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Leica Photogrammetry Suite OrthoBASE & OrthoBASE Pro User's Guide

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Preface

About This Manual

The *OrthoBASE & OrthoBASE Pro® User's Guide* contains theory that explains the photogrammetric applications of the Leica Photogrammetry Suite (LPS), tour guides that help you begin to use these programs, practical applications of the software, and appendices that give you additional information.

This manual serves as a handy reference while using OrthoBASE and OrthoBASE Pro for your own projects. A comprehensive index is included so that you can easily locate specific information as needed.

Nomenclature

With the release of Leica Photogrammetry Suite, Leica Geosystems GIS & Mapping has improved and integrated some familiar products. Therefore, names of products you were once familiar with may have changed.

- The product formerly known as IMAGINE OrthoBASE has evolved into a component of Leica Photogrammetry Suite that is now known as LPS Project Manager.
- The product formerly known as IMAGINE OrthoBASE Pro has evolved into a component of Leica Photogrammetry Suite that is now known as LPS Automatic Terrain Extraction (ATE).
- The product formerly known as Stereo Analyst for IMAGINE has evolved into a component of Leica Photogrammetry Suite that is now known as Stereo Analyst.
- LPS components also include Terrain Editor and PRO600.

We are continuing to use the original names to assist our existing customers in their transition to the new products. These names will be fully transitioned in a future release of Leica Photogrammetry Suite.

Example Data

Data sets are provided with the OrthoBASE and OrthoBASE Pro software so that your results match those in the tour guides. This data is loaded, optionally, during the software installation process into /examples/orthobase. The example data sets are further divided by the example they pertain to: /frame, /digital, /spot, and /laguna_beach.

Documentation

This manual is part of a whole suite of printed and on-line documentation that you receive with ERDAS IMAGINE software.

Printed Documentation

Following is a list of printed documentation that comes with LPS and ERDAS IMAGINE software. The *.pdf files may be found in /help/hardcopy:

- Leica Photogrammetry Suite Configuration Guide (LPS_ConfigGuide.pdf)
- Leica Photogrammetry Suite OrthoBASE & OrthoBASE Pro User's Guide (OrthoBASE.pdf)

- Leica Photogrammetry Suite Stereo Analyst User's Guide (StereoAnalyst.pdf)
- Leica Photogrammetry Suite Terrain Editor Tour Guides (TerrainEditor.pdf)
- ERDAS Field Guide™ (FieldGuide.pdf)
- ERDAS IMAGINE Configuration Guide (Unix_ConfigGuide.pdf and Win_ConfigGuide.pdf)
- ERDAS IMAGINE Tour Guides™ (TourGuide.pdf)
- ERDAS IMAGINE Release Notes and Important Information

On-line Documentation

Following is a list of on-line manuals that can be found in the On-Line Help:

- ERDAS IMAGINE
  - Introduction
  - Annotation
  - AOI (Area of Interest)
  - Classification
  - DPPDB (Digital Point Positioning Database) Workstation
  - Expert Classifier
  - HyperSpectral
  - Image Catalog
  - Image Interpreter
  - IMAGINE Interface
  - Imagizer
  - Import/Export
  - Importing Native Formats
  - Map Composer
  - Mosaic Tool
  - NITF
  - Preferences
  - Radar Mapping Suite
  - Rectification
  - Session
  - Spatial Modeler
  - Spectral Analysis
  - Tools and Utilities
  - Vector
  - Viewer
  - Viewer Raster Tools
  - VirtualGIS
  - Appendices
- Leica Photogrammetry Suite
  - OrthoBASE
  - OrthoBASE Pro
  - Stereo Analyst
  - Terrain Editor
  - Viewplex

- ImageEqualizer

Documentation Functions

The following table details the different types of information you can extract from ERDAS IMAGINE documentation.

If you want to...	Read...
Install ERDAS IMAGINE	ERDAS IMAGINE Release Notes, then ERDAS IMAGINE Configuration Guides
Set up hardware for use with ERDAS IMAGINE	ERDAS IMAGINE Configuration Guides
Learn about new features in the latest release	What's new in ERDAS IMAGINE
Learn to use LPS	LPS OrthoBASE & OrthoBASE Pro User's Guide, LPS Terrain Editor Tour Guides, LPS Stereo Analyst User's Guide, LPS Installation and Configuration Guides
Learn to use ERDAS IMAGINE	ERDAS IMAGINE Tour Guides
Learn about GIS and image processing theory	ERDAS Field Guide
See what you can do with a particular dialog	On-Line Help
Get quick information about a button or function	On-Line Help or Status Bar Help
Learn how to most effectively use the On-Line Help system	Introduction to ERDAS IMAGINE On-Line Help
Learn more about the Image Interpreter functions	ERDAS IMAGINE Tour Guides
Use the Spatial Modeler Language to write models	On-Line Spatial Modeler manual
Customize the ERDAS IMAGINE graphical user interface	On-Line ERDAS Macro Language (EML) Reference Manual
Write custom application programs within ERDAS IMAGINE	On-Line IMAGINE Developers' Toolkit™ manual

Conventions Used in This Book

In ERDAS IMAGINE, the names of menus, menu options, buttons, and other components of the interface are shown in bold type. For example:

"In the Select Layer To Add dialog, select the **Fit to Frame** option."

When asked to use the mouse, you are directed to click, double-click, Shift-click, middle-click, right-click, hold, drag, etc.

- click — designates clicking with the left mouse button.
- double-click — designates clicking twice with the left mouse button.
- Shift-click — designates holding the Shift key down on your keyboard and simultaneously clicking with the left mouse button.

- middle-click — designates clicking with the middle mouse button.
- right-click — designates clicking with the right mouse button.
- hold — designates holding down the left (or right, as noted) mouse button.
- drag — designates dragging the mouse while holding down the left mouse button.

The following paragraphs are used throughout the ERDAS IMAGINE documentation:

These paragraphs contain strong warnings or important tips.

These paragraphs direct you to the ERDAS IMAGINE or LPS software function that accomplishes the described task.

These paragraphs provide information about Leica Geosystems products.

These paragraphs lead you to other areas of this book or other manuals for additional information.

NOTE: Notes give additional instruction.

Blue Box

These boxes contain supplemental technical information.

Section I

Introduction to OrthoBASE & OrthoBASE Pro

Chapter 1

Introduction to OrthoBASE & OrthoBASE Pro

Introduction

Welcome to OrthoBASE and OrthoBASE Pro, which are two of the primary components of LPS. Provided in one easy-to-use environment is a comprehensive digital photogrammetry package that allows for the fast and accurate triangulation and orthorectification of images collected from various types of cameras and satellite sensors.

OrthoBASE drastically reduces the cost and time associated with triangulating and orthorectifying aerial photography, satellite imagery, digital, and video camera imagery when collecting geographic information. The product addresses issues and problems related to:

- Collecting ground control points (GCPs) in the field or office.
- Measuring GCPs and tie points on multiple images.
- Performing quality control in order to verify the overall accuracy of the final product.
- Accommodating photography and satellite imagery from various camera and satellite sensor types, including standard aerial, digital, video, amateur 35 mm cameras (including terrestrial and oblique photography), and SPOT pushbroom sensors.
- Integrating data from airborne global positioning system (GPS) and other photogrammetric sources.
- Using photography scanned from desktop scanners.
- Triangulating multiple images automatically.
- Extracting DTMs automatically from imagery.

For more information about Leica Photogrammetry Suite utilities, see Appendix A "Leica Photogrammetry Suite Utilities".

Using OrthoBASE

Due to the large geometric distortion associated with raw aerial photography and satellite imagery, measurements made on data sources that have not been rectified for the purpose of collecting geographic information are not reliable. Generally, the geometric distortion is caused by various systematic and nonsystematic errors such as camera and sensor orientation, terrain relief, Earth curvature, film and scanning distortion, and measurement errors (Wolf 1983, Konecny and Lehmann 1984, Kraus 1984, Wang, Z. 1990, Jensen 1996).

To rectify image data, various geometric modeling methods such as polynomial transformation, multisurface (radial basis) functions, finite element analysis (rubber sheeting), and collinearity equations can be applied (Yang 1997). While the choice of the proper modeling method depends on data sources and data availability, the collinearity equation based orthorectification produces the most reliable solution for raw image data by incorporating the sensor or camera orientation, relief displacement, and the Earth's curvature in its modeling process.

Orthorectification in OrthoBASE generates planimetrically true orthoimages in which the displacement of objects due to sensor or camera orientation, terrain relief, and other errors associated with image acquisition and processing has been removed. The orthoimage has the geometric characteristics of a map and the image qualities of a photograph. The objects on an orthoimage are in their true orthographic positions. Therefore, orthoimages are geometrically equivalent to conventional line and symbol planimetric maps. Any measurement taken on an orthoimage reflects a measurement taken on the ground.

Orthoimages serve as the ideal information building blocks for collecting geographic information required for a geographic information system (GIS). They can be used as reference image backdrops to maintain or update an existing GIS. Using the IMAGINE Vector™ module, ground features can be collected and subsequently attributed to reflect the spatial and nonspatial characteristics associated with a feature. Using ERDAS IMAGINE, multiple orthoimages can be mosaicked to form seamless orthoimage base maps.

OrthoBASE uses the self-calibrating bundle block adjustment method in its triangulation process. By doing so, the internal geometry of each image and the relationships between overlapping images are determined. When multiple images are involved in a data block, such a modeling method can significantly ease the need of acquiring many GCPs.

Image tie points are the common points in overlapping areas of two or more images. They connect the images in the block to each other and are necessary input for the triangulation. OrthoBASE automates the identification and measurement of tie points so that your work and time for manual measurement are drastically reduced.

In addition to orthoimages, digital elevation models (DEMs) and topographic features are two other major geographic information components of a GIS. In order to extract a DEM and topographic features from imagery, the image orientations need to be known. The triangulation results of OrthoBASE determine the image position and orientations required for the purpose of DEM extraction and stereo feature collection.

Using OrthoBASE Pro

OrthoBASE Pro fits seamlessly into the existing OrthoBASE workflow. DTM extraction can be performed after complete setup of the block file. In order to automatically extract DTMs from imagery, the sensor model information associated with the imagery must be computed. Performing interior orientation and aerial triangulation ensures that the availability of the sensor model.

Using a robust algorithm, OrthoBASE Pro compares two images and looks for the image positions of conjugate features appearing in the overlap portions of the images. It then computes the 3D position of the features in the block projection system. This process is referred to as digital image matching and three-dimensional (3D) coordinate determination.

As a result of the matching and the 3D coordinate determination processes, an output DTM is generated that can be used in the final step of the OrthoBASE workflow, orthorectification. The output DTM can also be used in other applications, such as ERDAS IMAGINE, Stereo Analyst, and IMAGINE VirtualGIS.

OrthoBASE Functionality

First, OrthoBASE allows you to easily model various camera and sensor types, referred to as sensor modeling. OrthoBASE's sensor modeling capabilities establish the internal characteristics (i.e., geometry) associated with a specific camera or sensor, and correct for systematic error.

Second, OrthoBASE allows you to model the position and orientation of a camera or sensor at the time of data collection, which dramatically improves the accuracy of the resulting orthoimages.

Third, OrthoBASE automatically measures the image positions of ground feature points appearing on multiple images, which is referred to as automatic tie point collection. Once the image positions of the tie points are established, the corresponding ground coordinates can be determined using aerial triangulation techniques. (If many tie points were automatically collected, a rough DEM can be interpolated using the tie points as mass points.)

Fourth, OrthoBASE gives you the flexibility to orthorectify images from a variety of camera and satellite sensor types. Additionally, it allows you to process multiple orthos sequentially.

Triangulation

Triangulation, or block triangulation, is the process of establishing a mathematical relationship between the images contained in a project, the camera or sensor model, and the ground. The information resulting from triangulation is required as input for the orthorectification process.

Classical aerial triangulation using optical-mechanical analog and analytical stereo plotters was primarily used for collection of ground points using the control point extension technique. This involved the manual measurement of tie points for the subsequent determination of their corresponding ground coordinates. These points were then identified as being GCPs for other applications. With the advent of digital photogrammetry, classical aerial triangulation has been extended to provide greater functionality.

OrthoBASE uses a technique known as bundle block adjustment for aerial triangulation. Bundle block adjustment provides three primary functions:

- The ability to determine the position and orientation of each image in a project as they existed at the time of photographic or image exposure. The resulting parameters are referred to as exterior orientation parameters.
- The ability to determine the ground coordinates of any tie points measured on the overlap areas of multiple images. The highly precise ground point determination of tie points is useful for generating GCPs from imagery in lieu of ground surveying techniques.
- The ability to distribute and minimize the errors associated with the imagery, image measurements, GCPs, and so forth. The bundle block adjustment processes information from an entire block of imagery in one simultaneous solution (i.e., a bundle) using statistical techniques to automatically identify, distribute, and remove error.

OrthoBASE Pro Functionality

The automated DTM extraction process of OrthoBASE Pro provides the following functional capabilities:

- The ability to automatically extract elevation data from an image pair. Robust photogrammetric techniques, such as digital image matching, are used to automatically extract 3D terrain information from imagery.

- A DTM can be extracted from standard frame photography, digital camera imagery, videography, nonmetric photography, SPOT, Indian Remote Sensing (IRS) 1C, and imagery provided with rational function coefficients (i.e., IKONOS).
- Optional output DTM formats include American Standard Code for Information Interchange (ASCII) files; TerraModel Triangulated Irregular Networks (TIN); raster DEMs; Environmental System Research Institute (ESRI) 3D Shape files; and, if you have a licensed version of SOCET SET on your system, SOCET SET TIN files.
- Individual DTMs can be extracted from the image pairs in a block.
- A single comprehensive DTM mosaic for an entire block of imagery can be extracted. All you provide is the output cell size, the output DTM name, and DTM type.
- The outer extent of a DTM can be trimmed, or subset, to remove erroneous portions.
- A new output projection, spheroid, and datum can be defined for the extracted DTM.
- New horizontal and vertical units can be defined for the extracted DTM.
- The overlap area used to extract a DTM for any given image pair can be minimized based on a percentage value. This eliminates those portions of the image that may introduce errors into the extraction process, such as fiducial marks.
- A series of image pairs contained within the OrthoBASE block file can be viewed, selected, and subsequently used for automated DTM extraction.
- The region for DTM extraction within any given image pair can be defined and digitized (e.g., square, rectangle, or polygon). Thus, the geographic area of the extracted DTM is defined by the region. Any image pair can have multiple inclusion and/or exclusion regions. This is useful if you are only interested in a given portion of land, such as islands.
- DTM collection strategy parameters can be defined for any given inclusion region. The strategy parameters govern and optimize the performance of the automated DTM extraction algorithm. Strategy parameter settings can be saved as an ASCII file for subsequent use.
- The automated DTM extraction performs differently as a function of topography type and land cover type. As a result, you have the option to define the type of topography and landcover within the region of interest.
- The accuracy and precision associated with a DTM can be determined based on 3D reference information such as check points, GCPs, an external DEM, or imported XYZ points. A footprint of the block and all of the 3D reference points associated with the block are graphically displayed within a view.
- Each extracted DTM has an associated report file and optional DTM Point Status image characterizing the quality, precision, and speed of processing.
- Contour lines are automatically extracted once the DTM has been generated. The Contour Map is stored as an ESRI 3D Shape file.

Tour Guide Examples

The following tour guide examples are used to highlight the unique capabilities available within OrthoBASE. Each example provides a representative workflow of a real-world scenario that may be encountered for jobs associated with triangulation and orthorectification. Of particular significance is the ability of OrthoBASE to accommodate data from various sources including different types of cameras and satellite sensors, airborne GPS, and various reference sources for collecting GCPs. Each tour guide example exemplifies the data flexibility provided by OrthoBASE.

Frame Camera Tour Guide

This example involves performing aerial triangulation and orthorectification on three overlapping aerial photographs that have a photo scale of 1:40000. A calibration report is provided that defines the internal geometry of the camera as it existed when the photographs were captured.

Several GCPs are measured on the overlapping images in order to better establish the relationship between the images, the camera, and the ground. Once the GCPs have been measured, automatic tie point collection tools are used to measure the corresponding image positions of tie points on overlapping images.

Additionally, a United States Geological Survey (USGS) DEM is provided to account for the effect of topographic relief during the orthorectification process. Orthorectification is performed for each image sequentially.

See the tour guide Chapter 4 “Frame Camera Tour Guide”.

Digital Camera Tour Guide

This example involves performing aerial triangulation and orthorectification on three overlapping digital camera images that have an image scale of 1:45000. The images were taken using a Kodak DCS 420 digital camera. The ground resolution of the imagery is approximately 0.40 meters. The only camera calibration information provided is the focal length and the pixel size of the Charge Coupled Device (CCD).

Airborne GPS and inertial navigation system (INS) data is available for each image. This information defines the position and orientation associated with each image as they existed during capture. This information can be referred to as exterior orientation. For this reason, GCPs are not required for this data set. In scenarios where exterior orientation is available, GCPs are not required. Additionally, since digital camera imagery does not have fiducial marks, the interior orientation is done automatically.

Automatic tie point collection tools are used to measure the corresponding image positions of tie points on overlapping images. Aerial triangulation is performed to adjust the exterior orientation parameters and determine the XYZ coordinates of the tie points. If so desired, the tie points can be converted to GCPs. This is referred to as control point extension. Lastly, orthorectification is performed for each image sequentially using a constant elevation value.

See the tour guide Chapter 5 “Digital Camera Tour Guide”.

SPOT Pushbroom Sensor Tour Guide

This example involves performing triangulation and orthorectification on two overlapping SPOT panchromatic images. The images are captured using a pushbroom sensor. The ground resolution of the images is 10 meters. OrthoBASE automatically uses the ephemeris information associated with the image to define the geometry of the sensor as it existed when the imagery was captured.

Using an existing SPOT XS orthorectified image (20-meter resolution), a 2-meter orthophoto, and a DEM, GCPs are measured. The SPOT ortho and aerial orthophoto are used for the collection of horizontal GCPs. A DEM is used for the vertical component (Z) of a GCP. This is done automatically once the horizontal components of the GCPs have been measured.

Automatic tie point collection tools are used to measure the corresponding image positions of tie points on overlapping images. Triangulation is performed to define the position and orientation of the sensor as they existed when the imagery was captured, and to determine the XYZ coordinates of the tie points. Using a DEM, the two SPOT images are sequentially orthorectified.

See the tour guide Chapter 6 "SPOT Pushbroom Sensor Tour Guide".

Automated DTM Extraction Tour Guide

This example involves automatically extracting a DTM from a pre-existing block file. The data used is of Laguna Beach, California, USA. The frame camera images are 1:40000 scale photographs, scanned at 50 microns for an approximate 2-meter ground resolution.

You are going to evaluate the images in the block file, select areas for special consideration in the DTM extraction process, and learn how to use additional sources of data (a DEM and control points) to compute the accuracy of the output DTM. You can proceed to orthorectify the imagery in the block file, but this is an optional step.

You also evaluate other types of output DTMs available from OrthoBASE Pro: a 3D Shape file, an ASCII file, and a TerraModel TIN.

NOTE: If you have a licensed version of SOCET SET on your system, you can also create SOCET SET TIN files. An example of a SOCET SET TIN file is not included in this example.

See Chapter 7 "Automated DTM Extraction Tour Guide".

Appendix Examples

Appendices are provided to detail processes commonly used both during and after DTM extraction.

Batch Processing

This appendix explains how you can set up your system for Batch processing. You can then set parameters for multiple output DTMs and load them into the Batch Wizard for execution at a later time. The Batch Wizard works in conjunction with the Microsoft Scheduler, which is located in the **Services** category of the **Control Panel.**

See Appendix B "Batch Processing".

DEM Editing

This appendix details how to perform post-processing on DEMs generated by OrthoBASE Pro. You have two options for editing DEMs: you can either do so in ERDAS IMAGINE using the DEM as a raster file, or you can do so in Stereo Analyst using a 3D Shape file. This appendix gives step-by-step instructions to help you complete the task.

See Appendix C "DTM Editing in ERDAS IMAGINE & Stereo Analyst".

About OrthoBASE and OrthoBASE Pro

Before you begin working with OrthoBASE, it may be helpful to go over some of the icons and menu options located on the interface. You use these menus and icons throughout the tour guides.

Before you begin working with OrthoBASE Pro, you should be familiar with the functionality of OrthoBASE. Additionally, it may be helpful to go over some of the icons and menu options located on the interface. You use these menus and icons throughout the tour guide tailored to OrthoBASE Pro (Chapter 7 “Automated DTM Extraction Tour Guide”).

Menu Bar

The menu bar across the top of the main Leica Photogrammetry Suite dialog has the following options, many of which are associated with OrthoBASE and OrthoBASE Pro:

Table 1-1: LPS Menu Bar

File	Edit	Process	Help
New... Open... Save Save As... Configure SOCET SET Access... Import SOCET SET Project... Export To SOCET SET Project... Register SOCET SET Project(s)... Close <Recent Files> Exit	Add Frame... Frame Editor... Compute Pyramid Layers... Update Pyramid Layer Status Delete Selected Image(s) Point Measurement... Block Properties... Auto. Tie Point Generation Properties... Triangulation Properties... DTM Extraction Properties...	Automatic Tie Point Generation Triangulate Block Triangulation Triangulation Report... Project Graphic Status... DTM Extraction... DTM Extraction Report... Interactive Terrain Editing... Ortho Rectification Resampling... Calibration... Mosaic... Feature Collection Stereo Analyst for IMAGINE Stereo Analyst for ArcGIS PRO600 for LPS	Help for Leica Photogrammetry Suite... Help for LPS Project Manager... About Leica Photogrammetry Suite...

Toolbar

The following icons are located in the Leica Photogrammetry Suite dialog toolbar:

Table 1-2: LPS Toolbar

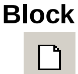
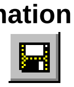
New Block File 	Click to start creating a new block file. A File Selector opens.
Open Existing Block File 	Click to open a block file that already exists. A File Selector dialog opens.
Save Block Information 	Click to save any changes you have made to the block file.

Table 1-2: LPS Toolbar (Continued)

Add Frame	Click to add a new image to the project file. A File Selector dialog opens.
Frame Editor	Click to specify interior orientation, exterior orientation, and fiducial coordinates for each image in the Frame Editor dialog.
Point Measurement	Click to measure check and GCPs in your block images. Views, a tool palette, and two CellArrays™ open within a single dialog.
Auto Tie	Click to run automatic tie point generation, which includes the following tasks: block configuration, tie point extraction, point transfer, gross error detection, and tie point selection.
Triangulation	Click to perform triangulation on your block images, which estimates the position of each image in a block at the time of image capture, the coordinates of tie points, the interior orientation parameters, and additional parameters.
DTM Extraction	This icon starts the OrthoBASE Pro application. Click to extract a single DTM or multiple DTMs from images in the block file. You can choose from the following types of output DTMs: DEM, ASCII, TerraModel TIN, 3D Shape file, or SOCET SET TIN. *NOTE: You must have a licensed version of SOCET SET on your system to generate SOCET SET TIN files.*
DTM Editing	This icon starts the Terrain Editor application. Click to edit the elevation of various kinds of DTMs including: DEMs and TINs.
Ortho Resampling	Click to resample your triangulated images and create orthoimages, which are planimetrically true images that represent ground objects in their real world X and Y positions.
Ortho Mosaicking	This icon starts the Mosaic Tool application. Click to join orthophotos or DTMs using the Mosaic Tool. For more information, see the Mosaic Tour Guide in *ERDAS IMAGINE Tour Guides* and the On-Line Help.
Feature Collection	This icon starts the feature collection application of your choice: Stereo Analyst for IMAGINE, Stereo Analyst for ArcGIS, or PRO600. You must have licenses to run these applications. Click to collect features from the orthoimages you create in LPS. For more information, see the *Stereo Analyst User's Guide* and On-Line Help, *Using Stereo Analyst for ArcGIS*, or the PRO600 user's guide.

Keyboard Shortcuts

You can access some OrthoBASE and OrthoBASE Pro options using the keyboard.

- Display the **File** menu by typing **Alt-f.**
- Display the **Edit** menu by typing **Alt-e.**
- Display the **Process** menu by typing **Alt-p.**
- Display the **Help** menu by typing **Alt-h.**

Next

In the next section of this document, you can learn about photogrammetric and terrain extraction theory.

Section II

Photogrammetric and Terrain Extraction Theory

Chapter 2

Introduction to Photogrammetry

Introduction

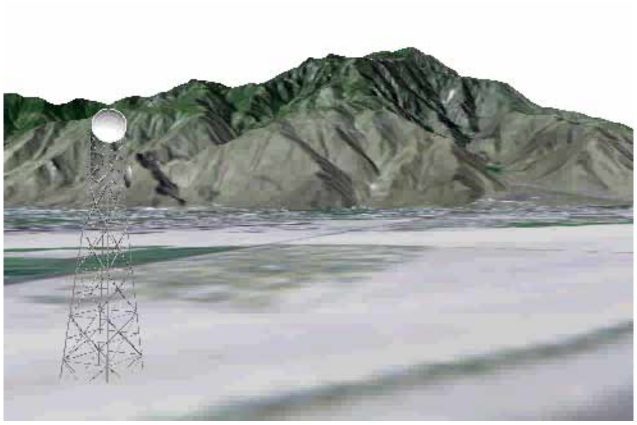
What is Photogrammetry?

Photogrammetry is the "art, science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring and interpreting photographic images and patterns of electromagnetic radiant imagery and other phenomena" (American Society of Photogrammetry 1980).

Photogrammetry was invented in 1851 by Colonel Aimé Laussedat, and has continued to develop over the last 150 years. Over time, the development of photogrammetry has passed through the phases of plane table photogrammetry, analog photogrammetry, analytical photogrammetry, and has now entered the phase of digital photogrammetry (Konecny 1994).

The traditional, and largest, application of photogrammetry is to extract topographic information (e.g., terrain models) from aerial images. Figure 2-1 illustrates rugged topography. Photogrammetric techniques have also been applied to process satellite images and close-range images in order to acquire topographic or nontopographic information of photographed objects. Topographic information includes spot height information, contour lines, and elevation data. Planimetric information includes the geographic location of buildings, roads, rivers, and so forth.

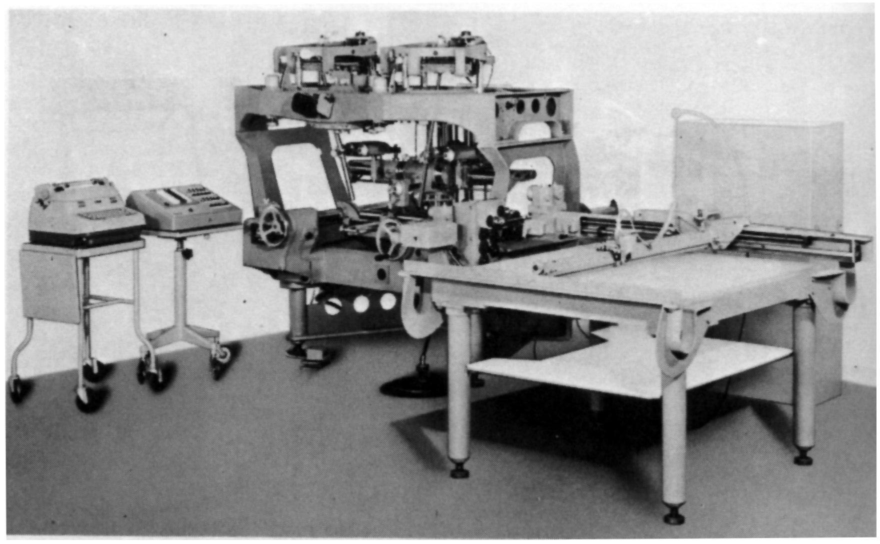
Figure 2-1: Topography



Prior to the invention of the airplane, photographs taken on the ground were used to extract the relationships between objects using geometric principles. This was during the phase of plane table photogrammetry.

In analog photogrammetry, starting with stereo measurement in 1901, optical or mechanical instruments were used to reconstruct three-dimensional geometry from two overlapping photographs. Figure 2-2 depicts a typical analog stereo plotter. The main product during this phase was topographic maps.

Figure 2-2: Analog Stereo Plotter

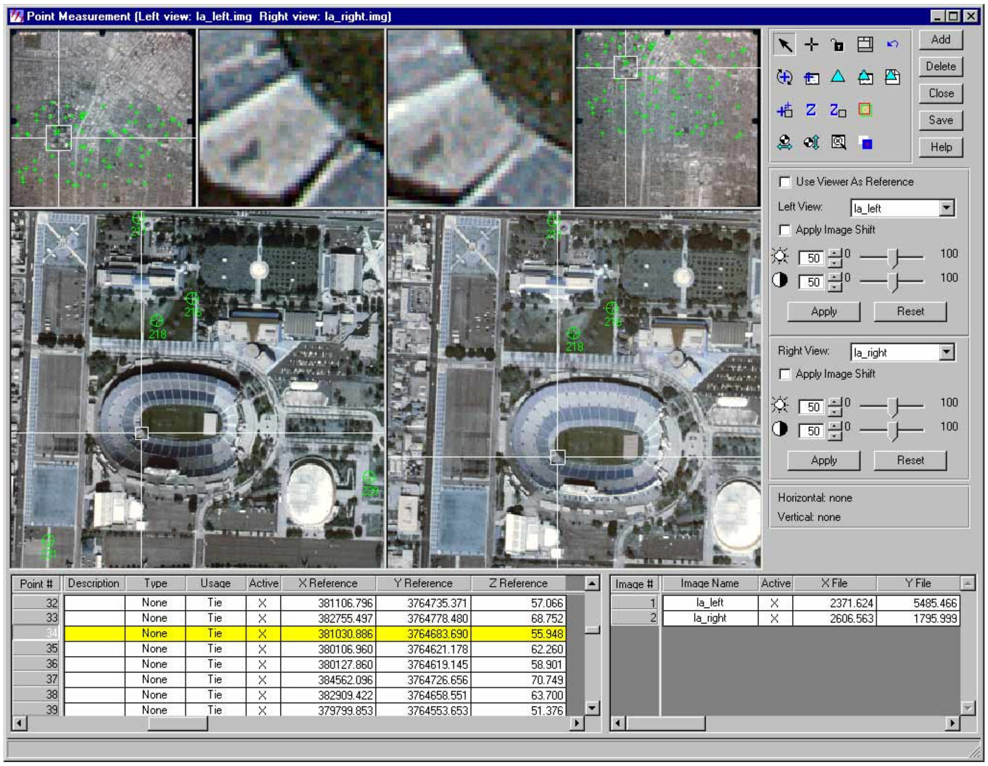


In analytical photogrammetry, the computer replaced some expensive optical and mechanical components. The resulting devices were analog/digital hybrids. Analytical aerotriangulation, analytical plotters, and orthophoto projectors were the main developments during this phase. Outputs of analytical photogrammetry can be topographic maps, but also can be digital products, such as digital maps and DEMs.

Digital photogrammetry is photogrammetry applied to digital images that are stored and processed on a computer. Digital images can be scanned from photographs or directly captured by digital cameras. Many photogrammetric tasks can be highly automated in digital photogrammetry (e.g., automatic DEM extraction and digital orthophoto generation). Digital photogrammetry is sometimes called softcopy photogrammetry. The output products are in digital form, such as digital maps, DEMs, and digital orthoimages saved on computer storage media. Therefore, they can be easily stored and managed by you. With the development of digital photogrammetry, photogrammetric techniques are more closely integrated into remote sensing and GIS.

Digital photogrammetric systems employ sophisticated software to automate the tasks associated with conventional photogrammetry, thereby minimizing the extent of manual interaction required to perform photogrammetric operations. OrthoBASE (Figure 2-3), which is part of the Leica Photogrammetry Suite, is such a photogrammetric system.

Figure 2-3: OrthoBASE Point Measurement Interface

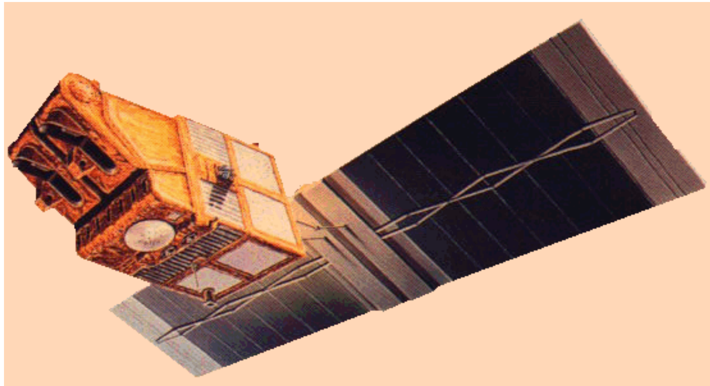


Photogrammetry can be used to measure and interpret information from hardcopy photographs or images. Sometimes the process of measuring information from photography and satellite imagery is considered metric photogrammetry, such as creating DEMs. Interpreting information from photography and imagery is considered interpretative photogrammetry, such as identifying and discriminating between various tree types (Wolf 1983).

Types of Photographs and Images

The types of photographs and images that can be processed with OrthoBASE include aerial, terrestrial, close-range, and oblique. Aerial or vertical (near vertical) photographs and images are taken from a high vantage point above the Earth's surface. In those photographs, the camera axis is commonly directed vertically (or near vertically) down. Aerial photographs and images are commonly used for topographic and planimetric mapping projects, and are commonly captured from an aircraft or satellite. Figure 2-4 illustrates a satellite. Satellites use onboard sensors to collect high resolution images of the Earth's surface.

Figure 2-4: Satellite



Terrestrial or ground-based photographs and images are taken with the camera stationed on or close to the Earth's surface. Terrestrial and close-range photographs and images are commonly used for applications involved with archeology, geomorphology, civil engineering, architecture, and industry.

Oblique photographs and images are similar to aerial photographs and images, except the camera axis is intentionally inclined at an angle with the vertical. Oblique photographs and images are commonly used for reconnaissance and corridor mapping applications.

Digital photogrammetric systems use digitized photographs or digital images as the primary source of input. Digital imagery can be obtained in various ways, including:

- digitizing existing hardcopy photographs
- using digital cameras to record imagery
- using sensors onboard satellites such as Landsat, SPOT, and IRS to record imagery

NOTE: This document uses the term imagery in reference to photography and imagery obtained from various sources. This includes aerial and terrestrial photography, digital and video camera imagery, 35 mm photography, medium to large format photography, scanned photography, and satellite imagery.

Why use Photogrammetry?

Raw aerial photography and satellite imagery have large geometric distortion that is caused by various systematic and nonsystematic factors. The photogrammetric modeling based on collinearity equations eliminates these errors most efficiently, and creates the most reliable orthoimages from raw imagery. Photogrammetry is unique in terms of considering the image-forming geometry, utilizing information between overlapping images, and explicitly dealing with the third dimension: elevation.

See "The Collinearity Equation" for information about the collinearity equation.

In addition to orthoimages, photogrammetry can also reliably and efficiently provide other geographic information such as a DEM, topographic features, and line maps. In essence, photogrammetry produces accurate and precise geographic information from a wide range of photographs and images. Any measurement taken on a photogrammetrically processed photograph or image reflects a measurement taken on the ground. Rather than constantly go to the field to measure distances, areas, angles, and point positions on the Earth's surface, photogrammetric tools allow for the accurate collection of information from imagery. Photogrammetric approaches for collecting geographic information save time and money, and maintain the highest accuracy.

Photogrammetry vs. Conventional Geometric Correction

Conventional techniques of geometric correction such as polynomial transformation are based on general functions not directly related to the specific distortion or error sources. They have been successful in the field of remote sensing and GIS applications, especially when dealing with low resolution and narrow field of view satellite imagery such as Landsat and SPOT data (Yang 1997). General functions have the advantage of simplicity. They can provide a reasonable geometric modeling alternative when little is known about the geometric nature of the image data.

Because conventional techniques generally process the images one at a time, they cannot provide an integrated solution for multiple images or photographs simultaneously and efficiently. It is very difficult, if not impossible, for conventional techniques to achieve a reasonable accuracy without a great number of GCPs when dealing with large-scale imagery, images having severe systematic and/or nonsystematic errors, and images covering rough terrain. Misalignment is more likely to occur when mosaicking separately rectified images. This misalignment could result in inaccurate geographic information being collected from the rectified images. Furthermore, it is impossible for a conventional technique to create a 3D stereo model or to extract the elevation information from two overlapping images. There is no way for conventional techniques to accurately derive geometric information about the sensor that captured the imagery.

The photogrammetric techniques applied in OrthoBASE overcome all the problems of conventional geometric correction by using least squares bundle block adjustment. This solution is integrated and accurate.

For more information, see "Bundle Block Adjustment".

OrthoBASE can process hundreds of images or photographs with very few GCPs, while at the same time eliminating the misalignment problem associated with creating image mosaics. In short: less time, less money, less manual effort, and more geographic fidelity can be obtained using the photogrammetric solution.

Single Frame Orthorectification vs. Block Triangulation

Single Frame Orthorectification

Single frame orthorectification techniques orthorectify one image at a time using a technique known as space resection. In this respect, a minimum of three GCPs is required for each image. For example, in order to orthorectify 50 aerial photographs, a minimum of 150 GCPs is required. This includes manually identifying and measuring each GCP for each image individually. Once the GCPs are measured, space resection techniques compute the camera/sensor position and orientation as it existed at the time of data capture. This information, along with a DEM, is used to account for the negative impacts associated with geometric errors. Additional variables associated with systematic error are not considered.

Single frame orthorectification techniques do not use the internal relationship between adjacent images in a block to minimize and distribute the errors commonly associated with GCPs, image measurements, DEMs, and camera/sensor information. Therefore, during the mosaic procedure, misalignment between adjacent images is common since error has not been minimized and distributed throughout the block.

Block Triangulation

Block (or aerial) triangulation is the process of establishing a mathematical relationship between the images contained in a project, the camera or sensor model, and the ground. The information resulting from aerial triangulation is required as input for the orthorectification, DEM creation, and stereopair creation processes. The term aerial triangulation is commonly used when processing aerial photography and imagery. The term block triangulation, or simply triangulation, is used when processing satellite imagery. The techniques differ slightly as a function of the type of imagery being processed.

Classic aerial triangulation using optical-mechanical analog and analytical stereo plotters is primarily used for the collection of GCPs using a technique known as control point extension. Since collecting GCPs is time consuming, photogrammetric techniques are accepted as the ideal approach for collecting GCPs over large areas using photography rather than conventional ground surveying techniques. Control point extension involves the manual photo measurement of ground points appearing on overlapping images. These ground points are commonly referred to as tie points. Once the points are measured, the ground coordinates associated with the tie points can be determined using photogrammetric techniques employed by analog or analytical stereo plotters. These points are then referred to as ground control points (GCPs).

With the advent of digital photogrammetry, classic aerial triangulation has been extended to provide greater functionality. OrthoBASE uses a mathematical technique known as bundle block adjustment for aerial triangulation. Bundle block adjustment provides three primary functions:

- Bundle block adjustment determines the position and orientation for each image in a project as they existed at the time of photographic or image exposure. The resulting parameters are referred to as exterior orientation parameters. In order to estimate the exterior orientation parameters, a minimum of three GCPs is required for the entire block, regardless of how many images are contained within the project.

- Bundle block adjustment determines the ground coordinates of any tie points manually or automatically measured on the overlap areas of multiple images. The highly precise ground point determination of tie points is useful for generating control points from imagery in lieu of ground surveying techniques. Additionally, if a large number of ground points is generated, then a DEM can be interpolated using the 3D surfacing tool in ERDAS IMAGINE.

- Bundle block adjustment minimizes and distributes the errors associated with the imagery, image measurements, GCPs, and so forth. The bundle block adjustment processes information from an entire block of imagery in one simultaneous solution (i.e., a bundle) using statistical techniques (i.e., adjustment component) to automatically identify, distribute, and remove error.

Because the images are processed in one step, the misalignment issues associated with creating mosaics are resolved.

Image and Data Acquisition

During photographic or image collection, overlapping images are exposed along a direction of flight. Most photogrammetric applications involve the use of overlapping images. By using more than one image, the geometry associated with the camera/sensor, image, and ground can be defined to greater accuracies and precision.

During the collection of imagery, each point in the flight path at which the camera exposes the film, or the sensor captures the imagery, is called an exposure station (see Figure 2-5 and Figure 2-6).

Figure 2-5: Exposure Stations Along a Flight Path

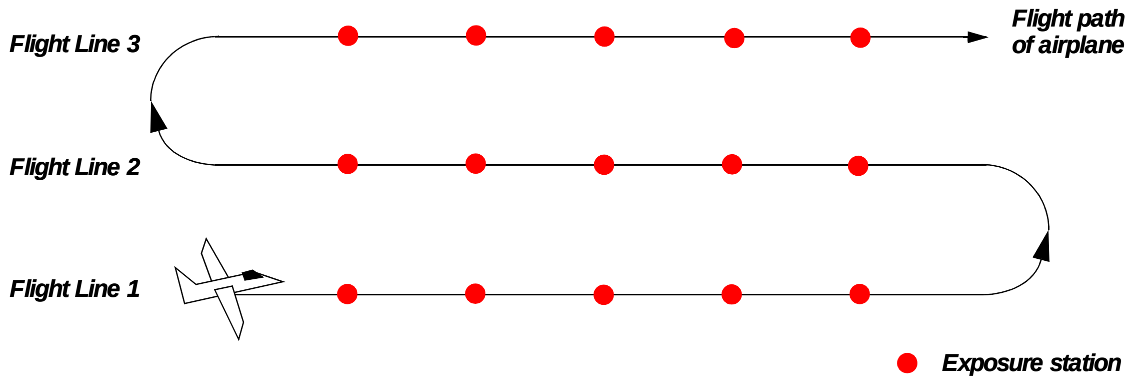
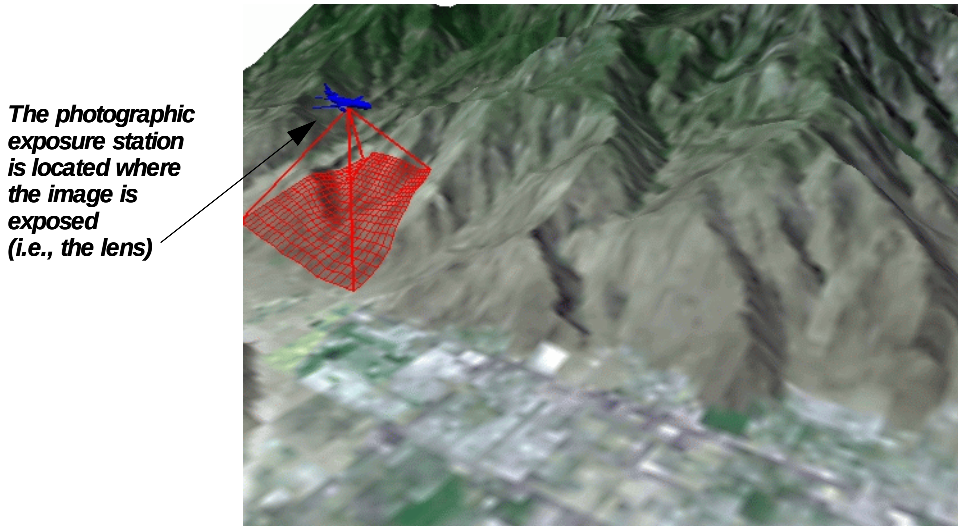


Figure 2-6: Exposure Station



Each photograph or image that is exposed has a corresponding image scale (SI) associated with it. The SI expresses the average ratio between a distance in the image and the same distance on the ground. It is computed as focal length divided by the flying height above the mean ground elevation. For example, with a flying height of 1000 m and a focal length of 15 cm, the SI would be 1:6667.

NOTE: The flying height above ground is used to determine SI, versus the altitude above sea level.

A strip of photographs consists of images captured along a flight line, normally with an overlap of 60%. All photos in the strip are assumed to be taken at approximately the same flying height and with a constant distance between exposure stations. Camera tilt relative to the vertical is assumed to be minimal.

The photographs from several flight paths can be combined to form a block of photographs. A block of photographs consists of a number of parallel strips, normally with a sidelap of 20-30%. Block triangulation techniques are used to transform all of the images in a block and their associated ground points into a homologous coordinate system.

A regular block of photos is commonly a rectangular block in which the number of photos in each strip is the same. Figure 2-7 shows a block of 5 × 2 photographs. Figure 2-8 illustrates two overlapping images.

Figure 2-7: A Regular Rectangular Block of Aerial Photos

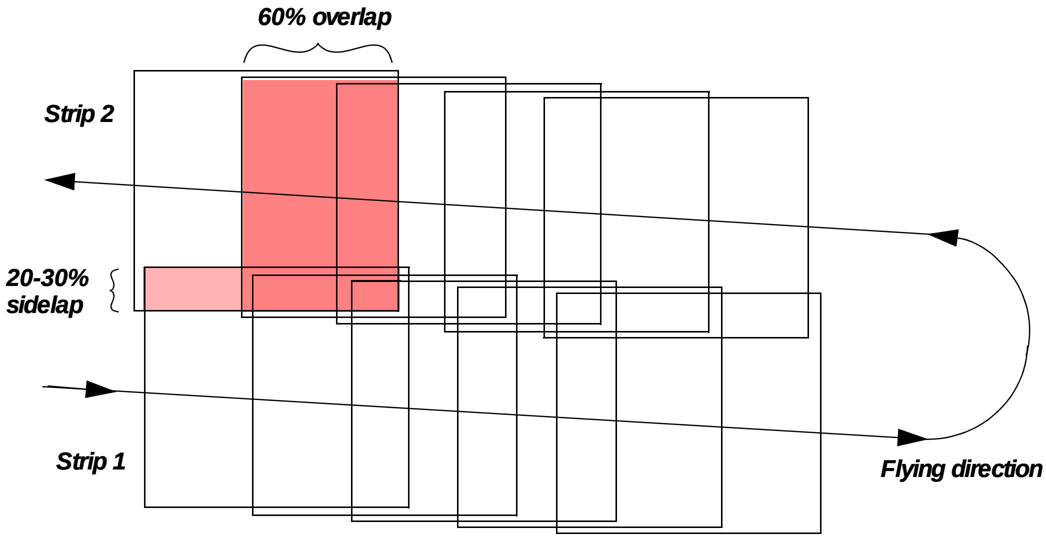
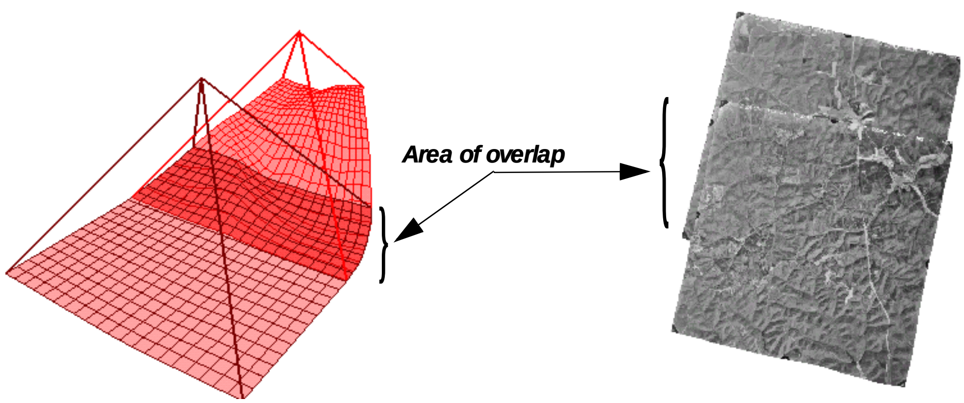


Figure 2-8: Overlapping Images



Photogrammetric Scanners

Photogrammetric scanners are special devices capable of producing high image quality and excellent positional accuracy. Use of this type of scanner results in geometric accuracies similar to traditional analog and analytical photogrammetric instruments. These scanners are necessary for digital photogrammetric applications that have high accuracy requirements.

Photogrammetric scanners usually scan only film because film is superior to paper, both in terms of image detail and geometry. These scanners usually have a Root Mean Square Error (RMSE) positional accuracy of 4 microns or less, and are capable of scanning at a maximum resolution of 5 to 10 microns (5 microns is equivalent to approximately 5,000 pixels per inch).

The required pixel resolution varies depending on the application. Aerial triangulation and feature collection applications often scan in the 10- to 15-micron range. Orthophoto applications often use 15- to 30-micron pixels. Color film is less sharp than panchromatic; therefore, color ortho applications often use 20- to 40-micron pixels. The optimum scanning resolution also depends on the desired photogrammetric output accuracy. Scanning at higher resolutions provides data with higher accuracy.

Desktop Scanners

Desktop scanners are general-purpose devices. They lack the image detail and geometric accuracy of photogrammetric quality units, but they are much less expensive. When using a desktop scanner, you should make sure that the active area is at least 9 × 9 inches, which enables you to capture the entire photo frame.

Desktop scanners are appropriate for less rigorous uses, such as digital photogrammetry in support of GIS or remote sensing applications. Calibrating these units improves geometric accuracy, but the results are still inferior to photogrammetric units. The image correlation techniques that are necessary for automatic tie point collection and elevation extraction are often sensitive to scan quality. Therefore, errors attributable to scanning errors can be introduced into GIS data that is photogrammetrically derived.

Scanning Resolutions

One of the primary factors contributing to the overall accuracy of block triangulation and orthorectification is the resolution of the imagery being used. Image resolution is commonly determined by the scanning resolution (if film photography is being used), or by the pixel resolution of the sensor.

In order to optimize the attainable accuracy of a solution, the scanning resolution must be considered. The appropriate scanning resolution is determined by balancing the accuracy requirements versus the size of the mapping project and the time required to process the project.

Table 2-1 lists the scanning resolutions associated with various scales of photography and image file size.

Table 2-1: Scanning Resolutions

Photo Scale 1 to	12 microns (2117 dpi) Ground Coverage (meters)	16 microns (1588 dpi) Ground Coverage (meters)	25 microns (1016 dpi) Ground Coverage (meters)	50 microns (508 dpi) Ground Coverage (meters)	85 microns (300 dpi) Ground Coverage (meters)
1800	0.0216	0.0288	0.045	0.09	0.153
2400	0.0288	0.0384	0.060	0.12	0.204
3000	0.0360	0.0480	0.075	0.15	0.255
3600	0.0432	0.0576	0.090	0.18	0.306
4200	0.0504	0.0672	0.105	0.21	0.357
4800	0.0576	0.0768	0.120	0.24	0.408
5400	0.0648	0.0864	0.135	0.27	0.459
6000	0.0720	0.0960	0.150	0.30	0.510
6600	0.0792	0.1056	0.165	0.33	0.561
7200	0.0864	0.1152	0.180	0.36	0.612
7800	0.0936	0.1248	0.195	0.39	0.663
8400	0.1008	0.1344	0.210	0.42	0.714
9000	0.1080	0.1440	0.225	0.45	0.765
9600	0.1152	0.1536	0.240	0.48	0.816
10800	0.1296	0.1728	0.270	0.54	0.918

Table 2-1: Scanning Resolutions (Continued)

Photo Scale 1 to	12 microns (2117 dpi) Ground Coverage (meters)	16 microns (1588 dpi) Ground Coverage (meters)	25 microns (1016 dpi) Ground Coverage (meters)	50 microns (508 dpi) Ground Coverage (meters)	85 microns (300 dpi) Ground Coverage (meters)
12000	0.1440	0.1920	0.300	0.60	1.020
15000	0.1800	0.2400	0.375	0.75	1.275
18000	0.2160	0.2880	0.450	0.90	1.530
24000	0.2880	0.3840	0.600	1.20	2.040
30000	0.3600	0.4800	0.750	1.50	2.550
40000	0.4800	0.6400	1.000	2.00	3.400
50000	0.6000	0.8000	1.250	2.50	4.250
60000	0.7200	0.9600	1.500	3.00	5.100
B/W File Size (MB)	363	204	84	21	7
Color File Size (MB)	1089	612	252	63	21

The Ground Coverage column refers to the ground coverage per pixel. Thus, a 1:40,000 scale black and white photograph scanned at 25 microns (1016 dpi) has a ground coverage per pixel of 1 m × 1 m. The resulting file size is approximately 85 MB, assuming a square 9 × 9 inch photograph.

Coordinate Systems

Conceptually, photogrammetry involves establishing the relationship between the camera or sensor used to capture the imagery, the imagery itself, and the ground. In order to understand and define this relationship, each of the three variables associated with the relationship must be defined with respect to a coordinate space and coordinate system.

Pixel Coordinate System

The file coordinates of a digital image are defined in a pixel coordinate system. A pixel coordinate system is usually a coordinate system with its origin in the upper-left corner of the image, the x-axis pointing to the right, the y-axis pointing downward, and the units in pixels, as shown by axes *c* and *r* in Figure 2-9. These file coordinates (*c*, *r*) can also be thought of as the pixel column and row number, respectively.

Figure 2-9: Pixel Coordinates vs. Image Coordinates

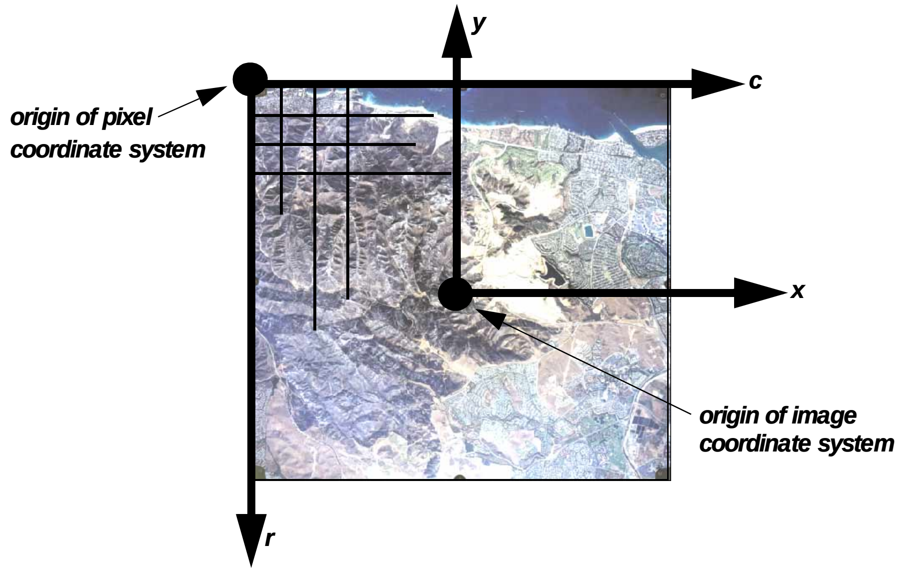


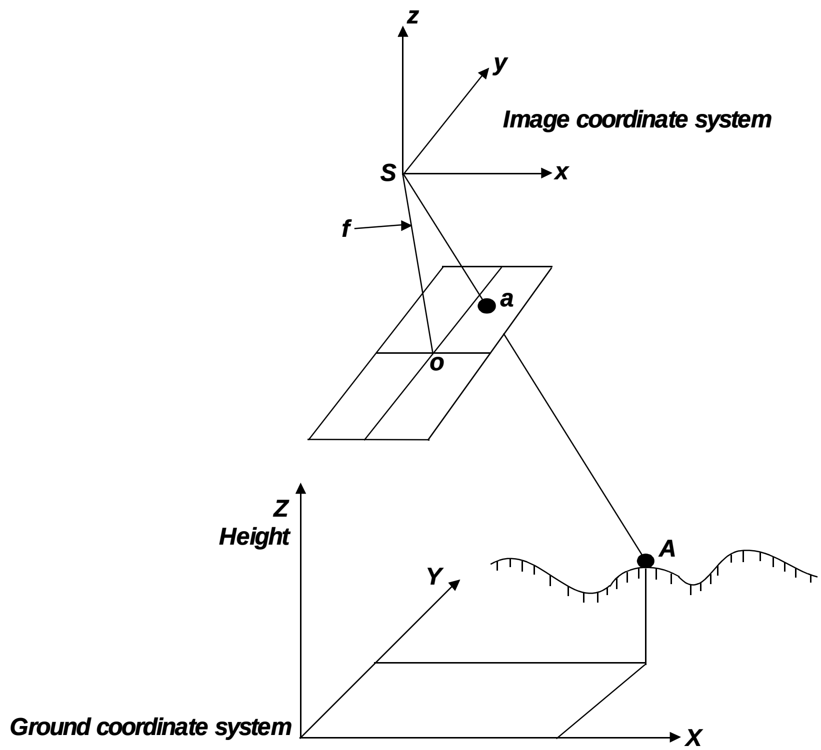
Image Coordinate System

An image coordinate system or an image plane coordinate system is usually defined as a two-dimensional (2D) coordinate system occurring on the image plane with its origin at the image center. The origin of the image coordinate system is also referred to as the principal point. On aerial photographs, the principal point is defined as the intersection of opposite fiducial marks as illustrated by axes *x* and *y* in Figure 2-9. Image coordinates are used to describe positions on the film plane. Image coordinate units are usually millimeters or microns.

Image Space Coordinate System

An image space coordinate system is identical to an image coordinate system, except that it adds a third axis (z) to indicate elevation. The origin of the image space coordinate system is defined at the perspective center *S* as shown in Figure 2-10. The perspective center is commonly the lens of the camera as it existed when the photograph was captured. Its x-axis and y-axis are parallel to the x-axis and y-axis in the image plane coordinate system. The z-axis is the optical axis, therefore the z value of an image point in the image space coordinate system is usually equal to -f (the focal length of the camera). Image space coordinates are used to describe positions inside the camera and usually use units in millimeters or microns. This coordinate system is referenced as image space coordinates (x, y, z) in this chapter.

Figure 2-10: Image Space and Ground Space Coordinate System



Ground Coordinate System

A ground coordinate system is usually defined as a 3D coordinate system that utilizes a known geographic map projection. Ground coordinates (X,Y,Z) are usually expressed in feet or meters. The Z value is elevation above mean sea level for a given vertical datum. This coordinate system is referenced as ground coordinates (X,Y,Z) in this chapter.

Geocentric and Topocentric Coordinate System

Most photogrammetric applications account for the Earth's curvature in their calculations. This is done by adding a correction value or by computing geometry in a coordinate system that includes curvature. Two such systems are geocentric and topocentric.

A geocentric coordinate system has its origin at the center of the Earth ellipsoid. The Z-axis equals the rotational axis of the Earth, and the X-axis passes through the Greenwich meridian. The Y-axis is perpendicular to both the Z-axis and X-axis, so as to create a three-dimensional coordinate system that follows the right hand rule.

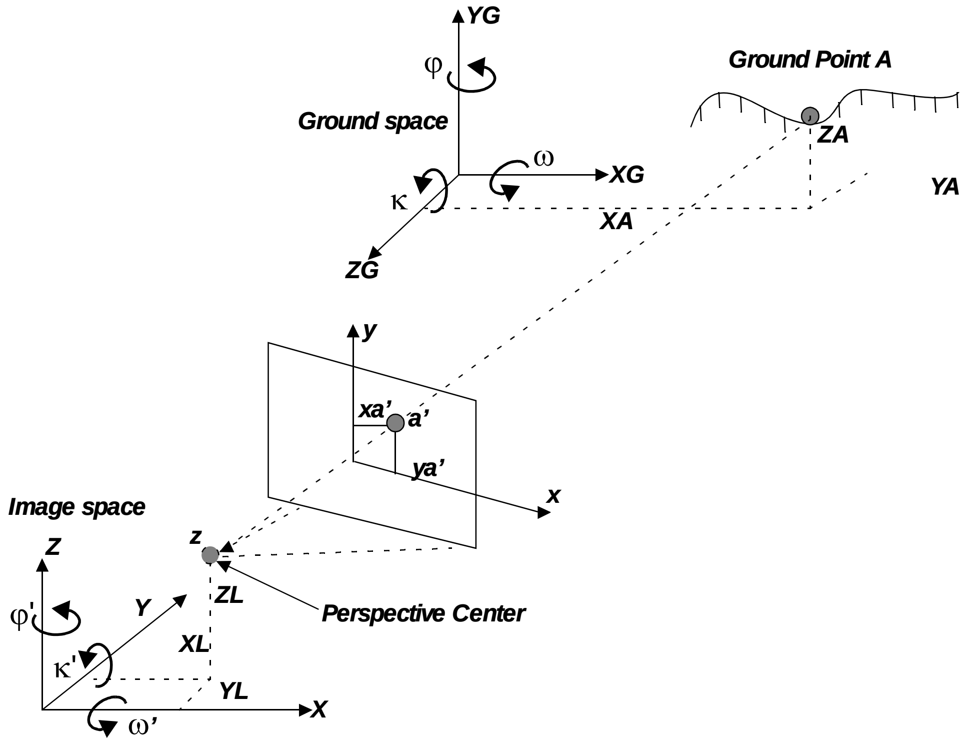
A topocentric coordinate system has its origin at the center of the image projected on the Earth ellipsoid. The three perpendicular coordinate axes are defined on a tangential plane at this center point. The plane is called the reference plane or the local datum. The x-axis is oriented eastward, the y-axis northward, and the z-axis is vertical to the reference plane (up).

For simplicity of presentation, the remainder of this chapter does not explicitly reference geocentric or topocentric coordinates. Basic photogrammetric principles can be presented without adding this additional level of complexity.

Terrestrial Photography

Photogrammetric applications associated with terrestrial or ground-based images utilize slightly different image and ground space coordinate systems. Figure 2-11 illustrates the two coordinate systems associated with image space and ground space.

Figure 2-11: Terrestrial Photography



The image and ground space coordinate systems are right-handed coordinate systems. Most terrestrial applications use a ground space coordinate system that was defined using a localized Cartesian coordinate system.

The image space coordinate system directs the z-axis toward the imaged object and the y-axis directed north up. The image x-axis is similar to that used in aerial applications. The X_L, Y_L, and Z_L coordinates define the position of the perspective center as it existed at the time of image capture. The ground coordinates of Ground Point *A* (X_A, Y_A, and Z_A) are defined within the ground space coordinate system (X_G, Y_G, and Z_G).

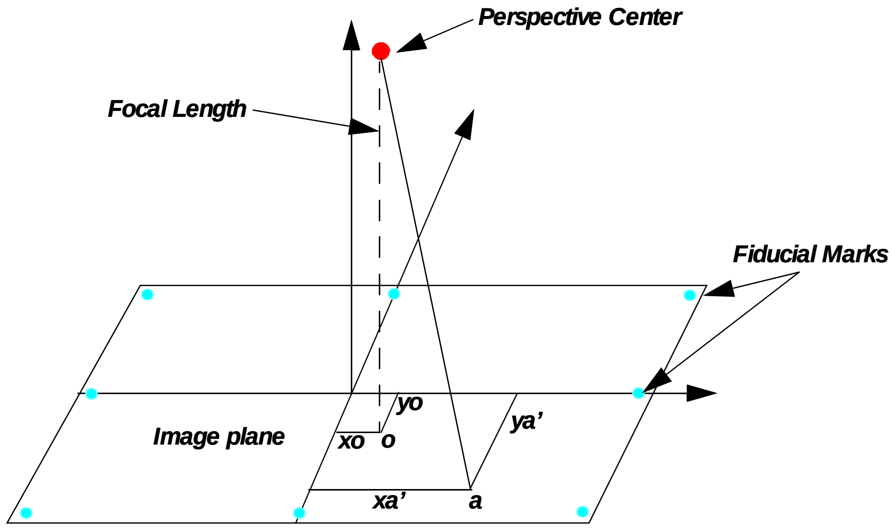
With this definition, the rotation angles ω (Omega), φ (Phi), and κ (Kappa) are still defined as in the aerial photography conventions. In OrthoBASE, you can also use the ground (X, Y, Z) coordinate system to directly define GCPs. Thus, GCPs do not need to be transformed. Then the definition of rotation angles ω', φ', and κ' is different, as shown in Figure 2-11.

Interior Orientation

Interior orientation defines the internal geometry of a camera or sensor as it existed at the time of image capture. The variables associated with image space are defined during the process of defining interior orientation. Interior orientation is primarily used to transform the image pixel coordinate system or other image coordinate measurement system to the image space coordinate system.

Figure 2-12 illustrates the variables associated with the internal geometry of an image captured from an aerial camera, where *o* represents the principal point and *a* represents an image point.

Figure 2-12: Internal Geometry



The internal geometry of a camera is defined by specifying the following variables:

- principal point
- focal length
- fiducial marks
- lens distortion

Principal Point and Focal Length

The principal point is mathematically defined as the intersection of the perpendicular line through the perspective center of the image plane. The length from the principal point to the perspective center is called the focal length (Wang, Z. 1990).

The image plane is commonly referred to as the focal plane. For wide-angle aerial cameras, the focal length is approximately 152 mm, or 6 in. For some digital cameras, the focal length is 28 mm. Prior to conducting photogrammetric projects, the focal length of a metric camera is accurately determined or calibrated in a laboratory environment.

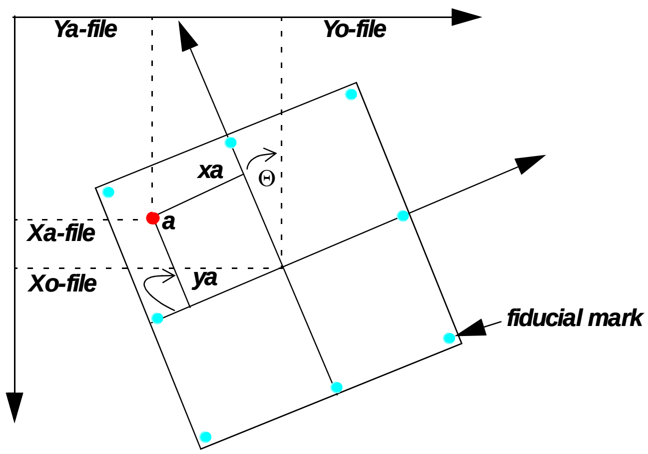
This mathematical definition is the basis of triangulation, but difficult to determine optically. The optical definition of principal point is the image position where the optical axis intersects the image plane. In the laboratory, this is calibrated in two forms: principal point of autocollimation and principal point of symmetry, which can be seen from the camera calibration report. Most applications prefer to use the principal point of symmetry since it can best compensate for any lens distortion.

Fiducial Marks

One of the steps associated with calculating interior orientation involves determining the image position of the principal point for each image in the project. Therefore, the image positions of the fiducial marks are measured on the image, and then compared to the calibrated coordinates of each fiducial mark.

Since the image space coordinate system has not yet been defined for each image, the measured image coordinates of the fiducial marks are referenced to a pixel or file coordinate system. The pixel coordinate system has an *x* coordinate (column) and a *y* coordinate (row). The origin of the pixel coordinate system is the upper left corner of the image having a row and column value of 0 and 0, respectively. Figure 2-13 illustrates the difference between the pixel and image space coordinate system.

Figure 2-13: Pixel Coordinate System vs. Image Space Coordinate System



Using a 2D affine transformation, the relationship between the pixel coordinate system and the image space coordinate system is defined. The following 2D affine transformation equations can be used to determine the coefficients required to transform pixel coordinate measurements to the corresponding image coordinate values:

$$x = a_1 + a_2X + a_3Y$$

$$y = b_1 + b_2X + b_3Y$$

The *x* and *y* image coordinates associated with the calibrated fiducial marks and the *X* and *Y* pixel coordinates of the measured fiducial marks are used to determine six affine transformation coefficients. The resulting six coefficients can then be used to transform each set of row (*y*) and column (*x*) pixel coordinates to image coordinates.

The quality of the 2D affine transformation is represented using a root mean square (RMS) error. The RMS error represents the degree of correspondence between the calibrated fiducial mark coordinates and their respective measured image coordinate values. Large RMS errors indicate poor correspondence. This can be attributed to film deformation, poor scanning quality, out-of-date calibration information, or image mismeasurement.

The affine transformation also defines the translation between the origin of the pixel coordinate system ($x_{a\text{-}file}$ and $y_{a\text{-}file}$) and the image coordinate system ($x_{o\text{-}file}$ and $y_{o\text{-}file}$). Additionally, the affine transformation takes into consideration rotation of the image coordinate system by considering angle Θ (theta). A scanned image of an aerial photograph is normally rotated due to the scanning procedure.

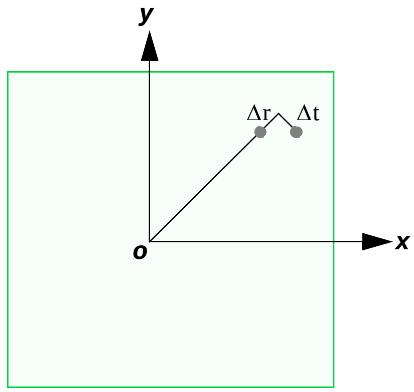
The degree of variation between the x- and y-axis is referred to as nonorthogonality. The 2D affine transformation also considers the extent of nonorthogonality. The scale difference between the x-axis and the y-axis is also considered using the affine transformation.

For more information, see *"Fiducial Orientation"*.

Lens Distortion

Lens distortion deteriorates the positional accuracy of image points located on the image plane. Two types of lens distortion exist: radial and tangential lens distortion. Lens distortion occurs when light rays passing through the lens are bent, thereby changing directions and intersecting the image plane at positions deviant from the norm. Figure 2-14 illustrates the difference between radial and tangential lens distortion.

Figure 2-14: Radial vs. Tangential Lens Distortion



Radial lens distortion causes imaged points to be distorted along radial lines from the principal point *o*. The effect of radial lens distortion is represented as Δr. Radial lens distortion is also commonly referred to as symmetric lens distortion.

Tangential lens distortion occurs at right angles to the radial lines from the principal point. The effect of tangential lens distortion is represented as Δt. Because tangential lens distortion is much smaller in magnitude than radial lens distortion, it is considered negligible. The effects of lens distortion are commonly determined in a laboratory during the camera calibration procedure.

The effects of radial lens distortion throughout an image can be approximated using a polynomial. The following polynomial is used to determine coefficients associated with radial lens distortion:

$$\Delta r = k_0 r + k_1 r^3 + k_2 r^5$$

where Δr represents the radial distortion along a radial distance r from the principal point (Wolf 1983). In most camera calibration reports, the lens distortion value is provided as a function of radial distance from the principal point or field angle. OrthoBASE accommodates radial lens distortion parameters in both scenarios.

Three coefficients—k_0, k_1, and k_2—are computed using statistical techniques. Once the coefficients are computed, each measurement taken on an image is corrected for radial lens distortion.

Exterior Orientation

Exterior orientation defines the position and angular orientation of the camera that captured an image. The variables defining the position and orientation of an image are referred to as the elements of exterior orientation. The elements of exterior orientation define the characteristics associated with an image at the time of exposure or capture. The positional elements of exterior orientation include *Xo*, *Yo*, and *Zo*. They define the position of the perspective center (*O*) with respect to the ground space coordinate system (*X*, *Y*, and *Z*). *Zo* is commonly referred to as the height of the camera above sea level, which is commonly defined by a datum.

The angular or rotational elements of exterior orientation describe the relationship between the ground space coordinate system (*X*, *Y*, and *Z*) and the image space coordinate system (*x*, *y*, and *z*). Three rotation angles are commonly used to define angular orientation. They are omega (ω), phi (φ), and kappa (κ). Figure 2-15 illustrates the elements of exterior orientation. Figure 2-16 illustrates the individual angles (ω, φ, and κ) of exterior orientation.

Figure 2-15: Elements of Exterior Orientation

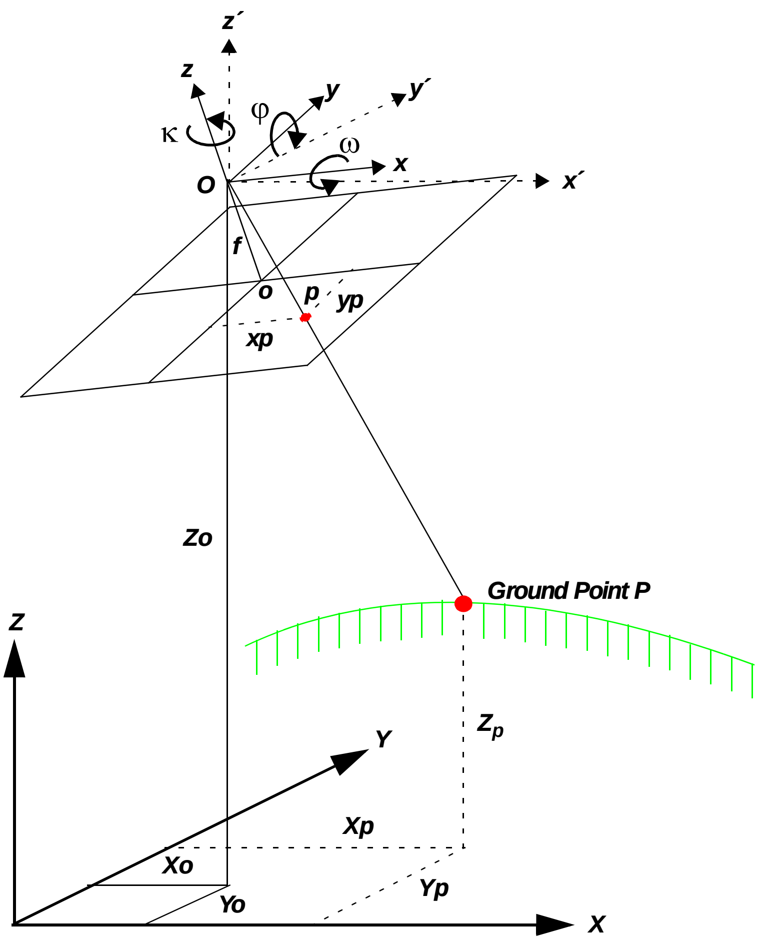
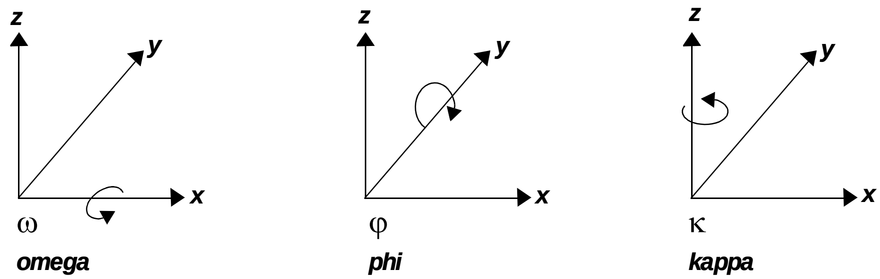


Figure 2-16: Omega, Phi, and Kappa



Omega is a rotation about the photographic x-axis, phi is a rotation about the photographic y-axis, and kappa is a rotation about the photographic z-axis. Rotations are defined as being positive if they are counterclockwise when viewed from the positive end of their respective axis. Different conventions are used to define the order and direction of the three rotation angles (Wang, Z. 1990). The ISPRS recommends the use of the ω, φ, κ convention. The photographic z-axis is equivalent to the optical axis (focal length). The *x'*, *y'*, and *z'* coordinates are parallel to the ground space coordinate system.

Rotation Matrix

Using the three rotation angles, the relationship between the image space coordinate system (*x*, *y*, and *z*) and ground space coordinate system (*X*, *Y*, and *Z;* or *x'*, *y'*, and *z'*) can be determined. A 3 × 3 matrix defining the relationship between the two systems is used. This is referred to as the orientation or rotation matrix, *M*. The rotation matrix can be defined as follows:

$$M = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix}$$

The rotation matrix is derived by applying a sequential rotation of omega about the x-axis, phi about the y-axis, and kappa about the z-axis.

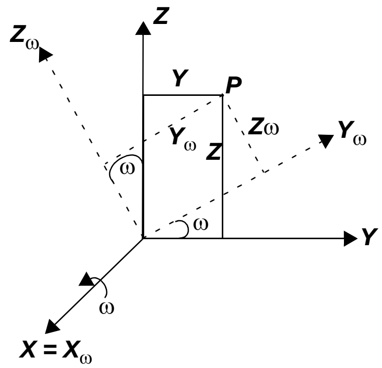
For more information, see "Rotation System Support".

Derivation of the Rotation Matrix

To derive the rotation matrix *M*, three rotations are performed sequentially: a primary rotation ω around the x-axis, followed by a secondary rotation φ around the y-axis, and a tertiary rotation κ around the z-axis.

Figure 2-17 illustrates the primary rotation ω about the x-axis.

Figure 2-17: Primary Rotation Omega About the X-axis



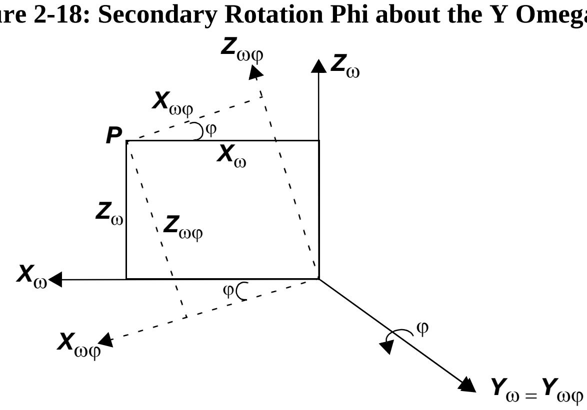
From Figure 2-17 above,

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\omega & -\sin\omega \\ 0 & \sin\omega & \cos\omega \end{bmatrix} \begin{bmatrix} X_\omega \\ Y_\omega \\ Z_\omega \end{bmatrix} = M_\omega \begin{bmatrix} X_\omega \\ Y_\omega \\ Z_\omega \end{bmatrix}$$

Equation 1

Secondary rotation φ about the Y_ω-axis is depicted in Figure 2-18.

Figure 2-18: Secondary Rotation Phi about the Y Omega-axis



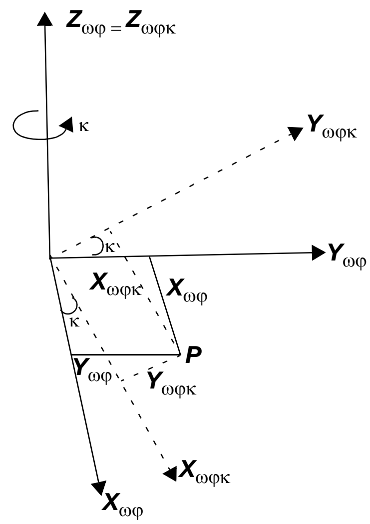
From Figure 2-18 above,

$$\begin{bmatrix} X_\omega \\ Y_\omega \\ Z_\omega \end{bmatrix} = \begin{bmatrix} \cos\varphi & 0 & \sin\varphi \\ 0 & 1 & 0 \\ -\sin\varphi & 0 & \cos\varphi \end{bmatrix} \begin{bmatrix} X_{\omega\varphi} \\ Y_{\omega\varphi} \\ Z_{\omega\varphi} \end{bmatrix} = M_\varphi \begin{bmatrix} X_{\omega\varphi} \\ Y_{\omega\varphi} \\ Z_{\omega\varphi} \end{bmatrix}$$

Equation 2

Figure 2-19 shows tertiary rotation κ around the $Z_{\omega\varphi}$ -axis:

Figure 2-19: Tertiary Rotation Kappa About the Z Omega Phi-axis



From Figure 2-19 above,

$$\begin{bmatrix} X_{\omega\varphi} \\ Y_{\omega\varphi} \\ Z_{\omega\varphi} \end{bmatrix} = \begin{bmatrix} \cos\kappa & -\sin\kappa & 0 \\ \sin\kappa & \cos\kappa & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_{\omega\varphi\kappa} \\ Y_{\omega\varphi\kappa} \\ Z_{\omega\varphi\kappa} \end{bmatrix} = M_{\kappa} \begin{bmatrix} X_{\omega\varphi\kappa} \\ Y_{\omega\varphi\kappa} \\ Z_{\omega\varphi\kappa} \end{bmatrix}$$ **Equation 3**

By combining Equation 1, Equation 2, and Equation 3, a relationship can be defined between the coordinates of an object point (P) relative to the (X, Y, Z) and ($X_{\omega\varphi\kappa}$, $Y_{\omega\varphi\kappa}$, $Z_{\omega\varphi\kappa}$) coordinate systems:

$$P = M_{\omega} \times M_{\varphi} \times M_{\kappa} \times P_{\omega\varphi\kappa}$$ **Equation 4**

In Equation 4, replace

$$M_{\omega} \times M_{\varphi} \times M_{\kappa}$$

with M, which is a 3×3 matrix:

$$M = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix}$$

where each entry of the matrix can be computed by:

$$M_{11} = \cos\varphi \times \cos\kappa$$
$$M_{12} = -\cos\varphi \times \sin\kappa$$
$$M_{13} = \sin\varphi$$

$$M_{21} = \cos\omega \times \sin\kappa + \sin\omega \times \sin\varphi \times \cos\kappa$$
$$M_{22} = \cos\omega \times \cos\kappa - \sin\omega \times \sin\varphi \times \sin\kappa$$
$$M_{23} = \sin\omega \times \cos\varphi$$

$$M_{31} = \sin\omega \times \sin\kappa - \cos\omega \times \sin\varphi \times \cos\kappa$$
$$M_{32} = \sin\omega \times \cos\kappa + \cos\omega \times \sin\varphi \times \sin\kappa$$
$$M_{33} = \cos\omega \times \cos\varphi$$

The Collinearity Equation

The following section defines the relationship between the camera/sensor, the image, and the ground. Most photogrammetric tools utilize the following formulas in one form or another.

With reference to Figure 2-15, an image vector *a* can be defined as the vector from the exposure station *O* to the Image Point *p*. A ground space or object space vector *A* can be defined as the vector from the exposure station *O* to the Ground Point *P*. The image vector and ground vector are collinear, inferring that a line extending from the exposure station to the image point and to the ground is linear.

The image vector and ground vector are only collinear if one is a scalar multiple of the other. Therefore, the following statement can be made:

$$a = kA$$

In this equation, *k* is a scalar multiple. The image and ground vectors must be within the same coordinate system. Therefore, image vector *a* is comprised of the following components:

$$a = \begin{bmatrix} x_p - x_o \\ y_p - y_o \\ -f \end{bmatrix}$$

Here, x_o and y_o represent the image coordinates of the principal point.

Similarly, the ground vector can be formulated as follows:

$$A = \begin{bmatrix} X_p - X_o \\ Y_p - Y_o \\ Z_p - Z_o \end{bmatrix}$$

In order for the image and ground vectors to be within the same coordinate system, the ground vector must be multiplied by the rotation matrix *M*. The following equation can be formulated:

$$a = kMA$$

where,

$$\begin{bmatrix} x_p - x_o \\ y_p - y_o \\ -f \end{bmatrix} = kM \begin{bmatrix} X_p - X_o \\ Y_p - Y_o \\ Z_p - Z_o \end{bmatrix}$$

The above equation defines the relationship between the perspective center of the camera/sensor exposure station and ground point *P* appearing on an image with an image point location of *p*. This equation forms the basis of the collinearity condition that is used in most photogrammetric operations.

The collinearity condition specifies that the exposure station, ground point, and its corresponding image point location must all lie along a straight line, thereby being collinear. Two equations comprise the collinearity condition:

$$x_p - x_o = -f\left[\frac{m_{11}(X_p - X_{o_1}) + m_{12}(Y_p - Y_{o_1}) + m_{13}(Z_p - Z_{o_1})}{m_{31}(X_p - X_{o_1}) + m_{32}(Y_p - Y_{o_1}) + m_{33}(Z_p - Z_{o_1})}\right]$$

$$y_p - y_o = -f\left[\frac{m_{21}(X_p - X_{o_1}) + m_{22}(Y_p - Y_{o_1}) + m_{23}(Z_p - Z_{o_1})}{m_{31}(X_p - X_{o_1}) + m_{32}(Y_p - Y_{o_1}) + m_{33}(Z_p - Z_{o_1})}\right]$$

One set of equations can be formulated for each ground point appearing on an image. The collinearity condition is commonly used to define the relationship between the camera/sensor, the image, and the ground.

Photogrammetric Solutions

As stated previously, digital photogrammetry is used for many applications, ranging from orthorectification, automated elevation extraction, stereopair creation, feature collection, highly accurate point determination, and control point extension.

For any of the aforementioned tasks to be undertaken, a relationship between the camera/sensor, the image(s) in a project, and the ground must be defined. The following variables are used to define the relationship:

- exterior orientation parameters for each image
- interior orientation parameters for each image
- accurate representation of the ground

Well-known obstacles in photogrammetry include defining the interior and exterior orientation parameters for each image in a project using a minimum number of GCPs. Due to the time-consuming and labor intensive procedures associated with collecting ground control, most photogrammetric applications do not have an abundant number3 of GCPs. Additionally, the exterior orientation parameters associated with an image are normally unknown.

Depending on the input data provided, photogrammetric techniques such as space resection, space forward intersection, and bundle block adjustment are used to define the variables required to perform orthorectification, automated DEM extraction, stereopair creation, highly accurate point determination, and control point extension.

Space Resection

Space resection is a technique that is commonly used to determine the exterior orientation parameters associated with one image or many images based on known GCPs. Space resection uses the collinearity condition. Space resection using the collinearity condition specifies that, for any image, the exposure station, the ground point, and its corresponding image point must lie along a straight line.

If a minimum of three GCPs is known in the X, Y, and Z direction, space resection techniques can be used to determine the six exterior orientation parameters associated with an image. Space resection assumes that camera information is available.

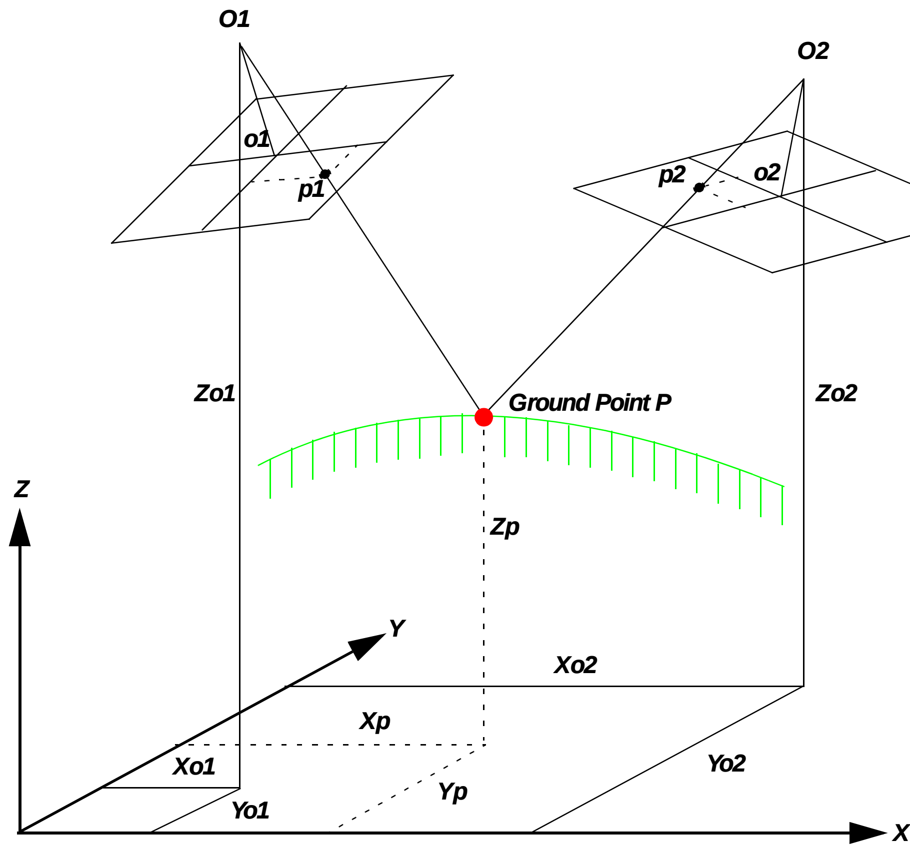
Space resection is commonly used to perform single frame orthorectification, where one image is processed at a time. If multiple images are being used, space resection techniques require that a minimum of three GCPs be located on each image being processed.

Using the collinearity condition, the positions of the exterior orientation parameters are computed. Light rays originating from at least three GCPs intersect through the image plane, through the image positions of the GCPs, and resect at the perspective center of the camera or sensor. Using least squares adjustment techniques, the most probable positions of exterior orientation can be computed. Space resection techniques can be applied to one image or multiple images.

Space Forward Intersection

Space forward intersection is a technique that is commonly used to determine the ground coordinates X, Y, and Z of points that appear in the overlapping areas of two or more images based on known interior and exterior orientation parameters. The collinearity condition is enforced, stating that the corresponding light rays from the two exposure stations pass through the corresponding image points on the two images, and intersect at the same ground point. Figure 2-20 illustrates the concept associated with space forward intersection.

Figure 2-20: Space Forward Intersection



Space forward intersection techniques assume that the exterior orientation parameters associated with the images are known. Using the collinearity equations, the exterior orientation parameters along with the image coordinate measurements of point *p1* on Image 1 and point *p2* on Image 2 are input to compute the X_p, Y_p, and Z_p coordinates of ground point *P*.

Space forward intersection techniques can also be used for applications associated with collecting GCPs, cadastral mapping using airborne surveying techniques, and highly accurate point determination.

Bundle Block Adjustment

For mapping projects having more than two images, the use of space intersection and space resection techniques is limited. This can be attributed to the lack of information required to perform these tasks. For example, it is fairly uncommon for the exterior orientation parameters to be highly accurate for each photograph or image in a project, since these values are generated photogrammetrically. Airborne GPS and INS techniques normally provide initial approximations to exterior orientation, but the final values for these parameters must be adjusted to attain higher accuracies.

Similarly, rarely are there enough accurate GCPs for a project of 30 or more images to perform space resection (i.e., a minimum of 90 is required). In the case that there are enough GCPs, the time required to identify and measure all of the points would be lengthy.

The costs associated with block triangulation and subsequent orthorectification are largely dependent on the number of GCPs used. To minimize the costs of a mapping project, fewer GCPs are collected and used. To ensure that high accuracies are attained, an approach known as bundle block adjustment is used.

A bundle block adjustment is best defined by examining the individual words in the term. A bundled solution is computed including the exterior orientation parameters of each image in a block and the X, Y, and Z coordinates of tie points and adjusted GCPs. A block of images contained in a project is simultaneously processed in one solution. A statistical technique known as least squares adjustment is used to estimate the bundled solution for the entire block while also minimizing and distributing error.

Block triangulation is the process of defining the mathematical relationship between the images contained within a block, the camera or sensor model, and the ground. Once the relationship has been defined, accurate imagery and geographic information concerning the Earth’s surface can be created.

When processing frame camera, digital camera, videography, and nonmetric camera imagery, block triangulation is commonly referred to as aerial triangulation (AT). When processing imagery collected with a pushbroom sensor, block triangulation is commonly referred to as triangulation.

There are several models for block triangulation. The common models used in photogrammetry are block triangulation with the strip method, the independent model method, and the bundle method. Among them, the bundle block adjustment is the most rigorous of the above methods, considering the minimization and distribution of errors. Bundle block adjustment uses the collinearity condition as the basis for formulating the relationship between image space and ground space. OrthoBASE uses bundle block adjustment techniques.

In order to understand the concepts associated with bundle block adjustment, an example comprising two images with three GCPs whose X, Y, and Z coordinates are known is used. Additionally, six tie points are available. Figure 2-21 illustrates the photogrammetric configuration. Figure 2-22 illustrates the photogrammetric configuration in the LPS Project Graphic Status window.

Figure 2-21: Photogrammetric Configuration

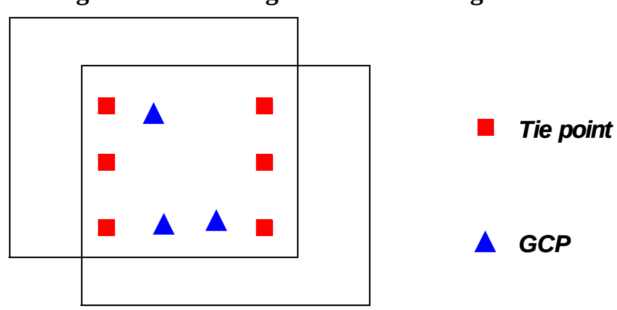
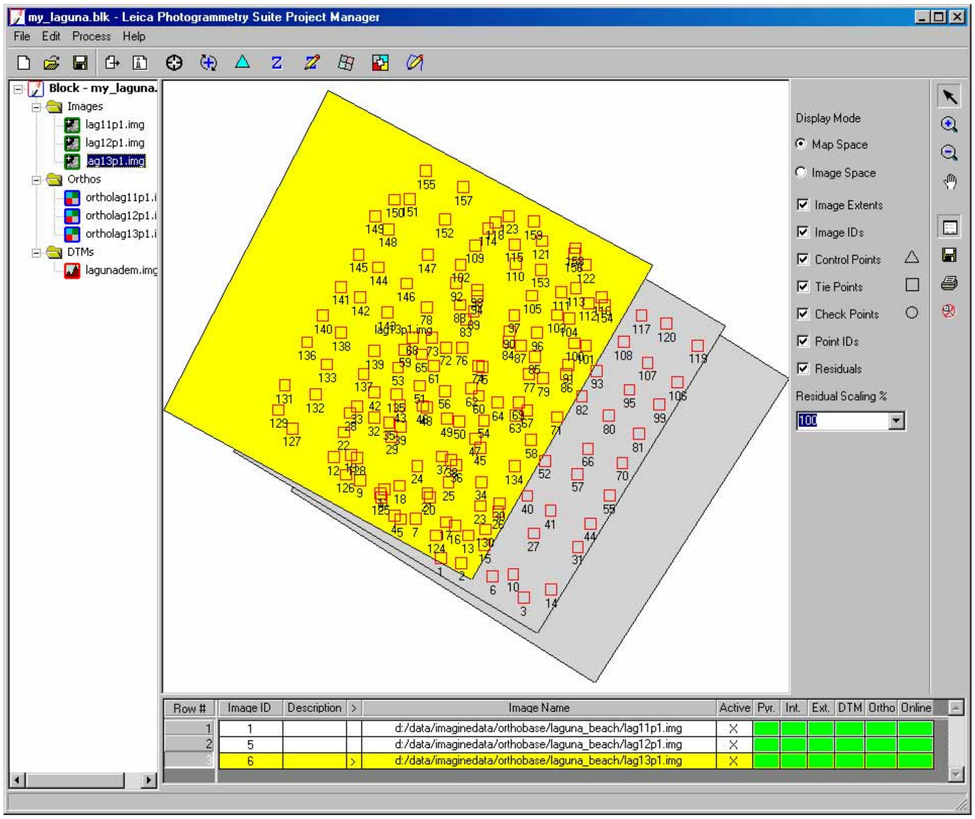


Figure 2-22: Photogrammetric Configuration - Project Graphic Status Window



Forming the Collinearity Equations

For each measured GCP, there are two corresponding image coordinates (x and y). Thus, two collinearity equations can be formulated to represent the relationship between the ground point and the corresponding image measurements. In the context of bundle block adjustment, these equations are known as observation equations.

If a GCP has been measured on the overlap area of two images, four equations can be written: two for image measurements on the left image comprising the pair and two for the image measurements made on the right image comprising the pair. Thus, GCP *A* measured on the overlap area of image left and image right has four collinearity formulas:

$$x_{a_1} - x_o = -f\left[\frac{m_{11}(X_A - X_{o_1}) + m_{12}(Y_A - Y_{o_1}) + m_{13}(Z_A - Z_{o_1})}{m_{31}(X_A - X_{o_1}) + m_{32}(Y_A - Y_{o_1}) + m_{33}(Z_A - Z_{o_1})}\right]$$

$$y_{a_1} - y_o = -f\left[\frac{m_{21}(X_A - X_{o_1}) + m_{22}(Y_A - Y_{o_1}) + m_{23}(Z_A - Z_{o_1})}{m_{31}(X_A - X_{o_1}) + m_{32}(Y_A - Y_{o_1}) + m_{33}(Z_A - Z_{o_1})}\right]$$

$$x_{a_2} - x_o = -f\left[\frac{m'_{11}(X_A - X_{o_2}) + m'_{12}(Y_A - Y_{o_2}) + m'_{13}(Z_A - Z_{o_2})}{m'_{31}(X_A - X_{o_2}) + m'_{32}(Y_A - Y_{o_2}) + m'_{33}(Z_A - Z_{o_2})}\right]$$

$$y_{a_2} - y_o = -f\left[\frac{m'_{21}(X_A - X_{o_2}) + m'_{22}(Y_A - Y_{o_2}) + m'_{23}(Z_A - Z_{o_2})}{m'_{31}(X_A - X_{o_2}) + m'_{32}(Y_A - Y_{o_2}) + m'_{33}(Z_A - Z_{o_2})}\right]$$

One image measurement of GCP *A* on Image 1:

$$x_{a_1}, y_{a_1}$$

One image measurement of GCP *A* on Image 2:

$$x_{a_2}, y_{a_2}$$

Positional elements of exterior orientation on Image 1:

$$X_{o_1}, Y_{o_1}, Z_{o_1}$$

Positional elements of exterior orientation on Image 2:

$$X_{o_2}, Y_{o_2}, Z_{o_2}$$

If three GCPs have been measured on the overlap area of two images, twelve equations can be formulated (four equations for each GCP).

Additionally, if six tie points have been measured on the overlap areas of the two images, twenty-four equations can be formulated (four for each tie point). This is a total of 36 observation equations.

The previous scenario has the following unknowns:

- six exterior orientation parameters for the left image (i.e., X, Y, Z, omega, phi, kappa)
- six exterior orientation parameters for the right image (i.e., X, Y, Z, omega, phi, kappa)

- X, Y, and Z coordinates of the tie points. Thus, for six tie points, this includes eighteen unknowns (six tie points times three X, Y, Z coordinates)

The total number of unknowns is 30. The overall quality of a bundle block adjustment is largely a function of the quality and redundancy in the input data. In this scenario, the redundancy in the project can be computed by subtracting the number of unknowns, 30, from the number of knowns, 36. The resulting redundancy is six. This term is commonly referred to as the degrees of freedom in a solution.

Once each observation equation is formulated, the collinearity condition can be solved using an approach referred to as least squares adjustment.

Least Squares Adjustment

Least squares adjustment is a statistical technique that is used to estimate the unknown parameters associated with a solution while also minimizing error within the solution. With respect to block triangulation, least squares adjustment techniques are used to:

- estimate or adjust the values associated with exterior orientation
- estimate the X, Y, and Z coordinates associated with tie points
- estimate or adjust the values associated with interior orientation
- minimize and distribute data error through the network of observations

Data error is attributed to the inaccuracy associated with the input GCP coordinates, measured tie point and GCP image positions, camera information, and systematic errors.

The least squares approach requires iterative processing until a solution is attained. A solution is obtained when the residuals, or errors, associated with the input data are minimized.

The least squares approach involves determining the corrections to the unknown parameters based on the criteria of minimizing input measurement residuals. The residuals are derived from the difference between the measured (i.e., user input) and computed value for any particular measurement in a project. In the block triangulation process, a functional model can be formed based upon the collinearity equations.

The functional model refers to the specification of an equation that can be used to relate measurements to parameters. In the context of photogrammetry, measurements include the image locations of GCPs and GCP coordinates, while the exterior orientations of all the images are important parameters estimated by the block triangulation process.

The residuals, which are minimized, include the image coordinates of the GCPs and tie points along with the known ground coordinates of the GCPs. A simplified version of the least squares condition can be broken down into a formula that includes a weight matrix *P*, as follows:

$$V = AX - L$$

In this equation,

V = the matrix containing the image coordinate residuals

A = the matrix containing the partial derivatives with respect to the unknown parameters, including exterior orientation, interior orientation, XYZ tie point, and GCP coordinates

X = the matrix containing the corrections to the unknown parameters

L = the matrix containing the input observations (i.e., image coordinates and GCP coordinates)

The components of the least squares condition are directly related to the functional model based on collinearity equations. The *A* matrix is formed by differentiating the functional model, which is based on collinearity equations, with respect to the unknown parameters such as exterior orientation, etc. The *L* matrix is formed by subtracting the initial results obtained from the functional model with newly estimated results determined from a new iteration of processing. The *X* matrix contains the corrections to the unknown exterior orientation parameters. The *X* matrix is calculated in the following manner:

$$X = (A^t PA)^{-1} A^t PL$$

In this equation,

X = the matrix containing the corrections to the unknown parameters ^{t}

A = the matrix containing the partial derivatives with respect to the unknown parameters

^{t} = the matrix transposed

P = the matrix containing the weights of the observations

L = the matrix containing the observations

Once a least squares iteration of processing is completed, the corrections to the unknown parameters are added to the initial estimates. For example, if initial approximations to exterior orientation are provided from airborne GPS and INS information, the estimated corrections computed from the least squares adjustment are added to the initial value to compute the updated exterior orientation values. This iterative process of least squares adjustment continues until the corrections to the unknown parameters are less than a user-specified threshold (commonly referred to as a convergence value).

The *V* residual matrix is computed at the end of each iteration of processing. Once an iteration is complete, the new estimates for the unknown parameters are used to recompute the input observations such as the image coordinate values. The difference between the initial measurements and the new estimates is obtained to provide the residuals. Residuals provide preliminary indications of the accuracy of a solution. The residual values indicate the degree to which a particular observation (input) fits with the functional model. For example, the image residuals have the capability of reflecting GCP collection in the field. After each successive iteration of processing, the residuals become smaller until they are satisfactorily minimized.

Once the least squares adjustment is completed, the block triangulation results include:

- final exterior orientation parameters of each image in a block and their accuracy
- final interior orientation parameters of each image in a block and their accuracy
- X, Y, and Z tie point coordinates and their accuracy
- adjusted GCP coordinates and their residuals

- image coordinate residuals

The results from the block triangulation are then used as the primary input for the following tasks:

- stereopair creation
- feature collection
- highly accurate point determination
- DEM extraction
- orthorectification

Self-calibrating Bundle Adjustment

Normally, there are more or less systematic errors related to the imaging and processing system, such as lens distortion, film distortion, atmosphere refraction, scanner errors, and so on. These errors reduce the accuracy of triangulation results, especially in dealing with large-scale imagery and high accuracy triangulation. There are several ways to reduce the influences of the systematic errors, like a posteriori compensation, test-field calibration, and the most common approach—self-calibration (Konecny 1994; Wang, Z. 1990).

The self-calibrating methods use additional parameters in the triangulation process to eliminate the systematic errors. How well it works depends on many factors such as the strength of the block (overlap amount, crossing flight lines), the GCP and tie point distribution and amount, the size of systematic errors versus random errors, the significance of the additional parameters, the correlation between additional parameters, and other unknowns.

There was intensive research and development for additional parameter models in photogrammetry in the ‘70s and the ‘80s, and many research results are available (e.g., Bauer and Müller 1972; Ebner 1976; Grün 1978; Jacobsen 1980 and Jacobsen 1982; Li 1985; Wang, Y. 1988; and Stojic, Chandler, Ashmore, and Luce 1998). Based on these scientific reports, OrthoBASE provides four groups of additional parameters for you to choose in different triangulation circumstances. In addition, OrthoBASE allows the interior orientation parameters to be analytically calibrated with its self-calibrating bundle block adjustment.

Automatic Gross Error Detection

Normal random errors are subject to statistical normal distribution. In contrast, gross errors refer to errors that are large and are not subject to normal distribution. The gross errors among the input data for triangulation can lead to unreliable results. Research during the ′80s in the photogrammetric community resulted in significant achievements in automatic gross error detection in the triangulation process (e.g., Kubik 1982; Li 1983 and Li 1985; Jacobsen 1984; El-Hakim and Ziemann 1984; Wang, Y. 1988).

Methods for gross error detection began with residual checking using data-snooping and were later extended to robust estimation (Wang, Z. 1990). The most common robust estimation method is the iteration with selective weight functions. Based on the scientific research results from the photogrammetric community, OrthoBASE offers two robust error detection methods within the triangulation process.

For more information, see “Automated Gross Error Checking”.

The effect of the automatic error detection depends not only on the mathematical model, but also depends on the redundancy in the block. Therefore, more tie points in more overlap areas contribute better gross error detection. In addition, inaccurate GCPs can distribute their errors to correct tie points; therefore, the ground and image coordinates of GCPs should have better accuracy than tie points when comparing them within the same scale space.

GCPs

The instrumental component of establishing an accurate relationship between the images in a project, the camera/sensor, and the ground is GCPs. GCPs are identifiable features located on the Earth's surface whose ground coordinates in X, Y, and Z are known. A full GCP has associated with it X, Y, and Z (elevation of the point) coordinates. A horizontal GCP only specifies the X, Y coordinates, while a vertical GCP only specifies the Z coordinate.

The following features on the Earth's surface are commonly used as GCPs:

- intersection of roads
- utility infrastructure (e.g., fire hydrants and manhole covers)
- intersection of agricultural plots of land
- survey benchmarks

Depending on the type of mapping project, GCPs can be collected from the following sources:

- theodolite survey (millimeter to centimeter accuracy)
- total station survey (millimeter to centimeter accuracy)
- ground GPS (centimeter to meter accuracy)
- planimetric and topographic maps (accuracy varies as a function of map scale, approximate accuracy between several meters to 40 meters or more)
- digital orthorectified images (X and Y coordinates can be collected to an accuracy dependent on the resolution of the orthorectified image)
- DEMs (for the collection of vertical GCPs having Z coordinates associated with them, where accuracy is dependent on the resolution of the DEM and the accuracy of the input DEM)

When imagery or photography is exposed, GCPs are recorded and subsequently displayed on the photograph or image. During GCP measurement in OrthoBASE, the image positions of GCPs appearing on an image, or on the overlap area of the images, are collected.

It is highly recommended that a greater number of GCPs be available than are actually used in the block triangulation. Additional GCPs can be used as check points to independently verify the overall quality and accuracy of the block triangulation solution. A check point analysis compares the photogrammetrically computed ground coordinates of the check points to the original values. The result of the analysis is an RMSE that defines the degree of correspondence between the computed values and the original values. Lower RMSE values indicate better results.

GCP Requirements

The minimum GCP requirements for an accurate mapping project vary with respect to the size of the project. With respect to establishing a relationship between image space and ground space, the theoretical minimum number of GCPs is two GCPs having X, Y, and Z coordinates (six observations) and one GCP having a Z coordinate (one observation). This is a total of seven observations.

In establishing the mathematical relationship between image space and object space, seven parameters defining the relationship must be determined. The seven parameters include a scale factor (describing the scale difference between image space and ground space); X, Y, and Z (defining the positional differences between image space and object space); and three rotation angles (omega, phi, and kappa) defining the rotational relationship between image space and ground space.

In order to compute a unique solution, at least seven known parameters must be available. In using the two XYZ GCPs and one vertical (Z) GCP, the relationship can be defined. However, to increase the accuracy of a mapping project, using more GCPs is highly recommended.

The following descriptions are provided for various projects:

Processing One Image

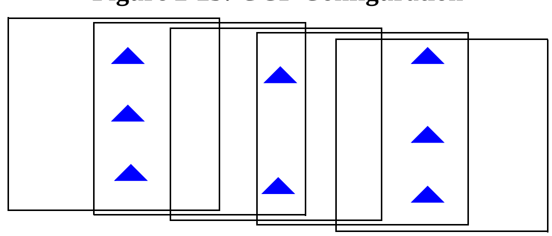
When processing one image for the purpose of orthorectification (i.e., a single frame orthorectification), the minimum number of GCPs required is three. Each GCP must have an X, Y, and Z coordinate associated with it. The GCPs should be evenly distributed to ensure that the camera/sensor is accurately modeled.

Processing a Strip of Images

When processing a strip of adjacent images, two GCPs for every third image are recommended. To increase the quality of orthorectification, measuring three GCPs at the corner edges of a strip is advantageous. Thus, during block triangulation a stronger geometry can be enforced in areas where there is less redundancy such as the corner edges of a strip or a block.

Figure 2-23 illustrates the GCP configuration for a strip of images having 60% overlap. The triangles represent the GCPs. Thus, the image positions of the GCPs are measured on the overlap areas of the imagery.

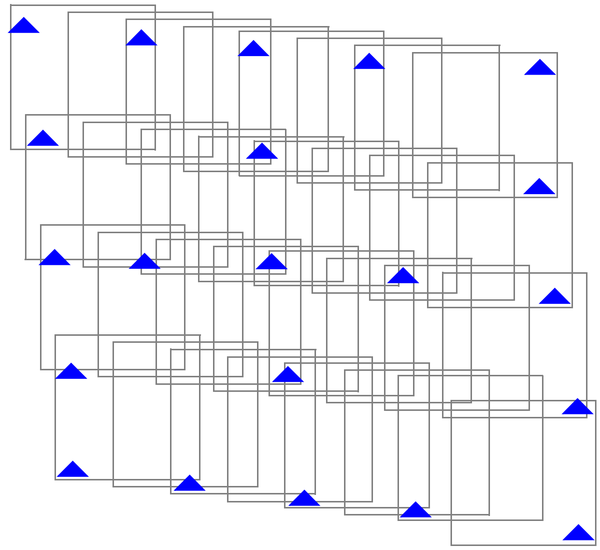
Figure 2-23: GCP Configuration



Processing Multiple Strips of Imagery

Figure 2-24 depicts the standard GCP configuration for a block of images, comprising four strips of images, each containing eight overlapping images.

Figure 2-24: GCPs in a Block of Images



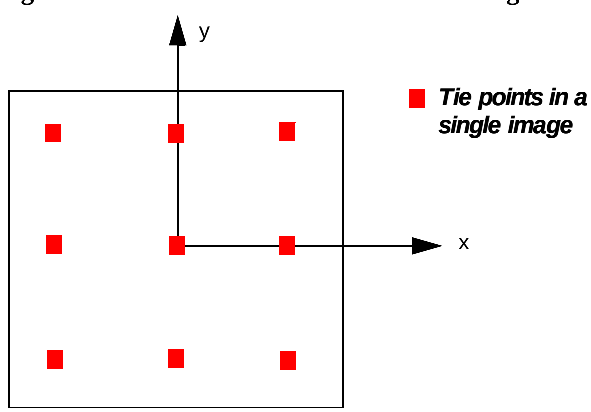
In this case, the GCPs form a strong geometric network of observations. As a general rule, it is advantageous to have at least one GCP on every third image of a block. Additionally, whenever possible, locate GCPs that lie on multiple images, around the outside edges of a block and at certain distances from one another within the block.

Tie Points

A tie point is a point whose ground coordinates are not known, but is visually recognizable in the overlap area between two or more images. The corresponding image positions of tie points appearing on the overlap areas of multiple images is identified and measured. Ground coordinates for tie points are computed during block triangulation. Tie points can be measured both manually and automatically.

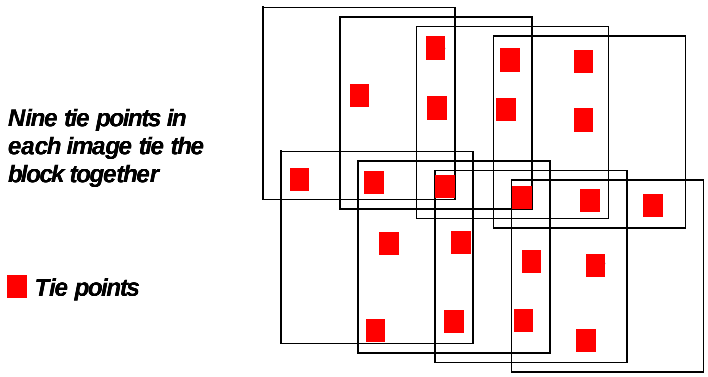
Tie points should be visually defined in all images. Ideally, they should show good contrast in two directions, like the corner of a building or a road intersection. Tie points should also be distributed over the area of the block. Typically, nine tie points in each image are adequate for block triangulation. Figure 2-25 depicts the placement of tie points.

Figure 2-25: Tie Point Distribution for Triangulation



In a block of images with 60% overlap and 25-30% sidelap, nine points are sufficient to tie together the block as well as individual strips (see Figure 2-26).

Figure 2-26: Tie Points in a Block



Automatic Tie Point Collection

Selecting and measuring tie points is very time-consuming. In recent years, one of the major focal points of research and development in photogrammetry has been automated triangulation with automatic tie point collection as the main issue.

Another issue of automated triangulation is the automatic control point identification, which is still unsolved due to the complexity of the scenario. There are several valuable research results detailing automated triangulation (e.g., Agouris and Schenk 1996; Heipke 1996; Krzystek 1998; Mayr 1995; Schenk 1997; Tang, Braun, and Debitsch 1997; Tsingas 1995; Wang, Y. 1998).

After investigating the advantages and the weaknesses of the existing methods, OrthoBASE was designed to incorporate an advanced method for automatic tie point collection. It is designed to work with a variety of digital images such as aerial images, satellite images, digital camera images, and close-range images. It also supports the processing of multiple strips including adjacent, diagonal, and cross-strips.

Automatic tie point collection within OrthoBASE successfully performs the following tasks:

- Automatic block configuration. Based on the initial input requirements, OrthoBASE automatically detects the relationship of the block with respect to image adjacency.

- Automatic tie point extraction. The feature point extraction algorithms are used here to extract the candidates of tie points.

- Point transfer. Feature points appearing on multiple images are automatically matched and identified.

- Gross error detection. Erroneous points are automatically identified and removed from the solution.

- Tie point selection. The intended number of tie points defined by the user is automatically selected as the final number of tie points.

The image matching strategies incorporated in OrthoBASE for automatic tie point collection include the coarse-to-fine matching; feature-based matching with geometrical and topological constraints, which is simplified from the structural matching algorithm (Wang, Y. 1998); and the least square matching for the high accuracy of tie points.

Image Matching Techniques

Image matching refers to the automatic identification and measurement of corresponding image points that are located on the overlapping areas of multiple images. The various image matching methods can be divided into three categories including:

- area-based matching
- feature-based matching
- relation-based matching

Area-based Matching

Area-based matching is also called signal based matching. This method determines the correspondence between two image areas according to the similarity of their gray level values. The cross-correlation and least squares correlation techniques are well-known methods for area-based matching.

Correlation Windows

Area-based matching uses correlation windows. These windows consist of a local neighborhood of pixels. One example of correlation windows is square neighborhoods (e.g., 3 × 3, 5 × 5, 7 × 7 pixels). In practice, the windows vary in shape and dimension based on the matching technique. Area correlation uses the characteristics of these windows to match ground feature locations in one image to ground features on the other.

A reference window is the source window on the first image, which remains at a constant location. Its dimensions are usually square in size (e.g., 3 × 3, 5 × 5, etc.). Search windows are candidate windows on the second image that are evaluated relative to the reference window. During correlation, many different search windows are examined until a location is found that best matches the reference window.

Correlation Calculations

Two correlation calculations are described in the following sections: cross-correlation and least squares correlation. Most area-based matching calculations, including these methods, normalize the correlation windows. Therefore, it is not necessary to balance the contrast or brightness prior to running correlation. Cross-correlation is more robust in that it requires a less accurate a priori position than least squares. However, its precision is limited to one pixel. Least squares correlation can achieve precision levels of one-tenth of a pixel, but requires an a priori position that is accurate to about two pixels. In practice, cross-correlation is often followed by least squares for high accuracy.

Cross-correlation

Cross-correlation computes the correlation coefficient of the gray values between the template window and the search window according to the following equation:

$$\rho = \frac{\sum_{i,j}[g_1(c_1, r_1) - \bar{g}_1][g_2(c_2, r_2) - \bar{g}_2]}{\sqrt{\sum_{i,j}[g_1(c_1, r_1) - \bar{g}_1]^2 \sum_{i,j}[g_2(c_2, r_2) - \bar{g}_2]^2}}$$

with

$$\bar{g}_1 = \frac{1}{n}\sum_{i,j} g_1(c_1, r_1) \qquad \bar{g}_2 = \frac{1}{n}\sum_{i,j} g_2(c_2, r_2)$$

In the above equations,

ρ	=	the correlation coefficient
g(c,r)=		the gray value of the pixel (c,r)
c_1,r_1	=	the pixel coordinates on the left image
c_2,r_2	=	the pixel coordinates on the right image
n	=	the total number of pixels in the window
i, j	=	pixel index into the correlation window

When using the area-based cross-correlation, it is necessary to have a good initial position for the two correlation windows. If the exterior orientation parameters of the images being matched are known, a good initial position can be determined. However, if the contrast in the windows is very poor, the correlation can fail.

Least Squares Correlation

Least squares correlation uses the least squares estimation to derive parameters that best fit a search window to a reference window. This technique has been investigated thoroughly in photogrammetry (Ackermann 1983; Grün and Baltsavias 1988; Helava 1988). It accounts for both gray scale and geometric differences, making it especially useful when ground features on one image look somewhat different on the other image (differences which occur when the surface terrain is quite steep or when the viewing angles are quite different).

Least squares correlation is iterative. The parameters calculated during the initial pass are used in the calculation of the second pass and so on, until an optimum solution is determined. Least squares matching can result in high positional accuracy (about 0.1 pixels). However, it is sensitive to initial approximations. The initial coordinates for the search window prior to correlation must be accurate to about two pixels or better.

When least squares correlation fits a search window to the reference window, both radiometric (pixel gray values) and geometric (location, size, and shape of the search window) transformations are calculated.

For example, suppose the change in gray values between two correlation windows is represented as a linear relationship. Also assume that the change in the window's geometry is represented by an affine transformation.

$$g_2(c_2, r_2) = h_0 + h_1 g_1(c_1, r_1)$$
$$c_2 = a_0 + a_1 c_1 + a_2 r_1$$
$$r_2 = b_0 + b_1 c_1 + b_2 r_1$$

In the equations,

c_1,r_1 = the pixel coordinate in the reference window

c_2,r_2 = the pixel coordinate in the search window

$g_1(c_1,r_1)$ = the gray value of pixel (c_1,r_1)

$g_2(c_2,r_2)$ = the gray value of pixel (c_2,r_2)

h_0, h_1 = linear gray value transformation parameters

a_0, a_1, a_2 = affine geometric transformation parameters

b_0, b_1, b_2 = affine geometric transformation parameters

Based on this assumption, the error equation for each pixel is derived, as shown in the following equation:

$$v = (a_1 + a_2 c_1 + a_3 r_1)g_c + (b_1 + b_2 c_1 + b_3 r_1)g_r - h_1 - h_2 g_1(c_1, r_1) + \Delta g$$
$$\textit{with} \qquad \Delta g = g_2(c_2, r_2) - g_1(c_1, r_1)$$

The values g_c and g_r are the gradients of g_2 (c_2,r_2).

Feature-based Matching

Feature-based matching determines the correspondence between two image features. Most feature-based techniques match extracted point features (this is called feature point matching), as opposed to other features, such as lines or complex objects. The feature points are also commonly referred to as interest points. Poor contrast areas can be avoided with feature-based matching.

In order to implement feature-based matching, the image features must initially be extracted. There are several well-known operators for feature point extraction. Examples include the Moravec Operator, the Dreschler Operator, and the Förstner Operator (Förstner and Gülch 1987; Lü 1988).

After the features are extracted, the attributes of the features are compared between two images. The feature pair having the attributes with the best fit is recognized as a match. OrthoBASE utilizes the Förstner interest operator to extract feature points.

Relation-based Matching

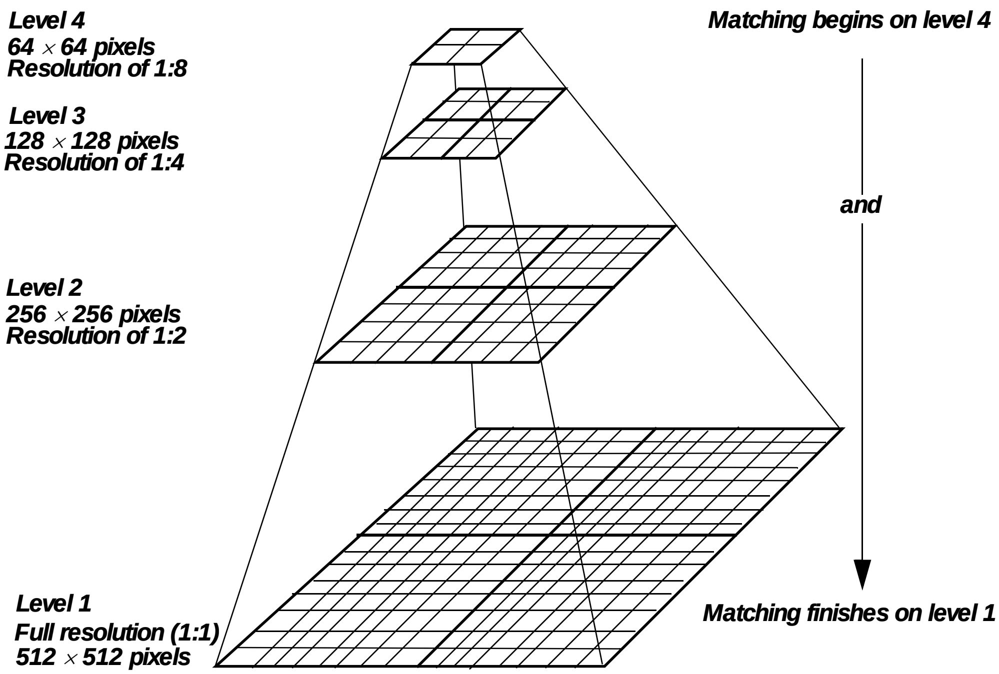
Relation-based matching is also called structural matching (Vosselman and Haala 1992; Wang, Y. 1994 and Wang, Y. 1995). This kind of matching technique uses the image features and the relationship between the features. With relation-based matching, the corresponding image structures can be recognized automatically, without any a priori information. However, the process is time-consuming since it deals with varying types of information. Relation-based matching can also be applied for the automatic recognition of control points.

Image Pyramid

Because of the large amount of image data, the image pyramid is usually adopted during the image matching techniques to reduce the computation time and to increase the matching reliability. The pyramid is a data structure consisting of the same image represented several times, at a decreasing spatial resolution each time. Each level of the pyramid contains the image at a particular resolution.

The matching process is performed at each level of resolution. The search is first performed at the lowest resolution level and subsequently at each higher level of resolution. Figure 2-27 shows a four-level image pyramid.

Figure 2-27: Image Pyramid for Matching at Coarse to Full Resolution



OrthoBASE Pyramid Layers

There are different resampling methods available for generating an image pyramid. Theoretical and practical investigations show that the resampling methods based on the Gaussian filter, which are approximated by a binomial filter, have superior properties concerning preserving the image contents and reducing the computation time (Wang, Y. 1994). Therefore, OrthoBASE uses this kind of pyramid layer instead of those currently available under ERDAS IMAGINE, which are overwritten automatically by OrthoBASE.

Satellite Photogrammetry

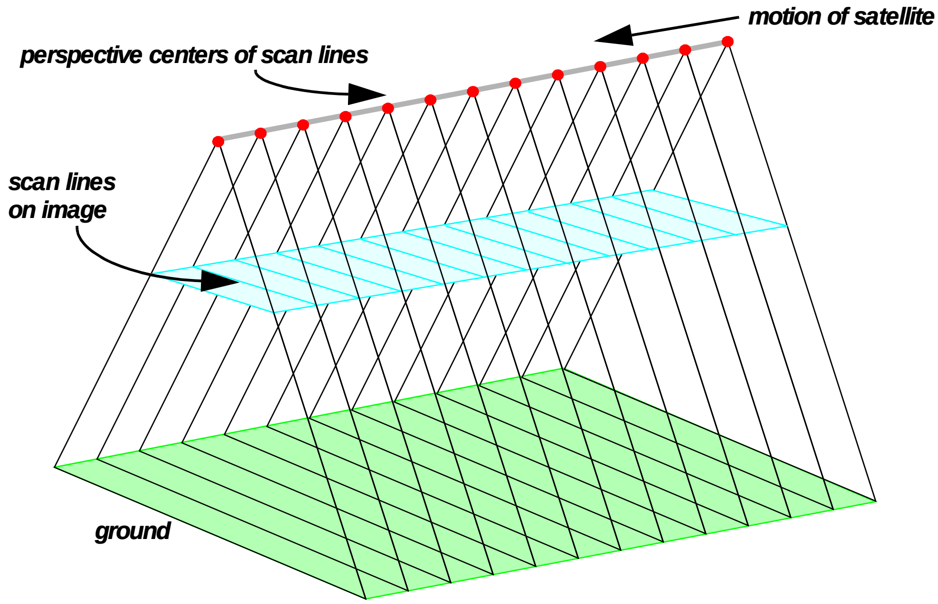
Satellite photogrammetry has slight variations compared to photogrammetric applications associated with aerial frame cameras. This document makes reference to the SPOT and IRS-1C satellites. The SPOT satellite provides 10-meter panchromatic imagery and 20-meter multispectral imagery (four multispectral bands of information).

The SPOT satellite carries two high resolution visible (HRV) sensors, each of which is a pushbroom scanner that takes a sequence of line images while the satellite circles the Earth. The focal length of the camera optic is 1084 mm, which is very large relative to the length of the camera (78 mm). The field of view is 4.1 degrees. The satellite orbit is circular, north-south and south-north, about 830 km above the Earth, and sun-synchronous. A sun-synchronous orbit is one in which the orbital rotation is the same rate as the Earth's rotation.

The IRS-1C satellite utilizes a pushbroom sensor consisting of three individual CCDs. The ground resolution of the imagery ranges between 5 to 6 meters. The focal length of the optic is approximately 982 mm. The pixel size of the CCD is 7 microns. The images captured from the three CCDs are processed independently or merged into one image and system corrected to account for the systematic error associated with the sensor.

Both the SPOT and IRS-1C satellites collect imagery by scanning along a line. This line is referred to as the scan line. For each line scanned within the SPOT and IRS-1C sensors, there is a unique perspective center and a unique set of rotation angles. The location of the perspective center relative to the line scanner is constant for each line (interior orientation and focal length). Since the motion of the satellite is smooth and practically linear over the length of a scene, the perspective centers of all scan lines of a scene are assumed to lie along a smooth line. The scanning technique is illustrated in Figure 2-28.

Figure 2-28: Perspective Centers of SPOT Scan Lines

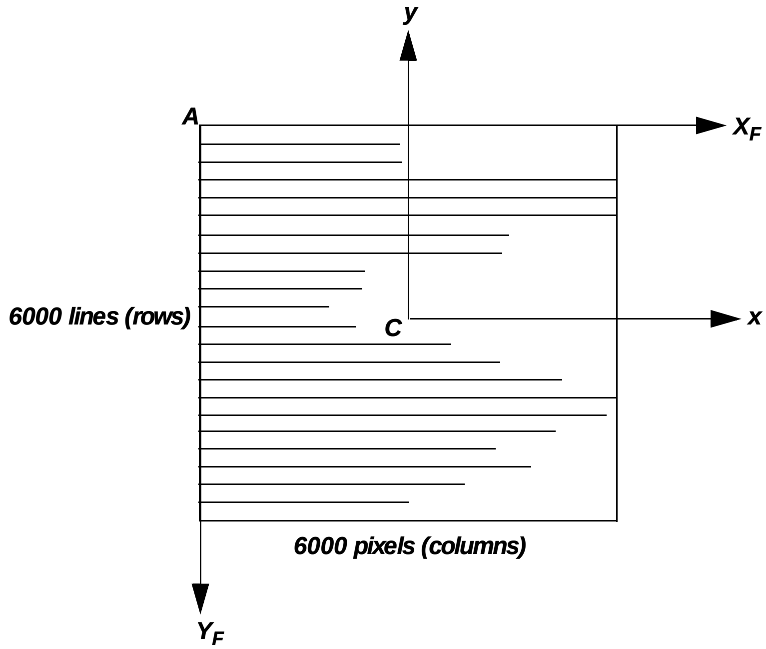


The satellite exposure station is defined as the perspective center in ground coordinates for the center scan line. The image captured by the satellite is called a scene. For example, a SPOT Pan 1A scene is composed of 6000 lines. For SPOT Pan 1A imagery, each of these lines consists of 6000 pixels. Each line is exposed for 1.5 milliseconds, so it takes 9 seconds to scan the entire scene. (A scene from SPOT XS 1A is composed of only 3000 lines and 3000 columns and has 20-meter pixels, while Pan has 10-meter pixels.)

NOTE: The following section addresses only 10-meter SPOT Pan data.

A pixel in the SPOT image records the light detected by one of the 6000 light-sensitive elements in the camera. Each pixel is defined by file coordinates (column and row numbers). The physical dimension of a single, light-sensitive element is 13 × 13 microns. This is the pixel size in image coordinates. The center of the scene is the center pixel of the center scan line. It is the origin of the image coordinate system. Figure 2-29 depicts image coordinates in a satellite scene.

Figure 2-29: Image Coordinates in a Satellite Scene



where,

A = origin of file coordinates

A-X_F, A-Y_F=file coordinate axes

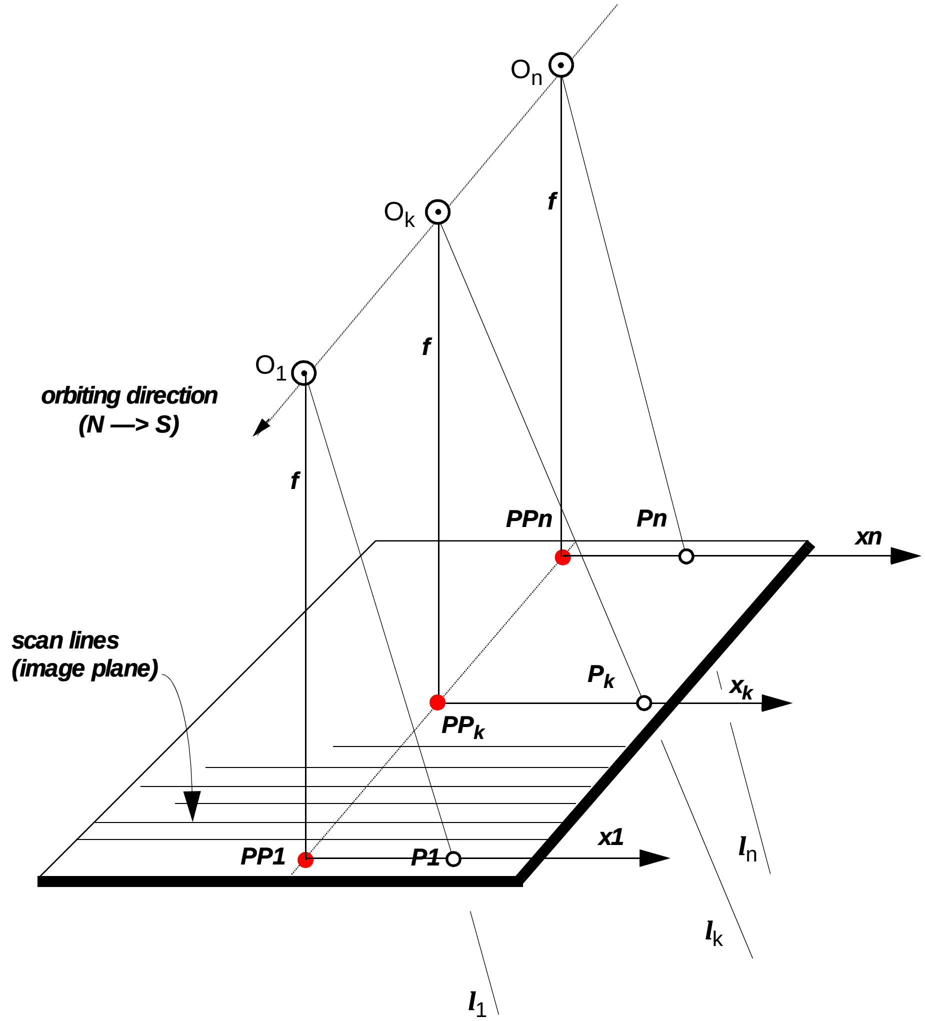
C = origin of image coordinates (center of scene)

C-x, C-y=image coordinate axes

SPOT Interior Orientation

Figure 2-30 shows the interior orientation of a satellite scene. The transformation between file coordinates and image coordinates is constant.

Figure 2-30: Interior Orientation of a SPOT Scene



For each scan line, a separate bundle of light rays is defined, where,

P_k	=	image point
x_k	=	x value of image coordinates for scan line k
f	=	focal length of the camera
O_k	=	perspective center for scan line k, aligned along the orbit
PP_k	=	principal point for scan line k
l_k	=	light rays for scan line, bundled at perspective center O_k

SPOT Exterior Orientation

SPOT satellite geometry is stable, and the sensor parameters, such as focal length, are well-known. However, the triangulation of SPOT scenes is somewhat unstable because of the narrow, almost parallel bundles of light rays.

Ephemeris data for the orbit are available in the header file of SPOT scenes. They give the satellite's position in three-dimensional, geocentric coordinates at 60-second increments. The velocity vector and some rotational velocities relating to the attitude of the camera are given, as well as the exact time of the center scan line of the scene. The header of the data file of a SPOT scene contains ephemeris data, which provides information about the recording of the data and the satellite orbit.

Ephemeris data that can be used in satellite triangulation include:

- position of the satellite in geocentric coordinates (with the origin at the center of the Earth) to the nearest second
- velocity vector, which is the direction of the satellite's travel
- attitude changes of the camera
- time of exposure (exact) of the center scan line of the scene

The geocentric coordinates included with the ephemeris data are converted to a local ground system for use in triangulation. The center of a satellite scene is interpolated from the header data.

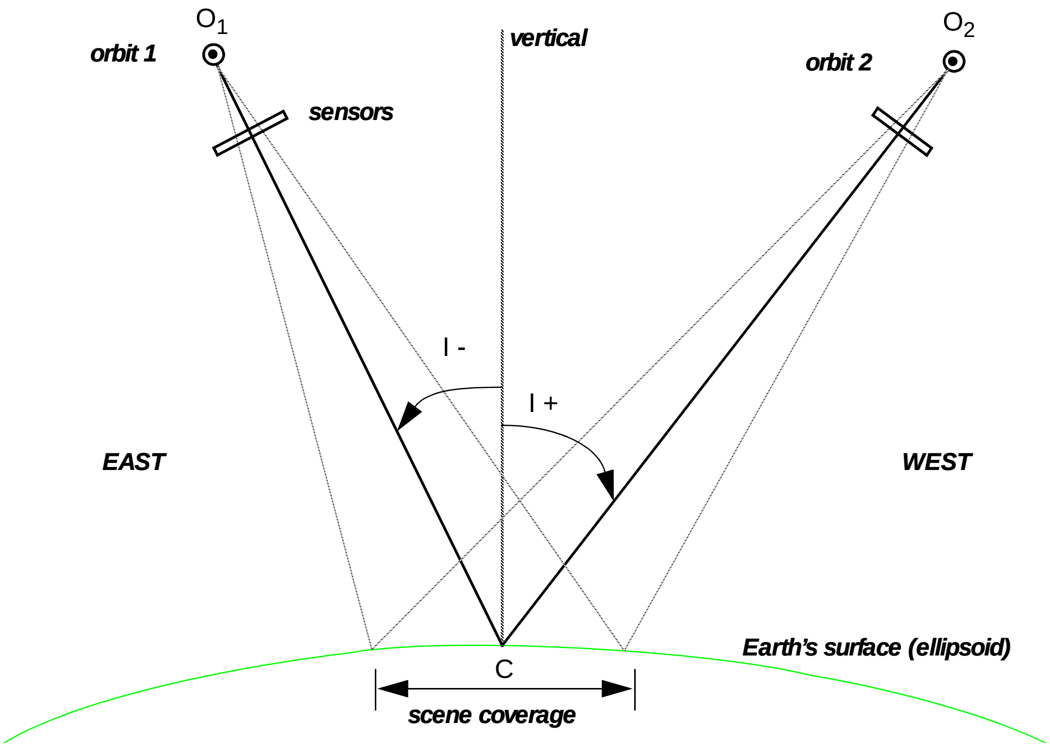
Light rays in a bundle defined by the SPOT sensor are almost parallel, lessening the importance of the satellite's position. Instead, the inclination angles (incidence angles) of the cameras onboard the satellite become the critical data.

Inclination is the angle between a vertical on the ground at the center of the scene and a light ray from the exposure station. This angle defines the degree of off-nadir viewing when the scene was recorded. The cameras can be tilted in increments of a minimum of 0.6 to a maximum of 27 degrees to the east (negative inclination) or west (positive inclination).

A stereo scene is achieved when two images of the same area are acquired on different days from different orbits, one taken East of the other. For this to occur, there must be significant differences in the inclination angles.

Figure 2-31 illustrates the inclination.

Figure 2-31: Inclination of a Satellite Stereo Scene (View from North to South)



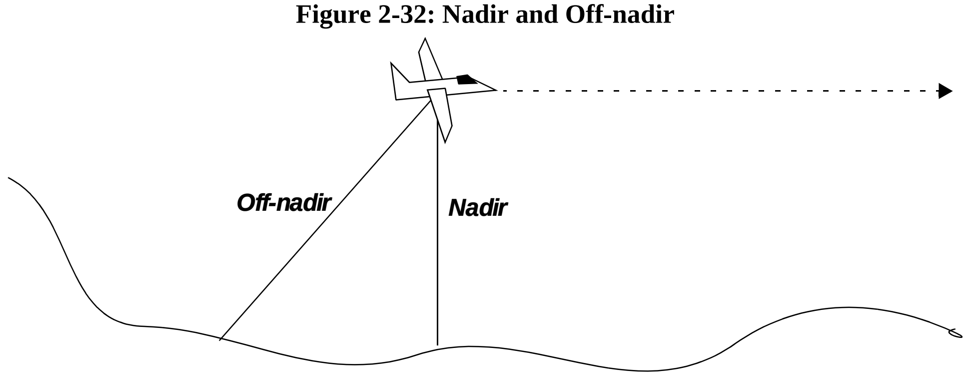
In Figure 2-31,

C	=	center of the scene
I-	=	eastward inclination
I+	=	westward inclination
O_1,O_2	=	exposure stations (perspective centers of imagery)

The orientation angle of a satellite scene is the angle between a perpendicular to the center scan line and the North direction. The spatial motion of the satellite is described by the velocity vector. The real motion of the satellite above the ground is further distorted by the Earth's rotation.

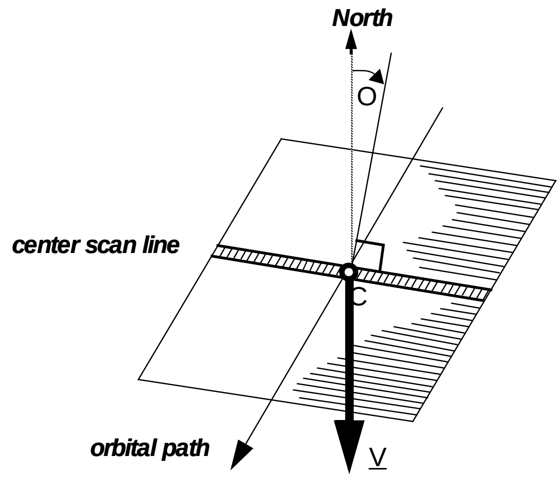
The scanner can produce a nadir view. Nadir is the point directly below the camera. SPOT has off-nadir viewing capability. Off-nadir refers to any point that is not directly beneath the satellite, but is off to an angle (i.e., East or West of the nadir), as shown in Figure 2-32.

Figure 2-32: Nadir and Off-nadir



The velocity vector of a satellite is the satellite’s velocity if measured as a vector through a point on the spheroid. It provides a technique to represent the satellite’s speed as if the imaged area were flat instead of being a curved surface (see Figure 2-33).

Figure 2-33: Velocity Vector and Orientation Angle of a Single Scene



In Figure 2-33,

O	=	orientation angle
C	=	center of the scene
V	=	velocity vector

Satellite block triangulation provides a model for calculating the spatial relationship between a satellite sensor and the ground coordinate system for each line of data. This relationship is expressed as the exterior orientation, which consists of:

- the perspective center of the center scan line (i.e., X, Y, and Z),
- the change of perspective centers along the orbit,
- the three rotations of the center scan line (i.e., omega, phi, and kappa), and
- the changes of angles along the orbit.

In addition to fitting the bundle of light rays to the known points, satellite block triangulation also accounts for the motion of the satellite by determining the relationship of the perspective centers and rotation angles of the scan lines. It is assumed that the satellite travels in a smooth motion as a scene is being scanned. Therefore, once the exterior orientation of the center scan line is determined, the exterior orientation of any other scan line is calculated based on the distance of that scan line from the center and the changes of the perspective center location and rotation angles.

Bundle adjustment for triangulating a satellite scene is similar to the bundle adjustment used for aerial images. A least squares adjustment is used to derive a set of parameters that comes the closest to fitting the control points to their known ground coordinates, and to intersecting tie points.

