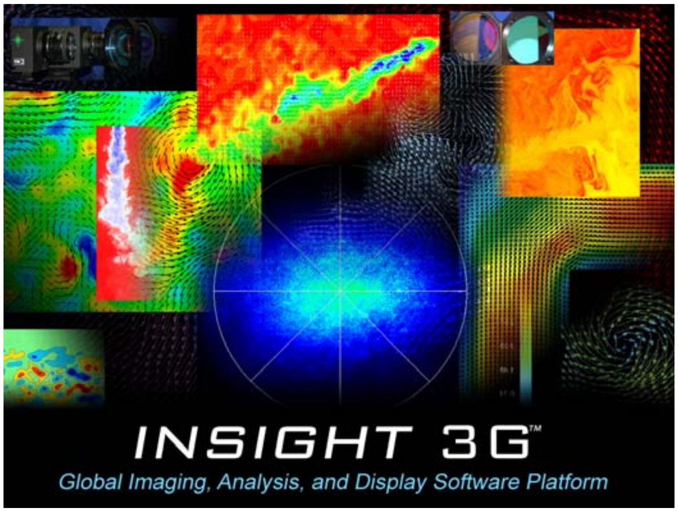
Fluid Mechanics

INSIGHT 3G™

Data Acquisition, Analysis, and Display Software

User's Guide

P/N 1980511, Revision E
May 2006



INSIGHT 3G™
Data Acquisition, Analysis, and Display Software

User's Guide

Manual History

This is a manual history of the *INSIGHT* 3G manual (Part Number 1980511).

Revision	Date
A	November 2004
B	March 2005
C	September 2005
D	January 2006
E	May 2006

Warranty

Part Number	1980511/ Revision E / May 2006
Copyright	
Address	TSI Incorporated / 500 Cardigan Road / Shoreview, MN 55126 / USA
Phone No.	1-800-874-2811 (USA) or (651) 490-2811
Fax No.	(651) 490-3824
E-mail Address	fluid@tsi.com

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Contents

About This Manual

Purpose

This manual describes how to use TSI's *INSIGHT* 3G data acquisition, analysis and display software.

Related Product Literature

Please refer to the other PIV manuals that were shipped to you for additional information.

Getting Help

To obtain assistance with this product, or simply to submit suggestions, please contact:

TSI Incorporated
500 Cardigan Road
Shoreview, MN 55126 USA
Fax: (651) 490-3824
Telephone: 1-800-874-2811 (USA) or (651) 490-2811
E-mail Address: technical.service@tsi.com
Web site: service.tsi.com

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TSI values your comments and suggestions on this manual. Please use the comment sheet, on the last page of this manual, to send us your opinion on the manual's usability, to suggest specific improvements, or to report any technical errors.

If the comment sheet has already been used, mail or fax your comments on another sheet of paper to:

TSI Incorporated
500 Cardigan Road
Shoreview, MN 55126
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E-mail Address: fluid@tsi.com

CHAPTER 1
Introduction

INSIGHT 3G™ software is a Microsoft® Windows® XP-based software that is used for global image capture, analysis and display purposes. It is used for PIV measurements (global velocity diagnostics), PLIF measurements (scalar property field) and for global spray diagnostics.

INSIGHT 3G acquires, analyzes global images (velocity field or particle images as well as scalar image fields) and displays the global properties and associated statistics. The images are generally obtained by a digital camera.

INSIGHT 3G automates the process of image capture, analysis and data validation for each image. This helps you obtain instant feedback, which makes the setup process for an experiment, fast and informative. *INSIGHT* 3G's batch-mode capturing and processing feature allows you to capture and process large number of images in actual experiments.

INSIGHT 3G software is functionally divided into two parts—an acquisition and processing part and a presentation part. The first acquires an image and processes it to obtain various properties such as velocity vectors, temperature or concentration information or spray geometry. The second part displays these results which can be enhanced for optimal viewing. Additional tools such as Tecplot and MATLAB can also be used, providing for additional viewing options.

INSIGHT 3G software is a true Global Image capture, analysis, and display package. You can use it to:

- measure microflows (using a microPIV system)
- make time-resolved measurements of flow fields (using high-frame rate cameras and high-pulse rate lasers)
- make global measurement of scalar properties (using PLIF and special cameras)
- make simultaneous velocity and scalar property (temperature, concentration, species) measurements (using same type of cameras or using different types of cameras to capture particle image and global fluorescence fields)
- make global spray diagnostics measurements.

The package allows the setup, control and operation of the entire diagnostics system and provides on-line or batch-mode analysis of the image fields and detailed display of the results.

CHAPTER 2

Getting Started

Before you start, make sure you have done the following:

- Unpacked and checked your *INSIGHT 3G* software package.
- Checked to see if you have the required hardware and software to run the program.
- Run the installation program.

After completing the above steps, you can start the program.

Note: *This manual assumes that you know the basics of using computer and Windows-based applications such as how to start applications, how to use your mouse, move and close windows and other such tasks. If you need help with these, consult your computer and Windows XP documentation.*

Unpacking and Checking Package Contents

The *INSIGHT 3G* software package includes:

- Installation CD
- Software key—the key connects to the USB port of your computer and is required to run the program
- User Guide (P/N 1980511)

Note*: The proper installation of INSIGHT 3G is determined by the software key used. Make sure that the software key has a label indicating the type of INSIGHT 3G that you will install. If there is any question on the type of INSIGHT 3G or if the label on the software indicates a different type from what you purchased, please contact TSI immediately.*

Carefully unpack and make sure you received all the listed items. If anything is missing or damaged, contact your nearest TSI sales office or representative or contact:

TSI Incorporated
500 Cardigan Road
Shoreview, MN 55126
Phone: 1-800-874-2811 (USA) or (651) 490-2811
Fax: (651) 490-3824
E-mail: fluid@tsi.com

Hardware and Software Requirements

INSIGHT 3G requires or recommends the following hardware and software:

- Dual Pentium IV computer (recommended) with Windows® XP Professional operating system
- CD ROM drive
- Minimum of 1 GB of RAM
- Disk drive with at least 20.0 GB
- Video card set for 32K colors or more
- 17-in. monitor; INSIGHT 3G works best with a 19 in. or larger monitor.

Installing INSIGHT 3G

To install INSIGHT 3G:

1. Insert the CD in the appropriate drive.
   The installation wizard starts automatically.
2. Click **Install** button and follow the instructions that are displayed on your screen to complete the installation process.

Starting INSIGHT 3G

To start INSIGHT 3G:

Double click the INSIGHT 3G icon on your desktop or from the Windows task bar, choose **Start** | **Programs** | **TSI Insight 3G** | **Insight 3G**. In order to run INSIGHT 3G without the splash screen, pass it the command-line option NO_SPLASH.

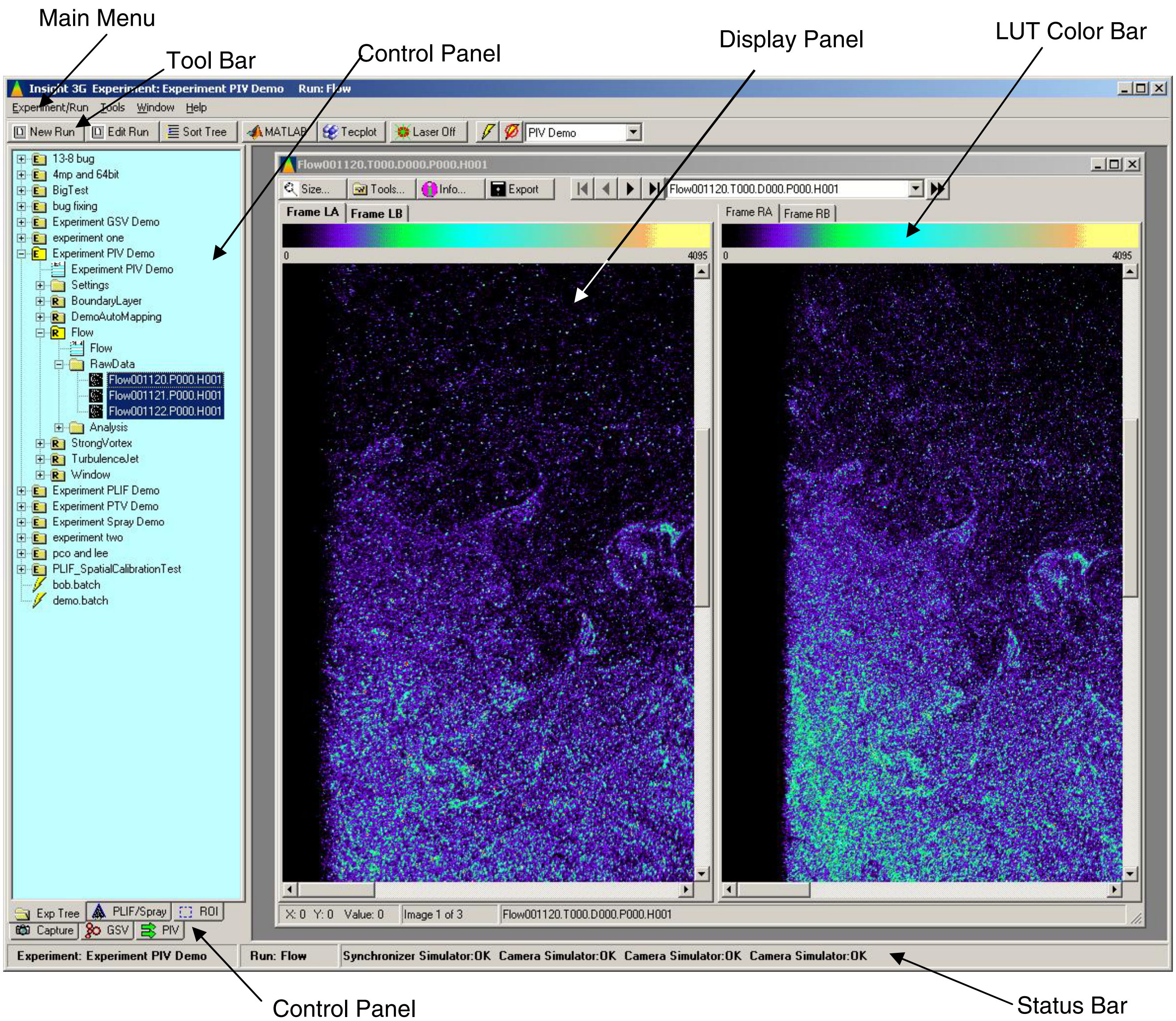
CHAPTER 3

Getting Acquainted with *INSIGHT* 3G

INSIGHT 3G™ provides many features to help you make flow and spray measurements. This chapter acquaints you with the *INSIGHT* 3G interface to give you an overview of the software and its capabilities. Details on each option and task performed in *INSIGHT* 3G are provided in subsequent chapters.

The *INSIGHT* 3G Desktop

When you start *INSIGHT* 3G, a desktop with menu, tool bar and tab options is displayed. As you use *INSIGHT* 3G to capture, process and display images, you will use several of these options. Review the following information to get acquainted with its many features and capabilities.



INSIGHT 3G Menu Options

The bar at the top of the INSIGHT 3G application window contains the following sets of drop-down menus.

Experiment/Run

The options in the Experiment menu allow you to open a new experiment or a run or edit a previously-saved experiment or run. It also allows you to sort and refresh the experiment tree display in the control panel. Following are brief descriptions of these commands.

Refer to Chapter 16, "Viewing Data Files," for details.

Option	Description
New Experiment	Creates a new experiment.
Edit Experiment	Opens an existing experiment for editing.
New Run	Creates a new run.
Edit Run	Opens an existing run for editing
Sort Tree	Sorts and displays your experiment and data files according to a set of specifications that you choose. See "Specifying the Sorting Order for Data Files" for details.
Refresh Tree	Refreshes and presents an updated tree structure.
Exit	Exits the *INSIGHT 3G* program.

Tools

The Tool menu provides tools to specify calibration parameters, capture PIV and PLIF calibration images, specify hardware components, and program macros that can automate your experiments and runs. Following are brief descriptions of these commands.

Option	Description
Spatial Calibration	Calibrates velocity for normal or 2-D PIV. See "2-D Calibration" for details.
Perspective Calibration	Calibrates images for perspective corrections. See "Chapter 8 Perspective Calibration" for details.
Capture Perspective Cal. Images	Captures images for Perspective Calibration. See "Step B: Recording Calibration Images" for details.
Insight Setup	Sets up experiment directory and computer for distributed processing.
Hardware Setup	Sets up parameters for the components to be used with the *INSIGHT 3G* software. See "Specifying Hardware Components in Your Experiment" in Chapter 4.
Component Setup	Sets up individual hardware components (e.g., individual cameras, lasers, etc.)
Image Tools	Provides tools to modify images not captured by *INSIGHT 3G* so they can be used by *INSIGHT 3G*.
Visual Macro Programmer	Programs macros through which you can automate the capturing, conditioning, and processing of images to be deployed later for different runs. See "Programming Macros" for details.

Window

The Window menu option allows you to control and arrange the open windows in the display panel. The following options are available:

Tool Bars	Description
Cascade	Cascades all open windows.
Tile Horizontal	Tiles all open windows in a horizontal format.
Tile Vertical	Tiles all open windows in vertical format.
Arrange Icons	Arranges the icons so they can be properly displayed.

Help

The Help menu option allows you to access the instruction and operational manuals available for *INSIGHT 3G* software.

INSIGHT 3G Tool Bar

INSIGHT 3G makes many options easily accessible to you through the toolbar. This tool bar appears under the main menu bar and contains a row of buttons and tools to allow you to quickly choose commonly used commands and options.

Option	Description
	**New Run** Creates a new run. Performs the same function as the corresponding command in the Experiment/Run menu option. See "Creating a Run" for details.
	**Edit Run** Opens an experiment. Performs the same function as the corresponding command in the Experiment/Run menu option. See "Editing an Experiment or Run" for details.
	**Sort Tree** Brings up the dialog box to allow you to specify how to sort and display files in the Experiment tab panel. Performs the same function as the corresponding command in the Experiment/Run menu option. See "Specifying the Sorting Order for Data Files" for details. .
	**MATLAB** Starts the MATLAB utility which allows you to perform time series and POD analyses on captured images. See "Using MATLAB" for details.

Option	Description
Tecplot	**Tecplot** Starts the Tecplot utility which allows you to view *INSIGHT 3G* vector files and compute flow properties. See "Presenting PIV Data with Tecplot" for details.
Laser Off	Turns the laser off. Performs the same function as the laser off button available on the tab on the control panel. See "Capturing Images: An Overview" for further information.
	Runs the macro listed in the drop-down list box next to the button. This list contains all the saved macros in the current experiment that were programmed using the Visual Macro Programming command available through the Tools menu option. See "Programming Macros" for details.
	Stops the macro that is running. See "Programming Macros" for details.

Control Panel

INSIGHT 3G control panel offers many options grouped into the following tabs:

Tab	Description
Exp Tree	Displays experiment and run data files specified and sorted through the Sort Tree dialog box. See Chapter 5, "Creating and Managing Experiment and Data Files."
Capture	Allows you to specify capture settings for various components in your experiment, save these settings and start and stop image capture. See Chapter 6, "Capturing Images" for detailed information.
PLIF/Spray	Allows you to specify PLIF and spray conditioning, analyses, and processing settings. See Chapter 11, "Processing PLIF Images" and Chapter 12, "Processing Spray Images" for details.
PIV	Allows you to specify PIV conditioning, processing, and validating settings. See Chapter 10, "Processing PIV Images" for details.
ROI	Allows you to define and specify regions of interest to be used when processing images. These specifications can be saved in the Settings folder of your experiment and programmed into macros. See Chapter 9, "Defining a Region of Interest" for details.

Tab	Description
	Allows you to specify GSV conditioning and processing.

Display Panel

INSIGHT 3G displays processed image files in the display panel. You can double-click on files in the Experiment tree or drag and drop them on the display panel to view these files. Each file opens in a separate window with controls offering more functions. Refer to Chapter 16, "Viewing, Enhancing and Displaying Image Files" for details.

Status Bar

The status bar on the bottom of the *INSIGHT* 3G desktop provides status on the hardware used in the experiment. You can get an updated status of a new hardware component in a system, by clicking on the component in the status bar. The status bar also lists the name of the current experiment and run indicating where the data is being saved or retrieved from.

CHAPTER 4

Setting Up *INSIGHT 3G*

Before you can acquire and process PIV, PLIF, and spray images, you need to perform the following tasks:

- Specify the directory to which the acquired data in an experiment is stored.
- Specify the hardware components in your experiment.
- (*Optional*) Set up *INSIGHT 3G* to perform distributed processing over a network of computers so that processing time for PIV images can be reduced.
- (*Optional*) Set up and configure dual monitors to help you visualize your images on more than one desktop.

The following sections provide details on how to perform these tasks.

Specifying the Experiment Folder

INSIGHT 3G allows you to save your experiment data to any directory and computer on your network.

Note: *To avoid causing errors in INSIGHT 3G, it is recommended that the experiment folder be used exclusively by INSIGHT 3G. Do* ***not*** *use it to store files from other applications.*

To specify an experiment folder:

1. From the main menu of *INSIGHT 3G*, select **Tools | Insight 3G Setup**... The Setup *INSIGHT 3G* dialog box appears.
2. In the Directory for Experiments box, type in the directory name where you want to save the data files or click ... to browse through your computer or network to select the designated folder. See "Control Panel" for more information.

Specifying Hardware Components in Your Experiment

INSIGHT 3G works with many types of cameras, lasers, and synchronizers. Before you can acquire images, you need to specify which models or types of hardware components are being used in your experiment and how they are connected.

To specify the hardware components in your experiment:

1. From the main INSIGHT 3G menu, select **Tools** | **Hardware Setup**... The Hardware Setup dialog box opens.
2. Perform the following:
   - **a.** Select the appropriate frame grabber from the following list of supported models for the first camera in your experiment:

Supported Frame Grabber Models
PIVCAM 13-8
High Speed (600068)
High Digital Performance (600069)
Camera Link
PIVCAM 14-10
POWERVIEW HS-500
64-bit Frame Grabber
Firewire for HS-2000/3000
HS-650 Frame Grabber
DVR Express CLFC
HS-650 Firewire

   - **b.** The list of cameras will automatically reduce to those supported by your selected frame grabber. Choose a camera appropriately.
   - **c.** Once the camera is selected, the list of ports will automatically reduce to those supported by your frame grabber/camera pair. Choose a port appropriately (refer to the appropriate device manual for an explanation of these ports):
   - **d.** Select the type of application that the camera will be used for. Possible applications include: PIV Mono, PIV Left, PIV Right, PLIF, and GSV.
   - **e.** Repeat **a** through **d** for the other two cameras, if they are being used.

f. Specify the synchronizer being used and specify the port it is connected to, in the adjoining box.

g. Select the laser being used.

h. Check **Traverse Installed**, if a traverse is installed.

i. Check **IO Board Installed**, if an I/O board is installed in the computer and if the I/O board needs to be activated for analog data input.

3. Click **OK**.

Next, you would also need to setup the parameters for these selected components, as described in "Setting Hardware Component Parameters."

Enabling History Logging

This feature allows you to log and save the process settings for the experiments in the process log. Enabling this feature allows you to go back and review the settings that were used in each step of an experiment. The names of the files stored in the Experiment directory include the P number which is incremented with each run.

To enable history logging:

1. From the main menu of *INSIGHT 3G*, select **Tools | Insight 3G Setup**... The Setup *INSIGHT 3G* dialog box appears.
2. Check **Enable History Logging**. History logging is enabled. To view either the process log or the capture log after images are captured and/or processed:
   - Right-click the captured and/or processed image files in the Experiment Tree and select **Show Capture Log** or **Show Process Log.** See "History Log Files" for example of the information displayed

Note: *History Logging is disabled when PIV distributed processing is selected. See "Enabling Distributed Processing (PIV Only)" for details.*

Enabling Distributed Processing (PIV and GSV Only)

To reduce data processing time for PIV and GSV images, *INSIGHT 3G* allows you to perform distributed processing over a network of computers. You can install *INSIGHT 3G* on another computer and run it as a Worker PC without a security key.

To setup your computers for distributed processing:

1. In the Setup *INSIGHT 3G* dialog box, check the **Enable Distributed Processing** box. Additional options become available.
2. Perform one of the following:

   If computer is a host:

   a. Click **This is the Host PC**.

      Note: *Make sure share permission has been specified for the experiment directory on the host computer.*

   b. In the Host Share Name box, type in the host name.

   c. Click **Test File Access** to make sure there are no connection errors. If the test connection fails, review the possible cause for the error and follow the recommended solution to fix it.

      Note: *If there is no hardware key, the machine is automatically set to be a worker PC (see the following).*

   If computer is the worker:

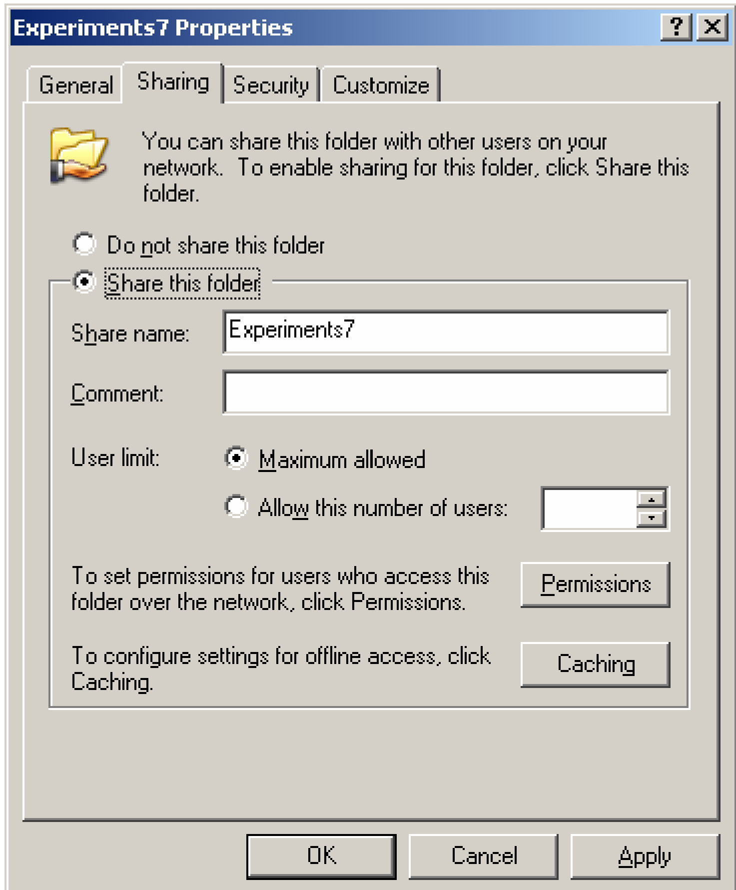
   a. Click **This is a Worker PC**.

   b. In the Hosts Experiments Directory, type in the host name or click  to browse through the connected networks to find and select the host name.

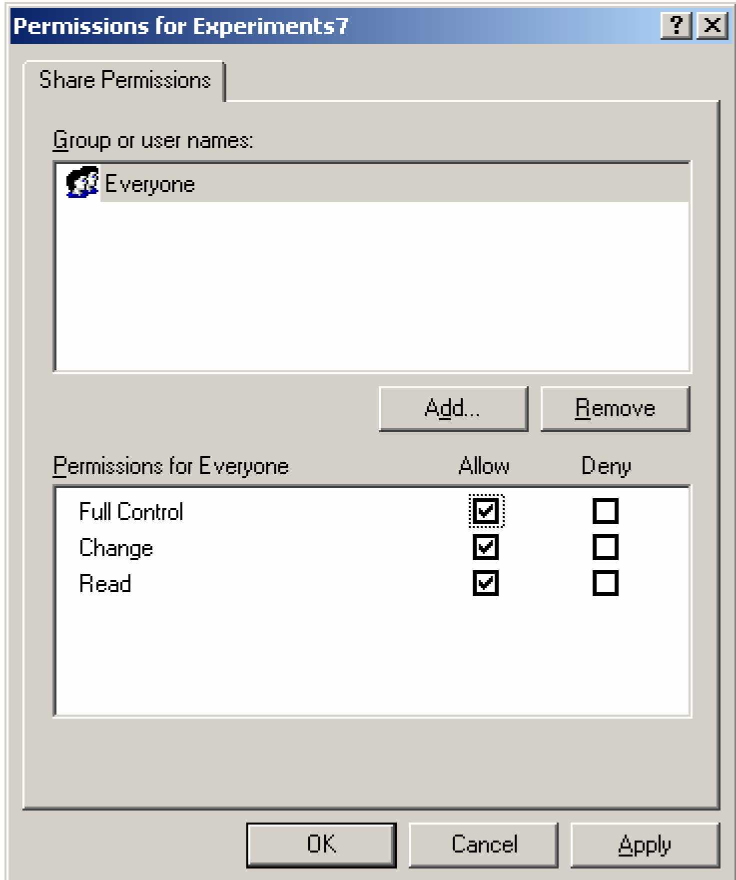
   c. Click **Test File Access** to make sure there are no connection errors. If the test connection fails, review the possible cause for the error and follow the recommended solution to fix it.
3. Click **OK.**

To setup a folder for distributed processing:

1. In Windows Explorer, locate the experiment folder you want to share for distributed processing.
2. Right-click on the folder. The properties dialog opens.
3. Select **Share this Folder**.



4. Click **Permissions**. The permissions dialog box appears.



5. Provide full access to everyone by selecting all the boxes under the Allow column.

Using Dual Monitors

INSIGHT 3G is designed to take advantage of dual monitor systems. If your computer has this capability, this feature allows you to connect and use more than one monitor on to your computer to provide a wider and more flexible display surface for your experiment results. It also allows you to dock the control panel on either the right or left side of your monitor to make it easy to drag and drop the files from the experiment tree to the display panel on the other monitor.

To use two monitors:

1. In the Setup INSIGHT 3G dialog box, check **Floating Image Window**. Additional options become available.

2. Depending on your preference and the placement of the monitors, check **Dock Right** or **Dock Left** to dock the control panel on either the left or the right end of the monitor.
3. Follow the instructions provided in your Windows manual on how to set the dual-monitor option.
4. Start *INSIGHT 3G*. You can move any child windows in the display panel of *INSIGHT 3G* to be displayed on the second monitor.

CHAPTER 5

Creating and Managing Experiment and Data Files

INSIGHT 3G's Experiment/Run menu options and the Experiment control tab allow you to create your experiment and run folders to store your experiment settings and data files as well as organize and access your raw and analyzed data files.

This chapter describes how to create and work with experiments and how to use the features provided in the Experiment tab to sort, organize and access the settings and data files for the experiments and runs.

Creating Experiment and Run Folders

An experiment is a collection of shared settings and run data. The shared settings consist of information such as capture setups, processing setups, image conditioning setups, ROI (Region of Interest) files, and macro files. The settings are shared across runs with in the experiment. After you create an experiment folder you need to create runs within each experiment before you can capture any images for the experiment. This section discusses how to create an experiment folder and runs within it.

