LARS Information Note 071069

CALIBRATION OF SCANNER DATA FOR OPERATION PROCESSING PROGRAMS AT LARS

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by

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I. Introduction

The research at LARS is primarily concerned with the use of multispectral measurements to develop techniques to survey earth resources from aerospace platforms. A general purpose digital computer has been selected for the implementation of research algorithms. A digital tape format was defined as the data archive for multispectral measurements from aerospace platforms. These tapes form the major data input to the software systems developed at LARS. A problem exists of calibrating the data from these tapes. This Information Note describes this problem, the current solution to the problem, and its implementation for use by the researcher.

II. Description of System

There are two major blocks in the system which deliver multispectral data to the research algorithms. The sensor system mounted in the aerospace platform makes irradiance measurements and converts them to a form easily transported to a ground based preprocessing system. The gound based system preprocesses the data from the sensor system and records it in a form useful for data analysis purposes.

There are several types of systems which have the general description given above. For example, a television camera mounted in a spacecraft can telemeter data to a ground station that digitizes and records the data on a digital data tape. Another example is a camera mounted in an aircraft delivering photographs to a film scanner system which digitizes and records the data on a digital data tape. A radar system could also be implemented in this way. Data from any such system can be calibrated and processed by the LARS data analysis system provided the following two requirements are met: (1) the output digital data tape must have the particular format defined for the LARS processing system called the Data Storage Tape Format, and (2) all data transformations on the original measured irradiances should be linear and the characteristics of the calibration measurements known.

The Data Storage Tape Format requires that eight-bit data samples and calibration measurements from all channels for each line of data be stored in a data record on the tape along with a line number. Since all measurements are stored as eight-bit integers, the measurements must be processed to a value (or number) stored on the tape ranging between 0 and 255. The calibration procedure used in the LARS processing system is linear. For this reason a linear transformation from measured irradinaces to data values on the digital tape is assumed. This is accomplished by the following equation:

$$D_T = A_m * D_m + B_m$$

where: D_T is the digitized value of the irradiance measurement

D_m is the irradiance at the sensor input

A_m and B_m are processing constants

A_m and B_m are adjusted both in the aerospace platform and on the ground to optimally use the range and accuracy of the instrumentation system. These constants are adjusted for each channel of data to force the measurements stored on tape to the range of 0 to 255 and at the same time use as much of the range as possible. These processing constants are assumed to be stable for a line of data but may vary during a run for two reasons. One, data taking conditions during a run may change causing the operator to change the processing constants. Two, the ability of the equipment to hold A_m and B_m to a constant is limited, thus, changes in equipment gain or bias can be expected.

The procedure of changing the amplification and bias is illustrated in Figure 1. Suppose that irradiance measurements as a function of look angle for two channels of data occur as shown in the figure. (Note that the data range of the two channels is quite different.) The amplification and bias of each channel would be adjusted as shown in the gain characteristic curve to produce the digitized data set shown as data output. The gain characteristics are determined for the amplification by the slope of the line and for the bias by the intercept of the line. The gain and bias were adjusted so that the resulting digitized data values have the same data range in both channels to best utilize the data storage medium. The original data values can be recovered by knowing any two data values for each channel in the original signal. The calibration sources in the system can be used to provide this information.

The primary source of sensor system data at LARS is from a multispectral optical-mechanical line scanner flown by the University of Michigan.* Data is measured in the aircraft and recorded on analog tape. The analog tape is digitized to a Bulk Digital Tape on the LARS Data Conversion System. The Bulk Tape is reformatted on the computer to form the Data Storage Tape.

*The airborne optical/infrared scanning equipments used in the research were made available by the U.S. Army Electronics Command (USAECOM), Fort Momouth, New Jersey, on a no-cost basis to the University of Michigan (who collected the data) for use on contracts administered by USAECOM.