The resulting parameters of satellite bundle adjustment are:

- ground coordinates of the perspective center of the center scan line
- rotation angles for the center scan line
- coefficients, from which the perspective center and rotation angles of all other scan lines are calculated
- ground coordinates of all tie points

Collinearity Equations and Satellite Block Triangulation

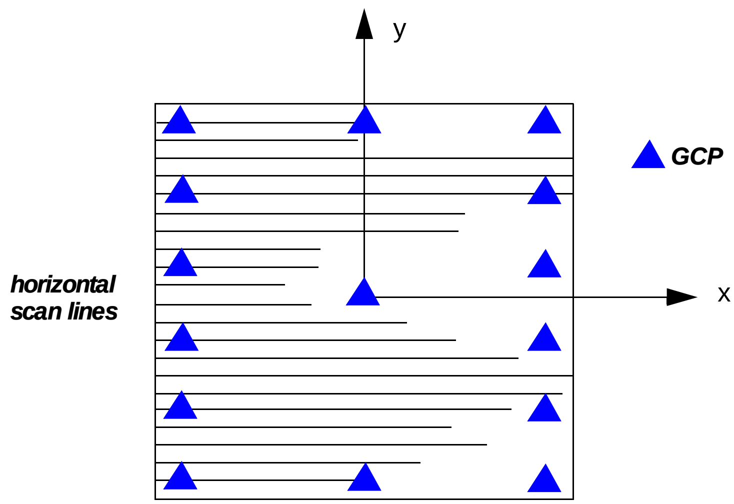
Modified collinearity equations are used to compute the exterior orientation parameters associated with the respective scan lines in the satellite scenes. Each scan line has a unique perspective center and individual rotation angles. When the satellite moves from one scan line to the next, these parameters change. Due to the smooth motion of the satellite in orbit, the changes are small and can be modeled by low-order polynomial functions.

Control for Satellite Block Triangulation

Both GCPs and tie points can be used for satellite block triangulation of a stereo scene. For triangulating a single scene, only GCPs are used. In this case, space resection techniques are used to compute the exterior orientation parameters associated with the satellite as they existed at the time of image capture. A minimum of six GCPs is necessary. Ten or more GCPs are recommended to obtain a good triangulation result.

The best locations for GCPs in the scene are shown in Figure 2-34.

Figure 2-34: Ideal Point Distribution Over a Satellite Scene for Triangulation



Orthorectification

Orthorectification is the process of reducing geometric errors inherent within photography and imagery. The variables contributing to geometric errors include, but are not limited to:

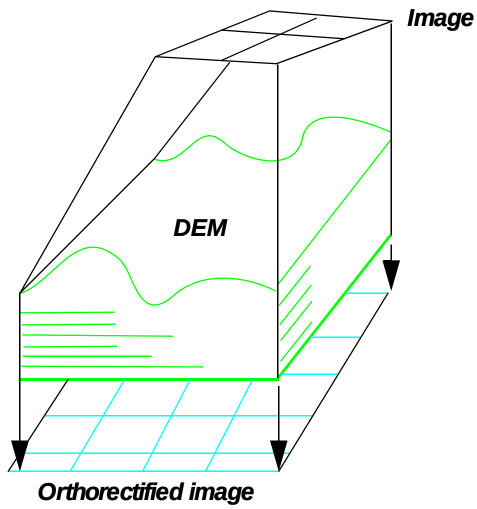
- camera and sensor orientation
- systematic error associated with the camera or sensor
- topographic relief displacement

- Earth curvature

By performing block triangulation or single frame resection, the parameters associated with camera and sensor orientation are defined. Utilizing least squares adjustment techniques during block triangulation minimizes the errors associated with camera or sensor instability. Additionally, the use of self-calibrating bundle adjustment (SCBA) techniques along with Additional Parameter (AP) modeling accounts for the systematic errors associated with camera interior geometry. The effects of the Earth's curvature are significant if a large photo block or satellite imagery is involved. They are accounted for during the block triangulation procedure by setting the proper option. The effects of topographic relief displacement are accounted for by utilizing a DEM during the orthorectification procedure.

The orthorectification process takes the raw digital imagery and applies a DEM and triangulation results to create an orthorectified image. Once an orthorectified image is created, each pixel within the image possesses geometric fidelity. Thus, measurements taken off an orthorectified image represent the corresponding measurements as if they were taken on the Earth's surface (see Figure 2-35).

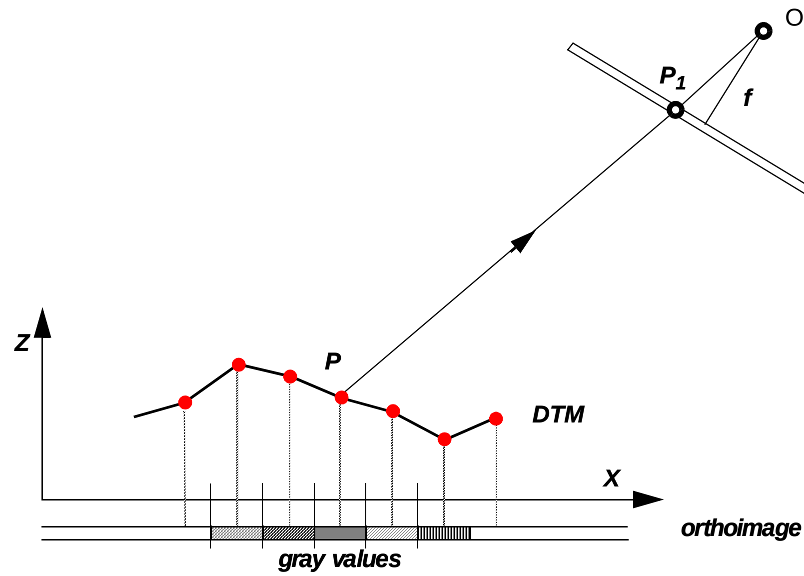
Figure 2-35: Orthorectification



An image or photograph with an orthographic projection is one for which every point looks as if an observer were looking straight down at it, along a line of sight that is orthogonal (perpendicular) to the Earth. The resulting orthorectified image is known as a digital orthoimage (see Figure 2-36).

Relief displacement is corrected by taking each pixel of a DEM and finding the equivalent position in the satellite or aerial image. A brightness value is determined for this location based on resampling of the surrounding pixels. The brightness value, elevation, and exterior orientation information are used to calculate the equivalent location in the orthoimage file.

Figure 2-36: Digital Orthoimage - Finding Gray Values



In Figure 2-36,

P	=	ground point
P_1	=	image point
O	=	perspective center (origin)
X,Z	=	ground coordinates (in DTM file)
f	=	focal length

In contrast to conventional rectification techniques, orthorectification relies on the digital elevation data, unless the terrain is flat. Various sources of elevation data exist, such as the USGS DEM and a DEM automatically created from stereo image pairs. They are subject to data uncertainty, due in part to the generalization or imperfections in the creation process. The quality of the digital orthoimage is significantly affected by this uncertainty.

OrthoBASE provides the necessary tools to ensure the creation of map-accurate DTMs, including DEMs. For more information, see Chapter 3 "Introduction to Automatic DTM Extraction from Imagery".

For different image data, different accuracy levels of DEMs are required to limit the uncertainty-related errors within a controlled limit. While the near-vertical viewing SPOT scene can use very coarse DEMs, images with large incidence angles need better elevation data such as USGS level-1 DEMs. For aerial photographs with a scale larger than 1:60000, elevation data accurate to 1 meter is recommended. The 1-meter accuracy reflects the accuracy of the Z coordinates in the DEM, not the DEM resolution or posting.

Cell Size

Resampling methods used are nearest neighbor, bilinear interpolation, and cubic convolution. Generally, when the cell sizes of orthoimage pixels are selected, they should be similar or larger than the cell sizes of the original image. For example, if the image was scanned 9K × 9K, one pixel would represent 0.025 mm on the image. Assuming that the SI of this photo is 1:40000, then the cell size on the ground is about 1 m. For the orthoimage, it is appropriate to choose a pixel spacing of 1 m or larger. Choosing a smaller pixel size oversamples the original image.

For SPOT Pan images, a cell size of 10 meters is appropriate. Any further enlargement from the original scene to the orthophoto does not improve the image detail. For IRS-1C images, a cell size of 6 meters is appropriate.

Chapter 3

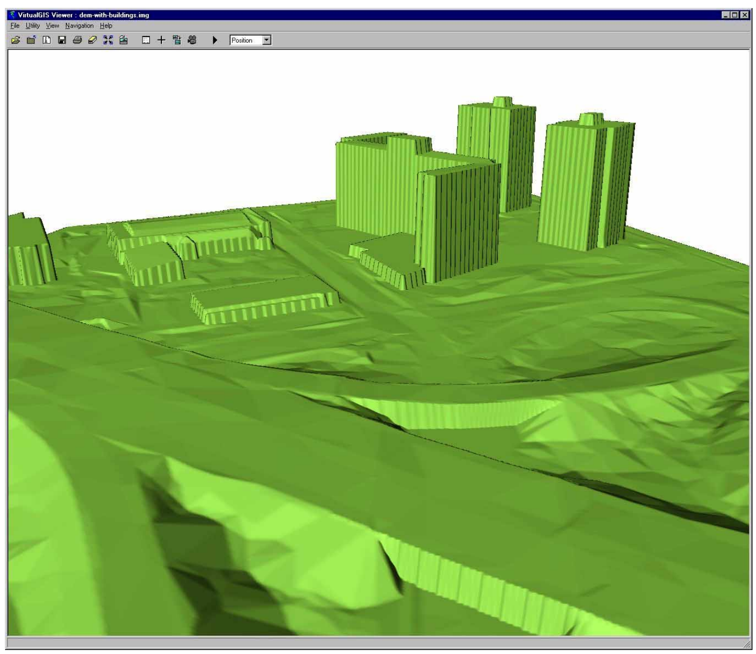
Introduction to Automatic DTM Extraction from Imagery

Introduction

A digital terrain model (DTM) is a 3D digital representation of the Earth's terrain or topography. Automatic DTM extraction involves the automatic extraction of elevation information from imagery and the subsequent creation of a 3D digital representation of the Earth's surface. A DTM represents the elevation associated with the Earth's topography and not necessarily the human-made (e.g., buildings) or natural (e.g., trees) features located on the Earth's surface.

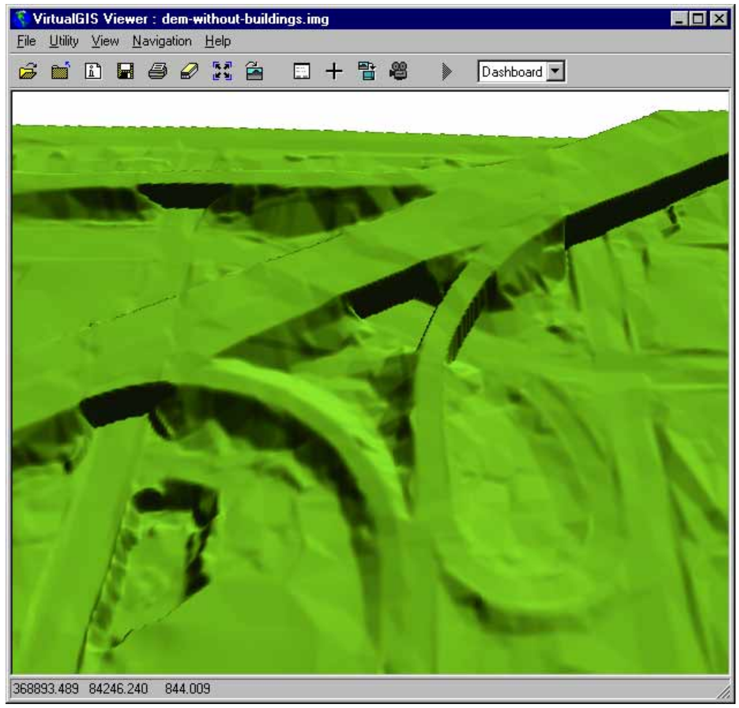
A digital surface model (DSM) represents the elevation associated with the Earth's surface including topography and all natural or human-made features located on the Earth's surface. The primary difference between a DSM and a DTM is that the DTM represents the Earth's terrain whereas a DSM represents the Earth's surface. Figure 3-1 illustrates a DSM.

Figure 3-1: DSM of an Area



A portion of the area illustrated in Figure 3-1 is shown in Figure 3-2. In this illustration, you can see the terrain effects associated with the data.

Figure 3-2: DTM of the Same Area



OrthoBASE Pro allows for the automatic extraction of DSMs and DTMs. In order to automatically extract topography only, specific parameters governing the elevation extraction process must be specified. However, typically additional editing outside of the DTM extraction process is required to obtain a 3D topographic representation only. This process is referred to as DTM editing. DTM editing techniques are used to remove invalid elevation points in order to create an accurate representation of the Earth's topography and surface.

Refer to Appendix C "DTM Editing in ERDAS IMAGINE & Stereo Analyst" for more information regarding DTM editing.

NOTE: The remaining portions of this chapter use and make reference to DTMs as the generic 3D digital representation extracted using OrthoBASE.

Imagery serves as the primary source of data input for the automatic extraction of DTMs. DTMs can only be extracted if two or more overlapping images are available. Prior to the automatic extraction of DTMs, sensor model information associated with an image must be available. This includes internal and external sensor model information.

Using OrthoBASE Pro, the interior orientation of an image must be defined and the exterior orientation of the image must be estimated or known from another source such as airborne GPS/INS. Without the internal and external sensor model information established, elevation information cannot be extracted from overlapping images.

Please refer to Chapter 10 "Defining the Camera or Sensor Model" for more information regarding internal and external sensor model information.

Introduction to DTM Creation

Techniques

Various other techniques and approaches can be used for the creation of DTMs. These techniques vary with respect to the technology used to collect elevation information from the Earth's surface. The different techniques include:

Ground Surveying

Surveying levels, total stations and/or ground GPS units can be used for the measurement of 3D information pertaining to the Earth's surface. Discrete points (i.e., spot heights) are surveyed and recorded. Each recorded point has a 3D coordinate associated with it. All of the 3D points are used to interpolate a 3D surface of the specific area of interest. This approach is highly accurate, but time-consuming. Ground surveying techniques are commonly used for civil engineering applications (e.g., road and bridge construction).

Traditional Photogrammetry

Analog and analytical stereo plotters have been used extensively to extract 3D mass points from stereopairs. The left and right photographs associated with a stereopair are first oriented within a stereo plotter. The operator then manually collects 3D mass points or contour lines one stereopair at a time. The placement and distribution of 3D mass points is dependant on the operator’s discretion. The output can be recorded digitally or on hardcopy paper (for future digitization). The 3D points are then used to interpolate a 3D surface. Traditional photogrammetric techniques are highly accurate, but time-consuming while also requiring high-level expertise.

Digital Stereo Plotters

Similar to the traditional stereo plotters, digital stereo plotters digitally record 3D mass points into a file for subsequent interpolation into a 3D surface. For example, Stereo Analyst allows for the collection of 3D mass points. The 3D mass points (stored as an ESRI 3D Shape file) can be interpolated to create a 3D surface. Semiautomated approaches can be used to place the 3D floating cursor on the terrain during collection.

Digitized Topographic Maps

Existing topographic maps can be digitized to record spot heights and contour lines. The elevation associated with the digitized spot heights and contour lines can be attributed. The resulting features can be interpolated to create a 3D surface. This process is not as accurate, but a good alternative for regions where up-to-date imagery is not available.

Radar

Radar makes use of the sensor models of two input images to derive stereo intersection geometry, which is used, in part, to calculate height. The parallax, or elevation-induced offset, for each pixel in the image is used to derive height information. Parallax is a function of both the difference in the two incidence angles (the angle between nadir and the path to the target area) and the local topography. An area with little elevation difference requires a large angle to produce the needed parallax. An area of great elevation difference requires a smaller angle.

Light Detection and Ranging (LIDAR)

A LIDAR system uses a powerful laser sensor, a GPS receiver, and an INS unit to record the elevation of the terrain being scanned. The laser sensor is mounted to the bottom of an aircraft. Once airborne, the sensor emits rapid pulses of infrared laser light, which are used to determine ranges to points on the terrain below. The ranges are processed together with the GPS/INS information to determine the elevation of the terrain on the Earth's surface.

Each approach has its advantages and disadvantages. The optimum approach depends on the nature and specific needs of the mapping project. OrthoBASE uses a fully automated approach for DTM creation. In certain instances, this is an advantage. In other cases, manual collection of 3D information may be more suitable (e.g., dense downtown urban areas).

Why are DTMs Required?

Topography governs many of the processes associated with the Earth and its geography. GIS professionals involved with mapping and geographical modeling must be able to accurately represent the Earth's surface. Inadequate and inaccurate representations can lead to poor decisions that can negatively impact our environment and the associated human, cultural, and physical landscape. DTMs are required as a necessary form of input for:

- Determining the extent of a watershed. Combining DTMs over a large region, a DTM is used as a primary source of input for determining the extent of a watershed.
- Extracting a drainage network for a watershed. Many GIS packages automatically delineate a drainage network using a DTM, primarily a DEM, as a primary source of input.
- Determining the slope associated with a geographic region. Slope is required when designing road networks, pipeline infrastructure, and various other forms of rural and urban infrastructure.
- Determining the aspect associated with a geographic region. Aspect illustrates and displays the direction of a slope. Aspect influences the growth of vegetation due to the availability of sunlight, the location of real estate, and intervisibility studies.
- Modeling and planning for telecommunications. A height model is required as a primary source of input for planning the location of radio antennas and performing point-to-point analysis for wireless communications.
- Orthorectifying. The orthorectification process requires highly accurate DTMs for the creation of map-accurate imagery for use in a GIS. Using DTMs lessens the effect of topographic relief displacement on raw imagery.
- Preparing 3D Simulations. DTMs are the fundamental data source required for preparing 3D perspectives and flight simulations. Without DTMs, 3D simulations cannot be created.
- Analyzing Volumetric Change. Comparing DTMs of a region from different time periods allows for the computation of volumetric change (e.g., cut and fill).
- Estimating River Channel Change. Rates of river channel erosion and deposition can be estimated using DTMs extracted from imagery collected at various time periods.
- Creating Contour Maps. Contour maps can be derived from DTMs. Using a series of mass points, contour lines for a given range in elevation can be automatically extracted.

In general, DTMs are a first generation data product derived from imagery using the principles of 3D geographic imaging. Second generation data products such as slope and aspect images, contour maps, and volumetric change analyses can be derived from DTMs for use in various GIS and engineering applications.

DTM Extraction Process

The process associated with automatic DTM extraction can be broken down into the following steps:

Step 1

Digital Image Matching for DTM Mass Point Collection

Ground points appearing within the overlap portion of the left and right images associated with a DTM are identified. This is referred to as digital image matching. The resulting output consists of the image location of ground points appearing within a DTM.

Step 2

Ground Point Coordinate Determination

The 3D coordinates of a ground point whose image positions have been automatically identified are computed using photogrammetric principles. This is referred to 3D ground point calculation. The calculated 3D ground points are also referred to as mass points.

Step 3

DTM Construction

The automatically extracted and calculated mass points are used as a basis for constructing a DTM. DTMs are constructed differently depending on the specified DTM output type.

The following sections explore the steps in more detail.

Step 1

The use of digital image correlation is common in remote sensing and GIS applications to find areas of similarity between two or more images that overlap or share a common geographic area. OrthoBASE Pro makes use of correlation and image matching to automatically extract DTMs. These DTMs are highly accurate, and can be used in other applications, such as Stereo Analyst and IMAGINE VirtualGIS.

The digital image correlation procedure used by OrthoBASE Pro utilizes the following generalized approach:

Interest Point Determination

Using an interest operator, a series of interest points (otherwise referred to as feature points) is identified on each image in a block. An interest point is the center of a template window that exhibits sufficient grey level variation and contrast. An interest point is usually also an image point that refers to a ground feature on the Earth's surface such as a road intersection or the corner of a house.

Interest Point Matching

Once an interest point has been identified on the image in a block, OrthoBASE Pro proceeds to identify and match interest points that correspond to the same ground feature appearing on two or more overlapping images.

The cross-correlation coefficients are calculated for each correlation window among the search window. A correlation window exists on the reference image and a search window exists on the neighboring overlapping image. An interest point located on the reference image may have more than one possible match on the adjacent overlapping images. For each set of possible image points identified by OrthoBASE Pro, a correlation coefficient is computed.

The correlation coefficient is used to represent the measure of similarity between a set of image points appearing within the overlapping portions of an image pair. A larger correlation coefficient value (i.e., 0.80-1.0) statistically indicates that the set of image points is more similar than a set of image points which has a lower correlation coefficient value (less than 0.50).

Strategy Parameters

The strategy parameters influence the success and accuracy of the matching process. Among the parameters, the search window size, correlation window size, and correlation coefficient limit have the most influence.

Search Window Size

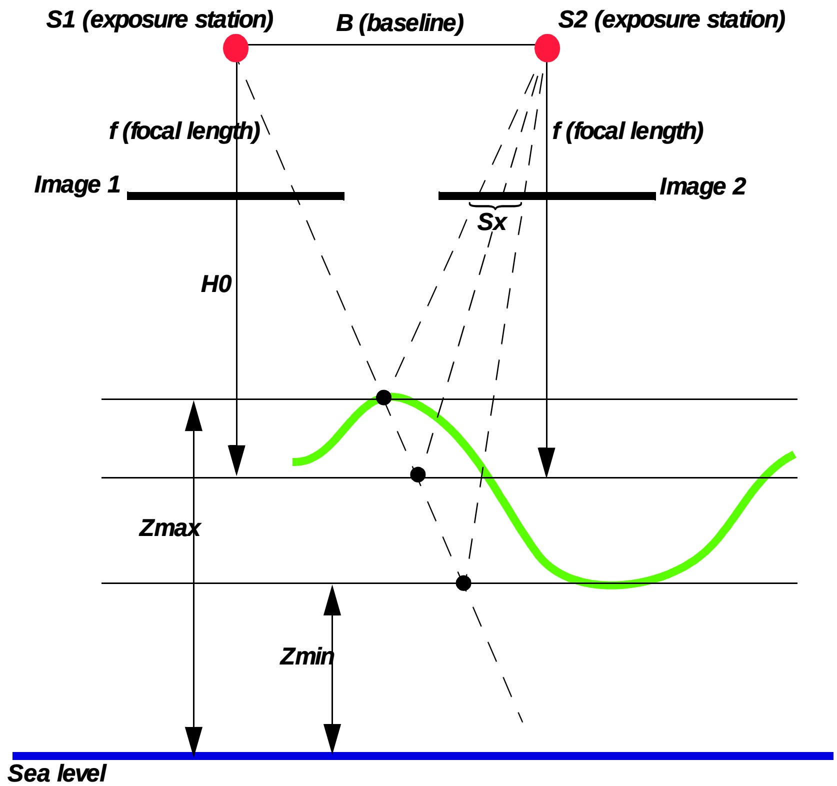
Once an interest or feature point has been identified on the first image in a block, OrthoBASE Pro estimates the approximate location of the same feature point on the neighboring second image. When an approximate location has been identified, OrthoBASE Pro searches for the corresponding image positions within a rectangular search window.

The search window X defines the search area length along the epipolar line; the search window size Y defines the search area width across the epipolar line. The search window size X reflects the variation of ground elevations for that given window appearing on the Earth's surface. The larger the range of ground elevation, the larger the search window size X.

For aerial frame camera images with good triangulation results, the epipolar line can be computed quite accurately; therefore, one to three pixels for the search window size Y are sufficient. For pushbroom images, the epipolar lines are less accurate, and three to five pixels are recommended. If the triangulation results are not good, the search window size Y should be increased further.

Figure 3-3 shows an ideal situation for aerial frame images where the images are horizontal (no omega and phi), and the two image exposure centers are at the same height.

Figure 3-3: Ideal Search Window Scenario



With regard to Figure 3-3, the search window size X can be estimated with the following formula:

$$Sx = \frac{Bf}{H_0} \cdot \frac{Z_{max} - Z_{min}}{H_0}$$

Since the hierarchical matching using pyramid structures is used in OrthoBASE Pro with the smallest pyramid size around 250 × 250 pixels, the above equation can be rewritten as the following equation if the image pair is regularly overlapped with an overlap percentage *p*.

$$Sx = 250\frac{Z_{max} - Z_{min}}{H_0}(1 - p)$$

For example, suppose the image pair overlap is 60%, the average flight height H_0 is 7500 meters, and the elevation range Z_{max} - Z_{min} is 500 meters. The search window size X is about 7 pixels, according to the above equation.

In practice, since there are image rotations, the image pair is not taken from the same height, the overlap percentage is irregular across the image, the initial estimation for the possible matching point could be away from the position corresponding to the average flight height, etc., the result from the above equation is usually too small. We recommend increasing the calculated result from the above equation with a factor of one and one-half to two times the search window size X. For example, a calculated window size of 7 would be increased to 11 or 15.

Correlation Window Size

Correlation window size defines the size of the window used to compute the correlation coefficient between image points of common ground points appearing on multiple overlapping images. The default window size is 7 × 7. For areas containing minimal variation in topographic relief, grey level, or color intensity (e.g., desert, agricultural fields, grassy areas), a larger value (e.g., 9 × 9 or greater) can be used. For areas containing large degrees of topographic relief, grey level variation, and color intensity variation, a smaller window size is recommended (e.g., 5 × 5).

Instead of a square (e.g., 7 × 7), the correlation window size can also be rectangular. Since variations caused by ground relief are larger in the epipolar line direction than across the epipolar line direction, size Y (across epipolar line) can be larger than size X (along epipolar line).

Correlation Coefficient Limit

The correlation coefficient limit defines the correlation coefficient threshold used to determine whether or not two points are considered possible matches. Once the correlation between two points appearing on two frames has been computed, the correlation limit is compared to the correlation coefficient. If the correlation coefficient is smaller than the correlation limit, the two points are not considered a match.

A larger correlation limit may result in greater accuracy, although fewer points may be collected. If a smaller correlation limit is used, it may increase the number of correlated points, but could introduce false match points into the solution. We recommend using a correlation coefficient larger than 0.7. For image pairs with good radiometric quality and moderate terrain relief, 0.8 is more appropriate.

Adaptive Changes

Search window size, correlation window size, and correlation coefficient limit can be allowed to adjust automatically if the corresponding checkbox is enabled in the Set Strategy Parameters dialog. If adaptive change is set, OrthoBASE Pro computes and analyzes the terrain features after each pyramid and sets the strategy parameters accordingly. With the adaptive change option on, the extracted mass points have fewer errors. However, if the terrain has some unusually high peaks and low valleys that are not detected in the previous pyramid lever, they are likely undetectable in the subsequent matching processes as well.

See "Set Strategy Parameters" for additional information about strategy parameters.

Matching Constraints

Geometric and radiometric characteristics (derived from sensor model information and image grey values) associated with the images comprising stereopairs (i.e., image pairs) are used to constrain the image matching process in order to produce highly accurate and reliable matching image point pairs. The most common constraint, which is epipolar geometry associated with an image pair, is used to constrain the search area used to establish a pair of matching image points. Figure 3-4 illustrates an image point on a reference image being located along the epipolar line of an adjacent overlapping image.

Figure 3-4: Matching Image Points

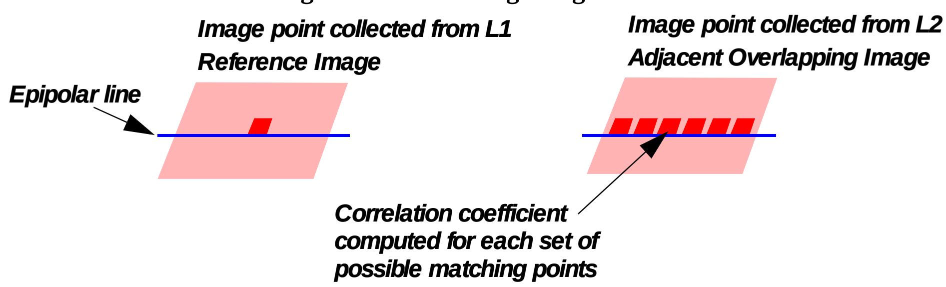
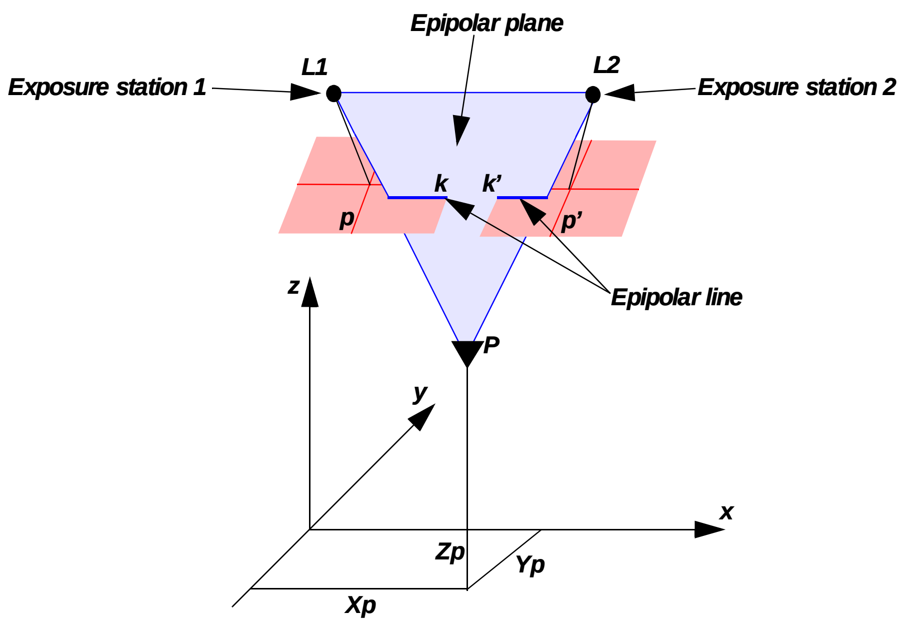


Figure 3-5 illustrates the image matching process using epipolar geometry as a geometric constraint. In the figure, L_1PL_2 marks the intersection of the images and the epipolar plane. Where the lines intersect, *pk* and *p*'*k*' mark the epipolar line. *P* is the ground point. X_p, Y_p, and Z_p mark the location of the image point in ground space. According to Wolf, the epipolar lines are useful because knowing that corresponding points lie along a single line, both the search area and the time to compute are reduced (Wolf 1983).

Figure 3-5: Epipolar Geometry and the Coplanarity Condition



Source: Keating, Wolf, and Scarpace 1975

Epipolar geometry is also commonly associated with the coplanarity condition. The coplanarity condition states that the two sensor exposure stations of a stereopair, any ground point, and the corresponding image position on the two images must all lie in a common plane.

The common plane is also referred to as the epipolar plane. The epipolar plane intersects the left and right images, and the lines of intersection are referred to as epipolar lines. The image positions of a ground point appearing on the left and right photos lie along the epipolar line. The search and matching process for digital image matching occurs along a straight line (i.e., epipolar line), thus simplifying the matching process. The epipolar constraint can only be applied if the image orientations and position of each sensor have been solved.

Step 2

Once the correlation coefficient has been computed for each set of possible matching image points, various statistical tests are used within OrthoBASE Pro to determine the final set of image points associated with a ground point on the Earth's surface. The row and column pixel coordinates associated with the final set of image points are recorded. As a result, a ground feature appearing within the overlapping portions of an image pair has row and column pixel coordinates for both left and right images.

Once the final set of image points has been recorded, the 3D coordinates associated with the ground feature are computed. The resulting computation creates a DTM mass point. A mass point is a discrete point located within the overlap portion of at least one image pair, and whose 3D ground coordinates are known. A technique known as space forward intersection is used to compute the 3D coordinates associated with a mass point.

Refer to "Space Forward Intersection" for more information.

Figure 3-6 illustrates a series of DTM mass points which were automatically extracted by OrthoBASE Pro.

Figure 3-6: 3D Shape File of DTM Mass Points

Step 3

OrthoBASE Pro allows for the creation of various DTM output types. This includes raster DEM, TerraModel TIN, ESRI 3D Shape file, and ASCII file.

The raster DEM and TerraModel TIN output options create a continuous DTM representation of the Earth's surface. The ESRI 3D Shape file and ASCII file output options create a discontinuous DTM surface. In each instance, the automatically extracted DTM mass points are used to create the output DTM type.

A TIN is a digital representation of the Earth's surface which is composed of a set of nonoverlapping triangles. The Delaunay triangulation approach is used to create a TIN from DTM mass points. In order to create a raster DEM output, the DTM mass points are used as reference points to interpolate an elevation value to create a raster grid DEM. The ESRI 3D Shape file and ASCII file output options simply detail the DTM mass points.

Section III

OrthoBASE & OrthoBASE Pro Tour Guides

Chapter 4

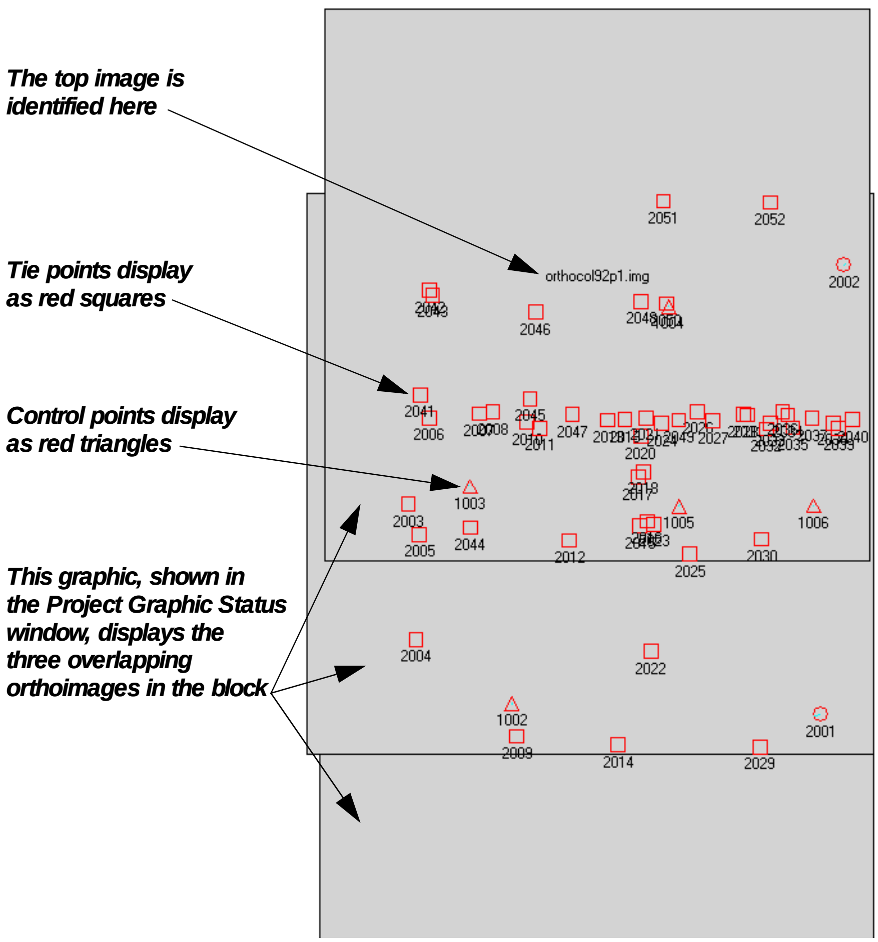
Frame Camera Tour Guide

Introduction

With OrthoBASE, you have access to many different types of geometric models with which to create a block file. This tour guide takes you through the steps with the frame camera model.

The graphic in Figure 4-1 represents the geometric relationship between three images, control points, and check points. The control points are shown at the positions that coincide with the image features they are associated with. Initially, the input images are not in the coordinate system of the control points. The input images are usually in file (pixel) coordinates, which can be defined as an arbitrary grid of coordinate values.

Figure 4-1: Geometric Relationship



During triangulation, the control points are used to establish a mathematical relationship between the camera, the photographs, and the 3D ground surface. Once this mathematical relationship has been defined, orthorectification can be performed. During orthorectification, the input image grid coordinates are resampled into the map coordinate system of the control points.

Before You Begin

This tour guide uses frame camera images of Colorado Springs, Colorado. They are National Aerial Photography Program (NAPP) black and white aerial photographs at a 1:40000 photo scale. The DEM used in this example has a ground resolution of 30 meters.

Approximate completion time for this tour guide is 1 hour, 15 minutes.

In this tour guide, you are going to perform the following basic steps:

- create a new project
- add imagery to the block file
- define the camera model
- measure GCPs and check points
- use the automatic tie point collection function
- triangulate the images
- orthorectify the images
- view the orthoimages
- save the block file

Create a New Project

In this section of the tour guide, you create a new project using frame camera images of Colorado Springs, Colorado.

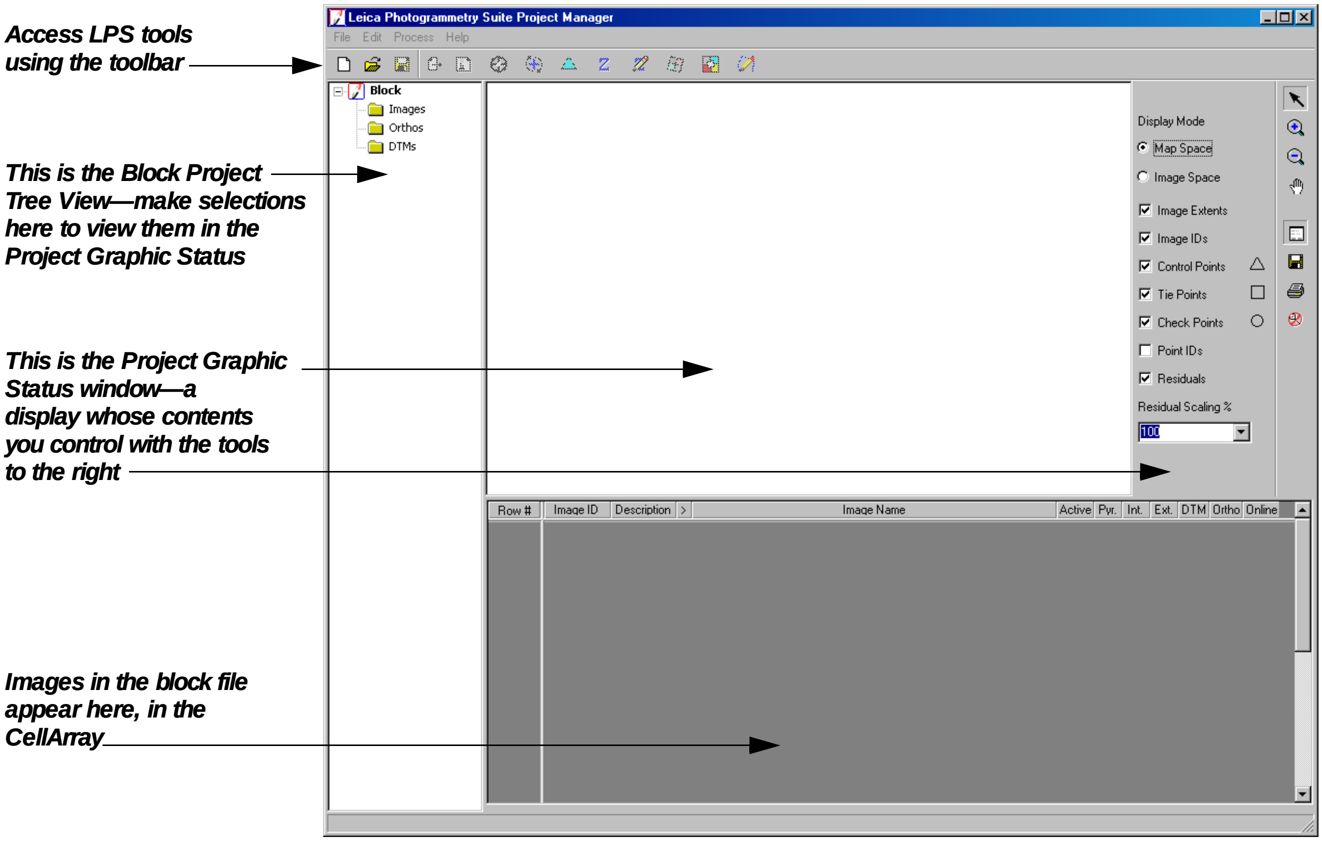
Prepare the Block File

1. Start Leica Photogrammetry Suite (LPS).

2. Click the LPS icon 

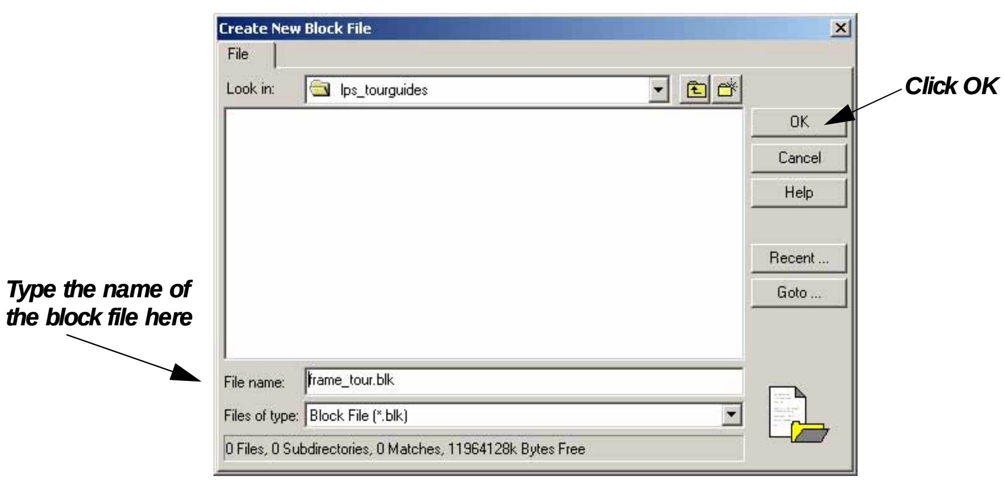
on the icon panel.

The LPS Project Manager opens.



3. Click the Create New Block File icon .

The Create New Block File dialog opens.



4. Navigate to a folder where you have write permission.

5. Next to **File name,** type **frame_tour,** then press Enter on your keyboard.

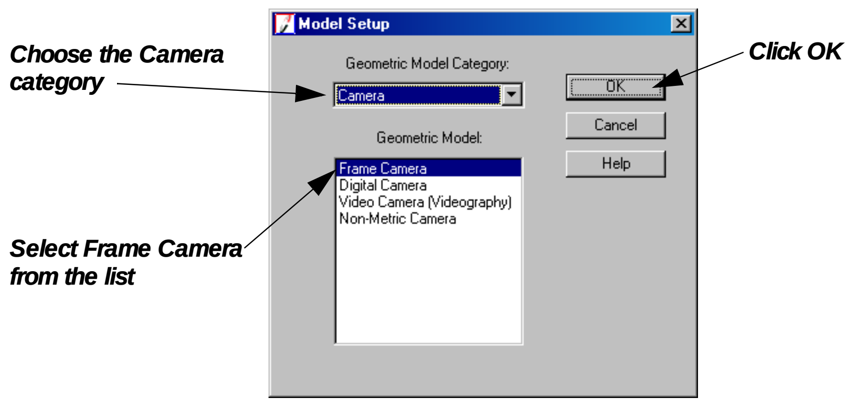
The *.blk extension, for a block file, is appended automatically.

> ***The block (.blk) file***
>
> When you use OrthoBASE, you create block files. Block files have the .blk extension. A block file may be made up of only one image, a strip of images that are adjacent to one another, or several strips of imagery.
>
> The .blk file is a binary file. In it is all the information associated with the block including imagery locations, camera information, fiducial mark measurements, GCP measurements, and the like.
>
> Block files can also be used in other LPS applications, such as Stereo Analyst and Terrain Editor, for the collection of 3D features, stereo viewing, and terrain editing.

6. Click **OK** to close the Create New Block File dialog.

Select Geometric Model

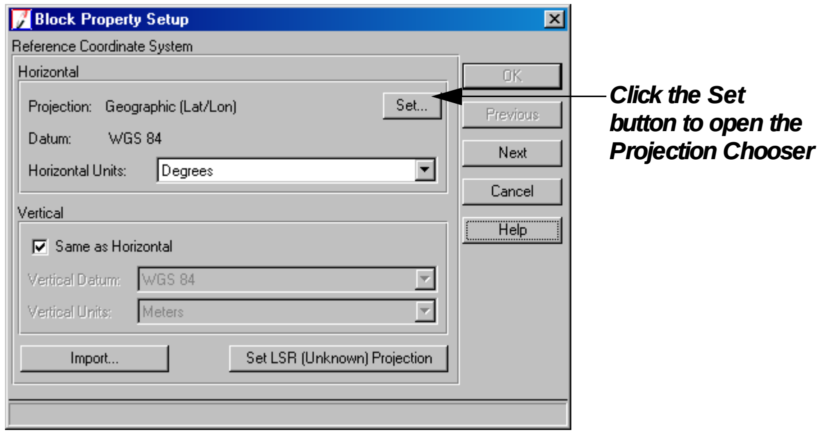
Once you have created a block file, the Model Setup dialog opens. Here, you select a geometric model that corresponds to the type of camera associated with the images.



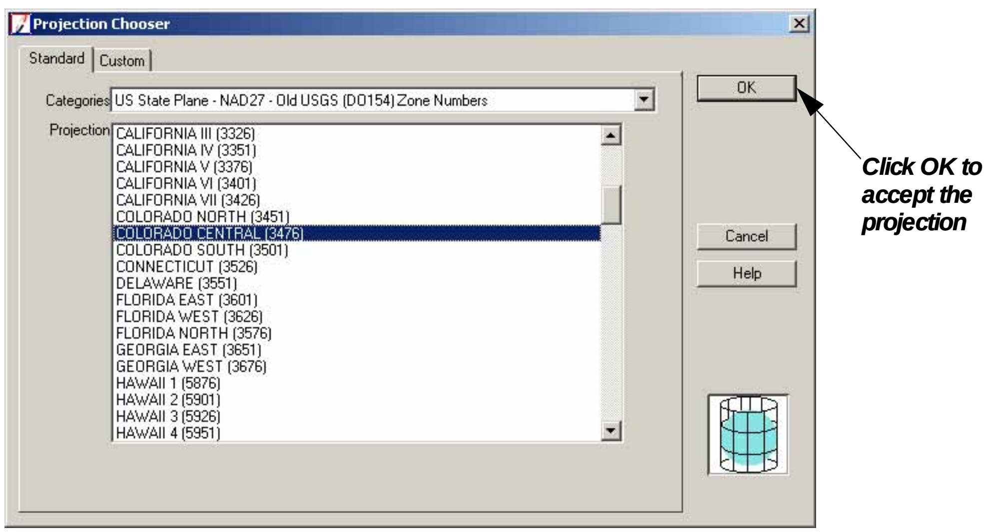
1. Click the **Geometric Model Category** dropdown list and select **Camera.**
2. Click **Frame Camera** in the **Geometric Model** list.
3. Click **OK** to close the Model Setup dialog.

Define Block Properties

The Block Property Setup dialog opens.

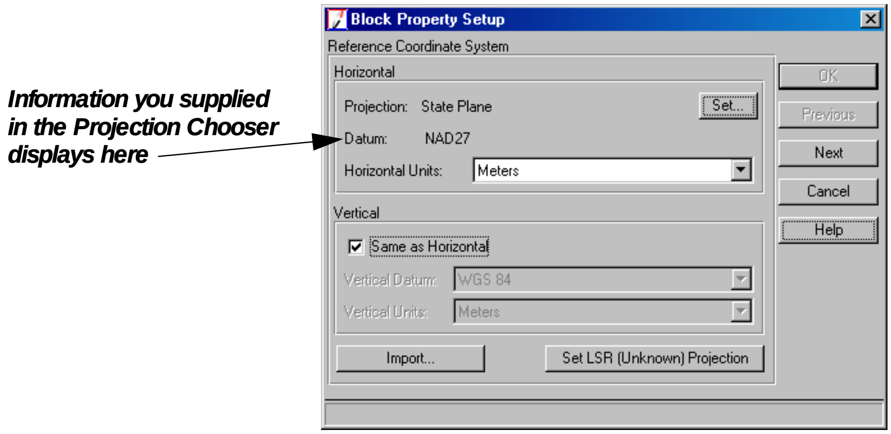


1. Click the **Set** button in the **Horizontal Reference Coordinate System** section of the Block Property Setup dialog.



2. Click the **Standard** tab in the Projection Chooser dialog.
3. Click the **Categories** dropdown list and select **US State Plane - NAD27 - Old USGS (DO154) Zone Numbers.**
4. Click the **Projection** scroll bar, then select **COLORADO CENTRAL (3476).**
5. Click **OK** to close the Projection Chooser dialog.
6. Click the **Horizontal Units** dropdown list and choose **Meters.**
7. In the **Vertical** section of the Block Property Setup dialog, click the checkbox to select **Same as Horizontal.**

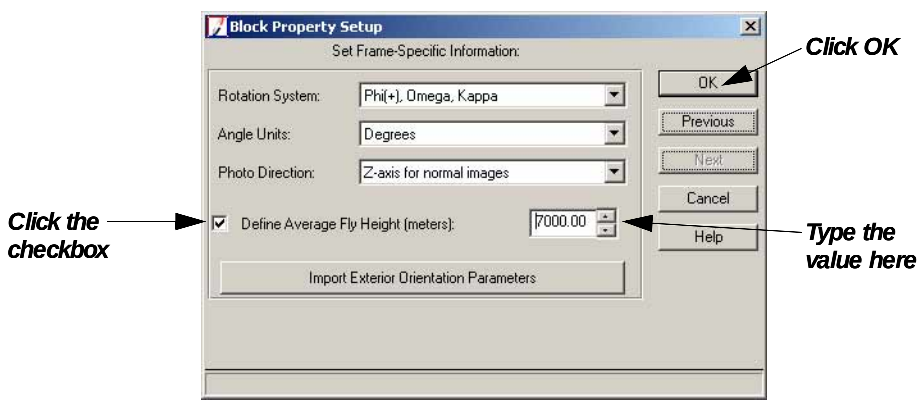
The projection information displays in the **Horizontal Reference Coordinate System** section of the dialog. In this case, the **Vertical** information should be the same as the **Horizontal.**



Ensure that the information you provide in the **Reference Coordinate System** *section of the Block Property Setup dialog is accurate. You are unable to return to this stage of the block setup process to change projection information once it has been set.*

8. Click **Next** in the Block Property Setup dialog.

The **Set Frame-Specific Information** section displays.



9. Click the checkbox next to **Define Average Fly Height (meters).**

The number field in this section is enabled.

10. Type **7000** in the **Define Average Fly Height (meters)** number field, then press Enter.

The average flying height is the distance between the camera at the time of exposure and the average ground elevation. The average flying height can be determined by multiplying the focal length by the image scale.

11. Click **OK** to close the Block Property Setup dialog.

Next, you specify the images that make up the block file.

The LPS CellArray

As you add images to the block file, they are listed in the LPS CellArray. Each image has a series of columns associated with it.

The **Row #** column enables you to select an image specifically for use with OrthoBASE. For example, you may want to generate pyramid layers for one image alone.

The **Image ID** column provides a numeric identifier for each image in the block. You can change the **Image ID** by typing inside the cell.

The **Description** field provides space for you to supply additional information about the image, such as date of capture.

The **>** column lets you designate the image that is currently active.

The **Image Name** column lists the directory path and file name for each image. When the full path to the image is specified, the corresponding **Online** column is green.

The **Active** column displays an **X** designating which images are going to be used in the OrthoBASE processes such as automatic tie point generation, triangulation, and orthorectification. By default, all images are active.

The final five columns' status is indicated in terms of color: green means the process is complete; red means the process is incomplete. The color of the columns is controlled by a preference setting. You can change the colors by going to the **LPS** category of the Preference Editor, then to **Status On Color** and **Status Off Color.**

The **Pyr.** column shows the presence of pyramid layers.

The **Int.** column shows if the fiducial marks have been measured.

The **Ext.** column shows if the final exterior orientation parameters are complete.

The **DTM** column shows if you have created DTMs, such as a DEM or a TIN, from the files in the block. This column is specifically related to OrthoBASE Pro functionality. For more information about OrthoBASE Pro, see *Chapter 7 "Automated DTM Extraction Tour Guide"*.

The **Ortho** column shows if the images have been orthorectified.

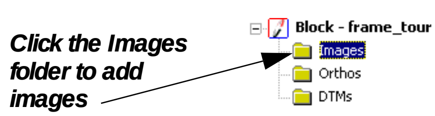
The **Online** column shows if the images have a specified location.

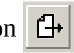
Add Imagery to the Block

Now that you have provided general information about the block, you can add images and create pyramid layers.

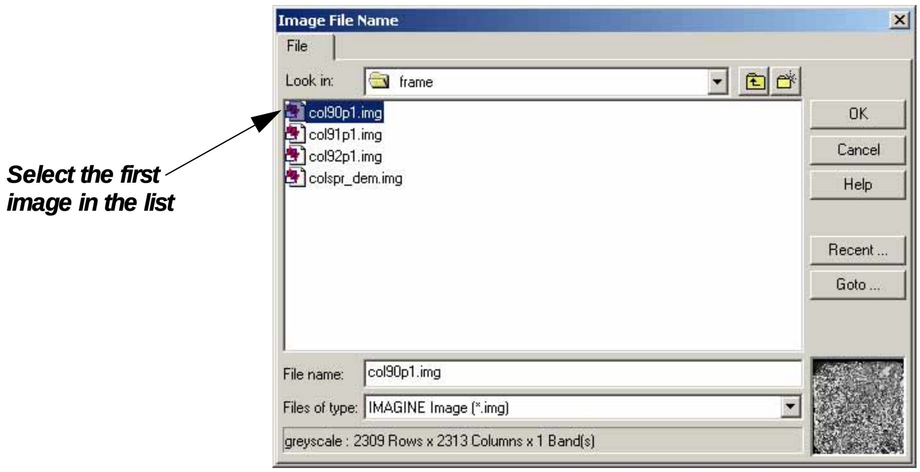
Add Frames

1. In the Block Project Tree View on the left side of the LPS Project Manager, click **Images.**



2. Select **Edit | Add Frame** from the menu bar, or click the Add Frame icon  .

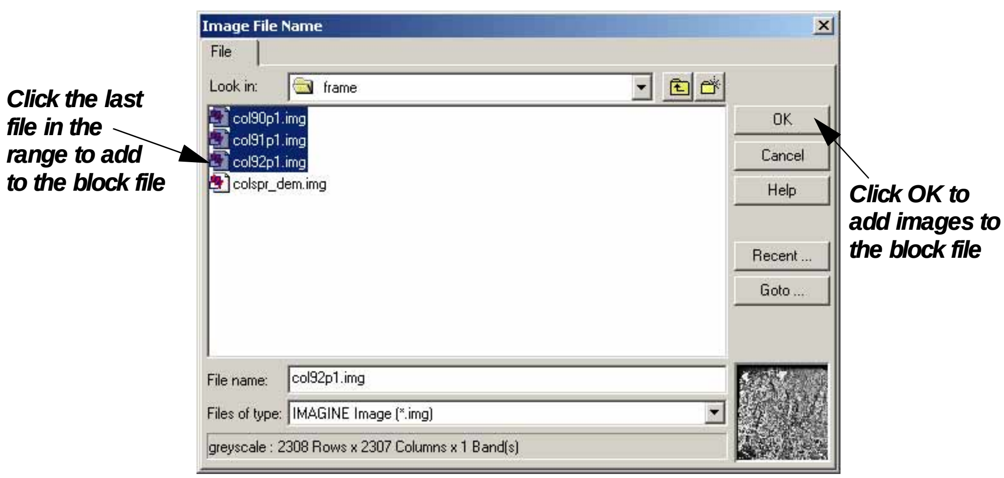
   The Image File Name dialog opens.



3. Navigate to /examples/orthobase/frame and select **col90p1.img.**

4. Hold down the Shift key and select the last *p1.img file in the list, **col92p1.img.**

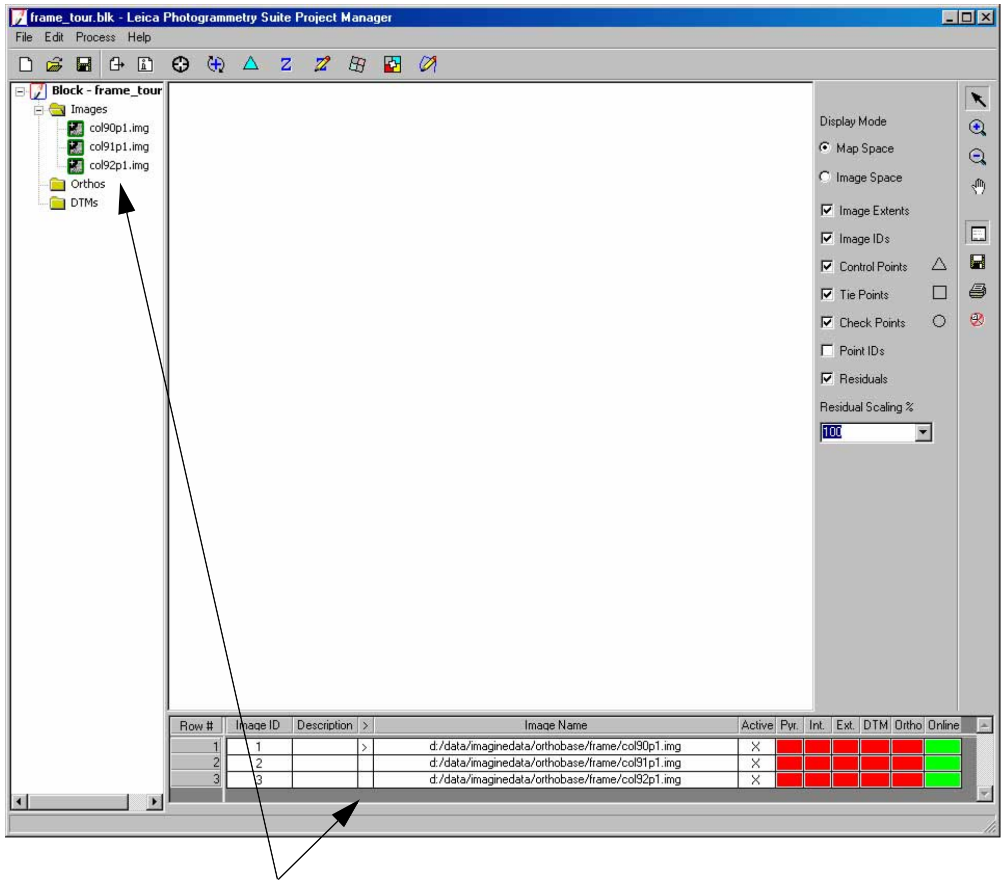
   All three *p1.img images are selected and can be added to the block file at once.



5. Click **OK** to close the Image File Name dialog.

   The three frame image files are loaded and display in the CellArray at the bottom of the LPS Project Manager. You can resize this portion of the LPS Project Manager so that the top window, the Project Graphic Status window, is enlarged.

6. Click the plus sign  next to the **Images** folder to see the list of images in the **frame_tour.blk** file.



The images in the Images folder display in the CellArray. As you work through the OrthoBASE workflow, the color of the columns in the CellArray indicates completed tasks.

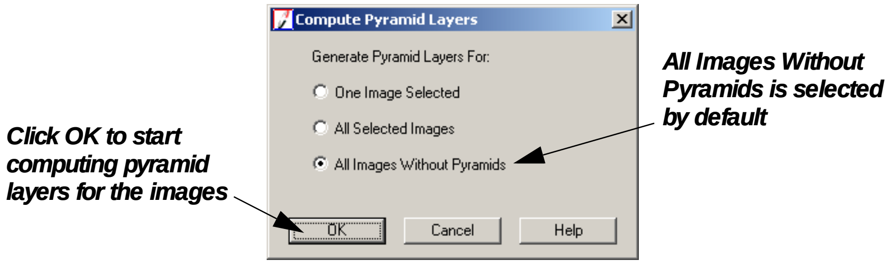
Compute Pyramid Layers

Next, you compute pyramid layers for the images in the block file. Pyramid layers are used to optimize image display and automatic tie point collection.

> ***OrthoBASE Pyramid Layers***
>
> Pyramid layers generated by OrthoBASE are based on a binomial interpolation algorithm and a Gaussian filter. Using this filter, image contents are preserved and computation times are reduced. Pyramid layers generated by OrthoBASE overwrite those generated by ERDAS IMAGINE, which uses different methods in pyramid generation.

1. Click the **Edit** menu, then choose the **Compute Pyramid Layers** option.

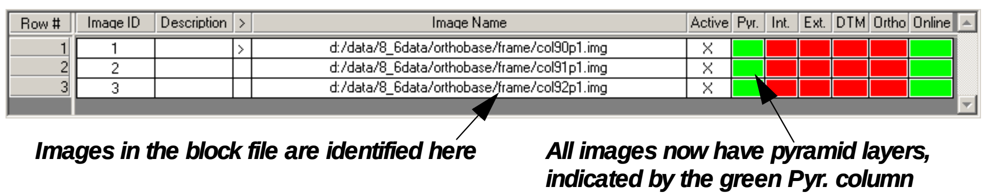
   The Compute Pyramid Layers dialog opens.



2. In the Compute Pyramid Layers dialog, confirm that the **All Images Without Pyramids** radio button is selected.

3. Click **OK** in the Compute Pyramid Layers dialog.

   A progress bar displays at the bottom of the LPS Project Manager as pyramid layers are created. When complete, the images' rows corresponding to the **Pyr.** column are all green.



Next, you define the camera model.

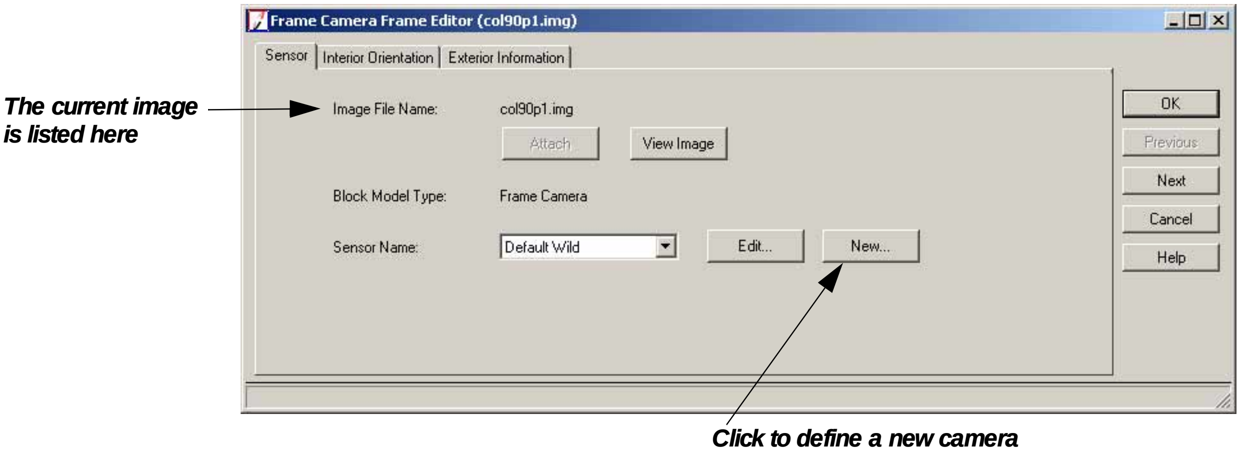
Define the Camera Model

When you define the camera model, you provide information about the position of the fiducials (interior orientation) as well as the camera position (exterior orientation) about the camera that collected the images.

Enter Specific Camera Information

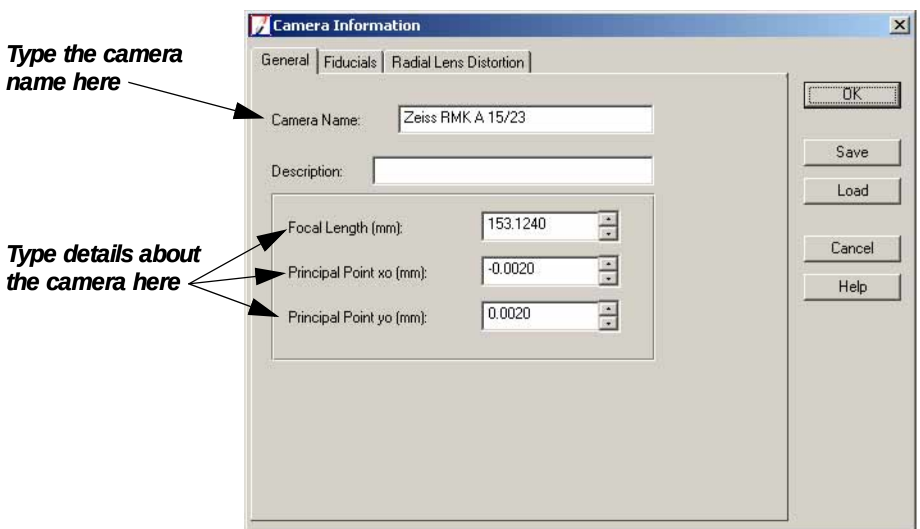
1. Select **Edit | Frame Editor** from the menu bar, or click the Frame Properties icon  .

   The Frame Camera Frame Editor dialog opens, displaying information about the active image listed in the CellArray, indicated with the **>, col90p1.img.**



2. In the **Sensor Name** section, click the **New** button.

   The Camera Information dialog opens.



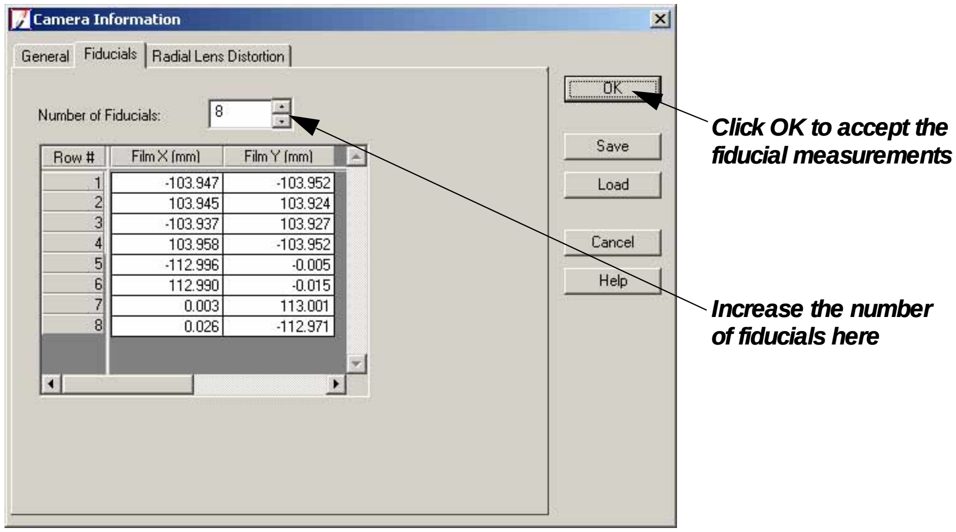
3. Enter **Zeiss RMK A 15/23** in the **Camera Name** text field.
4. Enter **153.124** in the **Focal Length (mm)** number field.
5. Enter **-0.002** in the **Principal Point xo (mm)** number field.
6. Enter **0.002** in the **Principal Point yo (mm)** number field.

For the complete calibration report, see the ReadMe file, **readme.doc,** *located in /examples/orthobase/frame.*

Add Fiducial Marks

1. Click the **Fiducials** tab in the Camera Information dialog.

The options for fiducials display.



2. Type **8** in the **Number of Fiducials** number field, then press Enter on your keyboard.

   The CellArray is populated by the additional fiducials, which are listed in the **Row #** column.

3. Enter the following information in the **Fiducials** tab CellArray:

Table 4-1: Frame Camera Fiducial Mark Locations

Row #	Film X (mm)	Film Y (mm)
1	-103.947	-103.952
2	103.945	103.924
3	-103.937	103.927
4	103.958	-103.952
5	-112.996	-0.005
6	112.990	-0.015
7	0.003	113.001
8	0.026	-112.971

You can also use the **Load** *button on the Camera Information dialog to load fiducial measurements contained in an ASCII file.*

4. Click **OK** to close the Camera Information dialog.

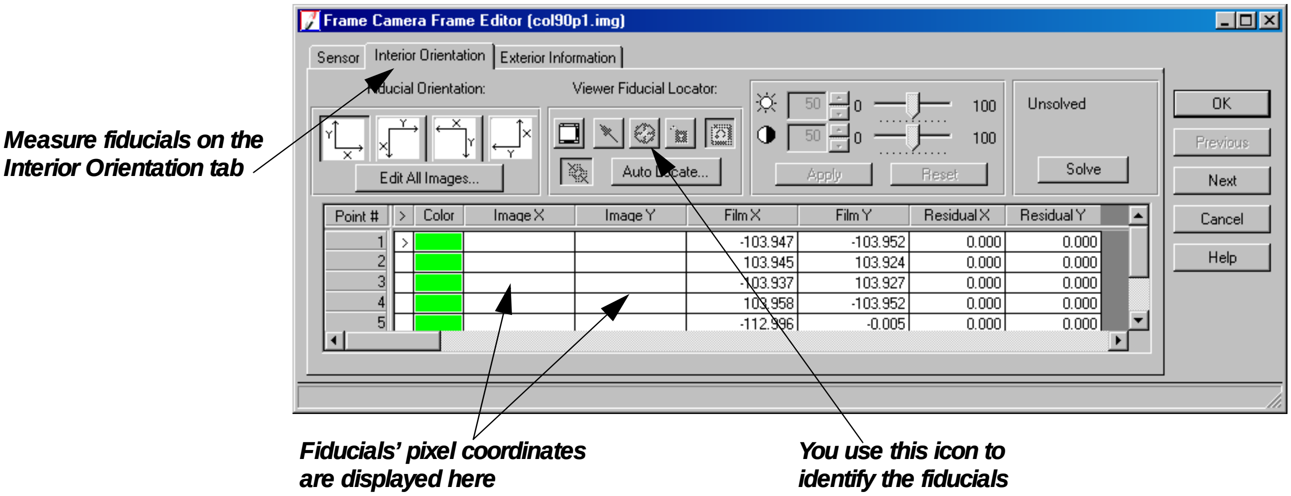
   The Frame Camera Frame Editor dialog remains, displaying the new camera information.

Measure Fiducials of the Images

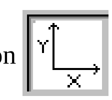
In this section, you are going to measure the fiducial marks in each of the three images.

1. Click the **Interior Orientation** tab of the Frame Camera Frame Editor dialog.

The tools for setting up the image's interior orientation information display. The image is identified in the title bar of the dialog.



To change the color of the fiducial marks, click in the **Color** *column, and select the color you would like from the* **Color** *menu.*

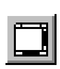
2. Make sure the first **Fiducial Orientation** icon  is selected.

Understanding Fiducial Orientation

To select the proper fiducial orientation, you should compare the axis of the photo-coordinate system, which is defined in the calibration report, with the orientation of the image.

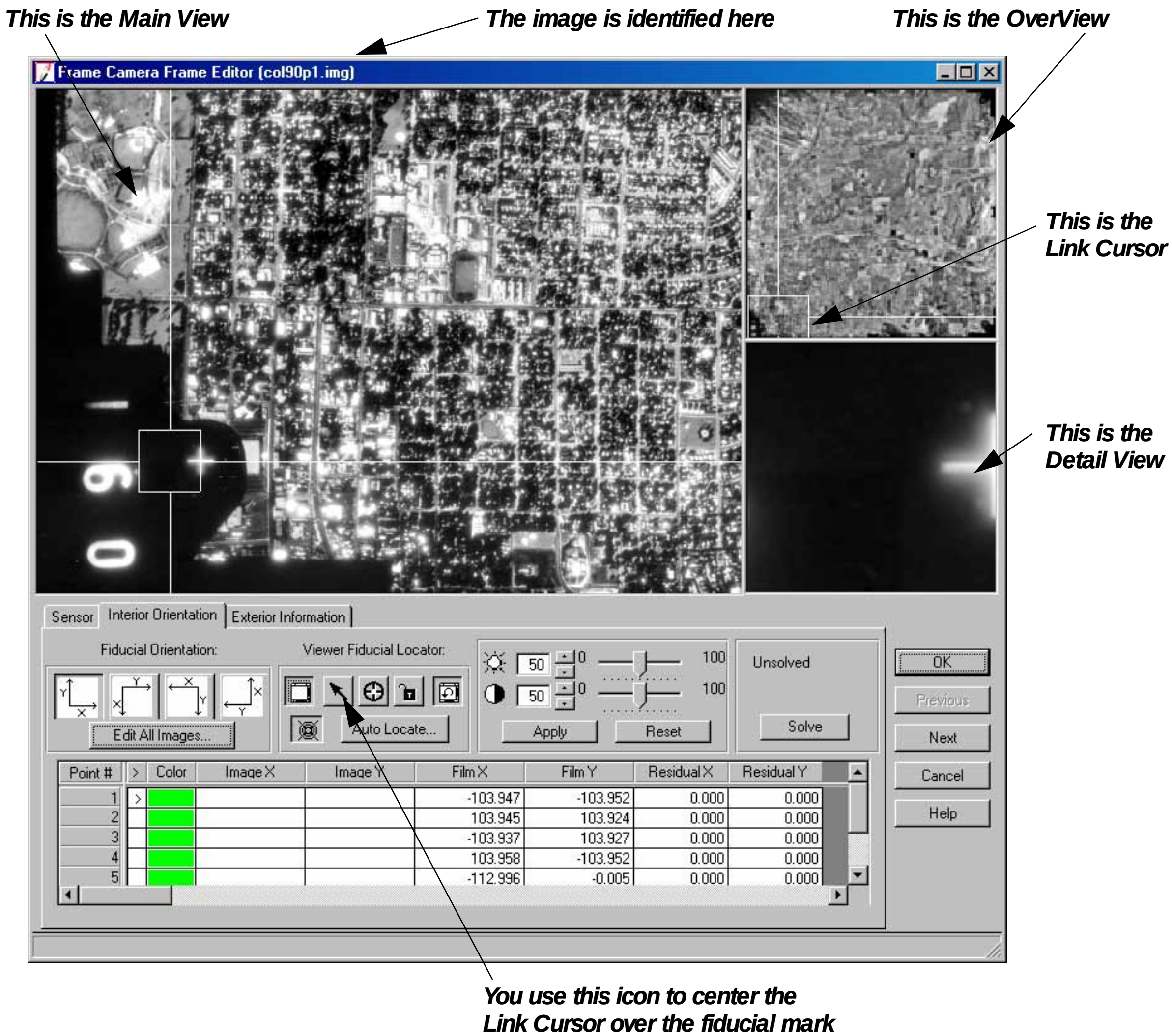
The four possible fiducial orientations are, in order:

1. photo-coordinate system parallel to image orientation,
2. image rotated 90° relative to the photo-coordinate system,
3. image rotated 180° relative to the photo-coordinate system, and
4. image rotated 270° degrees relative to the photo-coordinate system.

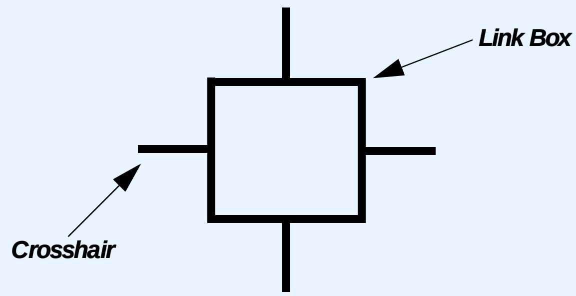
3. Click the View icon .

A Main View opens on top of the Frame Camera Frame Editor dialog, with an OverView that shows the entire image and a Detail View that shows the part of the image that is within the Link Box in the Main View. Any of the three views can be used for measuring the fiducials; however, it is usually easiest to place them in the Detail View.

If changing the color of the Link Cursor makes it easier to collect fiducials, you may do so by right clicking in the view, selecting **Link Box Color,** *and choosing a different color.*

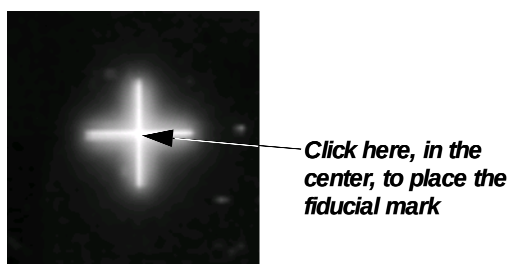


The approximate area of the first fiducial is identified by the Link Cursor in the Main View, and the area within the Link Box displays in the Detail View.

> ### *Link Cursor Elements*
>
> The Link Cursor, which appears in the Main View and the OverView, is a useful tool to resize the display of a feature of interest in any of the views. It is composed of various parts:
>
> 
>
>
> To reposition the Link Cursor grab a crosshair or the center of the link box and drag it to the desired location. To resize the Link Box, grab a corner and adjust it larger or smaller. To rotate the Link Box, middle-hold inside the Link Box and drag right or left.
>
> You use the Link Cursor extensively to select control, check, and tie points.

4. Click in the center of the Link Box in the Main View and drag it so that the cross-shaped fiducial mark is in the center.

The fiducial mark is centered in the Detail View. You can adjust its display (zoom in or out) by adjusting the size of the Link Box.

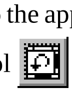


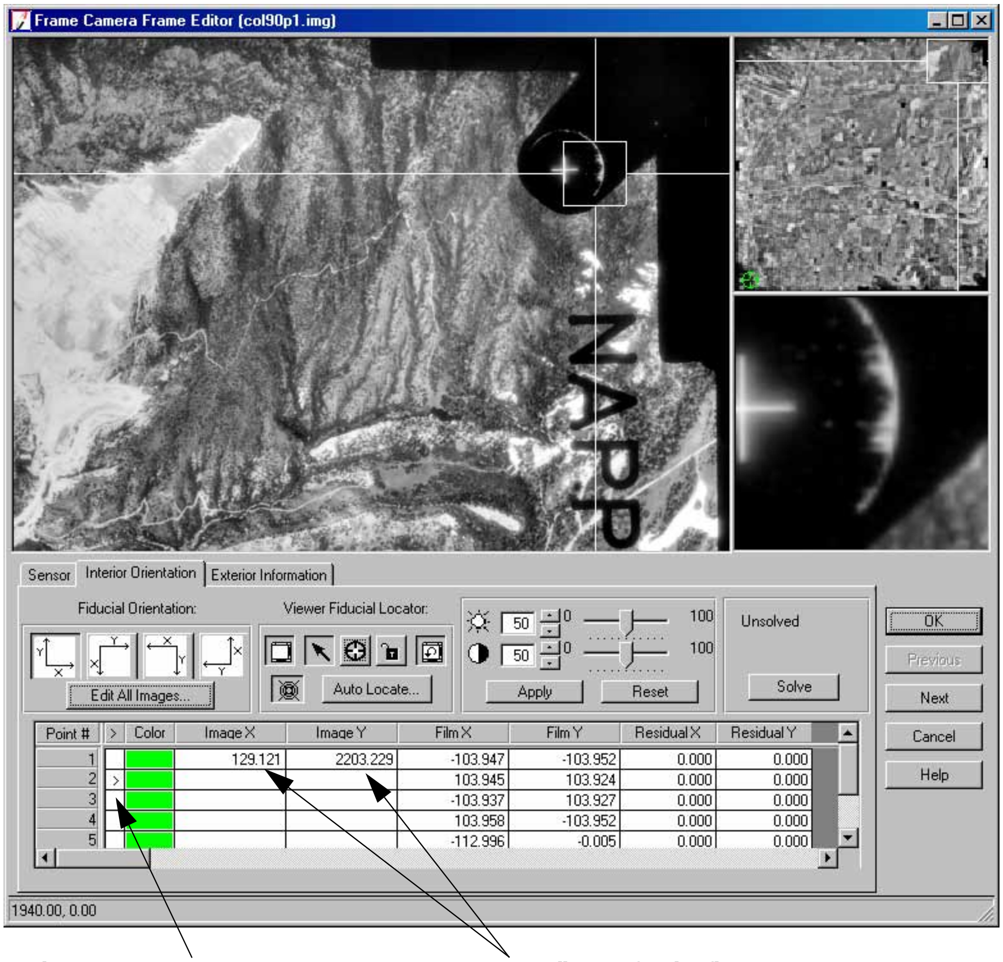
5. Click the Place Image Fiducial icon  on the **Interior Orientation** tab.

Your cursor becomes a crosshair when placed over any one of the views.

6. Measure the first fiducial by clicking in its center in the Detail View.

The fiducial point is measured and reported in the **Image X** and **Image Y** columns of the CellArray, and the display automatically moves to the approximate location of the next fiducial.

This is controlled by the Set Automatic Move tool  , which is enabled by default.



OrthoBASE moves to the next fiducial to be measured

Coordinates for the first fiducial have been recorded

You can click the Lock icon to lock the Place Image Fiducial icon . This means that you can use the icon repeatedly without having to select it each time you measure a fiducial in the image.

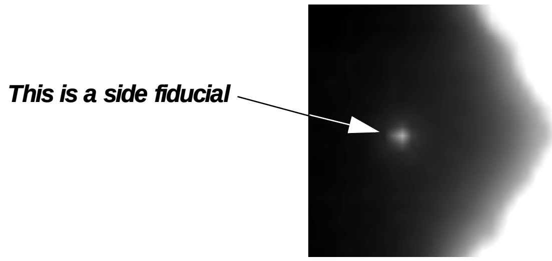
Using Auto Locate

Rather than measure each fiducial independently, LPS provides the **Auto Locate** option.

Used in conjunction with the Set Automatic Center icon , you can apply Auto Locate to find and mark fiducials in the one image displayed, in only active images in the block file, in the unsolved images, or in all images in the block file. A report generates to show you the results. If the results are acceptable and you apply them, the fiducial marks are then indicated in the view and CellArray. Of course, you can review the position of individual fiducial marks and change the location, if necessary.

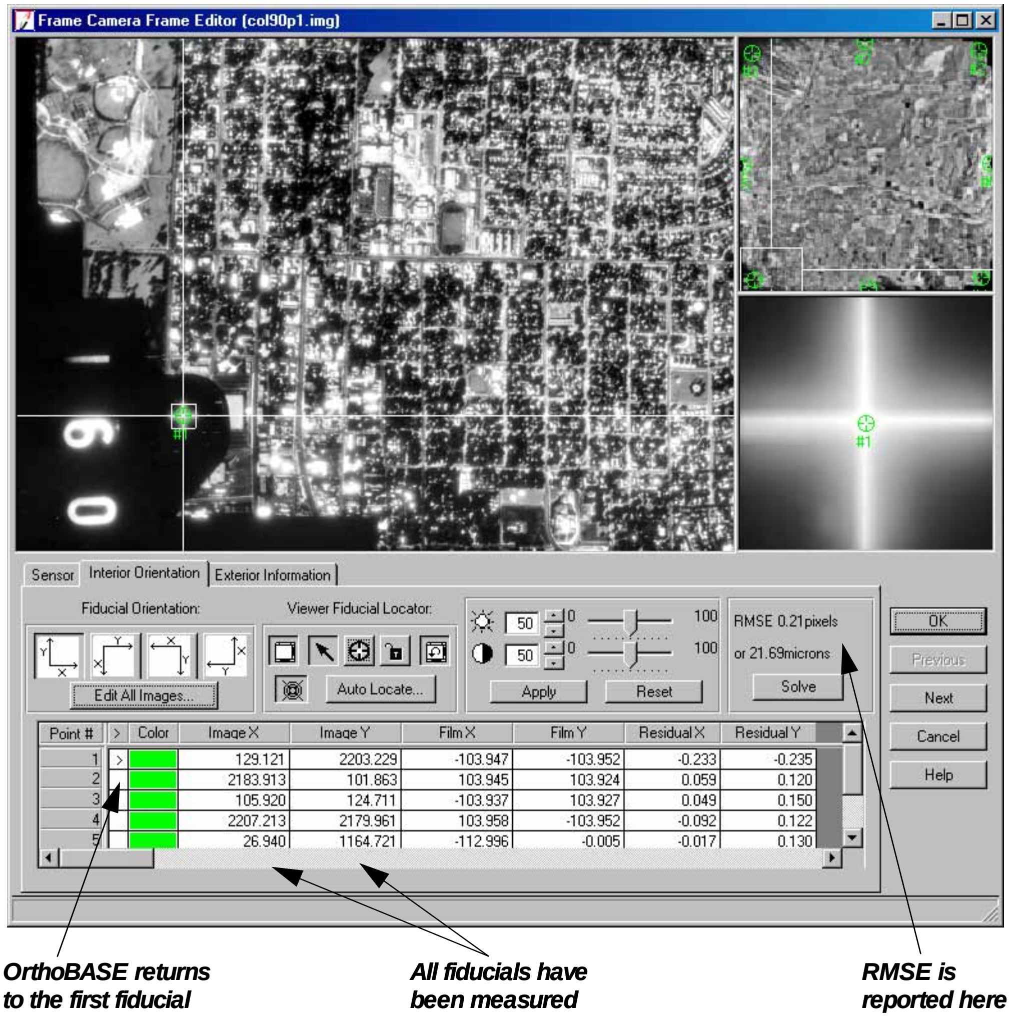
7. Measure the remaining fiducials, including side fiducials, using step 4 through step 6.

NOTE: Rather than plus signs (+), fiducials 5 through 8 display as dots in the Detail View. These are side fiducials.



When all eight fiducials are measured, the display returns to the first fiducial mark.

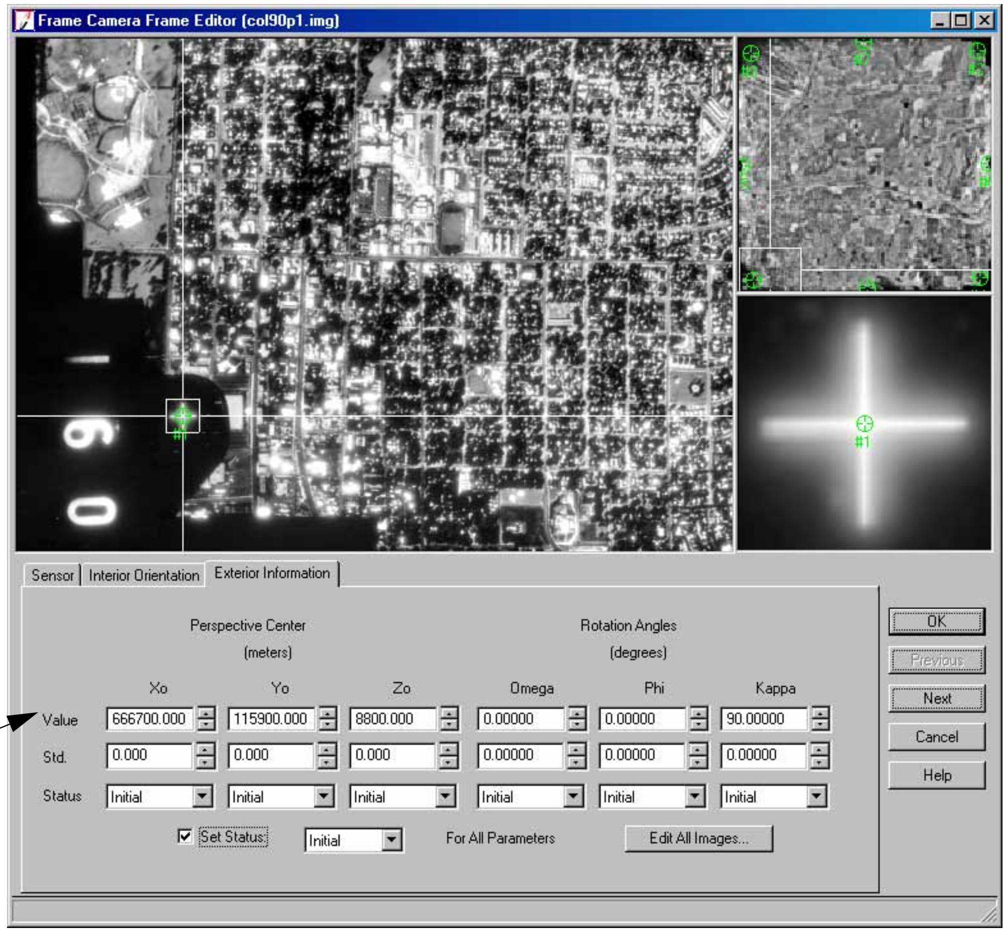
Your solution (displayed over the **Solve** button on the **Interior Orientation** tab of the Frame Camera Frame Editor) should be less than a pixel.



NOTE: If your solution is greater than 0.33 pixels, remeasure some of your fiducials. Frequently, the first few measurements are not quite as accurate as the later measurements. To remeasure, click in the row of the **Point #** *you wish to change, click the Select icon , then reposition the fiducial mark in the Detail View.*

Enter Exterior Orientation Information

1. Click the **Exterior Information** tab on the Frame Camera Frame Editor dialog.



2. Enter the following information in the **Value** number fields. These values correspond to the exterior orientation of the camera that captured the image **col90p1.**

Table 4-2: Exterior Orientation for col90p1

	Xo	Yo	Zo	Omega	Phi	Kappa
Value	666700.000	115900.000	8800.000	0.0000	0.0000	90.0000

3. Click the **Set Status** checkbox.

4. Confirm that the **Set Status** dropdown list is set to **Initial.**

Edit the Remaining Images in the Project

Now, you need to measure fiducials and define the exterior orientation for the remaining images in the block file.

1. Click on the **Sensor** tab in the Frame Camera Frame Editor dialog.

   This returns you to the beginning of the process. You complete this process two more times, once for each remaining image in the block file, measuring fiducials and providing exterior orientation for each.

2. Click the **Next** button on the Frame Camera Frame Editor dialog.

   The **Image File Name** on the **Sensor** tab changes to the next image, **col91p1,** in the CellArray. The image also displays in the views.

3. Note that the camera, **Zeiss RMK A 15/23,** is the same as that entered for the first image.

4. Click on the **Interior Orientation** tab.

5. Measure the fiducial marks in the second image, **col91p1.**

   If you need to review the steps, refer to "Measure Fiducials of the Images".

   Once you have finished measuring the eight fiducials in the **col91p1** image, the RMSE is reported.

6. After fiducials for the second image have been measured, click the **Exterior Information** tab.

7. Enter the following information in the **Value** number fields:

Table 4-3: Exterior Orientation for col91p1

	Xo	Yo	Zo	Omega	Phi	Kappa
Value	666700.000	119400.000	8800.000	0.0000	0.0000	90.0000

8. Click the **Set Status** checkbox.

9. Confirm that the **Set Status** dropdown list displays **Initial.**

10. Click the **Sensor** tab.

11. Click the **Next** button on the Frame Camera Frame Editor dialog to advance to the final image in the block file, **col92p1.**

12. Click the **Interior Orientation** tab.

13. Measure the fiducial marks in the third image, **col92p1.**

14. After fiducials for the third image have been measured, click the **Exterior Information** tab.

15. Enter the following information in the **Value** number fields, which corresponds to the position of the camera as it captured the last image in the block file, **col92p1.**

Table 4-4: Exterior Orientation for col92p1

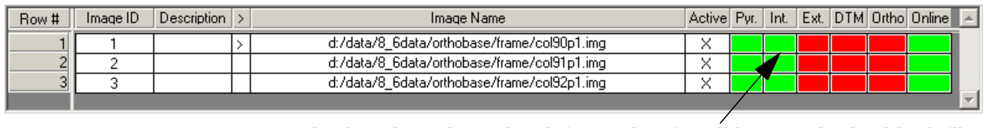
	Xo	Yo	Zo	Omega	Phi	Kappa
Value	666800.000	122900.000	8800.000	0.0000	0.0000	90.0000

16. Click the **Set Status** checkbox.

17. Confirm the **Set Status** dropdown list displays **Initial.**

18. Click **OK** to close the Frame Camera Frame Editor dialog.

Note that the **Int.** column of the CellArray is green, indicating that the interior orientation information has been specified for each image in the block file.



The interior orientation information for all images in the block file is complete, indicated by the green Int. column

An alternate method to the one presented here is to process each element completely (that is, identify all the sensors, measure all of the fiducials, then input all of the exterior orientation information), instead of proceeding image-by-image.

19. Click **File | Save** to save the interior orientation information to the block file, or click the Save icon.

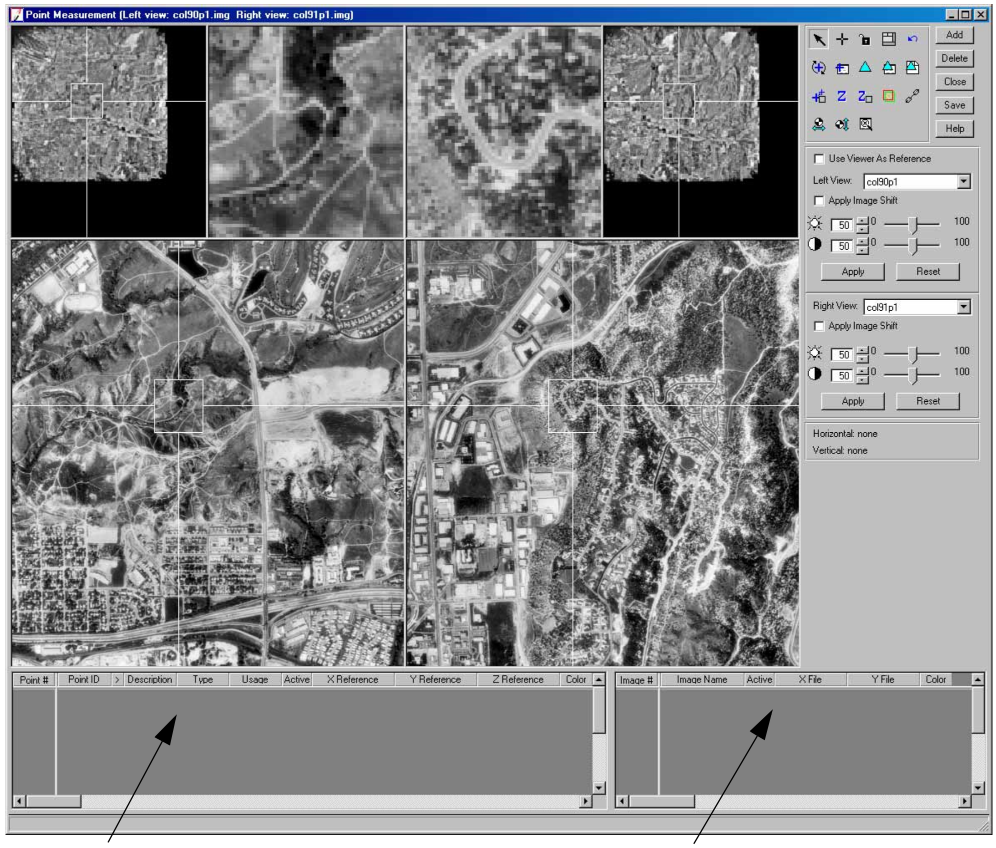
Measure GCPs and Check Points

Now that you have measured the fiducials and provided interior orientation for each image that makes up the block, you are ready to use the Point Measurement tool to measure the position of GCPs, tie points, and check points in the images. This determines exterior orientation.

1. Select **Edit | Point Measurement** from the menu bar.

You can also click the Point Measurement icon on the toolbar to open this dialog.

The Point Measurement tool opens. It displays the first two images in the block file, **col90p1** and **col91p1,** in the **Left View** and the **Right View,** respectively.



This is the reference CellArray: reference coordinates display here

This is the file CellArray: coordinates from the images (in pixels) display here

To change the color of points, click the Viewing Properties icon to access the **Viewing Properties** *dialog. In the* **Point Table Info** *section, click the* **Advanced** *radio button, click the* **Color** *checkbox, then click* **OK.** *This adds a* **Color** *column to the reference CellArray and the file CellArray. You can then left-click and choose the color you want.*

The Point Measurement tool consists of a tool palette, a reference CellArray (which gives coordinate values), a file CellArray (which gives pixel values), and six views in two groups of three that display different views of two of the image files in a block file. In this case, the first two files in the block, **col90p1** and **col91p1,** are shown. This is a single dialog that can be resized by dragging the corners and sides.

For information about the tools contained in the Point Measurement tool, see the On-Line Help.

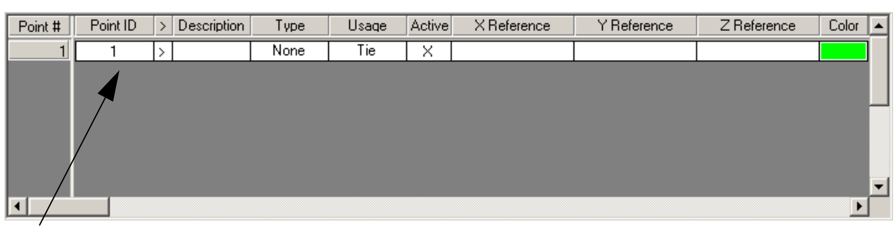
Collect Point ID 1002

The next series of steps takes you through the process of collecting a GCP.

> ***Real-world Application***
>
> When you use OrthoBASE in your own work, you might have a photo overview of an area along with other sources of information to locate GCPs. This type of application is simulated in this tour guide using a reference image, a reference sketch, and a Detail View of each control point.
>
> GCPs are typically placed in areas such as road intersections, building corners, or landmarks. You should avoid placing control points on features that vary, such as forest lines and water features. You might use a 1:24000 topographic map, state surveys, or sketches drawn in the field to help you locate appropriate points.
>
> In general, the process of collecting GCPs involves studying the topographic map for the location of a specific point, such as a road intersection. Once you have determined its location, you use OrthoBASE to collect and record the position. Then, you check the reference image to see where that point is located. Control point collection can be a time-consuming process, but accurate collection is imperative to the successful triangulation and orthorectification of images in your block file.
>
> Once you have collected some well-distributed GCPs that are common to two or more images in the block file, you can perform triangulation. Triangulation ties the images together so that they can then be orthorectified and linked together.
>
> *NOTE: The minimum amount is three vertical GCPs (with a Z coordinate) and two horizontal GCPs (with X and Y coordinates) per photo. If you use the auto tie function, you can collect fewer GCPs.*

1. Click the **Add** button in the upper right-hand corner of the Point Measurement tool to add a new **Point #.**

   This adds a new row to the reference CellArray in the lower portion of the Point Measurement tool.



Point IDs are added sequentially, but can be edited

2. Click in the **Point ID** column and type the new ID number, **1002.**

Specify the Type and Usage

1. Click in the **Type** column to access the dropdown list.
2. Select **Full** from the dropdown list.

   A **Full** GCP has X, Y, and Z (elevation) coordinates.
3. Click in the **Usage** column to access the dropdown list.

4. Select **Control** from the dropdown list.

   Control denotes a control point (versus a check point or tie point).

   Next, you are going to use a reference image of the area as well as a sketch and Detail View of control point **1002** to collect it in the image.

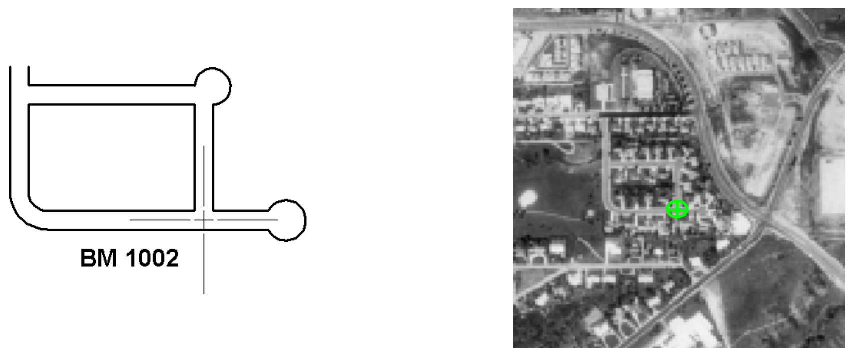
Collect Point ID 1002 in col90p1

Figure 4-9 shows you where points are located in the first image in the block, **col90p1.** You refer back to this graphic as you collect points. **Point ID** locations are indicated with boxes, and labeled accordingly.

Figure 4-2 is an example of the type of sketch produced in the field that you might use to locate the precise location of a point. BM, or benchmark, stands for the location of a point with known coordinates. Also included is a Detail View of **Point ID 1002.**

Each one of the following points also has a reference sketch and Detail View to help you select the point.

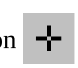
Figure 4-2: Reference Sketch and Detail View of Point ID 1002



1. Make sure that the Select Point icon  is active in the Point Measurement tool palette.

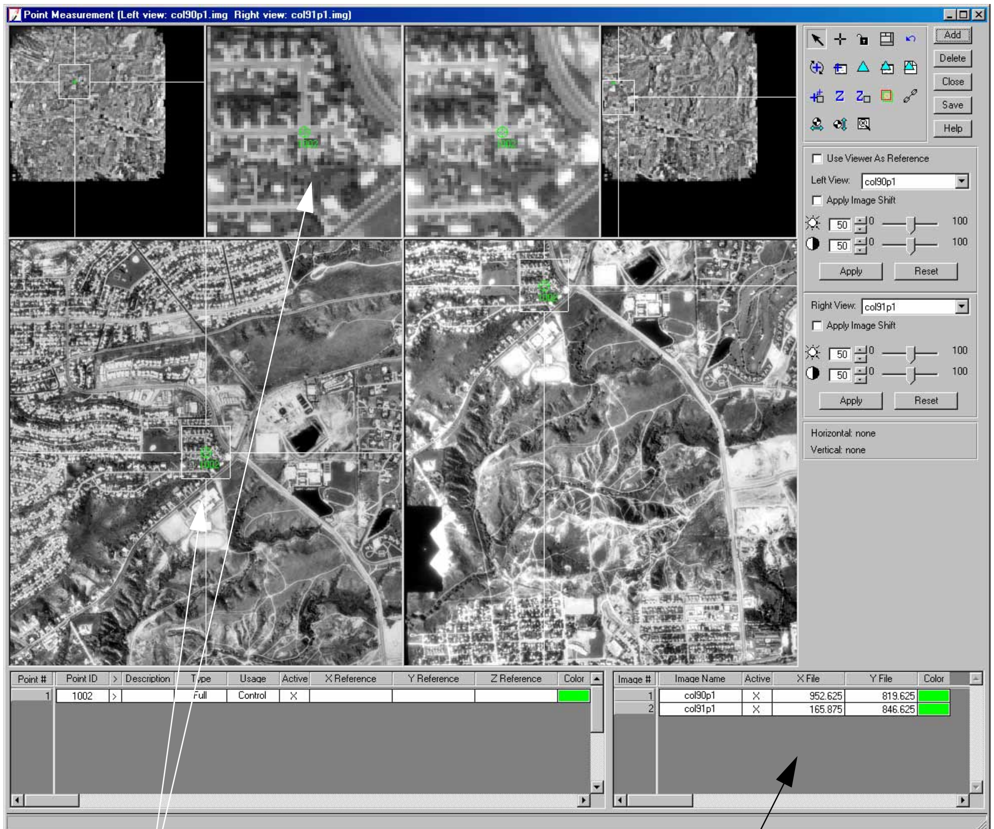
2. Using Figure 4-9 as a guide, move the Link Cursor in the OverView until you can see the area where **Point ID 1002** is located.

3. In the Main View, move the Link Cursor until the control point feature is visible in the Detail View. Resize the Link Box as necessary in the views.

4. Click the Create Point icon  in the Point Measurement tool palette.

5. Using Figure 4-2 as a guide, click in the Detail View to place control point **1002.**

   The point is placed in the views corresponding to **col90p1,** and labeled **1002.** The file CellArray reflects the coordinates of the point.



The control point displays in both the Main View and the Detail View

File coordinates of the control point in the first image display here

Collect Point ID 1002 in col91p1

Now that you know the approximate area in the reference image and the exact location in the Detail View, you are going to collect **Point ID 1002** in the second image of the block file, **col91p1.**

The graphic Figure 4-10 is a reference image that shows you where points are located in the second image in the block, **col91p1.** You refer back to this graphic as you collect points. **Point ID** locations are indicated with boxes, and labeled accordingly.

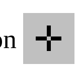
1. Using Figure 4-10 as a guide, apply the Select Point icon  and Create Point icon  to collect **Point ID 1002** in the second image, **col91p1.**
2. Check your results against the following **X File** and **Y File** coordinates for **Point ID 1002.**

Table 4-5: PID 1002 File Coordinates

Image	X File	Y File
col90p1	952.625	819.625
col91p1	165.875	846.625

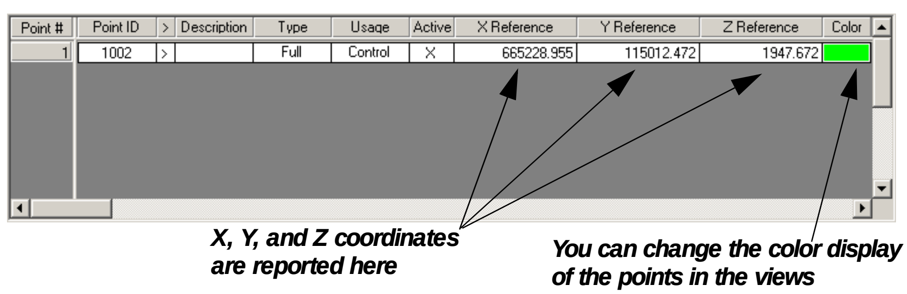
3. If your **X File** and **Y File** coordinates do not match those above to within two pixels, type the correct values into the file CellArray.

Enter Reference Coordinates for Point ID1002

Since you have successfully located **Point ID 1002** in the two images, **col90p1** and **col91p1,** you are ready to enter the reference control point coordinates. In this exercise, reference control points' coordinates are provided for you.

In Chapter 6 "SPOT Pushbroom Sensor Tour Guide", instead of typing in values, you are going to collect reference control points from a reference image displayed in a view.

1. Click in the **X Reference** column corresponding to **Point ID 1002.**
2. Type the value **665228.955** in the **X Reference** column.
3. Click in the **Y Reference** column corresponding to **Point ID 1002.**
4. Type the value **115012.472** in the **Y Reference** column.
5. Click in the **Z Reference** column corresponding to **Point ID 1002.**
6. Type the value **1947.672** in the **Z Reference** column, then press Enter on your keyboard.



7. When you are finished, click **Save** in the Point Measurement tool.

   Now, you are ready to place the second control point.

Collect Point ID 1003

1. Click the **Add** button in the upper right-hand corner of the Point Measurement tool to add a new **Point #.**

2. Click in the **Point ID** column and type the new ID number, **1003.**

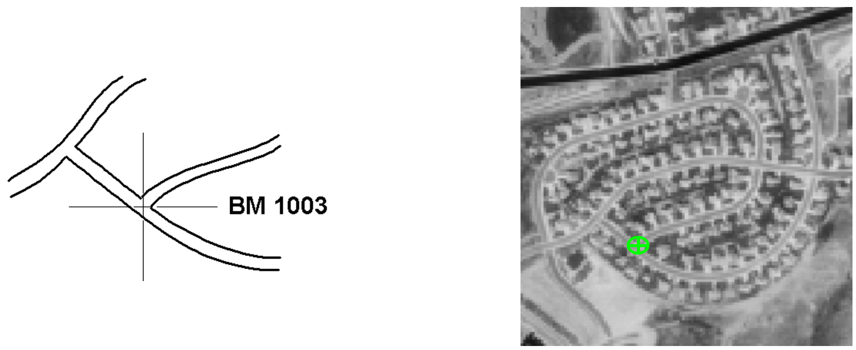
Specify the Type and Usage

1. Click in the **Type** column to access the dropdown list and select **Full.**

2. Click in the **Usage** column to access the dropdown list and select **Control.**

Collect Point ID 1003 in col90p1

Figure 4-3: Reference Sketch and Detail View of Point ID 1003



1. Make sure that the Select Point icon  is active in the Point Measurement tool palette.

2. Using Figure 4-9 as a guide, move the Link Cursor in the OverView until you can see the area where **Point ID 1003** is located.

3. In the Main View, move the Link Cursor until the control point feature is visible in the Detail View. Resize the Link Box as necessary in the views.

4. Click the Create Point icon  in the Point Measurement tool palette.

5. Using Figure 4-3 as a guide, click in the Detail View to place control point **1003.**

   The point is placed in the views and labeled **1003.** The file CellArray reflects the coordinates of the point.

Collect Point ID 1003 in col91p1

Now that you know the approximate area in the reference image and the exact location in the Detail View, you are going to collect **Point ID 1003** in the second image of the block file, **col91p1.** That image is displayed in the right three views (the **Right View** in the Point Measurement tool).

1. Check Figure 4-10 to locate the position of **Point ID 1003** in the reference image.

2. Use the Select Point and Create Point icons to collect **Point ID 1003** in the second image, **col91p1.**

Collect Point ID 1003 in col92p1

Point ID 1003 is visible in all three images that make up the block file. Right now, you can only see the images **col90p1** and **col91p1** in the Point Measurement tool. Using the **Right View** dropdown list, you can display the third image in the block, **col92p1,** and collect the control point in that image.

NOTE: In a real-world scenario, the images you work with may be much larger than those provided for this example, and would load slowly in the views. Therefore, you may want to select all of the points located in the two images currently displayed in the **Right View** *and* **Left View** *before loading another image. In the case of this tour guide, however, the images are small enough so that changing the displayed image does not take much time.*

1. In the Point Measurement tool, click on the **Right View** dropdown list.
2. From the **Right View** dropdown list, click **col92p1.**

   The third image, **col92p1,** is displayed in the right three views.
3. Using Figure 4-11, locate **Point ID 1003** in the reference image.
4. Use the Select Point and Create Point icons to collect **Point ID 1003** in the third image, **col92p1.**
5. Check your results against the following **X File** and **Y File** coordinates for **Point ID 1003.**

Table 4-6: PID 1003 File Coordinates

Image	X File	Y File
col90p1	1857.875	639.125
col91p1	1064.875	646.375
col92p1	286.875	639.125

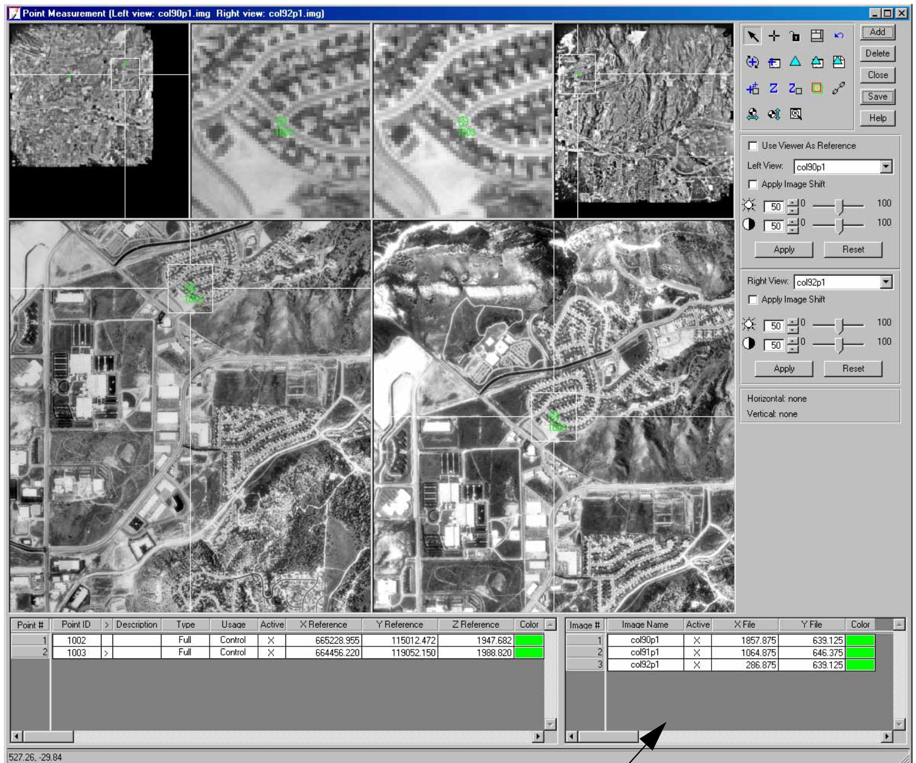
6. If your **X File** and **Y File** coordinates do not match those above to within two pixels, type the correct values into the file CellArray.

Enter Reference Coordinates for Point ID 1003

1. Click in the **X Reference** column corresponding to **Point ID 1003** and type the value **664456.22.**
2. Click in the **Y Reference** column corresponding to **Point ID 1003** and type the value **119052.15.**
3. Click in the **Z Reference** column corresponding to **Point ID 1003** and type the value **1988.820,** then press Enter on your keyboard.

4. When you are finished, click **Save** in the Point Measurement tool.

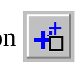
   When you have finished, the Point Measurement tool looks like the following:

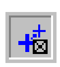


All three images in the block file are listed in the file CellArray—you maneuver between images using the Left View and Right View dropdown lists

Set Automatic (x, y) Drive Function

OrthoBASE provides some automatic functions to help you select GCPs more rapidly. One such function is the Automatic (x, y) Drive function. This function becomes available after you have selected two points, but is actually implemented after collection of the third point.

1. In the Point Measurement tool palette, click the Automatic (x, y) Drive icon  .

   The icon changes to  .

   Using the Automatic (x, y) Drive function, OrthoBASE approximates the location of the point in the second image based on the location of the point in the first image.

Collect Point ID 1004

Point ID 1004 is located in the images **col91p1** and **col92p1.** The last point you collected was in **col92p1,** which is displayed in the **Right View.** You are going to adjust the **Left View** to display **col91p1** before you begin.

1. Click the **Left View** dropdown list and select **col91p1.**

   The image **col91p1** displays in the left three views; **col92p1** is displayed in the right three views.

2. Click the **Add** button in the upper right-hand corner of the Point Measurement tool to add a new **Point #.**

3. Click in the **Point ID** column and type the new ID number, **1004.**

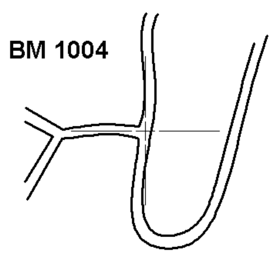
Specify the Type and Usage

1. Click in the **Type** column to access the dropdown list and select **Full.**

2. Click in the **Usage** column to access the dropdown list and select **Control.**

Collect Point ID 1004 in col91p1

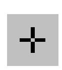
Figure 4-4: Reference Sketch and Detail View of Point ID 1004



1. Make sure that the Select Point icon  is active in the Point Measurement tool palette.

2. Using Figure 4-10 as a guide, move the Link Cursor in the OverView until you can see the area where **Point ID 1004** is located.

3. In the Main View, move the Link Cursor until the control point feature is visible in the Detail View. Resize the Link Box as necessary in the views.

4. Click the Create Point icon  in the Point Measurement tool palette.

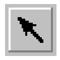
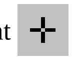
5. Using Figure 4-4 as a guide, click in the Detail View to place the control point **1004.**

   The point is placed in the views and labeled **1004.** The file CellArray reflects the coordinates of the point.

Collect Point ID 1004 in col92p1

Now that you know the approximate area in the reference image and the exact location in the Detail View, you are going to collect **Point ID 1004** in the third image in the block file, **col92p1.** That image is in the right three views (the **Right View** in the Point Measurement tool).

1. Check Figure 4-11 to locate the position of **Point ID 1004** in the reference image.

2. Use the Select Point  and Create Point  icons to collect **Point ID 1004** in the third image, **col92p1.**

3. Check your results against the following **X File** and **Y File** coordinates for **Point ID 1004.**

Table 4-7: PID 1004 File Coordinates

Image	X File	Y File
col91p1	1839.52	1457.43
col92p1	1050.60	1465.23

4. If your **X File** and **Y File** coordinates do not match those above to within two pixels, type the correct values into the file CellArray.

Enter Reference Coordinates for Point ID 1004

1. Click in the **X Reference** column corresponding to **Point ID 1004** and type the value **668150.61.**

2. Click in the **Y Reference** column corresponding to **Point ID 1004** and type the value **122404.68.**

3. Click in the **Z Reference** column corresponding to **Point ID 1004** and type the value **1972.056,** then press Enter on your keyboard.

4. When you are finished, click **Save** in the Point Measurement tool.

Collect Point ID 1005

The next control point, **Point ID 1005,** is located in all three of the images in the block file. It is usually best to select control points in the images' order in the block file (i.e., collect in **col90p1,** then **col91p1,** then **col92p1**). This order corresponds to the images' order in the strip. First, you use the **Left View** and **Right View** dropdown lists to get the images back in order.

1. Click the **Left View** dropdown list and select **col90p1.**

2. Click the **Right View** dropdown list and select **col91p1.**

3. Click the **Add** button in the upper right-hand corner of the Point Measurement tool to add a new **Point #.**

4. Click in the **Point ID** column and type the new ID number, **1005.**

Specify Type and Usage

1. Click in the **Type** column to access the dropdown list and select **Full.**
2. Click in the **Usage** column to access the dropdown list and select **Control.**

Collect Point ID 1005 in col90p1

Figure 4-5: Reference Sketch and Detail View of Point ID 1005

1. Make sure that the Select Point icon is active in the Point Measurement tool palette.
2. Using Figure 4-9 as a guide, move the Link Cursor in the OverView until you can see the area where **Point ID 1005** is located.
3. In the Main View, move the Link Cursor until the control point feature is visible in the Detail View. Resize the Link Box as necessary in the views.
4. Click the Create Point icon in the Point Measurement tool palette.
5. Using Figure 4-5 as a guide, click in the Detail View to place control point **1005.**

Note that, because you set the Automatic (x, y) Drive function, OrthoBASE adjusts the images in the views to display the same approximate area in the second image, **col91p1.**

Collect Point ID 1005 in col91p1

1. Use the Select Point and Create Point icons to collect **Point ID 1005** in the second image, **col91p1.**

Collect Point ID 1005 in col92p1

1. Click the **Right View** dropdown list and select **col92p1.**
2. Use the Select Point and Create Point icons to collect **Point ID 1005** in the third image, **col92.p1.**
3. Check your results against the following **X File** and **Y File** coordinates for **Point ID 1005.**

Table 4-8: PID 1005 File Coordinates

Image	X File	Y File
col90p1	1769.450	1508.430
col91p1	1007.250	1518.170
col92p1	224.670	1510.670

4. If your **X File** and **Y File** coordinates do not match those above to within two pixels, type the correct values into the file CellArray.

Enter Reference Coordinates for Point ID 1005

1. Click in the **X Reference** column corresponding to **Point ID 1005** and type the value **668338.22.**
2. Click in the **Y Reference** column corresponding to **Point ID 1005** and type the value **118685.9.**
3. Click in the **Z Reference** column corresponding to **Point ID 1005** and type the value **1886.712,** then press Enter on your keyboard.
4. When you are finished, click **Save** in the Point Measurement tool.

Collect Point ID 1006

Point ID 1006 is also located in all three images that make up the block file.

1. Click the **Right View** dropdown list and select **col91p1.**
2. Click the **Add** button in the upper right-hand corner of the Point Measurement tool to add a new **Point #.**
3. Click in the **Point ID** column and type the new ID number, **1006.**

Specify Type and Usage

1. Click in the **Type** column to access the dropdown list and select **Full.**
2. Click in the **Usage** column to access the dropdown list and select **Control.**

Collect Point ID 1006 in col90p1

Figure 4-6: Reference Sketch and Detail View of Point ID 1006

1. Make sure that the Select Point icon is active in the Point Measurement tool palette.

2. Using Figure 4-9 as a guide, move the Link Cursor in the OverView until you can see the area where **Point ID 1006** is located.

3. In the Main View, move the Link Cursor until the control point feature is visible in the Detail View. Resize the Link Box as necessary in the views.

4. Click the Create Point icon in the Point Measurement tool palette.

5. Using Figure 4-6 as a guide, click in the Detail View to place control point **1006.**

Collect Point ID 1006 in col91p1

1. Use the Select Point and Create Point icons to collect **Point ID 1006** in the second image, **col91p1.**

Collect Point ID 1006 in col92p1

1. Click the **Right View** dropdown list and select **col92p1.**

2. Use the Select Point and Create Point icons to collect **Point ID 1006** in the third image, **col92.p1.**

3. Check your results against the following **X File** and **Y File** coordinates for **Point ID 1006.**

Table 4-9: PID 1006 File Coordinates

Image	X File	Y File
col90p1	1787.875	2079.625
col91p1	1023.625	2091.390
col92p1	215.125	2083.790

4. If your **X File** and **Y File** coordinates do not match those above to within two pixels, type the correct values into the file CellArray.

Enter Reference Coordinates for Point ID 1006

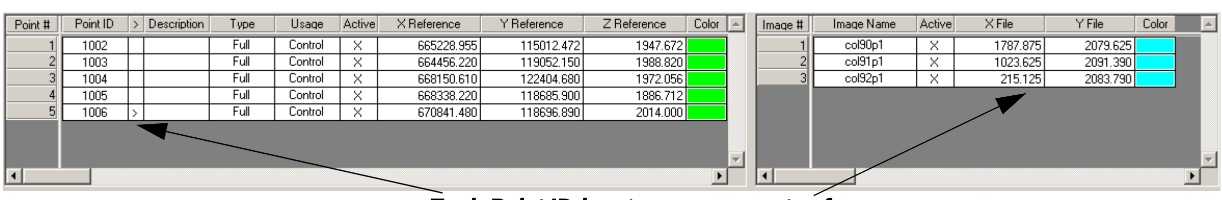
1. Click in the **X Reference** column corresponding to **Point ID 1006** and type the value **670841.48.**

2. Click in the **Y Reference** column corresponding to **Point ID 1006** and type the value **118696.89.**

3. Click in the **Z Reference** column corresponding to **Point ID 1006** and type the value **2014.0,** then press Enter on your keyboard.

4. When you are finished, click **Save** in the Point Measurement tool.

   When you are finished selecting the control points and entering reference coordinates into the CellArrays, they look like the following.



Point #	Point ID	>	Description	Type	Usage	Active	X Reference	Y Reference	Z Reference	Color
1	1002			Full	Control	X	665228.955	115012.472	1947.672	
2	1003			Full	Control	X	664456.220	119052.150	1988.820	
3	1004			Full	Control	X	668150.610	122404.680	1972.056	
4	1005			Full	Control	X	668338.220	118685.900	1886.712	
5	1006	>		Full	Control	X	670841.480	118696.890	2014.000	

Image #	Image Name	Active	X File	Y File	Color
1	col90p1	X	1787.875	2079.625	
2	col91p1	X	1023.625	2091.390	
3	col92p1	X	215.125	2083.790	

Each Point ID has two or more sets of file (pixel) coordinates associated with it

Input Check Points

Now, you are going to input two check points into the reference CellArray and the file CellArray. Check points are input in the same way as control points. The only difference is the **Check** designation in the **Usage** column.

NOTE: Check points are additional GCPs that are used to quantify the accuracy of the triangulation. Check points are not needed to actually perform the triangulation.

Collect Point ID 2001

Like control points, it is best to select the check points in the same order as the images in the block file.

1. Click the **Right View** dropdown list and select **col91p1.**

2. Click the **Add** button in the upper right-hand corner of the Point Measurement tool to add a new **Point #.**

3. Click in the **Point ID** column and type the new ID number, **2001.**

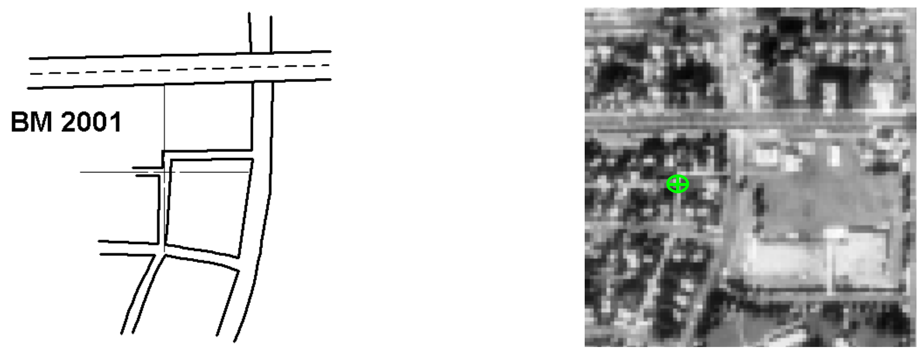
Specify Type and Usage

1. Click in the **Type** column to access the dropdown list and select **Full.**

2. Click in the **Usage** column to access the dropdown list and select **Check.**

Collect Point ID 2001 in col90p1

Figure 4-7: Reference Sketch and Detail View of Point ID 2001



1. Make sure that the Select Point icon is active in the Point Measurement tool palette.

2. Using Figure 4-9 as a guide, move the Link Cursor in the OverView until you can see the area where **Point ID 2001** is located.

3. In the Main View, move the Link Cursor until the check point feature is visible in the Detail View. Resize the Link Box as necessary in the views.

4. Click the Create Point icon in the Point Measurement tool palette.

5. Using Figure 4-7 as a guide, click in the Detail View to place check point **2001.**

Collect Point ID 2001 in col91p1

The Automatic (x, y) Drive function is still active, so OrthoBASE adjusts the display of the image in the views accordingly.

1. Use the Select Point and Create Point icons to collect **Point ID 2001** in the second image, **col91p1.**

2. Check your results against the following **X File** and **Y File** coordinates for **Point ID 2001.**

Table 4-10: PID 2001 File Coordinates

Image	X File	Y File
col90p1	915.02	2095.71
col91p1	160.90	2127.84

3. If your **X File** and **Y File** coordinates do not match those above to within two pixels, type the correct values into the file CellArray.

Enter Reference Coordinates for Point ID 2001

1. Click in the **X Reference** column corresponding to **Point ID 2001** and type the value **670970.45.**
2. Click in the **Y Reference** column corresponding to **Point ID 2001** and type the value **114815.23.**
3. Click in the **Z Reference** column corresponding to **Point ID 2001** and type the value **1891.888,** then press Enter on your keyboard.
4. When you are finished, click **Save** in the Point Measurement tool.

Collect Point ID 2002

Point ID 2002 is located in the last two images of the block file, **col91p1** and **col92p1.**

1. Click the **Right View** dropdown list and select **col92p1.**
2. Click the **Left View** dropdown list and select **col91p1.**

   NOTE: The same image cannot be displayed in both the **Right View** *and the* **Left View** *at the same time. This is why you are instructed to select from the* **Right View** *dropdown list first.*

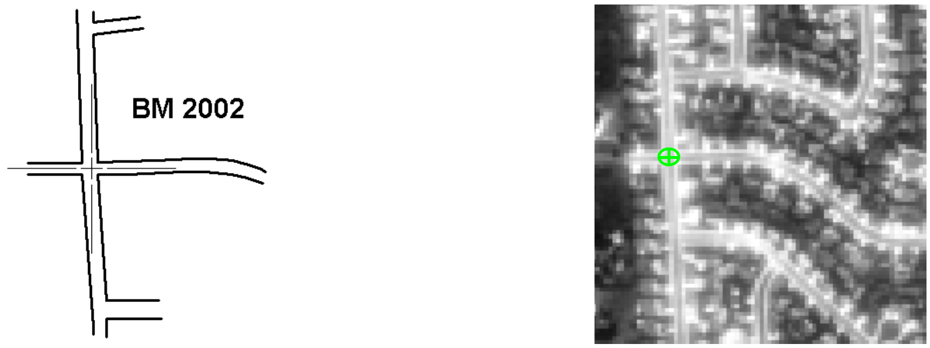
3. Click the **Add** button in the upper right-hand corner of the Point Measurement tool to add a new **Point #.**
4. Click in the **Point ID** column and type the new ID number, **2002.**

Specify Type and Usage

1. Click in the **Type** column to access the dropdown list and select **Full.**
2. Click in the **Usage** column to access the dropdown list and select **Check.**

Collect Point ID 2002 in col91p1

Figure 4-8: Reference Sketch and Detail View of Point ID 2002



1. Make sure that the Select Point icon is active in the Point Measurement tool palette.
2. Using Figure 4-10 as a guide, move the Link Cursor in the OverView until you can see the area where **Point ID 2002** is located.
3. In the Main View, move the Link Cursor until the check point feature is visible in the Detail View. Resize the Link Box as necessary in the views.
4. Click the Create Point icon in the Point Measurement tool palette.
5. Using Figure 4-8 as a guide, click in the Detail View to place check point **2002.**

Collect Point ID 2002 in col92p1

1. Use the Select Point and Create Point icons to collect **Point ID 2002** in the third image, **col92p1.**
2. Check your results against the following **X File** and **Y File** coordinates for **Point ID 2002.**

Table 4-11: PID 2002 File Coordinates

Image	X File	Y File
col91p1	2032.030	2186.530
col92p1	1227.375	2199.125

3. If your **X File** and **Y File** coordinates do not match those above to within two pixels, type the correct values into the file CellArray.

Enter Reference Coordinates for Point ID 2002

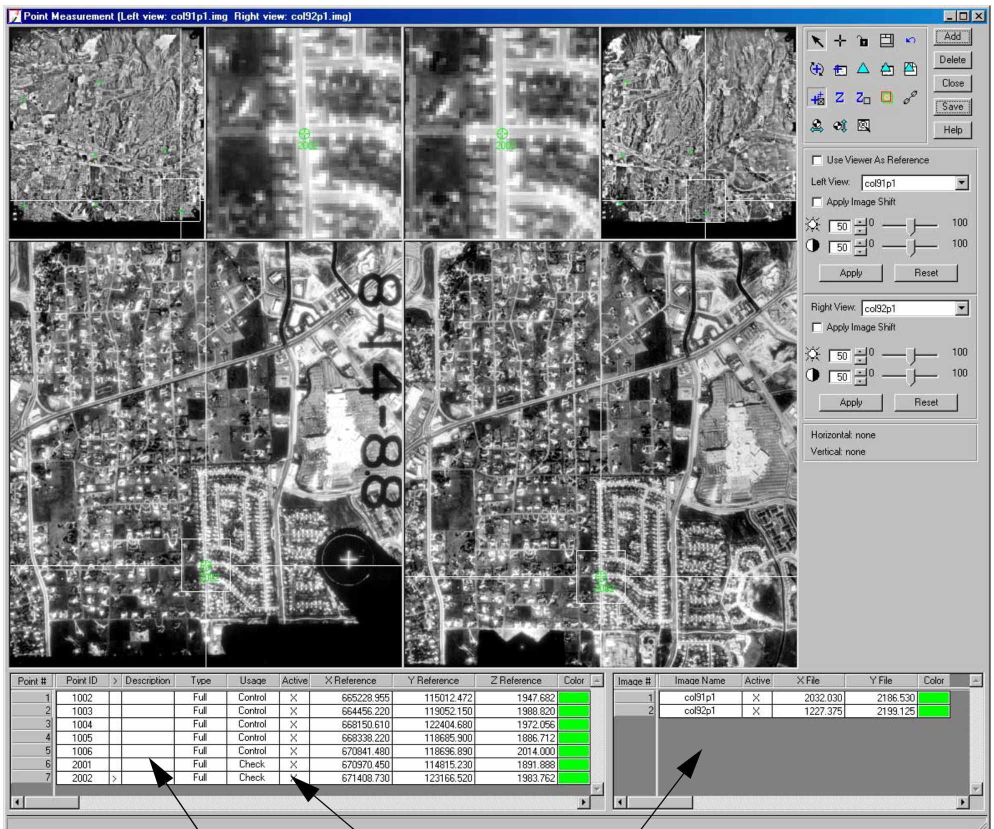
1. Click in the **X Reference** column corresponding to **Point ID 2002** and type the value **671408.73.**

2. Click in the **Y Reference** column corresponding to **Point ID 2002** and type the value **123166.52.**

3. Click in the **Z Reference** column corresponding to **Point ID 2002** and type the value **1983.762,** then press Enter on your keyboard.

4. When you are finished, click **Save** in the Point Measurement tool.

   When you are finished, the Point Measurement tool looks like the following:

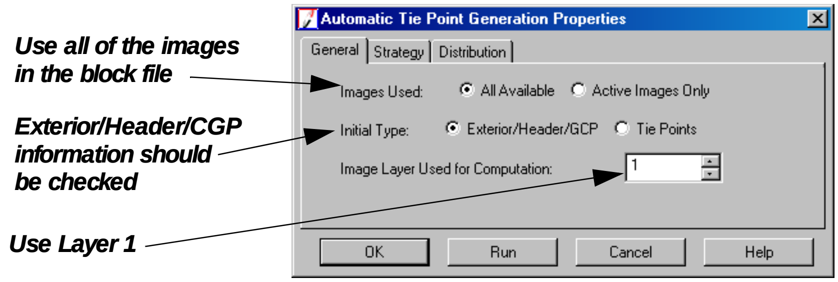


Perform Automatic Tie Point Generation

The tie point generation process measures the image coordinate positions of the control points, which are present in two or more overlapping images.

1. In the Point Measurement tool palette, click the Automatic Tie Point Collection Properties icon  .

   The Automatic Tie Point Generation Properties dialog opens.

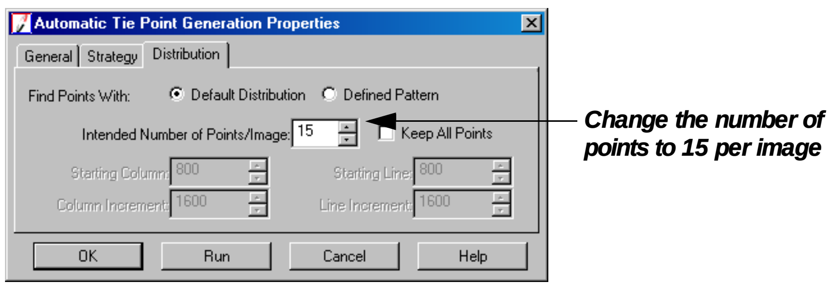


2. In the **General** tab, check to confirm that the **Images Used** radio button is set to **All available.**

3. Check to confirm that the **Initial Type** radio button is set to **Exterior/Header/GCP.**

   This option tells OrthoBASE to use the initial exterior orientation parameters to calculate image topology.

4. Check to confirm that the **Image Layer Used for Computation** is set to **1.**



5. Click the **Distribution** tab in the Automatic Tie Point Generation Properties dialog.

6. Click in the **Intended Number of Points Per Image** field and type **15,** then press Enter.

   The actual number of points generated by auto tie is greater than or less than 15. The number depends, in part, on the amount of overlap between the images.

7. Check to confirm that the **Keep All Points** checkbox is off (unchecked).

8. Click the **Run** button in the Automatic Tie Point Generation Properties dialog.

   OrthoBASE starts the automatic tie point generation process, indicated by a progress bar at the bottom of the Point Measurement tool. When complete, the tie points display in the views. The tie points have the **Type** designation **None** (no X, Y, and Z coordinates), and the **Usage** designation **Tie** in the reference CellArray. Their coordinates are added to the file CellArray in the **X File** and **Y File** columns.

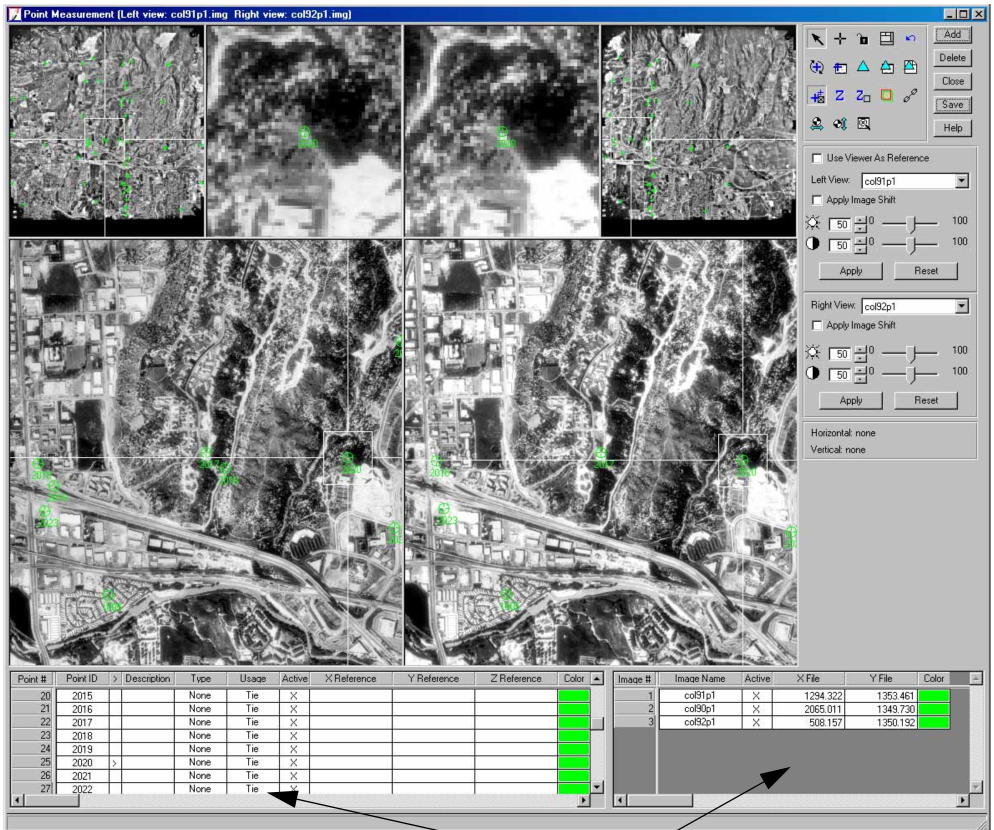
Check Tie Point Accuracy

You should always check a few of the tie points to ensure accuracy. If a point is not as accurate as you would like, you can always adjust it with the Select Point tool, deactivate it by clicking to remove the **X** in the **Active** column, or delete it by selecting the row in the CellArray (**>** column) and clicking the **Delete** button.

1. In the reference CellArray, click the scroll bar and scroll to any point, such as **Point ID 2020.**

2. Click in the **>** column to display **Point ID 2020.**

   The point displays in the views. This appears to be an acceptable tie point.



Tie points have File Coordinates, which are listed in the file CellArray, but no Reference coordinates

3. Click in the **>** column of other **Point ID**s to see where tie points were placed.

   NOTE: Since all tie points are not common to all images, there can be cases where the displayed images do not have corresponding tie points. In such cases, verify the tie point by opening a different adjacent image in one of the views. To do so, use the **Left View** *or* **Right View** *dropdown list.*

4. If the position of a tie point needs to be adjusted, click the Select Point icon  and move it in the Detail View.

5. When you are finished reviewing the automatically generated tie points, click the **Save** button.

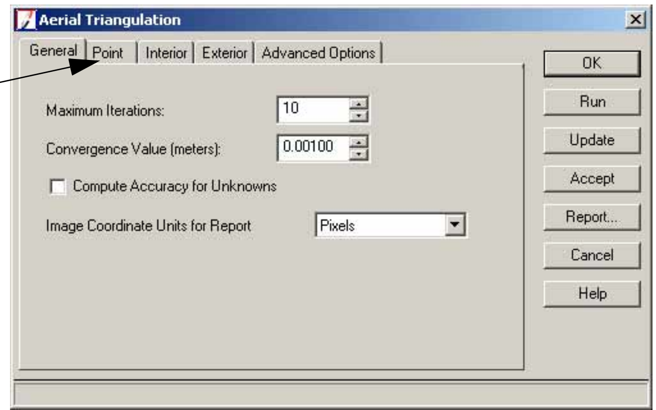
6. Click the **Close** button to close the Point Measurement tool.

Perform Aerial Triangulation

Now that you have obtained control, check, and tie points, OrthoBASE has all the information it needs to perform aerial triangulation. This step in the process establishes the mathematical relationship between the images that make up the block file and calculates exterior orientation.

1. From the **Edit** menu, select **Triangulation Properties.**

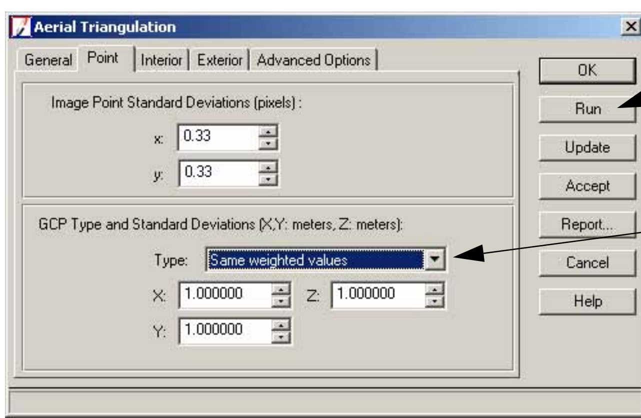
   The Aerial Triangulation dialog opens.



You can also access the Aerial Triangulation dialog from the Point Measurement tool by clicking the Triangulation Properties icon .

2. Click the **Point** tab in the Aerial Triangulation dialog.

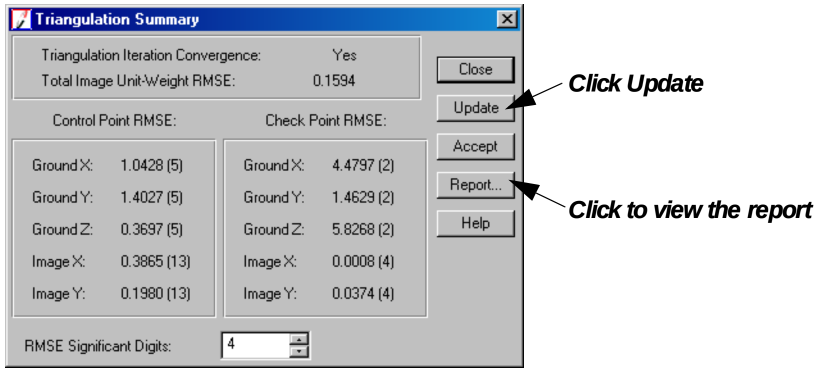
   The **Point** options display. These control the statistical weights (i.e., the confidence in their accuracy) assigned to the GCP parameters. These are commonly defined by the precision of the GCPs (i.e., the reference source). For example, a weight of 1 meter is better accuracy than a weight of 5 meters.