Creating an Experiment

To create an experiment:

1. Choose **New Experiment** from the Experiment/Run menu. The New Experiment Information dialog box appears.
2. Specify a name for your experiment in the Experiment Name box and provide any additional information in the Notes section. *INSIGHT 3G* creates a folder by that name in the directory that you created when setting up *INSIGHT 3G*. (See Chapter 4, "Setting Up *INSIGHT 3G*.") It also creates an experiment folder with two subfolders in the Exp. Tree tab in the control panel. The experiment folder is marked with the icon and by default is designated as current. Two subfolders—a file with

information specified for the experiment and a folder called Settings are created. See “Accessing the Experiment Tree” in this section for details.

Creating a Run

To create a run within an experiment:

1. Make sure the experiment you wish to create the run for is current. (See “Setting an Experiment or Run as Current” in this section.)
2. Choose **New Run** from the Experiment/Run menu or from the tool bar.
3. The New Run Information dialog box appears.
4. Specify a name for the run. Provide any additional information in the Notes section. *INSIGHT* 3G creates a folder by the name you specified in the directory that you created when setting up *INSIGHT* 3G. It also creates a run folder under the selected experiment in the Exp. Tree tab in the control panel. The run folder is marked with the icon and by default is designated as current. See “Accessing the Experiment Tree” in this section for details.

Editing an Experiment or Run

To edit the notes for a previously created experiment or run:

1. Choose **Edit Experiment** or **Edit Run** from the Experiment/Run menu.

   The Experiment Information or Run Information dialog box appears.
2. Edit the information in the Notes section and click **OK**.

Managing *INSIGHT* 3G Files

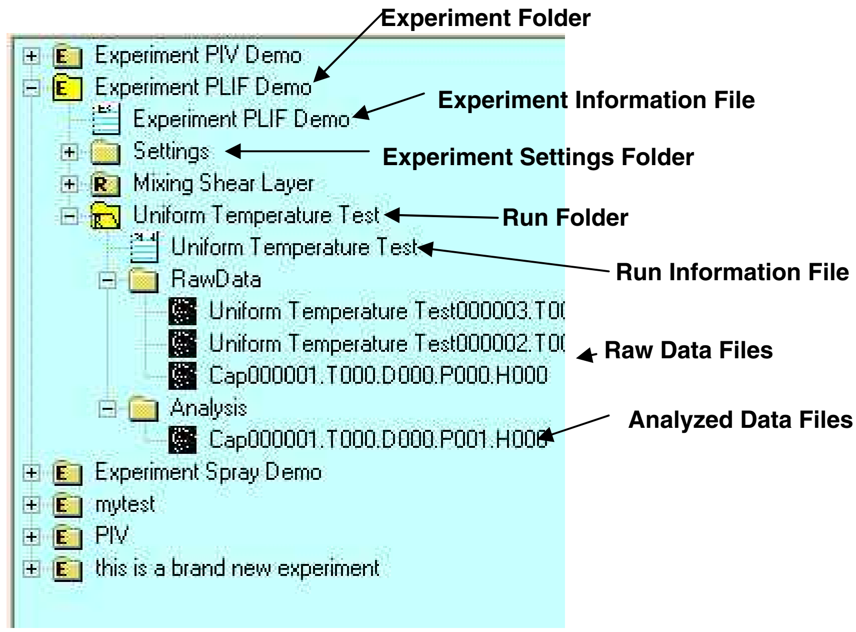
As mentioned earlier, when you create a new experiment or run, *INSIGHT* 3G creates the experiment folders files in the directory that you created when setting up *INSIGHT* 3G as well as in the Experiment Tree tab within the *INSIGHT* 3G interface. The Experiment Tree tab allows you to manage, access and organize all your data files easily. The following sections provide details on the various tasks that can be performed using the Experiment Tree command options.

Accessing the Experiment Tree

To access the Experiment Tree display:

Click 

on the control panel. The experiment tree display opens. The following shows an example with a single expanded experiment folder and its contents.



The following sections describe the various tasks you can perform from the Experiment Tree.

Specifying the Sorting Order for Data Files

You can specify the order in which data files should be displayed, using the Sort Tree option.

To specify the display order of data files:

1. Choose **Sort Tree** from the Experiment/Run menu or from the tool bar. The Experiment Tree: Sort Order dialog box appears.

   Note: *You can also edit the sort order by right-clicking on the experiment name in the tree and selecting* ***Edit Sort Order****.*

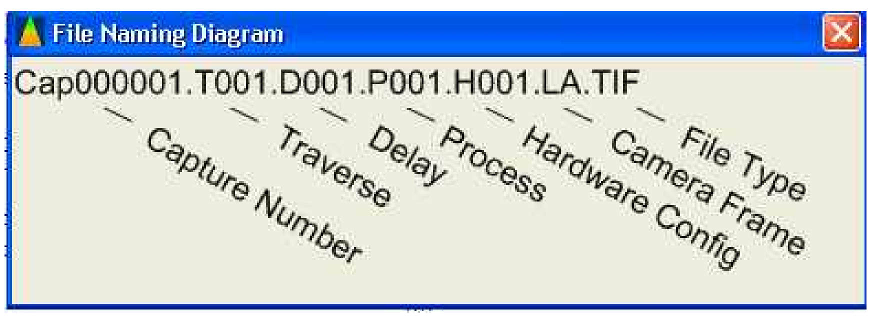
2. Select the order in which you would like files to be sorted by clicking the preferred display option in each of the boxes. The choices include:

Option	Description
Capture	Select to sort files in the order of in which they were captured.
Traverse	Select to sort files in the order of their specified traverse setting.
Delay	Select to sort files in the order of their specified delay time.
Process	Select to sort files in the order of their specified process.
File Type	Select to sort files in the order of their file types.

3. Choose the file fields to be displayed in the file name from the following:

Option	Description
Show Traverse	Select to display the traverse field setting in the filename.
Show Process	Select to display the process field setting in the filename.
Show Delay	Select to display the delay time field setting in the filename.
Show Process	Select to display the process field setting in the filename.
Show Hardware	Select to display the hardware field setting in the filename.

4. Click **OK**. The data files, when available, are sorted and displayed in the specified order in the Raw Data and Analysis folders. The following figure illustrates the fields in the filename when they are all selected.



Setting an Experiment or Run as Current

When you select an experiment or run and set it to be current, all the data files are saved in the current run and settings are saved and accessed from the current experiment folder.

To specify an experiment or run as current:

1. Right-click the experiment or run folder you wish to make current.
2. Choose **Set Experiment as Current** or **Set Run as Current.** The icon color changes to a bright yellow indicating that it is the current experiment or run. The status bar as well as the title bar displays the name of the experiment set as current.

Renaming an Experiment/Run Folder

To rename an experiment or run:

1. Right-click the experiment/run folder you wish to rename.
2. Choose **Rename Experiment** or **Rename Run.** The Rename Experiment box or Rename Run box appears.
3. Enter a new name and click **OK.**

Deleting an Experiment/Run Folder

To delete an experiment or run folder:

1. Right-click the experiment or run folder you wish to delete.
2. Choose **Delete Experiment** or **Delete Run.** A warning message appears alerting you that changes are permanent.
3. Click **OK.**

Expanding or Collapsing the Experiment Tree

You can expand an experiment tree to display the contents of the entire experiment and run folders and subfolders or collapse it to hide the subfolders.

To expand an experiment folder:

- Single-click **+** next to the experiment or run folder or right-click the experiment or run folder and select **Expand Tree**. The tree structure expands and displays the contents of all the folders.

To collapse an experiment tree:

- Single-click **-** next to the experiment or run folder or right-click the experiment or run folder and select **Collapse Tree**. The tree structure collapse and displays only the top-level folders.

CHAPTER 6

Capturing Images

INSIGHT 3G offers options to capture images for PIV measurements, PLIF measurements, simultaneous PIV and PLIF measurements, as well as measurements. The setup and controls for capturing these images are grouped together on a tab in the control panel.

This chapter describes how to specify the capture settings for the components for your experiments, how to save them for future use, and how to adjust and manipulate other settings for optimal data acquisition.

Capturing Images: An Overview

The Capture tab on the control panel provides options to:

- Set parameters to capture images
- Perform image captures, and
- Save image capture settings for future use.

Note: *All these tasks can be performed dynamically anytime during an experiment.*

Following gives a quick look at the steps involved in capturing images. Details on each of these steps are provided later in this chapter.

Set parameters to capture images:

1. Click 

tab on the control panel. The capture options appear.
2. Select the application for which the image is being captured. Click to select **PIV**, **PLIF**, **PIV-PLIF**, or **GSV**.
3. Set up the hardware components parameters. Click **Component Setup..**Refer to "Setting Hardware Component Parameters" for details.
4. Set up the traverse, if you are using one. Click **Traverse Setup** Refer to "Setting Traverse Parameters" for details.

5. Set up the timing parameters for your capture. Click **Timing Setup..**.Refer to "Setting Timing Parameters" for details.

6. Select the exposure mode in the Exposure selection box. Refer to "Selecting the Exposure Mode" for details.

7. Select the capture mode in the Capture selection box. Refer to "Selecting the Capture Mode" for details.

8. Specify name for the capture files.

9. Click  and select the laser power for each of lasers. See "Selecting Laser Power and Pulse Energy."

10. Click **Laser On** to turn on the lasers.

11. *(optional)* If capturing PIV images, check **Process PIV After Capture**.

Capture Images:

12. Click **Capture.**

Save capture settings and images to disk:

13. Save capture settings, load previously saved capture settings by using the **Saved Capture Setup** options. See "Saving and Loading Image Capture Settings" for details.

14. If you had not already selected the option of saving RAM images to the hard drive when selecting the capture mode (see "Selecting the Capture Mode"), click **Save RAM Images**. Images are saved in the Experiment folder.

15. Click **Laser Off** to turn off the lasers.

Refer to the following sections for detailed information on each of these steps.

Setting Hardware Component Parameters

Before you can capture images, you need to specify and set values for the hardware components that you had specified earlier. The following describes how to set the parameters for the following hardware components:

- Synchronizer
- Camera
- Laser

The parameters are set by selecting **Tools | Component Setup** from the INSIGHT 3G main menu. This causes the Component

Setup dialog to be displayed. The summary tab in this dialog box displays the selected models for each of these components.

Setting Synchronizer Parameters

This procedure involves setting up the parameters for the synchronizer that was selected during the *INSIGHT 3G*™ setup. See “Specifying Hardware Components.”

To set the synchronizer parameters:

1. From the Tools menu, select **Component Setup**.
2. Select the **Synchronizer Setup** tab in the Component Setup dialog box. The Synchronizer Setup dialog is displayed.

   The synchronizer uses TTL signals to communicate with most of the other system components. These TTL signals come in two polarities + and –. Each component has a standard polarity setting that is set when the component is selected. You may need to set the polarity if you are supplying an external trigger to the system
3. Select the polarity for each of the components listed under **Polarity**. Make the selection based on the following descriptions.

Option	Description
+ Polarity	Normally at ground and goes high to trigger another device. Timing is set for the rising edge.
- Polarity	Normally high and goes to ground to trigger another device. Timing is set for the falling edge of the signal.

   Version indicates the version number and date of the firmware used in the synchronizer. The version number is helpful when checking with the factory to see if the firmware is up-to-date, especially when problems occur on the synchronizer.

   Send All sends all the synchronizer settings for the software to the synchronizer. Under normal circumstances, it is not necessary to use this button. Any changes in the settings are sent to the synchronizer automatically. Use this button mainly to confirm if the parameters were transmitted.
4. Select **Laser Setup** tab to setup the laser parameters, described next.

Setting Laser Parameters

This procedure involves setting the parameters for the laser that was selected during the INSIGHT 3G setup. See "Specifying Hardware Components in Your Experiment."

To set the laser parameters:

1. On the INSIGHT 3G™ main menu, select **Tools | Component Setup.** Select the **Laser Setup** tab in the dialog box.
2. Make appropriate selections for the selected laser in the Laser Setup tab. "Laser Setup Parameters" table provides detailed descriptions.

Laser Setup Parameters

The following describes the parameters for all types of lasers. These parameters need to be specified in the respective laser setup dialog boxes.

Option	Description
Model	Displays the model of the selected laser. Displayed here for reference only. When the laser model is specified in the hardware setup menu, the default values for all of the other parameters are also selected.
Laser Frequency (Hz)	Displays the flashlamp frequency and allows you to change it. A laser gives the most energy per pulse and best beam quality when it is run at the designed frequency. ***Frequency:*** Refers to the flashlamp frequency, which is the rate at which the flashlamps are pulsed when the External Trigger box is checked. In most cases, the flashlamp frequency should be set at the Maximum Flashlamp frequency value where the laser was optimized. ***Minimum Frequency:*** The minimum flashlamp frequency for the laser. Some lasers will not fire if pulsed below this frequency. ***Maximum Frequency:*** The maximum flashlamp frequency for the laser. The laser will not fire with a flashlamp frequency above the maximum flashlamp frequency.

3. Select **Camera 1 Setup** tab to setup the camera parameters.

Setting Camera Parameters

This procedure involves setting up the parameters for the cameras that were selected during the INSIGHT 3G™ setup. See "Specifying Hardware Components."

To set the camera parameters:

1. From the Tools menu, select **Component Setup.** Select the **Camera 1 Setup** tab in the dialog box. Depending on the type of camera that was specified, an appropriate camera setup dialog box appears.
2. Make appropriate selections for camera one. See "Camera Setup Parameters" table for detailed descriptions.

Camera Setup Parameters

The following lists and describes the parameters for all types of cameras. These parameters need to be specified in their respective camera setup dialog boxes.

Option	Description
Regular camera models setup	
Model and Version	Displays model and version of the selected camera.
Resolution	Displays the number of pixels in the selected camera and the spacing between pixels. ***Pixels X Y:*** The number of light sensitive pixels on the camera. ***Spacing (µm):*** Displays the distance between pixels on the CCD chip. This value is used in computing the Pixel Aspect Ratio when converting pixel values to velocity measurement values. Refer to Chapter 9, "2-D Calibration" for information on the Pixel Aspect Ratio.
Exposure	***Frame Rate (Hz):*** Displays the camera's frame rate, which is fixed.
Digital Gain	Enter a value to increase the image brightness level. The value of the digital gain will be multiplied times each pixel intensity to adjust for varying levels of environmental illumination. For example, a gain of 2 will double each pixel intensity. **Caution**; Setting the gain too high will saturate pixels and result in the loss of intensity information. This happens because the number of bits allocated for each pixel remains the same regardless of the gain level. The default value is 4. Refer to your camera manual for further details.
Test Image	Select box to generate a test image that you can use to verify your camera connections.
Flip Image	Select box to horizontally flip the images that are being captured. Also see "Camera Location" in Chapter 9.
Timeout (ms)	Specify a time, in milliseconds, for the camera to wait to get an image. If the camera does not capture an image within this specified timeout setting, a timeout message is displayed.

3. Repeat step 2 for other two cameras, if they are being used.
4. Click **OK** to have the changes accepted and to exit the Component Setup dialog box.

Enabling and Setting Traverse

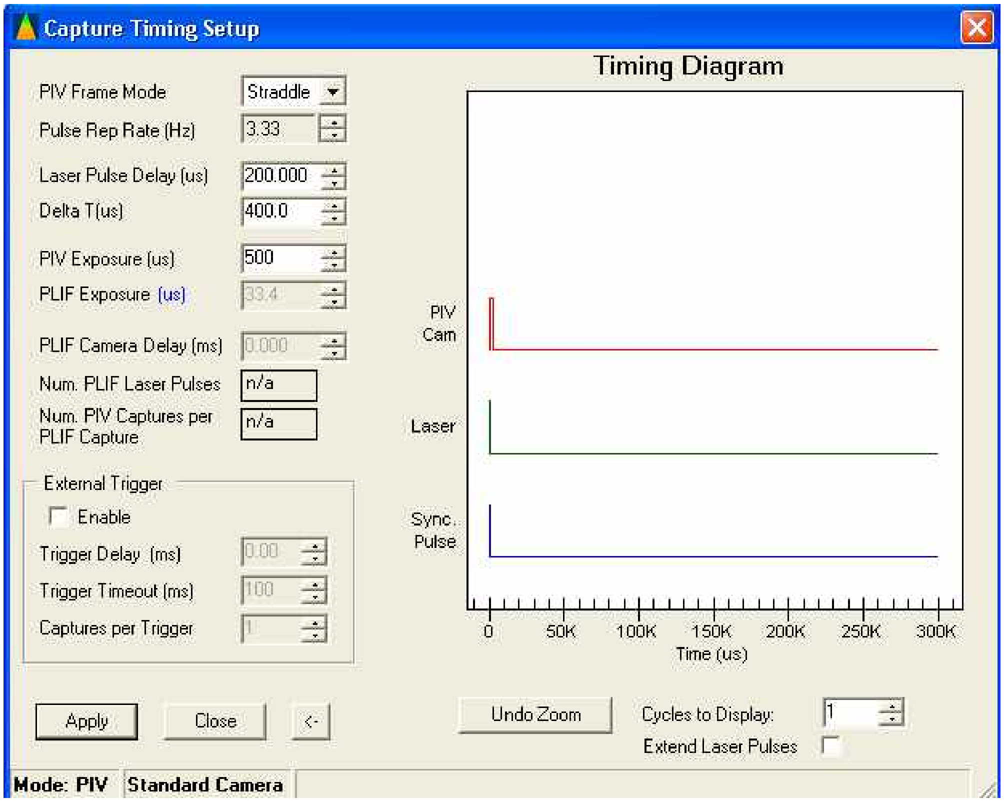
If you have a traverse in your experiment and you checked **Traverse Installed** in the Hardware Setup dialog, you need to enable the traverse and set parameters of it. Refer to Appendix C, "Enabling and Setting the Traverse" for details.

Setting Timing Parameters

Depending on your application and the exposure mode selected, you need to adjust the timing for the selected hardware components to help capture the desired images. All the options to set timing are available in the Capture Timing Setup dialog box. This dialog box also provides a dynamic graphical display of the capture timing values to help you adjust the synchronizer and laser pulses with the image capture cameras. See "Viewing and Adjusting Timing Parameters."

To setup timing for image captures:

1. From the Capture tab, select **Timing Setup.** The Capture Timing Setup dialog box appears.



2. Make appropriate selections. "Timing Setup Parameters" table provides detailed descriptions.

Timing Setup Parameters

The following describes the parameters in the timing setup dialog box.

Option	Description
PIV Frame Mode	Defines the number of frames the camera captures when it receives a trigger from the synchronizer. Select one of the following: **Single:** The camera acquires a single-frame image. **Straddle:** The camera acquires two consecutive single-exposure images.
Pulse Rep Rate (Hz)	Select the pulse repetition rate for the laser. This value specifies the timing from the start of one laser pulse sequence to the start of the next laser pulse sequence.

Option	Description
Laser Pulse Delay	Enter a value for the pulse delay time. Pulse delay time is the amount of time to wait from the start of a pulse sequence to until the first laser pulse. The pulse delay is the parameter that is adjusted to pulse the laser precisely towards the end of the first frame. For Nd:YAG systems, the Pulse Delay is the time from the start of a pulse sequence until the firing of Q Switch 1.
Delta T (us)	Enter a value for pulse separation. The pulse separation (dT) is a key parameter for matching the PIV system to the flow velocity. Choose a pulse separation value so that the particle image displacements are optimized, typically less than 16-pixel displacement for a 64-pixel spot. See the "Rules of Thumb," in the PIV Reference Manual for more information on how to select a pulse separation value that would lead to good measurements. Pulse separation in YAG lasers is the time between the firing of Q Switch 1 and Q-Switch 2.
PIV Exposure (us)	Enter the time that the first frame on your PIV camera(s) is open. Refer to your camera operations manual for specific details.
PLIF Exposure	Enter the time that the shutter of your PLIF camera is open. Refer to your camera operations manual for specific details.
PLIF Camera Delay	Specify an appropriate delay time, in microseconds, for the PLIF camera. This value is required so that the laser pulses are situated within the camera exposure.
Num PLIF Laser Pulses	Indicates the number of laser pulses within a single PLIF camera exposure.
Num. PIV Captures per PLIF Capture	Indicates the number of PIV images that will be captured for each PLIF image being captured.

Option	Description
External Trigger	***Enable:*** Check this box to make the synchronizer wait for an external trigger input before starting a pulse sequence. Leave unchecked to have the synchronizer start the next pulse sequence according to the pulse repetition rate that was specified earlier in this dialog box. ***Trigger Delay (ms):*** Enter a value for delaying the camera trigger. This value indicates the time from the start of a pulse sequence until the camera is triggered. This parameter is most useful in experiments that use an external trigger such as rotating machinery with a once-per-revolution mechanism. By adjusting this value, measurements are made at specific rotation angles. ***Trigger Timeout (ms):*** Enter a value for the duration of time that the synchronizer must wait to receive an external trigger input. If no external trigger input is received in the specified time duration, a timeout message appears. ***Laser Pulses / Trigger:*** Specify the number of laser pulses per external trigger.

Viewing and Adjusting Timing Parameters

INSIGHT 3G™displays the timing settings for the synchronizer, laser and the camera in a graphical form. Viewing this display you can quickly assess if all the component timings are adjusted so that when the synchronizer triggers, the laser is pulsed and the pulses occur in between the two camera frames..

To view the timing diagram:

If the dialog box is collapsed, click  on the Capture Timing Setup dialog box. The box expands and the timings you selected for the different components are displayed graphically.

To modify the data display:

Right-click the graph and select the various options. Refer to the online help for specific information on each of these options.

To customize the timing diagram:

Double-click on the graph. The Timing Diagram Customization dialog box opens. Use the options provided to customize the display. Refer to the online help for specific information on each of these options.

To view the online help for the timing diagram:

Right-click the graph and select **Help.**

Selecting the Exposure Mode

To select the exposure mode:

- From the Capture tab. click **Exposure** selection box and select one of the following capture mode options.

Option	Description
Free	Select this to have the frame grabber in the computer capture and display images as fast as it can, depending on the camera frame rate.
Synchronized	Select this to have the synchronizer trigger control the camera shutter and the laser pulsing according to the values set in the Timing Setup dialog box.

Selecting the Capture Mode

To select the Capture Mode:

- From the Capture tab. click **Capture** selection box and select one of the following capture mode options.

Option	Description
Single	Select to acquire images one capture at a time.
Continuous	Select to acquire images and display them continuously. Images are displayed and refreshed at the maximum camera acquisition rate. When each new frame is acquired, it is written over the previous frame. Use this mode initially, when you are setting up the experiment, to focus the camera and display the images on the screen. ***Note:*** *Continuous mode must be stopped before processing.*

Option	Description
Sequence	Select this to acquire a sequence of captures. The number of captures is controlled by the values specified in the Sequence Setup dialog box (see below). The maximum number of images that can be captured depends on the camera type, available storage space, and the memory option you selected. If you exceed the limitation of your computer memory, an error message is displayed. To specify Sequence mode values: **A.** Click . The Sequence Setup dialog box opens. **B.** Specify the following: **Number of Captures:** Specify the number of files to be captured. **Start Number:** Enter the starting file number. The Start Number increments automatically based on the last file number. **Image Save Mode:** Select how the files should be saved. Options include: • ***Save Images to Disk*** Saves images to the Experiment folder in the location specified on the computer hard drive. • ***Save Images to RAM*** Saves images temporarily to RAM. These images are discarded and not saved when INSIGHT 3G program is closed. ***Note:*** *INSIGHT 3G displays the estimated disk space or number of images that can be saved to disk or RAM.* **C.** Click **OK.**

Selecting Laser Power and Pulse Energy

If you are using an Nd:YAG laser in your experiment, depending on the task you are performing, you can control the laser power levels by using either the preset values for the energy per pulse or by changing it.

The energy per pulse for the laser power you select, is controlled with the Q-Switch delay values which are entered in the Laser Energy Setup box. By editing the Q-Switch delay value, you can define High, Medium, and Low power for your laser.

To check or set the Q-Switch delay for each power level:

1. Click on  on the Capture tab control panel.
2. The Laser Energy Setup box opens with the Q-Switch Delay/Pulse Energy default values for High, Medium and Low laser power settings for the two (A and B) lasers.
3. Change or accept the values using the up and down arrows, or by entering the appropriate values in the boxes.
4. Click **OK**.

To select laser power level:

In the Laser A and Laser B boxes on the Capture tab control panel, enter the desired laser power level. Values include:

Setting	Description
Low	Sets the power so that the laser is just producing a consistent green beam. Use Low Power during alignment.
Medium	Medium can be used for alignment that requires a little more power than Low. Could also be used to make measurements in experiments where full power is not required.
High	Sets to a level that gives the maximum laser pulse energy.
Off	Sets the Q-Switch Delay value to zero. The flashlamp still fires but the laser pulse energy is zero.

To turn the laser on or off:
Occasionally, during the course of an experiment, you may want to stop and restart the laser. The following two buttons are available:

Button	Description
	The laser on button on the Capture control panel starts the laser. It starts the laser pulsing and causes the external device, camera, frame grabber, to operate as selected (the cameras capture images, but will not be retrieved from the frame grabber unless "Capture" is clicked). The system continues to run until the Laser Off button is pressed, the number of frames is reached, or an error occurs.
	The laser off button on the Capture control panel stops the synchronizer sequence and turns off the laser and all triggers. ***Note:*** *With Nd:YAG systems, clicking the Laser off button once turns the laser Q-Switch off so that the laser does not pulse but the laser flashlamps are running at the flashlamp frequency. This keeps the laser at the operating temperature. Clicking the Laser Off button twice turns off both the flashlamps and the Q-Switch.*

Capturing Calibration Images

INSIGHT 3G provides options to capture images for calibration. Refer to "Step B: Recording Calibration Images" and "PIV Calibration Process" for detailed information.

Starting and Stopping Image Captures

To start capturing images:

1. Select the Capture tab and make sure all the capture parameters are selected. Alternately you can load saved capture settings as described in, "Saving and Loading Image Capture Settings."
2. Select a run where the image captures will be saved; right-click and make it current.
3. (*Optional*) Select the **Process After Capture** check box if you would like the images to be processed right after they are captured.
4. Click **Capture.** The captured images are stored in the computer RAM or disk and displayed in the display panel. See "Viewing, Enhancing and Displaying Image Files" for details. Also see "Saving Image Captures."

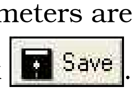
To stop capturing images:

- ❑ Click **Stop.** Image capturing is stopped. The captured images are held in the computer RAM until they are saved in the current run folder. See "Saving Image Captures."

Saving, Loading and Deleting Image Capture Settings

INSIGHT 3G™ allows you to save image capture settings so that they can be loaded and used for other runs or for other experiments. Alternately, these settings can be deleted when they are no longer needed.

To save capture settings:

1. Select the Capture tab, and make sure all the capture parameters are selected as desired.
2. Click 

.

3. In the Save dialog box, enter the name of Capture Setup file.
4. Click **OK**. The saved file appears in the scroll-down box under Saved Capture Setups.

To load capture settings:

1. In the Capture tab, select the desired capture settings file from the scroll down box under Saved Capture Setups.
2. Click **Load**. The capture settings are loaded.

To delete previously-loaded capture settings:

1. In the Capture tab, select the capture settings file you wish to delete from the scroll down box under Saved Capture Setups.
2. Click **Del**. The capture settings file is deleted.

