Lens Cone Calibration Process Specification

Leica Geosystems

This document contains general information about the *Camera Calibration Certificate* issued by *SwissOptic AG*. Described are the used standards, methods, accuracy and validity relating to the enclosed Calibration Certificate.

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This document completes the Leica Lens Cone Calibration Certificate issued by *SwissOptic AG*. The used guidelines, standards and methods, the accuracy of the calibrated values are explained. Some general rules for calibration and service intervals of the lens cones are given. Information is also given about the certification of the measuring equipment and the validity of the Calibration Certificate.

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1 Applied international guidelines and standards

The laboratory calibration tests of this lens cone at *SwissOptic AG* comply with existing international regulations and standards. The SwissOptic calibration centre is certified according to *ISO 9001*.

The methods used in the ***lens cone calibration process*** itself are based on the following publications or recommendations:

„Recommended procedures for calibrating photogrammetric cameras and for related optical tests", International Society of Photogrammetry and Remote Sensing, Commission. 1 (1960, reaffirmed 1984).

The determination of the *radial distortion* complies with:

ISO 9039 1994-08-01	„Optics and optical instruments - Quality evaluation of optical systems Determination of distortion" (internat. equivalent to DIN 58187- 1986).

The determination of the *resolution (resolving power)* complies with:

ISO 6328 - 1982-09-01	„Photography - Photographic materials - Determination of ISO resolving power"
ANSI PH3.63-1974	„Method for determining the photographic resolving power of photographic lenses", American National Standard (revision 1991)
ANSI PH3.609-1980	„Dimensions for resolution test targets for photographic optics" American National Standard (revision 1987).

2 Calibration Methods

2.1 Determination method of the resolution

The resolution values are obtained by photographing test bars mounted in collimators. The difference of log luminance between the bars and the background is 2.0, corresponding to a contrast of 100:1. The set of patterns has spatial frequencies in geometric series having a step factor of the 20th root of 10 (approx. 1.12 or 12% size increase or decrease).

Radial resolution corresponds to radial lines (parallel to a radius from the image format centre) and tangential resolution to tangential lines (perpendicular to a radius).

The maximum aperture is used on the lens cone. The film and developer type is defined in the Calibration Certificate. The colour temperature of the collimator illumination device is approx. 5600 K. The required filtering for matching the usual recorded spectral range of B&W aerial panchromatic film type is introduced in the collimator illumination device. The filtering is specified in the Calibration Certificate.

2.2 Determination of the geometric calibration

The geometrical calibration of the lens cone is made in the Leica EVG1 Electronic Vertical Goniometer *. The maximum aperture is used on the lens cone. The required filtering for matching the usual recorded spectral range of B&W aerial panchromatic film type is introduced in the EVG illumination device. The filtering is specified in the Certificate: e.g. VIS 400 - 700 nm (VIS for visual spectral range).

* *Note*: A description of the EVG1 equipment is given in *„Electronic Vertical Goniometer: a new instrument for the geometric calibration of aerial camera lenses"* (E. Mathieu, ISP Congress 1980, Commission 1). This brochure is available on request at Leica Geosystems GIS & Mapping GmbH , 9435 Heerbrugg, Switzerland.

2.3 Determination of the fiducial marks

The fiducial mark coordinates of each calibrated lens cone are measured on a photoplate in a high-precision mono-comparator. The measured coordinate values are adjusted to an ideal square-shaped figure by a mathematical conformal transformation maintaining the figure scale (Helmert with scale factor 1). This mono-comparator is also used for calibrating the reference grid plate placed on the lens cone image frame in the Leica EVG1 Vertical Goniometer.

3 Accuracy of the calibrated parameters

General:
- The values in the Calibration Certificate are related to the controlled environment 20°C ± 2°C.
- The accuracy of the calibrated values is described by the standard error *RMS* (root mean squares error). This means a 99% probability that the real value is within ± 2.58 x RMS.

3.1 Resolution

- Mean error of radial / tangential resolution at individual incidence angles: 1 pattern figure (step $10^{1/20}$ or 12%)

- Mean error of AWAR (Area Weighted Average Resolution, as mean value for the whole image-format), expressed in L/p (line pairs / mm): 5% of given AWAR

3.2 Calibrated Focal Length

- CFL (Calibrated Focal Length) or PD (Principal Distance): RMS = 0.8 µm

CFL applies for the focusing distance of infinity.
This is standard for f = 88 mm and 153 mm
and non-standard for f = 213 mm and 303 mm lens cones.

PD applies for the standard focusing distance of
900 m for f = 213 mm and
850 m for f = 303 mm lens cones.