3. In the **GCP Type and Standard Deviations** section, click the **Type** dropdown list and select **Same Weighted Values.**

4. Click the **Run** button to run the aerial triangulation.

A Triangulation Summary dialog generates and opens.

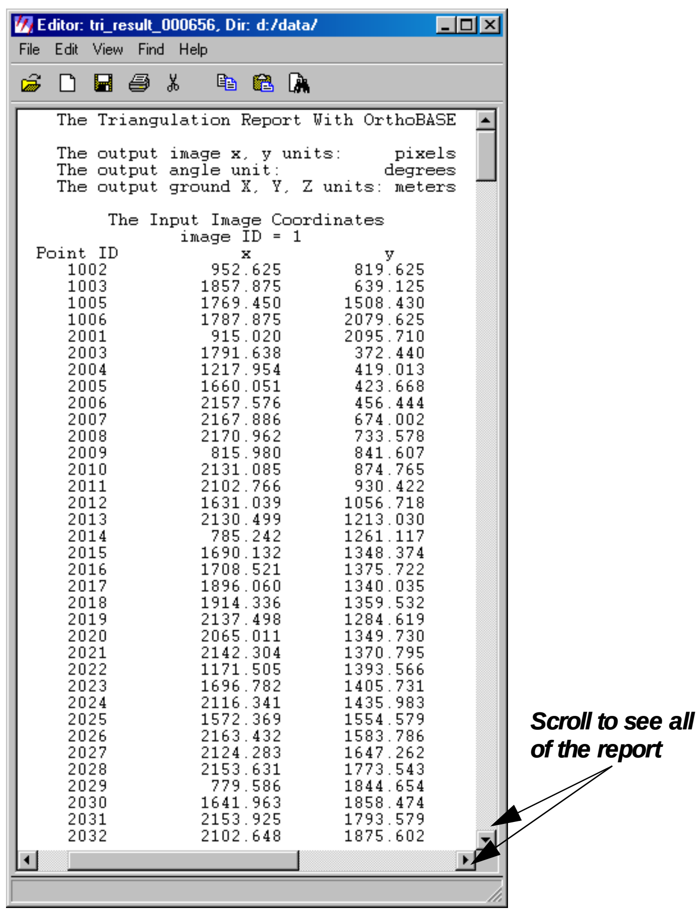


Find Information in the Triangulation Report

You may wish to consult the Triangulation Report for more detailed numbers corresponding to the triangulation. You can save the report as a text file for future reference.

1. In the Triangulation Summary dialog, click the **Report** button.

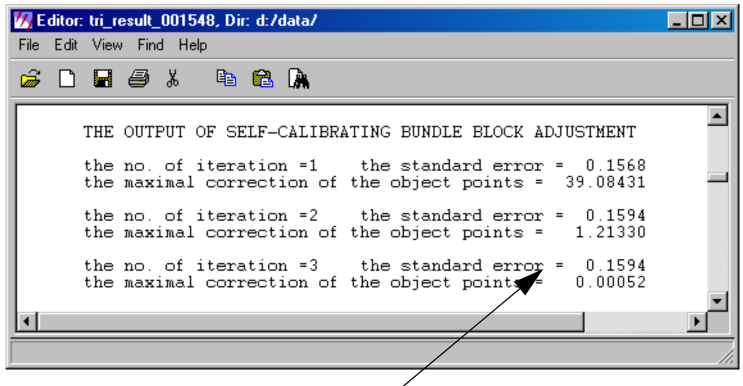
The Triangulation Report opens.



2. Resize the Triangulation Report so that it is all visible in the window.

Check the Results

1. Scroll down until you reach **The Output of Self-calibrating Bundle Block Adjustment** section of the report.

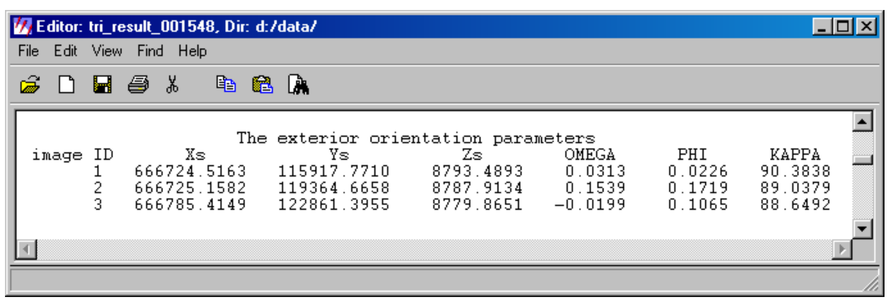


The standard error of the last iteration is the most important

2. Note the **standard error** of **iteration** number **3.**

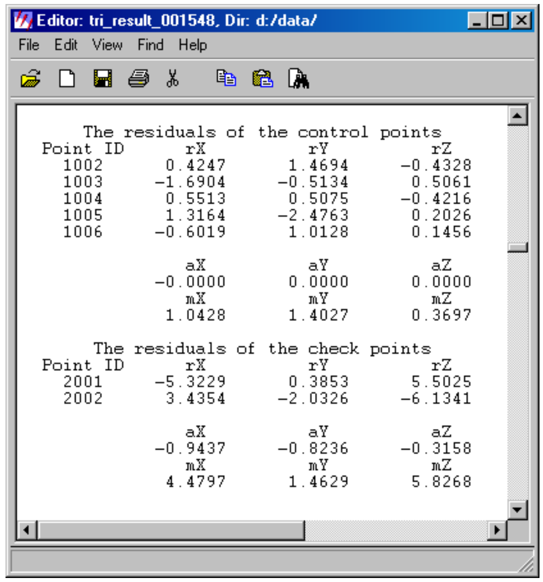
   In the report above, the **standard error** is **.1594.** This is the standard deviation of unit weight, and measures the global quality of that iteration.

3. Note the **exterior orientation parameters.**



   These are the exterior orientation parameters associated with each image in the block file.

4. Note the **residuals of the control points** and the **residuals of the check points.**



Editor: tri_result_001548, Dir: d:/data/

File Edit View Find Help

The residuals of the control points

Point ID	rX	rY	rZ
1002	0.4247	1.4694	-0.4328
1003	-1.6904	-0.5134	0.5061
1004	0.5513	0.5075	-0.4216
1005	1.3164	-2.4763	0.2026
1006	-0.6019	1.0128	0.1456

aX	aY	aZ
-0.0000	0.0000	0.0000
mX	mY	mZ
1.0428	1.4027	0.3697

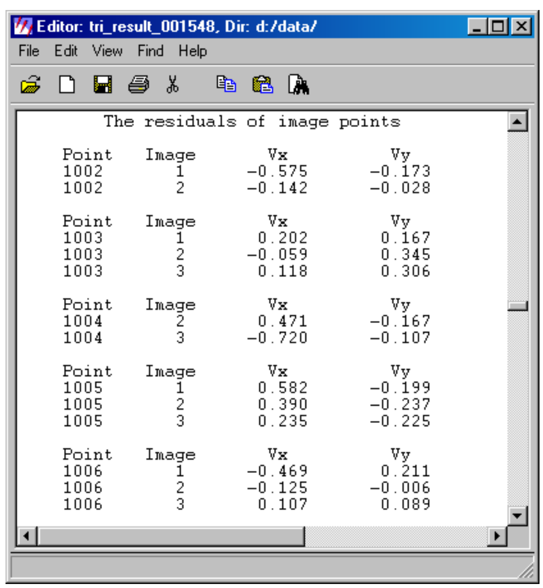
The residuals of the check points

Point ID	rX	rY	rZ
2001	-5.3229	0.3853	5.5025
2002	3.4354	-2.0326	-6.1341

aX	aY	aZ
-0.9437	-0.8236	-0.3158
mX	mY	mZ
4.4797	1.4629	5.8268

The control point X, Y, and Z residuals define the accuracy in both the average residual and the geometric mean residual. The X, Y, and Z residuals of the check points serve as an independent check in defining the average quality of the solution.

5. Scroll down to the **residuals of image points** section of the Triangulation Report.



Editor: tri_result_001548, Dir: d:/data/

File Edit View Find Help

The residuals of image points

Point	Image	Vx	Vy
1002	1	-0.575	-0.173
1002	2	-0.142	-0.028

Point	Image	Vx	Vy
1003	1	0.202	0.167
1003	2	-0.059	0.345
1003	3	0.118	0.306

Point	Image	Vx	Vy
1004	2	0.471	-0.167
1004	3	-0.720	-0.107

Point	Image	Vx	Vy
1005	1	0.582	-0.199
1005	2	0.390	-0.237
1005	3	0.235	-0.225

Point	Image	Vx	Vy
1006	1	-0.469	0.211
1006	2	-0.125	-0.006
1006	3	0.107	0.089

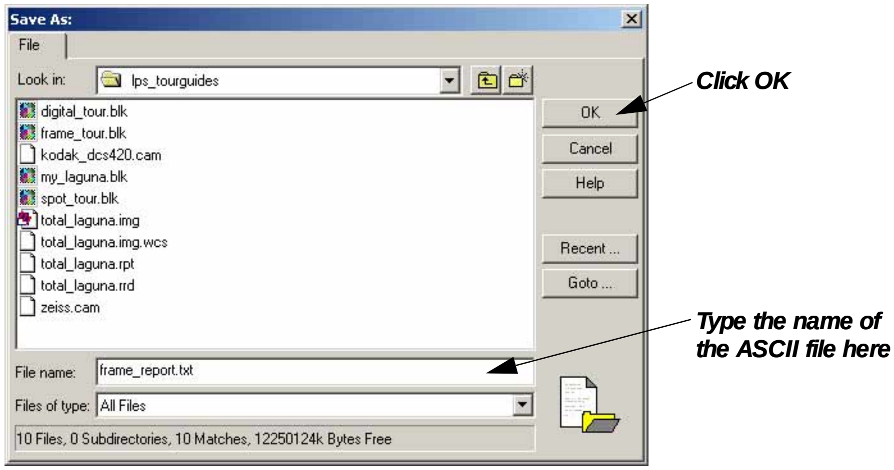
These are the photo or image coordinate residuals. They can be used to determine the less accurate points. The inaccurate points generally have large residuals.

Save the Triangulation Report

If you save the Triangulation Report, you can always refer back to it.

1. From the **File** menu of the ERDAS IMAGINE Text Editor, select **Save As.**

   The Save As dialog opens.



2. Navigate to a folder in which you have write permission.

3. In the **File name** text field, type the name **frame_report.txt,** then press Enter.

4. Click **OK** in the Save As dialog.

5. When you are finished viewing the Triangulation Report, select **File | Close** in the ERDAS IMAGINE Text Editor.

   You are returned to the Triangulation Summary dialog.

To open the Triangulation Report in ERDAS IMAGINE, click the **Tools** *menu in the ERDAS IMAGINE menu bar. Then, select* **Edit Text Files.** *Use the Open icon to open the report in the IMAGINE Text Editor dialog.*

Update the Exterior Orientation

1. In the Triangulation Summary dialog, click the **Update** button to update the exterior orientation parameters.

   This replaces the **Initial** exterior orientation parameters you entered during the measurement of fiducials with the exterior orientation computed by OrthoBASE based on control and tie points in the images making up the block file.

You also have the option to use check points to determine exterior orientation. That option is located in the Aerial Triangulation dialog, **Advanced Options** *tab.*

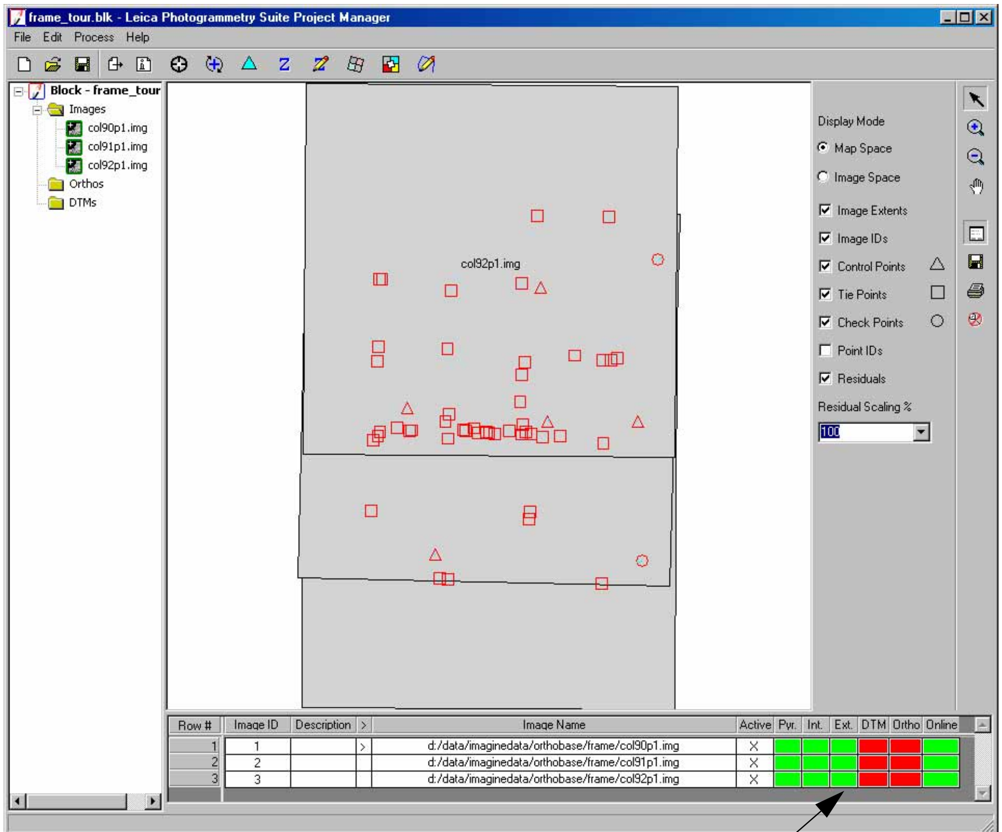
2. Click the **Close** button to close the Triangulation Summary dialog.

3. In the Aerial Triangulation dialog, click the **Accept** button to accept the triangulation parameters.

4. Click **OK** in the Aerial Triangulation dialog to close it.

   The Project Graphic Status window and CellArray of the LPS Project Manager update to reflect the completion of the exterior orientation step. Notice that the **Ext.** column is now green.

5. Click the **Images** folder to see the graphic display of the block file in the Project Graphic Status window.



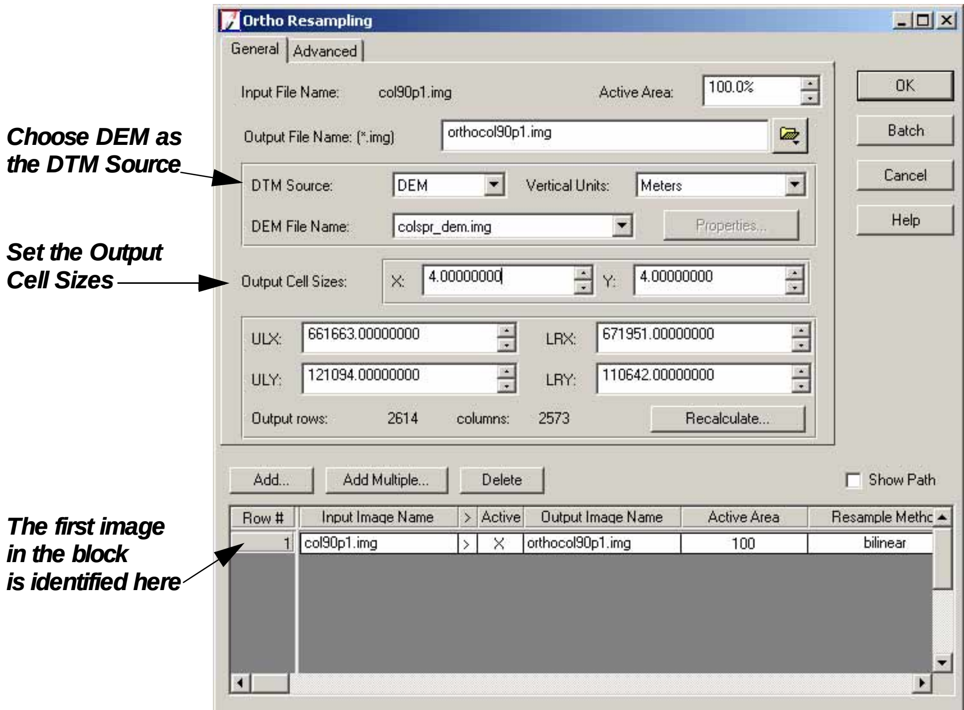
The Ext. column is green, indicating the exterior orientation has been calculated

Ortho Resample the Imagery

The next step creates orthorectified images of your block file images. Orthorectified images have fewer relief displacements and geometric errors than nonorthorectified images, and thus are considered more accurate. The orthorectified images display objects in their real-world X, Y, and Z positions.

1. On the LPS toolbar, click the Ortho Resampling icon  .

   The Ortho Resampling dialog opens on the **General** tab.



2. Click the **DTM Source** dropdown list, then select **DEM.**

   The DEM file is used to supply elevation information to create the orthorectified imagery.

3. Confirm that the **Vertical Units** are set to **Meters.**

4. Click the dropdown list associated with the **DEM File Name,** and select **Find DEM.**

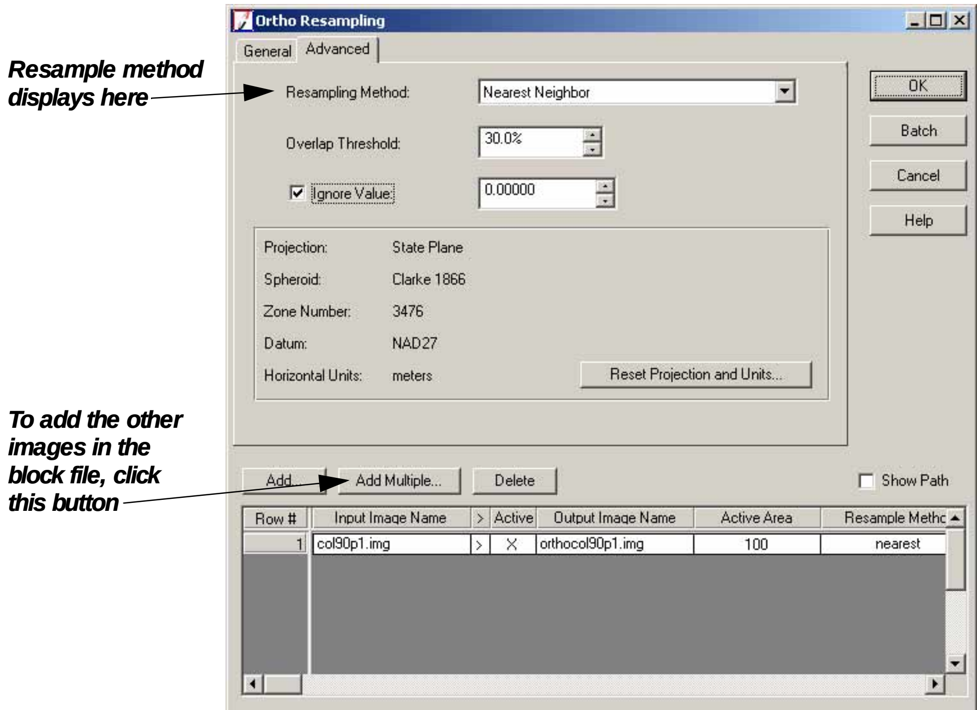
5. In the File Selector, navigate to /examples/orthobase/frame and select **colspr_dem.img** as the **DEM File.**

6. Click **OK** in the File Selector dialog.

7. Confirm that the **Output Cell Sizes** for **X** and the **Y** are **4.0.**

   This value is determined based on the ground resolution of the images. See Table 2-1.

8. Click the **Advanced** tab at the top of the Ortho Resampling dialog.



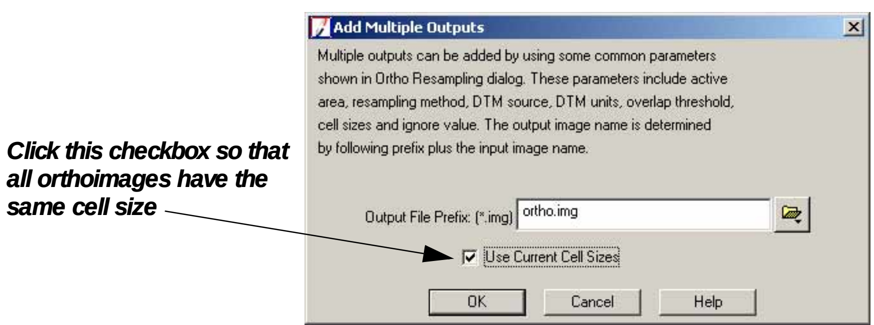
9. Click the **Resample Method** dropdown list and select **Nearest Neighbor.**

10. Click the checkbox next to **Ignore Value,** and keep the value of **0.**

    By default, OrthoBASE assumes you only want to generate an orthoimage for the first image in the block file. You can use the **Add Multiple** utility to add all of the images in your block file to the Ortho Resampling dialog.

11. Click the **Add Multiple** button located at the bottom of the dialog.

    The Add Multiple Outputs dialog opens.

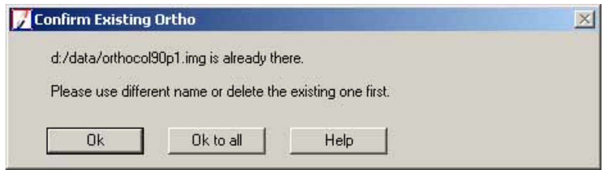


12. Click the checkbox next to **Use Current Cell Sizes.**

    This ensures each output orthoimage has X and Y cell sizes of 4.0.

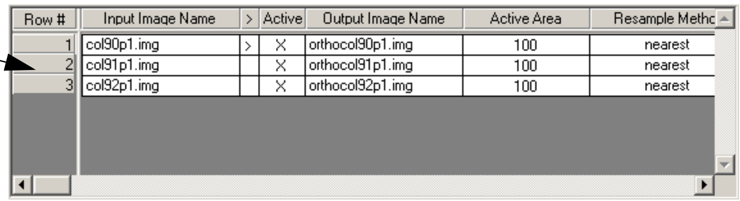
13. Click **OK** in the Add Multiple Outputs dialog.

14. Click **OK** in the Confirm Existing Ortho dialog.



The other images in the block file are added to the CellArray in the Ortho Resampling dialog.

All images and corresponding orthoimages are listed here



15. Use the scroll bar at the bottom of the CellArray to see the parameters for each of the files in the block.

16. Click **OK** in the Ortho Resampling dialog.

A status dialog opens, tracking the ortho resampling process.

17. When the status dialog reaches 100% complete, click the **OK** button to dismiss it.

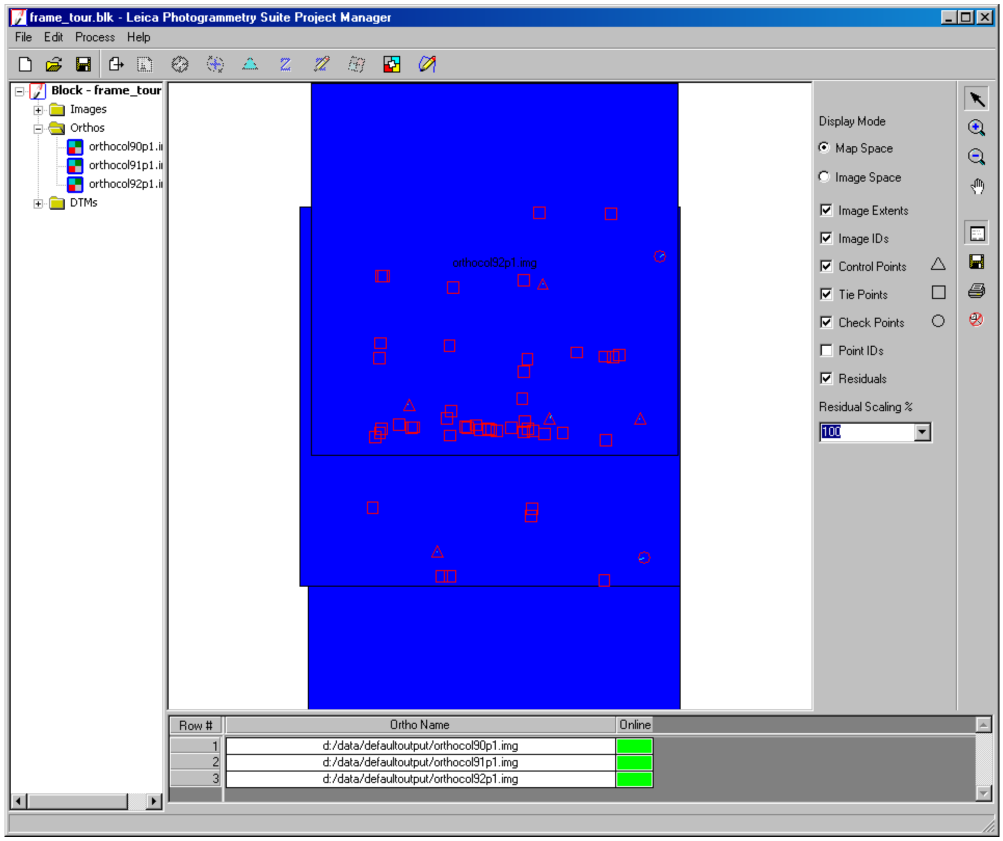
The presence of the status dialog is controlled by a preference. It is located in the **User Interface & Session** *category of the Preference Editor:* **Keep Job Status Box.**

View the Orthoimages

First, you can see the orthos display in the LPS Project Graphic Status window.

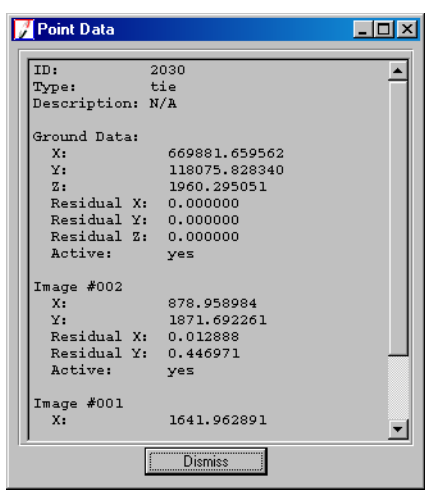
Display Graphic View

1. Click the **Orthos** folder in the Block Project Tree View.



You can also use the Project Graphic Status window to get information about points in the orthoimages.

2. Click on one of the points (a square, a triangle, or a circle) displayed in the Project Graphic Status window.



In this example, the point is a tie point and is located in the first two images in the block file. The residual values are acceptably low.

3. Click **Dismiss** to close the Point Data dialog.

   Now that the images have been ortho resampled, you can check how well they fit together in a Viewer.

Use the Viewer

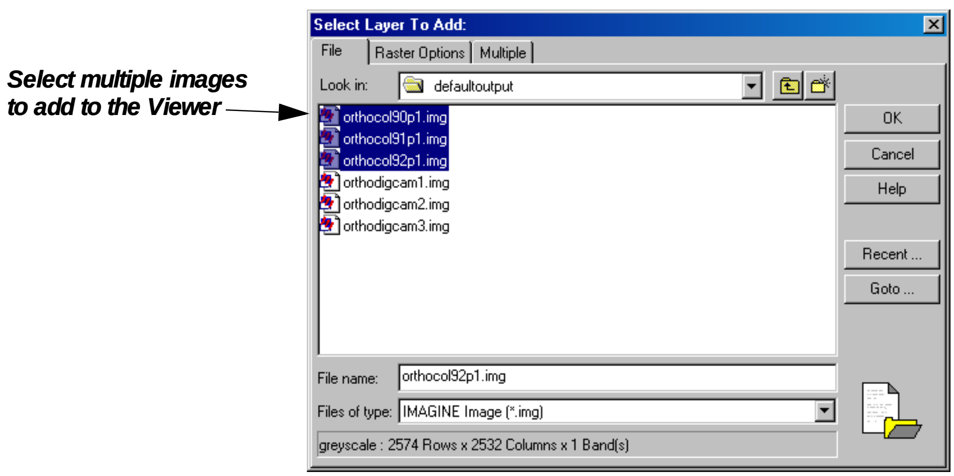
1. From the ERDAS IMAGINE icon panel, click the Viewer icon  .

   If necessary, select the type of Viewer you want to work with: **Classic Viewer** *or* **Geospatial Light Table.**

2. Click the Open icon  to access the Select Layer To Add dialog.

3. Navigate to the location in which you saved the orthorectified images.

4. Click the image **orthocol90p1.img,** then Shift-click **orthocol92p1.img.**



5. In the Select Layer To Add dialog, click the **Raster Options** tab.

6. Deselect the **Clear Display** checkbox.

7. Click the **Fit to Frame** and **Background Transparent** checkboxes.

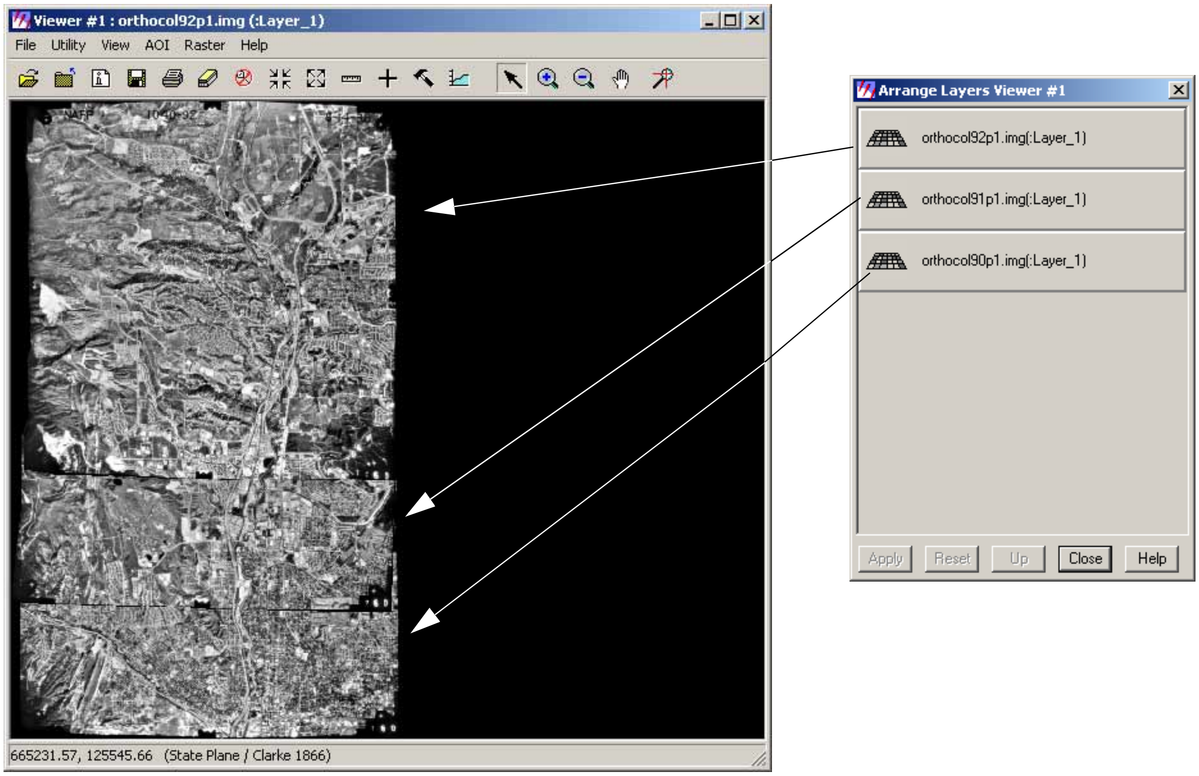
   The default settings of these options can be defined in the **Viewer** *category of the Preference Editor.*

8. Click the **Multiple** tab and confirm that the radio button **Multiple Independent Files** is selected.

9. Click **OK** in the Select Layer To Add dialog.

10. From the **View** menu, select **Arrange Layers.**

The images are displayed in the Viewer. If you would like to rearrange the images in the Viewer, click and drag the images in the Arrange Layers dialog accordingly, then click **Apply.**



Magnify Areas of Overlap

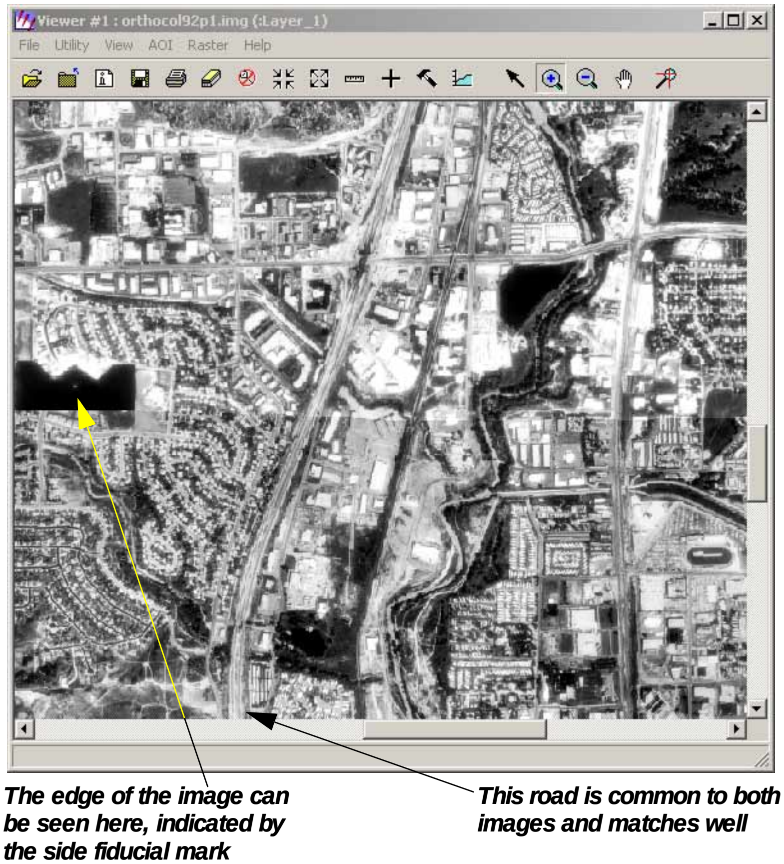
Now, you can check the areas of overlap to see how well OrthoBASE orthorectified the images. Take special note of features such as roads, rivers, and parcels of land.

1. In the Viewer, click the Zoom In icon  .

2. Click on an area in the Viewer where two of the images obviously overlap.

3. Apply the Zoom In icon as many times as necessary to see the portion of overlap clearly in the Viewer.

You can see that OrthoBASE successfully put images into the same reference coordinate space. In the following picture, the presence of two images is indicated by the side fiducial mark. Notice how the road on either side of the side fiducial matches very well.

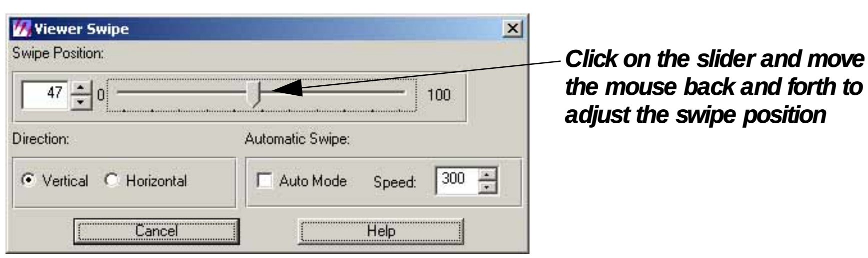


Use the Swipe Utility

You can use the Swipe utility to see how well the images overlap.

1. Click the **Utility** menu on the Viewer menu bar.
2. Choose **Swipe.**

   The Viewer Swipe dialog opens.



3. Right-click in the Viewer to access the **Quick View** menu.
4. Click **Fit Image to Window.**
5. Click the slider bar in the Viewer Swipe dialog and move it to the left and right to see how well the top image, **col92p1,** overlaps the others.

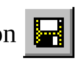
You can also choose the **Horizontal** *radio button from the Viewer Swipe dialog.*

6. When you are finished, click **Cancel** in the Viewer Swipe dialog.

7. Click **Close** in the Arrange Layers dialog.

8. Once you are done examining the orthoimages, choose **File | Close** from the Viewer menu bar.

Save and Close the Block File

1. Now that you have verified the accuracy of the OrthoBASE output orthoimages, in the LPS Project Manager, click the **File** menu, then select **Save,** or click the Save icon  .

   Notice that all of the columns are green, with the exception of the **DTM** column which is a separate process, indicating that all of the process steps have been executed. You can open the complete project any time you like.

Row #	Image ID	Description	>	Image Name	Active	Pyr.	Int.	Ext.	DTM	Ortho	Online
1	1		>	d:/data/8_6data/orthobase/frame/col90p1.img	X						
2	2			d:/data/8_6data/orthobase/frame/col91p1.img	X						
3	3			d:/data/8_6data/orthobase/frame/col92p1.img	X						

All columns are green; the project is complete

The **DTM** *column is still red, which indicates that DTMs were not generated from the images in the block file. Use OrthoBASE Pro to create DTMs. For more information about OrthoBASE Pro, see* *Chapter 7 "Automated DTM Extraction Tour Guide"*.

2. To exit OrthoBASE, choose **File | Close** from the menu.

3. To exit LPS, choose **File | Exit** from the menu.

4. If you want to exit ERDAS IMAGINE, select **Session | Exit IMAGINE.**

Conclusions

In this example, you have learned that the use of ground control can greatly improve the accuracy of your output orthoimages. The more accurate your ground control, the better quality of your output.

Next, you can see how to orthorectify imagery without ground control or a DEM.

Reference Images

Figure 4-9: Reference Image of col90p1

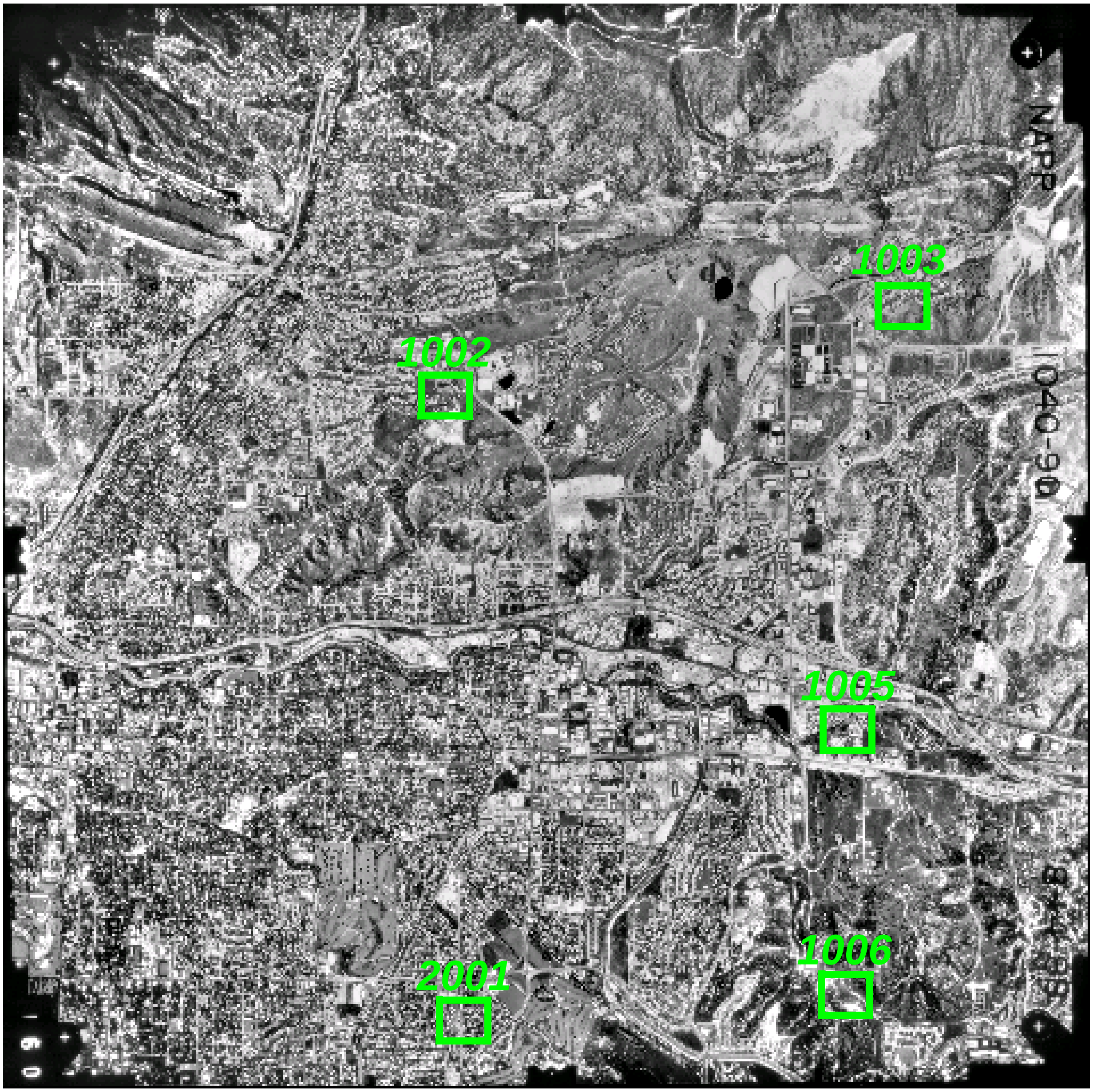


Figure 4-10: Reference Image of col91p1

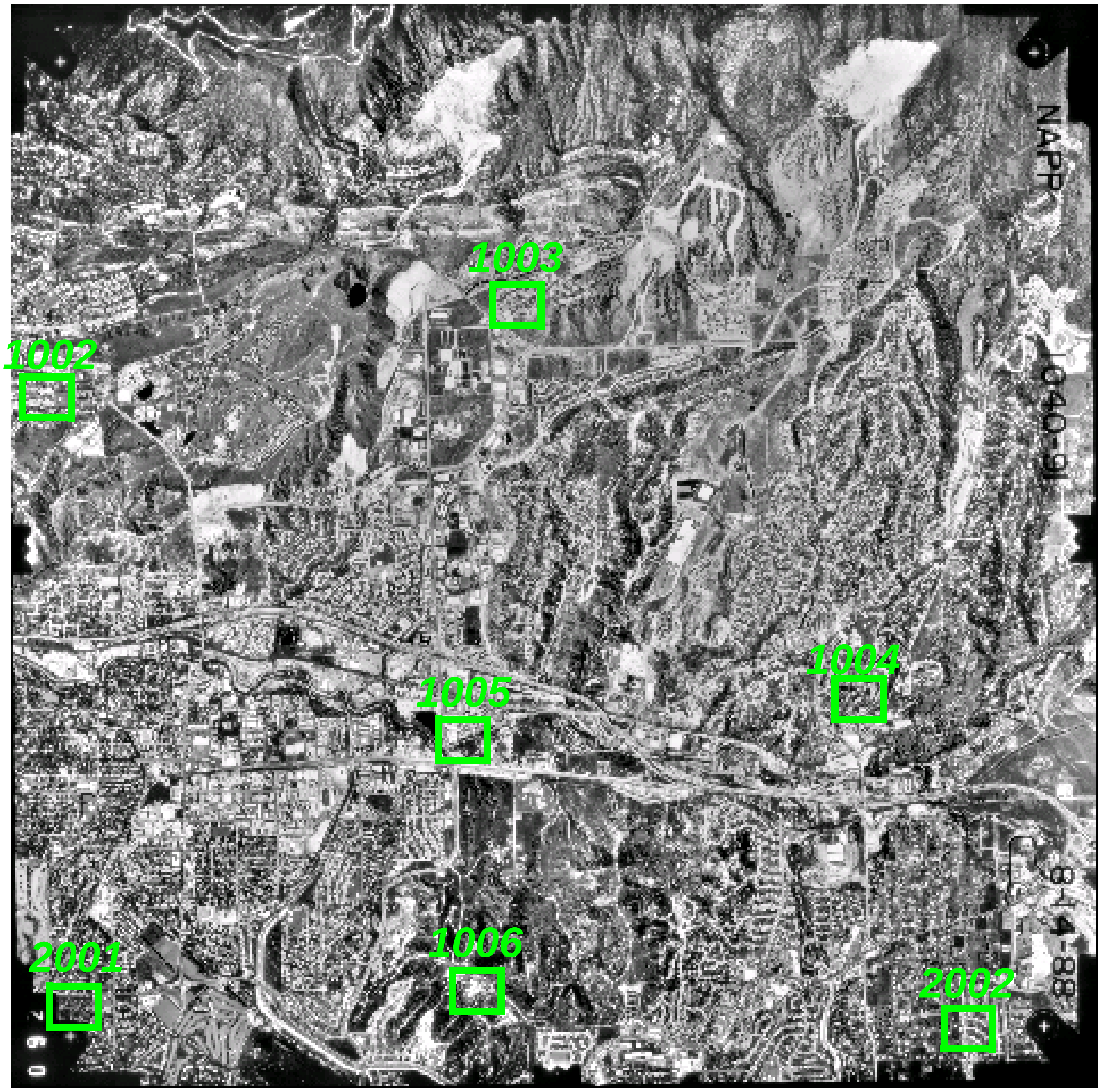
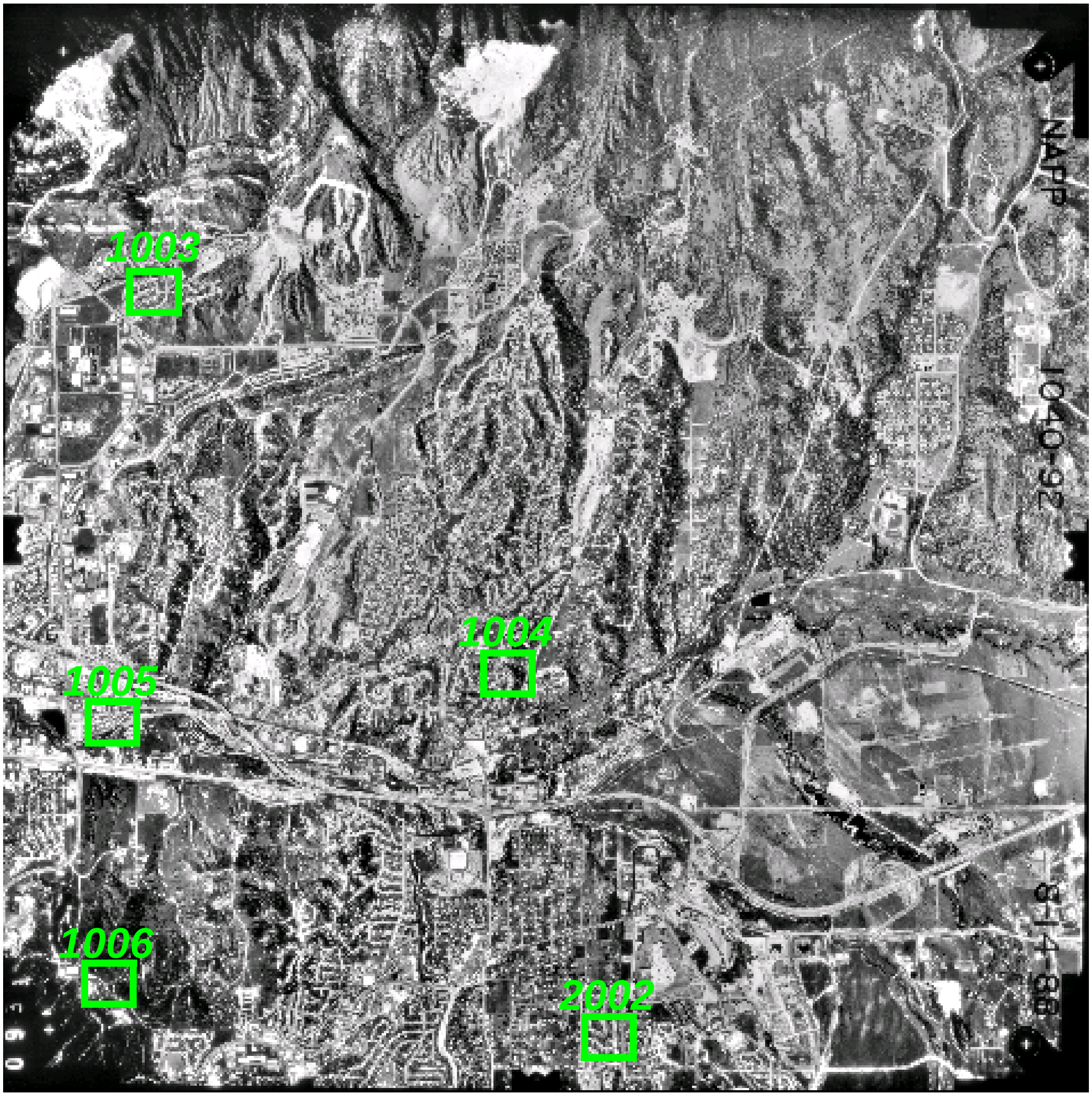


Figure 4-11: Reference Image of col92p1



Chapter 5

Digital Camera Tour Guide

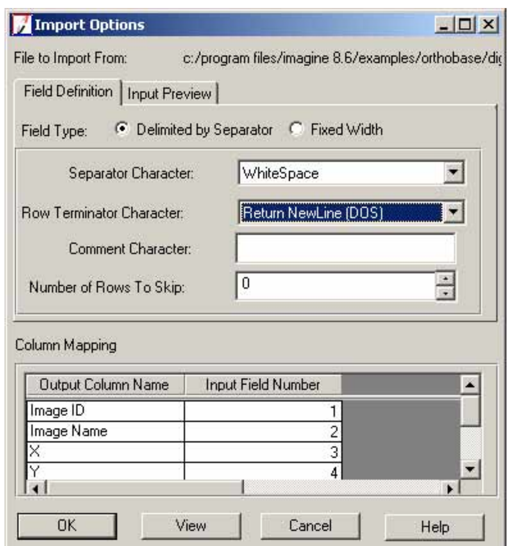
Introduction

Using OrthoBASE, you have access to many different types of geometric models with which to create and orthorectify a block of images. This tour guide takes you through the steps using the digital camera model.

This tour guide demonstrates the ability of OrthoBASE to orthorectify imagery without ground control or a DEM to very high accuracy. In this case, because the data you use also has airborne GPS information (which details the exact position of the camera at the time of image acquisition), the need for collecting ground control is eliminated.

After defining the interior orientation and exterior orientation parameters, you can proceed directly to auto tie and orthorectification of the input images. Figure 5-1 shows the Import Options dialog you can use to load orientation information.

Figure 5-1: Imported Orientation Information



Information about the exact location of the camera at the time of image exposure eliminates the need for you to collect ground control

Before You Begin

The data you use with this tour guide comes from southeast Spain. The data is 1:45000 scale (ground pixel size of .40 meters) imagery that was collected using a Kodak DCS 420 digital camera.

Approximate completion time for this tutorial is 45 minutes.

In this tour guide, you are going to perform the following basic steps:

- create a new project
- add imagery to the block file
- define the camera model
- perform automatic tie point collection
- perform aerial triangulation
- orthorectify the images
- view the orthoimages
- save and close the block file

Create a New Project

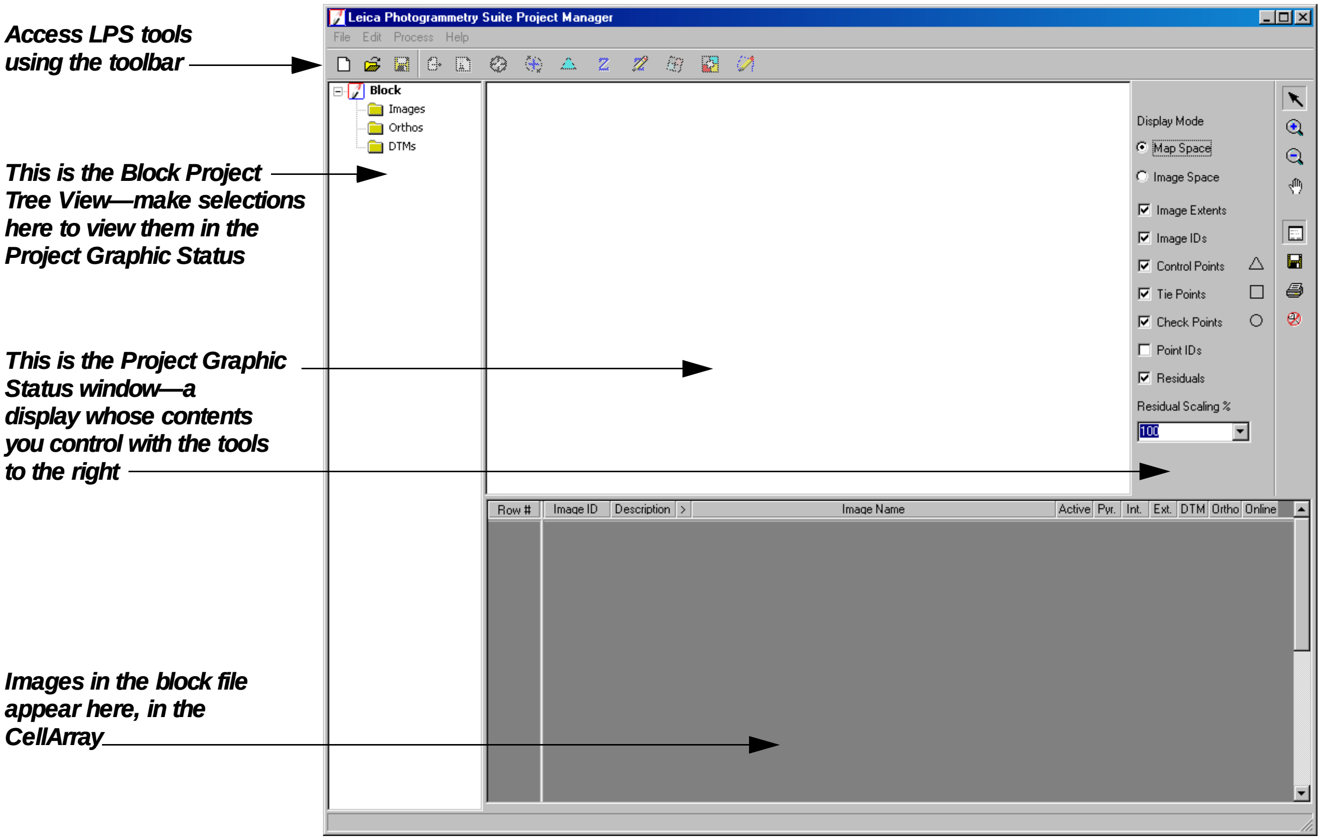
In this section of the tour guide, you create a new project using three digital camera images of southeast Spain. In this case, the images are .tif images, but you can also use other formats such as .jpg, .img, MrSid, raw and generic binary, and Grid.

Prepare the Block File

1. Start Leica Photogrammetry Suite (LPS).

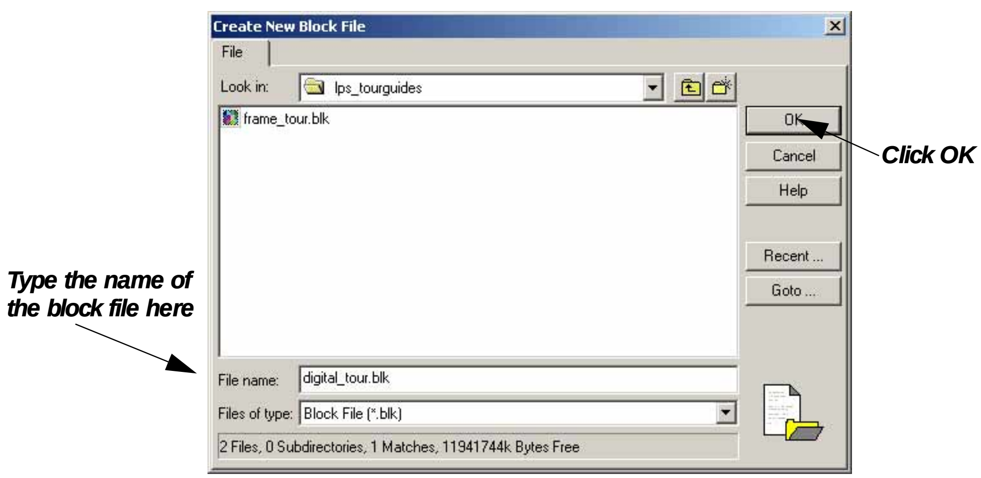
2. Click the LPS icon  on the icon panel.

The LPS Project Manager opens.



3. Click the Create New Block File icon .

   The Create New Block File dialog opens.



4. Navigate to a folder in which you have write permission.

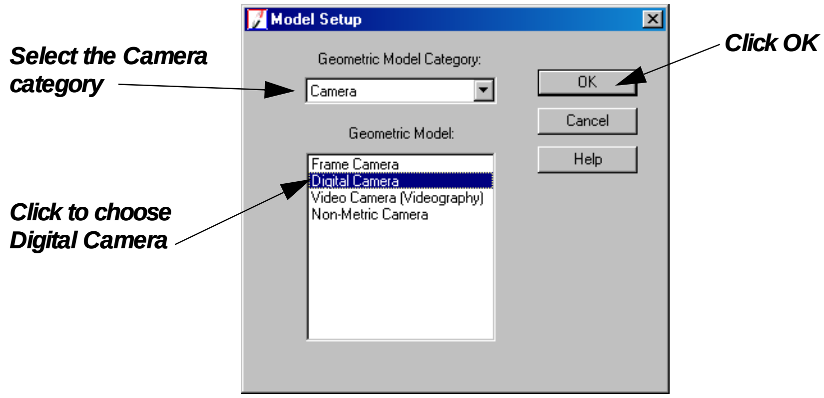
5. Next to **File name,** type **digital_tour,** then press Enter on your keyboard.

The *.blk extension, which stands for block file, is appended automatically.

6. Click **OK** to close the Create New Block File dialog.

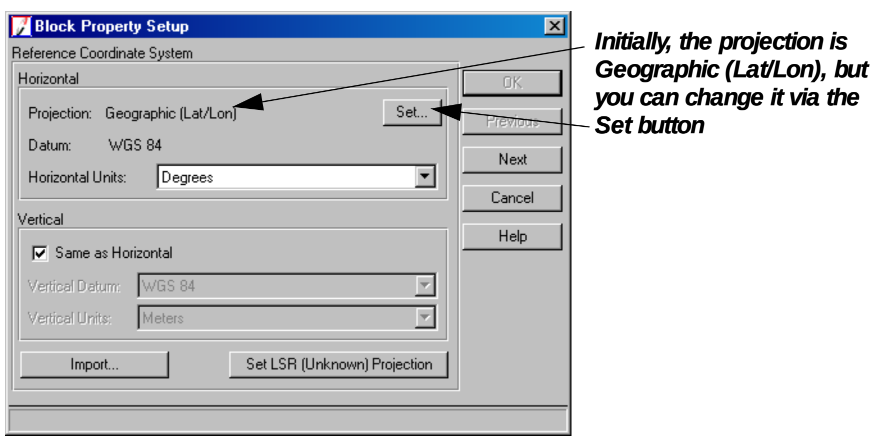
   The Model Setup dialog opens.

Select Geometric Model



1. Click the **Geometric Model Category** dropdown list and select **Camera.**
2. Click in the **Geometric Model** section and select the **Digital Camera.**
3. Click **OK** in the Model Setup dialog.

   The Block Property Setup dialog opens.

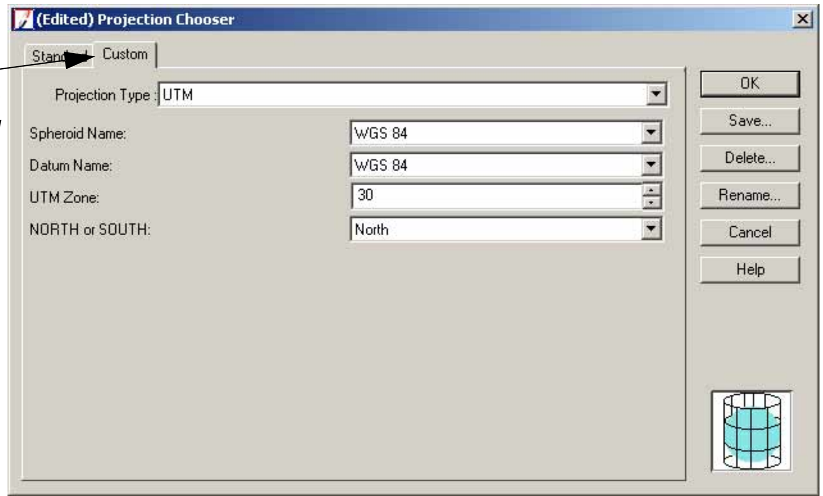


Define Block Properties

1. In the **Horizontal Reference Coordinate System** section of the Block Property Setup dialog, click the **Set** button.

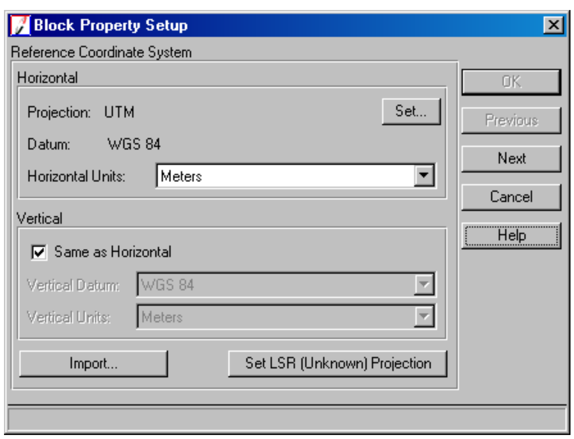
   The Projection Chooser dialog opens.

The information you supply in the Custom tab is transferred to the Block Property Setup dialog



2. Click the **Custom** tab in the Projection Chooser dialog.
3. Click the **Projection Type** dropdown list and select **UTM.**
4. Click the **Spheroid Name** dropdown list and select **WGS84.**
5. Confirm that the **Datum Name** dropdown list shows **WGS84.**
6. Type **30** in the **UTM Zone** field and press Enter, or use the increment nudgers to the right of the field.
7. Confirm that the **NORTH or SOUTH** dropdown list shows **North.**
8. Click **OK** in the (Edited) Projection Chooser dialog.
9. In the Block Property Setup dialog, confirm that the **Horizontal Units** are set to **Meters.**

   The **Horizontal Reference Coordinate System** section of the Block Property Setup dialog should look like the one below.

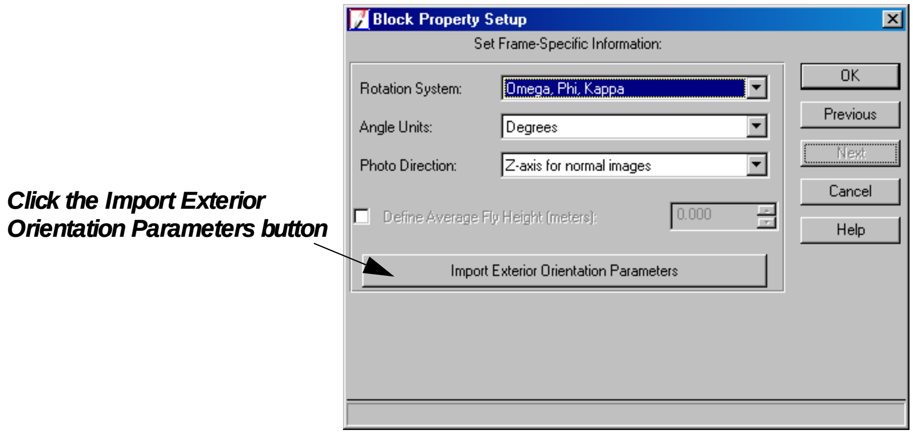


For more information about projections, see the On-Line Help.

10. Click the **Next** button in the Block Property Setup dialog.

Import Exterior Orientation Parameters

The **Set Frame-Specific Information** section of the Block Property Setup dialog opens.



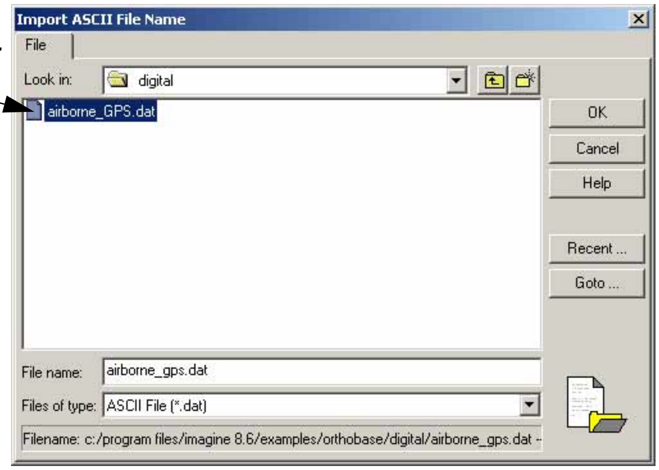
When these images were acquired, the position of the aircraft was recorded using airborne GPS and INS technology. The airborne GPS provides position information (i.e., X, Y, and Z) about where the camera/sensor is at the time of image capture. The INS provides orientation information (i.e., omega, phi, and kappa) about where the camera/sensor is at the time of image capture.

The accuracy of the measurements is within 2 meters in the X, Y, and Z direction. In omega, phi, and kappa, the accuracy of the measurements is within 0.1 degrees. With this information, there is no need to collect GCPs in the images making up the block file. Instead, you provide exterior orientation values.

1. In the **Set Frame-Specific Information** section of the Block Property Setup dialog, click the **Import Exterior Orientation Parameters** button.

The Import ASCII File Name dialog opens.

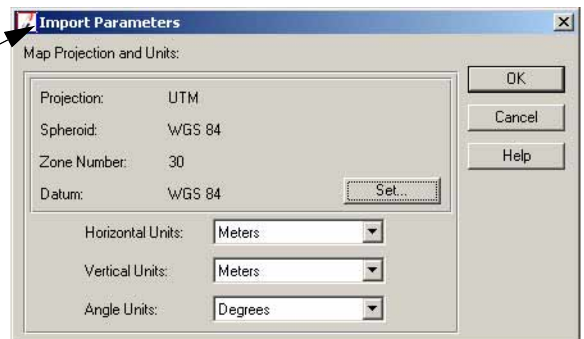
Select the .dat file for exterior orientation information



2. Navigate to /examples/orthobase/digital, select the file **airborne_GPS.dat,** then click **OK.**

   The Import Parameters dialog opens. In this dialog, you check to see if the map information matches that which you specified during the block setup.

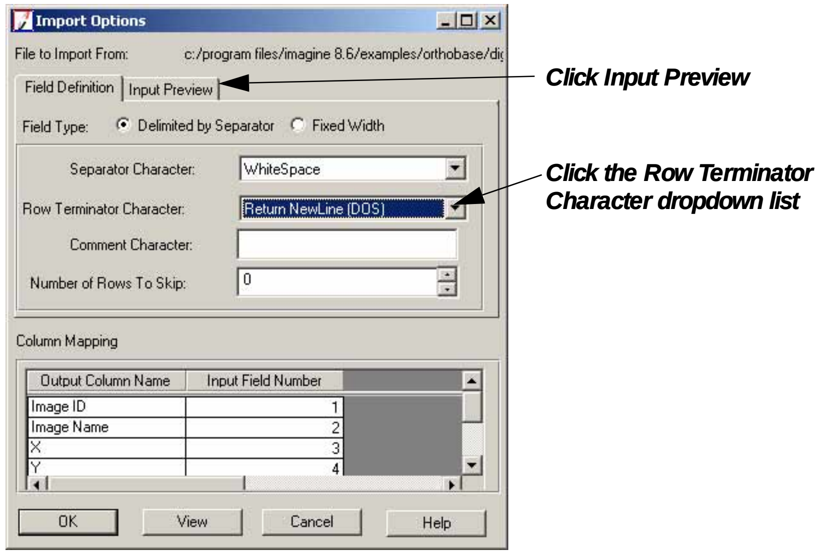
Projection in the Import Parameters dialog must match Block Properties



If the projection information contained in the .dat file does not match what you have specified for the block, the projection, spheroid, datum, and units must be changed so that they do match. You can use the **Set** *button in the Import Parameters dialog to specify the correct map projection.*

3. Click **OK** in the Import Parameters dialog.

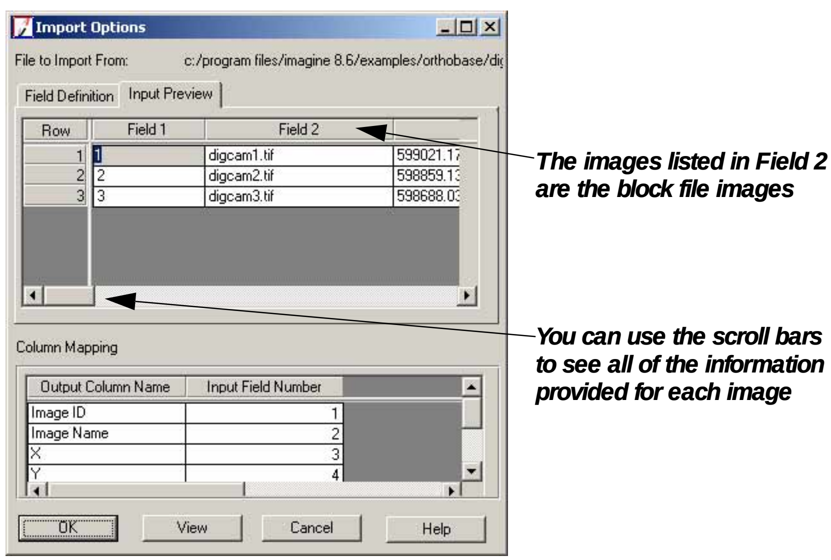
   The Import Options dialog opens.



4. In the **Field Definition** tab of the Import Options dialog, click the **Row Terminator Character** dropdown list.

5. Select **Return NewLine (DOS)** from the dropdown list.

6. Click the **Input Preview** tab on the Import Options dialog and view the fields.



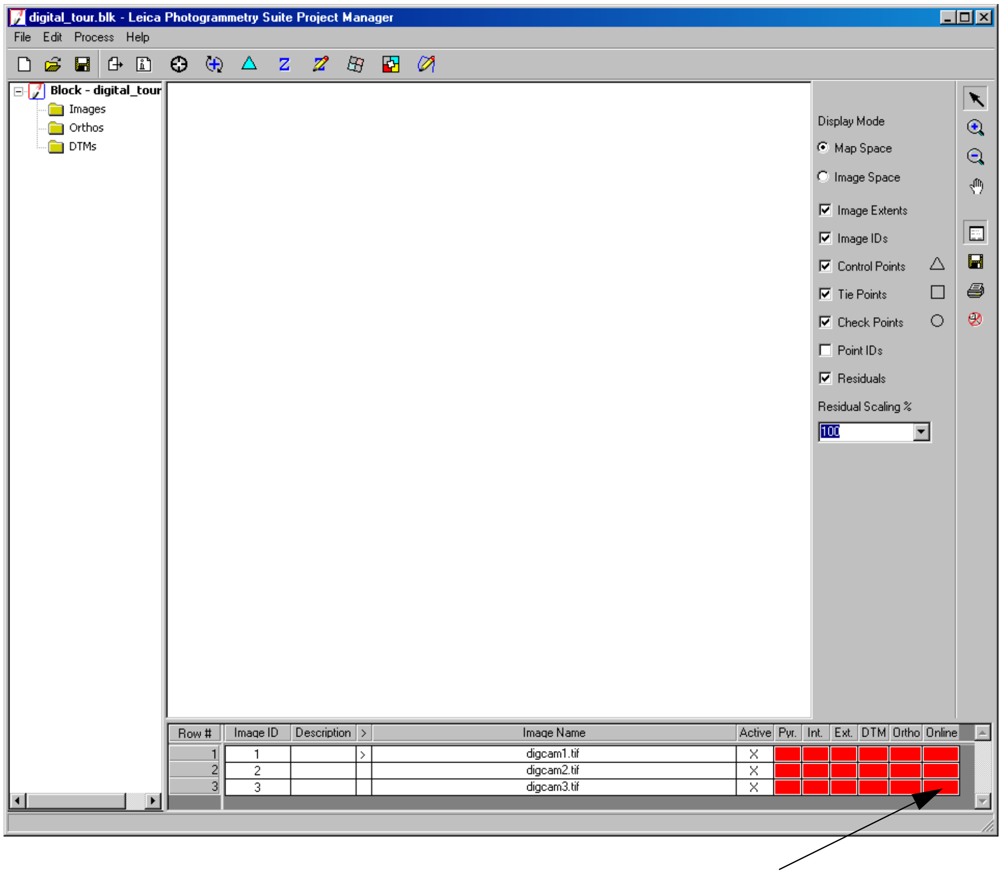
7. Click **OK** in the Import Options dialog.

   Once you click **OK,** the image names along with their X, Y, Z, Omega, Phi, and Kappa values are noted, imported, and saved by OrthoBASE.

8. Click **OK** in the Block Property Setup dialog to complete block setup.

Add Imagery to the Block

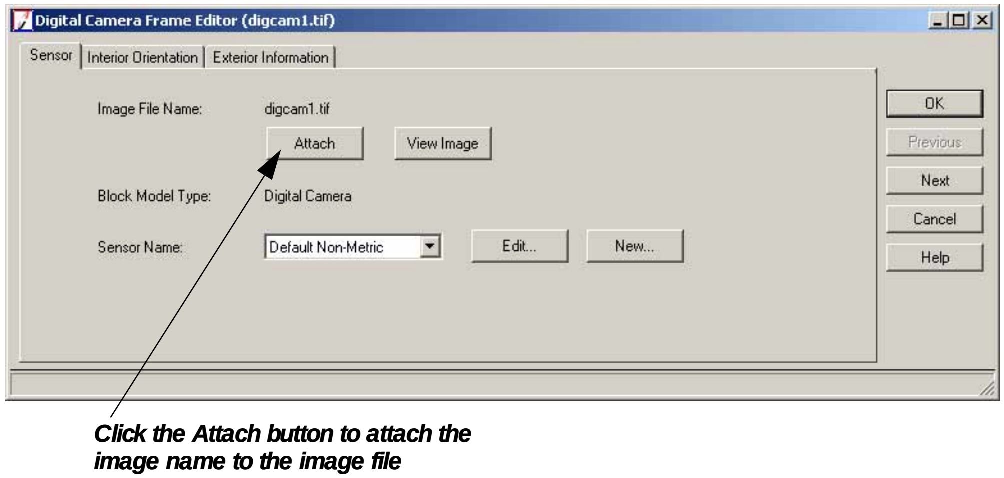
The CellArray updates. The **Image Name** field is updated for you. This is based on the information contained in the .dat file, **airborne_GPS.dat,** that you selected during the Import Exterior Orientation process. You can resize the elements of this dialog to suit you.



To begin, the images need to be online. Online means that the image name is attached and linked to the corresponding image file, which may be located on the hard drive or the network.

1. Click on the **Online** cell associated with **digcam1.tif.**

   The Digital Camera Frame Editor dialog opens.



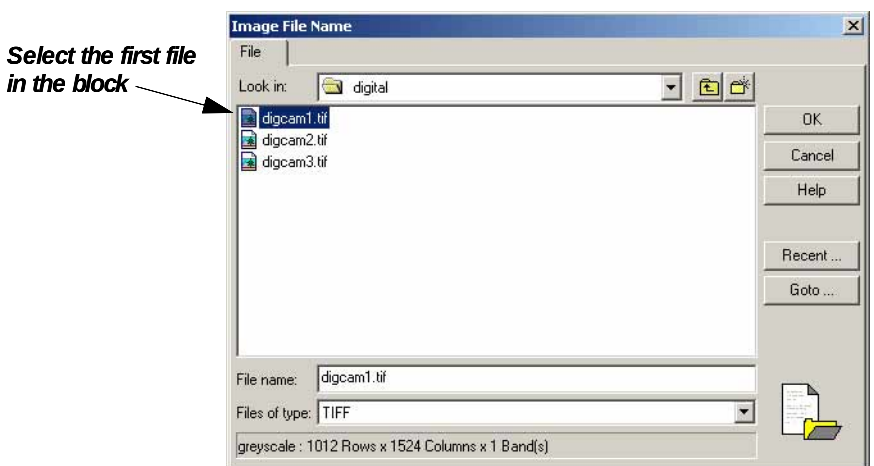
2. In the Digital Camera Frame Editor dialog, click the **Attach** button.

   The Image File Name dialog opens. Now, you attach the files in the block.

3. Navigate to /examples/orthobase/digital.

4. Click the **Files of type** dropdown list and select **TIFF.**

5. Click the file **digcam1.tif.**



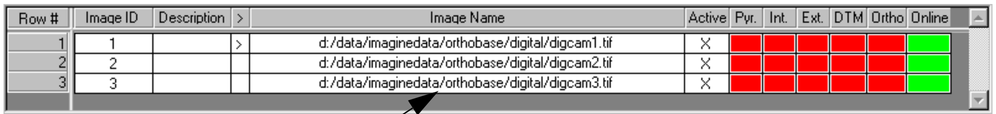
6. Hold down the Shift key on the keyboard, then click the last *.tif file in the list, **digcam3.tif.**

   All of the *.tif files are selected for inclusion in the block file.

7. Click **OK** in the Image File Name dialog to return to the Digital Camera Frame Editor dialog.

8. Click **OK** in the Digital Camera Frame Editor dialog.

   You are returned to the LPS Project Manager. The cells in the **Online** column of the CellArray are now green, indicating that the files in /examples/orthobase/digital have been matched with the three image files specified in the .dat file.



The complete path and image name are now listed in the Image Name section of the LPS CellArray

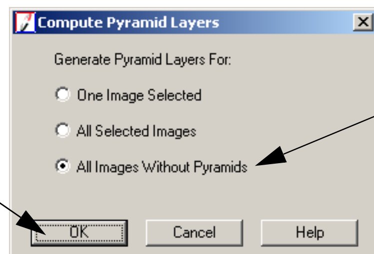
The color of the columns is controlled by two preferences: **Status On Color** *and* **Status Off Color** *in the* **LPS** *category of the Preference Editor.*

Compute Pyramid Layers

Next, you compute pyramid layers for the images in the block file. Pyramid layers are used to optimize image display and automatic tie point collection.

1. Click the **Edit** menu, then choose **Compute Pyramid Layers.**

   The Compute Pyramid Layers dialog opens.



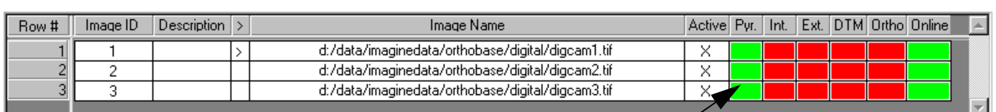
Click OK to start computing pyramid layers for the images

All Images Without Pyramids is selected by default

2. In the Compute Pyramid Layers dialog, confirm that the **All Images Without Pyramids** radio button is selected.

3. Click **OK** in the Compute Pyramid Layers dialog.

   A progress bar displays at the bottom of the LPS Project Manager as pyramid layers are created for each image. When complete, the cells corresponding to the **Pyr.** column are all green.



Now, the images have pyramid layers, indicated by the green Pyr. column

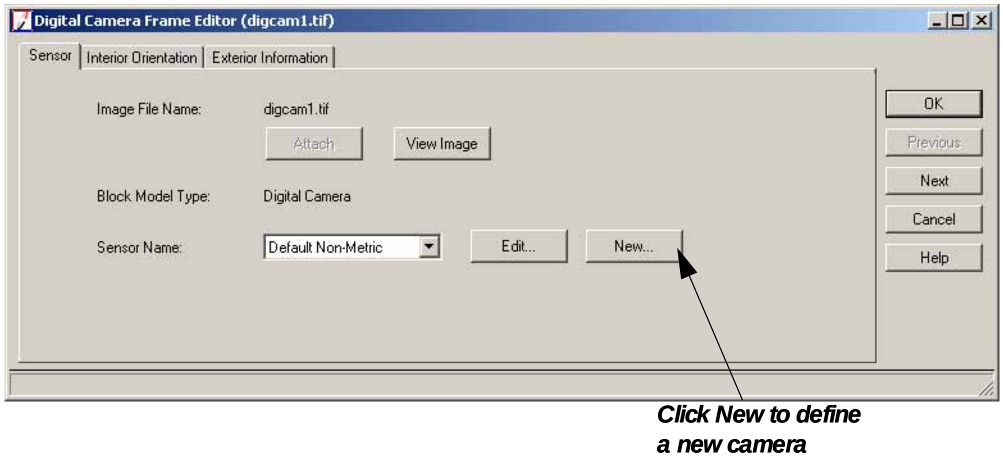
Define the Camera Model

Since you have specified projection, imported exterior orientation parameters, and identified the images to be used in the block file, now you need to define the camera model.

Enter Specific Camera Information

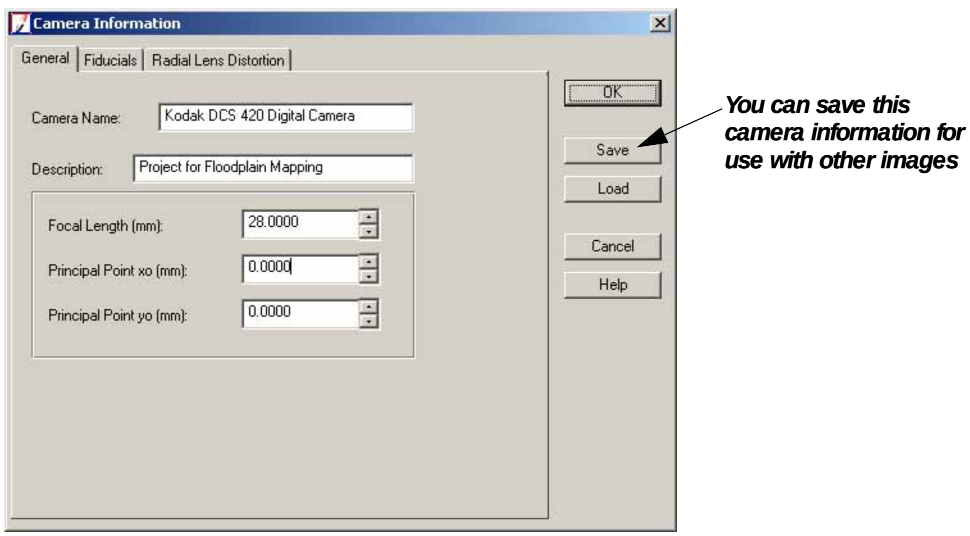
1. On the LPS toolbar, click the Frame Properties icon  .

The Digital Camera Frame Editor dialog opens. You attached the images here, and now you specify the camera that goes with each image.



2. Click the **New** button in the Digital Camera Frame Editor dialog.

   The Camera Information dialog opens.

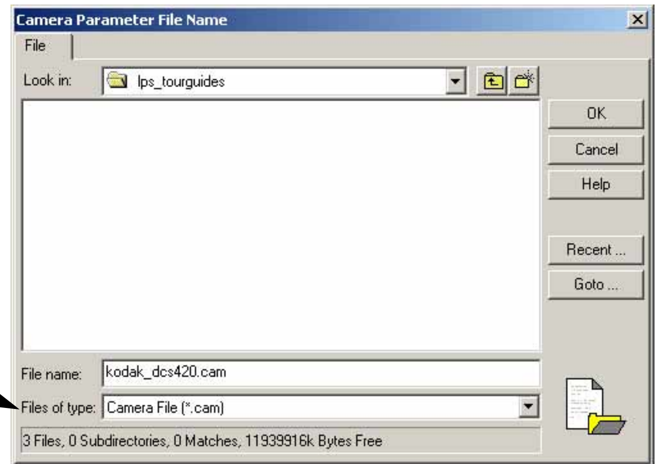


3. In the **Camera Name** section of the Camera Information dialog, type the name **Kodak DCS 420 Digital Camera.**
4. In the **Description** field, type **Project for Floodplain Mapping.**
5. In the **Focal Length** field, type **28.0,** then press Enter, or use the increment nudgers to the right of the field.
6. Confirm that the **Principal Point xo** and the **Principal Point yo** values are set to **0.0000.**

Save the Camera Information

1. Click the **Save** button to save the camera model information.

   The Camera Parameter File Name dialog opens.



Camera files are saved with the .cam extension

2. Navigate to a folder where you have write permission.

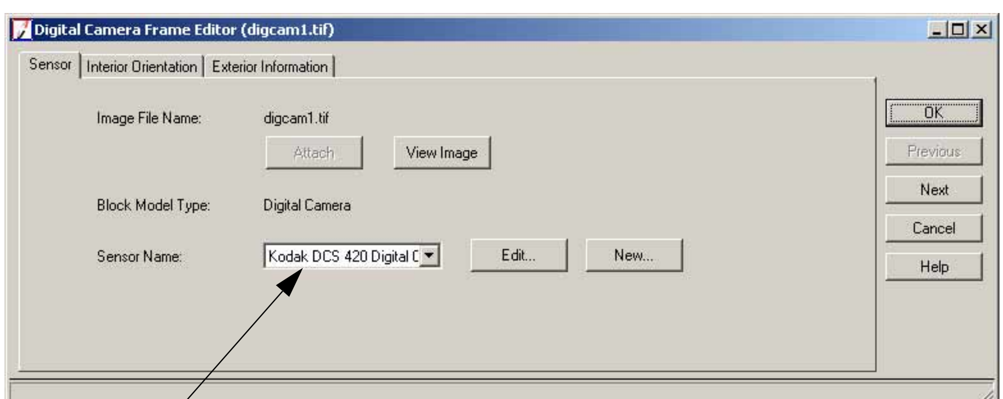
3. Confirm that the **Files of type** section says **Camera File.**

4. Type the name **kodak_dcs420** in the **File name** field, then press Enter on your keyboard. The .cam extension is automatically appended for you.

5. Click **OK** in the Camera Parameter File Name dialog.

6. Click **OK** in the Camera Information dialog.

   You are returned to the Digital Camera Frame Editor dialog. The camera information you supplied is located in the **Sensor Name** section of the dialog.



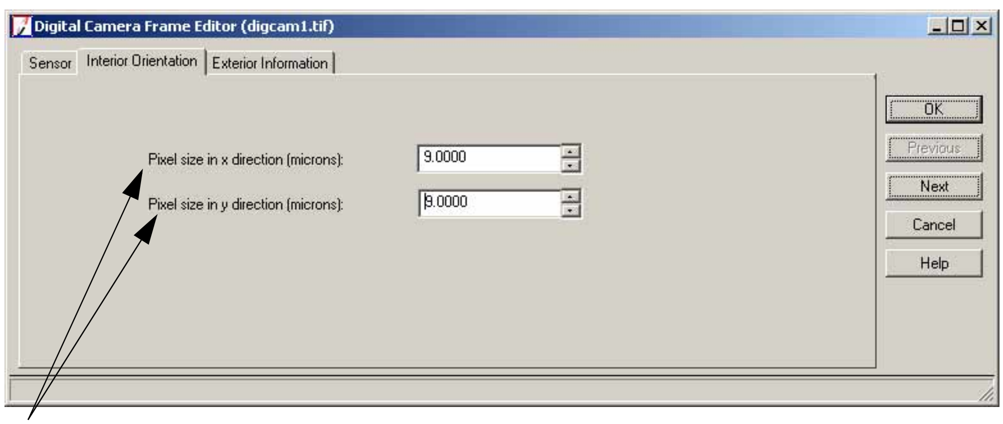
The correct camera is identified here

Check Camera Information of the Other Images

1. Click the **Next** button to display the information for **digcam2,** which is displayed in the Image File Name section of the dialog.
2. Confirm that the **Sensor Name** dropdown list shows **Kodak DCS 420 Digital Camera.**
3. Click the **Next** button to display the information for **digcam3.**
4. Confirm that the **Sensor Name** dropdown list shows **Kodak DCS 420 Digital Camera.**
5. Click the **Previous** button twice to return to **digcam1.**

Enter Interior Orientation Information

1. In the Digital Camera Frame Editor, click the **Interior Orientation** tab.



Pixel size is applied to all images in the block

2. Click in the **Pixel size in x direction** field, and type **9.0.**
3. Click in the **Pixel size in y direction** field, and type **9.0,** then press Enter.

   These values come from the CCD of the camera that captured the images. The number is a function of illumination.

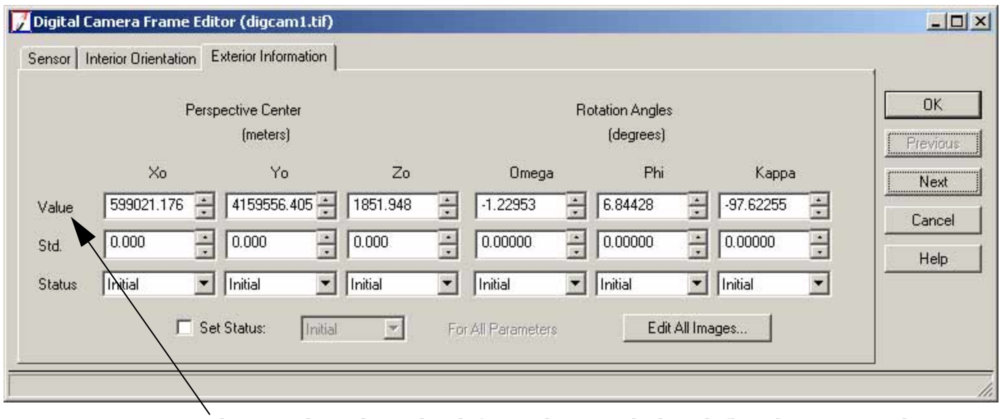
   For information about digital camera CCDs, see "Digital Camera".

4. Click the **Next** button twice to see that the same interior orientation information is transferred to **digcam2** and **digcam3.**
5. Click the **Previous** button twice to return to **digcam1.**

Enter Exterior Orientation Information

1. Click the **Exterior Information** tab in the Digital Camera Frame Editor dialog.

   The information is already supplied for you. It comes from the .dat file, **airborne_GPS.dat,** you selected when you imported the information in the GPS file.



The exterior orientation information needed to define the Perspective Center and Rotation Angle values is contained in the .dat file

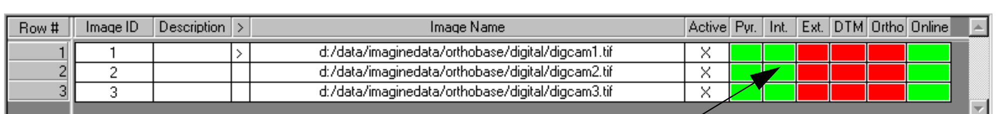
2. Click the **Next** button to see the Exterior Information values for the second image in the block file, **digcam2.**

3. Click the **Next** button again to see the Exterior Information values for the third image in the block file, **digcam3.**

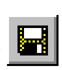
   Note that the values for each image are different. This is due to the altered position of the camera during each exposure.

4. Click **OK** to close the Digital Camera Frame Editor dialog.

   You are returned to the LPS Project Manager. Note that the **Int.** column for all of the files is green, indicating that the interior orientation has been supplied.



Interior orientation information has been supplied

5. Click the Save icon  to save your changes so far.

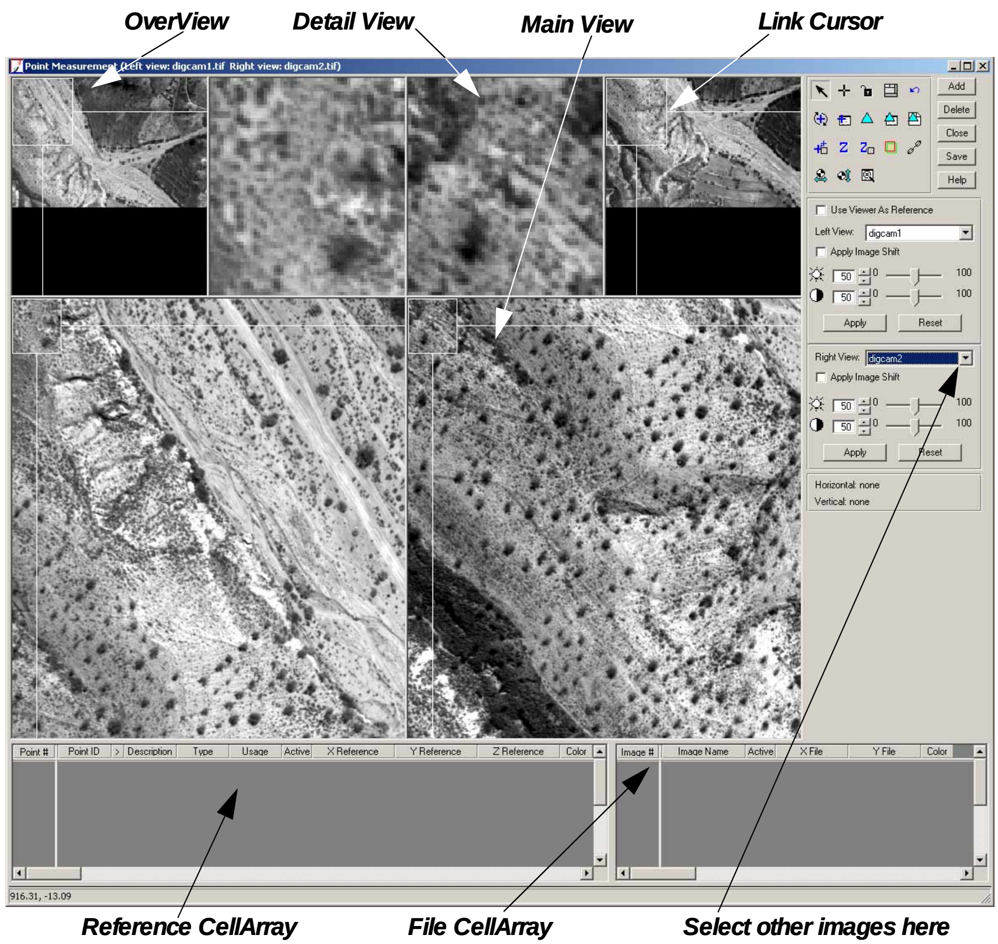
Perform Automatic Tie Point Collection

Generally, at this point in the process you collect control points in overlapping areas of images in the block file that determine the approximate exterior orientation parameters. Because this data includes the GPS and INS information, there is no need to collect GCPs in order to obtain the exterior orientation information.

In a case such as this, the next step is to run the auto tie process. This process further defines the geometry between the files in the block.

1. On the LPS toolbar, click the Point Measurement icon .

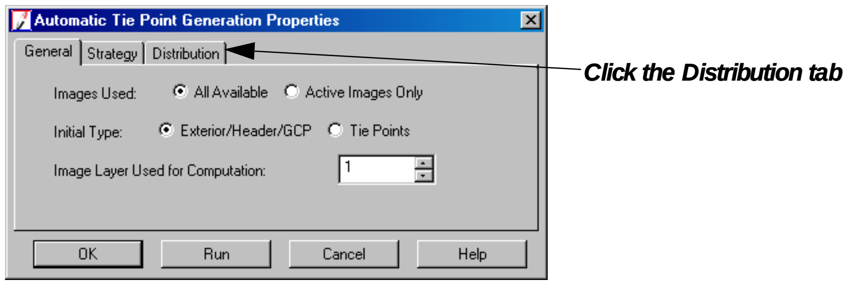
   The Point Measurement tool opens on your screen. In the **Left View** you see the first image in the block file, **digcam1.** In the **Right View,** you see the second image in the block file, **digcam2.** You can use the **Right View** or **Left View** dropdown list to see the third image in the block file, **digcam3,** as well.



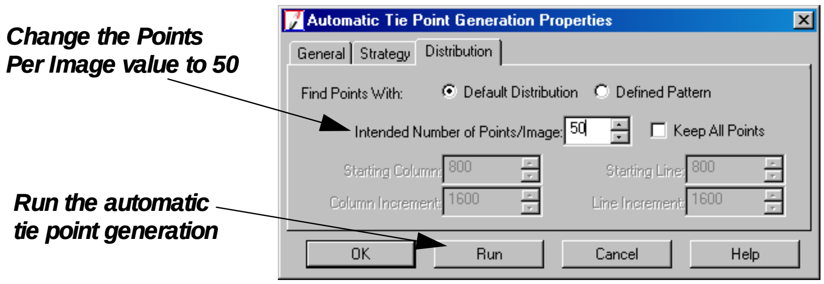
To change the color of points in the Point Measurement tool, click the Viewing Properties icon to access the Viewing Properties dialog. In the **Point Table Info** *section, click the* **Advanced** *radio button, then the* **Color** *checkbox, then* **OK.** *This adds a* **Color** *column to the reference CellArray and the file CellArray.*

2. In the Point Measurement tool palette, click the Auto Tie Properties icon .

   The Automatic Tie Point Generation Properties dialog opens on the **General** tab.



3. In the Automatic Tie Point Generation Properties dialog, click the **Distribution** tab.



4. Type **50** in the **Intended Number of Points Per Image** field, then press Enter.

   This produces approximately 50 tie points per image.

5. Click **Run** in the Automatic Tie Point Generation Properties dialog.

   A progress bar displays at the bottom of the Point Measurement tool. When the process is complete, the tie points display in the views, and their corresponding file coordinates display in the file CellArray.

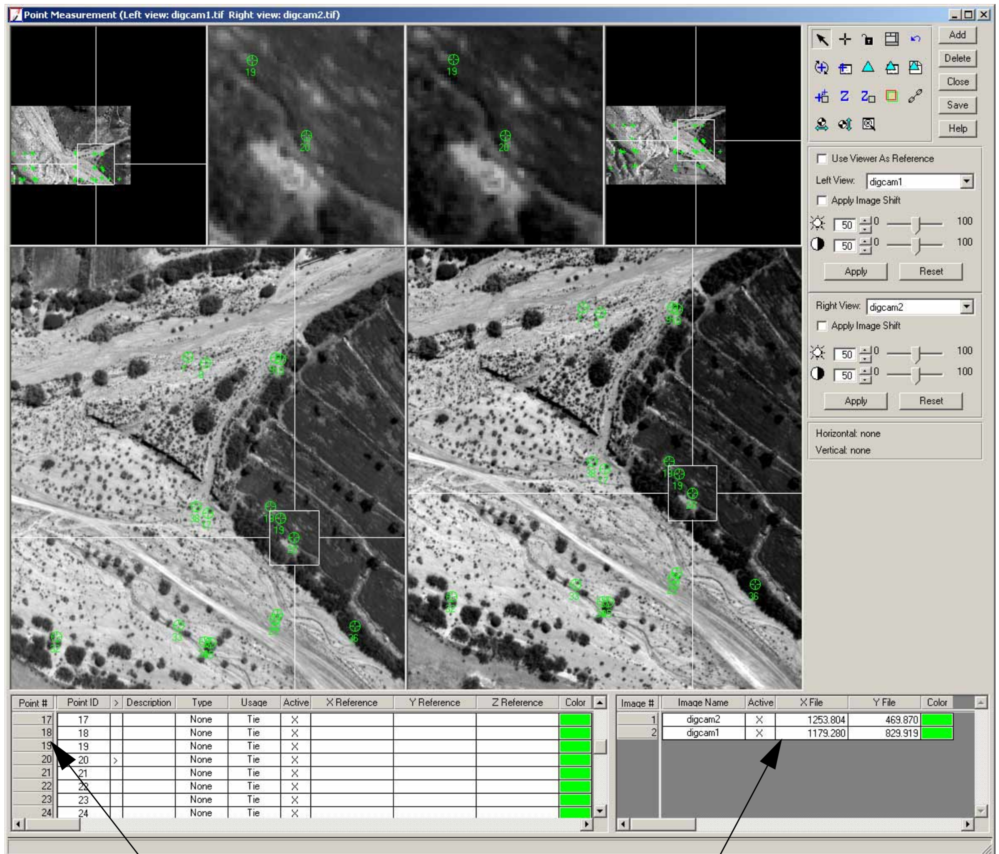
For more information about automatic tie point collection see Chapter 12 "Automatic Tie Point Collection".

Check Tie Point Accuracy

At this point, tie points are recorded in the file CellArray with their image positions in X and Y. After you check their accuracy and run the aerial triangulation, the map coordinates, displayed in the reference CellArray, are available.

1. Click in the **Point #** row of a tie point to see its position in the views.

   NOTE: Since all tie points are not common to all images, there are cases where the displayed images do not have common tie points. In such cases, verify the tie point by opening a different adjacent image in one of the views. To do so, use the **Left View** *or* **Right View** *dropdown list.*



Click the Point # row of the tie point you want to view

The tie point's file coordinates in each image are displayed here

2. Click other points to see the position of other tie points in the views.

3. Click the **Save** button in the Point Measurement tool.

4. Click the **Close** button in the Point Measurement tool.

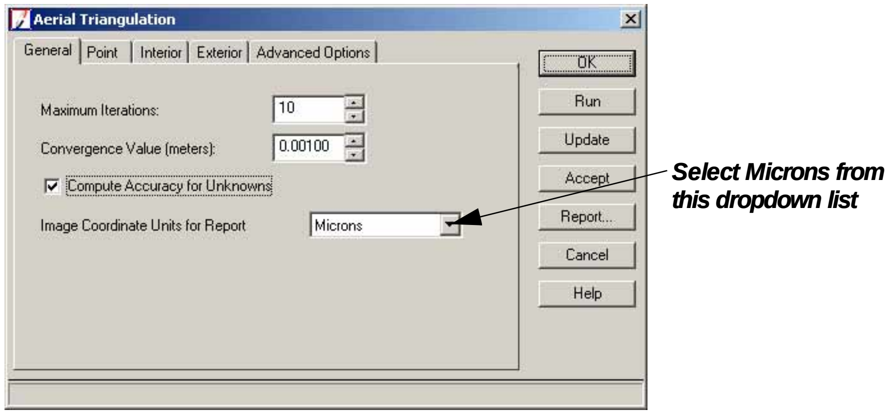
   You are returned to the LPS Project Manager.

Perform Aerial Triangulation

Now that you have used auto tie to create tie points in the images, you can progress to the triangulation process.

1. In the LPS Project Manager, click **Edit | Triangulation Properties.**

   The Aerial Triangulation dialog opens.

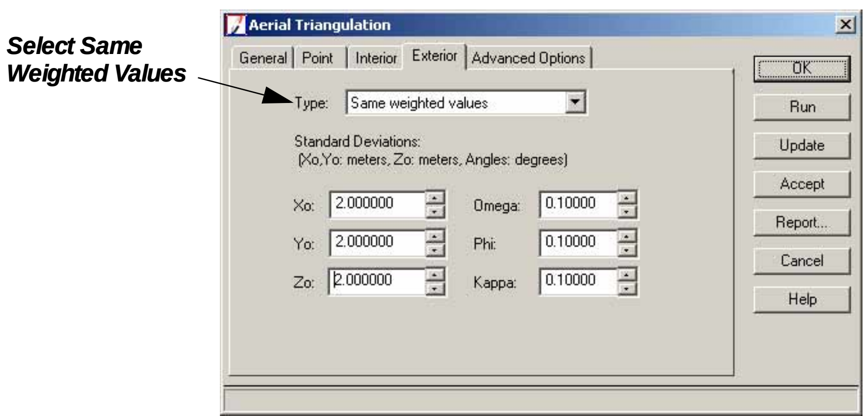


2. Click the checkbox for **Compute Accuracy for Unknowns.**

   This computes the accuracy of the adjusted exterior orientation parameters and the X, Y, and Z tie point coordinates.

3. Click the **Image Coordinate Units for Report** dropdown list and select **Microns.**

4. In the Aerial Triangulation dialog, click the **Exterior** tab.



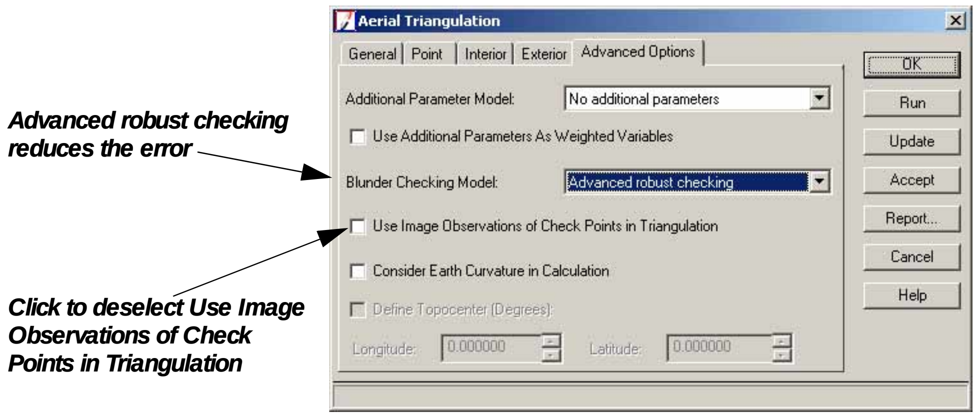
5. Click the **Type** dropdown list and select **Same weighted values.**

6. Click in each of the **Xo, Yo,** and **Zo** fields and type **2.0.**

   This means that the X, Y, and Z values are accurate within 2 meters. The omega, phi, and kappa values are accurate within 0.1 degree.

7. Confirm that the **Omega, Phi,** and **Kappa** fields are set to **0.1.**

8. Click the **Advanced Options** tab.



9. Click the **Blunder Checking Model** dropdown list and select **Advanced robust checking.**

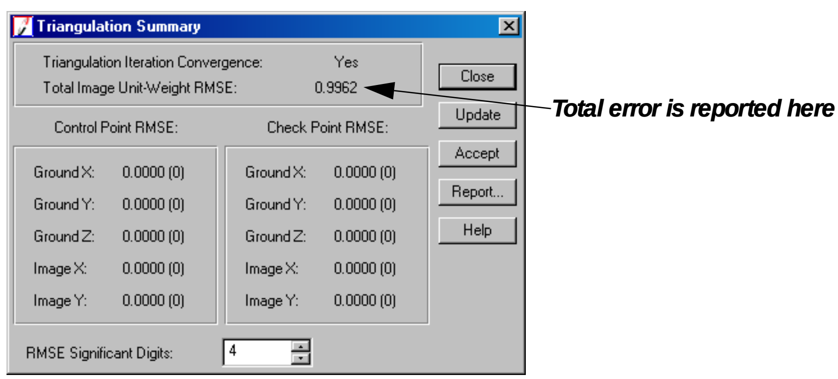
   Advanced robust checking automatically identifies and removes poor tie points from the solution.

10. Click to deselect **Use Image Observations of Check Points in Triangulation.**

    You do not have any check points displayed in the Point Measurement tool at this time; therefore, this option is not applicable.

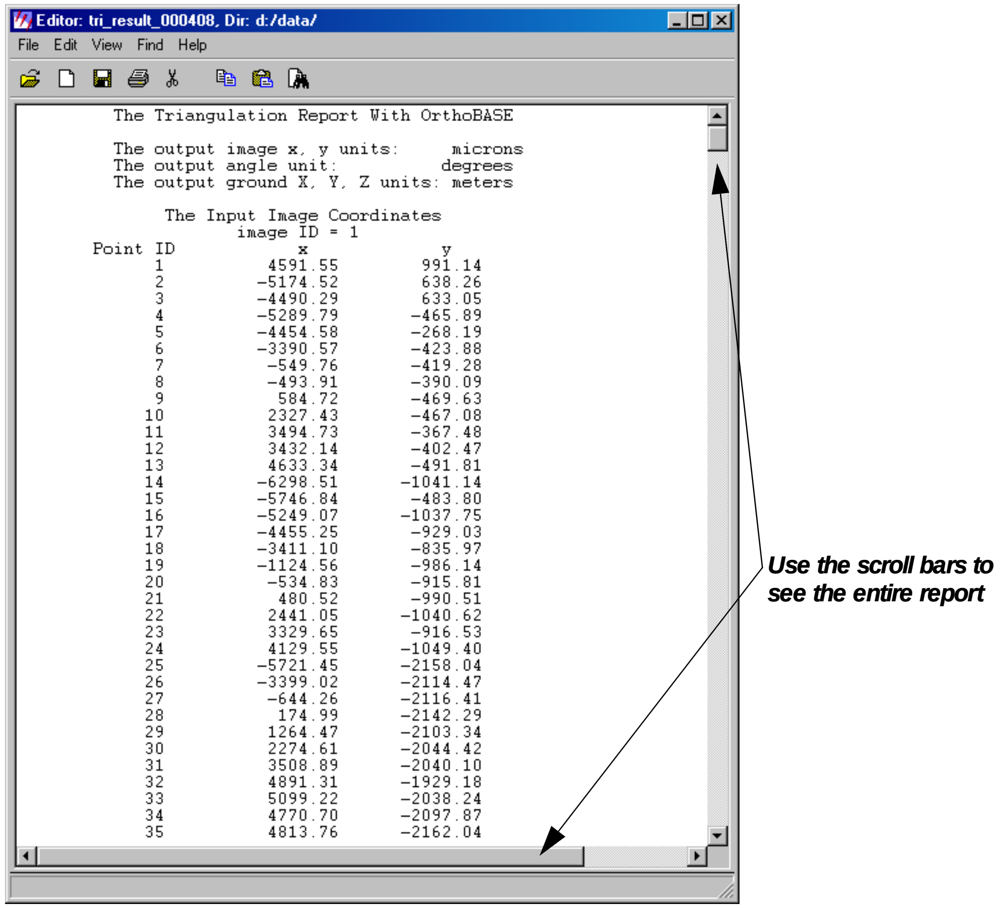
11. Click the **Run** button in the **Advanced Options** tab of the Aerial Triangulation dialog.

    The Triangulation Summary dialog opens. The result, reported in the **Total Image Unit-Weight RMSE** section, is around 1 micron. This (1 micron) equates to less than one-fourth of a pixel.



12. Click the **Report** button in the Triangulation Summary dialog.

    The Triangulation Report opens, which contains all the information pertaining to the tie points used during the triangulation process. This report can be saved as a text file for future reference.



The Triangulation Report With OrthoBASE

The output image x, y units: microns
The output angle unit: degrees
The output ground X, Y, Z units: meters

The Input Image Coordinates
image ID = 1

Point ID	x	y
1	4591.55	991.14
2	-5174.52	638.26
3	-4490.29	633.05
4	-5289.79	-465.89
5	-4454.58	-268.19
6	-3390.57	-423.88
7	-549.76	-419.28
8	-493.91	-390.09
9	584.72	-469.63
10	2327.43	-467.08
11	3494.73	-367.48
12	3432.14	-402.47
13	4633.34	-491.81
14	-6298.51	-1041.14
15	-5746.84	-483.80
16	-5249.07	-1037.75
17	-4455.25	-929.03
18	-3411.10	-835.97
19	-1124.56	-986.14
20	-534.83	-915.81
21	480.52	-990.51
22	2441.05	-1040.62
23	3329.65	-916.53
24	4129.55	-1049.40
25	-5721.45	-2158.04
26	-3399.02	-2114.47
27	-644.26	-2116.41
28	174.99	-2142.29
29	1264.47	-2103.34
30	2274.61	-2044.42
31	3508.89	-2040.10
32	4891.31	-1929.18
33	5099.22	-2038.24
34	4770.70	-2097.87
35	4813.76	-2162.04

See "Aerial Triangulation Report" for a complete explanation of the Triangulation Report.

To improve the triangulation results, you can look through the Triangulation Report and identify the points with the most error. These commonly have relatively large residuals. Then, you can go back to the Point Measurement tool, deactivate those points by clicking in the **Active** *column to remove the* **X,** *and run the triangulation again.*

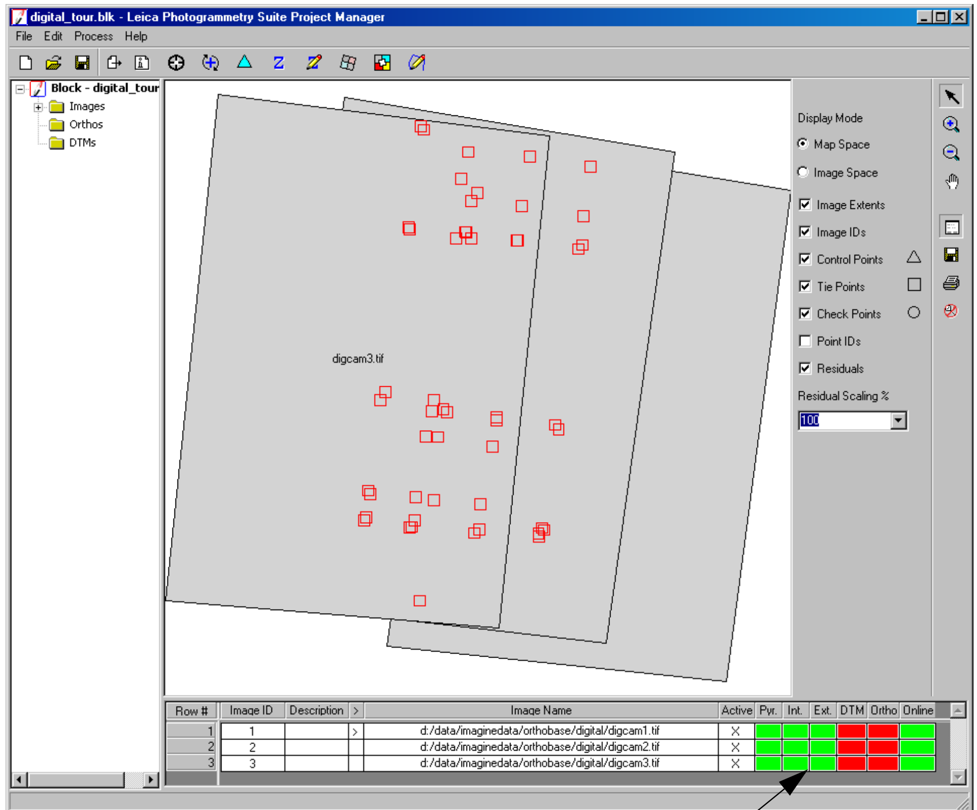
13. When you are finished looking at the report, select **File | Close.**

14. Click the **Accept** button in the Triangulation Summary dialog.

15. Click the **Close** button to close the Triangulation Summary dialog.

16. Click **OK** in the Aerial Triangulation dialog to accept the triangulation.

    You are returned to the LPS Project Manager. The **Ext.** column is now green and the images display in the Project Overview window.



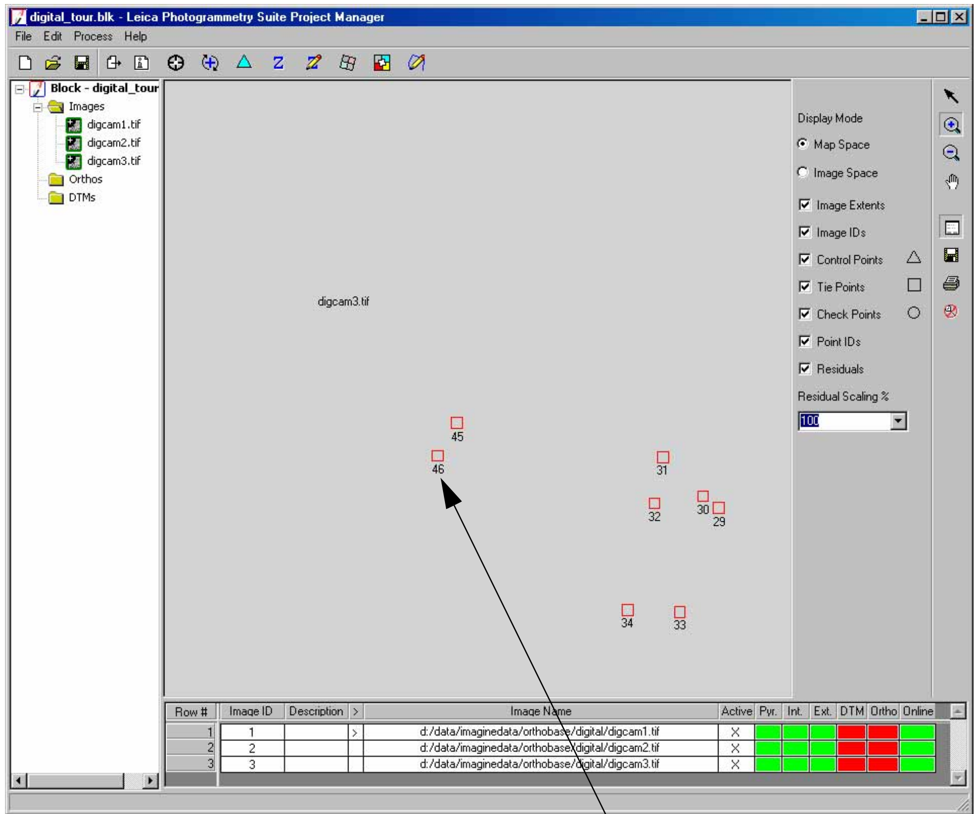
The Exterior Orientation Information has been calculated

Check Project Graphic Status

The Project Graphic Status window offers you an easy way to evaluate the GCPs, check points, and tie points associated with images in the block file. You can also get information about each specific points in this dialog.

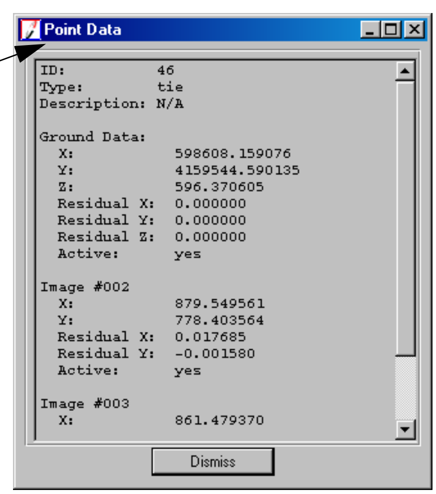
1. In the LPS Project Manager, click plus sign  next to the **Images** folder in the Block Project Tree View.
2. In the **Display Mode** section of the LPS Project Manager, click the checkbox next to **Point IDs.**

   The **Point IDs** are listed below each of the **Tie Points** in the display.
3. Click the Zoom In icon  and drag a box around an area containing tie points.



4. Click on the Select icon  to deactivate the Zoom In icon.

5. Click on a **Tie Point** square to display the Point Data dialog.

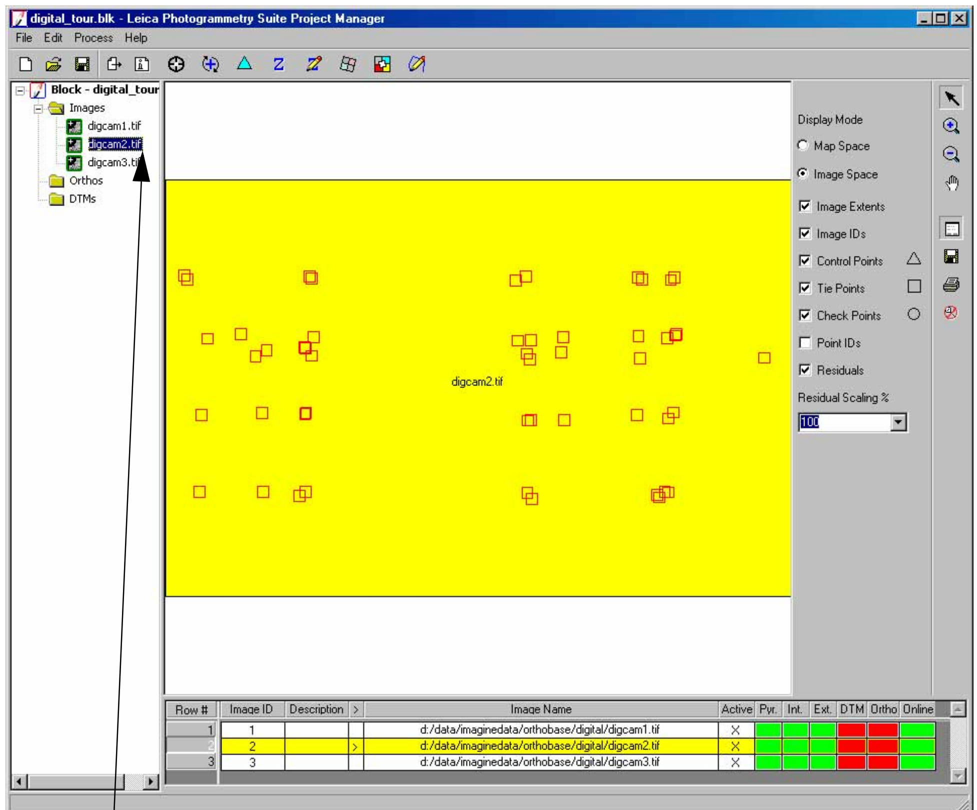


6. When you are finished viewing information in the Point Data dialog, click the **Dismiss** button.

7. Click the **Image Space** radio button in the **Display Mode** section of the LPS Project Manager.

8. In the Block Project Tree View on the left side of the dialog, click **digcam2.tif** under the **Images** folder to display the points associated with that image.

   The active image is identified in both the Block Project Tree View and the CellArray. The tie points are shown for the identified image.



Select the image to display in the Image Space mode in the Block Project Tree View

9. Click the to select the next image in the block file, **digcam3.** The tie points redisplay in the Project Graphic Status window of the LPS Project Manager accordingly.

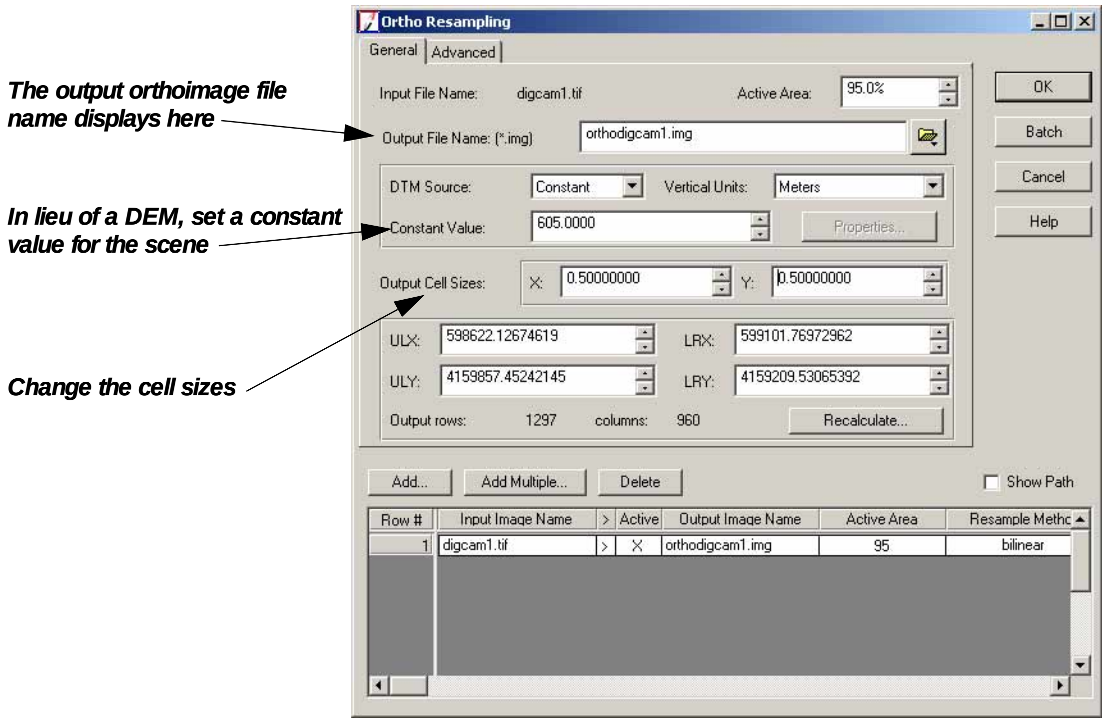
10. When you are finished, click the **Map Space** radio button in the **Display Mode** section of the LPS Project Manager.

Ortho Resample the Imagery

The final step in the process is to orthorectify the images in the block file.

1. In the CellArray of the LPS Project Manager, click on a red cell within the **Ortho** column, or select the Ortho Resampling icon  from the toolbar.

The Ortho Resampling dialog opens. The Ortho Resampling dialog opens on the **General** tab. Here, you can set the parameters to be applied to each of the images in the block.



1. Click in the **Active Area** field and type **95,** or use the increment nudgers to the right of the field.
2. Confirm that the **DTM Source** dropdown list shows **Constant.**
3. In the **Constant Value** field, type **605.0.**

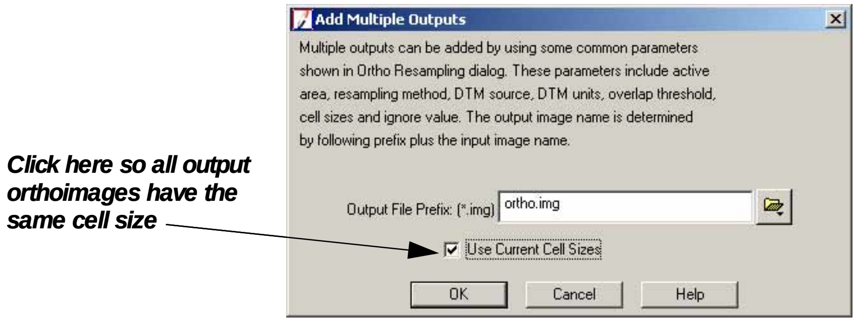
   Use of a constant value is appropriate in relatively flat areas; however, areas with large relief displacement benefit from a DTM source, such as a DEM.
4. In the **Output Cell Sizes** section, change both **X** and **Y** to **0.50.**
5. Click the **Advanced** tab.
6. Confirm that the **Resampling Method** is **Bilinear Interpolation.**

Add Multiple Images

In the CellArray of the Ortho Resampling dialog, you can add multiple images in your block file to be resampled. You can do so either in the **General** tab or the **Advanced** tab.

1. In the **Advanced** tab of the Ortho Resampling dialog, click the **Add Multiple** button.

   The Add Multiple Outputs dialog opens. It automatically adds the **ortho** output file prefix for you. This option adds all files in the block to the Ortho Resampling dialog CellArray.

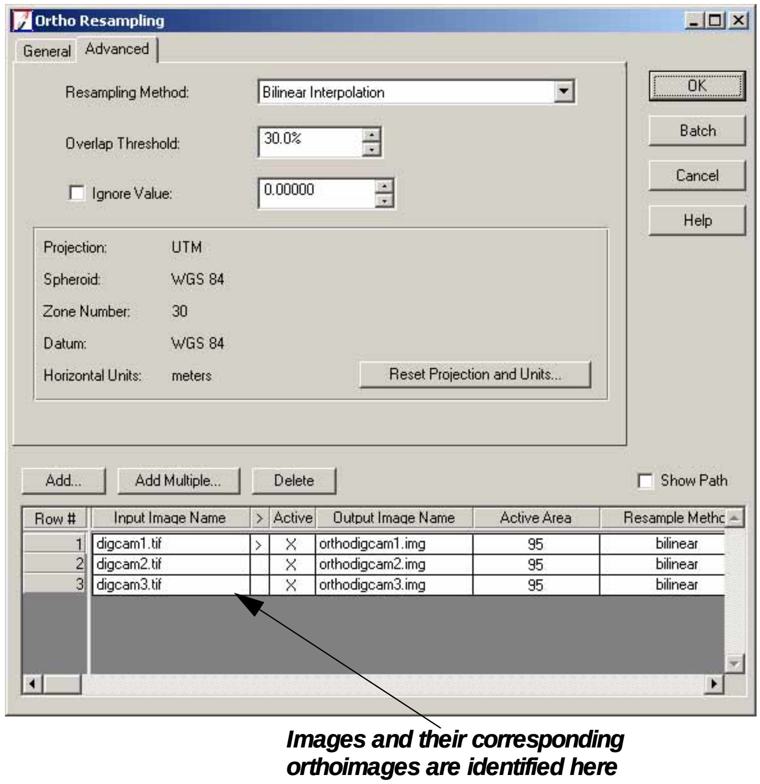


2. Click the **Use Current Cell Sizes** checkbox so that all orthoimages have X and Y cell sizes of **0.50.**

3. Click **OK** in the Add Multiple Outputs dialog.

4. Click **OK** in the Confirm Existing Ortho dialog, which alerts you that the first image in the block file, **digcam1**, is already set for ortho resampling.

The remaining images in the block file are added to the Ortho Resampling CellArray.



5. Click **OK** in the Ortho Resampling dialog to begin the process.

   A status dialog opens.

6. When the process is 100% complete, click **OK** in the status dialog to close it.

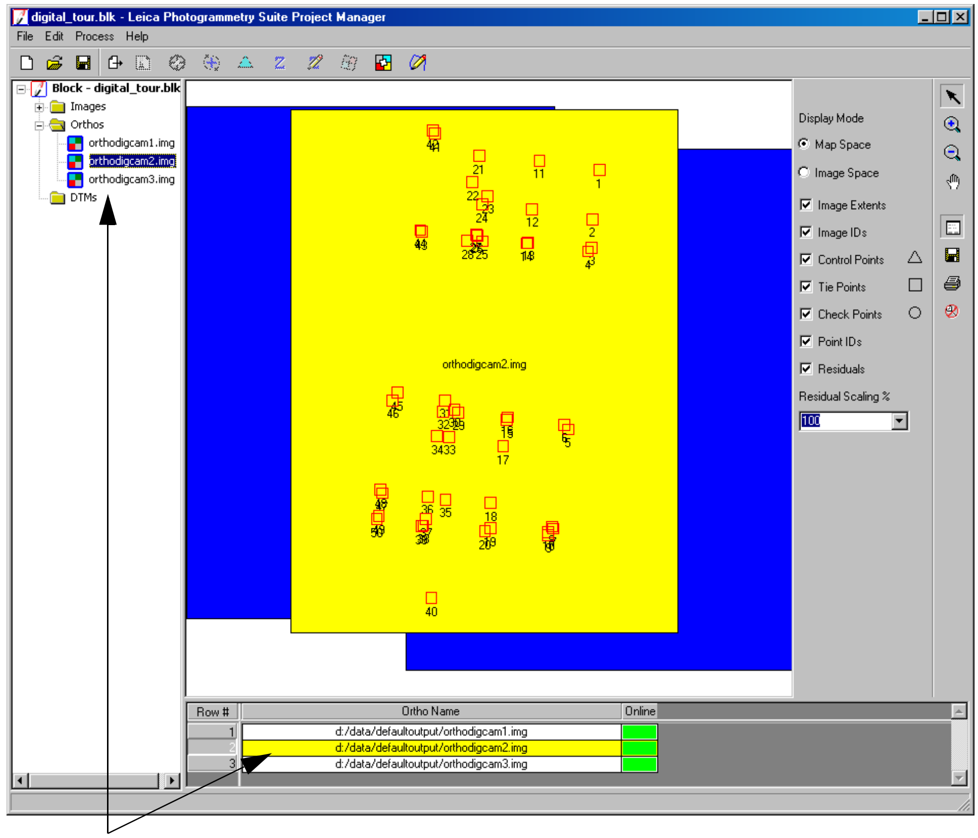
View the Orthoimages

Now that the resampling process is complete, indicated by the green cells in the **Ortho** column of the CellArray, you can check the orthoimages in an ERDAS IMAGINE Viewer.

Use LPS

1. Click the plus sign [+] next to the **Orthos** folder in the Block Project Tree View of the LPS Project Manager.

2. Click on one of the orthos in the list to highlight it in the Block Tree View, CellArray, and the Project Graphic Status window.



The highlighted ortho is indicated in the Block Project Tree View and the CellArray

To see the actual orthoimage, not just a graphical representation, you can use a Viewer.

Use a Viewer

1. From the LPS toolbar, click the Viewer icon  .

If necessary, choose the type of Viewer you want to work with: **Classic Viewer** *or* **Geospatial Light Table**.

2. From the Viewer menu bar, select **File | Open | Raster Layer.**
3. In the Select Layer To Add dialog, navigate to the location in which you saved the resampled images.
4. Click the first orthoimage in the block file, **orthodigcam1.img.**
5. Hold down the Shift key and select the last orthoimage, **orthodigcam3.img.**
6. Click the **Raster Options** tab.
7. Deselect **Clear Display.**

8. Select the **Fit to Frame** checkbox and the **Background Transparent** checkbox, then click **OK.**

   The default settings of these options can be defined in the **Viewer** *category of the Preference Editor.*

9. Click the **Multiple** tab.

10. Make sure that the **Multiple Independent Files** radio button is selected, then click **OK.**

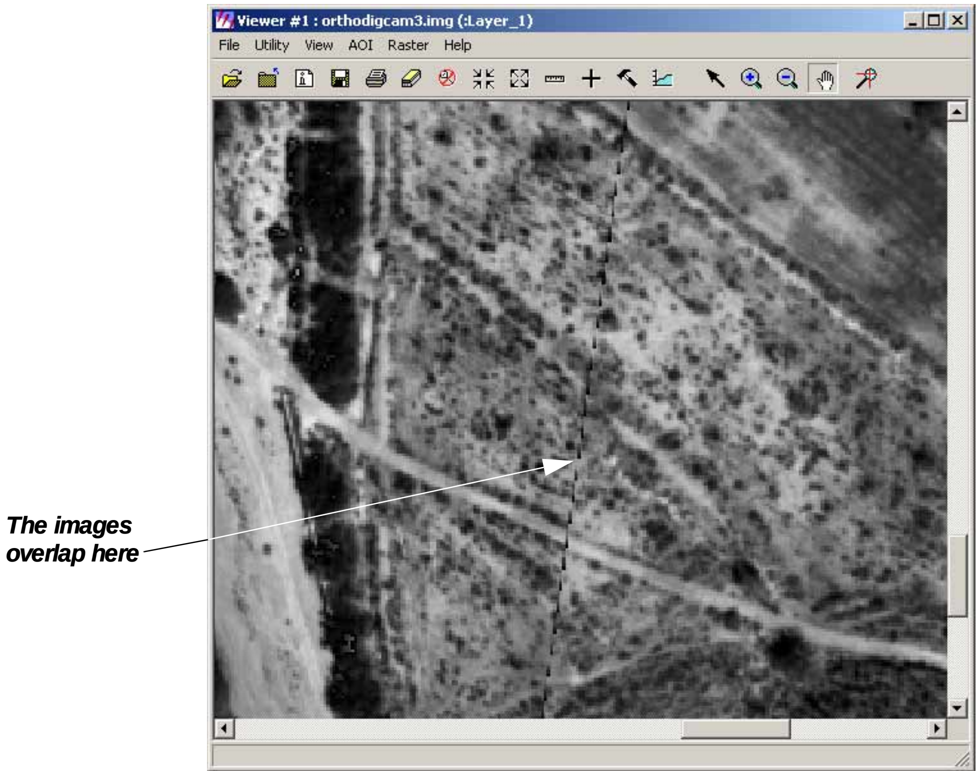
    The three orthoimages display in the Viewer.

Magnify Areas of Overlap

You can visually check the accuracy of the orthoimages by using the Zoom In tool.

1. In the Viewer containing the images, click the Zoom In icon  .

2. Click an area that interests you. You may have to apply the Zoom In tool more than once to see the details.

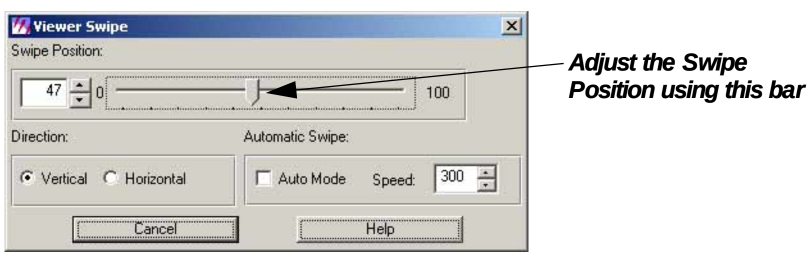


Use the Swipe Utility

You can also use the Swipe utility to see how well the images overlap.

1. Click the **Utility** menu on the Viewer menu bar.
2. Choose **Swipe.**

   The Viewer Swipe dialog opens.



3. Right-click in the Viewer to access the **Quick View** menu.
4. Click **Fit Image To Window.**
5. Click the slider bar in the Viewer Swipe dialog and move it to the left and right to see how well the top orthoimage, **orthodigcam3.img,** overlaps the others.

If you wish, you can click the **View** *menu, then select* **Arrange Layers.** *You can change the order of the images as they display in the Viewer to see how they look with the Swipe utility.*

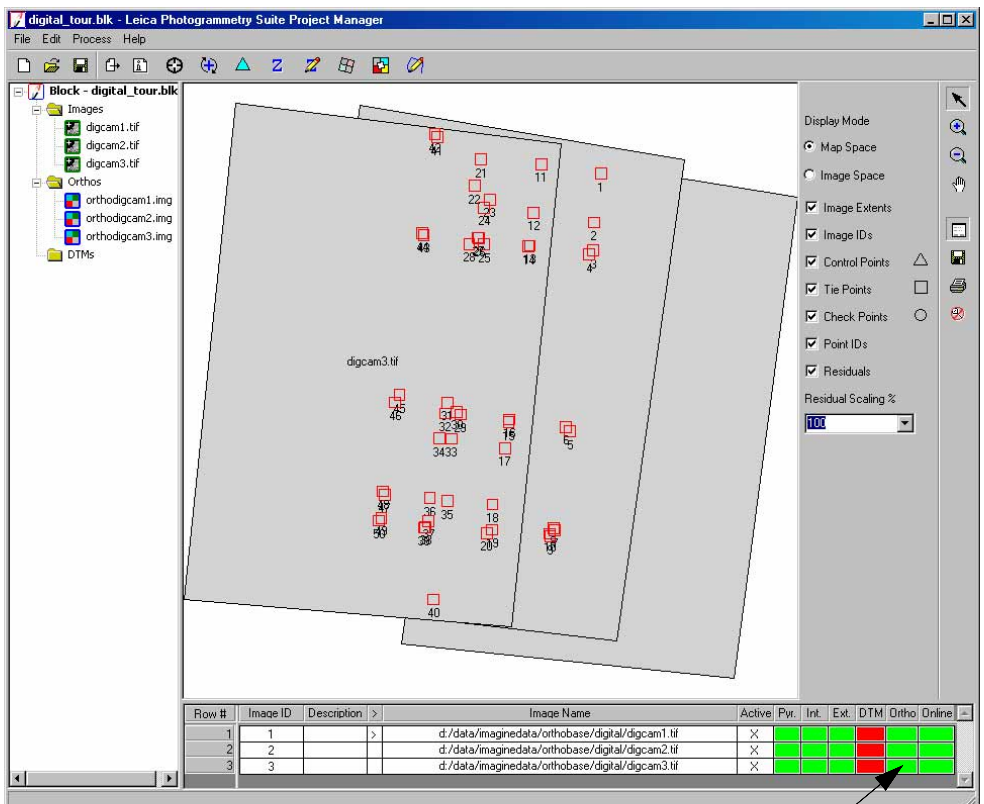
6. When you are finished, click **Cancel** in the Viewer Swipe dialog.

7. Click **File | Close** in the Viewer containing the orthoimages.

   You are returned to the LPS Project Manager,

8. Click the plus sign [+] next to the **Images** folder in the Block Project Tree View.

   In the Project Manager, you can see that the CellArray columns are green (with the exception of the **DTM** column, which is specific to OrthoBASE Pro), indicating that the process is complete.



Columns are green; the project is complete

Save and Close the Block File

1. In the LPS Project Manager, select **File | Save,** or click the Save icon .

You can now refer to the complete block file whenever you like.

2. In the LPS Project Manager, select **File | Close.**
3. To close LPS, select **File | Exit.**

Conclusions

Interior and exterior orientation information from airborne GPS and INS data is accurate enough to eliminate the need for ground control. Simply import the data, and LPS uses that information to create accurate orthoimages.

Next, you can learn how to select both horizontal and vertical reference points from images outside the block file.

