



CATALYST  
**PROFESSIONAL**

## Aerial Bundle: Description

**CATALYST Professional Aerial** bundle comes with everything geospatial professionals need to process and analyze Earth imagery captured from any aerial platform. The Aerial bundle is our advanced solution for geospatial professionals to access powerful processing, visualizations, and analytical capabilities to prototype, build and automate workflows for optical aerial imagery from digital, analog, and ADS pushbroom sensors.

With CATALYST Professional Aerial bundle, you get more for less:

- High-performance viewer that supports all major sensors and file types
- Advanced photogrammetry and mosaicking workflows for aerial imagery
- Visualization tools to enhance viewing and data extraction
- Object-based Image Analysis
- Intuitive wizards to accelerate prototyping and interactive workflows
- Access to hundreds of algorithms through python to build and productize automated workflows
- Plus, full customer support

**CATALYST is a PCI Geomatics Enterprises Inc. brand**, which has been introduced to put our leading-edge technology into the hands of decision makers. CATALYST provides proven algorithms rooted in photogrammetry and remote sensing to offer engineers, environmental management, and geospatial professionals access to leading edge and scalable software solutions and platforms.

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## Introduction

The Aerial Bundle of CATALYST Professional includes all the capabilities found in the Essential bundle, including state-of-the-art tools for geometric correction, data visualization and editing, image classification, cartographic map production plus a whole lot more, including applications for raster spatial analysis, radar analysis, hyperspectral analysis, along with a comprehensive desktop automation environment.

The additional tools provided in the Aerial bundle include both rigorous models used to correct the geometry of analogue and digital cameras and to produce orthorectified air photos. These models compensate for the effects of varying terrain and for the distortions inherent to a camera, such as the curvature of the lens, focal length, perspective effects, and the camera's position and orientation. The computed math model calculates the camera's position and orientation when an image is taken.

## Supported Air Photo Formats

CATALYST Professional supports the following aerial image formats in the Aerial Bundle, which is a combination of the Air Photo Ortho Suite (Standard and Digital/Video) and ADS Ortho Suite (ADS):

### Standard

These are images scanned from film or prints. These images often measure 9 inches by 9 inches in size and usually contain calibration (fiducial) marks. Normally, a camera calibration report is supplied with the images. The camera calibration report provides data about the camera; such as the focal length, fiducial coordinates and radial distortion parameters.

### Digital/Video

These are images generated from CCD arrays (Charged Coupled Devices) in digital cameras. A camera calibration report may not be supplied with the images. Most companies that provide calibration services for standard aerial cameras can provide camera calibration services for digital and video cameras. The minimum required parameters are focal length (determined when the lens is set) and chip size (which can be obtained from the camera manufacturer). Oblique imagery is not supported.

### Leica Airborne Digital Sensor (ADS)

The Leica airborne digital sensor (ADS) is a line-scanning sensor that collects images in long strips up to 24,000 pixels wide. This camera can simultaneously collect panchromatic, color, infrared and stereo imagery. All multispectral bands are collected simultaneously providing five-band, co-registered imagery at a common, high resolution.

## Camera calibration

Camera calibration information is essential in the orthorectification of air photos. The camera calibration information includes essential camera parameters, distortions and fiducial mark measurements.

### Calibration Information Entry

The calibration panel has two modes:

- Focal length (FL) and principal point offset (PPO)
- Focal length (FL), principal point of autocollimation (PPA) and principal point of symmetry (PPS)

The following calibration information can be entered:

- Focal length
- Principal point offset or Principal point of symmetry / Principal point of autocollimation
- Radial lens distortion
- Decentering distortion
- Fiducial marks from calibration report
  - Entered as Edge or Corner or Edge and corner positions
- Photo scale
- Select whether or not to apply atmospheric refraction correction
- Select whether or not to apply earth curvature correction
  - Earth radius
- Chip size and y-scale factor (digital/video image projects)
- Apply self-calibration (analog projects only)
  - Deviation limits required for focal length and principal point offset

The camera calibration information can also be exported, using the Tools->Export->Camera Calibration Parameters to XML menu item. If the user has an existing XML file, they can easily import that in the Calibration panel.

### Fiducial Mark Collection

- Interactively selects fiducials from scanned images
- Links camera calibration fiducials with selected fiducials

## Ground Control

The OrthoEngine air photo models support imported GPS/INS data and existing triangulation solutions, as well as GCP and tie-point ground control.

### Import GPS/IMU Data

Using the onboard Global Positioning System (GPS) and Inertial Measurement Unit (IMU) you can:

- Skip GCP and tie-point collection
- Import from any sensor system that uses omega, phi, and kappa
- Use GPS/IMU only, or supplement with ground control points, tie points, or both
- Perform kappa rotations
- Manually edit GPS and IMU data

### Import Existing Triangulation Solutions

Using existing triangulation solutions, you can:

- Skip GCP and tie-point collection
- Manually edit existing triangulation solutions

### GCP Collection

GCPs can be collected manually, or automatically by using:

- A geocoded image
- Geocoded vectors
- A chip database
- An imported text file

Other features include:

- Stereo (and multi-way) GCP collection
- Conversion of GCPs to check points to exclude them from model calculation
- Display of individual and overall RMS error for GCPs

### Tie Point Collection

- Extends ground control over areas without GCPs
- Identifies how images in a project relate to each other
- Ensures the best fit for all the images in the project
- Imports and exports tie point locations
- Allows entry of tie point elevations manually or extracts them from a DEM automatically
- Show individual and overall RMS errors

