CAMERA GEOMETRIC CALIBRATION – CURRENT STATUS

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ABSTRACT

USGS has terminated their camera calibration services effective this year(Kelly, 2016). However, it has been suggested that "..laboratory and in situ processes be in accordance with manufacturer recommendations and/or common community standard practice". What defines "common community standard practice" has not been specified. It is the purpose of this paper to identify and describe these *in situ* geometric camera calibration methods that will provide acceptable solutions. A brief history is offered along with a discussion of published Guidelines provided by the ASPRS Camera Calibration Committee. An example of *in situ* calibration results of an aerial camera system is included.

KEYWORDS: calibration, *in situ*, camera, system, aerial, guidelines

INTRODUCTION

With the announcement by the USGS/EROS office that they intended to stop offering calibration of film-based cameras, the question naturally arose about alternative means for a quality calibration for photogrammetric work. The announcement coincided with the ASPRS annual meeting held in Milwaukee in March of 2011. This provided an opportunity at the PDAD meeting to organize a committee to address concerns regarding future calibration practices. With approximately 25 signatures, indicating interest in supporting the recommendation that an appropriate committee be established, the "Camera Calibration Committee" began its work.

At the end of the PDAD meeting, a group of those indicating interest gathered to discuss the next step. During this informal gathering, it was learned that the ORL (USGS) would be able to buy small lots of micro-flat photo plates suitable for continuing use of the bank collimator equipment used for calibration. With the many expressions of concern and given the possibility of buying the plates on an as required basis, the USGS elected to continue offering film based camera calibration services.

During the next six months, the Camera Calibration Committee worked on a bi-weekly cycle basis to develop draft guidelines that could lead to an *in situ* approach to camera system calibration. The acceptance of the two notions of *in situ* and system were fundamental to the development of the characteristics of the new calibration guidelines. The guidelines draft was subject to refinement by committee members, then consisting of nearly fifty, and then by a series of external reviews. The draft titled " GUIDELINES FOR THE *IN SITU* GEOMETRIC CALIBRATION OF THE AERIAL CAMERA SYSTEM" was then published in the July 2013 issue of PERS for comments. After further refinement, the document was accepted by the ASPRS Board at its meeting in San Antonio on October 28th, 2013.

It remains to encourage adoption of the *in situ* calibration by the photogrammetric community as a procedure to replace the camera calibration method used at the ORL in Reston Virginia.

BACKGROUND

All photogrammetric work is founded on calibration of its measurement system. The quality of the calibration for the aerial case has exhibited a wide range of geospatial accuracies. The results of Brown (Brown, D) when working with the USAF's USQ-28 Geodetic Subsystem, approached one part in one million of the flight height. This was using the Fairchild K6A film-based camera system operating at 20,000 feet over the McClure control field in northern Ohio. The calibration was accomplished by Brown's approach based on an *in situ* method. If it were practical to calibrate camera systems in this manner, aerial photogrammetry could be a geodetic tool with little need for ground control.

At the other end of the geospatial accuracy spectrum is the use of the camera **only** calibration. Whereas the camera calibration conducted at the ORL based on a bank-collimator provided an excellent assessment of the geometry of the camera alone, the remaining components of the aerial photogrammetric system can make substantial error contributions if not considered. In the laboratory at Reston Virginia, the temperature and humidity is controlled, the banks of collimators rest on a stable concrete base and measurements are made on fine grain emulsions coated on a micro-flat plate. Contrast this environment with a typical aerial photo mapping mission. The outside air temperature typically, during "leaves off" periods, ranges down to 30 degrees C below that at which the camera was calibrated. Experience has shown that under these conditions, geospatial accuracies in elevation approach only one part in one thousand. You may recall, the maximum closure error for third order surveys was one part in 3000, otherwise, it was back to the field for a re-survey. As you will see, a camera system (*in* situ) calibration of a film-based camera will provide better results if the calibration photography is collected at a temperature closer to that of a typical operational flight. Modern digital mapping cameras are generally designed to accommodate temperature changes but still are likely to be influenced by them..

