

Leica ADS L1 SDK

User Manual

Version 1.1
English

- when it has to be **right**

Leica
Geosystems

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Available documentation

Name of documentation	Description
Leica ADS L1 SDK User Manual	All instructions required in order to operate the product to a basic level are contained in this User Manual. Provides an overview of the system together with technical data and safety directions.

Table of Contents

1	About Leica ADS L1 SDK	5
2	Leica ADS L1 SDK Introduction	7
2.1	What's New	8
2.2	Naming Conventions	9
3	Installation	11
4	Leica ADS L1 Sensor Model	13
4.1	Math Model	13
4.1.1	Image to Ground Transformation for Level 0 Imagery	13
4.1.2	Image to Ground (LSR) Transformation for Level 1 Imagery	13
4.2	Interior Orientation	14
4.2.1	Camera Calibration	14
4.2.2	IMU Misalignment	14
4.3	Exterior Orientation	15
4.4	Rectification	15
5	Selected Ground Processing supplied by Leica Geosystems	17
5.1	Downloading	17
5.2	Positioning Post-Processing	17
5.3	Level 1 Creation	18
6	Meta Data Information	19
6.1	Support File	19
6.2	Image	20
6.3	Camera Calibration	21
6.4	Orientation Data	23
7	Coordinate Systems	25
7.1	Image Coordinate System	25
7.2	Focal Coordinate System	26
7.3	Ground Coordinate System LSR	26
8	Usage of the SDK	27
8.1	Getting Data	27
8.2	Usage of the SDK for native 64-bit Software	28
8.3	Usage of the SDK for native 32-bit Software	30

1 About Leica ADS L1 SDK

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References

Tempelmann U., Börner A., Chaplin B., Hinsken L., Mykhalevych B., Miller S., Recke U., Reulke R., Uebbing R., 2000. Photogrammetric Software for the LH Systems ADS40 Airborne Digital Sensor, XIXth ISPRS Congress, Amsterdam.

Internet

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Asia / Pacific (including Australia, China, Japan and Korea)	sensors-ap@leica-geosystems.com
Europe, Middle East & Africa	sensors-emea@leica-geosystems.com

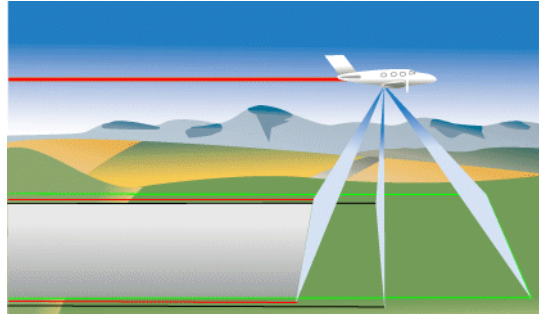
2 Leica ADS L1 SDK Introduction

Description

This document is intended to enable users and developers understanding the process workflow of the Leica ADS Digital Line Sensor. It describes the file formats and structures, used in the data processing. Additionally, it details the math model, so developers can create software which handles Leica ADS L1 imagery correctly, specifically image to ground and ground to image transformations.

Workflow

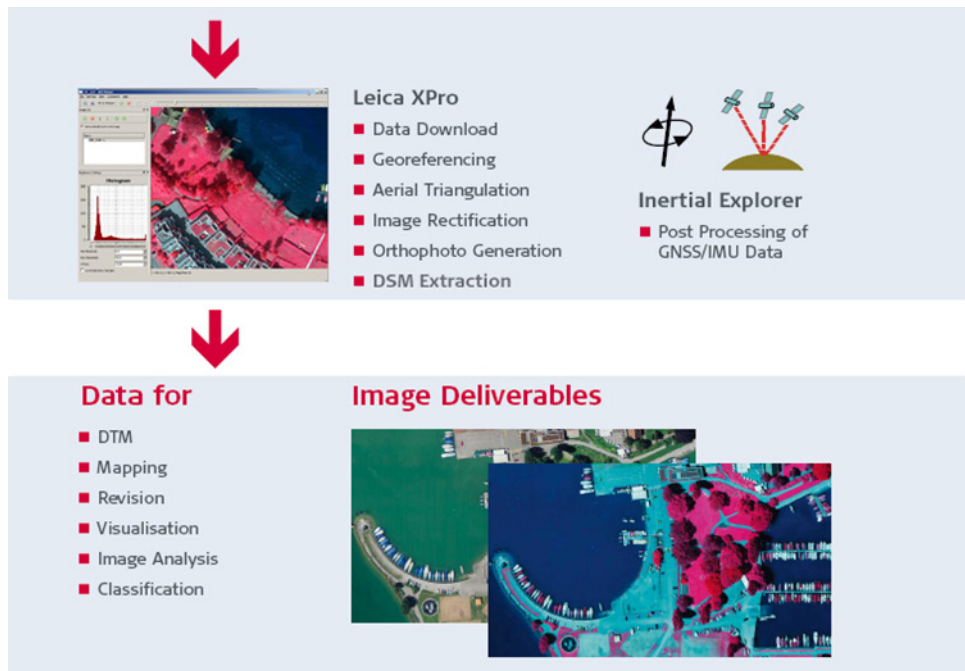
Figure 1 - Three line digital sensor principal



The Leica ADS is a multiple Digital Line Sensor, built on the three-line principle, recording continuously as the aircraft moves, Figure 1. The produced imagery can be viewed in stereo and used for all further photogrammetric processes, for example DTM generation, orthophoto production, feature extraction and image analysis. For a more detailed discussion of the characteristics of the sensor and the ground processing software, please refer to Tempelmann et al, 2000. For an overview of the ground processing flow see Figure 2.

Figure 2 - Leica ADS workflow





2.1 What's New

In the context of a pushbroom sensor, local variations in pitch produce local variations in parallax that can disturb stereo impression as well as calculated a high dense digital elevation model. This effect can be increased if the rectification plane of L1 images differs significantly from the digital elevation model (DEM).

Leica XPro 6.3 correct this by smoothing the external orientation parameters (EOP) and using a DEM for the processing of L1 images instead of a flat surface. These changes results in a new SDK and also a new plugin for Socet Set 5.6.

To get the full performance a global elevation model is needed. It is necessary to use the same elevation source in the SDK as it was used for generating the Leica ADS L1 image with the product generator. For example you can use the 30 m "SRTM" data, for example:

http://dds.cr.usgs.gov/srtm/version2_1/SRTM30/

2.2 Naming Conventions

Anchor Point

Origin of the LSR in geographic coordinate system, reference ellipsoid is WGS84 [radians]

CCD Line

A Line of Charge-coupled Device (CCD, Photosensitive hardware device)

DEM

Digital Elevation Model represents a 3D surface or terrain model. It is not defined if buildings or trees are included or not.