## Bundle Adjustment

Using the option for bundle adjustment settings, found in the Tools menu within OrthoEngine, you can adjust the methodology used during the model calculation. The following modes are available:

- Traditional block bundle
- Enforced fitting

- Relative-absolute orientation
- Relative orientation
- Absolute orientation
- Free network adjustment

## Residual Report

Using residual reports, you can:

- Show GCP, check-point, tie-point, GPS/IMU and stereo (and multi-way) GCP error information in one report
- Edit points and update bundle adjustments
- View in ground units, photo pixels, or photo microns
- Print the report to a file

## Project Summary Information

### Raw Image Summary Table

A summary of information about all of the images in your OrthoEngine project can be viewed in the Raw Image Summary Table window. This window provides information about the following:

- Total number of images in the project
- Total number of ground control points (GCPs), tie points (TPs), and check points (CPs)
- Image-specific information, including image ID, GCPs, TPs, CPs, root mean square (RMS) error, number of overlapping pairs connected by TPs, number of potential overlapping pairs that could be connected by TPs, and the percentage of all overlaps connected by TPs

The Raw Image Summary Table provides you with a dynamic view of your project, allowing you to better target your quality assurance efforts to achieve your desired project requirements.

Image-specific information is displayed in tabular format. The tabular contents can be sorted, making it easier for you to analyze the data in your project and identify areas on which to focus your quality assurance activities.

The Raw Image Summary Table window displays both active and inactive images in your project. You can activate and deactivate one or more of the images in your project using the check box column. An active image is included in any processing you want to do on your project. When you deactivate an image, it is still in your project, but is excluded from processing. You can also activate and deactivate images in the Project Overview window.

### Project Overview

The Project Overview window provides a graphical display of the raw images in your project, while the Raw Image Summary Table lists all pertinent information in table format. You can use both windows together to gather relevant information about each image in your project, allowing you to better target your quality control efforts and manage your project.

By default, the Project Overview window displays centers of each raw image in project. You can choose to display image centers, geocoded vector footprints, and/or thumbnails of the imagery. You can also toggle the display of ground control points, tie points, and check points, as well as Image and Point IDs, for all images or for selected images only.

Note: When the Raw Image Summary Table is open, the Project Overview window displays the current image with a yellow border and its image ID.

This viewer helps users to better assess their project using a graphical overview. It also includes some simple tools to assist in project management like:

- Ability to display reference imagery or vectors
- Rotating the kappa of the input imagery
- Measurement tools

## Orthorectification

- Can run as a batch process
- Utilizes a DEM for terrain correction
- Can increase the size of the working cache for faster processing
- Can increase the sampling interval for faster processing
- Offers the following resampling methods:
  - Nearest Neighbor
  - Bilinear Interpolation
  - Cubic Convolution
  - 8-pt Sin X/X
  - 16-pt Sin X/X
  - Average filter
  - Median filter
  - Gaussian filter
  - User-defined filter
- Clips the image size upon orthorectification
- Can use a scheduled start time
- Provides approximately one-third of a pixel accuracy for VIR satellite images, and approximately one pixel for radar images when quality ground-control coordinates are used

## Mosaicking

When you initiate mosaicking OrthoEngine opens the Mosaic Tool application, in which you can perform all of the tasks necessary to create the mosaic.

If the images in your project are orthorectified, the Mosaic Tool New Project Wizard appears, and the images appear in the Source file box on the Source Images page of the wizard; otherwise, a message appears, prompting you to create the orthorectified images.



## Mosaic Tool

Mosaic Tool features a wizard to make creating your mosaic project quick and easy. The wizard walks you through the following steps to ensure you have everything set up to create your mosaic:

- Source files to use
- Key details, such as size and extents
- Applying color balancing, normalization, or both to the input images
- Selecting how to create cutlines and mask layers
- Previewing the mosaic

## Other

When working with an airphoto project in OrthoEngine, users also have the ability to import or export their project for use with the following third-party software packages:

- BINGO
- DAT/EM
- PATB
- Supresoft

You can import and export:

- Camera-calibration information, such as a distortion grid
- An exterior orientation (EO) file (x, y, and z coordinates of image centers and orientation angles of the photo: omega, phi, kappa)
- Corrected point coordinates and errors (standard deviations)

You can use either of the following recommended workflows:

Start a project in BINGO, DAT/EM, or PATB as applicable. After completing point collection and error refinement, import the project into OrthoEngine. You can then perform orthorectification and mosaicking on the project, as necessary.

Start a project in OrthoEngine. After collecting your tie points (TP) and stereo ground control points (GCP), export to BINGO, DAT/EM, PATB. or Supresoft, as applicable.

## DEM Extraction

Automatic DEM Extraction is included with the Airphoto bundle. It can be used with all digital and video frame images, as well as with all scanned, standard air photos.

### DEM Extraction Methods

Users can choose from one of two methods for extracting their digital elevation model (DEM).

Normalized cross-correlation (NCC)

Semi-global matching (SGM)

### NCC

Matching points in a left and right input image are found using image correlation. The image disparity for the point pair is computed and this value, combined with the geometric model for each image, is used to compute the scene elevation for the corresponding scene point.

The image correlation is performed on an image pyramid that is constructed for each of the input images. The base level of an image pyramid is the original image, the next highest level is the original image resampled to a coarser spatial resolution, the level after that is the previous level resampled to a coarser spatial resolution, and so on. The location in one image that matches the current point in the other is first found at the coarsest resolution level for both images. This location is then used as the starting point for finding the match at the second coarsest resolution, and so on until the match is found in the original images.

