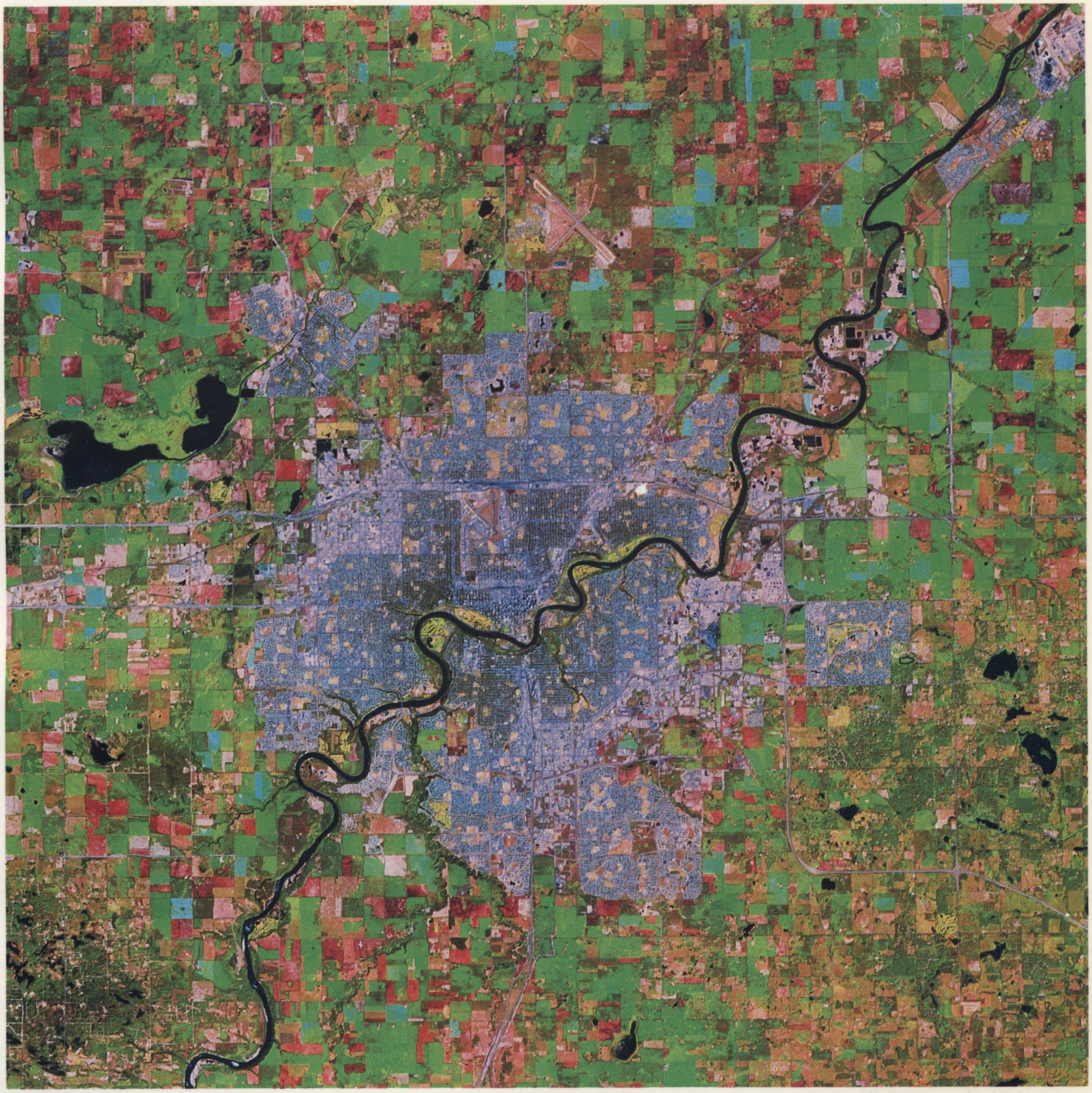
10th CANADIAN SYMPOSIUM ON REMOTE SENSING

10e SYMPOSIUM CANADIEN SUR LA TELEDETECTION



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A DIFFERENTIAL LIGHT METERING SYSTEM FOR AERIAL PHOTOGRAPHY

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ABSTRACT

The development of a differential brightness exposure system and its application to aerial photography is discussed. Current I.C.A.S. specifications for black and white aerial photography used for photogrammetric mapping and reconnaisance reflect the need for coordinated exposure and processing control. Past attempts and present efforts for an exposure control system are reviewed. The development of a differential brightness metering system is outlined with emphasis placed on correlating the variable film speed effects of processing and the determination of camera exposure. Discussed are the hardware and software components of the photosensor unit including a detailed analysis of the data processing software. Calibration of this system is briefly investigated.