Saving Image Captures

INSIGHT 3G™ saves captured images in RAM unless you explicitly save them on the hard drive of your computer.

To save captured images to the hard drive:

- Click **Save RAM Images**. The images are saved to the current run in the current experiment folder.

CHAPTER 7

Conditioning Images

After acquiring images for your PIV, PLIF, spray measurements, or GSV, you can condition the images to improve these images by using different conditioning techniques. These conditioners can then be saved and applied to other images.

This chapter describes how to condition the images by

- Setting up the background image processor
- Setting up the conditioners
- Applying a set of conditioners

Setting Up Background Image Processors

Along with background subtraction image processor, described later in this chapter, background image processors can be used to calculate background images over sets of captured images. Processed background images are saved (to the Experiment folder in either Setting or Analysis folders in your current run).

To setup the background image processor:

1. From the 

tab, select a sequence of images to be used in calculating the background.
2. Drag and drop them into the display panel.
3. From the PIV or PLIF/Spray control tabs, click **Background Setup** or **Setup Images**. The Background Setup Processor or Setup Images selection box opens.
4. Select the appropriate background processor from the scroll box, based on the following explanations:

Option	Description
None	Do not apply background image processors.
Average Intensity Image Processor	Use the average intensity image processor to find over the sequence of images, and over each pixel, the average intensity of those pixels.

Option	Description
Maximum Intensity Image Processor	Use the maximum intensity image processor to generate an image which contains the maximum pixel intensity at every location across a sequence of images.
Minimum Intensity Image Processor	Use the minimum intensity image processor to generate an image which contains the minimum pixel intensity at every location across a sequence of images.

5. Click **Generate**. The Generator box opens.
6. Specify a Generated Name and specify a destination.
7. Click **Analysis** to save the data to Analysis folder or **Settings** to save it in the Settings folder.
8. Click **OK**.

Setting, Saving, Loading, Applying Conditioners

Image conditioners may be applied to images before they are processed. Image conditioners help clarify the images to be processed. The settings for each camera and each frame can be configured through the PIV or the PLIF/Spray Conditioner Setup dialog boxes. These configurations can then be saved and applied to other images.

To set up conditioners for PIV images:

1. From the PIV control tab, click **Condition Setup**. The PIV Image Conditioner Setup dialog box opens.
2. Select the appropriate realization conditioner from the scroll box, based on the following descriptions:

Option	Description
None	Do not apply any image conditioners.
ArithmathicLogicalImageProcessor	Provide arithmetic and logical operations for two images.
BackgroundSubtractionImage Processor	Subtract a previously calculated background image from raw images before processing them.
BinningImageProcessor	Bin raw images to the bin size as specified.
DwarpingImageProcessor	Dwarp images based on the results of the Perspective Calibration.

Option	Description
LinearFilterImageProcessor	Provide linear filters including mean, Gaussian, Laplacian, and Laplacian of Gaussian (LOG).
NonlinearFilterImageProcessor	Provide non-linear filters including median, maximum, minimum and range.

3. Click **Frame A** or **Frame B** under the desired camera. The appropriate setup dialog appears. For example, if you have chosen BackgroundSubtractionImageProcessor as the realization conditioner, when you click the **Frame A** button, the Background Subtraction Setup box opens.
4. Make the appropriate selection and click **OK**.

To set up conditioners for PLIF or Spray images:

1. From the PLIF/Spray control tabs, click **Condition Setup**. The PLIF Image Conditioner dialog box opens.
2. Select the appropriate image conditioner from the scroll box, based on the following descriptions:

Option	Description
None	Do not apply any image conditioners.
ArithmathicLogicalImageProcessor	Provide arithmetic and logical operations for two images.
BackgroundSubtractionImage Processor	Subtract a previously calculated background image from raw images before processing them.
BinningImageProcessor	Bin raw images to the bin size as specified.
DwarpingImageProcessor	Dwarp images based on the results of the Perspective Calibration.
LinearFilterImageProcessor	Provide linear filters including mean, Gaussian, Laplacian, and Laplacian of Gaussian (LOG).
NonlinearFilterImageProcessor	Provide non-linear filters including median, maximum, minimum and range.

3. Click **Image Conditioner Settings**. Based on the selection you made in the previous step, do one of the following:

Option	Description
ArithmathicLogicalImageProcessor	In the Arithmetical and Logical Conditioner setup box specify the following: ***Operation:*** Select the operation to be performed from the following choices: ***Add, Subtract, Multiply, Divide, And, Or XOR, None.*** ***Operand:*** Choose one of following: ***Constant:*** Click box and provide a value. ***Image:*** Click box and specify path of image or click **Browse** to search for the appropriate file on the hard drive.
BackgroundSubtractionImage Processor	In the Background Subtraction Setup box, specify path of image to subtract or click **Browse** to search for the appropriate file on the hard drive.
Binning Image Processor	In the Binning size setup box, specify the size of the binning.
DewarpingImageProcessor	In the Dewarping Setup box, specify path of the calibration image or click **Browse** to search for the appropriate file on the hard drive.
LinearFilterImageProcessor	In the Linear Filter Setup box, select filter type from the drop-down list, and specify the filter size. Some filters require a filter parameter: sigma for Gaussian filter and LOG filter, alpha for Laplacian filter.
NonlinearFilterImageProcessor	In the Non-linear Filter Setup box, select filter type from the drop-down list, and specify the filter size.

4. Click **Close.**

To save conditioner configuration files:

1. If there was a previously selected configuration filename specified, the settings will be automatically saved within that file when **Close** is clicked. Otherwise, in the Configuration box, specify a conditioner configuration filename.
2. Click **Close**. The file is saved in the Settings folder and the name appears in Configuration box.

To load conditioner configuration files:

1. Click the filename in the Configuration box on the PIV/PLIF Conditioner Setup dialog box.

To apply conditioners:

1. Open the images files.
2. Select the desired configuration settings file in the scroll box in the Conditioner section of the PIV/PLIF Conditioner Setup dialog box.
3. Click **Apply Conditioner**. The conditioner configurations are applied to the images.

To delete conditioner configuration files:

1. Click the filename in the Configuration box on the PIV/PLIF Conditioner Setup dialog box.
2. Click **Delete.** The previously saved configuration file is deleted.

To create new conditioner configuration files:

1. Click **New**. Specify new configuration name.

CHAPTER 8

Perspective Calibration

INSIGHT 3G and Perspective Calibration, software supplied with INSIGHT 3G, are used in calibrating a 3-D PIV system or a single camera system where the calibration can be used to dewarp the image. For Perspective Calibration calculations, it is important to have the appropriate *x*.PIVPERCAL or the *x*.PLIFPERCAL file in the Settings folder of the appropriate Experiment folder. The calibration steps described in this chapter provide these files. The following gives an overview of the calibration process.

Calibration Overview

The calibration or mapping process uses a calibration target, which is a rectangular grid of marker points with known (x, y, z) locations. The target is mounted on a traverse, or a target with two-planes is used without traversing and positioned in the fluid. Since this grid defines the coordinate system it is important to align the grid with the light sheet. Details on how to set up this grid are provided in the PIV Systems Manual.

Perspective Calibration analyzes the calibration target images that were captured with INSIGHT 3G. The image analysis finds the location of each calibration marker point in the sequence of image frames and matches the image (X, Y) location to the target marker (x, y, z) location in the fluid. This set of calibration points is used to create a calibration mapping function.

Target Surface Planes

The calibration can use either a single surface target that is traversed or a two-plane target that does not require traversing. The one-plane target has a set of calibration markers on the surface.

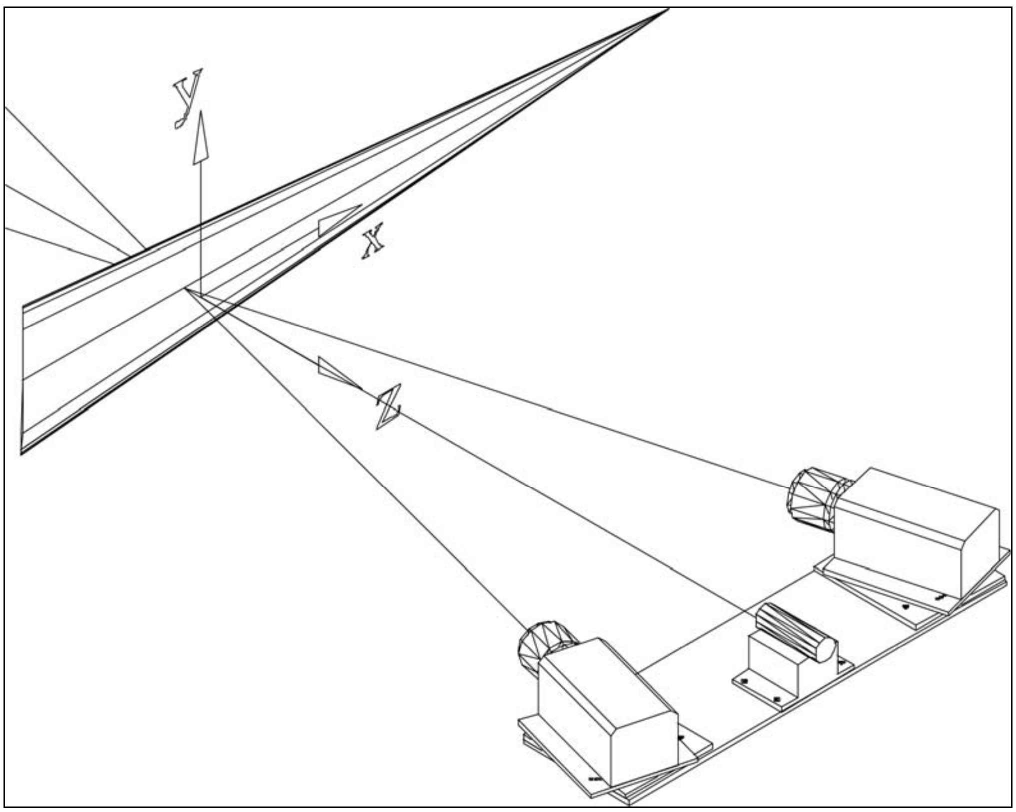
To get a 3-D calibration, the target is traversed. A pair of images is captured at each z plane location. A calibration points file is created for each camera at each traverse position.

The two-plane target uses calibration marker points that alternate between two depths. This allows a 3-D calibration to be performed without having to traverse the target. Only a single left and right image is used with the two-plane target.

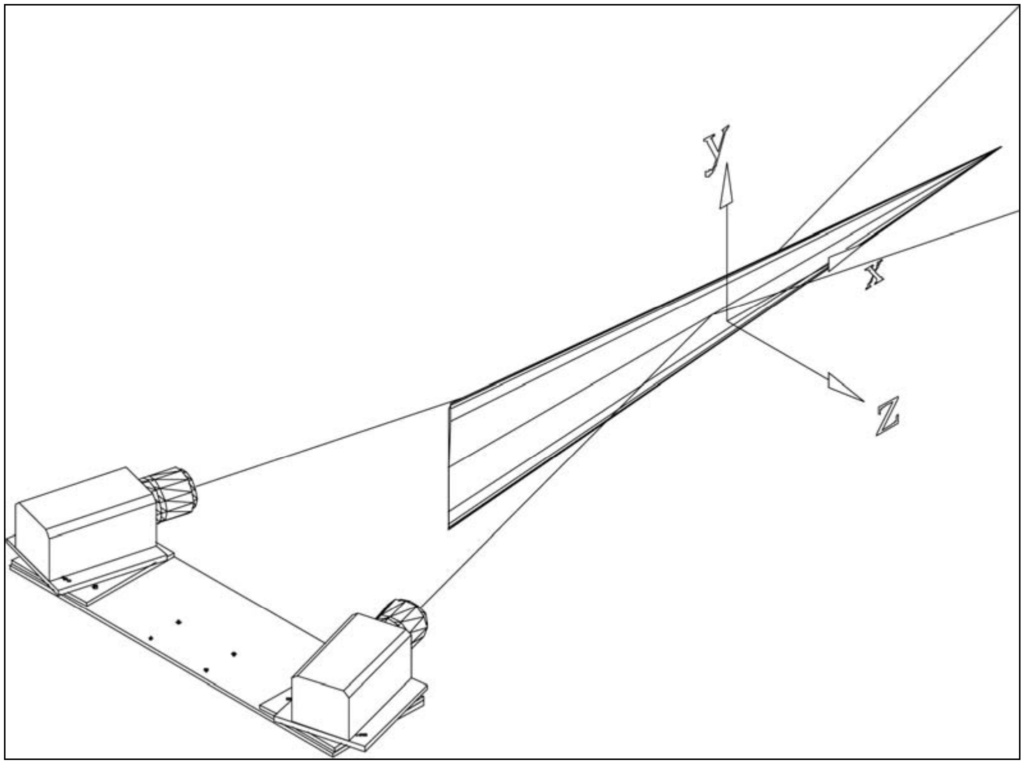
Camera Location

The cameras may either be located on the same side of the light sheet or on both sides of the light sheet. The choice in configurations is largely dependent on your experiment and flow model. Having both cameras on the same side of the light sheet requires less physical and optical access to the experiment.

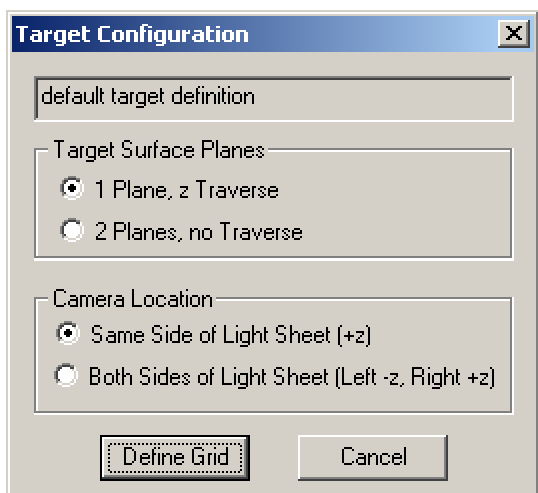
The main advantage of having the cameras on both sides of the light sheet is that both cameras may be in forward scatter where the light intensity is higher. In the following figure both cameras are on the same side of the laser light sheet, and have positive z positions.



In the following figure, the laser light sheet passes between the cameras. The left camera has a negative z position, the right camera has a positive z position.



The grid definition dialog changes depending on which of these configuration parameters are specified. The grid definition may be saved in GridDef.txt in the settings folder of the current experiment. If this file is found, the saved grid definition parameters are filled in the grid definition dialog box. If a GridDef.txt file is located, it appears in the Target Configuration dialog as shown in the following figure.



The calibration uses a fiducial cross as a reference point for defining the target coordinates. The advantage of using the fiducial grid is that Perspective Calibration determines the fiducial mark and can use any number of marker points available in the image. The left and right cameras may see different numbers of marker points, and marker points can enter or leave the field of view with traversing.

When a mirror is used in the imaging optics between the camera and the laser light sheet, the image must be flipped to maintain the correct coordinate system. Perspective Calibration is designed for optical configurations that do not include mirrors. Flipping the image about the Y-axis reverses the image left and right sides, reversing the image flip caused by the mirror. The image is then as it would have been if no mirror were in the imaging system. The image reversal is set in Camera Setup tab in the Component Setup options (See "Camera Setup Parameters" in Chapter 6.) Flipping is done during capture time and has no effect on images already captured.

Each camera with a mirror must be flipped to maintain the correct coordinate system. If one camera has a mirror and it is not flipped, the calibration for the two cameras would have the X axes reversed. If both cameras have mirrors, both left and right images must be flipped or else the vector field would have the X and Z axes backwards.

When the cameras are on both sides of the light sheet, the calibration software expects the right camera to be looking at the front-side of the light sheet and the left camera to be looking at the back-side of the light sheet. The left camera image X-axis is opposite the right camera X-axis because it is looking from behind. When mirrors are in the imaging system, the images must be flipped so that the left and right cameras will still have the opposite X-axis directions the calibration software expects. The calibration software accounts for this difference when combining the vectors. Do **not** flip the left camera image so that both camera images have the same X-axis direction when the cameras are on both sides.

Perspective Calibration Process

Following is an overview of the steps involved in a perspective calibration:

Note: *Step A does not involve using the INSIGHT 3G software. Step B is performed using the Capture feature of INSIGHT 3G, Steps C and D are performed using the Perspective Calibration software within INSIGHT 3G.*

Step A	Align the cameras and set the Scheimpflüg angle set.
Step B	Record images of the calibration target at multiple Z-axis locations using *INSIGHT 3G*.
Step C	Process these calibration images using Perspective Calibration.
Step D	Create and view the Calibration File using Perspective Calibration.

Step A: Aligning the Cameras

Before calibrating, the cameras must be aligned and the Scheimpflüg angle set. The camera alignment is done by first setting the camera angles using a target, then setting the focus and the Scheimpflüg angle looking at particles in the laser light sheet. Although the focus and the Scheimpflüg angle can be set by looking at the target, looking at particle images is more precise.

To align the cameras:

- Align the camera using the calibration target or any other target where you can relate the image to a physical location. Because the magnification varies across the field of view, the best overlap is not when the image centers are viewing the same point. Instead, check the left and right edge of the images. This is most useful when both the cameras are on the same side of the light sheet configuration. Use the **Tools | CrossHair** option to help in overlapping the image.
- Remove the target and image the flow with the laser light sheet. With particle images you can discern whether they are in focus or out of focus better with a calibration target. The particle images also have a high resolution for setting the Scheimpflüg angle.
- From the menu bar of the image file in the display panel, select **Size | Zoom In**. Adjust using the various selections until the entire left and right images are visible. You can zoom into 1:1 magnification or higher and pan from left to right for the most accurate view of the Scheimpflüg angle setting.
- Lock down the Scheimpflüg angle and do not refocus the camera after this step.
- Place the calibration target in the laser light sheet plane.

Step B: Recording Calibration Images

In this step you capture and save a set of images of the calibration target that can be analyzed and used as data points for the calibration file. Refer to the PIV Installation Manual for details on hardware setup. Perform one of the following two sets of procedures depending on which calibration tool you are using:

- Single-plane target mounted on a traverse
- Two-plane or four-plane target.

Single-Plane Target Mounted on a Traverse

If you are using a single plane target mounted to a traverse, follow these steps.

1. Click the **Capture** tab and make the following selections from the Capture control panel:

Parameter	Value
Exposure Mode	Free
Capture Mode	Continuous

Note: *Be sure the Start Capture button is not activated. Having the system capturing live video when starting the Capture PIV Calibration Images or the Capture PLIF Calibration Images process, can cause distorted images.*

2. Select **Tools | Capture Perspective Cal. Images** from the main INSIGHT 3G menu. The Perspective Calibration Image selection box appears.

3. Click **Capture**. A pair of left and right images are captured as PLIFCalibration000001.T000.D000.P000.H000.LA.TIF and PLIFCalibration000001.T000.D000.P000.H000.RA.TIF or PIVCalibration000001.T000.D000.P000.H000.LA.TIF and PIVCalibration000001.T000.D000.P000.H000.RA.TIF are stored in the experiment's setting folder. 000001in the filenames is the image sequence index number. This number is always 0 when the Capture PIV or Capture PLIF Calibration Images dialog box is opened.

   This index number is used later by the Perspective Calibration program to compute the target Z-axis location. The calibration image sequence should start with 0 so that the Z-axis positions are computed correctly. The formula for converting sequence number to target z position is listed later in this section. It is recommended that the entire calibration image capture sequence be performed in one Capture PIV or Capture PLIF Calibration Images session. If for some reason one of the images in the sequence has a problem, the entire sequence of images should be captured again. This prevents introducing errors in calibrations resulting from traversing back to the correct Z-axis location in the middle of the image sequence. To capture a new sequence move the traverse to the start position. Close the Capture Calibration Images selection box and reopen it to reset the sequence count.

z = z Start + (Sequence Number * z Step)

4. Move the traverse to the back of the light sheet thickness. For example, to map a 1-mm thick light sheet with five target planes, start with the target at -0.5 mm and translate it in +0.25 mm increments.
5. Click **Capture** again on the appropriate Capture Calibration selection box to save the image at this z location.
6. Traverse forward one step and save left and right camera images. Continue traversing and saving until images from all calibration planes are saved.

Two-Plane or Four-Plane Target

If you are using a two-plane or four-plane target, follow these steps.

1. Place the target in the laser light sheet using the mirror with slit to align the target to the laser light sheet. Use a bright light to illuminate the target, and a large f/# lens setting so that depth of field is high enough to have the all the target points in focus.
2. Click the **Capture** tab and make the following selections from the Capture control panel.

Parameter	Value
Exposure Mode	Free
Capture Mode	Continuous

Note: *Be sure the Start Capture button is not activated. Having the system capturing live video when starting the Capture PIV or Capture PLIF Calibration Images process, can cause distorted images.*

3. Select **Tools | Capture Perspective Cal. Images** from the main INSIGHT 3G menu. The appropriate Capture Calibration Image selection box appears.
4. Click **Capture**. A pair of left and right images are captured as PLIFCalibration000001.T000.D000.P000.H000.LA.TIF and PLIFCalibration000001.T000.D000.P000.H000.RA.TIF or PIVCalibration000001.T000.D000.P000.H000.LA.TIF and PIVCalibration000001.T000.D000.P000.H000.RA.TIF are stored in the experiment's setting folder. With the two-plane target only one set of calibration images are used.

Step C: Processing the Calibration Images

In this step the calibration images acquired in Step A, are analyzed using the Perspective Calibration program. The pixel location of each calibration marker on the calibration target is stored in a calibration points (*.CPT) file which is created from each image file. This file has the same name as the image file but with a .CPT file extension; it is stored in the calibration folder.

Calibration Processing: Overview

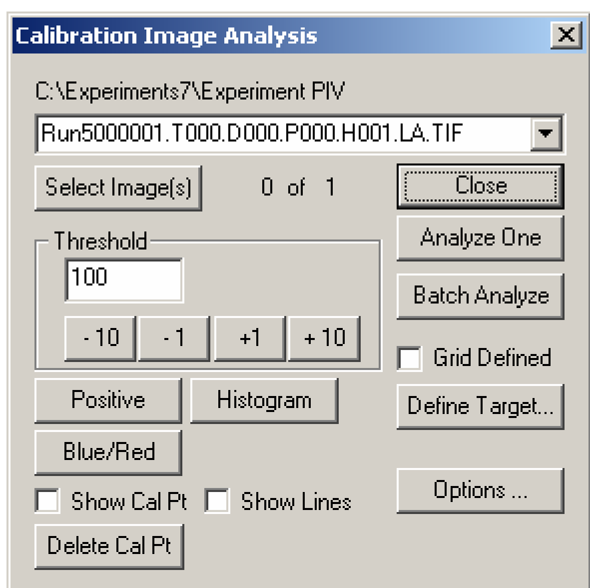
The following is an overview of all the steps that are involved in processing a calibration image. Details on each of these steps are provided at the end of this section.

Until you are familiar with the calibration process, you may want to follow and perform all these steps. Once you are familiar with the process, some of these steps may become optional.

In some experiments, all of the parameters can be set so that all calibration images can be analyzed together. In many experiments, it is easier to analyze the left camera images with one set of parameters and then the right calibration images with a different set of parameters.

To calibrate:

1. On the INSIGHT 3G main menu bar, click **Tools | Perspective Calibration.** The Perspective Calibration program opens.
2. Select **Image** from the main menu. The Calibration Image Analysis dialog box appears.



3. Click **Select Image(s)**. The Open TIF Image box opens.
4. Select a calibration image captured with the left camera.
5. Click **Positive** to toggle to the appropriate setting. See "Choosing Positive and Negative Buttons," for details on how to make this selection.
6. Select a color scheme by clicking **Blue/Red | Gray**. See "Choosing Gray and Blue/Red Color Schemes" for details on how to make this selection.
7. Click **Histogram.** A histogram is displayed. See "Using the Histogram to Set Threshold Level" for details on how to use this histogram for making the minimum and maximum threshold selections.
8. Enter a **Threshold** value. Refer to "Setting the Threshold Value" for details.
9. Click **Define Target.** See "Defining the Target" later in this section for information on how to define the target and the Fiducial Marker Based Grid.
10. Click **Analyze One** Inspect the screen display to make sure there are boxes around the calibration markers and a diamond around the fiducial mark in the center.

    If there are errors, repeat step 7 and enter new threshold values. Also, click **Options** and perform the steps outlined in "Creating Bad Pixels Map" and "Defining Area of Interest and Object Size," later in this section.
11. Repeat step 3 to select an image from the right camera. Repeat steps 4–9 with this image file.
12. Repeat step 3 and select all the calibration images. To select more than one image file, hold the control key down while selecting the files. To select a group of files, select the first file, hold the shift and control keys down, and select the last file.

    The displayed image can be selected using the list of selected filenames.
13. Click **Batch Analyze**. All the selected images are scanned for the calibration marker points and the results are written to target files. The current file is displayed and its position is listed as the first number under the Select Image(s) button. After all of the images are analyzed, the Image Control dialog closes and the Create Calibration File dialog opens with the list of analyzed images and the calibration filename pre-selected. If only one image was selected for batch analysis, the Create Calibration File dialog does not open. See "Step D: Creating and Viewing a Calibration File" for the next step.
14. Verify that the software found the calibration markers in the image. Click **Show Cal Pts.** See "Verifying Calibration Markers

in the Calibration Points and Calibrations Files" for further details.

15. View the calibration equations by checking **Show Lines**. The lines are the mapping of a grid midway between the calibration grid points on the fiducial plane. Calibration points with boxes should be centered between the lines. With a two-plane target the circled points are not centered between the lines because they are not in the fiducial plane.

16. Remove image noise spot from the calibration points file if is seen as a calibration marker point by clicking **Delete Cal Pt.**

17. If the software is not able to generate a grid, change image processing parameters such as Grid Tolerance Pixels, Maximum Object Size or Minimum Object Size fields in the Options dialog.

18. Click **Close**.
The current image display closes and if open, the analysis summary dialog also closes. If you are manually switching images (not in batch mode), **Close** is the best way to clean up one image setting and get ready to select the next image. If you are manually switching images (not in batch mode), the close image button is the best way to clean up one image setting and get ready to select the next image.

The following sections provide background and detailed information on each of the preceding steps.

Choosing Positive or Negative Settings

The image analysis is designed to work with bright calibration markers on a dark background. This is a positive image and you should select the positive setting. If you are using the TSI-supplied calibration plate, use the default setting of Positive.

Sometimes it is easier to generate a calibration target that has dark calibration markers on a bright background, this is a negative image. Use the Negative button to invert the pixel values in the image and in the image display.

To toggle between Negative and Positive settings:

1. On the *INSIGHT 3G* main menu bar, click Tools | **Perspective Calibration**. The Perspective Calibration program opens.
2. Click **Image**. The Calibration Image Analysis dialog box appears.
3. Click **Positive** to toggle between the two values.

Choosing Blue/Red | Gray and Color Schemes

After opening a calibration image and before selecting the threshold value, use the **Blue/Red | Gray** button to help you select the correct threshold values. This feature is designed to help you select the correct threshold values by highlighting the calibration markers and isolating them from the background.