DSM

Digital Surface Model represents a 3D model (grid) of the elevation with objects on surface like buildings and trees.

DSNU

Dark Signal Non Uniformity. Each pixel "delivers" a gray value even no light falls on it. For corrections non exposed images are used, so called dark images.

DTM

Digital Terrain Model represents a 3D surface model without objects like buildings and trees.

ECEF

Space rectangular coordinate system, Earth-Centered, Earth-Fixed coordinate system

EOP

Exterior Orientation Parameter, mainly x, y, z and omega, phi, kappa. Describing sensor position and orientation in a 3D Coordinates system.

L0

Raw data corrected by radiometric calibration, no geometric calibration at all. Not accessible via SDK.

L1

Geometrically corrected L0 image, rectified to a given plane.

L1 with DEM correction

Smoothed EOPs and using DEM for rectification.

L2

Orthophoto

Latitude φ

Measured from the equator, positive to the north

Longitude λ

Measured from 0 Meridian (Greenwich), positive to east

LSR

Local Space rectangular coordinate system, see also ECEF

Number of Lines

Number of Lines in flight direction

Number of Samples

Number of Pixel across flight line or image in image coordinate system

PRNU

Photo Response Non Uniformity. Different sensitivity of single pixel on a chip. Will be corrected normally by "bright images".

Scan Line

Captured lines during flight

3 Installation

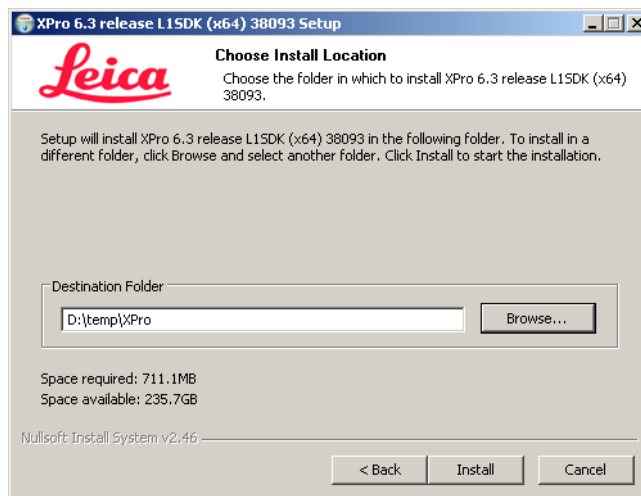
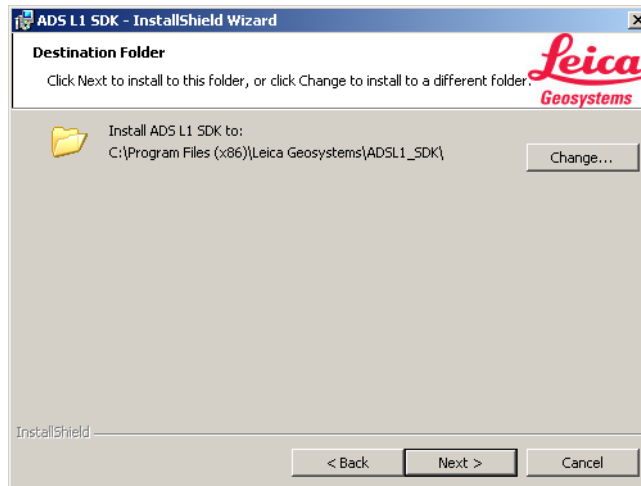
Description

The Leica ADS L1 SDK Installer contains all necessary files to access Leica XPro features from own software products to process Leica ADS L1. Also example source code for Microsoft Visual Studio 2010 projects is delivered. Additionally the installer delivers also an extension for Socet Set 5.6 (Sensor Model plugin).

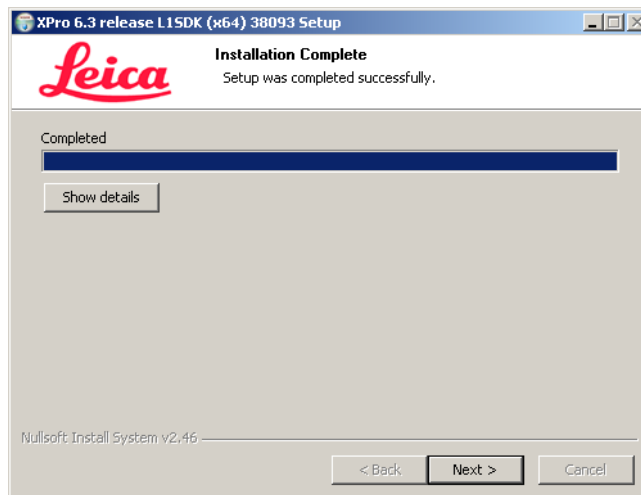
Installation

During the installation the destination directory of the SDK can be set.

Set installation folder for the SDK:



Installation starts right after confirmation by clicking the "Install" button.



The main part of the installation is done.

It might be necessary to update the xpro.ini file from Leica XPro (bin\xpro.ini):

- The mapping section should contain:
"< Location of you installation >/runtime_data/geodetic".
- The GTopo section should contain:
"< Location of you installation >/runtime_data/dem/gtopoDem_ell.jptf"

The following table shows the areas where changes might be necessary, especially for setting path to SRTM data which is not done automatically:

[GTopo]

; location and filename for the GTopo global elevation database file

; default is \$etc_folder/dem/gtopoDem_ell.jptf

datafile = T:/testdata/runtime_data/dem/gtopoDem_ell.jptf

[SRTM]

datapath = U:/corelibs/dsmttools/SRTM3_unittests

[Persistence]

; location and filename for the schema file

; default is \$etc_folder/schemas/persschema.xml

; commented out by default

; schemafile = \$etc_folder/schemas/persschema.xml



Note: Use slash "/" instead backslash "\". Otherwise the path will not be set correctly.