UN SYSTEME DE POSEMETRE DIFFERENTIEL POUR LA PHOTOGRAPHIE AERIENNE

RESUME

La mise au point d'un système d'exposition de la brillance différentielle et son application à la photographie aérienne est traitée. Les spécifications actuelles d'I.C.A.S. en ce qui concerne la photographie aérienne en noir et blanc utilisée en cartographie et reconnaissance photogrammétriques reflètent le besoin d'un réglage coordonné de l'exposition et du traitement. Les essais antérieurs et les travaux actuels portant sur un système de réglage de l'exposition de la chambre. Les éléments du matériel et du logiciel du photocapteur sont analysés, en particulier le logiciel de traitement des données. Le calibrage de ce système est brièvement analysé.

Keywords/Mots-Clés: Differential brightness, exposure system software, film processing, photosensor, lightmeter calibration

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INTRODUCTION

The light meter is an indispensable tool for most photographic applications. Proper light measurement provides the user with a compatible exposure and, most important, with a consistent quality product. In black and white aerial photography used for mapping and reconnaisance the simple equation for proper exposure is complicated by several factors. The effects of atmospheric haze, changing terrain, variable processing, among others, confuse the derivation of the compatible exposure by conventional light meters, and ultimately, with obtaining consistent quality. E.A. Fleming (1983) states the situation tersely, "... there is no reason for complacency until the inaccuracies in exposure and processing ... are overcome". This predicament applies in Alberta and is probably true in other parts of the country as well. Frustration with attempting to obtain properly exposed and properly processed black and white aerial photography is a troublesome reality and represents the impetus for developing the differential brightness light meter.

BACKGROUND

The I.C.A.S. Specification for Aerial Photography (1981) is a cornerstone reference for judging photographic performance in Canada. Failure to meet the Specification's parameters have lead toward faulting either the Specification's characteristics or the firms procuring the photography. Investigation into these two possible problem areas result in no major short-coming with either, but the photographic problems are persistent. The Specification accurately defines what the quality criteria should be for the final product; there are no ambiguities concerning its density range objective. In fact, I.C.A.S. publishes a Manual of Procedures which gives extensive information on sensitometric control and specifically, negative density range control. Contractors similarly attempt to provide the best product given their available resources. Delivery of their best product, however, is inconsistent even when camera compatible light meters such as the Wild PEM are used. It is evident that the type of information which conventional light meter systems obtain, and which aerial photographers base their experienced judgements on, are insufficient to effectively provide control for the negative density range parameter of the Specification. The fact that this parameter is empirically judged and not quantified is a source of the inconsistencies observed.

There have been a number of endeavours which have addressed a proper light data gathering system for negative density range control. Carmen and Carruthers (1951) made use of a telephotometer to record ground luminance detail in selected areas. They obtained a range of brightness values for a given scene and derived from this range a measure of the scene's contrast. Later, Carmen (1967) applied this information toward systemizing an effective control of the negative density range. Euling (1962) proposed a theory of operation for a multi-cell exposure system applied to pictorial photography. The system was oriented toward a photographic resolution of the intrascene dynamic range exposure problem. The statistical methods Euling outlined for estimating population scene brightness have been applied in this work. More recently P. Williams (personal communication, Oct. 1983) has devised a narrow angle radiometer for direct application to aerial photography. His system, again, focused on obtaining the critical information concerning the range of brightness for a proper quantification of contrast.

Evidently, insights into the use of the brightness range information and its potential benefits have existed for the past 35 years. It is only recently, however, that aerial survey camera manufacturers are attempting to integrate its use with exposure/processing based light metering information; the Zeiss Jena LMK is one (and only) such camera. The system presented in this paper could supplement the numerous camera systems that either have a built in integrated type light metering format or those having no metering system at all. At this point the differential light meter is a completely independent data system oriented toward providing the photographer and not the camera with exposure control information.

THE DIFFERENTIAL LIGHT METER

Investigations into the design of the light meter lead to a definite set of requirements. Economy of space, easy adaptation to typical remote sensing aircraft, an independent power source, and most importantly, operator use simplicity are considered to be essential factors. In addition, a completely automated data acquisition system for sensing ground luminance is necessary to prevent operator bias and also will distinguish the instrument from past efforts in this area.

The components considered essential for the lightmeter consist of a remote sensor apparatus for data sensing and a terminal for data processing. The remote sensor's functions include sampling the light reflected from the ground and converting the acquired readings to calibrated values (ft. Lamberts) with the aid of a Z8603 microprocessor. The terminal controls data input from the sensor and contains the necessary software for processing the calibrated light values. It also functions as a display screen for either prompting the photographer for basic information or acting as a readout screen from which the photographer obtains exposure values. An additional cabin component includes the independent rechargeable power pack for supplying the necessary voltages to the remote sensor and the terminal.