Chapter 6

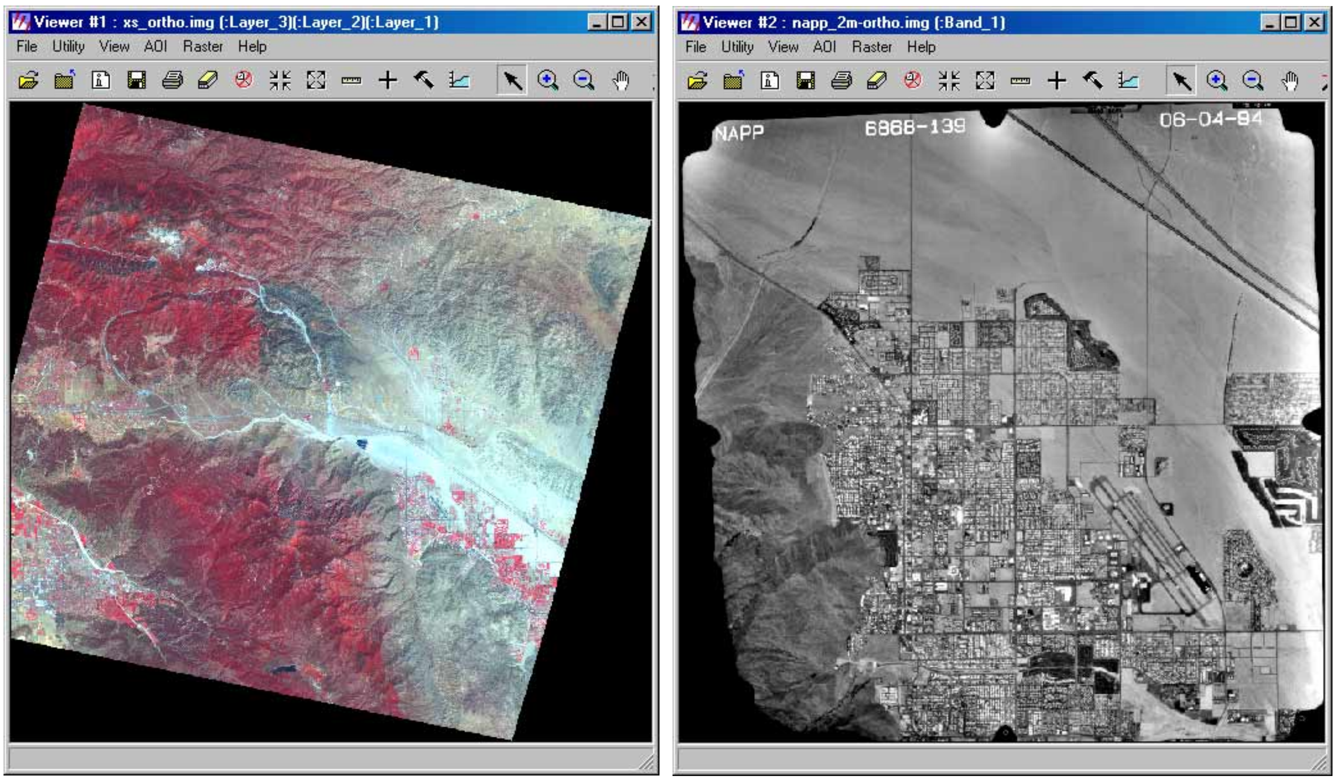
SPOT Pushbroom Sensor Tour Guide

Introduction

Using OrthoBASE, you have access to many different types of geometric models with which to create a block file. This tour guide takes you through the steps with the SPOT pushbroom model.

This tour guide demonstrates the use of existing orthorectified imagery as a source for ground control measurements. In this case, two images (**xs_ortho.img** and **NAPP_2m-ortho.img,** in Figure 6-1) are used for that purpose.

Figure 6-1: Reference Images: xs_ortho.img and NAPP_2m-ortho.img



When you use images outside of the block file as reference sources, you must identify whether you are using them as horizontal (X, Y) or vertical (Z) reference sources. The benefit of using existing orthorectified imagery in the collection of your GCPs is that the GCPs you collect are more accurate than those collected from nonorthorectified imagery.

Other types of external reference sources you can use with OrthoBASE include: geocorrected images, vector Arc coverages, annotation layers, ASCII text files, and digitizing tablets.

Before You Begin

The data you use with this tour guide comes from Palm Springs, California. You choose reference coordinates in two images: one a SPOT image, and one an orthorectified aerial photo. The block itself consists of two images, both SPOT panchromatic images with 10-meter resolution.

For more information about the data used in this tour guide, see *"SPOT Example Data"*.

This tour guide takes approximately 1 hour, 30 minutes to complete.

In this tour guide, you are going to perform the following basic steps:

- create a new project
- select a horizontal reference source
- collect GCPs
- add a second image to the block file
- collect GCPs in the second image
- perform automatic tie point collection
- triangulate the images
- orthorectify the images
- view the orthoimages
- save the block file

Create a New Project

In this section of the tour guide, you create a new project using SPOT satellite images of Palm Springs, California.

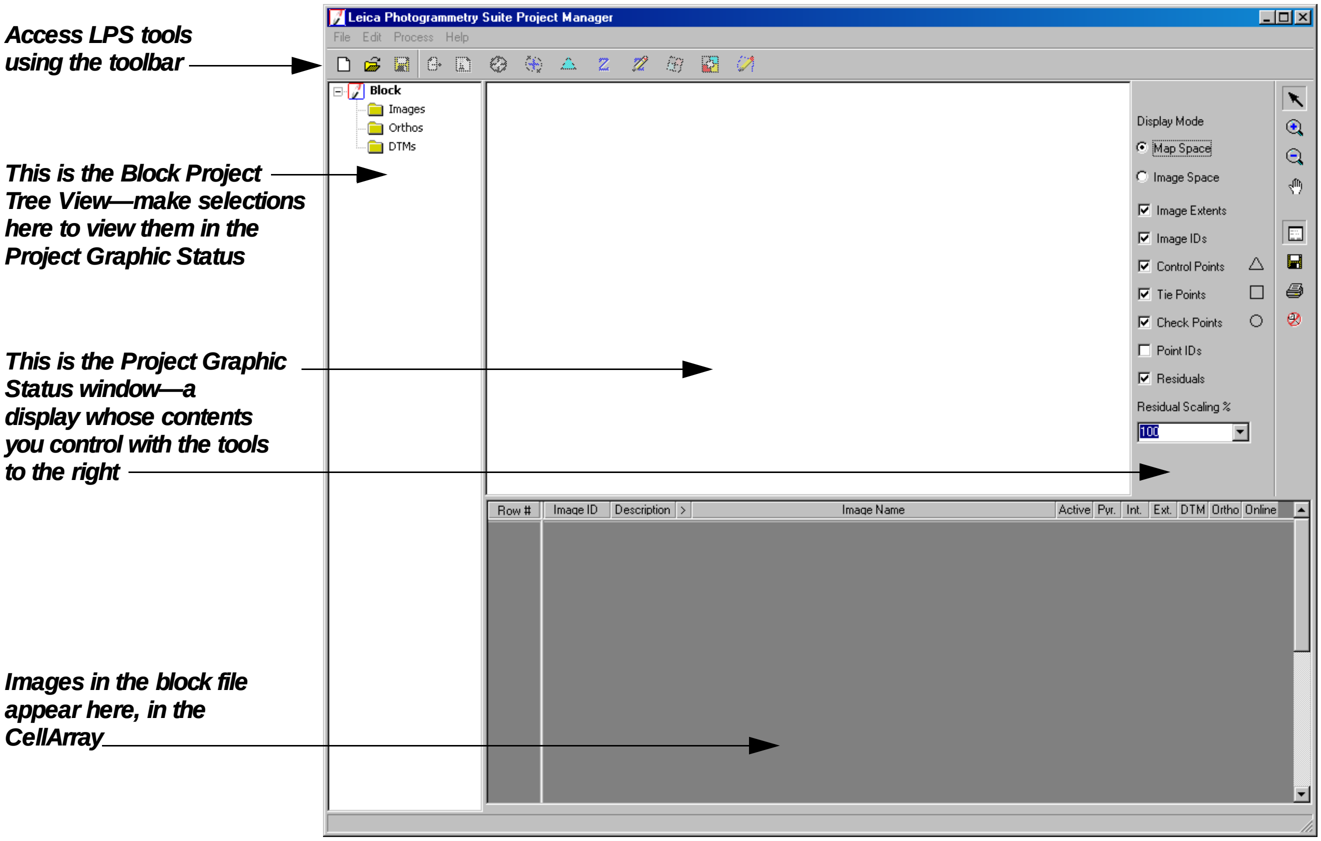
Prepare the Block File

1. Start Leica Photogrammetry Suite (LPS).

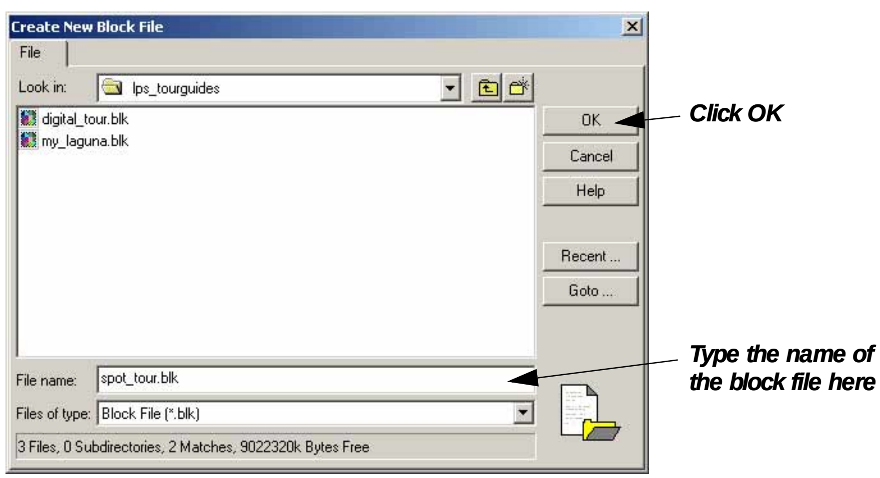
2. Click the LPS icon 

on the icon panel.

   The LPS Project Manager opens.



3. Click the New File icon to open the Create New Block File dialog.



4. Navigate to a folder in which you have write permission.

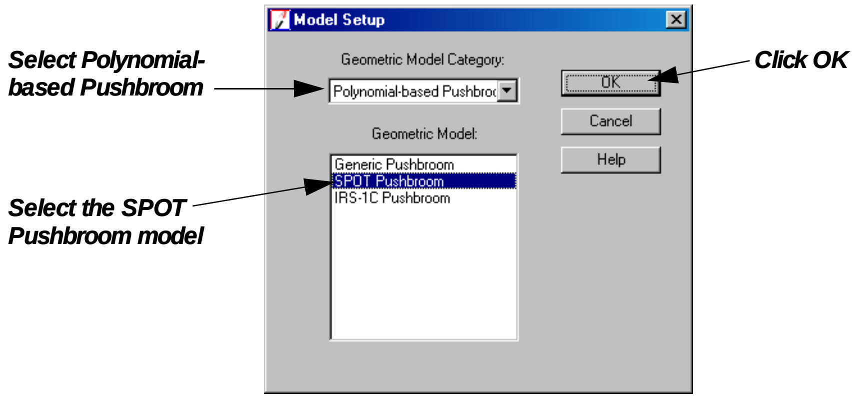
5. Click in the text field next to **File name,** and type **spot_tour,** then press Enter on your keyboard.

The *.blk extension is appended automatically.

6. Click **OK** to close the Create New Block File dialog.

Choose Camera Model

The Model Setup dialog opens.

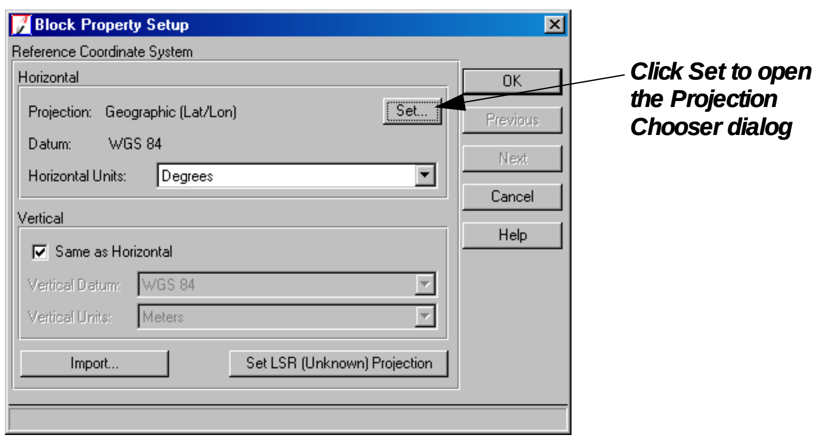


1. Click the **Geometric Model Category** dropdown list and choose **Polynomial-based Pushbroom**.

2. In the **Geometric Model** section click **SPOT Pushbroom.**

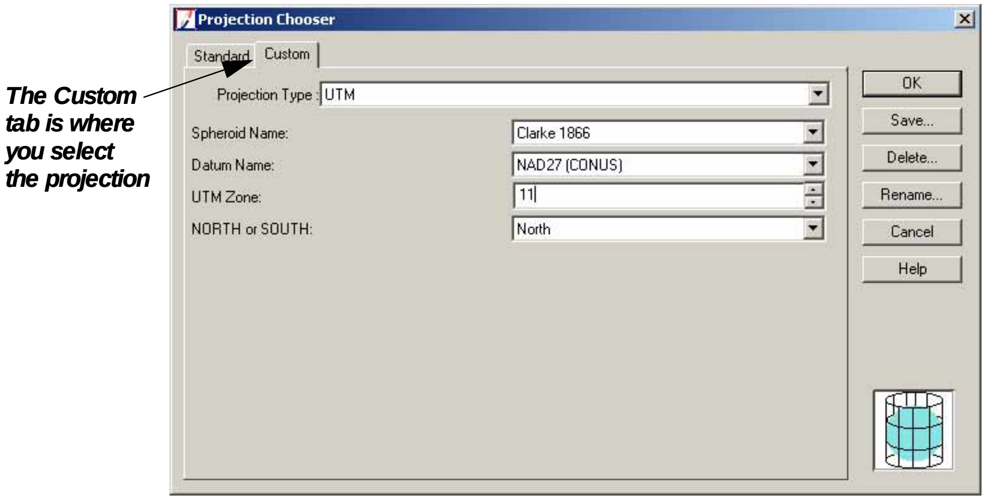
3. Click **OK** to close the Model Setup dialog.

   The Block Property Setup dialog opens.



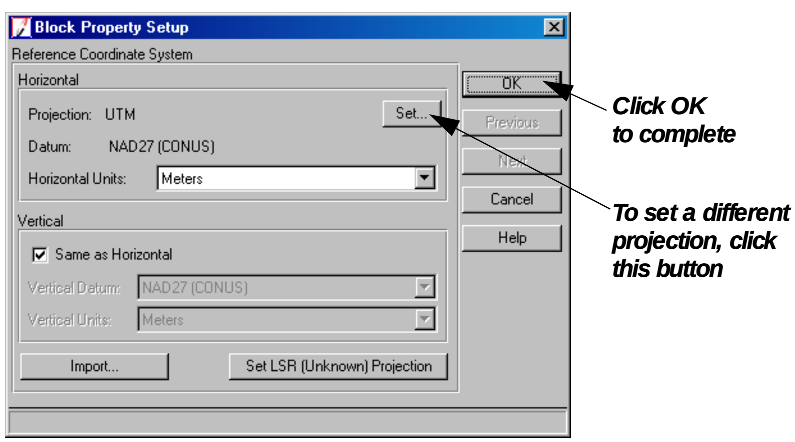
4. Click the **Set** button in the **Horizontal Reference Coordinate System** section of the Block Property Setup dialog.

   The Projection Chooser dialog opens.



5. In the **Custom** tab, click the **Projection Type** dropdown list and choose **UTM.**
6. Confirm that the **Spheroid Name** dropdown list shows **Clarke 1866.**
7. Click the **Datum Name** dropdown list and choose **NAD27 (CONUS).**
8. Click in the **UTM Zone** field and type **11.**
9. Verify that the **NORTH or SOUTH** field is set to **North.**
10. Click **OK** in the (Edited) Projection Chooser dialog.
11. Make sure that the **Horizontal Units** are set to **Meters.**

    The **Reference Coordinate System** section of the Block Property Setup dialog reflects the projection you selected.
12. In the **Vertical** section, click the checkbox for **Same as Horizontal.**

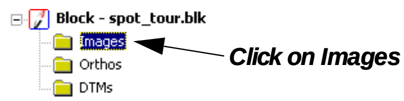


Make sure that the reference system is correct. You cannot revise the projection system once you click **OK** *to complete setup in the Block Property Setup dialog.*

13. Click **OK** to close the Block Property Setup dialog.

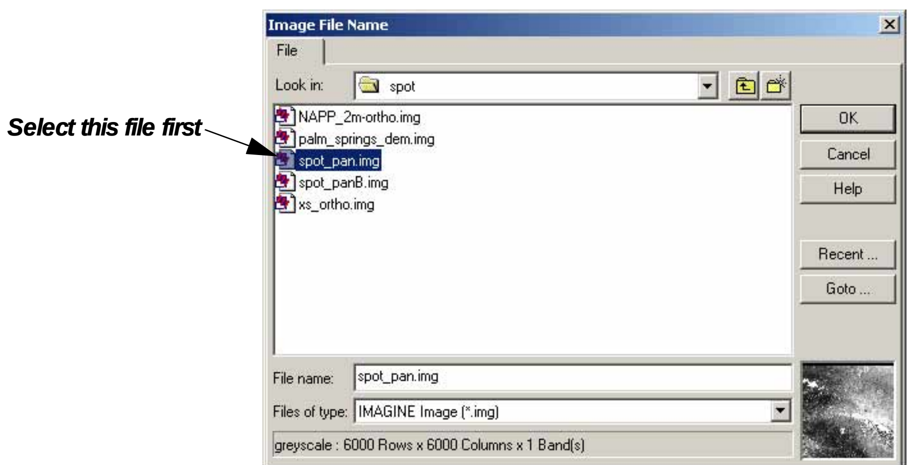
Add Imagery to the Block

1. In the Block Project Tree View on the left side of the LPS Project Manager, click the **Images** folder.



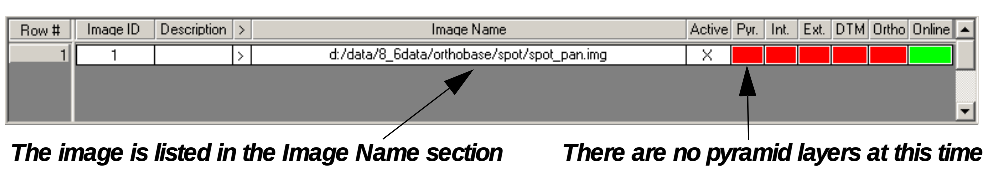
2. Select **Edit | Add Frame** from the LPS Project Manager menu bar, or click the Add Frame icon  .

   The Image File Name dialog opens.



3. Navigate to /examples/orthobase/spot, select **spot_pan.img,** then click **OK.**

   The image is loaded into the LPS Project Manager and displays in the CellArray.



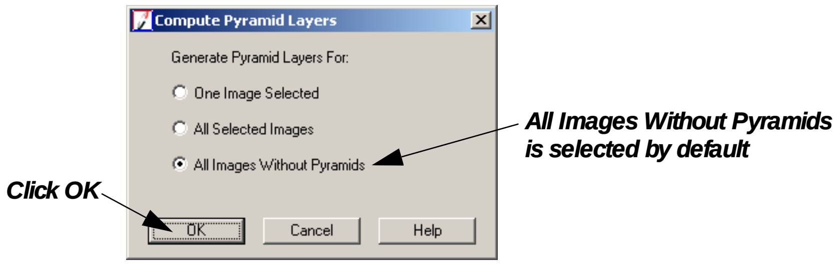
Generate Pyramid Layers

To conserve space in the /examples/orthobase/spot folder, the pyramid layers associated with the SPOT image are not included. However, LPS has a utility that enables you to quickly compute pyramid layers for your images. Pyramid layers make your image display more rapidly in the views.

1. Click in the red column labeled **Pyr.** for the **spot_pan** image.

   This cell controls the creation of pyramid layers for the image(s) in the block file.

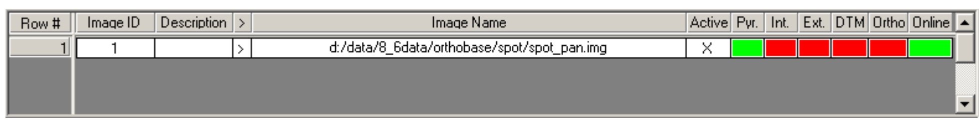
   The Compute Pyramid Layers dialog displays.



2. Confirm that the **All Images Without Pyramids** radio button is checked.

3. Click **OK** in the Compute Pyramid Layers dialog.

   A status bar displays at the bottom of the dialog, indicating the progress of pyramid layer creation. When complete, the **Pyr.** column for **spot_pan** is green, indicating that pyramid layers are present for this image.



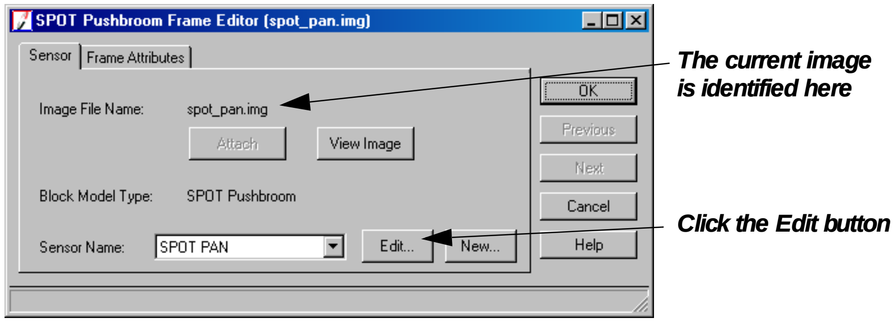
Define the Sensor Model

Next, you are going to verify the parameters of the sensor. In this case, it is a SPOT pushbroom sensor. The parameters are supplied by the images you are going to be working with, contained in their header files.

> ***Header Files***
>
> Header files precede image data on storage media, be it tape or CD. In general, header files contain the following information: number of columns (in pixels), number of rows (in pixels), data storage format, pixel depth (e.g., 8-bit), number of bands, blocking factor, and number of header files and header records.
>
> With sensor data, such as that obtained by the SPOT pushbroom sensor, data in the header file (also called ephemeris data) also includes the orientation of the sensor as it existed at the time of image capture. This information, x, y, z, omega, phi, kappa, can be read directly into LPS and used in the creation of block files. Moreover, you can also get information such as velocity vector and the exact time of the center scan line from the header file.
>
> You can use the **Tools | View Binary Data** option to view the header information of any file.

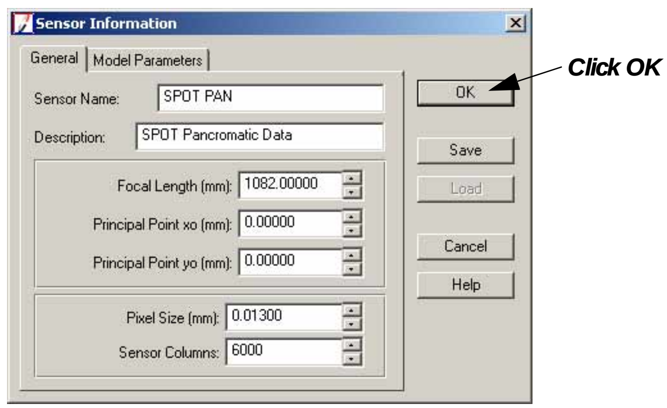
1. Select **Edit | Frame Editor** from the menu bar, or click the Frame Properties icon  .

   The SPOT Pushbroom Frame Editor dialog opens, which displays information about the current image listed in the LPS CellArray, **spot_pan.**



2. In the **Sensor** tab of the SPOT Pushbroom Frame Editor dialog, click the **Edit** button.

   The Sensor Information dialog displays.



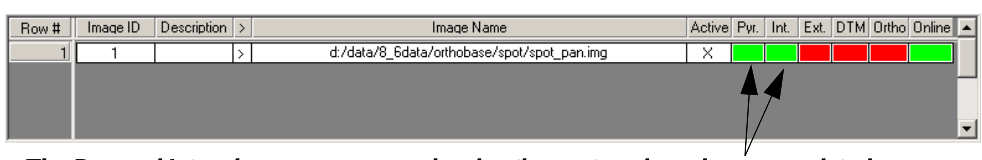
3. Check the fields in the Sensor Information dialog.

   The data in the Sensor Information dialog corresponds to the SPOT pushbroom sensor that obtained the image, **spot_pan.** The information is derived from the header file of the image.

4. Click **OK** in the Sensor Information dialog to confirm that the information is correct.

5. Click **OK** in the SPOT Pushbroom Frame Editor dialog.

   You are returned to the LPS Project Manager. As you can see, the **Int.** column that corresponds to the SPOT image is now green, indicating that the sensor has been specified.

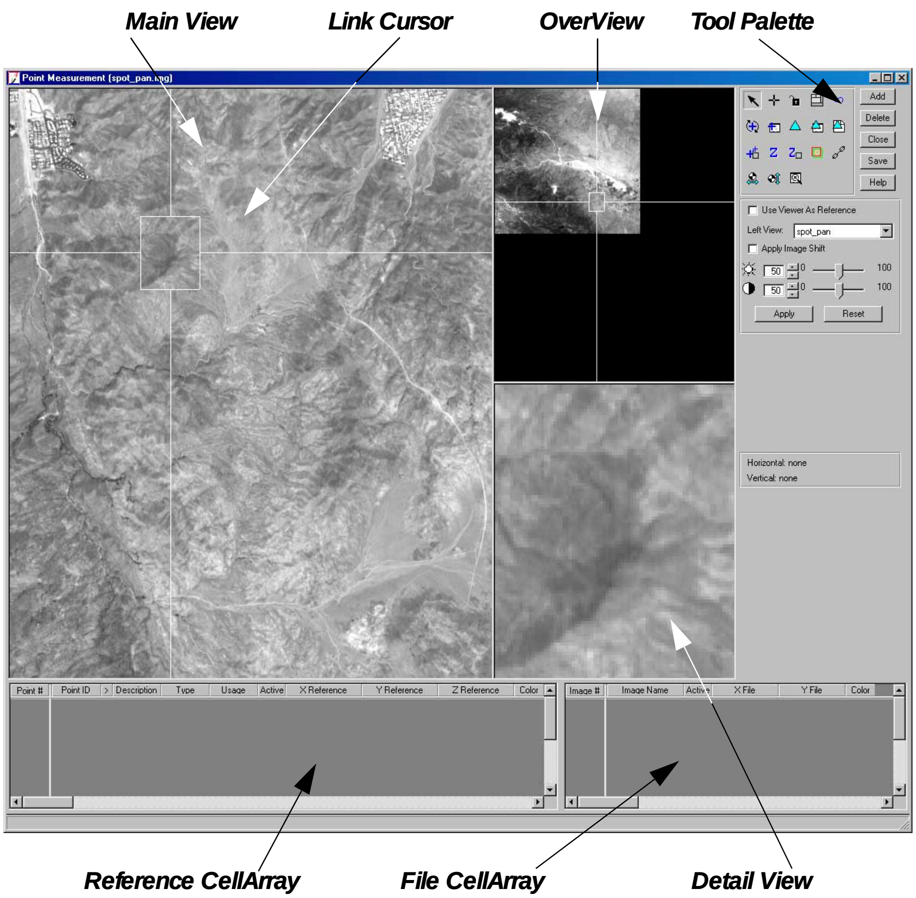


The Pyr. and Int. columns are green, showing those steps have been completed

Start the Point Measurement Tool

1. In the dialog, click the Point Measurement icon  .

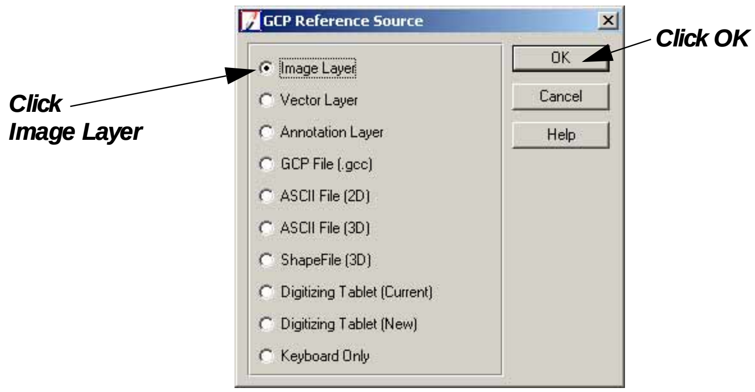
The Point Measurement tool opens displaying three views, a tool palette, and two CellArrays: one for recording reference coordinates, and one for recording file coordinates.



Specify the Horizontal Reference Source

1. In the Point Measurement tool palette, click the Horizontal Reference Source icon  .

The GCP Reference Source dialog opens.



NOTE: An existing image layer that has been orthorectified is going to be used for the collection of horizontal (X, Y) control points.

2. In the GCP Reference Source dialog, click the **Image Layer** radio button.

3. Click **OK** in the GCP Reference Source dialog.

   The Reference Image Layer dialog opens.

4. Navigate to /examples/orthobase/spot and select the file **xs_ortho.img.**

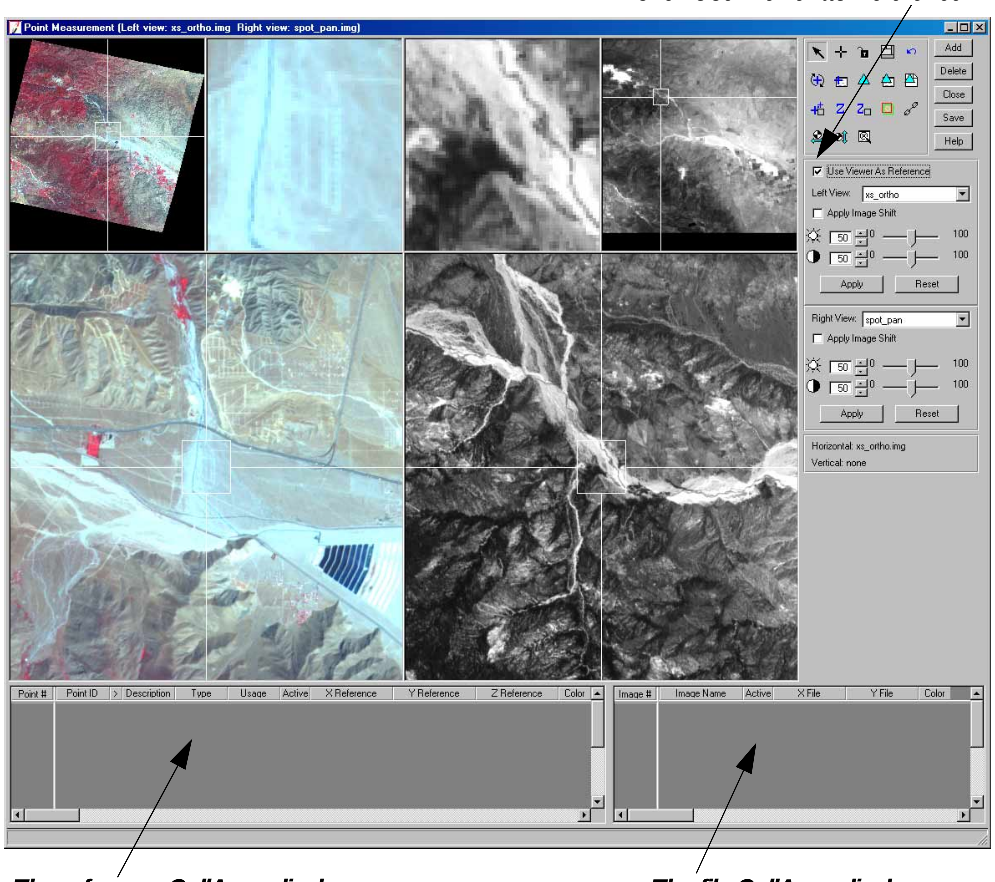
5. Click **OK** in the Reference Image Layer dialog.

   The Reference Image Layer dialog closes, and you are returned to the Point Measurement tool.

6. In the Point Measurement tool, click the checkbox next to **Use Viewer As Reference.**

   The Point Measurement tool automatically changes to display the new reference image, **xs_ortho,** in the **Left View** of the Point Measurement tool, and the original image, **spot_pan,** in the **Right View** of the Point Measurement tool. You are going to obtain reference coordinates by selecting points in **xs_ortho,** the reference image, that correspond to points also in the block image, **spot_pan.**

Click Use Viewer as Reference



The reference CellArray displays here, under the reference image

The file CellArray displays here, under the block image

Now, you are ready to begin collecting control points.

Collect GCPs

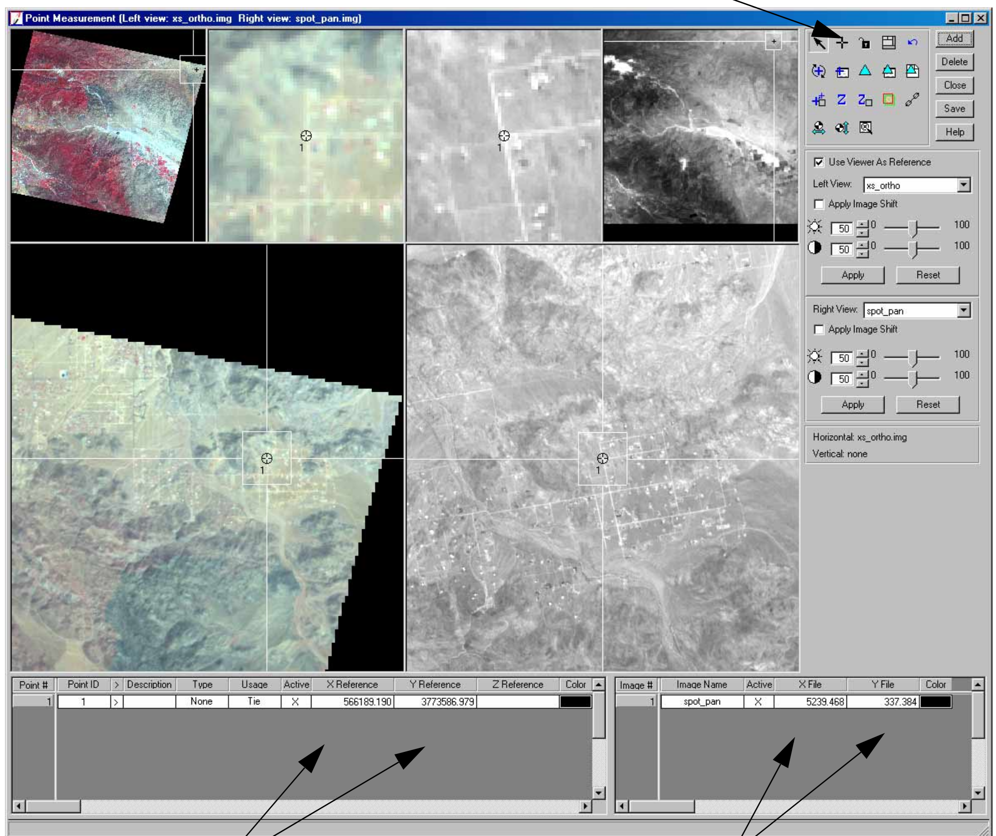
In this section, you are going to use screen captures of the reference image, **xs_ortho,** and the first image in the block, **spot_pan,** to collect the GCPs and identify their X and Y coordinates.

NOTE: The GCPs displayed in this tour guide are shown in different colors to enable you to see them better. Therefore, **Color** *columns have been added to the reference and file CellArrays. By default, GCPs are added to the views in green, and the* **Color** *column does not display.*

To change the color of points, click the Viewing Properties icon  *to access the Viewing Properties dialog. In the* **Point Table Info** *section, click the* **Advanced** *radio button, then the* **Color** *checkbox, then* **OK.** *This adds a* **Color** *column to the reference CellArray and the file CellArray.*

Collect Point ID 1

Figure 6-2: Location of Point ID 1



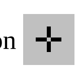
1. Click the **Add** button in the Point Measurement tool.

   A row for **Point ID 1** is added to the reference CellArray.

2. Check Figure 6-2 for the location of **Point ID 1** in **xs_ortho** displayed in the **Left View** of the Point Measurement tool.

3. Click the Select Point icon  and use it to move the Link Cursors in the views until you see the road intersection.

   When you have found the road intersection and centered it in the views, you are ready to collect the control point.

4. Click the Create Point icon  .

5. Move the cursor into the Detail View displaying the reference image, **xs_ortho,** and click the intersection.

   NOTE: In the **xs_ortho** *OverView, the Link Cursor is located in the upper right corner of the image. If you need more detailed information to find the intersection, it is located at the following ground coordinates in the reference image,* **xs_ortho:** *566189.190, 3773586.979; and the following pixel coordinates in the first block image,* **spot_pan:** *5239.468, 337.384.*

   A control point is placed on the intersection and labeled **1.** The reference CellArray updates to include the **X Reference** and **Y Reference** coordinates of the point in the reference image, **xs_ortho.**

6. Check your control point coordinates. They should match those in the following table:

Table 6-1: PID 1 Reference Coordinates

Point ID	X Reference	Y Reference
1	566189.190	3773586.979

7. If your coordinates do not approximate (within 10 meters) those listed in step 6 above, type the correct coordinates in the reference CellArray, then press Enter on your keyboard.

   The **Z Reference** *column is empty at this time. You are going to input Z values using a DEM later in the exercise, in "Set the Vertical Reference Source".*

   Now, you are going to collect the point on the block image, **spot_pan.**

8. Check Figure 6-2 for the location of **Point ID 1 spot_pan** displayed in the **Right View** of the Point Measurement tool.

9. Click the Select Point icon  and use it to move the Link Cursors in the views until you see the road intersection.

   When you have found the road intersection and centered it in the views, you are ready to collect the control point.

10. Click the Create Point icon  .

11. Move the cursor into the Detail View containing **spot_pan** and click the intersection.

    A control point is placed on the intersection and labeled **1.** The file CellArray updates to include the point in the **spot_pan** image, and the **X File** and **Y File** coordinates are updated.

12. Check your control point coordinates. They should approximate those in the following table:

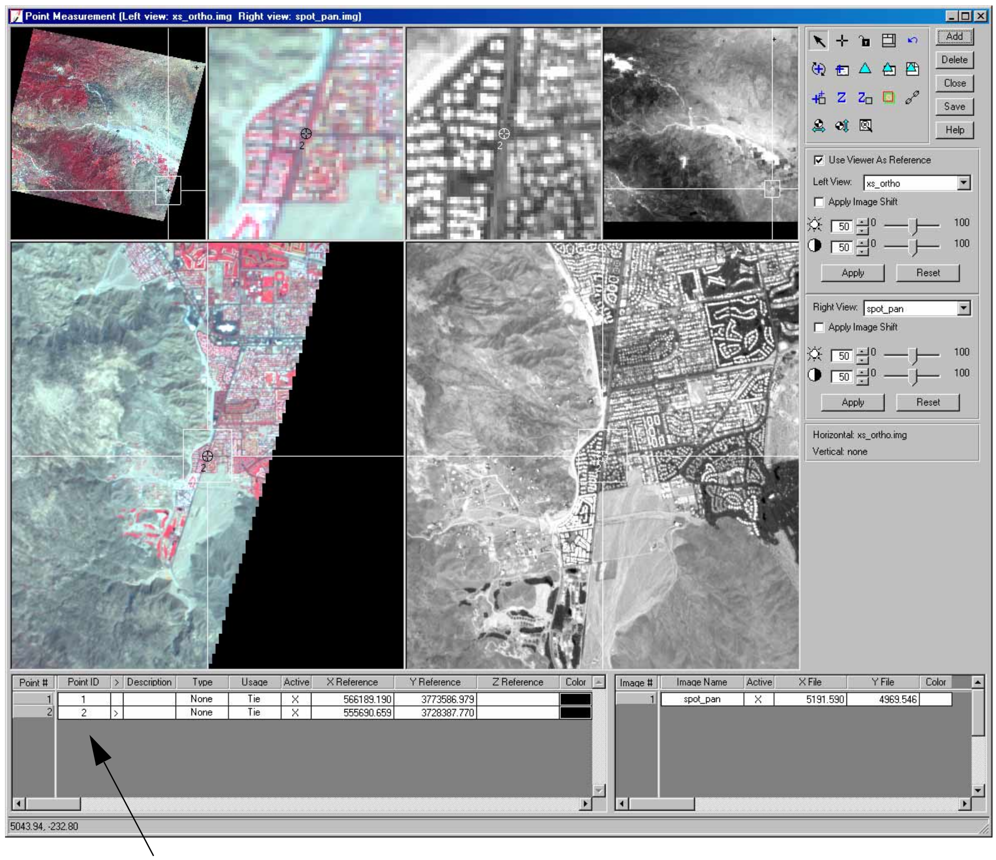
Table 6-2: PID 1 File Coordinates

Image Name	X File	Y File
spot_pan	5239.468	337.384

13. If your coordinates do not approximate (within two pixels) those listed in step 12 above, type the correct coordinates in the file CellArray, then press Enter on your keyboard. The point changes location accordingly.

Collect Point ID 2

Figure 6-3: Location of Point ID 2



Point ID 2 displays in the next row

1. Click the **Add** button in the Point Measurement tool.

2. Check Figure 6-3 for the location of **Point ID 2** in the **xs_ortho** views on the left side of the Point Measurement tool.

3. Click the Select Point icon  and use it to move the Link Cursors in the views until you see the road intersection.

4. Click the Create Point icon  .

5. Move the cursor into the Detail View containing the reference image, **xs_ortho,** and click the intersection.

   NOTE: In the **xs_ortho** *OverView, the box is located in the lower right corner of the image. If you need more detailed information to find the point location, it can be found at the following ground coordinates in the reference image,* **xs_ortho:** *555690.659, 3728387.770; and the following pixel coordinates in the first block image,* **spot_pan:** *5191.590, 4969.546.*

   A control point is placed on the intersection and labeled **2**. The reference CellArray updates to include the **X Reference** and **Y Reference** coordinates of the point in the reference image, **xs_ortho.**

6. Check your control point coordinates. They should approximate those in the following table:

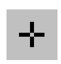
Table 6-3: PID 2 Reference Coordinates

Point ID	X Reference	Y Reference
2	555690.659	3728387.770

7. If your coordinates do not approximate (within 10 meters) those listed in step 6 above, type the correct coordinates in the reference CellArray, then press Enter on your keyboard.

8. Check Figure 6-3 for the location of **Point ID 2** in **spot_pan** displayed in the **Right View** of the Point Measurement tool.

9. Click the Select Point icon  and use it to move the Link Cursors in the views until you find the road intersection.

10. Click the Create Point icon  .

11. Move the cursor into the Detail View containing **spot_pan** and click the intersection.

12. Check your control point coordinates. They should approximate those in the following table:

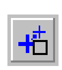
Table 6-4: PID 2 File Coordinates

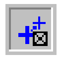
Image Name	X File	Y File
spot_pan	5191.590	4969.546

13. If your coordinates do not approximate (within two pixels) those listed in step 12 above, type the correct coordinates in the file CellArray, then press Enter on your keyboard. The point changes location accordingly.

Set Automatic (x, y) Drive Function

LPS provides an automatic function to enable you to select ground control points more rapidly. Next, you are going to activate the Automatic (x, y) Drive function. This function is only available after the first two points have been selected.

1. Click the Automatic (x, y) Drive icon.  .

The icon changes to  .

This icon allows LPS to approximate the position of a GCP in the block image file, **spot_pan,** based on the position in the reference image, **xs_ortho.**

Collect Point ID 3

Figure 6-4: Location of Point ID 3

Image chip from xs_ortho

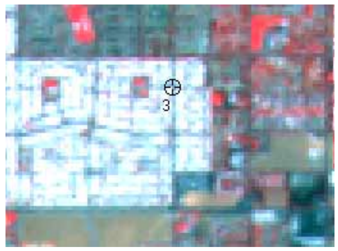
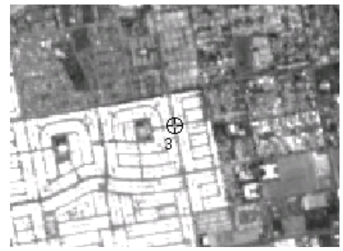


Image chip from spot_pan



1. Click the **Add** button in the Point Measurement tool.

   A row for **Point ID 3** is added to the reference CellArray.

2. Using the following table, type the **X Reference** and **Y Reference** coordinates for the third control point into the reference CellArray, then press Enter on your keyboard.

Table 6-5: PID 3 Reference Coordinates

Point ID	X Reference	Y Reference
3	501918.953	3732595.411

OrthoBASE adjusts the reference image in the views and places the control point at the coordinates you specify.

Because the Automatic (x, y) Drive icon is enabled, LPS moves **spot_pan** to the same approximate area in the views. The placement improves with subsequent points.

3. Check Figure 6-4. Then, click the Select Point icon  , and move the Link Cursor until you can see the location of the point in **spot_pan.**

4. Click the Create Point icon  in the Point Measurement tool palette.

5. Move the cursor into the Detail View containing **spot_pan** and click the intersection.

6. Check your control point coordinates. They should approximate those in the following table:

Table 6-6: PID 3 File Coordinates

Image Name	X File	Y File
spot_pan	230.925	5378.823

7. If your coordinates do not approximate (within two pixels) those listed in step 6 above, type the correct coordinates in the file CellArray, then press Enter on your keyboard. The point changes location accordingly.

Collect Point ID 4

Figure 6-5: Location of Point ID 4

Image chip from xs_ortho

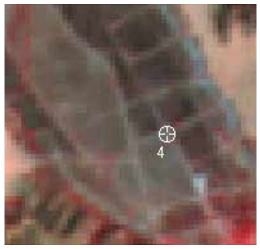
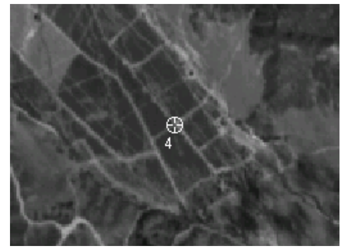


Image chip from spot_pan



1. Click the **Add** button in the Point Measurement tool.

2. Using the following table, type the **X Reference** and **Y Reference** coordinates for the fourth control point into the reference CellArray, then press Enter on your keyboard.

Table 6-7: PID 4 Reference Coordinates

Point ID	X Reference	Y Reference
4	515114.084	3759740.576

3. Check Figure 6-5. Then, click the Create Point icon in the Point Measurement tool palette.

4. Move the cursor into the Detail View containing **spot_pan,** and click the intersection.

5. Check your control point coordinates. They should approximate those in the following table:

Table 6-8: PID 4 File Coordinates

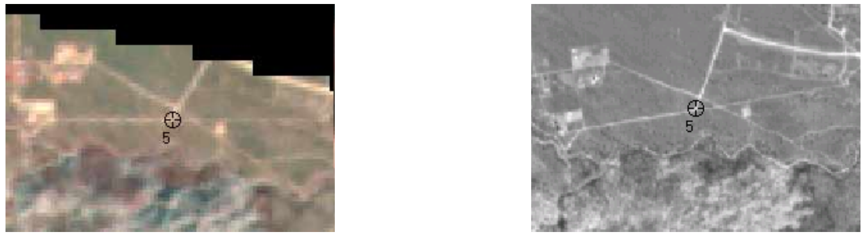
Image Name	X File	Y File
spot_pan	869.542	2487.996

6. If your coordinates do not approximate (within two pixels) those listed in step 5 above, type the correct coordinates in the file CellArray, then press Enter on your keyboard. The point changes location accordingly.

Collect Point ID 5

Figure 6-6: Location of Point ID 5

Image chip from xs_ortho ***Image chip from spot_pan***



1. Click the **Add** button in the Point Measurement tool.
2. Using the following table, type the **X Reference** and **Y Reference** coordinates for the fifth control point into the reference CellArray, then press Enter on your keyboard.

Table 6-9: PID 5 Reference Coordinates

Point ID	X Reference	Y Reference
5	543537.306	3779981.255

3. Check Figure 6-6. Then, click the Create Point icon in the Point Measurement tool palette.
4. Move the cursor into the Detail View containing **spot_pan,** and click the intersection.
5. Check your control point coordinates. They should approximate those in the following table:

Table 6-10: PID 5 File Coordinates

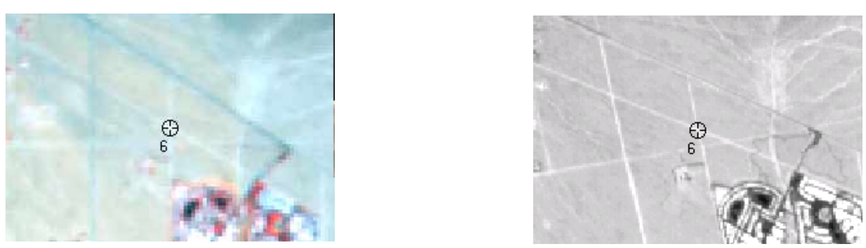
Image Name	X File	Y File
spot_pan	3027.570	51.432

6. If your coordinates do not approximate (within two pixels) those listed in step 5 above, type the correct coordinates in the file CellArray, then press Enter on your keyboard. The point changes location accordingly.

Collect Point ID 6

Figure 6-7: Location of Point ID 6

Image chip from xs_ortho ***Image chip from spot_pan***

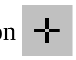


1. Click the **Add** button in the Point Measurement tool.

2. Using the following table, type the **X Reference** and **Y Reference** coordinates for the sixth control point into the reference CellArray, then press Enter on your keyboard.

Table 6-11: PID 6 Reference Coordinates

Point ID	X Reference	Y Reference
6	558640.300	3751516.718

3. Check Figure 6-7. Then, click the Create Point icon  in the Point Measurement tool palette.

4. Move the cursor into the Detail View containing **spot_pan,** and click the intersection.

5. Check your control point coordinates. They should approximate those in the following table:

Table 6-12: PID 6 File Coordinates

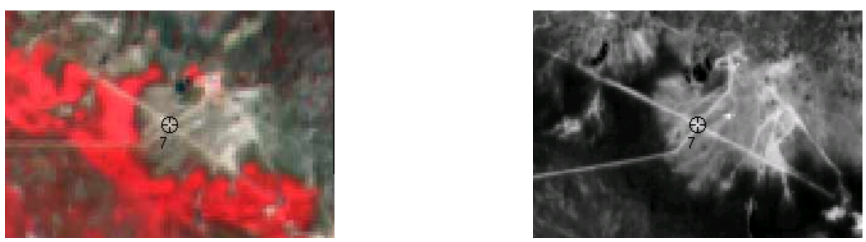
Image Name	X File	Y File
spot_pan	4999.412	2636.848

6. If your coordinates do not approximate (within two pixels) those listed in step 5 above, type the correct coordinates in the file CellArray, then press Enter on your keyboard. The point changes location accordingly.

Collect Point ID 7

Figure 6-8: Location of Point ID 7

Image chip from xs_ortho ***Image chip from spot_pan***



1. Click the **Add** button in the Point Measurement tool.

2. Using the following table, type the **X Reference** and **Y Reference** coordinates for the seventh control point into the reference CellArray, then press Enter on your keyboard.

Table 6-13: PID 7 Reference Coordinates

Point ID	X Reference	Y Reference
7	532062.982	3724946.633

3. Check Figure 6-8. Then, click the Create Point icon in the Point Measurement tool palette.

4. Move the cursor into the Detail View containing **spot_pan,** and click the intersection.

5. Check your control point coordinates. They should approximate those in the following table:

Table 6-14: PID 7 File Coordinates

Image Name	X File	Y File
spot_pan	3064.254	5673.794

6. If your coordinates do not approximate (within two pixels) those listed in step 5 above, type the correct coordinates in the file CellArray, then press Enter on your keyboard. The point changes location accordingly.

Collect Point ID 8

Figure 6-9: Location of Point ID 8

Image chip from xs_ortho ***Image chip from spot_pan***

1. Click the **Add** button in the Point Measurement tool.

2. Using the following table, type the **X Reference** and **Y Reference** coordinates for the eighth control point into the reference CellArray, then press Enter on your keyboard.

Table 6-15: PID 8 Reference Coordinates

Point ID	X Reference	Y Reference
8	539381.670	3768419.388

3. Check Figure 6-9. Then, click the Create Point icon in the Point Measurement tool palette.

4. Move the cursor into the Detail View containing **spot_pan,** and click the intersection.

5. Check your control point coordinates. They should approximate those in the following table:

Table 6-16: PID 8 File Coordinates

Image Name	X File	Y File
spot_pan	2890.880	1258.852

6. If your coordinates do not approximate (within two pixels) those listed in step 5 above, type the correct coordinates in the file CellArray, then press Enter on your keyboard. The point changes location accordingly.

Collect Point ID 9

Figure 6-10: Location of Point ID 9

Image chip from xs_ortho ***Image chip from spot_pan***

1. Click the **Add** button in the Point Measurement tool.
2. Using the following table, type the **X Reference** and **Y Reference** coordinates for the ninth control point into the reference CellArray.

Table 6-17: PID 9 Reference Coordinates

Point ID	X Reference	Y Reference
9	526013.661	3753709.856

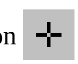
3. Check Figure 6-10. Then, click the Create Point icon  in the Point Measurement tool palette.
4. Move the cursor into the Detail View containing **spot_pan,** and click the intersection.
5. Check your control point coordinates. They should approximate those in the following table:

Table 6-18: PID 9 File Coordinates

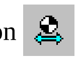
Image Name	X File	Y File
spot_pan	1978.138	2919.004

6. If your coordinates do not approximate (within two pixels) those listed in step 5 above, type the correct coordinates in the file CellArray, then press Enter on your keyboard. The point changes location accordingly.
7. Click the **Save** button to save your points.

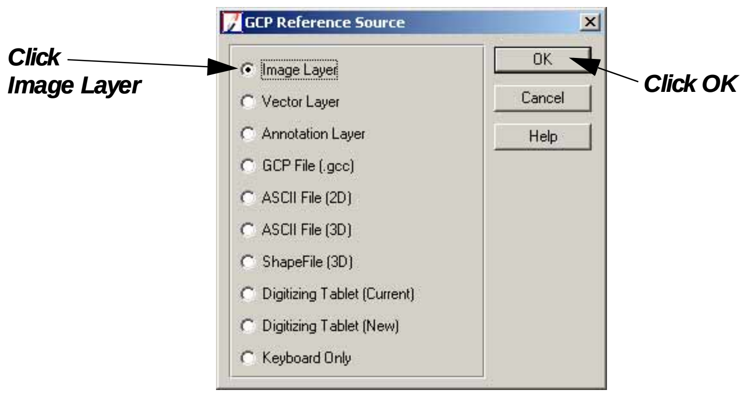
Collect the Last Two Control Points

The last two control points, **Point ID 11** and **Point ID 12,** use a different horizontal reference source than the previous control points. For them, you are going to use an image called **NAPP_2m-ortho.img.** This is an orthoimage of 1:40,000 scale photography with a 2-meter resolution.

Set the Horizontal Reference

1. In the Point Measurement tool palette, click the Horizontal Reference Source icon  .

   The GCP Reference Source dialog opens.



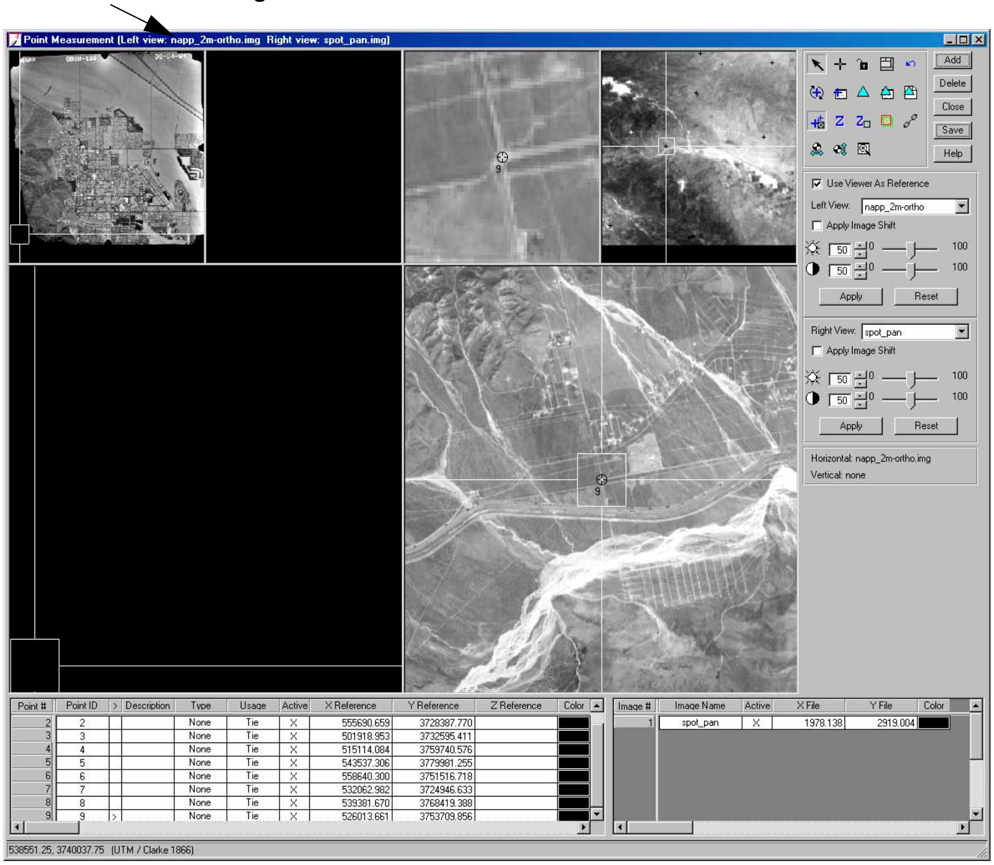
2. In the GCP Reference Source dialog, click the **Image Layer** radio button.
3. Click **OK** in the GCP Reference Source dialog.

   The Reference Image Layer dialog opens.

4. Navigate to /examples/orthobase/spot and select the file **NAPP_2m-ortho.img.**
5. Click **OK** in the Reference Image Layer dialog.

The Reference Image Layer dialog closes, and you are returned to the Point Measurement tool. The file, **NAPP_2m-ortho,** is automatically loaded into the **Left View.**

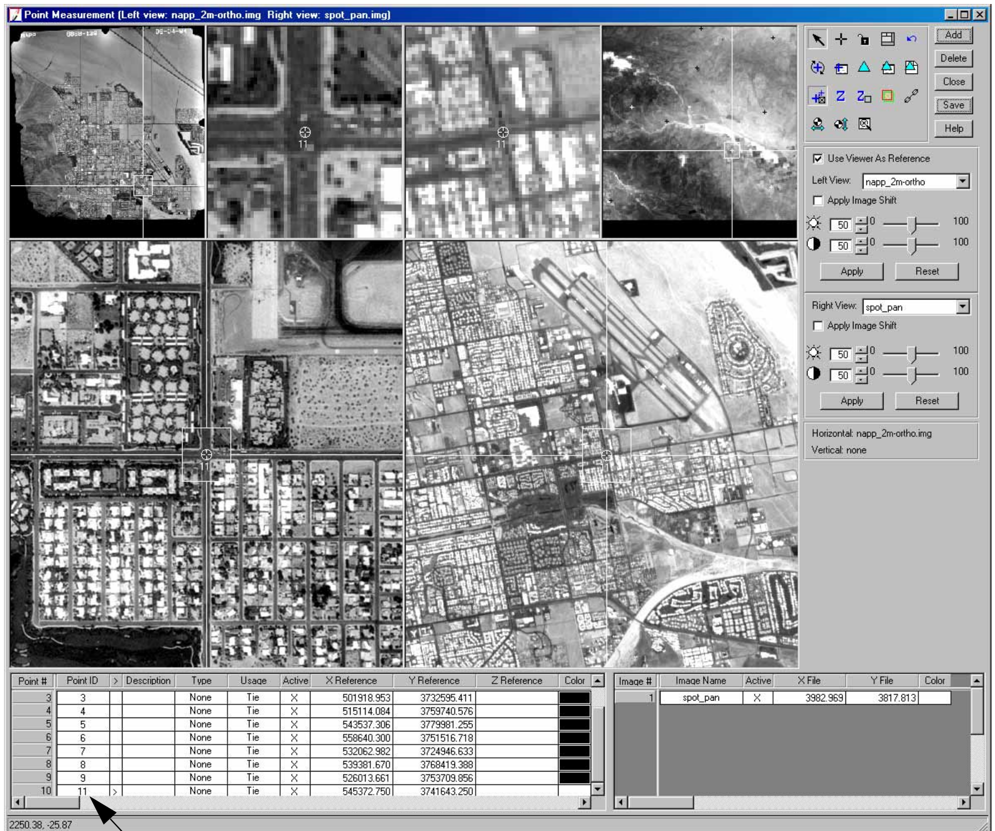
The new reference image is added to the Left View



Collect Point ID 11

To make the distinction between two different horizontal reference sources (**xs_ortho** and **NAPP_2m-ortho**) more clear, we skip **Point ID 10,** and name the next control point **Point ID 11.**

Figure 6-11: Location of Point ID 11



The last two Point IDs are located in a different reference image

1. Click the **Add** button in the Point Measurement tool.
2. Click in the **Point ID** column for **Point # 10**, and type **11.**

   Point ID 11 is the first of the points you collect from **NAPP_2m-ortho.**

3. Using the following table, type the **X Reference** and **Y Reference** coordinates for the next control point into the reference CellArray, then press Enter on your keyboard.

Table 6-19: PID 11 Reference Coordinates

Point ID	X Reference	Y Reference
11	545372.750	3741643.250

The control point is placed in the views displaying **NAPP_2m-ortho.**

4. Click the Create Point icon ✛ in the Point Measurement tool palette.
5. Move the cursor into the Detail View containing **spot_pan** and click the intersection.
6. Check your control point coordinates. They should approximate those in the following table:

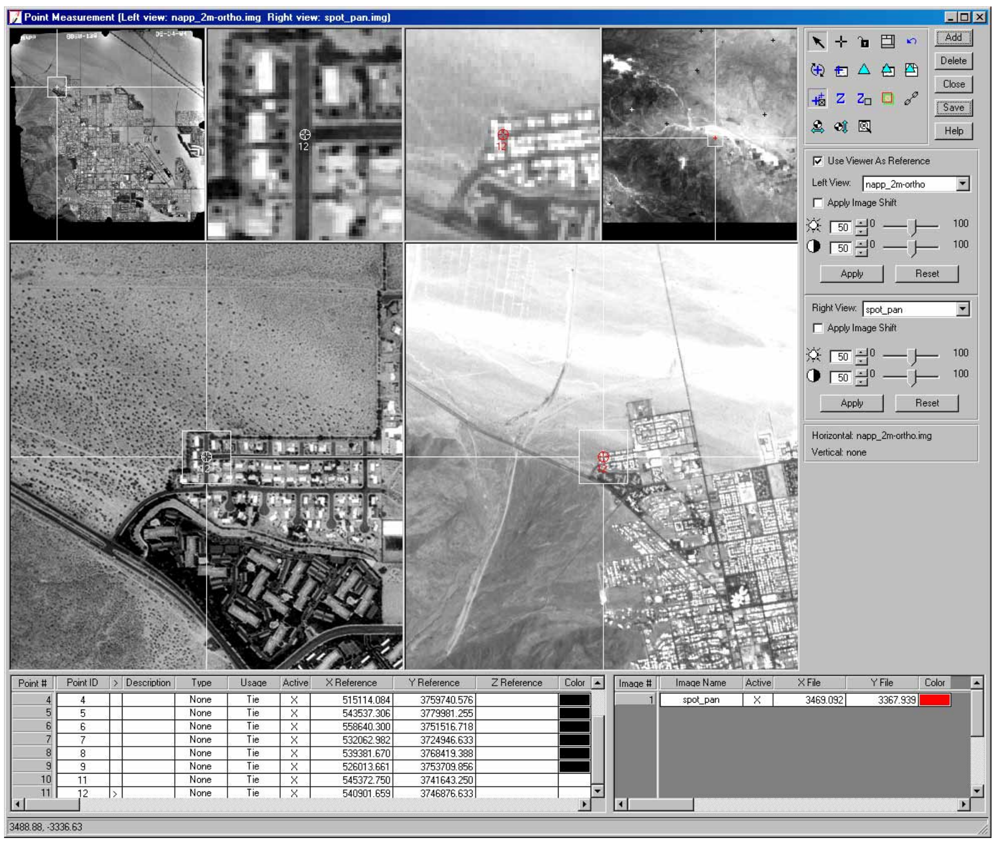
Table 6-20: PID 11 File Coordinates

Image Name	X File	Y File
spot_pan	3982.969	3817.813

7. If your coordinates do not approximate (within two pixels) those listed in step 6 above, type the correct coordinates in the file CellArray, then press Enter on your keyboard. The point changes location accordingly.

Collect Point ID 12

Figure 6-12: Location of Point ID 12



1. Click the **Add** button in the Point Measurement tool.

Note that the **Point ID** column identifies the new point as **12.**

2. Using the following table, type the **X Reference** and **Y Reference** coordinates for the control point into the reference CellArray, then press Enter on your keyboard.

Table 6-21: PID 12 Reference Coordinates

Point ID	X Reference	Y Reference
12	540901.659	3746876.633

3. Click the Create Point icon in the Point Measurement tool palette.

4. Move the cursor into the Detail View containing **spot_pan,** and click the intersection.

5. Check your control point coordinates. They should approximate those in the following table:

Table 6-22: PID 12 File Coordinates

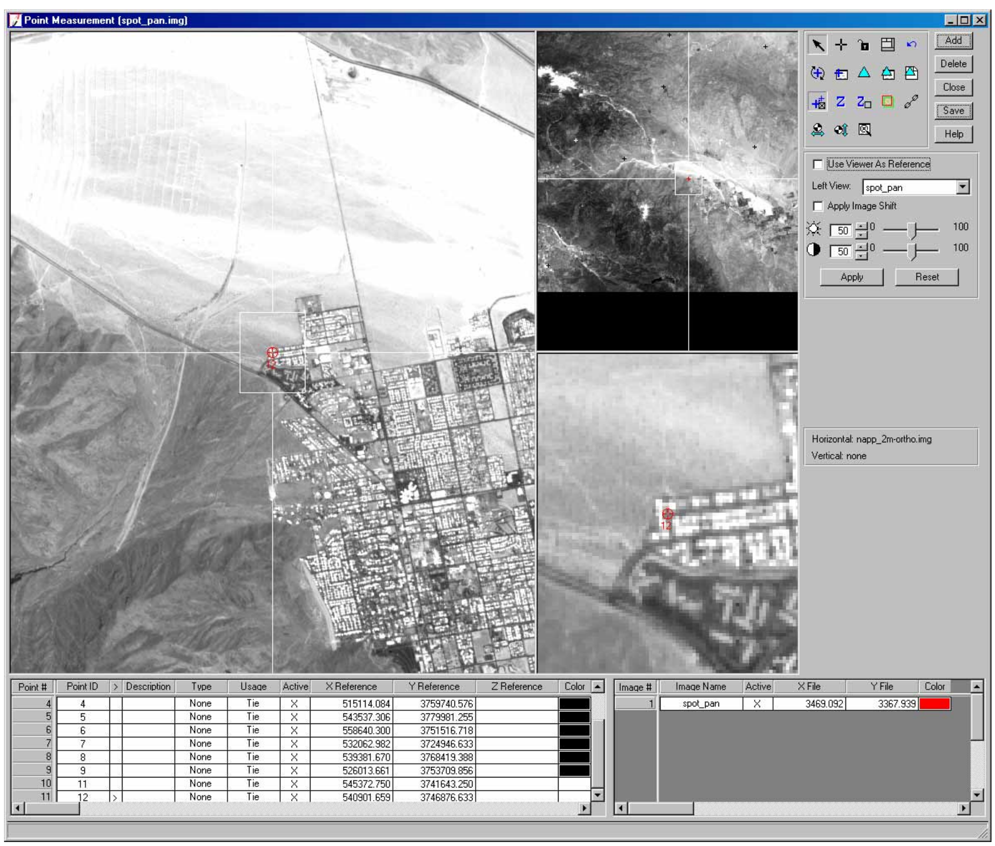
Image Name	X File	Y File
spot_pan	3469.092	3367.939

6. If your coordinates do not approximate (within two) pixels those listed in step 5 above, type the correct coordinates in the file CellArray, then press Enter on your keyboard. The point changes location accordingly.

7. In the Point Measurement tool, click **Save** to save your work to this point.

8. In the Point Measurement tool palette, click to deselect the **Use Viewer As Reference** checkbox.

   The reference file **NAPP_2m-ortho** closes, and **spot_pan** displays alone.

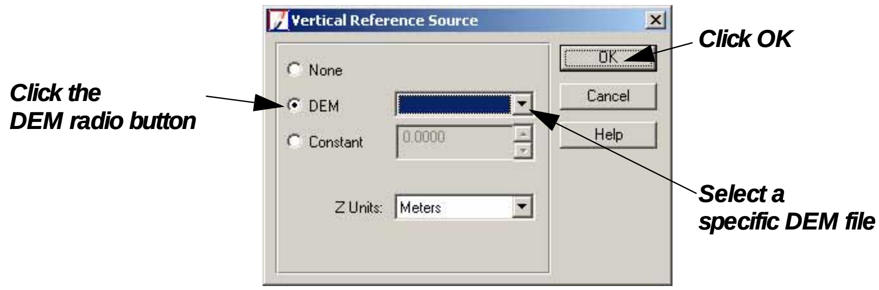


Set the Vertical Reference Source

To provide Z (elevation) values for all of the reference control points you selected in the reference images, **xs_ortho** and **NAPP_2m-ortho,** you are going to specify a DEM that contains height information, **palm_springs_dem.img.**

1. Click the Vertical Reference Source icon .

   The Vertical Reference Source dialog opens, in which you select the DEM that is going to supply height information.



The DEM must be in the same projection as that of the block file. If it is not, you can use the ERDAS IMAGINE reproject utility to put it in the correct projection. **Select Image Interpreter | Utilities | Reproject Images,** *and enter the correct information in the dialog. You can then use the new DEM as a vertical reference source.*

2. Click the **DEM** radio button.

3. Click the dropdown arrow and select Find DEM from the list.

4. In the Add DEM File Name dialog, navigate to /examples/orthobase/spot and select the DEM **palm_springs_dem.img.**

5. Click **OK** in the File Selector.

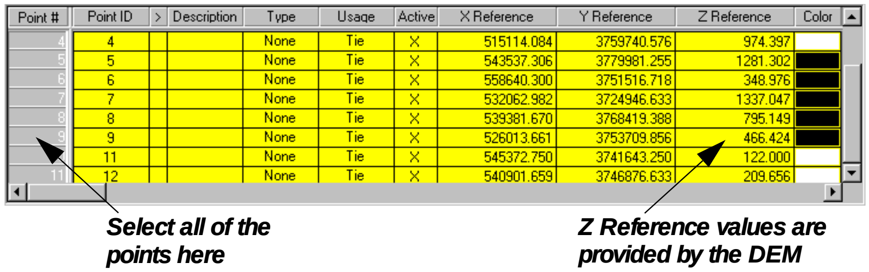
   The DEM file you selected is shown in the **DEM** section of the Vertical Reference Source dialog.

6. Click **OK** in the Vertical Reference Source dialog.

7. Right-click in the **Point #** column of the reference CellArray to access the **Row Selection** menu and select **Select All.**

8. Click on the Update Z Values on Selected Points icon .

   The Z Values of all the reference points are updated in the reference CellArray based on the values in the DEM you selected, **palm_springs_dem.**



Point #	Point ID	>	Description	Type	Usage	Active	X Reference	Y Reference	Z Reference	Color
4	4			None	Tie	X	515114.084	3759740.576	974.397	
5	5			None	Tie	X	543537.306	3779981.255	1281.302	
6	6			None	Tie	X	558640.300	3751516.718	348.976	
7	7			None	Tie	X	532062.982	3724946.633	1337.047	
8	8			None	Tie	X	539381.670	3768419.388	795.149	
9	9			None	Tie	X	526013.661	3753709.856	466.424	
[illegible]	11			None	Tie	X	545372.750	3741643.250	122.000	
11	12			None	Tie	X	540901.659	3746876.633	209.656	

9. Right-click in the **Point #** column and choose **Select None.**

Another function of LPS is the automatic Z value update. Before you even begin choosing control points, you can set a vertical reference source, then click the Automatic Z Value icon in the Point Measurement tool palette. The icon then changes to , indicating that the Z value is updated automatically each time you choose a point.

Set Type and Usage

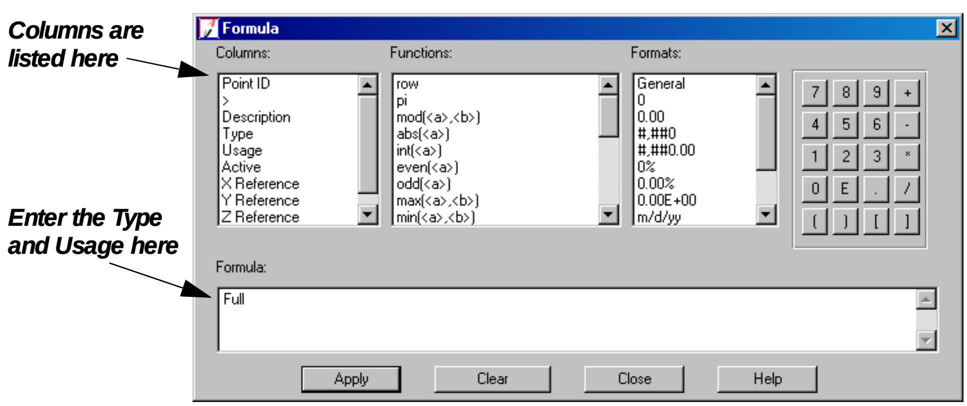
Up until this point, the **Type** and **Usage** for each of the control points has been set to **None** and **Tie,** respectively. Follow the next series of steps for a quick application of new classes of **Type** and **Usage** with ERDAS IMAGINE's Formula dialog.

For more information about the Formula dialog, see the On-Line Help.

1. Left-click the title bar of the column titled **Type** to select all of the column, which is highlighted in blue.

2. Right-click on **Type** to access the **Column Options** menu, then select **Formula.**

   The Formula dialog opens.



3. In the **Formula** section of the Formula dialog, type **Full.**

4. Click **Apply** in the Formula dialog.

   All of the points' **Type** are revised to indicate **Full** (X, Y, and Z coordinates).

5. Left-click in the column titled **Usage** to select all of the column, which is highlighted in blue.

6. In the **Formula** section of the Formula dialog, type **Control** (remove **Full**).

7. Click **Apply** in the Formula dialog.

   All of the points' **Usage** are revised to indicate **Control.**

8. Click **Close** in the Formula dialog.

9. Right-click in the **Usage** column to access the **Column Options** menu, then choose **Select None.**

   When you are finished, your CellArray should look like the following (with the exception of the **Color** column).

Point #	Point ID	>	Description	Type	Usage	Active	X Reference	Y Reference	Z Reference	Color
4	4			Full	Control	X	515114.084	3759740.576	974.397	
5	5			Full	Control	X	543537.306	3779981.255	1281.302	
6	6			Full	Control	X	558640.300	3751516.718	348.976	
7	7			Full	Control	X	532062.982	3724946.633	1337.047	
8	8			Full	Control	X	539381.670	3768419.388	795.149	
9	9			Full	Control	X	526013.661	3753709.856	466.424	
10	11			Full	Control	X	545372.750	3741643.250	122.000	
11	12			Full	Control	X	540901.659	3746876.633	209.656	

All of the Point IDs have the correct Type and Usage description now

Another way of assigning the same **Type** *and* **Usage** *designations to all points is to right-click in the* **Point #** *column and choose* **Select All.** *Then, click the title of the* **Type** *or* **Usage** *column. Right-click, then select the designation you want for the points.*

Save the Block File

At this time, you should save the block file to preserve your work.

1. In the Point Measurement tool, click the **Save** button.

2. Click the **Close** button on the Point Measurement tool.

   You are returned to the LPS Project Manager.

Add a Second Image to the Block

Now that you have successfully collected reference coordinates in the reference images, **xs_ortho** and **NAPP_2m_ortho,** and file coordinates in the first block file, **spot_pan,** you can progress to the second image in the block, **spot_panb.**

1. Select **Edit | Add Frame** from the LPS menu bar, or click the Add Frame icon .

   The Image File Name dialog opens.

2. Navigate to /examples/orthobase/spot, select **spot_panB.img,** then click **OK.**

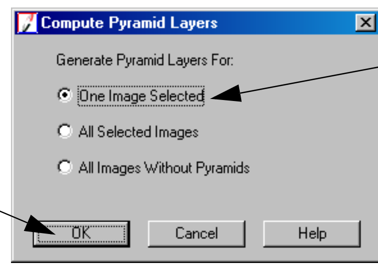
   The image is loaded into the LPS Project Manager and displays in the CellArray.

Generate Pyramid Layers

Like the first image in the block file, you are going to create pyramid layers for **spot_panb** to make it display more quickly in the views.

1. Click **Row #2** to highlight the row corresponding to **Image ID 2**, **spot_panb.**
2. Click in the red column labeled **Pyr.** for the **spot_panb** image.

   The Compute Pyramid Layers dialog displays.



3. Click the **One Image Selected** radio button.
4. Click **OK** in the Compute Pyramid Layers dialog.

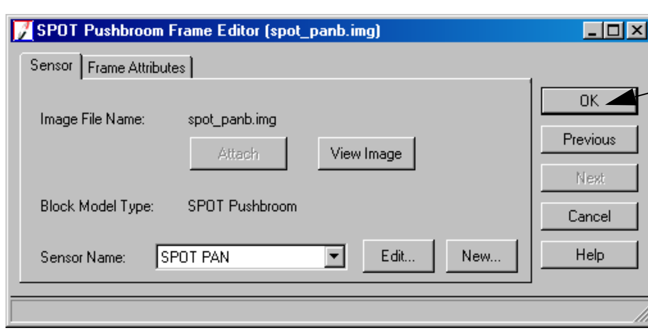
   A status bar displays at the bottom of the LPS Project Manager, indicating the progress of pyramid layer creation. When complete, the **Pyr.** column for **spot_panb** is green, indicating that pyramid layers are present for this image.

Define the Sensor Model

Next, you are going to provide LPS the parameters of the sensor, in this case a SPOT pushbroom sensor, that supplied the image you are working with.

1. Select **Edit | Frame Editor** from the LPS Project Manager menu bar, or click the Frame Properties icon  .

   The SPOT Pushbroom Frame Editor dialog opens, displaying information about the currently selected image (**>**) listed in the LPS CellArray, **spot_panb.**



2. Click **OK** in the SPOT Pushbroom Frame Editor to accept the parameters.

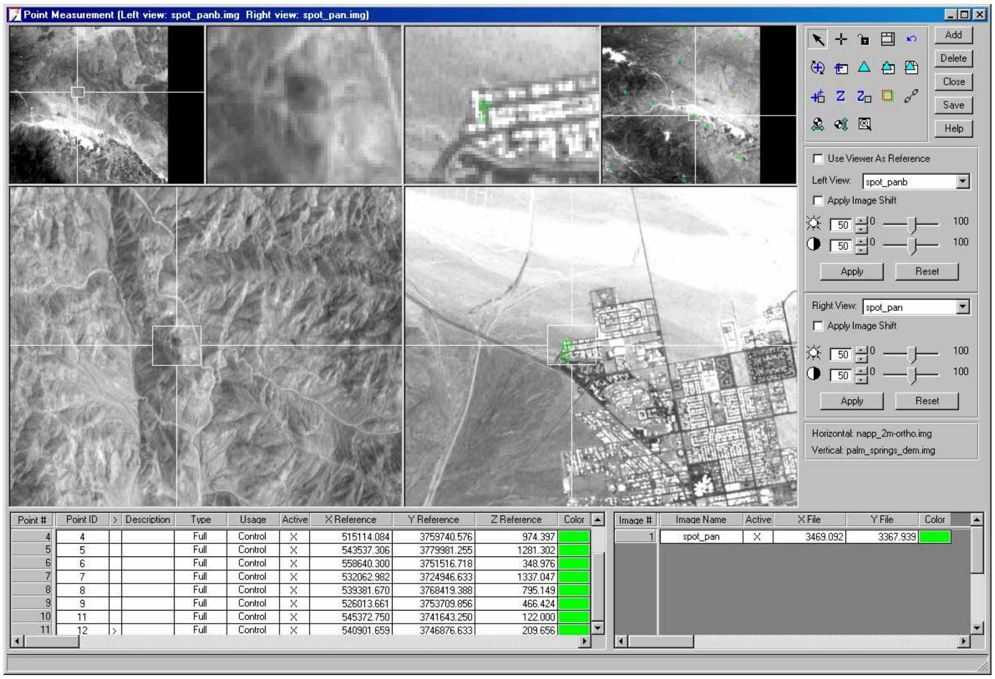
   The **Int.** column in the LPS Project Manager CellArray becomes green. Remember, the header file of the image contains the necessary orientation information.

Start the Point Measurement Tool

Now, you are going to open the Point Measurement tool so that you can locate the points you collected in the first image in the block, **spot_pan,** in the second image, **spot_panb.**

1. In the LPS Project Manager, click the Point Measurement icon  .

   The Point Measurement tool opens, displaying views, a Point Measurement tool palette, and two CellArrays: one for recording reference coordinates, and one for recording file coordinates. The image you are going to collect points in, **spot_panb,** is in the **Right View;** the image **spot_pan** is in the **Left View.**



Use the locations of the points in spot_pan to place the same points in spot_panb

Collect Ground Control Points

Collect GCPs in **spot_panb** based on those you have already collected in **spot_pan.** In this portion of the tour guide, you are provided **X File** and **Y File** coordinates to speed the GCP collection process. However, if you would rather visually select the GCPs in **spot_panb,** we encourage you to do so.

Collect Point ID 1

1. In the reference CellArray, click on **Point #1** to highlight the row.

   The image **spot_pan** automatically changes position in the **Left View** to show **Point ID 1.**

2. Move the Link Cursor in the views displaying **spot_panb** until you can see the location of **Point ID 1.**

3. Click the Create Point icon in the Point Measurement tool palette.

4. Click the approximate point in the Detail View of **spot_panb,** displayed in the **Right View.**

   A point is placed in the Detail View and labeled **1.**

5. Check your results against the following table. If your results are not within two pixels, type the **X File** and **Y File** coordinates for the point in **spot_panb** into the file CellArray, then press Enter on your keyboard. The point changes location accordingly.

Table 6-23: PID 1 File Coordinates

Image Name	X File	Y File
spot_panb	2857.270	753.852

Make sure you enter **X File** *and* **Y File** *coordinates on the appropriate row. The row corresponding to* **spot_panb** *is the second row in the file CellArray.*

Collect Point ID 2

1. In the reference CellArray, click on **Point #2** to highlight the row.

2. Move the Link Cursor as necessary in the views displaying **spot_panb.**

3. Click the Create Point icon in the Point Measurement tool palette.

4. Click the approximate point in the Detail View of **spot_panb.**

5. Check your results against the following table. If your results are not within two pixels, type the **X File** and **Y File** coordinates for the point in **spot_panb** into the file CellArray, then press Enter on your keyboard. The point changes location accordingly.

Table 6-24: PID 2 File Coordinates

Image Name	X File	Y File
spot_panb	3003.782	5387.892

Next, you collect **Point ID 5** in **spot_panb. Point ID**s **3** and **4** are not located on **spot_panb.**

Collect Point ID 5

1. In the reference CellArray, click on **Point #5** to highlight the row.

2. Move the Link Cursor as necessary in the views displaying **spot_panb.**

3. Click the Create Point icon in the Point Measurement tool palette.

4. Click the approximate point in the Detail View of **spot_panb.**

5. Check your results against the following table. If your results are not within two pixels, type the **X File** and **Y File** coordinates for the point in **spot_panb** into the file CellArray, then press Enter on your keyboard. The point changes location accordingly.

Table 6-25: PID 5 File Coordinates

Image Name	X File	Y File
spot_panb	1022.701	644.456

Collect Point ID 6

1. In the reference CellArray, click on **Point #6** to highlight the row.

   Note that, because the Automatic (x, y) Drive function is still enabled, LPS locates the position of **Point ID 6** for you. This occurs after three points (e.g., **1, 2,** and **5**) have already been identified in the images.

2. Click the Create Point icon in the Point Measurement tool palette.

3. Click the approximate point in the Detail View of **spot_panb.**

4. Check your results against the following table. If your results are not within two pixels, type the **X File** and **Y File** coordinates for the point in **spot_panb** into the file CellArray, then press Enter on your keyboard. The point changes location accordingly.

Table 6-26: PID 6 File Coordinates

Image Name	X File	Y File
spot_panb	2736.125	3070.227

Next, you are going to collect **Point ID 8** in **spot_panb. Point ID 7** is not located in **spot_panb.**

Collect Point ID 8

1. In the reference CellArray, click on **Point #8** to highlight the row.

2. Click the Create Point icon in the Point Measurement tool palette.

3. Click the approximate point in the Detail View of **spot_panb.**

4. Check your results against the following table. If your results are not within two pixels, type the **X File** and **Y File** coordinates for the point in **spot_panb** into the file CellArray, then press Enter on your keyboard. The point changes location accordingly.

Table 6-27: PID 8 File Coordinates

Image Name	X File	Y File
spot_panb	937.482	1862.696

Collect Point ID 9

1. In the reference CellArray, click on **Point #9** to highlight the row.
2. Click the Create Point icon in the Point Measurement tool palette.
3. Click the approximate point in the Detail View of **spot_panb.**
4. Check your results against the following table. If your results are not within two pixels, type the **X File** and **Y File** coordinates for the point in **spot_panb** into the file CellArray, then press Enter on your keyboard. The point changes location accordingly.

Table 6-28: PID 9 File Coordinates

Image Name	X File	Y File
spot_panb	221.445	3594.113

Next, you are going to collect **Point ID 12** in **spot_panb.**

Collect Point ID 12

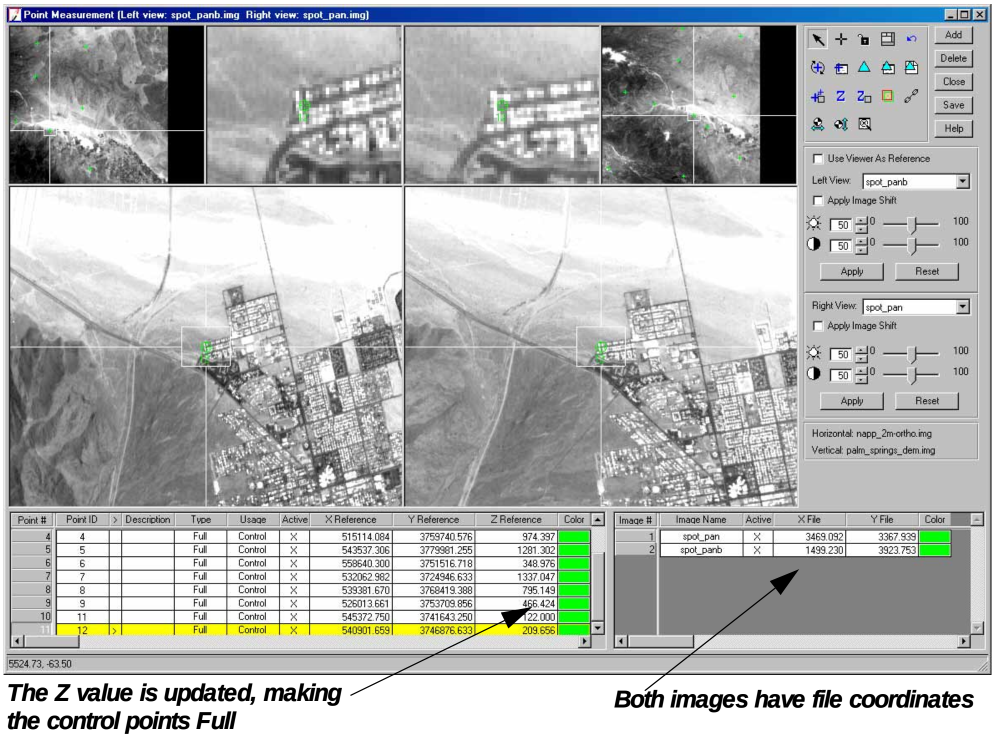
1. In the reference CellArray, click on **Point #11,** which corresponds to **Point ID 12,** to highlight the row.
2. Click the Create Point icon in the Point Measurement tool palette.
3. Click the approximate point in the Detail View of **spot_panb.**
4. Check your results against the following table. If your results are not within two pixels, type the **X File** and **Y File** coordinates for the point in **spot_panb** into the file CellArray, then press Enter on your keyboard. The point changes location accordingly.

Table 6-29: PID 12 File Coordinates

Image Name	X File	Y File
spot_panb	1499.230	3923.753

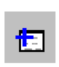
5. Right-click in the **Point #** column and choose **Select None.**

6. In the Point Measurement tool, click the **Save** button.

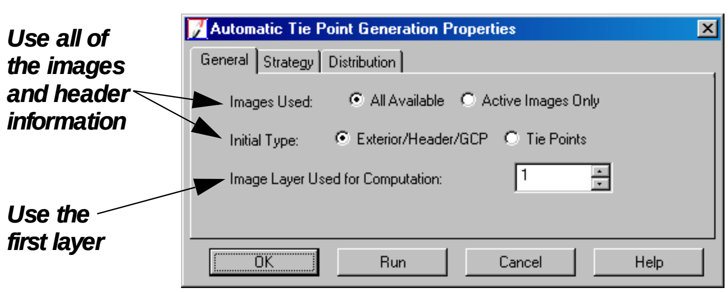


Perform Automatic Tie Point Collection

The tie point collection process measures the image coordinate positions of ground points appearing on the overlapping area of the two SPOT images: **spot_pan** and **spot_panb.**

1. In the Point Measurement tool palette, click the Automatic Tie Point Collection Properties icon  .

   The Automatic Tie Point Generation Properties dialog opens on the **General** tab.

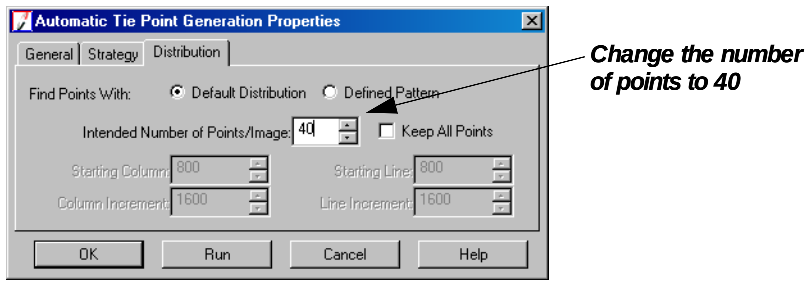


2. Check to confirm that the **Images Used** radio button is set to **All Available.**

3. Check to confirm that the **Initial Type** radio button is set to **Exterior/Header/GCP.**

4. Check to confirm that the **Image Layer Used for Computation** is set to **1.**

5. Click the **Distribution** tab in the Automatic Tie Point Generation Properties dialog.



6. Click in the **Intended Number of Points Per Image** field and type **40,** then press Enter.

7. Check to confirm that the **Keep All Points** checkbox is not checked.

   By not selecting this option, poor tie points are discarded.

8. Click the **Run** button in the Automatic Tie Point Generation Properties dialog.

   LPS starts the automatic tie point generation process, indicated by a progress meter at the bottom of the Point Measurement tool, and displays the tie points in the Point Measurement views when complete. The tie points have the **Type** designation **None,** and the **Usage** designation **Tie.** They are added to the reference CellArray with their corresponding **X File** and **Y File** values in the file CellArray.

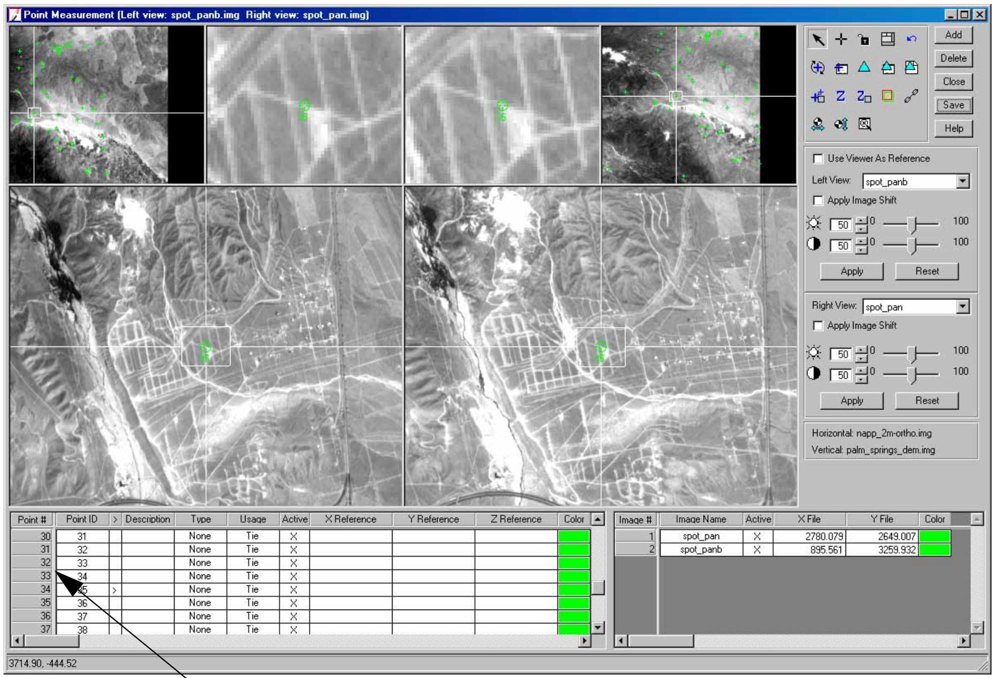
Check Tie Point Accuracy

You should always check a few of the tie points to ensure accuracy. If a point is not as accurate as you would like, you can adjust it using the Select Point tool. Alternately, you can delete it by selecting the row in the reference CellArray and clicking the **Delete** button in the Point Measurement tool. You can also make it inactive by clicking in the **Active** column to remove the **X.**

1. In the reference CellArray, click the scroll bar and scroll to **Point ID 35.**

2. Click in the **>** column to select **Point ID 35.**

   The point displays in the views. This is an acceptable tie point.



Select points to view by highlighting the Point #, or clicking in the > column

3. Click in the **>** column of other **Point ID**s to see where LPS placed tie points.

4. When you are finished, click the **Save** button in the Point Measurement tool.

5. Click the **Close** button to close the Point Measurement tool.

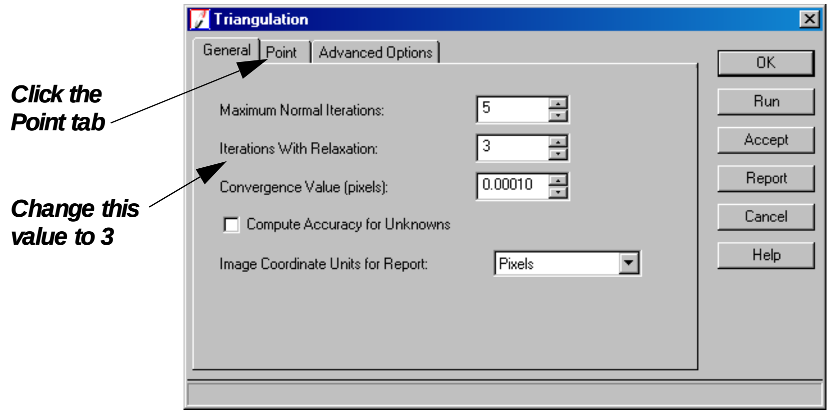
   You are returned to the LPS Project Manager.

Perform Triangulation

Now that you have obtained control and tie points, LPS has all the information it needs to perform triangulation. This step establishes the mathematical relationship between the images that make up the block file, the sensor model, and the ground.

1. From the **Edit** menu of the LPS Project Manager, select **Triangulation Properties.**

   The Triangulation dialog opens.

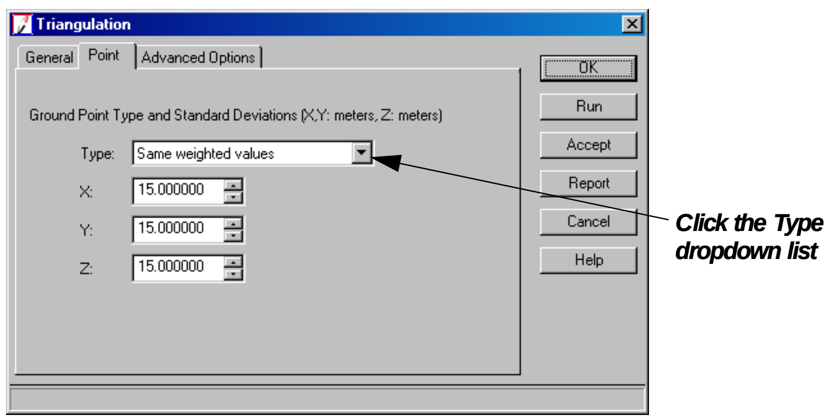


2. Change the **Iterations With Relaxation** value to **3.**

3. Confirm that the **Image Coordinate Units for Report** is set to **Pixels.**

4. Click the **Point** tab in the Triangulation dialog.

   The **Point** options display. These control the GCP parameters.

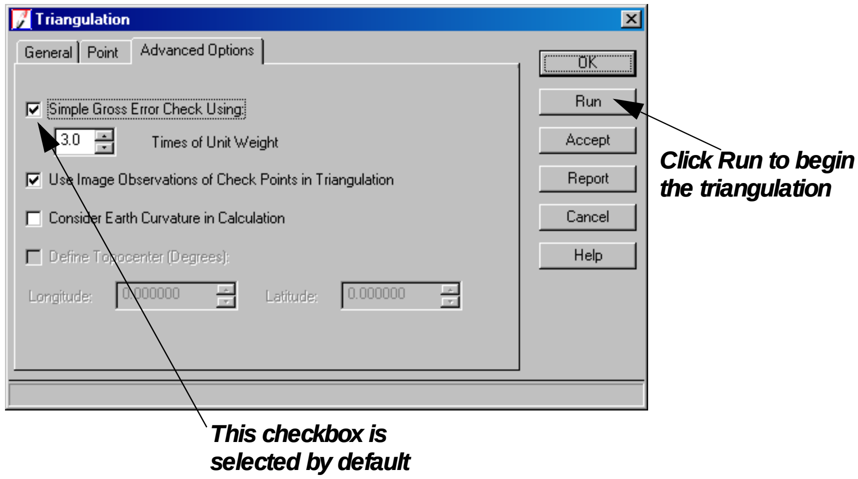


5. In the **Ground Point Type and Standard Deviations** section, click the **Type** dropdown list and select **Same Weighted Values.**

6. Click in the **X, Y,** and **Z** number fields, and change each of the values to **15.**

   The value **15** is used because the resolution of the SPOT image, **xs_spot**, that you used as reference for **Point IDs** **1** through **9** has 20-meter pixels. This value assures that the GCPs are precise to approximately 15 meters.

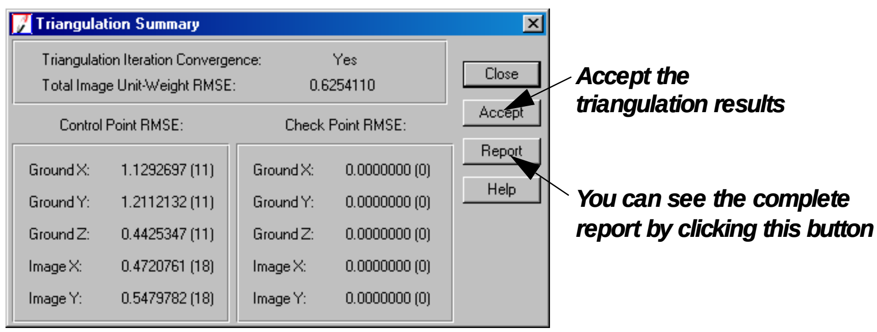
7. Click the **Advanced Options** tab.



8. Confirm that the **Simple Gross Error Check Using** checkbox is enabled. The default value of **3.0 Times of Unit Weight** is acceptable.

9. Click the **Run** button to run the triangulation.

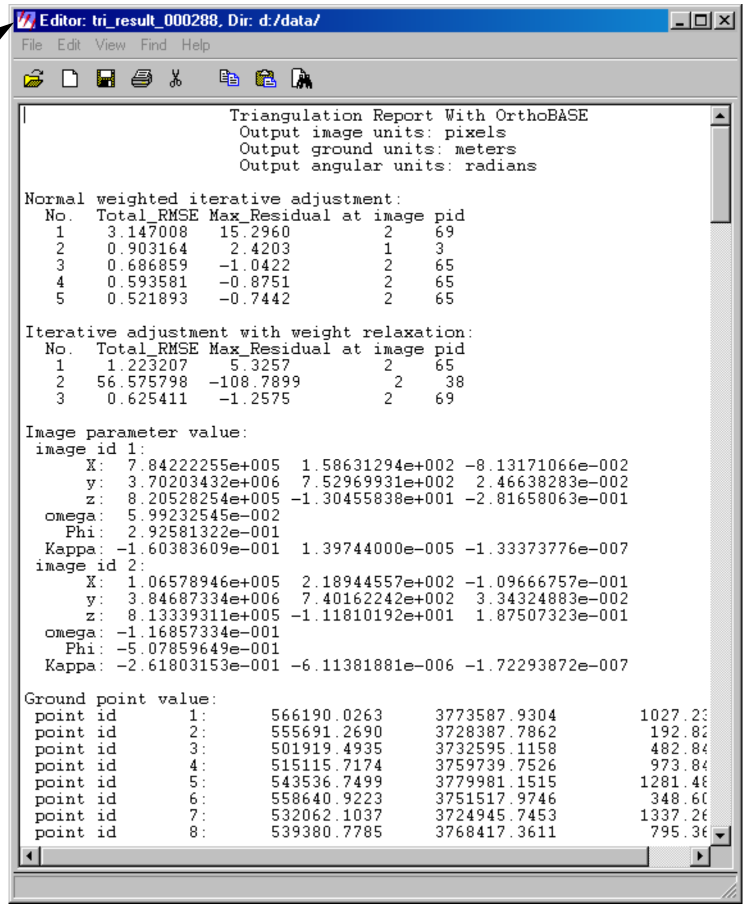
   A Triangulation Summary report opens.



10. In the Triangulation Summary dialog, click the **Report** button.

    The report, Triangulation Report With OrthoBASE, opens in a separate window. You can save this report as you would any text file, then refer to it as needed.

The Triangulation Report displays in a text editor




```
                    Triangulation Report With OrthoBASE
                     Output image units: pixels
                     Output ground units: meters
                     Output angular units: radians

Normal weighted iterative adjustment:
  No.   Total_RMSE Max_Residual at image pid
   1     3.147008    15.2960        2     69
   2     0.903164     2.4203        1     3
   3     0.686859    -1.0422        2     65
   4     0.593581    -0.8751        2     65
   5     0.521893    -0.7442        2     65

Iterative adjustment with weight relaxation:
  No.   Total_RMSE Max_Residual at image pid
   1     1.223207     5.3257        2     65
   2    56.575798  -108.7899         2     38
   3     0.625411    -1.2575        2     69

Image parameter value:
 image id 1:
      X:  7.84222255e+005  1.58631294e+002 -8.13171066e-002
      y:  3.70203432e+006  7.52969931e+002  2.46638283e-002
      z:  8.20528254e+005 -1.30455838e+001 -2.81658063e-001
  omega:  5.99232545e-002
    Phi:  2.92581322e-001
  Kappa: -1.60383609e-001  1.39744000e-005 -1.33373776e-007
 image id 2:
      X:  1.06578946e+005  2.18944557e+002 -1.09666757e-001
      y:  3.84687334e+006  7.40162242e+002  3.34324883e-002
      z:  8.13339311e+005 -1.11810192e+001  1.87507323e-001
  omega: -1.16857334e-001
    Phi: -5.07859649e-001
  Kappa: -2.61803153e-001 -6.11381881e-006 -1.72293872e-007

Ground point value:
 point id        1:      566190.0263     3773587.9304        1027.2
 point id        2:      555691.2690     3728387.7862         192.8
 point id        3:      501919.4935     3732595.1158         482.8
 point id        4:      515115.7174     3759739.7526         973.8
 point id        5:      543536.7499     3779981.1515        1281.4
 point id        6:      558640.9223     3751517.9746         348.6
 point id        7:      532062.1037     3724945.7453        1337.2
 point id        8:      539380.7785     3768417.3611         795.3
```

11. Resize the window and scroll through the report to see the information it contains.

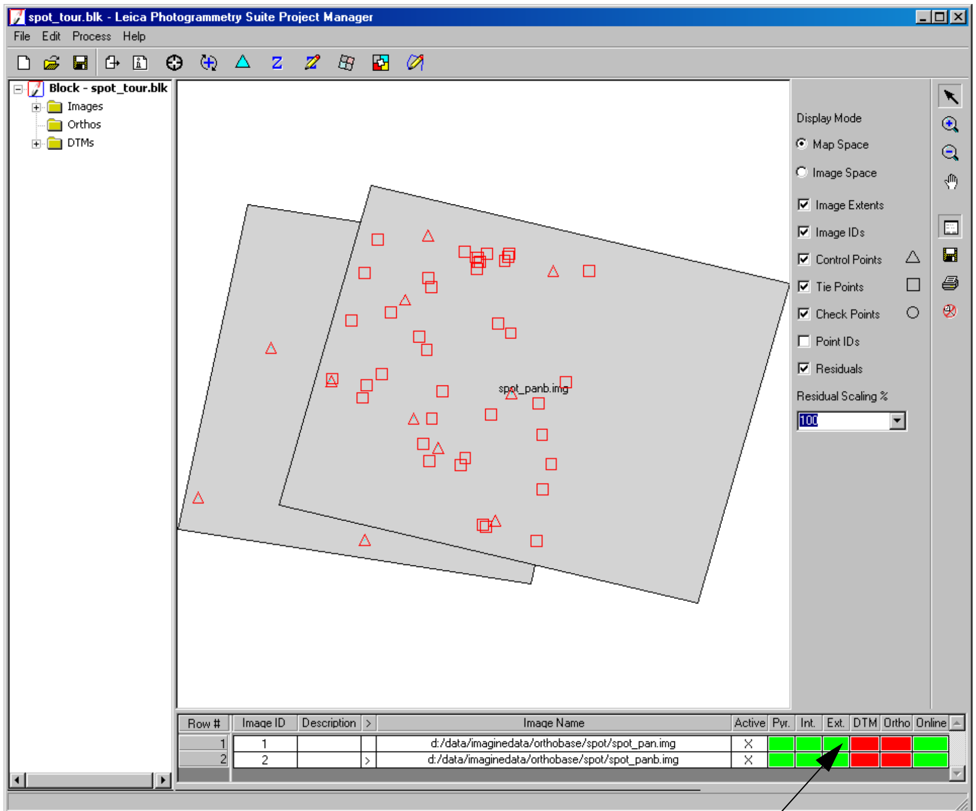
For more information about the Triangulation Report, see Chapter 13 "Block Triangulation".

12. When you are finished viewing the report, select **File | Close.**

13. Click the **Accept** button in the Triangulation Summary dialog to accept the results.

14. Click the **OK** button in the Triangulation dialog.

You are returned to the LPS Project Manager. Notice that the **Ext.** columns in the CellArray are now green, indicating that the exterior orientation information has been supplied.



The Ext. columns are green, indicating the exterior orientation information has been supplied

15. In the LPS Project Manager, click the **File** menu and select **Save.**

Ortho Resample the Imagery

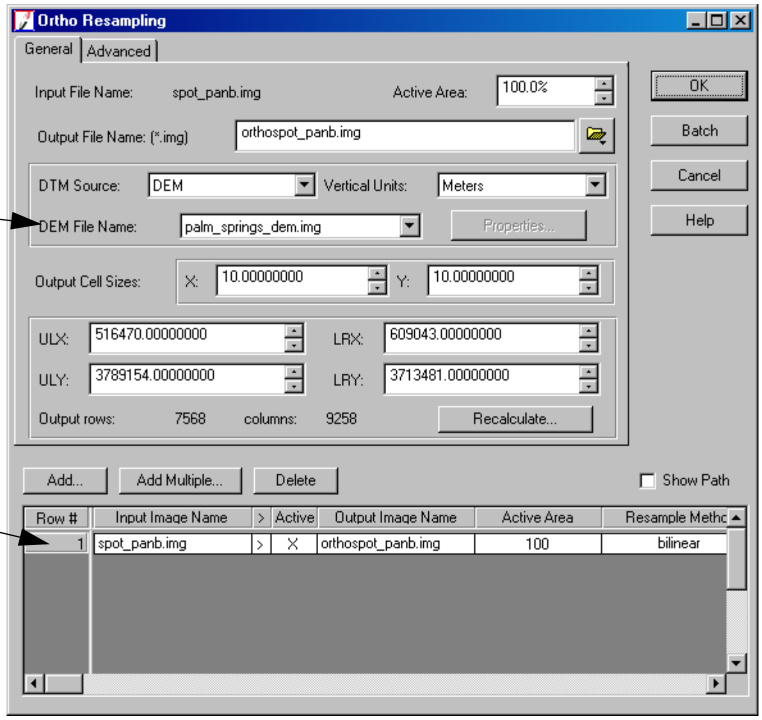
The next step creates orthorectified images wherein relief displacements and geometric errors have been adjusted and accuracy has been improved. The orthorectified images display objects in their real-world X and Y positions.

1. In the LPS Project Manager, click the Ortho Resampling icon  .

The Ortho Resampling dialog opens.

A DEM improves the accuracy of the output orthoimage

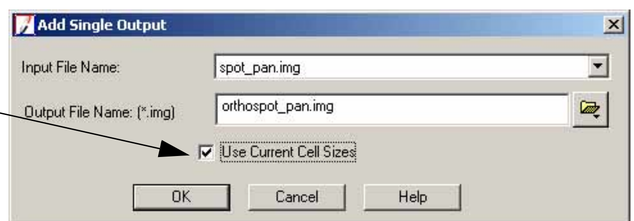
The first image in the block is identified here



1. In the **General** tab, click the **DTM Source** dropdown list and select **DEM.**
2. Click the **DEM File Name** dropdown list, and choose **Find DEM.**
3. If necessary, select the DEM **palm_springs_dem.img** from the /orthobase/spot folder, then click **OK** in the File Selector.
4. Click in the **Output Cell Sizes** fields for both **X** and **Y,** and type **10.0.**
5. Click the **Advanced** tab of the Ortho Resampling dialog.
6. Confirm that the **Resampling Method** is **Bilinear Interpolation.**
7. Click the **Add** button on the **Advanced** tab.

   The Add Single Output dialog opens.

Click this checkbox so that the second orthoimage has the same cell size as the first

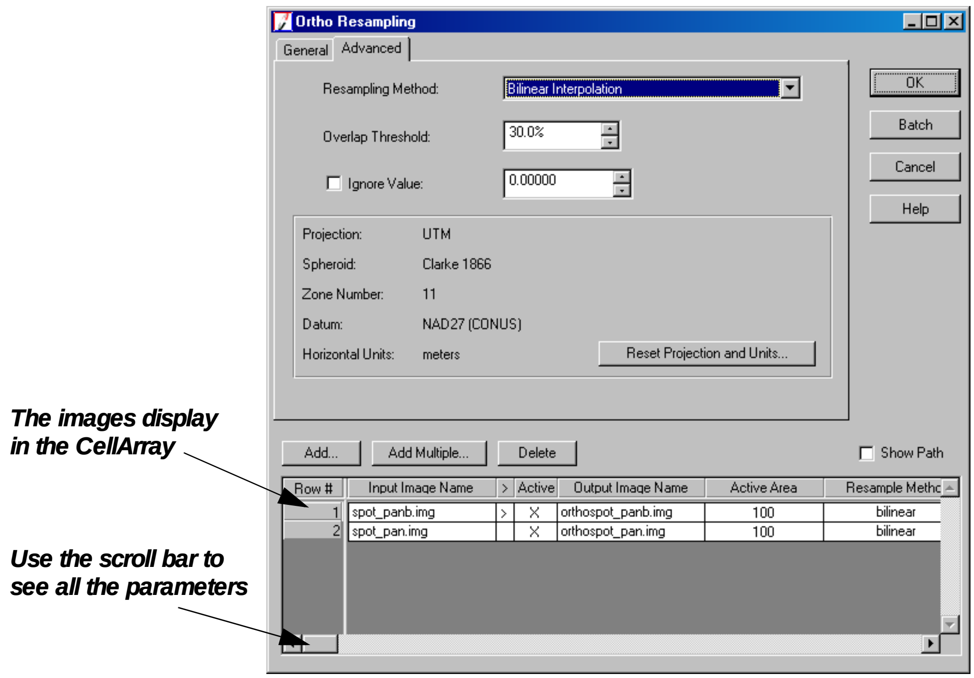


The **Input File Name** identifies the other image in the block file, **spot_pan.img.** It also automatically attaches the prefix **ortho** to the output file.

8. Click the checkbox next to **Use Current Cell Sizes.**

9. Click **OK** in the Add Single Output dialog.

   The second image in the block file, and its corresponding orthoimage, is added to the Ortho Resampling CellArray. It has the same parameters as the first image. You can use the scroll bar at the bottom of the dialog to confirm that all information is correct before proceeding to resampling.



10. Click **OK** in the Ortho Resampling dialog to start the process.

    A Status dialog opens, tracking the progress.

11. Once the status dialog shows that the process is 100% complete, click **OK** in the dialog.

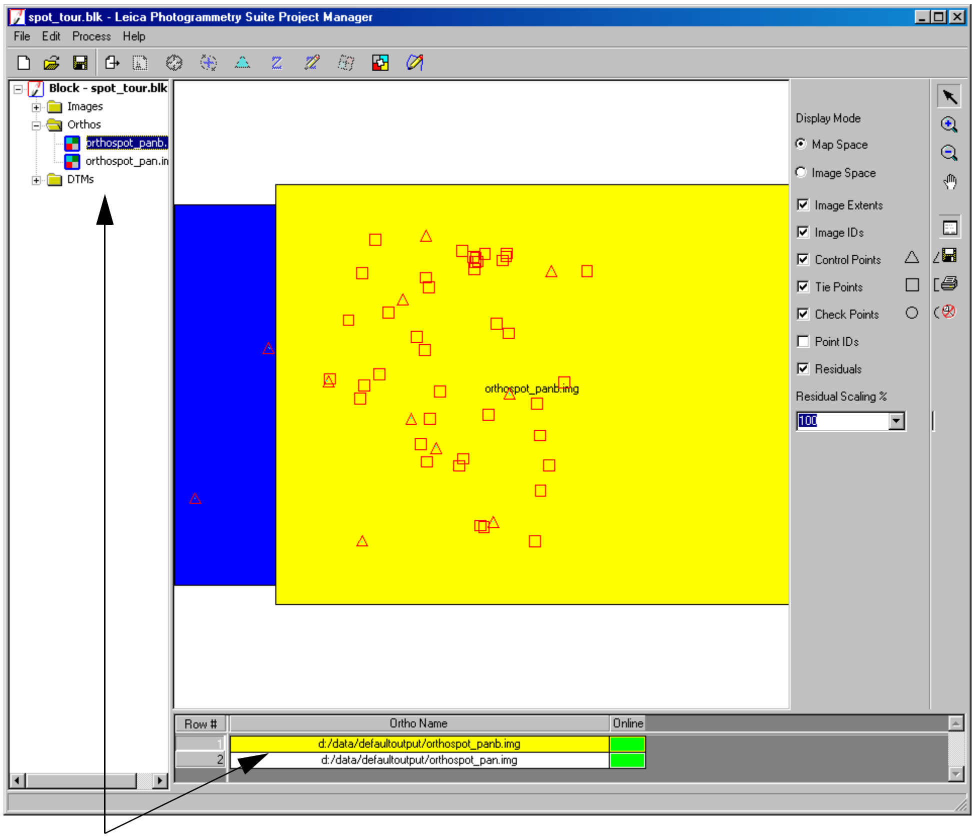
View the Orthoimages

Now you can check how the orthoimages fit together in the LPS Project Graphic Status window and in a Viewer.

Use LPS

1. In the LPS Project Manager, click the plus sign + next to the **Orthos** folder in the Block Project Tree View.

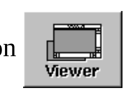
2. Click on one of the orthos in the list to highlight it in the Block Tree View, CellArray, and the Project Graphic Status window.

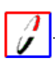


The highlighted ortho is indicated in the Block Project Tree View and the CellArray

To see the actual orthoimage, not just a graphical representation, you can use a Viewer. You can get details about the control and tie points displayed in the Project Graphic Status window by clicking on them with the Selector icon  .

Use a Viewer

1. From the ERDAS IMAGINE toolbar, click the Viewer icon  .



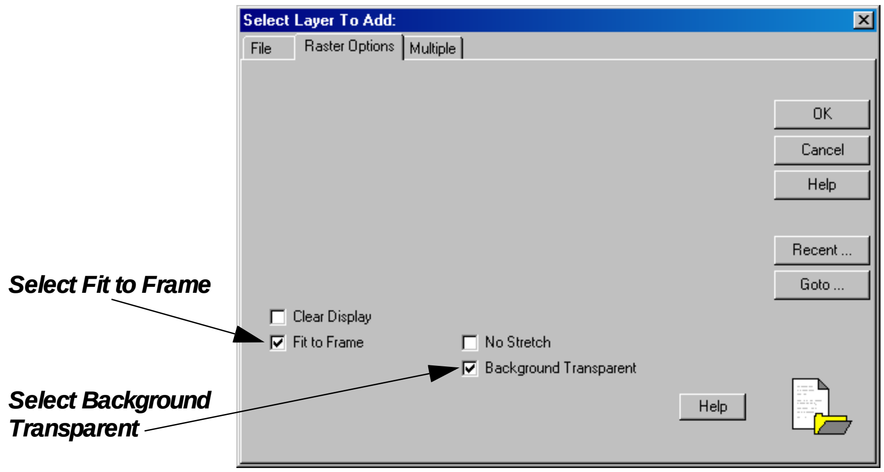
If necessary, select the type of Viewer you want to work with: **Classic Viewer** *or* **Geospatial Light Table.**

A Viewer opens in the workspace.

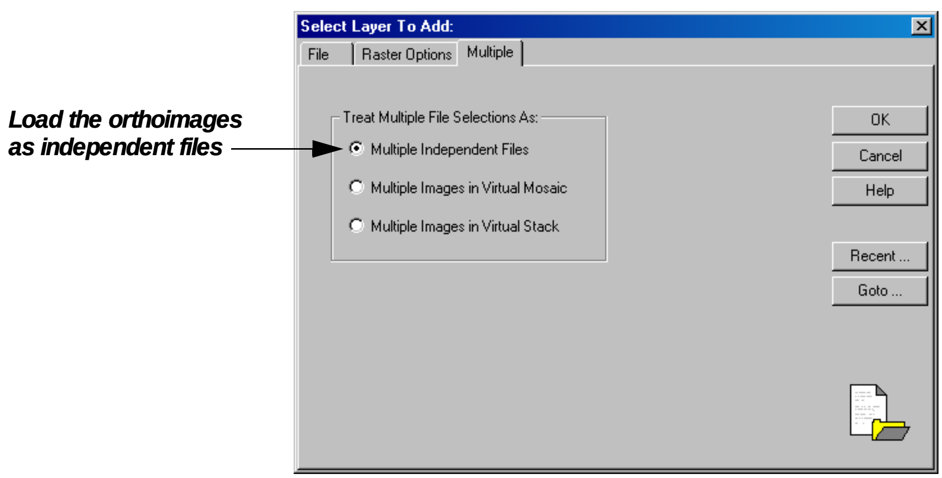
2. Click the Open icon  to access the Select Layer To Add dialog.

3. Navigate to the location in which you saved the orthorectified images.

4. Hold down the Ctrl key and click **orthospot_pan.img** and **orthospot_panb.img.**
5. Click the **Raster Options** tab.

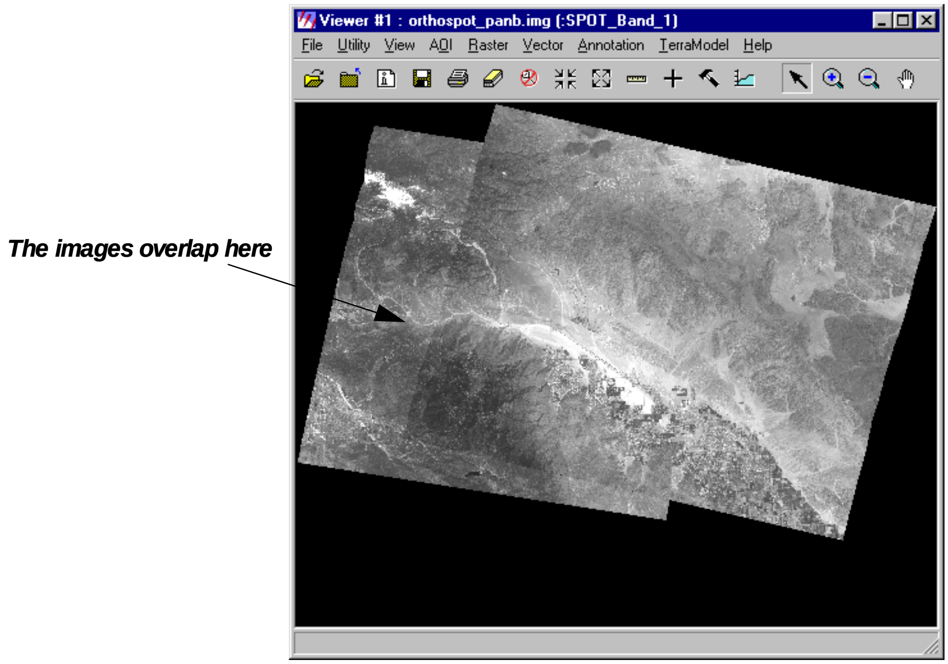


6. Deselect the **Clear Display** checkbox.
7. Click the **Fit to Frame** and **Background Transparent** checkboxes.
8. Click the **Multiple** tab.



9. Make sure that the radio button next to **Multiple Independent Files** is selected.
10. Click **OK** in the Select Layer to Add dialog.

    The overlapped images display in the Viewer.

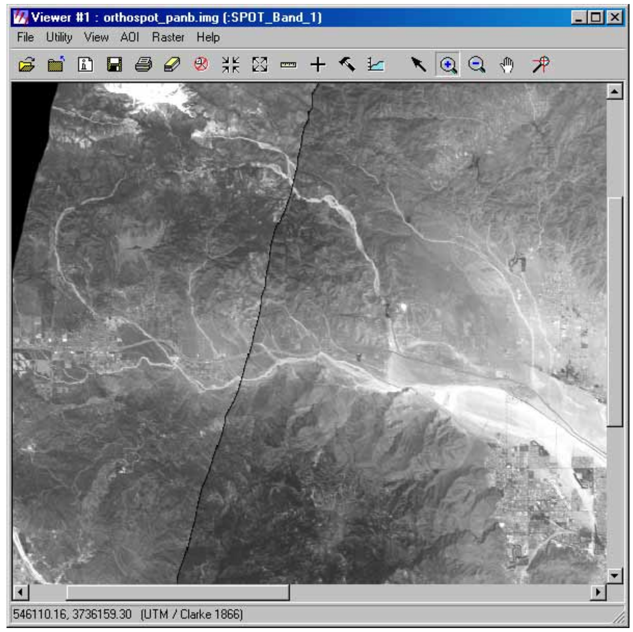


Magnify Areas of Overlap

Now, you can check the areas of overlap to see how well LPS orthorectified the images. Take special note of features such as roads, rivers, and parcels of land.

1. In the Viewer, click the Zoom In icon  .
2. Click on an area in the Viewer where the images obviously overlap.
3. Apply the Zoom In icon as many times as necessary to see the portion of overlap clearly in the Viewer.

   You can see that LPS successfully overlapped the images in the following picture. Geographic features of interest are well matched.



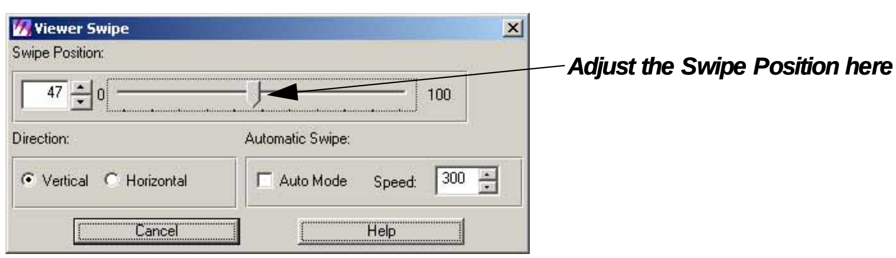
If you wish, you can click the **View** *menu, then select* **Arrange Layers.** *You can change the order of the images' display in the Viewer to see how they look with the Swipe utility.*

Use the Swipe Utility

You can also use the Swipe utility to see how well the images overlap.

1. Click the **Utility** menu on the Viewer menu bar.
2. Choose **Swipe.**

   The Viewer Swipe dialog opens.



3. Right-click in the Viewer to access the **Quick View** menu.
4. Click **Fit Image To Window.**
5. Click the slider bar in the Viewer Swipe dialog and move it to the left and right to see how well the top image, **orthospot_panb.img** overlaps the bottom image, **orthospot_pan.img.**

If you wish, you can click the **View** *menu, then select* **Arrange Layers.** *You can change the order of the images' display in the Viewer to see how they look with the Swipe utility.*

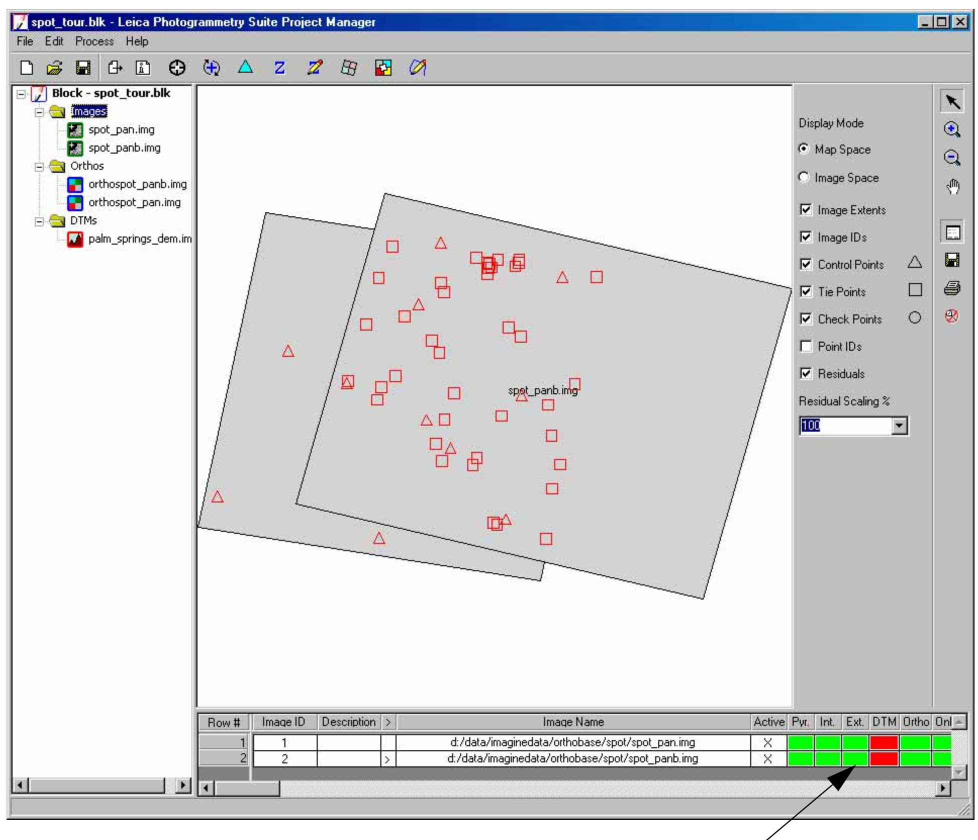
6. When you are finished, click **Cancel** in the Viewer Swipe dialog.

7. When you are finished viewing the images, select **File | Close** from the Viewer menu bar.

Save and Close the Block File

1. In the LPS Project Manager, click the **File** menu, then select **Save.**

   Notice that all of the columns are green (with the exception of the **DTM** column, which is specific to OrthoBASE Pro), indicating that all of the process steps have been executed. You can open the complete block file any time.



Steps have been executed; the block file is complete

2. From the **File** menu, select **Exit.**

3. To close ERDAS IMAGINE, select **Session | Exit IMAGINE.**

Conclusions

As you have learned, you can easily select control points from images outside the block file. Points can be horizontal or vertical and come from many sources, including a reference image.

Next, you can learn about the DTM extraction capability of LPS. It is an automatic terrain extraction program designed to produce DTMs in various formats.

SPOT Example Data

This section describes the data used in this chapter.

Project Location

Palm Springs, California, USA

Imagery

Image 1: spot_pan.img (35.5 MB), SPOT Panchromatic scene with 10-meter ground resolution

Image 2: spot_panB.img (35.5 MB), SPOT Panchromatic scene with 10-meter ground resolution

NOTE: This image is named spot_panb.img (i.e., the "B" becomes lowercase) in the Windows environment.

Image 3: xs_ortho.img (50.4 MB), SPOT orthorectified image with 20-meter ground resolution

Image 4: NAPP_2m-ortho.img (33.2 MB), NAPP orthorectified image with 2-meter ground resolution

NOTE: The xs_ortho.img and NAPP_2m-ortho.img files are used as reference sources for collecting GCPs.

DEM

palm_springs_dem.img with 75-meter ground resolution in X and Y

Projection

UTM

Spheroid

Clarke 1866

Zone Number

11

Datum

NAD27 (CONUS)

Horizontal Units

Meters

Vertical Units

Meters

Sensor Information

spot_pan.img
Side Incidence (degrees) = 16.8
Focal Length = 1082.0 mm
Pixel Size = 0.013 mm
Sensor Columns = 6000

spot_panB.img
Side Incidence (degrees) = -30.0
Focal Length = 1082.0 mm
Pixel Size = 0.013 mm
Sensor Columns = 6000

GCP Map Coordinates

GCPs are accurate to 15.0 meters (standard deviation) in the X, Y, and Z direction. The following table details the positions of the GCPs in map coordinates.

Table 6-30: GCP Map Coordinates

Pt. ID	Map X	Map Y	Elevation
1	566189.190	3773586.979	996.200
2	555690.659	3728387.770	229.080
3	501918.953	3732595.411	484.000
4	515114.084	3759740.576	1022.972
5	543537.306	3779981.255	1318.440
6	558640.300	3751516.718	325.973
7	532062.982	3724946.633	1331.120
8	539381.670	3768419.388	765.880
9	526013.661	3753709.856	427.760
11	545372.750	3741643.250	122.000
12	540901.659	3746876.633	224.000

GCP Pixel Coordinates

The following table details the image coordinate positions of the GCPs in pixels.

Table 6-31: GCP Pixel Coordinates

Control Point	Images	X File	Y File
1	spot_pan	5239.468	337.384
	spot_panB	2857.270	753.852
2	spot_pan	5191.590	4969.546
	spot_panB	3003.782	5387.892
3	spot_pan	230.925	5378.823
4	spot_pan	869.542	2487.996
5	spot_pan	3027.570	51.432
	spot_panB	1022.701	644.456
6	spot_pan	4999.412	2636.848
	spot_panB	2736.125	3070.227
7	spot_pan	3064.254	5673.794
8	spot_pan	2890.880	1258.852
	spot_panB	937.482	1862.696

Table 6-31: GCP Pixel Coordinates (Continued)

Control Point	Images	X File	Y File
9	spot_pan	1978.138	2919.004
	spot_panB	221.445	3594.113
11	spot_pan	3982.969	3817.813
12	spot_pan	3469.092	3367.939
	spot_panB	1499.230	3923.753

Chapter 7

Automated DTM Extraction Tour Guide

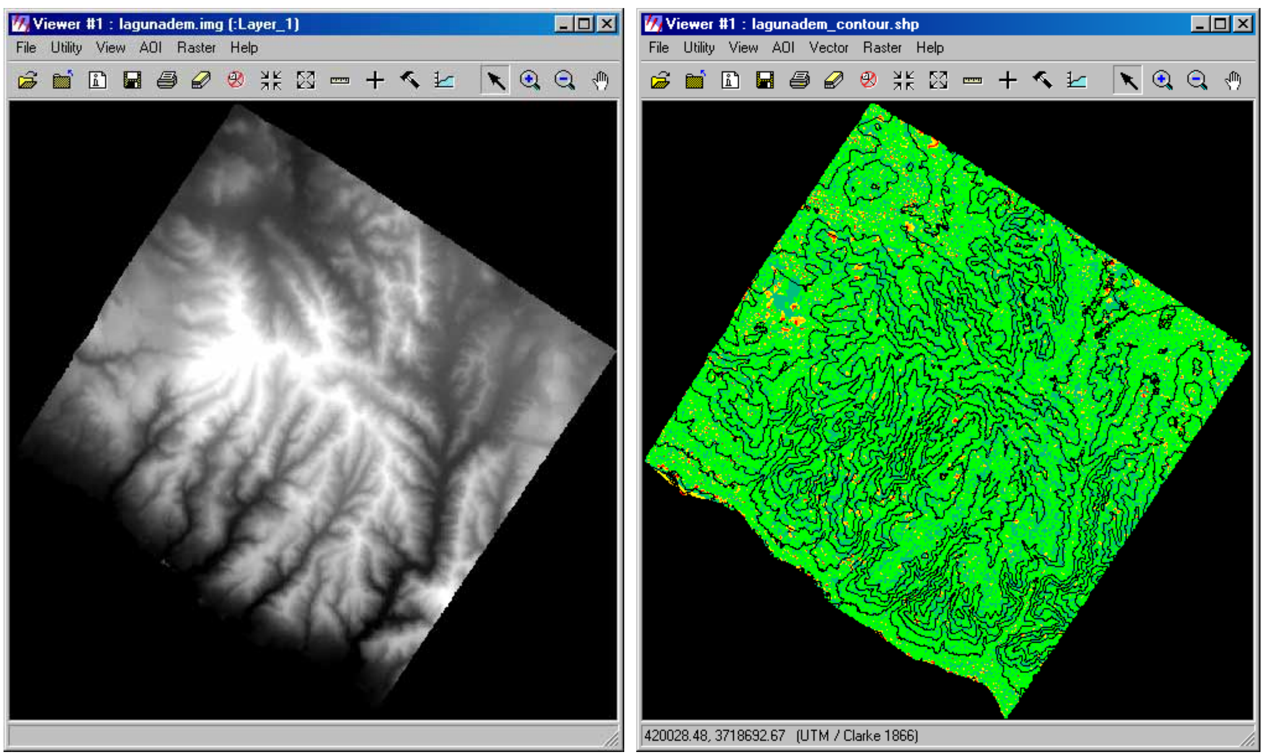
Introduction

Using OrthoBASE Pro, you can create DTMs for use in other applications, including IMAGINE VirtualGIS and Stereo Analyst.

To begin, you must go through the general OrthoBASE process of entering information regarding the camera that captured the imagery and the type of imagery you are using. Then, triangulation must be performed. Once the triangulation process is complete, you can proceed to DTM extraction.

Figure 7-1 shows a DEM produced by OrthoBASE Pro, as well as its corresponding Contour Map which is overlaid on the DTM Point Status image. The DTM Point Status image helps you check the quality of the output DTM that may benefit from post-processing.

Figure 7-1: DEM and Associated Contour Map and DTM Point Status Image



Before You Begin

This tour guide uses frame camera images of Laguna Beach, California. They are 1:40,000 scale photographs, scanned at 50 microns (equivalent to 508 dots per inch), which results in a ground resolution of approximately 2 meters.

For information about setting up a block with frame camera images, see Chapter 4 "Frame Camera Tour Guide".

Approximate completion time for this tour guide is 1 hour.

In this tour guide, you are going to perform the following basic steps:

- open an existing block file
- check the automatically extracted tie points in the Point Measurement tool
- set DTM extraction options
- edit the General tab contents
- view and manipulate images in the Image Pair tab
- edit the Area Selection tab contents
- edit the Accuracy tab contents
- extract and view the DTM
- view the output Contour Map
- view the output DTM Point Status image
- save the block file
- check the DTM Extraction Report

You can also see other types of output DTMs at the end of this tour guide.

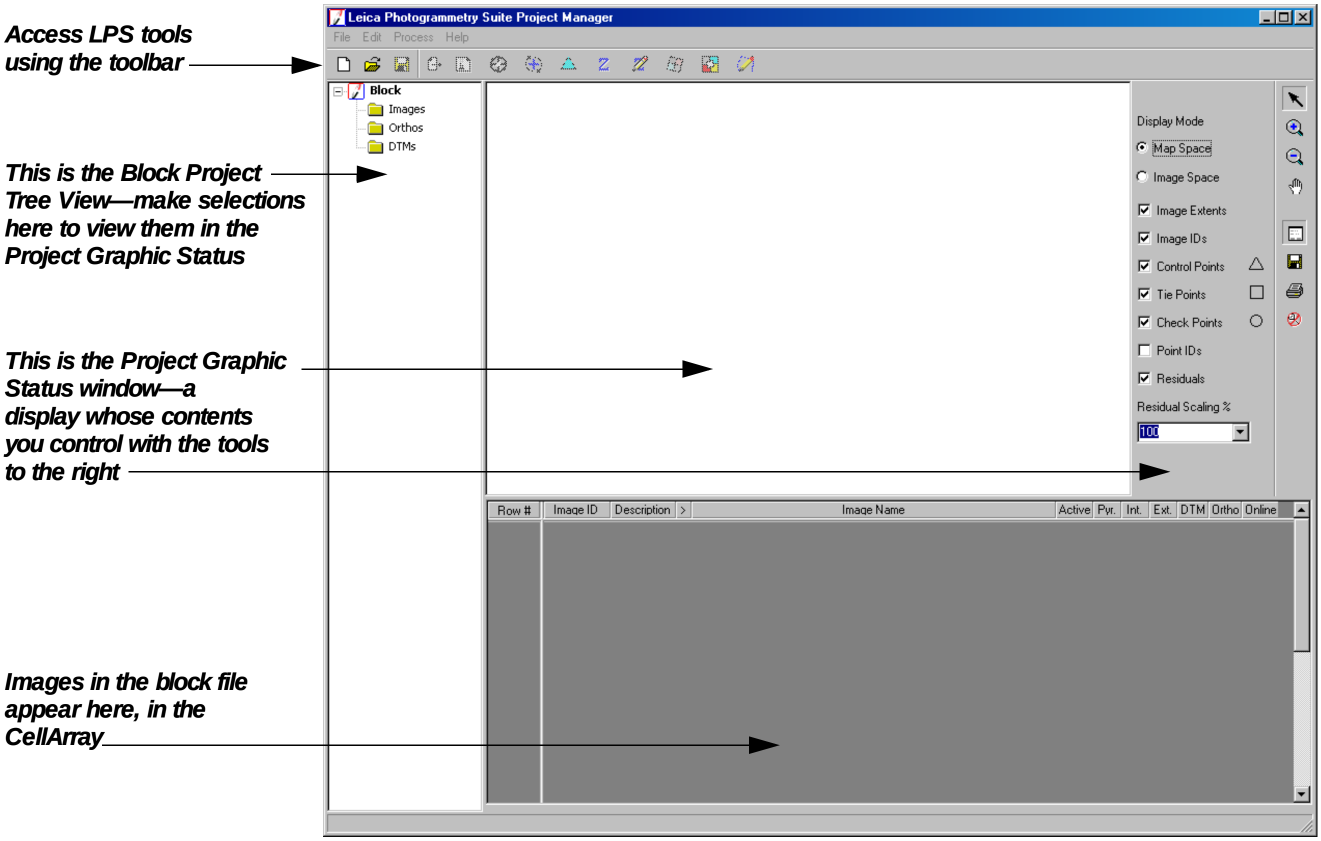
Open a Block File

For this tour guide, you are provided with a block file that is complete with the exception of the DTM extraction and generation of orthoimages.

1. Start the Leica Photogrammetry Suite (LPS).
2. Click the LPS icon 

on the ERDAS IMAGINE icon panel.

The LPS Project Manager opens.