4 Leica ADS L1 Sensor Model

Description

The Leica ADS is a line scanner which records multiple lines simultaneously and creates digital images built from sequential lines. To reconstruct the line of sight for each image point, the exterior orientation need to be known for each scan line of the image to apply collinearity equation for the given line. In the case of the Leica ADS, the orientation is recorded continuously together with the actual image data. Thus, for each scan line - with a well-defined set of orientation data - ground to image and image to ground (with a fixed ground height) transformations can be accessed after some ground pre-processing steps. Unfortunately, the (raw) orientation data is not recorded in the coordinate system that is later used in the photogrammetric processing nor synchronized with the image. This lack is resolved by utilizing the Leica IPAS post-processing software to convert the attitude data to a local frame system with its origin at each GPS recording time. The output is then synchronized with the actual image data and the position and attitude information is transformed to a local space rectangular (LSR) system that is used for photogrammetric processing.

Both, the digital frame sensor model and the Leica ADS sensor model, are based on the collinearity equations, there are significant differences in handling the data and performing image matching (required for triangulation). The following table gives an overview of the differences between the digital frame sensor and Leica ADS sensor models:

	Leica ADS	Digital Frame Sensor
Camera Calibration	Position in the focal plane is known for each pixel	Usually distortion parameters and principal point offsets are known
Orientation	Is given for each scan line	Is computed (or given) for a single image
Matching	Image must usually be rectified for matching	No rectification necessary
Triangulation	Strip or block triangulation - solved for orientation and IMU misalignment [optional: self calibration]	Strip or block triangulation - solved for orientation [optional: self calibration]

4.1 Math Model

Description

This chapter gives an overview of the used math model. All calculations are done inside the SDK.

4.1.1 Image to Ground Transformation for Level 0 Imagery

As in traditional photogrammetry the image to ground transformation for ADS imagery is based on the collinearity equations. The main difference is that each scan line must be treated as an individual image with its own exterior orientation. During the pre-processing steps the orientation for each scan line in the imagery is defined. The transformation is conducted in two steps and uses the focal plane coordinates as an intermediary.

4.1.2 Image to Ground (LSR) Transformation for Level 1 Imagery

The transformation of a Level 1 (L1) image into an "object space L1" (a L1 image in the position and orientation to which it was projected) is fairly trivial. In this case, only the image coordinate system needs to be considered. The origin pixel is defined as mid of the upper left pixel (see chapter 7.1 "Image Coordinate System"):

$$P_x = \frac{1}{m}(p_s^1 + xoffset) \cos(\alpha) + \frac{1}{m}(lines - p_l^1 + yoffset) \sin(\alpha)$$

$$P_y = -\frac{1}{m}(p_s^1 + xoffset) \sin(\alpha) + \frac{1}{m}(lines - p_l^1 + yoffset) \cos(\alpha)$$

$$P_z = height$$

The inverse transformation is defined as:

$$p_s = m \cdot (P_x \cos(\alpha) - P_y \sin(\alpha)) - xoffset$$

$$p_l = lines - (m(P_x \sin(\alpha) + P_y \cos(\alpha)) - yoffset)$$

Where

m	is the rectification scale (keyword RECT_SCALE)
xoffset	is the rectification offset in x (RECT_XOFFSET)
yoffset	is the rectification offset in y (RECT_YOFFSET)
α	is the rectification rotation angle (RECT_ROTATION)
height	is the rectification height (RECT_HEIGHT)
p_s^1	image coordinate in image width/sample direction, origin of the coordinate system is mid of upper left pixel, unit is [Pixel]
p_l^1	image coordinate in image height/line direction, origin of the coordinate system is mid of upper left pixel, unit is [Pixel]
lines	Number of lines / rows of L1 image

4.2 Interior Orientation

Description This chapter gives a short overview about parameters of the interior orientation where the IMU misalignment is playing an important role.

4.2.1 Camera Calibration

During calibration a set of pixels are measured, which represent the scan line. Each measured pixel is represented through its number (position in the scan line) and its x, y coordinates in the focal plane. The actual measurement is done by observing a pair of orientation angles for a selected set of pixels per line, dense enough to ensure far subpixel. Additionally, the nominal focal length, which is used to convert from angles into x-y coordinates, is given for the sensor. For each scan line a separate file is created and stored as an ASCII text file. The format of the ASCII file is described in chapter 6.3 "Camera Calibration". For Leica ADS 100 sensor systems a new format is used, containing equal information.

4.2.2 IMU Misalignment

Since the inertial measurement unit (IMU) must be mounted on the sensor and that the physical axes of the IMU can only be determined approximately, a mounting misalignment will remain as a small error. Opposed to the error remaining from the offset measurement between GPS antenna and IMU center (that is smaller than GPS measurement itself), this misalignment will have an influence on the image orientation accuracy.

4.3 Exterior Orientation

The position and attitude of the sensor together with the time are each recorded at a constant frequency and stored in the Mass Memory (MM) during the flight. As the image data itself are also recorded together with the time, the imagery can be later synchronized with the orientation data. To convert from the data on the MMs to the orientation, which can be used later, two processing steps are necessary.

1. Convert the raw attitude data into the local frame system used by Leica IPAS. This step is performed by standard Leica IPAS Pro software. The output is the attitude given as raw, pitch and yaw angles.
2. Transformation of the local frame system into LSR systems. The LSR systems are the object spaces used for photogrammetric processing. To define this system an anchor point in WGS84 must be established. Also the time synchronization is done in this step. The output is a set of orientation data (X, Y, Z, omega, phi, kappa) for each scan line of the image.

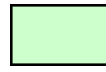
4.4 Rectification

Owing to the movements of the aircraft the resulting level 0 image (L0) will be not matched. Also, stereo viewing and feature extraction are usually not possible with L0 imagery. To generate (rectified imagery that fulfils the requirements for data processing mentioned above, L1 rectifiers (disk-to-disk or disk-to-viewer "on the fly") are included in the Leica ADS ground processing packages. This program rectifies the image content on the horizontal plane in object space by usage of orientation data, camera calibration and L0 image. The resulting images can be viewed in stereo (any combination of two lines), assuming the user has access to an adequate system. Also, image matching could be applied afterwards.