THE REMOTE SENSOR

The remote sensor comprises three basic parts: the light gathering optics, the photosensor array, and the data acquisition elements. The actual device housing these components is a metal box of approximately 11.6 cm X 9.1 cm X 5.1 cm. Its size is accommodated in one of the camera port corners of the aircraft where is performs its light sensing task. Two cables connect the box to the cabin components, one for data communication and the other for power.

The Optics

The optical requirement addresses the amount of ground viewed or area sensed by the phototransistors. The idea is based on simulating the approximate coverage of the aerial camera's lens in a smaller format. The characteristic lens used on aerial cameras has a focal length of about 153 mm, this lens produces an image size of about 33 cm in diameter on the focal plane and has a view angle of approximately 84°. The optical conditions for the remote sensor must approximate the aerial camera's configuration if the area sensed by the photocells is to be similar to that of the camera; however, the remote sensor only requires a focal plane image of about 5 cm to illuminate the array of photo transistors. In effect, a lens giving a factor of eight reduction in the focal plane image size (ie. from 33 cm to 5 cm) and providing about an 80° view angle would simulate the imaging characteristics of the aerial camera as required by the remote sensor. Lenses used in 35 mm photography provide the required scale reduction, while the 28 mm lens in this photographic format satisfies the view angle condition. A 35 mm lens can also be utilized if the extremities of the image are disregarded. This lens may be more appropriate for meeting the critical requirements of the Specification which concerns density measurements taken within a 10 cm radius from the negative's fiducial center.

The Phototransistors

The type of light sensing device used is the BPW39 A phototransistor manufactured by General Instrument (1983). The spectral response of the BPW39A, like most silicon sensors, ranges between 450 nm and about 1100 nm. The peak sensitivity is situated at approximately 825 nm. This physical characteristic of the sensor introduces both conveniences and problems, depending on the type of emulsion in use. Infra-red emulsions are spectrally sensitized to about 930 nm, this correlates well with the BPW39A and only an attenuation of I.R. light is required; a 4605 (2 mm thick) Corning glass filter is used for this purpose. Panchromatic emulsions, however, are sensitized to about 700 nm, therefore requiring more radical modification to the spectral sensitivity of the BPW39A. An infra-red cutoff filter (KODAK 301A) will absorb much of the infra-red radiation from 700 nm to about 1000 nm. As a result, the BPW39A senses radiation in the 450 to 700 nm range when used in conjunction with this filter. Unfortunately the sensitivity of the BPW39A is also reduced by almost 50% with the use of the 301A filter but given the high photon gain of this particular sensor the lower effective light levels remain adequate. Diagram 1 demonstrates the characteristics of the two filters and their effects on the sensitivity of the BPW39A.

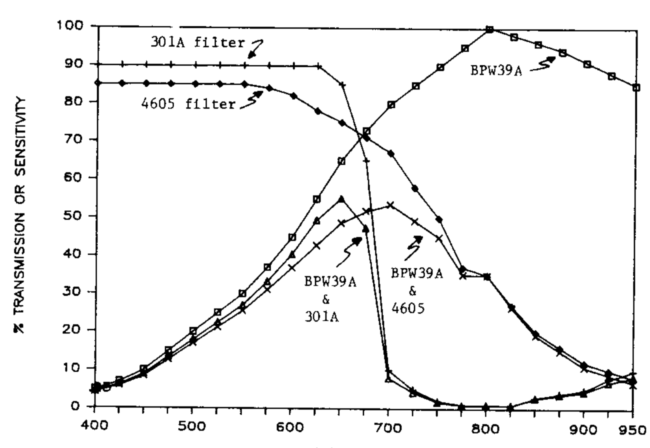

Diagram 1. Sensor sensitivity and filtration

The photoactive area of the BPW39A corresponds to a square area of about .33 cm X .33 cm on the actual aerial photo frame. This sensing area is a constant and would be similar for photography flown regardless the scale. The dimensions of the photo cells are an attempt to correlate the photoactive sensing area with typical densitometer apertures used in measuring the densities of the processed negative. These aperture diameters usually range between 1 mm and 4 mm with the 2 mm or 3 mm used most commonly. Illustration 1 provides an example of the ground area viewed by each individual photo transistor.

Data Acquisition Circuitry

The circuitry contained in the remote sensor can be divided into two functional groups; the digital/communications circuitry and the analogue/conversion circuitry.

The digital and communications circuitry consists of a dedicated microprocessor, rom memory, clock and communication interface. This grouping provides the primary intelligence of the sensor, converting the analogue output of the phototransistors to a digital value and outputting it to the host computer.

The analogue and conversion circuitry includes eight phototransistors, analogue switching and analogue to digital conversion. The output of the desired phototransistor is channeled through the analogue switch to the A/D converter where it is converted to a digital value. This digital value, which is proportional to the amount of light falling on the phototransistor is then provided to the microprocessor.