The **Blue/Red** color scheme shows pixels above the threshold value as red and pixels outside the threshold values as a shade of blue. The red pixels are "lit" and they are joined together to define the calibration markers. This allows you to visualize which pixels would be included in the marker points for analysis. If the markers cannot be isolated from the background, you need to capture the images again. Change the lighting or exposure so that the contrast is better or the background is more uniform the second time.

The **Gray** color scheme shows the image as shades of gray. This is the normal view of the image.

To select a color scheme:

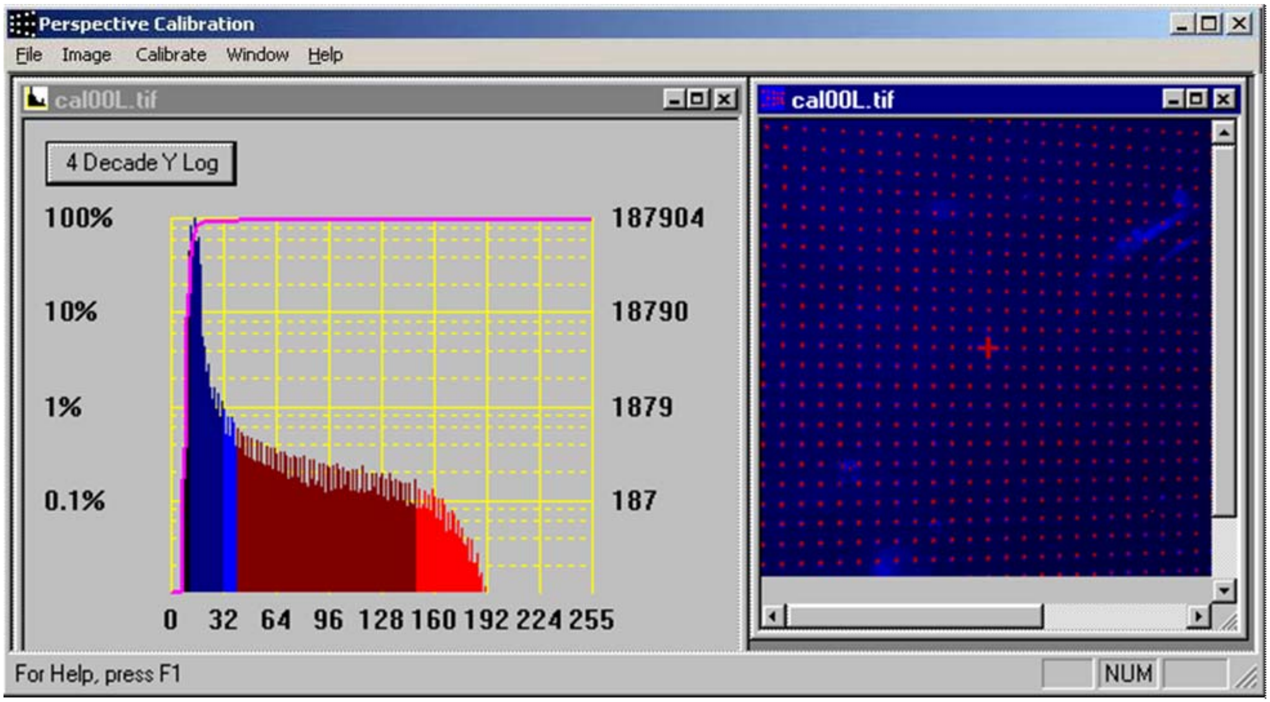
1. Click **Perspective Calibration** from the *INSIGHT 3G* main menu bar. The Perspective Calibration program opens.
2. Click **Image**. The Calibration Image Analysis dialog box appears.
3. Click either **Blue/Red** or **Gray** to select one of the two color schemes.

Using the Histogram to Set Threshold Level

Use the histogram to help you set the correct threshold levels. The histogram shows the number of pixels at each intensity level. The X-axis is the histogram bin or pixel intensity level from 0 to 255. The Y-axis is the number of pixels in the bin. The histogram uses the Positive/Negative setting (See "Choosing Positive or Negative Settings") when displaying the pixel intensities. This means that the histogram intensities are reversed if negative setting is selected.

To display the histogram:

1. On the *INSIGHT 3G* main menu bar, select **Tools | Perspective Calibration**. The Perspective Calibration program opens.
2. Click **Image**. The Calibration Image Analysis dialog box appears.
3. Click **Histogram**. The histogram appears.



As shown in the preceding figure, the histogram shows the pixel intensity distribution in two ways—number of pixels at each intensity level and cumulative pixels less than or equal to the intensity level. The bins are drawn using the color for that intensity in the image. Viewing the histogram with the Red/Blue color scheme can show exactly where the threshold value lies in the intensity distribution. The number of pixels in a bin can be read from the counts labels on the right side of the histogram. The ratio of the number of counts in a bin to the number of counts in the highest bin can be read from the percentage scale on the left of the histogram. The magenta line is the cumulative histogram, showing the number of pixels less than or equal to a pixel value. The cumulative histogram value is read as a % of total pixels from the left axis.

Although Perspective Calibration is able to read 12-bit *INSIGHT* 3G TIF images, it can only operate on the eight most significant image bits and shows the scale as 0 to 255. If the actual image maximum pixel value is 4095, the histogram scale is off by a factor of 16. If the grayscale values in the 12-bit image are all less than 255, the image is scaled 0 to 255 and the histogram scale is the same as the image scale. To verify the actual grayscale range of an image use *INSIGHT* 3G and set the **Tools | LUT** to Pseudo Color. You will be able to see the pixel value range by the range of colors in the image.

When the histogram bins are shown with normal scaling, the histogram may just show a spike at the background intensity level with nothing visible in the foreground. By changing to a Log scale factor, bins with fewer counts may show on the graph.

To change the Y log scale factor in the histogram:

- Click **Log/Normal**. The scale factor cycles from Normal, 2 Decade Log, 3 Decade Log, 4 Decade Log, 5 Decade Log, 6 Decade Log.

Setting the Threshold Value

When the frame is being analyzed for calibration marker images, it uses the threshold value to determine if the pixel is "lit" or not. When a pixel is greater than or equal to the threshold value and less than or equal to the maximum value, it is lit. The Calibration Image Analysis program joins the lit pixels into objects that identify the location of the calibration marks in the image.

The values must be between 0 and 255 inclusive. The pixel intensities are modified with the Positive/Negative setting (see "Choosing Positive or Negative Settings"). Generally, the threshold is used to separate the marker pixels from the background.

This threshold level is a simple test for identifying the lit pixels. For this to work well, the images must have a clear intensity separation between the markers and the background, and this level must work over the entire field of view. Therefore, during the image capture process, you should adjust the exposure and lighting to create this intensity difference.

To specify the minimum and positive threshold values:

1. On the *INSIGHT 3G* main menu bar, select **Tools | Perspective Calibration**. The Perspective Calibration program opens.
2. Click **Image.** The Calibration Image Analysis dialog box appears.
3. Click **Blue/Red | Gray**. See "Choosing Blue/Red | Gray and Color Schemes" for additional information.
4. Click **Histogram**. See "Using the Histogram to Set Threshold Level."
5. Enter the appropriate values in the Threshold box. The Threshold value can be set by using one of the four buttons **-10, -1, +1, +10,** or by typing the threshold value in directly.
6. Increase or reduce the threshold values until all saturated levels are reduced. Use the **-10, -1, +1, +10** buttons to make quick modifications.

Defining the Target

The target definition dialog is used to define the fluid space (x, y, z) coordinates of markers in the calibration points file.

To define the target:

1. On the *INSIGHT 3G* main menu bar, select **Tools | Perspective Calibration**. The Perspective Calibration program opens.
2. Click **Image.** The Calibration Image Analysis dialog box appears.
3. Click **Define Target**. The Target Configuration dialog box appears.
4. Select the appropriate Target Surface Plane option:

Option	Description
1 Plane, z Traverse	Select for a single surface target with traverse.
2 Plane, no Traverse	Select for a two-plane target with no traverse

5. Select the appropriate Camera Location option:

Option	Description
Same Side of Light Sheet (+z)	Select if camera or cameras are located on same side of the light sheet.
Both Sides of Light Sheet (Left –z, Right +z)	Select if camera or cameras are located on both sides of the light sheet.

6. Click **Define Target**. Follow the appropriate set of instructions given in "Defining and Using the Fiducial Marker Based Grid" for defining single-plane, two-plane and four-plane fiducial marker-based grids.

Defining and Using the Fiducial Marker Based Grid

With the fiducial marker-based calibration and the standard calibration target, the cross in the center of the target is the fiducial mark. It can be identified as the mark larger than all the other calibration markers. The fiducial marker is highlighted with a diamond during the display of the calibration points. With fiducial marker calibration, you enter the (x, y, z) location of this cross in the first calibration image. The grid is validated using the fiducial marker as the starting point, with each grid node having an index relative to the marker point. One advantage of using the fiducial marker calibration is that you do not have to set up the calibration target with a specific number of calibration points. The software is able to find all of the markers and reject points that are too close to the edges of the image. This method allows for calibration points to leave the valid image area as the target is traversed. It also allows the left and right cameras to view slightly different fields of view.

To define the single-plane fiducial marker grid values:

1. Perform steps 1-6 outlined in “Defining the Target.”
2. Enter the appropriate values in Fiducial Mark Based Grid dialog box. Following are descriptions of the parameters available on the single-plane grid dialog boxes:

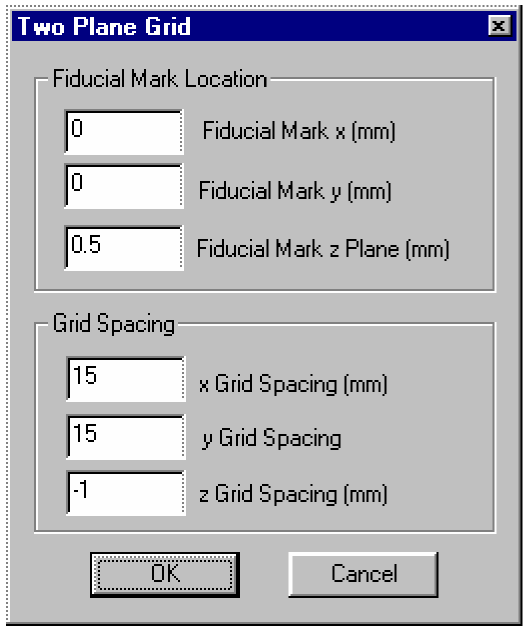
<table>
<tr><th>Parameter</th><th>Description</th></tr>
<tr><td>x & y mm Fiducial Mark Coordinates</td><td>Enter (x, y) value in mm for the fiducial mark in the 3-D vector file. For example, if your camera field of view is 50 mm × 50 mm and you leave the fiducial mark (x, y) set to (0, 0), your vector field will be from (-25, -25) to (25, 25). If you change the fiducial mark (x, y) to (25, 25), your vector field range will be from (0, 0) to (50, 50).

Note: These example numbers are approximate and assume that the fiducial mark is in the center of the image, that the two images are well overlapped and that you are processing the whole images and your points file covers the entire image. (See “Creating the Points File,” later in this chapter.)

If you want to have precise coordinates for some point in the vector field:
a. Create a calibration using approximate coordinates for the (x, y) fiducial mark.
b. Process a vector field and see what the coordinates are in the vector field output.
c. Compute the error in the field of view coordinates.
d. Reprocess the calibration images used adjusted fiducial mark (x, y) coordinates.</td></tr>
<tr><td>z mm First Target Plane</td><td>The Z-axis location for the first calibration image files, image sequence number 00. For example, if the first traverse position is 0.5 mm from the center of the laser light sheet away from the cameras, enter the value -0.5 mm. If the first traverse was 0.5 mm towards the cameras from the center of the laser light sheet, enter the value 0.5 mm.</td></tr>
<tr><td>x & y Grid Spacing (mm)</td><td>Enter the distance between the horizontal grid points in the x grid spacing box and the vertical grid spacing in the y grid spacing box.</td></tr>
</table>

Parameter	Description
z Grid Spacing mm (can be + or -)	The z grid spacing is the distance traversed between each calibration image capture. If the traversing moves the target closer to the cameras, the value is positive. If the traversing moves the target away from the cameras, enter a negative value. ***Note:*** *The calibration image file sequence number is used to compute the Z-axis position. It is important that when capturing a sequence of calibration images that you keep the sequence numbers correct.*

3. Click **OK**. The Grid Defined box is checked.



To define the two-plane fiducial marker grid values:

1. Perform steps 1-6 outlined in "Defining the Target."

2. Enter the appropriate values in the Two-Plane Grid dialog box. Following are descriptions of the parameters available on the two-plane grid dialog boxes:

<table>
<tr><th>Parameter</th><th>Description</th></tr>
<tr><td>Fiducial Mark Location
(x, y) mm</td><td>Enter (x, y) values in mm for the fiducial mark. For example, if your camera field of view is 50 mm × 50 mm and you leave the fiducial mark (x, y) set to (0, 0) your vector field will be from (-25, -25) to (25, 25). If you change the fiducial mark (x, y) to (25, 25), your vector field range will be from (0, 0) to (50, 50).

Note: These example numbers are approximate and assume that the fiducial mark is in the center of the image, that the two images are well overlapped, and that you are processing the whole images and your points file covers the entire image. (See “Creating the Points File,” later in this chapter.)

If you want to have precise coordinates for some point in the vector field:
a. Create a calibration using approximate coordinates for the (x, y) fiducial mark.
b. Process a vector field and see what the coordinates are in the vector field output.
c. Compute the error in the field of view coordinates.
d. Reprocess the calibration images used to adjust fiducial mark (x, y) coordinates.</td></tr>
<tr><td>Fiducial Mark z Plane (mm)</td><td>The Z-axis location for the fiducial marker on the target.

For example if the two target planes are 1 mm apart and the fiducial mark is on the raised surface (closest to the camera), enter +0.5 mm for the fiducial mark z location and -1.0 for the target z spacing. If the fiducial mark is on the recessed plane (away from the camera), enter -0.5 mm for the fiducial mark z location and +1.0 mm for the z spacing.</td></tr>
<tr><td>x & y Grid Spacing (mm)</td><td>Enter the distance between the horizontal grid points in the x grid spacing box and the vertical grid spacing in the y grid spacing box.</td></tr>
<tr><td>z Grid Spacing mm (can be + or -)</td><td>The z grid spacing is the distance between the two target surfaces. (See the z fiducial mark location entry above for example.)</td></tr>
</table>

3. Click **OK** when you are prompted to save changes.

To define the four-plane fiducial marker grid values:

1. Perform steps 1-6 outlined in "Defining the Target."
2. Enter the appropriate values in the Four-Plane Grid dialog box. Following are descriptions of the parameters available on the four-plane grid dialog boxes:

Parameter	Description
Fiducial Mark Location (x, y) mm	Enter (x, y) values in mm for the fiducial mark. For example, if your camera field of view is 50 mm × 50 mm and you leave the fiducial mark (x, y) set to (0, 0) your vector field will be from (-25, -25) to (25, 25). If you change the fiducial mark (x, y) to (25, 25), your vector field range will be from (0, 0) to (50, 50). ***Note:*** *These example numbers are approximate and assume that the fiducial mark is in the center of the image, that the two images are well overlapped, and that you are processing the whole images and your points file covers the entire image. (See "Creating the Points File," later in this chapter.)* If you want to have precise coordinates for some point in the vector field: **a.** Create a calibration using approximate coordinates for the (x, y) fiducial mark. **b.** Process a vector field and see what the coordinates are in the vector field output. **c.** Compute the error in the field of view coordinates. **d.** Reprocess the calibration images used to adjust fiducial mark (x, y) coordinates.
Fiducial Mark z Plane (mm)	The Z-axis location for the fiducial marker on the target. For example if the two target planes are 1 mm apart and the fiducial mark is on the raised surface (closest to the camera), enter +0.5 mm for the fiducial mark z location and -1.0 for the target z spacing. If the fiducial mark is on the recessed plane (away from the camera), enter -0.5 mm for the fiducial mark z location and +1.0 mm for the z spacing.
x & y Grid Spacing (mm)	Enter the distance between the horizontal grid points in the x grid spacing box and the vertical grid spacing in the y grid spacing box.

Parameter	Description
z Grid Spacing mm (can be + or -)	The z grid spacing is the distance between the two target surfaces. (See the z fiducial mark location entry above for example.)

3. Click **OK** when you are prompted to save changes.

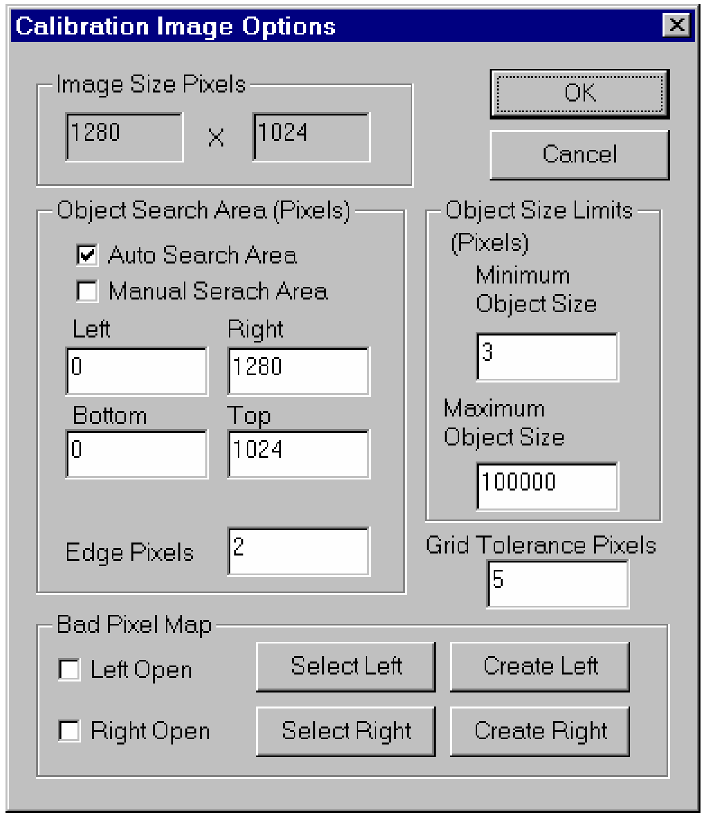
Creating Bad Pixels Map, Defining Area of Interest and Object Size

You can use the Calibration Image Analysis options dialog to:

- Define or select an area of interest to look for calibration marker points. You can use a set of inputs to reduce the area of interest for the image analysis, setting different number of pixels to exclude for the left, right, top and bottom edges.
- Define object size. By defining an object size, only objects greater than or equal to the minimum object size and less than or equal to the maximum size will pass through the filter and be used when matching the image objects to the grid definition.
- Define or identify defective pixels and modify them in the image before scanning for the calibration marker points. Defective pixels appear because some CCD cameras have a few pixels that do not work properly. The most common pixel defect is that a pixel is bright even when the lens cap is on. These defective pixels can cause problems during the calibration as they are identified as lit when there is no object there. The left and right cameras each have these functions.

To create a bad pixel map:

1. First capture and save an image from the camera with the lens cap on as outlined in "Step B: Recording Calibration Images." In this image, all bright pixels are defective and can be excluded from the image analysis. If the image of the marker point includes any bad pixels, that marker is not included in the calibration points file.
2. Select and process the image as outlined in "Step C: Processing the Calibration Images," making sure to use the **Set Threshold** and **Red/Blue | Gray** buttons in the Calibration Analysis dialog box. When pixels are highlighted in red, perform the next step.
3. Click **Options** in the Calibration Analysis dialog box. Click **Create Left** or **Create Right**, depending on whether you are generating a map file for an image captured with either a left or right camera.



To specify the region of interest, object size, or identify and create bad pixels map:

1. On the *INSIGHT 3G* main menu bar, select **Tools | Perspective Calibration**. The Perspective Calibration program opens.
2. Click **Image.** The Calibration Image Analysis dialog box appears.
3. Click **Options**. The Calibration Image options dialog box appears.
4. Enter the appropriate values for the parameters described below:

Parameter	Description
Image Size Pixels	Displayed for reference purpose only. The first number is the image width, the second the image height in pixels. The left and right search limits must be between 0 and the image width. The bottom and top search limits must be between 0 and the image height.

Parameter	Description
Object Search Area Pixels	Enter different number of pixels to exclude for the left, right, top and bottom edges. **Auto Search Area:** Selects the entire image for image analysis. If you have entered limit values but Auto Search Area is selected, your input limits are ignored. **Manual Search Area:** Reduces the area of interest. When this button is checked, the input area is the image analysis area of interest. **Edge Pixels**: Excludes the same number of pixels from all four edges.
Object Size Limits (Pixels)	Enter a value to help filter the objects found in the image analysis by size. Only objects greater than or equal to the minimum object size and less than or equal to the maximum size pass through the filter and will be used when matching the image objects to the grid definition.
Grid Connection Order)	Used when an image has a large amounts of distortion. Allows the calibration point to be verified with higher order location predictors.
Grid Tolerance Pixels	Used when calibration points are being added to the grid. A calibration point must be within this tolerance of the predicted pixel location to be added to the grid. The tolerance must be loose enough to allow for the image distortion that is being measured but tight enough so that it finds only the correct points.
Bad Pixel Map	**Left/Right Bad Pixel Map Open:** *INSIGHT 3G* checks these boxes when you have created a bad pixel map for an image, or selected a previously created bad pixel map, using the Select or Create buttons. **Create Left/Right:** Analyzes the current image you have opened in the Calibration Image Analysis dialog with the current minimum and maximum threshold values. The pixels between the threshold values are classified as "Bad." The list of bad pixels is stored in either badPixL.tif or badPixL.tif (Bad Pixel Map) in the calibration folder. **Select Left/Right:** Allows you to select a Bad pixel map file: Left.BPM or Right.BPM. These filenames are fixed. You could have several of these files on your computer in different folders.

5. Click **OK.**

Verifying Calibration Markers in the Calibration Points and Calibrations Files

During the batch processing the calibration markers are highlighted and boxes drawn around them to show the results of the image analysis. This highlighted view flashes quickly to verify that the image analysis did, in fact, find the calibration markers correctly.

To verify markers:

1. On the *INSIGHT* 3G main menu bar, select **Tools | Perspective Calibration**. The Perspective Calibration program opens.
2. Click **Image** in the main menu of the Perspective Calibration program. The Calibration Image Analysis dialog box opens.
3. Click **Select Images** and open one or more calibration images.
4. Check **Show CPT Pt**.

Diamonds are drawn around the fiducial point and a box around the other target points on the same plane as the fiducial mark. If a two-plane target is being used, the calibration points *not* on the fiducial plane are shown with circles.

Note: *A calibration points (CPT) file must exist for the calibration markers to be shown.*

By looking at the analysis results you can verify the fiducial mark and the calibration markers were properly identified, and that noise was not used as a calibration marker. If a few noise spots are identified as calibration points you can remove them by doing the following:

To remove noise spots:

1. On the *INSIGHT* 3G main menu bar, select **Tools | Perspective Calibration** bar. The Perspective Calibration program opens.
2. Click I**mage** in the main menu of the Perspective Calibration program. The Calibration Image Analysis dialog box opens.
3. Click **Select Images** and open one or more calibration images.
4. Click **Delete Cal Pt**. Click the box you want to delete and then confirm the selected point is the correct one to eliminate.
5. Repeat step 4 until all bad points are eliminated and then go the next step.
6. Select **Calibrate | Create Calibration**. Select the CPT files, and create a new calibration file.

To fix improperly identified markers:

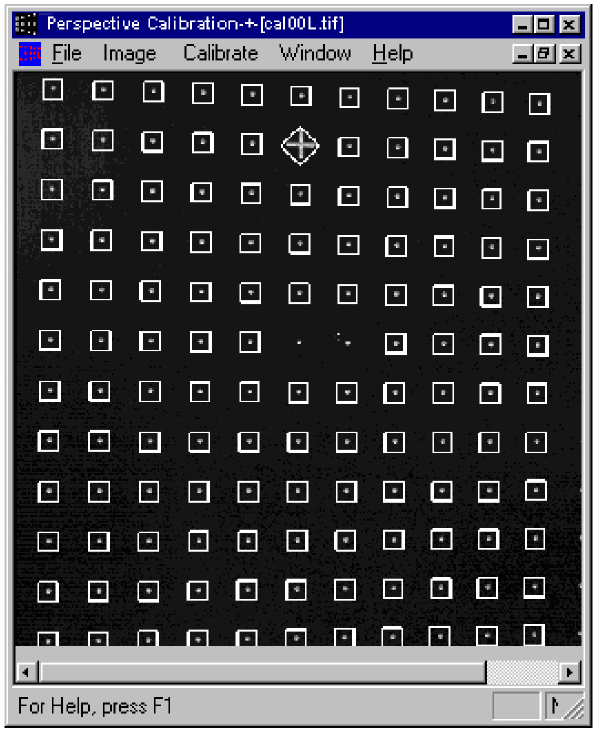
- Rescan image with a different threshold value if too many of the markers are not properly identified. If a good threshold value cannot be found, recapture the calibration images with better lighting and exposure settings so that the calibration markers can be isolated from the background.

It is acceptable to have an image where a few of the calibration markers were not located. There are several reasons why a calibration point could be missed:

- If it is too close to the edge of the image, it is eliminated.
- If the threshold value does not isolate the marker pixels from the background, it is not identified.
- If the marker image is broken up into unconnected pixel groups, all of the marker groups will be eliminated. If there is a bad pixel in the calibration marker image, it will be eliminated. If there is a bright spot like a reflection or bubble in the image between calibration markers, both the good marker and the noise marker will be removed so that only good markers remain.

The fiducial marker may not be properly identified if it is not in the central area of the image, or if it is not the largest object in the image. You may be able to use the **Options...** dialog to configure the software to work with your image.

The calibration is computed using a least-square fit of all calibration points. If a few marker locations are missing, a good calibration can still be computed.



The above figure shows the results of an image analysis. The fiducial mark cross is highlighted with a diamond and the calibration marks are highlighted with boxes. Two marker dots in the center of the grid are not highlighted. This is because there are bright pixels between these two markers. In the grid validation step the local grid spacing for these dots was found to be outside the tolerance and these points were removed from the grid. This removed both the extraneous bright pixels and the calibration markers. This image still has enough good calibration points to be used to create a calibration file.

Four calibration marks very close to the right edge of the image are visible in the lower-right corner. These marks were eliminated for being too close to the image edge.

After a calibration file has been created, you can view a grid of lines from the fluid mapped into the image with the **Show Lines** checked. The lines are located midway between calibration points and mapped into the fiducial plane. The boxed calibration points should be centered between the lines. Circled points are not on the fiducial plane and will not be centered between the lines. Look at the edges of the calibration grid, the mesh should not become too warped or fold upon itself. If is too warped, using a lower equation order can improve the calibration—especially at the edges of the image. If the grid looks good, you may want to try increasing the calibration equation order for improved accuracy. If you use a higher order grid, be sure to view it again to verify that it looks okay.

Step D: Creating and Viewing a Calibration File

After the images have been analyzed by Perspective Calibration, the calibration points are stored in files with the *.CPT extension. The next step is to create a calibration file from these calibration points and view the graphical display to verify that the calibration was done properly and check if:

- All the calibration points appear in a reasonable grid in the camera fields of view
- All the camera fields of view look like trapezoids in the fluid point of view.