5 Selected Ground Processing supplied by Leica Geosystems

Description

The following describes the different software components for basic processing of the Leica ADS data. The ground processing can be split up into the three parts, namely Downloading, Positioning post-processing and L1 creation. Each color presents a different significance:



= Software supplied by Leica Geosystems



= File interface specified in the document

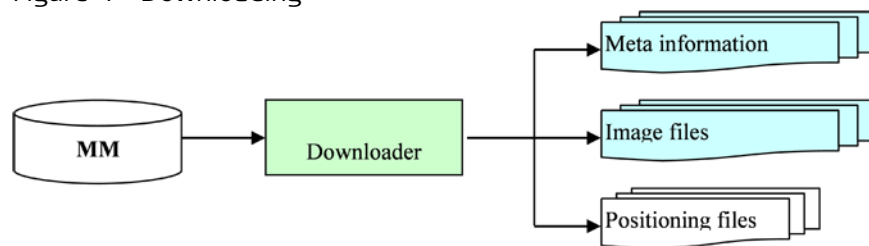


= External input (not coming from the MMS)

5.1 Downloading

To provide the files described in detail below it is necessary to run low-level software that reads out the Leica ADS Mass Memory (MM) and separates the data stream into readable files (download step in Figure 2). These files can be categorized into meta-files (session, take, image information), image data files and positioning data files.

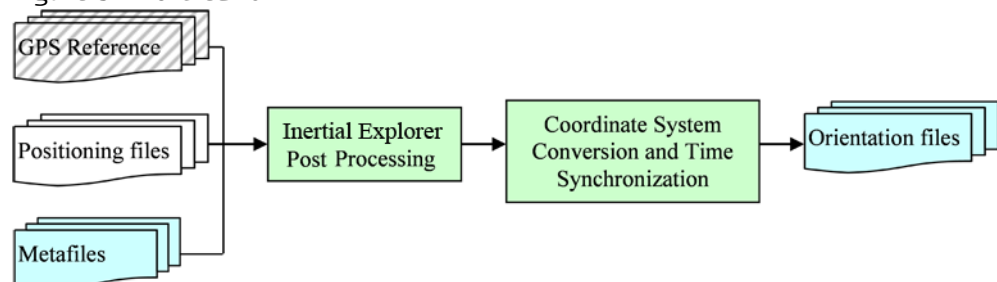
Figure 4 - Downloading



5.2 Positioning Post-Processing

At this point L0 imagery can be displayed plus the corresponding meta information gets interpreted. The files are somewhat worthless for further data processing without a time-tagged exterior orientation. To create these orientation files, two further processing steps are necessary. The positioning files as part of the output files from the Downloader and GPS reference files from the GNSS Ground Reference Station must be post-processed with the Inertial Explorer software. Afterward those need to be time-tagged and converted into the appropriate coordinate system, see Figure 5. The resulting orientation files allow easy retrieval of the exterior orientation at any position in the image. Images which have exterior and interior orientation are called L0 images.

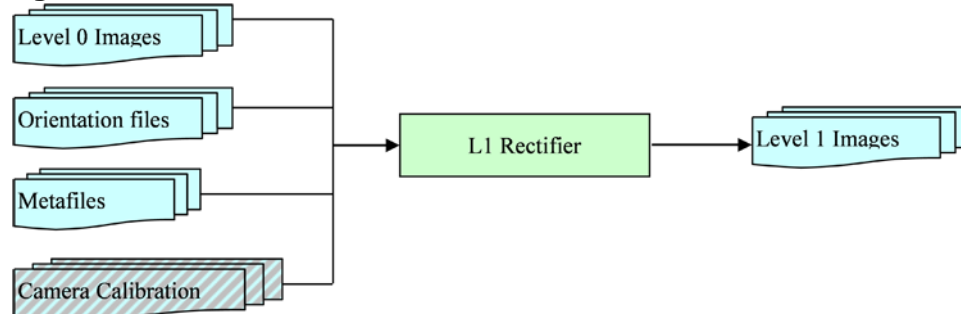
Figure 5 - L0 creation



5.3 Level 1 Creation

Together with the images and the camera calibration, the orientation files are the basis for generating L1 images. The L1 rectification is done by projecting each pixel of the L0 image onto a horizontal plane, rigorously applying the interior and exterior orientation. Besides an "on the fly" rectifier in Leica XPro, there are two different types of disk-to-disk rectifiers in Leica GPro (direct resampling) and Leica XPro (indirect resampling).

Figure 6 - L1 creation



6 Meta Data Information

Description

This chapter describes the different files and meta information used by the SDK. More details about generating these files can be found in chapter 8.1 "Getting Data".

6.1 Support File

The meta data information for an image is stored in a standard SOCET SET support file. The support file is an ASCII file containing keywords. Each keyword may have one or more parameter sets. The following table shows the general keywords and their descriptions.

Keyword	Description
Support_file	Version number of the support file. Currently set to d.
IMAGE_ID	Base name of the image, do not contain any extensions or other information.
IMAGE_FILE_NAME x LINES SAMPLES	Concrete file name of an image with a given minification level (overviews) The x value starts with one and doubles always for the next minification levels (2,4,8,16,32,...). If the overviews are included, only one file is given. If external overviews are used, several files will be set. This parameter comes always with LINES and SAMPLES showing the size of the image.
IMAGE_LEVEL	Indicates the image level. The SDK can handle only L1 images. Therefore this parameter must be set to 1.
MEAN_TERRAIN_HEIGHT	Mean terrain height of the project given in project units.
LINE_STAGGERED	Indicates whether the output is in high res mode (staggered lines) or not (True/False).
VIEW_OF_LINE	Indicates the view of the CCD-line, could be NADIR, FORWARD, BACKWARD
RADIOMETRIC_PROPERTY	Indicates the bands used for this image. Depending on the sensor system it could be RGB, PANCHROMATIC, RED, GREEN, BLUE, NEAR_INFRARED, FAR_INFRARED.
IMAGE_DATE	Date of image recording
ANCHOR_LATITUDE	Latitude of anchor point using WGS84, geographical coordinate system units in radians Latitude is measured from the equator, positive to the north.
ANCHOR_LONGITUDE	Longitude of anchor point using WGS84,. Longitude is measured from Greenwich Meridian to the east, Unit is radians.
NUMBER_SCAN_LINES	Number of original scan lines, is normally not equal with image width of the L1 image.
SENSOR_ROTATON	Flag to indicate whether sensor has rotated at installation, normally FALSE otherwise TRUE.
ORIGINAL_ORIENTATION	Name of the original orientation file (ODF-Format). Not given for ADS100 L1 images with DEM correction. Here the files recorded by the sensor system (EOP Files) are used.
ADJUSTED_ORIENTATION	Name of the orientation file after bundle adjustment (ODF-Format). Not given for ADS100 L1 images with DEM correction. Here the adjusted EOP files are used.
CALIBRATION	For all none L1 images with DEM the file is given in CAM-Format. For L1 images with DEM a calibration folder is given only. While for ADS100 the folder has XML files for all other systems the CAM format is used.
ADJUSTED_CALIBRATION	Same as for calibration, but containing corrected calibration parameter after bundle adjustment ("Self-Calibration").
SENSOR_TYPE	Showing the used Sensor Type. The new SDK is listening to: - ADS: All L1 images without DEM - ADS_L1: L1 images with DEM For all other sensor types the software will quit work with the error message "Unknown Sensor Type".

