ATTACHMENT 9

IMAGE QUALITY PERFORMANCE PROGRAM

1.0 INTRODUCTION

The purpose of this attachment is to describe a program sponsored by the Program Office that is now underway for studying the image quality performance of the overall image chain of the EOI System. This Image Chain Performance Program is an integrated set of activities directed towards a detailed analysis of the EOI System image quality performance, support for the establishment of system image quality requirements, and the generation of system and subsystem functional specifications necessary to meet those requirements.

The program is structured into three specific areas of activity, namely, the Image Processing Laboratory, the Image Chain Analysis, and the Array Flight Testing.

The planned activities in these individual areas have been scheduled and coordinated so as to provide timely and relevant support to the EOI System during all phases of development. The planned development and implementation also incorporates sufficient flexibility to ensure its continued utility in support of long range system growth and evolutionary improvement.

The following three sections outline each of the specific areas of activity. The final section enumerates those specific image chain functional elements which will be studied, lists the parameters to be determined during the next six to eight months, and incorporates those preliminary conclusions which have been drawn from the earlier experiments in sampled imagery and first generation breadboard array testing.

2.0 IMAGE PROCESSING LABORATORY

2.1 Introduction

The Image Processing Laboratory (IPL) is an operating facility developed initially for testing the performance of breadboard solid-state arrays. The initial capabilities are currently being expanded to include a complete hardware and software simulation capability as well as the advanced testing of actual arrays. The IPL is being developed as the single, integrated facility for the generation, processing, and reconstruction of images produced under the EOI Program. This includes all simulated imagery, imagery derived from actual array testing, and imagery generated under the [redacted] activity.

The IPL was developed late in 1969 in order to achieve early imaging experience with the first-generation solid-state array transducer breadboards. Both [redacted] breadboard arrays were tested early in 1970. The purpose of these tests was to demonstrate that the electrical signals generated by the arrays under simulated operating conditions could be adequately compensated to account for variations in response between detectors and geometrically processed in the current format for image reconstruction.

The preliminary testing was completed and further testing has been accomplished to refine various aspects of the test and reconstruction process.

During the past several months the primary objectives at the IPL have been to increase the capabilities of the facility to include reconstruction of the [redacted] imagery, the development of the hardware and software required for an expanded simulation capability, and the continued testing of second-generation breadboard arrays.

2.2 Description

Figure 1 is a block diagram depicting the essential functions of the IPL. The equipment in the Imaging Section is concerned with generating a realistic simulation of real-world scenes and projecting these onto the solid-state array breadboards. In the Data Processing Section, the output digital data stream generated by the solid-state array breadboards is recorded and processed by a general purpose computer. In the third section, the processed data is reconstructed into an image by the write-out device and photographically processed into a hard-copy print.

The Data Processing Section incorporates a digital data buffer and software capability to handle the data rates of the second-generation breadboard arrays. A major area of development has been in the software for processing the data on a general purpose computer. This processing includes the capability for geometric reformatting and gain equalization of the data, in addition to the newly developed capabilities to simulate the DPCM encoding and decoding of the data, provide transfer function compensation processing, and permit the use of frequency-dependent tonal reproduction techniques. Development of these data processing capabilities has been completed, and they have been used to process image data obtained during earlier testing with the first-generation breadboard arrays.

2.3 Capabilities Under Development

There are several additional capabilities currently under development which will greatly expand the utility of the IPL. The primary purpose of these additional capabilities is to achieve a single integrated facility capable of producing imagery simulating the EOI System characteristics, using either an actual breadboard solid-state array as shown in Figure 1, or simulating the imaging function of an array with an image scanning device. These increased capabilities are in two specific areas: The development of an improved image scanning device for use in both scanning input scene transparencies and the reconstruction of output images, and the development of extensive software to simulate the various EOI image chain parameters that have a direct effect on image quality.