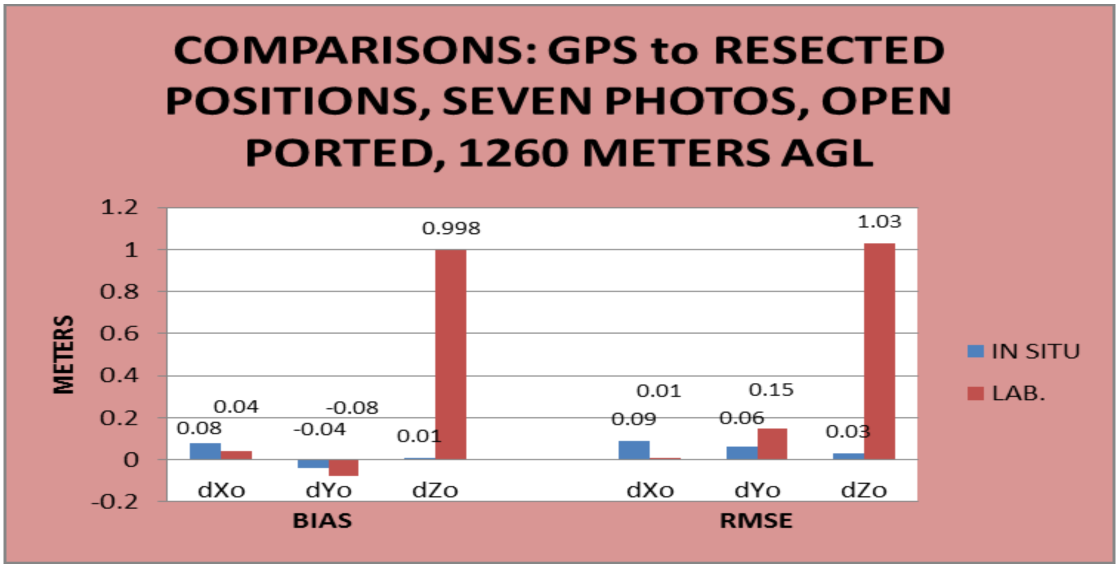

Figure 1. Comparison of GPS to Photogrammetric Resected Positions Based on Laboratory and Open Ported *In Situ* Camera Calibrations (Merchant, D., 2014a)

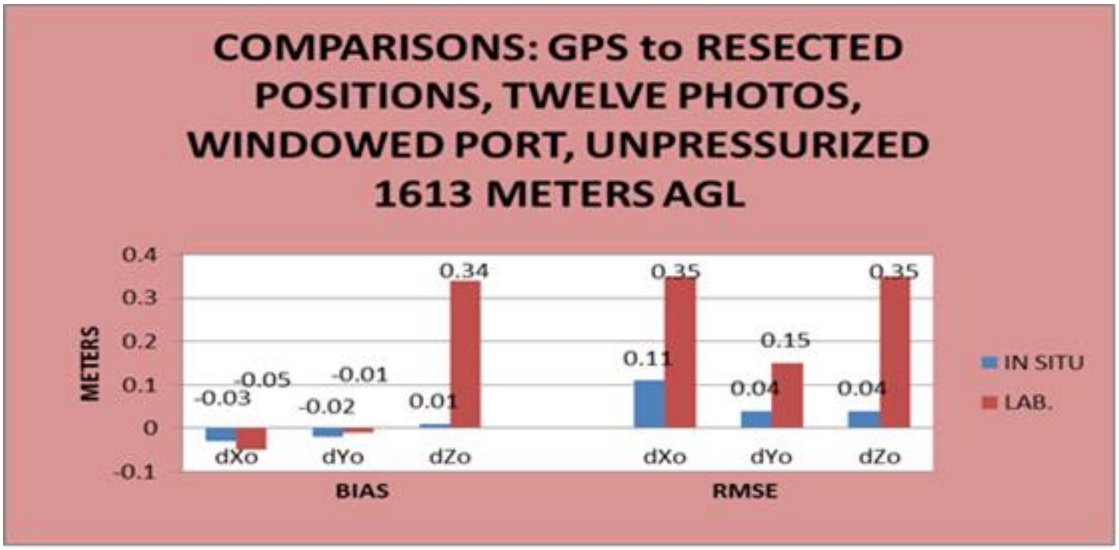

Figure 2. Comparison of GPS to Photogrammetric Resected Positions Based on Laboratory and on *In Situ* Windowed Camera Port Camera Calibrations (Merchant, D., 2014a)

