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Preface

About This Manual

The IMAGINE OrthoBASE™ Tour Guide is comprised of tour guides that help you begin to use this module. The tour guide is not intended to tell you everything there is to know about any one topic, but to show you how to use some of the basic tools you need to get started.

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

Example Data

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

<IMAGINE_HOME> is the variable name of the directory where ERDAS IMAGINE resides. When accessing data files, you must replace <IMAGINE_HOME> with the name of the directory where ERDAS IMAGINE® was loaded on your system.

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 is available with ERDAS IMAGINE software:

• ERDAS Field Guide™
• ERDAS IMAGINE V8.4 Installation Guide
• ERDAS IMAGINE Tour Guides™
• ERDAS IMAGINE Release Notes and Important Information

On-line Documentation

Following is a listing of on-line manuals that can be found in the On-Line Help in ERDAS IMAGINE software.

• Annotation
• Area Of Interest (AOI)
• Classification

Tour Guide
Preface

- C Tools (IMAGINE Developers’ Toolkit™)
- ERDAS Macro Language (EML)
- Graphical Models
- HyperSpectral
- ERDAS IMAGINE Interface
- Image Catalog
- Image Interpreter
- Import/Export
- Map Composer
- OrthoBASE
- Radar
- Rectification
- Session
- Spatial Modeler Language (SML)
- Spatial Modeler
- Tools and Utilities
- Vector
- Viewer
- Viewer Raster Tools
- Virtuality (IMAGINE VirtualGIS™)

**Documentation Functions**

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

<table>
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<td>ERDAS IMAGINE Release Notes, then ERDAS IMAGINE Installation Guide</td>
</tr>
<tr>
<td>Set up hardware for use with ERDAS IMAGINE</td>
<td>ERDAS IMAGINE Installation Guide</td>
</tr>
<tr>
<td>Learn about new features in the latest release</td>
<td>ERDAS IMAGINE Release Notes</td>
</tr>
<tr>
<td>Learn to use ERDAS IMAGINE</td>
<td>ERDAS IMAGINE Tour Guides</td>
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### 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:

<table>
<thead>
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<td>Customize the <strong>ERDAS IMAGINE</strong> graphical user interface</td>
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</tr>
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<td>Write custom application programs within <strong>ERDAS IMAGINE</strong></td>
<td><strong>On-Line IMAGINE Developers’ Toolkit manual</strong></td>
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</table>

⚠️ *These paragraphs contain strong warnings or important tips.*
Preface

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

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

NOTE: Notes give additional instruction.

These boxes contain supplemental information that is not required to execute the steps of the tour guides, but is noteworthy.
CHAPTER 1
Introduction to IMAGINE OrthoBASE

Introduction
Welcome to IMAGINE OrthoBASE™. 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.

IMAGINE 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 and 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
• Automatically triangulating multiple images
• Orthorectifying multiple images

Using IMAGINE 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. The geometric distortion is generally 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, 1980; Konecny, 1984; Kraus, 1984; Wang, 1990; Jensen, 1996).
Introduction to IMAGINE OrthoBASE

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, which is rigorously applied in IMAGINE OrthoBASE, 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 IMAGINE 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. Orthoimages are, therefore, 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.

IMAGINE 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. IMAGINE 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 DEM and topographic features from imagery, the image orientations need to be known. The triangulation results of IMAGINE OrthoBASE determine the image position and orientations required for the purpose of DEM extraction and stereo feature collection.

The Primary Capabilities of IMAGINE OrthoBASE

First, IMAGINE OrthoBASE allows you to easily model various camera and sensor types, referred to as sensor modeling. IMAGINE 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, IMAGINE 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 orthos.

Third, IMAGINE 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, IMAGINE OrthoBASE gives you the flexibility to orthorectify images from a variety of camera and satellite sensor types. Additionally, the product 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 stereoplotters 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.

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

First is 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.

Second is 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.

Third is 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.
Introduction to IMAGINE OrthoBASE

Tour Guide Examples

The following tour guide examples are used to highlight the unique capabilities available within IMAGINE 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 IMAGINE 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 IMAGINE OrthoBASE.

Frame Camera Tour Guide

This example data set involves performing aerial triangulation and orthorectification on three overlapping aerial photographs that have a photo scale of 1:40,000. A calibration report is provided that defines the internal geometry of the camera as it existed when the photography was 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 USGS DEM is provided to account for the effect of topographic relief during the orthorectification process. Orthorectification is performed for each image sequentially.

Digital Camera Tour Guide

This example data set involves performing aerial triangulation and orthorectification on three overlapping digital camera images that have an image scale of 1:45,000. 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.

SPOT Pushbroom Sensor Tour Guide

This example data set 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. IMAGINE 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.

**About IMAGINE OrthoBASE**

Before you begin working with IMAGINE 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 three tour guides that follow.

**IMAGINE OrthoBASE Menu Bar**

The menu bar across the top of the main IMAGINE OrthoBASE dialog has the following options:

<table>
<thead>
<tr>
<th>File</th>
<th>Edit</th>
<th>Process</th>
<th>Help</th>
</tr>
</thead>
<tbody>
<tr>
<td>Save</td>
<td>Add Frame...</td>
<td>Automatic Tie Point Generation</td>
<td>Help for OrthoBASE...</td>
</tr>
<tr>
<td>Save As...</td>
<td>Frame Editor...</td>
<td>Triangulate</td>
<td></td>
</tr>
<tr>
<td>Close</td>
<td>Compute Pyramid Layers...</td>
<td>Report...</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Delete Selected Image(s)</td>
<td>Graphic Status...</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Point Measurement...</td>
<td>Ortho Rectification</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Block Properties...</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Auto. Tie Point Generation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Properties...</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Triangulation Properties...</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** The underlined letters indicate keyboard shortcuts.

**Keyboard Shortcuts**

You can access some IMAGINE OrthoBASE options using the keyboard.

- Display the **File** menu by typing **Alt-f**.
- Display the **Edit** menu by typing **Alt-e**.
- Save a project file by typing **Ctrl-S**.
- Close a project file by typing **Ctrl-F**.
**Introduction to IMAGINE OrthoBASE**

**IMAGINE OrthoBASE Tool Bar**

The following icons are located in the IMAGINE OrthoBASE main dialog tool bar:

<table>
<thead>
<tr>
<th>Icon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Add Frame" /></td>
<td>Click to add a new image to the IMAGINE OrthoBASE project file. A File Selector dialog opens.</td>
</tr>
<tr>
<td><img src="image" alt="Frame Editor" /></td>
<td>Click to specify interior orientation, exterior orientation, and fiducial coordinates for each image in the Frame Editor dialog.</td>
</tr>
<tr>
<td><img src="image" alt="Point Measurement" /></td>
<td>Click to measure check and GCPs in your block images. Viewers, a tool palette, and two CellArrays™ open within a single dialog.</td>
</tr>
<tr>
<td><img src="image" alt="Auto Tie" /></td>
<td>Click to run automatic tie point generation.</td>
</tr>
<tr>
<td><img src="image" alt="Triangulation" /></td>
<td>Click to perform triangulation on your block images.</td>
</tr>
<tr>
<td><img src="image" alt="Ortho Resampling" /></td>
<td>Click to resample your triangulated images and create orthoimages.</td>
</tr>
</tbody>
</table>
CHAPTER 2
Photogrammetry and IMAGINE OrthoBASE™

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" (ASP 1980).

Photogrammetry was invented in 1851 by Laussedat, and has continued to develop over the last 140 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., topographic maps) from aerial images. However, photogrammetric techniques have also been applied to process satellite images and close range images in order to acquire topographic or non-topographic information of photographed objects.

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 stereomeasurement in 1901, optical or mechanical instruments were used to reconstruct three-dimensional geometry from two overlapping photographs. The main product during this phase was topographic maps.

In analytical photogrammetry, the computer replaces 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 can also be digital products, such as digital maps and DEMs.

Digital photogrammetry is 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. 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 orthophotos saved on computer storage media. Therefore, they can be easily stored, managed, and applied by the user. With the development of digital photogrammetry, photogrammetric techniques are more closely integrated into remote sensing and GIS.
Photogrammetry and IMAGINE OrthoBASE™

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. IMAGINE OrthoBASE is such a photogrammetric system.

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 as represented on a photograph or image (Wolf, 1983).

The types of photographs and images that can be processed within IMAGINE 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. The camera axis of aerial or vertical photography is commonly directed vertically (or near vertically) down. Aerial photographs and images are commonly used for topographic and planimetric mapping projects. Aerial photographs and images are commonly captured from an aircraft or 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, industry, etc.

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 from various sources. These include:

- Digitizing existing hardcopy photographs
- Using digital cameras to record imagery
- Using sensors on board satellites such as Landsat and SPOT to record imagery

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?

As stated in the previous section, 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 the raw imagery. It is unique in terms of considering the image-forming geometry, utilizing information between overlapping images, and explicitly dealing with the third dimension: elevation.
In addition to orthoimages, photogrammetry can also provide other geographic information such as a DEM, topographic features, and line maps reliably and efficiently. 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 accuracies.

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.

However, 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 threedimensional 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.

Photogrammetric techniques overcome all the problems mentioned above by using least squares bundle block adjustment. This solution is integrated and accurate.

IMAGINE 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, but more geographic fidelity can be realized using the photogrammetric solution.

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 utilize 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.

Aerial 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 aerial triangulation is required as input for the orthorectification, DEM, 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 the cost of collecting GCPs is very large, 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 control points (GCPs).

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

- To determine 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.

- To determine 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 Create Surface tool in ERDAS IMAGINE.

- To minimize and distribute 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.
During photographic or image collection, overlapping images are exposed along a direction of flight. Most photogrammetric applications involve the use of overlapping images. In 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 2-1).

Each photograph or image that is exposed has a corresponding image scale associated with it. The image scale 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 image scale (SI) would be 1:6667.

NOTE: The flying height above ground is used, 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 ground points into a homologous coordinate system.

A regular block of photos is a rectangular block in which the number of photos in each strip is the same. Figure 2-2 shows a block of $5 \times 2$ photographs.
Photogrammetric and IMAGINE OrthoBASE™

Photogrammetric quality scanners are special devices capable of 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.

These units usually scan only film because film is superior to paper, both in terms of image detail and geometry. These units 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.

Figure 2-2 A Regular Rectangular Block of Aerial Photos

Photogrammetric Scanners

Photogrammetry and IMAGINE OrthoBASE™

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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 $9 \times 9$ inches (i.e., A3 type scanners), enabling 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 can be introduced into the photogrammetric solution that are attributable to scanning errors. IMAGINE OrthoBASE accounts for systematic errors attributed to scanning errors.

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, “Scanning Resolutions,” on page 14 lists the scanning resolutions associated with various scales of photography and image file size.
Photogrammetry and IMAGINE OrthoBASE™

Table 2-1  Scanning Resolutions

<table>
<thead>
<tr>
<th>Photo Scale 1 to</th>
<th>12 microns (2117 dpi)</th>
<th>16 microns (1588 dpi)</th>
<th>25 microns (1016 dpi)</th>
<th>50 microns (508 dpi)</th>
<th>85 microns (300 dpi)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ground Coverage (meters)</td>
<td>Ground Coverage (meters)</td>
<td>Ground Coverage (meters)</td>
<td>Ground Coverage (meters)</td>
<td>Ground Coverage (meters)</td>
</tr>
<tr>
<td>1800</td>
<td>0.0216</td>
<td>0.0288</td>
<td>0.045</td>
<td>0.09</td>
<td>0.153</td>
</tr>
<tr>
<td>2400</td>
<td>0.0288</td>
<td>0.0384</td>
<td>0.06</td>
<td>0.12</td>
<td>0.204</td>
</tr>
<tr>
<td>3000</td>
<td>0.036</td>
<td>0.048</td>
<td>0.075</td>
<td>0.15</td>
<td>0.255</td>
</tr>
<tr>
<td>3600</td>
<td>0.0432</td>
<td>0.0576</td>
<td>0.09</td>
<td>0.18</td>
<td>0.306</td>
</tr>
<tr>
<td>4200</td>
<td>0.0504</td>
<td>0.0672</td>
<td>0.105</td>
<td>0.21</td>
<td>0.357</td>
</tr>
<tr>
<td>4800</td>
<td>0.0576</td>
<td>0.0768</td>
<td>0.12</td>
<td>0.24</td>
<td>0.408</td>
</tr>
<tr>
<td>5400</td>
<td>0.0648</td>
<td>0.0864</td>
<td>0.135</td>
<td>0.27</td>
<td>0.459</td>
</tr>
<tr>
<td>6000</td>
<td>0.072</td>
<td>0.096</td>
<td>0.15</td>
<td>0.3</td>
<td>0.51</td>
</tr>
<tr>
<td>6600</td>
<td>0.0792</td>
<td>0.1056</td>
<td>0.165</td>
<td>0.33</td>
<td>0.561</td>
</tr>
<tr>
<td>7200</td>
<td>0.0864</td>
<td>0.1152</td>
<td>0.18</td>
<td>0.36</td>
<td>0.612</td>
</tr>
<tr>
<td>7800</td>
<td>0.0936</td>
<td>0.1248</td>
<td>0.195</td>
<td>0.39</td>
<td>0.663</td>
</tr>
<tr>
<td>8400</td>
<td>0.1008</td>
<td>0.1344</td>
<td>0.21</td>
<td>0.42</td>
<td>0.714</td>
</tr>
<tr>
<td>9000</td>
<td>0.108</td>
<td>0.144</td>
<td>0.225</td>
<td>0.45</td>
<td>0.765</td>
</tr>
<tr>
<td>9600</td>
<td>0.1152</td>
<td>0.1536</td>
<td>0.24</td>
<td>0.48</td>
<td>0.816</td>
</tr>
<tr>
<td>10800</td>
<td>0.1296</td>
<td>0.1728</td>
<td>0.27</td>
<td>0.54</td>
<td>0.918</td>
</tr>
<tr>
<td>12000</td>
<td>0.144</td>
<td>0.192</td>
<td>0.3</td>
<td>0.6</td>
<td>1.02</td>
</tr>
<tr>
<td>15000</td>
<td>0.18</td>
<td>0.24</td>
<td>0.375</td>
<td>0.75</td>
<td>1.275</td>
</tr>
<tr>
<td>18000</td>
<td>0.216</td>
<td>0.288</td>
<td>0.45</td>
<td>0.9</td>
<td>1.53</td>
</tr>
<tr>
<td>24000</td>
<td>0.288</td>
<td>0.384</td>
<td>0.6</td>
<td>1.2</td>
<td>2.04</td>
</tr>
<tr>
<td>30000</td>
<td>0.36</td>
<td>0.48</td>
<td>0.75</td>
<td>1.5</td>
<td>2.55</td>
</tr>
<tr>
<td>40000</td>
<td>0.48</td>
<td>0.64</td>
<td>1</td>
<td>2</td>
<td>3.4</td>
</tr>
<tr>
<td>50000</td>
<td>0.6</td>
<td>0.8</td>
<td>1.25</td>
<td>2.5</td>
<td>4.25</td>
</tr>
<tr>
<td>60000</td>
<td>0.72</td>
<td>0.96</td>
<td>1.5</td>
<td>3</td>
<td>5.1</td>
</tr>
<tr>
<td>B/W File Size (MB)</td>
<td>363</td>
<td>204</td>
<td>84</td>
<td>21</td>
<td>7</td>
</tr>
<tr>
<td>Color File Size (MB)</td>
<td>1089</td>
<td>612</td>
<td>252</td>
<td>63</td>
<td>21</td>
</tr>
</tbody>
</table>