This multi-resolution approach to image matching is faster than searching for matches in only the full-resolution images, and results in fewer false matches.

### SGM

The implementation of SGM is done by image-matching along epipolar lines using the SGM method first proposed by Hirschmuller in 2005. The SGM algorithm produces excellent detail and few blunders, or *errors*, even at full resolution. However, the basic algorithm does have some drawbacks, such as higher computation time, very high memory consumption, and sensitivity to variations in local lighting conditions. With each implementation of the SGM algorithm, various approaches have been taken to work around these difficulties with varying degrees of success.

Our implementation of the SGM algorithm was developed in-house. It is proprietary and full details are not available. Our implementation uses a tiled approach based on pyramid resolutions with multiple cost functions (including mutual information) to achieve stability over varying local lighting conditions while retaining the highest possible detail. The algorithm self-adjusts to compensate for small errors in the epipolar line. Innovative memory-management techniques limit RAM usage to 2 GB or less, even if the disparity in the images is thousands of pixels (which can occur in some satellite scenes of mountain ranges).

### Epipolar Pairs

Epipolar pairs increase the correlation process speed and reduce the possibility of incorrect matches. Stereo pairs are reprojected, ensuring that the left and right images have a common orientation, and matching features between the images appear along a common x-axis.

Using epipolar pairs, you can:

Choose from the following pairs:

- User Select – selects a pair manually
- Maximum Overlapping Pairs – selects the pair with the highest amount of overlap
- Minimum Percentage Overlap – specifies the lowest percentage of acceptable overlap
- All Overlapping Pairs – selects all pairs that overlap above a minimum percentage

- Limit the amount of memory used to generate epipolar pairs
- Define a Down-sample factor to reduce an epipolar image resolution
- Define a Down-sample filter
- Set up epipolar-pair start times

### DEM Extraction

Using DEM extraction, you can:

- Specify the minimum and maximum elevation to estimate a search-area correlation
- Specify a failure value to represent any failed (uncorrelated) pixel values in the resulting DEM
- Specify a background value to represent any 'no-data' pixel values
- Set the DEM detail to high, medium, or low for the needed level of detail
- Select an output DEM channel type to 16-bit signed or 32-bit real
- Specify a pixel sampling interval for the number of image pixels and lines used to extract one DEM pixel
- Use a clip region to process a specific area only
- Fill holes and filter interpolated failed values and filter elevation values automatically
- Create a score channel to represent the correlation score for each DEM pixel
- Delete an epipolar pair after use
- Create a Geocoded DEM by using geocoding stored in the project
- Set up DEM extraction start times

### DEM Editing

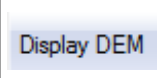


The DEMs may contain pixels with failed or incorrect values. You can edit a DEM to smooth out irregularities and create a more accurate model, and in turn, generate more accurate orthorectified images. For example, areas such as lakes often contain misleading elevation values; setting those areas to a constant value improves the model that will produce a more accurate representation of the lake in the ortho image.







Using the Focus DEM Editing window requires only a DEM; that is, a raster channel in a writable format. To fully use all the functionality available in the DEM Editing window, however, and to produce the best possible DEM, the DEM file should contain additional information. In particular, if the DEM file was extracted from epipolar images, you can make use of that imagery to help with your editing.

DEM files created using our technology contain extra information that facilitates DEM editing, including a cutline vector segment and file-level metadata.

The main toolbar on the DEM Editing window provides quick access to several functions that facilitate working with the DEM.

The following table describes the buttons on the DEM Editing toolbar:

Button	Label	Description
	Display DEM	Toggles the display of the digital elevation model layer in the Focus viewer.
	DEM Display Options	<p>Allows you to set display options for the DEM layer. Choose from:</p> <p><i>Grayscale Shaded Relief</i>: displays the DEM using grayscale hill-shading, where a top-left light source and the elevation values are used to cast shadows.</p> <p><i>Color Shaded Relief</i>: displays the DEM using colored hill-shading, where a top-left light source and the elevation values are used to cast shadows.</p> <p><i>Dynamic Color Shade Relief</i>: displays the DEM using colored hill-shading, where a top-left light source and the elevation values are used to cast shadows. This option, the default setting, automatically re-renders the color display of the DEM as you pan or zoom across the viewer so that only the pixels currently being viewed are the basis of the colorization.</p> <p>Typically, editing is most effective when the DEM is displayed as a <i>Dynamic Color Shaded Relief</i>.</p>
	Enhancements	<p>Allows you to apply enhancements to the images automatically loaded in the Focus viewer.</p> <p>Available enhancements are:</p> <ul style="list-style-type: none"> <li>None</li> <li>Linear</li> <li>Root</li> <li>Adaptive</li> <li>Equalize</li> <li>Infrequency</li> <li>Tail Trim (toggle)</li> <li>Exclude Min/Max (toggle)</li> <li>Set Trim %</li> </ul> <p>Select the Auto Re-enhance option so that, as you pan across the data, the view is automatically refreshed in the Focus viewer to apply the selected enhancement.</p>

Button	Label	Description
	View DEM Polygons	Toggles the visibility of existing DEM polygons. If a Status layer exists, this option also displays polygons from that layer.
	Set View As Verified	Creates a status polygon using the full extents of the current display area and sets its status to <i>Verified</i> .
	Define Preview Region	Allows you to specify a rectangular region to be displayed in a separate viewer. After you define the preview region, the Full Res. Ortho Preview window opens, displaying a preview of the full-resolution ortho image computed using the modified DEM.
	Open FLY!	Launches CATALYST Professional's FLY! application. FLY! uses the modified DEM and ortho imagery (when available) to allow interactive 3-D display. The FLY! view is centered on the current view, but is restricted to 4096 DEM pixels in x and y.
	Save	Saves the modified DEM and all other associated layers.
	Undo/Redo	Allows you to undo or redo previous actions.