The following sections describe how to:

- Create a calibration file from the calibration points file and the optical configuration information and how to optimize calibration.
- View a calibration file.

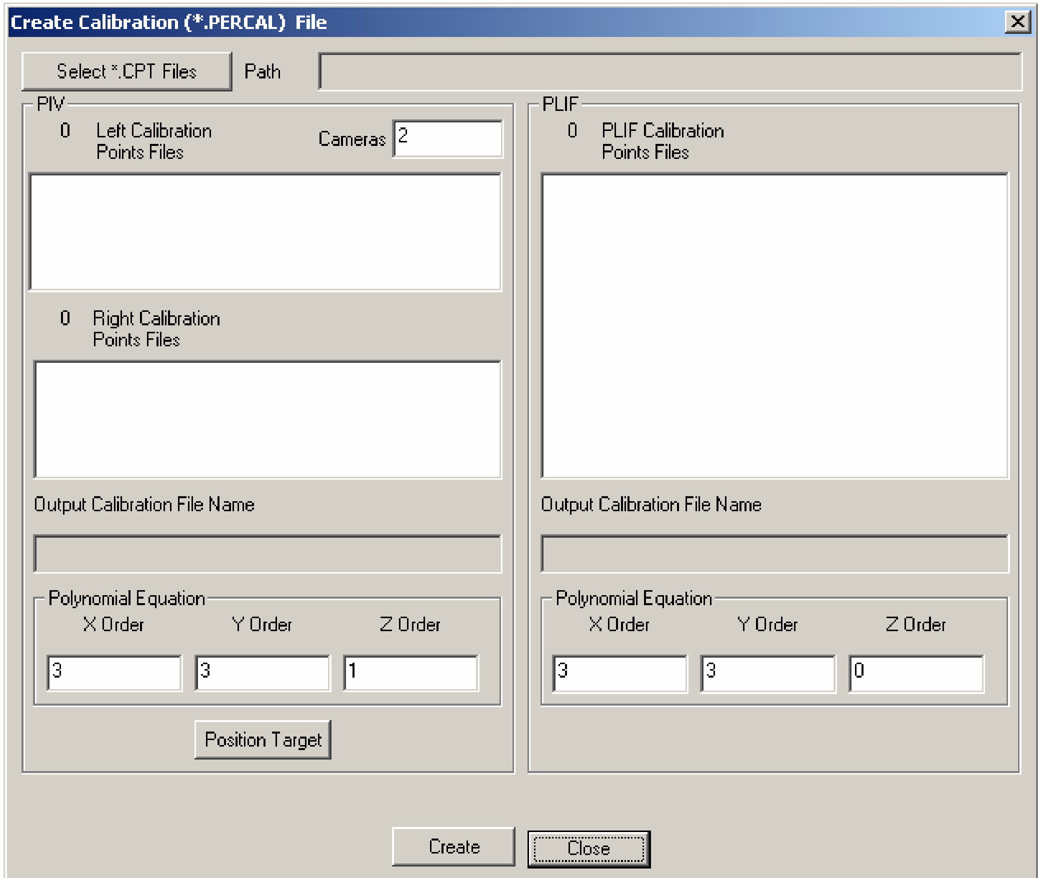
Creating a Calibration File From the Calibration Points Files

The Create Calibration File dialog in the Perspective Calibration program reads in files with a (*.CPT) extension that were created with the image analysis functions and creates the calibration (*.PIVPERCAL or *.PLIFPERCAL) file. This file contains a set of polynomial equations for mapping an (x, y, z) position in the fluid to an (X, Y) camera pixel and for mapping a camera pixel (X, Y) location into fluid (x, y, z) space. The calibration file contains this pair of mapping functions for both the left and right cameras.

Note: *This dialog opens automatically after you perform image analysis on a batch of files. When it is opened automatically, the calibration filename is derived from the first image filename, and the files in the batch process are filled into the Left and Right .CPT files lists. You can accept or edit any of these default filenames.*

To create a calibration file:

1. On the *INSIGHT 3G* main menu bar, select **Tools | Perspective Calibration**. The Perspective Calibration program opens.
2. Click **Calibrate** in the main menu of the Perspective Calibration program and select **Create Calibration**. The Create Calibration File dialog box appears.



3. In the Camera box, enter the number of cameras in your experiment. For Stereo PIV, set **2** Cameras. If you are calibrating a single camera system, set **1** camera

4. Click **Select *.CPT Files**. Select all the calibration points (*.CPT) files that will be used to create the calibration file from the File Open dialog box. The path is shown in the box to the right of the button. The files are sorted by their names into left and right calibration points files. If you wish to change the selected files, you need to select all of the calibration points files for the calibration. You cannot add or remove individual files from this list.

   To select multiple files you can hold the control key down and click on each file, or to select sequential group of files you can hold the **<Shift>+<Ctrl>** keys then click on the first and last file in the list.

5. Set the order of the polynomial mapping equations with the X, Y and Z Order edit boxes. The polynomial mapping equations can be from 1st to 5th order for each axis. Generally, using high order equations can give better accuracy, but the conversion from two 2-D to a 3-D vector file will take a little longer. The maximum equation order that you should use is number of calibration

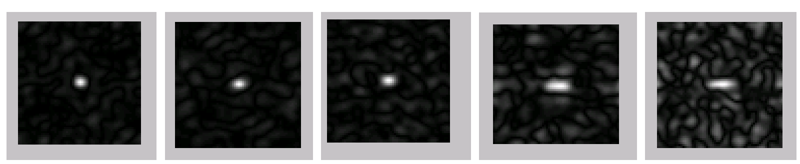
points in that axis -1. For example if you are using 3 z calibration planes, 2 is the maximum z equation order that you should use.

6. Click **Create.** Perspective Calibration creates the calibration file with the input parameters. The calibration file *X*. PIVPERCAL or *X*. PLIFPERCAL is located in the settings folder of the current experiment.

Optimizing Calibration by Finding the Light Sheet Position in the Target Coordinate System

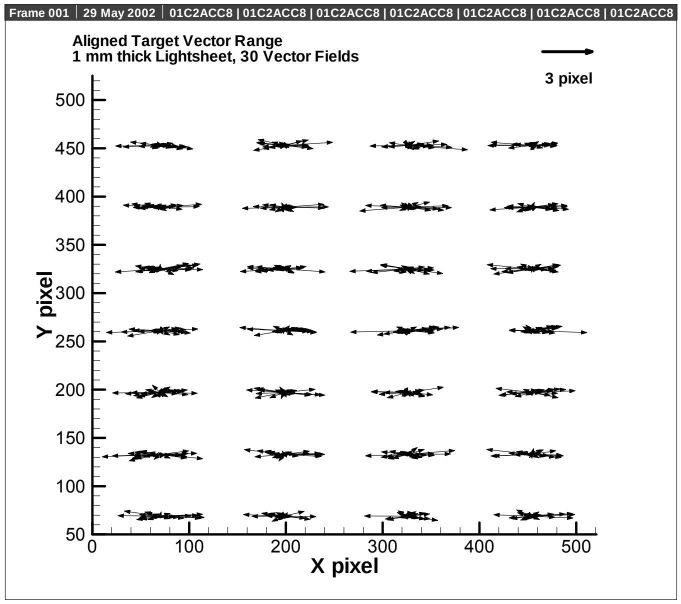
Accurately placing the calibration target in the laser light sheet plane is the largest error in most calibrations. The misalignment manifests itself as mapping errors between world locations and the two camera images. The mapping error, or disparity, can be measured by dewarping and cross correlating the images. In dewarping an image with a constant pixel magnification is created by mapping from a world location into a camera image and interpolating the camera image pixel intensity for each world (dewarped) pixel location. The dewarped image is trapezoidal with the field of view increasing with object distance. If the calibration was perfect and the light sheet had zero thickness, the disparity between dewarped left frame A and dewarped right frame A would be zero since both images have captured the same particle field, but from two different perspectives.

The light sheet has some thickness which results in the disparity correlation maps being elongated in the horizontal direction due to the depth range within the light sheet.



Correlation Peak Elongation with Increasing Light Sheet Thickness

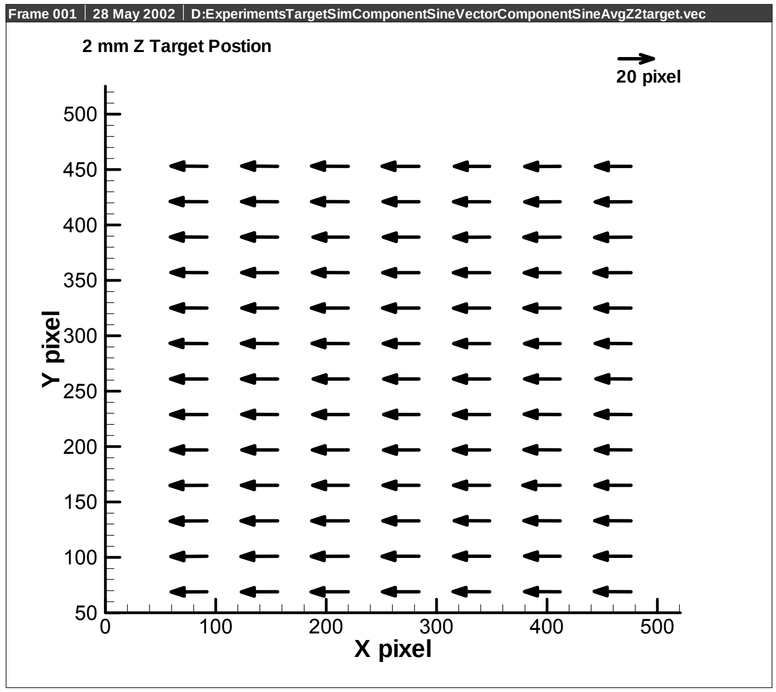
The figures show how the correlation map peak width increases with increasing light sheet thickness. The correlation maps were created from very high concentration images. For typical particle image concentrations the measured peak may be anywhere along the elongated peak as can been seen in this disparity vector map.



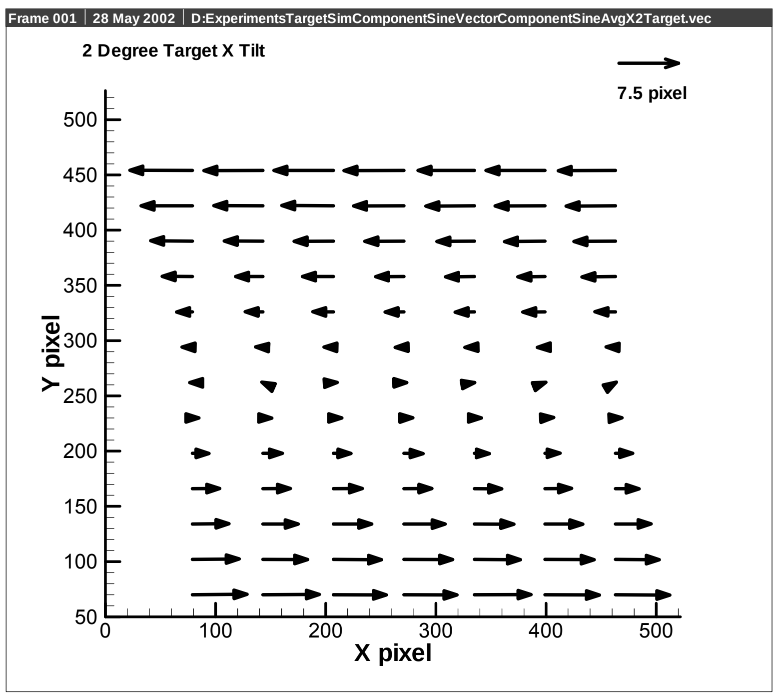
Disparity Vector Field with Many Single Realization Disparity Vectors

This disparity vector field shows all the vectors from a sequence with a vector shown at each node from each realization. The range of vector lengths matches the elongation of the peak. Ensemble Average Correlation is the preferred averaging method for measuring the disparity with *INSIGHT 3G*. With ensemble processing the correlation maps are summed together. When a sufficient number of realizations have been ensemble processed, the correlation map peak will be filled in allowing accurate location of the peak center position. A second vector averaging method is to compute the disparity from each realization, like the above disparity map, and then average the disparity vector fields using the Tecplot add-on. If the light sheet is thin and particle image concentration is high you may be able to measure the disparity with a single realization vector field.

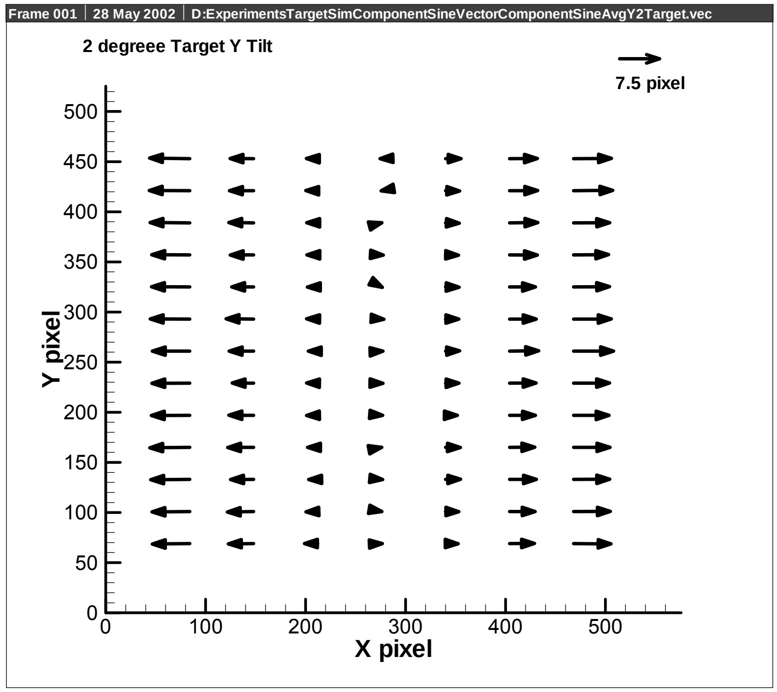
The laser light sheet position in the target coordinate system can be estimated from the disparity vector field. When the target is parallel to the light sheet, but in front or behind the light sheet, the disparity vectors will be uniform left or right. When the target has a rotation about the X-axis relative to the light sheet, the disparity vectors will have a top to bottom gradient. When the target has a rotation about the Y-axis relative to the light sheet, the disparity vectors will have a left to right gradient. When the target has a combination of Z-translation X-axis rotation and Y-axis rotation, the disparity map will have combination of uniform left or right with a top to bottom gradient and a left to right gradient. Examples of these target positioning errors are shown in the following disparity vector fields.



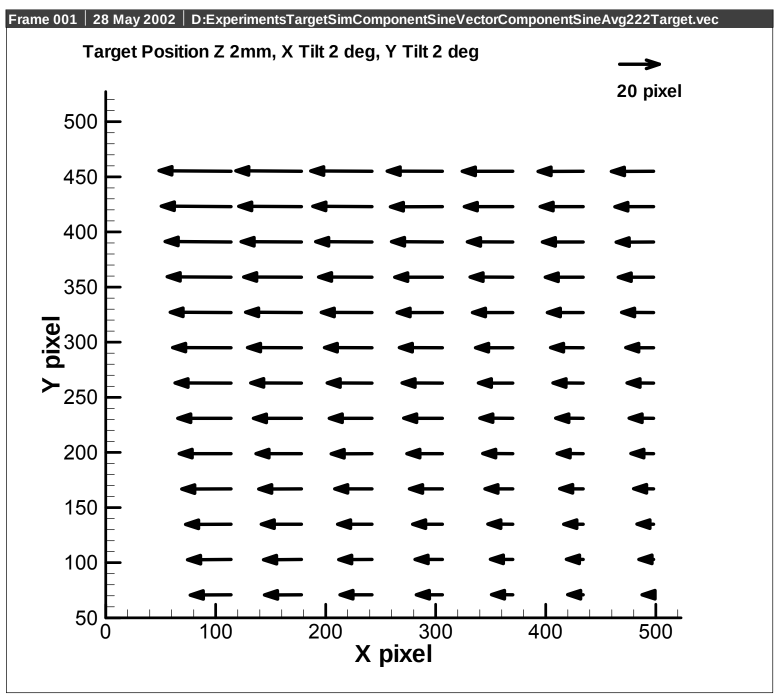
Target at Z = 2 mm



Target X tilt = 2 deg



Target Y tilt = 2 degrees



Target Z = 2 mm X tilt = 2 deg, Y tilt = 2 deg

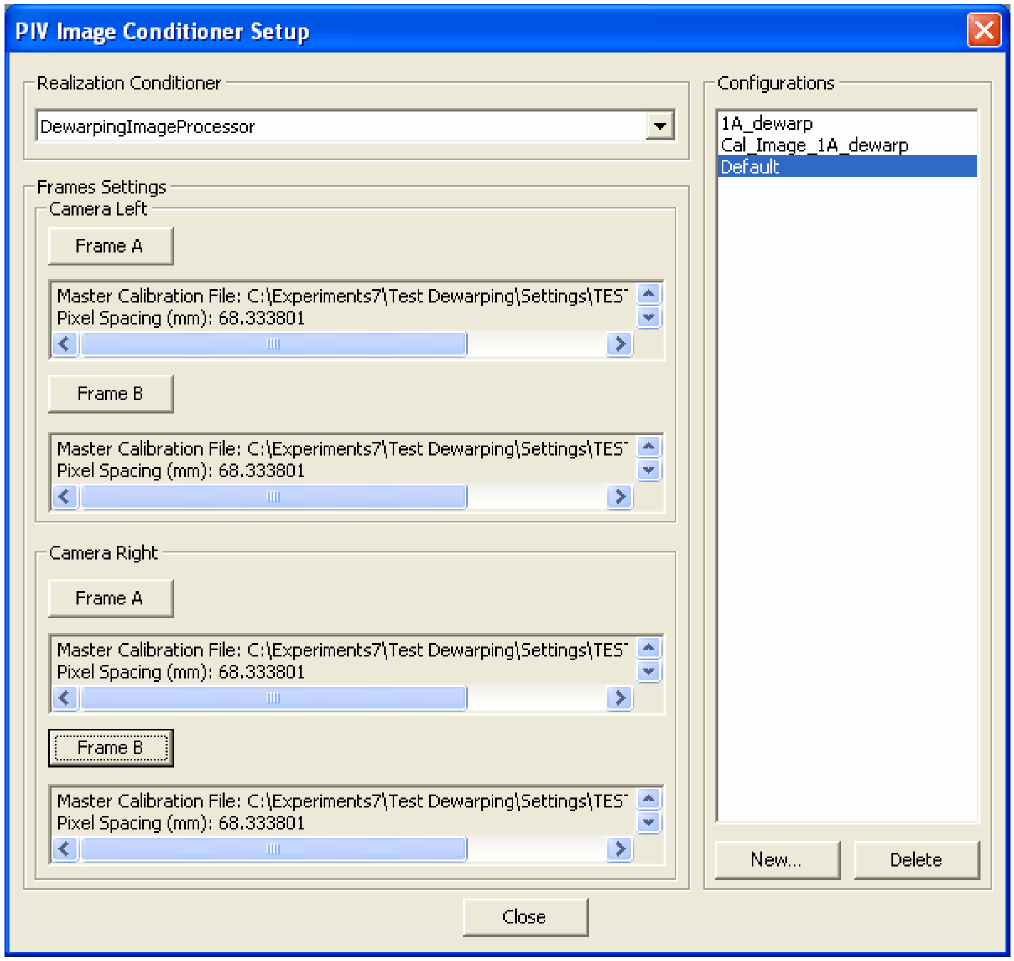
To correct the calibration target positioning errors, *INSIGHT 3G* includes software that analyzes the disparity vector field and computes the light sheet position in the target coordinate system. The light sheet position is included in the perspective calibration file so that the dewarping and vector combination are done in the light sheet plane in the target coordinate system.

The following gives an overview of the steps involved in this procedure:

- Capture a sequence of particle flow images.
- Calibrate the system.
- Dewarp the particle flow images.
- Cross correlate the dewarped images using the Dewarp Test processing and ensemble processing to create the average disparity vector field.
- Open the CPT files, dewarped calibration file, WarpKey,txt, and the average disparity vector field using the Perspective Calibration program.
- Analyze the error and compute the light sheet position in target coordinates to optimize the calibration in the Perspective Calibration program.

To verify and optimize calibration target location:

1. Capture a sequence of particle flow images as described in Chapter 6 "Capturing Images."
2. Calibrate the system as described earlier in this chapter.
3. From the PIV tab, select **Conditioner Setup.** The Conditioner Setup dialog appears.



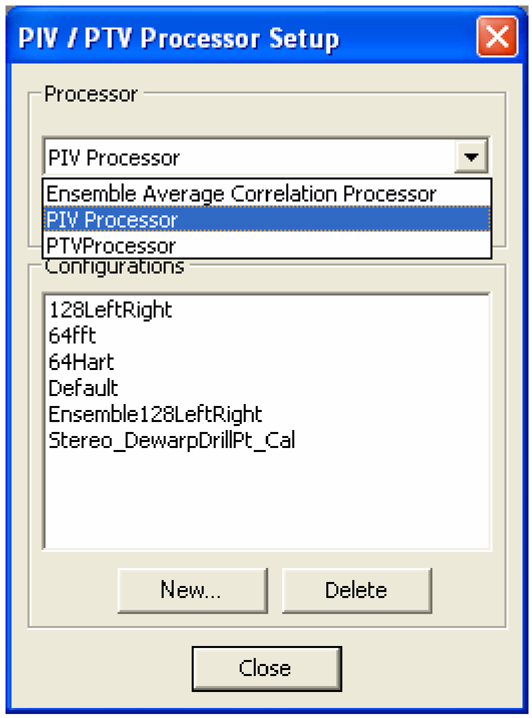
4. In Realization Conditioner box, select **DewarpingImageProcessor**.
5. In the four Frame boxes, select the calibration file. Select the ExperimentName.PIVPerCal calibration file not the dewarp_ExperimentName.PIVPerCal file. The ExperimentName.PIVPerCal is the calibration between the image and the world. The dewarp_ExperimentName.PIVPerCal is the calibration between the dewarped images and the world, the calibration of the images after this dewarping is complete.

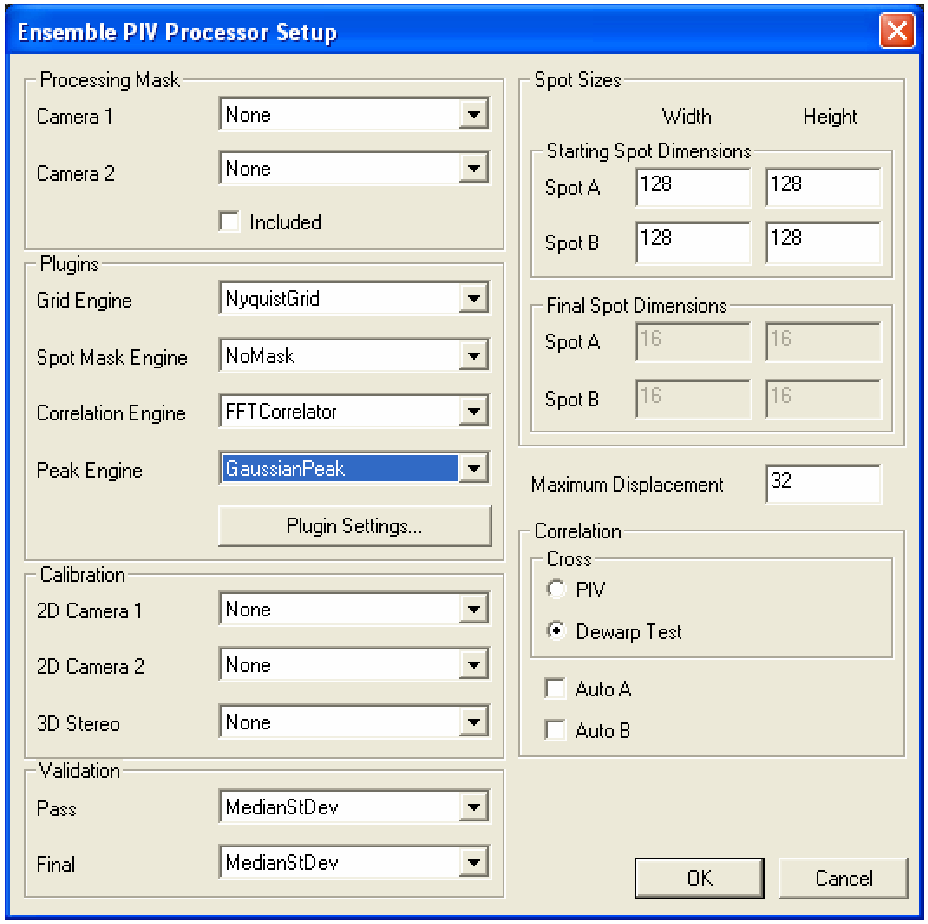
   The default dewarped image parameters are set so that all of the image area from each camera is included in the dewarped image. The image height in pixels is the same as the camera height in pixels and the pixel magnification factor is computed from the image height and all of the cameras vertical field of view. The image width in pixels is computed from all cameras horizontal field of view and the pixel magnification computed from the vertical image size.
6. Click **Save** the dewarped image processor settings.

7. From the Exp.Tree tab, select and open a flow image or a sequence of images.

8. Select PIV tab. In the PIV Conditioning box, verify that the dewarping image processor you just created is selected and click **Apply Condition**. The selected images are dewarped and saved in the Analysis folder.

9. Open the Ensemble Average Correlation Processor setup dialog by pressing **PIV Tab | Process Setup..** button to open the PIV Processor Setup Dialog and selecting Ensemble Average Correlation Processor from the Processor drop down list.