Data Acquisition Software

The machine level programming of the remote sensor unit is quite straight forward.

On power-up, the microprocessor initializes all of the required internal registers, timers, port and status conditions. After initialization is complete, a loop is entered waiting for an input character from the host computer. On receipt of a character, the microprocessor verifies that it is a valid request (an ASCII value from 1 to 8). The valid request character is then used to select the required sensor through the analogue switch and subsequently, the A/D converter provides the raw digital sensor information to the microprocessor. The microprocessor then converts the raw data to calibrated light levels and outputs this in ASCII characters to the host computer. On completion, the program returns to the input loop for the next request.

THE TERMINAL

The terminal used as a display and data processing station is the Radio Shack TRS 80 model 100 portable computer. Its versatility and attractive price makes it a logical choice upon which to build the exposure system. Its compactness and portability is also well adapted to the economy of space within the aircraft cabin.

Features

The size of the model 100 is approximately 30 cm x 22 cm x 5 cm. The standard version comes equipped with 8K memory expandable to 32K with additional RAM chips. The version used with the lightmeter is equipped with 24K memory, this provides sufficient memory space to contain the main data processing program and a number of peripheral files used for accessing or updating the sensitometric film information.

The computer has a powerful built in BASIC by Microsoft for high level programming ease. This version of BASIC encompasses any special requirement imposed by the data processing commands or by the communication commands of the software. An RS 232 communication port facilitates data retrieval from the remote sensor while an eight line LCD screen delivers data to the photographer in a readable format.

Data Processing Software

The software program is written in Basic for accommodation by the model 100. It examines 3 necessary requirements for attaining proper exposure information. These are:

- Obtaining a proper data sample of ground luminosities.
- Obtaining a proper film processing gradient for density range control.
- Using the Exposure Value System to obtain the camera exposure settings.

Ground Sampling. Sampling ground luminosities involves a two part process, first determining the total luminance information needed, second defining the rate at which it is obtained. The information quantity is best resolved with some elementary sampling statistics. If the average scene illumination is to be estimated within .05 log ft. Lamberts (1/8 stop) with a probability of .95, then an appropriate sample is required. The derived sample size of 216 data points is approximated by applying the Empirical Rule to the estimation equations; Mendenhall (1971) provides a complete description of this procedure.

The phototransistors are scanned by the remote sensing unit's software at about 24 cell readings per second. Complete ground coverage relating to the aerial photo frame is performed in a sequence of timed scans which in turn are determined by the aircraft speed and flying altitude. Figure 3 box A shows the input parameters supplied by the photographer while box D calculates the timing interval based on the input data. Boxes E and F demonstrate a loop routine which apply the timing interval for each scan until a total of 216 light level readings are obtained. Once the data are accumulated the range and the mean of the data are determined (Box G). The mean is required for estimating the overall illumination while the range indicates the degree of contrast on the ground. The range is calculated utilizing standard deviation techniques thereby eliminating isolated extreme values in the brightness data distribution. This method of calculating variance assumes a normally distributed data curve.

Average Gradient G. The processing average gradient for a black and white film must be known in order to obtain the Effective Aerial Film Speed (E.A.F.S.) and determine exposure. It is essential that the laboratory obtain a range of G and their associated film speeds for any given emulsion batch used. These data are stored in the sensitometric data files in the computer and are accessed during the actual flying missions. The importance of having a film processing machine in control when obtaining the sensitometric data and later when processing the exposed film is a key procedural step. If these basic tasks are not performed with care the uniqueness of the overall system is lost and the final results prone to error. The software analysis of the sensitometric film data is the key element and possibly the main feature of the overall system. The computer's correlation of the average gradient, the film speed, and exposure outcome addresses the long-standing need for better communication between the photographer exposing film and the laboratory personnel processing film.

The flowchart is resumed at box H where a decision regarding the average gradient is made. The program features a choice of either entering a user desired G (Box I) or letting the computer determine the most appropriate G (Box J) given the terrain contrast conditions. This option lets the photographer first use the computer to sample the range of G likely to be encountered and then set the one G the photographer considers best adapted to the ground terrain. The film is later processed to the G chosen during exposure. The computer determined G is calculated to give the resulting negative density range a value of 1.00 or as close to 1.00 as possible as stipulated by the I.C.A.S. specification. With knowledge of the G required, a search is performed for the array of average gradients and film speeds corresponding to the film type in use (Box L). The sensitometric data for this segment of the software are obtained from Fleming, Landreville, and Nagy (1982) and Fent (1983); however, the most current film batch data are required for general use. These data are subjected to a regression analysis whereby the E.A.F.S. for the operational G is obtained (Box T). There is a further check noting whether the G required either exceeds or is deficient given the bounds of the laboratory derived data. If either is the case, a warning statement is indicated to the photographer (Boxes N, O, P, Q) and the density range is adjusted below 1.00 or above 1.00 (Box R). Box K requires a decision concerning color or black and white emulsions. Information related to average gradient and filmspeed derivation is disregarded in the color mode; color emulsions are not subjected to processing variations for contrast control.

