

Professional Analyst, Flight Path Edition for Visible Cameras

User Manual

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Overview

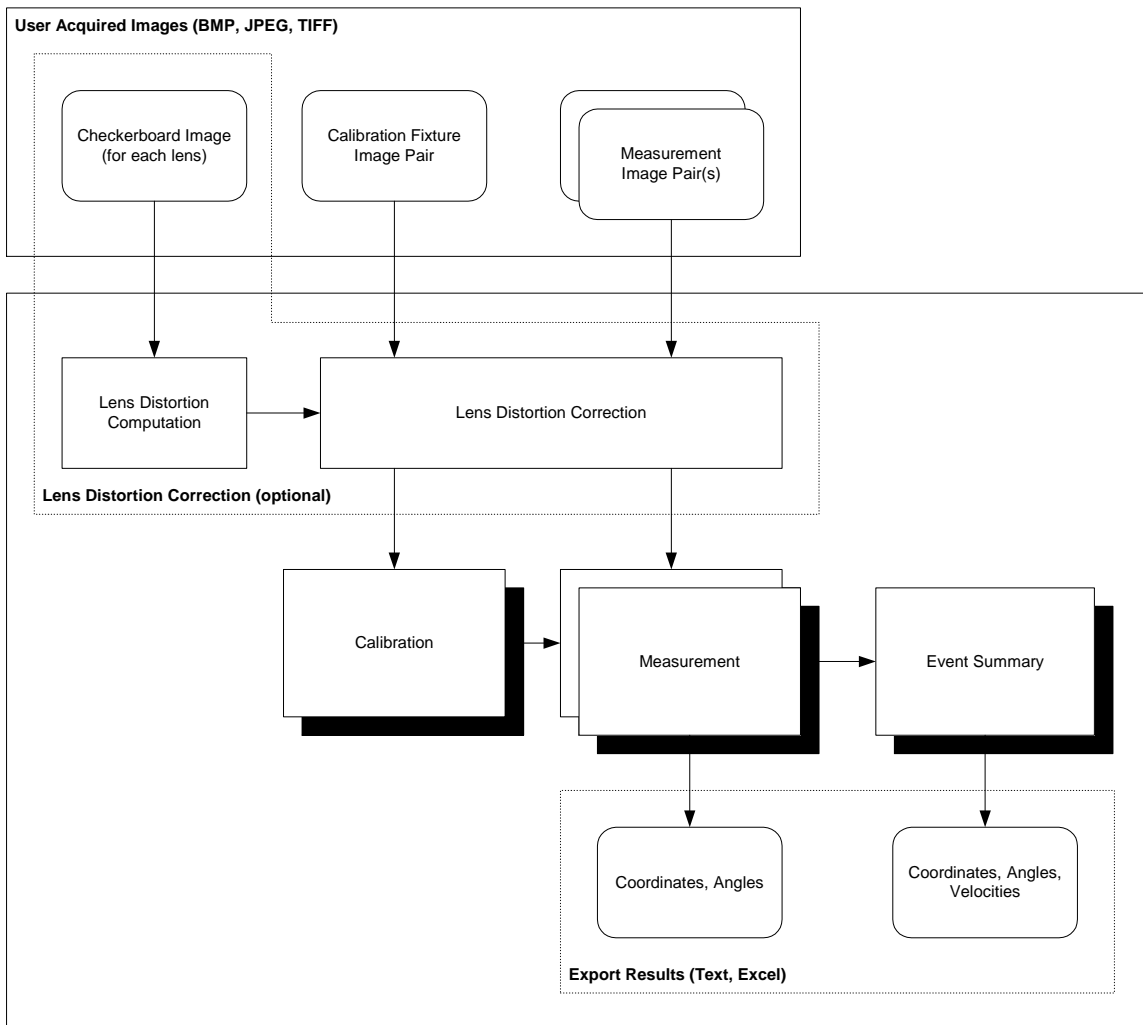
The Professional Analyst, Flight Path Edition software can provide accurate 3-D measurements of points and angles using simultaneously acquired images from a pair of cameras. This document describes the application interface, the calibration and measurement procedure, and the data export capabilities of the software.

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Application

The application has three main document types: Calibration, Measurement, and Event Summary. The Calibration document uses images of a calibration fixture taken by a pair of cameras and computes a calibration for each camera. The resulting calibration pair is used by the Measurement document to do precise measurements on a pair of images from an event. A sequence of Measurement documents is used to construct an Event Summary document that compares the results from each of the Measurement documents to produce a summary of the event. Each of these document types will be explained in more detail in the later sections.



In addition to the Calibration and Measurement images, an optional Lens Distortion Correction tool is provided for removing radial lens distortion from images. If distortion is present in your lenses, then images of a checkerboard target should be taken using each

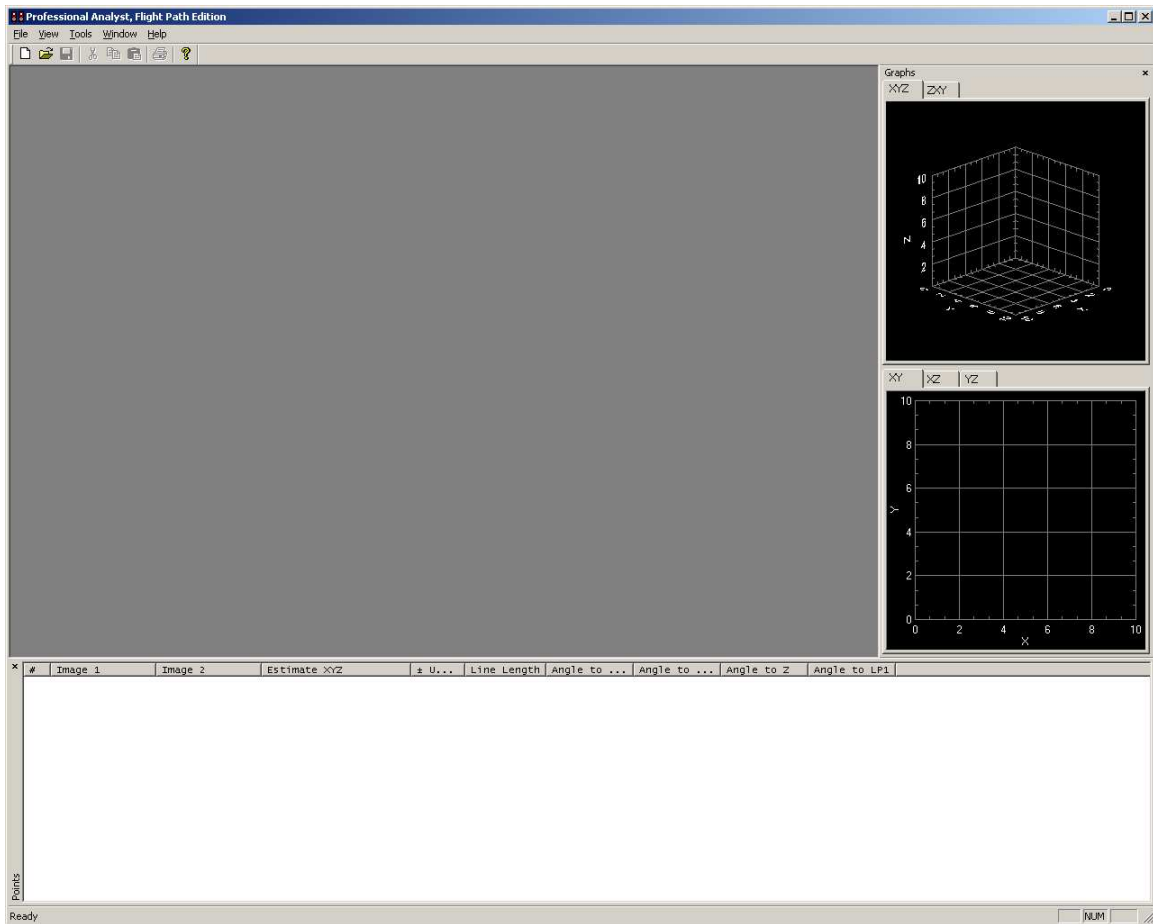
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lens and the resulting lens distortion correction computed. See the Appendix for more details on Lens Distortion Correction.

Application Windows

The main application window has three primary sections: the main desktop area where documents appear, the Graph windows, typically docked on the right, and the Points List, typically docked on the bottom.



The Graphs dialog contains a set of 3D graphs and a set of 2D graphs. The 3D graph can be rotated by clicking and dragging the left mouse button. To pan the 3D and 2D graphs, hold the **Shift** key while clicking and dragging the left mouse button. To zoom the 3D and 2D graphs, hold the **Alt** key while clicking and dragging the left mouse button. If your mouse is equipped with a wheel button, the wheel can also be used to zoom the graph windows. Additional options are available in the context menu by clicking the right mouse button over the graphs.









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The Points List provides information about all selected points for the Calibration and Measurement Documents and it provides information about the Measurement Line Pairs for the Event Summary Documents.

Document windows typically have controls on the right and images on the left. The images can be panned and zoomed using the same controls as the graphs. **Shift** + left mouse button for panning, and **Alt** + left mouse button for zooming. The mouse wheel also controls zooming. When using the mouse wheel to zoom, the image will zoom in/out on the currently selected point. This allows the user to very quickly zoom in and out on a particular feature. Click where you would like to zoom, then use the mouse wheel. The application will automatically center the current selected point.

Document windows will have a toolbar across the top of each window. The document toolbar typically contains some or all of the following controls. Many of the items below have separate settings for the top and bottom views. Click on the view that you wish to change the settings for and then click on the desired toolbar button. A green box in the upper right corner of each view indicates which view is currently active.

-  **Toggle Side Panel**
Switch the side panel between a small toolbar version and the full size version.
-  **Image Settings**
Adjust image settings such as brightness, contrast, gamma, etc.. This control has separate settings for the top and bottom views.
-  **Locate Point Settings**
Adjust parameters for the automatic location of points for Calibration Documents. This feature will be discussed later in this document. This control has separate settings for the top and bottom views.
-  **Define World Reference Frame**
Define the transformation to the world reference frame for Calibration Documents. This feature will be discussed later in this document.
-  **Define Reference Markers**
Define location of reference markers. These markers are used to perform approximate compensation for small camera motions.
-  **Enable Midpoint Finder**
Enable the midpoint finder tool. This tool allows you to click and drag two endpoints of a line in the image. The program will draw a marker that indicates the center of the line. The program will also draw a circle through the two endpoints and centered on the center of the line. To hide the midpoint finder tool, click anywhere in the image, but do not drag.
-  **Enable Reticle**
Show or hide the reticle (cross-hairs) in the view. This control has separate settings for the top and bottom views.
-  **Enable Rulers**

Show or hide rulers along the edges of the view. This control has separate settings for the top and bottom views.

 Show Point Labels

Show point labels (numbers) next to each point in the view. This control has separate settings for the top and bottom views.

 Flip Vertical

Flip the image vertically. This control has separate settings for the top and bottom views.

 Flip Horizontal

Flip the image horizontally. This control has separate settings for the top and bottom views.

 View Actual Size


Resize the displayed image so that it is shown at the actual resolution of the image. This control has separate settings for the top and bottom view.

 Fit in Window

Resize the displayed image so that the complete image is shown in the view. This control has separate settings for the top and bottom view.

 Pan Mode

Set the mouse mode to pan mode so that all left click and drag mouse operations will pan the image. This control has separate settings for the top and bottom views.

 Zoom Mode

Set the mouse mode to zoom mode so that all left click and drag mouse operations will zoom the image. This control has separate settings for the top and bottom views.

Typical Test Scenario

A typical test scenario has multiple steps. The first step is camera calibration. During calibration, you prepare the cameras to be able to perform precise measurements by determining properties of the cameras. This is typically done by capturing images of a calibration fixture and then analyzing these images to produce a calibration file. The next step is to run the actual projectile tests to conduct measurements. During measurement, images of the projectile are captured by the calibrated cameras. These measurement images, combined with the calibration from the cameras, are then used to produce 3D measurements of points on the projectile.