CURRENT STATUS OF METRIC CAMERA CALIBRATION

Traditional Methods

Our traditional need for calibration of the mapping camera has been met by a laboratory approach. In Europe, the optical goniometer supplied the laboratory approach to camera calibration. The early development of the bank collimator method was reported by Dr. Francis Washer while working at Wright Patterson AFB. His research was directed toward compensation of an apparent "wedge" distortion in the Metrogon type lenses. As his method was refined, the bank collimator method was adopted by the National Bureau of Standards as a means for servicing both government and civilian needs. Fairchild Camera also used the bank collimator as a means to finish cameras produced at their Long Island plant. Their calibration facility was under the long time direction of Mrs. Clarice Norton and was active in the calibration of their long line of film-based cameras for military and civilian use. Perhaps the last of the bank collimator approaches in the United States was adopted by the US Air Force at Hill AFB. It was used to calibrate the KC6A Fairchild reseau- based film cameras used in the USQ28 Geodetic Subsystem. Others in the Western Hemisphere using the bank collimator method include the National Research Council of Canada.

The *in situ* Methods

As mentioned, the calibration of the KC-6A cameras of the USQ28 system, designed and implemented by Duane Brown is a prime example of an *in situ* approach. Another *in situ* method for calibration was conducted using imagery from a Zeiss RMK-AR reseau based film camera, sponsored by the USAF (Merchant, D. 1972b). Photography over the Casa Grande Arizona targeted range and over Mt. Graham Arizona was used. It was intended that the Mt Graham range elevation difference could offer sufficient difference in elevation to separate the focal length from the flight height in calibration computations. Even though the height difference was about half the flight height above the base, it was not sufficient to sharply separate the two parameters.

With the practical availability of GNSS , the possibility of positioning the exposure station became a reality. Improvements in data processing made it possible to rapidly recover a loss of GNSS phase lock after aircraft turns that blocked the signal. The question still remains concerning the spatial accuracy for exposure stations, still remains an essential element in the *in situ* calibration method. Ground based experiments at White Sands Proving Ground have shown that accuracies on the order of millimeters are possible for a vehicle moving approximately 20 mph. With care, and with today's improvements in technology, it may be reasoned that similar accuracies may be obtained in the air. When well known component observational accuracies are used to compute and apply parameter weights, the only remaining unknown is the exposure station accuracy. Experience has shown that if an observational weight is based on a horizontal accuracy of 2 cm and vertical of 3 cm, the unit variance approaches one, an indication that all weights are appropriately chosen. Accordingly, the geo-spatial accuracies are verified.

Current methods of calibration of the aerial camera include the method employed by the European community and that proposed by the ASPRS under its guidelines. In Europe, generally speaking, the parameters of calibration are carried as part of the aerial triangulation computations. This requires additional ground control on every operational mission. This is an effective means of system calibration in that it treats the environmental contributions as part of the operational mission. Recently, aerial camera system "verification" has been used in place of a periodic system re-calibration. If done often enough, the verification concept can fall in line with Eisenhart's measurement system guidelines (ASP,1980).

The system calibration guidelines (ASPRS) use a densely controlled calibration field and depends on the stability of the camera system between periodic recalibrations. With the development of the digital camera possessing more spatially stable camera systems, the ASPRS guidelines offer a realistic alternative to operationally requiring more ground control.

Verification

An alternative to full system calibration is provided by collecting a block of photography over a targeted control field. A conventional aerial triangulation is conducted but some additional targeted control is withheld. The additional controlled targets are used for verification. If the expected accuracy is achieved, it can be assumed the camera system remains in a "state of statistical control" in accord with Eisenhart's concept of measurement system calibration (Eisenhart, 1963).

CONCLUSION

The current state of camera calibration has recently moved into a state of flux due primarily to the announcement by the USGS that they plan to no longer offer calibration services at their OSL facility in Reston, Virginia. The purpose of this paper is to provide some background and calibration results to help make decisions to move ahead with accomplishing *in* situ camera system calibrations. Addressing primarily film-based camera systems, most of the aspects discussed pertain as well to digital camera systems.