Exposure. The Exposure settings are derived using the Exposure Value system (E.V.). An indepth description of the system is available from Stimson (1962), detail will thus be restricted to aspects applicable to the lightmeter.

The use of the E.V. system requires a lightmeter calibration color temperature of 4700°K. The color temperature is specified in response to a predetermined exposure constant which sets the luminance value of the E.V. scale at 0; the field luminance at this value is 1 ft. Lambert. The scale, in effect, is zeroed and consequently standardized for compatibility with other light meters using the E.V. system.

A major consideration in using the E.V. system is its film speed scale. Stimson's paper defines the film speed in terms of the A.S.A. criteria (CSA Z7.0.2.2), the arithmetic definition being:

$S_{ASA} = .8 / \text{LOG } E$

where E is the exposure at a density of .1 above Base and Fog on the characteristic curve. The effective aerial film speed is defined as (CSA Z7.3.2.1):

$S_{EAFS} = 3 / 2 \text{ LOG } E$

where E is the exposure at a density of .3 above Base and Fog on the characteristic curve.

Although the difference and methods used in defining the speed seem to pose a problem in correlation, they are irrelevant. The arithmetic scale that the E.V. system uses is simply a series of numbers progressing by a factor of two; the speed value scale is a Log Base 2 conversion. The significance the scale assumes depends upon how the numbers in the series are derived. If the ASA method is used then the speed value will correspond to the ASA criteria; alternatively, if the E.A.F.S. method is used then its criteria is applied. Obviously the two systems cannot be interchanged nor can an exact conversion factor from one system to another be introduced. The identity of the film speed is dependent on the toe region of the characteristic curve which will change depending on processing conditions and film batches. The two speed systems are therefore used independently.

Box V in figure 3 denotes the stage at which the E.V. system is derived and applied to obtain the exposure conditions. The critical variables which are known at this point are the average luminance value (from box G) and the film speed value (from box T). It is from this information that the time value and the aperture value are calculated for the final f/stop and shutter speed settings.

CALIBRATION

The calibration of the light meter requires addressing a number of factors in order to provide correct exposure information. The color temperature of the calibration light source must be set at 4700°K to conform with the E.V. system as previously mentioned (ANSI PH3.49-1971). The light sources presently in use are 3400°K photo flood lamps; their spectral response is matched to that of a lamp at 4700°K by mounting an 80 C filter on the remote sensor box and on the calibrating probe. The reference is a TEXTRONIX J16 photometer with a J6503 photometric probe. This instrument's dynamic range is 0.1 to 199,990 ft. Lamberts which encompasses the complete range of ground luminosities encountered in the field and provides the reliable data source for setting and checking the lightmeter. The photo floods total light output is 4000 watts, this provides a calibration range between 50 and 3150 ft. Lamberts over a distance of about 4 meters on the optical bench. The photometric readings are obtained off a white reflecting surface while the surrounding areas reflect 18% grey. The readings obtained from the phototransistors are then correlated with those from the Tektronix photometer, each phototransistor is checked independently at a number of distances to ensure the relationship between current and illuminance is satisfied. The sensor values and their photometric equivalents are then installed as part of the look up table in the data acquisition software (see figure 2) where they are referenced each time a reading of the sensor values is performed.

CONCLUSION

The differential light meter introduced here is not the final nor the ultimate product in differential lightmeter design for aerial photography. This system, as with its predecessors, will undergo changes and improvements as it keeps pace with an ever expanding electronics industry, but the main ideas still apply, they will only be applied more efficiently with the arrival of new components.

Preliminary airborne tests have been conducted with the lightmeter and the results have been very encouraging. However, a more extensive testing program is needed for the verification under varying terrain, scale, and emulsions, this testing program is currently underway and results will be available in the autumn of 1986.

The importance of this lightmeter and its future generations lies in that it provides the photographer a measure of control. It is certainly hoped that this control will translate into more consistent quality in the aerial photography product and more confidence in achieving that desired quality.

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Illustration 1 - This photograph illustrates the frequency at which the terrain data is acquired, it also provides an indication of the sampling area provided by a single cell value. 216 of these cell values provide the basis for determing the contrast and overall exposure levels for the lightmeter. The flight direction is from top to bottom and the original scale of the photography is at 1:15 000.