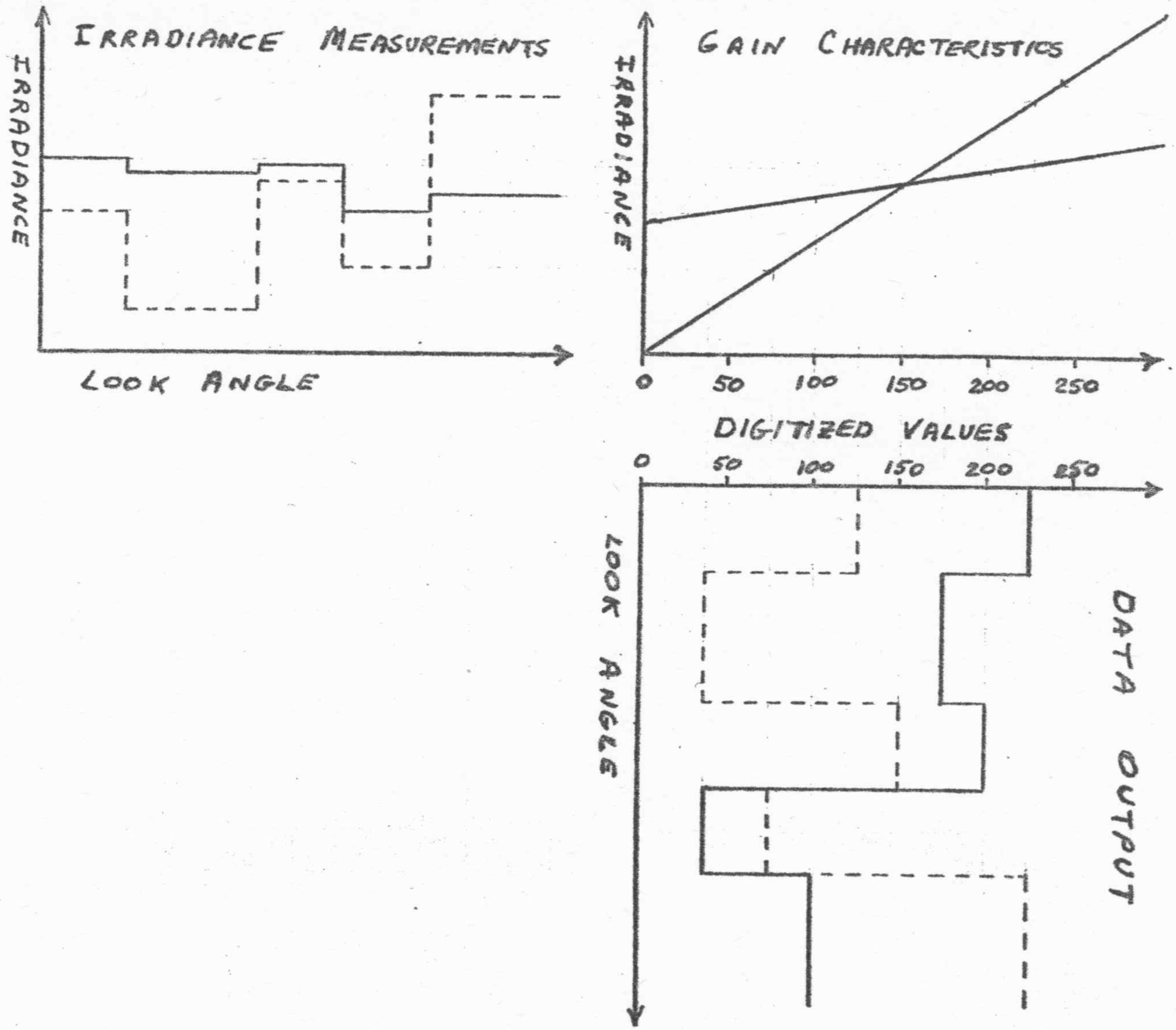

Figure 1. Gain Changes in Multispectral Data Handling System

For each scan line of data measured by the Michigan scanner, three measurements of calibration sources or light levels are also taken.* In the digitization process at LARS, several samples of each light level are recorded on the Bulk Digital Tape. When the Bulk Digital Tape is reformatted, the mean and variance of these several samples for each light level are recorded on the Aircraft Data Storage Tape as the last six samples in each line of data. They are in order of appearance on the tape: CO - calibration mean zero, VCO - variance of calibration mean zero, C1, VC1, C2, and VC2. The means can be used to calibrate the data from the scanner field of view in a variety of ways. The variances are recorded only for documentation purposes.

For data taken by the Michigan scanner prior to May 1967, the three light sources recorded on the Aircraft Data Storage Tape are: CO - dark level inside the scanner (zero radiation), C1 - an unfiltered low current constant light source useful for calibrating channels in the .6 to 1.0 micron region of the spectrum, and C2 - an unfiltered, high current constant light source useful for calibrating channels in the 0.3 to 0.6 micron region of the spectrum. For data taken after May 1967 all three recorded calibration values are useful for the 0.3 to 4.1 micron region of the spectrum. They are: CO - dark level, C1 - constant light source filtered to closely approximate the spectral energy curve of solar illumination, and C2 - solar illumination at the aircraft altitude as determined by a hemispheric sensor on the top of the aircraft.

III. Description of Calibration Procedure

A linear calibration function has been implemented in LARSYS Version 2 which provides the flexibility to calibrate the aircraft data from each wavelength band in the best way required by the user's problem and data. The data is calibrated according to the equation:

$$D_D = A_c * D_T + B_c$$

where: D_D = the data delivered to the program

D_T = The data stored on the Aircraft Data Storage Tape

A_c and B_c are calculated for each scan line of data and used throughout the whole scan line for which they have been calculated. Two types of calibration are available to the user in the implementation of the calibration function. The calibration function becomes a clamping function when A_c is set to 1 and B_c is set to a value which clamps or forces one of the calibration means to a fixed level for each scan line of data. Assuming the measurement of the calibration mean is accurate, the clamping function removes low frequency

* "Calibration of An Airborne Multispectral Optical Sensor", P. G. Hasell, Jr., and L. M. Larson, September 1968, Technical Report ECOM-00013-137, report of Project Michigan to United States Army Electronics Command, Fort Momouth, New Jersey, Contract DA-28-043 AMC-00013(E).

drift from the data. The clamping function forcing CO to the fixed level 232 has been the normal calibration function used at LARS.