Beside the general keywords there are some more specific ones for the L1 ADS images, especially for the new sensor model. For mapping data between image and ground the rectification parameters are internally used, too.

Keyword	Description
RECT_SCALE	Rectification Scale, (inverse GSD)
RECT_ROTATION	Rotation angle used for rectification, given in radians
RECT_XOFFSET	X offset between coordinate origin of LSR and origin of Level 1 image
RECT_YOFFSET	Y offset between coordinate origin of LSR and origin of Level 1 image
RECT_HEIGHT	Height of the rectification plane, given in project units. Calling Function image2ground of the SDK will use this height if no other height is given.

The next few entries are only visible for L1 images with DEM corrections:

Keyword	Description
MODEL_INFORMATION	Path to information to calculate the mapping between L1 image and ground. Use only for ADS100 L1 images with DEM corrections.
REFERENCE_BAND	Master band of multispectral image (e.g. RGB image). The calibration of this band is used. Only available for L1 images with DEM corrections.
MODEL_METHOD	Showing used method, available only for L1 images with DEM corrections. Should be STEREO_DSM.
ELEVATION_SOURCE	DEM to correct L1 images. Currently only global DSM (parameter: GlobalDEM) with SRTM (parameter SRTMElevationSource) or GTopo (parameter GTopoElevationSource) is used. In general: GlobalDEM SRTMElevationSource or GlobalDEM GTopoElevationSource

6.2 Image

Description

Imagery can be stored and read with either 8-bit or 16-bit pixel depth. The actual image format depends on the option set by the user at processing time. A variety of formats are supported by Leica XPro. Cause of compatible reasons with as many systems as possible, it is recommended to use TIFF tiled format for 8 and 16-bit imagery (optionally JPEG compressed for 8-bit imagery). Downloaded raw images are normally stored in proprietary formats, which use hardware compression method.

Due to the nature of the Leica ADS imagery, typically spanning over multiple gigabytes for output products, a Leica ADS file format was developed. This format is discussed in detail below.

Leica ADS file format

Due to the limitations of popular formats, such as TIFF (4GB), it was necessary to define a new format to extend them. The aim was to retain the underlying format, but to allow limitless image file sizes. The notion of sub-blocking was introduced where the format would define a number of images that were butt matched.

The Leica ADS file is a simple ASCII header that describes the sub-image blocks sizes and how the images are arranged. The image handling software has to be coded to handle the butt matched sub-image blocks. In the example dataset the RGB L1 image was created with 3 sub-blocks with a maximal sub-block size of 2GB. This size is selectable in.

Keyword	Description	Value (or example value)
ADS_HEADER	Notification that this is the ADS header	1
BANDS	Number of bands in the image	3
DEPTH	Image depth	2
BITS	Number of bits (DEPTH * 8)	16
LINES	Total number of lines in the image	12640
SAMPLES	Total number of samples in the image	57008

TILE_Y	Number of pixels in the TILE in the Y direction	400
TILE_X	Number of pixels in the TILE in the X direction	400
HARDWARE_COMPRESSED	Is the image hardware compressed? 0 for No and 1 for Yes	0
LINES_PER_BLOCK	Number of lines in each block	12640
SAMPLES_PER_BLOCK	Number of samples in each block	24400
BLOCK_DATA	Three parameters indicating the line and sample position and the file name. Note: The line and sample positions are also defined in the file name.	0 0 L106260944RGBF16A_0_0.tif

The following is the full listing of the Leica ADS file for the RGB L1 image. Note, it consists of six sub images.

```

ADS_HEADER          1
BANDS                3
DEPTH               2
BITS                16
LINES               12640
SAMPLES             57008
TILE_Y              400
TILE_X              400
HARDWARE_COMPRESSED 0
LINES_PER_BLOCK     12640
SAMPLES_PER_BLOCK   24400
BLOCK_DATA           0 0 L106260944RGBF16A_0_0.tif
BLOCK_DATA           0 1 L106260944RGBF16A_0_1.tif
BLOCK_DATA           0 2 L106260944RGBF16A_0_2.tif

```

6.3 Camera Calibration

A strict hierarchy exists for the calibration file within the project due to the possible calibration of the sensor from within a project. The versioning of the calibration is manifested in the folder naming, i.e. v001 and v002.

The camera calibration is stored in an ASCII text file or XML File for Leica ADS100 L1 images with DEM correction. The next section gives an overview of the format.

CAM-Format

The file contains a header with exactly 9 lines and shows the following:

Keyword	Description
ADS_CALIBRATION_FILE	Version number of the calibration file
CALIBRATION_SOURCE	Name of the calibration source
CAMERA_NAME	Name of the camera
SENSOR_LINE	Line identifier
CALIBRATION_DATE	Date of calibration
FOCAL_LENGTH_MM	Focal length in mm
NUM_PIXELS	Number of calibrated pixel
PIXEL_SIZE	Pixel size in mm
PAV_Z_OFFSET	Offset from the PAV to the lens node (m)
RADIOMETRIC_GAIN	Radiometric gain
IRRADIANCE_GAIN	Irradiance gain
LEFTHAND_GAIN	Left side gain
START_XY	Indicator that the following is calibration data
END_XY	End of the calibration data

The doublet, in x and y order, that follows the START_XY tag is a series of double values representing the calibration for each sample in the CCD.



Note: The order of lines 2 through 8 is not fixed. Although the above order is written in the order above, the reader should never rely on this order.

The coordinate system of the sensor focal plane is defined as the x axis in the direction of the flight, the z axis pointing to the earth and the y axis complementing a right-handed system. The first pixel of a scan line is the point with the smallest Y value and corresponds to the left edge of the L0 image. So, the first pixel of the first scan line will correspond to the upper left pixel of the image.

XML-Format

For compatibility reasons with old SDK implementation, the XML format is used only for Leica ADS100 L1 images with DEM correction. The calibration folder contains corrections for PRNU and DSNU as well as for the geometric correction. The next figure shows an excerpt.