The calibration step only needs to be performed as necessary. If none of the cameras have been moved or changed since the last calibration, then the previous calibration should be satisfactory. The uncertainty in the measurements can be used to determine if a

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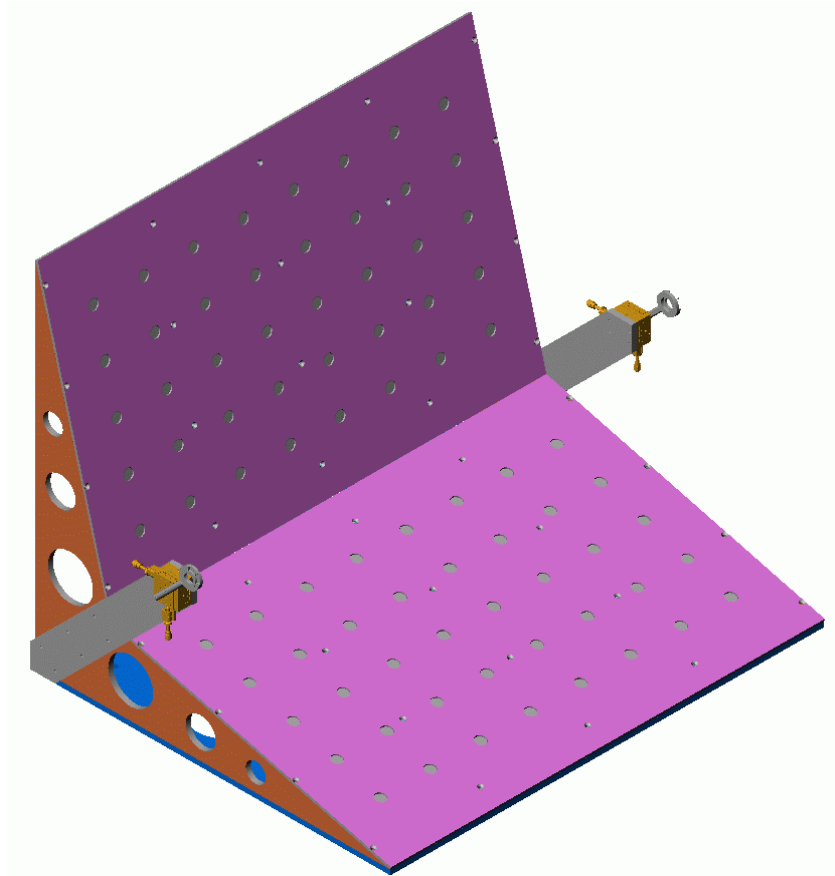
new calibration is required. If the uncertainty exceeds a desired limit, then a new calibration must be performed.

If there are multiple camera stations located along the firing path, then calibration and measurement must be performed for each station. The measurements from each of the camera stations are then combined to produce an event summary. An event summary is a collection of measurements from multiple camera or X-Ray stations for a single firing event. The event summary computes additional information by comparing the results from each of the measurements, such as velocity and angular velocity.

Calibration

In order to perform accurate measurements using the camera system, a calibration must first be performed. This calibration computes necessary information about the properties and location of each camera. If any of the cameras are moved or changed after calibration, then a new calibration must be performed.

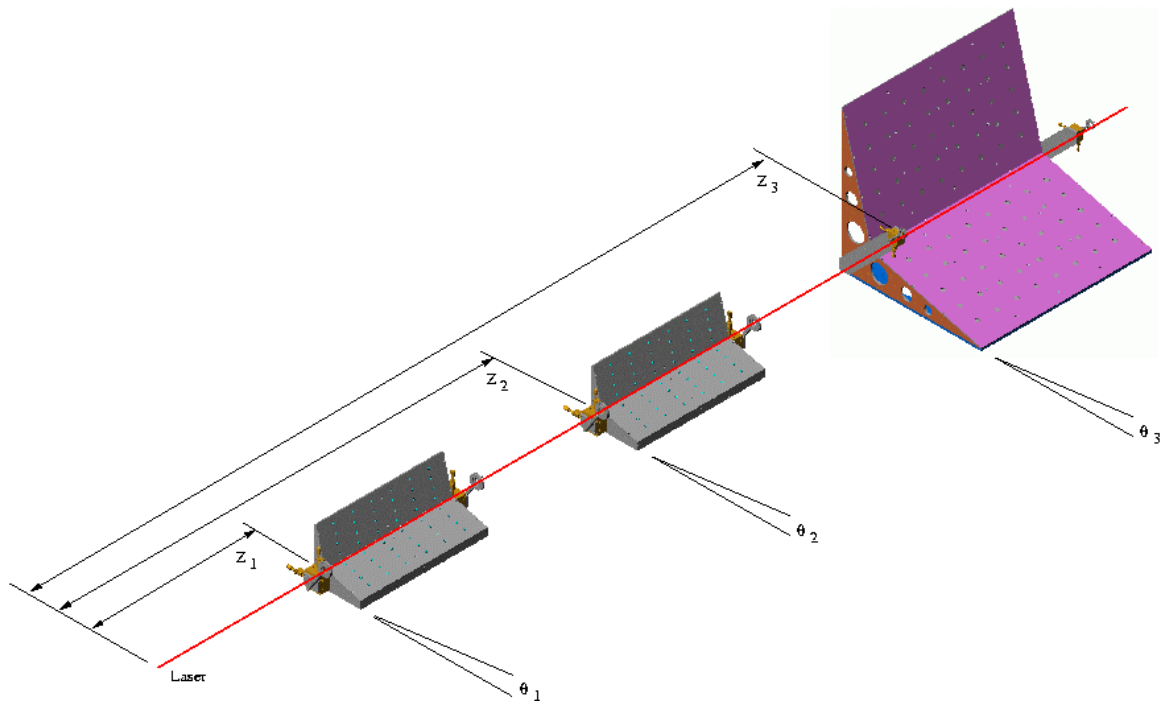
Calibration is performed by capturing images of special *calibration fixtures* that have fiducial markers at precisely known locations. These images can then be analyzed and the properties of the camera systems can be determined.



A typical calibration procedure for an event with multiple stations:

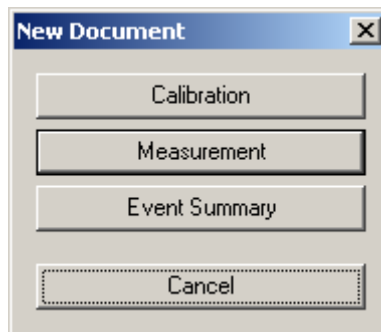
1. A laser should be used to ensure alignment of each calibration fixture relative to the firing path. Place the laser next to the gun barrel and shine it down the expected path of the projectile.
2. Place the calibration fixture in the center of the field of view of each camera, roughly aligned to the path of the projectile (within $\pm 6-7\text{mm}$). The entire calibration fixture (including irises) should be completely visible in both camera views.
3. Adjust the position of the irises on the ends of the calibration fixture using the fine adjustment screws so that the laser passes through the exact center of both irises when they are closed. If the laser cannot be centered on the irises, then shift the whole calibration fixture so that the laser can be centered in the irises.
4. Measure the distance from the gun barrel to the first iris on each calibration fixture. This will be the *Z Coordinate of the First Point* for each fixture. This value is used to help define the world reference frame.
5. Measure the angle of each calibration fixture in the direction perpendicular to the path of the projectile. This will be the *Base Angle* for each fixture. This value is used to help define the world reference frame.
6. Capture images of each calibration fixture from each camera.

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The resulting images are then used to create *Calibration Documents* for each camera pair.

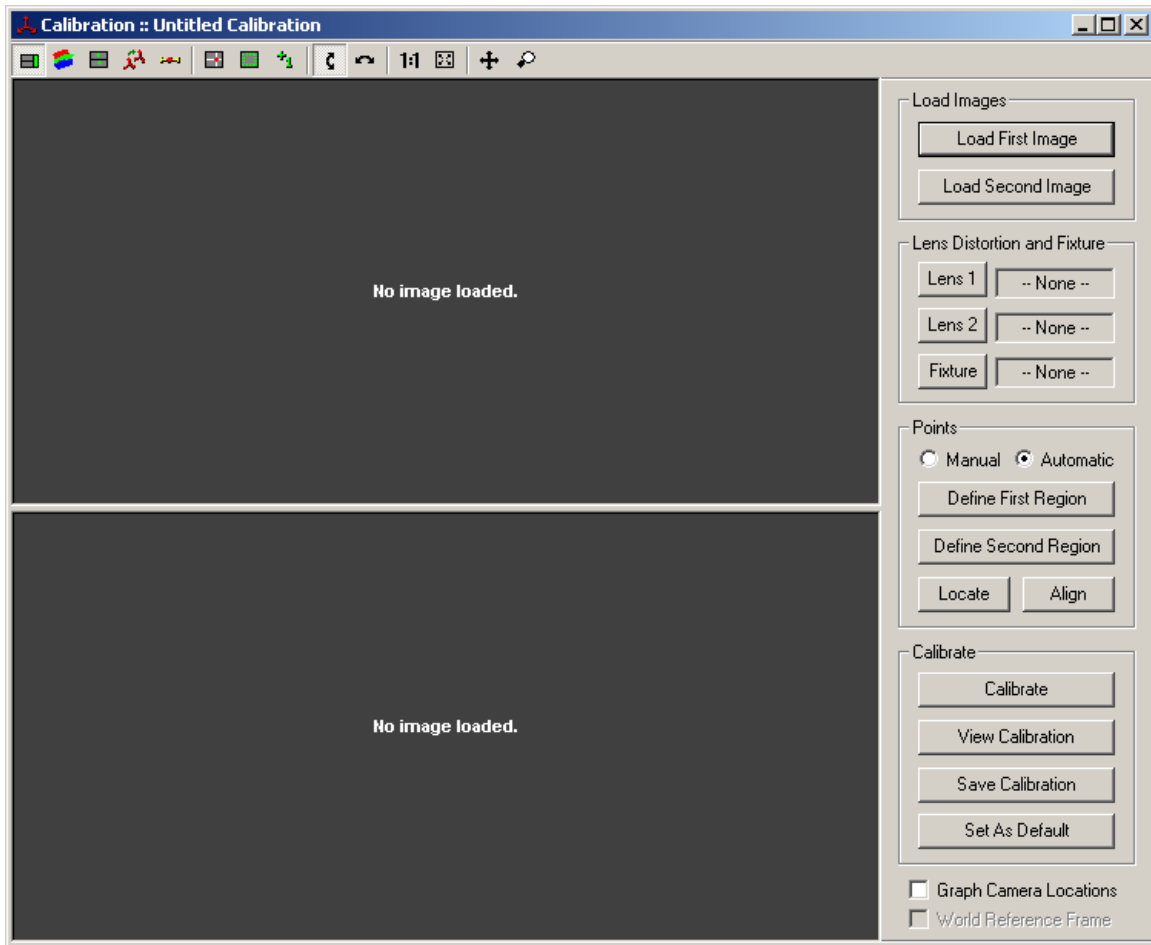
A Calibration Document is created by selecting **File** → **New**.



Then select **Calibration**. An empty calibration document will appear.

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All controls are located on the top toolbar and on the left panel of the Calibration Document window. The toolbar controls were described earlier in this document.

The standard procedure for calibrating cameras is as follows:

1. Load the first calibration image by clicking on the **Load First Image** button and select the correct image file (BMP, TIFF, or JPEG). This image should be the top view looking down upon the calibration fixture.
2. Load the second calibration image by clicking on the **Load Second Image** button and select the correct image file. This image should be the side view looking horizontally at the calibration fixture.
3. If the lenses that are being used require distortion correction, load the appropriate lens coefficient files using the **Lens 1** button or the **Lens 2** button for the first and second images respectively. The lens coefficient files (*.lens) should be generated using the Lens Distortion Correction Tool described in the Appendix.
4. Load the fixture information file for the specific calibration fixture that is being used. The fixture file (*.fixt) should have been supplied with each calibration fixture. The fixture file contains information about the location of the fixture points and the default units of measure.

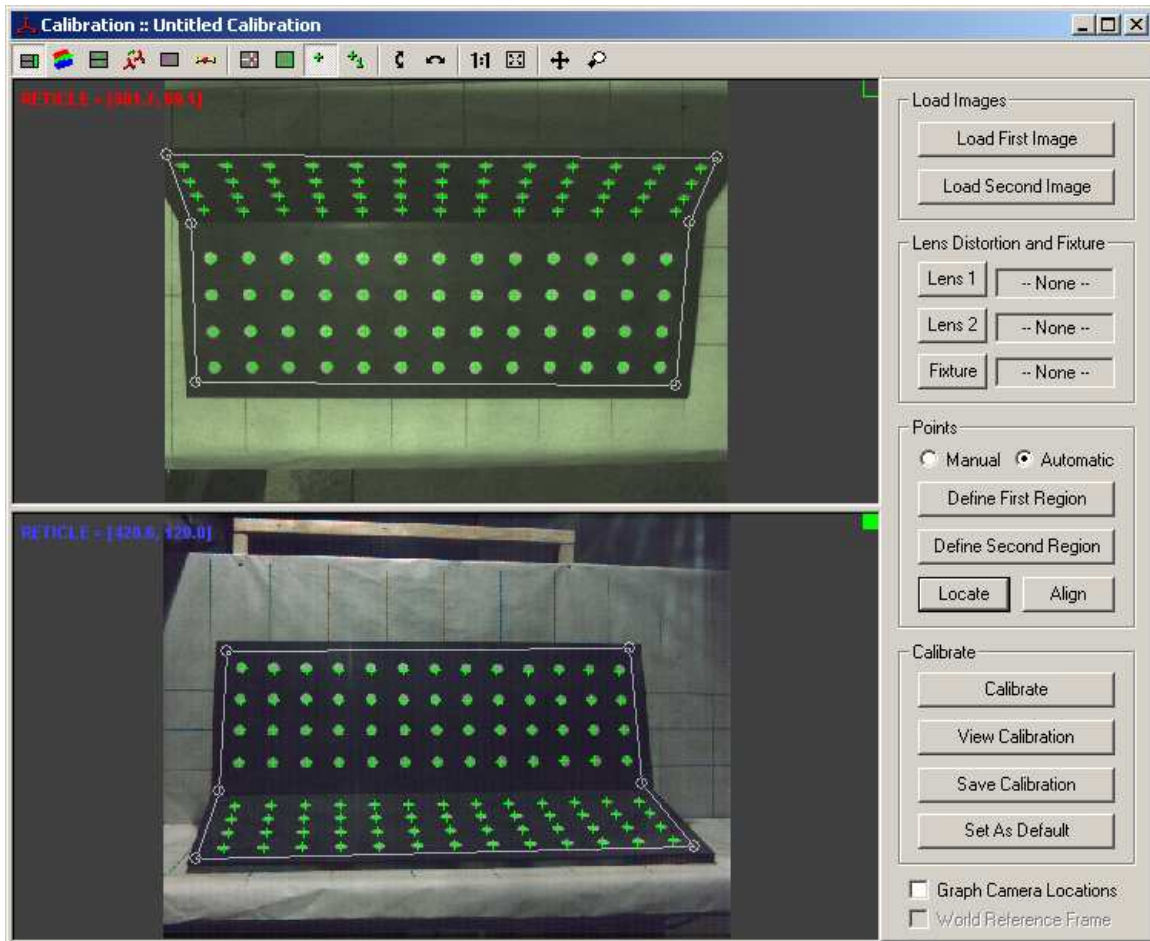
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5. Now the fixture points need to be identified in the top and bottom images. There are multiple options for locating the fixture points. It can be done manually or automatically.