The ground coverage column refers to the ground coverage per pixel. Thus, a 1:40000 scale 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 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 unit in pixels, as shown by axis c and r in Figure 2-3. 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 \((c, r)\) in this chapter.

![Figure 2-3 Pixel Coordinates and Image Coordinates](image)

Image Coordinate System

An image coordinate system or an image plane coordinate system is usually defined as a two-dimensional coordinate system occurring on the image plane with its origin at the image center, normally at the principal point or at the intersection of the fiducial marks as illustrated by axis x and y in Figure 2-3. Image coordinates are used to describe positions on the film plane. Image coordinate units are usually millimeters or microns. This coordinate system is referenced as image coordinates \((x, y)\) in this chapter.
Image Space Coordinate System

An image space coordinate system (Figure 2-4) is identical to image coordinates, except that it adds a third axis (z). The origin of the image space coordinate system is defined at the perspective center S as shown in Figure 2-4. 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 (focal length). 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.

Ground Coordinate System

A ground coordinate system is usually defined as a three-dimensional coordinate system that utilizes a known 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 which includes curvature. Two such systems are geocentric and topocentric coordinates.

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 2-5 illustrates the two coordinate systems associated with image space and ground space.

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.

---

*Figure 2-5 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 $\omega$, $\varphi$, and $\kappa$ are still defined as in the aerial photography conventions. In IMAGINE 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 $\omega'$, $\varphi'$, and $\kappa'$ are different, as shown in Figure 2-5.

**Interior Orientation**

Interior orientation defines the internal geometry of a camera or sensor as it existed at the time of data capture. The variables associated with image space are defined during the process of 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 2-6 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.
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 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 inches. 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 the lens distortion.

**Fiducial Marks**

As stated previously, one of the steps associated with 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 subsequently 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 2-7 illustrates the difference between the pixel coordinate system and the image space coordinate system.
Using a two-dimensional affine transformation, the relationship between the pixel coordinate system and the image space coordinate system is defined. The following two-dimensional affine transformation equations can be used to determine the coefficients required to transform pixel coordinate measurements to the image coordinates:

\[
\begin{align*}
    x &= a_1 + a_2 X + a_3 Y \\
    y &= b_1 + b_2 X + b_3 Y
\end{align*}
\]

The quality of the two-dimensional 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 and the image coordinate system \((x_{o-file}, y_{o-file})\). Additionally, the affine transformation takes into consideration rotation of the image coordinate system by considering angle \(\Theta\). 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 two-dimensional 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.

Lens Distortion

Lens distortion deteriorates the positional accuracy of image points located on the image plane. Two types of radial 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 2-8 illustrates the difference between radial and tangential lens distortion.

![Figure 2-8 Radial vs. Tangential Lens Distortion](image)

Radial lens distortion causes imaged points to be distorted along radial lines from the principal point 0. 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. Since 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:

\[
\Delta r = k_0 r + k_1 r^3 + k_2 r^5
\]

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. IMAGINE OrthoBASE accommodates radial lens distortion parameters in both scenarios.
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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 associated with 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 $X_o$, $Y_o$, and $Z_o$. They define the position of the perspective center ($O$) with respect to the ground space coordinate system ($X$, $Y$, and $Z$). $Z_o$ 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 ($\omega$), phi ($\phi$), and kappa ($\kappa$). Figure 2-9 illustrates the elements of exterior orientation.
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, which 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 1990). The ISPRS recommends the use of the \( \omega, \phi, \kappa \) 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.

Using the three rotation angles, the relationship between the image space coordinate system \((x, y, z)\) and ground space coordinate system \((X, Y, Z\) or \(x', y', z'\)) can be determined. A \( 3 \times 3 \) 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:

![Figure 2-9 Elements of Exterior Orientation](image)
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.

The Collinearity Equation

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

With reference to Figure 2-9, 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:

\[
a = kA
\]

where \( k \) 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:

\[
a = \begin{bmatrix} xp - xo \\ yp - yo \\ -f \end{bmatrix}
\]

where \( xo \) and \( yo \) represent the image coordinates of the principal point.

Similarly, the ground vector can be formulated as follows:

\[
A = \begin{bmatrix} Xp - Xo \\ Yp - Yo \\ Zp - Zo \end{bmatrix}
\]

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.

\[
x_p - x_o = -f \left[ \frac{m_{11}(X_p - X_{o1}) + m_{12}(Y_p - Y_{o1}) + m_{13}(Z_p - Z_{o1})}{m_{31}(X_p - X_{o1}) + m_{32}(Y_p - Y_{o1}) + m_{33}(Z_p - Z_{o1})} \right]
\]

\[
y_p - y_o = -f \left[ \frac{m_{21}(X_p - X_{o1}) + m_{22}(Y_p - Y_{o1}) + m_{23}(Z_p - Z_{o1})}{m_{31}(X_p - X_{o1}) + m_{32}(Y_p - Y_{o1}) + m_{33}(Z_p - Z_{o1})} \right]
\]

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.

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 costs and labor intensive procedures associated with collecting ground control, most photogrammetric applications do not have an abundant number 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 ressection 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 ressection is based on the collinearity condition. Space ressection 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 number of three GCPs is known in the X, Y, and Z direction, space ressection techniques can be used to determine the six exterior orientation parameters associated with an image. Space ressection assumes that camera information is available.

Space ressection is commonly used to perform single frame orthorectification, where one image is processed at a time. If multiple images are being used, space ressection 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 ressection 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 orientation and known 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 2-10 illustrates the concept associated with space forward intersection.
Figure 2-10 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 \( p \) on Image 1 and Image 2 are input to compute the \( X_p \), \( Y_p \), and \( Z_p \) coordinates of ground point \( p \).

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

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 costly.

The costs associated with block triangulation and 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 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. IMAGINE 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 2-11 illustrates the photogrammetric configuration.
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 overlapping areas 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 areas of image left and image right has four collinearity formulas.

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

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

Figure 2-11 Photogrammetric Configuration
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\[ x_{a_2} - x_o = -f \frac{m'_{11}(X_A - X_{o_2}) + m'_{12}(Y_A - Y_{o_2}) + m'_{13}(Z_A - Z_{o_2})}{m'_{31}(X_A - X_{o_2}) + m'_{32}(Y_A - Y_{o_2}) + m'_{33}(Z_A - Z_{o_2})} \]

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

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 areas of two images, twelve equations can be formulated, which includes 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, which includes 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 and kappa), and
- 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, by 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 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 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 formulation as follows:
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\[ V = AX - L, \text{ including a weight matrix } P \]

where

\[ V = \text{the matrix containing the image coordinate residuals} \]
\[ A = \text{the matrix containing the partial derivatives with respect to the unknown parameters, including exterior orientation, interior orientation, XYZ tie point, and GCP coordinates} \]
\[ X = \text{the matrix containing the corrections to the unknown parameters} \]
\[ L = \text{the matrix containing the input observations (i.e., image coordinates and GCP coordinates)} \]

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:

\[ X = (A^tPA)^{-1}A^tPL \]

where

\[ X = \text{the matrix containing the corrections to the unknown parameters } t \]
\[ A = \text{the matrix containing the partial derivatives with respect to the unknown parameters} \]
\[ t = \text{the matrix transposed} \]
\[ P = \text{the matrix containing the weights of the observations} \]
\[ L = \text{the matrix containing the observations} \]

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 completed, 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
- $X, Y, \text{ and } Z$ 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:

- Stereo pair 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, etc. 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 $a \text{ posteriori}$-compensation, test-field calibration, and the most common approach—self-calibration (Konecny 1984; Wang 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 70’s and the 80’s, and many research results are available (e.g., Bauer 1972; Brown 1975; Ebner 1976; Grün 1978; Jacobsen 1980 and 1982; Li 1985; Wang 1988; Stojić et al. 1998). Based on these scientific reports, IMAGINE OrthoBASE provides four groups of additional parameters for you to choose for different triangulation circumstances. In addition, IMAGINE OrthoBASE allows the interior orientation parameters to be analytically calibrated within its self-calibrating bundle block adjustment capability.
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 80's in the photogrammetric community resulted in significant achievements in automatic gross error detection in the triangulation process (e.g., Kubik 1982; Li 1983 and 1985; Jacobsen 1984; El-Hakin 1984; Wang 1988).

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

It is worth mentioning that 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. Horizontal control only specifies the X,Y, while vertical control only specifies the Z. 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 photography or imagery. During GCP measurement in IMAGINE OrthoBASE, the image positions of GCPs appearing on an image or on the overlap areas 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 and one GCP having a Z coordinate associated with it. 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, 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**

If 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**

If processing a strip of adjacent images, two GCPs for every third image is 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 2-12 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.
Processing Multiple Strips of Imagery

Figure 2-13 depicts the standard GCP configuration for a block of images, comprising four strips of images, each containing eight overlapping 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 well-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 well distributed over the area of the block. Typically, nine tie points in each image are adequate for block triangulation. Figure 2-14 depicts the placement of tie points.

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**Figure 2-14  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 2-15).
Selecting and measuring tie points is very time-consuming and costly. Therefore, in recent years, one of the major focal points of research and development in photogrammetry has concentrated on the automated triangulation where the automatic tie point collection is the main issue.

The other part of the automated triangulation is the automatic control point identification, which is still unsolved due to the complication of the scenario. There are several valuable research results available for automated triangulation (e.g., Agouris and Schenk 1996; Heipke 1996; Krzystek 1998; Mayr 1995; Schenk 1997; Tang 1997; Tsingas 1995; Wang 1998).

After investigating the advantages and the weaknesses of the existing methods, IMAGINE 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 IMAGINE OrthoBASE successfully performs the following tasks:

- Automatic block configuration. Based on the initial input requirements, IMAGINE 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 IMAGINE 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 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 area 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., $3 \times 3$, $5 \times 5$, $7 \times 7$ 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., $3 \times 3$, $5 \times 5$, 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:
Photogrammetry and IMAGINE OrthoBASE™

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. Also, 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.

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

where

- \( c_1, r_1 \) = 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 \( (c_1, r_1) \)
- \( h_0, h_1 \) = 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:

\[ v = (a_1 + a_2 c_1 + a_3 r_1) g_c + (b_1 + b_2 c_1 + b_3 r_1) g_r - h_1 - h_2 g_1(c_1, r_1) + \Delta g \]

with \[ \Delta g = g_2(c_2, r_2) - g_1(c_1, r_1) \]

where \( g_c \) 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. IMAGINE 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 1994 and 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 2-16 shows a four-level image pyramid.

Figure 2-16 Image Pyramid for Matching at Coarse to Full Resolution

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 the superior properties concerning preserving the image contents and reducing the computation time (Wang 1994). Therefore, IMAGINE OrthoBASE uses this kind of pyramid layer instead of those currently available under ERDAS IMAGINE, which are overwritten automatically by IMAGINE OrthoBASE.
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 Indian Remote Sensing (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. Figure 2-17 illustrates the scanning technique.

![Figure 2-17 Perspective Centers of SPOT Scan Lines](image-url)
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 the 10 meter SPOT Pan scenario.

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 2-18 depicts image coordinates in a satellite scene:

![Figure 2-18 Image Coordinates in a Satellite Scene](image)

where

- A = origin of file coordinates
- A-X, A-Y = file coordinate axes
- C = origin of image coordinates (center of scene)
- C-x, C-y = image coordinate axes
Figure 2-19 shows the interior orientation of a satellite scene. The transformation between file coordinates and image coordinates is constant.

**Figure 2-19 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 on board the satellite become the critical data.

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).

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.

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). Figure 2-20 illustrates the inclination.
Figure 2-20 Inclination of a Satellite Stereo-Scene (View from North to South)

Where

- $C$ = 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 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 2-21).
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

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 2-22.