The use of the calibration function will vary according to the user's data and problem. If the data amplifiers are known to have a drift throughout a run and no amplification changes, then clamping calibration would be appropriate. Usually CO would be selected to be clamped because it is the easiest to measure as noted by the lower variances of the measurement.

The full utilization of the linear calibration function is realized by setting A_c and B_c to values which force two calibration means to fixed levels for each scan line of data. This function can remove low frequency drift and amplification changes from the system. If the system drift and gain are known to vary in a run, then the full calibration function is required. When using the full calibration function, the definition of "the system" must be taken into account. If the system is defined to be all equipment between the measured irradiance at the scanner input and the data delivered to the user, then calibration of system gain for a given channel should be through the use of CO and a constant light source. If the system is defined to be the above with the addition of the light energy transfer function between the solar illumination input measured at the aircraft altitude and the illumination input to the scanner, then system calibration should be attained with CO and the solar illumination at the aircraft altitude. In the first sample the data delivered to the user is proportional to the irradiance as measured at the aircraft altitude, and the second example is an attempt to deliver data proportional to the percentage of reflectance of the target.

After the method of calibration is chosen by the user, the question of selecting values for the fixed levels in the calibration should be answered. Recall that the calibration function calculates parameters A_c and B_c for each line of data that will force the calibration measurements to a fixed level. The program must know what fixed level (or levels) to use. The answer to this question can be simple or complex according to the user's requirements.

In the algorithms available to the user, the data must be proportional to the irradiance measured at the aircraft altitude or to the percentage of target reflectance. However, the constant of proportionality is not required to be the same for each channel of data. Thus the actual value of the fixed levels is unimportant in the use of the algorithms. For this reason fixed levels are stored on the Data Storage Tape in the ID record for calibration use.

If the user requires the data to have the same constant of proportionality for each channel or measured values which have physical meaning, then the fixed levels must be inserted by the user. In this case the user must decide on fixed levels which give the results he desires. For example, if the user wants the significant digits of his data to be equal to the significant digits of the irradiance measurement, then the fixed levels should be the actual significant digits of the calibration measurements for each wavelength band. Experimentation must be performed before these measurements can become known; however, the programs will provide the ability to perform these experiments.

IV. Use of the Calibration Function

In LARSYS the Calibration Function is implemented through the use of a CHANNEL card. The general form of a CHANNEL card is:

CHANNEL A(I/P,Q/,J/R,S/,...),B(K/W,X/,L/Y,Z),...),...

Where A and B are calibration codes which indicate to the program how the channels in the parenthesis are to be calibrated. The table below shows what the codes select.

Calibration Code	Data Calibrated Using
1	C0
2	C1
3	C2
4	C0 and C1
5	C0 and C2
6	C1 and C2
7	Uncalibrated

In the general form of the CHANNEL card the integers I, J, K, and L are the channels selected. Channels I and J are to be calibrated using calibration code A while channels K and L are to be calibrated using calibration code B. The integers P, Q, R, S, W, X, Y, and Z are fixed levels inserted for the channels they follow.

A program which recognizes the CHANNEL card has been written and is used in the LARSYS Version 2 software system. This program allows several forms of the CHANNEL card to be used. If the user desires not to enter fixed levels into the system (use fixed levels from the tape), he can enter the card in the form:

CHANNEL A(I,J,...),B(K,L,...)

If the user wants to assume a calibration code of 1 and the fixed level of C0 to be from the tape for all desired channels, a card can be used in the form:

CHANNEL I,J,K,L,....

Three examples of using the CHANNEL card are given below. Suppose the user wanted to select channels 1, 3, 4, and 10 with channels 1, 3, and 4 to be clamped by setting C0 to zero. Also suppose he wanted to set C0 to zero and C1 to 800 for channel 10. The following card would achieve this objective.

CHANNEL 1(1/0.0/,3/0/,4/0/),4(10/0,800/)

The following card will assume a calibration code of 1 for selected channels 1, 3, 4, and 10 and use CO stored on the tape.

CHANNEL 1,3,4,10

Note that the use of the CHANNEL card does not require the user to determine the processing constants of the system or the constants required to calibrate the data. He is required to know the irradiance values (or percent reflectance) of the calibration sources used in the system and the numerical value he wants to assign to these measurments. At present the characteristics of the sources are not known. What is significant here is that the program now has the ability to experiment with the data to determine these characteristics, to test hypothesized characteristics, or to use determined characteristics when they are known.

V. Conclusions

In the Phase I Data System and LARSYSAA, fixed calibration procedures were implemented. These procedures were good for limited sets of data and it was determined that experiments with various calibration procedures should be pursued. In the new system, LARSYS Version 2, the calibration procedure will provide the flexibility for experiments. When calibration procedures become fixed, then the program can be fixed according to the needs of the user.

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