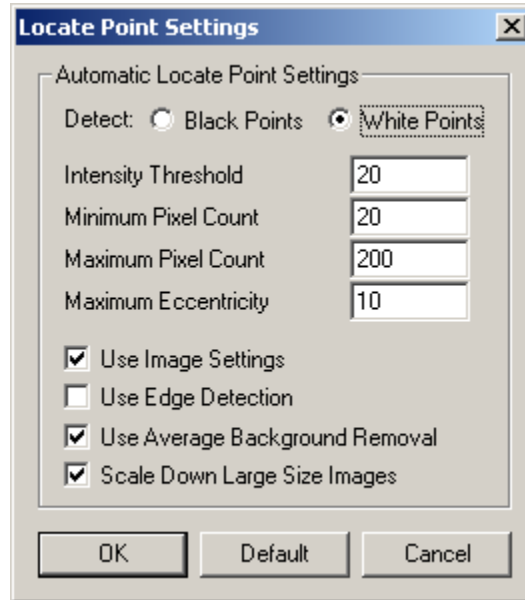
To locate points automatically:

- Select **Automatic** in the Points section of the right panel.
- Define a region around all the fixture points in the top image by clicking on **Define First Region**. Then click on six points that outline all points in the upper image. If you make a mistake, click on **Define First Region** again and redraw the six point region.
- Define a region around all the fixture points in the bottom image by clicking on **Define Second Region**. Then click on six points that outline all points in the bottom image.
- Click on **Locate** to automatically locate fixture points in both images.



- If the automatic location of points fails, there are parameters that can be adjusted to change the behavior of the automatic location scheme.

- i. Click on the **Locate Point Settings** icon on the toolbar, or right-click on the top or bottom image and select **Locate Point Settings** from the drop down menu.

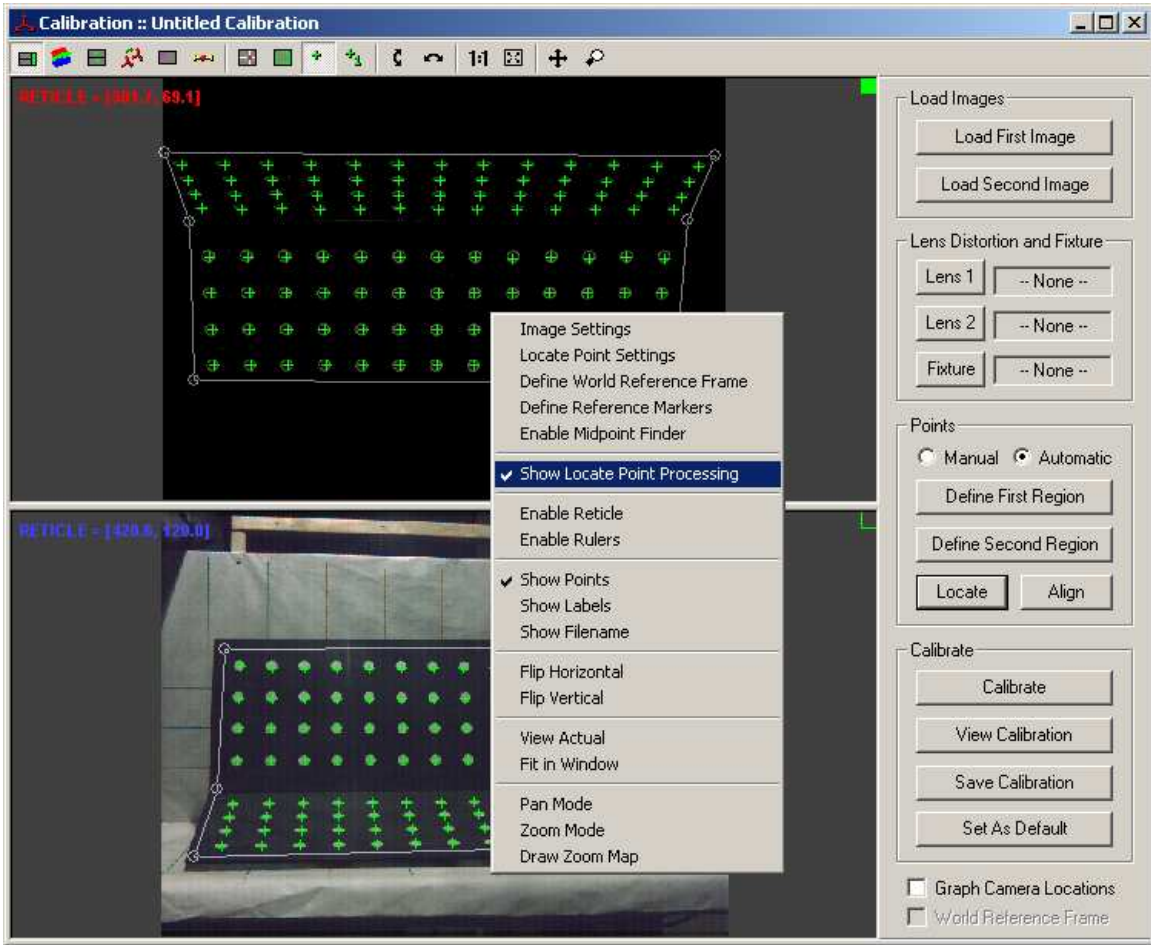


There are different settings for the top and bottom images, so if necessary, change both settings separately.

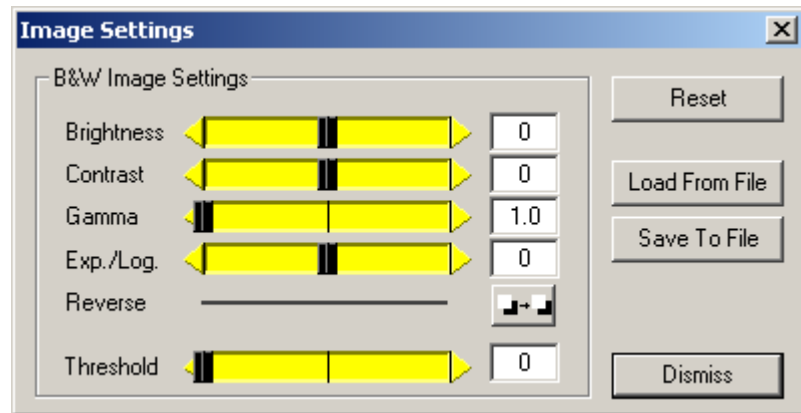
A useful tool for helping to know how to adjust the Locate Point Settings is the Show Locate Point Processing option available in the context menu of the image window. Right-click on the image and select **Show Locate Point Processing**.

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- ii. In addition, improving the contrast of the fixture points can also help in automatically locating them. You can change the image settings for the top and bottom images by clicking on the **Image Settings** icon on the toolbar, or right-click on the image and select **Image Settings** from the drop down menu.



To locate points manually:

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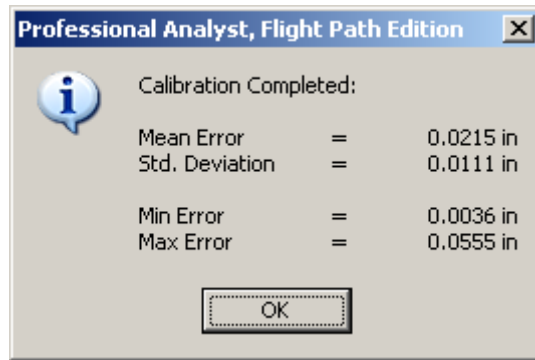
- Select **Manual** in the Points section of the right panel.
- Click on a point in the top image corresponding to a fixture point.
- Click on a point in the bottom image corresponding to the same fixture point.
- Click on the **Add Point** button.
- If you wish to adjust the coordinates of a point, select the point in the Points list. Click on the correct points in the top and bottom images. Then click on the **Update Point** button.

#	Image 1	Image 2	Calibration XYZ	Estimate XYZ	Error
1	15.5,	77.0	69.9, 138.6	3.08, 11.49, 0.00	
2	54.8,	77.0	99.3, 138.9	3.08, 11.49, 3.00	
3	93.9,	77.0	128.5, 138.9	3.08, 11.49, 6.00	
4	133.5,	77.0	157.5, 139.1	3.08, 11.49, 9.00	
5	173.0,	77.2	186.7, 139.0	3.08, 11.49, 12.00	
6	212.6,	76.9	215.7, 138.9	3.08, 11.49, 15.00	
7	252.0,	77.0	244.6, 139.4	3.08, 11.49, 18.00	
8	291.6,	77.3	272.8, 139.5	3.08, 11.49, 21.00	
9	331.1,	77.5	300.8, 139.7	3.08, 11.49, 24.00	
10	370.5,	78.0	329.1, 140.2	3.08, 11.49, 27.00	
11	409.6,	78.0	357.0, 139.9	3.08, 11.49, 30.00	
12	448.8,	78.3	384.2, 140.1	3.08, 11.49, 33.00	
13	487.9,	78.9	411.3, 140.8	3.08, 11.49, 36.00	
14	21.6,	91.2	68.5, 167.2	2.30, 8.60, 0.00	

- To remove a point, select the points to remove in the Points list. Then click on the **Remove** button.
- After you have set all the fixture points, if you wish for them to be automatically aligned to a standard grid pattern used by typical calibration fixtures, then click on the **Align** button.

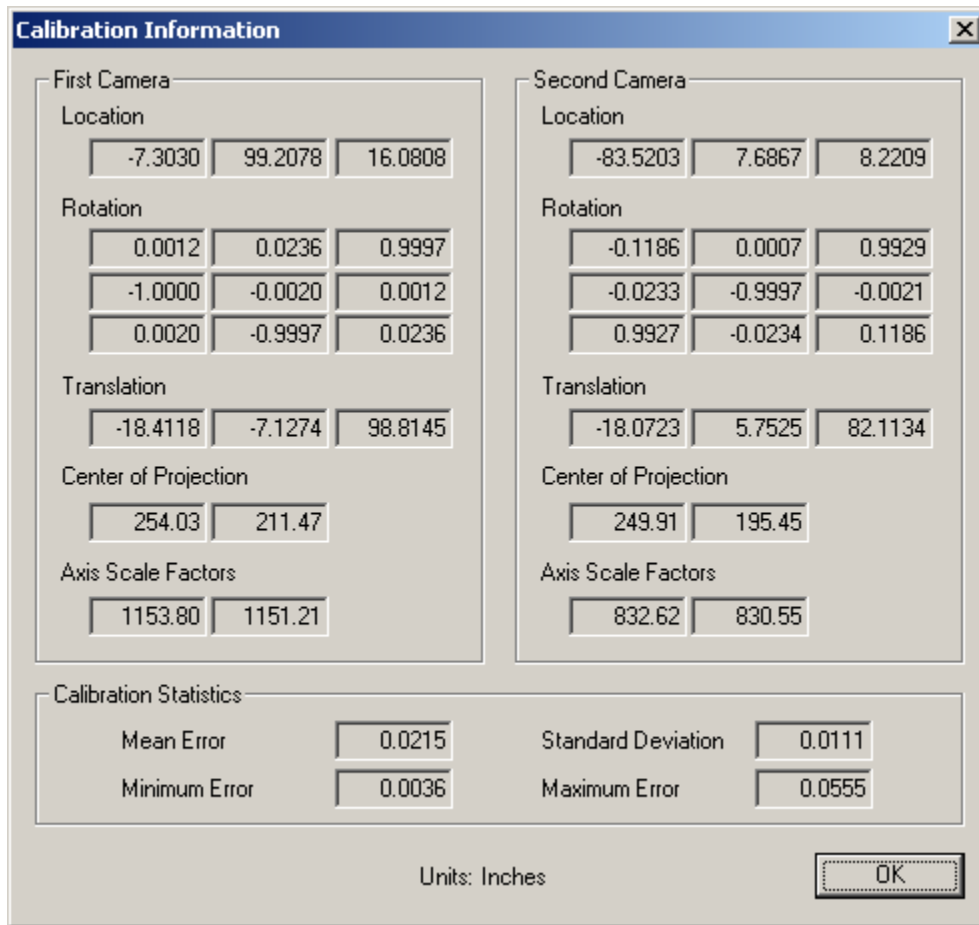
6. Once all fixture points have been located, click on the **Calibrate** button.

