LANTMÄTERIET

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PRODUCT DESCRIPTION

Digital aerial photographs

DOKUMENTVERSION: 2.0

Figure 1. Example image of an aerial photograph.

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1 General description

An aerial photograph is a central projection, where no corrections have been made for variations in the terrain or the cameras angle of inclination, hence the scale varies in the photograph.

Aerial photography is carried out, and has been carried out, from different altitudes (2500 m - 7400 m) depending on the type of camera used and the desired resolution of the photograph.

Until 2005 only analogue cameras were used. The last aerial photograph taken by an analogue camera in the national image provision programme was in 2006. From 2005 onwards, digital cameras have been used on a regular basis and there is a nationwide coverage of digital photographs, updated according to the long term aerial photography plan.

More information about the National image provision programme.

1.1 Contents

The product contains digital aerial photographs in different light spectra, together with associated orientation data which makes it possible to place the image in a coordination system. The photographs are mainly taken during april-september and have from 2019 a resolution of 0,15 m and 0,37 m, respectively, while the photographs taken until 2018 had a resolution of 0,24 m and 0,48 m, respectively (mainly 0,48 m).

The aerial photographs can be delivered in 4-channels (from 2019), colour or IR. The images in 4-channels consist of visible red, green, blue, as well as infrared.

The colour image (RGB) and the infrared image (IR) are produced from the same exposure. The spectre of the colour image consists of visible red, green and blue. The spectre of the IR-image consists of infrared, red and green. The images are delivered as 8-bit images.

The image size of a photograph from the DMC-camera is 13 824 x 7 680 pixels, from the UCE-camera 20 010 x 13 080 pixels, from the UCXp wa-camera 17 310 x 11 310 pixels and from the UCE Mark 3-camera 26 460 x 17 004 pixels.

Overview information of the product.

1.2 Geographic coverage

The national image provision programme covers Sweden’s entire territory, limited by country and territorial borders. Open water is excluded when there are no objects above the water surface.

Digital aerial photographs have a nationwide coverage and are available with a resolution of 0,48 m/pixel from 2005 onwards. From 2019 the photographs are taken with a resolution of 0,37 m/pixel instead of 0,48 m/pixel.

Aerial photographs with a resolution of 0,24 m/pixel cover the largest localities from 2006 onwards, and from 2012 this was extended to cover the whole southern part of the country and along the coast of Norrland, a total of approximately 44 % of the country. From 2019 onwards, this photography is carried out with a resolution of 0,15 m/pixel instead of 0,24 m/pixel. More information about the coverage of the national image provision programme.

GeoLex is available for up-to-date and detailed presentation of coverage and timeliness.

1.3 Geographic cut-out

The size of the surface that an aerial photograph covers on the ground depends on the type of camera used, flight altitude and resolution, see table 1 below.

Table 1. Relation between camera type, flight altitude, resolution and ground coverage.

Camera type	Flight altitude (m)	Resolution (pixel/m)	Ground coverage (km)
DMC	2 500	0,24	3,4 x 1,9
DMC	4 800	0,48	6,6 x 3,7
UCE	3 700	0,24	4,9 x 3,2
UCE	7 400	0,48	9,9 x 6,5
UCXp wa	2 800	0,24	4,2 x 2,7
UCXp wa	5 600	0,48	8,3 x 5,4
UCE Mark 3	3 000	0,15	4,0 x 2,6
UCE Mark 3	7 400	0,37	9,8 x 6,3

1.4 Coordinate system

The orientation data of the aerial photograph is used to place the image in a coordination system. Orientation data is produced in connection with the block triangulation of the aerial photograph and is delivered in SWEREF 99 TM (horizontal) and RH 2000 (vertical).

2 Quality description

In Table 2 quality, including quality themes and quality parameters as described in the standard SS-EN ISO 19157:2013 Geografisk information – Datakvalitet, is presented. More detailed description of lineage and quality can be found in the text below.

Table 2. Quality themes and quality parameters for Digital aerial photographs.

Quality theme	Quality parameter	Quality
Positional accuracy	• Absolute positional accuracy • Positional accuracy of raster data	In aerial photographs with a resolution of 0,48 m distinct objects will after block triangulation have a horizontal standard error (RMSE) less than 0,6 m and a vertical standard error (RMSE) less than 0,8 m. In aerial photographs with a resolution of 0,24 m distinct objects will after block triangulation have a horizontal standard error (RMSE) less than 0,25 m and a vertical standard error (RMSE) less than 0,35 m. In aerial photographs with a resolution of 0,37 m the corresponding expected horizontal and vertical standard errors (RMSE) are less than 0,5 m and 0,7 m respectively. In aerial photographs with a resolution of 0,15 m the corresponding expected horizontal and vertical standard errors (RMSE) are less than 0,20 m and 0,25 m respectively. Also see chapter 2.4.1 Positional accuracy.