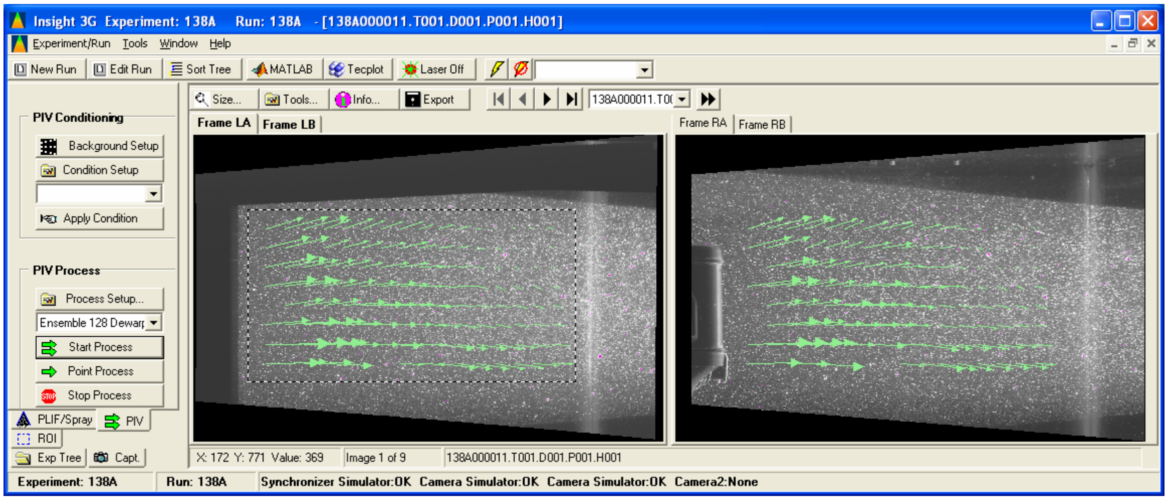


10. Check the **Dewarp Test** box.

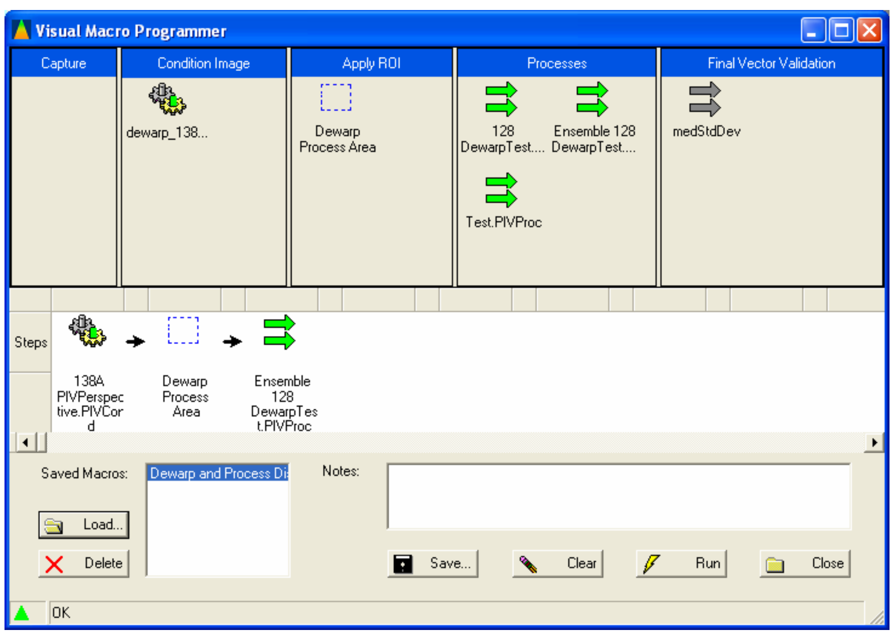
11. Enter 128 × 128 in the Spot A and B boxes as shown in the above figure. Enter a Maximum Displacement in the range of 32 to 63, to allow large disparities to be measured.

Ensemble Average combines the correlation maps from each image in the sequence to giving the highest signal to noise ratio average vector field. Ensemble processing works best where the displacement does not change from realization to realization, just the case we have for calibration errors. The last vector field in the sequence is the ensemble average vector field that should be used to for calibration optimization. The Dewarp Test button correlates Left A with Right A and Left B with Right B. The A disparity vector field is displayed on the left image and the B disparity vector field is displayed on the right image. The output left disparity vector fields show the position of the first laser pulse and the right disparity vector fields show the position of the second laser pulse.

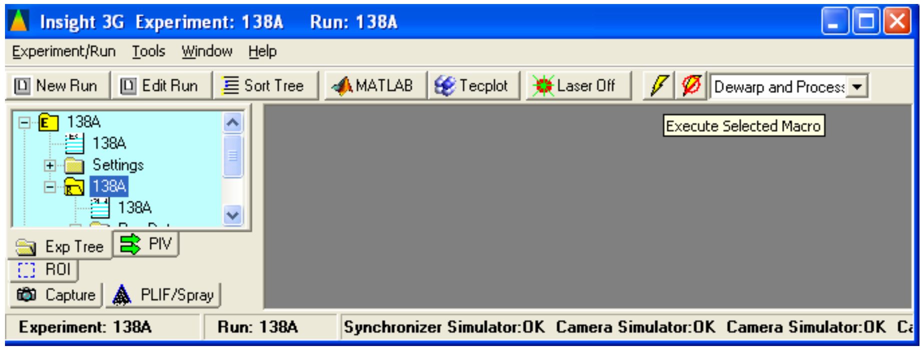
The following shows the results of the Dewarp Test processing and ensemble average of nine realizations.



12. The disparity computation can be automated using the Macro programming feature of *INSIGHT 3G*. First create a dewarping conditioner, dewarp test processor, and a region of interest (ROI). Open the Macro Editor with the **Tools | Visual Macro Programmer..**.dialog. Drag and drop the dewarping conditioner, the ROI, and a dewarp test processor into the steps panel. Save the macro. Then select the macro in the INSIGHT top toolbar. Play the macro by pressing the play macro, lightning button. The macro will dewarp all of the open images then process them using the specified ROI and disparity processor.



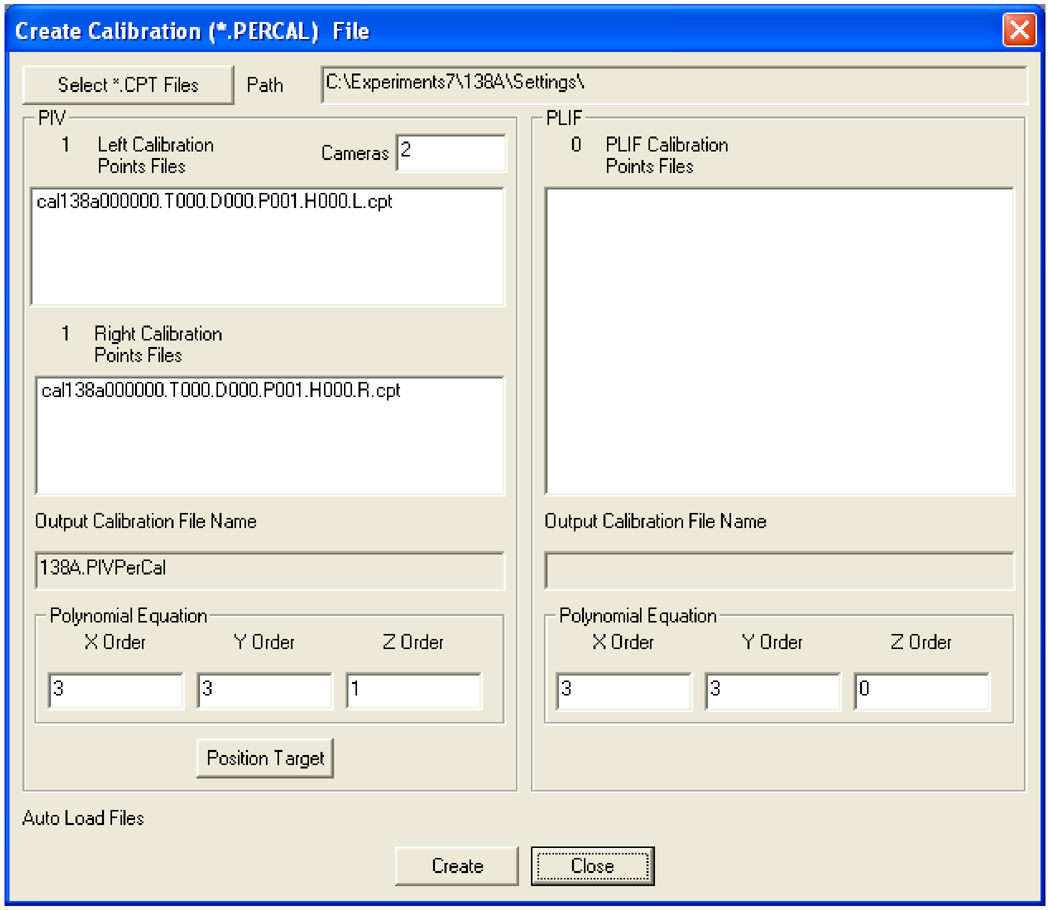
Visual Macro Programmer



The Lightning Bolt is Used to Play the Selected Macro

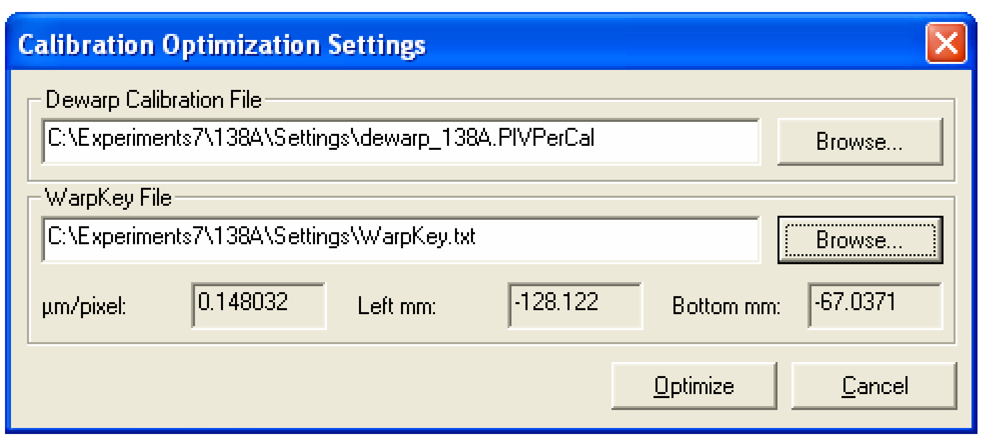
13. An alternative method for creating an average disparity field to use for the calibration optimization is to use the PIV Processor instead of the Ensemble Average Correlation Processor to compute a disparity field for each realization. The disparity vector fields can then opened as group in Tecplot with the TSI add-in. Using the **Avg | Save** option in the add-in dialog will compute and save the average of the selected disparity vector fields to disk. The Ensemble Average method is the preferred technique, but you may find the averaging of individual realization disparity vector fields more convenient in some experiments.

14. Select **Tools | Perspective Calibration | Calibrate | Create Calibration**. The Create Calibration File dialog box appears.

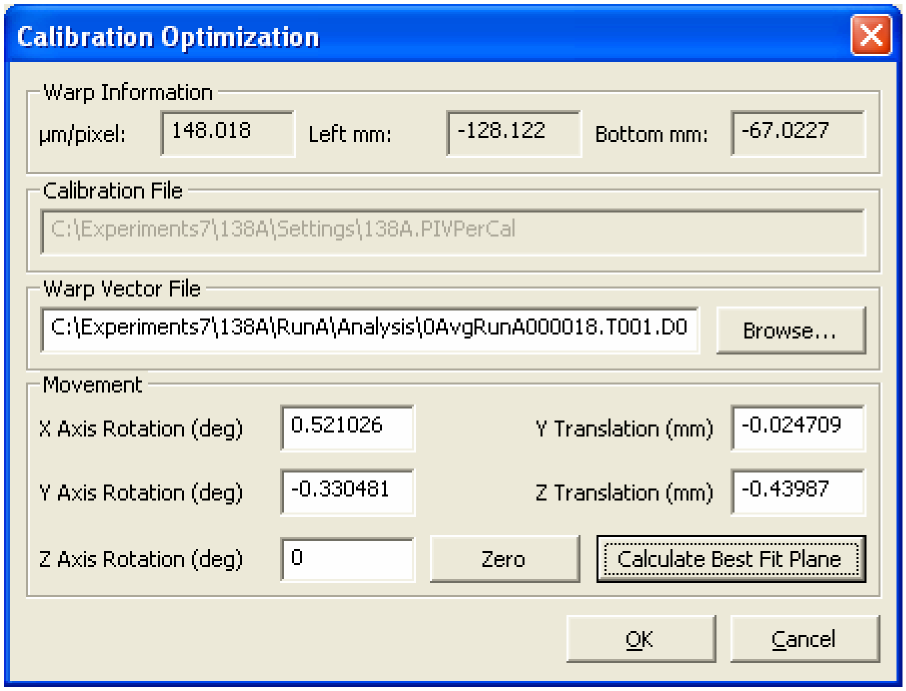


15. Click ***CPT Files** and select the calibration files.

16. Click **Position Target...**

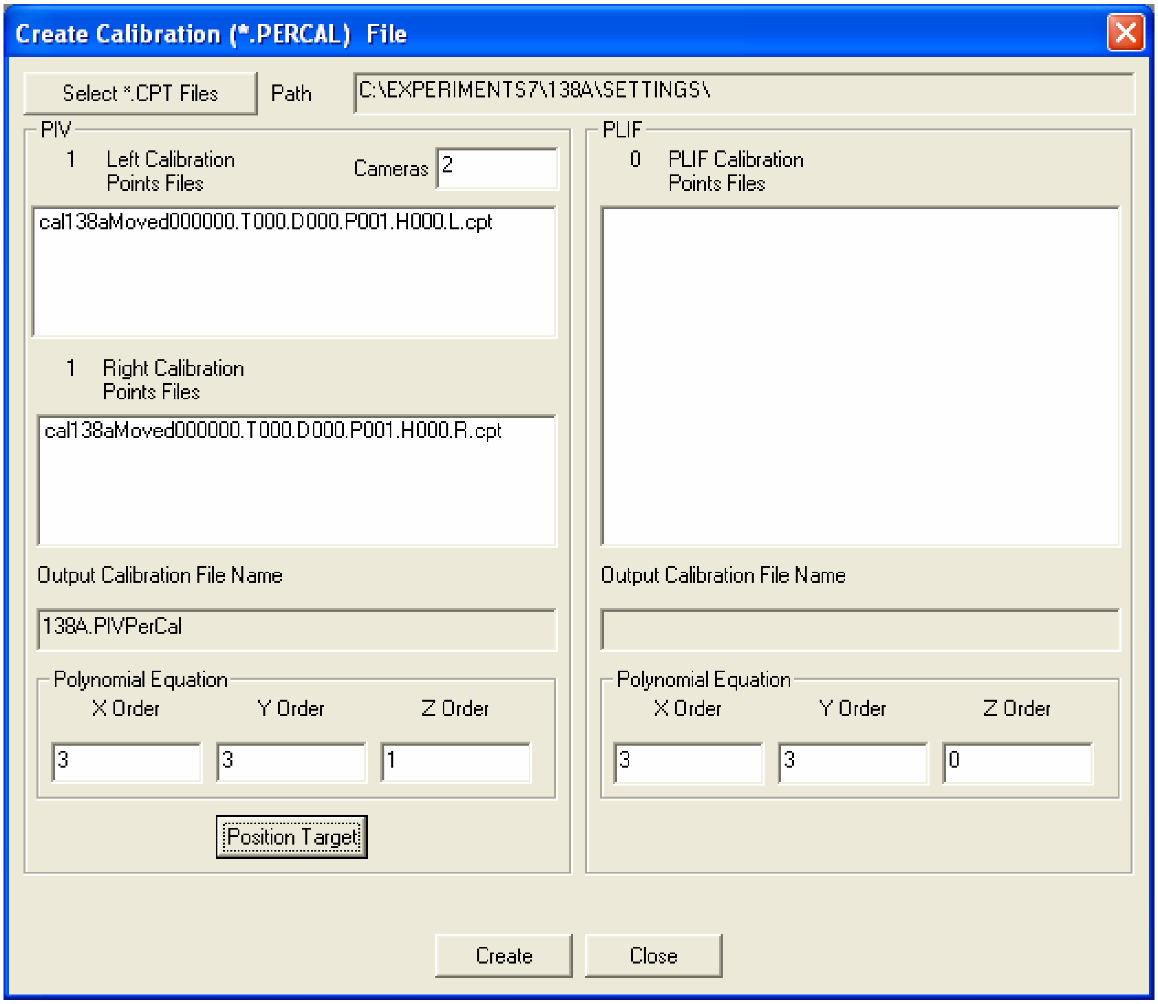


17. From the Calibration Optimization Settings dialog, select the dewarp_*.PIVPerCal and WarpKey.txt files and click **Optimize**. The dwarp_*.PIVPerCal is created with the *.PIVPerCal file. The dewarp_*.PIVPerCal is the calibration of the images after dewarping, it is the same calibration you would get if you dewarped the calibration images and rescanned them.

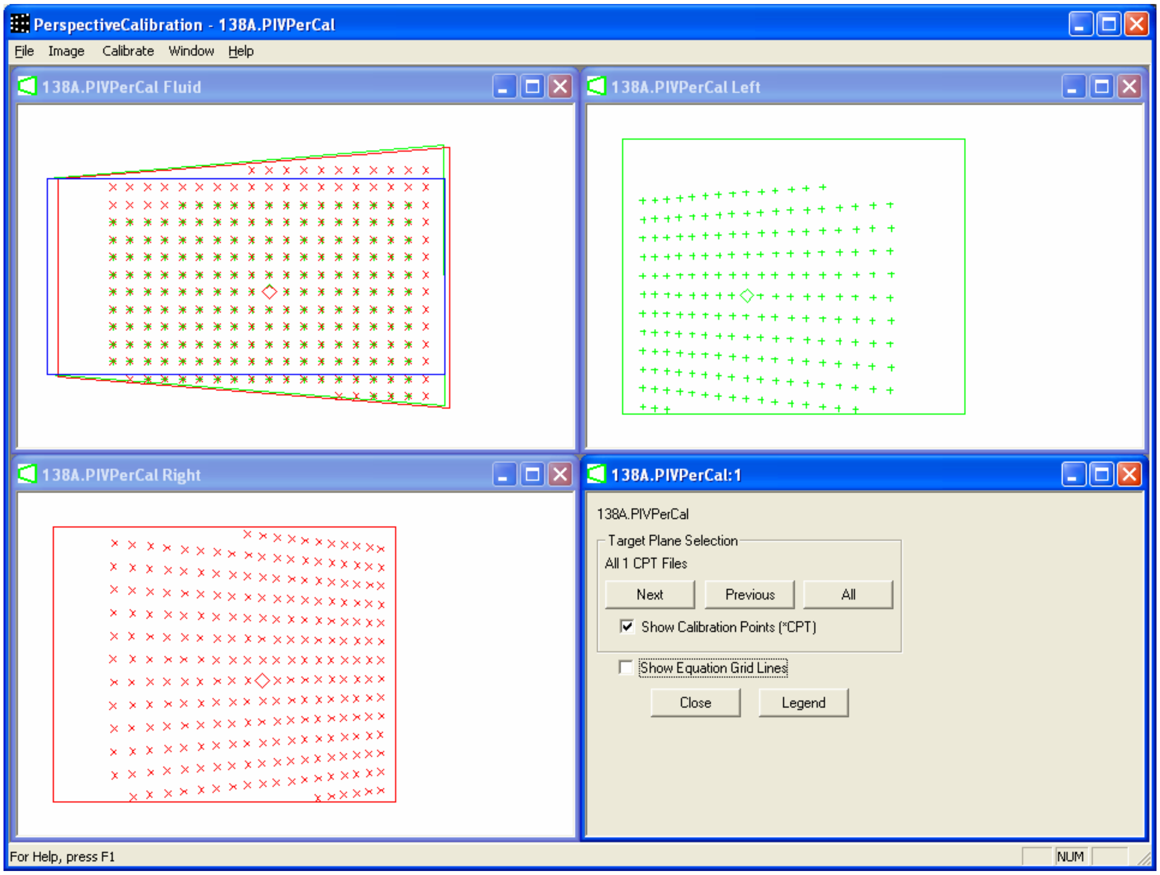


18. From the Calibration Optimization dialog box, select the average dewarp test vector field and click **Calculate Best Fit Plane**. The calibration target misalignment is computed and the corrections are filled in. The corrections are cumulative. If you press Calculate Best Fit Plane twice, you will get twice the correction. If you are using a multi-pass optimization on the second pass, start with the values saved from the first optimization pass. The second pass corrections are added to these starting values giving the full light sheet position.

19. Click **OK.** As shown in the following Create Calibration File dialog box.



20. Click **Create.** A graphical display of the calibration information appears.



The original *.PIVPerCal file is overwritten with the re-aligned target calibration.

Note: *If you prefer to verify the accuracy of the calibration after correction, repeat steps 13 to 18 by opening the raw images again and performing the dewarping, dewarp test processing, and Perspective Calibration analysis, as described earlier.*

On the verification of the target location when the Create Calibration dialog is opened the original calibration points file, PIVPerCal and WarpKey.txt files are pre-selected from information in the Settings\Optimization.PCO file.

Calibration for Measurements Through a Window

In some experiments the flow is enclosed and the measurement must be made through a window. If the access to the flow area is difficult, the system may be calibrated on a bench top and then moved into position to make measurements through the window. This procedure only works for airflows.

The optimization procedure is the same as for standard light sheet position correction in the previous section. A few tips for getting good results follow.

The bench top calibration could be performed with a similar window of the same material, thickness, and position as the actual experiment. Using a similar window will minimize the light sheet position errors that must be corrected. The window should be large enough for both cameras to look through. Uncorrectable calibration errors will result if two windows are used and they are not in the same plane.

The calibration can also be performed with just air between the cameras and the target. When the camera system is moved to the light sheet, there will be an apparent Z-axis translation due to the added glass between the cameras and the light sheet.

If the correlation processing does not give good results on the dewarped images, it may be because the disparity is too great. Larger disparities can be processed by using the **PIV Tab | Process Setup...| Processor Settings...| Plugin Settings...| xSpotOffset** plugin parameter. This plugin parameter offsets the spots by input number of pixels. Entering the approximate disparity will may give better results. The xSpotOffset may be positive or negative.

Creating a Calibration from Optical Configuration Information

The Optical Configuration Calibration is provided to help you in designing an experiment. With it you can easily try several optical configurations and assess what the approximate calibration factors would be and decide on a suitable configuration for your experiment. However, to make accurate measurements, you would need to do an actual calibration using target images.

To create a calibration from an optical configuration:

1. On the *INSIGHT 3G* main menu bar, select **Tools | Perspective Calibration**. The Perspective Calibration program opens.
2. Select **Calibrate | Optical Configuration Calibration**. The Optical Configuration Calibration dialog opens.
3. Specify the following options in the Optical Configuration Calibration dialog box:

Option	Description
Number of Cameras	Enter the number of cameras in your system.
Lens to Light sheet Distance	Enter the distance from the lens principle plane to the light sheet along the camera's optical axis. The principle plane is the plane where the lens appears to function. Knowing the correct location of the principle plane is the largest uncertainty in this procedure. With simple thin lenses the principle plane can be assumed to be at the center of the lens. But with multi-element, thick lens used at short working distances, the principle plane can be located outside of the physical lens. The principle plane moves with focus distance and focal length setting on zoom lenses. If you do not know the location, assume that it is at the center of the lens.
Lens Focal Length	Enter the focal length of the lens.
Camera Optical Axis Angle Degrees	Enter the camera body angle read from the dial on the camera mount.
Camera/Lens Tilt Angle	The angle between the camera body and the lens. Four camera configurations may be selected: Scheimpflüg, Angular Offset, Lens Translation, or Custom. With the first three types the camera/lens tilt angle is computed for you. With custom you may enter the tilt angle directly. See the *Stereoscopic PIV Camera Installation Manual,* "Stereoscopic Camera Configurations," for a detailed explanation of the camera configurations.

Option	Description
Stereoscopic Type	Enter one of the following: **Scheimpflüg** Computes the Scheimpflüg angle, the tilt angle where light sheet is best focus across the image field of view, and enters this angle in the tilt angle input. **Angular Offset** No tilt between the camera body and the lens. Angular offset camera is when you take two standard cameras with lens attached to the camera and pointed the two cameras at the same object. **Lens Translation** A lens translation stereoscopic camera has the laser light sheet plane, the camera lens plane and the image plane parallel. The camera optical axis is the angle between the center of the CCD and the lens center. The lens angle is the same as the camera angle. **Custom** Allows you to enter in the camera tilt angle.
CCD	Enter in the number of pixels in images and the pixel size for your camera. This information is used in computing the Field of View of the system.

4. Click **Create Calibration**. A file selection dialog box appears.
5. Select a calibration filename. The default filename is Virtual.PIVPERCAL or Virtual.PLIFPERCAL. This filename indicates that it does not come from measured calibration data. If you want to create a calibration file that *INSIGHT 3G* can use, set the calibration filename to match your experiment name. The calibration file is X order 2, Y order 2, Z order 1. When the calibration file is created, the Calibration View appears with the new calibration file.

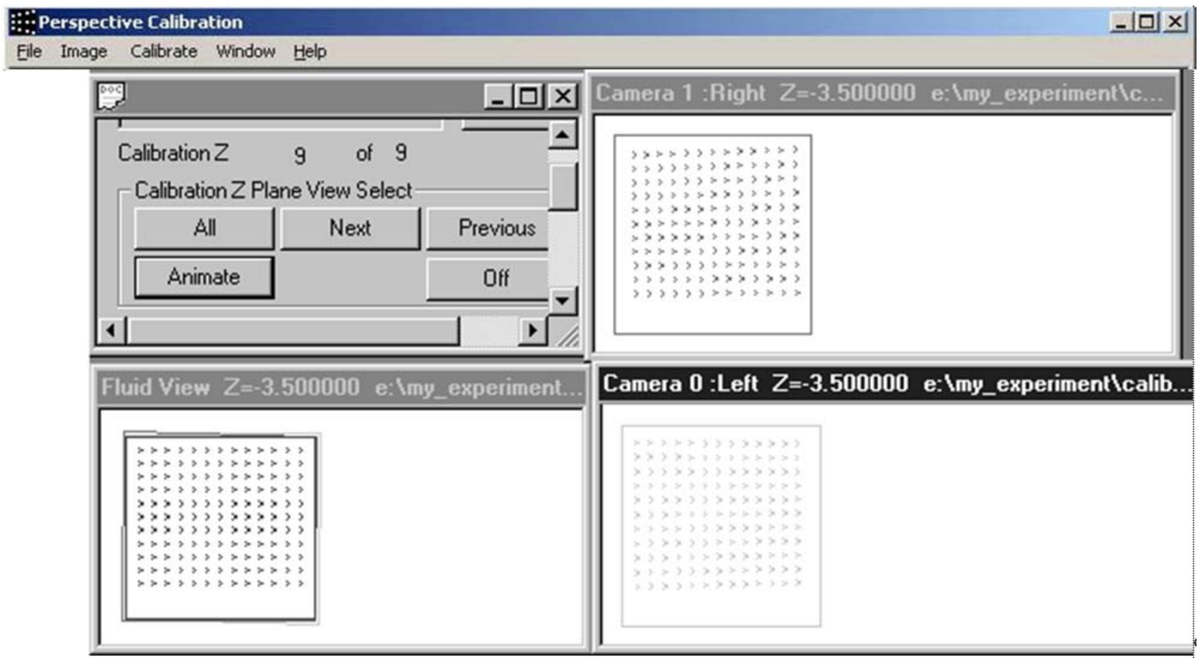
Viewing a Calibration File

As shown in the following figure, the graphical representation of the calibration has a dialog box and three windows. The dialog box allows you to control what you are viewing. The other three windows show the field of view from the left camera, right camera, and fluid perspectives. To view a calibration file:

1. Click **Perspective Calibration** from the *INSIGHT 3G* main menu bar. The Perspective Calibration program opens.
2. Click **Calibrate | Open Calibration File**. The file selection dialog opens.

3. Select the calibration file, with a *.PIVPERCAL or *PLIFPERCAL file extension. When the file is selected, the calibration file and the calibration points files *.CPT files are opened and shown graphically. For the calibration points to be shown, the CPT files must be in the directory named in the calibration file. If you do not see X's showing the calibration marker locations, check to make sure the CPT files are there.