## Historical Aerial Processing (HAP)

Historical aerial photography archives can contain valuable information that remains largely untapped by many organizations. Aerial imagery that is scanned digitally and georeferenced properly makes it possible to analyze and visualize historical information in a modern geographic information system (GIS).

To help you unlock the information hidden in your aerial photography, CATALYST Professional includes Historical Airphoto Processing (HAP), a customized software program that automates the correction of historical imagery. With HAP, you can properly prepare historical data and set up workflows to create mosaics that are aligned and orthorectified perfectly for use in a GIS.

## HAP Features and benefits

Historical Airphoto Processing can reduce labor intensity and increase productivity with program features and benefits that include:

- Automated collection of fiducial marks
- Automated collection of ground control points (GCP) and tie points (TP)
- Large-volume block-bundle adjustment
- Automated mosaicking and color balancing
- Quality assurance tools to assist with inspecting color balancing and quality of GCPs, TPs, and seam lines

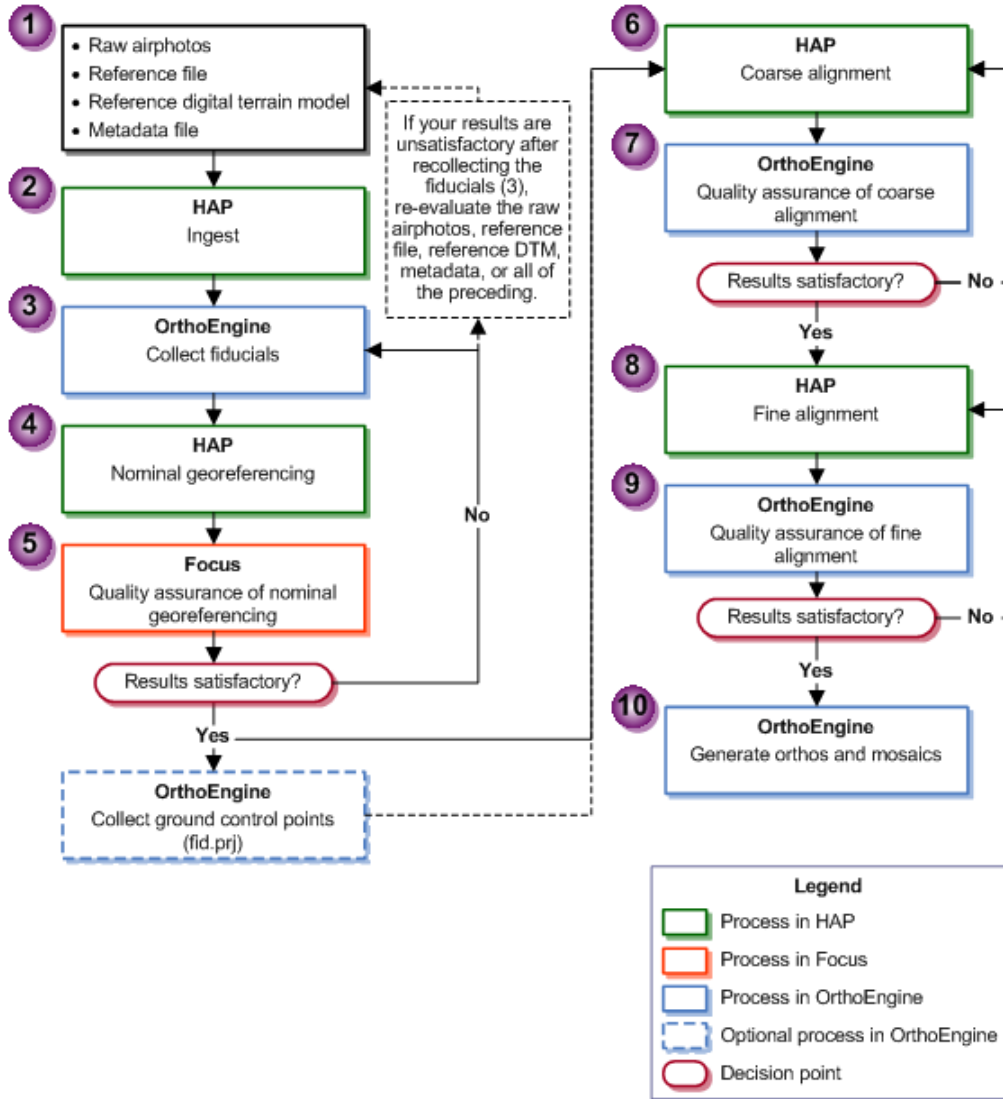
## Areas of function

There are three main areas of function in Historical Airphoto Processing:

- *Ingestion*: Converting your imagery to a format compatible with Historical Airphoto Processing
- *Nominal georeferencing*: Scaling, rotating, translating, or deskewing, or any combination thereof to match the image to a particular size and position
- *Alignment*: Refining the positioning of the imagery by using an iterative process to collect GCPs and TPs

## Workflow

The following figure shows the basic workflow of processing airphoto images with CATALYST Professional Historical Airphoto Processing, OrthoEngine, and Focus.