2.1 Purpose and utility

An aerial photograph is a central projection, where no corrections have been made for variations in the terrain or the cameras angle of inclination, hence the scale varies in the photograph.

The aerial photos have been processed to achieve as neutral and reality consistent colours as possible, red and blue discolourations have been removed from the images.

The most common area of application is mapping as a base for producing plans, maps, terrain models, 3D-models etc. The IR-information can be used for interpreting vegetation and make different kinds of forest analyses.

The aerial photos have been radiometrically processed so that the pixel values will have standardized mean values and standard deviations per band, so called spectral signatures, for different kind of objects, such as buildings and forests. This means that the same types of terrain and land cover look similar in different images when other conditions are the same.

Images taken within the same aerial photography area and at the same photography occasion have the same colour balance. But the time of photography as well as the conditions on the ground (drought or wet soil) and in the atmosphere at the time of photography also affect how good the result can be. The time of season also affects to a large extent, due to more or less developed vegetation, for example before or after leafing.

The images are taken with overlap, which makes processing in stereo possible, for example 3D-measurement.

2.2 Data capture

2.2.1 LINEAGE

Aerial photography has since the 1950's been carried out nationwide according to an established aerial photography plan, mainly during spring and summer. From 2007 all photography has been done with digital cameras.

Aerial photography is carried out from different altitudes (2500 m-7400 m), depending on the type of camera used and the desired resolution of the image.

The images are taken with overlap, which makes processing in stereo possible. The image overlap (within the flight line) is approximately 60 %, but from 2021 onward 80 % over the areas photographed with the lower resolution 0,37 m. The side overlap (between flight lines) is approximately 20-30 %. Within some larger localities in-between-flight lines have also been photographed, in order to achieve better view in densely built-up areas with high buildings.

GEOMETRIC RESOLUTION

Flight altitude and the type of camera used in the photography determines the geometric resolution of the images, see table 1.

RADIOMETRIC RESOLUTION

The digital DMC-camera (Digital Mapping Camera), with 12 bits colour depth, was introduced in 2005 and used until 2013. A new type of digital camera, UCE (UltraCam Eagle) with 14 bits colour depth, was then introduced 2013. During 2014 a camera of the type UCXp wa, with 14 bits colour depth, was also used. From 2019 a camera of the type UCE Mark 3, with 14 bits colour depth, is being used.

In the production of aerial photographs in 4 channels, colour and IR the panchromatic band is used in a so-called pan-sharpening, which means that the

four colour bands red, green, blue and near-infrared are used to colour the more high-resolution pan-chromatic image.

The digital aerial photographs in the national image provision programme have from 2019 a resolution of 0,15 m and 0,37 m, respectively, in the pan-chromatic band. Until 2018 the resolution was 0,24 m and 0,48 m, respectively, in the pan-chromatic band.

The resolutions of the single colour bands in relation to the pan-chromatic band are however significantly lower; in the DMC images the relation is 1:4,8 and in the UCE-, UCXp wa-, and UCE Mark 3-images the ratio is 1:3, see the effects of these differences in the examples below.

Figure 2. Aerial photograph DMC 0,24 m (left) Aerial photograph UCE 0,24 m (right).

Table 3. Presentation of the different digital aerial photographs.

Photography year	Camera	Flight altitude (m)	Pixel size (m)	Spectra
2005–2013	DMC	4 800	0,48	Colour and IR (8 bits)
2006–2013	DMC	2 500	0,24	Colour and IR (8 bits)
2013–2018	UCE	3 700 / 7 400	0,24 / 0,48	Colour and IR (8 bits)
2014	UCXp wa	2 800 / 5 600	0,24 / 0,48	Colour and IR (8 bits)
2019 -	UCE Mark 3	3 000 / 7 400	0,15 / 0,37 m	4 channels, colour and IR (8 bits)

2.3 Maintenance

2.3.1 MAINTENANCE FREQUENCY

The ambition is to each year photograph approximately 30 % of the country; frequently and with higher resolution (0,15 m) in more densely built-up areas in the south of Sweden and along the coast of Norrland (every other year), but less frequently and with lower resolution (0,37 m) in Norrland's interior and in the mountain regions (every 4:th and every 6:th-10:th year respectively).

The southern part of the country and areas along the coast of Norrland is photographed alternately before leafing and after. The remaining 11 localities within the low altitude programme, that are situated outside the 0,15 m coverage area, are photographed with an interval of two to four years, depending on usage and demand.