Specific capabilities to be provided by the hardware and software under development will allow the generation of simulated images which demonstrate the impact on image quality performance of the following key elements of the EOI System image chain:

a) Atmospheric attenuations and backscatter

b) Optical modulation transfer function

c) Image motion components

d) Sensor noise levels

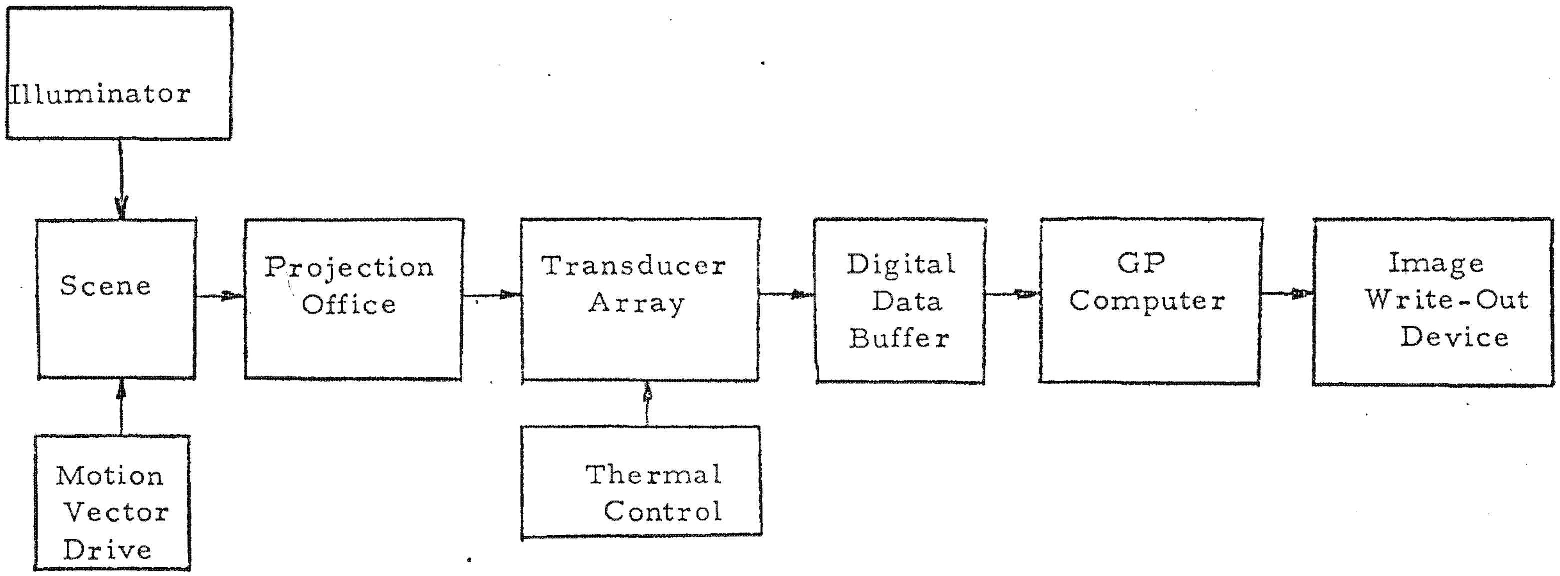
e) Sensor modulation transfer function

f) Sensor non-uniformity of response and calibration

g) Communication subsystem bit error rates

FIGURE 1

IMAGE PROCESSING LABORATORY BLOCK DIAGRAM



Imaging Section

Data Processing, Image Reconstruction Section

h) Data encoding and decoding, including memory word and updating

i) Ground-based image data processing including modulation transfer function compensation processing

j) Image reconstruction

All of these developments are proceeding on schedule and will allow a full simulation capability early in October.

3.0 IMAGE CHAIN ANALYSIS

3.1 Introduction

The Image Chain Analysis (ICA) activity is an analytical effort currently underway with the primary objectives of providing support for the establishment of the EOI System image quality performance requirements and the development of detailed image quality performance tradeoffs at both the system and subsystem level. It is anticipated that the results obtained under the ICA will allow for the establishment of detailed functional specifications for each element of the EOI System design which critically impacts overall image quality performance.