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If the calibration statistics are unsatisfactory, you must check your sources of error. Check that all points have been located properly. Check that there is no unwanted distortion introduced by the camera lenses, mirror, or other optics.

After a pair of cameras has been calibrated, you can view the results of the calibration by selecting **View Calibration**.



After the cameras have been calibrated, for every point that you click on in the top image, an epipolar line will be drawn in the bottom image and vice versa. The epipolar line

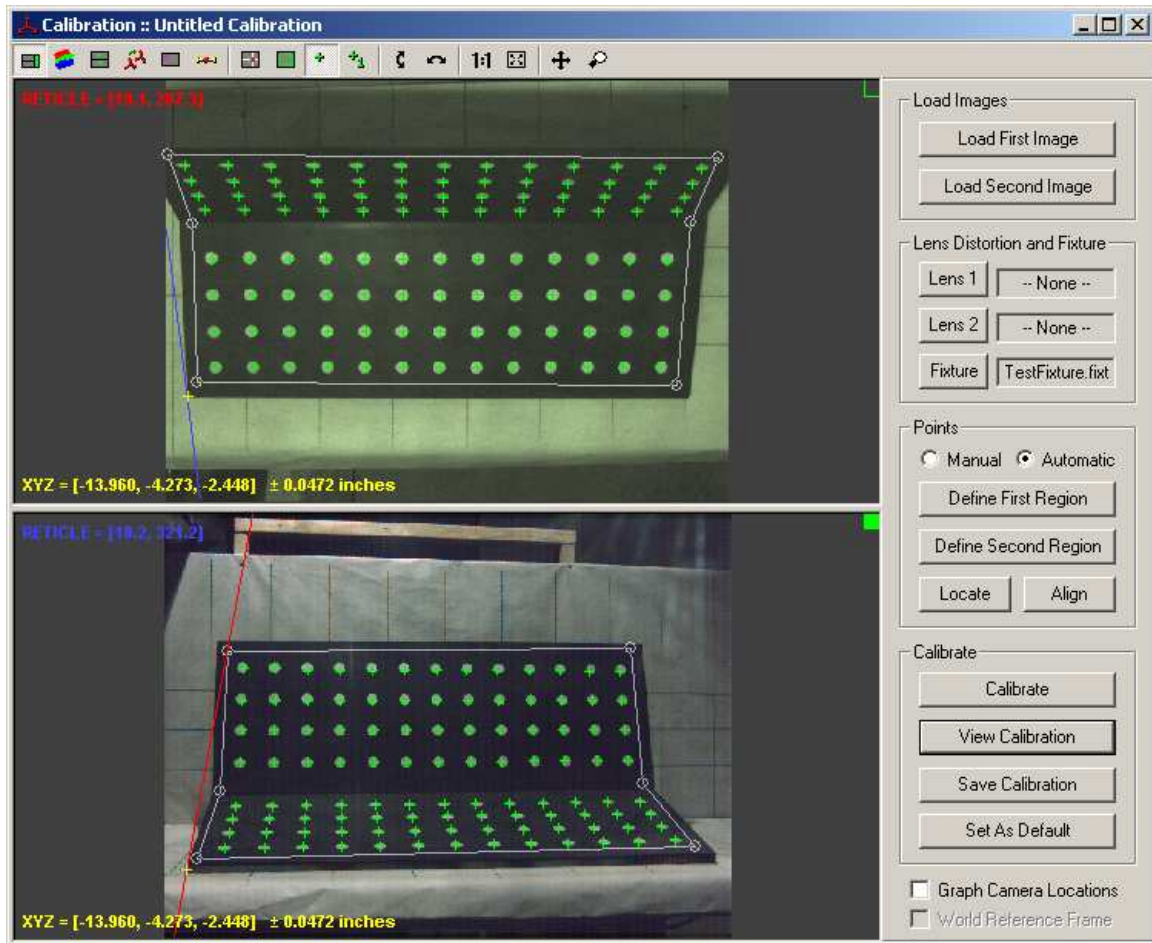
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indicates which points in the bottom image could correspond with the point that you have clicked on in the top image.

The current point in the top image is shown with a red plus symbol. The corresponding epipolar line in the bottom image is shown as a red line. The current point in the bottom image is shown with a blue plus symbol. The corresponding epipolar line in the top image is shown with a blue line.

The red plus and the blue line and the blue plus and the red line may not exactly intersect. The red and blue lines represent images of two rays coming from each camera. Since they do not exactly cross, the midpoint of the shortest distance between the two lines is shown with a yellow plus symbol in both the top and bottom views. The distance from the yellow plus to the red and blue lines is the uncertainty in the position estimate. Information along the bottom of each view indicates the 3D coordinates of the midpoint and the uncertainty associated with the 3D coordinates.



When you are satisfied with the calibration results, you can save the calibration to a file using the **Save Calibration** button. This will save all the calibration information to a

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calibration file (*.calb) that can be used by the Measurement document to perform measurements on other images taken by the same cameras.

If you would like the same calibration to be used for all newly created Measurement documents, then select the **Set As Default** button after the calibration has been saved to a file.

World Reference Frame

The coordinate frame of the calibration is the coordinate frame that is used by the calibration fixture file that was loaded. All the coordinates in the fixture file are referenced from some point of origin on the fixture. In order to compare information from one pair of cameras to another pair of cameras or X-Ray systems, the coordinates need to be referenced to some mutual world reference frame. All coordinates can then be transformed from the local calibration fixture reference frame to the world reference frame.

A tool is provided to help define the transformation between the calibration fixture and world reference frame. You can access this tool by selecting the **Define World Reference Frame** button on the toolbar, or by right-clicking in the image and selecting **Define World Reference Frame**.

There are two methods for entering information about the world reference frame. You can directly type in the rotation and translation matrix used to transform calibration coordinates to world coordinates. Or you can select two points that lie on the world reference frame Z-axis and supply the Z coordinate of the first point and the base angle of the fixture.

For the first method, if the rotation matrix and translation vector are known, simply enter them into the appropriate boxes and hit **OK**.

For the second method, the standard calibration fixture that was designed to be used with this software should be equipped with two adjustable irises, one on each side of the fixture. The calibration fixture should have been positioned so that the irises are aligned with the flight path and are visible in both the top and bottom camera views. To define the world reference frame:

1. The system should have been calibrated already, as described earlier.
2. Click on the center of the left iris in the top and bottom views of the calibration document window. Check the uncertainty in the coordinates to make sure that a suitable point has been chosen.
3. Click on **Get Current** for the **First Point** in the Define World Reference Frame dialog. An orange box should appear in the calibration document window to indicate the first point.

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4. Click on the center of the right iris in the top and bottom views of the calibration document window. Check the uncertainty in the coordinates to make sure that a suitable point has been chosen.
5. Click on **Get Current** for the **Second Point** in the Define World Reference Frame dialog. An orange box should appear in the calibration document window to indicate the second point and a dotted line should be drawn between the first and second points.
6. Enter in the **Z Coordinate of the First Point** and the units of the Z coordinate. This should have been measured when the calibration fixtures were being aligned.
7. Enter in the **Base Angle** in degrees. This should have been measured when the calibration fixtures were being aligned.
8. Hit **Apply** and the equivalent rotation and translation will be computed and applied.

#	Image 1	Image 2	Calibration XYZ	Estimate XYZ	Error		
1	305.4	1458.8	415.3	519.4	15.42, 57.56, 0.00	15.63, 57.58, -0.01	0.13
2	497.1	1456.6	598.6	520.3	15.42, 57.56, 12.70	15.51, 57.57, 12.76	0.11
3	607.9	1454.4	780.2	521.2	15.42, 57.56, 25.40	15.49, 57.57, 25.44	0.08
4	880.4	1452.2	961.3	522.1	15.42, 57.56, 38.10	15.47, 57.56, 38.15	0.07
5	1071.	1450	1142.5	523.0	15.42, 57.56, 50.80	15.45, 57.55, 50.79	0.03
6	1262.	1448	1323.6	523.9	15.42, 57.56, 63.50	15.43, 57.54, 63.45	0.05
7	1453.	1446	1505.6	524.7	15.42, 57.56, 76.20	15.40, 57.53, 76.13	0.07
8	1644.	1443	1689.6	525.6	15.42, 57.56, 88.90	15.38, 57.52, 88.89	0.06
9	310.5	1412.2	413.3	677.1	12.46, 46.52, 0.00	12.58, 46.53, -0.04	0.13
10	501.4	1409.9	596.7	678.0	12.46, 46.52, 12.70	12.56, 46.52, 12.74	0.10
11	690.9	1407.7	778.5	678.9	12.46, 46.52, 25.40	12.53, 46.52, 25.42	0.07
12	881.9	1405.4	960.0	679.8	12.46, 46.52, 38.10	12.50, 46.51, 38.14	0.05
13	1071.	1403	1141.2	680.7	12.46, 46.52, 50.80	12.47, 46.50, 50.79	0.02
14	1261.	1401	1322.4	681.6	12.46, 46.52, 63.50	12.44, 46.49, 63.45	0.06
15	1451.	1399	1504.7	682.5	12.46, 46.52, 76.20	12.41, 46.49, 76.14	0.08
16	1641.	1396	1689.0	683.5	12.46, 46.52, 88.90	12.38, 46.48, 88.90	0.09
17	315.6	1365.6	411.2	834.9	9.51, 35.48, 0.00	9.59, 35.48, -0.07	0.11
18	505.8	1363.4	594.8	835.8	9.51, 35.48, 12.70	9.56, 35.48, 12.73	0.07
19	691.8	1361.2	776.9	836.7	9.51, 35.48, 25.40	9.54, 35.48, 25.41	0.03

Once the world reference frame has been defined, the coordinates of all points can be displayed in either the local calibration reference frame or the world reference frame. You can select which frame to display in by checking the **World Reference Frame** checkbox in the side control panel. When displaying coordinates in the world reference frame, the graphs will label the axes as Xw, Yw, and Zw.

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The world reference frame must be defined for each calibration if you want to compare the measurements from one camera pair to another camera or X-Ray pair. For example, the Event Summary document, that is described later, compares the results from multiple measurement documents to compute velocity and angular velocity. In order to compare these results, all the coordinates must be transformed into the same reference frame (the world reference frame).