3.3 Radial distortion

- Individual radial distortion for the semi-diagonals referred to PPS (Principal Point of Symmetry): RMS = 1 µm

- Mean radial distortion (independent of reference point): RMS = 0.5 µm

Note: The given radial distortion is mathematically strictly correlated to the Calibrated Focal Length. Using another value than CFL / PD in the photogrammetric restitution would lead to wrong distortion values and affect the quality of the plotting results.

3.4 Fiducial marks

- Accuracy of coordinates of fiducial marks: RMS = 1.5 µm

These coordinates are given in a rectangular X, Y system defined by the fiducial marks. The origin of this system is the intersection FC (Fiducial Centre) of the diagonal lines connecting fiducial marks, which lie diametrically apart.

3.5 Principal Point of Symmetry. Principal Point of Autocollimation

- The coordinates of PPS (Principal Point of Symmetry) and PPA (Principal Point of Autocollimation) are given in a rectangular X, Y system defined by the fiducial marks.
The origin of this coordinate system is the intersection FC (Fiducial Center) of the diagonal lines connecting fiducial marks, which lie diametrically apart.

- The accuracy of the PPS is decreasing with the field angle of the lens cone.

- See following table for the estimated accuracy of PPS and PPA:

Focal length (mm)	Lens cone type (RC20 / RC30 cameras)	RMS of coordinates (µm) PPS	PPA
88	8.8/4 SAGA-F	2	2.5
153	15/4 UAG-S	3	2.5
213	21/4 NAGA-F	5	2.5
303	30/4 NAT-S	8	2.5

4 Position of the Entrance Pupil

In conjunction with the post-processing of GPS data, the components (in typical aircraft flight attitude) of the vector GPS-antenna to the entrance pupil of the lens cone have to be known. This entrance pupil, also called projection centre, is the image of the diaphragm opening given by the lens elements in front of the diaphragm, towards the object. The location of this entrance pupil below the image plane of each lens cone type is given in the following table.

Focal length (mm)	Lens cone type	Distance from image plane (mm)	
88	8.8/4 SAGA-F	181	
153	15/4 UAGA-F	282	
153	15/4 UAG-S	283	for lens N° up to 13269
153	15/4 UAG-S	277	for lens N° from 13301 onwards
213	21/4 NAGA-F	271	
303	30/4 NATA-F	270	
303	30/4 NAT-S	314	

5 Calibration and Service intervals

Staffed by highly qualified specialists, the service centre of Leica Geosystems GIS & Mapping and the calibration laboratory at SwissOptic are fully equipped for all types of maintenance jobs on WILD / LEICA aerial cameras. To make full use of services, the following points should be taken into consideration.

5.1 Definitions

Calibration of lens cone

The lens cone calibration includes the checking of the optical quality of the lens cone by measuring its geometry (distortion, position of fiducial marks, optical centring) and resolution. A calibration certificate will be delivered.

Service and calibration of lens cone

In addition to calibration, this includes the upgrading of the system firmware to the latest version, and the servicing of components subject to wear and tear (shutter, diaphragm, etc.). Components will be replaced as necessary. A calibration certificate will be delivered.

Complete overhaul of lens cone

In addition to service and calibration, this involves dismantling, inspection servicing or replacement of individual parts as necessary. Assembly and functional checks including acceptance testing and quality control. A calibration certificate will be delivered.

Warranty

– Labor and parts of the "*Service and Calibration*" and the "*Complete overhaul of a lens cone*" are subject to the Leica Geosystems GIS & Mapping general warranty conditions, whereas the calibration certificate only documents the condition in which the lens cone was at time of calibration at SwissOptic AG.
– The "*Calibration*" procedure is a measurement process, which does not change the lens mechanically or optically and is therefore *not* subject to the Leica Geosystems GIS & Mapping general warranty conditions.

5.2 Intervals

Various factors determine the calibration and service intervals, in particular:

- Operating hours and number of photographs
- Environmental conditions in use and in storage
- Care in use, handling and storage

The intervals can be determined based on the following matrix. When any one of these limits is reached the lens cone or the camera should have the appropriate calibration or service made.

Type of job	*Operating hours*	*Photos taken*	*Intervals*
Calibration of lens cone	150-200	20,000	1 - 2 years
Service and calibration of lens cone	300-400	40,000	2 - 4 years
Complete overhaul of lens cone	500-600	60,000	5 - 6 years
Service and repair of camera system	300-400	40,000	2 - 4 years
Complete overhaul of camera system	500-600	60,000	5 - 6 years

Note: The 15/4 UAG-S and 30/4 NAT-S lens cones are equipped with a 4-digit operating-hours counter, a convenient way to determine the necessary service intervals.