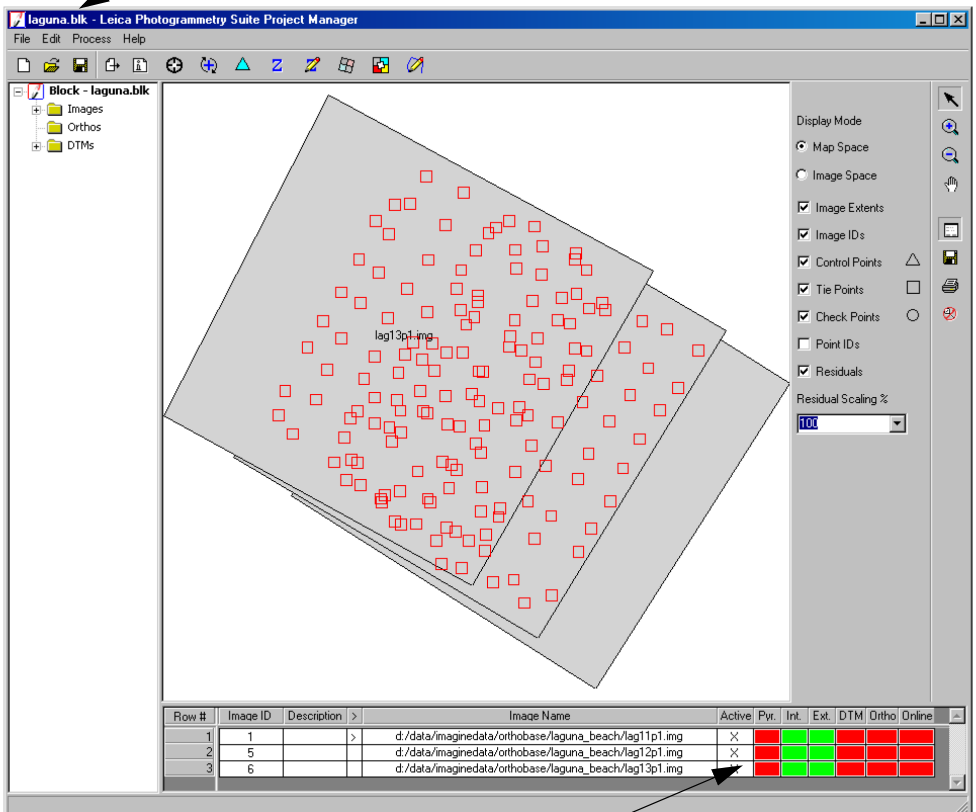
3. Click the Open File icon  .

4. Navigate to /examples/orthobase/laguna_beach and select **laguna.blk.**

5. Click **OK** in the File Selector.

   The Project Graphic Status window and CellArray update to show the files in the block. You can resize the elements of this dialog to meet your needs.

You save laguna.blk as my_laguna.blk



Pyramid layers do not yet exist—indicated by the red cells

Copy the Block File

To preserve the original block file, you are going to make a copy of it to use in this tour guide.

1. From the **File** menu, select **Save As.**
2. In the File Selector, navigate to a folder where you have write permission.
3. Confirm that the **Files of type** field displays **Block File.**
4. Type the name **my_laguna,** then press Enter. The *.blk extension is added automatically.
5. Click **OK** in the File Selector.

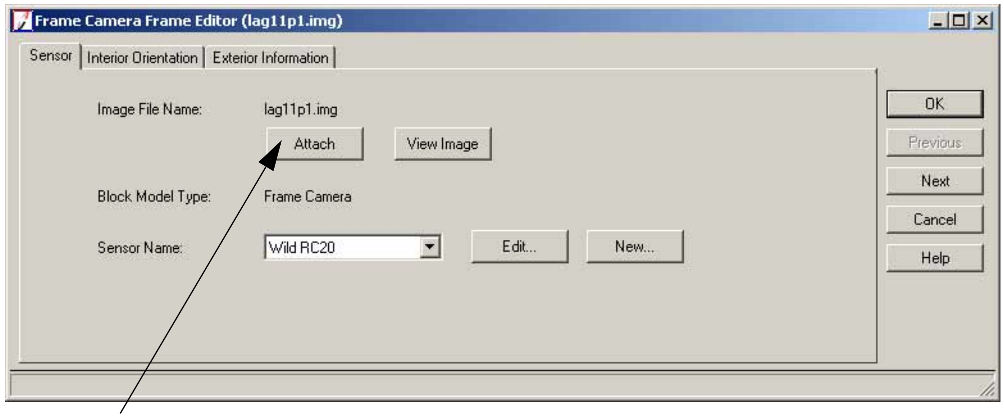
   Notice that the title bar of the LPS Project Manager and the title in the Block Project Tree View reflect the name change, now you are working with **my_laguna.blk.**

Attach Images

Next, you need to attach the images to the block file.

1. Click the Frame Properties icon  .

   The Frame Camera Frame Editor dialog opens, displaying details for the first image in the block file, **lag11p1.img.**



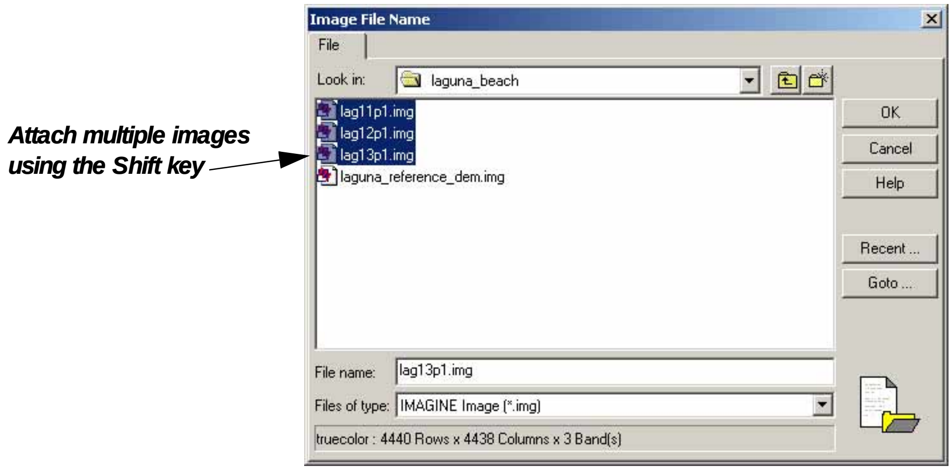
Use Attach to attach images to the block file

2. Click the **Attach** button to open the Image File Name dialog.

3. Navigate to examples/orthobase/laguna_beach and.select the first file, **lag11p1.img.**

Select the first image, then hold the Shift key and select the last

4. Hold the Shift key on the keyboard, then click the last *p1.img file, **lag13p1.img.**

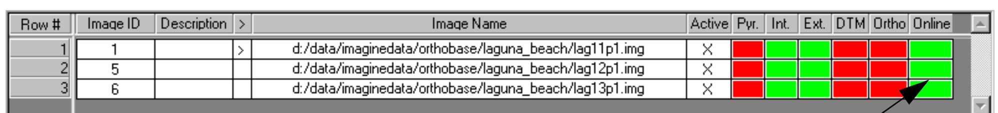


5. Click **OK** in the Image File Name dialog.

6. In the Frame Camera Frame Editor dialog, click the **Next** button to confirm that both **lag12p1.img** and **lag13p1.img** are attached as well (the **Attach** button is greyed out).

7. Click **OK** in the Frame Camera Frame Editor dialog.

   The CellArray updates: the images are all now online.



The column is green, indicating that the images are online

Compute Pyramid Layers

As you can see in the CellArray, the pyramid layers for the images in the block file have not yet been generated. This is to conserve space in /examples/orthobase/laguna_beach. OrthoBASE and OrthoBASE Pro have an easy method for you to calculate OrthoBASE pyramid layers.

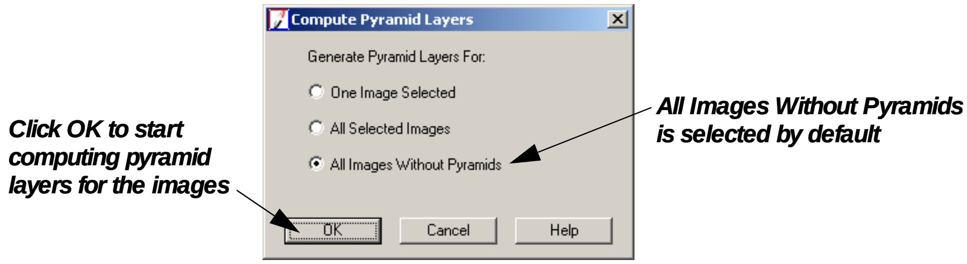
Pyramid layers are used to optimize image display and are also used during the automatic tie point collection process and the DTM extraction process. Note that the pyramid layers used by OrthoBASE are not the same as those used by ERDAS IMAGINE. You must generate OrthoBASE pyramid layers.

For more information, see "OrthoBASE Pyramid Layers".

1. Click the **Edit** menu, then choose the **Compute Pyramid Layers** option.

You can also click in the **Pyr.** *column to access the dialog.*

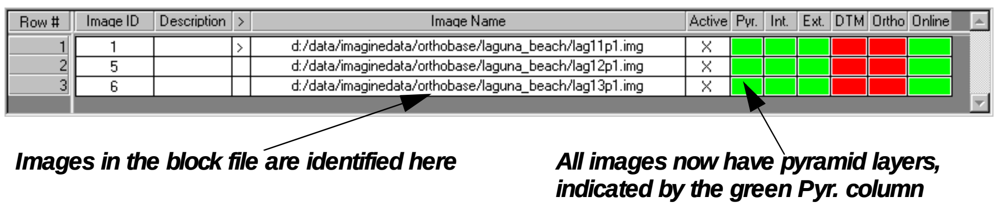
The Compute Pyramid Layers dialog opens.



2. In the Compute Pyramid Layers dialog, confirm that the **All Images Without Pyramids** radio button is selected.

3. Click **OK** in the Compute Pyramid Layers dialog.

   A progress meter displays at the bottom of the LPS Project Manager as pyramid layers are created. When complete, the images' cells corresponding to the **Pyr.** column are all green.



The color of the columns in the dialog is controlled by preferences, **Status On Color** *and* **Status Off Color,** *in the* **LPS** *category of the Preference Editor.*

4. Click the Save icon to save the pyramid layers you have just generated with the block file.

Check the Point Measurement Tool

One of the interfaces you work with in the DTM extraction process, the **Accuracy** tab of the DTM Extraction Properties dialog, is linked to the points displayed in the Point Measurement tool. The tie points automatically extracted by OrthoBASE can be used as 3D reference points to compute the accuracy of the output DTM. By checking the Point Measurement tool before you proceed with DTM extraction, you can gain familiarity with points in the block, and decide how you can use them in DTM extraction.

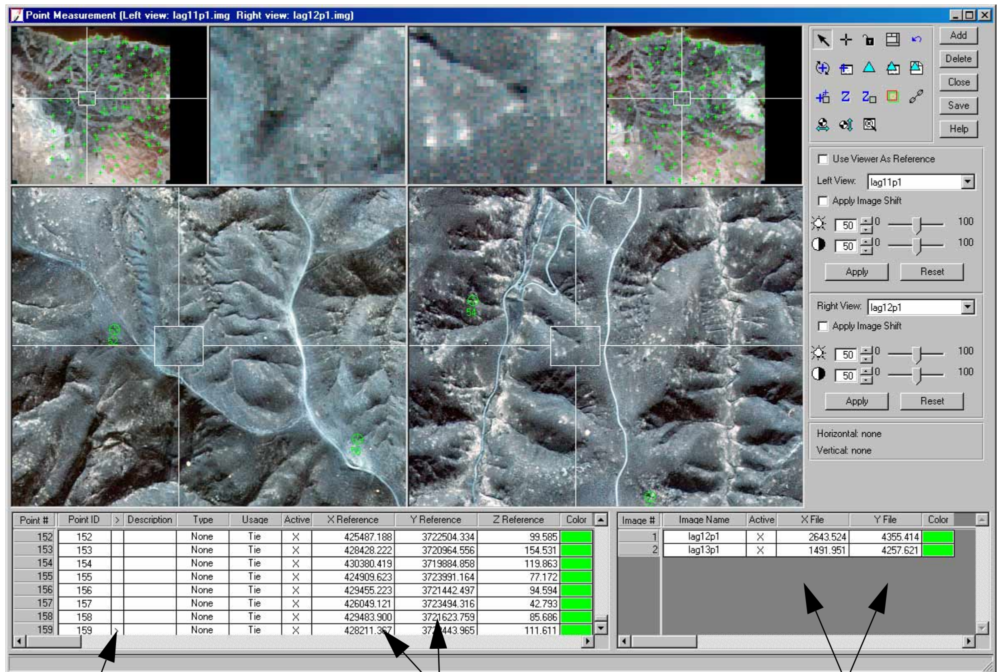
Open the Point Measurement Tool

1. On the LPS toolbar, click the Point Measurement icon , or click the **Edit** menu and choose **Point Measurement**.

   The Point Measurement tool opens, displaying the first two images in the block file: **lag11p1.img** and **lag12p1.img.**

2. Click in a **>** cell of the reference CellArray, located on the left side of the dialog, to see a tie point located in the images.

   NOTE: You may need to adjust the images displayed in the **Left View** *and* **Right View** *to see tie points.*



Coordinates for the tie points display in the Reference CellArray

Corresponding image coordinates display in the File CellArray

Click in this column to see tie points in the Detail Views

3. Click in other **>** columns; notice that the points are well-distributed throughout the overlap portions of the images in the block file.

   Points are placed in all three images of the block file. Their pixel coordinates display in the file CellArray located on the right side of the Point Measurement tool.

4. Click **Close** in the Point Measurement tool.

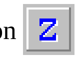
   You are returned to the LPS Project Manager. Next, you proceed with the DTM extraction process.

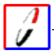
Set Extraction Options

Now that you have calculated the pyramid layers for the images in the block file and have performed an initial survey of the data, you are going to define the DTM extraction options and properties. The first dialog you work with is the DTM Extraction dialog. It allows you to select the type of DTM you wish to create, as well as some of the parameters you want to apply during the extraction of the DTM.

Open the DTM Extraction Dialog

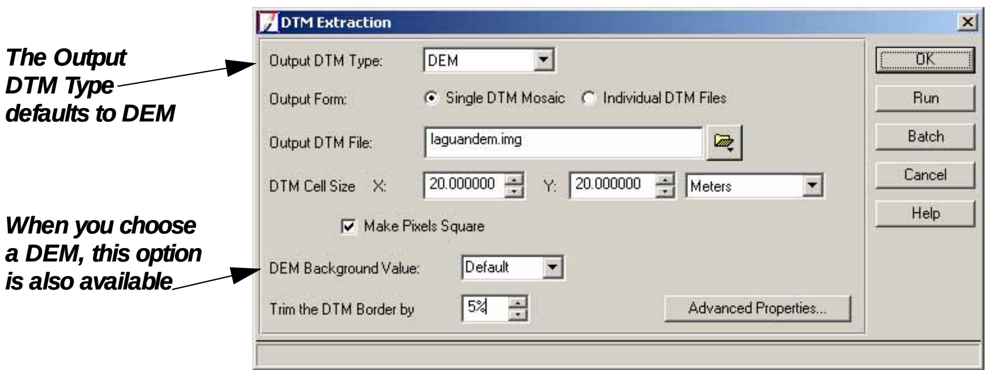
Like the other processes in the LPS workflow, you can access the next series of dialogs via the LPS Project Manager.

1. On the LPS toolbar, click the DTM Extraction icon  .



You can also select **Process | DTM Extraction** *from the menu bar, or click in the* **DTM** *column of the CellArray to open the DTM Extraction dialog.*

The DTM Extraction dialog opens.



Next, you select the type of DTM you want to generate from the image pairs in the block file.You have four choices: **3D Shape, ASCII, DEM,** and **TerraModel TIN.** In the next series of steps, you generate a DEM.

Choose the Output DTM Type

1. In the DTM Extraction dialog, notice that the **Output DTM Type** defaults to **DEM.**
2. In the **Output Form** section, click the **Single DTM Mosaic** radio button.

   The **Single DTM Mosaic** option creates a single DTM from all of the image pairs in the block file. When you select this option, the following field reads **Output DTM File.**

   The **Individual DTM Files** option creates DTMs from all of the image pairs in the block as individual files. When you select this option, you must supply an **Output DTM Prefix.**

3. In the **Output DTM File** section, click the Open icon  to access a File Selector.
4. Navigate to a folder in which you have write permission.
5. Confirm that the **Files of type** dropdown list displays **IMAGINE image (*.img).**
6. Type the name **lagunadem** in the **File name** text box, then press Enter on your keyboard.
7. Click **OK** in the File Selector.

   You are returned to the DTM Extraction dialog. The file name you specified for the output DTM, **lagunadem.img,** displays in the **Output DTM File** section of the dialog.

Set Cell Size and Trim Percent

In order to select the appropriate cell sizes for the output DTM, you need to know the resolution of your imagery. Table 2-1 helps you do the conversion.

OrthoBASE Pro automatically defaults to an X, Y cell size that is calculated based on the ground resolution of the input imagery. This computation is based on a 1 pixel to 10 pixel DTM posting logic.

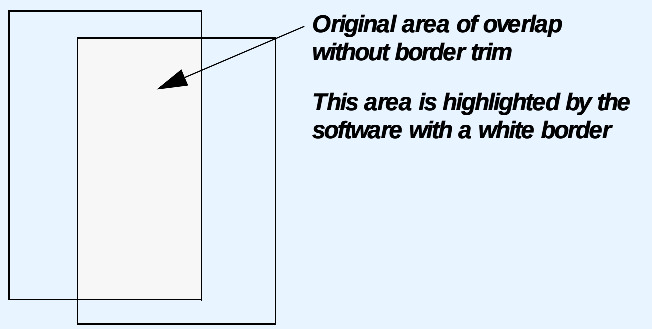
For example, if the original imagery has a ground resolution of 1 meter, the recommended output cell size for the DTM is 10 meters. In the case of these images, the resolution is 1:40000 (approximately 2.7-meter pixels), so an appropriate cell size is 27.

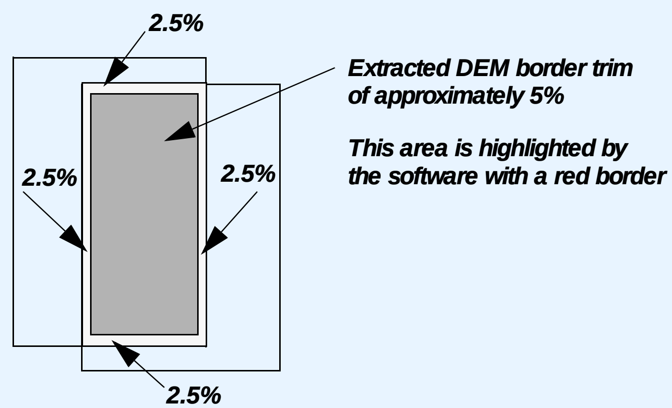
1. Click the checkbox next to **Make Pixels Square.**
2. Double-click in the **DTM Cell Size X** field and type **20** and press Enter**,** or use the increment nudgers to the right of the field to change the value.

   The **DTM Cell Size Y** field updates automatically.
3. Confirm that the units are set to **Meters.**
4. In the **Trim the DTM Border by** field, type **5,** then press Enter on your keyboard, or use the increment nudgers to the right of the field.

Trim the DTM Border

Each time you extract a DTM, you have the option of trimming the borders of the output DTM by a percentage. This is a valuable tool because it eliminates the need to subset the final DTM to remove the less accurate edges.





In the above example, in order to obtain a trim percent of 5%, 2.5% is removed from each of the four sides of the overlap area of the image pair. This occurs after mass points are extracted and before DTM generation.

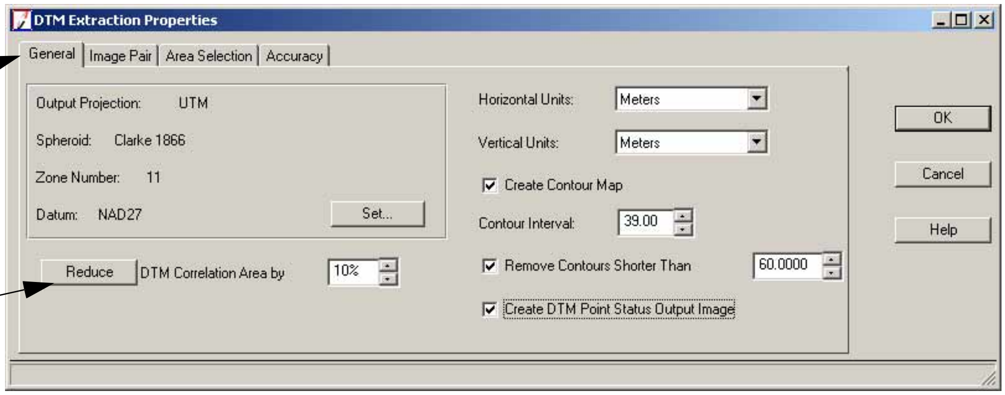
Set Extraction Properties—General

You can further fine-tune the properties associated with the DTM extraction process. With the advanced properties, you can select specific image pairs for processing, create regions (both inclusion and exclusion), and specify 3D reference information to be used for accuracy assessment. You start with the general settings.

1. On the DTM Extraction dialog, click the **Advanced Properties** button to access the DTM Extraction Properties dialog.

   The DTM Extraction Properties dialog opens on the **General** tab.

Projection and Units information on the General tab is obtained from the block file



You must click the Reduce button to affect the correlation area

Check Projection

1. Notice the current **Output Projection, Spheroid, Zone Number,** and **Datum.**

   These settings are inherited from the block file. You can change the projection information by clicking the **Set** button to access the Projection Chooser.

2. In the **General** tab, confirm that both the **Horizontal Units** and the **Vertical Units** are set to **Meters.**

   Again, the unit measurements are inherited from the block file.

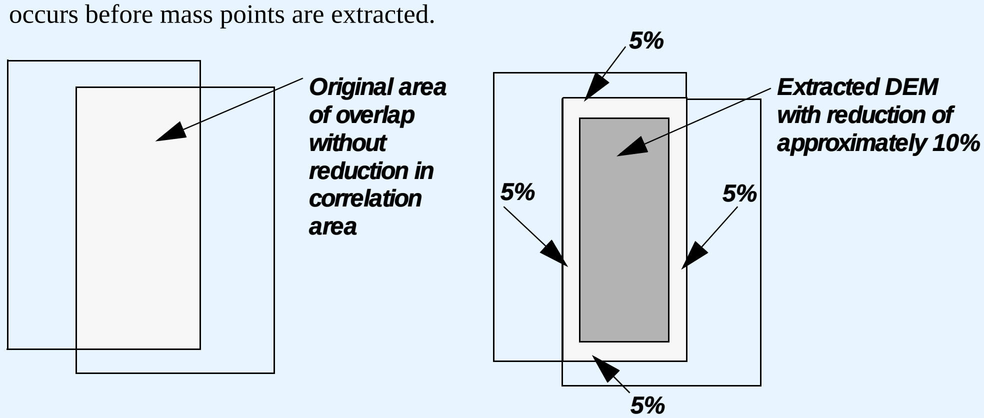
Set Correlation Area

In general, **Reduce DTM Correlation Area by** is used to prevent the extraction of erroneous DTM mass points that may be present at the extreme edges of the images. Any change you make to the correlation area parameter is graphically evident in the subsequent two tabs of the DTM Extraction Properties dialog: **Image Pair** and **Area Selection.**

1. Type the value **10** in the **Reduce DTM Correlation Area by** text field, then press Enter.

2. Click the **Reduce** button to accept the reduction value.

The **Reduce** *button must be clicked for the reduction to take place.*

> ***Reduce the DTM Correlation Area***
>
> Reduction of the correlation area works in the same way as the trim percentage. In this case, to obtain a reduction of 10%, 5% is removed from each of the four sides of the overlap area of the image pair. This reduction is applied to the left and right images of the image pair and occurs before mass points are extracted.
>
> 
>

Select Contour Map and DTM Point Status Image

OrthoBASE Pro takes evaluation of the DTM easier by providing you with two files after DTM extraction: the Contour Map and the DTM Point Status image.

The Contour Map is a 3D Shape file illustrating the topographic variation in the output DTM. The DTM Point Status image is a thematic image that depicts areas of Excellent, Good, Fair, Isolated, and Suspicious correlation in the DTM. You can choose to generate these images by clicking the appropriate checkboxes in the **General** tab of the DTM Extraction Properties dialog.

1. In the **General** tab, click the checkbox next to **Create Contour Map.**

2. In the **Contour Interval** field, type the value **40,** then press Enter, or click the increment nudgers to the right of the field.

   The default contour interval is computed as being three times the DTM cell size. For example, the original 27-meter cell size provides a default value of 81 meters for the contour interval.

3. Click the checkbox next to **Remove Contours Shorter Than.**

   This option automatically removes small peaks and pits from the contour map as defined by dense contour lines.

4. In the field next to **Remove Contours Shorter Than,** type **60.**

   This option removes contours shorter than 60 meters, thus making your contour map easier to interpret. By default, the value is calculated as being five times the original cell size of the output DTM. In this case, the value defaults to 135 (27 multiplied by 5).

5. Click the checkbox next to **Create DTM Point Status Output Image.**

   The DTM Point Status image illustrates the quality associated with the correlated DTM postings. A DTM posting can be categorized as being Excellent, Good, Fair, Isolated or Suspicious.

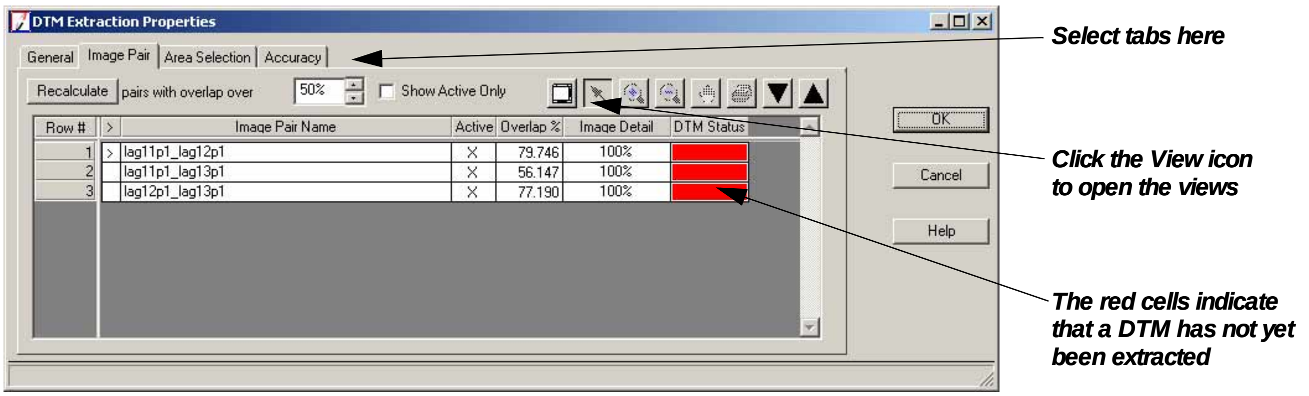
For further information about the DTM Point Status image, see "Create DTM Point Status Image".

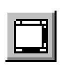
Set Extraction Properties—Image Pair

The **Image Pair** tab is used to evaluate image pairs and determine which image pairs you want to use for automated DTM extraction. Only those image pairs that overlap by the specified overlap threshold (i.e., 50%) are active.

If you want to change the overlap percentage, you can do so. If, for example, you want to increase the overlap percentage so that only images with 60% overlap are active, you may do so in this dialog.

1. Click the **Image Pair** tab at the top of the DTM Extraction Properties dialog.

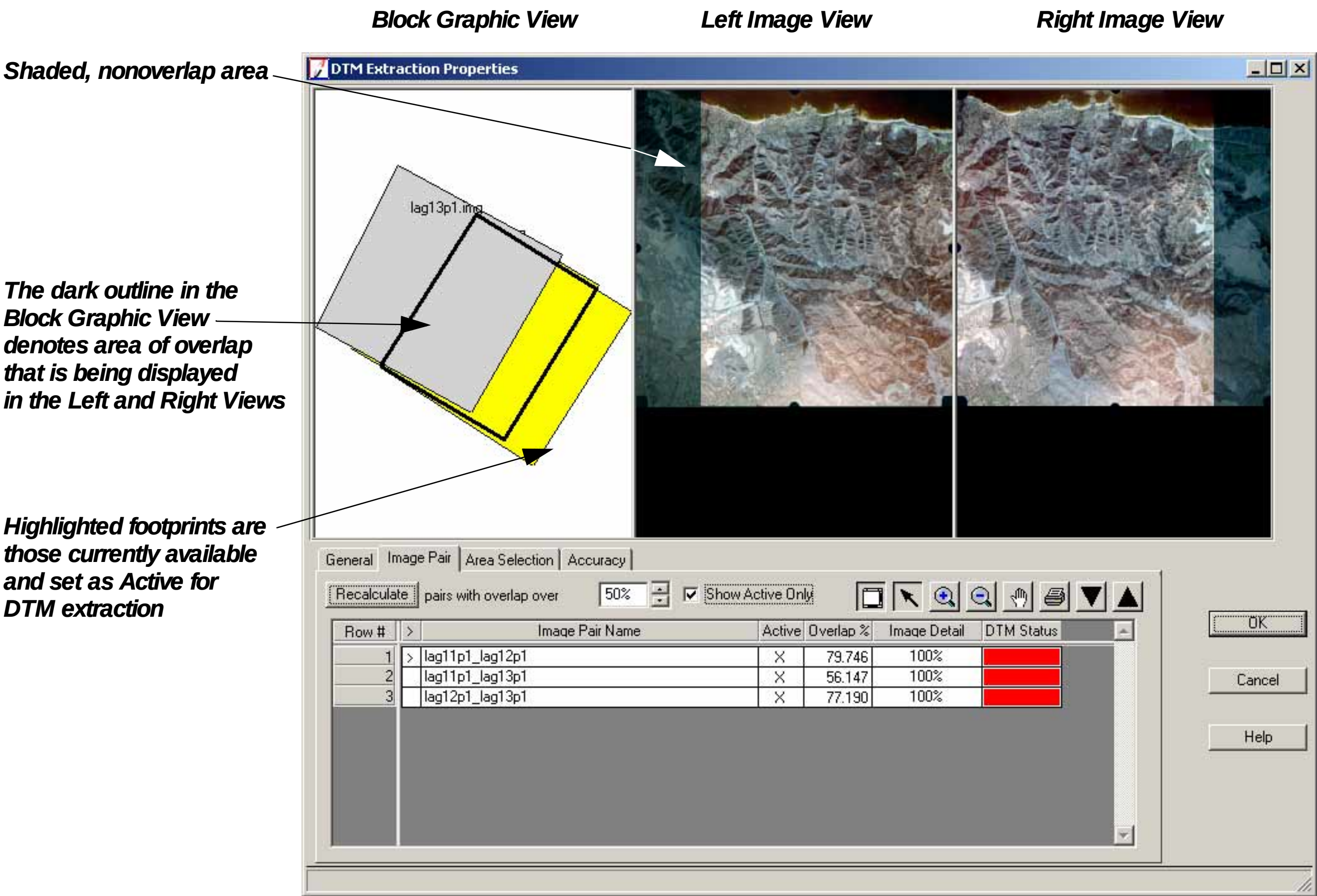


2. Click the View icon  to open the views at the top of the **Image Pair** tab.

   The Block Graphic View, Left Image View, and Right Image View display. Once the views are open, the remainder of the view icons within the **Image Pair** tab become active.

3. Click the **Show Active Only** checkbox.

   When this box is checked, only the active pairs appear in the CellArray. Also, only the active pairs are selectable from the **Current Pair** dropdown list in the **Area Selection** tab.



Check Image Pairs

The views are designed such that, if you choose an image pair other than the default (the first image pair in the block file), the Left Image View and the Right Image View update accordingly.

1. Click in the **>** column of **Row # 3** to select the third image pair, **lag12p1_lag13p1.**

   Notice that the image pair highlights in the Block Graphic View, and the left image of the pair is displayed in the Left View, and the right image of the pair is displayed in the Right Image View. By default, nonoverlap areas are shaded. They cannot be used in the generation of a DTM.

   The appearance of these shaded areas is controlled by an OrthoBASE preference, **Remove Nonoverlap Areas in DTM Viewers,** *which you can set in the* **LPS** *category of the Preference Editor. If you choose not to use this preference, the images appear in their entirety, without any distinguishing characteristics between areas of overlap and those without overlap.*

2. Click the Move to Previous Image icon to see other image pairs in the block file. Notice how the display changes accordingly.

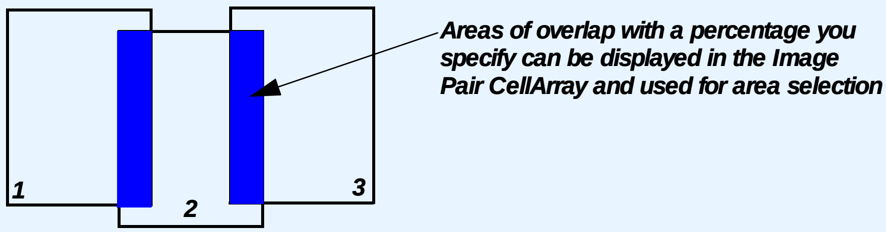
3. Click in the **Active** column for the second image pair, **lag11p1_lag13p1,** to remove the **X** and deactivate it.

NOTE: This image pair totally overlaps with the first and second image pairs, so it is not necessary. Making it inactive also speeds processing time.

Overlap Percentage

Typically, images in a block file have approximately 60% overlap and 20% sidelap. By default, OrthoBASE Pro uses image pairs with at least 50% overlap. However, you may have a block of images with less overlap. You can use the **Recalculate** option to make OrthoBASE Pro use those image pairs with less than the default (50%) overlap.

For example, the following graphic depicts a three-image block file in which the two image pairs have approximately 20% overlap. By entering this value in the **Recalculate** text field and recalculating the overlap percentage, these image pairs would be added to the **Image Pair** CellArray.

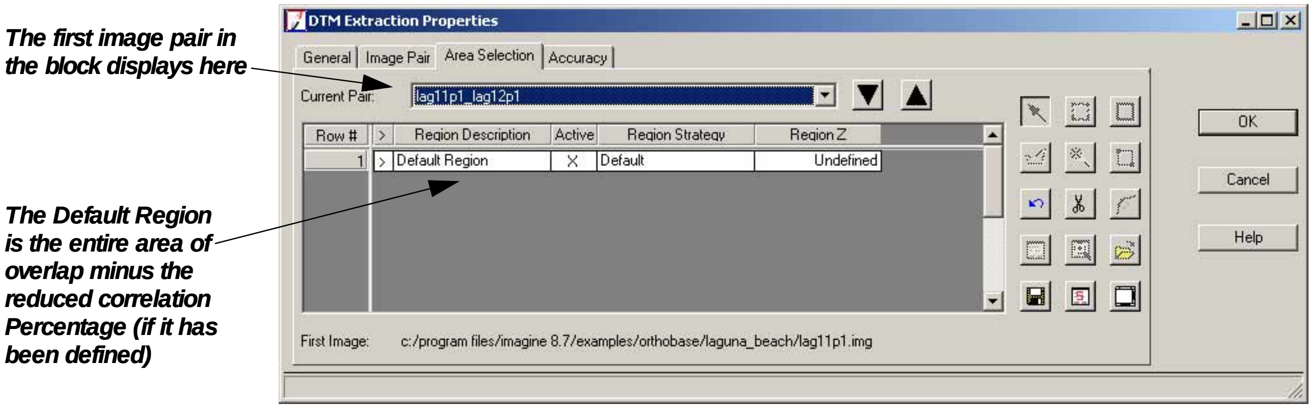


Set Extraction Properties—Area Selection

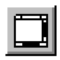
The **Area Selection** tab is provided so that you can specify which geographic regions contained within an image pair are or are not used for DTM extraction. The process involves the creation of regions. Additionally, you can create custom strategies applicable to particular regions.

1. Click the **Area Selection** tab located at the top of the DTM Extraction Properties dialog.

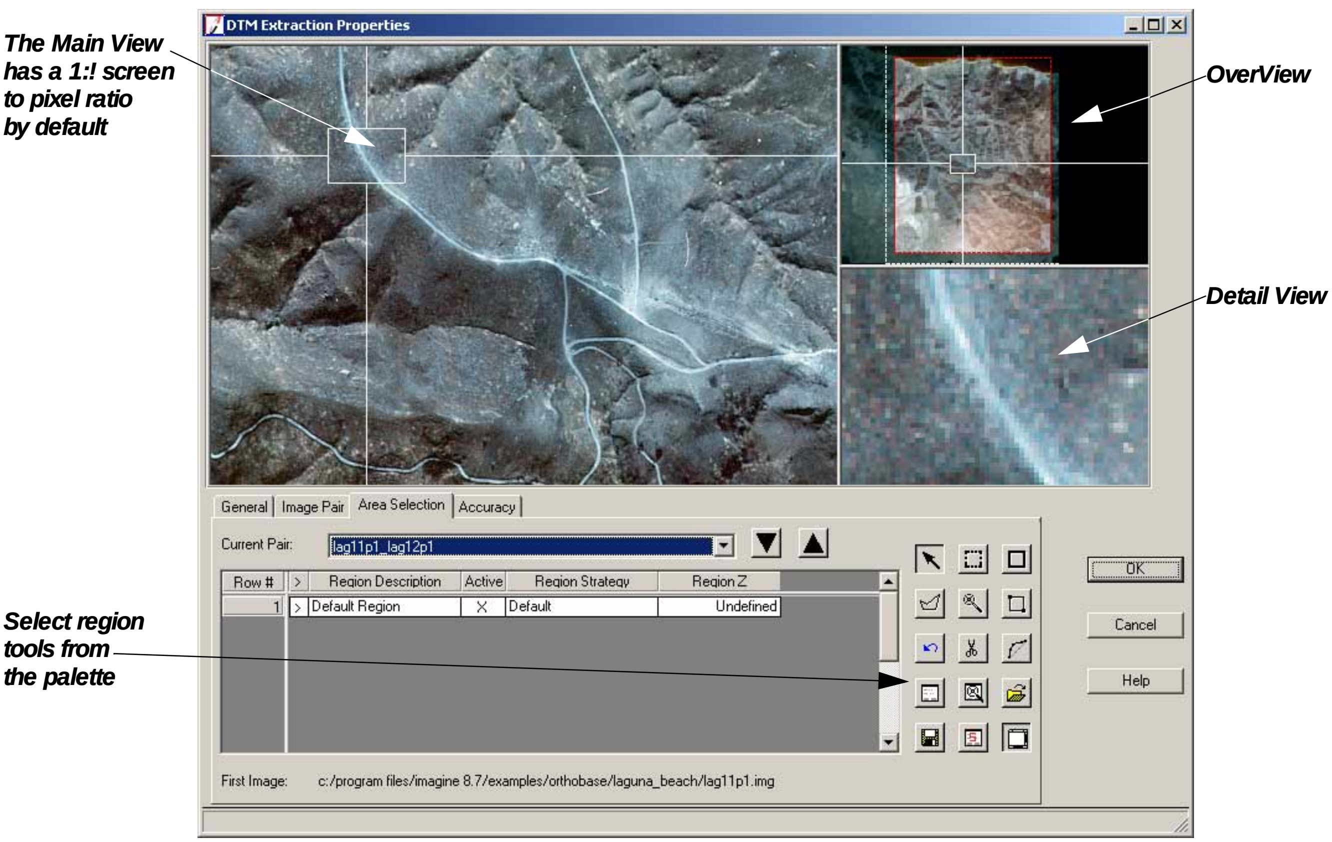
   The **Area Selection** tab and its options display.



By default, the first image pair in the block file, **lag11p1_lag12p1,** displays in the **Current Pair** field. You can switch to other image pairs by clicking the Move to Previous Image and Move to Next Image icons, or by clicking the dropdown list and selecting an image pair.

2. Click the View icon  to open the views at the top of the **Area Selection** tab.

The Main View, OverView, and Detail View display, and the view icons become active.



> ***Extraction Area***
>
> As you have learned, two factors influence the size of the output DTM: **Trim the DTM Border by** and **Reduce DTM Correlation Area by.** These two values are combined for a total trim/reduction percentage.When you specify a percentage by which to reduce the DTM correlation area, OrthoBASE Pro automatically adjusts the display of the image pairs in the views. This way, you are always aware of the exact region to be used for DTM extraction.
>
> By default, the area to be used for DTM extraction is identified with a red bounding box in the OverView. The color of the bounding box is controlled by a preference, **DTM Region Color,** which is located in the **LPS** category of the Preference Editor.
>
> If you do not specify an amount to reduce the correlation area by, the bounding box still appears, but covers the entire area of overlap.

Work with the Link Cursor

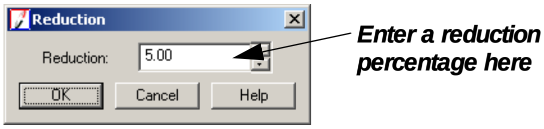
The Link Cursor and its Link Box are provided so that you can easily manipulate the image pair in one of the views to affect its display in another. Adjusting the location of the Link Cursor in the OverView affects the Main View. Likewise, adjusting the cursor in the Main View affects the Detail View. The Detail View does not have a Link Cursor. By sizing the Link Box, you can view specific areas in as much or as little detail as you like.

For information about the Link Cursor, see "Link Cursor Elements".

To change the color of the Link Cursor, select **Link Box Color** *from the right-button Quick Menus in the Main View and the OverView.*

1. Right-click in the Main View and select **Zoom Out By X** from the Quick Menu.

   The Reduction dialog opens with a default of **2.**

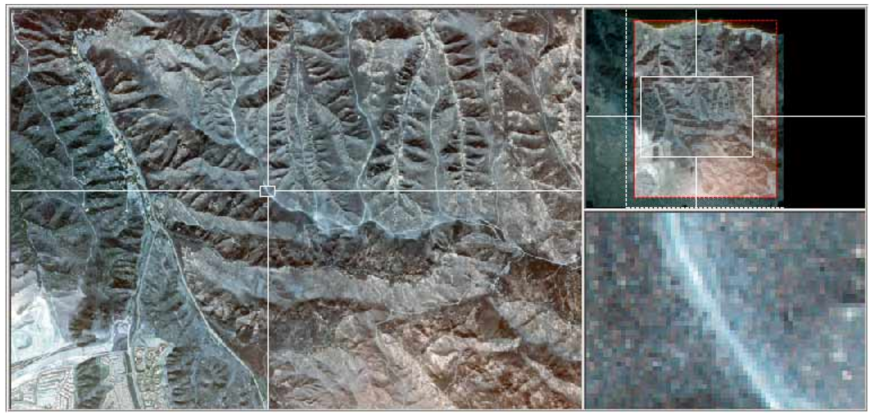


2. Type the value **5** in the **Reduction** text field and type Enter, or use the increment nudgers to the right of the field to increase the value.

3. Click **OK** in the Reduction dialog.

   The image pair redisplays in the Main View and the OverView.

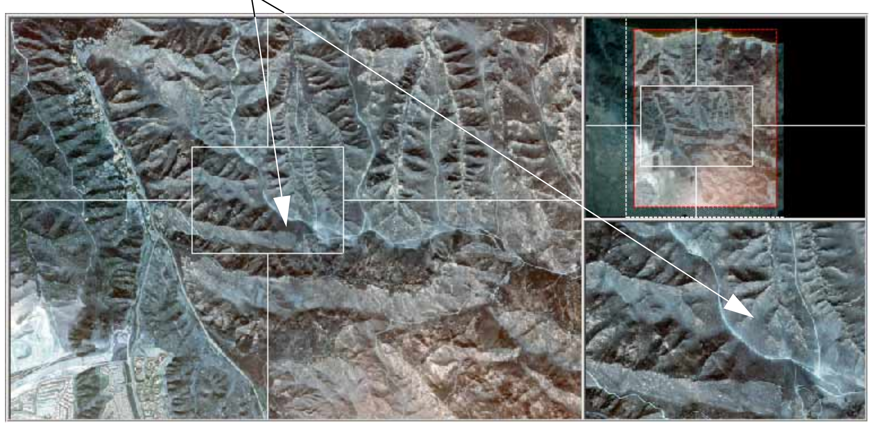
With a reduction of 5%, more of the image pair is evident in the Main View



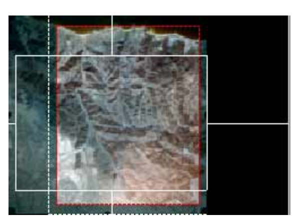
4. In the Area Selection tool palette, make sure that the Select icon  is enabled.
5. Click and hold a corner of the Link Box in the Main View, and drag it outward.

   The Link Box increases in size, and the image pair redisplays in the views. Specifically, the appearance in the Detail View is affected.

The area inside the Link Box corresponds to that shown in the Detail View

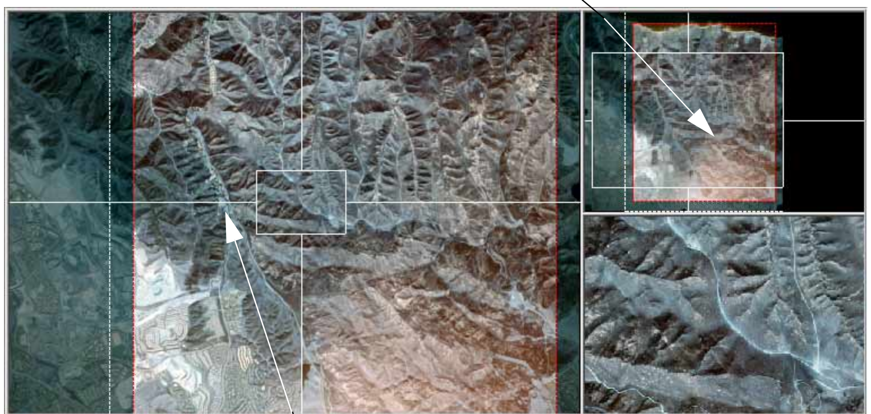


6. Click and hold on the corner of the Link Box in the OverView and drag it outward, past the overlap extent of the image pair.



The image pair redisplays again in the Main View.

Adjusting the Link Cursor in the OverView...



...affects the display of the image pair in the Main View

Now that you are familiar with how the Link Cursor and Link Box can be used to alter the display of the images in the views, you are ready to start defining regions.

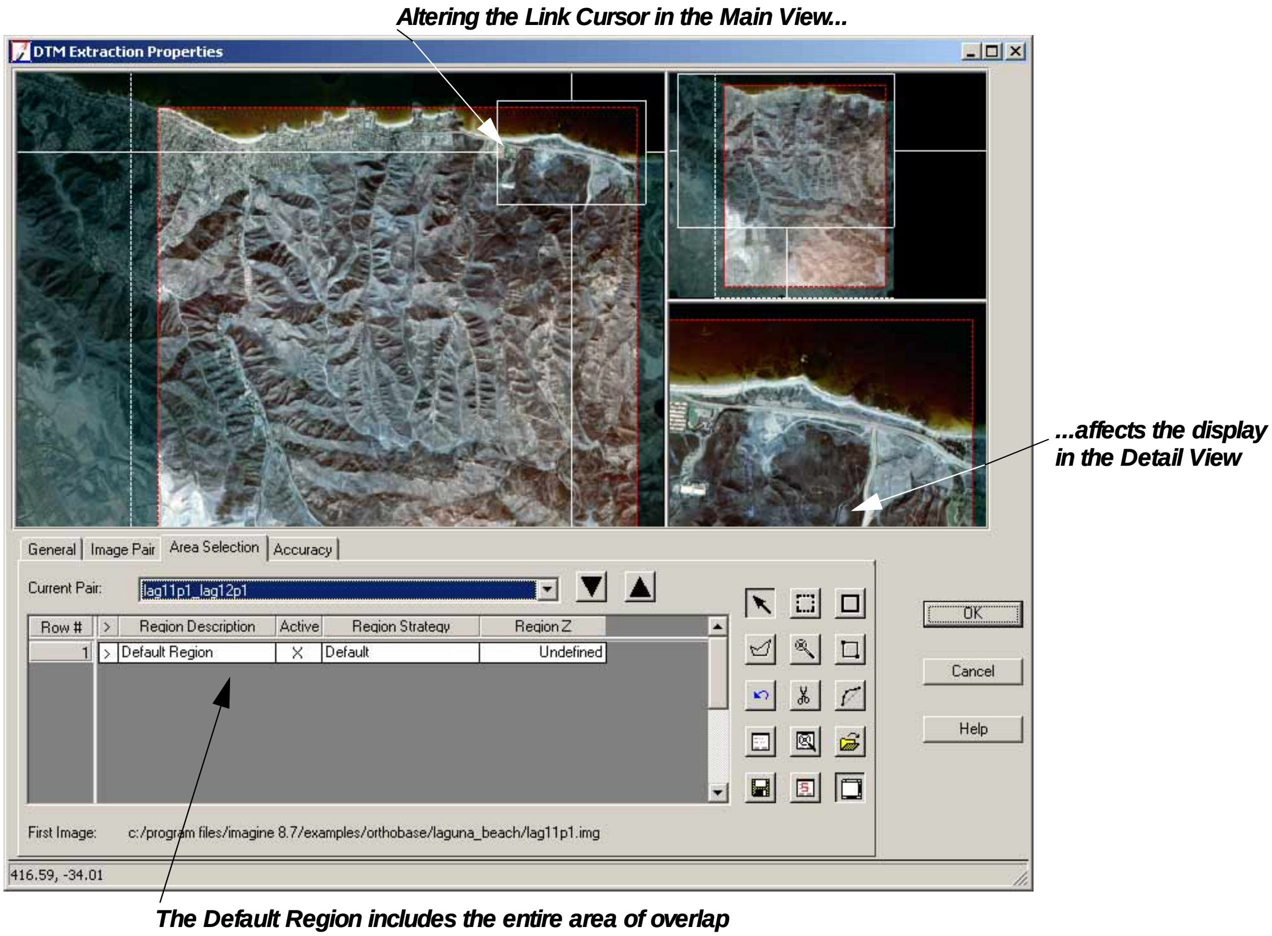
Add a New Region

By default, the first region listed in the CellArray of the **Area Selection** tab is the region that corresponds to the entire area of overlap of the image pair displayed (less any correlation area reduction). In this case, that image pair is **lag11p1_lag12p1.** The **Region Description** for that first region is **Default Region.** A unique description can be assigned to the region.

In the next series of steps, you add a region and apply a strategy to it. In general, regions are areas with special characteristics. Such features include lakes, forested areas, dense urban areas, and so on, for which a DTM can (inclusion) or cannot (exclusion) easily be extracted.

1. In the Main View, click and hold inside the Link Box and drag it to the area at the uppermost right corner of the image, which shows the shoreline.

   Your display should look similar to the following:

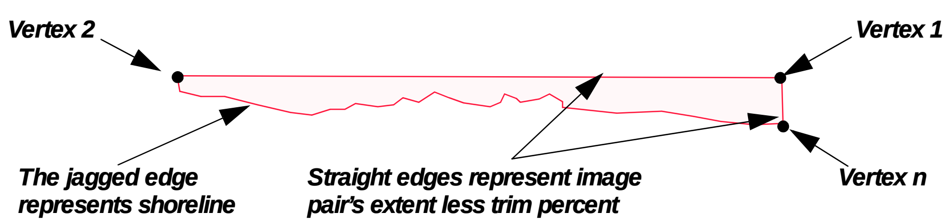


In the case of the shoreline, you are going to use the Create Polygon Region icon to create an exclusion area. Because the water has a constant elevation value, you want to exclude it from the output DTM. The region selection tools in OrthoBASE Pro function like the other AOI tools in ERDAS IMAGINE: simply click to collect vertices.

For more information about AOI collection, see the On-Line Help.

2. From the Area Selection tool palette, click the Create Polygon Region icon  .

The following diagram illustrates the collection sequence of vertices along the shoreline.



3. Using the above diagram as a guide, click in the Main View at the upper rightmost extent of the ocean (within the red boundary indicating the extent of the overlap area less trim percent), and click to digitize the first vertex of the polygon.

NOTE: You can also digitize regions in the Detail View.

4. Move the cursor to the upper leftmost extent of the ocean and click to digitize the second vertex of the polygon.

5. Move the cursor to the actual shoreline, and collect vertices along the shoreline.

6. Double-click to terminate the collection of the polygon at the lower rightmost extent of the shoreline.

The termination of the polygon is controlled by a preference, **Polyline/Polygon termination button,** *in the* **Viewer** *category of the Preference Editor.*

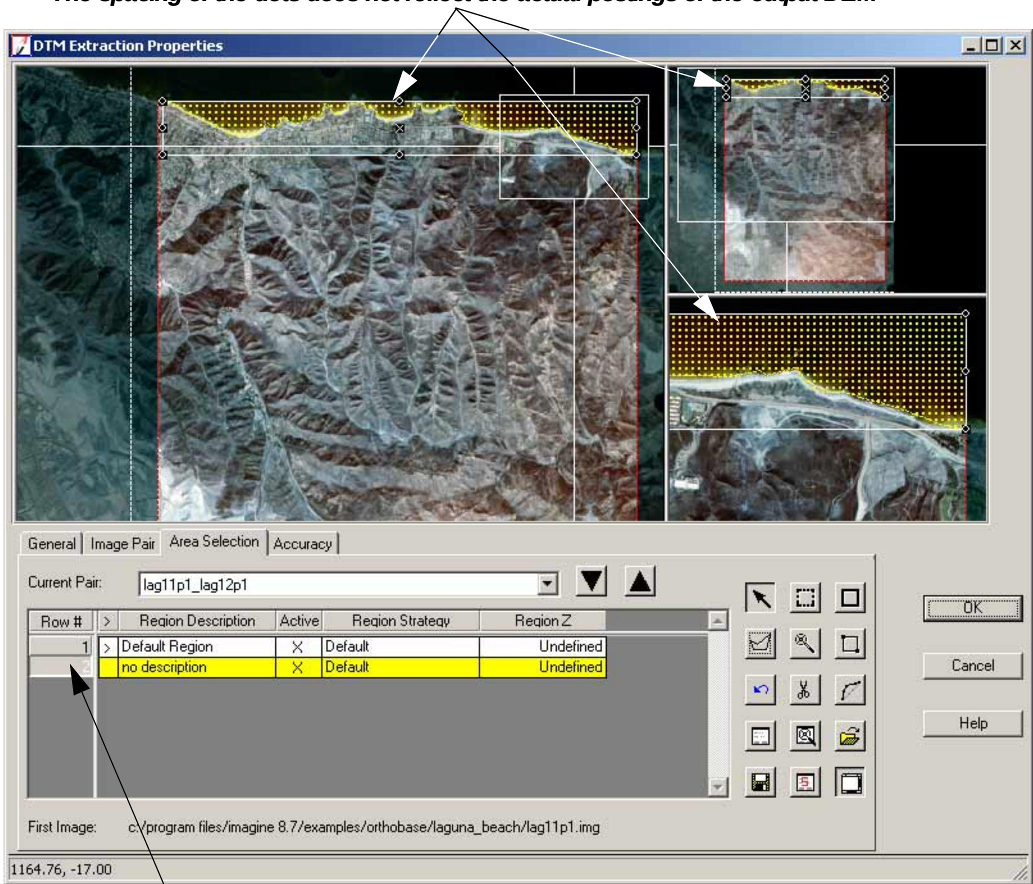
When you are finished, the new region is added to the **Area Selection** tab CellArray.

7. Click the **Row #** cell **2** to highlight the feature in the views.

The highlight color in the views is also controlled by a preference, **DTM Selected Region Color,** *in the* **LPS** *category of the Preference Editor.*

Your views of the **Area Selection** tab should look similar to the following:

The polygon you digitized is highlighted in yellow in each of the views
The spacing of the dots does not reflect the actual postings of the output DEM



Select the region to highlight here

Set Strategy Parameters

1. Click in the **Region Description** cell corresponding to the area and type **Ocean.**
2. Click in the **Region Strategy** cell corresponding to the area, and select **Exclude Area** from the dropdown list.
3. Right-click in the **Row #** column and select **Select None.**

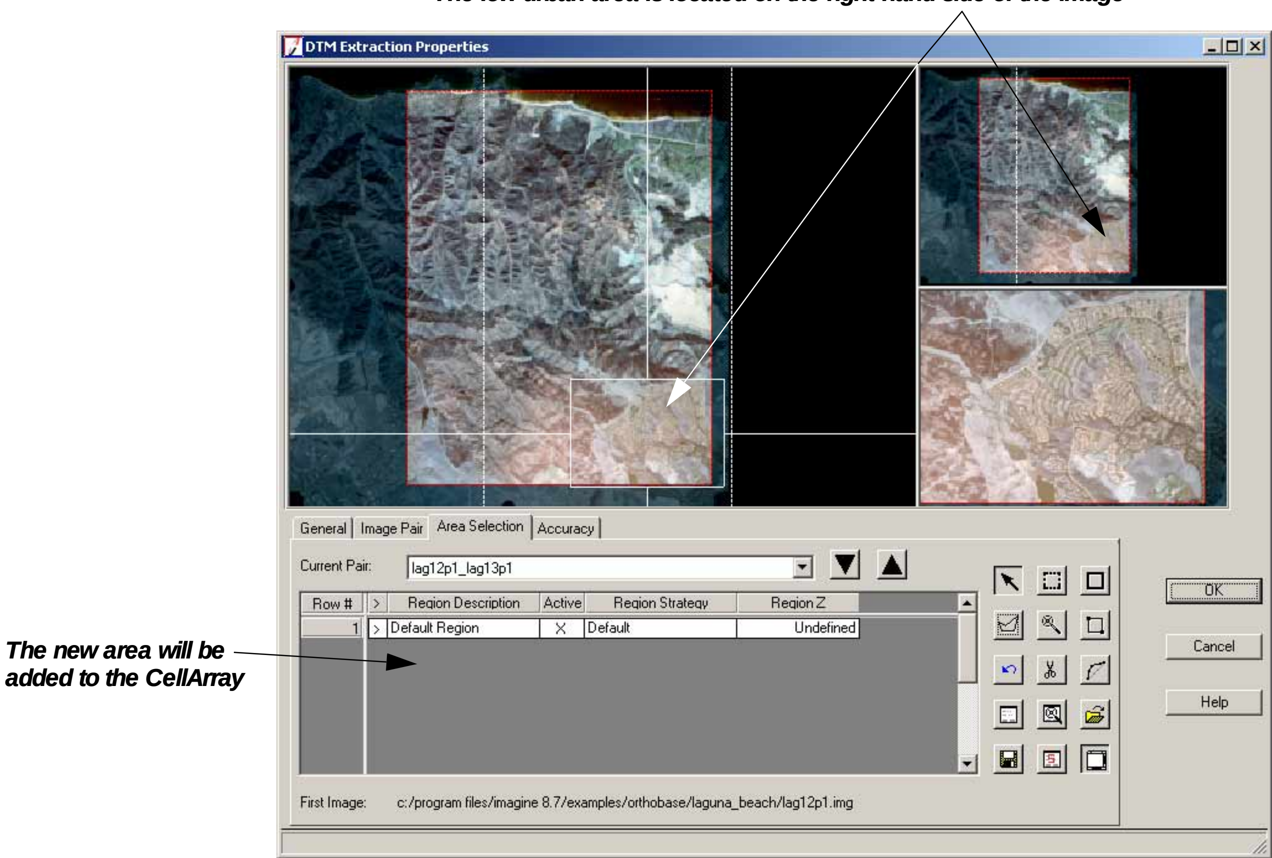
   The **Ocean** exclusion area assumes the color for the exclusion area type of region, cyan.

   The color of exclusion areas is controlled by a preference, **DTM Exclude Region Color,** *in the* **LPS** *category of the Preference Editor.*

Add a Second Region

1. Click the dropdown list for the **Current Pair,** and choose the pair in the block: **lag12p1_lag13p1.**

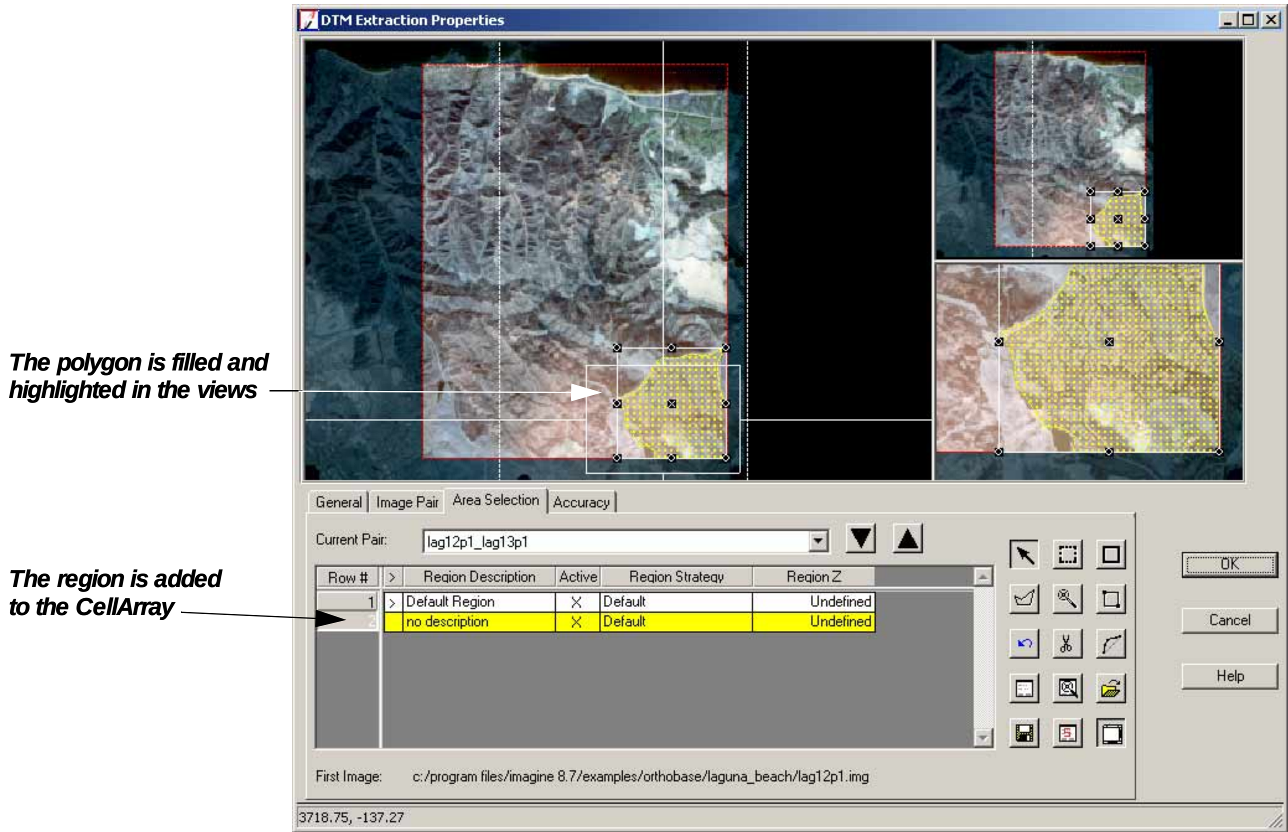
2. Right-click in the Main View and select **Fit Image To Window** from the Quick Menu.
3. In the Main View, select the Link Cursor and drag it to the lower right side of the image, which shows an urban area.
4. Resize the Link Box as necessary to see the urban area in the Detail View.



Once again, you are going to digitize a region to cover this area. Then, you are going to apply a custom strategy to it since the terrain in the region differs from the terrain in the remainder of the image, which is predominantly mountainous.

5. Click the Create Polygon Region icon  .
6. In the Main View or the Detail View, digitize around the border of the area, and double-click to terminate the polygon.
7. Click in the **Row #** cell **2** to highlight the area.

   Your polygon should look similar to the following:



8. Click in the **>** cell corresponding to the area you just digitized to make it the active region.

9. In the CellArray of the **Area Selection** tab, click in the **Region Description** cell corresponding to the area you just digitized, and type **Urban Area.**

10. Click in the **Region Strategy** cell to access the dropdown list and select **Low Urban.**

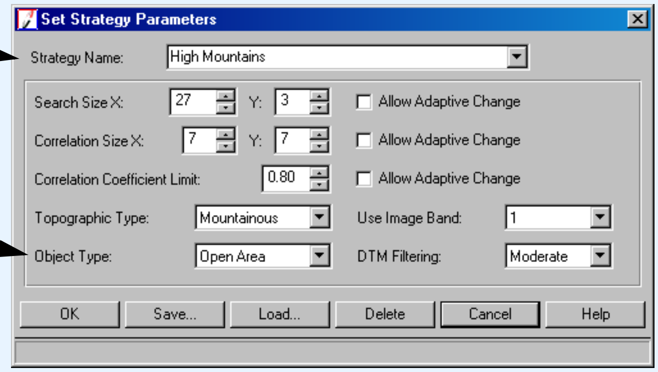
11. Right click in the **Row #** column and choose **Select None.**

Set Strategy Parameters

To access the Set Strategy Parameters dialog, click the Strategy Parameters icon, or right-click in the **Region Strategy** cell corresponding to the region and choose **Custom.**

Select a custom strategy from the dropdown list

Parameters consistent with the region defined by the strategy name are updated automatically



By default, the Set Strategy Parameters dialog opens with the **Exclude Area** strategy displayed (its settings are greyed-out, but can be changed via the preferences). These settings are applied to all nonexclusion regions. In order to apply a custom, pre-defined strategy to a region, select it from the **Strategy Name** dropdown list.

NOTE: You can also create your own custom strategies. For more information, see the On-Line Help.

Add a Third Region

In this image pair, you can also find a lake. In areas such as this, the correlator may experience difficulty in matching left and right image points of a common ground feature since they all look the same. As a result, these areas are best digitized separately. Once you have digitized the area, you can give it a specific elevation.

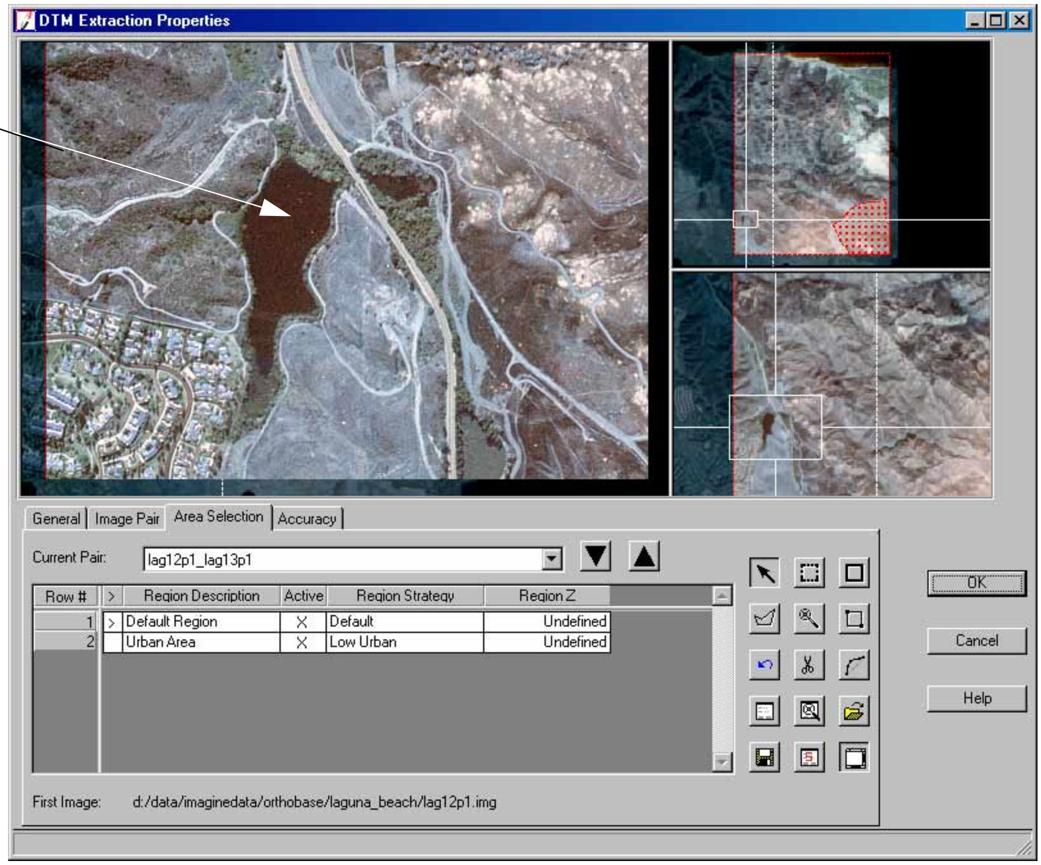
1. Right-click in the Main View and select **Default Zoom** from the Quick Menu.

2. Adjust the position of the Link Cursor in the OverView so that it covers the lower left portion of the image.

   The next area you are going to digitize, a lake, is also located in the third image pair, **lag12p1_lag13p.**

3. Adjust the size of the Link Box in the Main View to affect the display in the Detail View as necessary.

This lake can be isolated using the Seed tool

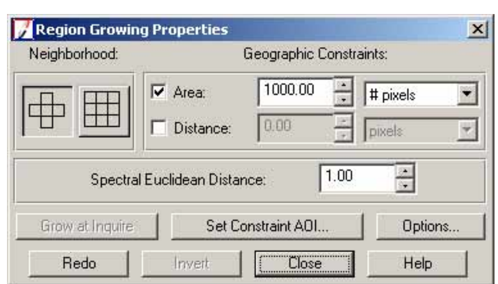


In an area such as this, you can use the Seed tool to automatically digitize contiguous areas with similar characteristics.

Set Region Growing Properties

1. Click the Region Growing Properties icon  .

   The Region Growing Properties dialog opens. To ensure the best possible polygon, you are going to change some of the settings in the dialog.



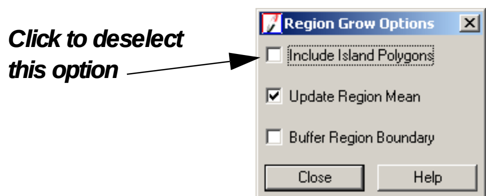
2. In the Region Growing Properties dialog, click the 8-pixel neighborhood icon  .

3. Click to deselect the **Area Geographic Constraints.**

4. In the **Spectral Euclidean Distance** field, type the value **60,** then press Enter on your keyboard.

> ***Spectral Euclidean Distance***
>
> The spectral euclidean distance is measured in digital number (DN) units on which the Seed tool accepts pixels as part of the region. The pixels that are accepted are within this spectral distance from the mean of the seed pixel you click. Inclusion is based on neighboring pixels' Euclidean distance from the selected pixel. In essence, the process categorizes neighboring pixels of similar grey level intensity to produce a uniform result.

5. Click the **Options** button to open the Region Grow Options dialog.



6. Click the checkbox to deselect **Include Island Polygons.**

   NOTE: Disabling this option ensures the creation of one contiguous region.

7. Click **Close** in the Region Grow Options dialog.

8. Click **Close** in the Region Growing Properties dialog to apply the settings.

Apply the Seed Tool to the Area

1. In the Area Selection tool palette, click on the Seed icon  .

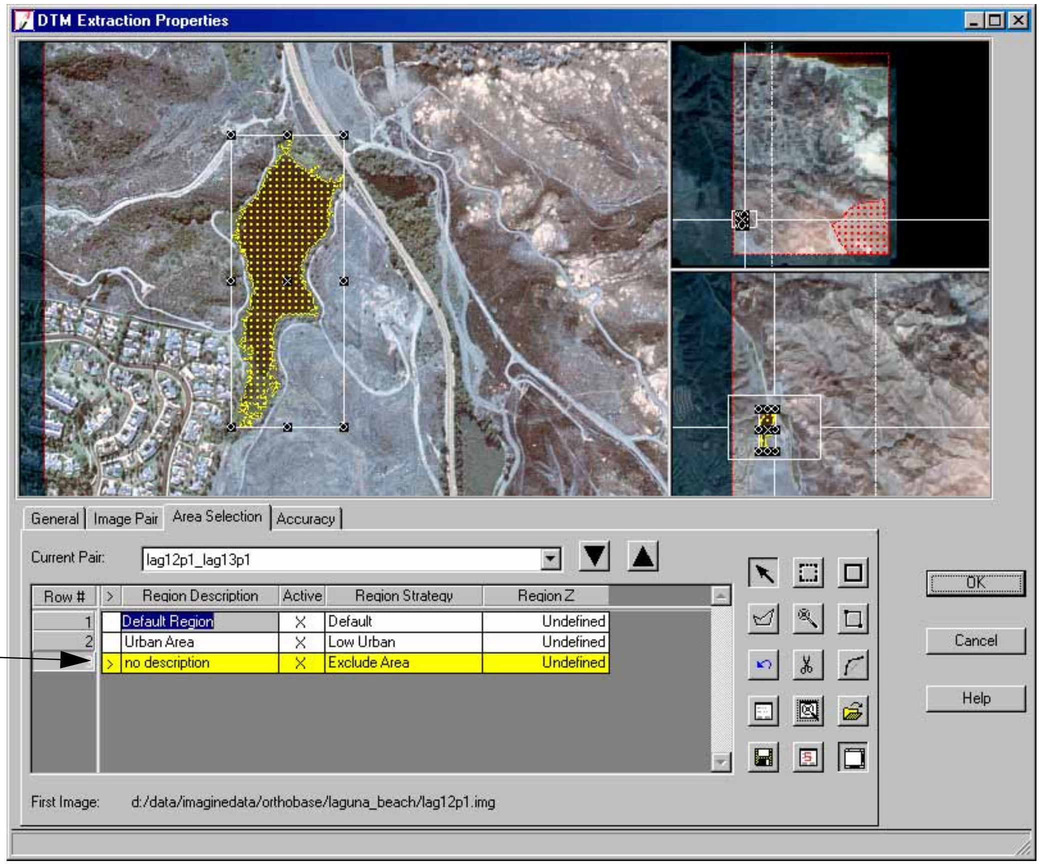
2. In the Main View or the Detail View, click inside the lake area to create the polygon.

   OrthoBASE Pro returns an area corresponding to the boundaries of the lake.

3. Click in the **>** cell corresponding to the new region to make it the active region.

4. Click in the **Row #** cell **3** to highlight the area.

   Your polygon should look similar to the following:

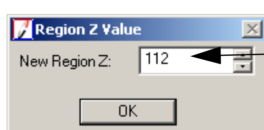


5. In the CellArray of the **Area Selection** tab, click in the **Region Description** cell corresponding to the area you just digitized, and type the name **Lake.**

6. Confirm that the **Region Strategy** is set to **Exclude Area.**

7. Click in the **Region Z** cell and select **Custom.**

   The Region Z Value dialog opens.



8. In the Region Z Value dialog, enter the value **112** in the **New Region Z** field, then press Enter.

   This value was obtained by opening the block file in Stereo Analyst and using the Terrain Following Cursor to measure the height of points adjacent to the lake, then taking an average elevation of those points.

9. Click **OK** in the Region Z Value dialog.

   The CellArray updates accordingly.

10. Right-click in the **Row #** column and select **Select None.**

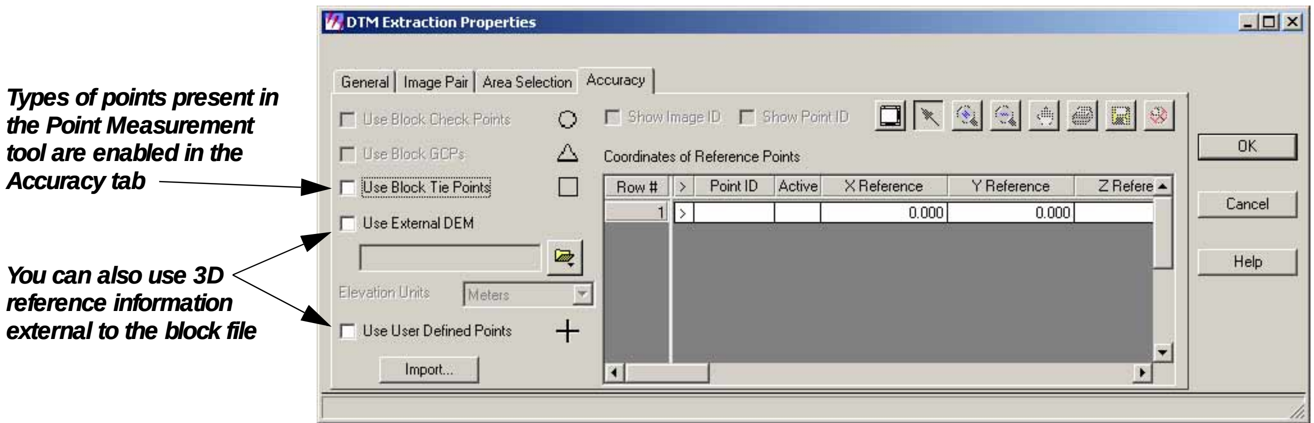
Now that you have specified areas for special consideration, you can proceed to the accuracy portion of the DTM extraction process.

Set Extraction Properties - Accuracy

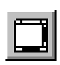
The **Accuracy** tab is provided so that you can define 3D reference information that is used to compute the accuracy of the output DTM.

1. Click the **Accuracy** tab located at the top of the DTM Extraction Properties dialog.

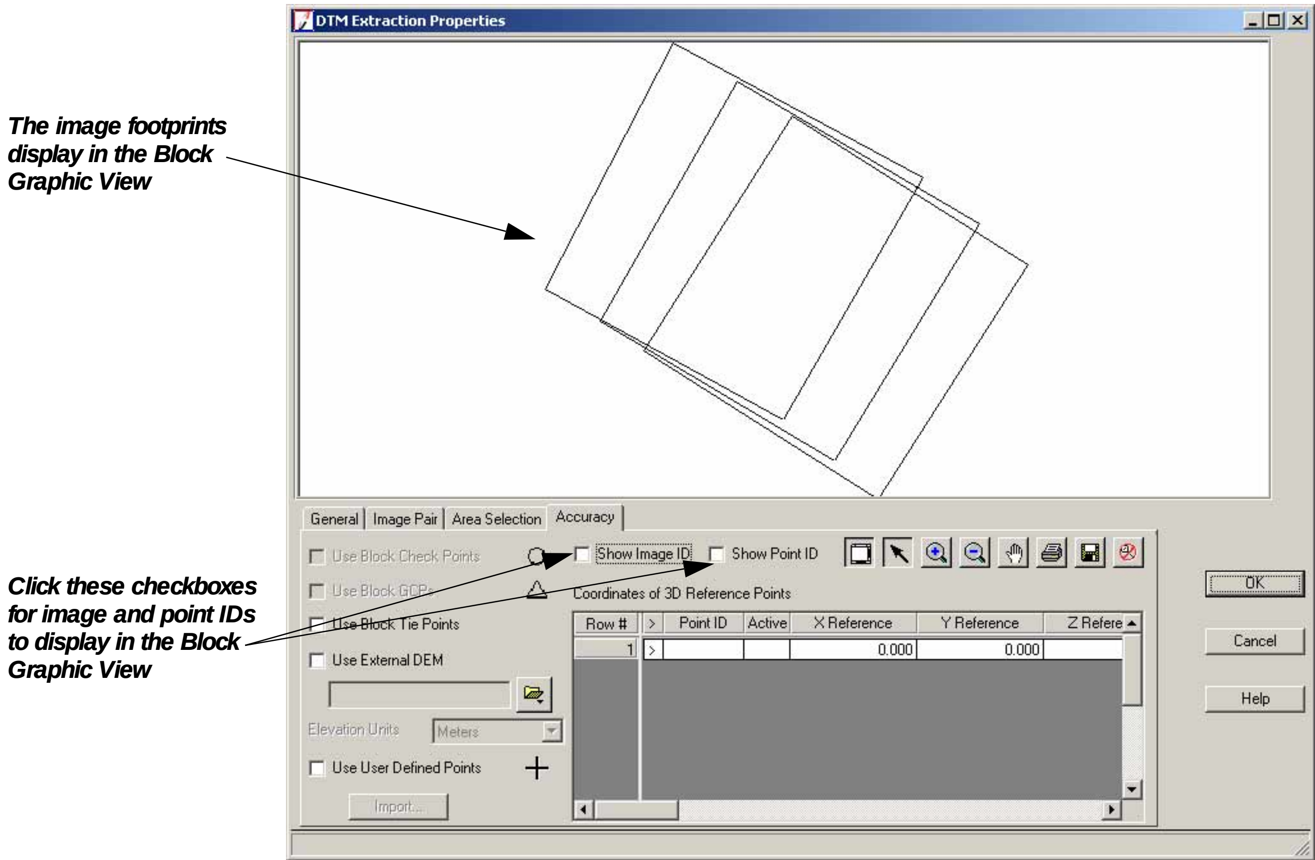
The **Accuracy** tab and its options display.



Like the **Image Pair** tab and the **Area Selection** tab, the **Accuracy** tab has a view that enables you to see the block footprint.

2. Click the View icon  in the **Accuracy** tab.

The Block Graphic View displays.



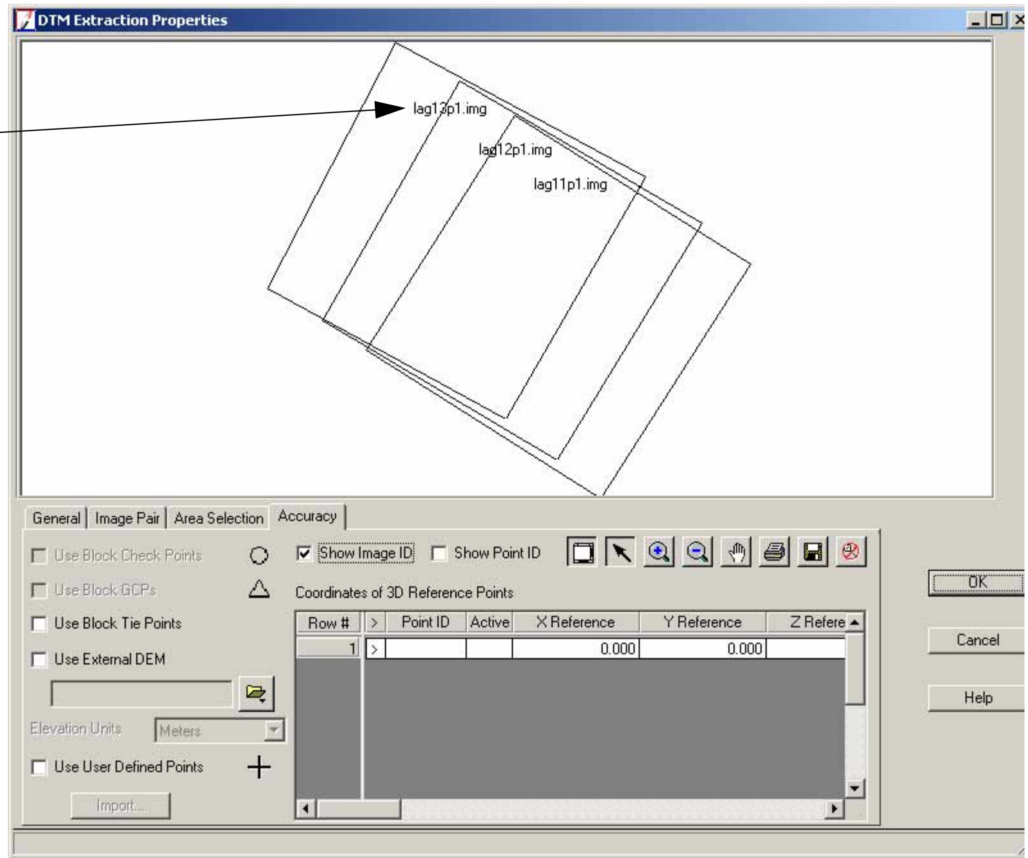
Set Display Options

To get more information from the Block Graphic View, you can display the Image IDs of each of the images in the block file.

1. In the **Accuracy** tab, click the **Show Image ID** checkbox.

   The block file in the Block Graphic View redisplays as follows.

Image IDs display in the top left corner of images in the block file

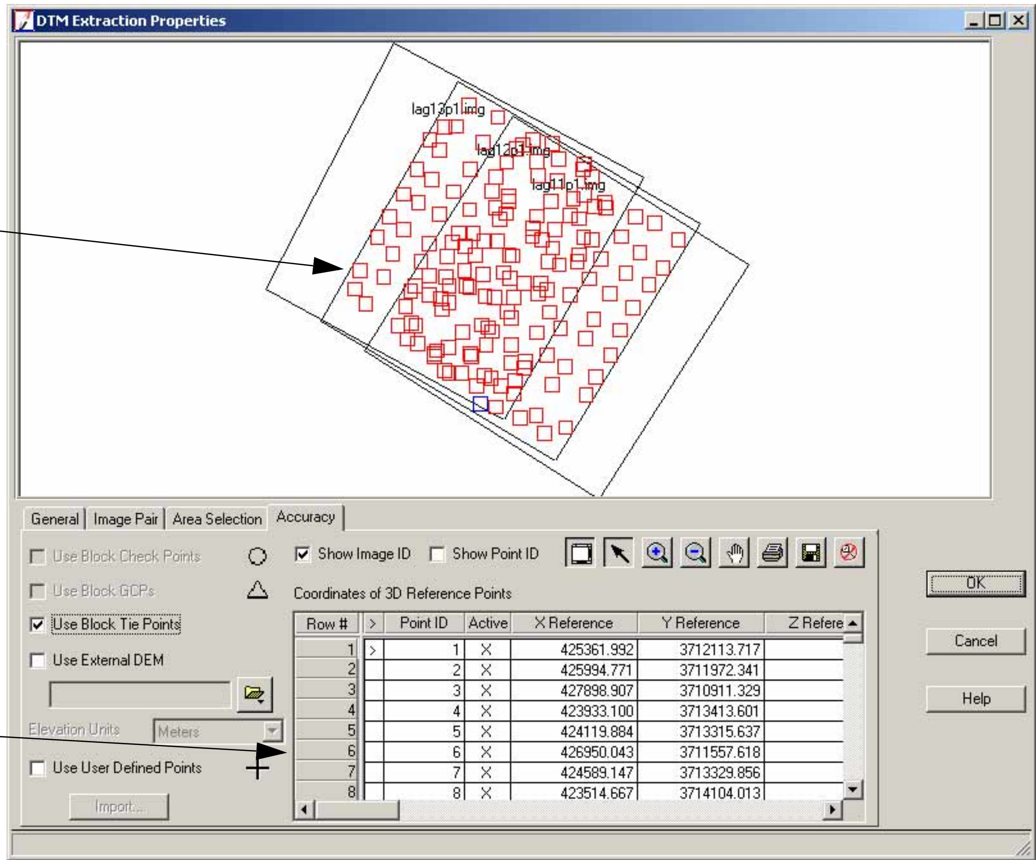


Most of the information in this dialog comes from the Point Measurement tool. If you remember, in the section "Open the Point Measurement Tool", you evaluated the tie points contained in the block file. Now, you can use those same tie points to check the accuracy of the output DEM.

2. In the **Accuracy** tab, click the checkbox next to **Use Block Tie Points.**

   The block file redisplays in the Block Graphic View.

Block tie points display as squares in the Block Graphic View...



...and are listed in the CellArray of the Accuracy tab

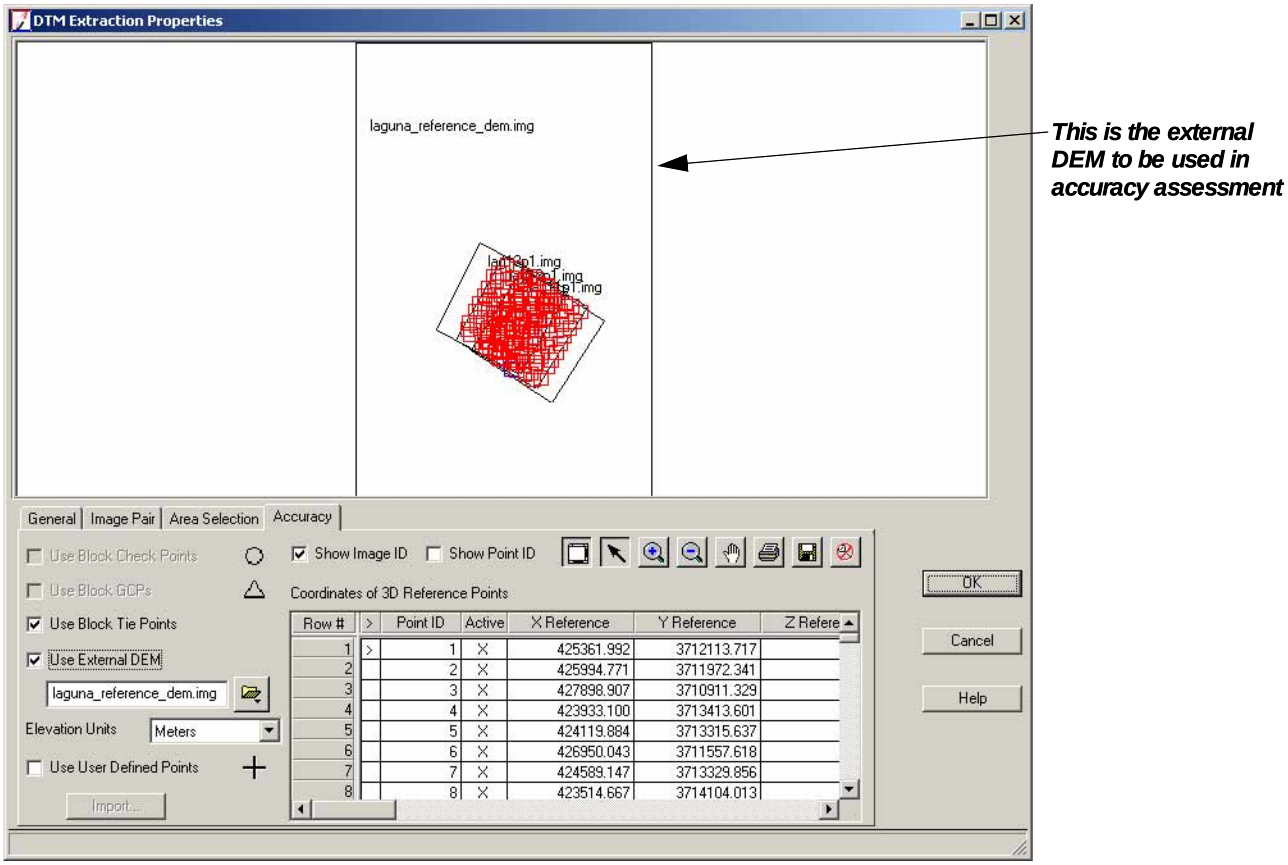
You can also display Point IDs for each of the points in the block file by checking the **Point ID** *checkbox.*

Specify External DEM

OrthoBASE Pro offers you the option of using an external DEM to check the accuracy of the output DTM. You choose the external DEM in the **Accuracy** tab.

1. Click the checkbox next to **Use External DEM.**
2. Click the Open icon .
3. Navigate to /examples/orthobase/laguna_beach and select **laguna_reference_dem.img.**
4. Click **OK** in the File Selector dialog.

   The DEM also displays in the Block Graphic View of the **Accuracy** tab. You can see the extent of the block file that it covers.



Specify Additional Points

In this tour guide, additional points are also provided to check the accuracy of your output DEM. The points were collected as 3D mass points using Stereo Analyst and are contained in an ASCII text file.

1. Click the **Use User Defined Points** checkbox.

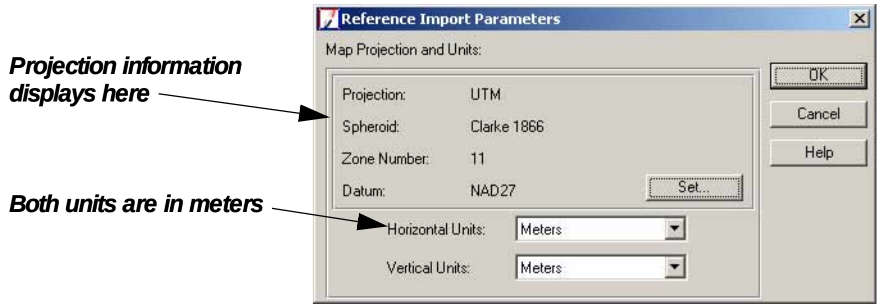
   The **Import** button becomes active.

2. Click the **Import** button to open a File Selector.

3. Navigate to /examples/orthobase/laguna_beach and select **check_points.txt.**

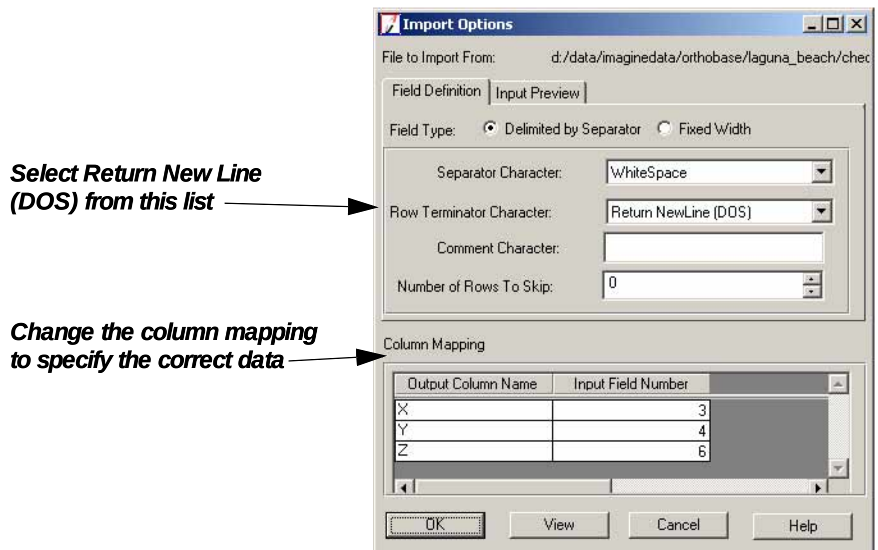
4. Click **OK** in the File Selector.

   The Reference Import Parameters dialog opens. This dialog is provided to input the projection that was used to collect those check points. In this example, the projection is already correctly set to **UTM.**



5. Click **OK** in the dialog.

   The Import Options dialog opens.



6. In the **Field Definition** tab of the Import Options dialog, click the **Row Terminator Character** dropdown list and select **Return New Line (DOS).**

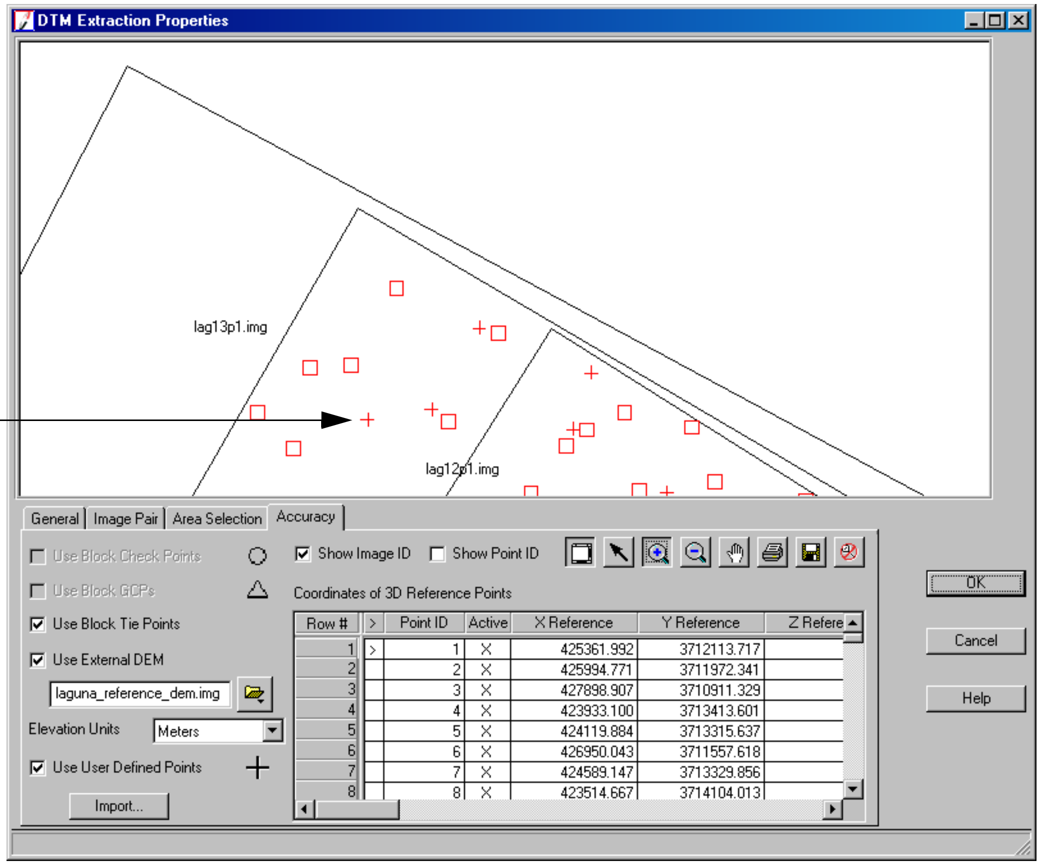
7. In the **Column Mapping** section of the **Field Definition** tab, change the **Input Field Numbers** for **X, Y,** and **Z** to **3, 4,** and **6,** respectively.

   You can check the **Input Preview** tab to confirm that **Field 3, Field 4,** and **Field 6** correspond to the appropriate data.

8. Click **OK** in the Import Options dialog.

   The additional points are displayed in both the Block Graphic View and the CellArray of the **Accuracy** tab. The points you imported display in the Block Graphic View as plus signs (+).

   In the following illustration, the Zoom In icon  has been applied so that you can see the points clearly in the Block Graphic View.



User-defined points display as plus signs

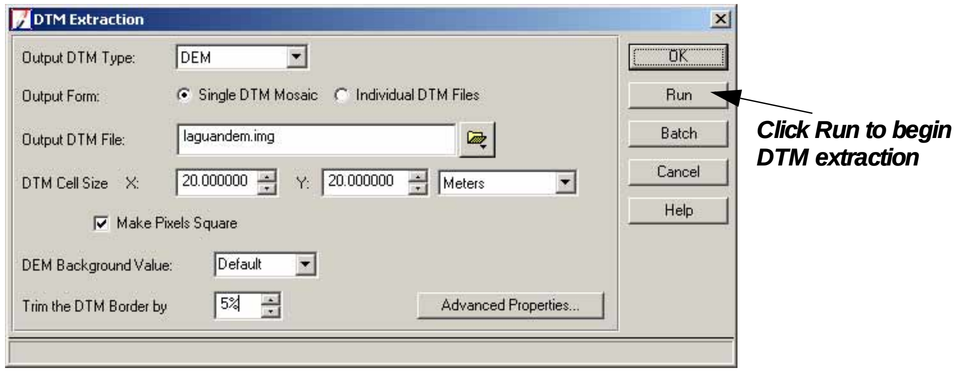
You can obtain information about any one of the points displayed in the Block Graphic View by clicking it to display the Point Data dialog.

9. Click **OK** in the DTM Extraction Properties dialog to save and transfer the information back to the DTM Extraction dialog.

You are returned to the DTM Extraction dialog. At this time, you are ready to extract the DEM.

Extract and View the DEM

Now, that you have set some advanced options, you are ready to generate the DEM. This is done with the simple click of the **Run** button. The output DEM, the Contour Map, and the DTM Point Status image are located in the same folder as the output DEM.



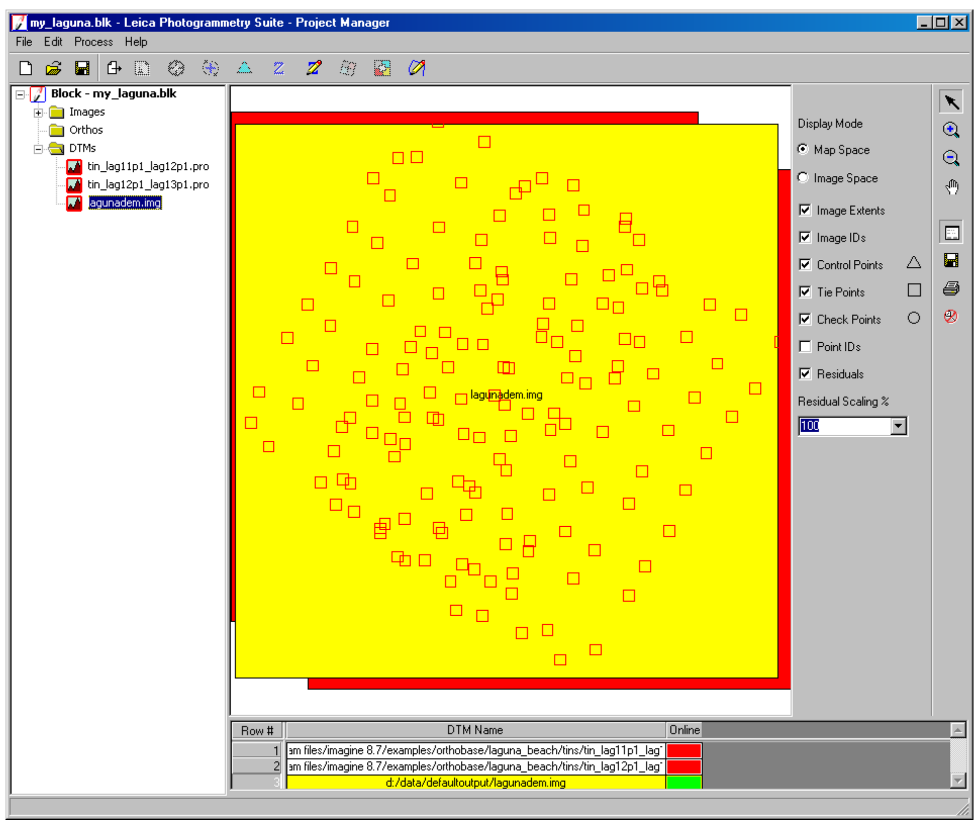
1. In the DTM Extraction dialog, click the **Run** button.

   The DTM Extraction dialog closes, and the LPS Project Manager becomes active with a status bar at the bottom of the dialog. It tracks the progress of the DEM generation.

   Once the process is complete, the cells in the **DTM** column of the CellArray become green.

2. In the Block Tree View of the LPS Project Manager, click on the plus sign [+] next to the **DTMs** folder.

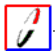
3. Click the generated DEM in the list.



Of course, if you want information about any of the tie points used in the creation of the DEM, you can use the Select icon  to click a point and obtain its Point Data.

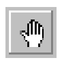
Use a Viewer

1. On the ERDAS IMAGINE toolbar, click the Viewer icon  .



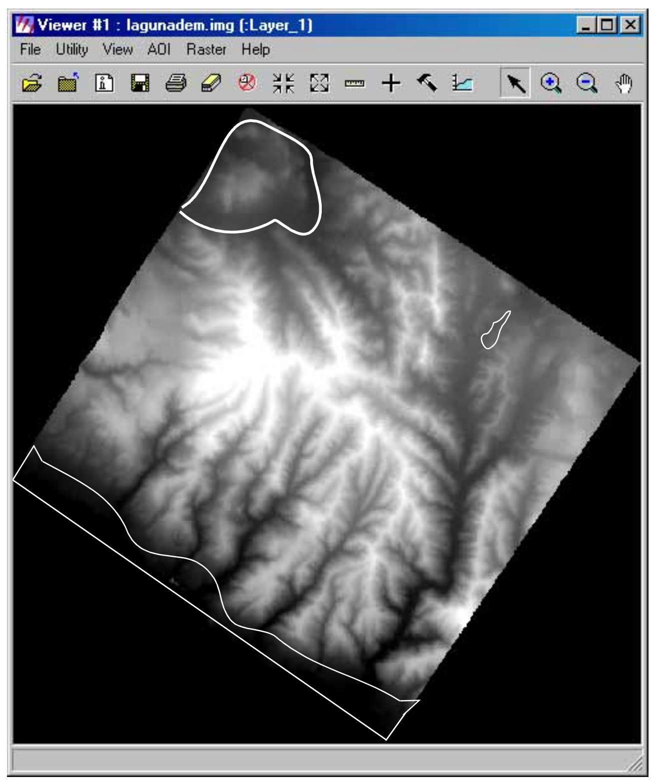
If necessary, select the type of Viewer you want to work with: **Classic Viewer** *or* **Geospatial Light Table.**

2. Click the Open icon  on the Viewer toolbar.
3. In the File Selector, click the **Recent** button.
4. In the List of Recent Filenames dialog, select **lagunadem.img** from the list, then click **OK.**
5. Click **OK** in the File Selector.

   The output DEM displays in the Viewer. You can use traditional Viewer tools, such as Zoom In  and Pan  , to evaluate the DEM.

Areas where regions and strategies were applied are identified

Note: The white lines associated with these regions do not appear on the output DEM, they are provided here as an example only



6. View the DEM closely, and locate the areas where you applied custom strategies.

For information about post-processing your DEM, see Appendix C "DTM Editing in ERDAS IMAGINE & Stereo Analyst".

View the Contour Map

The Contour Map is a 3D Shape file that also illustrates the topography in your DEM, but in a vector format. Creation of the Contour Map is an optional step. Contour Maps are automatically named as the DTM with the additional "_contour" element.

1. Click the Viewer icon 

on the ERDAS IMAGINE toolbar.

2. Click the Open icon  to access a File Selector.

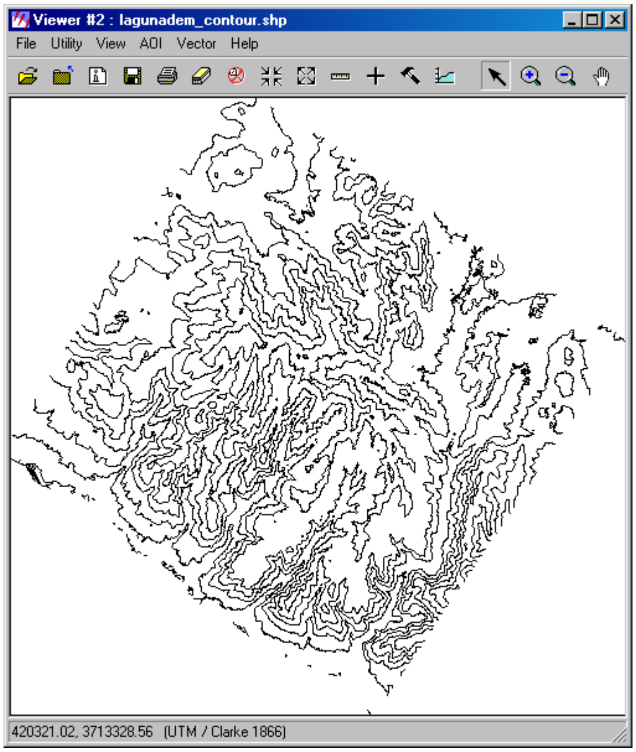
3. Navigate to the location in which you saved **lagunadem.img.**

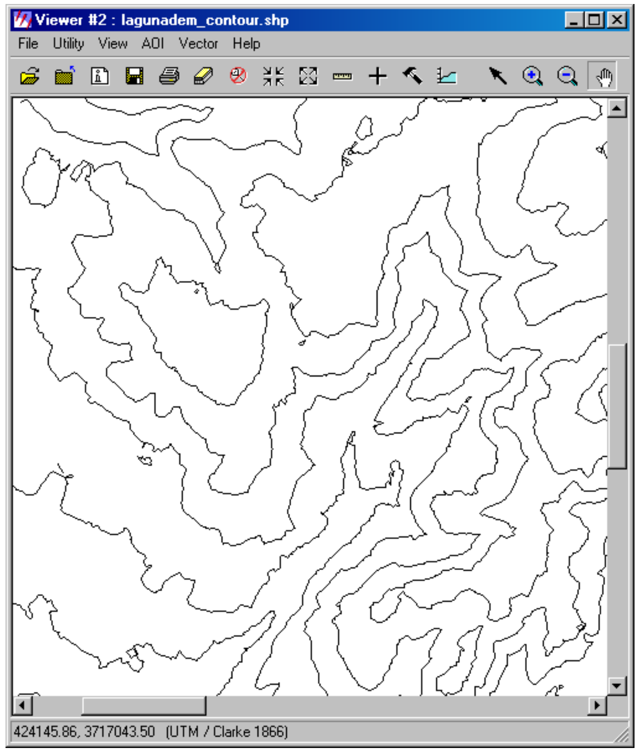
4. Click the **Files of type** dropdown list and select **Shapefile (*.shp).**

5. Select the Contour Map, **lagunadem_contour.shp** from the list.

6. Click the **OK** button.

   The Contour Map displays in the Viewer. This image is a 3D Shape file, and can be used in other applications such as ERDAS Stereo Analyst, IMAGINE VirtualGIS, and ArcView. Use the Zoom In icon  to see contour details.





You can also view the attributes of the 3D Shape file to see the Z elevation. To do so, select **Vector | Attributes** to open an attribute table.

View the DTM Point Status Image

The DTM Point Status image, like the Contour Map, is an optional output during the DTM extraction process. It is a raster representation detailing the quality of the output DTM.

1. Click the Viewer icon  .

2. Click the Open icon  .

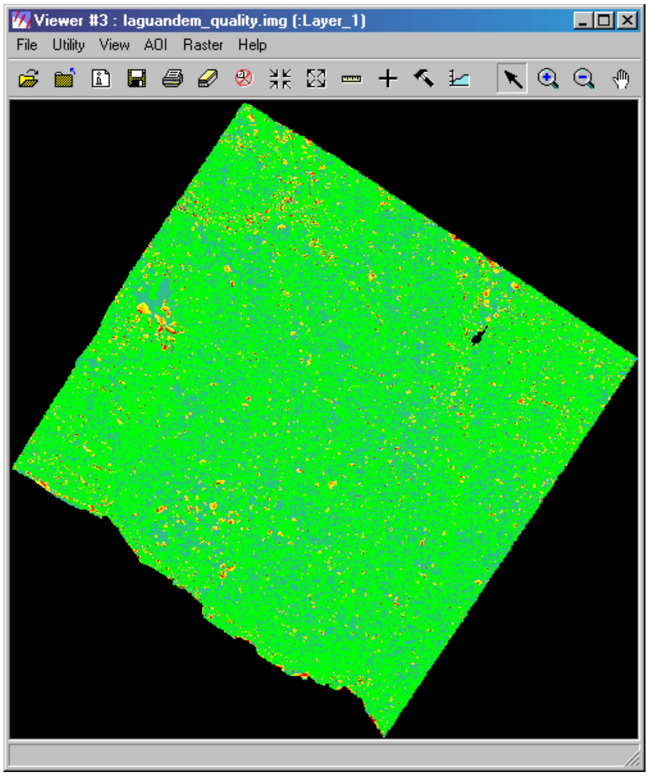
3. Click the **Files of type** dropdown list and select **IMAGINE Image (*.img).**

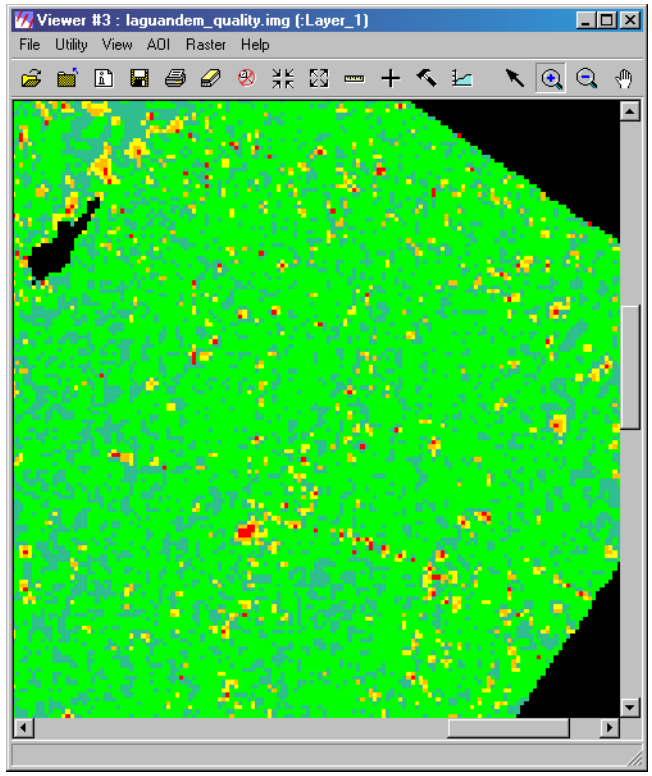
4. Select **lagunadem_quality.img** from the list.

5. Click the **OK** button.

6. Right-click in the Viewer and select **Fit Image to Window.**

   The quality image displays in the Viewer. Again, you can use the Zoom In icon to view the image in more detail.

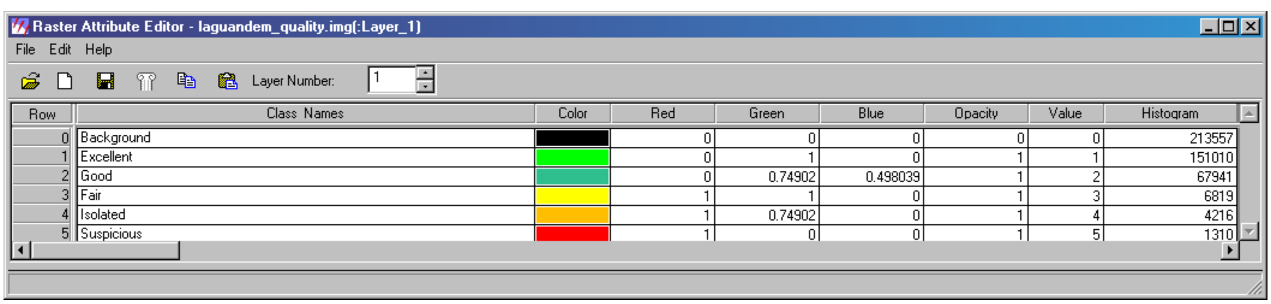




Next, you can evaluate the areas of Excellent, Good, and Fair correlation.

7. From the **Raster** menu, select **Attributes.**

   The Raster Attribute Editor dialog opens. Resize the dialog until you can see all of the columns.



Row	Class Names	Color	Red	Green	Blue	Opacity	Value	Histogram
0	Background		0	0	0	0	0	213557
1	Excellent		0	1	0	1	1	151010
2	Good		0	0.74902	0.498039	1	2	67941
3	Fair		1	1	0	1	3	6819
4	Isolated		1	0.74902	0	1	4	4216
5	Suspicious		1	0	0	1	5	1310

Overall, the accuracy of the output DTM is quite good; however, the pixels that appear to be red in the quality image should be inspected to ensure a high-quality output DTM. The value in the **Histogram** column represents the number of points in a particular class.

For information about post-processing, see *Appendix C "DTM Editing in ERDAS IMAGINE & Stereo Analyst"**.*

8. Close the Raster Attribute Editor and the Viewers containing the output images.

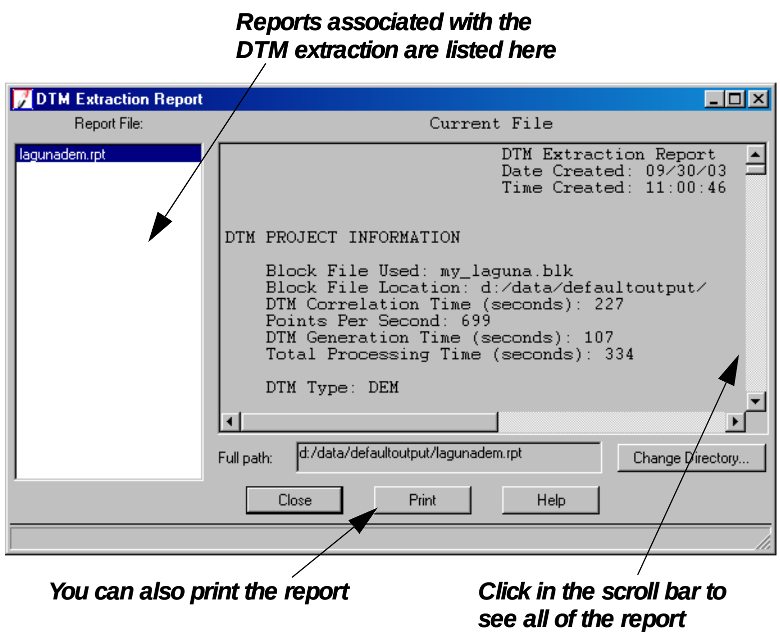
Check the DTM Extraction Report

Once you have successfully generated a DTM, you can view the report associated with it. Like the triangulation reports associated with OrthoBASE Pro, the DTM Extraction Report gives you statistical details about the accuracy and quality of the output DTM.

For information about the triangulation report, see "Aerial Triangulation Report" and "Triangulation Report".

1. From the **Process** menu, select **DTM Extraction Report.**

   The DTM Extraction Report dialog opens:

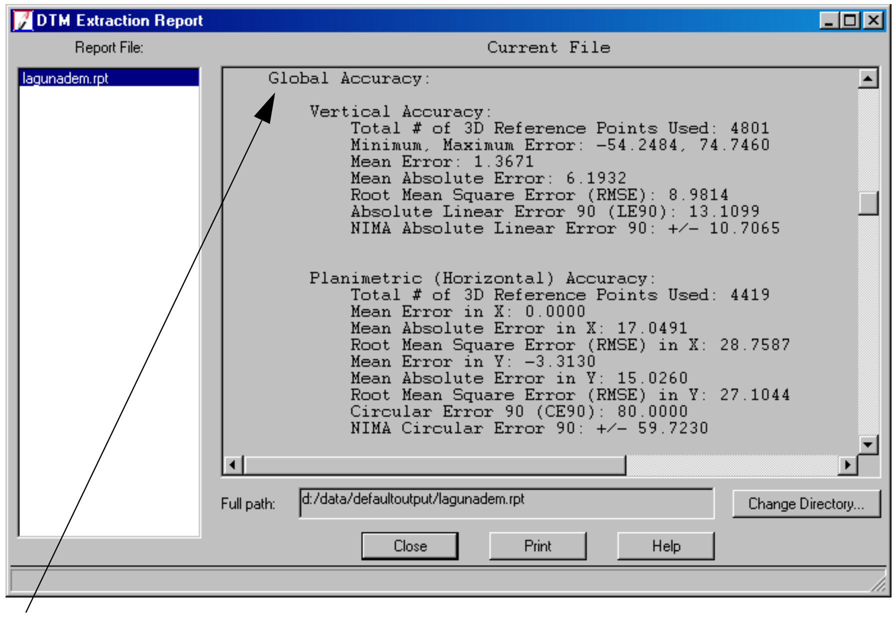


2. Notice that the **Report File** section lists a single report file, **lagunadem.rpt.**

   This section of the dialog displays a report for each DTM generated. If you had chosen to generate multiple files, a report for each individual output DTM would be listed here.

3. Click in the vertical scrolling region to see the contents of the report.

   A good section of the report to check is **Global Accuracy,** as depicted in the following illustration.



Check the Global Accuracy results to determine if you need to re-run the process with different strategy parameters

In general, you want the RMSE value to be within two times of the original pixel size of the imagery for the output DTM to be considered accurate to real-world conditions.

To improve the accuracy results, you can try adjusting strategy parameters applied to specific regions to improve accuracy. Ultimately, however, you must revisit the block file from which you extracted the DTM. Poor triangulation results in your block file yield poor DTMs. In this case, you can select more GCPs in the Point Measurement dialog, retriangulate, and run the DTM extraction process again.

4. Click **Close** in the DTM Extraction Report dialog.

For more information about the report's contents, see "DTM Extraction Report".

Save and Close the Block File

1. From the LPS Project Manager **File** menu, select **Save.**

If you wish, you can proceed to generate an orthoimage from the files in the laguna block file. See "Ortho Resample the Imagery" for instructions.

2. From the **File** menu, select **Exit.**

3. To exit ERDAS IMAGINE, select **Session | Exit IMAGINE.**

Conclusions

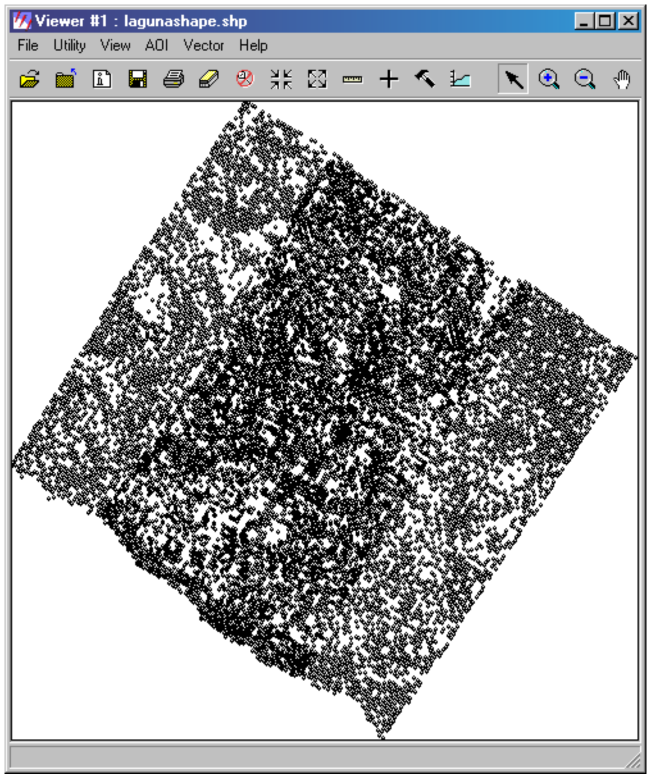
This tour guide has shown you some of the options you can select when creating an output DTM using OrthoBASE Pro. Whether you choose to specify complex strategies or use the default settings, OrthoBASE Pro applies a rigorous algorithm to produce DTMs of great accuracy.

View Types of DTMs

While this tour guide was written to extract a DEM, you can also choose from three other types of DTMs. This section shows you the output you get when you select 3D Shape, ASCII, or TerraModel TIN as your output DTM type.

3D Shape

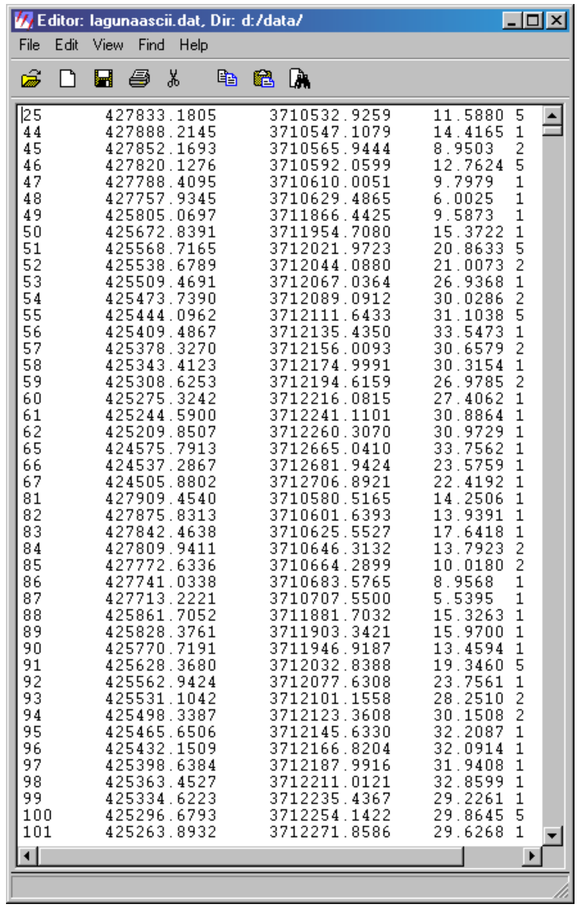
One type of output DTM is an ESRI 3D Shape (*.shp) file. This format is native to the ESRI ArcView and ArcInfo applications; however, it can be used in other ERDAS IMAGINE applications, such as Stereo Analyst. The following example shows a 20-meter Shape file generated from the Laguna Beach block file.



This can be brought into ArcView and ArcInfo applications for hydrological modeling, to create a TIN, or for use with 3D Analyst and ArcScene.

ASCII

An ASCII file can also be chosen as the output DTM type. This type of file can be used in many other applications such as Stereo Analyst, IMAGINE VirtualGIS, and ERDAS IMAGINE. A simple text file with a *.dat extension, the output is as follows:



25	427833.1805	3710532.9259	11.5880	5
44	427888.2145	3710547.1079	14.4165	1
45	427852.1693	3710565.9444	8.9503	2
46	427820.1276	3710592.0599	12.7624	5
47	427788.4095	3710610.0051	9.7979	1
48	427757.9345	3710629.4865	6.0025	1
49	425805.0697	3711866.4425	9.5873	1
50	425672.8391	3711954.7080	15.3722	1
51	425568.7165	3712021.9723	20.8633	5
52	425538.6789	3712044.0880	21.0073	2
53	425509.4691	3712067.0364	26.9368	1
54	425473.7390	3712089.0912	30.0286	2
55	425444.0962	3712111.6433	31.1038	5
56	425409.4867	3712135.4350	33.5473	1
57	425378.3270	3712156.0093	30.6579	2
58	425343.4123	3712174.9991	30.3154	1
59	425308.6253	3712194.6159	26.9785	2
60	425275.3242	3712216.0815	27.4062	1
61	425244.5900	3712241.1101	30.8864	1
62	425209.8507	3712260.3070	30.9729	1
65	424575.7913	3712665.0410	33.7562	1
66	424537.2867	3712681.9424	23.5759	1
67	424505.8802	3712706.8921	22.4192	1
81	427909.4540	3710580.5165	14.2506	1
82	427875.8313	3710601.6393	13.9391	1
83	427842.4638	3710625.5527	17.6418	1
84	427809.9411	3710646.3132	13.7923	2
85	427772.6336	3710664.2899	10.0180	2
86	427741.0338	3710683.5765	8.9568	1
87	427713.2221	3710707.5500	5.5395	1
88	425861.7052	3711881.7032	15.3263	1
89	425828.3761	3711903.3421	15.9700	1
90	425770.7191	3711946.9187	13.4594	1
91	425628.3680	3712032.8388	19.3460	5
92	425562.9424	3712077.6308	23.7561	1
93	425531.1042	3712101.1558	28.2510	2
94	425498.3387	3712123.3608	30.1508	2
95	425465.6506	3712145.6330	32.2087	1
96	425432.1509	3712166.8204	32.0914	1
97	425398.6384	3712187.9916	31.9408	1
98	425363.4527	3712211.0121	32.8599	1
99	425334.6223	3712235.4367	29.2261	1
100	425296.6793	3712254.1422	29.8645	5
101	425263.8932	3712271.8586	29.6268	1

In the above example, the ASCII file has five columns. The first column is the ID number of a point, the second column is the X value of that point, the third is the Y value of that point, and the fourth is the Z value of that point. The fifth is the status (based on correlation coefficiency) of each mass point. The number of points contained in the ASCII file is a function of the DTM cell size you select. You can use this ASCII file in other applications, such as ERDAS IMAGINE.

*The *.wcs file, which is located in the same folder as the output ASCII file, contains information regarding projection. You can open the *.wcs file in the HfaView. Select* **Tools | View IMAGINE HFA File Structure** *from the ERDAS IMAGINE menu bar to view the information.*

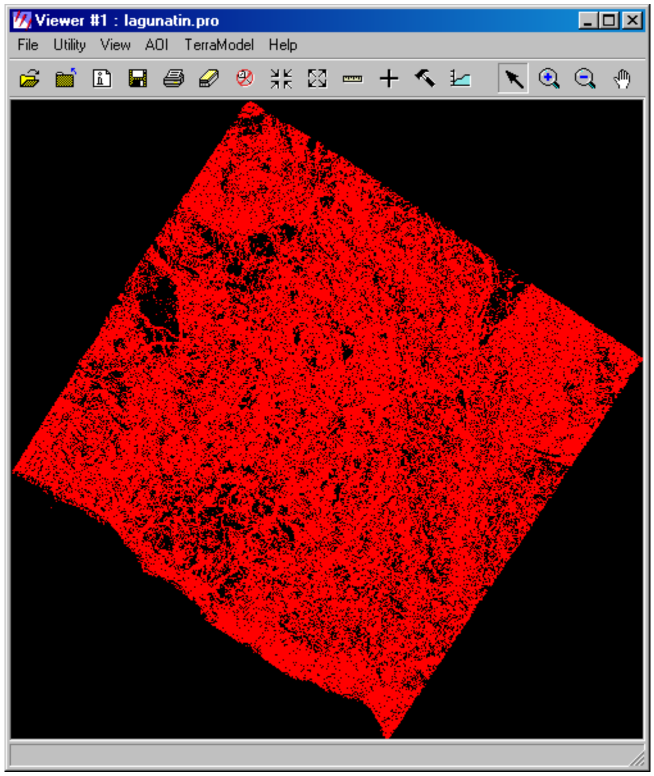
SOCET SET TIN

The SOCET SET TIN option produces a triangulated irregular network file that can be used in the SOCET SET product. SOCET SET TIN images are saved with the *.dth extension.

You can only use OrthoBASE Pro to generate a SOCET SET TIN if you have a licensed version of SOCET SET on your system.

TerraModel TIN

A TerraModel TIN file is composed of irregularly shaped triangles which denote changes in elevation in the images. TerraModel TIN images are saved with the *.pro extension. The following example shows a 20-meter TIN generated from the Laguna Beach block file:



In the above illustrations, the TerraModel TIN is displayed. TerraModel TIN files can be used as input for various engineering applications, and used in the various TerraModel software packages.

Section IV

Practical Applications

Chapter 8

Getting Started with OrthoBASE

Introduction

The chapters in this section give a detailed description of OrthoBASE and the photogrammetric concepts used within the software to bridge the fundamental concepts of photogrammetry, and the practical tools of OrthoBASE. Additional tips and tricks are provided to increase the production associated with block triangulation and orthorectification.

What is a Block?

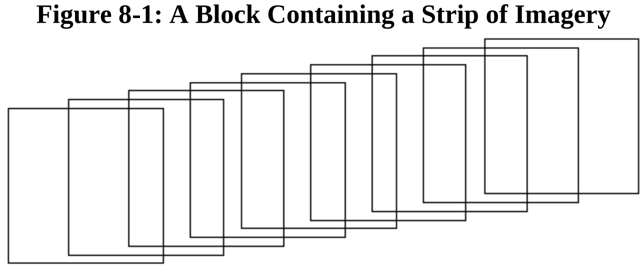
Prior to performing any photogrammetric tasks within OrthoBASE, a block must be created. Block is a term used to describe and characterize all of the information associated with a photogrammetric mapping project, including:

- projection, spheroid, and datum information,
- imagery used within a project,
- camera or sensor model information associated with the imagery,
- GCPs and their measured image positions, and
- geometric relationships between the imagery in a project and the ground.

OrthoBASE supports the processing of various types of blocks, including:

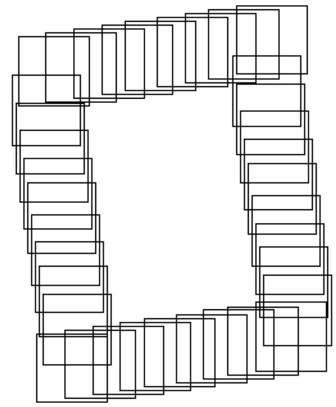
- A block containing one image for applications associated with single frame orthorectification. Single frame orthorectification is the process of orthorectifying one image using several GCPs and an elevation model. The GCPs are used to determine camera/sensor orientation, and the DEM is used to represent topographic relief. Both factors being considered, the geometric distortions associated with an image can be removed.
- A block containing a strip of imagery (see Figure 8-1). A strip of imagery comprises two or more images adjacent to one another containing common overlap areas. Typically, adjacent images or photographs contain approximately 60% overlap.

Figure 8-1: A Block Containing a Strip of Imagery



- A block containing several strips of imagery (see Figure 8-2). Adjacent strips of imagery commonly contain 20% to 30% sidelap. It is also common for adjacent strips to contain 60% sidelap, since this type of block configuration can provide greater accuracy and reliability during aerial triangulation. Additionally, OrthoBASE can accommodate cross-strips.

Figure 8-2: A Block Containing Several Strips of Imagery



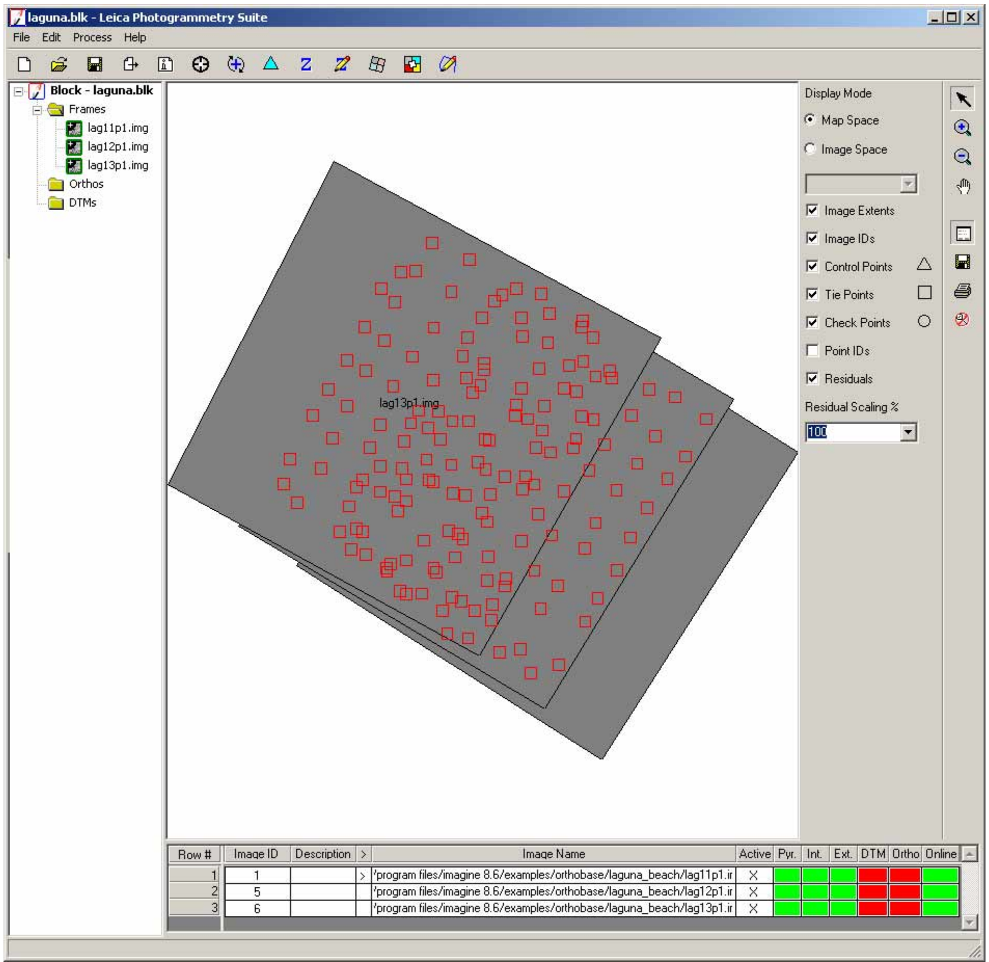
OrthoBASE provides a linear workflow for the creation of a block. The following steps are required to create the block:

- define a project name,
- define the sensor model,
- define the reference coordinate system,
- define the units,
- define the mapping sensor rotation systems,
- define the characteristics of the imagery (e.g., aerial or ground-based), and
- import the exterior orientation information, which is the position and orientation of the camera/sensor at the time of exposure.

OrthoBASE Project

Once you click the LPS icon  within the ERDAS IMAGINE icon bar, the linear workflow associated with creating a block is enabled. The first dialog is depicted in Figure 8-3.

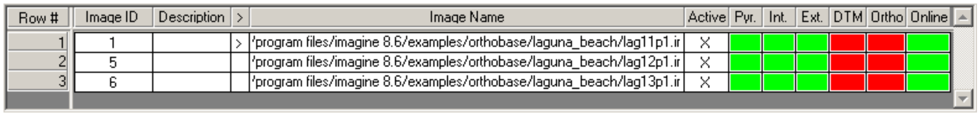
Figure 8-3: The Leica Photogrammetry Suite Dialog



You can create a new OrthoBASE project by choosing **File | New**, or open an existing OrthoBASE project, by choosing **File | Open**, from this dialog. In either case, you work with a block file (*.blk). The block file is a binary file containing all of the information associated with a block. Select the **View IMAGINE HFA File Structure** option within the ERDAS IMAGINE **Tools** menu to view the contents of the binary file.

In an existing block file is open, laguna.blk (which is located in the examples that come with LPS). If you open an existing block file, the LPS Project Manager's CellArray is populated with information about the images contained in the block, as in Figure 8-4.

Figure 8-4: LPS CellArray

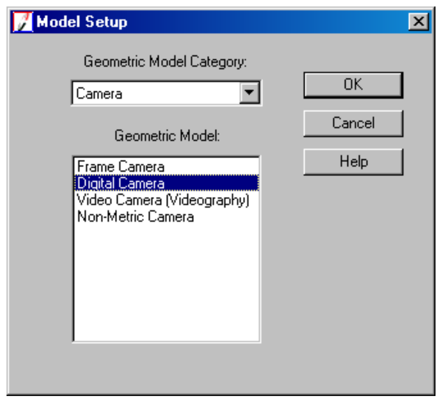


For information about height extraction, which is indicated by the **DTM** *column in the LPS Project Manager CellArray, see Chapter 14 "Automatic DTM Extraction".*

Geometric Model

OrthoBASE supports the orthorectification of photography and imagery from various camera and satellite sensor types. In order to process the various types of photography and imagery, the appropriate camera or sensor model which defines the geometry of the sensor must be selected. Figure 8-5 shows the Model Setup dialog.

Figure 8-5: Model Setup Dialog



The geometric properties of a camera or sensor model define the internal and external characteristics associated with it. Internal characteristics include parameters which define the internal geometry of the camera or sensor as it existed when the imagery was captured. The external parameters define the original position and orientation of the camera or sensor when the imagery was captured.

Each camera and sensor type has different internal and external properties associated with it. OrthoBASE estimates both the internal and external characteristics associated with a sensor model in order to accurately model the geometry of the camera or sensor model. This information is required for point determination and the creation of orthorectified images, DEMs, and stereopairs.

Frame cameras, digital cameras, videography, and nonmetric cameras have a perspective center. The perspective center is the optical center of a camera lens. All light rays that pass through a lens pass through the perspective center. The elements of exterior orientation define the position of the perspective center relative to the ground coordinate system. Cameras have one perspective center. Pushbroom sensors have multiple perspective centers, according to the number of scan lines in the image.

Cameras

The properties associated with cameras can include, but are not limited to, focal length, principal point, calibrated fiducial mark positions, and radial lens distortion. The following geometric models are supported within OrthoBASE:

Frame Camera

This type of camera is commonly associated with aerial cameras having an approximate focal length of 6 inches (152 mm). The photographic format size from these cameras is 9 × 9 inches. Frame cameras have fiducial marks positioned within the camera body. The fiducial marks are exposed onto the film emulsion when the photography is captured. The fiducial marks are subsequently measured to determine the interior orientation of the camera. Frame cameras are considered metric cameras since they have been calibrated in a laboratory.

Digital Camera

This type of camera can be used for aerial and ground-based (terrestrial) mapping applications. The focal length for a digital camera may range in size from 10 mm to 50 mm or greater. Rather than using film to record an image, digital cameras make use of a CCD. A CCD contains an array of cells which record the intensity associated with a ground feature or object. The x and y pixel size of the CCD array must be defined. Digital cameras do not have fiducial marks, and for that reason they do not need to be measured. Digital cameras are considered nonmetric, noncalibrated cameras.

Video Camera (Videography)

This type of camera can be used for aerial and ground-based (terrestrial) mapping applications. The focal length for a video camera may range in size from 10 mm to 50 mm or greater. A video camera can use either film or a CCD to record an image. If a film video camera is used, the film scanning resolution must be used for interior orientation. If a CCD type is used, the x and y pixel size of the CCD array must be defined. Video cameras do not have fiducial marks, and for that reason they do not need to be measured. Video cameras are considered nonmetric, noncalibrated cameras.

Non-metric Camera (35 mm, Medium, and Large Format Cameras)

This type of camera can be used for aerial and ground-based (terrestrial) mapping applications. This type of camera may include amateur 35 mm cameras and medium to large format cameras (e.g., 75 mm focal length). The focal length for a nonmetric camera may range in size from 10 mm to 152 mm or greater.

A nonmetric camera is a camera which has not been calibrated in a laboratory to define its internal geometry. The primary camera parameters which have not been calibrated include focal length, principal point, lens distortion, and fiducial marks. The minimum interior orientation input requirements include an approximate focal length, and the scanning resolution used to digitize the film.

DPPDB

DPPDB is the acronym for Digital Point Positioning Data Base. This type of camera is for data, designed by NIMA, which is classified. Not everyone has access to DPPDB data. It can be described as high-resolution stereo data with support files, which normally covers a 60 nautical mile range (Federation of American Scientists, 2000).

Pushbroom Sensors

Pushbroom data is collected along a scan line, with each scan line having its own perspective center. The following geometric models are supported:

Generic Pushbroom

This type of satellite pushbroom sensor can be used for satellites other than SPOT, IKONOS, and IRS-1C, which scan along a line to collect data. Sensor model parameters associated with the internal geometry of the sensor must be provided.

SPOT Pushbroom

The SPOT pushbroom sensor supports SPOT Panchromatic (10-meter ground resolution), and SPOT XS Multispectral (20-meter ground resolution) imagery. Sensor model properties associated with the satellite are automatically derived from the header file of the imagery and subsequently used in OrthoBASE. The ERDAS IMAGINE Import tool can be used to import the SPOT imagery.

IRS-1C Pushbroom

The IRS-1C sensor model supports imagery collected from the IRS-1C pushbroom sensor model (5-meter ground resolution). Sensor model properties associated with the satellite are automatically derived from the header file of the imagery and subsequently used in OrthoBASE. The ERDAS IMAGINE Import tool can be used to import the IRS-1C imagery.