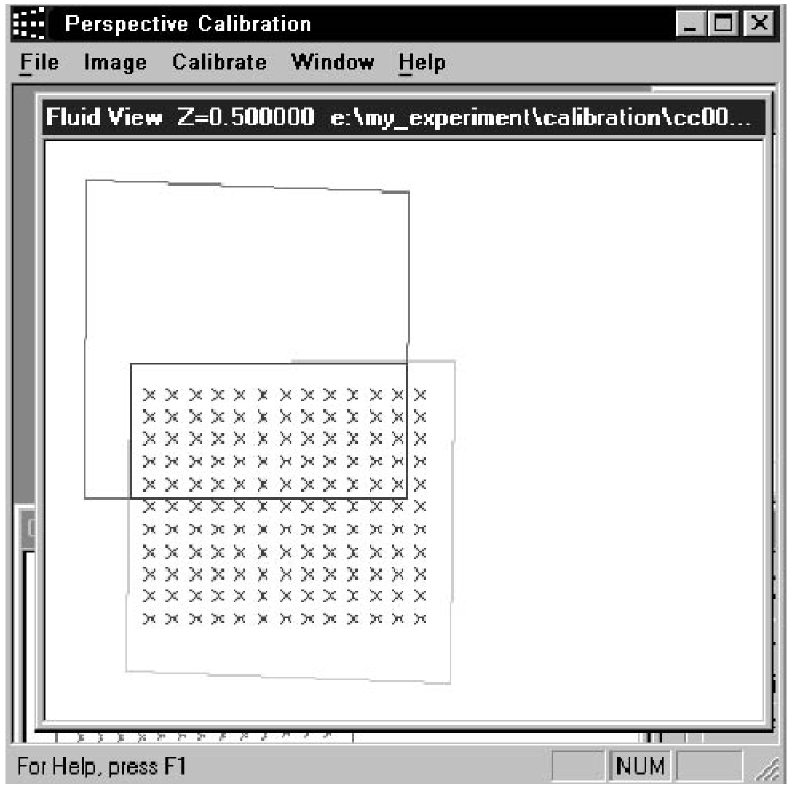
   The following shows an example of the calibration file display.



You need to look for the following in the calibration view:

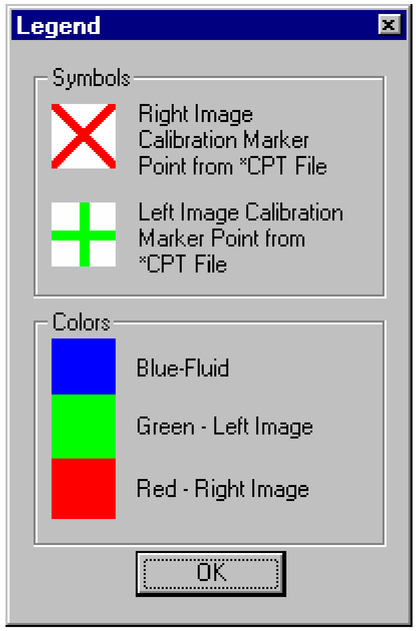
1. Are the left and right images showing the correct distortion in the fluid view?
2. Are the camera fields of view trapezoids?
3. Are any corners out of place or the field of view a strange shape?
4. Do the fields of view overlap well?
5. In looking at the left or right image with a multi-plane calibration, do the calibration markers move a little bit as you cycle through the image planes using the Next, Previous and All buttons?

The following is an example showing that calibration was not done properly.



The default display shows the calibration marker points as Xs from the left camera, right camera and fluid perspectives. The camera views show the pixel location of the measured marker images. The fluid locations show the marker locations as defined in the calibration grid display dialog. The camera field of view is shown as a rectangle in the camera views and the camera views are shown with the perspective distortion when mapped into the fluid view. In the fluid view, the right camera field-of-view is shown in red, the left camera field of view in green, and the field of view overlap area is shown in blue.

4. Click **Legend** on the parameter pane of the calibration file display, to get visual descriptions of the calibration display symbols.


Legend
Symbols
Right Image Calibration Marker Point from *CPT File
Left Image Calibration Marker Point from *CPT File
Colors
Blue-Fluid
Green - Left Image
Red - Right Image
OK

CHAPTER 9

Defining a Region of Interest

INSIGHT 3G allows you to define and select any shape in the analysis region and study flow dynamics in two distinctly separate flow areas. This feature also helps in saving time and system resources by eliminating areas in your flows that are not of interest to you and need not be processed and analyzed. *INSIGHT 3G* also allows you to save these defined regions of interest so they can be applied to other images either manually or through a macro. All the options to define and save a region of interest are provided in the ROI tab in the control panel.

The following sections describe how to:

- Define a region of interest
- Display a defined region of interest
- Save a defined region of interest
- Apply a previously-defined region of interest setting
- Delete a previously-defined region of interest setting.

Defining Region of Interest (ROI)

To define a region of interest:

1. Select an image from the Exp. Tree, for which you want to define an ROI. Drag and drop it onto the display panel.
2. Select the 

tab on the control panel. The ROI options become available.
3. Check **Enable ROI** box. The following ROI shape options become available:
    - Rectangle
    - Line
    - Polygon
    - Ellipse

After you define the desired shaped, you can then process and analyze it. This selection can also be saved and applied later, either manually or as part of a macro. Refer to "Saving Defined Regions of Interest (ROI)."

Note: *You can add additional ROI to your current ROI by defining it while holding the **Shift** key.*

Displaying Defined Region of Interest (ROI)

To display only the defined region of interest and hide the portions not selected:

1. Select an image from the Exp. Tree, for which you want to define an ROI. Drag and drop it onto the display panel.
2. Select the  tab on the control panel. The ROI options become available.
3. Define the region of interest as described in "Defining Region of Interest (ROI)."
4. Check **Hide non-ROI**. The areas not defined are removed and only the defined shapes of the image are displayed.

Saving Defined Regions of Interest (ROI)

To save a defined region of interest for future use:

1. Select the  tab on the control panel. The ROI options become available.
2. Select a region of interest in any of the shapes described earlier. Click **Save**. A save box opens.

Enter a name for the defined ROI and click **OK**. The saved ROI name appears in the Saved ROIs box and saved in the Settings folder of your experiment. These saved ROI settings can later be applied manually or in a macro to other images. Refer to Chapter 15, "Programming Macros" for further information on macros.

Applying a Defined Region of Interest (ROI) Setting

To apply a previously-defined and saved region of interest setting:

1. Select an image from the Exp. Tree, for which you want to apply the previously-defined ROI. Drag and drop it onto the display panel.
2. Select the 

tab on the control panel. The ROI options become available.
3. Select the saved region of interest file from the Saved ROIs box and click **Apply.**

   The defined region is applied and is displayed on the open image in the display panel.

Deleting a Defined Region of Interest (ROI) Setting

To delete a previously-defined and saved region of interest setting:

1. Select the 

tab on the control panel. The ROI options become available.
2. Select the saved region of interest file from the Saved ROIs box and click **Delete.**

The defined region is deleted and removed from the Settings folder of your experiment.

CHAPTER 10

Calibrating, Processing and Viewing PIV Images

Particle Image Velocimetry (PIV) and Ensemble Particle Image Velocimetry (EPIV), measures the velocity of a fluid at many locations in a plane. The fluid is seeded with small tracer particles that move with the flow. A thin laser light sheet illuminates the particles in a plane. A camera focused on the light sheet records the images of the particles in the light sheet. By pulsing the light sheet twice, recording two images of the particle field, the flow velocity can be estimated by measuring the distance the particles have moved in the time between the light sheet pulses.

This chapter discusses how to:

- Calibrate a PIV system
- Process a PIV image
- View and analyze PIV images using Tecplot and MATLAB packages.

PIV Calibration Process

INSIGHT 3G™ provides enhanced calibration techniques which allow you to select automatic calibration, two-dimensional calibration and multi-plane calibration using the Dual-Plane Dual-Sided (DPDS) target. The following section describes how to perform a 2-D calibration, For information on how to perform, 3-D Calibration, see Chapter, 8, "Perspective Calibration."

2-D Calibration

Two-dimensional calibration allows you to enter a calibration factor to compute the flow velocity using meters per second.

INSIGHT 3G uses the following formula to provide the conversion:

Velocity = (pixel displacement * (mm/pixel)) / dt (in msecs)

You can enter or compute calibration factors using any one of the following three methods:

- Manually enter Field of View values
- Manually enter Micrometers per Pixel (µm/pixel) values
- Compute Millimeters per Pixel (mm/pixel) through INSIGHT 3G.

To perform 2-D Calibration:

1. From the main menu of INSIGHT 3G, select **Tools | Spatial Calibration**. The PIV 2-D Calibration dialog opens.
2. Select a unit of measurement in the Units box:

Option	Description
Pixels	Select to specify if velocity vector magnitude should be computed in pixels. The vector file (.VEC), contains *x* and *y* as pixel locations in the image and *u* and *v* as pixel displacements.
Velocity (m/s)r	Select to specify if velocity vector magnitude should be computed in meters per second (m/sec). When you select velocity measurement, *x* and y are locations in millimeters and *u* and *v* are velocity components in meters per second. A calibration factor is needed to convert the pixels measurements to meters per second.

3. If you selected Pixels, click **Close.** INSIGHT 3G calculates velocity vector magnitude in pixels.

   If you selected Velocity, perform the rest of the following steps.
4. Enter a value for the Pixel Aspect Ratio which is the *x*-pixel spacing divided by the *y*-pixel spacing.
5. Select one of the following options under Calibration Methods and follow the appropriate set of substeps:
   - Field of View
   - Object Measure
   - Manual

   Field of View
   Field of View is the entire image. INSIGHT 3G uses the mm/pixel value in the conversion formula. To use this:

   A. Place a scale/ruler in the flow.

   B. Capture a calibration image. See "Capturing Calibration Images" for details.

C. Using the scale, enter either the Horizontal or Vertical Field of View value.

Horizontal (mm) = X mm/pixel $\times$ No. of x pixels in the image
Vertical (mm) = Y mm/pixel $\times$ No. of y pixels in the image.

These values are all related; editing one causes the other two to be recomputed. For example:

You have a 640 × 480 pixel image. Using a ruler you measure the horizontal field of view in the flow as 50 mm; you enter 50 in the Horizontal (mm) box.

mm/pixel = 50 mm/640 pixel = 0.078125mm/pixel=78.125µm/pixel

Vertical Camera Field of View = 480 pixels * 0.078125 mm/pixel = 37.5 mm

Manual (Calibration Numbers):
If you know either the X or the Y µm/pixel value, directly enter that value in the appropriate box. Based on this value, *INSIGHT 3G* calculates other values.

Object Measure:
If you would like *INSIGHT 3G* to calculate the millimeters per pixel value:

A. Place an object of known size, such as a flow model or a scale/ruler in the flow.

B. Type in the object size in millimeters in the Object Size in the mm box.

C. Click **Calculate**.

D. Place the cursor on the start of the object. Click the left mouse button and drag to the end of the object. Release the mouse button.

6. Save the calibration file, if you wish to use it again. (See "Capturing Calibration Images").

7. Click **Close**.

Using PIV Processor

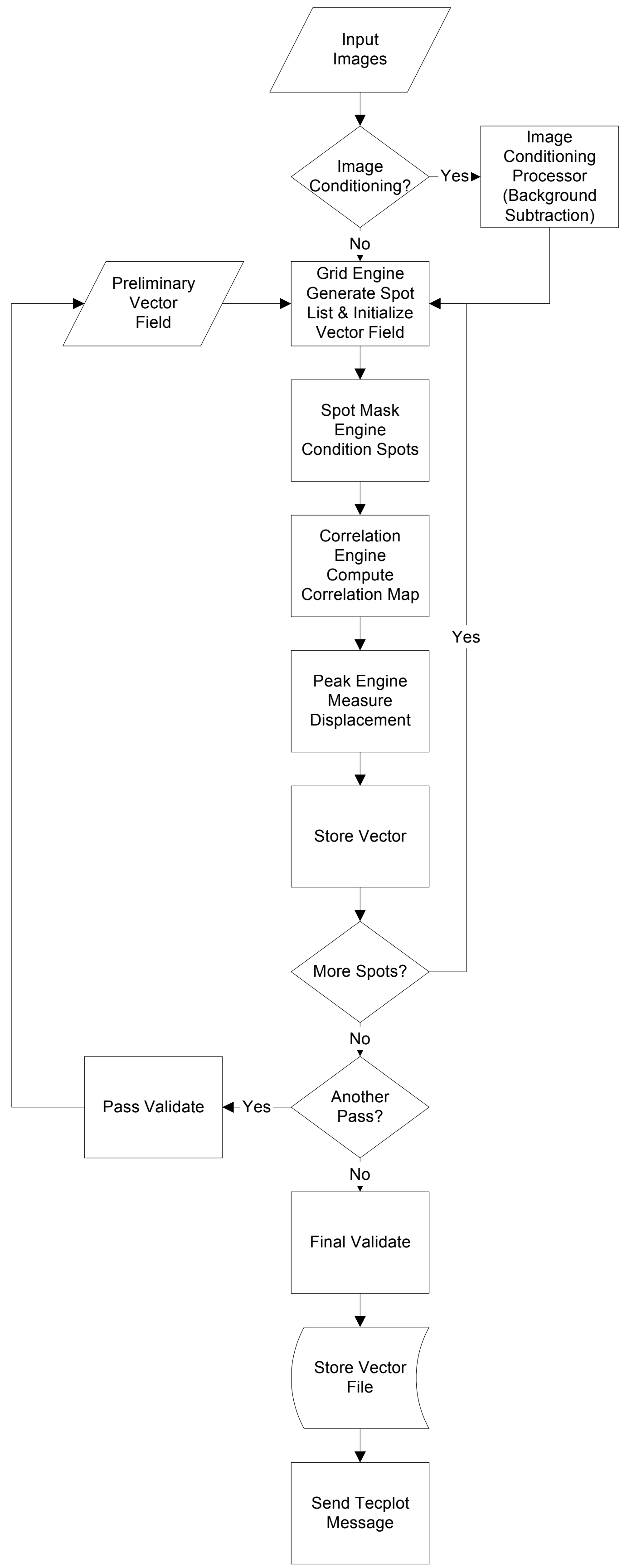
INSIGHT 3G™ allows you to process PIV images using cross-correlation techniques including FFT correlation, Hart correlation and ensemble PIV technique.

Processing steps can be broken down into these steps:

- Performing Image Conditioning,
- Generating grids
- Masking spots
- Performing correlation
- Locating peaks and
- Performing validation

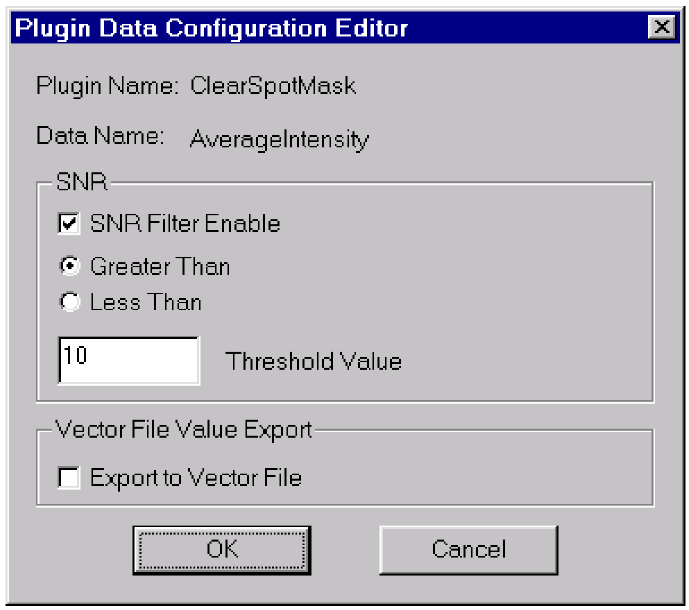
The flow chart shows the processing steps and how a vector field is generated from the input images and the process data. There are several algorithms that could be used for the processing steps: grid generation, spotmasking, correlation and peak location. The best choices depend on the flow, velocity gradients, seeding, and allowable processing time. INSIGHT 3G is designed to enable you to match the algorithms to your flow. INSIGHT 3G comes with several algorithms to choose from for each of the processing steps. These algorithms produce good results for the majority of experiments. However, to facilitate measurements in flows with special challenges and research, user -created algorithms can be plugged into one of these processing points. See "Developing and Using Plugin Dynamic Link Libraries (DLL)."

Each plugin can have any number of parameters that can be used to configure the algorithm. These parameter values are used as input during processing. Plugin parameters may be boolean, integer, float or string variables. The settings for a plugin can be saved using the PIV Process | Processor Setup dialog box. See "Processing PIV Images."



Input Images
Image Conditioning?
Yes
Image Conditioning Processor (Background Subtraction)
No
Preliminary Vector Field
Grid Engine Generate Spot List & Initialize Vector Field
Spot Mask Engine Condition Spots
Correlation Engine Compute Correlation Map
Yes
Peak Engine Measure Displacement
Store Vector
More Spots?
No
Another Pass?
Yes
Pass Validate
No
Final Validate
Store Vector File
Send Tecplot Message

Each plugin can also have data values that are measurements made during processing for each grid point. Data can be used as signal-to-noise ratio (SNR) measurement to filter out bad vectors based on the spot and correlation map information. When the SNR Filter Enable is checked in the PlugIn Data Configuration Editor, the measured must pass the threshold test to be included in the vector field. If the value does not pass the threshold test the vector is marked with choice code SNR_FAIL. The SNR filter can be set for either Greater Than or Less Than threshold testing. The best ways to set the threshold is to watch the Process Monitor with Point processing or view the results in Tecplot to see what the values are. Plugin Data can be exported when the Export to Vector File box is checked.



The following gives you an overview of each of the processing algorithms:

The **GridEngine** breaks the input images up into smaller spots for processing and initializes the vector field. For each grid point, the process manager copies the pixels from the input images into the spots and passes the spots to the SpotMaskEngine.

With frame straddle image capture, Spot A is from Frame A and Spot B is from Frame B. The Process Grid is a list of Grid Points. Each Grid Point defines the pixels that make up Spot A and Spot B. The spots must be rectangular, but other shapes may be effectively achieved using a SpotMask, such as the Gaussian Spot Mask. The aspect ratio is set with the spot width and height values. Spot B may be a different size or aspect ratio than Spot A. The GridEngine may offset the spots. In addition to the spot grid there is a vector grid called a vector field. In grid generation, the vector field is initialized with vectors with their location set and the vector code set to not set.

The GridEngine can process the vector field in single as well as in multiple passes. In a typical multiple-pass processing, on the first pass, the spots are set to follow the ¼ displacement rule of thumb with no spot offsets. After the first processing pass, the vector field from the previous pass can be used to optimize the spot grid for the next processing pass. By offsetting the spots by the particle image displacement distance, lost pairs due to in-plane motion are eliminated increasing the correlation signal-to-noise ratio. Offsetting the spots by the particle image displacement distance also allows for smaller spots since the ¼ displacement rule no longer applies. Using recursive grid algorithms allow for more accurate and higher density flow measurements.

When a single-pass GridEngine is used, only the Start Spot Size values are used, and the Final Spot Size is disabled. With a multi-pass grid the first processing pass uses the Start Spot Size values and the last processing pass uses the Final Spot Size values. The GridEngine determines the number of processing passes. Use the Process Monitor to view the spots during processing.

Valid spot sizes depend on the CorrelationEngine. The FFTCorrelator requires the input spots to be square, and the dimensions to be a power of two. This can be done either by entering in all values that match these criteria, or by using the ZeroPadSpotMask. The ZeroPadSpotMask adds zero intensity pixels around the image pixels to increase the spot size up to a square power of two. The HartCorrelator can be used with non-square spots. Spot B does not have to be the same size as Spot A.

Having Spot B larger than Spot A may produce better results than equal sized spots. With equal sized spots and the maximum displacement set to ½ the spot size or larger, all of the spot pixels are used only in the zero displacement case. When Spot B is shifted by 1 pixel in the X direction, the first column of pixels from Spot A and the last column of pixels from Spot B are not used because the spot images do not overlap. The maximum correlation is reduced because fewer pixels are used. By using a larger Spot B then all of the Spot A pixels overlap with a Spot B pixel and are included in the correlation.

The GridEngine can use user-developed plugins. You can develop you own GridEngine and run it in *INSIGHT* 3G. For more information on how to write a plugin, see "Developing and Using Plugin Dynamic Link Libraries (DLL)."

Each of the GridEngine plugins provided by INSIGHT 3G may have any number of PluginData and PluginParameter settings.

The **SpotMaskEngine** conditions the spots for processing and passes the spots to the CorrelationEngine. It is used to modify or condition the image spots before processing. This can increase the signal-to-noise ratio of the correlation map. The SpotMaskEngine is a user plugin. You can write your own SpotMaskEngine and use it within INSIGHT 3G™. For information on creating a plugin, see "Developing and Using Plugin Dynamic Link Libraries (DLL)."

The **CorrelationEngine** computes the correlation function and returns it as a correlation map. It computes the correlation function of the masked Spot A and Spot B returning the result as a correlation map. The correlation function is an algorithm that sums the particle image matches at all pixel displacements within the displacement range. The highest correlation map pixel is assumed to be the particle image displacement peak caused by the contributions of many particle pairs. Other peaks are assumed to be noise peaks caused by the random pairings of images of different particles.

Correlation algorithms may generate peaks with different sizes, shapes, or slopes. The measurement accuracy may be improved by matching the peak algorithm to the correlation algorithm. The CorrelationEngines may set a default PeakEngine that is automatically selected each time the CorrelationEngine is selected.

Each of the CorrelationEngine plugins provided by INSIGHT 3G may have any number of PluginData, and PluginParameter setting.

The settings for a plugin are set to the default values each time the plugin is selected. When a vector field is processed, the current plugin settings are recorded in the Process Log file in the Vector folder. When an Experiment is selected, the Process Log file is read from disk, the plugins listed in the Process Log file are loaded and their settings are input from the process.ini file. If you have configured plugin settings, and then select a different plugin, or the plugin is set to the default settings you can change the settings in the Plugin Settings dialog. Refer to Chapter 17 "Developing and Using Plugin Dynamic Link Libraries (PIV Only)" and "History Log Files" for more information.

The CorrelationEngine is one of the INSIGHT 3G™ user plugin points. You can develop your own CorrelationEngine and run it in INSIGHT 3G. For more information on how to write a plugin, see "Developing and Using Plugin Dynamic Link Libraries (DLL)."

The **PeakEngine** finds the peak location in the correlation map. The process manager then stores the velocity, and export Plugin data into the vector. This loop continues until all of the grid points have been processed.

If a multi-pass GridEngine is used and there are more processing passes to go, the vector field is validated using the **pass validate** macro. The pass validate macro is set to filter out bad vectors and fill in holes with interpolated vectors. This preliminary vector field is then fed into the GridEngine and used to optimize the next processing pass spots based on the displacements measured in the previous pass. The new optimized list of grid points is then processed.

If the processing is the final pass, the vector field is validated using **final validate macro**. The macro validate is used to remove bad vectors, interpolate vector holes, and smooth the vector field before saving to a vector file. The final validate macro is typically less aggressive than the pass validation in interpolating and filling holes. The vector field is then saved to disk and a message sent to **Tecplot** for advanced flow field analysis and display.

Setting up PIV Processing Parameters

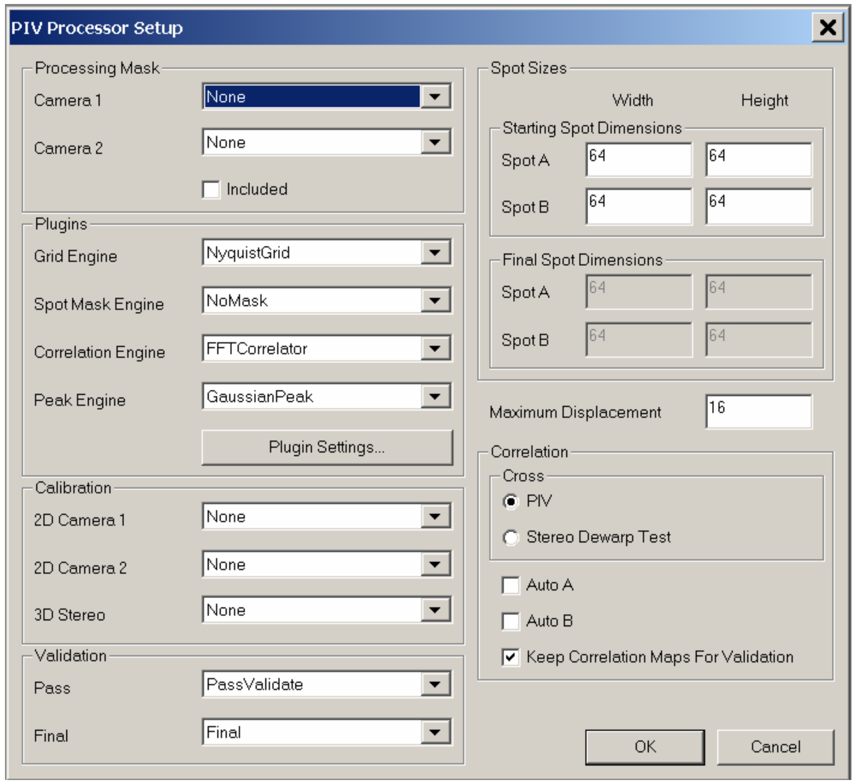
Before processing PIV images, you need to set up the processing parameters.

To set up processing parameters:

1. Select an image from the Exp.Tree, for which you want to setup the processing parameters. Drag and drop it onto the display panel. See “Viewing Data Files” for detailed information on how to display and enhance images for processing.
2. Select the PIV tab on the control panel. Click **Process Setup**. The PIV/PTV Processor Setup box opens.
3. Select one of the following options from the processor drop-down list:

Option	Description
None	Do not perform any PIV processing when **Start Process** is selected.
PIVProcessor	Perform traditional, single-image set, PIV processing, when **Start Process** is selected.
Ensemble PIVProcessor	Perform multi-image set, ensemble correlation PIV processing.

4. Click **Processor Settings**. The PIV Processor Setup dialog opens.



5. Enter Processing Masks for Camera 1 and Camera 2 that were defined earlier. Processing masks are defined using the ROI tab. See "Defining a Region of Interest" for details. In the default mode, the defined areas are masked and excluded from being processed. To do the reverse, click **Included** to have the defined area included in the processing.