Example geometric calibration, example contains only data of one sensor. Normally data for all sensors are given.

```
<?xml version="1.0" encoding="UTF-8"?>
<DigitalSensorHeadInteriorOrientation Version="1.0.0">
  <!--Leica Geosystems ADS camera calibration file-->
  <System Type="ADS100">
    <SystemInfo Component="SensorHead" SerialNo="10517" Revision="-" ArticleNo="795360"/>
    <SystemInfo Component="LensSystem" SerialNo="0021" Revision="-" ArticleNo="773612"/>
    <SystemInfo Component="BeamSplitter" SerialNo="2014-0031" Revision="-"
ArticleNo="797541"/>
    <SystemInfo Component="FocalPlate" SerialNo="15092013-012" Revision="-"
ArticleNo="795225"/>
    <SystemInfo Component="IMU" SerialNo="56063801" Revision="-" ArticleNo="747070"/>
  </System>
  <Creation Name="From lens system data" Location="&quot;ORIMA&quot;"
Environment="Laboratory" Remark="Initial">
    <DateTime Type="UTC" Date="20141217" Time="101945"/>
  </Creation>
  <LensSystem PrincipalDistance_mm="62.7000" SigmaPrincipalDistance_mm="0.0010"/>
  <Misalignment_deg Omega="0.00601" SigmaOmega="0.00011" Phi="0.01404" SigmaPhi="0.00012"
Kappa="-0.05140" SigmaKappa="0.00026"/>
  <Sensors>
    <Sensor i="0">
      <Sensor Type="LineCCD" Structure="Mono" PixelSize_mm="0.0050" Rows="1"
Columns="20064"/>
      <DistortionGrid Channel="NIRF26A" Columns="20064">
        <GridRow i="0">
          <Row_mm> ... </Row_mm>
          <Column_mm>
          <SigmaRow_mm>
          <SigmaColumn_mm>
        </GridRow>
      </DistortionGrid>
    </Sensor>
  </Sensors>
</DigitalSensorHeadInteriorOrientation>
```

6.4 Orientation Data

Description The system delivers two different formats. While L1 images the orientation of a single line is given in the ODF Format, for L1 images with DEM correction taken with Leica ADS100 the EOP Format is used. The data itself is given in respect to L0 image.

ODF-Format The orientation file is a binary file that stores a set of orientation (X, Y, Z - position; and omega, phi, kappa - attitude) for each scan line of the L1 image. In addition, the time and the standard deviations of the positions and angles stored in this file. To keep the files within a reasonable size the information is compressed by storing base numbers of the values in the header of the file and storing the single values as integer offsets from the base numbers.

The coordinate system is an LSR system. Its origin is a specified latitude and longitude in WGS84 with a height of 0 (anchor point). The direction of the X axis is East, the Y axis points towards North, and the Z axis is perpendicular to the plane defined by X and Y complementing a right handed coordinate system.

The orientation file holds the exterior orientation for each scanned image line from the Leica ADS. The orientation file has exactly one set of orientation per image line in the L0 image. Additionally to the actual orientation (x, y, z, omega, phi, kappa) also the GPS time and the standard deviations for the positions and angles are stored in this file.

The orientation is crucial for geo-referencing any kind of Leica ADS imagery and plays a central role in the triangulation process. The orientation data is stored in a binary file with an ASCII header and has an "ODF" (orientation data file) extension. Its header has a size of 512 Byte:

Parameter	Example	Size [Bytes]	Offset [Bytes]
File Identifier + Version number	ODF 1.2	16	0
Data source	GPro 3.0	32	16
Project Name and ID	30018_20040626093146_20040626072409 _UNPLANNED	64	48
Strip Name and ID	12	64	112
Number of orientation data sets	119480	16	176
Units position	0 (meters)	2	192
Precision position	1000	14	194
Units angles	3 (radian)	2	208
Precision angles	1000000	14	210
Rotation sequence	0 (OPK)	16	224
Absolute time	152409600	16	240
Comments		96	256
Anchor Latitude	0.8539992993	16	352
Anchor Longitude	0.1561354580	16	368
Base time	553572	12	384
Precision time	10000	20	396
Base X (Easting)	17	12	416
Precision std. dev. Position	100000	20	428
Base Y (Northing)	-6	12	448
Precision std. dev. Angles	10000000	20	460
Base Z	1883	32	480

All entries are terminated with a CR ("\r") character.

The binary part of the file contains the actual orientation data. The amount of orientation sets and scan lines are exactly the same within one image. Each orientation set has a size of 40 bytes and contains the following binary structure:

Type	Contents
int	GPS time
int	X
int	Y
int	Z
int	Omega
int	Phi
int	Kappa
unsigned short	Standard deviation X
unsigned short	Standard deviation Y
unsigned short	Standard deviation Z
unsigned short	Standard deviation omega
unsigned short	Standard deviation phi
unsigned short	Standard deviation kappa

EOP Format

The EOP file can be found in the folder /strips after Leica ADS100 L1 images with DEM correction have been calculated.

Compared to the ODF it is not directly synchronized with the L1 image. Therefore an interpolation with the data is needed getting the correct orientation for each scan line of L1 images.

7 Coordinate Systems

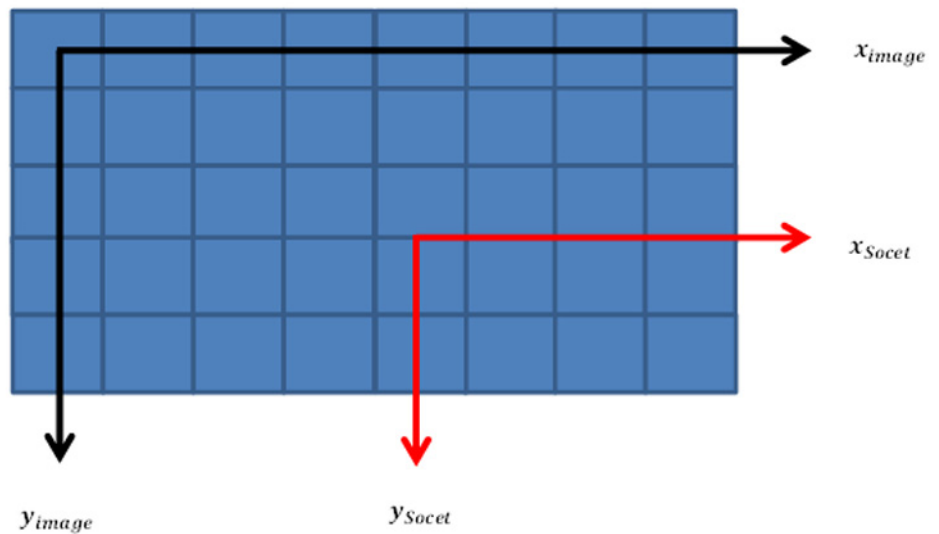
Description

This chapter describes the different coordinate systems used in the SDK. In general the image coordinate system is used in the SDK for images base on Socet Set definition while the ground system is a local space coordinate system (LSR).