FIGURE 1

FUNCTIONAL BLOCK DIAGRAM

(REMOTE SENSOR)

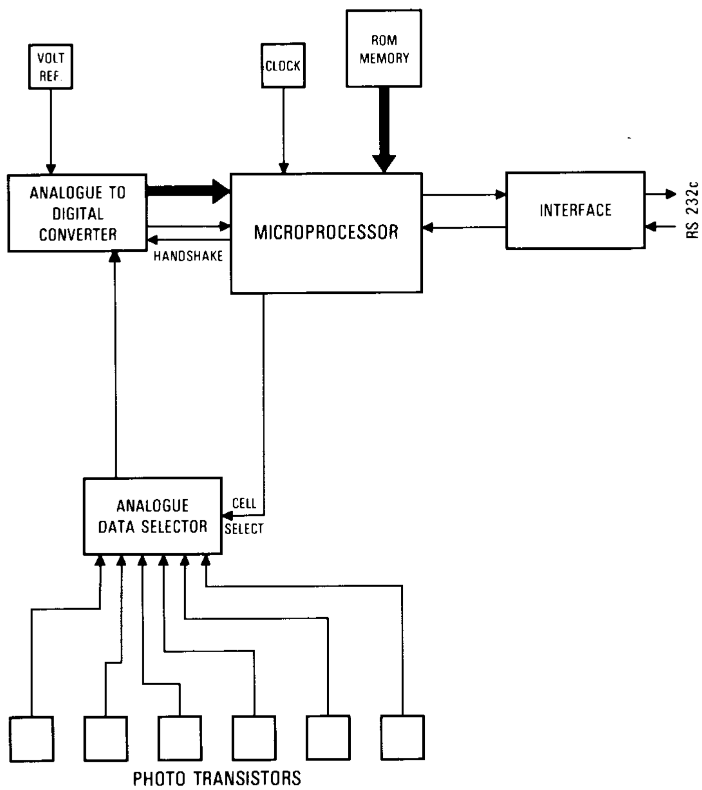


FIGURE 2