Reference Markers

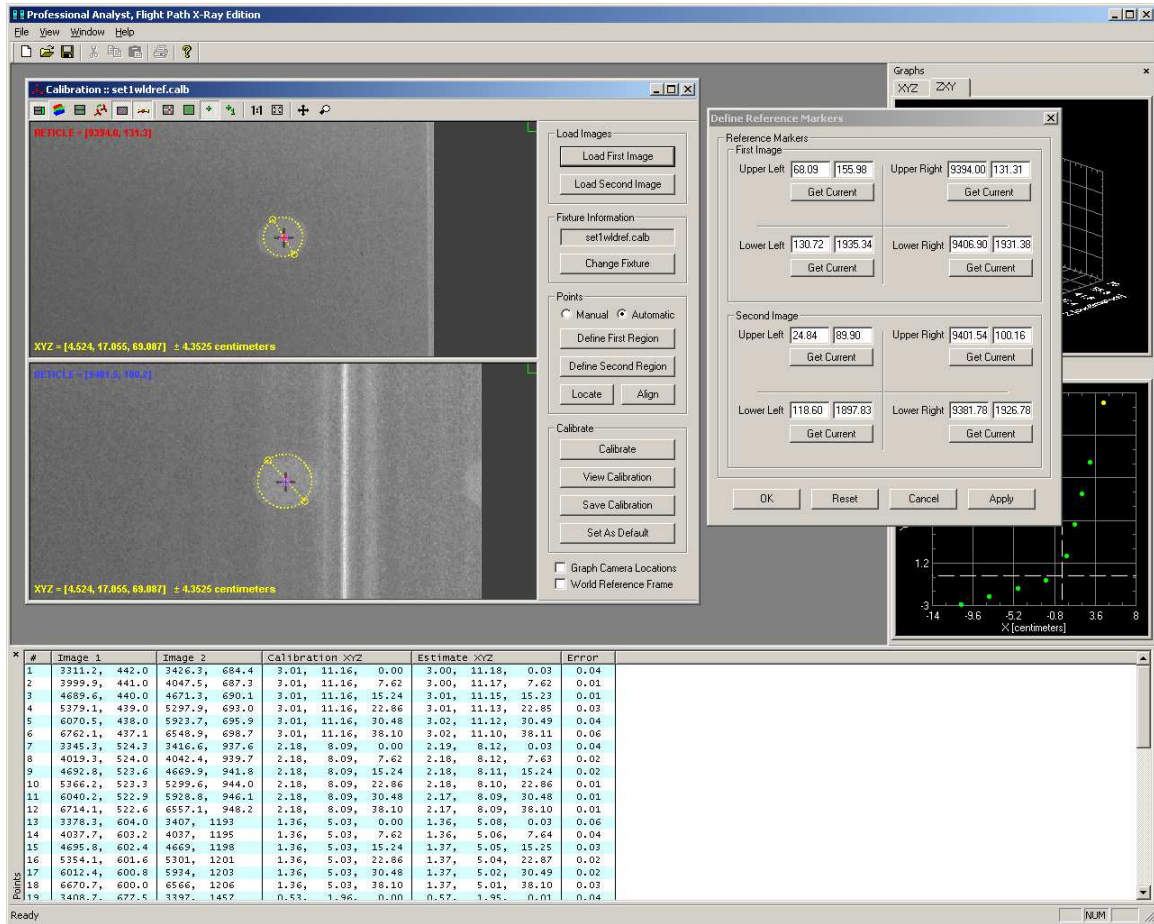
In order to approximately compensate for small camera motions between calibration and measurement, reference markers can be placed in the field of view of both cameras.

There should be reference marks located in all four corners of each camera image. The compensation algorithm will compute the necessary transformation to ensure that the reference marks in the measurement images exactly overlap the reference marks in the calibration images.

You must identify and store the location of each of the reference marks for each calibration. Click on the **Define Reference Markers** button on the toolbar. Click on each of the reference markers in the first and second image and click on the appropriate **Get Current** button for each mark.

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After all eight reference markers have been located, hit **Apply**. The location of these markers will be saved with the calibration information when the calibration is saved. These values will be used during measurement to try to compensate for any movement of the cameras between shots.

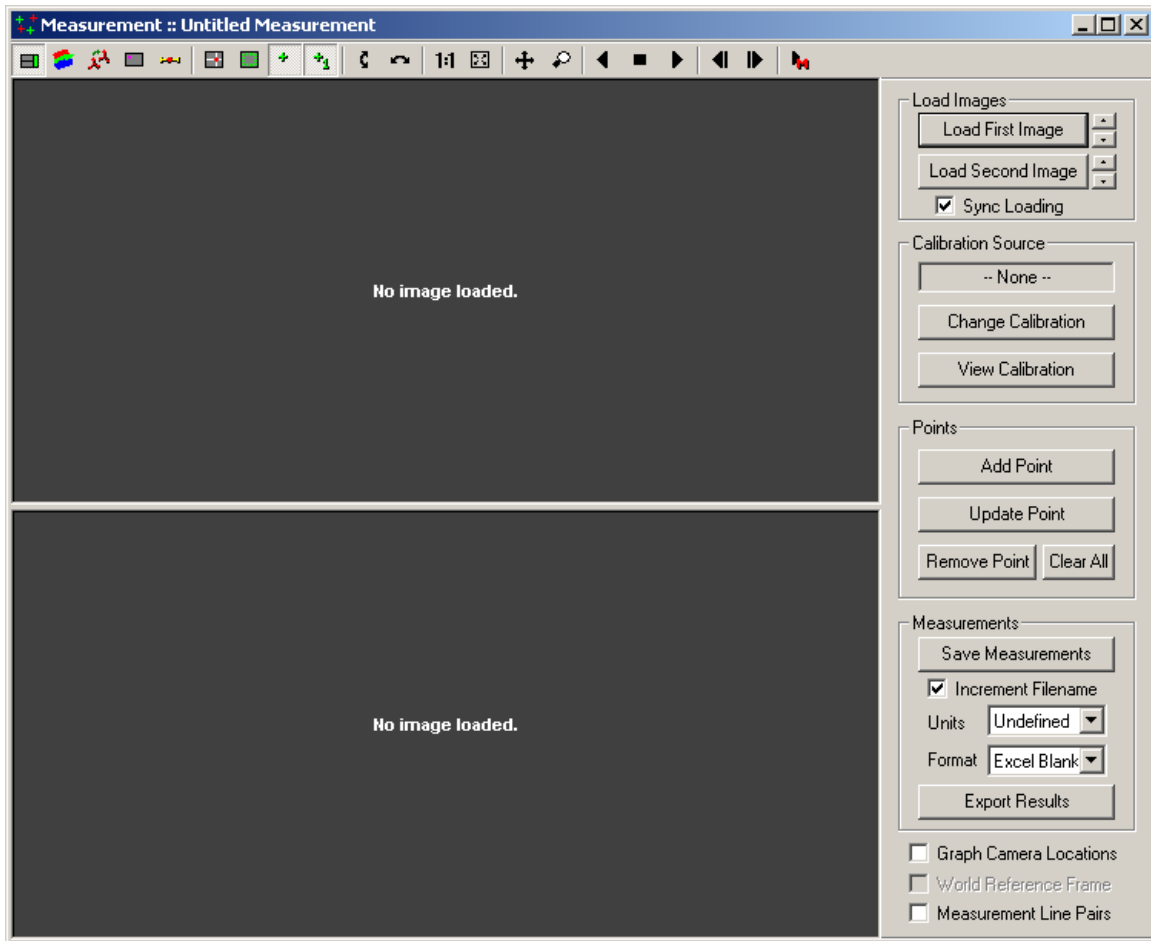
Measurement

After a calibration has been completed and a test has been conducted. The resulting images from the test can be used to perform measurements.

A Measurement Document is created by selecting **File** → **New**. Then select **Measurement**.

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All the controls are located on the toolbar or on the panel on the right. The toolbar controls were described earlier in this document.

A pair of images from an actual test should be loaded into the Measurement document. An image from the top camera should be loaded using the **Load First Image** button. An image from the side camera should be loaded using the **Load Second Image** button.

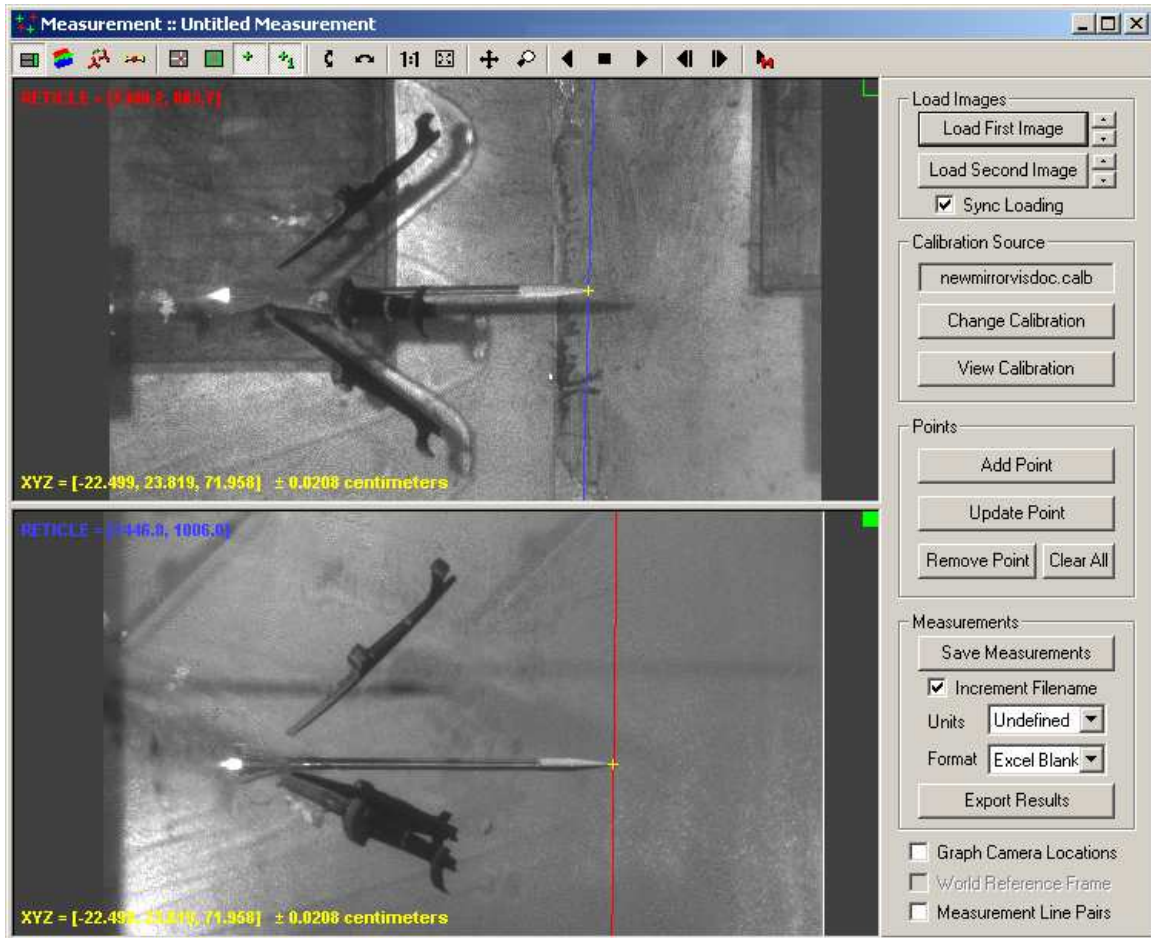
To perform measurements, a calibration must have already been performed for the cameras being used. If a default calibration had been set, the default calibration is automatically loaded. If a default has not been set, then a calibration must be loaded by using the **Change Calibration** button.

When a calibration is loaded, any lens distortion information is also automatically loaded and applied. See the Appendix for more information on lens distortion correction.

The units of measure and the world reference frame transformation are also loaded from the calibration file. The units of measure that are displayed can be changed by changing the units in the panel on the right. The world reference frame transformation can be viewed or modified using the toolbar button or the right-click context menu.

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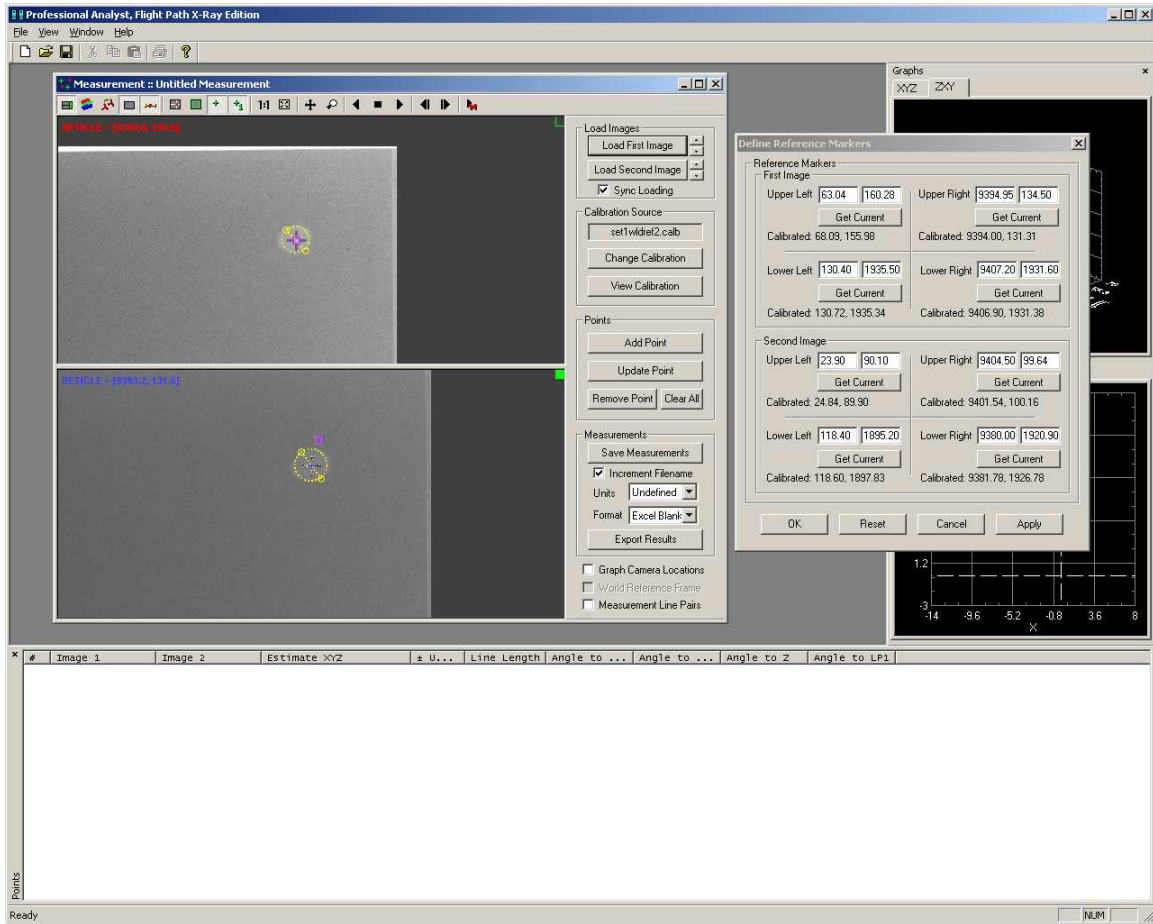


If you would like to review the calibration information, select the **View Calibration** button.