---

*Figure 2-22  Ideal Point Distribution Over a Satellite Scene for Triangulation*
Orthorectification

As stated previously, orthorectification is the process of removing 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 2-23).

![Orthorectification Diagram](image-url)

**Figure 2-23 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 2-24).

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 2-24 Digital Orthophoto - Finding Gray Values

Where

\[ P = \text{ground point} \]
\[ P_1 = \text{image point} \]
\[ O = \text{perspective center (origin)} \]
\[ X,Z = \text{ground coordinates (in DTM file)} \]
\[ f = \text{focal length} \]
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. 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.

Detailed discussion of DEM requirements for orthorectification can be found in Yang and Williams (1997). See “References” on page 197.

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
Frame Camera Tour Guide

Introduction

With IMAGINE OrthoBASE software, 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 following graphic represents the geometric relationship between the three images and control points, and the two check points. The control points are shown at the positions that coincide with the image features with which they are associated. Initially, the input images are not in the coordinate system of the control points. The input images are usually in file coordinates, which can be defined as an arbitrary grid of coordinate values.

During triangulation, the control points are used to establish a mathematical relationship between the camera, the photography, and three-dimensional 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.

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 IMAGINE OrthoBASE project
Create a New IMAGINE OrthoBASE Project

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

Prepare the Block File

1. Start ERDAS IMAGINE.
2. Close the Viewer that automatically opens when starting ERDAS IMAGINE.
3. Click the OrthoBASE icon on the ERDAS IMAGINE icon panel.

The OrthoBASE Startup dialog opens.

4. Confirm that the radio button next to Create a new OrthoBASE project is active.
5. Click OK to close the OrthoBASE Startup dialog.
The Create New Block File dialog opens.

6. Navigate to a directory in which you have write permission.
7. Next to **File name**, type **frame_tour.blk**, then press Enter on your keyboard.
8. Click **OK** to close the Create New Block File dialog.

The Model Setup dialog opens.

---

**The IMAGINE OrthoBASE .blk file**

When you use IMAGINE OrthoBASE in your own work, 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.
Frame Camera Tour Guide

Select Geometric Model

1. From the Select Geometric Model list, select Frame Camera

   ![Select Frame Camera from the list](image)

   ![Click OK](image)

2. Click OK to close the Model Setup dialog.

   The Block Property Setup dialog opens.

Define Block Properties

1. Click the Set Projection button in the Set Reference System section of the Block Property Setup dialog.

   The Projection Chooser dialog opens.

2. In the Standard tab, click the Categories dropdown list and select US State Plane - NAD27.

3. Use the Projection scrolling list, then select COLORADO CENTRAL (3476).
4. Click **OK** to close the Projection Chooser dialog.

The projection information displays in the **Set Reference System** section of the dialog.

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

The **Reference Units** section displays.

---

Ensure that the information you provide in the Set Reference 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.
6. Click the popup list next to **Horizontal Units** to select **Meters**.

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

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

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

The number field in this section is enabled.

9. Type **7000** in the **Define Average Fly Height** number field of the **Set Frame-Specific Information** section, then press Enter.

10. Click **OK** to close the Block Property Setup dialog.
The main IMAGINE OrthoBASE dialog opens.

The Main IMAGINE OrthoBASE Dialog

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

The Row # column enables you to select an image specifically for use with IMAGINE 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 if you wish.

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 IMAGINE OrthoBASE processes such as automatic tie point generation, triangulation, and orthorectification.

The final five columns’ status is indicated in terms of color: green means the process is complete and accurate; red means the process is incomplete.

The Pyr. column indicates the presence of pyramid layers. The Int. column indicates if the fiducial marks have been measured. The Ext. column indicates if the final exterior orientation parameters are complete. The Ortho column indicates if the images have been orthorectified. The Online column indicates if the images have a specified location.
Now that you have provided general information about the block, you can add images and define the camera model.

**Add Imagery to the Block**

Add Images to the IMAGINE OrthoBASE Project

1. Select **Edit | Add Frame** from the IMAGINE OrthoBASE menu bar, or click the Add Frame icon.

   ![Add Frame Icon]

   The Image File Name dialog opens.

2. From the filename list, select **col90p1.img**.

   The file **col90p1.img** is located in the `<IMAGINE_HOME>/examples/orthobase/frame` directory, where `<IMAGINE_HOME>` is the location of ERDAS IMAGINE on your system.

3. Click the **Add Options** tab.

   The options for adding images to your block file display.

4. Click the **Add Selected File Plus** radio button.

   The **Files Matching** text field is enabled.

5. In the text field, enter `*.p1.img`.

   ![Image File Name Dialog]

   `Click OK to add images to the block file`
By entering the * in front of p1.img, IMAGINE OrthoBASE selects all images in the directory with the common element p1.img. In this case, col90p1.img, col91p1.img, and col92p1.img are selected and added to the block file.

6. Click OK to close the Image File Name dialog.

The three frame image files are loaded into IMAGINE OrthoBASE and display in the CellArray.

**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 the **Compute Pyramid Layers** option.

   The Compute Pyramid Layers dialog opens.

   ![Compute Pyramid Layers dialog](image)

   - **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** option is chosen.

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

   A progress bar displays at the bottom of the main IMAGINE OrthoBASE dialog 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, as well as the exterior orientation information of the camera that collected the images.

**Enter Specific Camera Information**

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

The Frame Editor dialog opens, displaying information about the current image listed in the IMAGINE OrthoBASE CellArray, indicated with the >.
Define the Camera Model

2. Next to **Sensor Name**, 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.
**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 CellArray:

<table>
<thead>
<tr>
<th>Row #</th>
<th>Film X (mm)</th>
<th>Film Y (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-103.947</td>
<td>-103.952</td>
</tr>
<tr>
<td>2</td>
<td>103.945</td>
<td>103.924</td>
</tr>
<tr>
<td>3</td>
<td>-103.937</td>
<td>103.927</td>
</tr>
<tr>
<td>4</td>
<td>103.958</td>
<td>-103.952</td>
</tr>
<tr>
<td>5</td>
<td>-112.996</td>
<td>-0.005</td>
</tr>
<tr>
<td>6</td>
<td>112.990</td>
<td>-0.015</td>
</tr>
<tr>
<td>7</td>
<td>0.003</td>
<td>113.001</td>
</tr>
<tr>
<td>8</td>
<td>0.026</td>
<td>-112.971</td>
</tr>
</tbody>
</table>
Define the Camera Model

When you are finished, the CellArray looks like the following:

![CellArray Diagram]

NOTE: Radial lens distortion is not specified in this tour guide.

4. Click OK to close the Camera Information dialog. The Frame Editor dialog opens.

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 Editor dialog.

The tools for setting up the image’s interior orientation information display.

![Frame Editor Diagram]

NOTE: The fiducial marks displayed in this tour guide are shown in different colors to enable you to see them better. By default, fiducial marks are added to the Viewers in green.
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.

3. Click the Viewer icon.

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

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

4. Click in the center of the Link Cursor 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.

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 Image X and Image Y coordinates, and the display automatically moves to the approximate location of the next fiducial.
If you wish, you can click the Lock tool to lock the Place Image Fiducial icon. This means that you can use the tool repeatedly without having to select it each time you measure a fiducial in the image.


NOTE: Rather than crosshairs, 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 Editor) should usually be less than 0.33 pixels.
Define the Camera Model

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 Selection tool , then reposition the fiducial mark in the Detail View.

8. Click on the Viewer icon to dismiss the views.

Enter Exterior Orientation Information

1. Click the Exterior Information tab on the Frame Editor dialog.
2. Enter the following information in the Value number fields. These values correspond to the image col90p1.
3. Click to select the Set Status checkbox.

4. Click the Set Status dropdown list and choose Initial.

When you are finished, the Exterior Information tab of the Frame Editor dialog looks like the following:

```
<table>
<thead>
<tr>
<th>Value</th>
<th>Xo</th>
<th>Yo</th>
<th>Zo</th>
<th>Omega</th>
<th>Phi</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>666700.000</td>
<td>115900.000</td>
<td>8800.000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>90.0000</td>
<td></td>
</tr>
</tbody>
</table>
```

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 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 Editor dialog.

   The Image File Name on the Sensor tab changes to the next image, **col91p1**, in the IMAGINE OrthoBASE CellArray.
3. Note that the camera displayed, **Zeiss RMK A 15/23**, is the same as that entered for the first image.

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

5. Click on the Viewer icon to open the views.

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

   *If you need assistance, refer to “Measuring Fiducials for the Image” on page 65.*

Once you have finished measuring the eight fiducials in the **col91p1** image, the RMSE is reported.
7. Click the Viewer icon to close the views.

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

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

<table>
<thead>
<tr>
<th></th>
<th>Xo</th>
<th>Yo</th>
<th>Zo</th>
<th>Omega</th>
<th>Phi</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>666700.000</td>
<td>119400.000</td>
<td>8800.000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>90.0000</td>
</tr>
</tbody>
</table>

10. Click to select the **Set Status** checkbox.

11. Click the **Set Status** dropdown list and choose **Initial**.

12. Click the **Sensor** tab.
13. Click the **Next** button on the Frame Editor dialog to advance to the final image in the block file, `col92p1`.

14. Click the **Interior Orientation** tab.

15. Click the Viewer icon to open the views.

16. Measure the fiducial marks in the third image, `col92p1`.

   If you need assistance, refer to “Measuring Fiducials for the Image” on page 65.
17. After fiducials for the third image have been measured, click the **Exterior Information** tab.

18. Enter the following information in the **Value** number fields, which corresponds to the last image in the block file, **col92p1**.

<table>
<thead>
<tr>
<th></th>
<th>Xo</th>
<th>Yo</th>
<th>Zo</th>
<th>Omega</th>
<th>Phi</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>666800.000</td>
<td>122900.000</td>
<td>8800.000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>90.0000</td>
</tr>
</tbody>
</table>

19. Click to select the **Set Status** checkbox.

20. Click the **Set Status** dropdown list and choose **Initial**.

21. Click **OK** to close the Frame Editor dialog.

Note that the **Int.** column of the main IMAGINE OrthoBASE dialog is green, indicating that the interior information has been specified.
An alternate method to the one presented here is to process each element completely (i.e., identify all the sensors, measure all of the fiducials, then input all of the exterior orientation information).

**Measure Ground Control and Check Points**

Now that you have measured the fiducials and provided exterior orientation of each image that makes up the block, you are ready to use the Point Measurement Tool to measure the position of ground control points, tie points, and check points in the images.

1. Select **Edit | Point Measurement** from the main IMAGINE OrthoBASE dialog menu bar.

   You can also click the Point Measurement icon on the IMAGINE OrthoBASE tool bar to open this dialog.

   The Point Measurement dialog opens.
NOTE: The GCPs displayed in this tour guide are shown in different colors to enable you to see them better. Therefore, Color columns were added to the Reference CellArray and the File CellArray to enable color selection. By default, ground control points are added to the Viewers in green, and the Color columns do not display.

To change the color of control points, click the Viewing Properties icon to access the Point Table Info dialog. Click the Advanced button, then the Color button, then OK. This adds a Color column to the Reference CellArray and the File CellArray. You can then left-click to select the color you want.

The Point Measurement dialog consists of a Tool Palette, a Reference CellArray and a File CellArray, and six Viewers in two groups that display different views of two of the IMAGINE OrthoBASE image files. 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 Palette, 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 IMAGINE OrthoBASE in your own work, you might have a photo overview of an area along with other sources of information for location of 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 IMAGINE OrthoBASE to collect and record the position. Then, you check the overview photograph 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.

NOTE: The minimum amount is three vertical GCPs and two horizontal GCPs per photo. If you use the auto tie function, you can collect fewer GCPs.

Triangulation ties the images together so that they can then be orthorectified and linked together. Accurate control points ensure successful triangulation and orthorectification.

If, during this exercise, you want to check the accuracy of the control points you collect in the block file images, refer to “Appendix A: Frame Camera Tour Guide Control and Check Point Coordinates” on page 195 for the exact coordinates.

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

This adds a new row to the Reference CellArray in the lower portion of the Point Measurement Tool.
Frame Camera Tour Guide

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 popup list.

2. Select **Full** from the popup list.

   A **Full** GCP has X, Y, and Z (elevation) coordinates.

3. Click in the **Usage** column to access the popup list.

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

   **Control** denotes a control point.

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

**Collect Point ID 1002 in col90p1**

The following graphic is a reference photo that 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.
The following graphic is an example of the type of sketch produced in the field that you might use to locate the precise location of a point. Also included is a Detail View of Point ID 1002.
Frame Camera Tour Guide

1. Make sure that the Select Point icon is active in the Point Measurement Tool Palette.

2. Using Figure 3-1 on page 79 as a guide, move the Link Cursor in the Over View window 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 Cursor as necessary in the views.

4. Click the Create Point icon in the Point Measurement Tool Palette.

5. Using Figure 3-2 on page 80 as a guide, click in the Detail View to place control point 1002.

The point is placed in the views and labeled 1002. The File CellArray reflects the coordinates of the point.
Collect Point ID 1002 in col91p1

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

The following graphic is a reference photo 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 3-3 on page 82 as a guide, apply the Select Point and Create Point tools to collect **Point ID 1002** in the second image, **col91p1**.

2. Turn to "Appendix A: Frame Camera Tour Guide Control and Check Point Coordinates" on page 195 and check your results against the **X File** and **Y File** coordinates for **Point ID 1002**.
3. If your X File and Y File coordinates do not match those in the Appendix 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.

Instead of typing in values, you are going to collect reference control points from a Viewer in “CHAPTER 5: SPOT Pushbroom Sensor Tour Guide” on page 145.

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 Palette.

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 Palette 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 popup list.