7.1 Image Coordinate System

All image coordinates are given in the Socet Set Coordinate System. This chapter describes the system in respect to a standard image coordinate system.

- Origin is in the mid of the upper left pixel
- X-Axis directs to the right and is named also "samples" or "width", unit in [Pixel]
- Y-Axis directs down and is named "lines" or "height", unit in [Pixel]



In general the origin of the Socet Set Coordinate system is shifted by $\frac{1}{2}$ pixel in x- and y-direction in respect to the image mid. x-axis and y-axis have the same direction as the image coordinate system.

Transformation between both systems:

Socet set to Image

$$x_{image} = x_{socet} + \frac{numSample}{2}$$

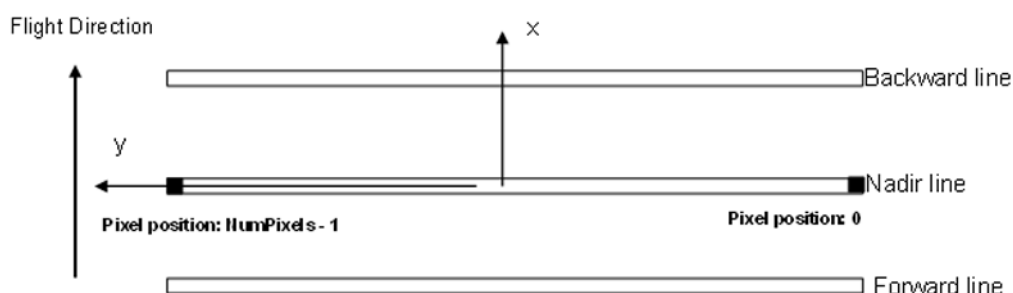
$$y_{image} = y_{socet} + \frac{numLines}{2}$$

Image to Socet Set

$$x_{socet} = x_{image} - \frac{numSample}{2}$$

$$y_{socet} = y_{image} - \frac{numLines}{2}$$

7.2 Focal Coordinate System



In the focal plane each pixel gets a physical location expressed in a coordinate system defined by the nadir line. The y-axis is defined by the nadir scan line and the x axis is perpendicular to the y axis going through the center of the scan line. Positive x follows the flight direction and y complements a right-handed system.



Note: The sensor might be rotated by 180 degrees. This can be checked by the keyword "SENSOR_ROTATION". See chapter 6.1 "Support File".

7.3 Ground Coordinate System LSR

The ground coordinate system is given in a local space rectangular system. The LSR is anchored to the WGS84 ellipsoid. The x-axis points east, the y-axis points to north and the z-axis complements a right-handed system.

More details about transformation between geographical coordinates systems, geocentric coordinates systems and local coordinate systems can be found for example in "Manual of Photogrammetry, Fifth Edition, page 188ff".

8 Usage of the SDK

Description

The Leica ADS L1 SDK is usable with native 32-bit or native 64-bit software. The operating system should be 64-bit based Windows. That is because Leica XPro is a 64-bit software which leads us to a 64-bit SDK environment. The 32-bit version of the SDK maps data between 32-bit and 64-bit processes. More details can be found in chapter 8.3 "Usage of the SDK for native 32-bit Software". General description of the SDK can be found in the chapter 8.2 "Usage of the SDK for native 64-bit Software".

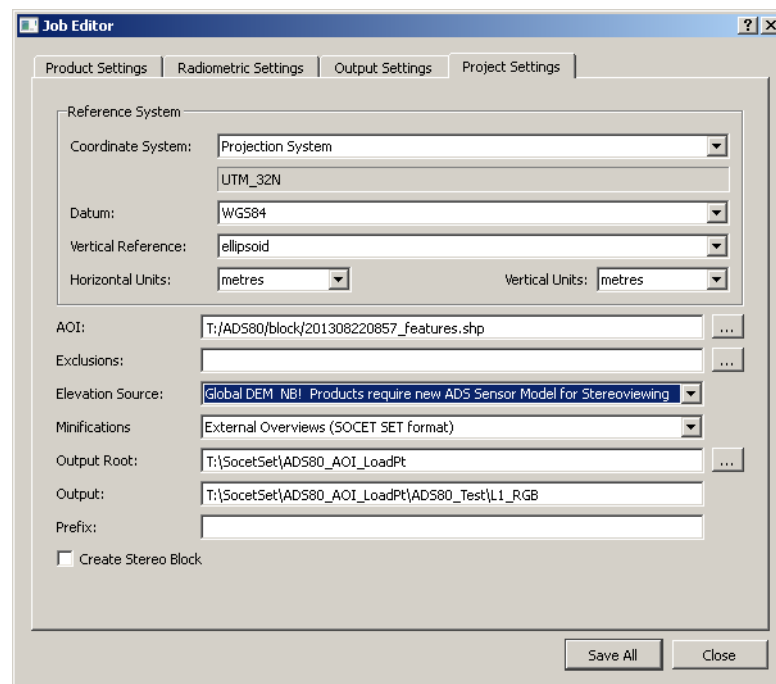
The SDK comes also with Microsoft Visual Studio project (VS 2010). The software is only tested and verified with this compiler.

8.1 Getting Data

The SDK can work only with L1 images. Therefore it is necessary to process such images with Leica XPro 6.3 or later. In general it is possible to write so called L1 images with DEM correction and image without this correction. The SDK recognized the different sensor models by different settings in the support file. More details about the support file can be found in chapter 6 "Meta Data Information".

The figure below in Leica XPro shows a typical data set where a DEM is used. Only with this settings L1 images with DEM correction will be calculated. Setting "Minifications" to External Overviews (Socet Set Format) is also recommended if you want to use the Socet Set 5.6 plugin (optional).

Typical setting to use Leica ADS L1 images in Socet Set:



The output is split into two views of processed stereo images. Folders like "Backward" and "Nadir" contain all necessary information about image sets. The first level contains the image data (including overviews) as well as the support file. Two sub folders, one (SHxx_yyyy) contains the calibration data and the other one ("strips") is having information about the flight parameters like exterior orientation.

All given paths in the support file are relative paths in respect to the location of the support file for the output. Because of this, the whole folder structure can be moved to any location without changing paths inside the support file.