After loading the calibration, you must locate the reference markers. Click on the **Define Reference Markers** button on the toolbar. Locate each of the reference markers and click on the **Get Current** button for each marker.

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After all reference markers have been located, click on **Apply**. This will transform each of the images so that the reference markers are in the same location as the calibration images.

Measurements can either be the 3D location of a single point, or the 3D locations of the end points of a *Line Pair*. A line pair is a grouping of two sequential measurement points (points 1 and 2, 3 and 4, 5 and 6, ...).

Each Measurement document can display information as single point measurements or as line pairs. To change the display, click on **Measurement Line Pairs** checkbox in the right hand panel. When the Measurement document is set to show information as line pairs, additional orientation and length information is computed for each line pair and displayed in the Points listing. In addition, the first point in a line pair is shown in green and the second point in a line pair is shown in magenta. The connecting line is shown in cyan.

Typical steps to perform a measurement:

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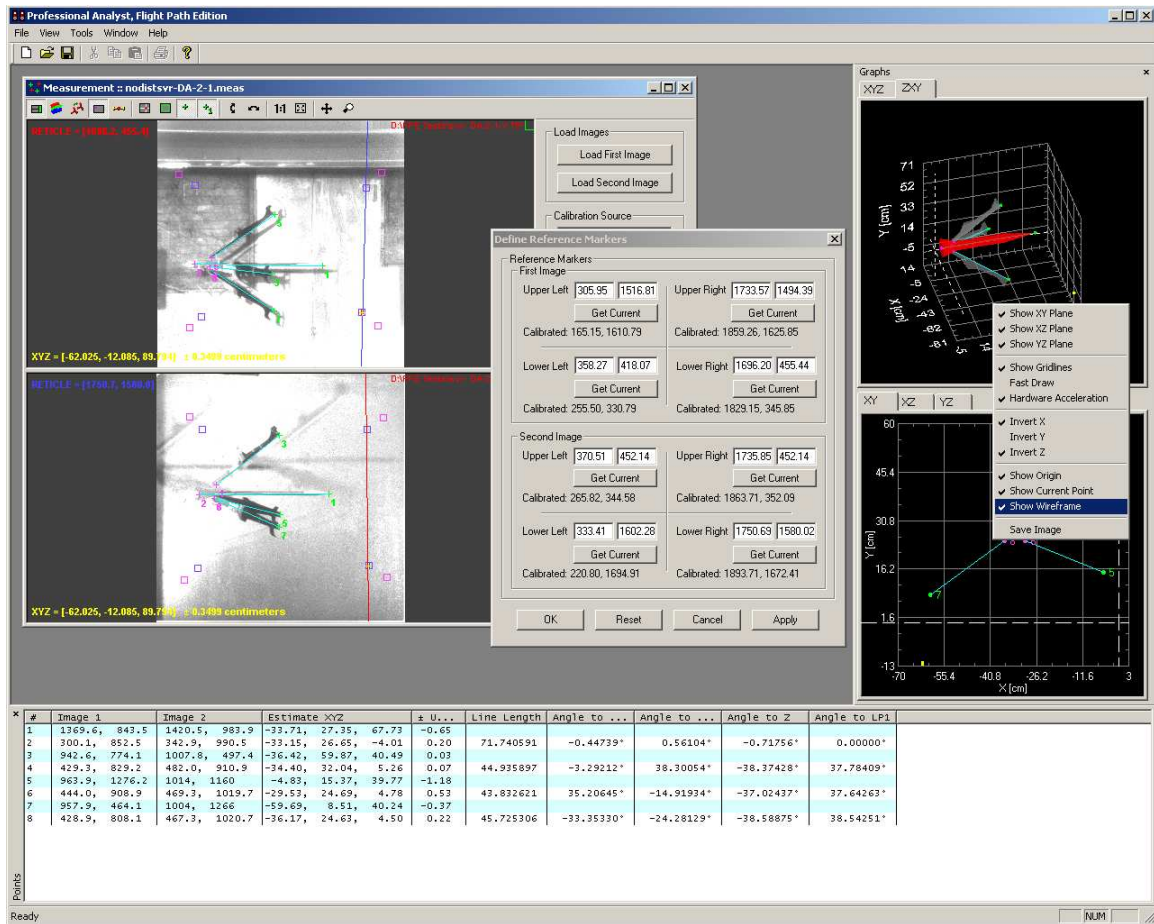
1. Click on a feature point in the top image. Zoom in using the mouse wheel to accurately select a feature point. The mouse wheel will zoom in/out on the currently selected point. It is always a good idea to zoom in on a feature point to ensure that you have selected the proper point.
2. Click on the corresponding feature point in the bottom image. Zoom in using the mouse wheel to accurately select a feature point. Verify that the uncertainty in the resulting image coordinates is acceptable. The uncertainty is shown on the bottom of each view. The red, blue, and yellow points and lines should be near one another in both images.
3. If you are satisfied with the feature points and uncertainty, click on **Add Point**.
4. If you would like to update the coordinates of a point, select the point in the Points list. Click on the correct feature point in the top and bottom image, then click **Update Point**.
5. To remove a point, select the point in the Points list and then click on **Remove Point**.

#	Image 1	Image 2	Estimate XYZ	± U...	Line Length	Angle to ...	Angle to ...	Angle to Z	Angle to LP1
1	1280.2, 883.7	1447, 1006	3.0, -0.3, 578.4	0.02					
2	343.7, 870.0	419.3, 1007.3	1.5, -0.9, 508.4	0.11	70.008930	1.22332°	0.43770°	-1.29923°	0.00000°
3	917.1, 822.8	1001.4, 476.8	-1.0, 35.3, 547.8	0.11					
4	461.4, 862.0	537.7, 924.6	1.1, 4.8, 516.5	0.16	43.720347	-3.83529°	44.32804°	-44.39533°	44.05653°
5	941.8, 1320.3	1002, 1205	32.7, -14.4, 548.1	0.08					
6	478.7, 936.2	551.5, 1038.1	6.1, -2.9, 517.3	0.12	42.253372	40.94314°	-20.47869°	-43.36557°	42.42241°
7	937.6, 484.0	1002, 1295	-24.8, -19.9, 548.6	0.09					
8	462.4, 823.6	533.4, 1056.1	-1.6, -4.1, 516.3	0.12	42.729142	-35.73434°	-26.12573°	-41.04757°	42.30591°

The resulting points are displayed in the graph to the right. A wireframe can also be displayed over the 3D graph. Click the right mouse button on the 3D graph and select **Show Wireframe**.

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When you have selected all the points of interest, you can save your measurement results to a file. This will save the calibration information and measurement information to a measurement file (*.meas).

Note that the measurement file contains a copy of the calibration information. Once it is saved to the measurement file, the measurement does not use the original calibration file. If you make any changes to the original calibration file, you must reload the calibration into the measurement document using the **Change Calibration** button in order to apply the changes.

You can also export the measurement results to a Text document or to an Excel spreadsheet. First select the units and the export format and then hit the **Export Results** button. Here is a sample of the export results in Excel format. The sections are color coded to correspond to the first and second points in the line pairs and the line information for each pair.

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The screenshot shows an Excel spreadsheet with the following structure:

- Row 1:** Title "Professional Analyst, Flight Path Edition Data Sheet" (background: black)
- Row 4:** Section header "Test Data" (background: blue)
- Row 6:** File Name: (empty)
- Row 7:** Date: 7/9/2004
- Row 8:** Time: 12:18:36 PM
- Row 9:** Units: Centimeters
- Row 12:** Section header "Measurement Data" (background: blue)
- Row 14:** Section header "First Points" (background: green)
- Row 15:** Section header "Second Points" (background: magenta)
- Row 16:** Headers for "First Points": Image 1 (U, V), Image 2 (U, V), Estimated Position (X, Y, Z), ± Uncertainty
- Row 16:** Headers for "Second Points": Image 1 (U, V), Image 2 (U, V), Estimated Position (X, Y, Z), ± Uncertainty
- Rows 17-21:** Data rows for both "First Points" and "Second Points" columns.

If the same calculations are always done in Excel, the export feature can also be told to use an existing Excel file as a template for the export results. This template can contain formulas, graphs, or any other Excel elements. Select **Excel Template** as the **Format** type before exporting. Then select the Excel file to use as a template.

Analyzing Sequences of Images

Additional controls have been added to the Measurement window to simplify the process of analyzing a sequence of images:

Play controls have been appended to the toolbar on the Measurements window.



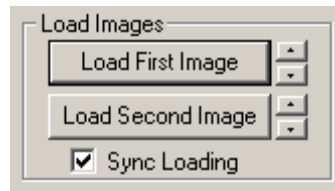
These play controls will play either images or measurements. The last button on the toolbar controls whether images or measurements are played. When playing images, the program will try to find the next similarly named image in the same

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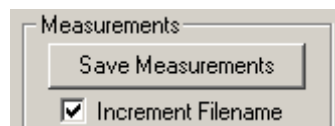
directory as the upper and lower images respectively. If a similarly named image file is found, that image file is loaded. When playing measurement files, the program will look for a similarly named measurement file in the same directory as the current measurement file. If a similarly named measurement file is found, that measurement file (and corresponding images and measurement points) is loaded. Similarly named files are files that have the same prefix and extension, but with a different set of digits at the end. For example: image01.tif, image02.tif, and image03.tif are similarly named image files.

Spin controls have been added to the right of the load image buttons.



These controls help you to browse through a sequence of image files. Press the up button to find the next similarly named file. Press the down button to find the previous similarly named file. If the **Sync Loading** checkbox is checked, then when you press the up or down for the first or second image, the other image will also locate the next or previous image file. When **Sync Loading** is checked, the spin controls behave the same as the play controls on the toolbar.

An **Increment Filename** checkbox has been added below the **Save Measurements** button.



When this is checked, when the **Save Measurements** button is pressed, the program will automatically increment the current document filename and use that as the default save filename. For example: if the current measurement has been saved to a file frame01.meas, when **Save Measurements** is pressed, the default save filename in the save dialog will appear as frame02.meas.

To take advantage of these new controls:

1. Create a new measurement document.
2. Load the first pair of images that you wish to measure.
3. Measure the desired points.
4. Perform any world reference frame or reference marker corrections.

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5. Save the measurement to a file that ends in a number, for instance: frame00.meas. Ensure there are enough digits to cover the total number of frames you will be analyzing. For instance, if you are analyzing 30 images, use at least 2 digits.
6. Make sure **Sync Loading** is checked and click on the up button next to the load image buttons. This should load the next similarly named image in each directory. You can right-click in each image and select **Show Filename** to see which specific file has been loaded.
7. Locate the desired points and click on **Update Point** for each point, or click on **Clear All** and use **Add Point** for each point.
8. There is no need to perform the world reference frame or reference marker corrections again, unless the settings have changed since the last set of images.
9. Make sure **Increment Filename** is checked and click on **Save Measurement**. This should open a save dialog with the next default filename in the sequence (e.g. frame01.meas). Click on **OK** to accept this filename
10. Repeat steps 6-9 for every set of images you wish to analyze.