## Object Analyst

CATALYST Professional provides Object Analyst tools for segmentation, classification, and feature extraction. Object Analyst includes an all-in-one interface within CATALYST Professional's Focus application that is designed to guide you through segmenting your imagery, extracting features, creating training sites, classification (including creating custom rules for classification), reforming shapes, and performing an accuracy assessment.

Researchers have more recently considered that a pixel is not a true geographical object, and it is not the optimal spatial unit for mapping a landscape. Moreover, the traditional pixel-based image-analysis algorithms showed their inability to cope with high-resolution imagery; that is, imagery with resolution typically finer than 5 meters per pixel. These factors have



contributed to the shifting of the model to and the wider use of object-based image analysis (OBIA).

OBIA does not analyze a single pixel, but rather a homogeneous group of pixels — image objects. An object, contrary to a pixel, provides richer information, including spectrum, texture, shape, spatial relationships, and ancillary spatial data. In turn, spatial context can be exploited to emulate a human analyst, who intuitively identifies various objects in an image, rather than individual pixels, by considering various properties, such as size, texture, shape, and the spatial arrangements of these objects to understand the semantics.

The fundamental objective of OBIA, therefore, is to use segmentation to reduce complexity of image data, and to use the extracted image objects and their corresponding attributes (features) to develop strategies for thematic classification. With OBIA, images are segmented to make image objects from various groups of pixels to represent meaningful objects in the scene. Ontologically, this provides more accurate and reliable identification and extraction of real-world features and at more appropriate scales. Moreover, it provides the opportunity to divide map data into homogenous objects of various spatial scales.

## Workflow

A simple process flow for object-based image analysis (OBIA) is shown in Figure 1. After preprocessing, a typical OBIA analysis starts with segmenting an image into primitive objects. You then further group the objects together into classes of interest by exploiting their spectral properties, shape measures, context, and so forth.



**Figure: Workflow of object-based classification**

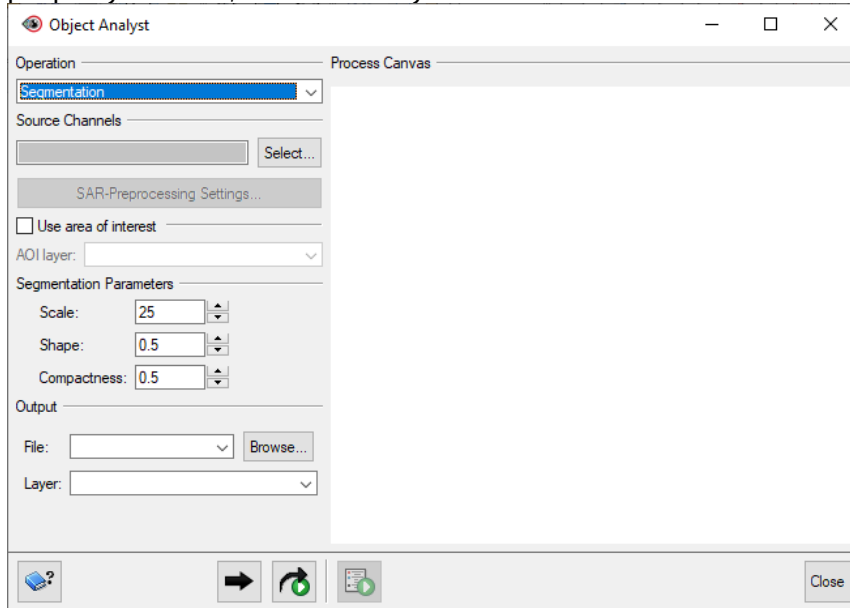
The preprocessing steps involve operations such as orthorectification, radiometric enhancement, removing shadow, detecting outliers, or creating a new layer(s) such as vegetation indices, texture channels and so forth, so that the data is suitable for image segmentation and feature extraction before classification.

Image segmentation is the first step in OBIA. The objective is to partition an image into statistically homogenous regions or objects (segments) that are more uniform within themselves and differ from their adjacent neighbors. Each segment is characterized by a variety of attributes (features), including spectral properties (band statistics of a segment), shape, texture, context, and so forth. The segments, however, do not have the thematic information at this stage and need classification to assign class (group) membership to each.



## Object Analyst in CATALYST Professional's Focus Application

Object Analyst can be accessed through the **Analysis** menu. The interface includes a Process Canvas, which guides users through process steps that can be run separately or once properly defined, automatically.



**Figure 2: Object Analyst's Process Canvas interface**

The process steps are listed here and described below:

- Segmentation
- Attribute Calculation
- Training Site Editing
- Classification
- Rule-based Classification
- Post-classification Editing
- Accuracy Assessment
- Batch Classification

### Segmentation

Segmentation is the process of extracting discrete regions of image objects. This is achieved by stratification of an image. These image-objects are used further as the basic unit of analysis for developing image-analysis strategies, including classification and change detection.

The underlying segmentation algorithm in Object Analyst is a hierarchical step-wise region grown by using random "seeds" spread over the entire image. This method can be classified as a "bottom-up" optimization routine that starts with a pixel and ends with segments that

are groups of like pixels. The criteria that define the growth of a region can be based on the difference between the pixel intensity and the mean of the region. The algorithm assesses the local homogeneity based on the spectral and spatial characteristics. The size of the object is controlled with the value for scale, which you specify. The larger the scale, the larger will be the output object. Other homogeneity criteria are based on shape and compactness.