2. Select Full from the popup list.

3. Click in the Usage column to access the popup list.

4. Select Control from the popup list.

**Collect Point ID 1003 in col90p1**

The following graphic is an example of the type of sketch produced in the field that you would use to identify the precise location of a point. Also included is a 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 3-1 on page 79 as a guide, move the Link Cursor in the Over View window 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 Cursor as necessary in the views.

4. Click the Create Point icon in the Point Measurement Tool Palette.
5. Using Figure 3-4 on page 84 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 photo 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 in the right three views (the Right View in the Point Measurement dialog).

1. Check Figure 3-3 on page 82 to locate the position of Point ID 1003 in the reference photo.

2. Use the Select Point and Create Point tools 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 dialog. 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. 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 Palette, click on the Right View dropdown list.
2. From the **Right View** dropdown list, click to select `col92p1`.

   The third image, `col92p1`, is displayed in the right three Viewers.

3. Using Figure 3-5 on page 86, locate **Point ID 1003** in the reference photo.

4. Use the Select Point and Create Point tools to collect **Point ID 1003** in the third image, `col92p1`.

5. Turn to "Appendix A: Frame Camera Tour Guide Control and Check Point Coordinates" on page 195 and check your results against the **X File** and **Y File** coordinates for **Point ID 1003**.

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

   **Enter Reference Coordinates for Point ID 1003**

   Since you have successfully located **Point ID 1003** in the three images, `col90p1`, `col91p1`, and `col92p1`, you are ready to enter the reference control point coordinates.

1. Click in the **X Reference** column corresponding to **Point ID 1003**.

2. Type the value **664456.22** in the **X Reference** column.

3. Click in the **Y Reference** column corresponding to **Point ID 1003**.

4. Type the value **119052.15** in the **Y Reference** column.

5. Click in the **Z Reference** column corresponding to **Point ID 1003**.

6. Type the value **1988.820** in the **Z Reference** column, then press Enter on your keyboard.

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

   When you have finished, the Point Measurement dialog looks like the following:
Frame Camera Tour Guide

The point is placed in the same position in all three images.

**Set Automatic (x, y) Drive Function**

IMAGINE OrthoBASE provides some automatic functions to enable you to select GCPs more rapidly. One such function is the Automatic (x, y) Drive function.

1. Click the Automatic (x, y) Drive icon.

The icon changes to:

Using the Automatic (x, y) Drive function, IMAGINE OrthoBASE approximates the location of the point in the second image based on the placement in the first image.
Collect Point ID 1004

If you are comfortable with the control point collection process, you can simply refer to the reference sketches and Detail Views of **Point IDs 4 through 6**, making note of the images they are located in, to collect the points. Then, progress to “Input Check Points” on page 95.

**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 Viewers; **col92p1** is displayed in the right three Viewers.

2. Click the **Add** button in the upper right-hand corner of the Point Measurement Tool Palette 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 popup list.
   2. Select **Full** from the popup list.
   3. Click in the **Usage** column to access the popup list.
   4. Select **Control** from the popup list.

**Collect Point ID 1004 in col91p1**

The following graphic is an example of the type of sketch produced in the field that you would use to locate the precise position of a point. Also included is a Detail View of **Point ID 1004**.

![Figure 3-6 Reference Sketch and Detail View of Point ID 1004](image)

1. Make sure that the Select Point icon is active in the Point Measurement Tool Palette.
2. Using Figure 3-3 on page 82 as a guide, move the Link Cursor in the Over View window 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 Cursor as necessary in the views.

4. Click the Create Point icon in the Point Measurement Tool Palette.

5. Using Figure 3-6 on page 89 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 photo 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 dialog).

1. Check Figure 3-5 on page 86 to locate the position of **Point ID 1004** in the reference photo.

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

3. Turn to "Appendix A: Frame Camera Tour Guide Control and Check Point Coordinates" on page 195 and check your results against the X File and Y File coordinates for **Point ID 1004**.

4. If your X File and Y File coordinates do not match those in the Appendix within two pixels, type the correct values into the File CellArray.

**Enter Reference Coordinates for Point ID 1004**

Since you have successfully located **Point ID 1004** in the images **col91p1** and **col92p1**, you are ready to enter the reference control point coordinates.

1. Click in the X Reference column corresponding to **Point ID 1004**.

2. Type the value **668150.61** in the X Reference column.

3. Click in the Y Reference column corresponding to **Point ID 1004**.
4. Type the value **122404.68** in the **Y Reference** column.

5. Click in the **Z Reference** column corresponding to **Point ID 1004**.

6. Type the value **1972.056** in the **Z Reference** column, then press Enter on your keyboard.

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

---

**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**). 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 Palette 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 popup list.

2. Select **Full** from the popup list.

3. Click in the **Usage** column to access the popup list.

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

---

**Collect Point ID 1005 in col90p1**

The following graphic provides you with a sketch as well as a Detail View of the location of **Point ID 1005**.

---

**Figure 3-7 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.
Frame Camera Tour Guide

2. Using Figure 3-1 on page 79 as a guide, move the Link Cursor in the Over View window 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 Cursor as necessary in the views.

4. Click the Create Point icon in the Point Measurement Tool Palette.

5. Using Figure 3-7 on page 91 as a guide, click in the Detail View to place control point 1005.

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

**Collect Point ID 1005 in col91p1**

1. Check Figure 3-3 on page 82 to locate the position of **Point ID 1005** in the reference photo.

2. Use the Select Point and Create Point tools 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. Using Figure 3-5 on page 86, locate the position of **Point ID 1005** in the reference photo.

3. Use the Select Point and Create Point tools to collect **Point ID 1005** in the third image, **col92p1**.

4. Turn to "Appendix A: Frame Camera Tour Guide Control and Check Point Coordinates" on page 195 and check your results against the **X File** and **Y File** coordinates for **Point ID 1005**.

5. If your **X File** and **Y File** coordinates do not match those in the Appendix within two pixels, type the correct values into the File CellArray.

**Enter Reference Coordinates for Point ID 1005**

Since you have successfully located **Point ID 1005** in the images **col90p1**, **col91p1** and **col92p1**, you are ready to enter the reference control point coordinates.

1. Click in the **X Reference** column corresponding to **Point ID 1005**.

2. Type the value **668338.22** in the **X Reference** column.

3. Click in the **Y Reference** column corresponding to **Point ID 1005**.

4. Type the value **118685.9** in the **Y Reference** column.

5. Click in the **Z Reference** column corresponding to **Point ID 1005**.
6. Type the value \(1886.712\) in the **Z Reference** column, then press Enter on your keyboard.

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

**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 Palette 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 popup list.
2. Select **Full** from the popup list.
3. Click in the **Usage** column to access the popup list.
4. Select **Control** from the popup list.

**Collect Point ID 1006 in col90p1**

The following graphic provides you with a sketch as well as a Detail View of the location of **Point ID 1006**.

![Reference Sketch and Detail View of Point ID 1006](image)

**Figure 3-8 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 3-1 on page 79 as a guide, move the Link Cursor in the Over View window 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 Cursor as necessary in the views.
4. Click the Create Point icon in the Point Measurement Tool Palette.
5. Using Figure 3-8 on page 93 as a guide, click in the Detail View to place control point **1006**.
Frame Camera Tour Guide

Collect Point ID 1006 in col91p1
1. Check Figure 3-3 on page 82 to locate the position of Point ID 1006 in the reference photo.
2. Use the Select Point and Create Point tools 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. Using Figure 3-5 on page 86, locate the position of Point ID 1006 in the reference photo.
3. Use the Select Point and Create Point tools to collect Point ID 1006 in the third image, col92.p1.
4. Turn to "Appendix A: Frame Camera Tour Guide Control and Check Point Coordinates" on page 195 and check your results against the X File and Y File coordinates for Point ID 1006.
5. If your X File and Y File coordinates do not match those in the Appendix within two pixels, type the correct values into the File CellArray.

Enter Reference Coordinates for Point ID 1006
Since you have successfully located Point ID 1006 in the images col90p1, col91p1, and col92p1, you are ready to enter the reference control point coordinates.
1. Click in the X Reference column corresponding to Point ID 1006.
2. Type the value 670841.48 in the X Reference column.
3. Click in the Y Reference column corresponding to Point ID 1006.
4. Type the value 118696.89 in the Y Reference column.
5. Click in the Z Reference column corresponding to Point ID 1006.
6. Type the value 2014.0 in the Z Reference column, then press Enter on your keyboard.
7. When you are finished, click Save in the Point Measurement Tool Palette.

The point is placed in all three images. When you are finished selecting the control points and entering reference coordinates into the CellArrays, they look like the following.
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.

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 Palette 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 popup list.
2. Select **Full** from the popup list.
3. Click in the **Usage** column to access the popup list.
4. Select **Check** from the popup list.

**Collect Point ID 2001 in col90p1**

The following graphic provides you with a sketch as well as a Detail View of the location of **Point ID 2001**.

---

### Input Check Points

<table>
<thead>
<tr>
<th>Point ID</th>
<th>Description</th>
<th>Type</th>
<th>Usage</th>
<th>Active</th>
<th>X Reference</th>
<th>Y Reference</th>
<th>Z Reference</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>1002</td>
<td></td>
<td>Full</td>
<td>Control</td>
<td>X</td>
<td>665239.855</td>
<td>115912.242</td>
<td>1947.672</td>
<td></td>
</tr>
<tr>
<td>1003</td>
<td></td>
<td>Full</td>
<td>Control</td>
<td>X</td>
<td>66449.620</td>
<td>115902.155</td>
<td>1986.630</td>
<td></td>
</tr>
<tr>
<td>1004</td>
<td></td>
<td>Full</td>
<td>Control</td>
<td>X</td>
<td>668139.070</td>
<td>118985.908</td>
<td>1986.712</td>
<td></td>
</tr>
<tr>
<td>1005</td>
<td></td>
<td>Full</td>
<td>Control</td>
<td>X</td>
<td>64639.220</td>
<td>118936.850</td>
<td>2014.000</td>
<td></td>
</tr>
</tbody>
</table>

*Each Point ID has two or more sets of File coordinates associated with it*
Figure 3-9 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 3-1 on page 79 as a guide, move the Link Cursor in the Over View window 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 Cursor as necessary in the views.

4. Click the Create Point icon in the Point Measurement Tool Palette.

5. Using Figure 3-9 on page 96 as a guide, click in the Detail View to place check point 2001.

Collect Point ID 2001 in col91p1

1. Check Figure 3-3 on page 82 to locate the position of Point ID 2001 in the reference photo.

2. Use the Select Point and Create Point tools to collect Point ID 2001 in the second image, col91p1.

3. Turn to "Appendix A: Frame Camera Tour Guide Control and Check Point Coordinates" on page 195 and check your results against the X File and Y File coordinates for Point ID 2001.

4. If your X File and Y File coordinates do not match those in the Appendix within two pixels, type the correct values into the File CellArray.

Enter Reference Coordinates for Point ID 2001

Since you have successfully located Point ID 2001 in the images col90p1 and col91p1, you are ready to enter the reference check point coordinates.

1. Click in the X Reference column corresponding to Point ID 2001.

2. Type the value 670970.45 in the X Reference column.

3. Click in the Y Reference column corresponding to Point ID 2001.

4. Type the value 114815.23 in the Y Reference column.
5. Click in the **Z Reference** column corresponding to **Point ID 2001**.

6. Type the value **1891.888** in the **Z Reference** column, then press Enter on your keyboard.

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

---

**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 Palette 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 popup list.

   2. Select **Full** from the popup list.

   3. Click in the **Usage** column to access the popup list.

   4. Select **Check** from the popup list.

---

**Collect Point ID 2002 in col91p1**

The following graphic provides you with a sketch as well as a Detail View of the location of **Point ID 2002**.

![Reference Sketch and Detail View of Point ID 2002](image)

---

**Figure 3-10 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 3-3 on page 82 as a guide, move the Link Cursor in the Over View window 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 Cursor as necessary in the views.

4. Click the Create Point icon in the Point Measurement Tool Palette.

5. Using Figure 3-10 on page 97 as a guide, click in the Detail View to place check point 2002.

**Collect Point ID 2002 in col92p1**

1. Check Figure 3-5 on page 86 to locate the position of **Point ID 2002** in the reference photo.

2. Use the Select Point and Create Point tools to collect **Point ID 2002** in the third image, col92p1.

3. Turn to "Appendix A: Frame Camera Tour Guide Control and Check Point Coordinates" on page 195 and check your results against the X File and Y File coordinates for **Point ID 2002**.

4. If your X File and Y File coordinates do not match those in the Appendix within two pixels, type the correct values into the File CellArray.

**Enter Reference Coordinates for Point ID 2002**

Since you have successfully located **Point ID 2002** in the images col91p1 and col92p1, you are ready to enter the reference check point coordinates.

1. Click in the X Reference column corresponding to **Point ID 2002**.

2. Type the value **671408.73** in the X Reference column.

3. Click in the Y Reference column corresponding to **Point ID 2002**.

4. Type the value **123166.52** in the Y Reference column.

5. Click in the Z Reference column corresponding to **Point ID 2002**.

6. Type the value **1983.762** in the Z Reference column, then press Enter on your keyboard.

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

When you are finished, the Point Measurement dialog looks like the following:
Perform Automatic Tie Point Collection

The tie point collection 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, click the Automatic Tie Point Collection Properties icon.

The Automatic Tie Point Generation Properties dialog opens.