MACHINE LANGUAGE SOFTWARE
(REMOTE SENSOR)

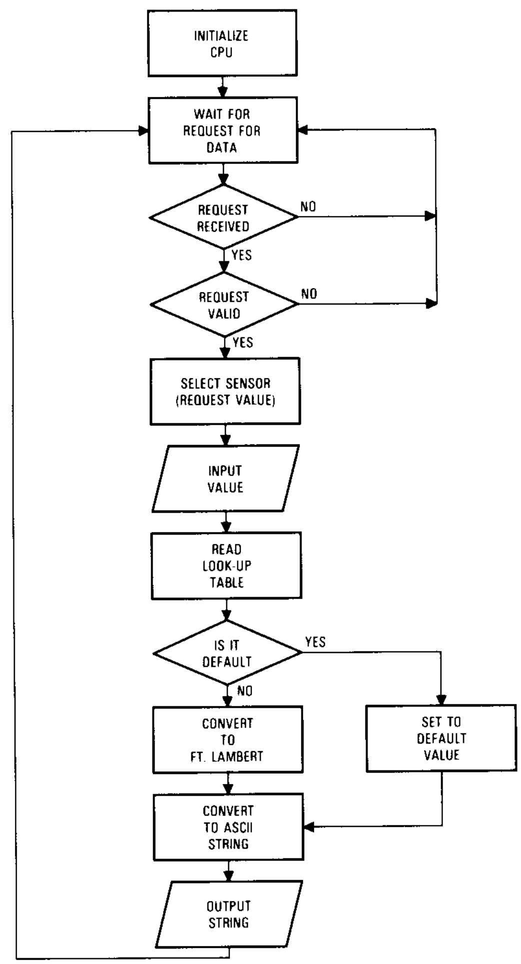
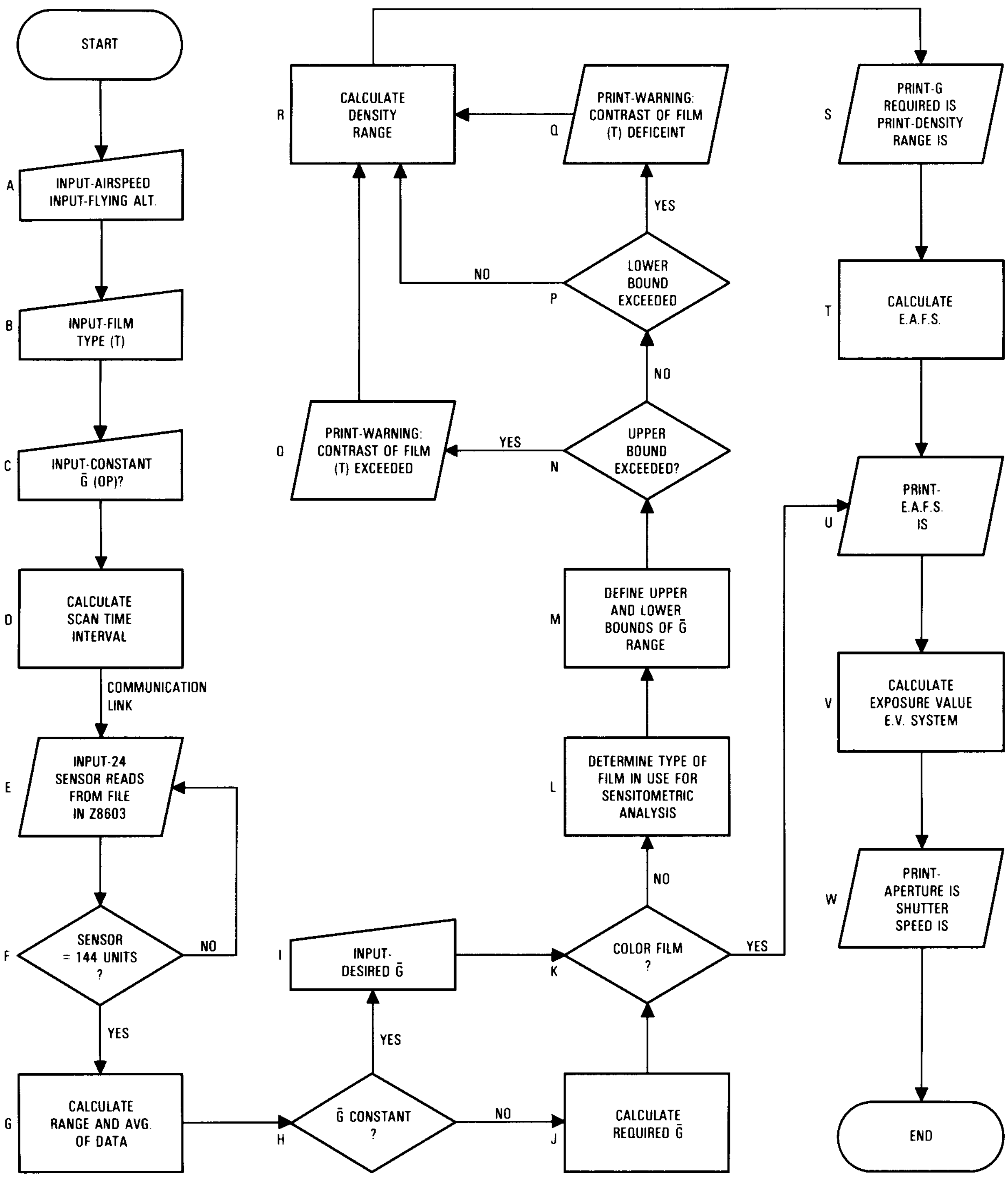