The result of the segmentation process is as follows:

- An initial abstraction of the original data
- Creation of a vector (polygon) representation of the image objects

The results of segmentation can be exported as a vector data set and viewed in third-party software.

### Constraining segmentation to an area of interest

If necessary, you can constrain segmentation to a specific area of interest (AOI). You do so by selecting a vector file in PCIDSK format you have created that contains only polygons of the AOI you want.

### Attribute Calculation

In Object Analyst an attribute represents some information about an image object. Various characteristics of image objects are referred to as attributes of a segment.

You can compute the following types of attributes:

1. Statistical - Statistical attributes are computed based on the image pixels under an object (polygon). Attributes are computed for each of the selected image bands and added to the attribute table of the vector segment layer as new fields. The following attributes can be collected:
  - Minimum value of the pixels beneath an object in a selected band.
  - Maximum value of the pixels beneath an object in a selected band.
  - Mean value of the pixels beneath an object in a selected band.
  - Standard deviation value of the pixels beneath an object in a selected band.
2. Geometric attributes - Geometric attributes are computed by analyzing the polygon boundary created during segmentation, so raster information is not required. Object Analyst computes many commonly used shape descriptors such as:
  - Compactness - A measure to indicate how closely packed a shape is. A circle is the most compact.  

$$\text{Compactness} = \text{Sqrt}(4 * A_s / \pi) / O$$
 where  $A_s$  is the area of the object, and  $O$  is the perimeter of the object (outer contour).
  - Elongation - The ratio of the height and width of a rotated minimal bounding box. In other words, rotate a rectangle so that it is the smallest rectangle in which the object fits, and then compare its height to its width.  

$$\text{Elongation} = \text{Major Axis Length} / \text{Minor Axis Length}$$

- Circularity - The circularity ratio represents how like the object's shape is to a circle. Circularity is the ratio of the area of a shape to the perimeter of the shape's square.  
 $C = A_s / O^2$ , where  $A_s$  is the area of the shape, and  $O^2$  is square of the shape's perimeter.
  - Rectangularity - How rectangular a shape is; that is, how much it fills its minimum bounding rectangle.  
 $R = A_s / A_R$ , Where  $A_s$  is the area of a shape, and  $A_R$  is the area of the minimum bounding rectangle.
  - Convexity - The relative amount that an object differs from a convex object. Convexity is calculated by forming the ratio of the perimeter of the convex hull of an object to the perimeter of the object itself.  
 $Convexity = convex-hull\ perimeter \div object\ perimeter$
  - Solidity - The density of an object. Solidity is calculated as the ratio of the area of an object to the area of a convex hull of the object. A value of 1 indicates a solid object, and a value less than 1 indicates an object having an irregular boundary or containing holes.  
 $Solidity = area \div convex-hull\ area$
  - Form Factor - The measure that compares the area of a polygon to the square of the perimeter. The form-factor value of a circle is 1, and the value of a square is  $\pi \div 4$ .  
 $Form\ factor = 4 \div \pi \div area \div \sqrt{perimeter}$
  - Major-axis length - The length of the major axis of an oriented bounding box enclosing the polygon.  
 Values are map units of the pixel size. If the image is not georeferenced, the values are pixels.
  - Minor-axis length - The length of the minor axis of an oriented bounding box enclosing the polygon.  
 Values are map units of the pixel size. If the image is not georeferenced, the values are pixels.
3. Vegetation Indices attributes - You can select from several Vegetation Indices (VI) to perform quantitative and qualitative evaluations of vegetation cover, vigor, growth dynamics, and more.

The following table provides descriptions of each Vegetation Index that can be calculated:

Attribute	Short name	Description
Green/Red Vegetation Index	GRVI	$GRVI = (Green - Red) \div (Green + Red)$

Attribute	Short name	Description
Greenness Index	GI	$GI = ((2.0 \times Green) - (Red + Blue)) \div ((2.0 \times Green) + Red + Blue)$
Vegetation Difference Index	VDI	$VDI = NIR - Red$
Ratio Vegetation Index	RVI	$RVI = NIR \div Red$
Normalized Difference Vegetation	NDVI	$NDVI = (NIR - Red) \div (NIR + Red)$
Transformed Difference Vegetation Index	TDVI	$TDVI = (NIR - Red) \div (NIR + Red) + .5$
Soil Adjusted Vegetation Index	SAVI	$SAVI = ((NIR - Red) \div (NIR + Red + L)) \times (1 + L)$ The L-value is based on the amount of green vegetative cover. L is a default of 0.5, which means, generally, areas of moderate green vegetative cover.
Modified Soil Adjusted Vegetation Index	MSAVI2	$MSAVI2 = (0.5) \times (2(NIR + 1) - \sqrt{((2 \times NIR + 1) - 8(NIR - Red))})$
Global Environmental Monitoring Index	GEMI	$GEMI = \eta \times (1 - 0.25 \times \eta) - ((Red - 0.125) \div (1 - Red))$ Where $\eta = (2 \times (NIR - Red) + 1.5 \times NIR + 0.5 \times Red) \div (NIR + Red + 0.5)$
Leaf Area Index	LAI	$LAI = (3.618 \times EVI) - 0.118$ Where EVI (Enhanced Vegetation Index) = $2.5 \times (NIR - Red) \div (1 + NIR + (6 \times Red) - (7.5 \times Blue))$

4. Texture attributes: Texture measures can be calculated for a specific direction or directional invariant for all pixels in an input image. The measures are based on second-order statistics calculated from the gray-level co-occurrence matrices.