<table>
<thead>
<tr>
<th>Point ID</th>
<th>Description</th>
<th>Usage</th>
<th>X Reference</th>
<th>Y Reference</th>
<th>Z Reference</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Full Center</td>
<td>x</td>
<td>664.456.330</td>
<td>1196.2.150</td>
<td>1988.5.9</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Full Center</td>
<td>x</td>
<td>668.58.615</td>
<td>1224.4.800</td>
<td>1972.95</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Full Center</td>
<td>x</td>
<td>668.35.220</td>
<td>1180.0.000</td>
<td>1966.10</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Full Center</td>
<td>x</td>
<td>673.94.480</td>
<td>11806.800</td>
<td>2014.00</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Full Center</td>
<td>x</td>
<td>678.75.490</td>
<td>11481.230</td>
<td>991.805</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Full Check</td>
<td>x</td>
<td>671.49.750</td>
<td>12116.150</td>
<td>1983.70</td>
<td></td>
</tr>
</tbody>
</table>

All of the Point IDs are listed in the Reference CellArray.

Check points are designated in the Usage column.

Images containing the point display here. Not all images contain all points.
2. Check to confirm that the **Images Used** option is set to **All available**.

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

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

5. 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. In the case of this data set, you should get 24 generated tie points.

6. Check to confirm that the **Keep All Points** option is off (unchecked).

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

   IMAGINE OrthoBASE starts the automatic tie point generation process, indicated by a progress bar, and displays the tie points in the Point Measurement dialog when complete. The tie points have the **Type** designation **None**, and the **Usage** designation **Tie**. They are added to the Reference CellArray with the 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 always adjust it with the Select Point tool or delete it by selecting the row in the CellArray and clicking the **Delete** button.

1. In the Reference CellArray, click the scroll bar and scroll to any point, such as **Point ID 2022**.

2. Click in the **>`** column to display **Point ID 2022**.

   The point displays in the Viewers. This appears to be an acceptable tie point.
3. Click in the > column of other **Point IDs** 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 Viewers. 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, click the **Save** button.

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

   You are returned to the main IMAGINE OrthoBASE dialog.
Perform Aerial Triangulation

Now that you have obtained control, check, and tie points, IMAGINE 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.

1. From the Edit menu of the main IMAGINE OrthoBASE dialog, select Triangulation Properties.

The Aerial Triangulation dialog opens.

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

The Point options display. These control the statistical weights assigned to the GCP parameters. These are commonly reflected by the precision of the GCPs (i.e., the reference source).
3. In the **Ground Point 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 is generated and opened.

---

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

In the report above, the **standard error** is **.2831**. 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**.

The control point X, Y and Z residuals define the precision quality 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.
These are the photo or image coordinate residuals. They can be used to determine the less accurate points. These 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, select **Save As**.

   The Save As dialog opens.

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

3. In the **File name** text box, 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**.

   You are returned to the Triangulation Summary dialog.

   

   To open the Triangulation Report in ERDAS IMAGINE, click the **Tools** menu on the main ERDAS IMAGINE tool bar. Then, select **Edit Text Files**. Use the Open icon to open the report in the 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 exterior orientation parameters you entered during the measurement of fiducials with the exterior orientation computed by IMAGINE OrthoBASE based on control and tie points in the images making up the block file.

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 main IMAGINE OrthoBASE dialog is updated to reflect the completion of the exterior orientation step. Notice that the **Ext.** column is now green.
The next step creates orthorectified images of your block file images. Orthorectified images have fewer relief displacements and geometric errors than non-orthorectified images, and thus are considered more accurate. The orthorectified images display objects in their real-world X, Y, and Z positions.

1. In the main IMAGINE OrthoBASE dialog, click the Ortho Resampling icon.

The Ortho Resampling dialog opens.
2. Click to select the **Multiple Output** option.

3. Click the Open icon, then navigate to a directory where you have write permission.

4. Confirm that the prefix `ortho` is in the **File name** field.

5. Click **OK** to accept the `ortho` prefix.

6. Click to select the **DEM File** option.

7. Click the Open icon and navigate to the `<IMAGINE_HOME>/examples/orthobase/frame` directory.

8. Select `colspr_dem.img` as the **DEM File**.

9. Click **OK** in the File Chooser dialog.

10. Confirm that the **Elevation Units** are set to **Meters**.
11. Click the **Resample Method** dropdown list and select **Nearest Neighbor**.

12. Click in the **Output Cell Sizes** section and change the X and the Y values to **4.0**.

13. Click **OK** in the Ortho Resampling dialog.

   A status dialog opens, tracking the ortho resampling process.

14. When the status dialog is 100% complete, click the **OK** button to dismiss it.

---

**Check the Ortho Resampled Images**

Now that the images have been ortho resampled, you can check how well they fit together in a Viewer.

1. From the main ERDAS IMAGINE tool bar, click the Viewer icon.

   ![Viewer](image)

   A Viewer opens in the workspace.

2. Click the Open icon to access the Select Layer To Add dialog.

3. Navigate to the directory in which you saved the orthorectified images.

4. Click to select the image **orthocol90p1.img**.

5. Click the **Raster Options** tab.

6. Deselect the **Clear Display** option.

7. Click to select the **Fit to Frame** and **Background Transparent** options.

8. Click **OK** in the Select Layer To Add dialog.

9. Repeat step 2. through step 8. in the same Viewer, selecting the files **orthocol91p1.img** and **orthocol92p1.img**.

   The images are displayed in the Viewer. You can see where they overlap.
Magnify Areas of Overlap

Now, you can check the areas of overlap to see how well IMAGINE 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 tool as many times as necessary to see the portion of overlap clearly in the Viewer.

You can see that IMAGINE 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 roads to the left and right of the side fiducial match very well.
Use the Swipe Tool

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 to select 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 overlaps the others.

   The edge of the image can be seen here, indicated by the side fiducial mark.

   This road is common to both images, and matches very well.
Orthorectify the Imagery

If you wish, you can also choose the **Horizontal** option from the Viewer Swipe dialog.

6. When you are finished, click **Cancel** in the Viewer Swipe dialog.

7. Once you are done examining the orthoimage, choose **File | Close** from the Viewer menu bar.

**Save and Close the Block File**

1. Now that you have verified the accuracy of the IMAGINE OrthoBASE output, in the main IMAGINE OrthoBASE dialog, click the **File** menu, then select **Save**.

Notice that all of the columns are green, indicating that all of the process steps have been executed.

2. To exit IMAGINE OrthoBASE, choose **File | Close** from the main IMAGINE OrthoBASE dialog.
Frame Camera Tour Guide
CHAPTER 4
Digital Camera Tour Guide

Introduction

With the IMAGINE OrthoBASE software, 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.

The data sets you use with this tour guide come from southeast Spain. The data is 1:45,000 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 IMAGINE OrthoBASE project
• Add imagery to the block file
• Define the camera model
• Use the automatic tie point collection function
• Triangulate the images
• Orthorectify the images
• Save the block file

Create a New IMAGINE OrthoBASE Project

In this section of the tour guide, you create a new IMAGINE OrthoBASE project using three digital camera images of southeast Spain.

Prepare the Block File

1. Start ERDAS IMAGINE.
2. Close the Viewer that automatically opens when starting ERDAS IMAGINE.
3. Click the OrthoBASE icon on the ERDAS IMAGINE icon panel.
Digital Camera Tour Guide

The IMAGINE OrthoBASE Startup dialog opens.

4. Confirm that the radio button next to **Create a new OrthoBASE project** is active.

5. Click **OK** to close the OrthoBASE Startup dialog.

The Create New Block File dialog opens.

6. Navigate to a directory in which you have write permission.

7. Next to **File name**, type **digital_tour.blk**, then press Enter on your keyboard.

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

The Model Setup dialog opens.
Create a New IMAGINE OrthoBASE Project

Select Geometric Model

1. Click to select the Digital Camera geometric model.
2. Click OK in the Model Setup dialog.

   The Block Property Setup dialog opens.

Define Block Properties

1. In the Set Reference System section of the Block Property Setup dialog, click to select the Set Projection button.

   The Projection Chooser dialog opens.

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.
Digital Camera Tour Guide

6. Type **30** in the **UTM Zone** field.

7. Confirm that the **NORTH or SOUTH** dropdown list shows **North**.

8. Click **OK** in the Projection Chooser dialog.

9. Click the **Next** button in the Block Property Setup dialog.

   The **Reference Units** section of the Block Property Setup dialog opens.

   ![Image of Block Property Setup dialog]

10. Confirm that both the **Horizontal Units** and the **Vertical Units** are set to **Meters**.

11. Confirm that the **Angle Units** are set to **Degrees**.

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

   The **Set Frame-Specific Information** section of the Block Property Setup dialog opens.

   ![Image of Block Property Setup dialog]

**Import Exterior Orientation Parameters**

When these images were acquired, the position of the aircraft was recorded using Airborne GPS and INS technology. The Airborne GPS provides positional information concerning where the camera/sensor is at the time of image capture. The INS provides orientation information (i.e., omega, phi, and kappa) concerning where the camera/sensor is at the time of image capture.

The accuracy of the measurements is to 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.
Create a New IMAGINE OrthoBASE Project

The Import ASCII File Name dialog opens.

2. Navigate to the <IMAGINE_HOME>/examples/orthobase/digital directory.
3. Click to 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.

*NOTE: If the information does not match, the projection, spheroid, datum, and units must be changed so that they do conform. You can use the **Set** button to specify the correct map projection.*
4. Click **OK** in the Import Parameters dialog.

The Import Options dialog opens.

5. In the **Field Definition** tab of the Import Options dialog, click the **Row Terminator Character** dropdown list.

6. Select **Return NewLine (DOS)** from the dropdown list.

7. Click the **Input Preview** tab on the Import Options dialog.
8. 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 and saved by IMAGINE OrthoBASE.

9. Click **OK** in the Block Property Setup dialog to complete block setup.

**Add Imagery to the Block**

The main IMAGINE OrthoBASE dialog is displayed. The **Image Name** field is filled out for you. This is based on the information contained in the .dat file that you selected during the Import Exterior Orientation process.

To begin, the images need to be Online. **Online** means that the image name is attached and linked to the corresponding images file, which may be located on the hard drive or the network.
Digital Camera Tour Guide

1. Click on the **Online** row associated with **digcam1**.
   The Frame Editor opens.

![Frame Editor](image1)

*Click the Attach button to attach the image name to the image file*

2. In the Frame Editor dialog, click the **Attach** button.
   The Image File Name dialog opens. Now, you select the files in the block.

3. Navigate to the `<IMAGINE_HOME>/examples/orthobase/digital` directory.

4. Click the **Files of type** dropdown list and select **TIFF (*.tif)**.

![Image File Name](image2)

*Select the first file in the block*

5. Click to select the file **digcam1.tif**.

6. Click the **Attach Options** tab in the Image File Name dialog.
7. In the **Attach Options** tab, click the **Attach selected file plus** option.

8. Type `dig*.tif` in the **Files Matching** field.

9. Click **OK** in the Image File Name dialog.

10. Click **OK** in the Frame Editor dialog.

You are returned to the main IMAGINE OrthoBASE dialog. The images’ rows in the **Online** column are now green, indicating that the files in the `<IMAGINE_HOME>/examples/orthobase/digital` directory have been matched with the three image files specified in the .dat file.

The complete path name is now listed in the Image Name section of the main IMAGINE OrthoBASE dialog.
Digital Camera Tour Guide

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 the **Compute Pyramid Layers** option.

   The Compute Pyramid Layers dialog opens.

   ![Compute Pyramid Layers dialog](image)

   **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** option is chosen.

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

   A progress bar displays at the bottom of the main IMAGINE OrthoBASE dialog as pyramid layers are created. When complete, the images’ rows corresponding to the **Pyr.** column are all green.

   ![Pyramid layers](image)

   **Now, the images have pyramid layers, indicated by the green Pyr. column**

Define the Camera Model

Since you have identified the images to be used in the block file, now you need to define the camera model that is going to be used by IMAGINE OrthoBASE.
Define the Camera Model

Enter Specific Camera Information

1. In the main IMAGINE OrthoBASE dialog, click to select the Frame Properties icon.

   The Frame Editor dialog opens.

2. Click to select the New button in the Frame Editor dialog.

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.

6. Confirm that the Principal Point \( xo \) and the Principal Point \( yo \) values are set to 0.0000.

When you have finished, the Camera Information dialog looks like the following:

Save the Camera Information

1. Click the Save button to save the camera model information.

   The Camera Parameter File Name dialog opens.
2. Navigate to a directory where you have write permission.

3. Type the name `kodak_dcs420` in the File name field, then press Enter on your keyboard. The .cam extension is automatically appended for you.

4. Click **OK** in the Camera Parameter File Name dialog.

5. Click **OK** in the Camera Information dialog.

   You are returned to the Frame Editor dialog. The camera information you supplied is located in the Sensor Name section of the dialog.

---

Apply Camera Information to the Other Images

1. Click the **Next** button to display the information for `digcam2`. 
Define the Camera Model

2. Note that the **Sensor Name** dropdown list shows **Kodak DCS 420 Digital Camera**.
3. Click the **Next** button to display the information for **digcam3**.
4. Note that the **Sensor Name** dropdown list shows **Kodak DCS 420 Digital Camera**.
5. Click **Previous** twice to return to **digcam1**.

**Enter Interior Orientation Information**

1. In the Frame Editor, click the **Interior Orientation** tab.
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.
4. Click the **Next** button twice to see that the same interior orientation information is transferred to **digcam2** and **digcam3**.
5. Click **Previous** twice to return to **digcam1**.

When you have finished, the **Interior Orientation** tab looks like the following. The 9.0-micron pixel size has been applied to each image in the block file.

[Diagram showing Interior Orientation Information]

**Enter Exterior Orientation Information**

1. Click the **Exterior Information** tab in the Frame Editor dialog.

The information is already supplied for you. It comes from the .dat file you selected during the Import Exterior Orientation process on page 118.
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*.

