spread measurements of images of artifical stars. These measurements will be made on axis and at selected off-axis points at various zoom and anamorphic lens settings (as determined by qualitative tests). They will be measured using "white" light as well as through red, green and blue filters (as time allows). The measurements will be made with either or both the Itek scanning microphotometer or a microphotometer capable of measuring the point spread function in the sagittal and tangential planes. The scanning aperture of either photometer will be a pinhole whose diameter is ≤ 1/10 of the diameter of the image of the point source where the intensity of the image is 1/10 of the maximum intensity.



pinhole diam $\leq \frac{d}{10}$

From the test data described above, the following comparisons, image effects and performance predictions can be accomplished:

1. Compare the optical characteristics of the breadboard with those predicted for the ATS AVE.
2. Through computerized correlation techniques, the quadratic content of scenes of known quality as affected by the characteristics

of the measured system can be determined and the "image degradation" demonstrated.

3. By utilizing the information developed in 2. and a psycho-physical data bank maintained by the Visibility Laboratory, the probabilities of accomplishing certain binary visual-perceptual tasks (presence-absence, same-different) can be computed.

F. F. Doppelt

L. L. Thomas

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SAN DIEGO, CALIFORNIA 92152

13 September 1967

MEMORANDUM

TO: Dr. S. Q. Duntley

SUBJECT: Simulation and Analysis of Imagery for Visual Optical Instruments

The purpose of this memorandum is to describe the study of computer simulation of optical imagery for visual use on telescopic and microscopic systems.

Background and General Description

At various stages in the design and development of an optical system for visual use, information with respect to the system resolution is evolved, first in the form of design calculations, and later in the form of optical bench test data on components of the system. This information may be in the form of point spread functions or optical transfer functions. While it is true that information in this form does properly define the system resolution, it is an extremely difficult and sometimes nearly impossible task to picture on the basis of these data how the images of real objects of interest will appear. Every optical system is designed and built with some specific data acquisition tasks in mind, and it is important to know at the earliest possible moment, how the performance of these tasks will be affected by the system resolution.

In the present study, high resolution photographs of selected objects of interest will be convolved with point spread function data to produce pictures which represent predictions of the imagery which will result from the completed optical instrument. By viewing these images and attempting to perform typical recognition and identification functions, it is believed that a more nearly correct judgement can be made as to the adequacy of the system resolution than can be made from numerical definitions of resolution or from viewing either point spread function of optical transfer function data.

Digitizing of Photographic Images

After selection of high resolution images of objects of interest, positive transparancies of these images will be made with scanning and digitizing of these films accomplished by means of our image processing film scanning equipments. The positive transparancies will be made at an enlargement such that the maximum object dimension on the film will be slightly less than 6.4 mm in order that digitizing can be performed on a 64 x 64 element matrix with 100 micron distance between elements. Each image so scanned will produce a deck of IBM cards. Digitized pictures will be made at the time of scan by means of the cathode-ray-tube display system in order that the resolution limitations associated with the scanning operations can be seen clearly. A proper criterion should be that, when viewed at the correct angular subtense, the discrete nature of the digitized images is not apparent.

Convolution Operations

The convolution operations will be accomplished with Fourier transform operations using existing computer programs. The first step in the procedure will be to Fourier transform the point spread function data to derive the two-dimensional complex, i. e. amplitude and phase, optical transfer function. The next step will be to Fourier transform the digitized images previously described. Complex multiplication of the two spectra will be performed to yield the degraded image spectrum. An inverse transform of this degraded spectrum will yield the degraded image. These operations will be performed on the UCSD CDC 3600.

Generation of Pictures of the Degraded Images

For each degraded image the computer will produce a deck of cards defining the image on a 64 x 64 matrix of points with 100 linear gray scale steps, i. e., each point in the degraded image will have an integer value between 0 and 99. These "picture decks" will serve as input to our image processing picture generation equipment in which the data is used to modulate a cathode-ray-tube display which is photographed by means of a Polaroid oscilloscope camera. Type PN film will be used in order that a photographic negative is obtained.

Positive transparancies will be made from these negatives and arrangements made for viewing of these films at the proper angular subtense. Positive transparancies will also be made from the original undegraded images so that a direct comparison of the effect of the degradation can be made.

Theoretical Back-Ups

It is probable that the viewing of the computer generated degraded images will be sufficient to answer questions as to the adequacy of the resolution of the optical system. There are a number of quantatative analysis techniques which can be applied to the problem if their application seems necessary. These techniques allow calculation of the probability of correctly performing specific binary decision tasks. For example, if we have a degraded image and we know a'priori, that the image is due to either object A or object B, then there are several mathematical formulations which allow us to be quantitative about the ability to decide correctly between the object alternatives based on the image information.

The first of these involves the concept of the summative function of the human visual system. It has been demonstrated that, for the purpose of determining visual detection thresholds, the visual system can be approximated by a linear spatial filter. This spatial filter is called the summative function. If the summative function is convolved with the object to be detected, detection will occur if the peak value of this convolution exceeds a threshold value which can be determined from existing basic vision data. An extension of this concept to the case of binary decisions has been made with limited but successful experimental verification. In the case of the binary decision it is first necessary to overlay the degraded images which would result from object A and object B with a position and orientation which maximizes the cross-correlation between the two images. A point-by-point difference is then taken and this "difference image" convolved with the summative function with the criterion that if the difference image is visually detectable, the binary decision can be properly made.

A second formulation of the binary decision process also involves the difference image as defined above. In this second formulation, however, the difference image is operated upon by the optical transfer function for the optical system of the human visual system in order to determine the retinal image which would be produced by the difference image. This retinal image is squared at each point and spatially integrated to determine the "quadratic content." This numerical value, coupled with retinal noise level, inferred from basic psychophysical data, allows statements to be made as to the probability of correctly making the required binary decision.

Psychophysical Back-Ups

Pairs of degraded pictures involving some typical binary decision can be generated by the techniques previously described and used as the basis of a forced choice vision experiment in which probability of correct decision is experimentally determined as a function of a variable such as a scale factor on the point spread function. This is probably not required for most applications because as the point spread function is scaled in size, the transition from certain identification to no identification is quite rapid and the subjective judgements described earlier can usually bracket the transition range rather well.

James L. Harris, Sr.
Associate Director

JLH:pw