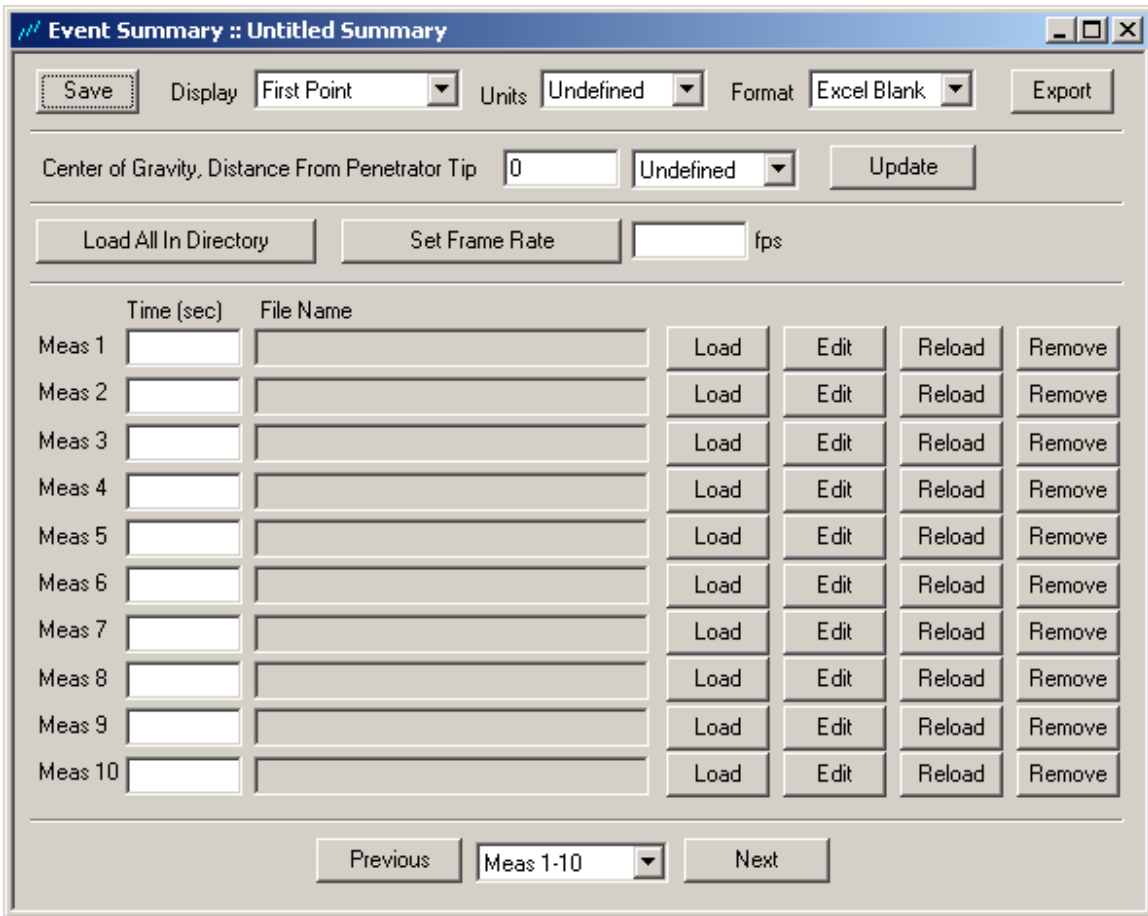
After you have analyzed a sequence of images and produced a sequence of similarly named measurement files, you can play these measurement files by clicking on the **Play Images or Measurements** button on the toolbar (the last button). When this button is depressed, the play controls will play measurement files instead of image files. Press any of the play controls to review the sequence of measurement files that you have just produced.

Event Summary

After you have created a set of Measurement documents for one event, you can combine these all in one Event Summary Document. An Event Summary document loads a set of Measurement documents and displays a summary of all the measurements contained in each of the Measurement documents.

An Event Summary Document is created by selecting **File → New**. Then select **Event Summary**.

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Load each measurement document by clicking on the corresponding **Load** button. For each measurement document, you must specify the time associated with that measurement. This allows the application to compute velocity information between measurements.

If you wish to load all similarly named measurement files in a given directory, click on the **Load All in Directory** button, and select one of the measurement files. Filenames of the measurement files must have the same prefix and end in a number in order to be recognized. For example: frame01.meas, frame02.meas, frame03.meas, ...

If all measurements were taken at equally spaced time intervals, you can specify the frame rate in the edit box next to the **Set Frame Rate** button. Then hit the **Set Frame Rate** button and the time values will be automatically filled in for all measurement files.

Up to 50 measurement documents can be combined into an event summary. After you have loaded all the measurement documents, you can save the event summary information by clicking on the **Save** button. All the time and measurement document information will be saved to an event summary file (*.esum).

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If you wish to make changes to a measurement document, you can hit the **Edit** button next to the measurement document file name. After you have finished making changes and have saved the measurement document, you must hit the **Reload** button so that the new changes are loaded by the event summary.

The Points listing will display information about each line pair contained in each measurement document. Which quantity is displayed is controlled by the **Display** drop down control in the Event Summary document window.

Line	Meas 1	Meas 2	Meas 3	Meas 4	Meas 5	Meas 6	Displayed	Units
1	-9, 12, 294	-9, 12, 548	-9, 12, 802	-9, 12, 1056	-9, 12, 1310	-9, 12, 1818	First Point	centimeters
2	-8, 14, 281	-8, 14, 535	-8, 14, 789	-8, 14, 1043	-8, 14, 1297	-8, 14, 1805	First Point	centimeters
3	-10, 12, 281	-10, 12, 535	-10, 12, 789	-10, 12, 1043	-10, 12, 1297	-10, 12, 1805	First Point	centimeters
4	-9, 11, 281	-9, 11, 535	-9, 11, 789	-9, 11, 1043	-9, 11, 1297	-9, 11, 1805	First Point	centimeters
5	-7, 16, 266	-7, 16, 520	-7, 16, 774	-7, 16, 1028	-7, 16, 1282	-7, 16, 1790	First Point	centimeters
6	-14, 13, 266	-14, 13, 520	-14, 13, 774	-14, 13, 1028	-14, 13, 1282	-14, 13, 1790	First Point	centimeters
7	-9, 8, 266	-9, 8, 520	-9, 8, 774	-9, 8, 1028	-9, 8, 1282	-9, 8, 1790	First Point	centimeters

The Event Summary results can also be exported to a Text document or to an Excel Spreadsheet.

Select the units and the export format and then hit the **Export** button. This will export all available information about the measurement line pairs. The current display setting is not used during export. All possible display values are exported simultaneously.

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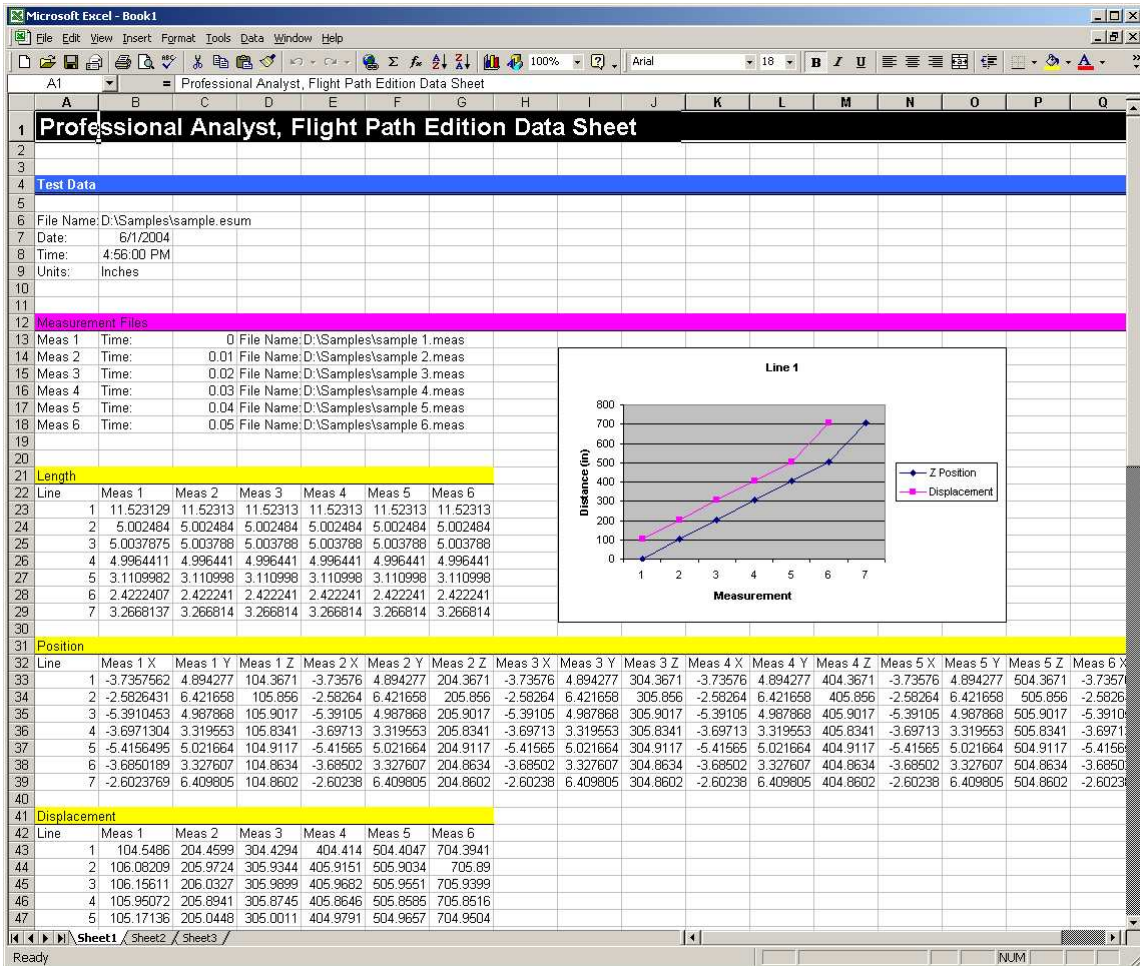
The screenshot shows an Excel spreadsheet with the following data:

Professional Analyst, Flight Path Edition Data Sheet																	
Test Data																	
6	File Name:	D:\Samples\sample.esum															
7	Date:	5/28/2004															
8	Time:	3:24:03 PM															
9	Units:	Inches															
Measurement Files																	
13	Meas 1	Time:	0 File Name: D:\Samples\sample 1.meas														
14	Meas 2	Time:	0.01 File Name: D:\Samples\sample 2.meas														
15	Meas 3	Time:	0.02 File Name: D:\Samples\sample 3.meas														
16	Meas 4	Time:	0.03 File Name: D:\Samples\sample 4.meas														
17	Meas 5	Time:	0.04 File Name: D:\Samples\sample 5.meas														
18	Meas 6	Time:	0.05 File Name: D:\Samples\sample 6.meas														
Length																	
22	Line	Meas 1	Meas 2	Meas 3	Meas 4	Meas 5	Meas 6										
23	1	11.523129	11.52313	11.52313	11.52313	11.52313	11.52313										
24	2	5.002484	5.002484	5.002484	5.002484	5.002484	5.002484										
25	3	5.0037875	5.003788	5.003788	5.003788	5.003788	5.003788										
26	4	4.9964411	4.996441	4.996441	4.996441	4.996441	4.996441										
27	5	3.1109982	3.110998	3.110998	3.110998	3.110998	3.110998										
28	6	2.4222407	2.422241	2.422241	2.422241	2.422241	2.422241										
29	7	3.2668137	3.266814	3.266814	3.266814	3.266814	3.266814										
Position																	
32	Line	Meas 1 X	Meas 1 Y	Meas 1 Z	Meas 2 X	Meas 2 Y	Meas 2 Z	Meas 3 X	Meas 3 Y	Meas 3 Z	Meas 4 X	Meas 4 Y	Meas 4 Z	Meas 5 X	Meas 5 Y	Meas 5 Z	Meas 6 X
33	1	-3.7357562	4.894277	104.3671	-3.73576	4.894277	204.3671	-3.73576	4.894277	304.3671	-3.73576	4.894277	404.3671	-3.73576	4.894277	504.3671	-3.73576
34	2	-2.5826431	6.421658	105.856	-2.58264	6.421658	205.856	-2.58264	6.421658	305.856	-2.58264	6.421658	405.856	-2.58264	6.421658	505.856	-2.58264
35	3	-5.3910453	4.987868	105.9017	-5.39105	4.987868	205.9017	-5.39105	4.987868	305.9017	-5.39105	4.987868	405.9017	-5.39105	4.987868	505.9017	-5.39105
36	4	-3.6971304	3.319553	105.8341	-3.69713	3.319553	205.8341	-3.69713	3.319553	305.8341	-3.69713	3.319553	405.8341	-3.69713	3.319553	505.8341	-3.69713
37	5	-5.4156495	5.021664	104.9117	-5.41565	5.021664	204.9117	-5.41565	5.021664	304.9117	-5.41565	5.021664	404.9117	-5.41565	5.021664	504.9117	-5.41565
38	6	-3.6850189	3.327607	104.8634	-3.68502	3.327607	204.8634	-3.68502	3.327607	304.8634	-3.68502	3.327607	404.8634	-3.68502	3.327607	504.8634	-3.68502
39	7	-2.6023769	6.409805	104.8602	-2.60238	6.409805	204.8602	-2.60238	6.409805	304.8602	-2.60238	6.409805	404.8602	-2.60238	6.409805	504.8602	-2.60238
Displacement																	
42	Line	Meas 1	Meas 2	Meas 3	Meas 4	Meas 5	Meas 6										
43	1	104.5486	204.4599	304.4294	404.414	504.4047	704.3941										
44	2	106.08209	205.9724	305.9344	405.9151	505.9034	705.89										
45	3	106.15611	206.0327	305.9899	405.9682	505.9551	705.9399										
46	4	105.95072	205.8941	305.8745	405.8646	505.8585	705.8516										
47	5	105.17136	205.0448	305.0011	404.9791	504.9657	704.9504										

If the same calculations are always done in Excel, the export feature can also be told to use an existing Excel file as a template for the export results. This template can contain formulas, graphs, or any other Excel elements. Select **Excel Template** as the **Format** type before exporting. Then select the Excel file to use as a template.