4. Click **OK** to close the Frame Editor dialog.

   You are returned to the main IMAGINE OrthoBASE dialog. Note that the **Int.** column for all of the files is green, indicating that the interior orientation has been supplied.

The exterior information needed to define the Perspective Center and Rotation Angle values is contained in the .dat file.

Interior information has been supplied
Perform Automatic Tie Point Collection

Generally at this point in the process you collect control points in overlapping areas of the block file that help to determine the approximate exterior orientation parameters. Because this data set 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. In the main IMAGINE OrthoBASE dialog, click to select the Point Measurement icon.

The Point Measurement Tool dialog 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 dropdown list to see the third image in the block file, digcam3, as well. Now, you are going to initiate the auto tie process.
NOTE: The tie points displayed in this tour guide are shown in different colors to enable you to see them better. Therefore, a Color column has been added to the Reference CellArray and the File CellArray. By default, tie points are added to the Viewers in green, and there is no Color column.

To change the color, click the Viewing Properties icon to access the Point Table Info dialog. Click the Advanced button, then the Color button, then OK. This adds a Color column to the Reference CellArray and the File CellArray.

2. In the Point Measurement Tool Palette, click to select the Auto Tie Properties icon.

The Automatic Tie Point Generation Properties dialog opens.
Perform Automatic Tie Point Collection

3. Double-click in the **Intended Number of Points Per Image** field, and type 50, then press Enter.

   This produces approximately 50 tie points per image.


   A progress bar displays at the bottom of the Point Measurement Tool dialog. When the process is complete, the tie points display in the views, and their corresponding file coordinates display in the File CellArray.

Check Tie Point Accuracy

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 corresponding tie points. In such cases, verify the tie point by opening a different adjacent image in one of the Viewers. To do so, use the **Left View** or **Right View** dropdown list.
2. Click other **Point #s** 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 main IMAGINE OrthoBASE dialog.

---

**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 main IMAGINE OrthoBASE dialog, 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.

   The precision quality of the exterior orientation parameters can be derived.

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**.

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 mismeasured tie points from the solution.

10. Click to deselect **Use Image Observations of Check Points in Triangulation**.
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 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.
To improve the triangulation results, you can look through the Triangulation Report and choose 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 Close to close the Triangulation Summary dialog.
16. Click OK in the Aerial Triangulation dialog to accept the triangulation.

You are returned to the main IMAGINE OrthoBASE dialog. The Ext. column is now green.

Tour Guide
Check Graphic Status

1. In the main IMAGINE OrthoBASE dialog, click the **Process** menu.

2. From the **Process** menu, select **Graphic Status**.

   A graphic containing the three images in the block file displays in the OrthoBASE Graphic Status Display dialog.

The Exterior Information has been supplied
3. In the **Display Mode** section of the OrthoBASE Graphic Status Display dialog, click the checkbox next to **Point IDs**.

The **Point IDs** are listed below each of the **Tie Points** in the dialog.

4. Click on a **Tie Point** box associated with a **Point ID** to display the Point Data dialog.
5. When you are finished viewing the Point Data dialog, click the **Dismiss** button.

6. Click the **Image Space** radio button in the OrthoBASE Graphic Status Display dialog. The tie points are shown for the image identified in the window.

7. Click the **Image Space** dropdown list to select the next image in the block file, **digcam2**. The tie points redisplay in the OrthoBASE Graphic Status Display dialog accordingly.
8. When you are finished, click the **Dismiss** button on the OrthoBASE Graphic Status Display dialog.

You are returned to the main IMAGINE OrthoBASE dialog.

---

**Orthorectify the Imagery**

The final step in the IMAGINE OrthoBASE process is to orthorectify the images in the block file.

1. In the main IMAGINE OrthoBASE dialog, click on a red row within the **Ortho** column.

The Ortho Resampling dialog opens.

2. Click to select the **Multiple Output** option.

3. Click the Open icon, then navigate to a directory where you have write permission.

4. Type the prefix **ortho** in the **File name** field, then press Enter.

5. Click **OK** to accept the **ortho** prefix.

6. In the **Constant Value** section, type the value **605.0**.

   A DEM is not available for this area, therefore you use an average elevation value.

7. Confirm that the **Resample Method** is **Bilinear Interpolation**.
Click in the **Output Cell Sizes** section and change both the X and the Y values to 0.50.

Click in the **Active Area Used** field and type 95.

When you are finished, the Ortho Resampling dialog looks like the following:

10. Click **OK** to start the ortho resampling process.

11. When the process is complete, click **OK** in the status dialog to dismiss it.

**Check the Ortho Resampled Images**

Now that the ortho resampling process is complete, you can check the images in an ERDAS IMAGINE Viewer.

1. From the ERDAS IMAGINE tool bar, click the Viewer icon.

2. From the Viewer menu bar, select **File | Open | Raster Layer**.

3. In the Select Layer To Add dialog, navigate to the directory in which you saved the ortho resampled images.

4. Click to select the first image in the block file, `orthodigcam1.img`. 
5. Click the **Raster Options** tab.

6. Deselect **Clear Display**.

7. Select the **Fit to Frame** option and the **Background Transparent** option, then click **OK**.

8. Add the two remaining images in the block file, `orthodigcam2.img` and `orthodigcam3.img`, to the same Viewer using step 2. through step 7.

   The three images display in the Viewer.

   ![Viewer with three images](image)

---

**Magnify Areas of Overlap**

You can visually check the accuracy of the block images by using the **Zoom In** tool.

1. In the Viewer containing the images, click the **Zoom In** tool.
2. Click in an area that interests you. You may have to apply the Zoom In tool more than once to see the details of the image.

Use the Swipe Tool

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 to select **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 overlaps the others.
Orthorectify the Imagery

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 rectified orthoimages.

You are returned to the main IMAGINE OrthoBASE dialog, where all of the columns are green, indicating that the process is complete.

Save and Close the Block File

1. In the main IMAGINE OrthoBASE dialog, select File | Save. You can now refer to the complete block file whenever you wish.

2. In the main IMAGINE OrthoBASE dialog, select File | Close.
CHAPTER 5
SPOT Pushbroom Sensor Tour Guide

Introduction

With the IMAGINE OrthoBASE software, 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.

The data sets you use with this tour guide come from Palm Springs, California. You choose reference coordinates in two images: one a SPOT image and one an orthorectified aerial photo. The block consists of two images, both SPOT panchromatic images with 10-meter resolution.

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 IMAGINE OrthoBASE project
- Start the Point Measurement Tool to select a reference source
- Collect GCPs
- Add a second image to the block file
- Use the Point Measurement Tool to collect GCPs in the second image
- Use the automatic tie point collection function
- Triangulate the images
- Orthorectify the images
- Save the block file

Create a New IMAGINE OrthoBASE Project

Prepare the Block File

1. Start ERDAS IMAGINE.
2. Close the Viewer that automatically opens when starting ERDAS IMAGINE.
3. Click the OrthoBASE icon on the ERDAS IMAGINE icon panel.
SPOT Pushbroom Sensor Tour Guide

The OrthoBASE Startup dialog opens.

4. Confirm that the radio button next to Create a new OrthoBASE project is active.

5. Click OK to close the OrthoBASE Startup dialog.

   The Create New Block File dialog opens.

6. Navigate to a directory in which you have write permission.

7. Click in the text field next to File name, and type spot_tour.blk, then press Enter on your keyboard.

8. Click OK to close the Create New Block File dialog.
Create a New IMAGINE OrthoBASE Project

Specify Information About the New IMAGINE OrthoBASE Project

1. From the Select Geometric Model list, select SPOT Pushbroom.

2. Click OK to close the Model Setup dialog.

The Block Property Setup dialog opens.

3. Click the Set Projection button in the Set Reference System section of the Block Property Setup dialog.

The Projection Chooser dialog opens.

4. Click the Custom tab in the Projection Chooser dialog.

5. 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 Projection Chooser dialog.

The Set Reference System section of the Block Property Setup dialog reflects the projection you selected.
11. Click **Next** in the Block Property Setup dialog.

The **Reference Units** section displays.

12. Confirm that both **Horizontal Units** and **Vertical Units** are set to **Meters**.

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

The main IMAGINE OrthoBASE dialog opens.
Create a New IMAGINE OrthoBASE Project

Add Imagery to the Block

1. Select Edit | Add Frame from the IMAGINE OrthoBASE menu bar, or click the Add Frame icon.

   ![Image File Name dialog](image)

   The Image File Name dialog opens.

2. From the filename list, select `spot_pan.img`, then click OK.

   ![CellArray](image)

   The file `spot_pan.img` is located in the `<IMAGINE_HOME>/examples/orthobase/spot` directory, where `<IMAGINE_HOME>` is the location of ERDAS IMAGINE on your system.

   The image is loaded into the IMAGINE OrthoBASE dialog and displays in the CellArray.
To conserve space in the IMAGINE/examples/orthobase/spot directory, the pyramid layers associated with the SPOT image are not included. However, IMAGINE OrthoBASE has a utility that enables you to quickly compute pyramid layers for your images. Pyramid layers make your image display more rapidly in the Viewers.

1. Click in the red column labeled **Pyr.** for the **spot_pan** image.

This cell controls the creation of pyramid layers for the image in the block file. The Compute Pyramid Layers dialog displays.

2. Confirm that the **All Images Without Pyramids** option is checked.

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

A status bar displays at the bottom of the main IMAGINE OrthoBASE 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.

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

The Frame Editor dialog opens, displaying information about the current image listed in the IMAGINE OrthoBASE CellArray, **spot_pan**.

2. In the **Sensor** tab of the Frame Editor dialog, click the **Edit** button.

The Sensor Information dialog displays.

3. Check the information included in the Sensor Information dialog.

The information 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.
SPOT Pushbroom Sensor Tour Guide

4. Click OK in the Sensor Information dialog to confirm that the information is correct.

5. Click OK in the Frame Editor dialog.

You are returned to the main IMAGINE OrthoBASE dialog. As you can see, the Int. column that corresponds to the SPOT image is now green, indicating that the sensor has been specified.

Start the Point Measurement Tool

1. In the main IMAGINE OrthoBASE dialog, click to select the Point Measurement icon.

The Point Measurement Tool opens, displaying three Viewers, a Point Measurement Tool Palette, and two CellArrays: one for recording reference coordinates, and one for recording file coordinates.
Specify the Horizontal Reference Source

2. 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.

3. In the GCP Reference Source dialog, click to select the **Image Layer** option.

4. Click **OK** in the GCP Reference Source dialog.

   The Reference Image Layer dialog opens.

5. Navigate to the `<IMAGINE_HOME>/examples/orthobase/spot` directory, and select the file **xs_ortho.img**.

6. Click **OK** in the Reference Image Layer dialog.

   The Reference Image Layer dialog closes, and you are returned to the Point Measurement Tool dialog.

7. In the Point Measurement Tool dialog, click the checkbox next to **Use Viewer as Reference**.

   The Point Measurement Tool automatically changes to display the new image, **xs_ortho**, in the three Viewers on the left of the Point Measurement Tool, and the original image, **spot_pan**, in the other three Viewers on the right 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 file image, **spot_pan**.
Now, you are ready to begin collecting control points.

**Collect GCPs**

In this exercise, 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 X and Y coordinates of the GCPs. Graphics and coordinates are provided to help you find the points.

**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 Viewers in green, and the **Color** column does not display.

**To change the color,** click the Viewing Properties icon to access the **Point Table Info** dialog. Click the **Advanced** button, then the **Color** button, then **OK**. This adds a **Color** column to the Reference CellArray and the File CellArray.

**Collect Point ID 1**

1. Click the **Add** button in the Point Measurement Tool Palette.
A row with **Point ID 1** is added to the left Reference CellArray.

2. Consult Figure 5-1 on page 156 for the location of **Point ID 1** in the `xs_ortho` Viewers on the left side of the Point Measurement Tool.

3. Click the Select Point icon to move the Link Cursors in the Viewers until you see the road intersection.

When you have found the road intersection and centered it in the Viewers, you are ready to collect the control point.

![Figure 5-1 Location of Point ID 1](image)

**Figure 5-1 Location of Point ID 1**

*NOTE: In the OverViews, the Link Cursor is located in the upper right corner of the images. If you need further 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.*
4. Click the Create Point icon.

5. Move the cursor into the Detail View containing the reference image, \textit{xs	extunderscore ortho}, and click to select the intersection.

A control point is placed on the intersection and labeled 1. The Reference CellArray updates to include the \textit{X Reference} and \textit{Y Reference} coordinates of the reference image, \textit{xs	extunderscore ortho}.

6. Check your control point coordinates. They should match the following table:

<table>
<thead>
<tr>
<th>Point ID</th>
<th>X Reference</th>
<th>Y Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>566189.190</td>
<td>3773586.979</td>
</tr>
</tbody>
</table>

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.

\textbf{Note:} The Z Reference column becomes active. You are going to input Z values using a DEM later in the exercise, in the “Set the Vertical Reference Source” section on page 172.

Now, you are going to collect the point on the block image, \textit{spot	extunderscore pan}.

8. Consult Figure 5-1 on page 156 for the location of \textbf{Point ID 1} in the \textit{spot	extunderscore pan} Viewers on the right side of the Point Measurement Tool.

9. Click the Select Point icon to move the Link Cursors in the Viewers until you see the road intersection.

When you have found the road intersection and centered it in the Viewers, you are ready to collect the control point.

10. Click the Create Point icon.
11. Move the cursor into the Detail View containing the first image in the block file, `spot_pan`, and click to select the intersection.