The entire country is photographed according to a long-term aerial photography plan. The annual aerial photography plan can however not always be completely carried out, due to for example poor weather conditions in the mountain areas.

Overview of available orthophotos and an up-to-date aerial photography plan is also presented in the service GeoLex.

2.4 Data quality

2.4.1 POSITIONAL ACCURACY

The positional accuracy is mainly affected by the coordinates of the exposure point and the rotation angle of the image. In table 4 below the expected horizontal and vertical standard errors (RMSE) for distinct objects after block triangulation are presented.

Table 4. Presentation of expected horizontal and vertical standard errors (RMSE) for distinct objects after block triangulation, for different resolutions.

Resolution (m/pixel)	Horizontal standard error (m)	Vertical standard error (m)
0,24	< 0,25	< 0,35
0,48	< 0,6	< 0,8
0,15	< 0,20	< 0,25
0,37	< 0,5	< 0,7

2.5 Metadata

The file name of every aerial photograph contains information regarding camera, resolution, time of photography, flight line number, image number etc. Every camera registration and image are marked with a unique identity (BildId), structured according to the following principles:

Normal altitude programme:

- ååohh_s~åååå-mm-dd_ttmmss_nr (2005-2006)
- ååohhffcc_s~åååå-mm-dd_ttmmss_nr (2007-2010)
- ååoiuuffcc_s~åååå-mm-dd_ttmmss_nr (2011-)
  2011-2013: i=2, 4 or 6. 2014-: i=4 or 6.

Low altitude programme:

- åållkkhh_s~åååå-mm-dd_ttmmss_nr (2005-2006)
- åållkkhhffcc_s~åååå-mm-dd_ttmmss_nr (2007-2010)
- åållkkuuffcc_s~åååå-mm-dd_ttmmss_nr (2011-)
  There also exist three special cases where kk=00: Skane 2012, Halland 2013 and Kronoberg 2013
- ååoiuuffcc_s~åååå-mm-dd_ttmmss_nr (2014-, where i=2)

Tabell 5. The meaning of the different letter combinations in the file name.

Letter combination	Meaning
åå	Last two digits of the flight year.
o	Area designation.
i	Aerial photography interval zone.
uu	Resolution of the aerial photo in the horizontal plane in cm.
ff	The last two letters of the airplanes registration mark (for example ss).
cc	Camera number (the two last digits of the serial number).
s(s)	Flight line number. May consist of 1 or 2 digits.
llkk	County and municipality code.
åå-mm-dd	Actual date of photography.
ttmmss	Time in hours, minutes and seconds (GPS-time).

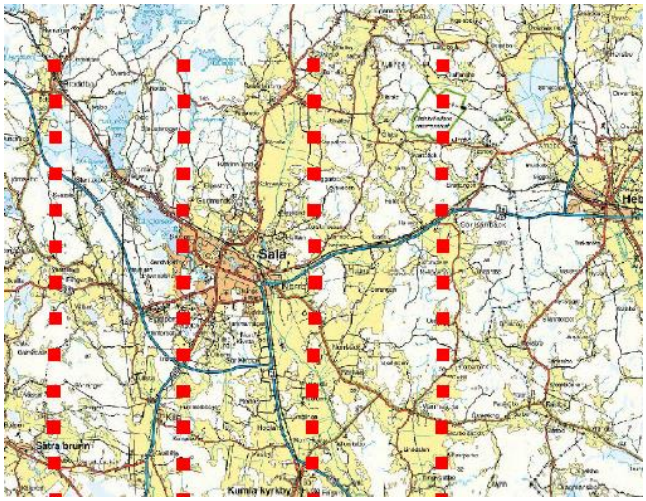
Letter combination	Meaning
nr	Image number in the flight line, may consist of up to 4 digits.
hh	Planned flight altitude (altitude over average ground level in hundreds of metres).

Image exposure position files in shape format can also be downloaded, containing the time of photography for every aerial photograph.

Figure 3. Example of contents in every exposure position.

Shape	Point
Bild_id	10g48zx08_15~2010-06-22_064929_74
Projekt	10g48
Omr_bet	10G48
Str	15
Bild_nr	74
X	6651364
Y	1547614
Hojd	4800
N	6650187
E	592527
Otis	62
Otms	24
Skuggl	1.5
Belys	
Betyg	
Kamera	Z/I DMC01-0008
Kamerak	120
Bildtyp	psc
Leverant	Lantmäteriet
Datum	20100622
Tid	08:49:29
Pixelst	12
Pixel_mark	0.48
Utbredning	6.6x3.7
Filnamn	10g48zx08_15~2010-06-22_064929_74_psc
Anm	
Flygr	359
Flygarcy	2010

Figure 4.Example from GeoLex with map overview containing the aerial exposure positions.