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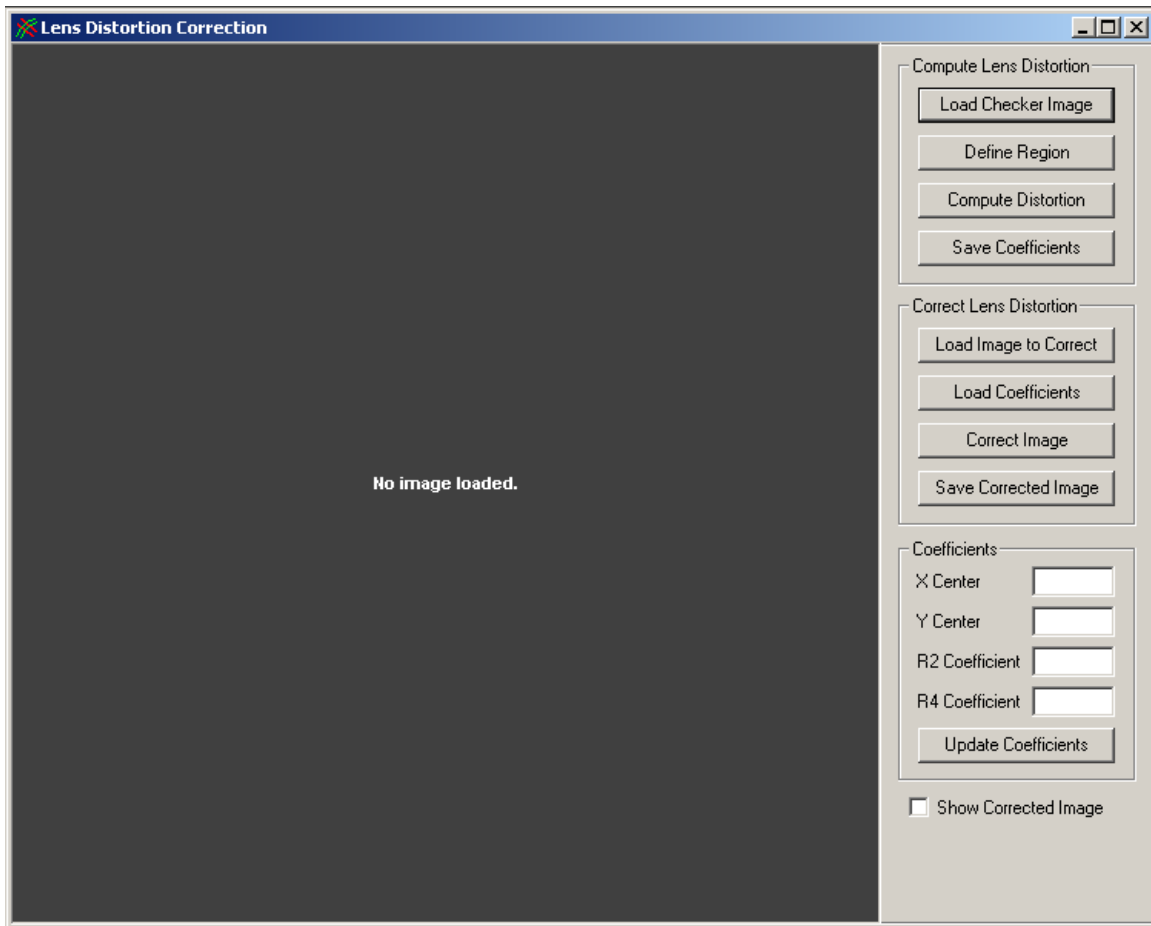
All the information is exported into the template file in Excel, with any calculations or graphs being automatically populated.

Appendix

Lens Distortion Correction

A tool is provided to help compensate for radial lens distortion. Select **Tools → Lens Distortion Correction** from the main menu..

For each lens that will be used, an image of a checkerboard pattern should be acquired. This image can be loaded into the Lens Distortion Correction window to compute whether or not distortion correction is necessary. The lens distortion correction tool will compute coefficients to compensate for radial distortion (barrel or pincushion).

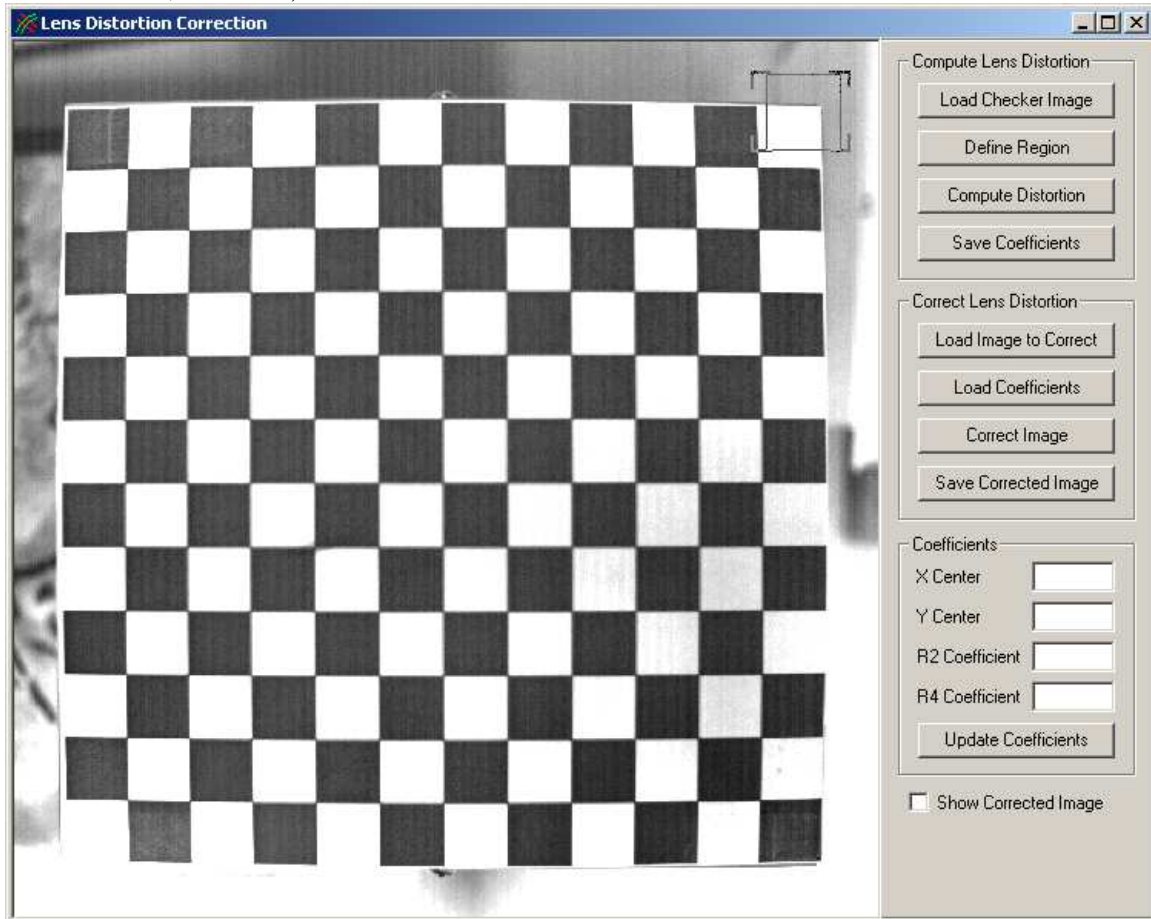


To compute lens distortion coefficients:

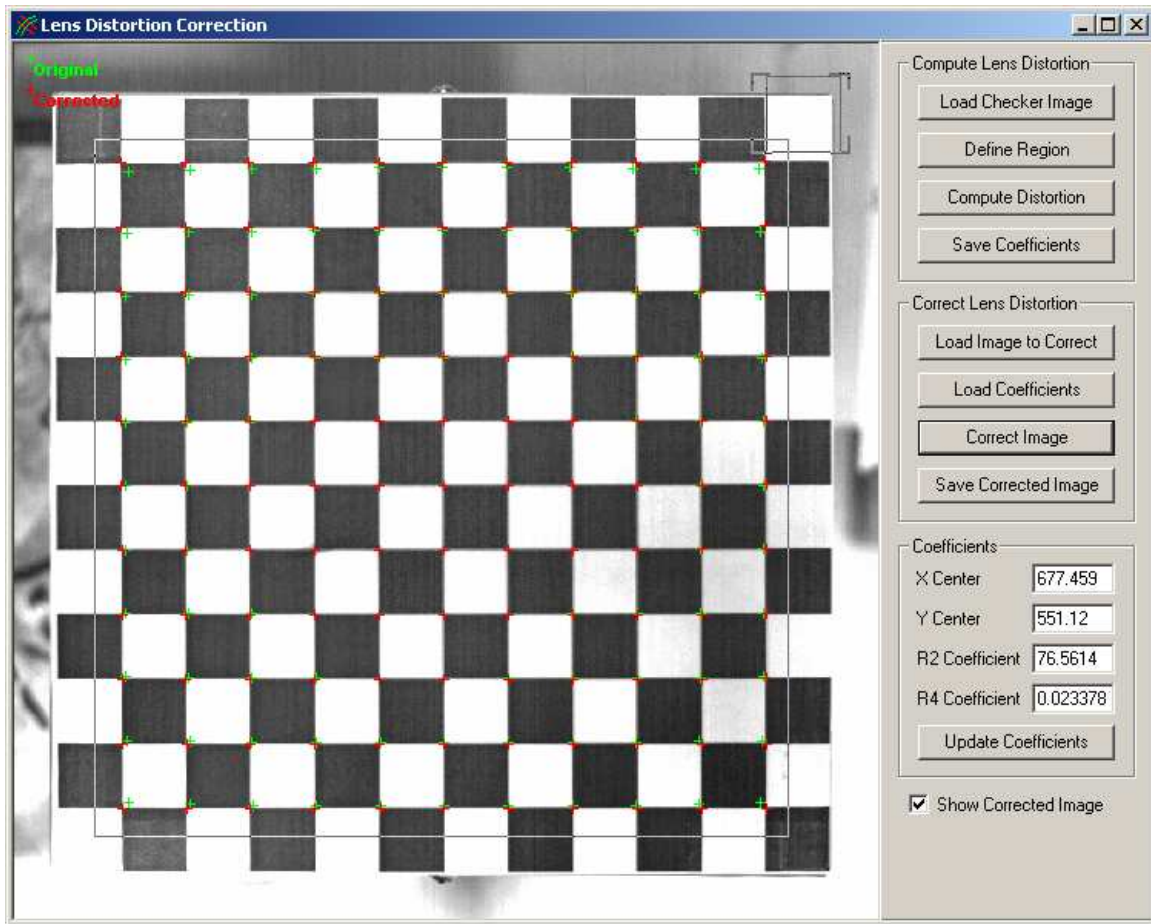
1. Capture an image of a checkerboard pattern using the camera and lens that will be used in testing.

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2. Click on **Load Checker Image** and select the checkerboard image file (BMP, TIFF, or JPEG).



3. Click on **Define Region** and click the left mouse button and drag a rectangle around the inside of the checker pattern. Make sure that the rectangle is inside the last set of checkerboard squares. Do not draw the region outside the entire checkerboard pattern, it must be inside the checkerboard pattern.
4. If you would like to redraw the region, click on **Define Region** again and redraw the rectangle.
5. Click on **Compute Distortion**. The distortion coefficients will be computed. If you wish to view the corrected image, you can hit the **Correct Image** button.
6. Click on **Save Coefficients** to save the distortion coefficients to a lens coefficients file (*.lens) that can be used by Calibration Documents.



The **Correct Lens Distortion** options are provided only for verification of removal of distortion and as a tool for recovering undistorted images. These options can be used to correct other images and save the corrected versions if desired. This is not necessary since the application will automatically correct images on-the-fly if lens distortion coefficients are set.

Do not use corrected images for measurement if the lens distortion coefficients are also specified. This will result in the correction being applied twice and the resulting measurements will be distorted.

If you wish to correct an image:

1. Load the image to correct by clicking on **Load Image to Correct**.
2. Load lens distortion coefficients to use in correction. These should have been saved using the **Compute Lens Distortion** buttons to create a lens coefficient file (*.lens).
3. Click on **Correct Image**.
4. You can switch between viewing the original and corrected image by clicking on the **Show Corrected Image** checkbox at the bottom of the control panel.

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5. If you wish to save the corrected image, click on **Save Corrected Image**. It is recommended that you save to a different filename so that you do not overwrite the original image.