A control point is placed on the intersection and labeled 1. The File CellArray updates to include 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>
<thead>
<tr>
<th>Image Name</th>
<th>X File</th>
<th>Y File</th>
</tr>
</thead>
<tbody>
<tr>
<td>spot_pan</td>
<td>5239.468</td>
<td>337.384</td>
</tr>
</tbody>
</table>

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**

1. Click the Add button in the Point Measurement Tool Palette.

2. Consult Figure 5-2 on page 159 for the location of Point ID 2 in the `xs_ortho` Viewers on the left side of the Point Measurement Tool.

3. Click the Select Point icon to move the Link Cursors in the Viewers until you see the road intersection.

When you have found the road intersection and centered it in the Viewers, you are ready to collect the control point.
4. Click the Create Point icon.

5. Move the cursor into the Detail View containing the reference image, xs_ortho, and click to select the intersection.

   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 reference image, xs_ortho.

6. Check your control point coordinates. They should approximate those in the following table:

<table>
<thead>
<tr>
<th>Point ID</th>
<th>Description</th>
<th>Type</th>
<th>Active</th>
<th>X Reference</th>
<th>Y Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>Tie</td>
<td>X</td>
<td>555690.190</td>
<td>3728387.770</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Tie</td>
<td>X</td>
<td>555690.659</td>
<td>3728387.770</td>
</tr>
</tbody>
</table>

Figure 5-2 Location of Point ID 2

NOTE: In the OverViews, the box is located in the lower right corner of the images. If you need further information to find the intersection, it is located 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.
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. Consult Figure 5-2 on page 159 for the location of Point ID 2 in the spot_pan Viewers on the right side of the Point Measurement Tool.

9. Click the Select Point icon to move the Link Cursors in the Viewers until you find the road intersection.

10. Click the Create Point icon again.

11. Move the cursor into the Detail View containing the first image in the block file, spot_pan, and click to select the intersection.

   A control point is placed on the intersection and labeled 2. The File CellArray updates to include 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>
<thead>
<tr>
<th>Image Name</th>
<th>X File</th>
<th>Y File</th>
</tr>
</thead>
<tbody>
<tr>
<td>spot_pan</td>
<td>5191.590</td>
<td>4969.546</td>
</tr>
</tbody>
</table>

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

IMAGINE OrthoBASE provides some automatic functions to enable you to select ground control points more rapidly. Now, you are going to activate the Automatic (x, y) Drive function.

1. Click the Automatic (x, y) Drive icon.

The icon changes to:
Collect GCPs

This icon allows IMAGINE OrthoBASE to approximate the position of the GCP in the block image file, `spot_pan`, based on the position in the reference image, `xs_ortho`.

Collect Point ID 3

1. Click the **Add** button in the Point Measurement Tool Palette.
   
   A row with **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>
<thead>
<tr>
<th>Point ID</th>
<th>X Reference</th>
<th>Y Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>501918.953</td>
<td>3732595.411</td>
</tr>
</tbody>
</table>

   IMAGINE OrthoBASE adjusts the reference image in the Viewers and places the control point at the coordinates you specified.

   ![Image chip from xs_ortho](image1.png)  ![Image chip from spot_pan](image2.png)

   **Figure 5-3 Location of Point ID 3**

Because the Automatic (x, y) Drive icon is enabled, IMAGINE OrthoBASE moves the first image in the block file, `spot_pan`, to the same approximate area in the Viewers. The placement improves with subsequent points.

3. Consult Figure 5-3 on page 161. Then, click the Select Point icon, and move the Link Cursor until you can see the point in `spot_pan`.

4. Click the Create Point icon in the Point Measurement Tool Palette.

*Tour Guide*
5. Move the cursor into the Detail View containing the first image in the block file, spot_pan, and click to select the intersection.

   **Point ID 3** is placed in the Viewers. To get the accurate point coordinates, you use the following table.

6. Check your control point coordinates. They should approximate those in the following table:

<table>
<thead>
<tr>
<th>Image Name</th>
<th>X File</th>
<th>Y File</th>
</tr>
</thead>
<tbody>
<tr>
<td>spot_pan</td>
<td>230.925</td>
<td>5378.823</td>
</tr>
</tbody>
</table>

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**

1. Click the **Add** button in the Point Measurement Tool Palette.

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>
<thead>
<tr>
<th>Point ID</th>
<th>X Reference</th>
<th>Y Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>515114.084</td>
<td>3759740.576</td>
</tr>
</tbody>
</table>

IMAGINE OrthoBASE places the control point in the reference image for you.

---

*Figure 5-4  Location of Point ID 4*
3. Consult Figure 5-4 on page 162. 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 to select the intersection.

5. Check your control point coordinates. They should approximate those in the following table:

<table>
<thead>
<tr>
<th>Image Name</th>
<th>X File</th>
<th>Y File</th>
</tr>
</thead>
<tbody>
<tr>
<td>spot_pan</td>
<td>869.542</td>
<td>2487.996</td>
</tr>
</tbody>
</table>

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**

1. Click the **Add** button in the Point Measurement Tool Palette.

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>
<thead>
<tr>
<th>Point ID</th>
<th>X Reference</th>
<th>Y Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>543537.306</td>
<td>3779981.255</td>
</tr>
</tbody>
</table>

IMAGINE OrthoBASE places the control point in the reference image for you.

![Image chip from xs_ortho](imagechip_xs_ortho.png)  
![Image chip from spot_pan](imagechip_spot_pan.png)

**Figure 5-5  Location of Point ID 5**

3. Consult Figure 5-5 on page 163. Then, click the Create Point icon in the Point Measurement Tool Palette.
SPOT Pushbroom Sensor Tour Guide

4. Move the cursor into the Detail View containing spot_pan, and click to select the intersection.

5. Check your control point coordinates. They should approximate those in the following table:

<table>
<thead>
<tr>
<th>Image Name</th>
<th>X File</th>
<th>Y File</th>
</tr>
</thead>
<tbody>
<tr>
<td>spot_pan</td>
<td>3027.570</td>
<td>51.432</td>
</tr>
</tbody>
</table>

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

1. Click the Add button in the Point Measurement Tool Palette.

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>
<thead>
<tr>
<th>Point ID</th>
<th>X Reference</th>
<th>Y Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>558640.300</td>
<td>3751516.718</td>
</tr>
</tbody>
</table>

IMAGINE OrthoBASE places the control point in the reference image for you.

![Image chip from xs_ortho](image1)

![Image chip from spot_pan](image2)

Figure 5-6 Location of Point ID 6

3. Consult Figure 5-6 on page 164. 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 to select the intersection.
5. Check your control point coordinates. They should approximate those in the following table:

<table>
<thead>
<tr>
<th>Image Name</th>
<th>X File</th>
<th>Y File</th>
</tr>
</thead>
<tbody>
<tr>
<td>spot_pan</td>
<td>4999.412</td>
<td>2636.848</td>
</tr>
</tbody>
</table>

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**

1. Click the **Add** button in the Point Measurement Tool Palette.

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>
<thead>
<tr>
<th>Point ID</th>
<th>X Reference</th>
<th>Y Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>532062.982</td>
<td>3724946.633</td>
</tr>
</tbody>
</table>

IMAGINE OrthoBASE places the control point in the reference image for you.

![Image chip from xs_orhio](image1.png)  ![Image chip from spot_pan](image2.png)

**Figure 5-7  Location of Point ID 7**

3. Consult Figure 5-7 on page 165. 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 to select the intersection.

5. Check your control point coordinates. They should approximate those in the following table:
**SPOT Pushbroom Sensor Tour Guide**

<table>
<thead>
<tr>
<th>Image Name</th>
<th>X File</th>
<th>Y File</th>
</tr>
</thead>
<tbody>
<tr>
<td>spot_pan</td>
<td>3064.254</td>
<td>5673.794</td>
</tr>
</tbody>
</table>

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**

1. Click the **Add** button in the Point Measurement Tool Palette.

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>
<thead>
<tr>
<th>Point ID</th>
<th>X Reference</th>
<th>Y Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>539381.670</td>
<td>3768419.388</td>
</tr>
</tbody>
</table>

IMAGINE OrthoBASE places the control point in the reference image for you.

![Image chip from xs_ortho](image1)

![Image chip from spot_pan](image2)

**Figure 5-8 Location of Point ID 8**

3. Consult Figure 5-8 on page 166. 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 to select the intersection.

5. Check your control point coordinates. They should approximate those in the following table:
Collect GCPs

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

1. Click the Add button in the Point Measurement Tool Palette.
2. Using the following table, type the X Reference and Y Reference coordinates for the ninth control point into the Reference CellArray.

<table>
<thead>
<tr>
<th>Point ID</th>
<th>X Reference</th>
<th>Y Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>526013.661</td>
<td>3753709.856</td>
</tr>
</tbody>
</table>

IMAGINE OrthoBASE places the control point in the reference image for you.

3. Consult Figure 5-9 on page 167. 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 to select the intersection.
5. Check your control point coordinates. They should approximate those in the following table:
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 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. In this case, you are going to use an image called **NAPP_2m-ortho.img**. This is an ortho image 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.

   ![Image Measurement Tool](image)

   The GCP Reference Source dialog opens.

   ![GCP Reference Source Dialog](image)

   **Click to select Image Layer**

   **Click OK**

2. In the GCP Reference Source dialog, click to select the **Image Layer** option.

3. Click **OK** in the GCP Reference Source dialog.

   The Reference Image Layer dialog opens.

4. Navigate to the `<IMAGINE_HOME>/examples/orthobase/spot` directory 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 dialog. The file, **NAPP_2m-ortho** is automatically loaded into the left three Viewers.

The new reference image is added to the left three Viewers

---

**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**.

1. Click the **Add** button in the Point Measurement Tool Palette.
2. Click in the **Point ID** column, and type **11**.
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>
<thead>
<tr>
<th>Point ID</th>
<th>X Reference</th>
<th>Y Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>545372.750</td>
<td>3741643.250</td>
</tr>
</tbody>
</table>
4. Click the Create Point icon in the Point Measurement Tool Palette.

5. Move the cursor into the Detail View containing the first image in the block file, spot_pan, and click to select the intersection.

6. Check your control point coordinates. They should approximate those in the following table:

<table>
<thead>
<tr>
<th>Image Name</th>
<th>X File</th>
<th>Y File</th>
</tr>
</thead>
<tbody>
<tr>
<td>spot_pan</td>
<td>3982.969</td>
<td>3817.813</td>
</tr>
</tbody>
</table>

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

1. Click the Add button in the Point Measurement Tool Palette. Note that the Point ID column identifies the 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>
<thead>
<tr>
<th>Point ID</th>
<th>X Reference</th>
<th>Y Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>540901.659</td>
<td>3746876.633</td>
</tr>
</tbody>
</table>

3. Click the Create Point icon in the Point Measurement Tool Palette.

4. Move the cursor into the Detail View containing the first image in the block file, spot_pan, and click to select the intersection.

5. Check your control point coordinates. They should approximate those in the following table:

Figure 5-11 Location of Point ID 12
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 Palette, click **Save** to save your work to this point.

8. In the Point Measurement Tool Palette, click to deselect the **Use Viewer as Reference** option.

   The reference file **NAPP_2m-ortho** closes, and **spot_pan** displays alone.

Set the Vertical Reference Source

To provide \( Z \), or 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 digital elevation model (DEM), **palm_springs_dem.img**, which contains height information.

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.

2. Click to select the **DEM** option.

3. Click the Open icon to access the File Chooser dialog.

4. Navigate to the `<IMAGINE_HOME>/examples/orthobase/spot` directory and select the DEM file **palm_springs_dem.img**.
5. Click **OK** in the File Chooser dialog. 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 and select the **Select All** option.

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`.

9. Right-click in the **Point #** column and choose **Select None**.

**Another function of IMAGINE OrthoBASE 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.

1. Left-click the title bar of the column labeled **Type** to select all of the column.

2. Right-click 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**.

5. Click **Close** in the Formula dialog.

6. Left-click in the column labeled **Usage** to select all of the column.

7. Right-click to access the **Column Options** menu, then select **Formula**.

8. In the **Formula** section of the Formula dialog, type **Control**.

9. Click **Apply** in the Formula dialog.

   All of the points’ **Usage** are revised to indicate **Control**.

10. Click **Close** in the Formula dialog.

11. 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.
Add a Second Image to the Block

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 point, you should save the block file to preserve your work.

1. In the Point Measurement Tool Palette, click the Save button.
2. Click the Close button on the Point Measurement Tool Palette.

You are returned to the main IMAGINE OrthoBASE dialog.

Add a Second Image to the Block

Now that you have successfully collected reference coordinates in the reference image, xs_ortho, and file coordinates in the first block file, spot_pan, you can progress to the second image in the block. This image, spot_panb, should be easier for you to navigate around since you have completed collection of control points in the first block image.

1. Select Edit | Add Frame from the IMAGINE OrthoBASE menu bar, or click the Add Frame icon.

The Image File Name dialog opens.

2. From the filename list, select spot_panB.img, then click OK.

The file spot_panB.img is in the <IMAGINE_HOME>/examples/orthobase/spot directory, where <IMAGINE_HOME> is the location of ERDAS IMAGINE on your system.

The image is loaded into the IMAGINE OrthoBASE dialog 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 Viewers.

1. Click in the > column of `Image ID 2, spot_panb`.

2. Click in the red column labeled `Pyr.` for the `spot_panb` image.

   This cell controls the creation of pyramid layers for the image in the block file.

   The Compute Pyramid Layers dialog displays.

   ![Compute Pyramid Layers dialog](image)

   *All Images Without Pyramids is selected by default*

3. Confirm that the **All Images Without Pyramids** option is checked.

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

   A status bar displays at the bottom of the main IMAGINE OrthoBASE dialog, 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 supply IMAGINE OrthoBASE with 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 main IMAGINE OrthoBASE dialog menu bar, or click the Frame Properties icon.