Early in the technology development phase of the EOI System a significant effort was undertaken by the Program Office to establish a preliminary but viable image chain simulation capability. The objective of the early program was to generate sampled images representative in a first order sense to those images which could be obtained at the output of a class of electro-optical imaging systems employing solid-state array transducers. The purpose in generating and evaluating these images was to ensure that the ranges of key system parameters utilized in the initial studies were compatible with the desired image quality performance. This capability was further exploited to support investigations of essential data handling techniques, including I/S data encoding and ground-based compensation processing. This effort has provided significant preliminary data in each of the noted areas and has matured to the point where a detailed image chain model development and an expanded image simulation and evaluation capability are required to ensure continued and orderly progress.

3.2 Description

The Image Chain Analysis is structured into three interrelated activities of, Analysis and Modeling, Model Development and Operation, and Image Evaluation.

A critical interface is also maintained between the ICA and IPL activities. The IPL is responsible for the acquisition and generation of all simulated images required for evaluation by the ICA. The ICA specifies the content and image chain parameters for these simulated images.

Analysis and Modeling

In general, the Analysis and Modeling activity involves defining the EOI System image chain, conducting a detailed analysis of each of the functional elements, developing the mathematical expressions which represent the operation of each of these elements on the image data, structuring these expressions into a useful configuration for software modeling, analyzing and evaluating the data resultant from the model operation and an image evaluation to establish the functional relationship between image quality performance and the key functional element parameters of the image chain. Sensitivity studies are also conducted to provide meaningful guidance in constraining the range of parameters and operating conditions to be encountered.

Model Development and Operation

The detailed mathematical expressions developed under the previously-described activity will be configured into a set of integrated software modules. Each module will be representative of a particular image chain functional element. This modular approach permits the input of parameters and the extraction of data at any element interface throughout the chain, and provides a balance between flexibility for future growth and economical on-line operation.

Model input is in the form of a grid sample matrix of ground brightness levels and element parameter values. The grid sample points are processed through each of the modular blocks of the simulated image chain and modified as dictated by the parameter values input to the model operation. Where possible, element operations are commuted to reduce running times and iterations are performed internal to the module(s) or function(s) under study. The model output consists of a properly normalized matrix of intensity levels for comparison with input levels or previous model operations as appropriate, and tabular listings of model parameters.

Image Evaluation

Based upon the results of the preliminary sensitivity analysis and subsequently upon model operations analysis, the requirements will be generated for a series of simulation images. These images will be produced by the IPL to the required specifications. After reconstruction and verification testing, these images will undergo a detailed photoevaluation, consisting of both objective and subjective ratings. Image quality data derived from these interpretation experiments will be fed back to the Analysis and Modeling activity for integration with the appropriate model outputs.

4.0

5.0 DISCUSSION

The purpose of this section is to briefly describe the activities to date under the Image Chain Performance Program as they apply to each of the key functional elements of the EOI System image chain and to present specific results which have been obtained. Specific elements or element parameters which will be investigated in depth during the next six months will also be identified.

5.1 Ground Sample Distance (GSD) and Signal-to-Noise Ratio (SNR)

A key system tradeoff impacting the image quality performance of a sampling system is that of GSD and SNR. Numerous combinations of GSD and SNR are attainable for a given set of transducer and optical subsystem performance parameters. These combinations can be accomplished at a fixed operating altitude by variation of the focal length and integration time, by fixing the system design characteristics and varying the operating altitude, or by a combination of either of the above with improved transducer noise performance.

A simulation has been conducted to study the effect of SNR on image quality for various values of GSD based on a fixed altitude and a variable focal length and integration time. The images generated were based on an operating altitude of 283 n. mi. and included an SNR from 10:1 to 1:1 and a range of GSD from 24 inches [redacted] The detailed evaluation of these images is currently on-going. However, based on a preliminary assessment of this operating situation, it appears that the SNR required to provide reconstructed imagery in which visual noise is not a limiting influence — both before and after system modulation transfer function compensation processing — is a relatively weak function of GSD. For example, at a SNR $\gtrsim$ 5 and a GSD of 12 inches, visual noise in the unprocessed image was not particularly disturbing and subsequent processing provided significant improvement in the overall quality of the image, both objectively and subjectively. These same results were also found to prevail at SNRs $\gtrsim$ 3 for a GSD [redacted] and SNRs $\gtrsim$ 8 for a GSD of 18 inches.