Orbital Pushbroom

The Orbital Pushbroom model is a generic model, which is able to compute the transformation between image pixel (image space, which is the source image pixel location) and ground point (ground space, which is the ground point location) for pushbroom sensors suck as QuickBird, EROS A1, ASTER, and SPOT. Generic modeling is based on the metadata information about the sensor orbit.

RPC

RPC (rational polynomial coefficient) files contain rational function polynomial coefficients that are generated by the data provider based on the position of the satellite at the time of image capture.

IKONOS

The IKONOS sensor model supports IKONOS imagery and its associated rational polynomial coefficient (RPC) and metadata files. The metadata files contain information regarding the images in the data set. RPC files contain the necessary information to determine interior and exterior orientation.

NITF RPC

The National Imagery Transmission Format (NITF) is the standard format for digital imagery and imagery-related products used by the Department of Defense and the intelligence community. NITF is designed to be a common format for exchange of imagery data between normally incompatible systems.The metadata files contain information regarding the images in the data set. RPC files contain the necessary information to determine interior and exterior orientation.

QuickBird RPC

QuickBird data, which is supplied by DigitalGlobe, in “Basic” and “Standard” formats can be used in OrthoBASE for the creation of block files. QuickBird images are delivered with image support data (ISD) files that detail information such as ephemeris and RPCs. The RPC data, which accompanies QuickBird images in GeoTIFF or TIFF format, can be used to define the sensor.

Mixed Sensor

The Mixed Sensor model supports OrthoBASE calibrated images, oriented images, and SOCET SET® support files. Images without geometric models already associated with them cannot be used with the Mixed Sensor geometric model. Using this model, the same block file may have multiple projections and the may also have images with different vertical datum and units.

NOTE: With the Mixed Sensor geometric model type, you cannot perform automatic tie point generation. Also, the triangulation process is used to check errors in GCPs only.

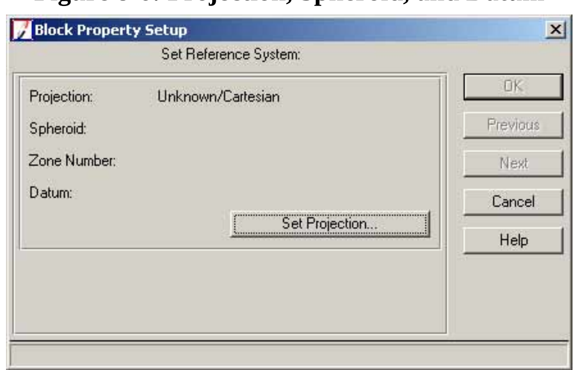
Once a sensor model has been selected for a block file, it cannot be changed within OrthoBASE.

Reference Coordinate System

A reference coordinate system defines the projection, spheroid, and datum for the block project. OrthoBASE supports the use of multiple projections (e.g., UTM, State Plane, Geographic), spheroids (e.g., Clarke 1866, GRS80, WGS84), and datums (e.g., NAD 27, NAD 83).

Once the appropriate geometric model has been selected, the Block Property Setup dialog, shown in Figure 8-6, is provided, which allows for the specification of a projection, spheroid, and datum.

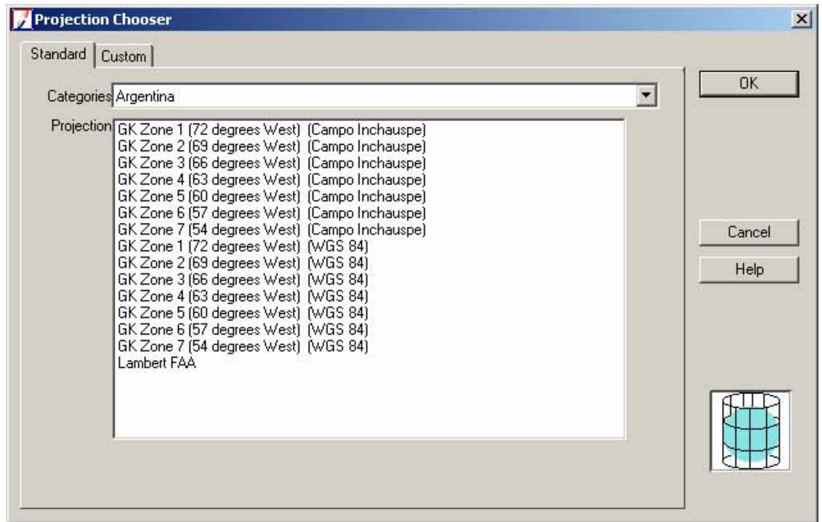
Figure 8-6: Projection, Spheroid, and Datum



A right-handed cartesian coordinate system is supported in the case that a projection, spheroid, and datum are not specified or required.

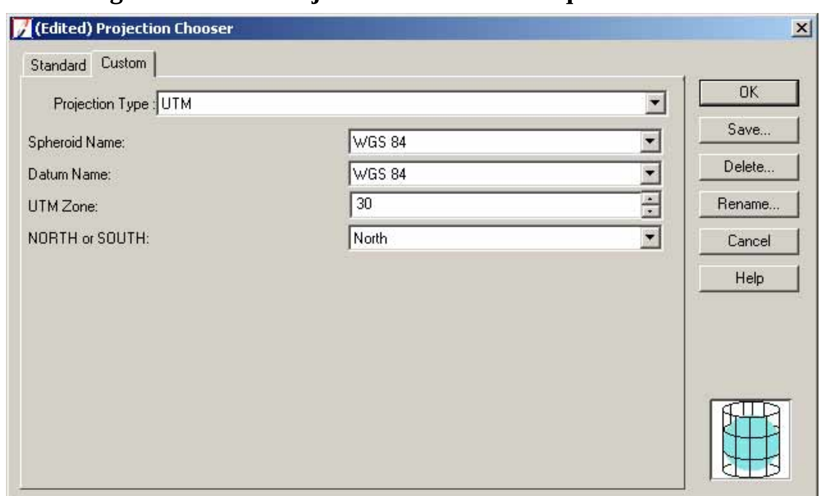
By selecting the **Set Projection** option within the Block Property Setup dialog, the Projection Chooser dialog opens, as shown in Figure 8-7.

Figure 8-7: The Projection Chooser



A standard set of existing projections is contained within the **Categories** dropdown list of the **Standard** tab. If a given projection/datum is not listed within the category list, the **Custom** tab can be selected to define a unique projection, spheroid, and datum, as shown in Figure 8-8.

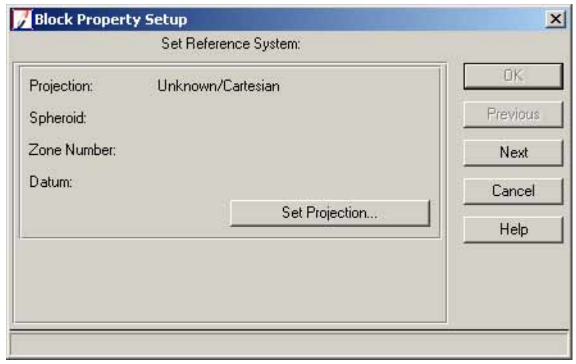
Figure 8-8: The Projection Chooser—Unique Parameters



Once a custom reference system has been defined, all of the projection information can be saved and reused for other mapping projects. If a reference system is saved, the corresponding system opens within the category list contained within the **Standard** tab of the Projection Chooser dialog. Additionally, existing reference systems contained within the category list can also be deleted and renamed.

Once a reference system has been selected, the respective projection/spheroid/datum information displays within the Block Property Setup dialog, as shown in Figure 8-9.

Figure 8-9: Block Property Setup Dialog

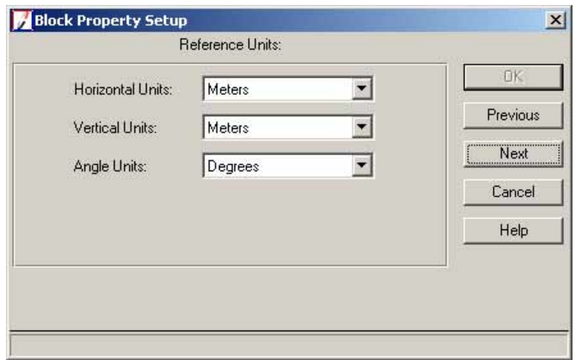


The **Next** and **Previous** buttons in the Block Property Setup dialog provide a linear project setup environment for the definition of an OrthoBASE project. During any portion of the setup, the next or previous steps associated with defining the project can be accessed.

Defining Units

Once **Next** has been selected, the horizontal, vertical, and angular units associated with a block project can be defined, as shown in Figure 8-10.

Figure 8-10: Horizontal, Vertical, and Angular Units



OrthoBASE supports the following horizontal and vertical units: **Meters, Feet, US Survey Feet, Indian Feet, International Feet, Centimeters,** and **Inches.** Angular unit support includes **Degrees, Radians,** and **Gons.**

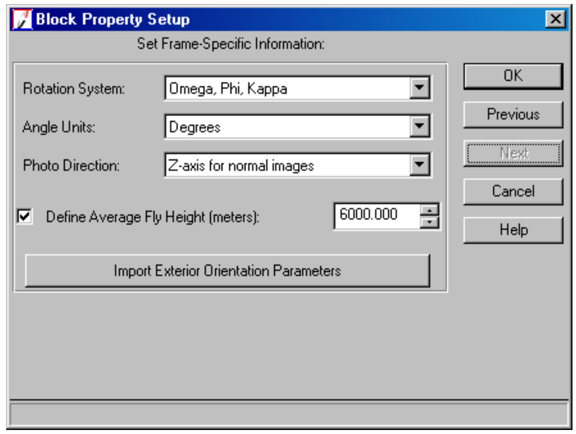
Defining Frame-specific Information

OrthoBASE allows for the specification of additional information associated with photogrammetric components of the mapping project. This includes:

- rotation system type
- photographic direction of the imagery in the project
- average flying height
- import of exterior orientation parameters

After the units types have been selected in the Block Property Setup dialog, select the **Next** button. The dialog that allows for the specification of photogrammetric information opens, as shown in Figure 8-11.

Figure 8-11: Photogrammetric Information in Block Property Setup Dialog



Rotation System Support

OrthoBASE accommodates the use of three rotation systems. A rotation system defines the axis used to characterize the orientation of a camera/sensor at the time of exposure. A rotation system is defined as having three rotation angles. These include an Omega rotation around the x-axis, Phi rotation around the y-axis, and Kappa rotation around the z-axis. The rotation angles define the angular relationships between the x, y, or z axes of a tilted image (defined by the photo/image coordinate system), and the X,Y, or Z axes of the ground (defined by the ground coordinate system).

Different countries around the world employ different conventions for rotation systems. The three options within the **Rotation System** dropdown list include:

Omega, Phi, Kappa

This convention is most commonly used throughout the world. Omega is a positive rotation around the x-axis, Phi is a positive rotation around the y-axis, and Kappa is a positive rotation around the z-axis. In this system, x is the primary axis, indicating that the first rotation in forming the rotation matrix is around the x-axis.

The positive axis is also known as the primary axis. The primary axis is the axis around which the first rotation occurs. Rotation follows the right-hand rule, which says that when the thumb of the right hand points in the positive direction of an axis, the curled fingers point in the direction of positive rotation for that axis.

Phi(+), Omega, Kappa

This convention is most commonly used in Germany. Phi is a positive rotation about the y-axis, Omega is a positive rotation around the x-axis, and Kappa is a positive rotation around the z-axis. In this system, y is the primary axis, indicating that the first rotation in forming the rotation matrix is around the y-axis.

Phi(-), Omega, Kappa

This convention is most commonly used in China. Phi is a negative rotation around the y-axis, Omega is a positive rotation around the x-axis, and Kappa is a positive rotation around the z-axis. In this system, y is the primary axis, indicating that the first rotation in forming the rotation matrix is around the y-axis.

Since various rotation systems are supported, additional transformations from one rotation system to another are not required.

Photographic Direction

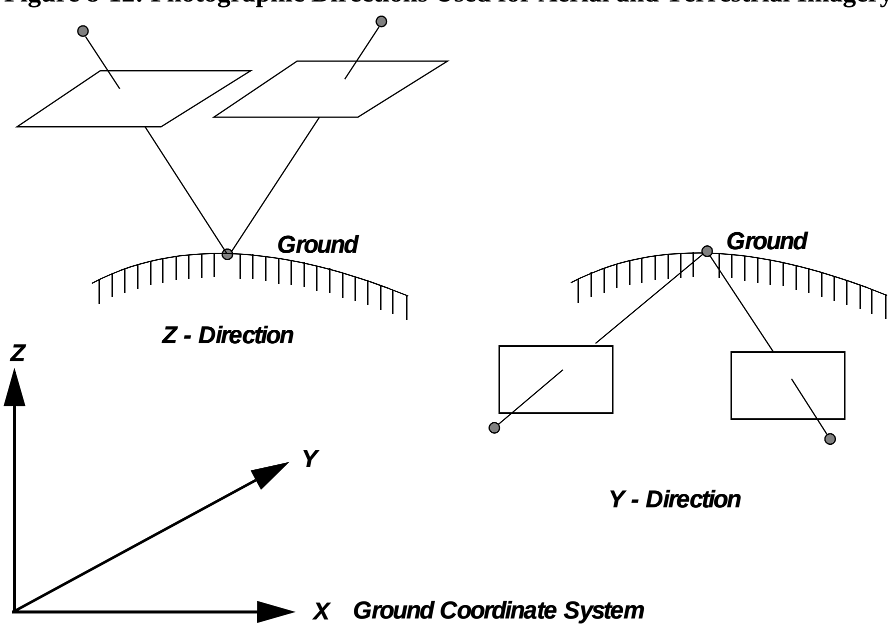
OrthoBASE supports the processing of aerial, terrestrial (ground-based), and oblique imagery. A photographic direction is specified in order to define the type of imagery to be processed.

Aerial photography and imagery are captured with the optical axis of the camera having a Z direction. This type of imagery is most commonly used for topographic and planimetric mapping applications. Therefore, when utilizing aerial or vertical photography, the **Z-axis for normal images** option should be selected within the **Photo Direction** dropdown list.

Terrestrial or ground-based photography has the optical axis of the camera directed toward the Y-axis of the ground coordinate system. Therefore, when utilizing terrestrial photography, the **Y-axis for close range images** option should be selected. This type of photo direction is commonly used for applications involving close-range photography (e.g., the distance between the imaged object and the camera station is minimal).

Figure 8-12 illustrates the differences between aerial or vertical imagery, and terrestrial photography and imagery:

Figure 8-12: Photographic Directions Used for Aerial and Terrestrial Imagery

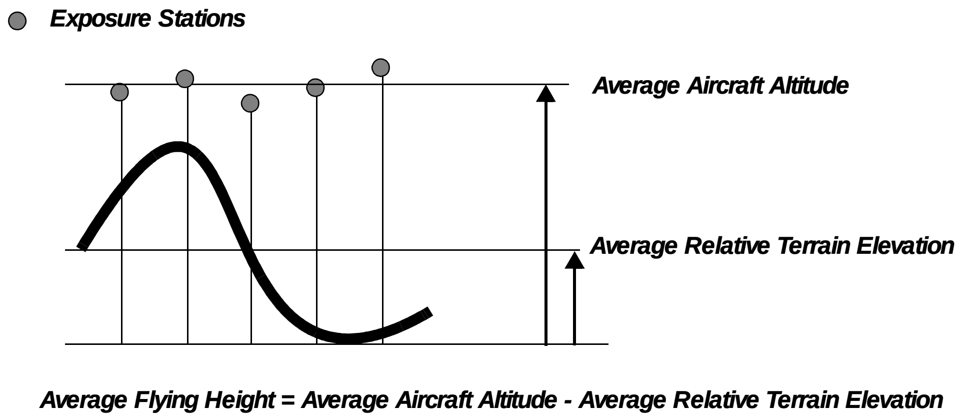


The photographic direction (vertical) for aerial photography is in the Z direction. The same photographic direction for terrestrial photography and imagery is in the Y direction. OrthoBASE automatically translates all of the coordinates from one system to another.

Average Flying Height

The average flying height is the distance between the camera position at the time of exposure and the average ground elevation. Figure 8-13 graphically illustrates the average flying height:

Figure 8-13: Average Flying Height of an Aircraft Above Ground Level



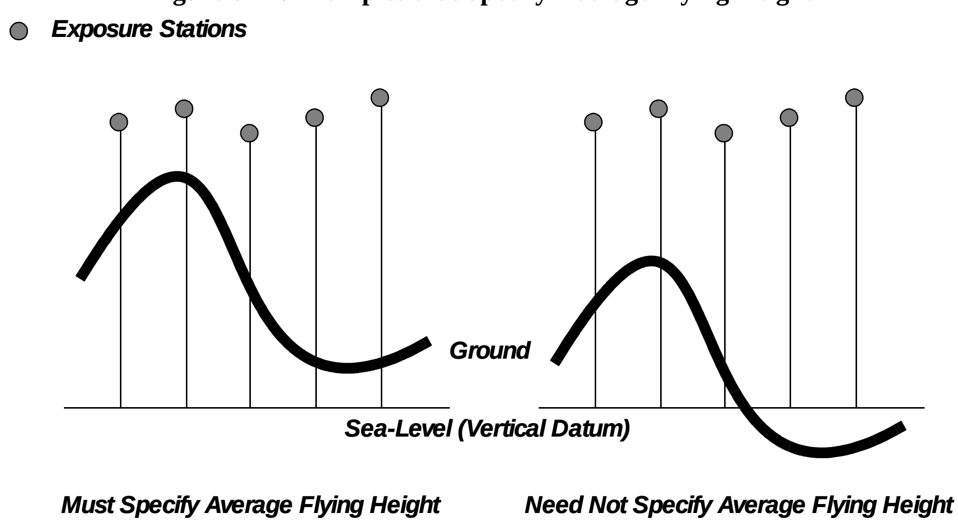
The average flying height is an optional input requirement that specifies the altitude or height of the camera/sensor at the time of exposure. This distance is above ground, not above mean sea level. The specification of this value assists the automatic tie point collection algorithm when the exterior orientation parameters (e.g., initial approximations or final values) have been entered.

If the average flying height is close to the exterior orientation Z coordinate values, the average flying height does not need to be specified. In other words, the average flying height does not need to be specified if the altitude of the aircraft over the average ground surface is similar to the altitude of the aircraft over mean sea level. Otherwise, it is recommended to specify the average flying height.

The average flying height is commonly provided by the photographic instrumentation used to capture the data. If the average flying height is not available (and the photo scale/image scale known), the average flying height can be determined by multiplying the focal length by the image scale.

The illustrations in Figure 8-14 define when the average flying height is not required.

Figure 8-14: Examples that Specify Average Flying Height



The average flying height should be specified when the Z plane (defined by the type of datum) deviates substantially relative to the average ground level. This is primarily the case for mountainous areas with large variations of topographic relief displacement.

NOTE: The Average Fly Height is helpful when you use the Exterior Initial Type option for auto tie. If the Tie Points Initial Type option is selected for auto tie, the Average Fly Height does not influence results.

For more information about auto tie, see "Minimum Input Requirements".

Importing Exterior Orientation Parameters

In cases where the position and orientation of the exposure stations (exterior orientation) for the images in a block are known, an ASCII file containing the respective information can be imported. The exterior orientation parameters define the position and rotation of a camera/sensor as they existed when the photography/imagery was captured. The positional elements are defined using the X, Y, and Z coordinates of the exposure station, and the rotational elements are defined as the degree of tilt in each image. This can be expressed using the three rotation angles (Omega, Phi, and Kappa). The exterior orientation parameters can be obtained from various sources, including:

- Airborne GPS and INS data. The GPS component provides the X, Y, and Z coordinates of the exposure station to a given accuracy. The INS provides the Omega, Phi, and Kappa rotation angles. The INS attempts to stabilize the movement of the platform during collection. For these reasons, the Omega and Phi rotations associated with the INS are minimal, and at times negligible.
- Existing photogrammetric workstations. Exterior orientation parameters have been determined by using external systems including analog stereo plotters, analytical stereo plotters, digital photogrammetric workstations, softcopy systems, and aerial triangulation packages.
- Initial values approximated from topographic maps. In this scenario, only the X, Y, and Z coordinates of exterior orientation can be approximated.

Why Import Exterior Orientation Parameters?

Overall, the availability of the exterior orientation parameters advances the automation of the workflow associated with creating orthorectified images. Following are some examples of the usefulness of exterior orientation parameters.

- If exterior orientation parameters are available, the manual steps of measuring at least two GCPs or tie points on the overlap areas of each image in the project are not required to perform automatic tie point collection. Instead, OrthoBASE uses the exterior orientation information to fully automate the measurement of points.
- If the values for exterior orientation are known to a high accuracy (i.e., less than one meter), the process of performing aerial triangulation is not required. Thus, the OrthoBASE workflow includes defining the block, adding imagery to the block, defining the camera, specifying interior orientation, and then performing orthorectification. Additionally, GCPs are not required.

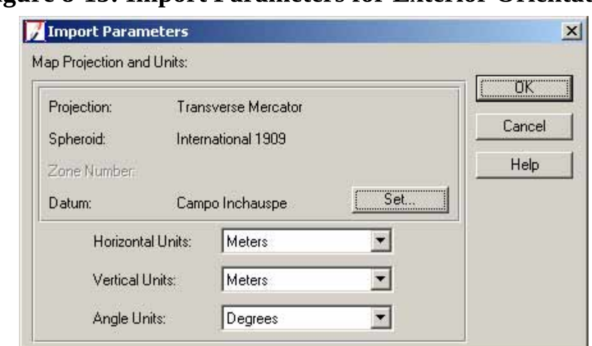
- If the values of exterior orientation are known to a given level of accuracy, the initial approximations are useful for ensuring a high accuracy when estimating the adjusted exterior orientation information and the X, Y, and Z coordinates of ground coordinates.
- If the relative orientation parameters between the images in the block are known, these values can be used to perform automatic tie point collection.
- If the SCBA is being used to determine the interior orientation parameters associated with the camera, statistically constraining the imported exterior orientation parameters increases the accuracy of the final solution.

The **Import Exterior Orientation Parameters** button within the Block Property Setup dialog activates the ERDAS IMAGINE Import Options dialog. The ASCII file to be imported must have a *.dat file extension. The contents of the ASCII file must include (in no particular order or delimitation):

- Image ID
- Image Name
- X
- Y
- Z
- Omega
- Phi
- Kappa

Once a *.dat file has been selected, the Import Parameters dialog opens, shown in Figure 8-15 wherein the reference coordinate system and units of the incoming exterior orientation parameters can be specified.

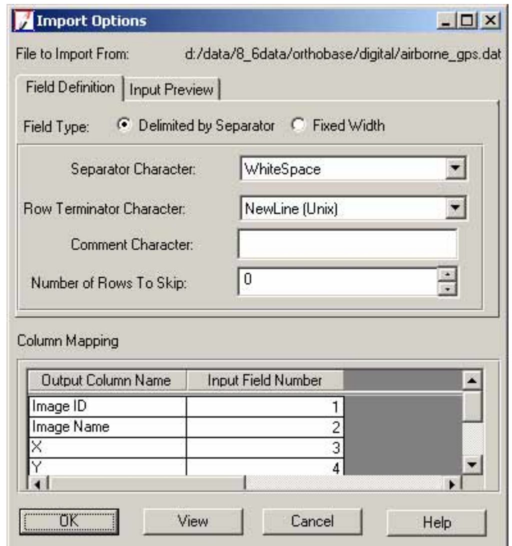
Figure 8-15: Import Parameters for Exterior Orientation



By selecting the **Set** option, the Projection Chooser opens. The reference coordinate system and the horizontal, vertical, and angular units of the information contained within the ASCII file can be defined. OrthoBASE automatically transforms the values contained within the ASCII file to the appropriate projection, spheroid, and datum used by the block project.

Once the reference coordinate system and units have been specified and verified, the Import Options dialog opens, as shown in Figure 8-16.

Figure 8-16: Import Options for Exterior Orientation



The following properties associated with the input ASCII *.dat file can be defined:

- **Field Type.** Choose either **Delimited by Separator** or **Fixed Width.**
- If **Delimited by Separator** is selected**,** the following **Separator Character** options are provided:
  - White Space
  - Tab
  - Colon
  - Comma
  - Semi-Colon
  - Vertical Bar (|)
  - Space
- Regardless of the **Field Type,** a **Row Terminator Character** must be specified. The options include:
  - New Line (UNIX)
  - Return New Line (DOS)
  - Return (MacOS)

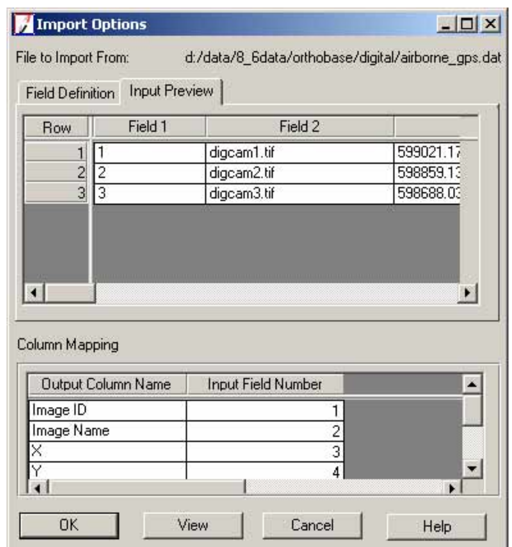
- Depending on the nature of the input, an ASCII **Comment Character** can also be specified. ASCII files tend to use comment characters such as "#" or "*" to differentiate user-specified comments from pertinent exterior orientation data.

- Depending on the nature of the ASCII file, an ASCII header file may exist at the beginning of the *.dat file. If this is the case, you can exclude this information from being considered during the import by defining the **Number of Rows To Skip** during the import.

The ASCII importer is flexible with respect to the column formatting of the input exterior orientation data. The **Column Mapping** section of the Import Options dialog associates the **Input Field Number** with the **Output Column Name.** The **Input Field Number** defines the column number within the ASCII file, and the **Output Column Name** defines the associated exterior orientation parameter. Selecting the **View** option displays the original ASCII *.dat file using the ERDAS IMAGINE ASCII Editor. Within this environment, you have the option of modifying, verifying, and saving the original ASCII file.

The **Input Preview** tab, shown in Figure 8-17, allows for the verification of the **Input Field Number** and **Output Column Name** associations.

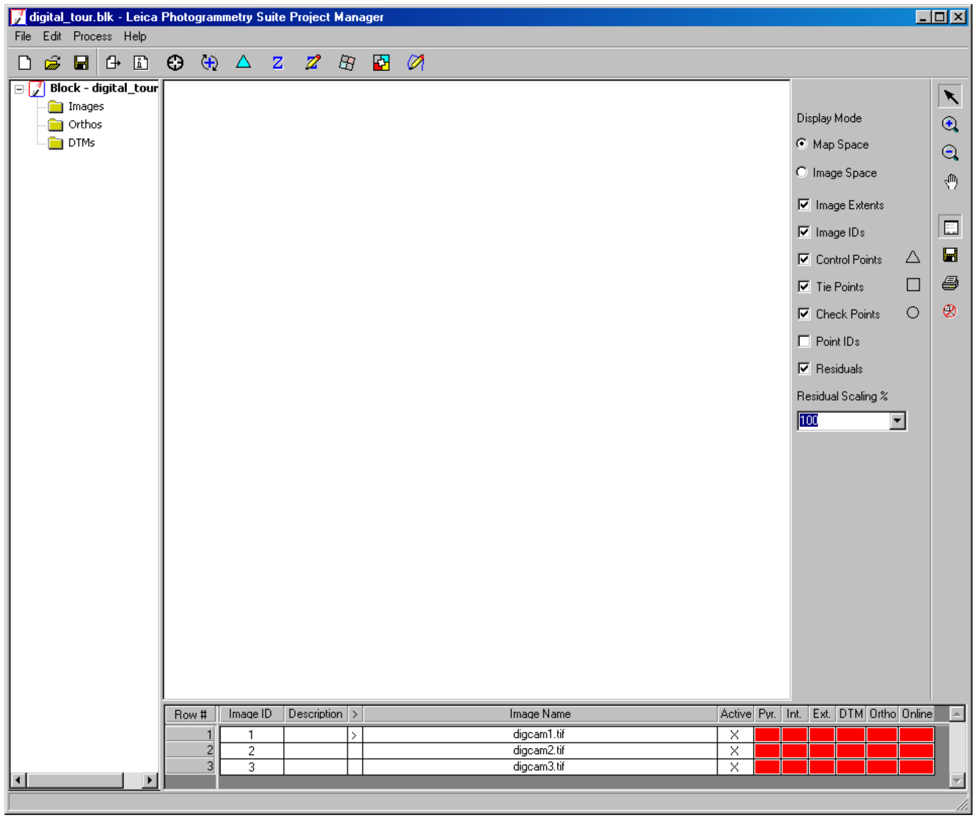
Figure 8-17: Preview the Contents of the Input ASCII File



If you wish to change the respective associations, the **Input Field Number** can be modified to reflect the input ASCII file. To import the exterior orientation parameters, select **OK.**

When the **OK** button within the Block Property Setup dialog has been selected, the CellArray updates. If the exterior orientation parameters were imported, the LPS Project Manager shown in Figure 8-18 opens.

Figure 8-18: The LPS Project Manager CellArray with Imported Exterior Data



Since the imagery was already added to the block when the exterior orientation parameters were imported, the image names must now be attached to the corresponding image files. See “Attaching Multiple Images”.

Once the **OK** *button has been selected within the Block Property Setup dialog, the geometric model, projection information, units and average flying height information cannot be modified.*

As an alternative approach, all of the images in a project can be added to the block within the LPS Project Manager, and the exterior orientation parameters imported using the **Edit All Images** option contained within the **Exterior Information** tab of the Frame Editor.

Project Setup for Sensor Models

The block property setup involves the following steps when the SPOT, IRS-1C, IKONOS, or Generic Pushbroom sensor models are selected within the Set Geometric Dialog:

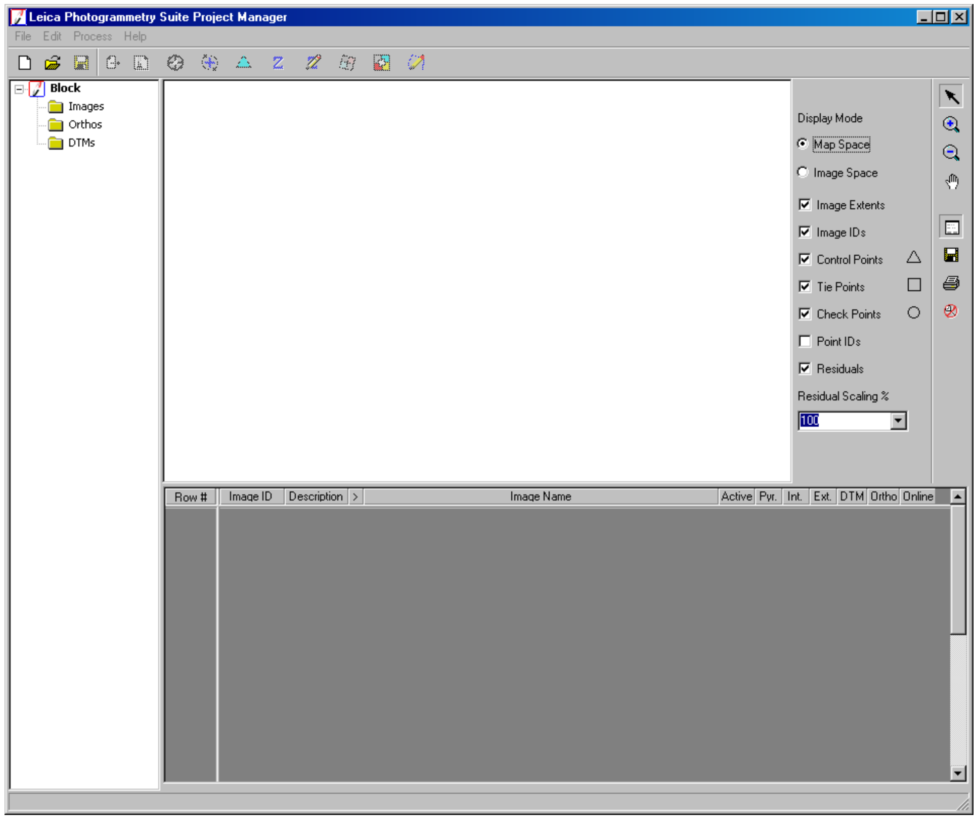
- Define the reference coordinate system. (i.e., projection, spheroid and datum). (See “Reference Coordinate System”.)
- Define the units. (See “Defining Units”.)

Once the block project has been defined, the LPS Project Manager opens.

The LPS Toolbar

When a new OrthoBASE block has been created or an existing block opened, the LPS Project Manager and CellArray open, as shown in Figure 8-19.

Figure 8-19: LPS Project Manager



Icons are located on the toolbar at the top of the LPS Project Manager that simulate the photogrammetric workflow associated with performing triangulation and creating orthorectified images. Each icon performs a given portion of the photogrammetric workflow.

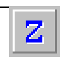
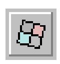
OrthoBASE Pro introduces an optional elevation extraction step in the photogrammetric workflow. You access the functionality by clicking the DTM Extraction icon Z on the toolbar. For more information, see Chapter 14 "Automatic DTM Extraction".

A photogrammetric workflow using LPS includes the following steps:

Table 8-1: LPS Workflow

1.		Add imagery to the block. This step involves adding one or multiple images to the project.
2.		Input parameters in the frame editor. This step defines the camera/sensor model properties used to collect the photography or imagery. If photography or imagery collected from a camera is used, additional dialogs are provided for defining the camera and performing interior orientation.

Table 8-1: LPS Workflow

3.		Perform point measurement. GCPs, tie points, and check points can be measured on one image or multiple images. Additionally, reference sources can be defined and used for the collection of GCPs.
4.		Conduct automatic tie point collection. OrthoBASE automatically measures the corresponding tie point positions of points appearing on more than one image.
5.		Run aerial triangulation. The aerial triangulation process simultaneously estimates the exterior orientation parameters of each camera/sensor station that existed at the time of image exposure, and the X, Y, and Z ground coordinates of tie points. The exterior orientation parameters are computed for each image in a block. Additionally, the camera's interior orientation parameters can be estimated by using the SCBA. If satellite imagery is being used, this process is referred to as triangulation.
6.		Create DTM. Click this icon to start OrthoBASE Pro, another component of the Leica Photogrammetry Suite
7.		Edit DTM Click this icon to start Terrain Editor, another component of the Leica Photogrammetry Suite.
8.		Perform orthorectification. This process creates orthophotos showing images of ground features in their true orthographic or planimetric positions. The orthorectification procedure reduces image distortions caused by topographic relief, sensor tilt, and systematic error in the imagery or the imaging device. Additionally, ortho calibration techniques can be used to create an orthorectified mathematical model associated with an image, without resampling the original image.
9.		Mosaic images. Click this icon to open the Mosaic Tool.Mosaicking is the process of joining georeferenced images together to form a larger image or set of images. The input images must all contain map and projection information; however, they need not be in the same projection or have the same cell sizes
10.		Collect features.Click this icon to open a feature collection application such as Stereo Analyst, Stereo Analyst for ArcGIS, or PRO600. The options available to you depend on which applications you have installed and licensed. For example, if you do not have Stereo Analyst for ArcGIS loaded and licensed on your system, it does not appear on the list

The digital photogrammetric workflow is linear. For example, when using frame cameras, automatic tie point collection cannot begin until fiducial marks have been measured for each image in the block. Using the icons located within the LPS Project Manager, moving through the various steps from left to right allows for the completion of the photogrammetric workflow.

Chapter 9

Adding Images to the Block

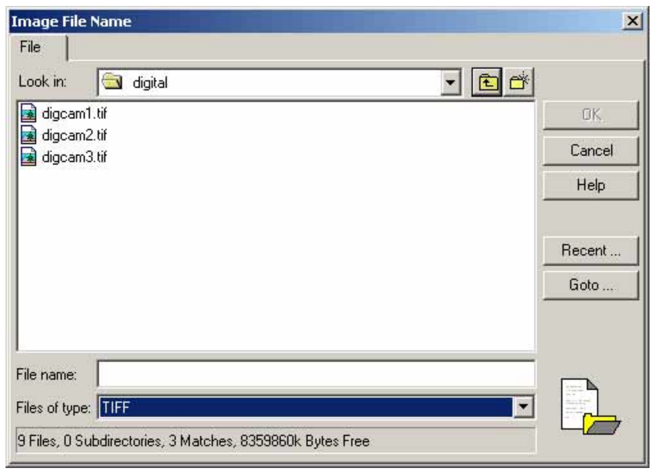
Introduction

An OrthoBASE block file can contain a few or many images. In this section, you learn how to add images and how to improve their display in the view using OrthoBASE pyramid layers.

Adding Images

A single image or multiple images can be added to the block by selecting the Add Frame icon or the **Add Frame** option from the **Edit** menu in the LPS Project Manager. Once the option has been selected, the Image File Name dialog opens, as shown in Figure 9-1.

Figure 9-1: Image File Name Dialog



Add Multiple Images

To add one image to the block, simply select the image and select **OK.** To add multiple images simultaneously, use the Shift and Ctrl (Control) keys on your keyboard. For example, to select a series of sequential images, hold down the Shift key, then click the first and last images in the series. Click **OK** to add the files to the block. To select multiple images that are not sequential in the file list, hold down the Ctrl key, then click the files you want to include. Click **OK** to add the files to the block.

OrthoBASE supports the following raster DLLs: IMAGINE IMG, JPEG, TIFF, GIF, LAN, Generic Binary, and RAW. Using the supported raster DLLs, the image files do not need to be imported.

LPS CellArray

Once the images have been added, the LPS Project Manager displays the CellArray with corresponding image names and associated process information. The LPS CellArray is shown in Figure 9-2.

Figure 9-2: The LPS CellArray with Added Imagery

Row #	Image ID	Description	>	Image Name	Active	Pyr.	Int.	Ext.	DTM	Ortho	Online
1	1		>	d:/data/imaginedata/orthobase/digital/digcam1.tif	X						
2	2			d:/data/imaginedata/orthobase/digital/digcam2.tif	X						
3	3			d:/data/imaginedata/orthobase/digital/digcam3.tif	X						

Each image has an associated **Row #.** Selecting a row within the **Row #** column selects that image for a subsequent operation within OrthoBASE. This operation may include deleting the image or creating a pyramid layer for the image.

A right-click on a cell contained within the **Row #** column opens the **Row Selection** menu of the CellArray. The options include: **Select None, Select All, Invert Selection, Delete Selection, Criteria, Sort,** and **Goto.**

Refer to the ERDAS IMAGINE On-Line Help for a detailed explanation of these features.

The **Image ID** column of the CellArray defines a numeric identifier for each image in the block. The entry must be numeric and unique for each image. The values can be modified.

The **Description** column allows you to enter information about the individual image.

The **>** column defines which image within a block is the current image to be used for interior orientation, point measurement, and orthorectification. For example, when the Frame Editor dialog is activated, the image to be operated on is that image having the **>** symbol assigned to it.

The **Image Name** column of the CellArray lists the directory path and image file name for each image. The entry cannot be modified and must correspond to the appropriate image file name and location.

The **Active** column of the CellArray denotes with an **X** which image(s) is used for automatic tie point collection, aerial triangulation, and orthorectification. Each image added to a project is automatically set to **Active.** By a selecting a cell element within the **Active** column, the **X** disappears. Selecting the same cell element once again displays **X**.

Color coding schemes are used as project management and organization tools within OrthoBASE. The default color schemes within the CellArray include red, indicating that an operation has not been performed for a specific image, and green, indicating that an operation has been performed for a specific image.

In order to change the default color codes, select the **LPS** *option within the Preference Editor. The preferences controlling color are* **Status On Color** *and* **Status Off Color.**

Five additional columns represent the tasks associated with a given process in OrthoBASE. These include:

- **Pyr. -** Refers to the creation of pyramid layers. If pyramid layers have been generated for an image, the cell element is green. If a pyramid layer has not been generated for an image, the cell element is red. The color codes are based on the default settings.

Remember, OrthoBASE pyramid layers are generated differently than ERDAS IMAGINE pyramid layers. For more information, see “Creating Pyramid Layers”.

- **Int.** - Refers to the completion of interior orientation. If using frame cameras, the fiducial marks must be measured in order to compute the interior orientation for the image. At this point, the cell element is green. If using digital, video, or nonmetric camera imagery, the x and y size of a pixel in the image must be specified for the color code to be green.

- **Ext.** - Refers to the availability of final exterior orientation parameters. If aerial triangulation has been successfully performed and the results accepted, the exterior orientation parameters associated with each image in the block have been computed. In this case, the respective cell elements are green. If exterior orientation parameters were imported from another photogrammetric system or airborne GPS system and accepted as fixed positions, the respective cell elements are green. Otherwise, the cell elements are red.

For information about height extraction, see Chapter 14 “Automatic DTM Extraction”.

- **Ortho** - Refers to the generation of orthorectified images or ortho calibration. If an orthorectified image was created or ortho calibration performed, the respective cell element for each image is green. Otherwise, the cell element is red.

- **Online** - These cell elements indicate whether the image is currently online or off-line. If an image is online, the image name and directory path corresponds to the appropriate image file on the hard-disk. When imagery is added to a block, the respective cell elements are green. If existing imagery is moved from its directory as indicated within the **Image Name** column, the cell element is red. Using the **Attach** option within the Frame Editor dialog, images that have been moved from their original locations can be reattached. If exterior orientation parameters were imported during block setup, the CellArray elements within the **Online** column are red since the image name to image file association has not been made.

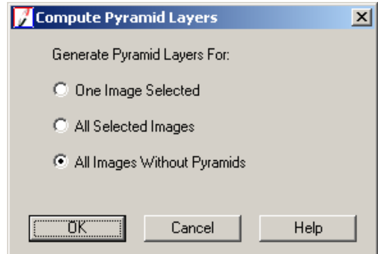
Creating Pyramid Layers

The **Compute Pyramid Layers** option allows for the creation of hierarchical pyramid layers. Pyramid layers are used by OrthoBASE to facilitate and optimize image zooming, panning, and roaming. Additionally, the pyramid layers are necessary for performing automatic tie point collection.

OrthoBASE uses a different construction model for the creation of pyramid layers as compared to ERDAS IMAGINE *.rrd (Reduced Resolution Data) pyramid layers. OrthoBASE pyramid layers are created using a binomial interpolation algorithm, whereas ERDAS IMAGINE pyramid layers are created using a user specified option of **Nearest Neighbor, Bilinear Interpolation,** or **Cubic Convolution.**

If the **Compute Pyramid Layers** option is selected from the **Edit** dropdown list, or a cell element within the **Pyr.** column is selected, the Compute Pyramid Layers dialog opens as shown in Figure 9-3.

Figure 9-3: Compute Pyramid Layers Dialog



The **One Image Selected** option creates pyramid layers for the image currently selected, as designated by the **>,** within the CellArray. You can select several images within the LPS CellArray for which pyramid layers are created (**All Selected Images** option). The third option, **All Images Without Pyramids,** creates pyramid layers for all the images in the block that do not have existing OrthoBASE pyramid layers.

Once the pyramid layers are created for the images within the block, the **Pyr.** column within the LPS Project Manager CellArray is green (completed status).

Chapter 10

Defining the Camera or Sensor Model

Introduction

Defining the camera or sensor model involves establishing the geometry of the camera/sensor as it existed at the time of photographic exposure or image acquisition. This includes defining both the internal and external information associated with a camera or sensor model.

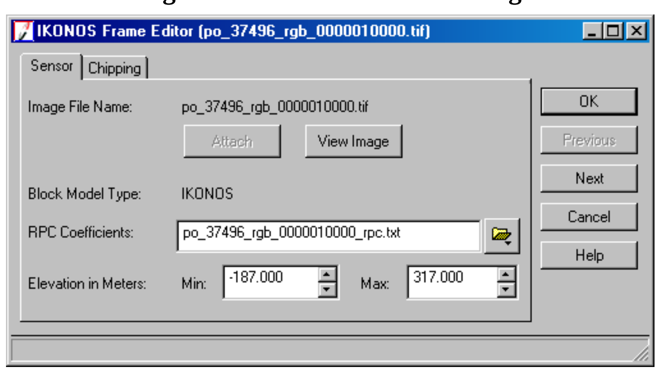
Interior and Exterior Orientation

When using cameras having one perspective center, including frame cameras, digital cameras, videography, and nonmetric cameras, the internal geometry is referred to as interior orientation. When using satellite sensors such as SPOT, IRS-1C, and other generic pushbroom sensors having a perspective center for each scan line, the process is referred to as internal sensor modeling.

Defining the external properties associated with a camera or sensor involves establishing the exterior orientation parameters associated with the camera/sensor as they existed at the time of photographic exposure or image acquisition.

Both the internal and external information associated with a camera/sensor can be defined within the Frame Editor dialog. By selecting either the Frame Editor icon  on the LPS toolbar or the **Frame Editor** option within the **Edit** menu, the Frame Editor dialog opens, as shown in Figure 10-1.

Figure 10-1: Frame Editor Dialog



Three tabs are provided within the Frame Editor dialog:

- **Sensor.** This tab allows for the definition of the image and the corresponding camera or sensor information associated with an image. The **Sensor** tab gives access to the following tasks:

    - specifying of the image file location

- viewing an image file
  (Selecting the **View** option activates the ERDAS IMAGINE Viewer and displays the image within the Viewer.)
- editing an existing camera or sensor model
- creating a new camera or sensor model

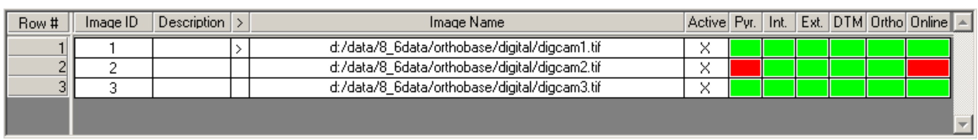
- **Interior Orientation.** When using frame cameras, measuring fiducial marks establishes the position of the principal point (i.e., the origin of the image coordinate system). When using digital, video, or nonmetric cameras, interior orientation involves defining the x and y pixel size of the camera CCD, or scanning resolution used to digitize the film obtained from a camera not using a CCD.

- **Exterior Information.** This tab allows for the input of exterior orientation parameters for a given image or multiple images.

Attaching One Image

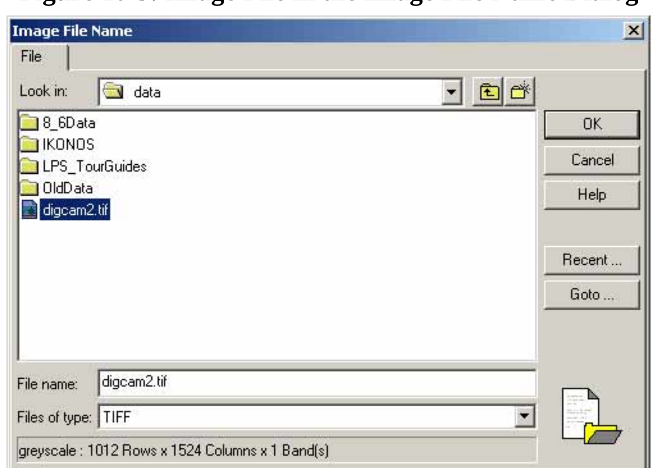
If an image has been moved from its original location on a computer as defined when the image was added to OrthoBASE, the image name can be associated with the corresponding image file and its new location. When a cell element within the **Online** column of the CellArray is red, the image is no longer online, as shown in Figure 10-2.

Figure 10-2: LPS CellArray with Off-line Image



By selecting the **Attach** option within the **Sensor** tab of the Frame Editor dialog, the image file can be associated with the corresponding image name as it appears in the CellArray.

Figure 10-3: Image File in the Image File Name Dialog



Within the Image File Name dialog, shown in Figure 10-3, the image file can be located and selected to attach the image name, as it appears in the **orthobase** folder, to the appropriate image file.

Attaching Multiple Images

For mapping projects containing two or more images, rather than attach each image separately, multiple images can be attached simultaneously. To attach multiple images in one directory, select the **Attach** option within the **Sensor** tab of the Frame Editor dialog. Use the Shift and Ctrl (Control) keys on the keyboard to select multiple files.

To attach files listed sequentially, hold down the Shift key, then click the first and last files in the list. To attach multiple files that are not listed sequentially, hold the Ctrl key and click to select each image. Once you have selected the files in this manner, click **OK** in the dialog. Once images have been attached, the cells within the CellArray are converted to green.

Defining or Editing Camera Information

This section is applicable to photography or imagery with one perspective center collected using frame, digital, video, or nonmetric cameras.

Selecting the **Edit** button within the **Sensor** tab of the Frame Editor dialog provides the ability to edit an existing camera model. The camera model to be edited is displayed within the **Sensor Name** dropdown list. Selecting the **New** button within the **Sensor** tab provides the ability to create a new camera model, and selecting the **Edit** button provides the ability to edit an existing camera model. Only those cameras appearing within the **Sensor Name** dropdown list can be edited.

NOTE: More than one camera can be used within a block project.

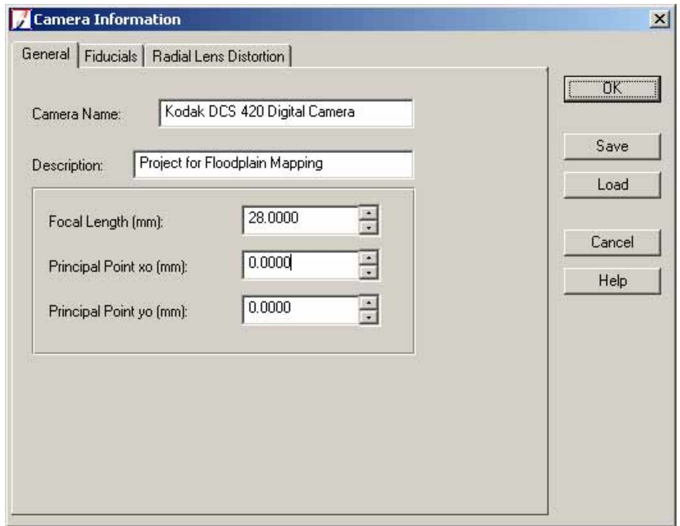
The **Sensor Name** dropdown list provides a list of existing cameras or sensors that are available for use within a block. Only those cameras or sensors that have been defined are displayed within the **Sensor Name** list.

Defining the properties associated with a camera creates a primary component of interior orientation. For aerial frame cameras, the interior orientation process involves defining the camera properties associated with a camera (e.g., focal length, principal point, radial lens distortion, and location of the fiducial marks).

For nonmetric cameras, including digital, video, and amateur cameras, the process involves defining the camera properties (e.g., focal length, principal point (optional), radial lens distortion (optional), and the x and y pixel size of the CCD if using digital or video cameras). If the cameras used photography at the time of exposure, the scanning resolution used to digitize the photography must be entered.

By selecting the **New** option within the **Sensor Name** list, the Camera Information dialog opens.

Figure 10-4: Camera Information Dialog



Within the Camera Information dialog, shown in Figure 10-4, the camera properties associated with using a frame, digital, video, or nonmetric camera can be defined. Within the **General** tab, the following parameters can be defined:

- **Camera Name.** The name of the new camera can be defined in this field.
- **Description.** A camera description can be assigned to a camera. It can be an alpha-numeric string of information.
- **Focal length (mm).** The focal length of a camera can be defined in millimeters. This is normally provided in a calibration report. A calibration report is provided when aerial photography has been flown and distributed for public use (e.g., USGS camera calibration reports). The focal length is required in order to continue photogrammetric processing.
- **Principal Point xo (mm).** This parameter defines the location of the principal point in the x direction, relative to the origin of the image or photo-coordinate system. The principal point location is the location where the optical axis of the camera intersects the image or photographic plane. The deformations existing within the camera body and lens cause the principal point to deviate from the image coordinate system origin, which is normally defined by the fiducials.
- **Principal Point yo (mm).** This parameter defines the location of the principal point in the y direction, relative to the origin of the image or photo-coordinate system.

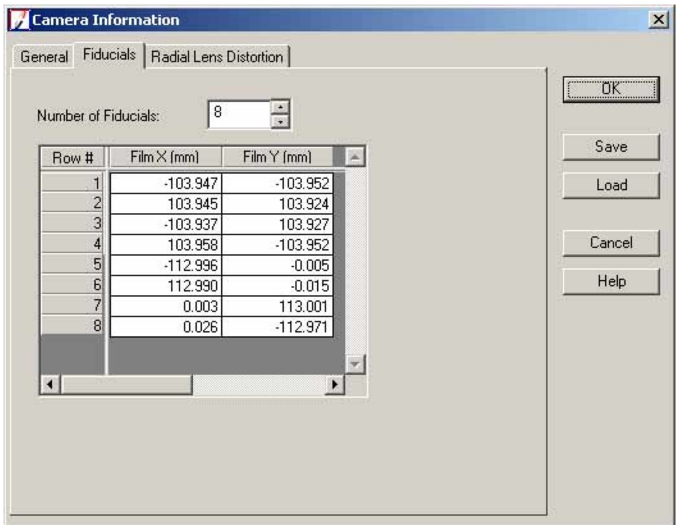
The **Load** button allows you to open an existing camera file having a *.cam extension. Once a *.cam file has been opened, all of the respective parameters within the Camera Information dialog are populated. The *.cam file is an ASCII file with a fixed structure.

The **Save** option allows you to save all of the information associated with a camera to a camera file having a *.cam extension. The file is an ASCII file with a fixed file structure. It is recommended that the camera information be saved once the camera model has been defined, so that the camera can be reused in future photogrammetric projects. The **Save** button saves the existing contents contained within the Camera Information dialog to the block project and correspondingly to the *.cam file.

Fiducial Marks

The **Fiducials** tab, shown in Figure 10-5, allows you to define the number of fiducials located on an image and enter their calibrated x and y image or photo-coordinate values.

Figure 10-5: Fiducials Tab



By entering a number in the **Number of Fiducials** field, the appropriate number of rows is allocated to the CellArray. The **Film X (mm)** and **Film Y (mm)** columns within the CellArray represent the calibrated coordinates of the fiducial mark positions on the images.

Fiducial marks are physical features located within the camera body. When an image is captured or exposed, the fiducial marks also become captured within the image or film emulsion. Prior to capturing imagery/photography, the positions of the fiducial marks are precisely determined and measured in a laboratory. These positions are then provided in a calibration report.

Importing Fiducial Marks Using the CellArray

The calibrated fiducial mark coordinates can be imported into the fiducials CellArray using the following steps:

1. Enter the number of fiducial marks.
2. Select the **Film X (mm)** and **Film Y (mm)** columns using a left-click and drag. Both columns become highlighted.
3. Right-click to display the column CellArray options.
4. Select the **Import** option.

5. Specify the input ASCII file.

6. Ensure that the appropriate column name (i.e., **Film X** and **Film Y**) is associated with the corresponding information in the ASCII file.

7. Click **OK** to import the fiducial coordinates.

NOTE: Fiducial mark coordinates can also be exported using the CellArray.

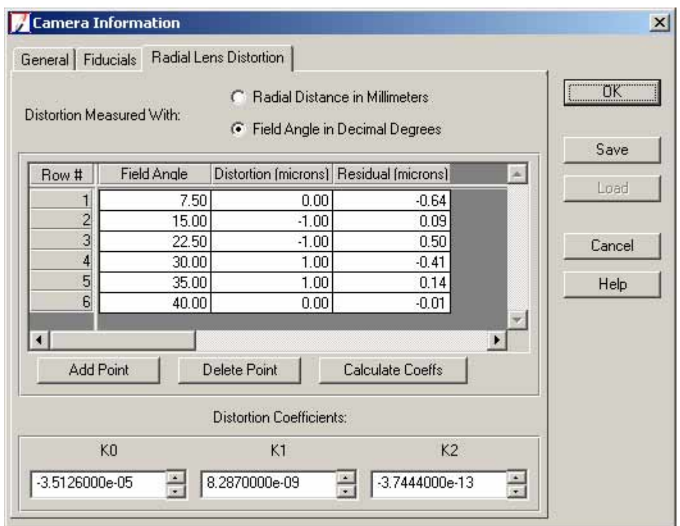
Fiducials for Digital, Video, and Nonmetric Cameras

Since fiducial marks are not present on digital, video, and nonmetric cameras, they are not required as input to define the camera model. OrthoBASE utilizes the corners of the image to define the origin of the image/photo-coordinate system. This procedure is performed automatically.

Radial Lens Distortion

The **Radial Lens Distortion** tab allows for the entry and computation of radial lens distortion parameters associated with a camera. It is shown in Figure 10-6.

Figure 10-6: Radial Lens Distortion Tab



Radial lens distortion is defined as the distortion of an image point along a radial line from the principal point. The result is displacement of the image point from its true position. Radial lens distortion is caused by wear and tear of a lens and inaccurate optics.

Radial lens distortion can be measured using two techniques. The first defines lens distortion as a function of radial distance from the principal point, and the second defines the distance as a function of the field angle from the principal point. The radial distortion values required for use with both options are provided in most calibration reports.

If the radial distortion values provided are based on the radial distance or field angle, they can be defined within this environment. The **Add Point** button must be selected for each radial distortion entry. The number of points to be added depends on the number of distortion values available.

If an entry is incorrect, the **Delete Point** button allows for the deletion of a row within the CellArray.

Once the distortion values have been entered, the radial lens distortion coefficients can be computed by selecting the **Calculate Coeffs** button. The resulting three lens distortion coefficients are displayed under the **K0, K1,** and **K2** text fields.

Once the lens distortion coefficients have been calculated, the **Residual** column within the **Radial Lens Distortion** CellArray displays residuals, indicating the degree to which the radial distortion parameters correspond to the radial lens distortion model.

In some instances, the lens distortion coefficients may be available or previously computed. In this scenario, the three coefficients can be entered rather than recomputed.

Selecting **OK** accepts all of the camera information defined within the Camera Information dialog and creates a new camera/sensor model to be used within OrthoBASE. The new camera model is displayed within the **Frame Editor Sensor Name** dropdown list. Additionally, once **OK** has been selected, the Camera Information dialog closes.

For more information, see "Lens Distortion".

Interior Orientation

Interior orientation for frame cameras varies in comparison to interior orientation for digital, video, and nonmetric cameras.

Interior orientation involves measuring the pixel coordinate positions of the calibrated fiducial marks on each image within a block (if using frame cameras). When using digital, video, or nonmetric camera imagery, the process involves defining the x and y pixel size of the CCD or scanning resolution used to digitize the film, if film was used.

The purpose of interior orientation is twofold:

- to define an image or photo-coordinate system within each image of the block, and
- to determine the origin and orientation of the image/photo-coordinate system for each image in the block.

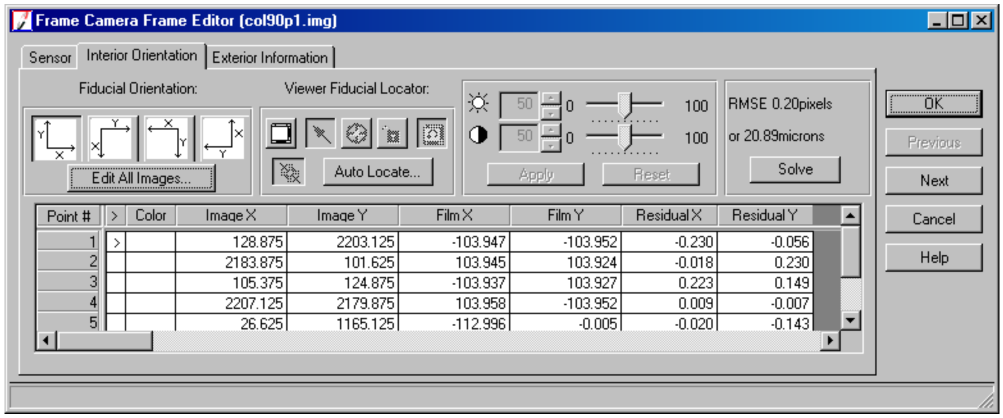
The origin of the photo-coordinate system for each image is the principal point. The principal point position is determined mathematically by intersecting opposite fiducial mark positions. A 2D affine transformation is used to determine the relationship between the pixel coordinates of the measured fiducials and the film, or photo-coordinates of the calibrated fiducials.

Interior orientation is semi-automated for frame cameras. For example, if the positions of two fiducial marks are measured on an image, OrthoBASE automatically adjusts to display each remaining fiducial mark. It is then the responsibility of the operator to measure the position of the fiducial mark. For digital, video, and nonmetric cameras, an automated procedure is used to determine the origin of the image/photo-coordinate system.

Frame Cameras

Upon selecting the **Interior Orientation** tab within the Frame Editor dialog, the Interior Orientation dialog opens as shown in Figure 10-7.

Figure 10-7: Interior Orientation Tab of the Frame Editor

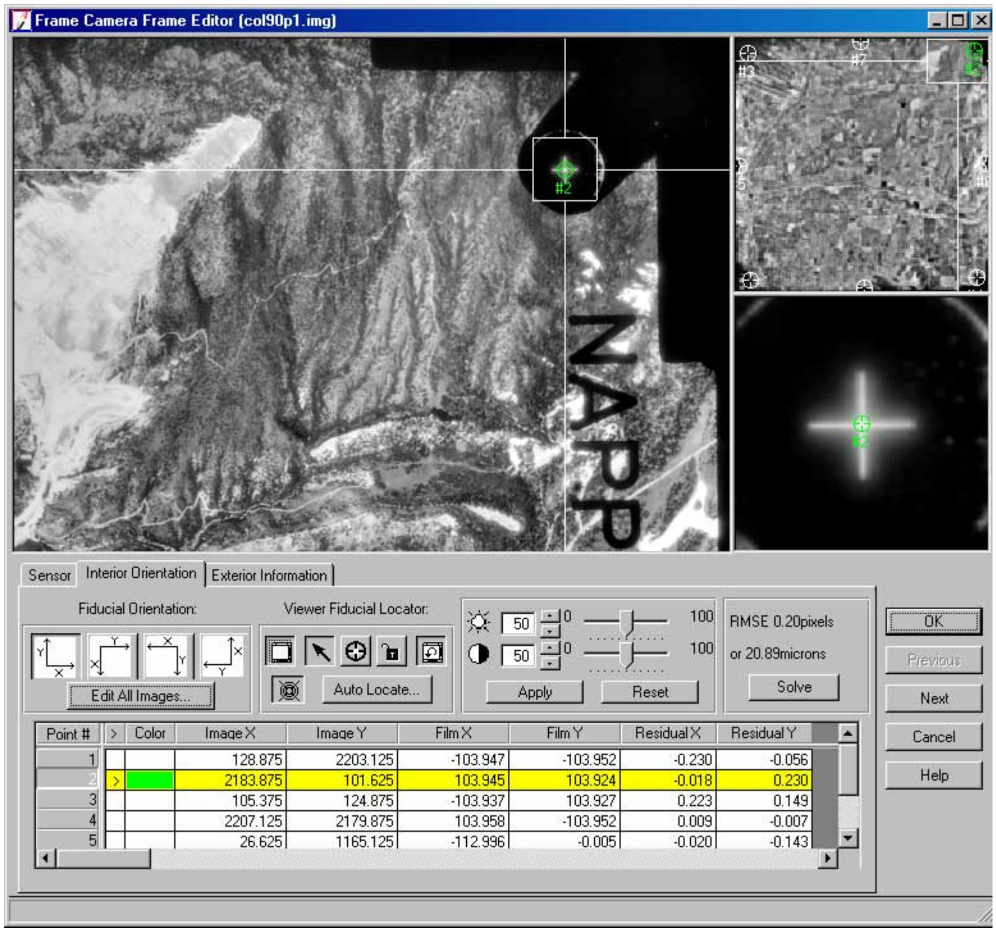


In the CellArray, the image that currently has the symbol **>** assigned to it has the corresponding interior orientation information also displayed within the **Interior Orientation** tab. The **Next** and **Previous** buttons can be used to navigate throughout the block during interior orientation. The currently active image name is displayed within the upper left-hand corner of the Frame Editor title bar.

To display the image, the Viewer icon (first icon from the left) must be selected. The image displays within three views. The views include an OverView, a Main View, and a Detail View.

The primary window displays the area enclosed in greater detail within the OverView window Link Cursor. The magnify window displays the area enclosed in greater detail within the primary window Link Cursor. Figure 10-8 shows the configuration of the windows.

Figure 10-8: Fiducial Marks within the Frame Editor



It is recommended that fiducial mark measurements be made on the Detail View to ensure sub-pixel accuracy.

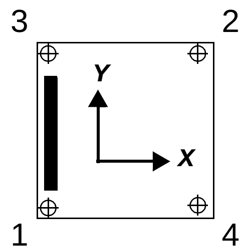
Fiducial Orientation

Fiducial orientation defines the relationship between the image/photo-coordinate system of a frame and the actual image orientation as it appears within a view. The image/photo-coordinate system is defined by the camera calibration information. The orientation of the image is largely dependent on the way the photograph was scanned during the digitization stage.

For information about scanners, see *"Desktop Scanners".*

Figure 10-9 shows a common fiducial orientation as a function of the image/photo-coordinate system, and the raw image orientation. Assume the photograph is aerial and has the following fiducial mark coordinates:

Figure 10-9: Fiducial Orientation of an Aerial Photograph

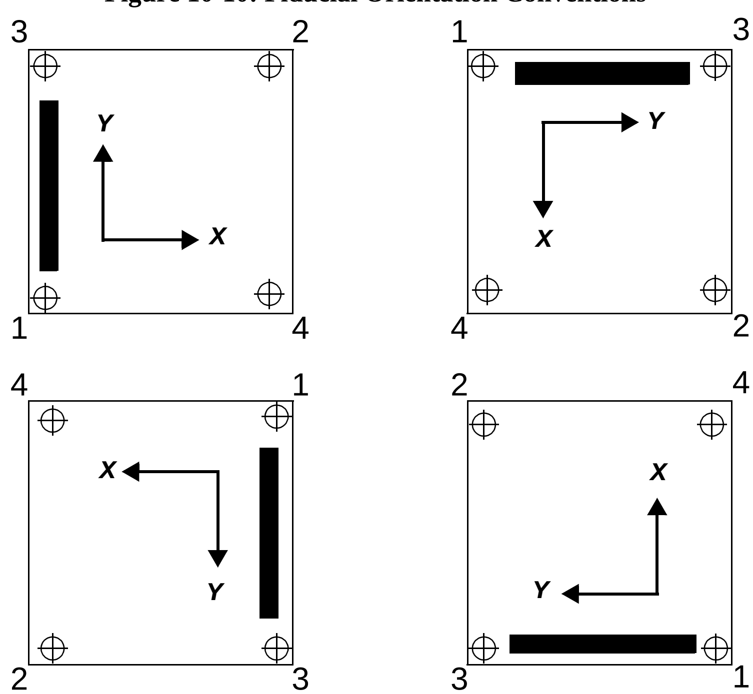


Fiducial	X	Y
1	-103.947	-103.952
2	103.945	103.924
3	-103.937	103.927
4	103.958	-103.952

The dark bar represents the data strip that is common to photography captured using frame cameras. The data strip is used as a reference in determining the manner in which the camera was calibrated. In this example, the corresponding image/photo-coordinate system X-axis is positive to the right, and the Y-axis is positive up.

The fiducial orientation to be used for the above scenario depends on the existing orientation of the image as it appears within a view. Figure 10-10 illustrates the fiducial orientation used for the various image orientation scenarios available.

Figure 10-10: Fiducial Orientation Conventions



Note: The black bar represents the image data strip.
The numbered corners represent the fiducials.

In order to select the appropriate fiducial orientation, compare the axis of the photo-coordinate system (defined in the calibration report) with the orientation of the image. Based on the relationship between the photo-coordinate system and the image, the appropriate fiducial orientation can be selected. The following illustrations demonstrate the fiducial orientation used under the various circumstances:

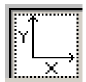


Photo-coordinate system parallel to image orientation.

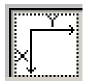


Image rotated 90° relative to the photo-coordinate system.

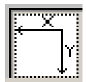


Image rotated 180° relative to the photo-coordinate system.

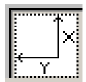


Image rotated 270° relative to the photo-coordinate system.

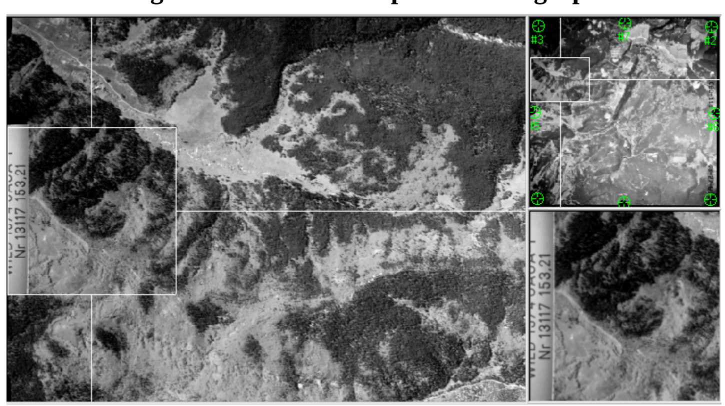
Selecting the inappropriate fiducial orientation results in large RMS errors during the measurement of fiducial marks for interior orientation and errors during the automatic tie point collection. If initial approximations for exterior orientation have been defined and the corresponding fiducial orientation does not correspond, the automatic tie point collection capability provides inadequate results. Ensure that the appropriate fiducial orientation is used as a function of the image/photo-coordinate system.

NOTE: Once the fiducial marks have been measured, do not change the fiducial orientation. To change the fiducial orientation you should delete the fiducial mark measurements, select the appropriate fiducial orientation, and remeasure fiducials.

How to Find the Data Strip

The data strip on a image may vary with respect to the type of frame camera used to capture the photography. Figure 10-11 displays a data strip contained within aerial photographs captured using a Wild camera.

Figure 10-11: Data Strip on a Photograph



The data strip commonly contains information associated with the type of camera (Wild, Zeiss, Jena), the number of the camera, and the approximate focal length of the camera (e.g., 152 mm).

If a data strip is not present within the photography, it is recommended that the first fiducial orientation used for photography be collected along a strip.

Interior Orientation CellArray

The interior orientation CellArray displays the calibrated fiducial mark coordinates, their associated row and column pixel coordinates, fiducial mark color codes, and x and y fiducial mark residuals. Once a fiducial mark has been measured, the row and column pixel coordinates associated with a fiducial mark are displayed within the CellArray.

Once the appropriate fiducial orientation has been selected, OrthoBASE automatically drives to display the approximate image location of the first fiducial mark. When the fiducial mark is measured, the image position of the second fiducial mark is approximated. The quality of the approximation increases drastically once the second fiducial mark has been measured.

Importing Fiducial Mark Measurements

If the row and column pixel coordinates of the fiducial marks are available, an ASCII file containing their values can be imported.

The following steps can be used to import an ASCII file containing the fiducial mark coordinates:

1. Select the **Image X** and **Image Y** columns using a left-click and drag. Both columns become highlighted.
2. Right-click to display each column's CellArray options.
3. Select the **Import** option.
4. Specify an ASCII file as input.
5. Ensure that the appropriate column name is associated with the corresponding information in the ASCII file.

Image Enhancement

To improve the quality of interior orientation, the image displayed within the view can be enhanced to optimize fiducial mark identification and measurement. The following options are provided for enhancing the display of an image:

- **Brightness and Contrast Controls.** These controls are located within the **Interior Orientation** tab. Changes to the brightness and contrast levels are applied to the Main View and Detail View in the **Interior Orientation** tab of the Frame Editor dialog.

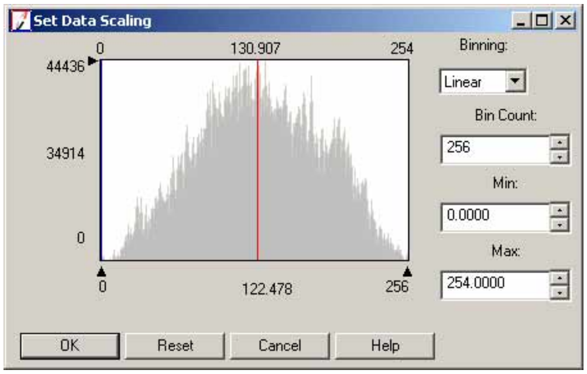
- **Set Resampling Method.** A right-click within any of the three views (OverView, Main View, Detail View) displays the **Set Resampling Method** dialog, shown in Figure 10-12. Selecting the **Set Resampling Method** option provides three image resampling methods: **Nearest Neighbor**, **Bilinear Interpolation**, **Cubic Convolution,** and **Bicubic Spline.**

  Selecting the **Nearest Neighbor** option within Detail View is optimum for identifying and measuring the location of a fiducial mark to sub-pixel accuracy, since the individual pixels of the image are displayed.

Figure 10-12: Set Resampling Method Dialog

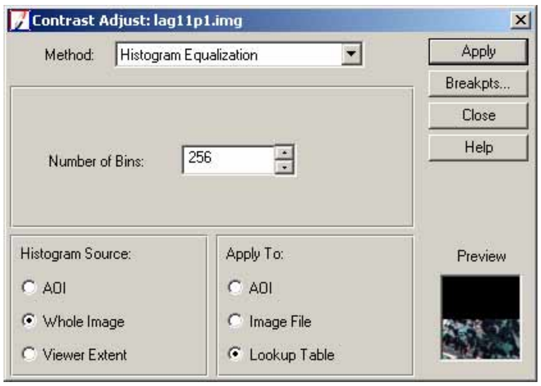
- **Data Scaling.** The distribution of grey levels for an image can be modified to enhance the display of fiducial marks. A right-click within any of the three views (OverView, Main View, Detail View) displays the Data Scaling dialog, shown in Figure 10-13. Adjusting the histogram adjusts the display of the image to ease fiducial mark identification and measurement.

Figure 10-13: Data Scaling Dialog



- **General Contrast Options.** Sophisticated image enhancement tools are provided that allow for the variation of image display. A right-click within any of the three views (OverView, Main View, Detail View) displays the Contrast Adjust dialog, shown in Figure 10-14.

Figure 10-14: Contrast Adjust Dialog



The minimum number of fiducial mark measurements required to obtain a solution is three. Once three measurements have been made, the **Solve** button within the **Interior Orientation** tab can be selected to derive a solution. RMS is not provided since the degree of redundancy is not sufficient. If four fiducial marks have been measured, the redundancy is sufficient to determine the statistical quality of the solution. If all of the fiudcial marks have been measured, the interior orientation solution is derived automatically without selecting the **Solve** button.

Fiducial Mark Residuals

If at least four fiducial mark positions have been measured, the corresponding residuals are displayed within the CellArray when the **Solve** option is selected. **Residual X** displays the x residual for a given fiducial mark, which is computed based on a mathematical comparison made between the original x fiducial mark position and the actual measured fiducial mark position in the x direction.

Residual Y displays the y residual for a given fiducial mark, which is computed based on a mathematical comparison made between the original y fiducial mark position and the actual measured fiducial mark position in the y direction.

The global RMSE is displayed in pixel and micron units. The RMSE represents the overall correspondence between the calibrated fiducial mark coordinates and their measured image coordinates. Values larger than 0.5 pixels, or half the scanning resolution of the image, infer systematic error and/or gross measurement errors associated with the image. The error can be attributed to:

- film deformation
- poor scanning quality
- mismeasured fiducial mark positions
- incorrect calibrated fiducial mark coordinates

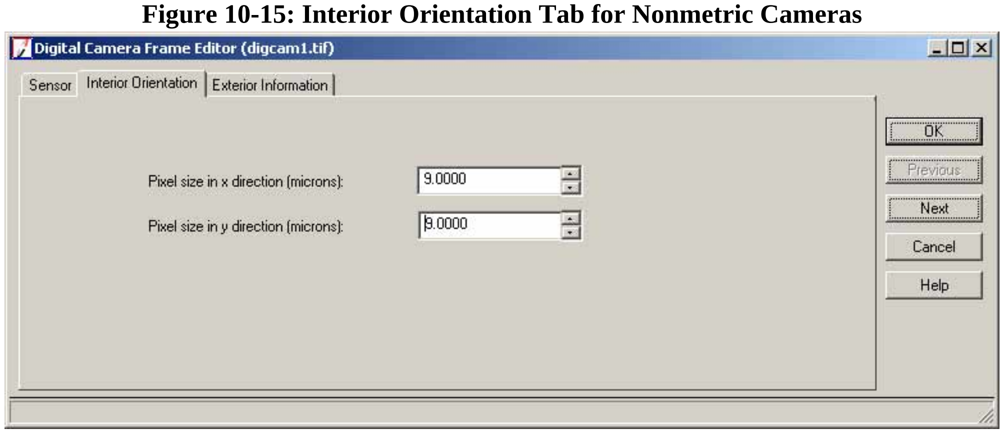
Deleting a Fiducial Mark Measurement

To delete the pixel coordinate information associated with a measured fiducial mark, the fiducial mark measurement or measurements must be selected. A right-click within the **Point #** column of the CellArray displays its CellArray options. Select the **Delete Selection** option to delete the measured fiducial mark row and column information. Only the row and column pixel coordinates are deleted.

Digital, Video, and Nonmetric Cameras

Since fiducial marks are not present in digital, video, and nonmetric cameras, the interior orientation procedure does not require their measurement on the images. For digital and video cameras employing a CCD, the x and y pixel size of the CCD must be defined. You can do so in the Interior Orientation tab, shown in Figure 10-15.

Figure 10-15: Interior Orientation Tab for Nonmetric Cameras



If photography captured from a nonmetric camera has been scanned, the x and y scanning resolution of the image can be defined in the x and y direction.

Defining Exterior Information of an Image

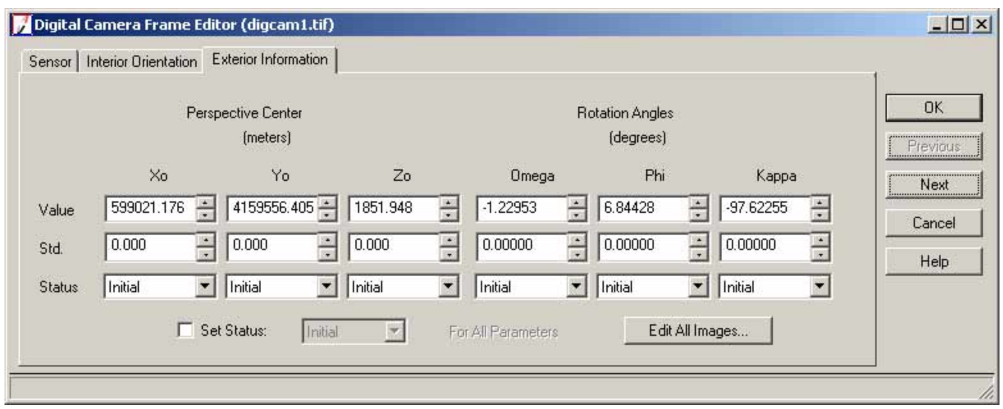
Defining the external properties associated with a camera or sensor involves establishing the exterior orientation parameters associated with the camera/sensor as they existed at the time of photographic exposure or image acquisition. Specifically, the exterior orientation parameters define the position and orientation of the perspective center. Thus, each image in a block has different exterior orientation parameters associated with it.

The exterior information associated with an image includes:

- the six exterior orientation parameters of an image,
- the statistical weights associated with the exterior orientation parameters of an image, and
- the status of each exterior orientation parameter.

Selecting the **Exterior Information** tab within the Frame Editor dialog displays the exterior orientation information associated with an image. It is pictured in Figure 10-16.

Figure 10-16: Exterior Information Tab for the Frame Editor



The positional elements defining the perspective center consist of Xo, Yo, and Zo coordinates. These coordinates are relative to the reference coordinate system, which is defined by the projection/spheroid/datum specified during block setup.

The rotational elements of exterior orientation consist of three rotation angles including Omega, Phi, and Kappa. The rotation information used by OrthoBASE is defined during block setup. If the exterior orientation parameters were imported during block setup, the respective values are displayed within the value text fields of the **Exterior Information** tab. The **Next** and **Previous** options can be used to view the exterior orientation values of other images contained within the block.

The **Std.** fields allow for the specification of precisional quality concerning the input of exterior orientation parameters. The definition of statistical weight is optional. Defining statistical weight assists in the distribution and minimization of error throughout the block. These values are determined in the following manner:

- Evaluating the statistical output of existing aerial triangulation results of other software packages.

- If existing topographic maps have been used to derive initial approximations for exterior orientation, a statistical quality can be deduced from the scale and quality of the topographic map.

- If airborne GPS and INS data are used as input for exterior orientation, the statistical quality of the post-processed data can be used as input for the precisional quality of exterior orientation.

Once aerial triangulation has been performed and the **Update** button (within the Aerial Triangulation dialog) is selected, the **Value** fields within the tab are updated.

Exterior orientation parameters can have three status types: **Fixed, Initial,** and **Unknown.** The status type defines the manner in which the exterior orientation parameters are used during the aerial triangulation process.

- A **Fixed** status assumes that an exterior orientation value is fixed in position or orientation, and is not estimated or modified during aerial triangulation.

- An **Initial** status assumes that the exterior orientation value is an initial approximation to the actual value. This status uses a statistical weight if assigned. The statistical value that is assigned governs the amount of value fluctuation that occurs during the process of aerial triangulation.

- An **Unknown** status assumes that the exterior orientation parameters are completely unknown. Therefore, the aerial triangulation process estimates the parameters during aerial triangulation.

Rather than define the status for each exterior orientation parameter, the **Set Status** checkbox can be selected and used to set the status for each parameter automatically.

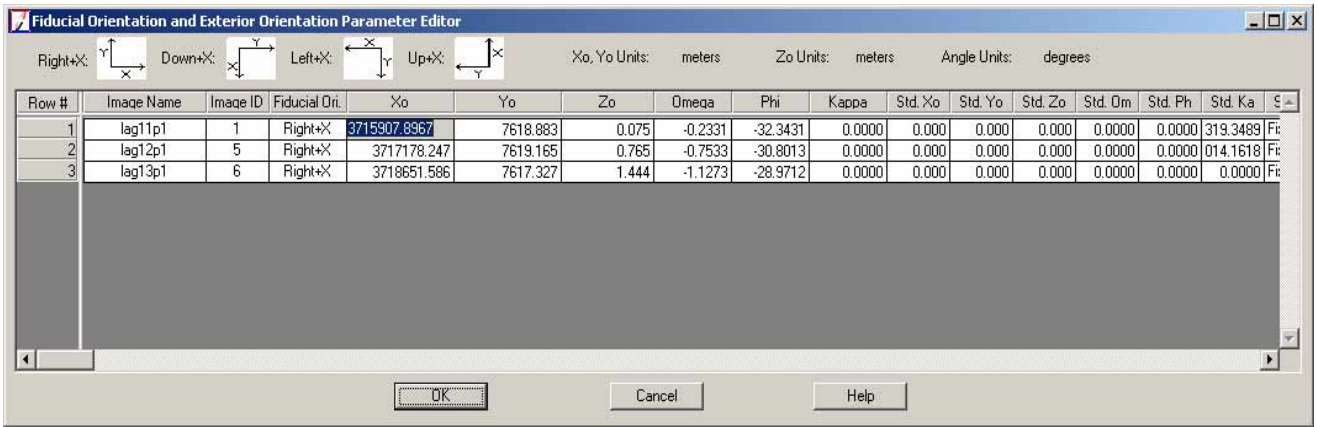
Selecting the **Next** or **Previous** button displays the exterior information for the next or previous image listed within the CellArray.

Editing Exterior Information for Multiple Images

Rather than edit the exterior orientation information for each image independently, functions are provided for editing multiple images simultaneously.

Selecting the **Edit All Images** button displays the Exterior Orientation Parameter Editor dialog, shown in Figure 10-17, containing all of the exterior information for each image in the block.

Figure 10-17: Exterior Orientation Parameter Editor Dialog



The Exterior Orientation Parameter Editor displays for each image:

- image name (cannot be edited)
- image ID (cannot be edited)
- X, Y, and Z coordinates of the perspective center
- Omega, Phi, and Kappa rotation angles
- standard deviation values for X, Y, and Z perspective center coordinates
- standard deviation values for Omega, Phi, and Kappa rotation angles
- status of X, Y, and Z perspective center coordinates (e.g., Initial, Fixed, Unknown)
- status of Omega, Phi, and Kappa rotation angles (e.g., Initial, Fixed, Unknown)

The status associated with the exterior orientation parameters can be changed by using the dropdown list activated with a left-click. Edits or modifications made within the editor are reflected within the Exterior Information tab. Once aerial triangulation has been performed and the **Update** button selected (within the Aerial Triangulation dialog), the results are updated within the **Exterior Information** tab and Exterior Orientation Parameter Editor.

Importing Exterior Orientation Values and Information

Using the CellArray capabilities of the Exterior Orientation Parameter Editor, an ASCII file containing the exterior orientation parameters and statistical information along with status information can be imported. The following steps can be used:

1. Within the Exterior Orientation Parameter Editor, select the columns to be imported using a left-click and drag. The selected columns become highlighted.
2. Right-click to display the column CellArray options.
3. Select the **Import** option.

4. Specify the input ASCII file.

5. Ensure that the appropriate column name is associated with the corresponding information in the ASCII file.

   Image Name and **Image ID** information cannot be imported since the information remains fixed once defined.

   Using the **Import** option within the CellArray, exterior orientation parameter information from other photogrammetric or GPS sources can be used within OrthoBASE. The various photogrammetric sources may include:

   - analog stereo plotters
   - analytical stereo plotters
   - existing aerial triangulation packages (e.g., BLUH, PAT-B, Albany, PC-GIANT, and SPACE-M)
   - digital photogrammetric software packages

Exporting Exterior Orientation Values and Information

Using the CellArray capabilities of the Exterior Orientation Parameter Editor, an ASCII file containing the exterior orientation parameters and statistical information along with status information can be exported. The following steps can be used:

1. Within the Exterior Orientation Parameter Editor, select the columns to be exported using a left-click and drag. The selected columns become highlighted.

2. Right-click to display the column CellArray options.

3. Select the **Export** option.

4. Specify the output ASCII file with a *.dat file extension.

5. Selecting the **Options** button within the Export Column Data dialog allows you to customize the output ASCII file.

Editing Statistical and Status Information

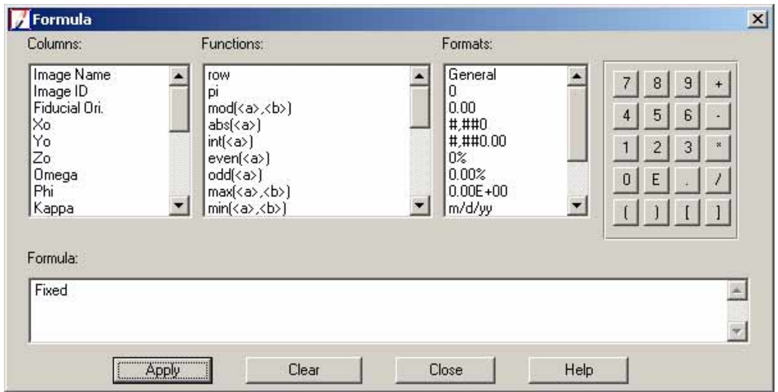
The Exterior Orientation Parameter Editor is also useful in scenarios where the standard deviation and status for each exterior orientation parameter is the same for each image in a large block. In this case, the statistical or status information can be specified once and applied to each image in the block. The following steps are used:

1. Within the Exterior Orientation Parameter Editor select the **Std.** (Standard Deviation) or **Sta.** (Status) columns to be edited using a left-click and drag. The selected columns become highlighted.

2. Right-click to display the column CellArray options.

3. Select the **Formula** option. The dialog in Figure 10-18 opens.

Figure 10-18: CellArray Formula Dialog



4. For standard deviation (**Std.**) values, define the numerical value. For the status (**Sta.**), enter **Fixed, Initial,** or **Unknown.**

5. Click the **Apply** button to apply the value or status to each image in the block selected.

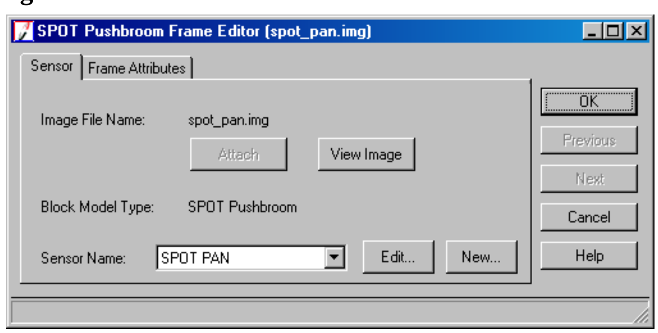
6. Select **Close** to return to the Exterior Orientation Parameter Editor.

Sensor Model Definition for SPOT, IRS-1C, and Generic Pushbroom Sensor Models

This section is applicable to imagery collected using the SPOT, IRS-1C, and generic pushbroom sensor models.

Selecting the **Frame Editor** option within the **Edit** menu or the Frame Editor icon  on the LPS toolbar displays the Frame Editor dialog for use with SPOT, IRS-1C, and generic pushbroom sensor models (Figure 10-19). The Frame Editor is used to define the properties associated with the internal and external parameters of the sensor models.

Figure 10-19: Frame Editor for Pushbroom Sensor Models

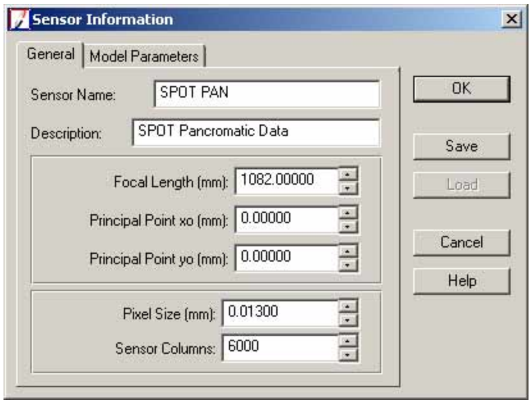


The **Sensor** tab allows for the attachment of an image name with the corresponding image file. The **Attach** button is used to attach image names to image files.

See "Attaching One Image" for more information.

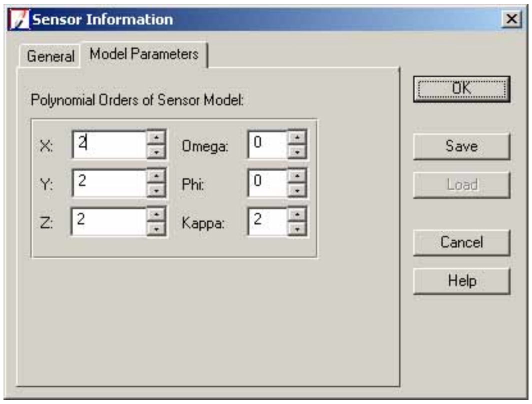
If the SPOT sensor model was selected, the SPOT Pan (10-meter resolution imagery) and the SPOT Multispectral (20-meter resolution imagery), options are provided within the **Sensor Name** dropdown list. To edit the properties associated with the SPOT model, the **Edit** button can be selected, which opens the dialog depicted in Figure 10-20.

Figure 10-20: Sensor Information Dialog for Pushbroom Sensor Models



The default sensor model information is displayed including the focal length of the sensor, pixel size of sensor, and the number of columns in the image. The information within the **General** tab was determined from the header file of the SPOT image. The **Model Parameters** tab displays the polynomial orders to be used during the triangulation process.

Figure 10-21: Model Parameters Tab of the Sensor Information Dialog



Uses of Model Parameters

Polynomial models are used to model the perspective center and rotation angles associated with the pushbroom sensor as they existed when the imagery was being collected. Since a pushbroom sensor has a perspective center for each scan line, the position and orientation of the sensor is different for each scan line. Thus, one-dimensional polynomial models are used to define the position and orientation of the sensor as they existed at the time of capture.

After triangulation has been performed, polynomial coefficients are calculated. The number of coefficients calculated is determined by the polynomial orders. If the polynomial order is defined as being 1 for each exterior orientation parameter, the total number of computed coefficients is 12 (i.e., 6 for each set of exterior orientation parameters).

The larger the polynomial order specified, the greater the number of GCPs required to solve the triangulation solution. It is recommended that 10 or more evenly distributed GCPs be used. It is also recommended to use the default parameter setting in which the second order one-dimensional polynomial is used for perspective center X, Y, and Z and rotation angle Kappa. In Figure 10-21, the 0 order model (i.e., single coefficient) is used for the rotation angles Omega and Phi.

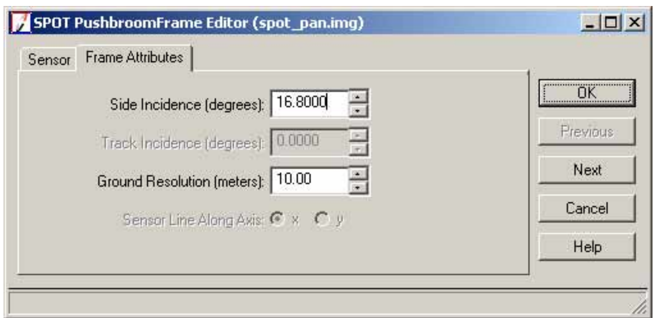
If edits to an existing sensor model are made, the sensor model can be saved by selecting the **Save** option within the Sensor Information dialog. Additionally, a new sensor model can be created by selecting the **New** button within the Frame Editor dialog.

If the IRS-1C or Generic Pushbroom model were selected, the appropriate information associated with the image would be displayed within the Sensor Information dialog.

Defining Frame Attributes for SPOT, IRS-1C, and Generic Pushbroom Sensors

Selecting the **Frame Attributes** tab within the Frame Editor dialog allows for the definition of external sensor model parameters associated with an image, as depicted in Figure 10-22.

Figure 10-22: Frame Attributes Tab for Pushbroom Sensor Models

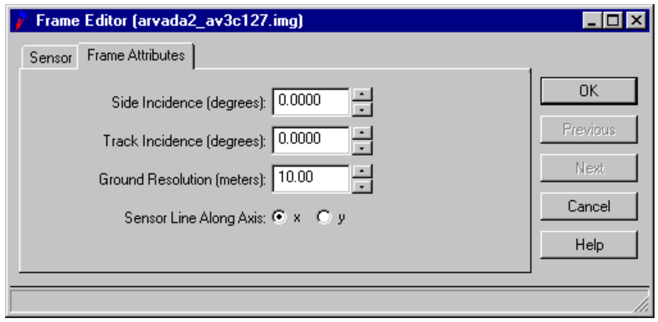


If a SPOT or IRS-1C image is being used, OrthoBASE automatically reads the header information contained within the image to determine the external sensor model information. For both SPOT and IRS-1C, the side incidence angle and ground resolution information is provided.

The side incidence angle is the angle between the vertical position of the satellite and the side viewing direction of the satellite when the sensor is scanning along the side. For SPOT imagery, the angle ranges between +27 to -27 degrees. The scanning direction is perpendicular to the direction of flight.

If the Generic Pushbroom model is being used, the additional options of defining the track incidence angles and scanning direction are also provided, as shown in Figure 10-23.

Figure 10-23: Frame Attributes Tab for Generic Pushbroom Sensor Models



The track incidence angle is the angle between the vertical position of the satellite and the forward or backward viewing direction of the satellite. Track incidence angle is used for the German MOMS satellite imagery. For SPOT data, the track incidence angle is 0.

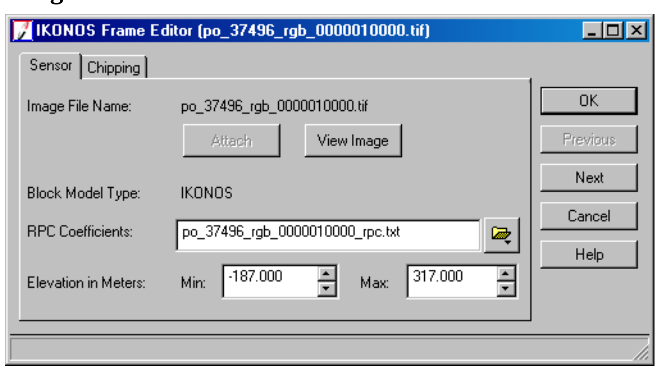
The sensor line defines the direction of the scan line which is used by the satellite to record the data. SPOT and IRS-1C use the x-direction as the scan line. Each scan line has associated with it a perspective center with six exterior orientation parameters including X, Y, Z, omega, phi, and kappa. OrthoBASE computes the exterior orientation parameters of the scan lines based on measured GCPs.

Sensor Model Definition for IKONOS Sensor Model

In order to accurately create or extract geographic information from raw IKONOS imagery, the Image Geometry Model (IGM) must accompany the imagery. The IGM consists of several metadata files which contain RPCs. The RPCs are a series of coefficients that describe the relationship between the image as it existed when captured and the Earth’s surface. With the availability of RPCs, the IKONOS interior and exterior orientation is very accurate.

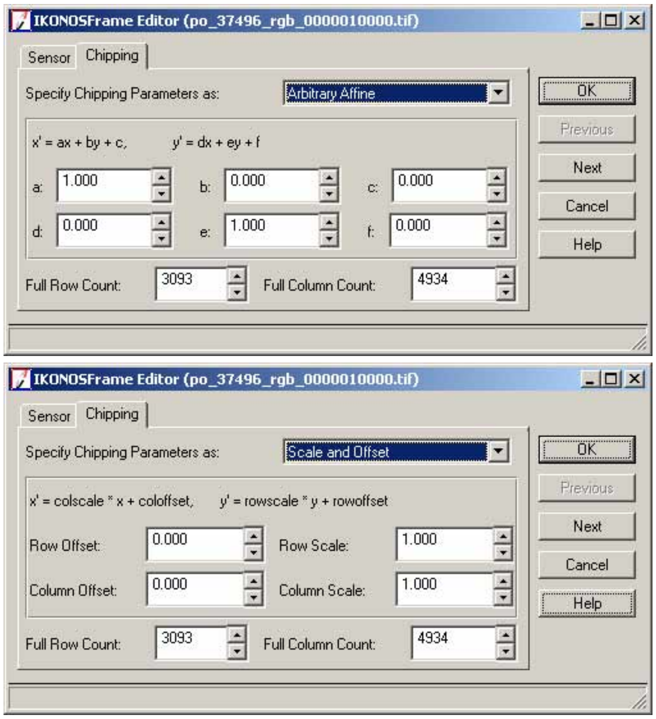
The Sensor tab on the Frame Editor dialog is where you provide OrthoBASE with RPC information necessary to create the sensor model. Figure 10-24 depicts the sensor setup of IKONOS imagery.

Figure 10-24: Sensor Tab for IKONOS Sensor Model



The software looks for the RPC file in the same directory as the .tif file you added to the block file. Also included is a place for you to supply the minimum and maximum elevation (in meters) of the IKONOS scene. This information improves the accuracy of the output orthoimage.

Figure 10-25: Chipping Tab for IKONOS Sensor Model



The chipping tab allows calculation of RPCs for an image chip rather than the full, original image from which the chip was derived. This is possible when you specify an affine relationship (pixel) between the chip and the full, original image.

Use of this tab is only required when the RPCs that accompany the image chip correspond to the full, original image and not the chip itself. Typically, this is not the case.

In the case of **Arbitrary Affine,** the formulas are as follows:

$$x' = ax + by + c$$
$$y' = dx + ey + f$$

In the formulas, x' (x prime) and y' (y prime) correspond to pixel coordinates in the full, original image. The values x and y correspond to pixel coordinates in the chip you are currently working with. Values for the following variables are either obtained from the header data of the chip, or default to predetermined values:

a	=	A scale factor which is also used in rotation. In the absence of header data, this value defaults to 1.
b	=	A value used in rotation. In the absence of header data, this value defaults to 0.
c	=	An offset value. In the absence of header data, this value defaults to 0.
d	=	A value used in rotation. In the absence of header data, this value defaults to 0.
e	=	A scale factor that is also used in rotation. In the absence of header data, this value defaults to 1.
f	=	An offset value. In the absence of header data, this value defaults to 0.

In the case of **Scale and Offset,** the formulas are as follows:

$$x' = colscale^{x}x + coloffset$$

$$y' = rowscale^{x}y + rowoffset$$

In the formulas, x' (x prime) and y' (y prime) correspond to the pixel coordinates for the full, original image. Otherwise, the values correspond to those used in the Arbitrary Affine, above, as follows:

colscale	=	(Column Scale) This value corresponds to value e, as defined above.
coloffset	=	(Column Offset) This value corresponds to value f, as defined above.
rowscale	=	(Row Scale) This value corresponds to value a, as defined above.
rowoffset	=	(Row Offset) This value corresponds to value c, as defined above.

The values for *b* and *d*, as defined above, are set to 0.

The **Full Row Count** is the number of rows in the full, original image. If the header data is absent, this value corresponds to the row count of the chip. Likewise, the **Full Column Count** is the number of columns in the full, original image. If the header data is absent, this value corresponds to the column count of the chip.

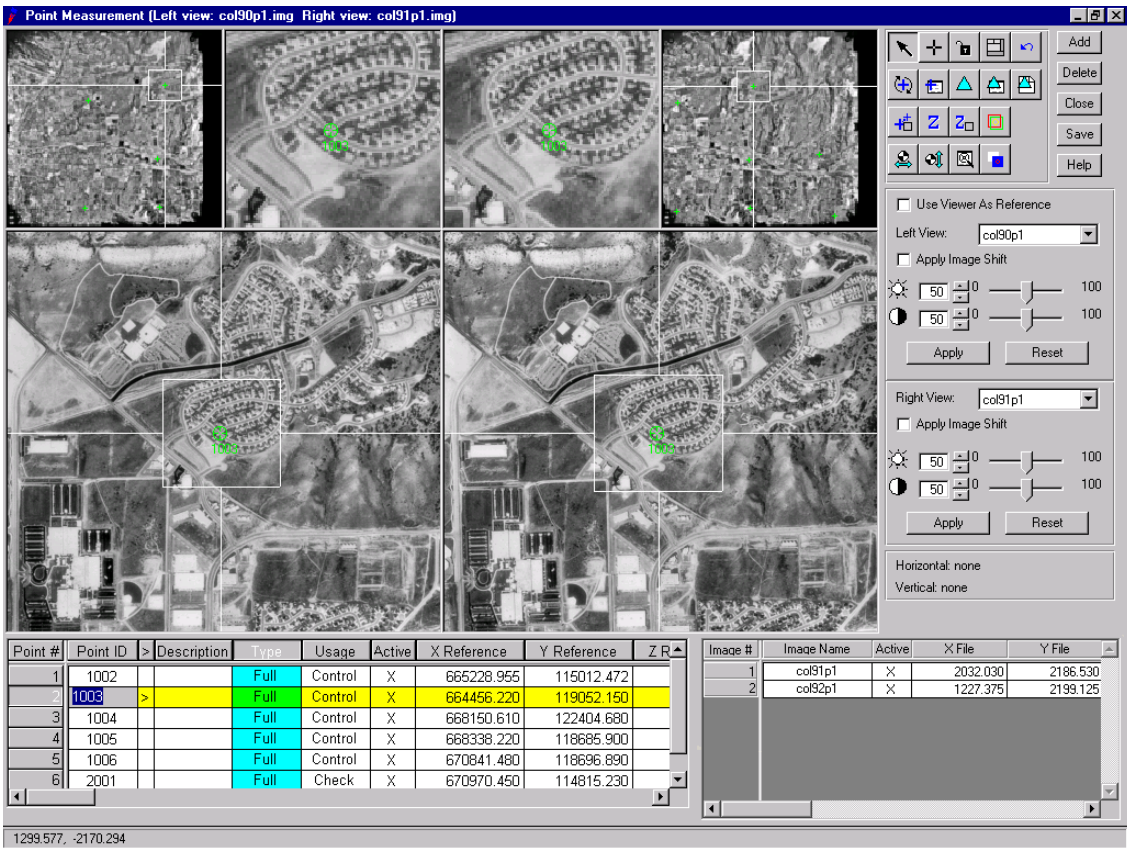
Measuring GCPs, Check Points, and Tie Points

Introduction

The Point Measurement tool, shown in Figure 11-1 is used to measure the GCPs, check points, and tie points appearing on one or more overlapping images. The Point Measurement tool serves several purposes including:

- collecting and entering GCP and check point coordinates
- measuring the image positions of GCPs, check points, and tie points
- defining the statistical quality of the GCPs
- launching processes associated with automatic tie point collection and aerial triangulation

Figure 11-1: Point Measurement Tool



The Point Measurement tool can be divided into three categories: Point Measurement views, Point Measurement CellArrays, and Point Measurement tools.

Point Measurement Views

The Point Measurement tool allows for the display of two images contained within a block. Each image has associated with it an OverView, Main View and Detail View. A Link Cursor located within the OverView and Main View is used to zoom in and out of an image area and roam around an image to identify the image positions of GCPs, check points, and tie points. Within the Point Measurement views, the image positions of GCPs, check points, and tie points can be measured. The Detail View is commonly used for image measurement.

Image Enhancement

To increase the quality of Point Measurement, the images displayed within the Point Measurement views can be enhanced to optimize GCP identification and measurement. The following options are provided for enhancing the display of an image:

- **Brightness and Contrast Controls.** Changes to the brightness and contrast levels can be applied to the Main View and Detail View in the Point Measurement tool.

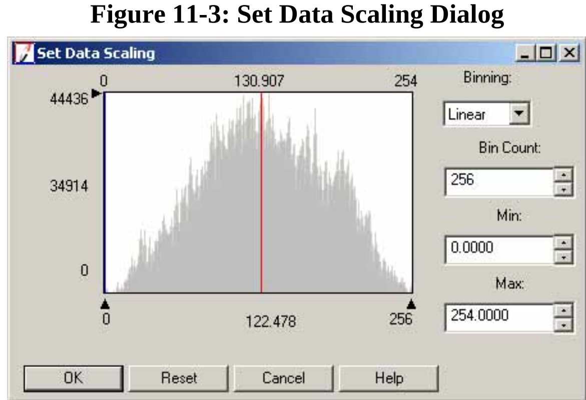
- **Set Resampling Method.** A right-click within any of the three views: OverView, Main View, Detail View) displays the **Set Resampling Method** option (Figure 11-2). Selecting the **Set Resampling Method** option provides three image resampling methods including **Nearest Neighbor, Bilinear Interpolation, Cubic Convolution,** and **Bicubic Spline.**

Figure 11-2: Set Resampling Method Dialog

Selecting the **Nearest Neighbor** option within the Detail View is optimum for identifying and measuring the location of a GCP to sub-pixel accuracy.

- **Data Scaling.** The distribution of grey levels for a image can be modified to enhance the display of the GCP locations. A right-click within any of the three views (OverView, Main View, Detail View) displays the **Set Data Scaling** dialog (Figure 11-3).

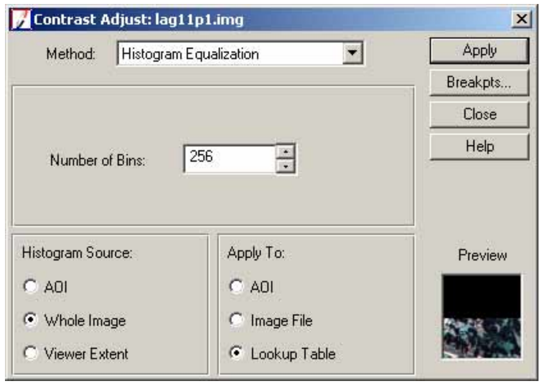
Figure 11-3: Set Data Scaling Dialog



Adjusting the histogram adjusts the display of the image to enhance point identification and measurement.

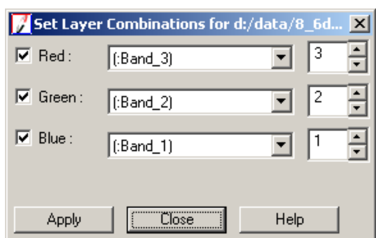
- **General Contrast Options.** Sophisticated image enhancement tools are provided that allow for the variation of image display. A right-click within any of the three views (OverView, Main View, Detail View) displays the **General Contrast** option, as shown in Figure 11-4.

Figure 11-4: Contrast Adjustment Dialog



- **Band Combinations.** If using color or multispectral images comprising several bands of imagery, the band combinations can be used to assist in distinguishing and identifying GCPs. Figure 11-5 shows the interface.

Figure 11-5: Set Band Combinations Dialog



Defining the Type of GCPs

The type of GCP defines the characteristics of the point and how the GCP is to be used by OrthoBASE during the aerial triangulation procedure. The **Type** column within the Point Measurement tool reference CellArray displays one of the four different GCP types including: **Full, Horizontal, Vertical,** and **None.**

A **Full** control or check point has X, Y, and Z coordinates associated with it. Each control point can also have a standard deviation associated with it. A standard deviation value can be used to specify the quality of the GCP during the aerial triangulation procedure.

A **Horizontal** control or check point has X and Y coordinates associated with it. Each horizontal control point can also have a standard deviation associated with it. The Z coordinate for the control point is unknown and is estimated during the aerial triangulation process.

A **Vertical** control or check point has a Z coordinate associated with it. Each vertical control point can also have a standard deviation associated with it. The X and Y coordinates for this control point are unknown and are estimated during the aerial triangulation process.

A **None** specification is used for tie points. Its image positions are known and have been measured, but its X, Y, and Z coordinates are estimated during the aerial triangulation procedure.

To edit the **Type** designation for one point in the project, right-click the **Type** cell and select the appropriate designation.

To edit the **Type** designation for all of the points within a project, select the **Type** column within the Point Measurement tool reference CellArray and choose the **Formula** option. Within the Formula dialog, input the appropriate designation and select **Apply.** The **Type** designation is applied to all of the points simultaneously.

Defining the Usage of GCPs

The usage of a GCP defines whether the GCP is a control point, check point, or tie point.

A control point has either its X, Y, and Z coordinates known (**Full**), X and Y coordinates known (**Horizontal**), or Z coordinates known (**Vertical**). During the aerial triangulation procedure, the X, Y, and Z coordinates of a **Full** GCP can be fixed. If a standard deviation is assigned to **Full** GCPs, the values are modified during aerial triangulation. The Z coordinate of a horizontal control point is estimated during the aerial triangulation procedure. The X and Y coordinates of a vertical control point are estimated during the aerial triangulation procedure.

A check point is used to independently verify the quality of an aerial triangulation solution. During aerial triangulation, the X, Y, and Z coordinates of a check point are not used. The image coordinates are used to compute new X, Y, and Z coordinates. The newly computed coordinates of the check points are subtracted from the input values. The differences in coordinate values are residuals which are displayed within the **X Residual, Y Residual,** and/or **Z Residual** columns of the Point Measurement tool CellArray.

Display the X, Y, and Z residual columns by selecting the Viewing Properties icon. Then click the **Advanced** *radio button and the* **Residual** *checkbox.*

A tie point is the image/photo-coordinate position of an object appearing on two or more images with overlapping areas. The X, Y, and Z coordinates of a tie point are determined by OrthoBASE during the aerial triangulation procedure. The resulting X, Y, and Z coordinates are then displayed within the **X Reference, Y Reference,** and **Z Reference** columns of the CellArray if the triangulation results are accepted. Once the coordinates of a tie point have been estimated, the point can be used as a control point for other applications (e.g., geo correction). This approach in creating control points is also known as control point extension.

To edit the **Usage** designation for one point in the project, right-click the **Usage** cell and select the appropriate designation.

To edit the **Usage** designation for all of the points within a project, select the **Usage** column within the Point Measurement tool CellArray and choose the **Formula** option. Within the Formula dialog, input the appropriate designation and select **Apply.** The **Usage** designation is applied to all of the points which were selected simultaneously.

Importing Ground Coordinates Using the CellArray

1. Add the number of points to be imported by clicking the **Add** button within the Point Measurement tool.

2. Within the Point Measurement tool CellArray, select the appropriate columns to be imported. This may include:
    - Point ID
    - Description
    - Type
    - Usage
    - X, Y, Z
    - Std X, Std, Y, Std Z

Hold the Shift key on the keyboard and left-click to select nonadjacent columns.

3. Right-click to display the column CellArray options.
4. Select the **Import** option.
5. Select the **Import** ASCII file name.
6. To customize the import procedure, select the **Options** button within the Import Column Data dialog. Customize the import procedure as a function of delimiters, row terminator, and column mapping.
7. Select **OK** to import the GCP information contained within the ASCII file.

Exporting Ground Coordinates Using the CellArray

1. Within the Point Measurement tool CellArray, select the appropriate columns to be exported. These may include:
    - Point ID
    - Description
    - Type
    - Usage
    - X, Y, Z
    - Std. Xo, Std. Yo, Std. Zo, etc.

Hold the Shift key on the keyboard and left-click to select nonadjacent columns.

2. Right-click to display the column CellArray options.
3. Select the **Export** option.
4. Enter the **Output** ASCII file name. The ASCII file is stored as a *.dat file.
5. To customize the export procedure, select the **Options** button within the Export Column Data dialog. Customize the export procedure as a function of delimiters, row terminator, and column mapping.

6. Select **OK** to export the ground coordinate information to the specified ASCII file.

Defining the Statistical Quality of GCPs

The quality of GCPs obtained from various reference sources can be defined to optimize the distribution of error throughout the block during the triangulation procedure. A standard deviation can be assigned to the GCPs to indicate the quality of the GCPs. For example, if a GCP was digitized off a topographic map, and the accuracy of the topographic map was 20 meters in X, Y, and 10 meters in Z, the corresponding standard deviation of the GCP would be 20 meters for X and Y, and 10 meters for Z.

If the GCPs have different standard deviation values associated with them, the Point Measurement tool should be used to input the statistical information. If all of the GCPs have the same standard deviation values, the **Point** tab of the Aerial Triangulation dialog can be used to input the statistical information.

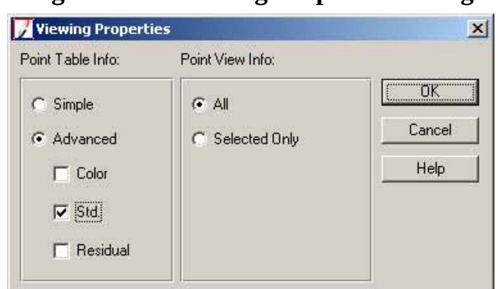
See "Assigning Statistical Weights to GCPs" for more information about assigning statistical weights.

The following steps are used to define the statistical quality of the GCPs:

1. Select the Viewing Properties icon  within the Point Measurement tool.

   The dialog shown in Figure 11-6 opens.

Figure 11-6: Viewing Properties Dialog



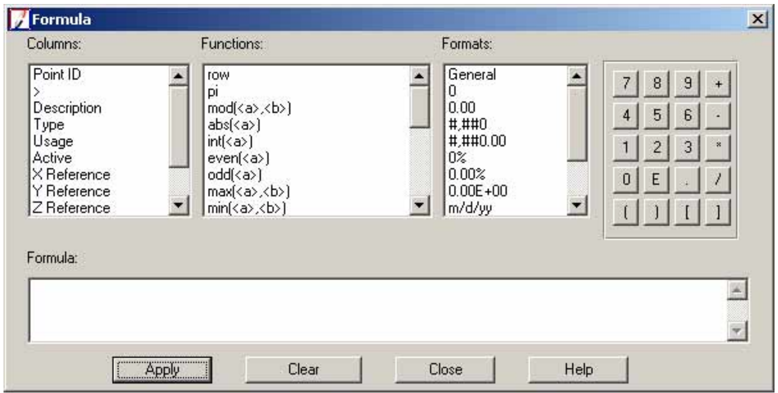
2. Select the **Advanced** radio button, and choose the **Std.** option. Select **OK.** The **X, Y,** and **Z Std.** columns are displayed within the Point Measurement tool CellArray.

3. Within the Point Measurement tool CellArray, select the appropriate **Std. X, Y, Z** (Standard Deviation) columns using a left-click and drag. The selected columns are highlighted.

4. Right-click to display the **Column Options** menu.

5. Select the **Formula** option. The dialog in Figure 6-7: "Formula Dialog of the OrthoBASE CellArray" opens.

Figure 11-7: Formula Dialog of the LPS CellArray



6. Within the Formula dialog, input the appropriate standard deviation values. Selecting the **Apply** button applies the value to each GCP selected.

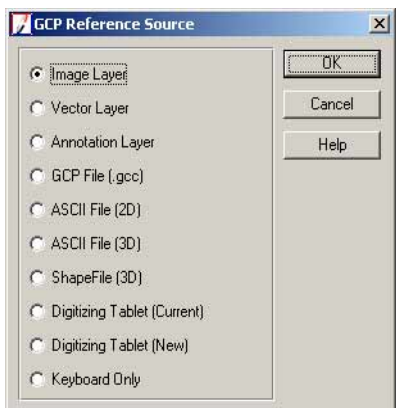
7. Select **Close** to return to the Point Measurement tool. Direct keyboard input can be used to specify the statistical quality of individual GCPs.

Collecting Horizontal Reference GCPs

OrthoBASE supports the use of GCPs obtained from various reference sources. This includes existing orthorectified images, geo corrected images, vector Arc Coverages, annotation layers, ASCII text files, and digitizing tablets.

The **Set Horizontal Reference Source** option allows for the collection of horizontal GCPs. You select the reference source from the dialog depicted in Figure 11-8

Figure 11-8: GCP Reference Source Dialog from the Point Measurement Tool



The following steps are used to collect GCPs from an existing orthorectified image:

1. Select the Set Horizontal Reference Source icon  .

2. Select the **Image Layer** option in the GCP Reference Source dialog, then click **OK.**

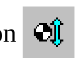
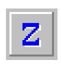
3. Within the Reference Image Layer File Selector, specify the orthorectified image as the input file, and select **OK.** The horizontal reference source file name is displayed within the lower right portion of the Point Measurement tool.

4. Within the Point Measurement tool, click on the **Use Viewer As Reference Source** option.
5. The existing orthorectified image is displayed within the left portion of the Point Measurement views.
6. Select the **Add** button to begin collecting GCPs. The Detail View is ideal for the identification and measurement of horizontal reference GCPs. Once a point has been measured, the corresponding X and Y ground coordinates are displayed within the Point Measurement CellArray.
7. Identify and measure the corresponding image positions of the GCPs on the block of imagery.

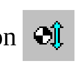
   Ensure that the horizontal reference GCPs conform to the same projection, spheroid, and datum as the block.

Collecting Vertical Reference GCPs

If horizontal GCPs have already been collected, the following steps are used to define the vertical (Z) component of existing horizontal GCPs:

1. Select the Set Vertical Reference Source icon  .
2. If a DEM is available, select the **DEM** option and define the DEM file. If a DEM is not available and the area is relatively flat, select the **Constant** option. The vertical reference source file name is displayed within the lower right portion of the Point Measurement tool.
3. Within the Point Measurement tool CellArray, left-click within the **Point #** column to select the GCPs. Its vertical component is automatically updated.
4. Select the Update Z icon  within the Point Measurement tool. The Z coordinates of the GCPs are updated and displayed within the CellArray.

   During the collection of horizontal GCPs, the vertical component of the GCPs can be automatically populated using the following steps:

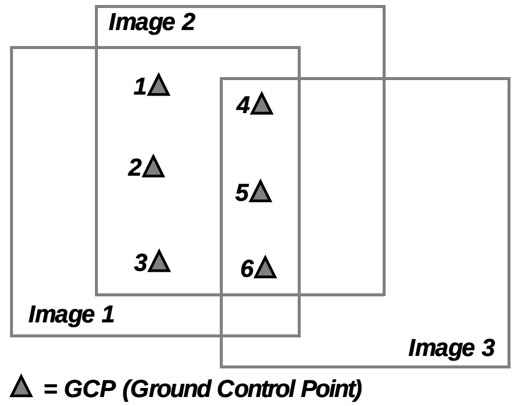
1. Select the Set Vertical Reference Source icon  .
2. If a DEM is available, select the **DEM** option and define the DEM file. If a DEM is not available and the area is relatively flat, select the **Constant** option. The vertical reference source file name is displayed within the lower right portion of the Point Measurement tool.
3. Select the Automatic Z Update icon  . An "x" is displayed within the icon once it has been selected  .
4. The vertical component of a GCP is automatically added once a horizontal GCP has been measured.

   Ensure that the vertical reference GCPs conform to the same projection, spheroid, and datum as the block.

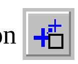
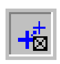
Collecting GCPs on Multiple Images

For projects comprising the use of three or more images within a strip, as illustrated by Figure 11-9, the following steps can be used for the collection of GCPs:

Figure 11-9: A Configuration of GCPs Located on Three Images



1. Within the Point Measurement tool, define Image 1 as the **Left View** and Image 2 as the **Right View.** The **Left View** and **Right View** image dropdown lists can be used to define which images are displayed within the Point Measurement tool.

2. Select the Automatic (X,Y) Drive icon  to automatically display the image positions of GCPs on the overlap areas of two images. This capability is enabled when at least two GCPs have been measured on the overlap areas of two images. Once selected, the icon changes to the following:  .

3. Select the **Add** button six times. Enter the GCP coordinates of GCPs, or use the Set Horizontal Reference Source and Set Vertical Reference Source tools to define the GCP coordinates.

4. Identify and measure the image positions of GCP 1, 2, and 3 on Image 1 and Image 2.

5. Repeat step 3 and step 4 for GCPs 4, 5, and 6 on Image 1 and Image 2. The image positions of GCPs 4, 5, and 6 are automatically displayed prior to the collection of each point.

6. Within the **Right View** tools group, select the **Apply Image Shift** radio button.

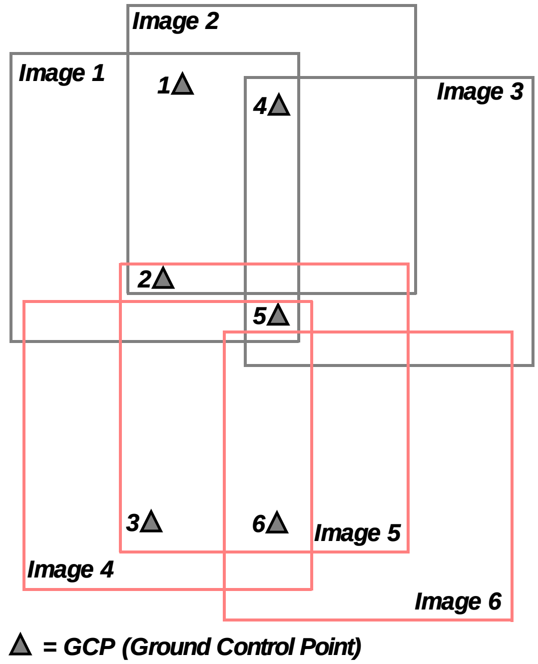
7. Within the **Right View** tools group image dropdown list, select Image 3. Image 2 is automatically placed within the **Left View** of the Point Measurement tool.

8. Identify and measure the image positions of GCPs 4, 5, and 6 on Image 3.

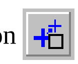
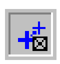
Collecting GCPs on Multiple Strips

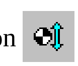
For projects comprising two or more strips within a block, as illustrated by Figure 11-10, the following steps can be used for the collection of GCPs:

Figure 11-10: A Configuration of GCPs Located on Six Images



1. Within the Point Measurement tool, define Image 1 as the **Left View** and Image 2 as the **Right View**. The **Left View** and **Right View** image dropdown lists can be used to define which images are displayed within the Point Measurement tool.

2. Select the Automatic (X,Y) Drive icon  to automatically display the image positions of GCPs on the overlap area of two images. This capability is enabled when at least two GCPs have been measured on the overlap area of two images. Once selected, the icon changes to the following:  .

3. Select the **Add** button six times. Enter the GCP coordinates of GCPs or use the Set Horizontal Reference Source icon  and Set Vertical Reference Source icon  to define the GCP coordinates.

4. Identify and measure the image positions of GCP 1, 2, and 4 on Image 1 and Image 2.

5. Within the **Right View** tools group, select the **Apply Image Shift** radio button.

6. Within the **Right View** tools group image dropdown list, select Image 3. Image 2 is automatically placed within the **Left View** of the Point Measurement tool.

7. Identify and measure the image positions of GCPs 4 and 5 on Image 3.

8. Deactivate the **Apply Image Shift** option within the **Right View** tools group.

9. Within the **Left View** tools group image dropdown list, select Image 4 and within the **Right View** tools group image dropdown list, select Image 5.

10. Select the **Apply Image Shift** radio button within the **Right View** tools group.

11. Identify and measure the image positions of GCP 2, 3, 5, and 6 on Image 4 and Image 5.

12. Within the **Right View** tools group image dropdown list, select Image 6. Image 5 is automatically displayed within the **Left View** of the Point Measurement tool.

13. Identify and measure the image positions of GCP 6 on Image 6.

    Once a GCP, check point, or tie point has been measured, the image coordinates are displayed within the right portion of the Point Measurement tool CellArray.

Chapter 12

Automatic Tie Point Collection

Introduction

Automatic tie point collection utilizes digital image matching techniques to automatically identify and measure the image positions of GCPs appearing on two or more images with overlap.

Rather than manually identify and measure tie points on the overlap areas of multiple images, OrthoBASE automates the procedure. OrthoBASE supports the processing of multiple strips of imagery, including adjacent, diagonal, and cross-strips.

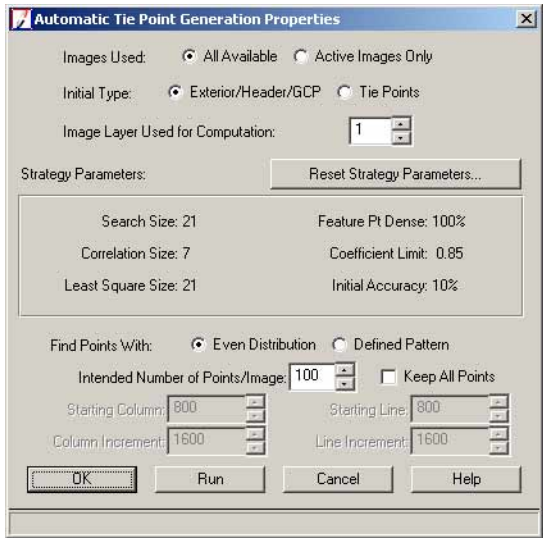
The maximum number of tie points intended for each image is 500. If the **Keep All Points** option is used, the number of tie points collected for each image exceeds 500 points.

Automatic tie point collection successfully performs the following tasks:

- Automatic block configuration. Based on the initial input requirements, OrthoBASE defines the extent of the block with respect to image adjacency.
- Automatic tie point extraction. Image feature points are automatically extracted using an interest operator.
- Point transfer. Ground points appearing on multiple images are automatically identified and matched.
- Gross error detection. Erroneous points are automatically identified and removed from the solution.
- Tie point selection. The intended number of tie points defined is automatically selected as the final number of tie points.

By selecting the Automatic Tie Point Generation Properties option within the **Edit** menu of the LPS Project Manager, or by selecting the Automatic Tie Point Generation Properties icon within the Point Measurement tool, the Automatic Tie Point Generation Properties dialog in Figure 12-1 opens.

Figure 12-1: Automatic Tie Point Generation Properties Dialog



Minimum Input Requirements

Since automatic tie point collection processes multiple images with overlap, OrthoBASE requires information regarding image adjacency. The minimum input requirements are used to determine the block configuration with respect to which image is adjacent to which image, and which strip is adjacent to which strip in the block.

The minimum input requirement can be one of the following three:

- If processing frame camera, digital camera, videography, or nonmetric imagery, initial approximations to exterior orientation (X, Y, Z, Omega, Phi, Kappa) can be specified for each image in the block. These can be obtained from existing aerial triangulation results, airborne GPS and INS data, or calculated from an existing cartographic map (Omega and Phi can be assumed 0 if the degree of photographic or image tilt is minimal). If processing multiple strips of images captured with different direction of flight, the appropriate Kappa element must be specified. The **Exterior/Header/GCP** radio button is selected as the **Initial Type.**

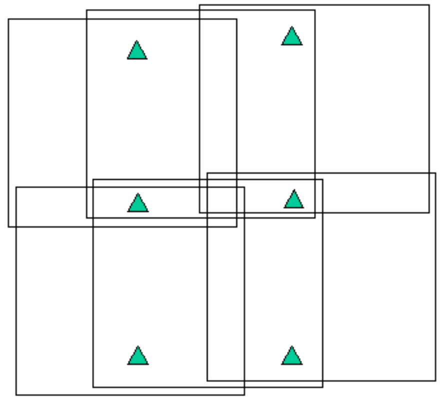
  If processing SPOT, IRS-1C, or generic pushbroom imagery, the ephemeris information (containing orbit and track information) contained within the header file of the image is used.

  If processing IKONOS imagery, the interior and exterior orientation information is contained within the RPC file associated with each image.

- At least two GCPs must be measured on the overlap areas for the imagery in the block. The **Exterior/Header/GCP** radio button is selected as the **Initial Type.**

- At least two tie points must be measured on the overlap areas of the imagery in the block. Figure 12-2 illustrates the GCP or tie point configuration required to perform automatic tie point collection on six overlapping images comprising two strips. The **Tie Points** radio button is selected as the **Initial Type.**

Figure 12-2: GCP Configuration for Six Images



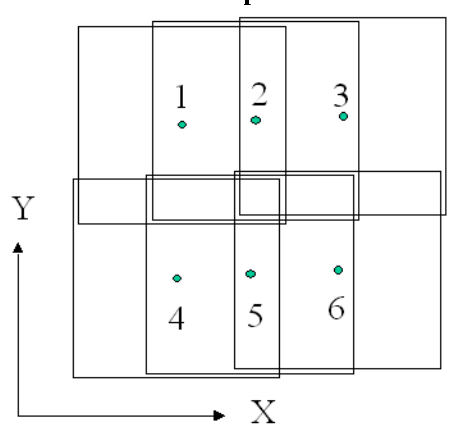
Performing Automatic Tie Point Collection: An Alternative Solution

For scenarios where initial approximations to exterior orientation are unknown, GCPs are unavailable and measuring two tie points is unrealistic (too many images in the block), but an alternative solution can be used to provide the minimum input required to perform automatic tie point collection.

The procedure involves establishing a relative relationship between the images contained in the block and the ground. The relative relationship is defined by establishing the relative X, Y, and Z coordinates of the perspective center for each image.

In order to compute the relative X, Y, and Z coordinates for the perspective center, the minimum input information includes a focal length (inches or in millimeters) and scale of photography. Figure 12-3 illustrates a sample block of images. Its relative X, Y, and Z perspective center coordinates can be determined. The circle appearing in the central portion of the individual images is the perspective center.

Figure 12-3: Location of the Perspective Center for Six Images



Assuming a 1:40000 scale photography (60% overlap and 30% sidelap), and a six inch (152 mm) focal length (9 × 9 inch image size), the relative X, Y, and Z coordinates of the individual perspective centers are given in Table 12-1.

Table 12-1: Perspective Center Coordinates

Image	X (meters)	Y (meters)	Z (meters)
1	0	0	6096
2	3658	0	6096
3	7316	0	6096
4	0	6401	6096
5	3658	6401	6096
6	7316	6401	6096

The perspective center of Image 1 would serve as the origin of the X and Y coordinate system (e.g., 0, 0). Every other X and Y perspective center coordinate is relative to Image 1. Assuming minimal photographic tilt, the Omega and Phi rotation angles are negligible. An ASCII file containing the approximate relative exterior orientation information can be imported into OrthoBASE and used for automatic tie point collection. The information can be imported using the **Edit All Images** option contained within the **Exterior Information** tab of the Frame Editor dialog.

In the previous scenario, the X coordinate is considered the base between the exposure stations along a strip having 60% overlap (i.e., 3658 meters). The X coordinate for Image 3 is doubled relative to its distance from Image 1. The Y coordinate is considered the base between the strips that have 30% sidelap. The Z coordinate is considered the average flying height (above sea level).

Table 12-2 provides the Base X (overlap with 60%), Base Y (sidelap with 30%), and average flying height for various scales of photography in feet.

Table 12-2: Photography Scale and Associated Data (Feet)

Photo Scale 1 to...	Flying Height (feet)	Ground Coverage (feet)	Overlap 60% (feet)	Sidelap 30% (feet)
1800	900	1350	540	945
2400	1200	1800	720	1260
3000	1500	2250	900	1575
3600	1800	2700	1080	1890
4200	2100	3150	1260	2205
4800	2400	3600	1440	2520
5400	2700	4050	1620	2835
6000	3000	4500	1800	3150

Table 12-2: Photography Scale and Associated Data (Feet) (Continued)

Photo Scale 1 to...	Flying Height (feet)	Ground Coverage (feet)	Overlap 60% (feet)	Sidelap 30% (feet)
6600	3300	4950	1980	3465
7200	3600	5400	2160	3780
7800	3900	5850	2340	4095
8400	4200	6300	2520	4410
9000	4500	6750	2700	4725
9600	4800	7200	2880	5040
10800	5400	8100	3240	5670
12000	6000	9000	3600	6300
15000	7500	11250	4500	7875
18000	9000	13500	5400	9450
24000	12000	18000	7200	12600
30000	15000	22500	9000	15750
40000	20000	30000	12000	21000
50000	25000	37500	15000	26250
60000	30000	45000	18000	31500

Table 12-3 provides the Base X (overlap with 60%), Base Y (sidelap with 30%) and average flying height for various scales of photography in meters.

Table 12-3: Photography Scale and Associated Data (Meters)

Photo Scale 1 to...	Flying Height (meters)	Ground Coverage (meters)	Overlap 60% (meters)	Sidelap 30% (meters)
1800	274	411	165	288
2400	366	549	219	384
3000	457	686	274	480
3600	549	823	329	576
4200	640	960	384	672
4800	732	1097	439	768
5400	823	1234	494	864

Table 12-3: Photography Scale and Associated Data (Meters) (Continued)

Photo Scale 1 to...	Flying Height (meters)	Ground Coverage (meters)	Overlap 60% (meters)	Sidelap 30% (meters)
6000	914	1372	549	960
6600	1006	1509	604	1056
7200	1097	1646	658	1152
7800	1189	1783	713	1248
8400	1280	1920	768	1344
9000	1372	2057	823	1440
9600	1463	2195	878	1536
10800	1646	2469	988	1728
12000	1829	2743	1097	1920
15000	2286	3429	1372	2400
18000	2743	4115	1646	2880
24000	3658	5486	2195	3841
30000	4572	6858	2743	4801
40000	6096	9144	3658	6401
50000	7620	11430	4572	8001
60000	9144	13716	5486	9601

To compute the Base X and Base Y components for photographs containing different percentage overlap and sidelap, multiply the Ground Coverage by the appropriate percentage. For example, to compute Base Y having a sidelap of 10%, multiply 0.9 by the ground coverage. Similarly, to compute the Base X having a overlap of 30%, multiply 0.7 by the ground coverage.

This approach is not suited for areas having large variations in relief displacement (e.g., mountainous regions).

Once the relative orientation parameters have been computed, an ASCII file containing the information can be imported, or the values can be entered directly within the **Exterior Information** tab of the Frame Editor.

Optimizing Automatic Tie Point Collection

Strategy parameters governing the operation of the automatic tie point collection procedure can be used to optimize the performance of automatic tie point collection. The factors governing the overall performance of automatic tie point collection include:

- image quality (poor scanning)
- image content (deserts, water bodies)

- topographic relief displacement
- input quality of the minimum input requirements

Six strategy parameters are provided including:

- search size (pixels)
- correlation size (pixels)
- least squares size (pixels)
- feature point density (10% to 900%)
- coefficient limit (0 to 0.99)
- initial accuracy (0% to 150%)

Search Size

Once all of the interest or feature points have been identified, OrthoBASE calculates the approximate location of feature points on the overlapping areas of multiple images. Once an approximate location has been identified, OrthoBASE searches for the corresponding image positions within a square search window. The size of the search window can be defined. For areas with large topographic relief displacement, a larger search size is recommended. If the default 21 × 21-pixel search window size is increased, an increase in computation time can be expected.

Correlation Size

Correlation size defines the size of the window to be used to compute the correlation between image points of common ground points appearing on multiple images. The default window size is 7 × 7. For areas containing minimal variation in topographic relief, grey level or color intensity (e.g., desert, agricultural fields, grassy areas), a larger value (e.g., 9 × 9 or greater) can be used. For areas containing large degrees of topographic relief and grey level or color intensity variation, a smaller window size is recommended (e.g., 5 × 5). If the default values are modified, ensure the quality of the resulting tie points.

Least Squares Size

Least squares matching techniques are used to ensure that the quality of the corresponding matched points is accurate to approximately 0.1 to 0.2 pixels. The least square size defines the window size of the two windows appearing over the overlapping area of two images during the least squares matching process. A larger window size reduces the number of false matches, but may also increase the percentage of false matches. Similarly, a smaller window size may increase the number of false matches while maintaining a large percentage of good matches. For areas with minimal relief displacement, a larger window size can be specified. For areas containing large degrees of variation in image content (urban areas) or relief displacement (rugged and mountainous terrain), a smaller value is recommended.

Feature Point Density

During the automatic extraction of feature points, OrthoBASE calculates interest or feature points which consist of points having large amounts of grey level variation within a local neighborhood of pixels. OrthoBASE automatically determines the density of points located throughout the overlapping areas of the images. The default feature density is 100%. A value of 300% stipulates that OrthoBASE automatically collects three times the number of points it normally collects. A value of 50% stipulates that OrthoBASE automatically collects 50% fewer points than it normally collects. For images containing poor image contrast, a higher value is recommended. For images containing large amounts of detail (forested and urban areas), or that have a sharp image contrast, using a smaller value is recommended.

Correlation Limit

The correlation limit defines the correlation coefficient threshold used to determine whether or not two points are to be considered as possible matches. Once the correlation between two points appearing on two frames has been computed, the correlation limit is compared to the correlation coefficient. If the correlation coefficient is smaller than the correlation limit, the two points are not considered a match. A larger correlation limit may result in greater accuracy, although fewer points may be collected. If a smaller correlation limit results, it may increase the number of correlated points, but could introduce false match points into the solution.

Initial Accuracy

Initial accuracy defines the input quality of the input minimum requirements. If exterior orientation parameters or header information is used, the parameters should be accurate to 25% of the true value. A larger value increases the initial search area to identify and match corresponding image points in the initial estimation process. If GCPs or tie points are used as the **Initial Type,** the initial accuracy is considered as the relative elevation difference (i.e., average elevation difference divided by the flying height). If the minimum input requirements are of poor precisional and relative quality, a larger value is recommended. Therefore, if accurate initial values are available, specify a low value. If inaccurate initial values are available, a larger value should be specified.

Avoid Shadow

When this option is enabled, tie points are not generated in areas of shadow, such as building and terrain shadows produced by the sun’s position at the time of image capture. Avoiding areas in shadow improves auto tie results. You should choose whether the images you are working with came from film (**Negative**) or photographs (**Positive**).

Performing Automatic Tie Point Collection on Color Imagery

With color imagery, automatic tie point collection is performed on one image layer or band, defined by the **Image Layer Used** option within the Automatic Tie Generation Properties dialog.

Prior to performing automatic tie point collection on color imagery, it is highly recommended that the individual image layers be viewed to identify which layer or band contains the greatest amount of grey level variation.

Automatically collected tie points can be verified within the Point Measurement tool by viewing the image positions of the tie points on the overlap area of the two frames.

Troubleshooting Tips

The following tips can be used in cases where the automatic tie point collection fails to successfully match image points appearing on multiple images:

- If exterior orientation parameters or GCPs were used as the **Initial Type,** manually measure two tie points within the overlapping areas of two images and **Run** the automatic tie point collection.
- If initial approximations for exterior orientation are used and the automatic tie point collection process fails to provide a solution, the Kappa element associated with the exterior orientation parameters should be checked and modified if required.

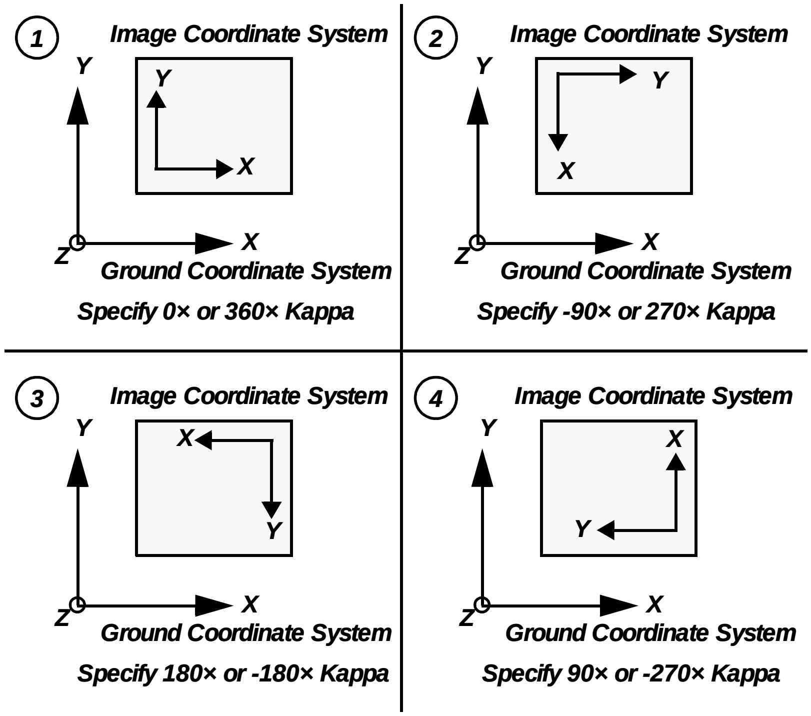
The following steps can be used to ensure that the appropriate Kappa element be defined:

- Ensure that the appropriate image/photo-coordinate system is defined. The image coordinate system defines the direction of the x and y image coordinate system. This system is defined by measuring the fiducial marks on the imagery and selecting the appropriate fiducial orientation.

