Mapping Matters

By Qassim A. Abdullah, Ph.D., PLS, CP**

Your Questions Answered

The layman's perspective on technical theory and practical applications of mapping and GIS

question:

There were a lot of discussions about camera calibration at the 2011 ASPRS conference in Milwaukee. In particular, the plan by the U.S. Geological Survey (USGS) to discontinue laboratory calibration within the next few years generated considerable concern. However, if I heard correctly, you made the point (during one of the conference events) that once the camera has been calibrated at the factory, then subsequent calibrations may not be altogether that useful. Other error sources, in particular, thermal expansion and contraction that affect the camera focal length during actual flight operations become much more important than the small changes that occur in a camera as it ages. And, a laboratory calibration does not address these other error sources. Could you please elaborate on the direction you believe camera calibration should go in the future? Is in situ calibration a viable alternative?

Jonathan W. Martin
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"The pursuit of sensor calibration by commercial enterprise will allow more room for growth and further development of the process as new technological advancements in digital sensors and auxiliary aerial acquisition systems are brought to market."

Dr. Abdullah: Your understanding of the USGS's position on camera calibration and my position on the challenges associated with digital sensor calibration are both correct. The USGS did announce during the ASPRS 2011 annual conference held recently in Milwaukee, Wisconsin, their decision to discontinue all programs related to film camera calibration for the public by the end of 2012 and for digital aerial type certification immediately. There was substantial concern by attendees about this decision and the course that map manufacturers and end-users will take in the absence of a federal agency responsible for camera calibration and certification. However, based on the concerns expressed during the conference which were conveyed to USGS management, the USGS is re-considering its decision by requesting the necessary funds needed for the procurement of the glass plates in order to extend the film camera calibration services beyond 2012.

In my opinion, the public reaction to the announcement is fueled by the fact that the USGS as a federal agency was the guardian of film camera calibration since the early 1950s and users have grown up with this knowledge. Therefore, the reaction is caused mainly by receiving the shocking news and not to a painful and practical reality of doing mapping business without a governmental agency performing sensor calibration. The USGS's decision to stay out of the business of performing public sensor calibration may not be a bad thing for several reasons:

1) The USGS camera calibration program was not intended for the calibration of cameras for the public but for government-related activities. However, the service was offered to the public over the years as a matter of courtesy and not as a mandatory, legislated task.
2) The film camera calibration program was initiated in the early 1950s and the original equipment remains in use today. Considering the advancements in technology and in our thinking over the past 60 years, one can easily ascertain that the calibration laboratory at the USGS is outdated and it is about time to donate it to the Museum of American History at the Smithsonian in Washington, D.C. for its uniqueness.
3) Unless it is used to set up stereo pairs on an analog plotter, a device which is very rare these days, the USGS camera calibration report in most cases is only used as an approximate initial value in the soft copy photogrammetric process. Most, if not all, of the aerial triangulation packages available in the market today are equipped with full camera self-calibration capabilities and users often times have to perform a camera self-calibration during the bundle block adjustment in order to adjust the calibrated camera parameters. This self-calibration makes it suitable for the modern image acquisition process. With the introduction of airborne GPS and the Inertial Measurement Unit (IMU), the imaging camera became part of an aerial acquisition system and not the sole acquisition apparatus as was the case a decade ago. Some of the parameters of the camera's interior orientation such as focal length and principal point coordinates, are correlated with the exterior orientation parameters measured by the Airborne GPS and IMU during the bundle block adjustment. Therefore, some inaccuracies or imperfections in the camera position and orientation measured by the airborne GPS and IMU may resemble inaccuracies in the camera's calibrated interior orientation parameters, forcing the user to perform self-calibration in order to calibrate the system as a whole and not just the camera. Thus, in most cases the calibrated camera focal length is re-calculated during the cam-

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era self-calibration process to accommodate imperfections in either the laboratory camera calibration process itself, changes in the camera calibrated interior orientation parameters values due to aging and changing operation conditions, and in the determination of the airborne GPS-based camera position. All of these reasons indicate that a static camera calibration is no longer productive when used in a modern imaging system.

4) The number of film cameras and users operating today in the United States of America are dwindling rapidly making room for more exciting and capable digital sensors.

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5) Countries of the European Union, for example, functioned over the years without a governmental calibration facility or agency, primarily relying on the camera manufacturers' calibration facilities.
6) As for calibrating digital sensors, the task is more daunting for the USGS, or any other agency for that matter, than the task of calibrating film cameras. There are only two main brands of aerial film camera, and they share the same design and geometry-- making it possible to build a calibration facility such as the one the USGS has run in Reston, Virginia since the early 1950s. Digital cameras today come in all forms, types, sizes, and shapes which makes it difficult, if not impossible, for one laboratory to handle the calibration for all types of digital sensors. In the last decade we witnessed the development of different camera architectures such as framing cameras of one single array, framing cameras with multiple arrays (heads) to form a larger frame of pseudo array geometry, rotating cameras, panoramic cameras, push broom linear array cameras, etc., just to mention a few.
7) Some of the digital sensors which are based on push broom design such as Leica Geo-system's ADS require an IMU for operation and therefore calibrating the camera without determining bore sight misalignment values (the angles of rotation between the camera body frame and the IMU frame) simultaneously is counter productive due to the fact that some of the camera's interior and exterior orientation parameters measured by the airborne GPS and IMU are correlated as I discussed in item 3. Such system calibration can only be achieved in a fully operational environment of the sensor by flying over a controlled calibration field. Moreover, the system calibrated parameters determined in this process is further refined during the self-calibration process of the aerial triangulation.
8) The industry has used digital cameras since the first large format metric camera offered commercially at the beginning of the last decade. Since then digital sensor users have primarily relied on the manufacturer's calibration. Stabilities in the new generation of digital metric cameras and system re-calibration by the manufacturer is rarely needed unless the sensor is subject to hardware replacement or repairs. Minor deficiencies or variation in the sensor calibration over time are always accommodated during the self calibration process of the aerial triangulation. The previous fact is evidenced by users surviving for over a decade operating digital sensors without the involvement of a government agency. Therefore, we should not be concerned about functioning without a governmental agency overseeing and controlling the calibration process of digital sensors.
9) The absence of a government agency responsible for sensor calibration encourages scientific and commercial enterprises to offer such services. The pursuit of sensor calibration by commercial enterprise will allow more room for growth and further development of the process as new technological advancements in digital sensors and auxiliary aerial acquisition systems are brought to market.

Finally, and based on the above reasoning, the initial manufacturer laboratory radiometric and geometric calibrations of the sensor (during sensor manufacturing) can thereafter be maintained through an *in-situ* calibration process assuming that the right planning, capable software, and scientific knowledge are utilized during that process.

Please send your question to Mapping_Matters@asprs.org and indicate whether you want your name to be blocked from publishing.

Answers for all questions that are not published in *PE&RS* can be found on line at www.asprs.org/Mapping Matters.

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