Detailed information about every aerial photography, for instance time of photography, is also presented in our web service GeoLex.

3 Contents of the delivery

3.1 Folder structure at delivery

An example of a delivery of digital aerial photographs can be seen here below.

Figure 5.Example of contents in a delivery.

3.2 Delivery format

Digital aerial photographs are delivered in JPEG or uncompressed TIFF-format. Aerial photographs in 4-channels can however only be delivered in uncompressed TIFF-format.

Orientation data is delivered in PatB-format (.ori-file) and as a project file for Match-AT (.prj-file). You can instead of these files obtain refined orientation data for the ESPA-system or for the Summit-project, or ready-to-use model files for these.

3.3 File sets

The folder *images* contains digital aerial photographs in JPEG or uncompressed TIFF-format.

The orientation file (ori-file) contains image number, camera position and camera orientation (rotation matrix). The project file for Match-AT (.prj-file) also contains, apart from orientation, camera settings and inner orientation for the images. Several systems support import of the formats. In appendix 1 there is a more detailed description of an ori-file.

In the delivery the files above can, if preferred, be replaced with refined orientation data for the ESPA-system or for the Summit-project, or ready-to-use model files for these.

An additional ori-file (_180.ori), which is rotated 180 degrees compared to the flight direction, is also included in the delivery.

Included in the delivery are also a text document (.doc) with information regarding the delivery, together with an additional overview document (.pdf), containing a map with the image exposure position in order to find the location more easily.

Calibration protocols for each of the cameras (in Swedish).

Appendix 1: Description of an ori-file

The orientation information in an ori-file consists of three rows for each image:

image nr	**Camera constant**	**E_{PC}**	**N_{PC}**	**H_{PC}**
k_1	**k_2**	**k_3**	**k_4**	**k_5**
k_6	**k_7**	**k_8**	**k_9**	

Example:

1705	120.00000000	567498.92018	6240003.14745	5036.79739
0.003487293108	0.999993910667	0.000131970599	0.999987383107	0.003486793127
0.003616061336	0.003615579163	0.000144579200	0.999993453321	

Description of the information:

Row 1: **image nr** is a unique image number within the actual block.

Camera constant, presented in mm.

E_{PC}, **N_{PC}**, **H_{PC}** is a position indication for the projection centre (PC) of the image, in the current plane coordination system, for instance SWEREF 99 TM, and the current height coordination system, for instance RH2000, presented in metres.

Since the geodetical plane and height system does not represent a right-angled three-dimensional system and the horizontal coordinates contain the errors of the map projection, the position information is adjusted in order to achieve the best adaptation on the ground. The value HPC is therefore adjusted for the scale factor of the map projection, which mainly depends on the distance from the central meridian.

Rad 2 och 3: coefficients in a 3x3 rotation matrix **R**, which describes the rotation from **image to ground**

$$\mathbf{R} = \begin{pmatrix} k_1 & k_2 & k_3 \\ k_4 & k_5 & k_6 \\ k_7 & k_8 & k_9 \end{pmatrix}$$

With the assumption that the geodetical plane and height system locally can be approximated with a right-angled three-dimensional system, the equation for the relation between the image coordinates for a certain point (**x**', **y**') and the coordinates for the ground (**E**, **N**, **H**) can be written as follows:

$$\begin{pmatrix} \mathbf{E} \\ \mathbf{N} \\ \mathbf{H} \end{pmatrix} = \begin{pmatrix} \mathbf{E}_{\mathrm{PC}} \\ \mathbf{N}_{\mathrm{PC}} \\ \mathbf{H}_{\mathrm{PC}} \end{pmatrix} + \mathbf{mR} \begin{pmatrix} \mathbf{x}' \\ \mathbf{y}' \\ -\mathbf{c} \end{pmatrix}$$

where **m** is the scale factor for the image in the current point.

Rotation angles (in radians) can be derived from the coefficients for the rotation matrix, as follows:

omega = – arctan (k_8 / k_9)

fi = arcsin (k_7)

kappa = – arctan (k_4 / k_1) + pi

The rotation angles are defined in a right-angled three-axis coordination system, with origo in the projection centre (PC) and the axes parallel with the geodetic system.

omega represents rotation around the E-axis of the coordinate system.

fi represents rotation around the N-axis of the coordinate system.

kappa represents rotation around the H-axis of the coordinate system.

The rotation direction is defined as clockwise positive in positive axis direction.

The rotation order is defined as: omega primary, fi secondary and kappa tertiary.

The ori-file is normally the result of a block triangulation, where the equalisation calculation is carried out with the following settings:

- correction for the rounding of the earth is applied.
- correction for atmosphere refraction is applied.