Attribute	Description	Algorithm
Mean	Cooccurrence mean	$Mean\_i = \sum(i,j=0,N-1)(i * P(i,j))$ Average gray-level in the local window.
Standard deviation	Cooccurrence standard deviation	$Var\_i = \sum(i,j=0,N-1)(P(i,j) * (i - Mean\_i)^2)$ $Std. Deviation\_i = \sqrt{Var\_i}$ Gray-level standard deviation in the local window. High when there is a large gray-level standard deviation in the local region.
Entropy	Cooccurrence entropy	$\sum(i,j=0,N-1)(-P(i,j) * \log_2(P(i,j)))$ , assuming that $0 * \log_2(0) = 0$ . Entropy is high when the elements of GLCM have relatively equal values. It is low when the elements are close to either 0 or 1 (that is, when the image is uniform in the window).
Angular second moment	Cooccurrence angular second moment	$\sum(i,j=0,N-1)(P(i,j)^2)$ This is the opposite of Entropy. It is high when the GLCM has few entries of large magnitude, low when all entries are almost equal. This is a measure of local homogeneity.
Contrast	Cooccurrence contrast	$\sum(i,j=0,N-1)(P(i,j) * (i-j)^2)$ Contrast is the opposite of Homogeneity. It is a measure of the amount of local variation in the image. It is high when the local region has a high contrast in the scale of SPATIAL.

### Training Site Editing

Before you can perform a classification or an accuracy assessment, you must have ground-truth data. In remote sensing, ground truth refers to information collected on location. With ground-truth data, image data can be related to real features and materials on the ground. By collecting ground-truth data, remote-sensing data can be calibrated, which aids in the interpretation and analysis of what is being sensed.

With supervised classification, the ground-truth data acts as a training set, which is used by the learning algorithm to generate a classification model.

In Object Analyst, you collect training samples for both the supervised classification and accuracy assessment in the same window. Primarily, you will use on-screen interpretation in the viewer and select segments of various classes.

## Classification

Classification is systematic grouping of objects into sets or classes based on their similarities. The goal in Object Analyst is to group extracted image objects or segments into appropriate classes that a human analyst can identify intuitively.

This is achieved through object-based classification. Classification of a segment can be achieved either by labeling a segment as a selected class and assigning a color to it, or by adopting more advanced more advanced computational procedures.

With Object Analyst, you can perform either of two types of classification:

1. **Supervised** - Supervised classification is a process to find a model, or function, by analyzing the features of a data set of which the class memberships are known. This function is then used to predict the class memberships for target population. Essentially, supervised classification is a two-step approach.
  - The first step is to build a learning model to describe predetermined classes for a data set. The construction of the learning model is based on the analysis of data items or concepts for which class memberships are predetermined or known: data items known collectively as training samples.
  - In the second step, the learned model is applied to new (target) data items to predict their class membership. The supervisory component of this procedure is in the training phase, which provides the classifier with a way to assess a dependency measure between features (attributes) and classes.

Users can select between Support Vector Machine (SVM) or Random Trees (Random Forest) algorithms for supervised classification.

Support Vector Machine (SVM) is a machine-learning methodology that is used for supervised classification of high-dimensional data. With SVM, the objective is to find the optimal separating hyperplane (decision surface, boundaries) by maximizing the margin between classes, which is achieved by analyzing the training samples located at the edge of the potential class.

Random Trees (Random Forest) is an ensemble learning method that has been implemented for image classification. It operates by constructing a multitude of decision trees during training and outputs the class selected by most trees.

2. **Unsupervised** - Object Analyst provides unsupervised classification based on the k-means clustering algorithm. Clustering algorithms search for generic data patterns among the feature [variable] spaces. No target variable is identified, as such. Clustering algorithms search for patterns among all the input features related to objects and group them into relatively homogeneous clusters.

The goal of clustering is normally descriptive and to discover new categories. Therefore, this strategy learns from observation rather than examples, and hence does not require a prior

hypothesis or training set. The core objective is finding the natural boundaries in feature space for the number of clusters you specify.

### Rule-based Classification

With Rule-based Classification, you can define a custom classification rule based on a specific property (feature), or properties, of a segment. You can define a rule to either assign a class to segments that meet the requirements of the rule or remove the segments from the class.

Object Analyst provides two methodologies for creating these rules or conditions:

1. Object Analyst Condition Builder window

In this window users can define a condition for rule-based classification. The condition can be based on up to two features (attributes). That is, you can construct a maximum of two conditions per rule. Both conditions can be based on a single attribute, or on two different attributes linked by a logical AND or OR operator.

For example, one could specify a two-part condition where i) classification occurs on an area attribute with a value of greater than 100800 and ii) less than 109800 for the same area attribute.

2. An alternative to creating a condition in the Object Analyst Condition Builder window is to use feature visualization. In the Feature Visualization window, you can dynamically select the vector objects (polygon segments) or update the existing selection in the vector layer based on a given feature (field) and its value range (filter).

You select the field you want, and then define the range. The polygon segments in that range are then selected in the viewer. Changing the range value reapplies the filter and update the selection set. You can immediately see the effects of the selected filter, and experiment to select the one most suitable.