Refer to "Interior Orientation" for more information.

- Define the direction of the X, Y, and Z ground coordinate axes. This involves determining the easting (X) and northing (Y) of the ground coordinate system. The Z coordinate is normally vertical.
- Determine the relationship between the image coordinate system and the ground coordinate system. Once the relationship has been determined, the appropriate Kappa value can be assigned to exterior orientation. The images in Figure 12-4 illustrate four different options for defining the Kappa element as a function of the relationship between the image/photo-coordinate system and the ground coordinate system.

Figure 12-4: Kappa as a Function



- Once the appropriate Kappa estimates have been determined, the sign or magnitude of the initial Kappa value should be changed in order for the automatic tie point collection procedure to work.

Chapter 13

Block Triangulation

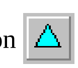
Introduction

Block triangulation is the process of defining the mathematical relationship between the images contained within a block, the camera or sensor model that obtained the images, and the ground. Once the relationship has been defined, accurate and intelligent imagery and information concerning the Earth's surface can be created.

Block triangulation simultaneously estimates:

- The position (X, Y, Z) and orientation (Omega, Phi, Kappa) of each image in a block as they existed at the time of image capture.
- The X, Y, and Z coordinates of tie points collected manually or automatically throughout the block of images (point determination and positioning). Once the X, Y, and Z coordinates of tie points are computed, they can be converted to control points.
- The interior orientation parameters associated with a camera or sensor model. This process is commonly referred to as SCBA.
- AP characterizing systematic error within the block of images and observations (lens distortion).

When processing frame camera, digital camera, videography, and nonmetric camera imagery, block triangulation is commonly referred to as aerial triangulation. When processing imagery collected with a pushbroom sensor, block triangulation is commonly referred to as triangulation.

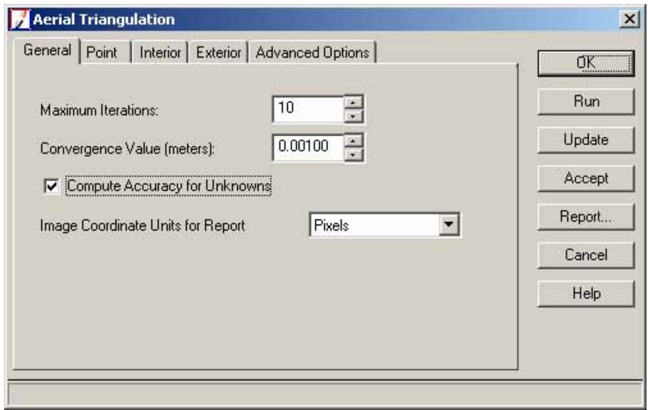
Both aerial triangulation and triangulation techniques utilize bundle block adjustment as the functional model to define the relationship between image space and ground space. To edit and view the properties associated with block triangulation, select the **Triangulation Properties** option within the **Edit** menu or select the Triangulation Properties icon  within the Point Measurement tool. To run the triangulation process, select the Triangulation icon  on the LPS toolbar, Point Measurement tool, or the **Triangulate** option within the **Process** menu in the LPS Project Manager.

Aerial Triangulation

Parameters governing the operation of aerial triangulation can be defined to optimize the results of using the estimated parameters.

The Aerial Triangulation dialog, shown in Figure 13-1, allows for the input and specification of parameters associated with performing aerial triangulation on frame camera, digital camera, videography, and nonmetric camera imagery.

Figure 13-1: General Tab of the Aerial Triangulation Dialog



Convergence Value

The convergence value is used as a threshold to determine the level and extent of processing during the iterative aerial triangulation procedure. During the iterative process of determining the unknown parameters, the amount of change between successive iterations is determined and compared to the convergence value. If the amount of change between successive iterations is greater than the convergence value, the iterative process continues. If the amount of change between successive iterations is less than the convergence value, the iterative process of estimating the unknown parameters ends.

For large scale mapping (e.g., 1:2000 photo scale), and projects requiring high accuracy, a value of 0.0001 meters can be used. For small scale mapping projects (e.g., greater than 1:40000), a value of 0.01 can be used, otherwise the default setting of 0.001 meters is satisfactory.

For scenarios where the quality of ground control is poor and an aerial triangulation solution cannot be solved, relaxing the convergence value (e.g., 0.01 meters) may provide a solution. In this case, the accuracy of the aerial triangulation results is compromised.

Accuracy Estimates

Regardless of the project, computing the accuracy estimates for the unknown parameters is highly recommended. The accuracy estimates describe the quality of the estimated parameters. The accuracy estimates are computed by multiplying the standard deviation of unit weight by the variance of the individual parameters. The variance of the computed parameters is determined and contained within an output covariance matrix. Accuracy estimates are computed for:

- exterior orientation parameters for each image
- X, Y, and Z coordinates of the tie points
- interior orientation parameters if SCBA is performed
- AP if a functional model is selected

The accuracy estimates are contained with the aerial triangulation report.

For information about the aerial triangulation report, see *"Aerial Triangulation Report"*.

Optimizing Aerial Triangulation Using Statistical Information

During the bundle block adjustment procedure of aerial triangulation, OrthoBASE uses a statistical technique referred to as least squares adjustment to estimate the unknown parameters associated with the block of imagery. The least squares adjustment procedure minimizes and distributes error throughout a block. In order to effectively minimize and distribute error, the least squares adjustment uses the input statistical properties associated with the input data to determine the extent and nature of error minimization and distribution.

The statistical properties associated with the input data reflect the quality (e.g., precision) of the data. The quality of the input data is defined using standard deviation values. For example, if a survey field crew used a GPS to collect GCPs accurate to 0.05 meters, the statistical property associated with the GCPs would be 0.05 meters. During aerial triangulation, the assigned statistical weight is used to govern the amount of allowable error which can be attributed and distributed to the GCPs.

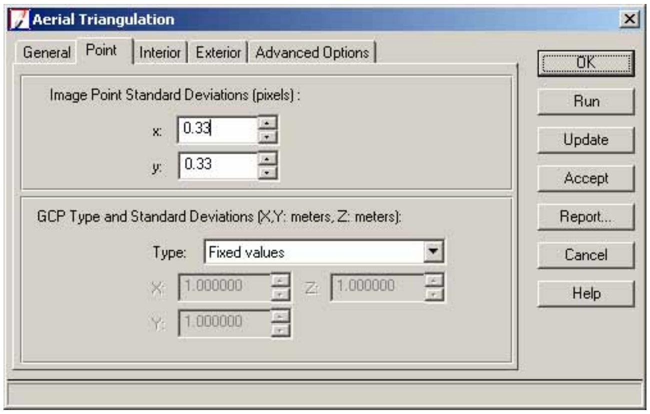
Standard deviations can be associated with the following observations:

- image/photo-coordinate positions of GCPs, check points, and tie points
- X, Y, and Z GCPs
- exterior orientation parameters for each image in the block
- interior orientation parameters
- AP

Assigning Statistical Weights to Image/Photo-coordinates

Statistical weights can be assigned to the x and y image/photo-coordinates representing the image position quality for GCPs, check points, and tie points. The **Point** tab within the Aerial Triangulation dialog, shown in Figure 13-2, is used to define the standard deviations associated with the image/photo-coordinates.

Figure 13-2: Point Tab of the Aerial Triangulation Dialog



If the quality of the measured image/photo-coordinates is weak, a larger value can be used. It is highly recommended that a value less than 1 pixel be used. During the iterative aerial triangulation procedure, the image/photo-coordinates fluctuate within the limits of the standard deviations. Once aerial triangulation has been completed, the image/photo-coordinate residuals can be examined to determine if the appropriate statistical weight has been used.

If the x and y image/photo-coordinates have different measurement accuracies, different statistical weights should be assigned.

Assigning Statistical Weights to GCPs

Statistical weights can be assigned to the X, Y, and Z coordinates representing the ground quality of the GCPs used in the block. The **Point** tab within the Aerial Triangulation dialog is used to define the standard deviations associated with the GCPs. Within the **Point** tab of the Aerial Triangulation dialog, several options are provided for defining the statistical quality of the GCPs. They include:

- **Fixed Values.** This option assumes that the GCPs are fixed in the X, Y, and Z direction. Statistical weight is not assigned to the GCPs. If this option is selected, large standard deviation values can be anticipated for the estimated exterior orientation parameters and the X, Y, and Z tie point positions. This can be attributed to the distribution of error into these parameters, since error was not allowed to propagate throughout the GCPs.
- **Same Weighted Values.** This option allows for the specification of a uniform statistical weight to the X, Y, and Z GCP coordinates. The statistical weight assigned can be determined as a function of the quality of the input GCP coordinates.
- **Different Weighted Values.** This option allows for the specification of unique statistical weights to the X, Y, and Z GCP coordinates within the Point Measurement tool. The statistical weights assigned can be determined as a function of the quality of the input GCP coordinates. The Viewing Properties dialog must be used to select the **Std.** option in order to input the standard deviation values of the input GCP coordinates.

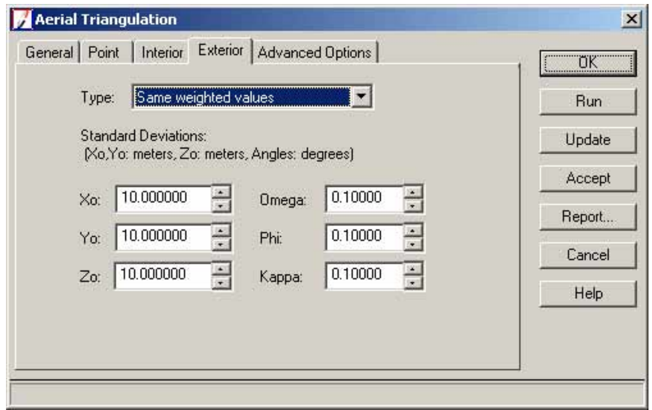
It is advantageous to assign unique statistical weights to different GCPs when the quality of the individual GCPs varies. Consider the following example where four GCPs were surveyed using a total station to an accuracy of 0.1 meters and five additional GCPs were measured from a topographic map having an accuracy of 10 meters. Since the quality of the surveyed GCPs is greater, the influence of these points during aerial triangulation should be increased as compared to the influence of the remaining five GCPs. Thus, smaller standard deviation values can assigned to the surveyed GCPs.

Assigning Statistical Weights to Exterior Orientation

Statistical weights can be assigned to the exterior orientation parameters representing the position and orientation of the camera/sensor exposure station as they existed at the time of capture. It is highly advantageous to statistically weight the exterior orientation parameters if they have been imported from an external source (e.g., airborne GPS, and the existing aerial triangulation results), or if the quality of the initial approximations is known. Statistically constraining the exterior orientation parameters ensures that the final estimated parameters do not deviate drastically from the user input values (assuming they are correct). The extent of the deviation or fluctuation is controlled by the specified standard deviation values.

The **Exterior** tab within the Aerial Triangulation dialog, depicted in Figure 13-3, is used to define the standard deviations associated with exterior orientation.

Figure 13-3: Exterior Tab of the Aerial Triangulation Dialog



Several options are provided for defining the statistical quality of the exterior orientation parameters. This includes:

- **No Weight.** This specification does not assign a statistical weight to the exterior orientation parameters. A **No Weight** specification can be used if initial approximations to exterior orientation are unknown or of poor quality.

- **Same Weighted Values.** This option allows for the specification of a uniform statistical weight to the X, Y, Z, and Omega, Phi, Kappa parameters. The statistical weight assigned can be determined as a function of the quality of the initial approximations to exterior orientation. Consider the use of airborne GPS and INS data, which has a positional quality of 2 meters and has a rotational quality of 0.1 degrees. This option should be used if the quality of input exterior orientation parameters is uniform.

- **Different Weighted Values.** This option allows for the specification of unique statistical weights to the X, Y, Z, and Omega, Phi, Kappa parameters within the **Exterior Information** tab of the Frame Editor dialog. The statistical weights assigned can be determined as a function of the quality of the input exterior orientation parameters.

It is advantageous to assign unique statistical weights to the different exterior orientation parameters when the strength of the geometric network comprising the block of imagery varies.

Consider the example where sixteen images comprise a block having four horizontal strips with four images per strip. Aerial triangulation has already been performed on the block and, due to the lack of redundancy (i.e., minimal control on the corner images) on the four corner images, the quality of the exterior orientation parameters for these images is less than the remaining images in the block.

To ensure that the error located within the four corner images does not negatively impact the quality of the remaining images, larger standard deviation values can be assigned to the corner images and smaller standard deviation values can be assigned to the remaining images. Smaller standard deviation values ensure that the exterior orientation parameters do not vary drastically as a result of the aerial triangulation procedure attempting to distribute and minimize error.

If the initial approximations for the exterior orientation parameters were imported from an external source and the accuracy of the values known, different statistical weights can be defined for exterior orientation parameters.

To increase the quality of the four corner images, additional GCPs can be measured.

SCBA

SCBA estimates the interior orientation parameters and AP associated with a camera/sensor. The interior orientation parameters that can be recovered include:

- focal length
- principal point in the x direction
- principal point in the y direction

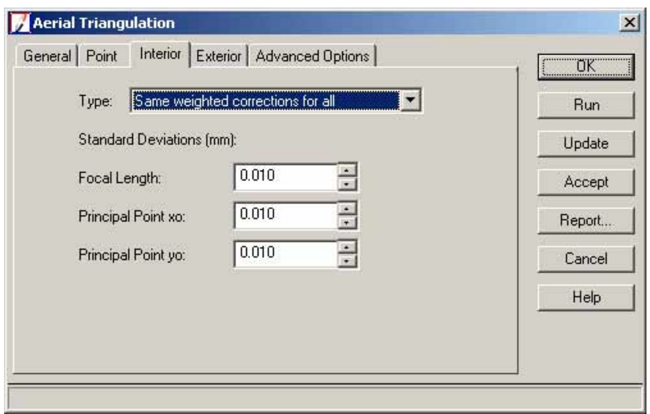
SCBA is most commonly used in the following scenarios:

- When the interior parameters associated with a camera or sensor are unknown. This is commonly the case when using a nonmetric camera (e.g., 35 mm amateur camera, and medium to large format cameras such as Hasselblad), digital camera, and videography using a CCD or film. Since these cameras were not designed for photogrammetric processing, camera calibration information is unknown.
- When the camera calibration parameters associated with a frame camera are outdated and incorrect.

Using SCBA, OrthoBASE accounts for the geometric errors associated with using noncalibrated cameras for photogrammetric processing (e.g., orthorectification, stereopair generation, and stereo feature collection).

The **Interior** tab of the Aerial Triangulation dialog, shown in Figure 13-4, is used to define whether or not the interior orientation parameters are estimated using the SCBA.

Figure 13-4: Interior Tab of the Aerial Triangulation Dialog



In order to perform SCBA within OrthoBASE, the statistical weights associated with interior orientation can be assigned.

Several options are provided for defining the statistical properties associated with the interior orientation parameters. They include Fixed for All Images, Same Weighted Corrections for All, Different Weighted Corrections, Same Unweighted Corrections for All, and Different Unweighted Corrections.

Fixed For All Images

The interior orientation parameters are not estimated and are assumed fixed for each image in the block.

Same Weighted Corrections For All

This option allows for the use of the SCBA capabilities to estimate the interior orientation parameters associated with the camera (e.g., the same camera) used to collect all of the photography or imagery in the block. Thus, one set of interior orientation parameters is used in the entire block. Statistical weights are assigned to the three interior orientation parameters. This option should be selected if the camera or sensor model was stable between successive exposure stations and the variation of interior orientation parameters is minimal. Statistical weights are used to control the fluctuation of the initial approximations for interior orientation during aerial triangulation. Use this option if few GCPs are available and the variation of interior orientation is small between successive exposure stations.

Different Weighted Corrections

This option estimates the interior orientation parameters associated with each image in the block (e.g., different interior orientation parameters for each exposure station). Thus, each image has three unique interior orientation parameters associated with it. This option should be selected if the camera or sensor model was not stable between successive exposure stations and the variation of interior orientation parameters is large. If the internal geometry of the camera varies during successive exposure stations, this option should be used. Unique statistical weight is assigned to the interior orientation parameter for each image in the block. The assignment of unique weight is done internally by OrthoBASE.

Same Unweighted Corrections For All

This option estimates the interior orientation parameters associated with the camera used to collect all of the photography or imagery in the block. Thus, one set of interior orientation parameters is used in the entire block. Statistical weights are not assigned to the three interior orientation parameters. This option should be selected if the internal geometry of the camera or sensor model was relatively stable between successive exposure stations and the variation of interior orientation parameters is minimal. Use this option if many GCPs are available. The variation of interior orientation is small between successive exposure stations, and the precision and accuracy of the interior orientation parameters are not known.

Different Unweighted Corrections

This option estimates the interior orientation parameters associated with each image in the block. Thus, each image has three unique interior orientation parameters associated with it. This option should be selected if the camera or sensor model was not stable between successive exposure stations and the variation of interior orientation parameters is large. If the internal geometry of the camera varies during successive exposure stations, this option should be used. Statistical weight is not assigned to the interior orientation parameter for each image in the block.

NOTE: Because of the instability of digital, video, and nonmetric cameras, the internal geometry of the cameras is not stable during the collection of imagery. For example, the CCD contained within a digital camera tends to move within the camera body during collection. Thus, unique interior orientation parameters can be associated with each camera station. In this scenario, OrthoBASE recovers the interior orientation parameters for each camera station. This is also applicable when using an amateur camera.

Optimizing the SCBA

In order to evaluate the results of the SCBA, review the estimated interior orientation values and their corresponding accuracy values. If the accuracy value for the principal point is larger than the principal point values, the confidence with which the parameter can be accurately estimated is low. Similarly, if the new focal length estimate varies drastically from the initial input value (e.g., several millimeters), recheck the initial input value and reexamine the SCBA.

The following tips can be used to optimize the results of the SCBA:

- Ensure that at least six **Full** GCPs are used in the overlap area of two images in the block.

- Rather than process each image in a block, apply the SCBA to several images containing an adequate number of GCPs. This minimizes the influence of weak geometry between many images.

- If results are inadequate, increase the number of GCPs in the overlapping areas of the images in the block.

- Since both the interior and exterior orientation parameters are being estimated in one solution, correlation exists between the interior and exterior orientation parameters. In other words, the reliability of estimating interior orientation is negatively impacted by the estimation of exterior orientation. To minimize the correlation between interior and exterior orientation, several options can be used. These include:

    - Use oblique imagery or photography. Oblique imagery minimizes the correlation between interior and exterior orientation because the optical axis of the camera is intentionally inclined away from the vertical direction of exterior orientation. Utilizing highly convergent (e.g., 80% overlap or greater) imagery also achieves this effect.
    - Use GCPs having a large amount of variation in the Z direction. If performing SCBA with imagery exposed over flat areas, the correlation between interior and exterior orientation negatively impacts the results. Introducing variable GCPs in the Z direction minimizes the correlation between interior and exterior orientation.

- If initial approximations to either interior or exterior orientation are known, assign statistical weights to the corresponding values indicating their quality. By not statistically constraining the unknown parameters, the quality of the SCBA can decrease.

- At least six tie points are common to the overlap areas of each image in the block. The more tie points that are used, the better the output SCBA results.

Estimating AP for SCBA

Due to systematic errors associated with the camera or sensor model and atmospheric refraction, the quality of the aerial triangulation is negatively impacted. The systematic errors can be partly or even largely eliminated by using the SCBA with AP. Under favorable conditions, improved triangulation results can be obtained if AP is used. The favorable conditions include:

- Strong geometry between the images in a block. A block can be geometrically strengthened by using adjacent images containing at least 60% overlap and 60% sidelap. Utilizing cross-strips also improves the geometry of a block.

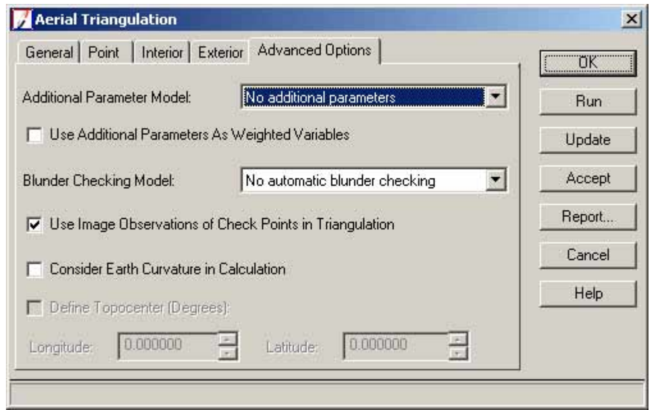
- Evenly distributed GCPs and tie points. Since additional unknown parameters are being estimated, the number of GCPs used in the block should also increase to maintain sufficient statistical redundancy. At least six GCPs in the overlap area of two frames should be used.

- Minimum correlation between the AP and the remaining unknown parameters associated with the block which may include exterior orientation, interior orientation, and tie point coordinates.

- The use of many evenly distributed tie points throughout the block.

The four AP models provided within OrthoBASE allow for the modeling of various systematic error. Select the **Advanced Options** tab within the Aerial Triangulation dialog, shown in Figure 13-5, in order to select the AP models.

Figure 13-5: Advanced Options Tab of the Aerial Triangulation Dialog



Bauer's Simple Model (3)

This model has three AP that come from the research results of Dr. H. Bauer. Two parameters mainly determine the extent of affine deformation and one parameter estimates symmetric lens distortion. Affine deformation is caused by the nonorthogonality of the image/photo-coordinate axis (e.g., the x an y axis are not perpendicular, or 90°). This model also accounts for scale differential between x and y pixel size. The mathematical form is as follows:

$$\Delta \boldsymbol{x} = \boldsymbol{a}_1 \boldsymbol{x}(\boldsymbol{r}^2 - \boldsymbol{r}_0^2) + \boldsymbol{a}_2 \boldsymbol{x}$$

$$\Delta \boldsymbol{y} = \boldsymbol{a}_1 \boldsymbol{y}(\boldsymbol{r}^2 - \boldsymbol{r}_0^2) - \boldsymbol{a}_2 \boldsymbol{y} + \boldsymbol{a}_3 \boldsymbol{x}$$

Jacobsen's Simple Model (4)

This model has four AP that are simplified from the research results of Dr. K. Jacobsen. The four parameters compensate for the first and second order distortions associated with affine deformation and lens distortion.

$$\Delta \boldsymbol{x} = \boldsymbol{a}_1 \boldsymbol{x}(\boldsymbol{r}^2 - \boldsymbol{r}_0^2) + \boldsymbol{a}_2 \boldsymbol{x} + \boldsymbol{a}_3 \boldsymbol{y}$$

$$\Delta \boldsymbol{y} = \boldsymbol{a}_1 \boldsymbol{y}(\boldsymbol{r}^2 - \boldsymbol{r}_0^2) - \boldsymbol{a}_2 \boldsymbol{y} + \boldsymbol{a}_3 \boldsymbol{x} + \boldsymbol{a}_4 \boldsymbol{x}^2$$

Ebner's Orthogonal Model (12)

This model has twelve AP that are derived from the research of Dr. H. Ebner. The twelve parameters compensate for various types of systematic error including lens distortion, scanner error, affine deformation, and film deformation. Since a greater number of parameters are being estimated, an increased number of GCPs and tie points is required. The AP are orthogonal to the one another and to the exterior orientation parameters under circumstances where the ground surface is flat, and nine tie points are distributed evenly throughout the images in a block.

$$\Delta x = a_1x + a_2y - a_3\left(2x^2 - \frac{4b^2}{3}\right) + a_4xy + a_5\left(y^2 - \frac{2b^2}{3}\right) + a_7x\left(y^2 - \frac{2b^2}{3}\right)$$
$$+ a_9y\left(x^2 - \frac{2b^2}{3}\right) + a_{11}\left(x^2 - \frac{2b^2}{3}\right)\left(y^2 - \frac{2b^2}{3}\right)$$
$$\Delta y = -a_1y + a_2x + a_3xy - a_4\left(2y^2 - \frac{4b^2}{3}\right) + a_6\left(x^2 - \frac{2b^2}{3}\right) + a_8y\left(x^2 - \frac{2b^2}{3}\right)$$
$$+ a_{10}x\left(y^2 - \frac{2b^2}{3}\right) + a_{12}\left(x^2 - \frac{2b^2}{3}\right)\left(y^2 - \frac{2b^2}{3}\right)$$

Brown's Physical Model (14)

This model has fourteen AP that are simplified from the research of Dr. D. C. Brown. The AP compensate for most of the linear and nonlinear forms of film and lens distortion. The AP are chosen according to the possible sources of physical errors such as film deformation, film plate flatness, lens distortion, etc.

$$\Delta x = a_1x + a_2y + a_3xy + a_4y^2 + a_5x^2y + a_6xy^2 + a_7x^2y^2$$
$$+ a_{13}\frac{x}{f}x^2y^2 + a_{14}x(x^2 + y^2)$$
$$\Delta y = a_8xy + a_9x^2 + a_{10}x^2y + a_{11}xy^2 + a_{12}x^2y^2$$
$$+ a_{13}\frac{y}{f}x^2y^2 + a_{14}y(x^2 + y^2)$$

If the Ebner or Brown AP model is selected, it is highly recommended that an increased number of control points and tie points be used in the solution.

Statistical constraints can be assigned to the estimated AP. OrthoBASE automatically assigns statistical weights to the AP by selecting the **Use Additional Parameters As Weighted Variables** radio button. It is highly recommended to assign statistical weights to the AP in scenarios where minimal or poor geometry exists between images and the number of GCPs.

Automated Gross Error Checking

OrthoBASE provides two error or blunder checking models which identify and remove errors from the photogrammetric network of observations. The input observations including the measured image/photo coordinates are analyzed to determine the erroneous input data contributing to the overall instability of output aerial triangulation results.

OrthoBASE provides two blunder checking models:

- **Time Saving Robust Checking.** This option uses a robust iteration with selective weight functions to detect gross error in the input observations. This option does not cause a significant increase in the aerial triangulation processing time since the individual redundancy of each observation is not computed.

- **Advanced Robust Checking.** This option uses a robust iteration solution with selective weight functions based on the redundancy of each observation. The weight functions used in this option meet the requirements of a rigorous robust estimation function. Using this option with large blocks could cause a significant increase in processing time because of the computation of redundancy for each observation.

After each iteration of processing, the weight of each observation (i.e., image coordinate measurements) is predicted for the next iteration of processing. The new weight is computed based on a weight function. The weight functions are models which compute a weight for an observation based on the observation residuals. During successive iterations, the weight for a bad observation decreases until it approaches 0. At this point, observations containing gross errors can be detected.

If blunders or errors have been identified, those observations are extracted from further aerial triangulation processing during the iterative least squares solution. Input observations containing error are listed within the output aerial triangulation report. Therefore, when the first least squares adjustment is completed, gross errors are identified and removed. The block triangulation is then repeated to derive the final solution.

Understanding the Aerial Triangulation Report

Once the aerial triangulation has been performed, a summary dialog and report are provided listing all of the aerial triangulation results. The information contained within the summary and the report can be used to determine the quality of the overall solution.

The aerial triangulation summary displays the following information:

- **Total RMS error of the solution.** The standard deviation of unit weight is a global indicator of the quality of the aerial triangulation solution. The value is based on the photo-coordinate residuals and the ground coordinate residuals. A general rule of thumb stipulates that the standard deviation of unit weight should be less than the pixel size of the original imagery. A smaller value indicates that the residuals within the network of observations have been minimized.

- **RMS errors of the GCPs in the X, Y, and Z direction.** These values reflect the amount of change between the original GCP coordinates and newly estimated values computed using the estimated unknown parameters. Large values indicate that the estimated unknown parameters do not conform with the original GCPs.

- **RMS error of the GCP photo-coordinates.** These values reflect the amount of change between the measured image/photo-coordinates of the GCPs and the newly estimated photo-coordinate values computed using the estimated unknown parameters.

- **RMS error of the check point coordinates.** These values reflect the amount of change between the original check point coordinates and the computed values derived by using the estimated unknown parameters (e.g., exterior orientation) and the original measured image/photo-coordinates). The check point RMS values provide an independent check on the accuracy of the aerial triangulation results.

- **RMS error of the check point photo-coordinates.** These values reflect the amount of change between the measured image/photo-coordinates of the check points and the newly estimated photo-coordinate values computed using the estimated unknown parameters. The photo-coordinate residuals provide an indicator of the quality of the derived exterior orientation values.

Update Results

The **Update** option updates the exterior orientation parameters computed by OrthoBASE. If the exterior orientation parameters were not known and triangulation was performed, the **Update** option updates all of the exterior orientation parameters and uses these values as initial approximations when a new aerial triangulation solution is solved.

The **Update** button should only be selected if the existing exterior orientation parameters are not satisfactory for use as initial approximations for performing aerial triangulation. The quality of the initial approximations for exterior orientation assists in providing better overall results for aerial triangulation.

Once **Update** has been selected, the corresponding exterior orientation parameters are used as the initial approximations for aerial triangulation. Selecting **Update** overwrites all of the existing exterior orientation values.

Accept Results

Block triangulation results should be accepted once the results associated with aerial triangulation have been accurately estimated. Once the **Accept** button has been selected, the computed exterior orientation parameters are used for orthorectification. Additionally, the X, Y, and Z ground coordinates associated with the tie points and GCPs are accepted and used.

Aerial Triangulation Report

The aerial triangulation report lists all of the input and output data used during the aerial triangulation process. The report can be divided into several categories including:

- triangulation report unit definition
- image coordinates and interior orientation results
- aerial triangulation results
- automated error checking results
- exterior orientation parameter results
- SCBA results
- control point residuals
- check point residuals
- control point, check point, and tie point coordinates, and accuracy estimates
- image coordinate residuals

The following explanations are provided to better understand the contents of the aerial triangulation report.

Triangulation Report Unit Definition

The units for the image coordinates, exterior orientation rotation angles, and GCPs are defined. The positional elements of exterior orientation use the same units as the GCPs. Image coordinate residuals are displayed in the units similar to input image coordinates. GCPs, tie points, and check points are displayed in ground units. The units listed are applicable to output with no specific unit specification.

```
The Triangulation Report With IMAGINE OrthoBASE:
The output image x, y units:        pixels
The output angle unit:              degrees
The output ground X, Y, Z units:    meters
```

If a Geographic Lat/Lon reference coordinate system is being used, the computed exterior orientation values are displayed in a topocentric coordinate system. The origin of the topocentric coordinate system can be internally defined by OrthoBASE or user-specified.

Image Coordinates and Interior Orientation Results

The image coordinates representing the image positions of GCPs, check points, and tie points are displayed for each image in the block. The Image ID as specified in the LPS Project Manager CellArray is used to represent the individual images.

```
The Input Image Coordinates:
       image ID = 90

Point ID      x          y
1002       952.625    819.625
1003      1857.875    639.125
1005      1769.450   1508.430
1006      1787.875   2079.625
2001       915.020   2095.710
2003       846.530    208.330
...
..
.
```

Six affine transformation parameters are displayed for each image. These coefficients are derived using a 2D affine transformation during interior orientation. The six coefficients represent the relationship between the file or pixel coordinate system of the image and the film or image space coordinate system. The file coordinate system has its origin in the upper left corner of the image (e.g., 0, 0). The origin of the image space coordinate system for each image is the principal point. The intersection of opposite fiducial mark positions is used to define the principal point location.

The six transformation coefficients are calculated once interior orientation has been performed. The six transformation parameters define the scale and rotation differences between two coordinate systems.

Once the image position of a ground point has been measured automatically or manually, the six coefficients are used to transform the pixel coordinates of the GCP to image (or film) coordinates:

```
Affine coefficients from file (pixels) to film (millimeters)
    A0         A1         A2         B0         B1         B2
-114.3590  0.100015  -0.001114  116.5502  -0.001117  -0.100023
```

Thus, the image coordinates and the six affine transformation coefficients are displayed for each image in the block:

```
                  image ID = 91
Point ID          x          y
1002        165.875    846.625
1003       1064.875    646.375
1005       1007.250   1518.170
1006       1023.625   2091.390
2001        160.900   2127.840
2002       2032.030   2186.530
1004       1839.520   1457.430
2003         49.303    237.343
...
..
.
```

Aerial Triangulation Results

Aerial triangulation is performed using a bundle block adjustment. This approach utilizes an iterative least squares solution. The unknown parameters are either estimated or adjusted. These estimated or adjusted parameters include:

- exterior orientation parameters (X, Y, Z, Omega, Phi, Kappa) for each camera exposure station
- X, Y, and Z coordinates of the tie points
- interior orientation parameters (focal length, principal point xo, and principal point yo)
- AP

The corresponding accuracy estimates for each set of estimated or adjusted parameters are also provided if the **Compute Accuracy For Unknowns** radio button within the Aerial Triangulation dialog is selected.

Input parameters are adjusted if initial approximations have been provided and statistically weighted. For example, if initial approximations for exterior orientation are input and statistically weighted, a new set of adjusted values is computed after aerial triangulation has been performed.

Input parameters are estimated if they are unknown prior to executing the aerial triangulation. For example, tie point coordinates are commonly unknown prior to aerial triangulation. Their X, Y, and Z coordinates are estimated using the bundle block adjustment.

Least Squares Iterative Results

A global indicator of quality is computed for each iteration of processing. This is referred to as the standard error (also known as the standard deviation of image unit weight). This value is computed based on summation of image coordinate residuals and ground coordinate residuals for that particular iteration of processing.

The units for the standard error are defined within the **General** tab of the Aerial Triangulation dialog. For the first iteration of processing, the global standard error is larger since the input observations have not been adjusted (e.g., GCPs, photo-coordinates, etc.).

After each iteration of processing, OrthoBASE estimates the exterior orientation parameters of each camera/sensor station and X, Y, and Z tie point coordinates. The newly estimated exterior orientation parameters are then used along with the GCP and tie point coordinates to compute new x and y image coordinate values. The newly computed image coordinate values are then subtracted from the original image coordinate values. The differences are referred to as the x and y image coordinate residuals.

If the exterior orientation parameters are incorrect, then the newly computed image coordinate values are also incorrect. Incorrect estimates for exterior orientation may be attributed to erroneous GCPs, data entry blunders, or mismeasured image positions of GCPs or tie points. Any error in the photogrammetric network of observations is reflected in the image coordinate residuals.

The computed standard error for each iteration accumulates the effect of each image coordinate residual to provide a global indicator of quality. The lower the standard error, the better the solution.

NOTE: The number of iterations using the least squares adjustment continues until the corrections to the control points (i.e., GCPs, tie points, and check points) are less than the user-specified convergence value (e.g., 0.001 default). After each iteration of processing, a new set of X, Y, and Z coordinates are computed for the GCPs, tie points, and check points. The new set of coordinates is differenced from the previous set of coordinates (i.e., previous iteration). The differences between the coordinates are also referred to as corrections to the unknowns. If the differences are greater than the convergence value, the iterations continue.

Automated Error Checking Results

OrthoBASE provides two blunder checking models that automatically identify and remove erroneous image measurements from the block. The blunder checking models can be specified by selecting the appropriate model within the blunder checking model dropdown list contained in the **Advanced Options** tab of the Aerial Triangulation dialog.

The results of the blunder checking model are displayed as follows:

```
The residuals of blunder points:
Point   Image           Vx        Vy
1005    90          0.4224   -0.5949   x wrong    y wrong
1005    91          0.7458   -0.6913   x wrong    y wrong
1005    92          0.9588   -0.6326   x wrong    y wrong
    Point 1005 is excluded in the further adjustment:
```

The x and y image coordinate residuals of the blunder points are displayed. OrthoBASE notifies you if a point is excluded from the aerial triangulation solution. Vx and Vy represent the x and y image/photo-coordinate residuals, respectively.

```
The OUTPUT of SCBA:

       the no. of iteration =1      the standard error =  0.1438
       the maximal correction of the object points =  40.30844

       the no. of iteration =2      the standard error =  0.1447
       the maximal correction of the object points =   0.74843

       the no. of iteration =3      the standard error =  0.1447
       the maximal correction of the object points =   0.00089
```

Exterior Orientation Parameters

The six exterior orientation parameters for each camera station are listed:

```
The exterior orientation parameters:

 image ID       Xs            Ys           Zs        OMEGA      PHI     KAPPA
    90      666724.3686   115906.5230   8790.3882   0.1140    0.0272   90.3910
    91      666726.8962   119351.8150   8790.0182   0.2470    0.1874   89.0475
    92      666786.3168   122846.5488   8787.5680   0.0923    0.1232   88.6543
```

A corresponding accuracy estimate is provided for each exterior orientation parameter. The accuracy estimates are computed from the covariance matrix of the final solution. The accuracy estimates reflect the statistical accuracy of each parameter.

```
The accuracy of the exterior orientation parameters:

 image ID       mXs           mYs           mZs       mOMEGA     mPHI     mKAPPA
    90           2.7512         3.4383        1.8624     0.0266     0.0207     0.0112
    91           2.7014         3.1999        1.5232     0.0252     0.0209     0.0109
    92           2.7940         3.3340        2.4975     0.0263     0.0204     0.0115
```

Interior Orientation Parameters

The interior orientation parameters associated with each camera station in the block are listed. Since SCBA has not been performed, the interior orientation parameters for each camera station are the same.

```
The interior orientation parameters of photos:
 image ID      f(mm)         xo(mm)         yo(mm)
    90       153.1240       -0.0020         0.0020
    91       153.1240       -0.0020         0.0020
    92       153.1240       -0.0020         0.0020
```

SCBA Results

If SCBA is performed, the focal length and principal point values are estimated. The output appears as follows:

```
The interior orientation parameters of photos:
 image ID      f(mm)         xo(mm)         yo(mm)
    90       153.1220       -0.0097        -0.0039
    91       153.1220       -0.0097        -0.0039
    92       153.1220       -0.0097        -0.0039

The accuracy of the interior orientation parameters:
 image ID     mf(mm)        mxo(mm)        myo(mm)
```

all	0.0586	0.0664	0.0650

In this case, it was assumed that the interior orientation parameters were common for each image in the block. For this reason, the interior orientation values are common for each image. Additionally, one set of accuracy estimates is computed.

If each camera station has a unique set of interior orientation parameters estimated, the output appears as follows:

The interior orientation parameters of photos:

image ID	f(mm)	xo(mm)	yo(mm)
90	153.1164	-0.0190	-0.0156
91	153.1230	-0.0135	0.0003
92	153.1288	-0.0018	0.0038

The accuracy of the interior orientation parameters:

image ID	mf(mm)	mxo(mm)	myo(mm)
90	0.0946	0.1020	0.0953
91	0.0936	0.0995	0.0954
92	0.0985	0.1031	0.0985

In this scenario, accuracy estimates are computed for each camera station.

Control Point Residuals

Once the bundle block adjustment is complete, new values for the control point coordinates are computed. The new control point coordinates are computed based on the estimated exterior orientation parameters and measured image coordinate values.

The control point residuals reflect the difference between the original control point coordinates and newly estimated control point coordinates. Relatively large residual values are indicative of error in the photogrammetric network of observations. Large error can be attributed to mismeasured control points, data entry error, and poor quality of control points. In the example below, the Z coordinate for control point 1004 is relatively larger than the remaining residuals, thus inferring a possible error.

The residuals of the control points:

Point ID	rX	rY	rZ
1002	1.4390	5.6596	6.9511
1003	-3.0263	-0.5553	-2.2517
1004	3.0679	2.0052	-11.1615

1005	2.9266	-4.0629	-2.3434
1006	-2.0842	2.5022	2.6007
	aX	aY	aZ
	0.4646	1.1098	-1.2410
	mX	mY	mZ
	2.5904	3.4388	6.1680

The aX, aY, and aZ values reflect the average residual values for the X, Y, and Z control point coordinates, respectively. The mX, mY, and mZ values reflect the root mean square residual values for the X, Y, and Z control point coordinates, respectively.

Check Point Residuals

Check points are used to independently verify the quality of the bundle block adjustment. Once the exterior orientation parameters have been solved, the image coordinate values of the check points are used to compute the X, Y, and Z coordinates. The computed coordinates are subtracted from the original input coordinates to compute the check point residuals. Check points serve as the best source for determining the accuracy of the bundle block adjustment.

The residuals of the check points:

Point ID	rX	rY	rZ
2001	-4.0786	0.0865	-1.9679
2002	1.6091	-3.0149	3.5757
	aX	aY	aZ
	-1.2348	-1.4642	0.8039
	mX	mY	mZ
	3.1003	2.1328	2.8860

The aX, aY, and aZ values reflect the average residual values for the X, Y, and Z check point coordinates, respectively. The mX, mY, and mZ values reflect the root mean square residual values for the X, Y, and Z check point coordinates, respectively.

Control, Check, and Tie Point Coordinates; and Accuracy Estimates

Once the bundle block adjustment is complete, new GCP, check point, and tie point coordinates are computed based on the estimated or adjusted exterior orientation parameters. The computation of X, Y, and Z coordinates for tie points is referred to as ground point determination. If the tie points are acceptable, they can be converted to control points within the Point Measurement tool. This process is referred to as control point extension.

NOTE: If the **Update** *or* **Accept** *buttons have been selected, the tie point coordinates are populated within the Point Measurement tool.*

```
                 The coordinates of object points:
Point ID        X            Y            Z        Overlap
1002       665230.0078  115015.7356  1947.0091      2
1003       664452.5217  119050.0976  1990.0849      3
1004       668152.5139  122406.1013  1971.3625      2
1005       668340.3906  118681.5541  1885.8520      3
1006       670840.0509  118698.6034  2014.9514      3
2001       670966.3714  114815.3165  1889.9201      2
2002       671410.3391  123163.5051  1987.3377      2
2003       662482.9556  114550.1580  1927.2971      2
2004       662662.3529  116234.8134  2064.6330      2
...
..
.
2041       671068.5733  123961.8788  1971.4592      2
                  The total object points = 46
```

The Overlap column specifies the number of images on which the point has been measured. This is also an indication for redundancy.

The accuracy of each control point, check point, and tie point is computed. The accuracy estimates are computed based on the respective diagonal elements of the covariance matrix for the final solution. The values reflect statistical accuracy.

```
The accuracy of object points:
Point ID      mX       mY       mZ       mP     Overlap
1002        1.0294   1.0488   1.2382   1.9217     2
1003        0.8887   0.8731   1.1739   1.7117     3
1004        0.9693   0.9593   1.2219   1.8311     2
1005        0.7181   0.7063   0.9397   1.3775     3
1006        0.9534   0.9119   1.1841   1.7727     3
2001        1.8123   1.5641   3.1611   3.9653     2
2002        1.9436   1.5091   2.8482   3.7639     2
2003        1.9684   1.7646   3.0069   4.0037     2
```

```
2004          1.7427    1.3758    2.6308    3.4426     2
...
..
.
2041          1.9419    1.6884    3.0368    3.9804     2


               amX       amY       amZ
              1.2681    1.1773    2.1932
```

The amX, amY, and amZ values represent the average accuracy estimates for the X, Y, and Z control, check, and tie point coordinates.

The Overlap column specifies the number of images on which the point has been measured.

Image Coordinate Residuals

Once the bundle block adjustment is complete, image coordinate residuals are computed. The residuals are computed based on the fixed, estimated, adjusted exterior orientation parameters, GCP, check point, tie point coordinates, and their respective image measurements. During the iterative least squares adjustment, the values of the new image coordinates are dependent on the estimated or adjusted parameters of the bundle block adjustment. Therefore, errors in the fixed, estimated, or adjusted parameters are reflected in the image coordinate residuals.

OrthoBASE computes the image coordinate residuals for each image measurement in the block.

```
          The residuals of image points:

       Point      Image       Vx         Vy
        1002        90      -0.176     -0.040
        1002        91      -0.001     -0.016

       Point      Image       Vx         Vy
        1003        90       0.053     -0.001
        1003        91       0.017      0.149
        1003        92       0.045      0.050

       Point      Image       Vx         Vy
        1004        91       0.103     -0.094
        1004        92      -0.182     -0.010

...
..
.

       Point      Image       Vx         Vy
        2001        90      -0.000     -0.016
        2001        91       0.000      0.016

       Point      Image       Vx         Vy
        2002        91       0.000      0.017
```

2002	92	0.000	-0.017

Point	Image	Vx	Vy
2003	90	-0.000	-0.094
2003	91	0.002	0.095

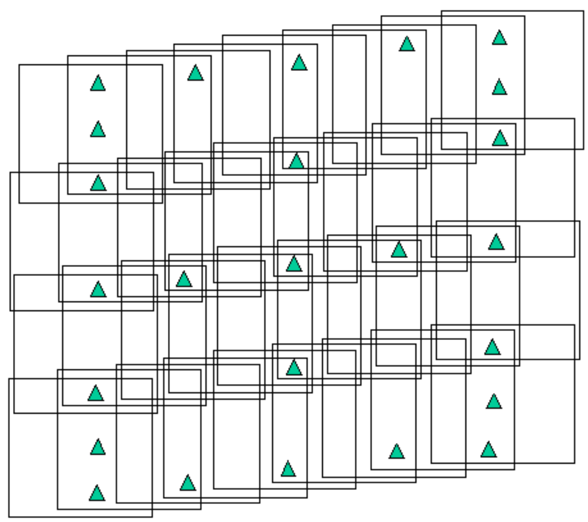
Point	Image	Vx	Vy
2004	90	0.000	0.074
2004	91	-0.002	-0.074

Optimizing the Aerial Triangulation Results

The output results of aerial triangulation can be improved in the following manner:

- Increase the number and quality of GCPs within the block of images.
- Evenly distribute GCPs throughout the block.
- Place at least one full GCP on every third photo if processing 20 or more images. Ensure that the edges and corners of the block contain sufficient ground control (see Figure 13-6).

Figure 13-6: A GCP Configuration for a Large Block of Images

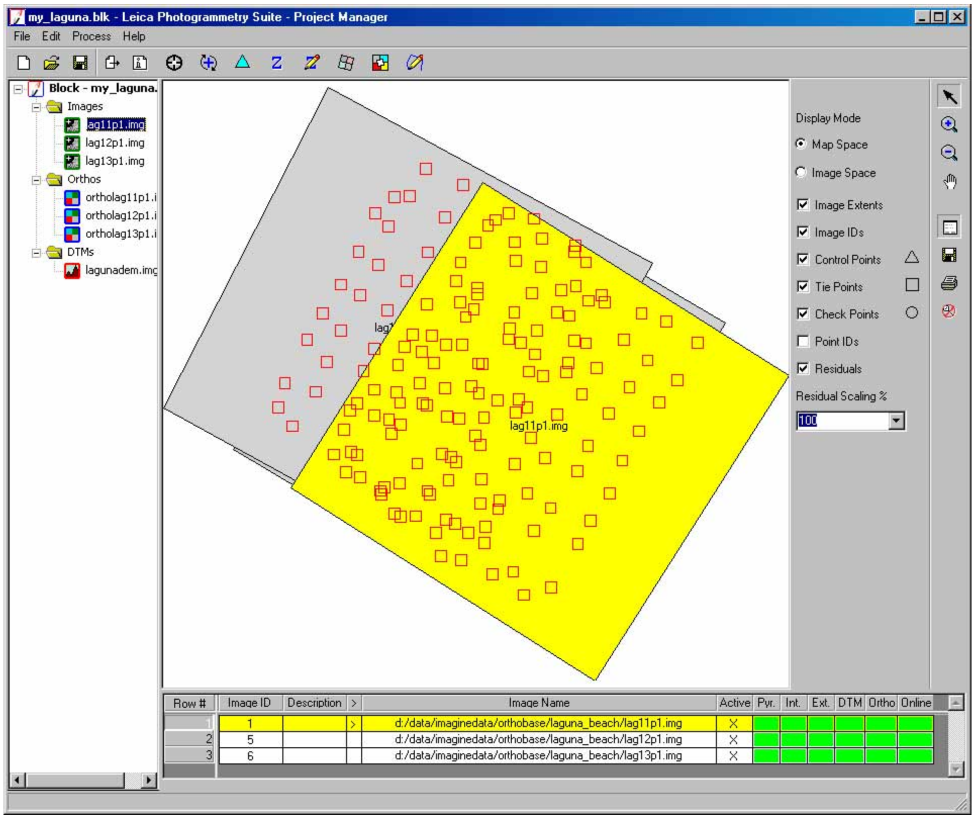


- Increase the number of tie points on the overlapping areas of the images contained within a block. Studies have indicated that a greater number of tie points (approximately 200 per image) per overlap area drastically increases the quality of the aerial triangulation solution. This can be attributed to the increase in data redundancy, thus allowing for the minimization and distribution of error throughout the photogrammetric network of observations.
- Statistically constrain the exterior orientation parameters and GCPs if their precision and accuracy are known.

Graphically Analyzing Aerial Triangulation Results

By selecting either the **Project Graphic Status** option within the **Process** menu, a graphical representation of the information pertaining to the block is displayed. An example of this is presented in Figure 13-7.

Figure 13-7: Project Graphic Status Window



The following information is graphically represented:

- image footprints of each image used in the block
- spatial location and distribution of GCPs, tie points, and check points
- image IDs for each image in the block
- point IDs for GCPs, tie points, and check points
- residual error vectors for the GCPs and check points

Two display modes are provided including:

- **Map space.** This display mode displays the observations and data pertaining to the entire block. This includes image footprints and all the measured GCPs, tie points, and check points. Ground coordinate residual error vectors are also displayed.

- **Image Space.** This display mode displays only one image at a time, and the photo-coordinate position of the measured GCPs, check points, and tie points. Photo-coordinate residual error vectors are also displayed. An image dropdown list is provided for selecting the image to be displayed.

Residual Error Scaling

The residual error vectors display the difference between the original GCP or check point values and the estimated positions determined by the aerial triangulation process. Based on the display, the nature and characteristics associated with systematic error in the block can be determined.

Residual error vectors with a consistent direction and magnitude infer systematic errors that can be attributed to inaccurate interior orientation information, film deformation, scanner error, camera instability, etc. Relatively large ground coordinate error vectors indicate poor GCP quality. Similarly, relatively large image/photo-coordinate error vectors indicate poor image/photo-coordinate quality.

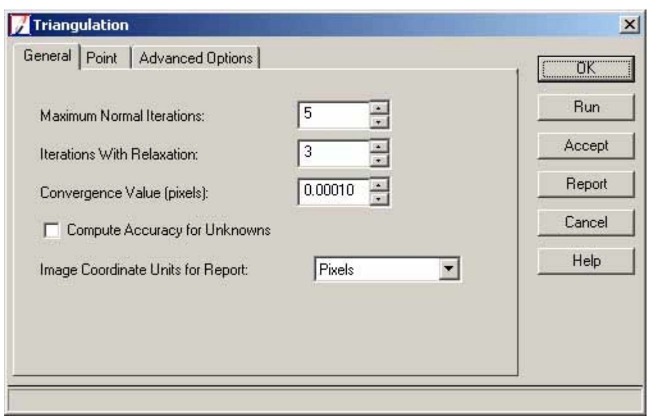
By default, the residual error vectors for the GCPs, tie points, and check points are displayed at a 1:1 scale. The display scale is relative to the image footprints. In order to increase the magnitude of the display, select a **Residual Scaling %** within the provided list. By selecting a 1000% display scale, the residual error vectors are scaled 1000 times greater than the original value. This option is strictly used as a visualization tool.

Triangulation of SPOT, IRS-1C, and Generic Pushbroom Imagery

Parameters governing the operation of triangulation for SPOT, IRS-1, and generic pushbroom sensor imagery can be defined to optimize the results of the estimated parameters (e.g., XYZ tie point coordinates and exterior orientation information).

The Triangulation dialog, shown in Figure 13-8, allows for the input and specification of parameters associated with performing triangulation on SPOT, IRS-1C, and generic pushbroom imagery.

Figure 13-8: General Tab of the Triangulation Dialog



In the SPOT model, only full GCPs or GCPs that are measured on two or more images are used in triangulation. Horizontal and vertical GCPs are not used in triangulation.

The **General** tab within the Triangulation dialog defines the necessary information concerning the iterative least squares approach for estimating the unknown parameters of the solution.

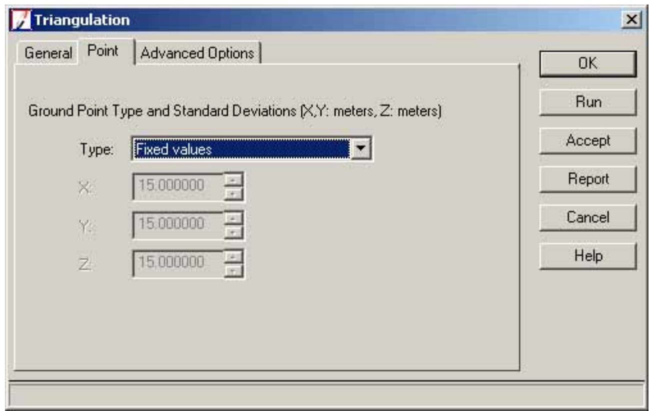
The **Maximum Normal Iterations** option defines the maximum number of iterations to be used during the least squares adjustment with constrained GCPs. The normal iterative solution utilizes the normal weights for the exterior orientation parameters. The normal weights are determined automatically.

The **Iterations With Relaxation** option allows the use of a free-weighted iterative adjustment for determining the position and orientation associated with a pushbroom sensor. In this case, very small weights are used for the coefficients associated with exterior orientation. If a value of 0 is specified, a free-weighted adjustment is not used. It may be advantageous to use a free-weighted adjustment in scenarios where the satellite sensor has complicated geometry.

Assigning Statistical Weights to GCPs

To optimize the quality of the triangulation solution, GCPs can be assigned statistical weights defining the quality of the GCPs. The standard deviations associated with GCPs can be assigned within the **Point** tab of the Triangulation dialog, depicted in Figure 13-9.

Figure 13-9: Point Tab of the Triangulation Dialog



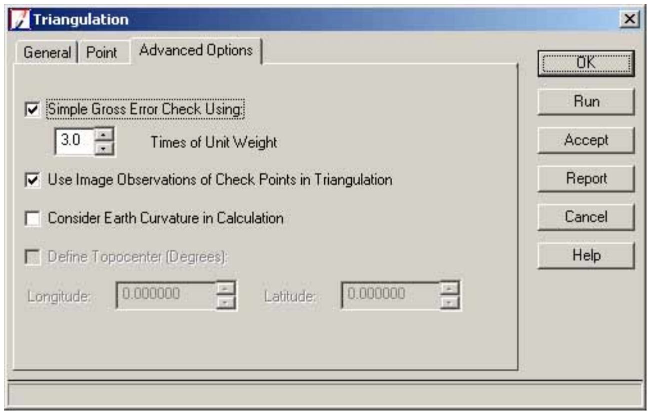
The options provided are similar to those outlined for aerial triangulation. The standard deviations should reflect the quality of the GCPs. If small standard deviation values are entered, the quality of the estimated exterior orientation parameters and X, Y, Z tie point coordinates suffer.

As a test, it is common to set the standard deviation values to the ground resolution of the imagery being processed. For example, if SPOT imagery is being used, a standard deviation of 10 meters can be used as a test to determine the unknown parameters. Based on the output results, the standard deviation value can be varied until the residuals to the GCP and image coordinates are at a minimum while increasing the accuracy of the estimated parameters (i.e., exterior orientation and X, Y, Z tie point coordinates).

Advanced Options

In order to optimize the triangulation results, several advanced options are provided within the **Advanced Options** tab, shown in Figure 13-10.

Figure 13-10: Advanced Options Tab of the Triangulation Dialog



A Simple Gross Error Check model is provided to identify and remove the erroneous observations (e.g., image coordinate measurements of GCPs) from the triangulation solution. The procedure multiplies the standard error (or standard deviation of unit weight) by a user-specified value (e.g., times of unit weight). The resulting value is used as a threshold and compared to the residuals of the image coordinates. Image coordinates having residuals larger than the threshold value are discarded from the triangulation solution.

The remaining options are similar to those used within the Aerial Triangulation dialog.

For more information, see "Aerial Triangulation".

Triangulation Report

The triangulation report lists all of the input and output data used during the triangulation process. The report can be divided into several categories including:

- triangulation report unit definition
- automated error checking model
- iterative triangulation results
- triangulation using a free-weighted adjustment
- exterior orientation results
- GCP residuals
- image coordinate information

The following explanations are provided to better understand the contents of the aerial triangulation report.

Triangulation Report Unit Definition

The units for the image coordinates, exterior orientation rotation angles, and GCPs are defined. The positional elements of exterior orientation use the same units as the GCPs. Image coordinate residuals are displayed in the units similar to input image coordinates.

```
The triangulation report with IMAGINE OrthoBASE:

The output image x, y units:            pixels
The output angle unit:                  degrees
The output ground X, Y, Z units:        meters
```

If a Geographic Lat/Lon reference coordinate system is being used, the computed exterior orientation values display in a topocentric coordinate system. The origin of the topocentric coordinate system is internally defined by OrthoBASE and can be modified by you.

Automated Error Checking Model

OrthoBASE provides an error checking model that automatically identifies and removes erroneous image measurements from the block. The error checking model can be specified by selecting the **Simple Gross Error Check Using** options within the **Advanced Options** tab of the Triangulation dialog. Once the radio button has been selected, the times of unit multiplier can be specified. This value is multiplied by the standard deviation of unit weight. If an image coordinate residual value is larger than the multiplied value, the image point is excluded from the triangulation.

The results of the gross error checking model are displayed as follows:

```
Points excluded with gross errors:

 image    pid      image_x     image_y    residual_x   residual_y
   1       4      869.5420   2487.9960     -1.8265       0.2271
   1       8     2890.8800   1258.8520      1.1212       0.4837
   1       9     1978.1380   2919.0040      2.1869       0.1647
```

The x and y image coordinate residuals of the erroneous points are displayed. OrthoBASE notifies you if a point is excluded from the triangulation solution. The pid designation defines the point id of a GCP.

Iterative Triangulation Results

The results for each iteration of processing are provided once the triangulation has been performed. A global indicator of quality is computed for each iteration of processing. This is referred to as the standard error (also known as the standard deviation of image unit weight). This value is computed based on the image coordinate residuals for that particular iteration of processing. The units for the standard error are defined within the **General** tab of the Triangulation dialog.

After each iteration of processing, OrthoBASE estimates the position and orientation parameters of the satellite sensor and X, Y, and Z tie point coordinates. The newly estimated parameters are then used along with the GCP and tie point coordinates to compute new x and y image coordinate values. The newly computed image coordinate values are then subtracted from the original image coordinate values. The differences are referred to as the x and y image coordinate residuals.

If the position and orientation information associated with a satellite is incorrect, then the newly computed image coordinate values are also incorrect. Incorrect estimates for the unknown parameters may be attributed to erroneous GCPs, not enough GCPs, data entry blunders, or mismeasured image positions of GCPs or tie points. Any error in the input observations is reflected in the image coordinate residuals.

The computed standard error for each iteration accumulates the effect of each image coordinate residual to provide a global indicator of quality. The lower the standard error, the better the solution.

OrthoBASE performs the first portion of the triangulation using the weighted iterative approach. In this scenario, the normal statistical weights associated with the exterior orientation coefficients are used. The solution continues until the corrections to the unknown parameters are less than the specified convergence value, or the specified number of normal iterations has been reached. The convergence value is specified within the **General** tab of the Triangulation dialog. The results of the normal-weighted iterative solution may appear as follows:

```
Normal-weighted iterative adjustment:
```

No.	Total_RMSE	Max_Residual	at image	pid
1	0.973941	4.1854	2	21
2	0.951367	4.0954	2	21
3	0.929783	4.0077	2	21
4	0.909040	3.9213	2	21
5	0.889105	3.8372	2	21

The standard error associated with each iteration is provided. The units of the standard error are the same as the image coordinate units. Additionally, the maximum image coordinate residual associated with a point is provided for each iteration of processing. Information pertaining to the point id and the image it is located on is also provided.

It is highly recommended that the number of maximum normal iterations be set to 5. A lower number may produce inadequate results.

Triangulation using a Free-weighted Adjustment

Once the weight-restrained iterative triangulation has been performed, OrthoBASE also has the ability to process the triangulation using a free-weighted adjustment. In this case, very small weights are assigned to the coefficients of exterior orientation parameters. This can be referred to as iterations with relaxation.

If the **Iterations With Relaxation** option is set to a value greater than 0, a free-weighted least squares adjustment is used. The iterative solution continues until the corrections to the unknown parameters are less than the convergence value, or the specified number of iterations has been reached.

This approach may be advantageous when the sensor geometry is complicated. The results appear as follows:

```
Iterative adjustment with weight relaxation:

 No.     Total_RMSE    Max_Residual   at image     pid

  4         0.200501         0.7890      1          11
```

The results for the free-weighted triangulation are displayed after the results of the normal-weighted triangulation.

Exterior Orientation Results

Once the triangulation solution has converged, the resulting coefficients associated with the exterior orientation parameters are displayed along with their corresponding precision estimates. The results are displayed for each image as follows:

```
Image parameter value and precision:

  image id 1:

           x:   7.85788145e+005   1.01160973e+000  -9.41131523e-006

                1.23371172e+003   5.48444936e-001   2.94370828e-006


           y:   3.69353383e+006   2.21320881e+000   5.47762346e-006

                1.13621691e+003   5.85348349e-001   3.22204830e-006


           z:   8.18549949e+005  -2.73735010e-001  -6.57266270e-005

                7.94892316e+002   3.56703998e-001   9.53403929e-006


       Omega:   7.04151443e-002   9.23492069e-006

                1.39654734e-003   7.20947218e-007


         Phi:   2.94805754e-001  -1.31834309e-006

                1.64134729e-003   7.29915374e-007


       Kappa:  -1.60676667e-001   1.39612089e-007

                8.63131836e-005   3.89509598e-008
```

In the above example, the polynomial order specified for X, Y, and Z is two. Three coefficients were computed including a0, a1, and a2. Just below each coefficient value is the associated quality. For the same example, the polynomial order specified for Omega, Phi, and Kappa is one. Thus, two coefficients were computed including a0 and a1. The polynomial coefficients can be used to compute the exterior orientation parameters associated with each scan line.

GCP Results

Once the triangulation solution has converged, ground point values for GCPs, tie points, and check points are computed. If you select the option Compute Accuracy for Unknowns in the Triangulation dialog, then the point values display with their corresponding accuracy. The results appear as follows:

```
Ground point value and precision in parenthesis:

point id  1:   566190.7372  ( 0.2989)  3773588.3997   ( 0.2982)  996.6927  ( 0.3002)

point id  2:   555691.3534  ( 0.2977)  3728387.0138   ( 0.2972)  228.0382  ( 0.3000)

point id  3:   501918.8209  ( 0.3004)  3732593.1751   ( 0.3000)  483.9667  ( 0.3007)

...

..

.
```

The accuracy of each GCP is displayed in brackets. The GCP information is displayed as Point ID, Image Number, X (accuracy), Y (accuracy), and Z (accuracy). Incorrect points commonly have less accuracy (i.e., larger accuracy value). A relative comparison of accuracy values can be used to identify suspect points.

Image Coordinate Information

Once the triangulation is complete, image coordinate residuals are computed. The residuals are computed based on the estimated exterior orientation parameters, GCP, check point, and tie point coordinates, and their respective image measurements. During the iterative least squares adjustment, the results from the previous iteration are compared to results of the most recent iteration. During this comparison, image coordinate residuals reflecting the extent of change between the original image coordinates and the new values are computed. The values of the new image coordinates are dependent on the estimated or adjusted parameters of the triangulation. Therefore, errors in the estimated parameters are reflected in the image coordinate residuals.

OrthoBASE computes the image coordinate residuals for each image measurement in the block. The results appear as follows:

```
Image points and their residuals:

image     pid       image_x       image_y      residual_x   residual_y

  1        1       5239.4680      337.3840       -0.2213       0.0647

  1        2       5191.5900     4969.5460       -0.7131       0.2838

  1        3        230.9250     5378.8230        0.0798       0.2689

  2        1       2857.2700      753.8520       -0.0267       0.0850
```

2	2	3003.7820	5387.8920	0.4579	0.3762
2	6	2736.1250	3070.2270	0.2412	0.7679

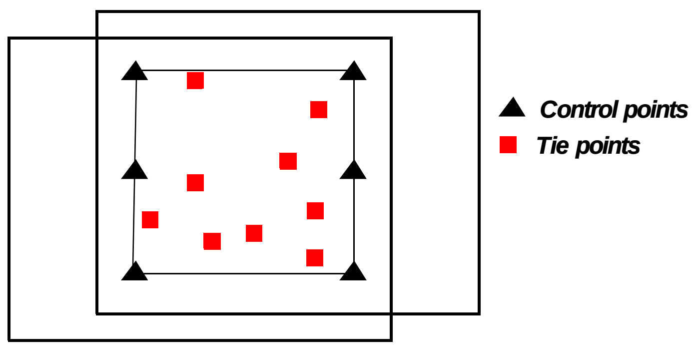
The information for each image coordinate is displayed as image number, point ID, image x coordinate, image y coordinate, image x residual, and image y residual. Relatively large residuals indicate erroneous points which can be attributed to image mismeasurement, data entry, and incorrect input data.

Optimizing the Triangulation Results

The output results of triangulation can be improved by considering the following:

- Increase the number and quality of GCPs within the block of images. Ten or more GCPs are recommended for the overlap area of two images.
- Evenly distribute GCPs throughout the block.
- Increase the number of tie points on the overlapping areas of the images contained within the block. Ensure that the tie points are placed within the GCP configuration (i.e., polygon defining the spatial coverage provided by the GCPs), as shown in Figure 13-11. The output quality of tie points outside of the photogrammetric network of GCPs is less accurate.

Figure 13-11: Tie Points Contained within a GCP Configuration



- If the quality of the GCPs or sensor information (i.e., incidence angles) is weak, increase the value for the **Iterations With Relaxation** option.

Refinement Summary Report

With IKONOS data, a separate report is provided, called the Refinement Summary report. Like other reports, you access it from the **Process | Report** option in the LPS Project Manager. The report can be divided into several categories including:

- adjustment report unit definition
- calculated point coordinates
- point residuals
- image accuracy
- RMSE for points

Adjustment Report Unit Definition

The units for the image coordinates, ground units, and Z units are defined.

```
            Adjustment Report With OrthoBASE
     Output image units:              pixels
     Output ground units:             degrees
     Output z units:                  meters
```

Calculated Point Coordinates

All of the points in the block file are listed with their type (GCP, control, tie, check), point ID, and ground x, y, and z coordinates.

```
Calculated ground x, y and z coordinates: degrees meters
  type         pid          ground_x       ground_y      ground_z
  gcp           1        -117.14884236   32.83552740  114.81895194
  gcp           2        -117.08593953   32.83715651  163.12255360
  gcp           3        -117.16395542   32.74989470   92.38122178
  tie           4        -117.18085392   32.70062813    3.64127580
  tie           5        -117.16605880   32.83797316   122.5852462
...
..
.
```

Point Residuals

The control point residuals reflect the difference between the original control point coordinates and the newly estimated control point coordinates.

```
Control and check point residuals: degrees meters
  type       pid       residual_x     residual_y     residual_z
  gcp         1        0.00006974    -0.00020760    -0.07104806
  gcp         2       -0.00010593     0.00010101    -3.90744640
  gcp         3        0.00003648     0.00010660     3.93122178
```

Image Accuracy

OrthoBASE computes the image coordinate residuals for each image measurement in the block. The results appear as follows:

```
Image accuracy for control and check points for each scene:
image id 1:
  pid        type       image_x      image_y     residual_x  residual_y
   1          gcp      4404.6250    608.8740       5.1079     -2.4929
   2          gcp      4746.6310   2037.8970      -2.0527      2.6564
   3          gcp      2006.1360    739.3350      -3.0552     -0.1636
         RMS Errors for 3 GCPs:             x:     3.6350
                                            y:     2.1054
                                        total:     4.2007

 image id 2:
  pid        type       image_x      image_y     residual_x  residual_y
   1          gcp      4401.6250    609.8740       5.5169     -3.0176
   2          gcp      4737.1400   2038.4850      -2.5303      2.5398
   3          gcp      2006.5250    739.1730      -2.9866      0.4777
         RMS Errors for 3 GCPs:             x:     3.9055
                                            y:     2.2938
                                        total:     4.5293
```

Summary RMSE

RMSE is reported on a point type basis in both the ground and image space coordinate system.

```
Summary RMSE for GCPs and CHKs (number of observations in parenthesis):
                  Control                         Check
Ground X:          0.0001  (3)                   0.0000  (0)
Ground Y:          0.0001  (3)                   0.0000  (0)
Ground Z:          3.2004  (3)                   0.0000  (0)
Image  X:          3.7726  (6)                   0.0000  (0)
Image  Y:          2.2016  (6)                   0.0000  (0)
```

Chapter 14

Automatic DTM Extraction

Introduction

This chapter tells you about the elevation extraction capabilities of OrthoBASE Pro. OrthoBASE Pro provides a variety of options and parameter settings.

Product Workflow

The workflow associated with extracting DTMs can be categorized as being either noninteractive or interactive. The noninteractive mode is suited for large-scale DTM production, where minimal interaction and input is needed to extract a DTM for an entire geographic area covered by a block of images.

The interactive mode allows you to select the image pairs, define DTM properties, digitize areas of interest, and specify 3D reference information for subsequent accuracy calculations. As a result, OrthoBASE Pro provides a scalable 3D mapping solution for both novice and experienced mapping professionals alike.

The following product workflow can be used to extract DTMs using OrthoBASE Pro:

1. In OrthoBASE Pro, create a block project; add images; define the camera/sensor model; measure ground control, tie, and check points; and perform automatic tie point collection and block triangulation. In order to automatically extract DTMs, the block triangulation results must be accepted or fixed (within the OrthoBASE Pro Frame Editor dialog).

2. Select the DTM Extraction icon  within the OrthoBASE Pro toolbar. General DTM extraction properties can be defined for subsequent DTM production. General options include:

   - Output DTM Type (ASCII, TerraModel TIN, DEM, 3D Shape)
   - Output a single mosaicked DTM for the entire project or individual DTMs for each image pair in the project
   - Output DTM name (for a single DTM) or DTM prefix (for multiple DTMs)
   - DTM Cell Size in the X and Y direction
   - DTM Trim percentage which automatically subsets each DTM once it has been extracted

   Selecting **Run** begins the extraction process. Selecting **Advanced Properties** allows for the interactive definition of additional DTM extraction properties.

3. Select the **Advanced Properties** option within the DTM Extraction dialog or **DTM Extraction Properties** from the OrthoBASE Pro dialog **Edit** menu.

4. Define output DTM projection, spheroid, datum and units (horizontal and vertical). This step is optional.

5. Specify contour interval to be used for the automatic creation of a Contour Map (i.e., 3D Shape file) using the output DTM.

6. Enable the option that creates a DTM Point Status image depicting the quality of the automatically extracted 3D mass points.

7. Graphically preview and select the image pairs from the block to be used for DTM extraction. By default, the software uses all of the image pairs above an overlap percentage defined by you. A default of 50% is used, but you can modify the percentage value.

   The overlap percentage default is controlled by a preference, **DTM Minimum Overlap Percentage.**

8. Interactively digitize areas of interest within the image pair, which are used to extract DTMs. Exclusion areas can also be defined (e.g., lakes, buildings). This is an optional step. By default, the software uses the overlap area for each image pair defined as the area of interest for the output DTM.

9. Define the DTM extraction strategy parameters for the areas of interest. The strategy parameters govern the operation of the automatic DTM extraction process. This is an optional step. If not defined, the default strategy parameters are used.

   For information about custom strategies, see "Set Strategy Parameters".

10. Input 3D reference information to be used for calculating the accuracy associated with individual DTMs or a mosaicked DTM. A comprehensive DTM accuracy report is provided for each DTM extracted.

11. The output DTMs can be used for orthorectification within OrthoBASE Pro. Output DTMs are also used as the primary input for IMAGINE VirtualGIS.

   For information about orthorectification, see Chapter 15 "Orthorectification".

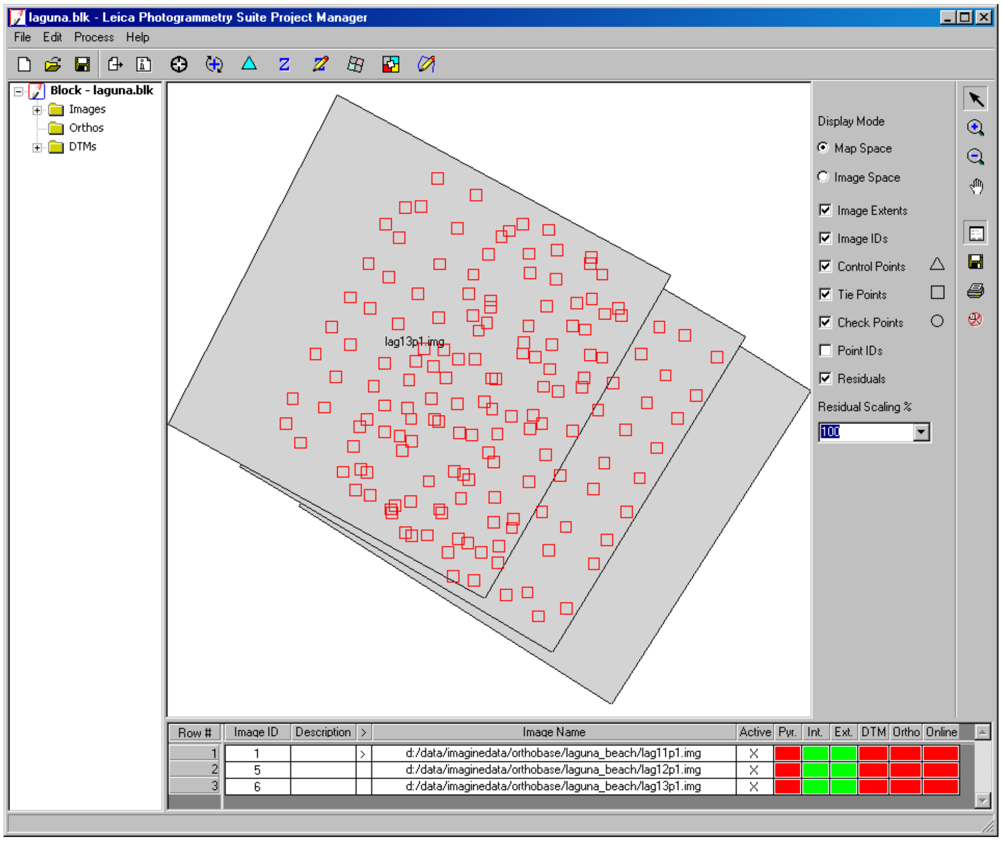
The following sections describe the interface in detail, and give helpful tips and tricks to successful DTM generation.

OrthoBASE Pro Dialog

The LPS Project Manager, shown in Figure 14-1, gives you access to both OrthoBASE and OrthoBASE Pro functionality. OrthoBASE Pro options include a DTM Extraction icon and an additional **DTM** column within the LPS Project Manager CellArray. Additional menu options are also present.

For information about menu items, see "Menu Bar".

Figure 14-1: Leica Photogrammetry Suite Dialog



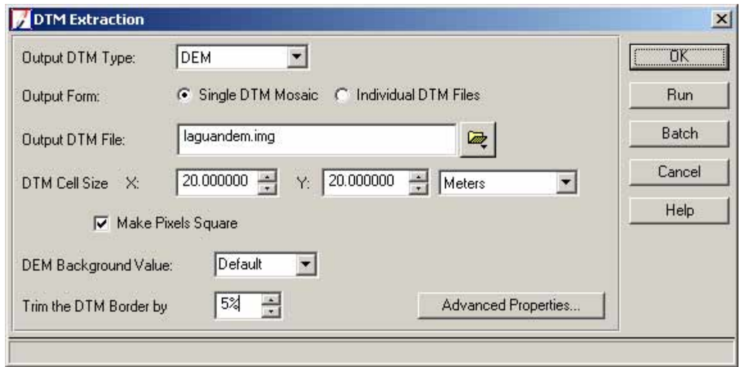
Selecting the DTM Extraction icon  displays the DTM Extraction dialog. Selecting a cell within the **DTM** column of the LPS Project Manager CellArray also displays the DTM Extraction dialog if a DTM has not already been extracted. A third way to access the DTM Extraction option is from the **Process** menu. Color cells are used to identify completion of a process. A DTM cell element is green when a DTM exists and overlaps the corresponding reference image. A DTM cell element is red when a DTM does not exist or overlap for the corresponding reference image.

You can change the cell color defaults using the **Status On Color** *and* **Status Off Color** *preferences.*

DTM Extraction Dialog

The DTM Extraction dialog, shown in Figure 14-2, is only activated once the block adjustment has been performed and accepted.

Figure 14-2: DTM Extraction Dialog



The DTM Extraction dialog is used as the interface for performing DTM extraction for an entire block in a production mode. The main concept behind this design is to minimize the number of selections while allowing you to generate one DTM for an entire project area (i.e., one block file). The primary goal of this design is to increase productivity.

The DTM Extraction dialog has the following options:

Output DTM Type

Four types of DTMs can be created with OrthoBASE Pro. This includes: 3D Shape, ASCII, DEM, and TerraModel TIN. To see examples of the various DTMs, refer to "View Types of DTMs".

3D Shape

The ESRI 3D Shape file generated by OrthoBASE Pro is composed of a number of mass points, each point having X, Y, and Z coordinate information which is automatically extracted by OrthoBASE Pro. The 3D Shape option should be selected if you want to edit the DTM in another program, such as Stereo Analyst. The 3D Shape option allows for attribution of each point that makes up the shape file. The 3D Shape file can also be used by ESRI GIS products. The elevation and status of each mass point contained in the 3D Shape file are stored as attributes.

ASCII

The ASCII format has a *.dat extension by default, but you can also save the ASCII file as a *.txt file. Each row in the ASCII file contains Pt ID, X, Y, Z, and Point Status information. The ASCII file is delimited by tabs, and the 3D coordinates have a number of values to the right of the decimal point (number of decimal places is a function of the units).

An example of the ASCII file format follows:

Table 14-1: ASCII File Format

Pt ID	X	Y	Z	Point Status
1	423971.5178	3712776.9865	9.3480	2
2	424526.0836	3712495.6806	34.3200	1

The Point Status column corresponds to the quality of the point. The values range from 1 to 5, with the following quality designations:

1 Excellent
2 Good
3 Fair
4 Isolated
5 Suspicious

For more information about point status, see “Create DTM Point Status Image”.

NOTE: Some text editors may be unable to display large ASCII files.

The ASCII files can be imported into other software products for subsequent DTM generation and GIS analysis and modeling.

DEM

A DEM is a raster file that can be in a variety of formats including ERDAS IMAGINE *.img file format. DEMs, 1-band files, display in gray scale where bright areas represent high elevations; dark areas represent low elevations. DEMs are very useful for orthorectifying imagery as well as being the primary input for IMAGINE VirtualGIS and other GIS analysis.

TerraModel TIN

A TIN is a set of nonoverlapping contiguous triangular facets of irregular sizes and shapes. The Delaunay triangulation approach is used to create a TIN from DTM mass points. The vertices that make up these areas are triangulated points, but are not necessarily present at regular postings.

The TerraModel TIN output option has a *.pro file extension. The TerraModel TIN can be used in TerraModel for a variety of engineering applications.

Output Form

DTMs can be output in two forms: **Single DTM Mosaic** or **Individual DTM Files.**

If the **Single DTM Mosaic** option is chosen, the DTMs generated for each image pair are merged into a single output file (i.e., similar to a mosaic). If the **Individual DTM Files** option is chosen, the DTMs extracted from each image pair have a separate output file.

Output DTM File or Output DTM Prefix

If the **Single DTM Mosaic** output is selected, an **Output DTM File** name must be specified.

If the **Individual DTM Files** output is chosen, the **Output DTM Prefix** option is enabled. You can specify a prefix name, which is tagged onto each DTM extracted. The resulting individual DTMs are named according to the prefix name and the image pair used to extract the DTM (e.g., dtmlag12p1_lag13p1.img).

DTM Cell Size X

You can specify a grid distance in the X direction which is used to extract a DTM posting. A dropdown menu defines the units of the output DTM. By default, the units are the same as the **Horizontal Units** defined in the DTM Extraction Properties dialog. Units are inherited from the block file. When the units are changed, the numerical values within the X and Y cell size fields remain the same and are not converted. Instead, the conversion is performed internally by OrthoBASE Pro.

DTM Cell Size Y

You can specify a grid distance in the Y direction which is used to extract a DTM posting. A dropdown menu defines the units of the output DTM. By default, the units are the same as the **Horizontal Units** defined in the DTM Extraction Properties dialog. Units are inherited from the block file. When the units are changed, the numerical values within the X and Y cell size fields remain the same and are not converted. Instead, the conversion is performed internally by OrthoBASE Pro.

NOTE: The default DTM Cell Size in X and Y is ten times the ground resolution of the input imagery.

Make Pixels Square

Click this checkbox so that the X and Y cell size for the output DTM are the same. The **DTM Cell Size X** and **Y** fields automatically update after the checkbox is selected.

DEM Background Value

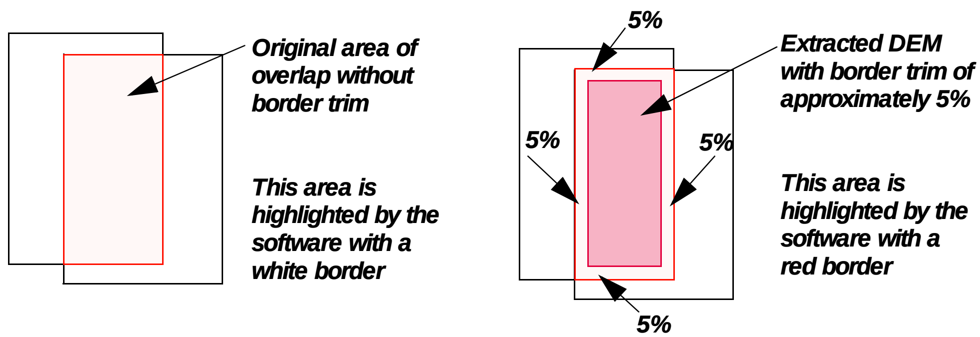
If the **Output DTM Type** selected is **DEM,** the **DEM Background Value** option is enabled. A value can be input within the DEM Background Value field. The background value is applied to the edges of the image outside of the overlap area where there is no DEM cover. This option is only enabled when the DEM output type is selected.

You can choose from the following options: **As Is, Default, 10** and **20. As Is** maintains the current background value. If the minimum DEM elevation value is positive, the **Default** is 0; otherwise, it is set to the minimum elevation minus five units. Selecting **10** or **20** imposes a 10- or 20-unit (e.g., meters) background value. You also have the option to type in a value of your choice (e.g., 5).

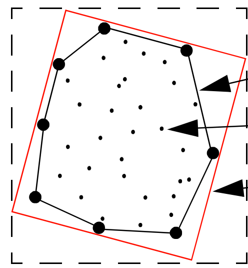
Trim the DTM Border by (%)

Before a DTM (of any type) has been extracted, the borders of the DTM can be trimmed according to a percentage value specified by you. This capability eliminates the need to subset the DTM once it has been extracted. Typically, the outer edges of an extracted DTM contain large errors. These regions are excluded from the final output DTM.

For example, a value of 10% would trim a rectangular DEM (extracted from the overlap areas of an image pair) by 5% on each of the four sides of the extracted DEM.



If your image pair is rotated, the trim is a bit more complex. The following diagram illustrates the application of the trim percentage when images are rotated.



For more information about the trim percentage, see "Case Study".

Advanced Properties

Selecting the **Advanced Properties** button displays the DTM Extraction Properties dialog, which is composed of four tabs. The DTM Extraction Properties dialog is used to input and define image pairs, geographic areas to be used for DTM extraction, and reference 3D coordinate information.

OK

Selecting **OK** saves all of the input DTM extraction properties. Once **OK** is selected, the DTM Extraction dialog closes.

Run

Selecting **Run** accepts all of the DTM extraction properties and begins the DTM extraction process.

Batch

Selecting the **Batch** option displays the Batch Wizard dialog. You can submit a DTM extraction process as an action item within the Batch process list.

For information about Batch processing, see Appendix B "Batch Processing".

Cancel

Selecting the **Cancel** option closes the DTM Extraction dialog and discards any changes made within the DTM Extraction dialog.

Help

Selecting **Help** displays the On-Line Help file related to the DTM Extraction dialog.

DTM Extraction Properties Dialog

The DTM Extraction Properties dialog can be displayed by selecting the **DTM Extraction Properties** option within the **Edit** menu of the LPS Project Manager, or by clicking the **Advanced Properties** button within the DTM Extraction dialog. The DTM Extraction Properties dialog is used to define and input specific information relating to the DTM extraction process. This includes:

- choosing projection and units information
- defining Contour Map generation properties
- selecting the image pairs to be used for DTM extraction
- selecting AOIs and exclusion areas

- defining DTM extraction strategy parameters
- defining 3D reference information to be used for accuracy assessment

OK

Selecting the **OK** button accepts all of the settings in the DTM Extraction Properties dialog. Once **OK** has been selected, the DTM Extraction Properties dialog closes and you are returned to the DTM Extraction dialog if you accessed the DTM Extraction Properties dialog via the **Advanced Properties** button. Otherwise, you are returned to the LPS Project Manager.

Cancel

Selecting the **Cancel** option closes the DTM Extraction Properties dialog and discards any changes made within it.

Help

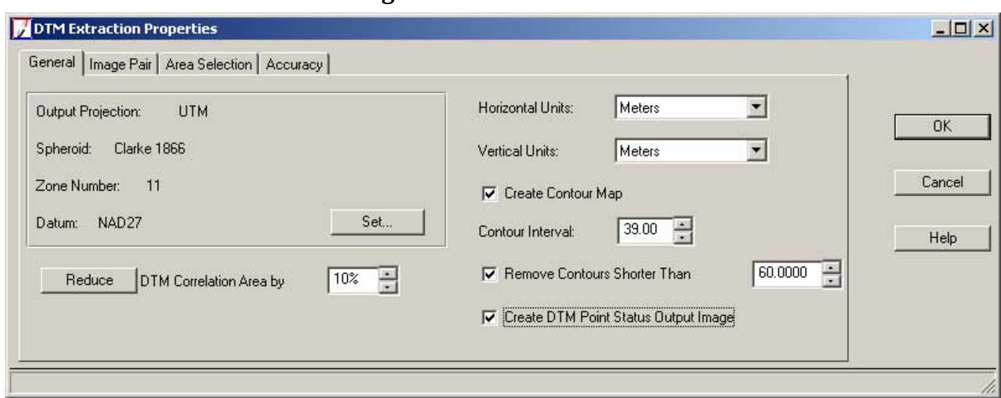
Selecting **Help** displays the On-Line Help related to the specific tab viewed within the DTM Extraction Properties dialog.

The next sections describe the tabs and their contents in detail.

General Tab

The **General** tab of the DTM Extraction Properties dialog is pictured in Figure 14-3.

Figure 14-3: General Tab



Projection

The first section of data in the tab is used to define the following information: **Output Projection, Spheroid, Zone Number,** and **Datum.** The default data displayed is the same as that used to define the OrthoBASE block file.

Selecting the **Set** button allows you to specify a new output projection, spheroid, and datum to be associated with the extracted DTM. Selecting the **Set** button displays the Projection Chooser dialog, which is used to input the new projection, spheroid, and datum. Once the new projection has been defined, it is displayed within the **General** tab.

Horizontal Units

You have the ability to define the output horizontal units (X and Y) associated with the output DTM. The default units displayed are the same as those defined for the OrthoBASE block file. Options include **Meters, Feet, US Survey Feet, Indian Feet, International Feet, Centimeters,** and **Inches.** If you are using Geographic (Lat/Lon) projection, your options are **Degrees** and **Radians.**

Vertical Units

You also have the ability to define the output vertical units (Z) associated with the output DTM. The default units displayed are the same as those defined for the OrthoBASE block file. Options include **Meters, Feet, US Survey Feet, Indian Feet, International Feet, Centimeters,** and **Inches.**

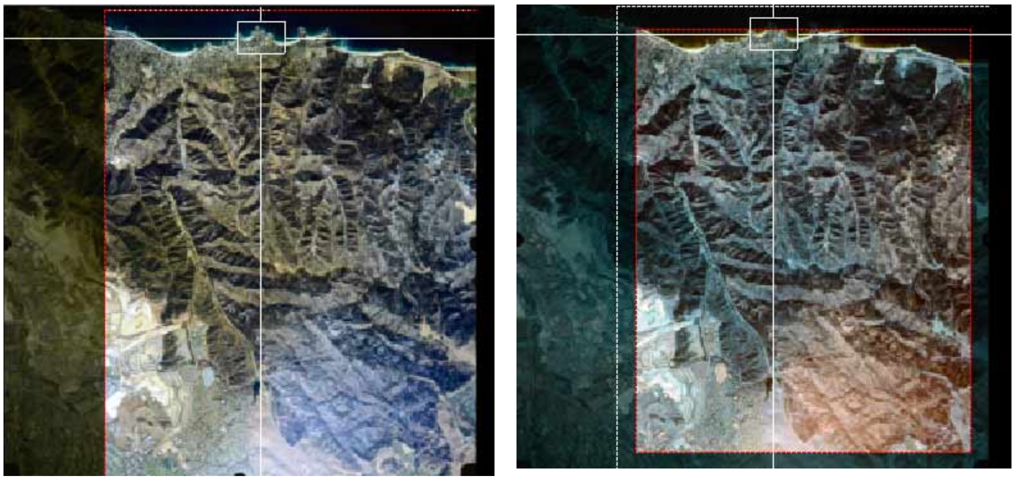
Reduce DTM Correlation Area by (%)

The overlap area of each image pair is calculated automatically based on the results computed from block triangulation. The remaining boundary area is reduced by a default percentage that can be defined by you.

Once the percentage value has been modified in the text field, clicking the **Reduce** button recalculates the default overlap area to be used for DTM extraction. The maximum correlation reduction value you can set is 80%.

Figure 14-4 shows an image before and after the correlation area has been reduced.

Figure 14-4: Image Before (Left) and After (Right) Correlation Area Reduction



A preference is included within the LPS Preferences which allows you to define the default percentage, **DTM Correlation Area Reduction Percentage.**

For more information about the correlation area, see "Set Trim/Correlation Reduction Percentage".

Create Contour Map

The Contour Map is an ESRI 3D Shape file corresponding to the output DTM. The generation of the Contour Map is optional, and controlled by selection of the **Create Contour Map** checkbox.

You must specify a **Contour Interval,** which is measured in vertical units, not horizontal units. By default, the interval is three times the output DTM cell size. For example, a DTM with a 10-meter cell size yields a default Contour Map with a 30-meter contour interval. An example Contour Map is presented in Figure 14-5.

Figure 14-5: Contour Map

NOTE: If a DTM trim percentage **(Trim the DTM Border by)** *is specified, the trim percentage is also applied to the Contour Map.*

Remove Contours Shorter Than

This option is provided so that you can eliminate small contours from the output Contour Map. By default, the value in this field is five times the default cell size.

Create DTM Point Status Image

A DTM Point Status image is a thematic raster image detailing the quality of mass points in the output DTM.

The generation of the DTM Point Status image is optional, and controlled by selection of the **Create DTM Point Status Output Image** checkbox. The image is divided into the following categories: Excellent, Good, Fair, Isolated, and Suspicious.

On the output thematic image, Excellent has a value of 1 and a color of light green, Good a value of 2 and a color of medium green, Fair a value of 3 and a color of yellow, Isolated a value of 4 and a color of orange, and Suspicious a value of 5 and a color of red.

Points considered Excellent have a correlation value between 1 and 0.85. Good DTM points have a correlation coefficient between 0.85 and 0.7. Fair points are between 0.7 and 0.5. DTM points which do not have any immediate neighbors are considered Isolated. DTM points are considered Suspicious by using the following technique.

NOTE: For more information regarding correlation coefficients, please refer to “Interest Point Matching”.

1. A 3 × 3 window is used to calculate an elevation value using the neighboring DTM postings.

2. The known (i.e., extracted) elevation value is subtracted from the interpolated value to compute the difference.

3. The standard deviation of the neighboring DTM postings is captured.

4. If the difference is three times larger than the standard deviation, the interpolated elevation value is used and the point is considered a Suspicious point.

NOTE: If a DTM trim percentage **(Trim the DTM Border by)** *is specified, the trim percentage is also applied to the DTM Point Status image.*

An example DTM Point Status image is presented in Figure 14-6.

Figure 14-6: DTM Point Status Image

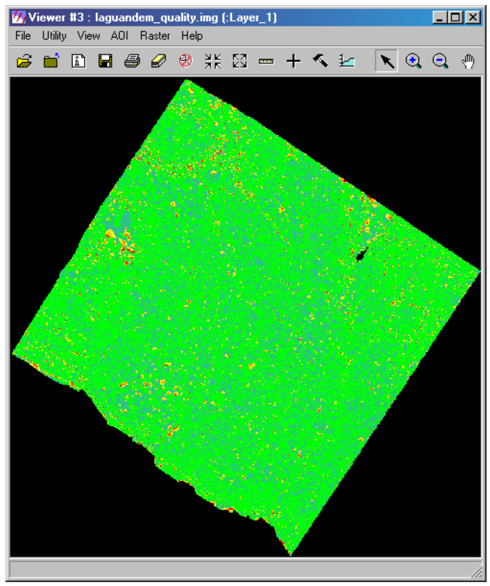
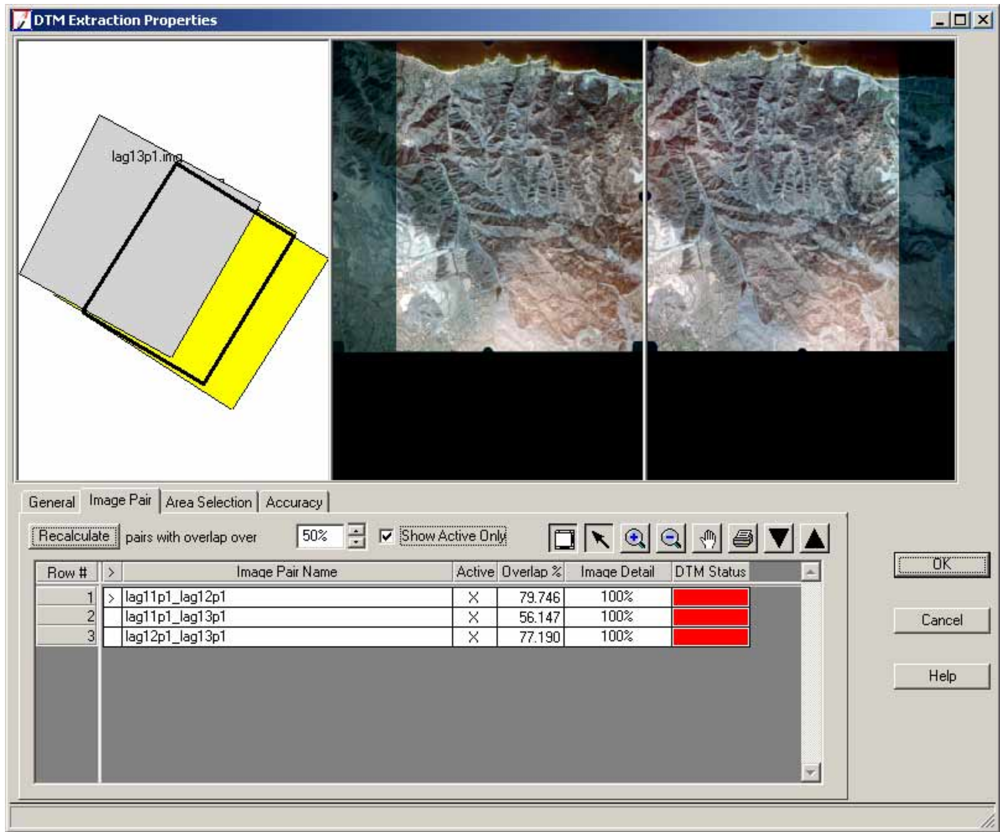


Image Pair Tab

The **Image Pair** tab is shown in Figure 14-7.

Figure 14-7: Image Pair Tab with Views

Block Graphic View ***Left Image View*** ***Right Image View***



NOTE: The left and right images can be rotated if the overlapping portions of the images are not displayed adjacent to one another within the left and right view. Right-click and select the **Rotate** *option within the Quick View Menu.*

The **Image Pair** tab is used to view and select the image pairs within the block to be used for DTM extraction. The **Image Pair** tab contains two components: the views and the CellArray. This is useful since not every image pair needs to be used for DTM extraction in order to create a comprehensive output DTM mosaic. Since images commonly overlap within the strip and between adjacent strips, redundant portions of the overlap areas do not need to be used for DTM extraction. The **Image Pair** tab allows you to identify unnecessary image pairs and choose the appropriate image pairs for DTM extraction.

Three views are used to preview the block, select an image pair from the block, and view the left and right images associated with an image pair. The CellArray component is used to view and browse image pairs within a table environment. The CellArray also allows for the interactive selection within the table of image pairs to be used for DTM extraction.

Image Pair Views

The following components are associated with the **Image Pair** tab views:

Block Graphic View

The Block Graphic View displays the graphical footprint of the block and the footprints of the images associated with the block. The image names are displayed within the upper-left portion of each image footprint.

An image pair selected within the CellArray is highlighted within the Block Graphic View. An image and its closest neighbor (based on selection) can be selected within the Block Graphic View and is subsequently marked as the reference image pair with the **>** designator in the CellArray. As a result, the left and right images comprising the image pair are displayed in the Left and Right Views.

Moving the cursor over any portion of the block highlights the specific image or image pair. Once an image pair is highlighted, it can be interactively selected and displayed in the left and right views accordingly.

The highlight color used to highlight an image pair is included as a preference, **Selected Image Pair Color,** *within the OrthoBASE preferences.*

The right mouse Quick View Menu options are not available in this view. The Block Graphic View is not linked with the Left or Right Image Views, and displays North up.

Left Image View

The Left Image View displays the left image associated with an image pair. The nonoverlap areas of the left image comprising an image pair can be masked-out, to only display the overlap areas associated with the left image. This option is an OrthoBASE preference, **Remove Nonoverlap Areas in DTM Viewers.**

Right Image View

The Right Image View displays the right image associated with an image pair. The nonoverlap areas of the right image comprising an image pair can be masked out, as described above.

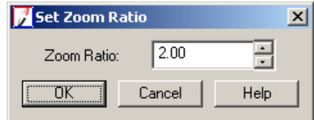
Left/Right Image View Quick View Menu

The right mouse Quick View Menu options can be used to modify band combinations, image enhancement, and so on, as described below:

NOTE: Menu options only affect the view to which they are applied.

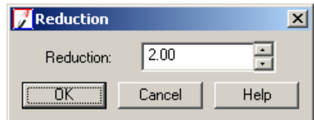
- **Zoom In by 2.** Quickly magnify the displayed data. The current zoom ratio is multiplied by 2.
- **Zoom Out by 2.** Quickly reduce the displayed data. The current zoom ratio is divided by 2.
- **Default Zoom.** Reset the zoom ratio to 1 in the view.
- **Zoom in by X.** Opens the Set Zoom Ratio dialog, shown in Figure 14-8, in which you can enter a numerical value by which to zoom in.

Figure 14-8: Set Zoom Ratio Dialog



- **Zoom out by X.** Opens the Reduction dialog, shown in Figure 14-9, in which you can enter a numerical value by which to zoom out.

Figure 14-9: Reduction Dialog

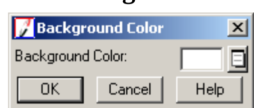


- **Set Resampling Method.** Options include **Nearest Neighbor, Bilinear Interpolation, Cubic Convolution,** and **Bicubic Spline.** This option only applies the resampling for image display and does not affect the actual image.

- **Fit Image to Window.** Fits the entire image within the view.

- **Background Color.** Opens the Background Color dialog, shown in Figure 14-10. Click the  icon to access different colors to apply to the background color of the view.

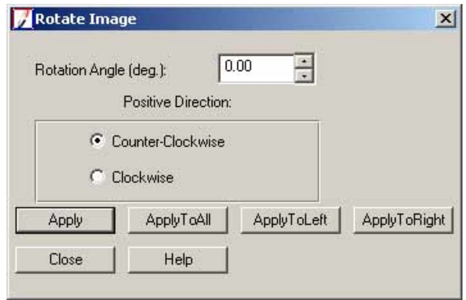
Figure 14-10: Background Color Dialog



- **Rotate.** Opens the Rotate Image dialog, shown in Figure 14-11. Input a number of degrees to rotate the image. Counter-clockwise takes a positive rotation angle and rotates the image counter-clockwise, or a negative rotation angle and rotates the image clockwise. Clockwise takes a positive rotation angle and rotates the image clockwise, or a negative rotation angle and rotates the image counter-clockwise. If necessary, you can apply rotation to individual images using the **ApplyToLeft** and **ApplyToRight** buttons, or to all images in the block file using the **ApplyToAll** button.

NOTE: The left and right images can be rotated if the overlapping portions of the images are not displayed adjacent to one another within the Left Image View and Right Image View.

Figure 14-11: Rotate Image Dialog



- **Band Combinations.** Opens the Set Layer Combinations dialog, shown in Figure 14-12. You can choose to display or not to display certain color displays (i.e., Red, Green, Blue), as well as assign different bands to different color displays.

Figure 14-12: Set Layer Combinations Dialog—Multiple Layers

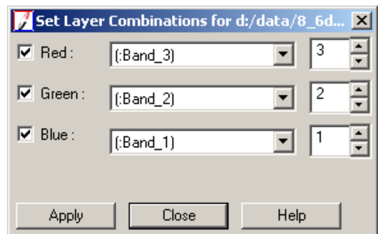
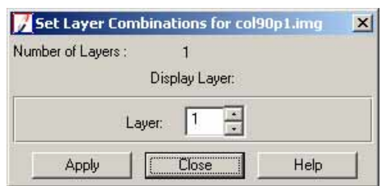
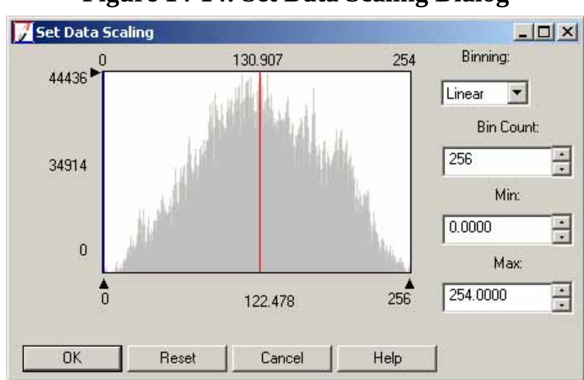


Figure 14-13: Set Layer Combinations Dialog—Single Layer



- **Data Scaling.** Opens the Set Data Scaling dialog, shown in Figure 14-13. Using the tools in this dialog, you can specify a data stretch to use when displaying the left and right images.

Figure 14-14: Set Data Scaling Dialog



- **General Contrast.** Opens the Contrast Adjust dialog, shown in Figure 14-14. You use this dialog to edit the lookup tables for the displayed raster layer.

Figure 14-15: Contrast Adjust Dialog

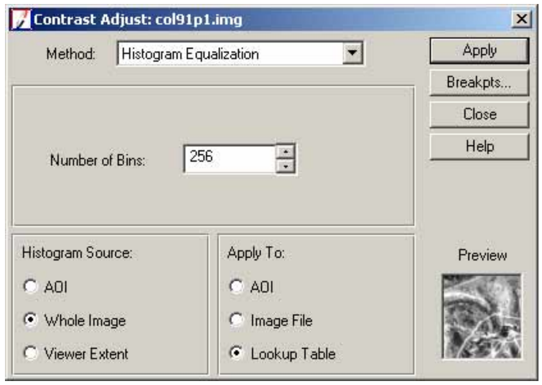


Image Pair Options

Recalculate pairs with overlap over (percentage)%

This option is used to generate a new list of image pairs to be used for DTM extraction. By entering a new overlap percentage value and selecting the **Recalculate** button, new image pairs are added to the existing list.

The overlap percentage is also a preference within the LPS Preferences, **DTM Minimum Overlap Percentage.**

The default overlap percentage is 50%. As a result, the CellArray displays all image pairs containing at least 50% overlap. Image pairs containing less than 50% overlap are not displayed in the CellArray.

For example, if a new value of 10% is input, the existing active image pairs remain within the CellArray, and a new list of image pairs (i.e., those having more than 10% and less than 50% overlap) are displayed within the CellArray as well.

The **Recalculate** *button does not check the image pairs already in the CellArray when specifying a new value which is less than the existing value.*

Show Active Only

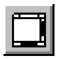
Selecting **Show Active Only** displays only the active image pairs (marked with an **X** in the **Active** column) within the CellArray. As a result, the active image pairs are also adjusted within the Block Graphic View used to illustrate the block footprint.

NOTE: The **Show Active Only** *option also affects the list of available image pairs in the* **Area Selection** *tab. This is useful for fast and easy access to specific image pairs.*

This setting also affects the **Current Pair** field in the **Area Selection** tab. If it is checked, only the active pairs appear in the dropdown list; if not, all image pairs appear in the list regardless of their active status.

Image Pair Icons

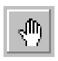
The view icons on the **Image Pair** tab include:

 Views - Selecting the Views icon displays the three views.

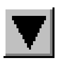
 Select - The Select icon is used to select an image pair within the Block Graphic View.

 Zoom In - Selecting the Zoom In icon allows you to continuously zoom in within any of the three views. It magnifies the display of the image pair by 2.

 Zoom Out - Selecting the Zoom Out icon allows you to continuously zoom out within any of the three views. It reduces the display of the image pair by 2.

 Roam - Selecting the Roam icon allows you to pan/roam within any of the three views, providing the image pair's display is beyond the extent of the view. If the image is fit to the window, this tool has no effect.

 Print - Selecting the Print icon prints the contents of the Block Graphic View. The entire graphic is printed.

 Move to Next Image Pair - Selecting the Move to Next Image Pair option selects the next image pair listed in the CellArray. If the views are open, the next image pair is highlighted in the Block Graphic View and displayed in the Left and Right Image Views.

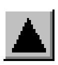
 Move to Previous Image Pair - Selecting the Move to Previous Image Pair option selects the previous image pair listed in the CellArray. If the views are open, the resulting image pair is highlighted in the Block Graphic View and displayed in the Left and Right Image Views.

Image Pair CellArray

The Image Pair CellArray consists of the following columns:

Row

A unique row number is assigned to each image pair. You can interactively select a cell within the **Row #** column to select an image pair. If an image pair is selected within the Block Graphic View illustrating the block footprint, the corresponding row associated with an image pair in the CellArray is indicated with the **>** symbol.

Once a **Row #** has been selected, you can use the CellArray **Row Selection** menu to Sort, Goto, and Search based on criteria you choose. You can access this menu with a right-click in the **Row #** column. The **Delete Selection** option is not enabled. Rather than delete a selection, the image pair can be defined as active or not active by clicking in the **Active** cell to place and remove the **X.**

> (Image Pair Indicator)

This column is used to indicate which image pair is currently the reference. If a **Row #** is selected, the **>** symbol is placed within the appropriate cell. The reference image pair is displayed in the Left Image View and Right Image View.

Image Pair Name

The image pair name is determined based on the names of the left and right images comprising the image pair. If the left image filename is image1.img and the right image filename is image2.img, the corresponding image pair name is image1_image2. You cannot edit the image pair name.

Active

The **Active** column indicates which image pairs to use for DTM extraction. An active image pair has an **X** within the appropriate cell. Interactively selecting within the cell activates or deactivates an image pair. By default, all image pairs are active.

Overlap %

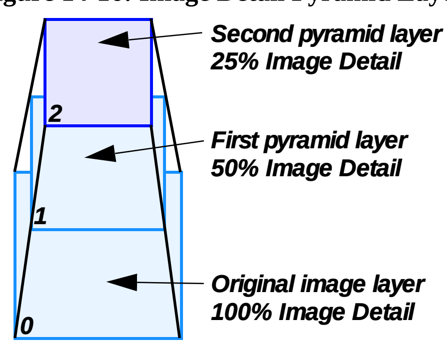
The **Overlap %** column indicates the amount (i.e., as a percentage) of overlap between the left and right images comprising a given image pair. The computation of the overlap is done in image space. The value can range from 0 to 100. This field cannot be edited.

A preference, **DTM Minimum Overlap Percentage,** *controls the overlap percent. Change the default value of 50, or use the* **Recalculate pairs with overlap over** *option in the* **Image Pair** *tab to view other image pairs without affecting the default.*

Image Detail

The **Image Detail** column indicates which pyramid layer is used last during the DTM mass point extraction. You can choose from the following options: **As Is, 100%, 50%,** or **25%.** A value of **100%** uses the original image as the last layer during the correlation process. A value of **50%** uses the largest pyramid layer (i.e., the first pyramid layer). A value of **25%** uses the second largest pyramid layer (i.e., the second pyramid layer). Figure 14-16 depicts the pyramid layers.

Figure 14-16: Image Detail Pyramid Layers



Reducing the **Image Detail** affects the size of the correlation window. If the correlation window is greater than the DTM Cell Size, then the correlation window size is used. However, the quality of the output DTM might be affected.

Figure 14-17: Cell Size Error Message

For more information about correlation windows, see "Correlation Size".

For example, when extracting DTMs over forested areas, it is advantageous to select either the **50%** or the **25%** image detail option in order to extract the forest canopy. If the original image is used, much of the noise and detail associated with individual leaves and branches produces erroneous DTM mass points.

It is also advantageous to use this option when the original imagery is scanned at a very high resolution, and the scale of imagery is greater than required.

NOTE: Selecting 25% or 50% reduces the time required to extract DTMs.

DTM Status

The **DTM Status** column is used to indicate whether or not a DTM has been extracted for any portion of the image pair. If a DTM has been extracted, the color code of the cell is green. If a DTM has not been extracted for that image pair, the color code is red. The cells within the **DTM Status** column are not interactive and cannot be selected.

The red and green color codes are controlled by the OrthoBASE Preferences **Status On Color** *and* **Status Off Color.**

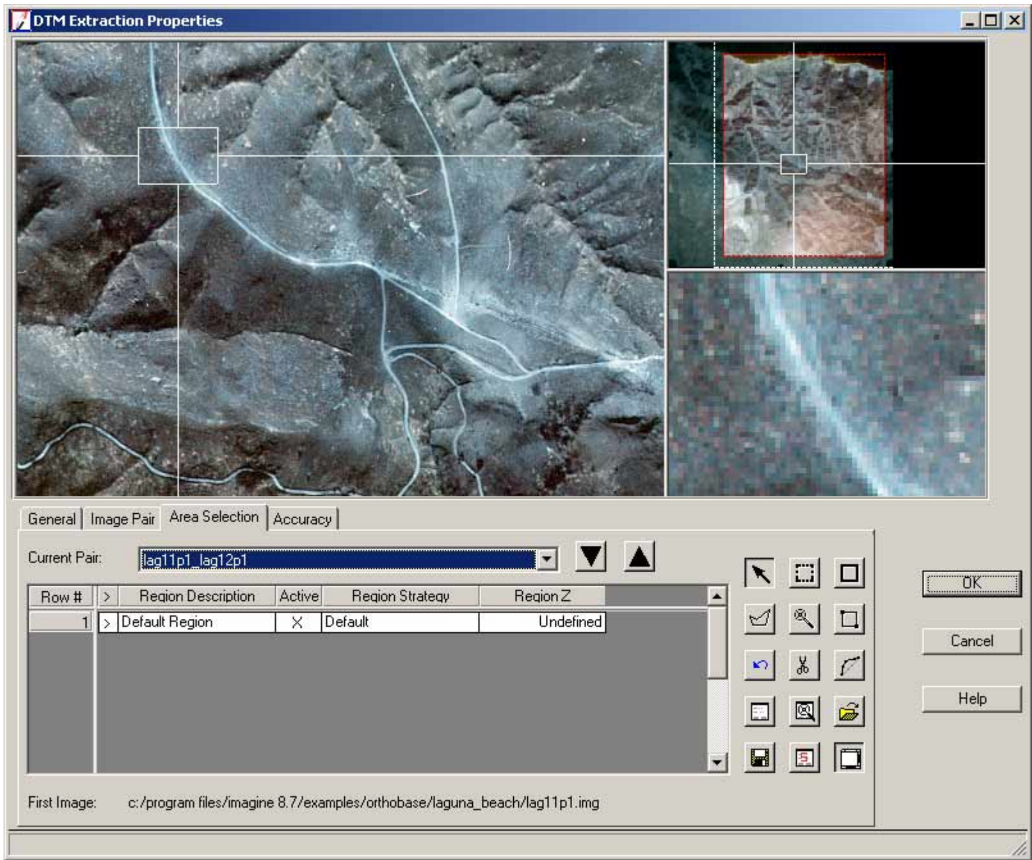
Area Selection Tab

The **Area Selection** tab is used to:

- Digitize specific geographic areas (i.e., polygons) within one of the images (the left image) comprising an image pair. If the area is to be used for DTM extraction, it is referred to as an inclusion area. An image pair can contain more than one inclusion area.
- Digitize specific geographic areas within the image which are not used for DTM extraction. These areas are referred to as exclusion areas. An image pair can have more than one exclusion area. A constant elevation value can be assigned to an exclusion area. For example, a lake can be digitized, designated an exclusion area, and assigned a constant elevation value. The resulting DTM for the image pair includes it as part of the output DTM with the elevation you specify.
- Input strategy parameters associated with an inclusion area. Strategy parameters can be input and applied to all inclusion areas, or a unique set of strategy parameters can be associated with each inclusion area. Strategy parameters are used to govern the operation of the DTM extraction algorithm during processing. Strategy parameters behave differently based on variations in topography and land cover.

The **Area Selection** tab, shown in Figure 14-18, contains two primary components: a CellArray and views.

Figure 14-18: Area Selection Tab with Views



Area Selection Views

The **Area Selection** tab contains three views, which are optionally displayed by clicking the Views icon . These include the Main View, OverView, and Detail View. The views are linked (via a link cursor): the OverView to the Main View, and the Main View to the Detail View. The views only display the left image associated with an image pair. The file name associated with the image displayed within the views is shown at the bottom of the tab in the **First Image** field.

The display of the image pair in the views is controlled by preferences. You have the option to select a preference, **Only Draw Image Pair Overlaps in DTM,** which only displays the overlap area (defined by the reduction percentage) for that given raster. If you prefer to view nonoverlap areas, you can choose how they display using the preference **Remove Nonoverlap Areas in DTM Viewers.**

All of these options are available so that you can easily identify and digitize the regions of inclusion and exclusion. Once a region has been digitized over a given portion of the raster, the pixel area covered by the region is bounded by a box and filled with a grid so that you can differentiate between the regions and the raster.

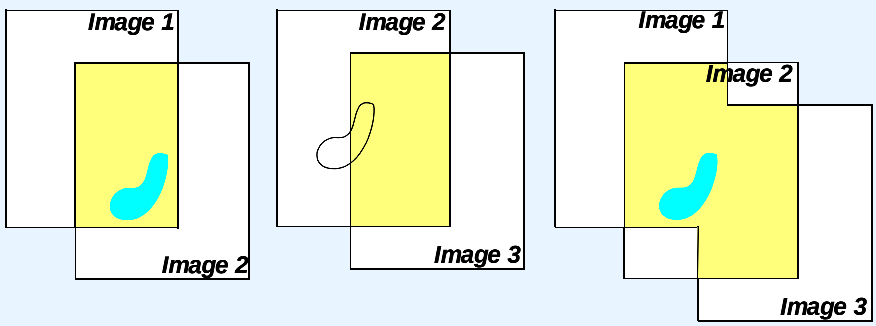
The color of the grid of inclusion regions depends on the preferences **DTM Region Color** *and* **DTM Selected Region Color.** *You have the option to not display the grid within the region by deactivating the* **Fill DTM Region Polygons In Area Selection Tab** *preference. By default, each region is filled.*

In the case of exclusion areas, those are differentiated by both color and the **Exclude Area** designation in the Area Selection CellArray.

The appearance of exclusion areas is controlled by the **DTM Exclude Region Color** *preference.*

Exclusion Region Hierarchy

If an exclusion area appears within multiple image pairs, it needs to be collected only within on image pair—not every image pair containing the geographic area to be designated an exclusion area. Exclusion areas take precedence over inclusion areas, so even if the same region is part of an inclusion area in another image pair, it is processed as an exclusion area. Consider the following diagrams:



In the first image pair (Image1_Image2), the overlap area, which is depicted in yellow, has an exclusion area, which is depicted in cyan. In the second image pair (Image2_Image3), the overlap area is also depicted in yellow. A portion of the exclusion area, which is shown only in outline, is also evident in this image pair, but is not designated an exclusion area. Thus, when you combine the image pairs together into a single DTM, the area is considered an exclusion area.

Main View

By default, the Main View displays a 1 to 1 view of the left raster associated with the current image pair. Adjust the size of the Link Box in the OverView to affect the display in the Main View. The Main View is used to display, digitize, edit, and delete regions.

OverView

The OverView displays the left raster associated with the current image pair. You can add and delete regions in this view.

Detail View

By default, the Detail View displays a magnified view the area within the link cursor displayed in the Main View. Adjust the size of the Link Box in the Main View to affect the display in the Detail View. The Detail View is also used to display, digitize, edit, and delete regions.

Quick View Menu

The Quick View Menu options available in the **Area Selection** tab follow. Note that options not applicable to a specific view are shown in parentheses.

For an explanation of the Quick View Menu options, see "Image Pair Views".

- Zoom In by 2 (not in OverView)
- Zoom Out by 2 (not in OverView)
- Default Zoom (not in OverView)
- Zoom in by X... (not in OverView)
- Zoom out by X... (not in OverView)
- Set Resampling Method... (not in OverView)
- Fit Image to Window (not in Detail View)
- Background Color...
- Link Box Color... (not in Detail View)
- Rotate...
- Band Combinations...
- Data Scaling...
- General Contrast...
- Scroll Bars (not in Detail View and OverView) - Select this option to display scroll bars in the Main View. Scroll bars allow you to adjust the display of the image in the view.

Area Selection Options

Current Pair

The current image pair is displayed within the **Current Pair** field. By selecting the dropdown list, you can select a different image pair. All pairs in the block file meeting the overlap percentage criteria area listed here, unless the **Show Active Only** checkbox is enabled in the **Image Pair** tab. If it is enabled, only **Active** image pairs are displayed in the dropdown list.

Move to Next Image Pair

Selecting the Move to Next Image Pair icon selects the next image pair in the block file. If the views are open, the next image pair is displayed in the Main View, OverView, and Detail View.

Move to Previous Image Pair

Selecting the Move to Previous Image Pair icon selects the previous image pair in the block file. If the views are open, the previous image pair is displayed in the Main View, OverView, and Detail View.

Area Selection Icons

The following icons are in the **Area Selection** tab to help you isolate regions in your image pairs:

Select - Choose this icon to select individual regions in the views.

Box Select Region - Click to select all regions that fall within the boundary of the rectangular marquee that you draw. To draw a perfect square, Shift-left hold when drawing.

Create Rectangle Region - Click to create a rectangular region. In the view, drag diagonally from the upper-left to the lower-right corner to create the rectangular region.

Create Polygon Region - Click to create a polygonal region. In the view, click to add each vertex. Double-click or middle-click (depending on how your **Polyline/Polygon termination button** preference is set) to close the polygon.

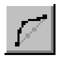
Region Grow Tool - Click to select a single pixel from which a region is generated based on the parameters set in the Region Growing Properties dialog.

Create a Region with Corners - Click to create a region by supplying the ULX, ULY, LRX, and LRY pixel coordinates of an area. The Set AOI with Bounding Box dialog opens.

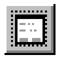
For information about creating a region with corners, see *"Set AOI with Bounding Box"*.

Undo Last Edit - An undo 'stack' of changes is maintained for one view session. The undo option allows you to undo a geometry change (i.e., change the size or shape of a region), view change, or a CellArray change. The undo option is only enabled once an action has been performed within the **Area Selection** tab. Once you change to a different tab, the undo stack is deleted.

Cut Selected Objects - Click to delete regions in the views, or to delete highlighted items from the CellArray.

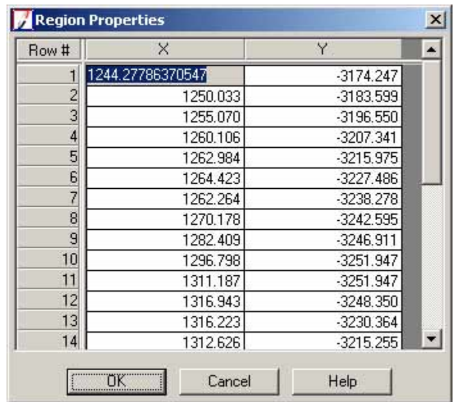


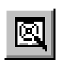
Reshape Polygon - Click this icon to reshape a selected polygon by adjusting individual vertices. You can add a vertex by middle-clicking on the polygon in between vertices. To delete a vertex, Shift-middle click the vertex.



Display Selected Region Properties - To use this icon, first select a region in the **Area Selection** tab, then click the icon. The Region Properties dialog, as shown in Figure 14-19, opens. It provides X and Y coordinate information for each vertex in the polygon. The X and Y coordinates are in pixel units.

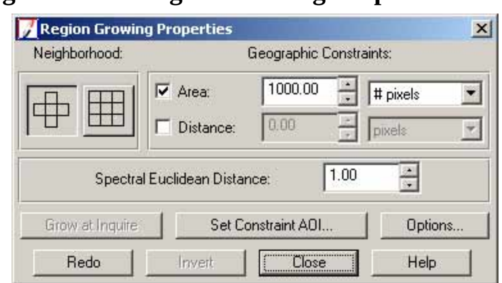
Figure 14-19: Region Properties Dialog





Region Growing Properties - Click to open the dialog, as shown in Figure 14-20. This is a standard ERDAS IMAGINE dialog that allows you to set parameters which govern the way regions are automatically created in the view.

Figure 14-20: Region Growing Properties Dialog



The neighborhood can be four or eight neighbors. Those neighbors are contiguous and are also part of the seed pixel you select. If selected, area and distance constraints control the size of the region in pixels, hectares, acres, square miles, meters, or feet. The Euclidean distance option accepts a pixel as part of the region whose digital number is within the spectral distance from the mean of the seed pixel. You can also access the Region Grow Options dialog to control other settings such as the inclusion of island polygons.

Load Region from file. Click this icon to open a File Selector, from which you can import both 2D and 3D Shape files, Arc Coverages, AOIs (*.aoi), and SDE Vector Layers (*.sdv). The imported regions are considered **Active,** and have default strategy parameters associated with them. This option is always enabled. AOIs that you load into the **Area Selection** tab can be in either image coordinates (pixels) or a map projection system.

Regions must be digitized in the left image of the image pair for them to appear correctly in the Area Selection views.

Save. Click this icon to save regions displayed in the **Area Selection** tab. Only those regions that are currently active, as denoted by the **X** in the **Active** column, are saved.

Edit Strategy - Click this icon to open the Set Strategy Parameters dialog. There, you can create new strategies to apply to inclusion regions in image pairs. You can also view settings of predefined strategies offered by OrthoBASE Pro.

For more information, see "Accuracy CellArray".

Views - Click to open the Area Selection views.

Area Selection CellArray

The **Area Selection** CellArray consists of the following columns:

Row

A unique row number is assigned to each region contained within an image pair (this includes inclusion and exclusion areas). By default, each image pair has at least one region associated with it. The default region is an inclusion region, and it encompasses the entire overlap area defined by the left and right images comprising the image pair, reduced by the percentage, if any, in the **Trim the DTM Border by** field.

You can interactively select a cell within the **Row #** column to select a region. Likewise, if a region is selected within the Main View, the **Row #** corresponding to the region is selected and highlighted. Once a **Row #** has been selected, you can use the CellArray **Row Selection** menu to Sort, Goto, and Search based on criteria you specify. More than one region can be selected at any given time by Shift-clicking on regions.

You have the ability to select and delete one, several, or all regions contained within the CellArray. If all of the regions are deleted in a CellArray and you change the current image pair, change tabs, or select **OK**, you are prompted with a warning dialog, shown in Figure 14-21, stating that there are no regions for the image pair. As a result, the image pair is deactivated in the **Image Pair** tab and is not used for DTM extraction.

Figure 14-21: Area Selection Warning

A preference, **Disable No Regions Warning Dialog,** *controls the appearance of this warning dialog.*

> (Region Indicator)

This column is used to indicate which region is currently active.

Region Description

The default region (i.e., overlap area between the left and right images) is named **Default Region** in the **Region Description** column. As additional regions are added, they are named **no description**. You can edit the region description by clicking in the cell and typing a new name.

Active

The **Active** column indicates which regions are to be used for DTM extraction. An active region has an **X** within the appropriate cell. Interactively clicking in the cell activates or deactivates a region. By default, the first region (i.e., overlap area of the left and right image) is active.

Region Strategy

The **Region Strategy** column displays the strategy applied to a specific region. The strategy parameters govern and optimize the performance of the DTM extraction process.

For any given region, you can click in the **Region Strategy** cell to select one of the several available options. These include **As Is, Exclude Area, Default, High Mountains, Middle Mountains, Rolling Hills, Flat Areas, High Urban, Low Urban, Forest,** and **Custom.**

The **As Is** option maintains the existing **Strategy Name** and parameters. **Exclusion Area** does not use the defined region during the DTM extraction process and assigns a user-defined constant elevation for that region in the output DTM. The **Default** option uses the default set of strategy parameters, which can be viewed and modified in the OrthoBASE Preferences.

Exclusion areas' appearance is governed by a preference, **DTM Exclude Region Color.**

Refer to "Predefined Strategies" for information about the strategies supplied with OrthoBASE Pro.

Selecting the **Custom** option displays the Set Strategy Parameters dialog. You can also select and view an existing strategy already created in the project using the Set Strategy Parameters dialog.

For information about the Set Strategy Parameters dialog, see "Set Strategy Parameters".

Region Z

This field displays the average elevation value to be assigned to an exclusion region. As a default, it is **Undefined.** The Region Z value is used to fill exclusion regions when the final DTM is created (i.e., for lakes or other geographic areas where the elevation is known and/or constant).

Clicking in the **Region Z** cell gives three options: **As Is, Undefined,** and **Custom.** The **As Is** option maintains the currently defined setting. The **Undefined** option states that an elevation is unknown and is not used to define the elevation of an exclusion region. If an **Undefined** designation is set for an exclusion area, the **DEM Background Value,** which is defined in the DTM Extraction dialog, is used. **Custom** opens the Region Z Value dialog, allowing you to enter a constant elevation value.

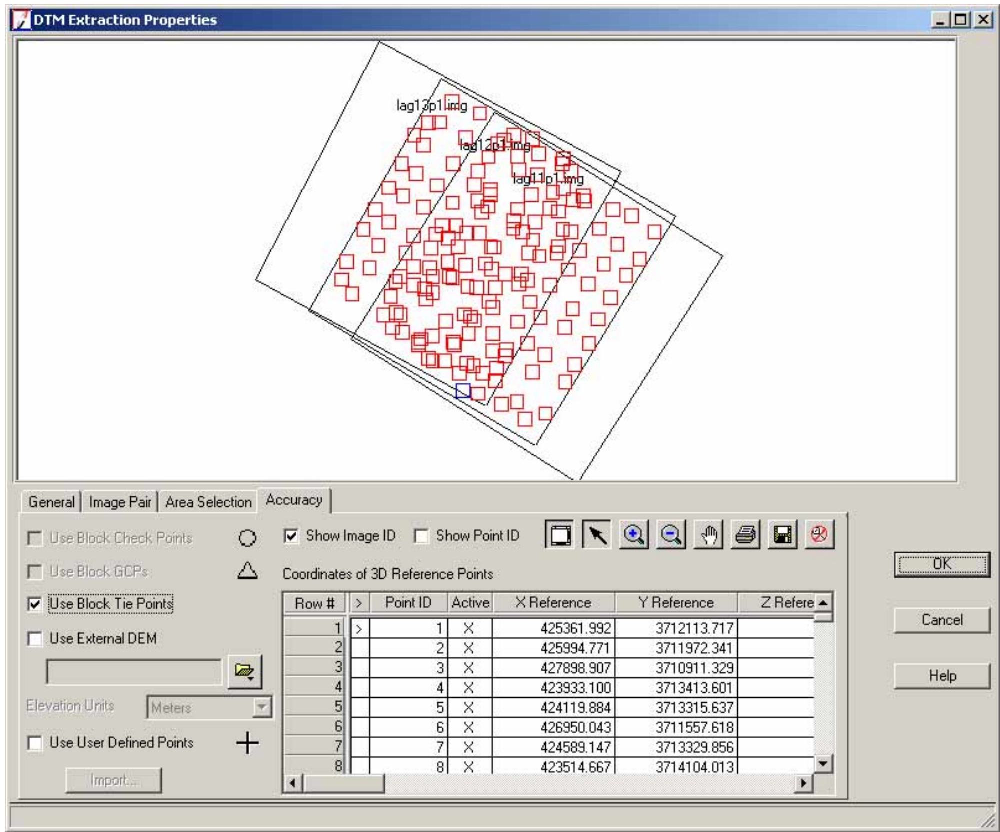
Do not arbitrarily assign a Z value of zero (0) unless it is the actual elevation of a region, otherwise you may have 'holes' in your output DTM.

For more information about the Region Z Value dialog, see "Region Z Value".

Accuracy Tab

The **Accuracy** tab, shown in Figure 14-22, is used to enter 3D reference information used by OrthoBASE Pro to calculate the accuracy associated with output DTMs. The **Accuracy** tab consists of a view and a CellArray. Additional options are provided within the **Accuracy** tab which allow you to specify the source and type of 3D reference information used for calculating DTM accuracy.

Figure 14-22: Accuracy Tab



The following 3D reference sources can be used to calculate DTM accuracy:

- check points contained within a block file
- GCPs contained within a block file
- tie points (whose XYZ coordinates have been computed) contained within a block file
- external raster DEM
- user-defined 3D coordinates contained within an ASCII file

Accuracy View

The **Accuracy** tab Block Graphic View is used to graphically display the following items:

- A footprint of the active images (from the block file) used for DTM extraction.
- A symbol for each of the active control points, tie points, and check points (from the block file) used for accuracy assessment. A unique symbol is used to represent the block file control points, check points, and tie points.
- A symbol for the user-defined check points used for accuracy assessment. A unique symbol is used to represent the user-defined check points.

- A footprint of the extent of the DEM used for accuracy assessment.

Accuracy Options

Show Image ID

If the **Show Image ID** checkbox is selected within the dialog, the image IDs (names) associated with the active images in the block are displayed in the Block Graphic View. The image ID is displayed within the upper-left portion of each individual image footprint.

Show Point ID

If the **Show Point ID** button is selected, the point IDs associated with the check points, control points, tie points, and user-defined points are displayed within the Block Graphic View.

Interactively selecting a check point, tie point, control point, or user-defined point displays the Point Data dialog. This is the same dialog used as that within the Project Graphic Status window of the LPS Project Manager, and supplies coordinate information.

For information about the Point Data dialog, see “Point Data”.

Use Block Check Points

Selecting this option enables the use of existing check points defined with the block to calculate DTM accuracy. OrthoBASE Pro uses **Full** (X, Y, and Z coordinates) check points. Only the **Active** check points as defined within the Point Measurement tool are used (see Chapter 11 “Measuring GCPs, Check Points, and Tie Points” for more information about the Point Measurement tool). All of the **Active** check points are displayed within the Block Graphic View and denoted with the check point symbol (a circle) and optional Point ID.

NOTE: For computing accuracy, only those check points inside the DTM area are used.

Use Block GCPs

Selecting this option enables the use of existing GCPs for accuracy assessment. OrthoBASE Pro only uses **Full** GCPs and **Vertical** (Z coordinate) GCPs. **Horizontal** (X and Y coordinates) GCPs are not used for DTM accuracy computation. Only **Active** GCPs as defined within the Point Measurement tool are used. All of the **Active** GCPs are displayed within the Block Graphic View and denoted with the GCP symbol (a triangle) and optional Point ID.

NOTE: For computing accuracy, only those GCPs inside the DTM area are used.

Use Block Tie Points

Selecting this option enables the use of existing tie points for accuracy assessment. OrthoBASE Pro uses all tie points whose X, Y, and Z coordinates have been calculated as a result of performing the aerial triangulation. Only **Active** tie points as defined within the Point Measurement tool are used. All of the **Active** tie points are displayed within the view and denoted with the tie points symbol (a square) and optional Point ID.

NOTE: For computing accuracy, only those tie points inside the DTM area are used.

For information about aerial triangulation, see “Aerial Triangulation”.

Use External DEM

An external raster DEM can be used as a 3D reference source for performing an accuracy assessment. The individual DEM postings contained within the reference DEM are compared with the extracted DTM. Once a DEM file has been defined, the footprint of the reference DEM is displayed within the Block Graphic View of the **Accuracy** tab.

NOTE: This option is only enabled if the **Output DTM Type** *specified is* **DEM.**

Use User Defined Points

Selecting **Use User Defined Points** activates the **Import** button, which enables you to import 3D reference points contained within an ASCII file. User-defined points display in the view as crosshairs.

Import

Selecting the **Import** button displays a series of dialogs for the import of 3D reference points contained within an ASCII file. Once the input ASCII file has been defined, you are provided within the Reference Import Parameters dialog. This dialog allows you to specify which projection, spheroid, and datum were used to collect these reference points. If the data is in a different projection, spheroid, and datum, the software transforms the data so that it conforms to the reference projection defined for the block.

Once **OK** has been selected, you are presented with the Import Options dialog, which enables you to define specific ASCII format information associated with importing the ASCII file.

Accuracy Icons

The following icons are included in the **Accuracy** tab.

For a description of the icons’ functionality, see “Image Pair Icons”.

View

Select

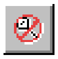
Zoom In

Zoom Out

Roam

Print

Save - Save graphical contents as an annotation file (*.ovr). You can open an annotation file in a Viewer in conjunction with the image files in the block, or, once the process is complete, orthorectified images in the block.

 Reset to default Zoom - Resets the zoom ratio (number of file pixels used to store the image) to the actual size. The block footprint fits in the view.

Accuracy CellArray

The **Accuracy** tab CellArray is used to display, input, and edit 3D reference coordinate information. The CellArray also displays all of the 3D reference information obtained from the block including the 3D coordinates associated with control, tie, check, and user-defined points. The 3D coordinates associated with reference DEMs, however, are not displayed in the CellArray. Upon start-up (i.e., for the first time in a project) and by default, the CellArray only contains one row entry.

Row

A unique row number is assigned to each 3D reference point contained within a block. You can interactively select a cell within the **Row #** column to select a 3D reference point. If a 3D reference point is selected within the Block Graphic View, the **Row #** corresponding to the reference point is selected and highlighted and the Point Data dialog opens. Once a **Row #** has been selected, you can use the CellArray **Row Selection** menu (accessed by a right-click in the **Row #** column) to Sort, Goto, and Search based on criteria. You may also delete a selection. More than one 3D reference point can be selected in the CellArray at any given time using the Shift-click method.

A 3D reference point can be deleted by selecting the point (or several points), and then selecting the **Delete Selection** *option from the* **Row Selection** *menu. To access the* **Row Selection** *menu, right-click in the* **Row #** *column.*

The color of the selected reference point is controlled by the **Selected Accuracy Point Color** *preference.*

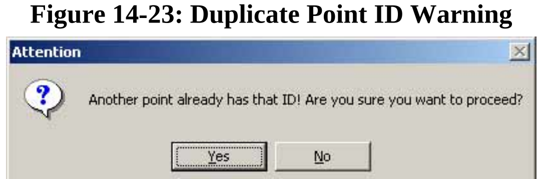
> (3D Reference Point Indicator)

This column is used to indicate which reference point is currently active. If a 3D reference point is selected, the **>** symbol is placed within the appropriate cell, and the point is identified in the Block Graphic View.

Point ID

The **Point ID** column displays the unique point ID associated with a 3D reference point. Each 3D reference point has a unique Point ID. If so desired, you can edit the Point ID. Once edited, the software checks to ensure the new Point ID is unique. If not, a warning message opens.

Figure 14-23: Duplicate Point ID Warning



Active

The **Active** column indicates whether or not the 3D reference point is to be used for the accuracy assessment of extracted DTMs. An active 3D reference point has an **X** within the appropriate cell. Interactively selecting within the cell activates or deactivates a 3D reference point. By default, all 3D reference points are initially set to **Active.**

X Reference

This column displays all of the X coordinates associated with the 3D reference points you have chosen to use (e.g., check points) in accuracy assessment.

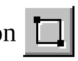
Y Reference

This column displays all of the Y coordinates associated with the 3D reference points you have chosen to use (e.g., check points) in accuracy assessment.

Z Reference

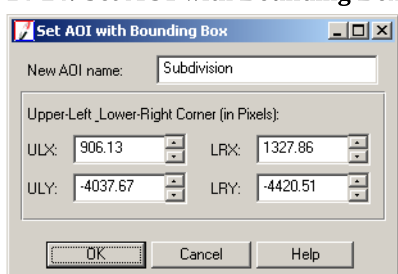
This column displays all of the Z coordinates associated with the 3D reference points you have chosen to use (e.g., check points) in accuracy assessment.

Set AOI with Bounding Box

The Set AOI with Bounding Box dialog, shown in Figure 14-24, is accessed by clicking the Create Region with Corners icon  in the **Area Selection** tab of the DTM Extraction Properties dialog.

The Set AOI with Bounding Box dialog is used to enter known pixel coordinates (upper-left and lower-right) and define a new AOI name. After selecting **OK,** a new, rectangular AOI is created and displayed. If **Cancel** is selected, the changes are discarded, the dialog closes, and you return to the DTM Extraction Properties dialog.

Figure 14-24: Set AOI with Bounding Box Dialog

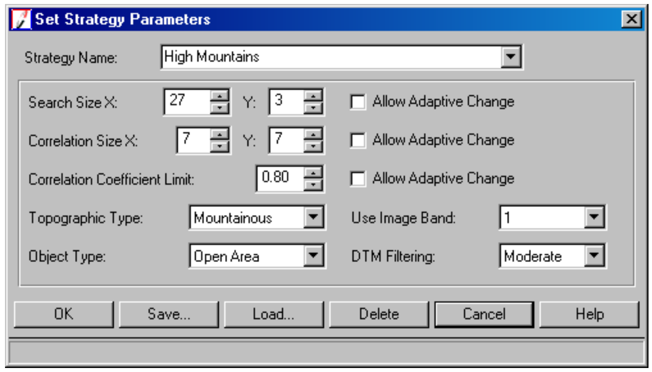


Set Strategy Parameters

You can access the Set Strategy Parameters dialog in the **Area Selection** tab of the DTM Extraction Properties dialog. You can either click the Edit Strategy icon , or you can click in the **Region Strategy** cell and select **Custom** from the dropdown list.

The Set Strategy Parameters dialog, shown in Figure 14-25, is primarily used to edit and define a unique set of strategy parameters for an inclusion AOI; however, you can view settings of existing strategies in the dialog as well.

Figure 14-25: Set Strategy Parameters Dialog



In the dialog, a new strategy name must be input in the **Strategy Name** field. The new strategy name associated with the customized set of parameters is displayed with the appropriate **Region Strategy** name in the CellArray after you click **OK** to accept the parameters. The names within the **Region Strategy** field cannot be edited. Once you create a custom strategy, it is added to the dropdown list you access from a **Region Strategy** cell. This way, you can apply it to other regions.

Strategy Name

Strategy Name is the name associated with a set of strategy parameters to be linked with the current reference region defined within the **Area Selection** tab CellArray with the **>** symbol.

Search Size

Search Size is the search window size (in pixels) used to search for corresponding image points appearing within the overlap areas of the left and right images. It is measured in the X and Y direction. Y direction is perpendicular to the epipolar line, X direction is along the epipolar line.

For more information about the epipolar line, see “Matching Constraints”.

Search size works in conjunction with **Allow Adaptive Change,** which permits the software to change the strategy parameter adaptively according to statistical rules and inferences. The adaptive change in parameter settings occurs between iterative pyramid layer processing.

Correlation Size

Correlation Size is the window size (in pixels) used for computing the correlation coefficient between image patches on the left and right images. It is measured in the X and Y direction. It works in conjunction with **Allow Adaptive Change,** which permits the software to change the strategy parameter adaptively according to statistical rules and inferences. The adaptive change in parameter settings occurs between iterative pyramid layer processing.