   The Frame Editor dialog opens, displaying information about the current image listed in the IMAGINE OrthoBASE CellArray, `spot_panb`.

   ![Frame Editor dialog](image)

   **Click OK to accept the parameters**

   2. Click **OK** in the Frame Editor to accept the parameters.

---

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 main IMAGINE OrthoBASE dialog, click to select the Point Measurement Tool icon.

   The Point Measurement Tool opens, displaying three Viewers, a Point Measurement Tool Palette, and two CellArrays: one for recording reference coordinates, and one for recording file coordinates. The image `spot_panb` is in the right three Viewers; the image `spot_pan` is in the left three Viewers.
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.

**Spot_pan** automatically changes position in the Viewers to show **Point ID 1**.

2. Move the Link Cursor in the Viewers 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 for **spot_panb**, displayed in the right three Viewers.
Collect Ground Control Points

A point is placed in the Detail View and labeled 1.

5. Using the following table, type the X File and Y File coordinates for `spot_panb` into the File CellArray, then press Enter on your keyboard. The point changes location accordingly.

⚠️ 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.

<table>
<thead>
<tr>
<th>Image Name</th>
<th>X File</th>
<th>Y File</th>
</tr>
</thead>
<tbody>
<tr>
<td>spot_panb</td>
<td>2857.270</td>
<td>753.852</td>
</tr>
</tbody>
</table>

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 Viewers displaying `spot_panb`.
3. Click the Create Point icon in the Point Measurement Tool Palette.
4. Click the approximate point in the Detail View for `spot_panb`.
5. Using the following table, type the X File and Y File coordinates for `spot_panb` into the File CellArray, then press Enter on your keyboard. The point changes location accordingly.

<table>
<thead>
<tr>
<th>Image Name</th>
<th>X File</th>
<th>Y File</th>
</tr>
</thead>
<tbody>
<tr>
<td>spot_panb</td>
<td>3003.782</td>
<td>5387.892</td>
</tr>
</tbody>
</table>

Next, you collect the control point in `spot_panb` for Point ID 5. Point IDs 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 Viewers displaying `spot_panb`.
3. Click the Create Point icon in the Point Measurement Tool Palette.
4. Click the approximate point in the Detail View for `spot_panb`.

Using the following table, type the X File and Y File coordinates for `spot_panb` into the File CellArray, then press Enter on your keyboard. The point changes location accordingly.

<table>
<thead>
<tr>
<th>Image Name</th>
<th>X File</th>
<th>Y File</th>
</tr>
</thead>
<tbody>
<tr>
<td>spot_panb</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SPOT Pushbroom Sensor Tour Guide

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 enabled, IMAGINE OrthoBASE locates the position of Point ID 6 for you. This occurs after three points (e.g., 1, 2, and 5) have already been placed in the Viewers.

2. Click the Create Point icon in the Point Measurement Tool Palette.

3. Click the approximate point in the Detail View for spot_panb.

Using the following table, type the X File and Y File coordinates for spot_panb into the File CellArray, then press Enter on your keyboard. The point changes location accordingly.

<table>
<thead>
<tr>
<th>Image Name</th>
<th>X File</th>
<th>Y File</th>
</tr>
</thead>
<tbody>
<tr>
<td>spot_panb</td>
<td>1022.701</td>
<td>644.456</td>
</tr>
</tbody>
</table>

Next, you are going to collect the control point in spot_panb for Point ID 8. 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 for spot_panb.

Using the following table, type the X File and Y File coordinates for spot_panb into the File CellArray, then press Enter on your keyboard. The point changes location accordingly.

<table>
<thead>
<tr>
<th>Image Name</th>
<th>X File</th>
<th>Y File</th>
</tr>
</thead>
<tbody>
<tr>
<td>spot_panb</td>
<td>2736.125</td>
<td>3070.227</td>
</tr>
</tbody>
</table>

Collect Point ID 9

1. In the Reference CellArray, click on Point #9 to highlight the row.
Perform Automatic Tie Point Collection

2. Click the Create Point icon in the Point Measurement Tool Palette.

3. Click the approximate point in the Detail View for **spot_panb**.

   Using the following table, type the **X File** and **Y File** coordinates for **spot_panb** into the File CellArray, then press Enter on your keyboard. The point changes location accordingly.

<table>
<thead>
<tr>
<th>Image Name</th>
<th>X File</th>
<th>Y File</th>
</tr>
</thead>
<tbody>
<tr>
<td>spot_panb</td>
<td>221.445</td>
<td>3594.113</td>
</tr>
</tbody>
</table>

   Next, you are going to collect **Point ID 12** in **spot_panb**.

   Collect Point ID 12

   1. In the Reference CellArray, click on **Point #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 for **spot_panb**.

       Using the following table, type the **X File** and **Y File** coordinates for **spot_panb** into the File CellArray, then press Enter on your keyboard. The point changes location accordingly.

       | Image Name | X File | Y File |
       |------------|--------|--------|
       | spot_panb  | 1499.230| 3923.753|

   4. Right-click in the **Point #** column and choose **Select None**.

   5. In the Point Measurement Tool Palette, 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 areas of the two SPOT images.

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

   The Automatic Tie Point Generation Properties dialog opens.
2. Check to confirm that the **Images Used** option is set to **All available**.

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

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

5. Click in the **Intended Number of Points Per Image** field and type **40**, then press Enter.

6. Check to confirm that the **Keep All Points** option is off.

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

   IMAGINE OrthoBASE starts the automatic tie point generation process, indicated by a progress bar, and displays the tie points in the Point Measurement Viewers when complete. The tie points have the **Type** designation **None**, and the **Usage** designation **Tie**. They are added to the Reference CellArray with the 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 delete it by selecting the row in the Reference CellArray and clicking the **Delete** button.

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 Viewers. This is an acceptable tie point.
3. Click in the > column of other Point IDs to see where IMAGINE OrthoBASE placed tie points. You may need to adjust the Brightness and Contrast sliders to clearly see other points.

4. When you are finished, click the **Save** button in the Point Measurement Tool Palette.

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

   You are returned to the main IMAGINE OrthoBASE dialog.
**Perform Triangulation**

Now that you have obtained control and tie points, IMAGINE OrthoBASE 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 main IMAGINE OrthoBASE dialog, 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 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 was made up of 20-meter pixels. This value assures that the GCPs are precise to approximately 15 meters. When you are finished, the dialog looks like this:

7. Click the **Advanced Options** tab.
8. Confirm that the **Simple Gross Error Check Using** option 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 is generated and opened.

10. In the Triangulation Summary dialog, click to select the **Report** button.

    The Report opens in a separate window. You can save this report as you would any text file, then refer to it as needed.
Perform Triangulation

11. Scroll through the report to see the information it contains.

![The Triangulation Report is displayed in a text editor]

For more information about the Triangulation Report, see the On-Line Help.

12. When you are finished viewing the report, select File | Close.

13. Click Accept in the Triangulation Summary dialog to accept the results.

14. Click OK in the Triangulation dialog.

You are returned to the main IMAGINE OrthoBASE dialog. Notice that the Ext. columns are now green, indicating that the exterior information has been supplied.
15. In the main IMAGINE OrthoBASE dialog, click the **File** menu and select **Save**.

**Orthorectify the Imagery**

The next step creates orthorectified images whose relief displacements and geometric errors have been adjusted and improved. The orthorectified images display objects in their real-world X and Y positions.

1. In the main IMAGINE OrthoBASE dialog, click to select the Ortho Resampling icon.

The Ortho Resampling dialog opens.
2. Click to select the **Multiple Output** option.

3. Click the Open icon, then navigate to a directory where you have write permission.

4. Confirm that the prefix **ortho** is in the **File name** field.

5. Click **OK** to accept the **ortho** prefix.

6. Confirm the **DEM File** option is selected.

7. Confirm that the identified **DEM File** is **palm_springs_dem.img**.

8. Confirm that the **Elevation Units** are set to **Meters**.

9. Confirm that the **Resample Method** list is set to **Bilinear Interpolation**.

10. Click in the **Output Cell Sizes** section and change the **X** and the **Y** values to **10.0**.

11. Click **OK** in the Ortho Resampling dialog.

   A Status dialog opens, tracking the ortho resampling process.
Ortho resampling takes several minutes to complete the processing of the images in the block file.

12. When the progress bar is 100% complete, click the **OK** button to dismiss it.

**Check the Ortho Resampled Images**

Now that the images have been ortho resampled, you can check how well they fit together in a Viewer.

1. From the main ERDAS IMAGINE tool bar, click the Viewer icon.

![Viewer icon](viewer_icon.png)

A Viewer opens in the workspace.

2. Click the Open icon to access the Select Layer To Add dialog.

![Select Layer To Add dialog](select_layer_to_add.png)

3. Navigate to the directory in which you saved the orthorectified images.

4. Click to select the **orthospot_pan.img** image.

5. Click the **Raster Options** tab.

6. Deselect the **Clear Display** option.

7. Click to select the **Fit to Frame** an **Background Transparent** options.

8. Click **OK** in the Select Layer to Add dialog.
9. Repeat step 2. through step 8. in the same Viewer, selecting the file `orthspot_panb.img`.

The overlapped images display in the Viewer.

![The images overlap here](image)

**Magnify Areas of Overlap**

Now, you can check the areas of overlap to see how well IMAGINE 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 tool.

2. Click on an area in the Viewer where the images obviously overlap.

3. Apply the Zoom In tool as many times as necessary to see the portion of overlap clearly in the Viewer.

You can see that IMAGINE OrthoBASE successfully overlapped the images in the following picture. You can see where one image overlays the other.
Use the Swipe Tool

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 to select 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 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. When you are finished viewing the images, select **File | Close** from the Viewer menu bar.

**Save and Close the Block File**

1. Now that you have verified the accuracy of the IMAGINE OrthoBASE output, in the main IMAGINE OrthoBASE dialog, click the **File** menu, then select **Save**.

Notice that all of the columns are green, indicating that all of the process steps have been executed. You can open the complete block file any time.

2. From the **File** menu, select **File | Close**.

---

**All steps have been executed; the block file is complete**
# Appendix A

## Frame Camera Tour Guide Control and Check Point Coordinates

### Introduction

As you work through the "Frame Camera Tour Guide," you may want to refer to the following table to compare your Reference and File coordinates to those obtained during testing of IMAGINE OrthoBASE.

### Control Point Coordinates

The following table gives precise coordinates for the control points you select in the Frame Camera tour guide, both Reference and File.

<table>
<thead>
<tr>
<th>Point ID</th>
<th>Type</th>
<th>Usage</th>
<th>X Reference</th>
<th>Y Reference</th>
<th>Z Reference</th>
<th>Image Name</th>
<th>X File</th>
<th>Y File</th>
</tr>
</thead>
<tbody>
<tr>
<td>1002</td>
<td>Full</td>
<td>Control</td>
<td>665228.955</td>
<td>115012.472</td>
<td>1947.672</td>
<td>col90p1</td>
<td>952.625</td>
<td>819.625</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>col91p1</td>
<td>165.875</td>
<td>846.625</td>
</tr>
<tr>
<td>1003</td>
<td>Full</td>
<td>Control</td>
<td>664456.22</td>
<td>119052.15</td>
<td>1988.82</td>
<td>col90p1</td>
<td>1857.875</td>
<td>639.125</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>col91p1</td>
<td>1064.875</td>
<td>646.375</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>col92p1</td>
<td>286.875</td>
<td>639.125</td>
</tr>
<tr>
<td>1004</td>
<td>Full</td>
<td>Control</td>
<td>668150.61</td>
<td>122404.68</td>
<td>1972.056</td>
<td>col91p1</td>
<td>1839.52</td>
<td>1457.43</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>col92p1</td>
<td>1050.60</td>
<td>1465.23</td>
</tr>
<tr>
<td>1005</td>
<td>Full</td>
<td>Control</td>
<td>668338.22</td>
<td>118685.9</td>
<td>1886.712</td>
<td>col90p1</td>
<td>1769.450</td>
<td>1508.430</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>col91p1</td>
<td>1007.250</td>
<td>1518.170</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>col92p1</td>
<td>224.67</td>
<td>1510.67</td>
</tr>
<tr>
<td>1006</td>
<td>Full</td>
<td>Control</td>
<td>670841.48</td>
<td>118696.89</td>
<td>2014.0</td>
<td>col90p1</td>
<td>1787.875</td>
<td>2079.625</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>col91p1</td>
<td>1023.625</td>
<td>2091.390</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>col92p1</td>
<td>215.125</td>
<td>2083.790</td>
</tr>
</tbody>
</table>
## Frame Camera Tour Guide Control and Check Point Coordinates

The following table gives precise coordinates for the check points you select in the Frame Camera tour guide, both Reference and File.

### Table A-2 Frame Camera Tour Guide Check Point Coordinates

<table>
<thead>
<tr>
<th>Point ID</th>
<th>Type</th>
<th>Usage</th>
<th>X Reference</th>
<th>Y Reference</th>
<th>Z Reference</th>
<th>Image Name</th>
<th>X File</th>
<th>Y File</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>Full</td>
<td>Check</td>
<td>670970.45</td>
<td>114815.23</td>
<td>1891.888</td>
<td>col90p1</td>
<td>915.02</td>
<td>2095.71</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>col91p1</td>
<td>160.9</td>
<td>2127.84</td>
</tr>
<tr>
<td>2002</td>
<td>Full</td>
<td>Check</td>
<td>671408.73</td>
<td>123166.52</td>
<td>1983.762</td>
<td>col91p1</td>
<td>2032.03</td>
<td>2186.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>col92p1</td>
<td>1227.375</td>
<td>2199.125</td>
</tr>
</tbody>
</table>
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