### Post-classification Editing

As a post-classification step, users may need to merge two or more polygons or split one or more polygons. You can do so by using either of two methods:

- Reforming shapes by using automatic dissolve  
Automatic dissolve, merges two adjacent polygons based on class membership; that is, segments belonging to the same class and that are adjacent to each other are dissolved to create a bigger object. The internal boundaries of such segments are removed. The output will exclude all the attribute fields, except the field that contains the class-membership information. It is this field that is used to dissolve the segments.
- Reforming shapes by using interactive edits  
An alternative to reforming shapes with Automatic dissolve is to use Interactive edits. To do so, you must select a layer that contains one or more polygons with class information. Object Analyst provides you with some basic tools to select and edit the polygon data.
- Adding, modifying, and removing classes.



You can add, modify, and remove classes, as necessary. You can also assign objects to a class and change the style of how classes are displayed in the view pane.

### Accuracy Assessment

You can evaluate the overall accuracy of a supervised classification by running Accuracy Assessment. This operation compares a reference field, generated by an analyst using training sites editing tool, and a classification field, generated by running a classification.

The reference field and the classification field must be of the same segmentation file. When a segmentation file contains several reference and classification fields, it is a good practice to compare a classification with the reference field used to create it.

This process generates an assessment report that includes:

- Sample Listing – Report includes all assessed samples, described with georeferenced position, image coordinates, classified value/name, and reference value/name are displayed.
- Error (Confusion) Matrix – Matrix of all classes between reference data and classified data is displayed.
- Accuracy Statistics – Various accuracy statistics, such as overall accuracy, kappa coefficient, and their confidence intervals are displayed.

### Batch Classification

By running a batch classification, you can run classification simultaneously on a group or collection of images with similar qualities of acquisition. The collection can be any aerial, satellite, or SAR imagery you want classify similarly, such as, but not limited to the following:

- Airphotos (strips or individual images)
- Stack of historical imagery
- Overlapping images
- Contiguous images

You first run classification on an individual image that you want to use as reference for the batch you want to process. After you are satisfied with the results, you can run a batch classification on several images to apply the same classification to each. The batch classification applies a segmentation step, an attribute-calculation step, a classification step using Support Vector Machine or Random Forest (based on the training-model file you create from the first individual image you classified), and any number of rule-based classification steps.

## Aerial Bundle Functions

In the Aerial bundle the following functions can be executed either independently or sequentially via an EASI™ or Python™ script. They may also be available in the Algorithm Librarian in Focus and Modeler.

- ADSADJUST – Adjusts the ADS math model in a standard ADS dataset.



- ADSCOPYCORR - copies ADS model-correction terms from one segment to another. For example, the panchromatic ADS model-correction terms can be copied to the multispectral file such that the panchromatic and multispectral models are synchronized.
- ADSLOTOL1 - converts airborne digital sensor (ADS) products from Level 0 to Level 1.
- ADSMODEL - performs a bundle-adjustment computation on photos acquired with an airborne digital sensor (ADS) that have ground control points (GCP) and tie points (TP)
- APMODEL - calculates the mathematical model required for orthorectifying a set of images in an OrthoEngine project file
- AUTODEM - Generates a digital elevation model from stereo images - OpenMP enabled
- CAMEXPORT - export the camera calibration information from an OrthoEngine project file to an XML file.
- CAMIMPORT - imports camera calibration parameters from an XML file into an OrthoEngine project file.
- DEMADJUST - Adjusts (raises/lowers) a raster DEM to elevation points held in a vector layer so that it better fits the elevation points.
- DEMMETA - Adds standard DEM-related metadata tags to an existing DEM raster.
- DSM2DTM - Convert a DSM to DTM
- DSMMERGE - Used to merge (multi-angle) geocoded DSMs that were typically produced by EPIPOLARDSM and geocoded using GEOCODEDEM. Imagery associated with the geocoded DSM can be simultaneously merged at the same time producing a rough ortho image co-registered with the DSM.
- ELEVRMS - Reads elevations from a digital elevation channel and compares the elevations with elevation values from a given GCP (ground control point) segment or from a vector segment
- ELGCPRMS - Generate elevation data RMS report - GCP
- ELVECRMS - Generate elevation data RMS report - vector
- EOEXPORT - export the exterior orientation data from an OrthoEngine project file into a text file.
- EOIMPORT - import the exterior orientation data into an OrthoEngine project file from a text file.
- EPIPOLAR - Generates epipolar images from stereo pairs or raw images - OpenMP enabled
- EPIPOLARDSM - Creates a raster digital surface model (DSM) from epipolar stereo pairs using the Semi-Global Matching (SGM) method.
- FLIGHTLINE - prints flight-line information for all the images in the selected file(s).
- GENAPEO - Calculate the exterior orientation of each photo in a project from the position of the first and last photo of each flight line.
- GENAPMODEL - uses camera information, exterior-orientation data, and map units to generate airphoto model segments for multiple files.
- GEOCODEDEM - geocodes epipolar digital elevation models by reprojecting to the ground coordinate system - OpenMP enabled

- MODEL2RPC - converts a math model to a RPC model
- OACALCATT – Calculate object attributes
- OACALCATTSAR – Calculate object attributes for SAR imagery
- OAFLDNMEXP - Export names of attribute fields from vector segment to a text file
- OASEG – Segment an image
- OASEGSAR – Segment a SAR image
- OASVMCLASS – Object-based SVM classifier
- OASVMTRAIN – Object-based SVM training
- OARTCLASS – Object-based Random Trees (Forest) classifier
- OARTTRAIN – Object-based Random Trees (Forest) training
- SGMMERGE - Merges a nadir-backward and nadir-forward epipolar DSM, created with the EPIPOLARDSM algorithm, into a single, final DSM, and then applies optional filtering.