Analysis of this data tends to support the concept that, for a given GSD, acceptable levels of image quality performance are determined by both the influence of noise at all spatial frequencies in the reconstructed images as well as the relative modulation levels of the system transfer function across the spatial passband and the complex mechanism by which these factors combine with the signal spectrum to establish the final image structure.

Experiments designed to provide further insight into this phenomena including the non-separable psychophysical process of interpretation are now underway. Quantitative results of these studies are geared to the key parameter affecting image quality and will be available within the next six months. In addition, results from the [redacted] will be analyzed to determine the utility of extending the usable spectral response characteristic of the sensor [redacted]

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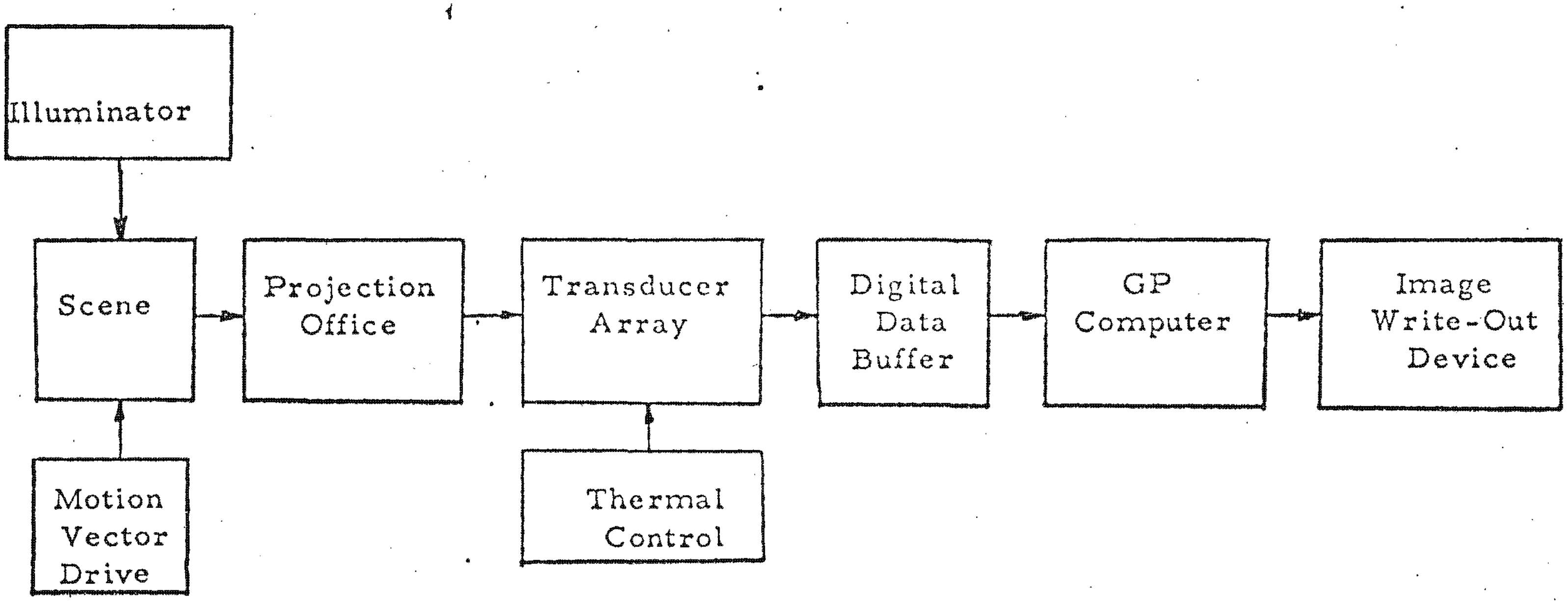
FIGURE 1

IMAGE PROCESSING LABORATORY BLOCK DIAGRAM



Imaging Section

Data Processing, Image Reconstruction Section

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