6 Certification of measuring equipment

The Certification of the X, Y glass scales of the mono-comparator used for operations 2.2 and 2.3 has been made by measuring them in the Swiss Federal Office of Metrology, Bern.
Metric characteristics of this instrument are checked by regular Quality Assessment procedures.

7 Validity of the Calibration Certificate

Each page of the Calibration Certificate is signed by the Calibration Department of *SwissOptic AG*, attesting the correctness of the results at time of calibration at SwissOptic AG.

Validity of the Calibration Certificate is defined by the contractor, who bases the validity period on national or international guidelines or rules. In some countries local or national authorities define rules for validity and expiry date of a Calibration Certificate.

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Important note on Camera Calibration Certificates

Very often the question comes up for what type of RC aerial camera system a Camera Calibration Certificate is issued. The purpose of this note is to give an answer of this question.

Leica Aerial Camera Systems

The name of a Leica Aerial Camera system has become a synonym for the performance of the components forming an aerial camera system. During the last two decades Leica has introduced to the market three generations of film based aerial cameras systems: RC10A, RC20 and RC30. Each system was at its release time state of the art. But nevertheless a system of the latest generation compared to a previous generation system has a superior performance. An aerial camera system consists of modular and interchangeable components. Components of older generations can be upgraded to the latest type. Example: The drive unit PTW10A of the RC10A generation can be upgraded to a PTW of the RC30 generation.
The components and performance of a camera system with 15 cm lens cone for the camera system generations RC30, RC20 and RC10A are given below.

Components and performance of the RC30 Aerial Camera System

Component	Name	Performance
Drive Unit	PTW30	Forward Motion Compensation and interface for external Data Annotation
Lens Cone	15/4 UAG-S	Three-digit AWAR, full performance already at f/4, output of MEP
Cassette	PKA4	Easy interchangeable in-flight
Mount	PAV30	Gyro-stabilized Camera Mount for sharper images

Components and performance of the RC20 Aerial Camera System

Component	Name	Performance
Drive Unit	PTW20	Forward Motion Compensation and annotation of internal data
Lens Cone	15/4 UAGA-F	Two-digit AWAR, output of MEP
Cassette	PKA4	Easy interchangeable in-flight
Mount	PAV20	Remote controlled Camera Mount

Components and performance of the RC10A Aerial Camera System

Component	Name	Performance
Drive Unit	PTW11A	Microprocessor controlled drive unit
Lens Cone	15/4 UAGA	Two-digit AWAR
Cassette	PKA4	Easy interchangeable in-flight
Mount	PAV11A	Remote controlled Camera Mount

Camera type on camera calibration certificates

Because a lens cone can be used in various camera system configurations, the certificate contains information on the camera system, of which a particular lens cone type was part of when introduced to the market. According to the tables above this is for a 15 cm lens cone as follows:

Lens cone type	Camera type
15/4 UAG-S	RC30
15/4 UAGA-F	RC20
15/4 UAGA	RC10A

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Using older components in a RC30 Aerial Camera System

The modular concept of the Leica RC30 Aerial Camera System allows the use of components from previous Leica Aerial Camera Systems. The components are listed in the tables below. The tables also show if an upgrade is required for use with an RC30. In the column 'Performance' is listed to which generation of Aerial Camera System a component performs.

RC20 components used for RC30 Aerial camera system

Component	Name	Required Modification / Upgrade	Performance equivalent to Camera System of RC30	RC20
Drive Unit	PTW20	Upgraded to PTW30	✓	
Lens Cone	8.8/4 SAGA-F	-		✓
	15/4 UAGA-F	-		✓
	21 NAGIIA-F	-		✓
	30/4 NATA-F	-		✓
Cassette	PKA4	-	✓	
Mount	PAV20	-		✓

RC10A components used for RC30 Aerial camera system

Component	Name	Required Modification / Upgrade	Performance equivalent to Camera System of RC30	RC20
Drive Unit	PTW10A	Upgraded to PTW30	✓	
Lens Cone	8.8/4 SAGA	Upgraded to 8.8/4 SAGA-F		✓
	15/4 UAGA	Upgraded to 15/4 UAGA-F		✓
	21 NAGIIA	Upgraded to 21 NAGIIA-F		✓
	30/4 NATA	Upgraded to 30/4 NATA-F		✓
Cassette	PKA4	Must be modified	✓	
Mount	PAV11A	Upgraded to PAV20		✓

RC10 components used for RC30 Aerial camera system

Component	Name	Required Modification / Upgrade	Performance equivalent to Camera System of RC30	RC20
Cassette	PKA4	Must be modified	✓	

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