If only the support file needs to be moved to another location (e.g. putting it in Socet Set Project Folder), the following paths need to be changed follow:

Keyword in Support File	Parameter	New with absolute path
Image File Name x (x=1...n)	"001_20130822_0944_RGB B16L1USER.ads"	T:\Project\L1_RGB\Backward\001_20130822_0944_RGBB16L1USER.ads
ORIGINAL_CALIBRATION	SH82_30030/v001	T:\Project\L1_RGB\Backward\SH82_30030/v001
MODEL_INFORMATION	strips/001_20130822_0944_/001_20130822_0944.stp	T:\Project\L1_RGB\Backward\strips/001_20130822_0944_/001_20130822_0944.stp

8.2 Usage of the SDK for native 64-bit Software

To use the SDK in your software you have to include the header file "L1SensorAds.h" as well as the library "adsl1sdk.lib". You have to make sure that the system will find all DLLs which are delivered within the SDK installer.

```
std::auto_ptr<L1SensorAds> sensorModel;
try {
    sensorModel.reset(L1SensorAds::create(parseCmd.supportFile.c_str()));
}
catch (std::exception& e)
{
    std::cerr << "Error during sensor model init: " << e.what() << std::endl;
    return -1;
}
```

The code fragment above gets the support file name from a parser of the command line (std::string) and creates a new sensor model (see also delivered project example). In case of failure an exception will be thrown showing up the reason.

Afterwards the SDK can be used for example to map an image coordinate, given in Socet Set Coordinate System (see chapter 7 "Coordinate Systems") to a ground given in LSR:

```
double image[] = {0,0};
double ground[3];

try {
    sensorModel->imageToGround(image[0], image[1],ground[0],ground[1],ground[2]);
    dataOut.Add(data,3);
}
catch (std::exception& e) {
    std::cerr << "Point : " << image[0] << "/" << image[1] << ": " << e.what() << std::endl;
}
```

The example above maps the image coordinate {0,0} to LSR, where the height is set to the rectification height automatically. The following section is describing all functions in detail:

```

/// Create sensor model. The only input parameter is a SUP file.
/// It recognize automatically which sensor model should be used
/// errors will be returned via exceptions
/// @param full path name to support file.
static L1SensorAds* create(const char* filename);

///! virtual public destructor for the derived classes to extend
virtual ~L1SensorAds() {}

/// Destroy the SDK
/// This becomes only important for the 32 bit implementation
/// otherwise the 64 bit process won't be destroyed
virtual void destroy() = 0;

/// Maps image Socet Set coordinates to LSR Ground on a given height
/// @param xlm coordinate [Pixel], origin image mid, x-direction (=image col,sample)
///     from left to right (image width)
/// @param ylm coordinate [Pixel], origin image mid, y-direction (=image row,lines)
///     from top to bottom (image height)
/// @param z [m] ground height to map image coordinates
/// @param x [m] x value on ground, mapped to Ground LSR
/// @param y [m] y value on ground, mapped to Ground LSR
virtual void imageToGround(const double xlm, const double ylm, const double height,
                          double &x, double &y, double &z) const = 0;

/// Maps image Socet Set coordinates to LSR Ground using rectification height
/// @param xlm coordinate [Pixel], origin image mid, x-direction (=image col,sample)
///     from left to right (image width)
/// @param ylm coordinate [Pixel], origin image mid, y-direction (=image row,lines)
///     from top to bottom (image height)
/// @param x [m] x value on ground, mapped to Ground LSR
/// @param y [m] y value on ground, mapped to Ground LSR
virtual void imageToGround(const double xlm, const double ylm,
                          double &x, double &y, double &z) const = 0;

/// Maps LSR ground coordinates to image Socet Set coordinate
/// @param x x-Value of the LSR Ground coordinate [m]
/// @param y y-Value of the LSR Ground coordinate [m]
/// @param z z-Value of the LSR Ground coordinate [m]
/// @param xlm Output, coordinate [Pixel], origin image mid, x-direction (=image col,sample)
///     from left to right (image width)
/// @param ylm Output, coordinate [Pixel], origin image mid, y-direction (=image row,lines)
///     from top to bottom (image height)
virtual void groundToImage(const double x, const double y, const double z,
                          double &xlm, double &ylm) const = 0;

/// Returns the image height of the image
/// @return image height [Pixel]
virtual int imageLines() const = 0;

/// Returns the image width of the image
/// @return image width [Pixel]
virtual int imageSamples() const = 0;

/// Returns Latitude of the anchor point [radians]
/// @return Latitude of the anchor point [radians]
virtual double anchorLat() const = 0;

/// Returns Longitude of the anchor point [radians]
/// @return Longitude of the anchor point [radians]
virtual double anchorLon() const = 0;

/// Returns height of anchor point [m], normally 0
/// @return Returns height of anchor point [m]
virtual double anchorAlt() const = 0;

```

8.3 Usage of the SDK for native 32-bit Software

In general there is no difference of the usage between the 32- and 64-bit version of the SDK. Only the linked library differs, since for 32-bit "adslsdk32.lib" and for 64-bit "adslsdk.lib" is dedicated.

While native 64-bit calls get directly interpreted by Leica XPro functions, 32-bit calls will be mapped to the 64-bit environment. This is done by the 32-bit SDK through calls via "adsl-sharedmem.exe". Such mapping cost processing time if 32-bit application uses the SDK.

About Leica Geosystems' Airborne Solutions

With over 80 years of experience, Leica Geosystems is a global leader in the design, delivery and support of airborne digital and LIDAR sensors for the geospatial marketplace. Along with the well-known Leica RC30, Leica Geosystems' airborne sensor portfolio today includes a wide range of innovative technologies and products such as the Leica RCD30 series of medium format digital frame sensors, the Leica ADS pushbroom sensors, the Leica ALS LIDAR series, and the Leica IPAS GNSS/IMU solutions.

Following the acquisition of Intergraph by Hexagon in 2010, the newly formed Geospatial Solutions Division has brought together Leica Geosystems Airborne Sensors and Z/I Imaging. Committed to continued innovation on all major product lines, the combined airborne sensor portfolio includes the widest range of medium and large format imaging as well as LIDAR technologies and offers a choice of sensor for every application. A full suite of software from flight planning to post-processing provides end-to-end workflow for high accuracy orthophoto generation, feature extraction and map production. In addition, Hexagon Geosystems operates a global network of customer service and support centers to ensure highest productivity around the clock.

When it has to be right.

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