FIGURE 3

DATA PROCESSING SOFTWARE FLOWCHART

(BASIC)



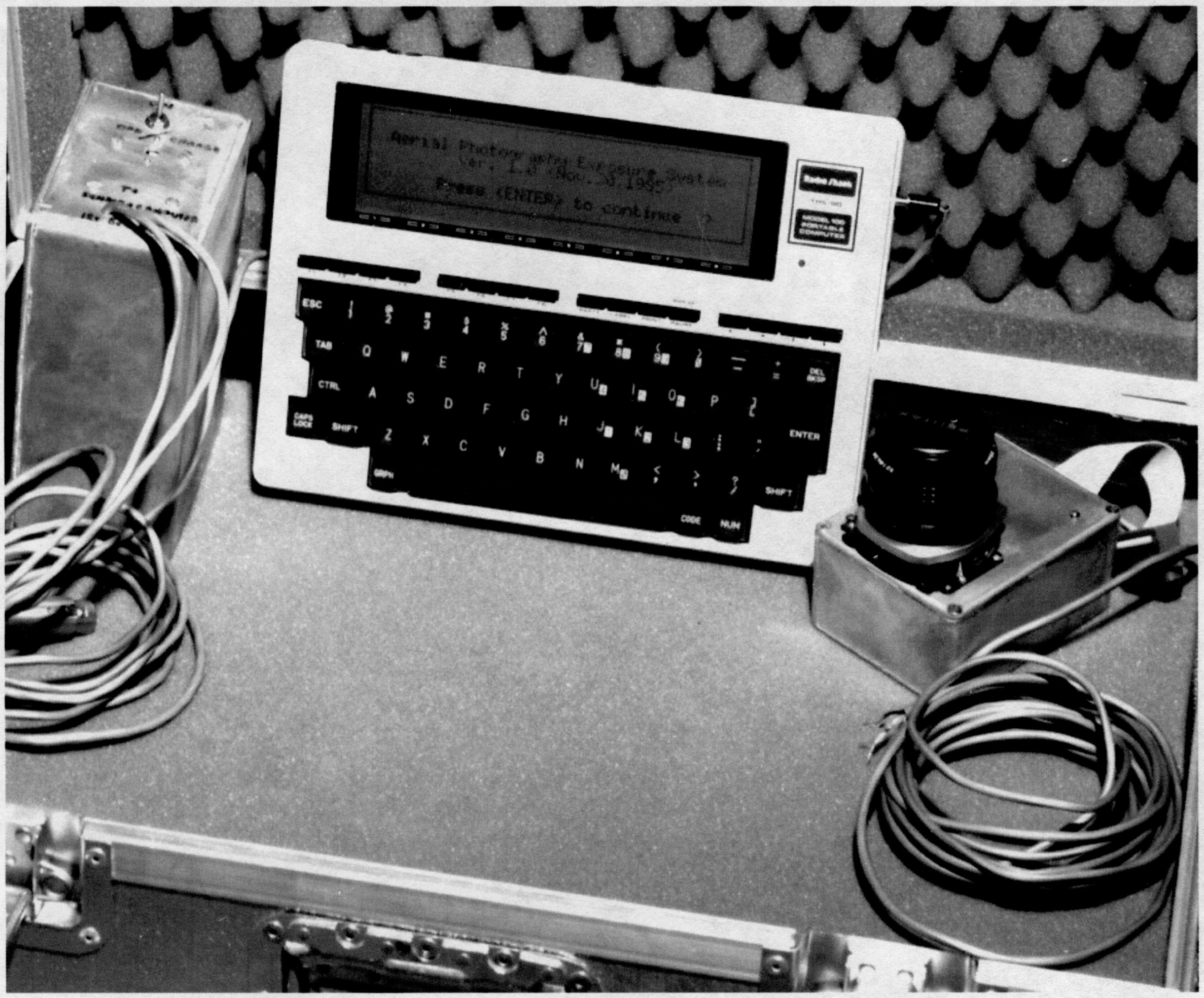


Illustration 2. TRS 80 laptop with sensor on the right and power supply on the left

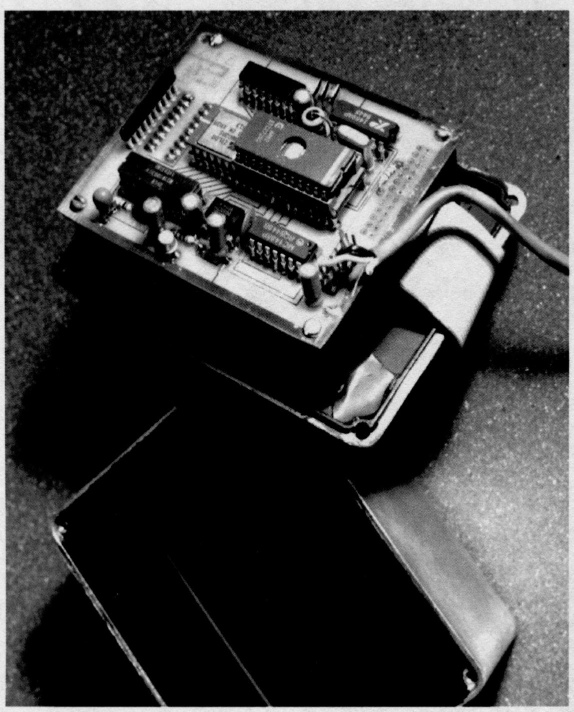


Illustration 3. Sensor circuitry featuring the Z8603 microprocessor (centre)

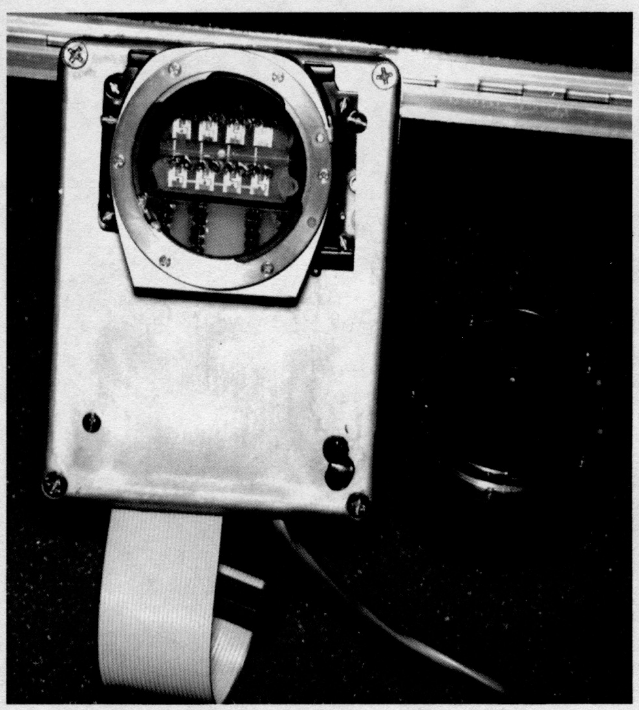


Illustration 4. Sensor lens porthole showing the double BPW39A sensor array