The correlation size that is set here is a minimum size that is used for the correlation. If your DTM cell size is larger than the correlation size, an appropriate correlation size is computed and used instead of the minimum correlation size. If you specify a DTM cell size smaller than the correlation size, the minimum correlation size is used. However, the quality of the output DTM might be affected.

Figure 14-26: Cell Size Warning

Correlation Coefficient Limit

Correlation Coefficient is the minimal correlation value (i.e., threshold) for accepting a pair of points as matching candidates. This value ranges from 0 to 1, with 1 being a perfect match. You cannot specify a correlation coefficient limit lower than 0.50.

NOTE: If the output DTM type is DEM, uncorrelated areas are interpolated.

It works in conjunction with **Allow Adaptive Change,** which permits the software to change the strategy parameter adaptively according to statistical rules and inferences. The adaptive change in parameter settings occurs between iterative pyramid layer processing.

Topographic Type

The **Topographic Type** option allows you to specify the general description of the terrain type. Three options are provided which include: **Flat** for flatlands, **Rolling Hills** for low relief, and **Mountainous** for high relief. The software uses this information for selecting internal DTM extraction parameters.

Object Type

The **Object Type** option allows you to classify the type of objects on the terrain. Four options are provided: **Open Area** for countryside without buildings, **Low Urban** for urban and suburban low buildings, **High Urban** for urban areas with high buildings, and **Forest** for densely forested area. The DTM extraction algorithm functions differently based on the selected designation for **Object Type.**

Use Image Band

This option is provided for multispectral or color imagery. You can select the band you want the correlator to use during DTM extraction. By default, the first band is used for the matching. If the left and right image have a different number of bands, and if you need to change the band used for correlation, the same band number in both images is used.

DTM Filtering

This section of the dialog gives you the option of filtering erroneous pits and peaks from the output DTM. Your choices are **None, Low, Moderate,** and **High.** If the data has many anomalies, select **High;** if the data has few anomalies, select **Low.** The setting you choose may affect processing time.

OK

Selecting **OK** saves all changes and returns you to the **Area Selection** tab.

Save

The strategy parameters can be saved as an ASCII file for future use with another region or block project. Selecting the **Save** option displays a File Selector, in which you can navigate to an appropriate folder and save the file. Strategy files have a *.dat extension.

Load

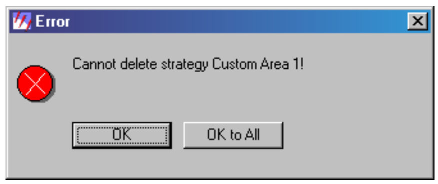
Strategy parameters stored in an ASCII file can be loaded into the Set Strategy Parameters dialog by selecting the **Load** option. Once the **Load** option has been selected, a File Selector opens. You then specify the appropriate ASCII file ensuring that it conforms to the format used by the software. An example strategy, named "New Strategy", follows:

```
New Strategy
Search Size = 27x9
Search Adaptive = FALSE
Correlation Size = 13x13
Correlation Adaptive = FALSE
Coefficient Limit = 0.85
Coefficient Adaptive = FALSE
Topographic Type = flat
Object Type = open_area
Use Band = 3
DTM Filtering = high
```

Delete

Click **Delete** to delete the strategy currently identified in the **Strategy Name** section of the Set Strategy Parameters dialog. If the strategy is in use in the block project, a warning message displays.

Figure 14-27: Delete Strategy Error Message



Cancel

Selecting **Cancel** discards all edits and returns to the **Area Selection** tab.

Predefined Strategies

OrthoBASE Pro provides you with a set of predefined custom strategies that you can apply to regions. Those strategies and a brief description of each follow:

Exclude Area

When you designate an area as an exclusion area, there is no need for special processing, it is simply avoided in processing; therefore, setting changes are neither necessary nor possible in the Set Strategy Parameters dialog.

Default

The Default strategy parameters are sufficient for uniform data. Should your data cover extreme areas, such as densely populated urban areas or mountainous areas, one of the other strategies is more appropriate. The search size is relatively large to enhance matching probability.

High Mountains

The High Mountain strategy has a search size of 27 × 3. Having a large number in the X direction improves the possibility of matching areas. The X value in this strategy is particularly large because high relief causes more distortions.

Middle Mountains

The Middle Mountains strategy has a search size of 21 × 3. Similar to the High Mountains strategy above, a large value in the X direction increases the possibility of finding a match.

Rolling Hills

The Rolling Hills strategy has a search size of 15 × 3. In this strategy, the X value has been reduced since lower elevations correspond to smaller X-parallax.

Flat Areas

The Flat Areas strategy has a search size of 7 × 3. In flat areas, a small search size is adequate because of the absence of errors brought about by high relief.

High Urban

This High Urban strategy has a search size of 19 × 3. In this strategy, like the High Mountain strategy, the X value is increased because extreme elevations produce error. By increasing the value in X, a greater chance the correlator has to find a match. If high buildings are excluded from the correlation, the search size in X should be reduced.

Low Urban

The Low Urban strategy has a search size of 11 × 3. Matches are easier to find in low areas, hence the X value is not large.

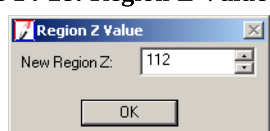
Forest

The Forest strategy has a search size of 17 × 3. In the case of the Forest strategy, a large value in X is used because similar features are hard for the correlator to differentiate.

Region Z Value

You access this dialog, pictured in Figure 14-28, via the **Area Selection** tab of the DTM Extraction Properties dialog. In the CellArray of this tab, click in the **Region Z** cell corresponding to the exclusion area you want to give a Z (height) value, and select **Custom** from the dropdown list.

Figure 14-28: Region Z Value Dialog



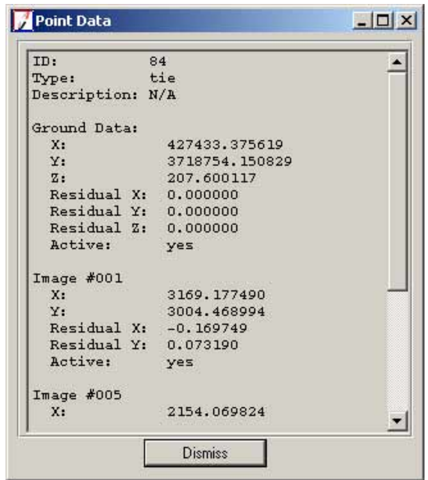
Simply type a value for the region in the **New Region Z** text field and click **OK.**

A good way to determine the Z value of a region is to open the block file in Stereo Analyst, survey the area in stereo, and use the 3D measuring capability to determine the average elevation for the region of interest.

Point Data

You can access the Point Data dialog, shown in Figure 14-29, by clicking on any point displayed in the Block Graphic View of the **Accuracy** tab, which is in the DTM Extraction Properties dialog. You can also get point data for points displayed in the Project Graphic Status window of the LPS Project Manager.

Figure 14-29: Point Data Dialog



The Point Data dialog supplies details about the map coordinate positions and elevation of the selected point. This dialog is not editable.

DTM Extraction Report

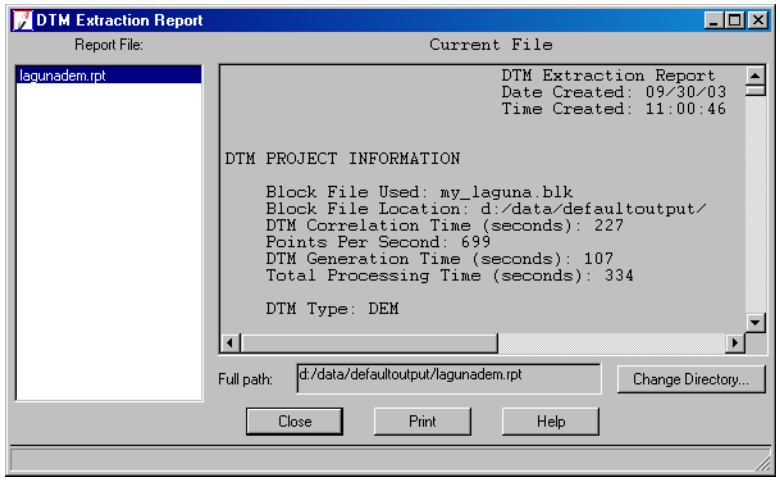
Once each DTM has been successfully extracted, a corresponding DTM ASCII report is created. An accuracy report is created for each output DTM extracted. Thus, if a single DTM is extracted from a block, one accuracy report is generated; if multiple DTMs are extracted from a block, multiple accuracy reports are generated. The following accuracy information is contained in each report:

- general information (i.e., processing time, size of DTM, type of DTM)
- strategy parameters used and their settings
- global RMS associated with the all of the 3D reference sources combined
- RMS errors associated with each set of 3D reference information
- the individual RMS errors associated with each 3D reference observation
- global Absolute Linear Error (LE) and Circular Error (CE) at 90% (This information is defined according to National Imagery and Mapping Agency [NIMA] specifications.)
- the percentage of excellent, good, fair, isolated, and suspicious points
- global quality of the output DTM

The output report file has a *.rpt file extension. The name of the report file is named the same as the automatically extracted DTM, and is located in the same folder.

Selecting the **DTM Extraction Report** option within the **Process** menu of the LPS Project Manager displays the DTM Extraction Report dialog, as shown in Figure 14-30. This dialog can be resized by dragging the corners and sides to the desired size.

Figure 14-30: DTM Extraction Report



The left window of the DTM report interface displays all of the DTM report file names in the short form. Each time you click on a report file name, the contents of that particular report file are shown in the right window. The full path of the report file displays in the **Full path** field. If the **Print** button is selected, the file contents of the report file are printed. Selecting the **Help** button opens the on-line help document. Selecting **Close** closes this report interface and returns to the LPS Project Manager.

Interpreting the Output DTM Report

The output DTM extraction report contains the following generalized information associated with DTMs extracted using OrthoBASE Pro.

- title and date information
- block file information
- processing time information
- general output DTM information
- DTM extraction strategy parameters used
- general DTM mass point quality information
- global vertical accuracy information
- global horizontal accuracy information
- OrthoBASE Pro block check point accuracy information
- OrthoBASE Pro block GCP accuracy information
- OrthoBASE Pro tie point accuracy information
- user-defined check point accuracy information

- reference DEM accuracy information

Title and Date Information

```
DTM Extraction Report
Date Created: 07/05/01
Time Created: 18:30:32
```

The date and time at which the DTM was generated is listed here.

Block File Information

Information associated with the block file used for creating the DTM is listed here. This information includes:

- block file used
- block file location
- image pairs used to extract DTMs

```
DTM PROJECT INFORMATION

Block File Used: colspr.blk
Block File Location: d:/imagine8.5/examples/orthobase/frame/
```

Processing Information

The time required to generate a DTM is listed here. This information includes:

- DTM Correlation Time (seconds). This consists of the time required to find corresponding image coordinates of ground features appearing within the overlap areas of an image pair. The total DTM correlation time is associated with the time required to complete the digital image matching process and computes the coordinates (mainly elevation), of the matched mass points.
- Points Per Second. This consists of the total number of corresponding image points that have been successfully identified and measured within a second.
- DTM Generation Time (seconds). This consists of the time required to construct an output DTM (TIN and DEM). Constructing the output DTM involves the interpolation of the DTM based on the extracted 3D mass points.
- Total Processing Time (seconds). This consists of the total time required to create the output DTM. This is a sum of the DTM correlation time and the DTM generation time.

```
DTM Correlation Time (seconds): 14
Points Per Second: 1870
DTM Generation Time (seconds): 8
Total Processing Time (seconds): 22
```

General Information

General output DTM information includes:

- DTM type generated
- name and location of output DTM generated
- number of columns and rows in the output DTM

- cell Size specified for the output DTM
  (This information is only applicable to output DEMs. If a TIN, 3D Shape file or ASCII file is specified as the output DTM type, the information consists of the total number of points extracted for the given image pair.)
- upper left and lower right X and Y map coordinates of the output DTM
- minimum, maximum and mean elevations of the output DTM
- projection, spheroid, datum and units of the output DTM

```
DTM Type: DEM
DTM Name: c:/temp/lagunadem.img
Number of Columns: 221
Number of Rows: 149
Cell Width: 40.0000 meters
Cell Height: 40.0000 meters
Upper left DEM corner coordinates: (662306.3143, 120622.9921)
Lower right DEM corner coordinates: (671143.4391, 114680.1088)
```

If a TIN is the specified output the following information displays:

```
DTM Type: TIN
DTM Name: c:/temp/lagunatin.pro
Number of Mass Points Extracted: 24431
Upper left corner of DTM Bounding Box:(419879.6550, 3724459.6093)
Lower right corner of DTM Bounding Box:(433656.9506, 3710095.3505)
```

If 3D Shape is the specified output the following information displays:

```
DTM Type: 3D Point Shapefile
DTM Name: c:/temp/lagunashp.shp
Number of Mass Points Extracted: 24431
Upper left corner of DTM Bounding Box:(419879.6550, 3724459.6093)
Lower right corner of DTM Bounding Box:(433656.9506, 3710095.3505)
```

If ASCII is the specified output the following information displays:

```
DTM Type: 3D Point in ASCII Format
DTM Name: c:/temp/lagunaascii.dat
Number of Mass Points Extracted: 24431
Upper left corner of DTM Bounding Box:(419879.6550, 3724459.6093)
Lower right corner of DTM Bounding Box:(433656.9506, 3710095.3505)
```

Additional information in this section of the report includes:

```
Minimum Mass Point Elevation: 1844.4921
Maximum Mass Point Elevation: 2255.9321
Mean Mass Point Elevation: 1947.2291

Projection: State Plane
Spheroid: Clarke 1866
Datum: NAD27
```

```
Horizontal Units: meters
Vertical Units: meters
```

Strategy Information

The strategy parameters used for a given region are displayed in this section of the report.

```
Strategy Parameter Settings:

  Image Pair Name: lag11p1_lag12p1
   Region Description: Default Region
   Name of Strategy Used: Default
   List All of the Strategy Parameter Values Used:
      Search Size: 21
         Allow Adaptive Change: No
      Correlation Size: 7
         Allow Adaptive Change: No
      Coefficient Limit: 0.8000
         Allow Adaptive Change: No
      Topographic Type: Rolling Hills
      Object Type: Open Area
      Use Image Band: 1
      DTM Filtering: low
```

In the above example, the region utilized the default strategy parameters.

```
  Image Pair Name: lag11p1_lag12p1
   Region Description: Mountains
   Name of Strategy Used: Mountains
   List All of the Strategy Parameter Values Used:
      Search Size: 21
         Allow Adaptive Change: Yes
      Correlation Size: 7
         Allow Adaptive Change: Yes
      Coefficient Limit: 0.8000
         Allow Adaptive Change: Yes
      Topographic Type: Mountains
      Object Type: Low Urban
      Use Image Band: 1
      DTM Filtering: low
```

In the above example, the ′Mountains′ region uses a strategy defined as mountainous for the topographic type and low urban as the object type. The correlation parameters are also set as being adaptive so that they can be modified, if required, after each iteration of processing.

```
  Image Pair Name: lag12p1_lag13p1
   Region Description: Rolling Hills
   Name of Strategy Used: Rolling Hills
   List All of the Strategy Parameter Values Used:
      Search Size: 21
         Allow Adaptive Change: Yes
      Correlation Size: 7
         Allow Adaptive Change: Yes
      Coefficient Limit: 0.8000
         Allow Adaptive Change: Yes
      Topographic Type: Rolling Hills
      Object Type: Low Urban
      Use Image Band: 1
      DTM Filtering: low
```

In the above example, the 'Rolling Hills' region uses rolling hills as the topographic type and low urban as the object type. The correlation parameters are also set as being adaptive so that they can be modified, if required, after each iteration of processing.

```
Region Description: Lake
Name of Strategy Used: Exclude Area
Elevation of Exclude Area: 112.0000
```

In the above example, an exclusion area described as 'Lake' is defined. Rather than the **Undefined** region Z value, a custom Z value of 112 (meters) is assigned to the region.

Mass Point Quality Information

The accuracy associated with an extracted DTM can be computed in a variety of ways. OrthoBASE Pro provides the following accuracy indices within the output DTM extraction accuracy report:

- minimum and maximum error of extracted DTM mass points
- mean error of DTM mass points
- mean absolute error of DTM mass points
- RMSE
- absolute linear error 90 (LE90)
- NIMA absolute LE90
- circular error 90 (CE90)
- NIMA CE90

The following text is an example of the accuracy information contained in a report.

Descriptions of the sections of the report begin with "Minimum/Maximum Error".

```
ACCURACY INFORMATION

   General Mass Point Quality:
      Excellent % (1-0.85): 80.7731 %
      Good % (0.85-0.70): 14.8919 %
      Fair % (0.70-0.50): 0.0000 %
      Isolated %: 0.0000 %
      Suspicious %: 4.3350 %
```

General mass point quality describes the percentage of DTM mass points that can be considered Excellent, Good, Fair, Isolated, and Suspicious. Mass points are designated as being Excellent, Good, or Fair based on the value computed for correlation coefficient.

For more information about Isolated and Suspicious mass points, see "Create DTM Point Status Image".

```
Global Accuracy:

      Vertical Accuracy:
         Total # of 3D Reference Points Used: 2278
         Minimum, Maximum Error: -3.5363, 12.2574
         Mean Error: 2.2111
         Mean Absolute Error: 4.0269
         Root Mean Square Error (RMSE): 4.0273
         Absolute Linear Error 90 (LE90): 3.2214
         NIMA Absolute Linear Error 90:  4.0101
```

In the above example, global vertical accuracy indices describe the global vertical accuracy of the DTM by combining all of the 3D reference information together to compute the various statistical accuracy values associated with vertical accuracy.

```
       Planimetric (Horizontal) Accuracy:
         Total # of 3D Reference Points Used: 1684
         Minimum, Maximum Error in X: -12.0000, 8.0000
         Mean Error in X: -2.8266
         Mean Absolute Error in X: 5.8385
         Root Mean Square Error (RMSE) in X: 6.4943
         Minimum, Maximum Error in Y: -12.0000, 8.0000
         Mean Error in Y: -0.9026
         Mean Absolute Error in Y: 5.4893
         Root Mean Square Error (RMSE) in Y: 6.5684
         Circular Error 90 (CE90): 4.2221
         NIMA Circular Error 90:  5.5592
```

In the above example, global horizontal accuracy indices describe the global horizontal accuracy of the DTM by combining all of the 3D reference information together to compute the various statistical accuracy values associated with horizontal accuracy.

```
Block Check Point to DTM Vertical Accuracy

      Total # of Check Points Used: 1
      Minimum, Maximum Error: 0.2439, 0.2439
      Mean Error: 0.2439
      Mean Absolute Error: 0.2439
      Root Mean Square Error: 0.2439
      Absolute Linear Error 90: 0.2439
      NIMA Absolute Linear Error 90:  0.0000

      Detailed Point Accuracy Information:
```

Pt. ID	X	Y	Z	DTM Z	Residual
2001	670970.4500	114815.2300	1891.8880	1892.1319	0.2439

The DTM residual is computed by differencing the reference Z value from the automatically extracted Z value.

```
   Block GCP to DTM Vertical Accuracy

      Total # of GCPs Used: 4
      Minimum, Maximum Error: 0.0425, 2.7308
      Mean Error: 1.7130
      Mean Absolute Error: 1.7130
```

```
Root Mean Square Error: 2.0020
Absolute Linear Error 90: 2.7308
NIMA Absolute Linear Error 90:  1.7057

Detailed Point Accuracy Information:
```

Pt. ID	X	Y	Z	DTM Z	Residual
1002	665228.9550	115012.4720	1947.6720	1950.0690	2.3970
1003	664456.2200	119052.1500	1988.8200	1991.5508	2.7308
1005	668338.2200	118685.9000	1886.7120	1886.7545	0.0425
1006	670841.4800	118696.8900	2014.0000	2015.6817	1.6817

```
Block Tie Point to DTM Vertical Accuracy

    Total # of Tie Points Used: 39
    Minimum, Maximum Error: -13.5363, 7.3861
    Mean Error: -4.3178
    Mean Absolute Error: 5.4810
    Root Mean Square Error: 5.9439
    Absolute Linear Error 90: 6.7852
    NIMA Absolute Linear Error 90:  6.7415

    Detailed Point Accuracy Information:
```

Pt. ID	X	Y	Z	DTM Z	Residual
2006	662661.9155	116234.7363	2063.9112	2063.9191	0.0079
2007	662885.7917	118342.1889	2112.1111	2116.0599	3.9488
2047	670870.1932	115786.2930	1889.4704	1888.4745	-0.9959
2057	662743.8050	119018.6562	2162.4088	2159.9739	-2.4349

```
User Defined Check Points to DTM Vertical Accuracy

    Total # of User Defined Check Points Used: 6
    Minimum, Maximum Error: -1.7639, 6.1986
    Mean Error: 2.0830
    Mean Absolute Error: 2.6710
    Root Mean Square Error: 3.2238
    Absolute Linear Error 90: 6.1986
    NIMA Absolute Linear Error 90:  2.9715

    Detailed Point Accuracy Information:
```

Pt. ID	X	Y	Z	DTM Z	Residual
2080	666819.0410	118604.7303	1920.6419	1918.8780	-1.7639
2084	670840.2574	118697.0791	2015.2045	2015.6868	0.4823

```
User Defined DEM to DTM Vertical Accuracy

      Total # of DEM Points Used for Checking Vertical Accuracy: 2228
      Minimum, Maximum Error: -8.0845, 12.2574
      Mean Error: 2.3275
      Mean Absolute Error: 4.0384
      Root Mean Square Error: 5.6418
      Absolute Linear Error 90: 5.3517
      NIMA Absolute Linear Error 90: 6.2812
```

Minimum/Maximum Error

This accuracy index describes the range of DTM mass point errors. A larger error range (e.g., -200 m to +300 m) indicates that the accuracy of the extracted DTM is low.

Mean Error

The mean error of the DTM is computed using 3D reference points based on the following equation:

$$\bar{e} = \frac{\Sigma e_i}{n}$$

where,

$\bar{e}$ = mean error

Σe_i = sum of all error values (e_i = Z_{model} - $Z_{reference}$)

n = total number of 3D reference points used

It is important to note that the mean error takes into consideration both positive and negative error values. For example, if three DTM mass points have errors of -5, 0, and 5, the mean error is 0. Since two of the observations contain errors other than 0, you cannot conclude that the DTM has no error.

Mean Absolute Error

The mean absolute error of the DTM is computed using 3D reference points based on the following equation:

$$\overline{|e|} = \frac{\Sigma |e_i|}{n}$$

where,

$\overline{|e|}$ = mean absolute error

$\Sigma |e_i|$ = sum of all absolute error values

n = total number of 3D reference points used

Unlike mean error, mean absolute error takes into consideration the sign associated with an error value. For example, all error values having a negative sign are made positive by multiplying them by -1. The mean absolute accuracy index is useful to determine the average accuracy of the extracted DTM.

For example, consider Table 14-2 in which ten mass points having the following error values:

Table 14-2: Mass Points and Error Values

Mass Point	Error Value
1	- 4
2	5
3	- 3
4	- 2
5	3
6	1
7	0
8	3
9	2
10	4

The mean error in this case is 0.9. The mean absolute error is 2.7.

RMSE

The root mean square error of the DTM is computed using 3D reference points based on the following equation:

$$RMSE = \sqrt{\frac{\Sigma e_i^2}{n}}$$

where,

$e_i = Z_{model} - Z_{reference}$

RMSE indicates the magnitude of error associated with all of the DTM based on the 3D reference points used.

Absolute LE90

Absolute LE90 is used to describe the error associated with 90% of the DTM based on the 3D reference points used. For example, consider Table 14-3 wherein seven 3D reference points have the following error values:

Table 14-3: Reference Point Error Values

3D Reference Points	Error Value (meters)
1	0.5
2	1
3	2.5
4	3.3
5	4.2
6	6.7
7	9.1

NOTE: The error values are sorted in ascending order by OrthoBASE Pro before calculation.

The total number of mass point error observations is multiplied by 90% (i.e., 0.9). Therefore, $7 \times 0.9 = 6.3$. The software rounds down to obtain a value of 6. As a result, the sixth observation within the data set is 6.7 meters. Therefore, 90% of the DTM has an error of less than 6.7 meters.

NIMA Absolute LE90

The NIMA LE90 statistic is based on the assumption that a normal distribution exists with the set of observations (Department of Defense 1990). In this case, the set of observations is the DTM errors computed using 3D reference points. The following equation is used to calculate NIMA LE90:

NIMA LE90 = $\pm$ 1.646 σ

where,

$$\sigma = \sqrt{\frac{\Sigma(|e_i| - \overline{|e|})^2}{n}}$$

where,

σ = standard deviation of error

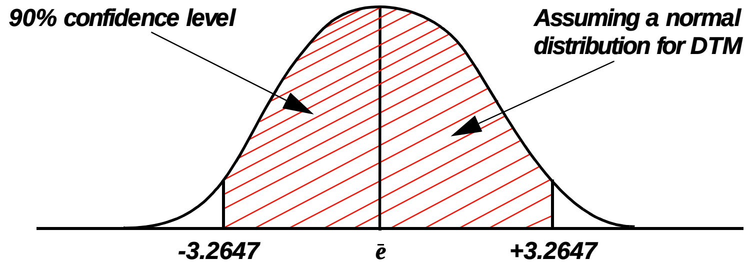
$|e_i|$ = absolute error of reference point *i*

$\overline{|e|}$ = mean absolute error for the entire set of reference points

n = total number of 3D reference points used

The value of 1.646 represents a 90% confidence interval derived from statistical tables. For example, if a value of ± 3.2647 meters is computed for NIMA LE90, it is safe to state that at a 90% confidence level, the DTM accuracy is within ± 3.2647 meters. Figure 14-31 illustrates NIMA LE90.

Figure 14-31: NIMA LE90



Horizontal Accuracy Computations Using a Reference DEM

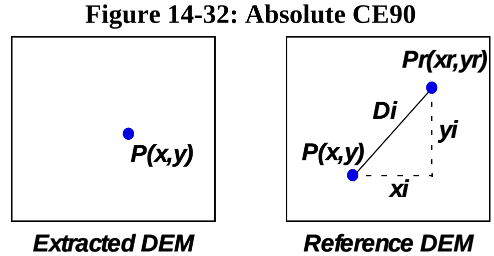
When an external DEM is used as a reference source to compute the accuracy associated with a DEM, CE90 is used as a statistic to reflect the quality of the automatically extracted DEM.

Digital correlation techniques are used to identify and measure the same ground X and Y position appearing within the reference DEM and the automatically extracted DEM. OrthoBASE Pro computes two types of circular error including absolute CE90 and NIMA CE90.

Absolute CE90

Figure 14-32 shows the image position of a ground point appearing within the reference DEM (P_r) and extracted DEM *(P)*. Error distance is represented by D_i.

Figure 14-32: Absolute CE90



In Figure 14-32,

x,y = the column, row pixel coordinates of a ground point *P* appearing on the extracted DEM

x_r, y_r = the column, row pixel coordinates of a ground point P_r appearing on the reference DEM

x_i, y_i = the x-shift and y-shift values computed by differencing the respective image coordinates obtained from the reference DEM and extracted DEM

Using digital image matching techniques, each pixel contained within the extracted DEM is matched with the corresponding pixel contained within the reference DEM. The error distance of each pixel is the distance between the pixel in the extracted DEM and the corresponding pixel in the reference DEM (between points *P* and P_r), as in the following equation:

$$D_i = \sqrt{(x_i - \bar{x})^2 + (y_i - \bar{y})^2}$$

where,

$\bar{x}$ $\bar{y}$ = mean x-shift and y-shift values computed from the total number of observations

D_i = error distance computed for each set of DTM pixels compared

An error distance is computed for each pixel appearing within the extracted DEM and the reference DEM. This is similar to the calculation of Absolute LE90 (see "Absolute LE90"). The error distances of all matched pixels are sorted in ascending order, and the error value that is above 90% of error distances is the final result of Absolute CE90.

Absolute CE90 is computed using the following equation:

$$CE = \sqrt{\frac{\Sigma(D_i - \bar{D})^2}{n}}$$

where,

D_i = error distance computed for each set of DEM pixels computed

$\bar{D}$ = mean error distance computed for the set of observations

n = total number of observations used

CE = Absolute CE90

NIMA CE90

NIMA CE90 is computed using the following equations (Department of Defense 1990):

NIMA CE 90 = ± 1.073 ($\sigma_x + \sigma_y$)

where,

$$\sigma_x = \sqrt{\frac{\Sigma(|x_i| - \overline{|x|})^2}{n}}$$

$$\sigma_y = \sqrt{\frac{\Sigma(|y_i| - \overline{|y|})^2}{n}}$$

where,

$|x_i|$ = x-shift value computed by differencing the x reference DEM coordinate from the x coordinate obtained from the extracted DEM

$|y_i|$ = y-shift value computed by differencing the y reference DEM coordinate from the y coordinate obtained from the extracted DEM

n = total number of observations

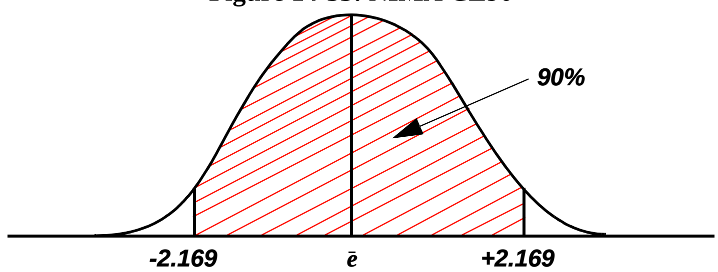
σ_x = standard deviation values associated with x-shift

σ_y = standard deviation values associated with y-shift

NOTE: A value of 1.073 represents a 90% confidence interval derived from statistical tables.

Once NIMA CE90 is computed, the value is translated to ground units by multiplying the value by the cell size of the reference DEM. For example, if the NIMA CE90 is ± 2.169 meters, it is safe to state that at a 90% confidence level, the planimetric accuracy of each pixel on the extracted DEM is within a radius of 2.169 meters based on the assumption that the errors are normally distributed, as illustrated in the following figure, Figure 14-33.

Figure 14-33: NIMA CE90

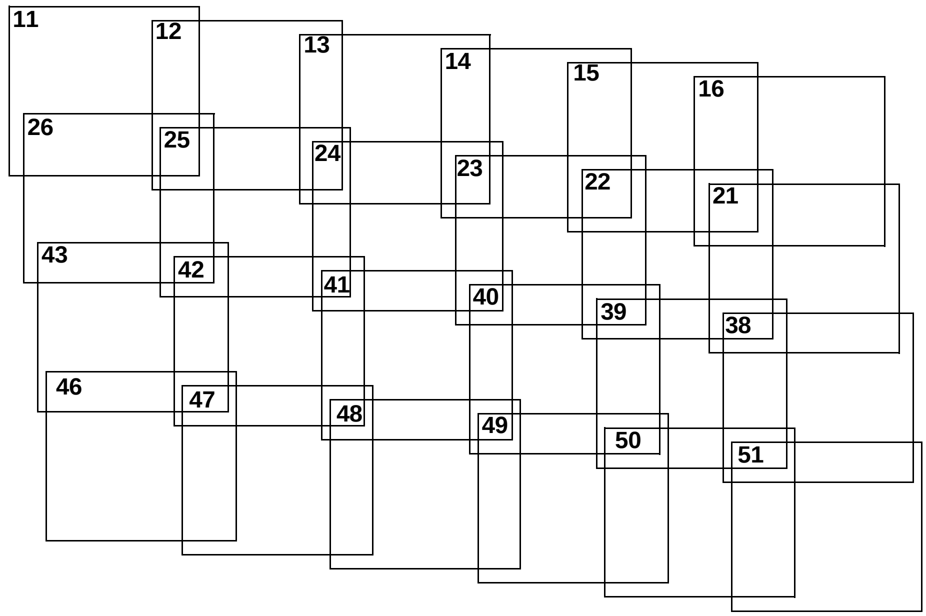


Case Study

In the following case study, a four by six block file is used in DTM generation with OrthoBASE Pro. The numbers follow a naming convention used for photos in a data directory after removing a prefix (e.g., forssa11.img).

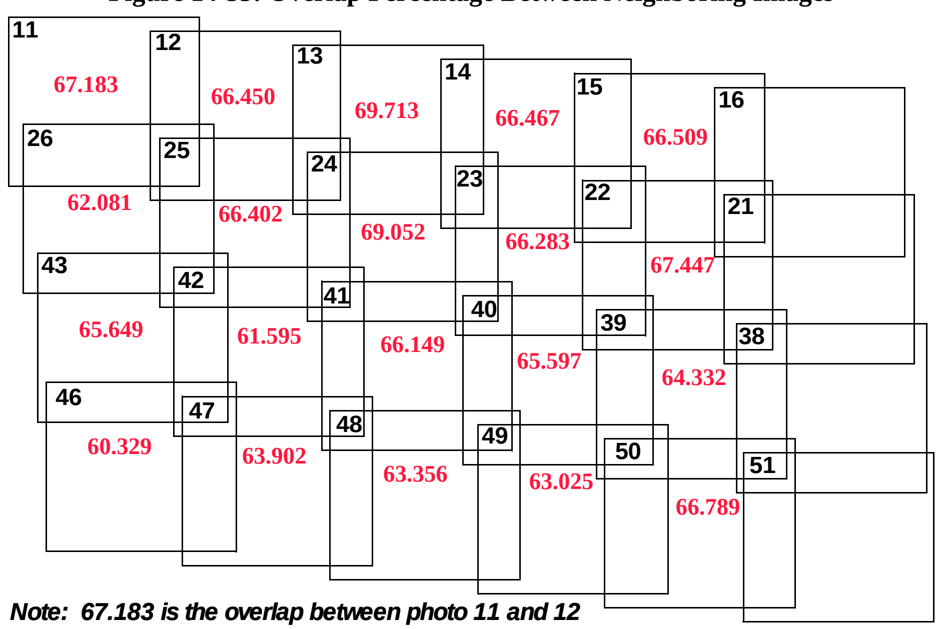
Given the block arrangement depicted in Figure 14-34, 108 image pairs are available using the default overlap threshold of 50%. Computation of DTMs for each of the 108 image pairs would be time-consuming and unnecessary since many of the image pairs overlap, thus creating redundant data.

Figure 14-34: Arrangement of Photos in a Block File



The block arrangement depicted in Figure 14-34, yields an overlap between immediate, contiguous neighbors as depicted in Figure 14-35.

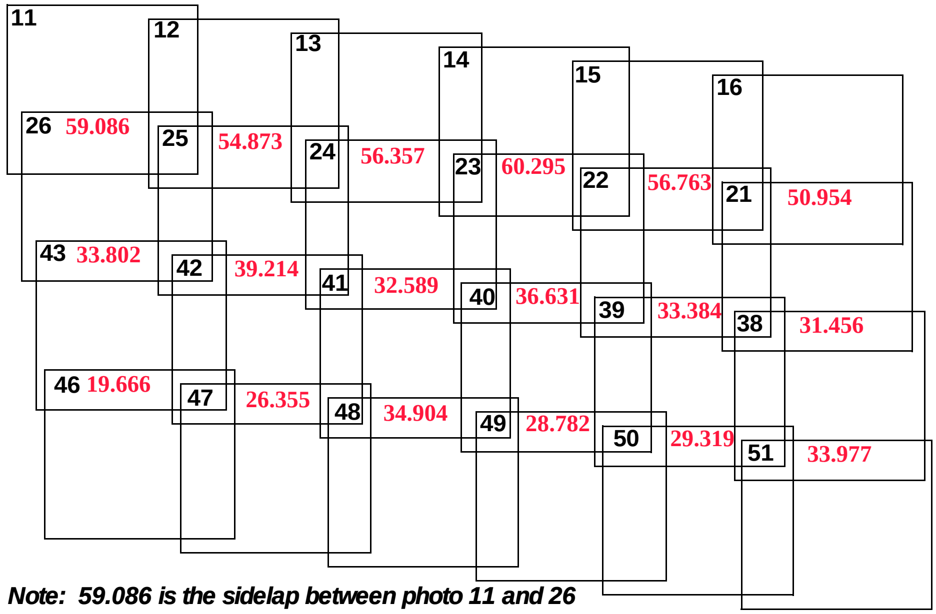
Figure 14-35: Overlap Percentage Between Neighboring Images



Note: 67.183 is the overlap between photo 11 and 12

The arrangement depicted in Figure 14-34, yields a sidelap between immediate, contiguous neighbors as depicted in Figure 14-36.

Figure 14-36: Sidelap Percentage Between Neighboring Images



Note: 59.086 is the sidelap between photo 11 and 26

Based on the preceding scenario, the following steps are suggested as guidelines for DTM extraction.

Set Overlap Threshold

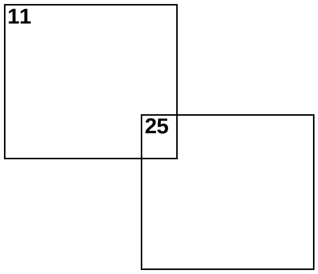
To select a reasonable threshold percentage, use the information presented in Figure 14-35 and Figure 14-36. Since you may want to include all the image pairs created from the overlap and sidelap areas, a guiding value is the minimum value from the two figures. In this case, from Figure 14-34 and Figure 14-35, the minimum overlap is 60.329% and the minimum sidelap is 19.666%. Hence, using 15% as a threshold value ensures that all image pairs are included.

After this stage, you are left with 92 active image pairs.

Select Inactive Pairs

Image pairs that are created from noncontiguous overlaps can be excluded without overly affecting the DTM generation process. These image pairs cover areas that are already covered by the overlap of adjacent photographs. For example, the area covered by the image pair created from photos 11 and 25 is already covered by image pairs created from photos 11 and 26 and photos 12 and 25. So, this and similar other image pairs may be safely excluded from the DTM extraction process.

Figure 14-37: Noncontiguous Image Pair



After this stage, you are left with 38 active image pairs.

Choose Output Option

Your choice of output depends on your application. If you are interested in generating a DTM for the entire area, choosing a single DTM mosaic saves processing time. Otherwise, individual DEMs are the appropriate option.

Set Trim/Correlation Reduction Percentage

In traditional frame camera photography, it is customary to have an overlap of 60% and a sidelap ranging from 20% to 40%. A 60% overlap between neighboring photos creates 20% overlap between the next adjacent photo. The sidelap between image pairs is the same as the sidelap of the photos that are used in triangulation.

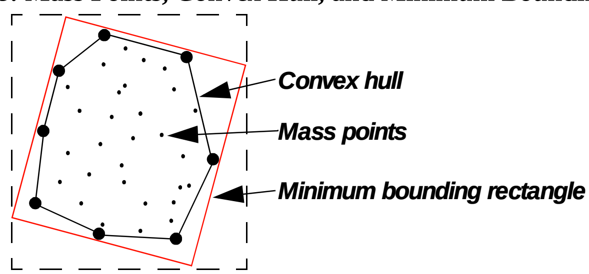
Trim Percentage

To decide on the trim percentage, consider the two cases:

- when a single DEM mosaic is chosen
- when individual DEMs are chosen

In the DTM creation process, mass points are collected and a convex hull is built around them. Then, a minimum bounding rectangle is built for the convex hull. This rectangle defines the boundary of the DTM to be generated. The trim is performed on this rectangle. See Figure 14-38 for a diagram of a convex hull.

Figure 14-38: Mass Points, Convex Hull, and Minimum Bounding Rectangle



For a single DTM mosaic, trimming does not affect the mosaicking in between image pairs, so a default of 5% can be used for removing possible erroneous points at the borders of the DTM.

One of the issues with the generation of individual files is if they can be mosaicked without a gap using ERDAS IMAGINE's Mosaic tool. Therefore, the limiting factors in this case are the overlap and sidelap between neighboring image pairs.

The sidelap between neighboring image pairs is the same as the sidelap between neighboring photos. The overlap between neighboring image pairs is the sum of the overlap of the photos that create the image pair minus 100 percent. The minimum of the two governs what should be used as the trimming percentage.

The following table, Table 14-4, may be used as a guideline for selecting the maximum trim percentage in order to have a minimum of 5% overlap and sidelap between the generated individual DTMs.

Table 14-4: Maximum Trim/Correlation Percentage for 5% Overlap Between Adjacent DTMs

Overlap/Sidelap	50	40	30	20	10	5
90	45	35	25	15	5	0
80	45	35	25	15	5	0
70	35	35	25	15	5	0
60	15	15	15	15	5	0
52.5	0	0	0	0	0	0

Correlation Reduction Percentage

Correlation reduction is performed prior to mass point extraction. Therefore, the effect it has on the single DTM mosaic option and individual DTMs is similar. As in the case of trimming for an individual output file, the concern here is not to reduce the correlation area as to have gaps in the final DTM mosaic. Table 14-4 above, which is presented as a guideline for maximum trimming percentage, can also be used as a guide for correlation reduction percentage computation.

Additive Effects

Be aware that the effects of specifying a trim factor and a correlation reduction percentage are additive. For example, you might have a block of files that have a minimum sidelap of 20% and an overlap of 60%. According to Table 14-4, in order to have a minimum of 5% overlap between adjacent DTMs, the sum of the trim and correlation reduction percentage should not exceed 15%.

Chapter 15

Orthorectification

Introduction

The orthorectification (ortho resampling) process removes the geometric distortion inherent in imagery caused by camera/sensor orientation, topographic relief displacement, and systematic errors associated with imagery.

Orthorectified images are planimetrically true images that represent ground objects in their true, real-world X and Y positions. For these reasons, orthorectified imagery has become accepted as the ideal reference image backdrop necessary for the creation and maintenance of vector data contained within a GIS.

During triangulation, the effects of camera/sensor orientation have been considered. In using frame cameras, systematic errors caused by lens distortion have been considered by specifying the radial lens distortion parameters associated with the camera. If using nonmetric cameras for image collection, AP models can be used to account for residual systematic error associated with the lens and camera instability.

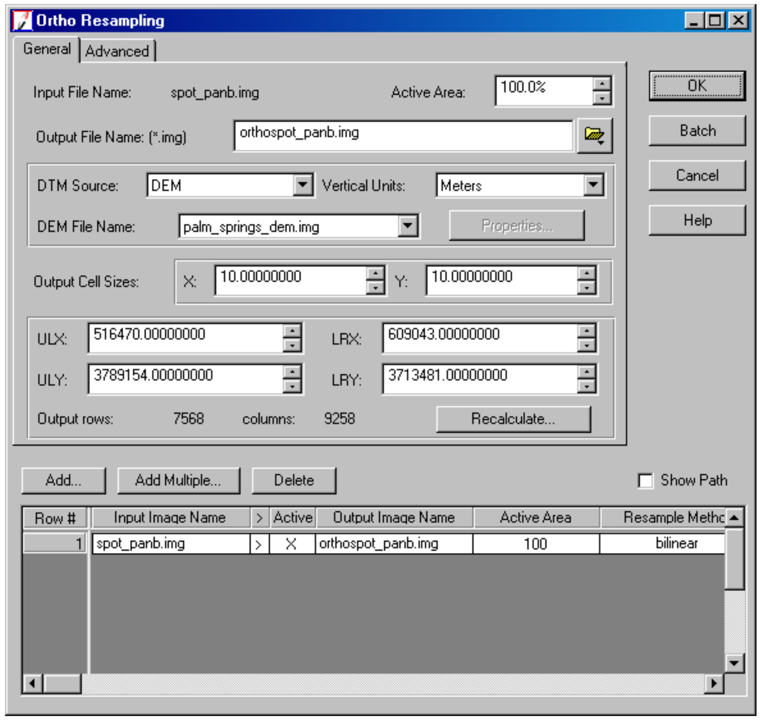
By defining a DEM or constant elevation value (ideal for use in areas containing minimal relief variation), the effects of topographic relief displacement can be considered.

Ortho Resampling

The final step in the OrthoBASE workflow is orthorectification.

By selecting the Orthorectification icon  on the LPS toolbar or the **Ortho Rectification | Resampling** option within the **Process** menu, the Ortho Resampling dialog opens, which is depicted in Figure 15-1.

Figure 15-1: Ortho Resampling Dialog—General Tab



General Tab

The following parameters can be defined and used for the orthorectification of each image in a block:

- By defining an **Active Area Used** percentage, the extent of the input image can be reduced while used to determine the default upper left and lower right output corners.
- A **DTM Source** can be specified and used for each image during orthorectification. It is highly recommended that the area coverage in the input DTM corresponds to the coverage provided by the images in a block. The DTM source could be one of the following: **DEM, TIN, 3D Shape, ASCII,** or a **Constant** value.
- Ground resolution can be defined in the X and Y direction (**Output Cell Sizes**).
- Upper left and lower right corners of the output orthoimage can be set using **ULX, ULY, LRX,** and **LRY.**

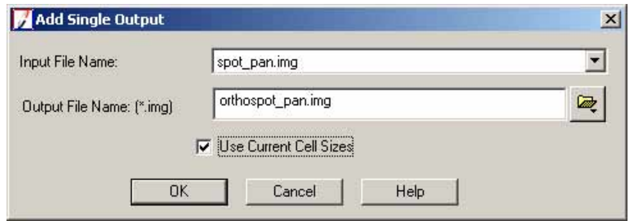
Adding Images

By default, the image in the LPS Project Manager that is currently the reference image, indicated by the **>** symbol in the CellArray, is loaded into the CellArray first. You then have the option of adding a single or multiple images to be processed.

To ensure that images added to the CellArray have the same parameters as the image currently displayed, set all parameters in each tab first, then add images.

In the case of adding a single image, you click the **Add** button and are prompted by the dialog depicted in Figure 15-2.

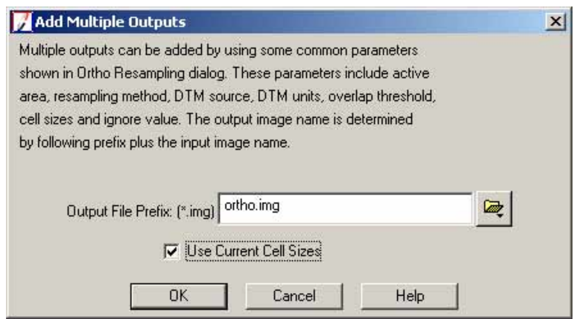
Figure 15-2: Add Single Output to Ortho Resampling CellArray



Here, you use a combination of the dropdown list and the File Selector to give your output orthoimage a name. Using the **Use Current Cell Sizes** option ensures that this orthoimage has the same cell size as the one already listed in the CellArray.

If you need to add multiple images, choose the **Add Multiple** button. You are prompted by the dialog shown in Figure 15-3.

Figure 15-3: Add Multiple Outputs to Ortho Resampling CellArray

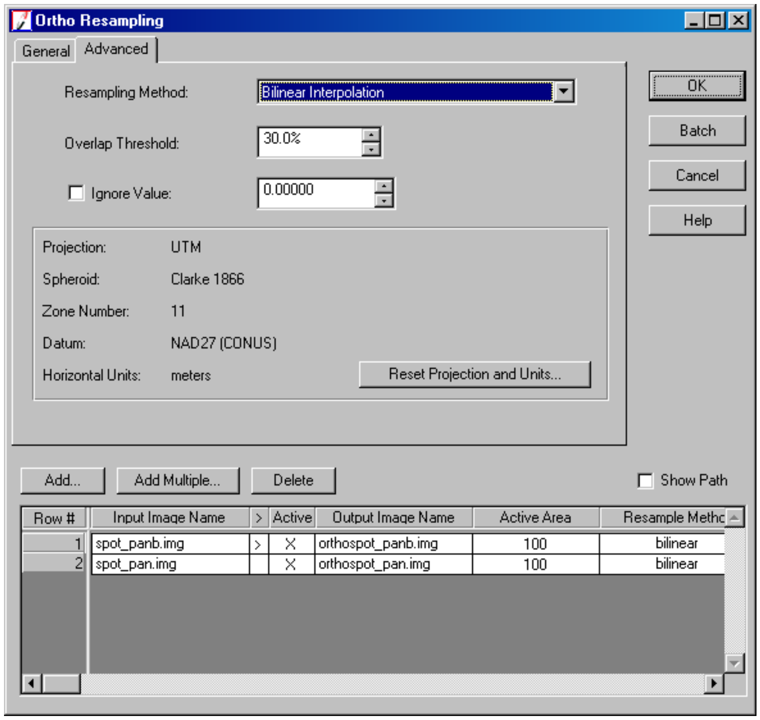


You can use the CellArray to rapidly scan the settings applied to each of your output orthoimages. To change any singular image's parameters, click in the **>** column to select the image, then make changes in the appropriate tab of the Ortho Resampling dialog.

Advanced Tab

The **Advanced** tab, shown in Figure 15-4, has options for **Resampling Method, Ignore Value, Overlap Threshold,** and **Projection.**

Figure 15-4: Ortho Resampling Dialog—Advanced Tab



- **Resampling Method** includes **Nearest Neighbor, Bilinear Interpolation,** and **Cubic Convolution.**

It is recommended that the DEM **Resampling Method** *within the OrthoBASE preferences be specified as* **Bilinear Interpolation.**

- **Overlap Threshold.** Any image that has less than the threshold percentage of overlap with the DTM is not orthorectified. Images with greater than the threshold percentage of overlap with the DTM result in orthorectified output for the intersection (overlap) areas only. By default, the value is **30%,** but the threshold can be set as low as 0.5%.

  For example, if the threshold value is 10% and the percentage of the overlap is 45% between the DTM and the image, the resulting orthoimage is the intersecting 45% of the original scene. If the percentage of the overlap is 5%, then orthorectification is not performed.

- **Ignore Value.** It is highly recommended to use this option if the imagery contains areas with 0 values in the background.

- **Projection** and **Units** of the output orthoimage can be reset.

Once the settings are accurate, you can proceed to the resampling process by clicking **OK,** or by clicking **Batch,** which can process the images at a later time.

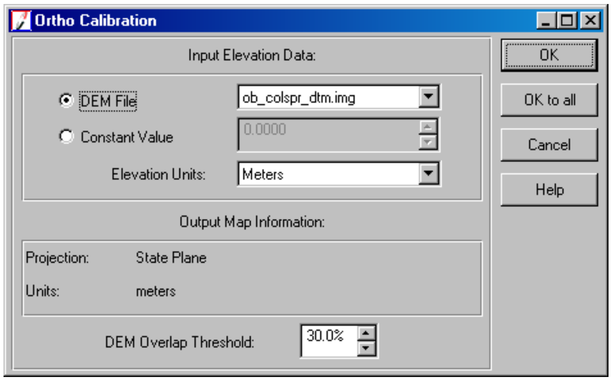
For more information on Batch, see Appendix B “Batch Processing”.

Ortho Calibration

Ortho calibration is the process of automatically creating an orthorectified mathematical model that associates the original image with the Earth’s surface. This process does not create a new image. Within an ortho-calibrated image, each pixel has orthorectified X and Y coordinates. This approach is ideal for retaining the original image quality while preserving disk space.

By selecting the **Ortho Rectification | Calibration** option within the **Process** menu, the Ortho Calibration dialog opens, as shown in Figure 15-5.

Figure 15-5: Ortho Calibration Dialog



Using ortho calibration techniques is preferred if the available disk space is low, and/or the spectral quality of the original image is poor. Otherwise, the **Resampling** option of orthorectification is recommended.

Section V

Appendices

Appendix A

Leica Photogrammetry Suite Utilities

Introduction

OrthoBASE and OrthoBASE Pro form the core of the Leica Photogrammetry Suite. This appendix briefly describes some of the other applications accessible using LPS.

Mosaic

The Mosaic Tool allows for:

- Image-based automated seam generation
- Seam smoothing
- Automatic area exclusion
- Orthorectification and mosaicking in one step
- Non north-up photographs
- Color balancing
- Map sheet composition
- Batch processing

For more information about the Mosaic Tool, read the on-line help. You can also read the tour guide for the Mosaic Tool, which is located in the ERDAS IMAGINE Tour Guides *and accessible via the on-line help in /help/hardcopy/TourGuide.pdf.*

PRO600

"PRO600 is a software package for collecting, manipulating and presenting data measured from stereo photographs. It is based on the CAD package MicroStation from Bentley Systems, Inc." (LH Systems 2002).

For more information about PRO600, read the PRO600 user's guide.

Stereo Analyst

You may also collect features using Stereo Analyst. Two different types of Stereo Analyst are accessible from LPS.

ERDAS Stereo Analyst

The first is Stereo Analyst®, which is a product of ERDAS IMAGINE. This version of Stereo Analyst allows you to perform 3D feature collection and stereo editing. Also, you can use photo texture to texture 3D shape files and the Texel Mapper to map 2D textures onto Stereo Analyst-derived 3D models.

For more information about Stereo Analyst in ERDAS IMAGINE, read the Stereo Analyst User's Guide, which is available via the on-line help in /help/hardcopy/StereoAnalyst.pdf.

Stereo Analyst for ArcGIS

The second method of feature collection using Stereo Analyst is Stereo Analyst® for ArcGIS. You must have ArcGIS and Stereo Analyst for ArcGIS installed and licensed to run Stereo Analyst from that application. This version of Stereo Analyst lets you access image and feature data, collect and edit features, update feature data, collect points for the creation of elevation models, and seamlessly work in conjunction with ArcMap.

For more information about Stereo Analyst for ArcGIS, read Using Stereo Analyst for ArcGIS.

Terrain Editor

To edit DTMs, you may use Terrain Editor. The Terrain Editor performs the following tasks:

- Provides point, area, and geomorphic editing tools
- Supports the display and editing of mass point, break lines, contours, and mesh TINs
- Edits raster DEMs, TINs, and 3D shapefiles
- Displays contours, mass points, break lines, and TINs

For more information about Terrain Editor functionality and theory, read the Leica Photogrammetry Suite Terrain Editor User's Guide.

Appendix B

Batch Processing

Introduction

When you are working with a block file that contains many images you wish to use in the generation of DTMs, you can use the ERDAS IMAGINE Batch Wizard to automate the process. The following sections give you steps to follow in using Batch to create multiple DTMs.

The DTM Extraction dialog in OrthoBASE Pro has a **Batch** button. This button is used to place the command in the Batch queue instead of actually performing the operation. Off-line processing allows unattended operation, enabling you to log off if you wish.

On Microsoft Windows NT, you must have administrator privilege to schedule Batch jobs at a later time.

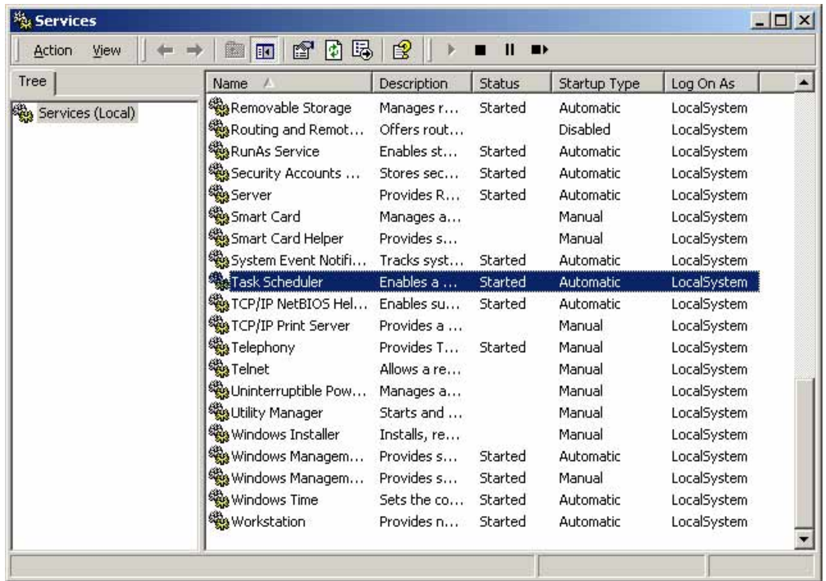
Set Up/Start the Scheduler

Before you can use the Batch Wizard to schedule jobs to run later, you must set up and run the Scheduler. This requirement means that the account that starts the Scheduler must remain logged-in for the scheduled job to run.

You must log in as an administrator or as a person with administrator privileges to set up and start the Scheduler. Once started, the Scheduler is available for use by any other person with administrative privileges.

1. From the **Start** menu, select **Settings | Control Panel.**
2. On the Control panel, select the **Administrative Tools** option.
3. Select **Services.**

   The Services dialog opens.



4. Scroll through the Services window and select **Task Scheduler.**

5. In the Services dialog, click the Properties icon.

6. Select **Automatic** as the **Startup Type.**

7. Click the **Log On** tab.

8. Click the **This Account** radio button. Enter your account name and password, confirm your password, click **Apply,** and then click **OK.**

9. If necessary, click the Start Services icon.

NOTE: The ability to run a Batch process at a later time is built using the Windows Scheduler, which is part of the `at` *command. Refer to the Windows help to learn more about the use of the* `at` *command.*

NOTE: (Microsoft Windows NT) If you are submitting jobs for processing later and you are using mapped network drives, then you need to ensure that these maps are in place when the Batch job runs. Typically, a mapped drive is only available to the current user unless the Reconnect at Logon option was checked on the Map Network Drive dialog when the drive was mapped.

If this option is not checked, then when the Batch process is run by the Scheduler, it is not able to find the drive. This is one of the reasons to make sure that the Scheduler service runs using your account name. This ensures that remembered network drivemaps are reestablished when the Batch process runs.

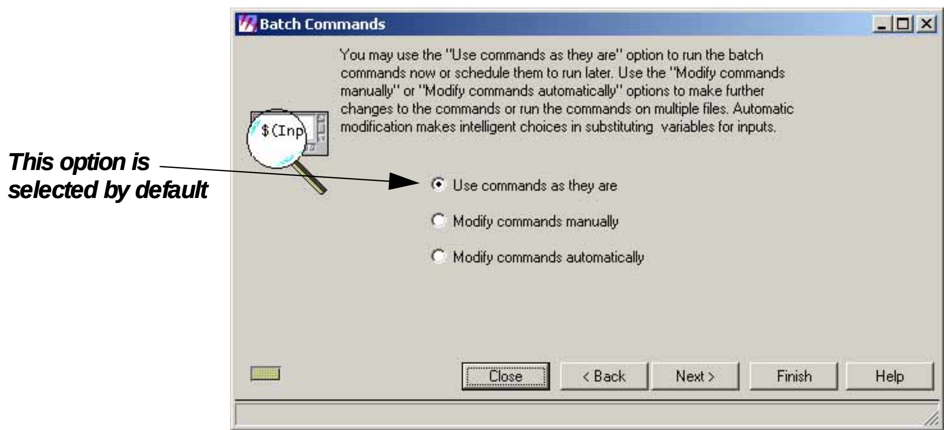
Execute Multiple Files/Single Command

You can use the Batch Wizard to set up multiple jobs with varying parameters. For example, you learned in Chapter 7 “Automated DTM Extraction Tour Guide” that OrthoBASE Pro has many options that you can apply to your images. You may want to add a series of jobs to the batch list, each with different parameters.

NOTE: The following steps assume you have completed setup through the actual application of automatic DTM extraction.

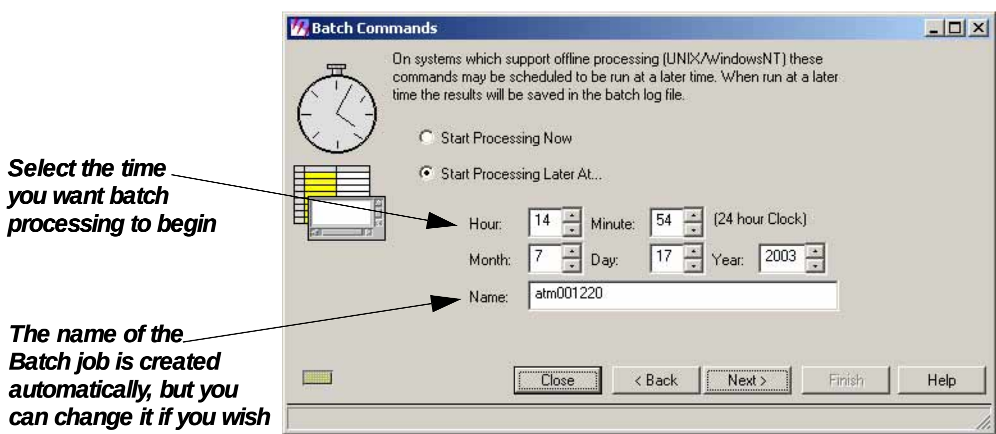
1. Once you have set all of your parameters in the DTM Extraction and DTM Extraction Properties dialogs, click the **Batch** button.

   The Batch Wizard opens.



1. Notice that the **Use commands as they are** option is selected by default.

2. Click the **Next** button to advance to the next frame.

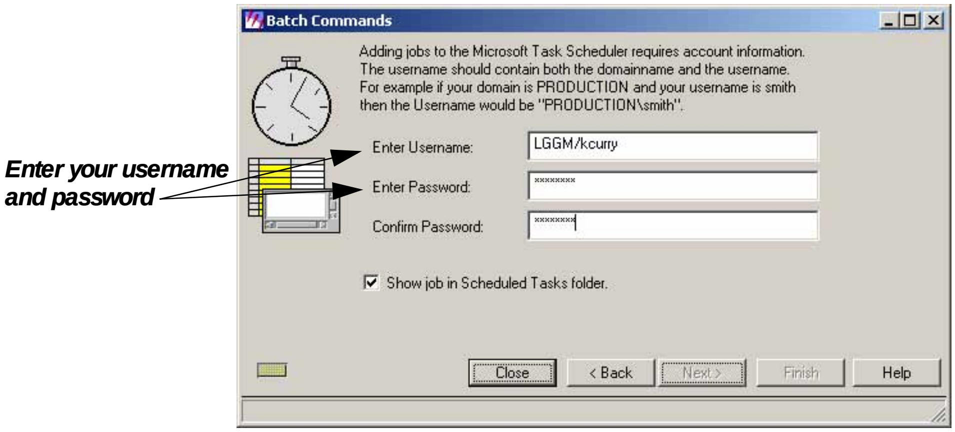


3. Click the **Start Processing Later At** radio button.

4. Type or use the increment nudgers to the right of the fields to set the time at which you want the process to run.

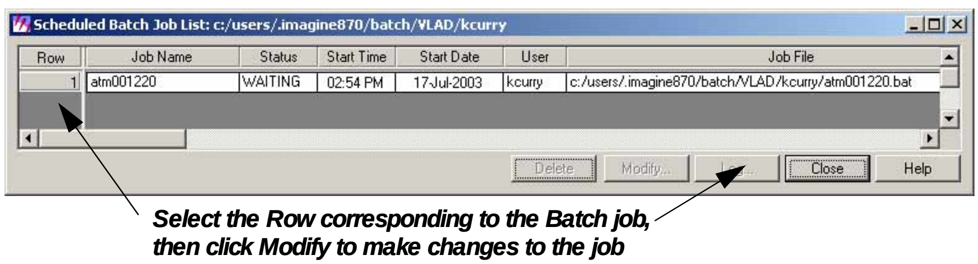
Notice that the **Name** field shows the prefix **atm,** followed by a number string. The **atm** prefix designates the Batch process as one from OrthoBASE Pro.

5. Click the **Next** button to advance to the next frame.



6. Click in the **Enter Username** field and type your user name.
7. Click in the **Enter Password** field and type your password.
8. Type your password again in the **Confirm Password** field.
9. Confirm that the **Show job in Scheduled Tasks folder** checkbox is checked.
10. Click **Finish** to schedule the batch processing.

    The Scheduled Batch Job List dialog opens.



If you decide that you want to alter parameters of the job (e.g., time) listed in the **Job Name** field, you can do so by selecting the job, then clicking the **Modify** button at the bottom of the Scheduled Batch Job List dialog. Similarly, if you want to delete a job, select the job, then click the **Delete** button at the bottom of the dialog.

If you wish to add other jobs to the scheduler, set the parameters you desire, then follow the same series of steps. The job is added to the Scheduled Batch Job List dialog.

Other Batch Applications

After you have processed a number of DTMs using Batch, you should check them for accuracy. Once you have verified the accuracy and performed any necessary post-processing, you can set up another Batch job to use those DTMs as input into the orthoresampling process.

Like the DTM Extraction dialog, the Ortho Resampling dialog also has a **Batch** button. Simply set the parameters for each output orthoimage, and add the process to the Batch job.

For more information about the Ortho Resampling dialog, see Chapter 15 "Orthorectification".

You cannot schedule an orthoresampling Batch job that uses a DTM generated by OrthoBASE Pro to immediately follow the DTM extraction Batch job. Files must be pre-existing to be used as elevation control in the Ortho Resampling dialog. Instead, use Batch to process the DTM extractions, then set-up a separate Batch job to process the orthoimages.

Appendix C

DTM Editing in ERDAS IMAGINE & Stereo Analyst

Introduction

This appendix tells you how you can edit the DTMs produced by OrthoBASE Pro in other applications such as ERDAS IMAGINE and Stereo Analyst.

ERDAS IMAGINE DEM Editing

In this example, you can learn to edit a DEM using ERDAS IMAGINE. The most common method of DEM editing in ERDAS IMAGINE is to use the Interpolate utility.

Edit a DEM with a Polygon AOI

ERDAS IMAGINE must be running with a Viewer open.

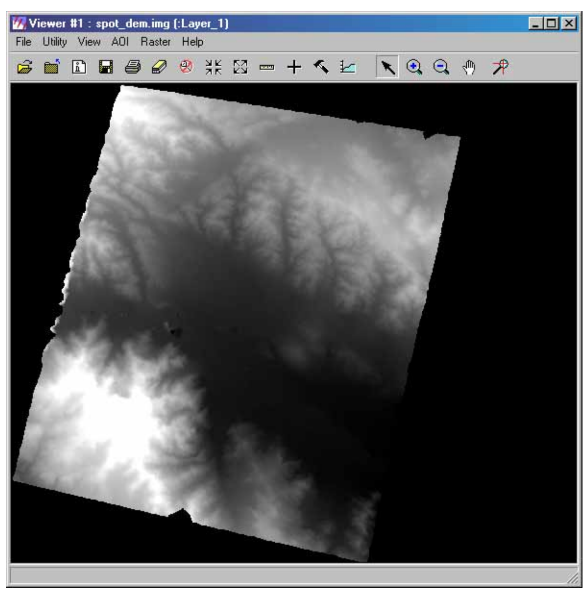
Open the DEM and Raster Tools

1. Click the Open icon  and navigate to the location where the DEM is stored.

   NOTE: Make a copy of the DEM for safekeeping and comparison if you wish.

2. Select the file, and click **OK** in the File Selector.

   The DEM displays in the Viewer.

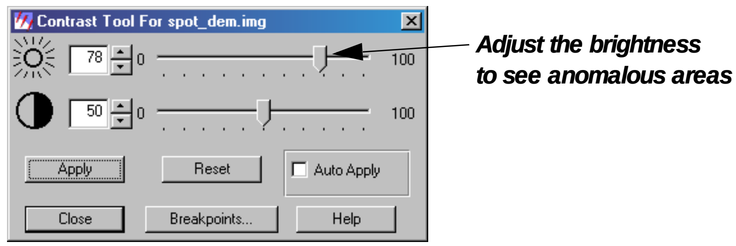


Adjust the Contrast

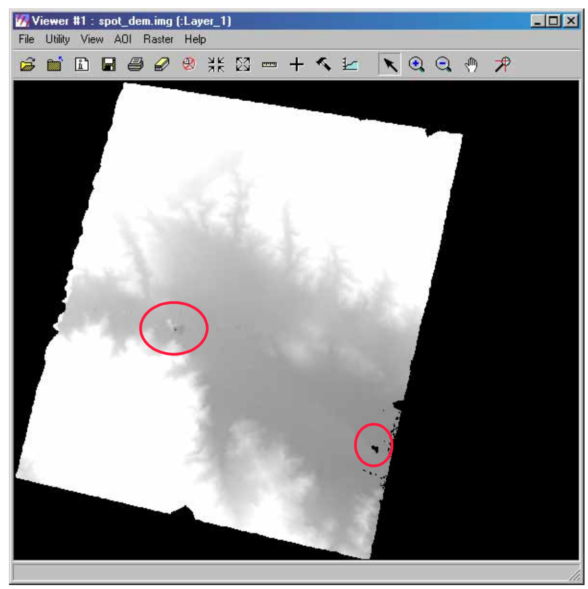
You can use the contrast adjustment tools to better see anomalies in the view.

1. From the **Raster** menu, select **Contrast | Brightness/Contrast.**

   The Contrast Tool opens.



2. Increase the brightness significantly so that anomalies in the data become more apparent.

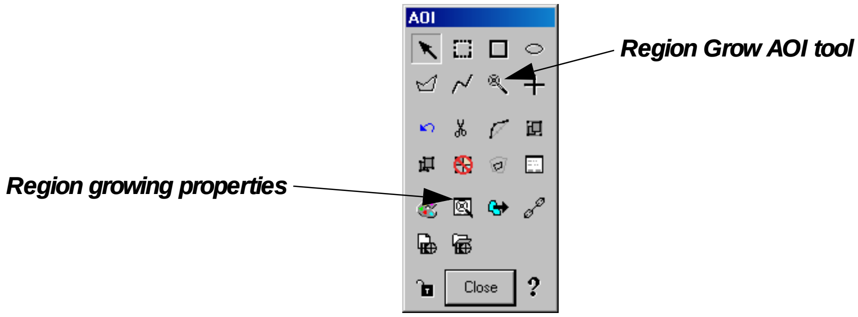


3. When you are satisfied with the brightness and contrast, click **Close** in the Contrast Tool.

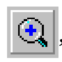
Open AOI Tools

1. Open the raster tools by selecting **Tools** from the **AOI** menu.

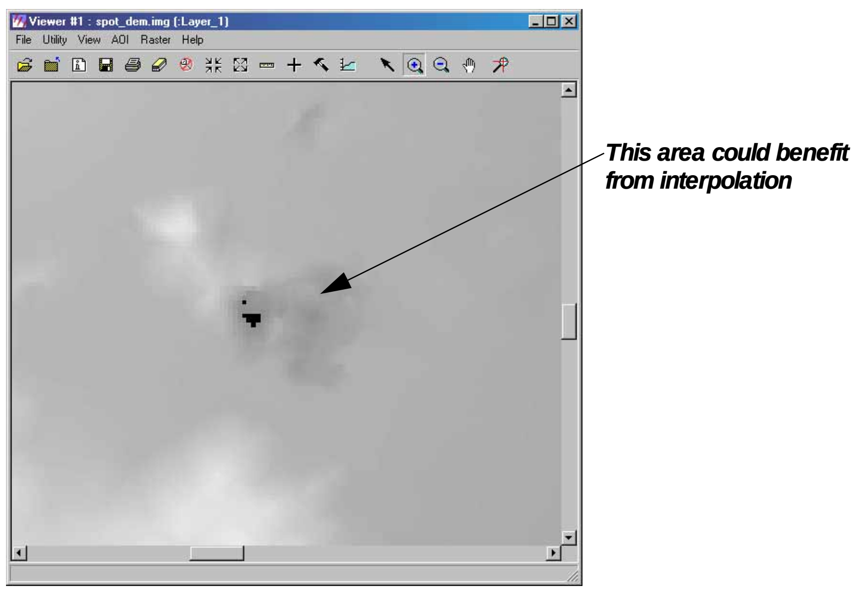
   The AOI tool palette displays.



Typically, areas suitable for editing are those which have obvious anomalies in the data (i.e, a sudden dip or rise in elevation). These areas are easy to distinguish in a DEM because of the gray scale color used to differentiate height elevations.

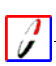
2. Click the Zoom In icon , and zoom into the area of the DEM that you wish to edit.

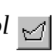
   The following area contains anomalous data.



Set Seed Tool Properties

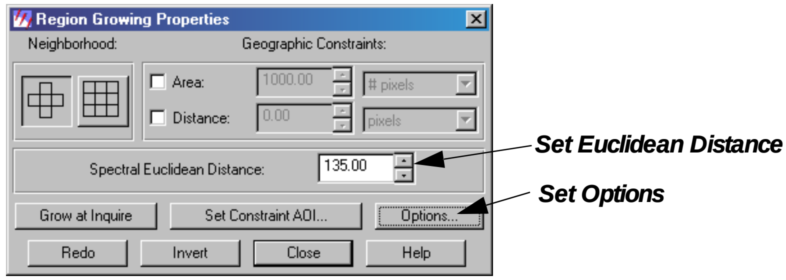
An easy way to delineate an area for interpolation is to use the Seed tool. With it, the need for tedious digitizing is eliminated: you simply set the properties.



You can also digitize a polygon yourself using the Polygon AOI tool  .

1. In the AOI tool palette, click the Region Growing Properties icon  .

   The Region Growing Properties dialog opens.

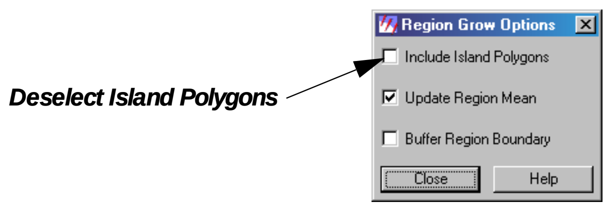


2. In the Region Growing Properties dialog, click to deselect both **Area** and **Distance** from the **Geographic Constraints** section.

3. In the **Spectral Euclidean Distance** field, type a large number, such as **135.**

4. Click the **Options** button.

   The Region Grow Options dialog opens.



5. Click to deselect the **Include Island Polygons** checkbox.

6. Click **Close** in the Region Grow Options dialog.

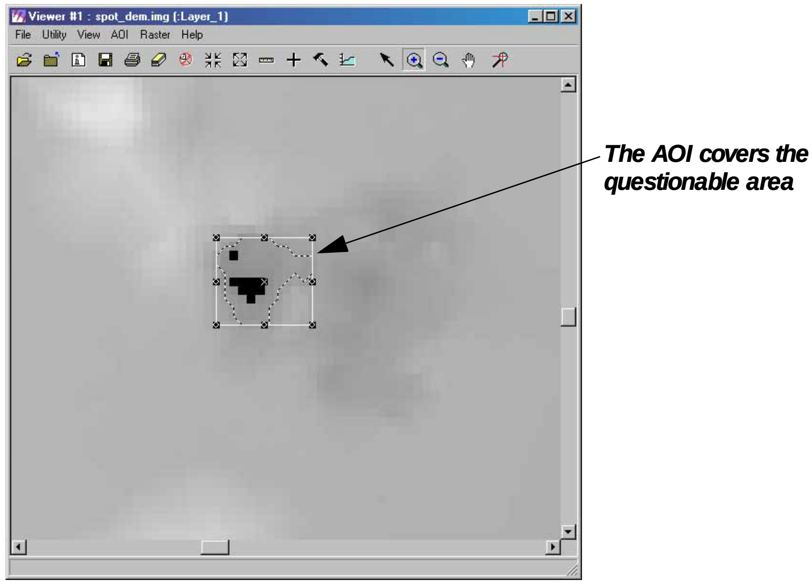
Create the AOI

1. Click the Region Grow AOI icon  in the AOI tool palette.

2. Click inside the area you want to delineate.

3. If necessary, increase the **Spectral Euclidean Distance** value, and click **Redo.**

   Your resulting AOI might look like the following:

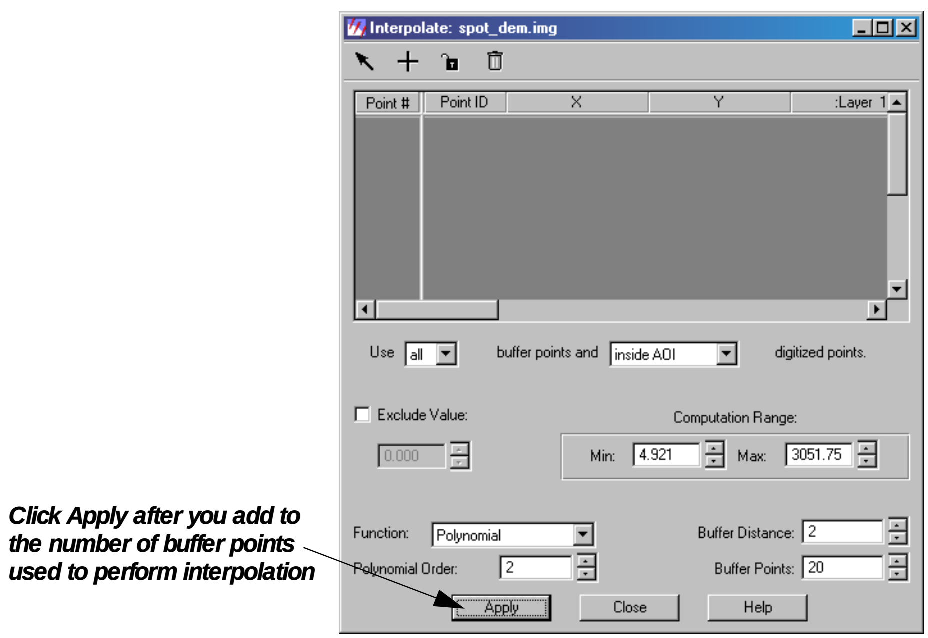


4. Click the Select icon  .

5. Click on one of the corners of the AOI and adjust the size until it covers all of the area plus some accurate pixels.

Interpolate

1. From the **Raster** menu, select **Interpolate**.



2. Increase the number of **Buffer Points** to at least double the default value of **10.**

3. Click **Apply** in the Interpolate dialog to accept the default values.

   In the Interpolate dialog, you can choose to use buffer points that determine the values with which the AOI is filled. Remember that if you save your changes, the image is permanently modified. You can, however, choose **Undo** from the **Raster** menu to reverse the application of an individual raster editing operation.

   By default, the interpolation proceeds by using all **Buffer Points.** These are points located just outside the AOI you digitize, and are selected based on a distance, which is measured in pixels. By default, the **Buffer Distance** is set at **2.** The number of points automatically selected by the software is controlled by the setting in the **Buffer Points** field, which is set to **10** by default. The interpolation **Function** is set to **Polynomial** by default. This function uses a 2D polynomial to perform surface approximation of the area inside the AOI.

4. In the Attention dialog, make your selection as to whether or not to remove the data stretch lookup table. By default, the option is **Yes.**

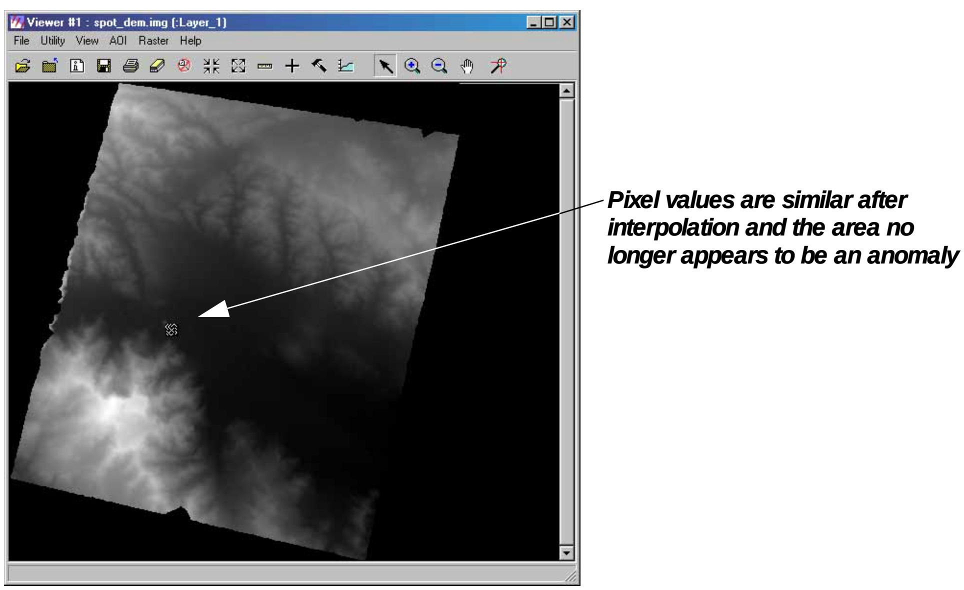
5. In the Warning dialog, make your selection as to whether or not to recalculate image statistics. The default option is **OK.**

View the Result

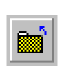
The DEM is updated accordingly. Notice that the area defined by the AOI now looks more like the surrounding pixels.

1. Right-click in the Viewer and select **Fit Image to Window.**

   The area of interpolation is identified.



2. Click **Close** in the Interpolation dialog.

3. Click the Close Top Layer icon  to close the AOI.

   Notice that the area blends in with the surroundings.

Locate Another Anomalous Area

1. Use the brightness and contrast tools to locate another anomalous area.

For instructions, see "Adjust the Contrast".

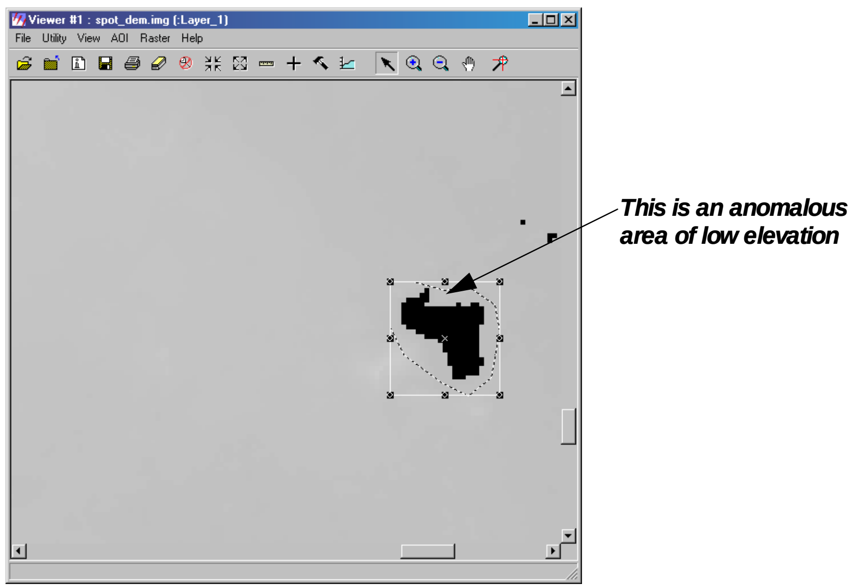
2. Click the Zoom in icon and click on the area to view it clearly.

Edit a DEM with Points

You can also edit portions of your DEM using the point AOI tool.

Create AOI and Set Interpolation Options

1. Click the Polygon AOI icon , and digitize the extent of the AOI you wish to interpolate in the Viewer.



2. From the **Raster** menu, select **Interpolate.**

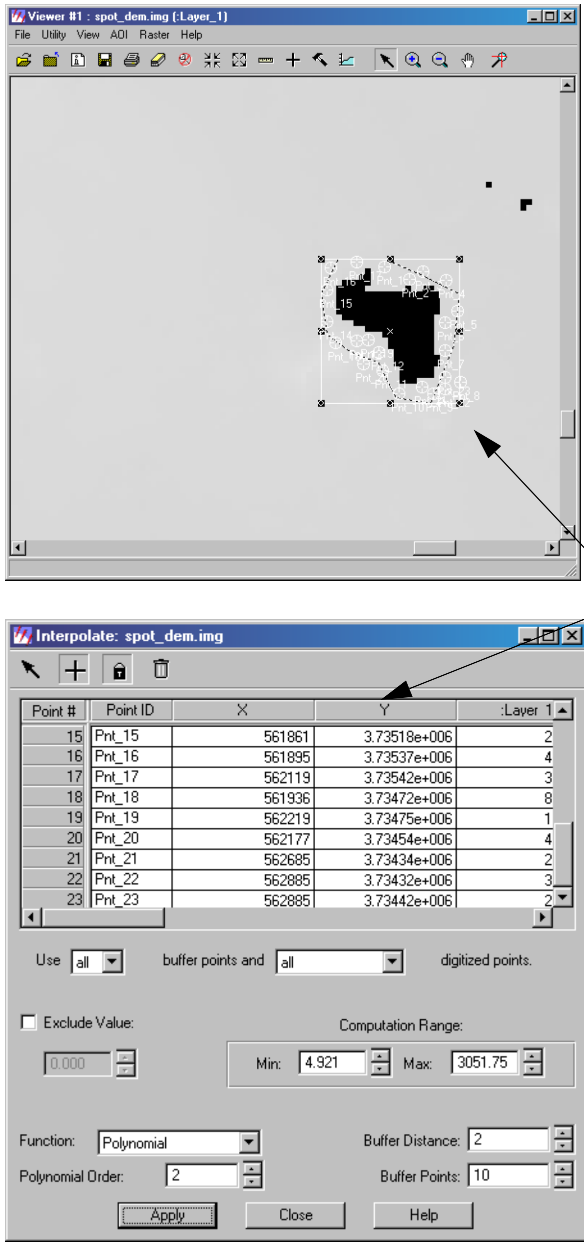
   The Interpolate dialog opens. Next, you select points inside and outside the bounding box of the AOI with which to interpolate the pixel values within the AOI.

3. In the Interpolate dialog, click the Digitize Point icon .

4. In the Interpolate dialog, click the Lock icon ; it changes to the locked position.

5. Click to digitize points both within the AOI bounding box.

   When you have finished, your Viewer and associated Interpolate dialog should look similar to the following:



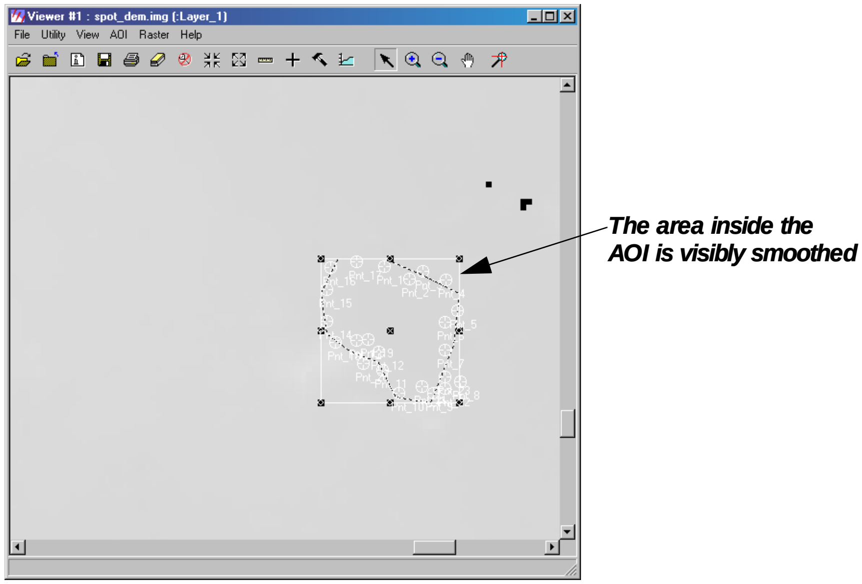
Each point you digitize in the Viewer is reflected in the CellArray of the Interpolate dialog

6. Confirm that the Interpolate dialog is set to Use **all** buffer points and **all** digitized points.

7. Click **Apply.**

View the Result

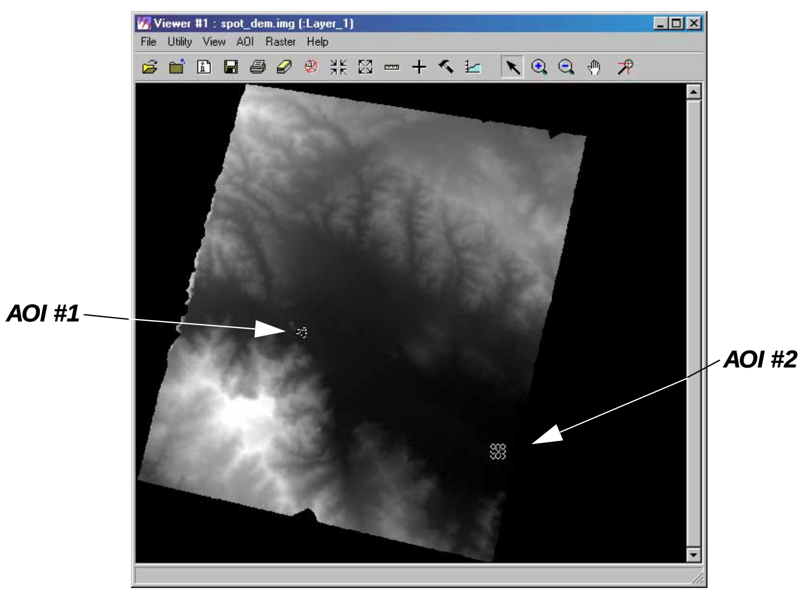
The pixel values within the AOI are recalculated and display as follows:



As you can see, the pixels within the AOI more closely relate to their neighbors after digitized points are used to recalculate the anomalous values.

1. Click **Close** in the Interpolate dialog and the AOI tools dialog.
2. Right-click to select **Fit Image to Window.**
3. If necessary, adjust the data scaling by selecting **Raster | Data Scaling.**

   Areas of interpolation are evident in the Viewer.



4. Click the Close Top Layer icon to remove the AOIs from the Viewer.

This only removes the display of the AOIs. The interpolated areas are not affected.

5. If you wish to save the AOIs to an *.aoi file, do so.
6. Select **File | Close** from the Viewer menu bar.
7. If you wish to save the DEM you just post-processed, do so.
8. Select **Session | Exit IMAGINE** if you wish.

Stereo Analyst 3D Shape File Editing

You can also edit DTMs using Stereo Analyst. In the case of this application, you can take DTMs in the 3D Shape file format, import them into Stereo Analyst, and then use the 3D editing capabilities to manually adjust the Z (elevation) value of individual points in the DTM.

Edit a 3D Shape File

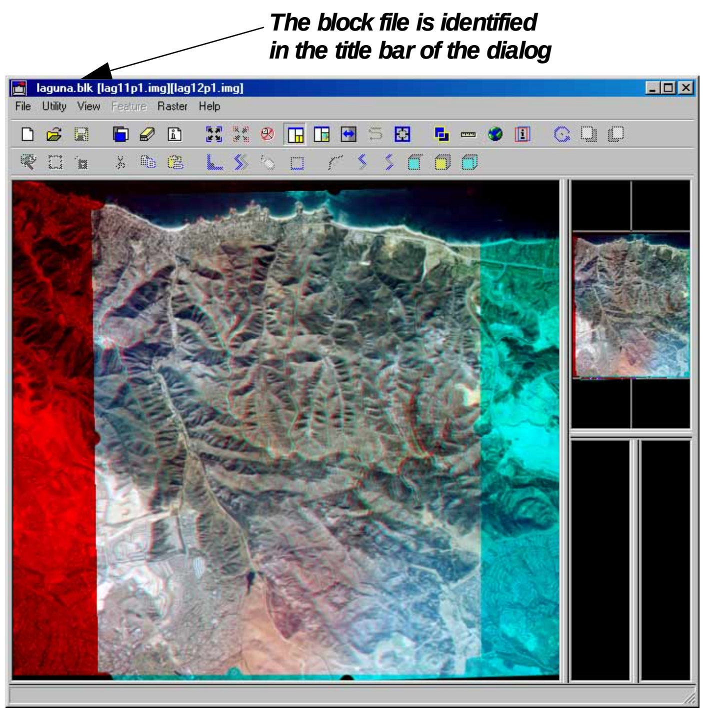
NOTE: Before you begin, you may want to make a copy of the 3D Shape file for safekeeping.

Stereo Analyst must be running.

Open the Block File

1. Click the Open icon  and navigate to the location where the block file associated with the 3D Shape is stored.
2. Select the block file, and click **OK** in the File Selector.

   The block file displays in the Stereo Analyst workspace.

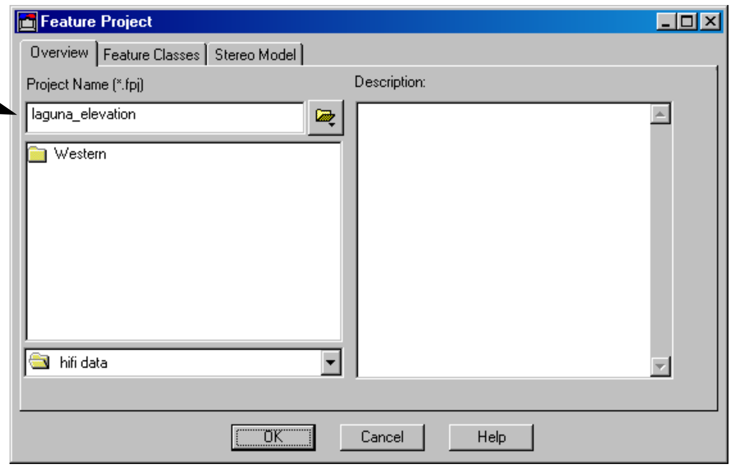


Create the Feature Project

1. From the Stereo Analyst menu bar, select **File | New | Stereo Analyst Feature Project.**

   The Feature Project dialog displays. Here, you create the project into which your 3D Shape file is imported.

Name the feature project into which you are going to import the 3D Shape file



2. In the **Overview** tab of the Feature Project dialog, type the name of the feature project in the **Project Name** field.

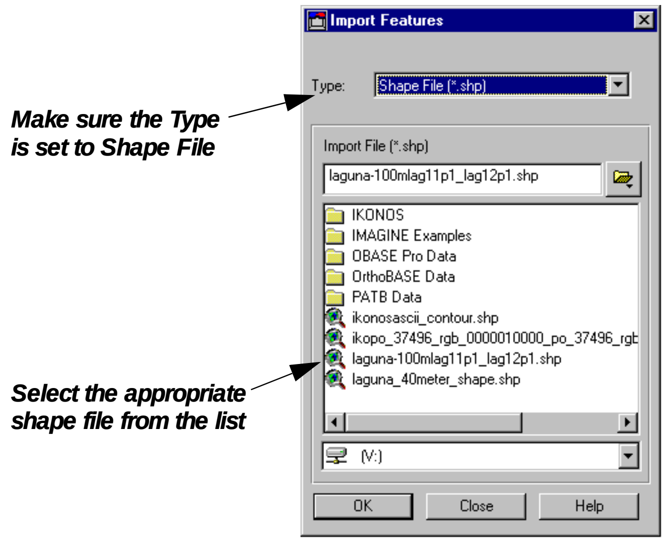
3. Click **OK** in the Feature Project dialog.

   An empty feature palette opens in the Stereo Analyst workspace.

Import 3D Shape File into the Feature Project

1. From the **Feature** menu, select **Import Features.**

   The Import Features dialog opens.



2. Select **Shape File** in the **Type** dropdown list.

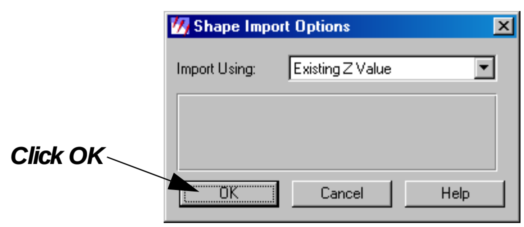
3. Click the Open icon and navigate to the location where the 3D Shape file is stored.

4. Select the file to import.

5. Click **OK** in the File Selector.

6. Click **OK** in the Import Features dialog.

   The Shape Import Options dialog opens.



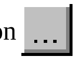
7. Confirm that the **Import Using** field shows **Existing Z Value.**

   This option applies the Z value from the project file to the imported class. Alternately, you could also use a DEM generated by OrthoBASE Pro in the Shape Import Options dialog. Simply choose the Z Value from DEM option.

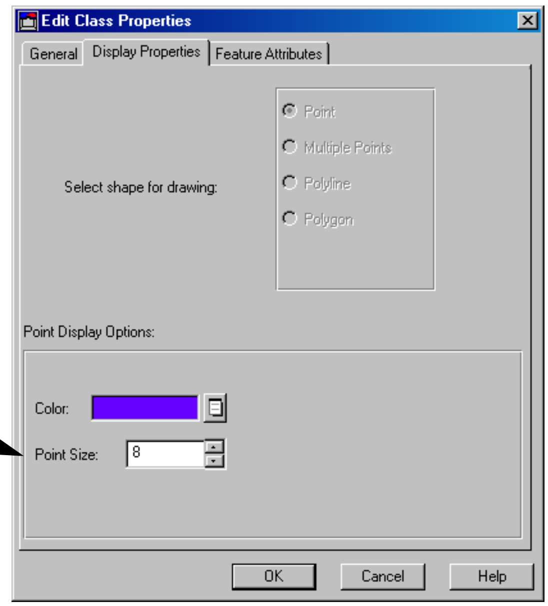
8. Click **OK** in the Shape Import Options dialog.

   The Edit Class Properties dialog opens.

Edit the Appearance of the Mass Points

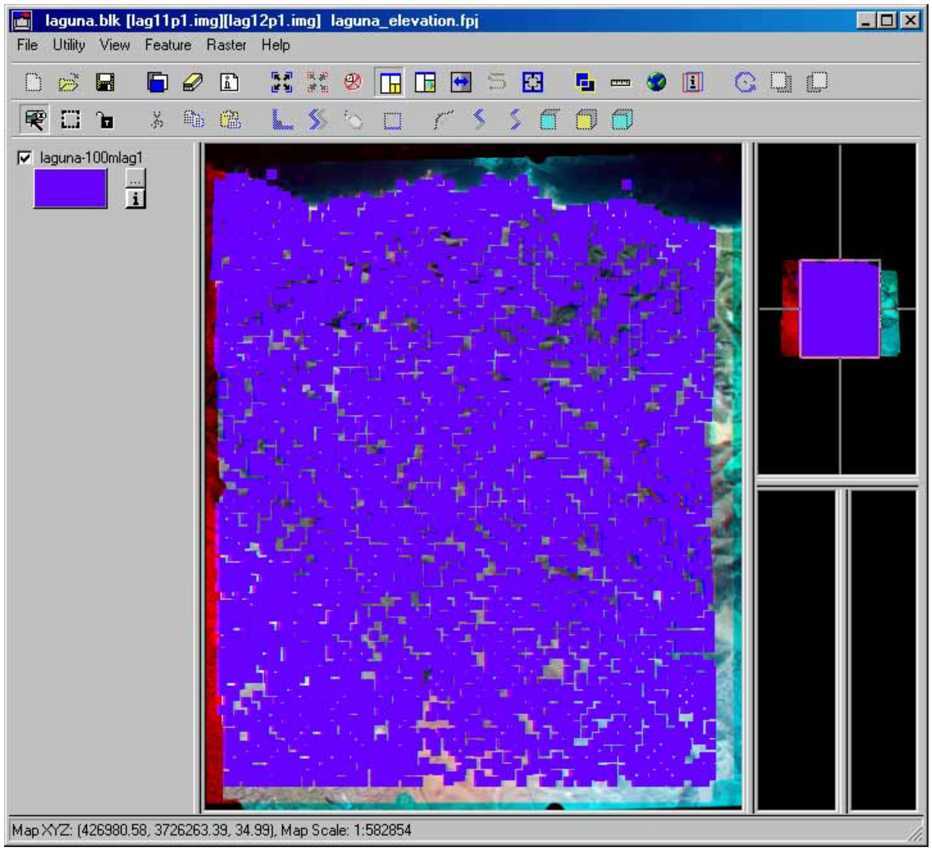
To see the mass points when you zoom into smaller areas of the stereopair, you may need to adjust their display properties. You can do so by clicking the Feature Class Properties icon  associated with the Shape file you just imported.

Changing the Point Size makes the mass points easier to see in the Stereo Analyst Workspace



9. In the **Display Properties** tab of the Edit Class Properties dialog, change the **Point Size** to **8.**
10. Click **OK** in the Edit Class Properties dialog.
11. Click **OK** to save the feature class if you wish.

    The Shape file displays in the Stereo Analyst Workspace.



Edit the Mass Points

The 3D Shape file is imported as a large mass point file, with the mass points evenly distributed throughout the image. You can edit each mass point individually, or you can use the box select tool to edit many points at once. This section tells you how to edit each point individually.

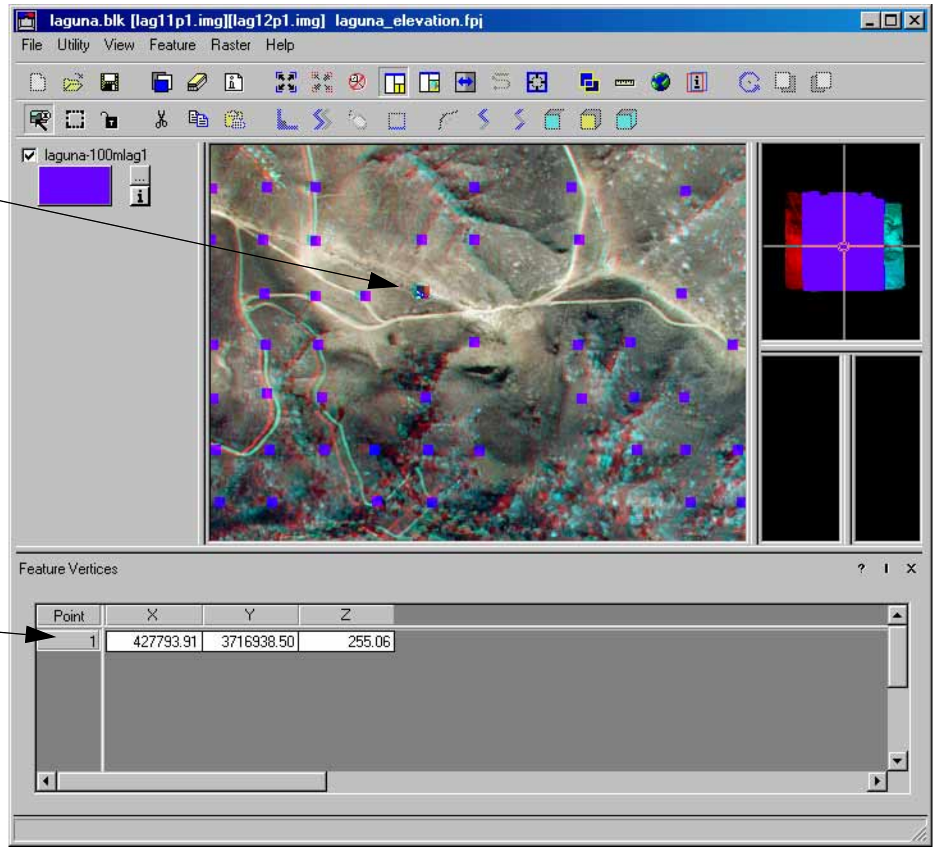
1. Zoom into a small section of the image in the Main View.

If you need to review the Stereo Analyst navigation capability, select **Help | Navigation Help** *from the Stereo Analyst workspace menu bar.*

2. Make sure that the Selector icon  is active, then click to select a mass point.

   The point becomes highlighted in the Main View.

3. From the **Feature** menu, choose **Show XYZ Vertices.**



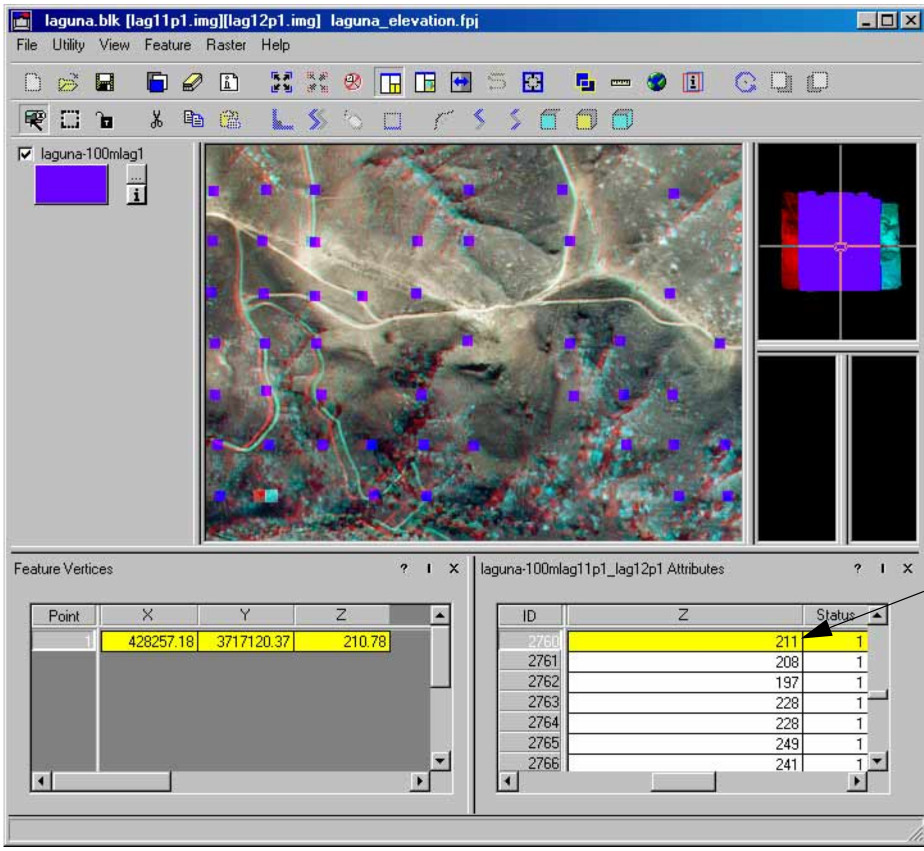
4. Use the mouse rolling wheel or combination of the Control and C keys to adjust the height of the mass point in the view, or type the **Z** value in the CellArray.

Check the Remainder of the Feature Vertices

1. Click the Feature Attributes icon  .

   The Feature Attributes table for the feature class you imported opens.

2. In the Feature Attributes table, click an **ID** number to see a different mass point highlighted in the Main View.



The updated value displays here here—export the attributes to create a new 3D Shape file

Save the File and Export the Project

At this point, you can save your edits to the feature Z values and export the changes to a new 3D Shape file. This way, you can use the updated file in other applications.

1. Select **File | Save Top Layer.**
2. Click **Yes** to save feature classes.
3. Select **File | Exit Workspace.**
4. Select **Session | Exit IMAGINE** if you wish.

Appendix D

References

Introduction

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Appendix E

Photogrammetric Glossary

Abbreviations and Acronyms

A

AT. aerial triangulation.

B

b/h. eye-base to height ratio.

C

CCD. charge-coupled device.

CTS. conventional terrestrial system.

D

DEM. digital elevation model.

DPW. digital photogrammetric workstation.

DSM. digital stereo model.

DTM. digital terrain model.

E

ECI. earth centered inertial.

ECF. earth centered fixed.

ECR. earth centered rotating.

G

GCP. ground control point.

GIS. geographic information system.

GPS. global positioning system.

I

IERS. International Earth Rotation Service.

INS. inertial navigation system.

ISPRS. International Society of Photogrammetry and Remote Sensing.

L

Lat/Lon. latitude/longitude.

LRX. lower right X.

LRY. lower right Y.

R

RMSE. root mean square error.

S

SCBA. self-calibrating bundle adjustment.

SI. image scale.

T

TIN. triangulated irregular network.

U

ULX. upper left X.

ULY. upper left Y.

File Types

***.aoi.** An Area of Interest file. Used to hold a point, line, or polygon that is selected as a training sample or as the image area to be used in an operation.

***.blk.** A block file. A block file can contain only one image. A block file that contains two or more images with approximately 60% overlap can be viewed in stereo in other applications such as Stereo Analyst.

***.cam.** An ASCII file with a fixed structure. Provides camera information such as focal length and principal point.

***.dat.** An ASCII file. In OrthoBASE, exterior orientation parameters are often contained in a .dat file. Typically, this data comes from the airborne GPS or INS used during image capture.

See also Airborne GPS
Inertial Navigation System

***.img.** An ERDAS IMAGINE image file. Data in the .img format are tiled data, which can be set to any size. A file containing raster image data. An .img file contains data such as sensor information, layer information, statistics, projection, pyramid layers, attribute data, etc.

***.shp.** An ESRI shape file. Shape files are in vector format, and can store attribute data.

***.txt.** An ASCII text file. Frequently used as an input GCP reference source for 2- and 3-dimensional control point and check point coordinates.

Symbols

κ. (Kappa) In a rotation system, Kappa is positive rotation about the Z-axis.

ω. (Omega) In a rotation system, Omega is positive rotation about the X-axis.

ϕ. (Phi) In a rotation system, Phi is positive or negative rotation about the Y-axis.

See also Phi (-), Omega, Kappa
Phi(+), Omega, Kappa

Terms

A

Additional parameter (AP). In block triangulation, additional parameters characterize systematic error within the block of images and observations, such as lens distortion. In OrthoBASE, four AP models can be used in the triangulation process, including: Bauer’s Simple Model, Jacobsen’s Simple Model, Ebner’s Orthogonal Model, and Brown’s Physical Model.

Adjusted stereopair. An adjusted stereopair is a pair of images displayed in a workspace that has a map projection associated and exterior orientation used to facilitate stereo viewing. A set of two remotely-sensed images that overlap, providing a 3D view of the terrain in the overlap area.

Aerial photographs. Photographs taken from positions above the Earth captured by aircraft. Photographs are used for planimetric mapping projects.

Aerial stereopair. Two photos with a common overlap area.

Aerial triangulation (AT). The process of establishing a mathematical relationship between images, the camera or sensor model, and the ground. The information derived is necessary for orthorectification, DEM generation, and stereopair creation. This term is used when processing frame camera, digital camera, videography, and nonmetric camera imagery.

See also Triangulation

Affine transformation. A 2D plane-to-plane transformation that uses six parameters (coefficients) to account for rotation, translation, scale, and nonorthogonality in between the planes. Defines the relationship between two coordinate systems such as a pixel and image space coordinate system.

Air base. The distance between two image exposure stations.

See also Base-height ratio

Airborne GPS. GPS stands for Global Positioning System. Airborne GPS is a technique used to provide initial approximations of exterior orientation, which defines the position and orientation associated with an image as they existed during image capture. GPS provides the X, Y, and Z coordinates of the exposure station.

See also Global positioning system

Airborne INS. INS stands for Inertial Navigation System. Airborne INS data is available for each image, and defines the position and orientation associated with an image as they existed during image capture.

See also Inertial navigation system

Algorithm. "A procedure for solving a mathematical problem (as of finding the greatest common divisor) in a finite number of steps that frequently involves repetition of an operation" (Merriam-Webster n.d.).

American standard code for information interchange (ASCII). A "basis of character sets. . .to convey some control codes, space, numbers, most basic punctuation, and unaccented letters a-z and A-Z" (Howe 1995).

Analog photogrammetry. In analog photogrammetry, optical or mechanical instruments, such as analog plotters, used to reconstruct 3D geometry from two overlapping photographs.

Analytical photogrammetry. The computer replaces some expensive optical and mechanical components by substituting analog measurement and calculation with mathematical computation.

a priori. Already or previously known.

Area of interest (AOI). A point, line, or polygon that is selected as a training sample or as the image area to be used in an operation. AOIs can be stored in separate .aoi files.

Auto-correlation. A technique used to identify and measure the image positions appearing within the overlap area of two adjacent images in a block file.

Automated interior orientation. Technique based on template matching used to identify and measure fiducial mark positions.

Automated tie point collection. OrthoBASE's ability to automatically measure tie points across multiple images.

See also Tie point

Average flying height. The distance between the camera position at the time of exposure and the average ground elevation. Average flying height can be determined by multiplying the focal length by the image scale.

See also Focal length
Image scale

B

Base-height ratio (b/h). The ratio between the average flying height of the camera and the distance between where the two overlapping images were captured.

Block. A term used to describe and characterize all of the information associated with a photogrammetric mapping project, such as: projection, spheroid, and datum; imagery; camera or sensor model information; GCPs; and geometric relationship between imagery and the ground. A block file is a binary file.

Block footprint. A graphical representation of the extent of images in a block file. The images are not presented as raster images. Rather, they are displayed as vector outlines that depict the amount of overlap between images in the block file.

Block of photographs. Formed by the combined exposures of a flight. For example, a traditional frame camera block might consist of a number of parallel strips with a sidelap of 20-30%, and an overlap of 60%.

Block triangulation. The process of establishing a mathematical relationship between images, the camera or sensor model, and the ground. The information derived is necessary for orthorectification, DEM generation, and stereopair creation.

Blunder. A blunder is a gross error resulting from incorrect data entry, incorrect measurement of ground points on imagery, and faulty identification of GCPs and tie points. In OrthoBASE, a blunder model identifies and removes errors from the photogrammetric network of observations.

Break line. A breakline is a polyline in the terrain model that models a change in terrain. Hard breaklines are used to model V-shaped changes in the terrain; soft breaklines are used to model U-shaped changes in the terrain.

Bundle. The unit of photogrammetric triangulation after each point measured in an image is connected with the perspective center by a straight light ray. There is one bundle of light rays for each image.

Bundle attitude. Defined by a spatial rotation matrix consisting of three angles: Omega (ω), Phi (φ), and Kappa (κ).

See also Omega
Phi
Kappa

Bundle block adjustment. A mathematical technique (triangulation) that determines the position and orientation of each image as they existed at the time of image capture, determines the ground coordinates measured on overlap areas of multiple images, and minimizes the error associated with the imagery, image measurements, and GCPs. This is essentially a simultaneous triangulation performed on all observations.

Bundle location. Defined by the perspective center, expressed in units of the specified map projection.

C

Calibration certificate/report. In aerial photography, the manufacturer of the camera specifies the interior orientation in the form of a certificate or report. Information includes focal length, principal point offset, radial lens distortion data, and fiducial mark coordinates.

Camera coordinate system. A camera coordinate system has its origin defined at the perspective center. Its x-axis and y-axis are parallel to the x-axis and y-axis in the regular image plane coordinate system. The z-axis is the optical axis; therefore the z value of an image point in the camera coordinate system is usually equal to -f (focal length). Camera coordinates are used to describe the positions inside the camera and usually use units in millimeters or microns. This coordinate system is referenced as camera coordinates (x, y, and z).

See also Perspective center

Cartesian coordinate system. "A coordinate system consisting of intersecting straight lines called axes, in which the lines intersect at a common origin. Usually it is a 2-dimensional surface in which a "x,y" coordinate defines each point location on the surface. The "x" coordinate refers to the horizontal distance and the "y" to vertical distance. Coordinates can be either positive or negative, depending on their relative position from the origin. In a 3-dimensional space, the system can also include a "z" coordinate, representing height or depth. The relative measurement of distance, direction and area are constant throughout the surface of the system" (Natural Resources Canada 2001a).

CellArray. In ERDAS IMAGINE, the CellArray is used to maintain and edit data in a tabular format.

Cell size. The area that one pixel represents, measured in map units. For example, one cell in the image may represent an area 30′ × 30′ on the ground. Sometimes called pixel size.

Charge-coupled device (CCD). A device in a digital camera that contains an array of cells which record the intensity associated with a ground feature or object.

Check point. An additional ground point used to independently verify the degree of accuracy of a triangulation.

Check point analysis. The act of using check points to independently verify the degree of accuracy of a triangulation.

Coefficient limit. The limit for the cross-correlation coefficient. This value ranges from .10 to .99. A larger limit results in fewer points accepted and less error. A smaller limit results in more correlated points, but also possibly more errors.

Collinearity. A nonlinear mathematical model that photogrammetric triangulation is based upon. Collinearity equations describe the relationship among image coordinates, ground coordinates, and orientation parameters.

Collinearity condition. The condition that specifies that the exposure station, ground point, and its corresponding image point location must all lie along a straight line.

Control point. A point with known coordinates in a coordinate system, expressed in the units (e.g., meters, feet, pixels, film units) of the specified coordinate system.

Control point extension. The process of converting tie points to control points. This technique requires the manual measurement of ground points on photos of overlapping areas. The ground coordinates associated with the GCPs are then determined using photogrammetric techniques.

Convergence value. A threshold to determine the level and extent of processing during the iterative aerial triangulation procedure.

Coordinate system. “A system, based on mathematical rules, used to measure horizontal and vertical distance on a surface, in order to identify the location of points by means of unique sets of numerical or angular values” (Natural Resources Canada 2001b).

Coplanarity condition. The coplanarity condition is used to calculate relative orientation. It uses an iterative least squares adjustment to estimate five parameters (B_y, B_z, Omega, Phi, and Kappa). The parameters explain the difference in position and rotation between two images making up the stereopair.

Correlation. Regions of separate images are matched for the purposes of tie point or mass point collection.

Correlation area. In OrthoBASE, the default correlation area is the total overlap area reduced by the shrink percentage.

Correlation limit. Defines the correlation coefficient threshold used to determine whether or not two points are to be considered as possible matches.

Correlation size. Defines the size of the window to be used to compute the correlation between image points of common ground points appearing on multiple images.

Correlation threshold. A value used in image matching to determine whether to accept or discard match points. The threshold is an absolute value threshold ranging from 0.100 to 1.000.

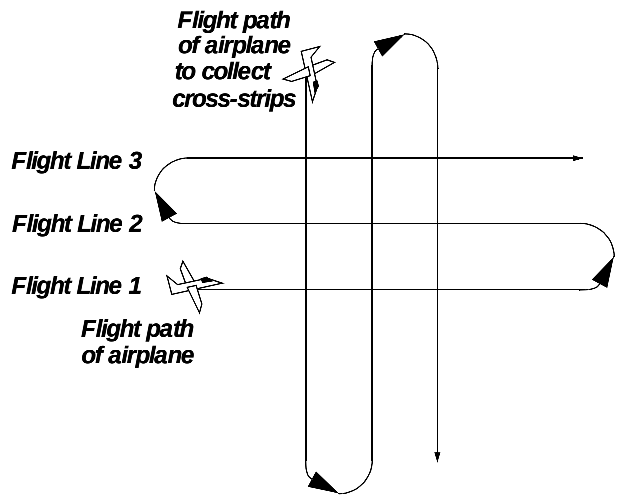
Correlation windows. Windows that consist of a local neighborhood of pixels. One example is square neighborhoods (e.g., 3 × 3, 5 × 5, 7 × 7 pixels).

Corresponding GCPs. The GCPs that are located in the same geographic location as the selected GCPs, but are selected in different images.

Cross-correlation. A calculation that computes the correlation coefficient of the gray values between the template window and the search window.

See also Search windows
Template window

Cross-strips. Strips of image data that run perpendicular to strips collected along the flight line.



D

Data strip. A strip contained within aerial photographs. The strip commonly provides information such as the type of camera, the number of the camera, and the approximate focal length of the camera.

Datum. "A datum is a system of reference for specifying the horizontal and vertical spatial positions of points" (Wolf and Dewitt 2000).

See also Reference plane

Degrees of freedom. Also known as redundancy. In the bundle block adjustment process, the number of unknowns is subtracted from the number of knowns. The resulting number is the redundancy, or degree of freedom in a solution.

Digital correlation. The process of automatically matching an image of a ground point to its corresponding (conjugate) image on another photo using digital correlation techniques. Also referred to as image matching and stereocorrelation.

Digital elevation model (DEM). Continuous raster layers in which data file values represent elevation. DEMs are available from the USGS at 1:24,000 and 1:250,000 scale, and can be produced with terrain analysis programs such as IMAGINE Ortho*MAX*™ and OrthoBASE.

Digital image matching. Also known as auto-correlation. The process of matching features common to two or more images for the purpose of generating a 3D representation of the Earth.

Digital orthoimage/orthophoto. An aerial photo or satellite scene that has been transformed by the orthogonal projection, yielding a map that is free of most significant geometric distortions.

Digital photogrammetric workstation (DPW). These include OrthoBASE, PCI OrthoEngine, SOCET SET, Intergraph, Zeiss, and others.

See also Digital photogrammetry

Digital photogrammetry. Photogrammetry as applied to digital images that are stored and processed on a computer. Digital images can be scanned from photographs or can be directly captured by digital cameras.

Digital stereo model (DSM). Stereo models that use imaging techniques of digital photogrammetry that can be viewed on desktop applications.

Digital terrain model (DTM). A discrete expression of topography in a data array, consisting of a group of planimetric coordinates (X,Y) and the elevations of the ground points and breaklines.

Digitizing. Any process that converts nondigital data into numeric data, usually to be stored on a computer. In ERDAS IMAGINE, digitizing refers to the creation of vector data from hardcopy materials or raster images. The data are traced using a digitizer keypad on a digitizing tablet, or a mouse on a display device.

Direction of flight. The direction in which the craft is moving (e.g., east to west). Images in a strip are captured along the aircraft or satellite's direction of flight. Images overlap in the same manner as the direction of flight.

E

Earth centered inertial (ECI) system. The ECI coordinate system is space fixed with its origin at the Earth's center of mass. The Z-axis corresponds to the mean north celestial pole of epoch J2000.0. The X-axis is based on the mean vernal equinox of epoch J2000.0. The Y-axis is the cross-product of the Z-axis and the X-axis.

Earth centered rotating (ECR) system. The ECR or ECF (Earth centered fixed) coordinate system is Earth fixed with its origin at the center of mass of the Earth. It corresponds to the conventional terrestrial system (CTS) defined by the International Earth Rotation Service (IERS), which is the same as the U.S. Department of Defense World Geodetic System 1984 (WGS84) geocentric reference system.

See also Geodetic coordinate system

Elements of exterior orientation. Variables that define the position and orientation of a sensor as it obtained an image. It is the position of the perspective center with respect to the ground space coordinate system.

Ephemeris. Data contained in the header of the data file of an image, provides information about the recording of the data and the satellite orbit.

Epipolar line. The line traced on each image representing the intersection of the epipolar plane with the image plane.

Epipolar plane. The plane, in space, containing a ground point and both exposure stations.

Epipolar-resampled imagery. Two images resampled (rectified or warped) such that clear stereo viewing is possible. Each line of the images is an epipolar line in which changes of height are effected by moving along the line (x-parallax); anomalies in stereo viewing represent displacement of images between lines (y-parallax).

Epipolar stereopair. A stereopair in which Y-parallax has been removed.

Exclusion AOI. An AOI purposely excluded from processing. The exclusion can be due to poor registration, or interest in some other feature. Exclusion AOIs are collected in the same manner as inclusion AOIs. OrthoBASE Pro makes use of exclusion AOIs for DTM extraction.

Exposure station. During image acquisition, each point in the flight path at which the camera exposes the film. The exposure station has elements that define its position and rotation: X, Y, Z, Omega, Phi, and Kappa.

See also Omega, Phi, Kappa

Exterior orientation. External sensor model information that describes the exact position and orientation of each image as they existed when the imagery was collected. The image's position is defined as having 3D coordinates, and the orientation is defined as having three rotations that include Omega, Phi, and Kappa.

Exterior orientation parameters. The perspective center's ground coordinates in a specified map projection and three rotation angles around the coordinate axes.

Eye-base to height ratio. The eye-base is the distance between a person's eyes. The height is the distance between the eyes and the image datum. When two images of a stereopair are adjusted in the X and Y direction, the eye-base to height ratio is also changed. Change the X and Y positions to compensate for parallax in the images.

F

Fiducial. Four or eight reference markers fixed on the frame of an aerial metric camera and visible in each exposure. Fiducials are used to compute the transformation from pixel coordinates to image coordinates.

Fiducial center. The center of an aerial photo; the intersection point of lines constructed to connect opposite fiducials.

Fiducial orientation. Defines the relationship between the image/photo-coordinate system of a frame and the actual image orientation as it appears in a view.

Focal length. The distance between the optical center of the lens and where the optical axis intersects the image plane. Focal length of each camera is determined in a laboratory environment.

Focal plane. The plane of the film or scanner used in obtaining an aerial photo.

Free-weighted iterative adjustment. In OrthoBASE, a free-weighted iterative adjustment does not assign statistical weights to the bundled adjustment used during aerial triangulation.

See also Aerial Triangulation

Full GCP. A GCP with X, Y, and Z coordinates.

See also Ground Control Point

Functional model. The mathematical form of photogrammetric equations consisting of unknown and observed parameters which are to be incorporated in a least squares adjustment approach.

G

Geodetic coordinate system. The geodetic coordinate system is based on the WGS84 reference frame with coordinates expressed in latitude, longitude, and height above the reference Earth ellipsoid. No ellipsoid is required by the definition of the ECR coordinate system, but the geodetic coordinate system depends on the selection of an Earth ellipsoid. Latitude and longitude are defined as the angle between the ellipsoid normal and its projection onto the equator and the angle between the local meridian and the Greenwich meridian, respectively.

Geographic information system (GIS). A unique system designed for a particular application that stores, enhances, combines, and analyzes layers of geographic data to produce interpretable information. A GIS may include computer images, hardcopy maps, statistical data, and any other data needed for a study, as well as computer software and human knowledge. GISs are used for solving complex geographic planning and management problems. A GIS consists of spatial data stored in a relational database with associated ancillary information.

Global positioning system (GPS). “A surveying method that uses a set of 24 satellites in geostationary position high above the Earth. Specially designed GPS receivers, when positioned at a point on Earth, can measure the distance from that point to three or more orbiting satellites. The coordinates of the point are determined through the geometric calculations of triangulation. GPS provides accurate geodetic data for any point on the Earth” (Natural Resources Canada 2001c).

Ground control point (GCP). An easily identifiable point for which the ground coordinates of the map coordinate system are known.

H

Horizontal control. A set of points with defined planimetric positions in a map coordinate system.

I

Image. A picture or representation of an object or scene on paper, or a display screen. Remotely sensed images are digital representations of the Earth.

Image center. The center of the aerial photo or satellite scene.

Image coordinate space. A 2D space where measurements are recorded in pixels.

Image coordinate system. A 2D coordinate system defined in the photographic plane. The axes are constructed by the intersection of opposing fiducials.

Image scale (SI). Expresses the ratio between a distance in the image and the same distance on the ground.

Image space coordinate system. A coordinate system composed of the image coordinate system with the addition of a Z axis defined along the focal axis.

Incidence angles. Angles specifying the position of sensors onboard a satellite. Also called inclination angles.

Inclination. The angle between a vertical on the ground at the center of the scene and a light ray from the exposure station, which defines the degree of off-nadir viewing when the scene was recorded.

Inclusion AOI. An AOI purposely included in processing, as in DTM extraction.

See also Exclusion AOI

Inertial navigation system (INS). A technique that provides initial approximations to exterior orientation. This data is provided by a device or instrument. The instrument collects data about the attitude of the airplane in which it is located. The information it collects includes pitch (tilting forward and backward), roll (tilting sideways), and heading (the direction of flight) (National Oceanic and Atmospheric Administration 2001).

See also Omega, Phi, Kappa

Interior orientation. Describes the internal geometry of a camera such as the focal length, principal point, lens distortion, and fiducial mark coordinates for aerial photographs.

International Earth Rotation and Reference Systems Service (IERS). The IERS provides celestial and terrestrial reference systems and frames that help “the astronomical, geodetic and geophysical communities” (International Earth Rotation and Reference Systems Service 2003). For more information, see the IERS website at www.iers.org.

International Society of Photogrammetry and Remote Sensing (ISPRS). An organization "devoted to the development of international cooperation for the advancement of photogrammetry and remote sensing and their application." For more information, visit the web site at http://www.isprs.org (International Society for Photogrammetry and Remote Sensing [1999?]).

Iterations with relaxation. During a free-weighted adjustment, each iteration of processing does not use the statistical weights associated with the GCPs in the block file.

K

Kappa. (κ) In a rotation system, Kappa is positive rotation around the Z-axis.

Konrady coefficients. Coefficients that define radial lens distortion. Expressed as K0, K1, and K2.

See also Radial lens distortion

L

Latitude/longitude (lat/lon). The coordinate components of a spherical map coordinate system.

Least squares adjustment. A technique by which the most probable values are computed for a measured or indirectly determined quantity based upon a set of observations. It is based on the mathematical laws of probability and provides a systematic method for computing unique values of coordinates and other elements in photogrammetry based on a large number of redundance measurements of different kinds and weights.

Least squares correlation. Uses the least squares estimation to derive parameters that best fit a search window to a reference window.

Least squares regression. The method used to calculate the transformation matrix from the GCPs. This method is discussed in statistics textbooks.

Lens distortion. Caused by the instability of the camera lens at the time of data capture. Lens distortion makes the positional accuracy of the image points less reliable.

Lower right X (LRX). The X map or file coordinate of the lower right pixel in the file.

Lower right Y (LRY). The Y map or file coordinate of the lower right pixel in the file.

M

Map coordinates. A system of expressing locations on the Earth's surface using a particular map projection, such as UTM, State Plane, or Polyconic.

Map coordinate system. A map coordinate system that expresses location on the Earth's surface using a particular map projection such as Universal Transverse Mercator (UTM), State Plane, or Polyconic.

Mass points. Points whose 3D coordinates are known (X, Y, and Z), which are used in creating a DEM or DTM.

See also Digital elevation model
Digital terrain model

Metric photogrammetry. The process of measuring information from photography and satellite imagery.

Multiple points. Multiple points can be collected from a DSM to create a TIN or DEM. Like a single point, multiple points have X, Y, and Z coordinate values.

See also Triangulated irregular network
Digital elevation model

N

Nadir. The area on the ground directly beneath a scanner's detectors.

Nadir line. The average of the left and right edge lines of a pushbroom image.

Nadir point. The intersection of the focal axis and the image plane.

Near vertical aerial photographs. Photographs taken from vertical or near vertical positions above the Earth captured by aircraft. Photographs are used for planimetric mapping projects.

Nonmetric camera. A camera that has not been calibrated in a laboratory to determine its internal geometry.

See also Focal length
Principal point
Lens distortion
Fiducial

Nonorthogonality. The deviation from perpendicularity between orthogonally defined axes.

O

Object space. "...the three-dimensional region that encompasses the physical features imaged in photographs" (Wolf and Dewitt 2000).

Off-nadir. Any point that is not directly beneath a scanner's detectors, but off to an angle. The SPOT scanner allows off-nadir viewing.

Omega. (ω) In a rotation system, Omega is rotation around the X-axis.

Omega, Phi, Kappa. A rotation system that defines the orientation of a camera/sensor as it acquired an image. Omega, Phi, Kappa is used most commonly, where Omega is positive rotation around the X-axis, Phi is a positive rotation around the Y-axis, and Kappa is a positive rotation around the Z-axis. This rotation system follows the right-hand rule.

See also Phi(+), Omega, Kappa
Phi(-), Omega, Kappa
Right-hand rule

Optical axis. "...The line joining the centers of curvature of the spherical surfaces of the lens" (Wolf and Dewitt 2000).

Orbital coordinate system. The orbital coordinate system is centered on the satellite and its orientation is based on the satellite position in inertial space. The origin is the satellite center of mass with the Z-axis pointing from the satellite center of mass to the Earth center of mass. The Y-axis is the normalized cross-product of the Z-axis and the instantaneous (inertial) velocity vector. It corresponds to the direction of the negative of the instantaneous angular momentum vector direction. the X-axis is the cross-product of the Y-axis and Z-axis.

Orientation. The position of the camera or satellite as it captured the image. Usually represented by six coordinates: X, Y, Z, Omega, Phi, and Kappa.

Orientation angle. The angle between a perpendicular to the center scan line and the North direction in a satellite scene.

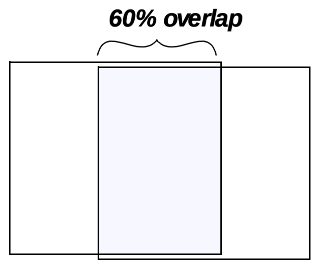
Orientation matrix. A three-by-three matrix defining the relationship between two coordinate systems (i.e., image space coordinate system and ground space coordinate system).

OrthoBASE block file. An OrthoBASE block file has the .blk extension. OrthoBASE block files contain at least one stereopair that is in a coordinate system. An OrthoBASE block file may also contain two or more sets of stereo images used for feature extraction and viewing.

Orthogonal axes. Axes that intersect traditional frame camera images at right angles.

Orthorectification. Also called ortho resampling. The process of removing geometric errors inherent within photography and imagery caused by relief displacement, lens distortion, and the like.

Overlap. In a traditional frame camera, when two images overlap, they share a common area. For example, in a block or strip of photographs, adjacent images typically overlap by 60%.



P

Parallax. "The apparent angular displacement of an object as seen in an aerial photograph with respect to a point of reference or coordinate system. Parallax is caused by a difference in altitude or point of observation" (Natural Resources Canada 2001d).

Perspective center. The optical center of a camera lens. (1) A point in the image coordinate system defined by the x and y coordinates of the principal point and the focal length of the sensor. (2) After triangulation, a point in the ground coordinate system that defines the sensor's position relative to the ground.

Phi. (φ) In a rotation system, Phi is rotation around the Y-axis.

Phi(-), Omega, Kappa. A rotation system in which Phi is a negative rotation about the Y-axis, Omega is a positive rotation about the X-axis, and Kappa is a positive rotation about the Z-axis. Y is the primary axis.

Phi(+), Omega, Kappa. A rotation system in which Phi is a positive rotation about the Y-axis, Omega is a positive rotation about the X-axis, and Kappa is a positive rotation about the Z-axis. Y is the primary axis. This system is most commonly used in Germany.

Photo direction. The direction of the optical axis looking down; Z. In close range photography, it is Y.

Photogrammetric quality scanners. Special devices capable of high image quality and excellent positional accuracy. Use of this type of scanner results in geometric accuracy similar to traditional analog and analytical photogrammetric instruments.

Photogrammetry. The "art, science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiant imagery and other phenomena" (American Society of Photogrammetry 1980).

Pixel coordinate system. The file coordinates of a digital image are defined in a pixel coordinate system. A pixel coordinate system is usually a coordinate system with its origin in the upper-left corner of the image—the x-axis pointing to the right, the y-axis pointing downward, and the units in pixels. These file coordinates (c, r) can also be thought of as the pixel column and row number. This coordinate system is referenced as pixel coordinates (c,r).

Plane table photogrammetry. Prior to the invention of the airplane, photographs taken on the ground were used to extract the geometric relationships between objects.

Principal point. The point in the image plane onto which the perspective center is projected.

Principal point of autocollimation. Part of the definition of principal point, the image position where the optical axis intersects the image plane. The principal point of autocollimation is near the principal point (Wolf 1983).

Principal point of symmetry. Part of the definition of principal point, the principal point of symmetry can best compensate for lens distortion. "The point about which [distortions] are symmetrical" (Wolf 1983).

Principal point xo. A parameter used to define the location of the principal point in the x direction, which is relative to the origin of the image or photo-coordinate system. The location in the x direction where the optical axis of the camera intersects the image or photographic plane.

Principal point yo. A parameter used to define the location of the principal point in the y direction, which is relative to the origin of the image or photo-coordinate system. The location in the y direction where the optical axis of the camera intersects the image or photographic plane.

R

Radial lens distortion. Imaged points are distorted along radial lines from the principal point. Also referred to as symmetric lens distortion.

Rational functions. Rational two-dimensional polynomials formed to handle the mapping of ground coordinates to an image space coordinate system after triangulation is complete.

$$line = (g\,(X, Y, Z)) \,/\, (g'\,(X, Y, Z))$$
$$sample = (f\,(X, Y, Z)) \,/\, (f'\,(X, Y, Z))$$

Redundancy. In a block of data, the amount of data that is duplicated, thus providing strong geometric fidelity.

See also Degrees of freedom

Reference plane. In a topocentric coordinate system, the tangential plane at the center of the image on the Earth ellipsoid, on which the three perpendicular coordinate axes are defined.

Regular block of photos. A rectangular block in which the number of photos in each strip is the same; this includes a single strip or a single stereopair.

Residual. "The difference between any measured quantity and the most probable value for that quantity" (Wolf and Dewitt 2000).

Right-hand rule. A convention in 3D coordinate systems (X, Y, Z) that determines the location of the positive Z-axis. If you place your right hand fingers on the positive X-axis and curl your fingers toward the positive Y-axis, the direction your thumb is pointing is the positive Z-axis direction (ERDAS 1999).

Root mean square error (RMSE). Used to measure how well a specific calculated solution fits the original data. For each observation of a phenomena, a variation can be computed between the actual observation and a calculated value. (The method of obtaining a calculated value is application-specific.) Each variation is then squared. The sum of these squared values is divided by the number of observations and then the square root is taken. This is the RMSE value.

Rotation matrix. A 3 × 3 matrix used in the aerial triangulation functional model. Determines the relationship between the image space coordinate system and the ground space coordinate system.

$$M = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix}$$

S

Satellite body coordinate system. A body coordinate system is fixed to the satellite with its origin at the satellite center of mass. The coordinate axes are defined by the satellite attitude control system. It is the orientation of this coordinate system relative to the orbital coordinate system that is captured in the attitude data.

See also Orbital coordinate system

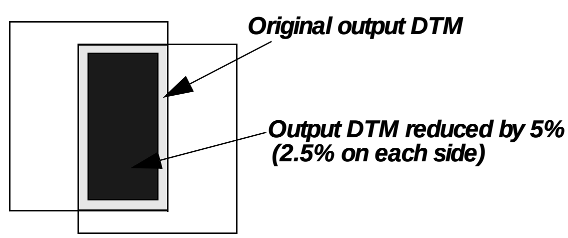
Search size. The window size (in pixels) to search for corresponding points in two images during correlation.

Search windows. Candidate windows on the second image of an image pair that are evaluated relative to the reference window in the first image.

Self-calibrating bundle adjustment (SCBA). Bundle adjustment which also estimates the interior orientation parameters associated with a camera or sensor model.

Self-calibration. A technique used in block bundle adjustment to determine internal sensor model information.

Shrink percentage. In OrthoBASE Pro, the percentage by which the output DTM is shrunk versus the original scale. The shrink percentage is applied to each side of the output DTM.



Side fiducial. Fiducials that are located at the sides of an image, rather than at the corners of an image.

See also Fiducial

Side incidence angle. The angle between the vertical position of the satellite and the side viewing direction of the satellite when the sensor is scanning along the side. For example, SPOT imagery side incidence angles can range from +27 to -27 degrees. The scanning direction is perpendicular to the direction of flight.

Sidelap. In a block of photographs consisting of a number of parallel strips, the sidelap (measured vertically) is usually 20-30% in traditional frame camera photos. Tie points are typically measured in the sidelap.

Softcopy photogrammetry.

See Digital photogrammetry

Space forward intersection. A technique used to determine the ground coordinates X, Y, and Z of points that appear in the overlapping areas of two or more images based on known interior orientation and exterior orientation parameters.

Space intersection. A technique used to determine the ground coordinates X, Y, and Z of points that appear in the overlapping areas of two images, based on the collinearity condition.

Space resection. A technique used to determine the exterior orientation parameters associated with one image or many images, based on the collinearity condition.

Spatial resolution. A measure of the smallest object that can be resolved by the sensor, or the area on the ground represented by each pixel.

Standard deviation of unit weight.

See Root mean square error

Stereopair. A set of two remotely-sensed images that overlap, providing a 3D view of the terrain in the overlap area.

Strategy. In OrthoBASE Pro, a strategy is a set of correlation parameters defined for a specific area in a stereopair for the purpose of DTM extraction. An appropriate strategy can improve the likelihood of obtaining reliable image matching results.

Strip of photographs. In traditional frame camera photography, consists of images captured along a flight-line, normally with an overlap of 60% for stereo coverage. All photos in the strip are assumed to be taken at approximately the same flying height and with a constant distance between exposure stations. Camera tilt relative to the vertical is assumed to be minimal.

See also Cross-strips

T

Tangential lens distortion. Distortion that occurs at right angles to the radial lines from the principal point.

Template window. A small subset of an image that you want to try to locate in another image based on specific matching criteria. A template usually remains fixed in one image during the matching process.

Terrestrial photographs. Ground-based photographs and images taken with a camera stationed on or near the Earth's surface. Photographs are usually used for archeology, geomorphology, and civil engineering.

Tie point. A point; its ground coordinates are not known, but can be recognized visually in the overlap or sidelap area between two images.

Topocentric coordinate system. A coordinate system that has its origin at the center of the image on the Earth ellipsoid. The three perpendicular coordinate axes are defined on a tangential plane at this center point. The x-axis is oriented eastward, the y-axis northward, and the z-axis is vertical to the reference plane (up).

Transformation matrix. A set of coefficients that is computed from GCPs, and used in polynomial equations to convert coordinates from one system to another. The size of the matrix depends upon the order of the transformation.

Triangulated irregular network (TIN). A specific representation of DTMs in which elevation points can occur at irregular intervals forming triangles.

Triangulation. Process of establishing the geometry of the camera or sensor relative to objects on the Earth's surface.

See also Aerial triangulation

U

Upper left X (ULX). The X map or file coordinate of the upper left pixel in the file.

Upper left Y (ULY). The Y map or file coordinate of the upper left pixel in the file.

X

X-parallax. The difference in position of a common ground point appearing on two overlapping images, which is a function of elevation. X-parallax is measured horizontally.

Y

Y-parallax. The difference in position of a common ground point appearing on two overlapping images, which is caused by differences in camera position and rotation between two images. Y-parallax is measured vertically.

Z

Z. The vertical (height) component of a point, floating cursor, or feature in a given coordinate system.

Z-axis. In the image space coordinate system, the Z-axis is the optical axis. The image space coordinate system directs the z-axis toward the imaged object. In object space, the Z axis is orthogonal to the X and Y axes and is directed out of the Earth's surface.

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