For those who would like more information on the ASPRS Camera Calibration Committee and its current activities, you are invited to contact me at my address (merchant.2@osu.edu).

Appended is a copy of a recent report for a typical film-based camera, calibrated in accord with the ASPRS Guidelines.

RESULTS OF SYSTEM (*IN SITU*) CAMERA CALIBRATION (film-based)

REPORT OF CAMERA SYSTEM CALIBRATION

PHOTO SYSTEM:

Aircraft: N5232U Cessna 206
Spatial Offsets, Antenna Phase Center to Lens entrance node (mm);
X[11] Y[-62] Z [-929]

Camera: Zeiss TOP 15/23
Nominal focal length: 152 mm
Pixel size: 0.014 mm
Frame Size (mm): [x =220, y = 220]
Body # 145844: Lens # 145891

Owner/Operator: Midwestern Aerial Photography

Photography: Date: August 6, 2016
Calibration Range: Plumwood, Ohio
Altitude: 3000 feet AGL; OAT: 24.5 C.
Pattern: Standard [ASPRS Guidelines]
Film Type: pan 200, AGFA

LENS CHARACTERISTICS: Uses SMAC Model by D. Brown

Element:	adjusted value	a postriori standard error
Focal length	-0.152989E+03	0.479E-02 (mm)
xo	0.806480E-03	0.264E-02 (mm)
yo	-0.319968E-02	0.265E-02 (mm)
K0	0.000000	--------
K1	0.645979E-08	0.645E-08
K2	-0.379910E-12	0.596E-12
K3	0.387997E-17	0.170E-16
P1	-0.136814E-10	0.995E-09
P2	0.378937E-10	0.995E-09

STATISTICS:

Standard Error of Unit Weight: 0.99 ; a priori estimated std. error: 0.014 mm
Number of photos: six
Number of Images Observed: 172
Standard Deviation of Image observational residuals: 0.0055 mm
Fiducial Fit (rmse): 0.0035 mm

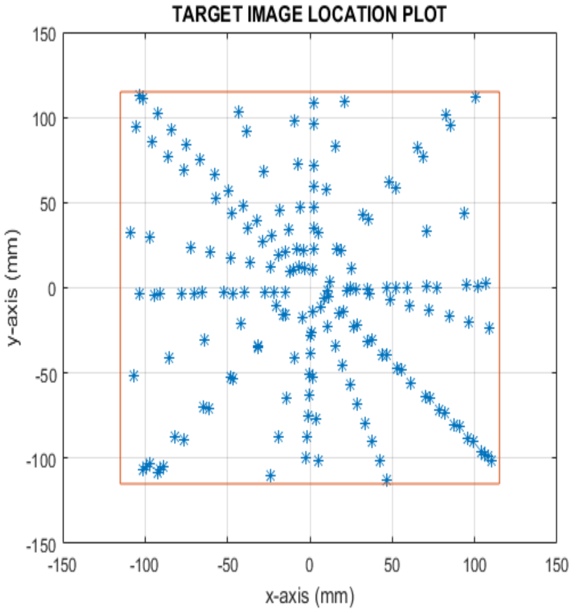

Figure 2. Collective Distribution of Target Images

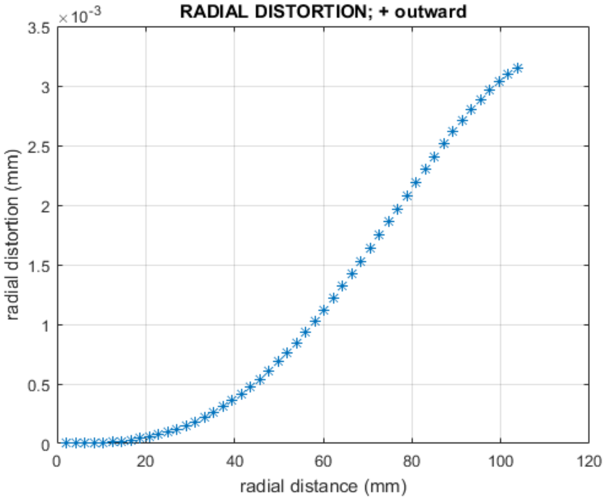

Figure 3. Radial Distortion (SMAC model)

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