6. Select the plugin algorithm for the Grid Engine. The Grid Engine plugins are:

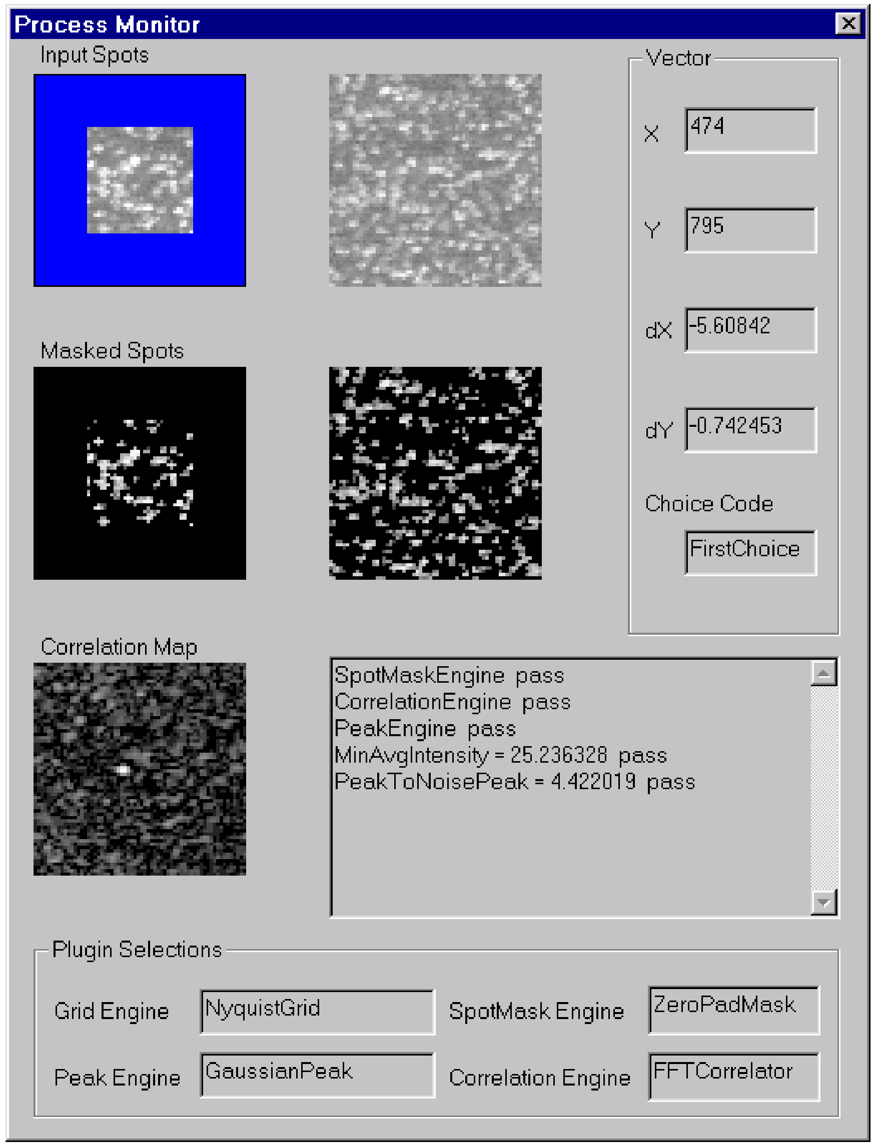
Plugin	Description
Deformation Grid	Use this plugin for flows with high shears and for highest accuracy. It performs sub-pixel deformation. It is also the slowest.
Nyquist Grid	Use this plugin for the fastest results; it is the classic PIV grid. It sets vectors with the x spacing equal to half Spot A width and the y spacing equal to half Spot A height. No spot offsets are used and the processing uses only a single pass. This gives a vector grid with 50% spot overlap fitting the Nyquist sampling criteria.

Plugin	Description
Rectangular Grid	Use this plugin for more control of the grid settings. It provides more user grid parameter control than the Nyquist or Recursive Nyquist Grids. With the default settings, the grid is the same as Recursive Nyquist Grid. If the Recursive setting is changed to false then it is the same Nyquist Grid. This grid has settings to change the spot spacing to values other than 50% overlap and to change the spot size reduction factor between processing passes.
Recursive Nyquist Grid	Use this plugin for increased accuracy or higher spatial resolution, compared to the Nyquist Grid. It processes the images in two or more passes. The first processing pass computes the vector field at the starting spot sizes with Nyquist, 50% overlap grid spacing. The vector field is then edited using the Pass Validation macro The results of the first processing pass are used to optimize the spot offsets for the second processing pass. The offset between the spots is equal to the integer pixel displacement measured in the first processing pass so that subsequent processing passes would have a peak location within a half pixel of the correlation center. If the final spot sizes are smaller than the starting spot sizes, the spot size are reduced by a factor of two and the number of vector rows and columns increased by a factor of two, giving four times the number of vectors with each pass. If the starting and final spot sizes are the same, the second pass uses the optimized window offsets to recompute the vector field with the same number of vectors. After the final processing pass, the Final Validation Macro is applied, if selected.

7. Select the plugin algorithm for the SpotMaskEngine plugin. The SpotMaskEngine plugins are:

Plugin	Description
DeformationMask	The Deformation Grid and Deformation Spot Mask were designed to be used together. The Deformation Grid and Mask improve correlation in areas of high velocity gradients where the particle image displacement varies across the spot. When this displacement difference is more than a particle image diameter the correlation map will have a splintered or elongated peak. In many cases a noise peak will be selected and an erroneous vector is created. The Deformation Grid and Spot Mask deform the spots according to the previous pass vector field so that after the deformation all the particle displacements will be at the same location. The splintered and elongated peaks are packed back together to form a Gaussian peak of the particle size. The Deformation Grid places the vectors at the same location for each processing pass. The grid spacing in ¼ the smallest spot size used, typically the final spot size. The limits of the vector field are determined by the largest spot passed into the spot mask. The first processing pass is standard processing with the spot offset set by the xOffsetPass1 and yOffsetPass1Plugin Parameters, default value 0. The second processing pass uses the first pass vector field to offset the spots by an integer pixel value. If the CenterOffset Plugin parameter is true then both spot A and spot B are offset. If CenterOffset is false only spot B is offset. This is the same processing as Recursive Nyquist Grid. Starting with the 3rd processing pass the four corner neighboring vectors are used to deform the spot. The Deformation Spot Mask interpolates the input spot using the velocity gradients from the corner vectors to minimize the peak splintering. When the spot us to be deformed the input spot is twice the user selected spot size so that no pixels required for deforming the spot are missing. The Primary Iterations Plugin Parameter sets the number of processing passes at the starting spot size. The default is 3 iterations no offset, integer pixel offset, and subpixel offset with deformation. The Second Iterations Plugin Parameter the number of processing passes at the final spot size. The default is 2 Secondary Iterations. All secondary iterations have subpixel offset with deformation.

Plugin	Description
Gaussian Mask	Multiplies each pixel value in spot A by a Gaussian weighing function so that the spot is bright in the center and dark around the edges. This weighting gives more value to the center pixels and less to the edge pixels. ***Note:*** *To show an example of how to create a user plugin, the source code for Gaussian Mask is included PluginSDK\ExampleCode\GaussianMask.*
No Mask	Makes no changes to the input spots. No Mask is used to process the image with no spot filtering. It has one plugin data: MinAvgIntensity.
ZeroPadMask	Zero padding is a technique used with FFT processing to remove large displacement aliasing. When the displacement is larger than ½ of the spot size the point is added at a location equal to ½ spot size – (displacement – ½ spot size). The ZeroPadMask computes the average pixel intensity of each spot and subtracts it from each pixel and pads the spot with 0 intensity pixels. The padded spots are a square power of 2 (8 x 8, 16 x 16, 32 x 32, 64 x 64 or 128 x 128). This allows the input spots to be non-powers of 2, non-square and Spot B may be larger than Spot A. For example if Spot A is 15 x 10 pixels and Spot 2 is 32 x 32 pixels, Spot A will be padded to 32 x 32 pixels and Spot 2 will not be padded. The advantage of zero padding is increased signal-to-noise ratio. The disadvantage is increased processing times.



ZeroPadMask with 32 × 32 Spot A and 64 × 64 Spot B. The blue around input Spot A shows that Spot A is smaller than Spot B and these pixels are not from the image. The Masked Spots show that Spot A size has been increased (no blue background) to the same size as Spot B. The mean subtraction is seen in the gray pixels in Spot A becoming black in Spot B.

8. Select the plugin algorithm for the Correlation Engine. The CorrelationEngines may use the Default PeakEngine PluginParameter to define the PeakEngine to be set when the CorrelationEngine is selected. When the CorrelationEngine is selected, the Default PeakEngine is also loaded. If you do not want to use the Default PeakEngine, first select the CorrelationEngine, then change the PeakEngine to your selection. The plugins for the Correlation Engine are:

Plugin Type	Description
HartCorrelator	Computes the correlation using the HartCorrelation Algorithm. This is a direct correlation method that processes only the most significant pixels to improve processing speed.
Direct Correlator	Computes the correlation by first computing and subtracting the spot mean intensity and then summing the product of pixel intensities at each pixel offset. The correlation map is then adjusted by an autocorrelation factor to increase the displacement measurement accuracy. Direct correlation is slower than FFT and HartCorrelation. The Direct Correlator source code is given in `PluginSDK\ExampleCode\DirectCorrelator` as an example of a correlation engine
FFTCorrelator	Computes the correlation using Fast Fourier Transform (FFT). The spots must be square powers of two and Spot A must be the same size as Spot A. The ZeroPadMask may be used to pad other spot sizes and shapes for FFT correlation.

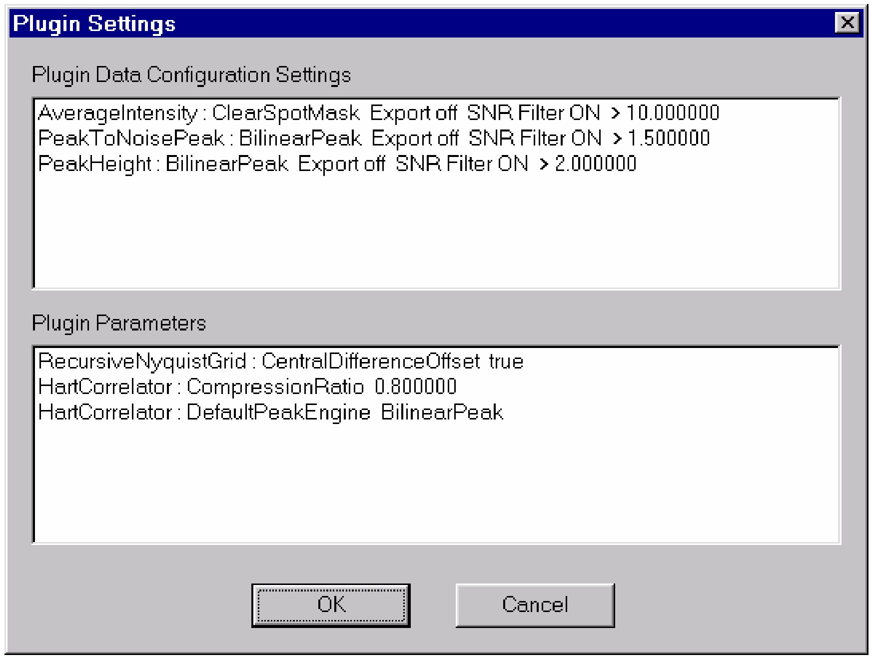
9. Select the plugin algorithm for the Peak Engine plugin. The plugins for Peak Engine include:

Plugin Type	Description
Bilinear Peak	Locates the correlation map peak with sub-pixel accuracy by fitting a set of linear functions to the highest pixel and its 4 nearest neighbors. Two 3-point fits are done one in the X direction with the peak pixel and the pixels to the left and right of the peak and one in the Y direction with the peak pixel and the pixels above and below the peak. The X pixel peak equation is: xRange = max((center-left), (center-right)); xSub = (right – left)/(2.0 * xRange); dX = x + xSub – xZero; *where:* left, center, right = pixel intensity of peak pixel and 2 neighbors xSub = sub-pixel peak location, relative to peak pixel x = x index of peak pixel xZero = x index of zero velocity pixel
Brownian TemperaturePeak	Used with micro PIV and ensemble processing and deformation grid. It estimates the Brownian motion by the correlation peak broadening of the cross correlation peak relative to an auto-correlation peak. The ensemble processing is used to increase the number of particles to a statistically relevant number. The deformation grid minimizes the peak broadened due to velocity gradient. Having a measurement of the peak broadening due to Brownian motion allows the temperature of the fluid to be estimated. For Brownian Temperature measurements, the autocorrelation A or Autocorrelation B must be checked in the Processing Setup dialog box.

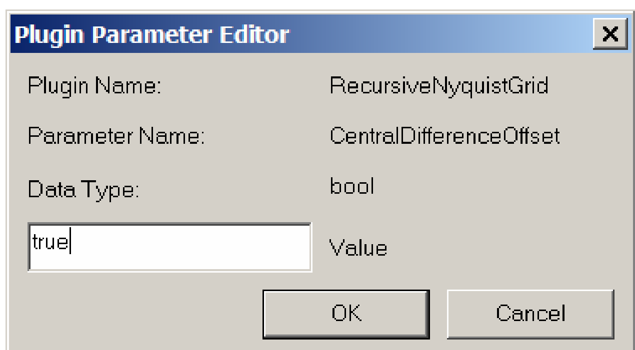
Plugin Type	Description
GaussianPeak	Locates the correlation map peak with sub-pixel accuracy by fitting a Gaussian curve to the highest pixel and its four nearest neighbors. Two 3-point fits are done—one in the X direction with the peak pixel and the pixels to the left and right of the peak and one in the Y direction with the peak pixel and the pixels above and below the peak. The X pixel peak equation is: xSub = (log(left)-log(right)) /(2.0*(log(left)-(2.0*log(center)) + log(right))); dX = x + xSub – xZero; where: left, center, right = pixel intensity value for peak pixels and neighbors xSub = the sub-pixel peak location dX = particle image displacement x = x index of peak pixel xZero = x index of zero velocity pixel Gaussian is the recommend PeakEngine for use with FFT and direct correlations. The source code is given in `PluginSDK\ExampleCode\GaussianPeak` as an example of how to create a peak engine plugin.

***Note**: It is recommended that you use the default parameter and data values and settings until you have processed a few images and have assessed your experiment needs properly. If you are using the defaults, skip steps 12 and 13.*

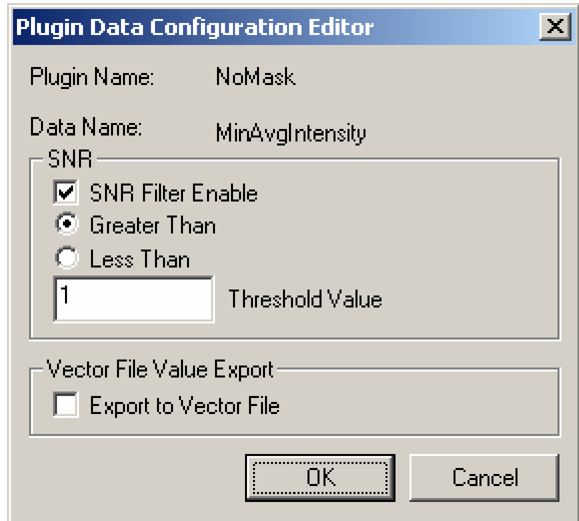
10. ***(Optional)*** Configure the plugin parameters and data for selected plugin algorithms, Click **Plugin Settings**. The Plugin Settings dialog box opens.



11. ***(Optional)*** In the Plugin Parameter box, double click each parameter for which you need to change the values. The Plugin Parameter Editor dialog box opens. Enter the appropriate value for each parameter. Refer to the appropriate tables after step 13 for details on these values.



12. ***(Optional)*** In the Plugin Data Configuration Settings box, double click each plugin data that you wish to configure. The Plugin Data Configuration Editor opens.



You can enable the SNR filter and specify if the vector file value should be exported to a vector file.

To enable SNR filter:

A. Check the **SNR Filter Enable** box.

B. Specify a value in the **Threshold Value** box.

C. Select either the **Greater Than** or **Less Than** box to specify if the filter should look at values greater or less than the threshold value specified.

To specify if the vector file should be exported:

- Check the **Export to Vector File** box.

The following lists the plugin parameters and data for each of the algorithm plugins.

Grid Engine: Rectangular Grid	
Parameters	**Value and Description**
RectangularGrid: Recursive	***True:*** **(Default)** Enables multi-pass processing. ***False:*** Sets single-pass processing.
RectangularGrid: xSpacing(spotWidth) and ySpacing(spotHeight):	Set the distance between grid points based on the spot width and height. ***Note:*** *Using the default value of 0.5, gives the same 50% spot overlap as Nyquist. Using values smaller than 0.5 gives oversampling. Values larger than 0.5 gives undersampling.*

Grid Engine: Rectangular Grid	
Parameters	**Value and Description**
RectangularGrid: SpotReduction: (Default 2.0)	Select the amount by which the spot size is reduced between processing passes. With the default 2.0 the spot size is ½ the width and ½ the height of the previous processing pass increasing the number of vectors 4 times. If the SpotReduction were increased to 4 the spotWidth and height would be ¼ the previous spot size and the number of vectors will increase by 16x
RectangularGrid: CenterOffset: (Default: True)	***True**:* Both Spot A and Spot B are displaced by ½ the offset distance. The vector is located halfway between the two spots. *False:* Spot A is centered on the vector location and only Spot B is offset.
RectangularGrid: xOffsetPass1 (Default = 0) yOffsetPass1-(Default = 0	The first pass-offset parameters allow you to enter a spot offset for the initial processing pass. In the second and later passes the spot offset is set using the previous pass vector field. First pass offset is most useful in flows with a large mean velocity and small variations from the mean.

Grid Engine: RecursiveNyquist Grid	
Parameters	**Value and Description**
RecursiveNyquistGrid: Central Difference Offset	***True:*** The spot offset algorithm moves both Spot A and Spot B by one-half the particle image displacement measured in the previous processing pass, relative to the vector (x, y) location. ***False**:* Spot A is centered on the vector (x, y) location, Spot B is offset by the particle image displacement distance.
RecursiveNyquistGrid: xOffsetPass1 (Default = 0) yOffsetPass1-(Default = 0	The first pass-offset parameters allow you to enter a spot offset for the initial processing pass. In the second and later passes the spot offset is set using the previous pass vector field. First pass offset is most useful in flows with a large mean velocity and small variations from the mean.

Grid Engine: Nyquist Grid	
Parameters	**Value and Description**
NyquistGrid: XSpotOffset 0, YSpotOffset	The first pass-offset parameters allow you to enter a spot offset for the initial processing pass. In the second and later passes the spot offset is set using the previous pass vector field. First pass offset is most useful in flows with a large mean velocity and small variations from the mean

Grid Engine: Deformation Grid	
PluginData	**Value and Description**
Deformation Grid: XGridSpacing YGridSpacing	The distance, in pixels, between vectors.
Deformation Grid: xSpotOffsetPixel ySpotOffsetPixel	The integer spot offset when copying the
Deformation Grid: Interpolate	Instructs Deformation Spot Mask to interpolate and deform the spot or leave the input spot as is.
Deformation Grid: dXCenterVector dYCenterVector dXLeftTopVector dYLeftTopVector dXLeftBottomVector dYLeftBottomVector dXRightTopVector dYRightTopVector dXRightBottomVector dYRightBottomVector	The velocity vector and the four corner vectors from the previous processing pass.
Deformation Grid: XOffSetPass 0.0 YOffSetPass 0.0	Spot offset used for first processing pass.
Deformation Grid: CenterOffset	***True:*** Use Center Spot Offset ***False:*** Use forward Offset.
Primary and Secondary Iteration	Number of processing passes at starting and final spot size.

Spot Mask: Gaussian Mask	
PluginData	**Value and Description**
Gaussian Mask: Minimum Average Spot Intensity	Use to filter out image spots that do not have any particle images. Set so that areas without particle images are below the threshold and spots with particle images are above the threshold. Use Point Processing and the Process Monitor to help you find the correct threshold value for your images.
Subtract Mean	Subtracts the spot mean value from each pixel before multiplying by the Gaussian weighting factor. Default = true.
Gaussian Mask: Gaussian Radius	Gaussian Mask has one PluginParameter—Gaussian diameter in spot sizes. The default Gaussian diameter, 1.0, reduces the intensity at edges of the horizontal and vertical axes to 13.5 % of the center pixel.

Spot Mask: No Mask	
PluginData	**Value and Description**
No Mask:Minimum Average Spot Intensity	Filters out image spots that do not have any particle images. The average spot intensity should be set so that areas without particle images are below the threshold and spots with particle images are above the threshold. Using Point Processing and the Process Monitor will help you find the correct threshold value for your images.

Spot Mask: ZeroPadMask	
PluginData	**Value and Description**
ZeroPad Mask:Minimum Average Spot Intensity	Filters out image spots that do not have any particle images. The average spot intensity should be set so that areas without particle images are below the threshold and spots with particle images are above the threshold. Using Point Processing and the Process Monitor will help you find the correct threshold value for your images.

Correlation Engine: Bilinear Peak	
PluginData	**Value and Description**
Peak-to-Noise Ratio	The base peak class used to derive PeakEngines from finds the largest peaks in the correlation map. The highest peak is used to locate the particle image displacement. The second highest peak is a noise peak caused by the random pairing of images from different particles. The ratio of the displacement peak height to the noise peak height shows how much the displacement peak stands out above the noise. Low Peak/Noise peak values indicate that there is less confidence that the selected peak is the correct peak

Correlation Engine: Direct Correlator	
Plugin Parameter	**Value and Description**
Default Peak Engine: Gaussian Peak	The GaussianPeak is the default PeakEngine for Direct Correlation. When the Direct Correlation is selected, the PeakEngine is set to the default PeakEngine setting.

Correlation Engine: FFT Correlator	
Plugin Parameter	**Value and Description**
IsSpotZeroPadded	Was the spot zero padded? The correlation map for non-zero padded spots is adjusted to account for the number of pixels that can be correlated to create the displacement peak. Default =false.
Default Peak Engine: Gaussian Peak	The GaussianPeak is the default PeakEngine for FFT Correlation. When the FFTCorrelation is selected, the PeakEngine is set to the default PeakEngine setting.

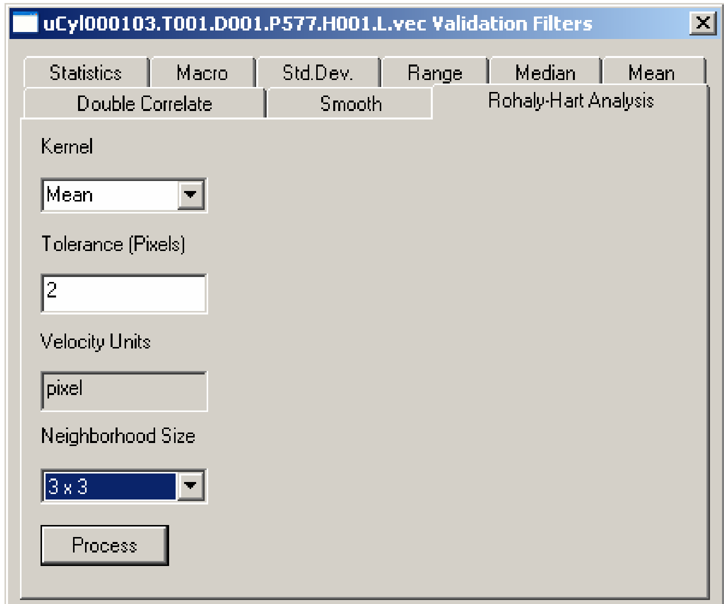
Correlation Engine: Hart Correlator	
Plugin Parameter	**Value and Description**
Compression Ratio—	The compression ratio is used to set how many pixels are used in computing the HartCorrelation. With the default compression value of 0.9, the 90% of pixels with the least significance are excluded and the 10% of the spot pixels that are most significant are used in computing the correlation. A high compression ratio will increase the processing speed. A lower compression ratio will include more pixels in the correlation and may, or may not, increase the correlation map signal-to-noise ratio. The effect of the compression ratio may be seen in the Process Monitor in the Masked Spots images. In the Masked Spots the pixels that were removed by compression are set to 0. If particle images are missing from the Masked Spots, the compression ratio is set too high.
DefaultPeakEngine: BilinearPeak	The BilinearPeak is the default PeakEngine for HartCorrelation. When the HartCorrelationEngine is selected, the PeakEngine is set to the default PeakEngine setting.

13. In the **Maximum Displacement** box, specify the maximum particle image displacement, in pixels, that will be looked for in processing. The Peak Engines use this value to limit the correlation map search area to ±max displacement pixels from the zero pixel. Some Correlation Engines, such as Hart, use this value to limit the size of the correlation map to increase processing speed and decrease memory usage.

14. In the **Spot Size** boxes, specify the dimensions of the interrogation spots in pixels.

Rohaly-Hart Analysis

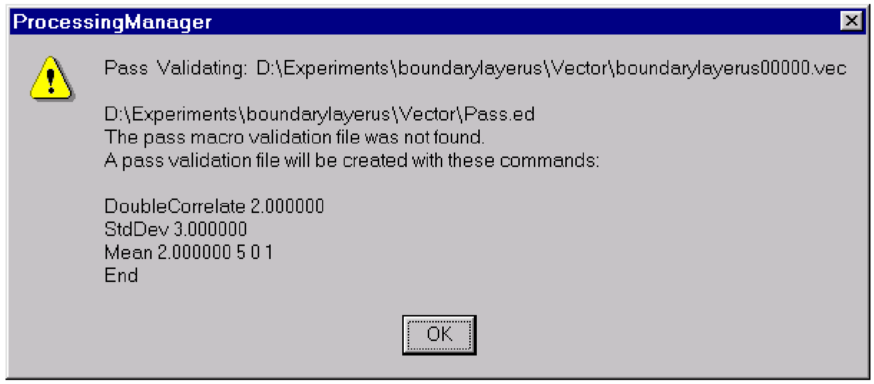
You can use the new Rohaly-Hart analysis scheme along with TSI's vector validation scheme to obtain vectors that may not be obtainable by standard PIV processing and validation. Rohaly-Hart analysis can be setup by clicking the **Validation Setup** button and the **Rohaly-Hart Analysis** tab. In order to use Rohaly-Hart analysis, you need to start with standard PIV processing procedures described in the above sections. A copy of the correlation map for each spot processed will be saved. After you get a vector field, you can use Rohaly-Hart analysis on the vector field directly by clicking the **Process** button, or you can use vector validation to get rid of invalid vectors first, use Rohaly-Hart analysis. The principle of Rohaly-Hard analysis is that if there is an invalid vector, it will add the correlation maps from neighbor spots saved before on top of the correlation map from current spot to get a good correlation peak, and it will then process the summed correlation map to get a vector. You can select a neighborhood size of 3×3, 5×5, 7×7, and 9×9 spots to sum the correlation maps centered on the invalid vector.



Validation

You can select and apply a macro for validation. The Pass Validation macro is applied to the vector field after each processing pass. In recursive processing two validation macros can be used, the Pass Validate Macro is used for the preliminary processing passes and the Final Validate Macro is used for the final pass. The Pass Validate Macro is separate from the Final Validate Macro so that different validation criteria can be used in the preliminary processing passes. You may want to be more aggressive about removing vectors and more aggressive in filling holes with the pass validation macro then with the final validation macro.

Note: *If **Pass Validate** is selected and the macro file is not found in the run, the Pass Validation Macro dialog appears. It shows the name of the macro to be recorded and the commands that will be used. Press **OK** to use this default macro.*



To select and play a Pass Validation Macro:

1. Select a macro in the Pass box under Validation in the Processing Setup dialog box.

To record a validation macro:

2. Process a vector field.
3. Click Interactive Validation in the PIV tab.

To select final validation:

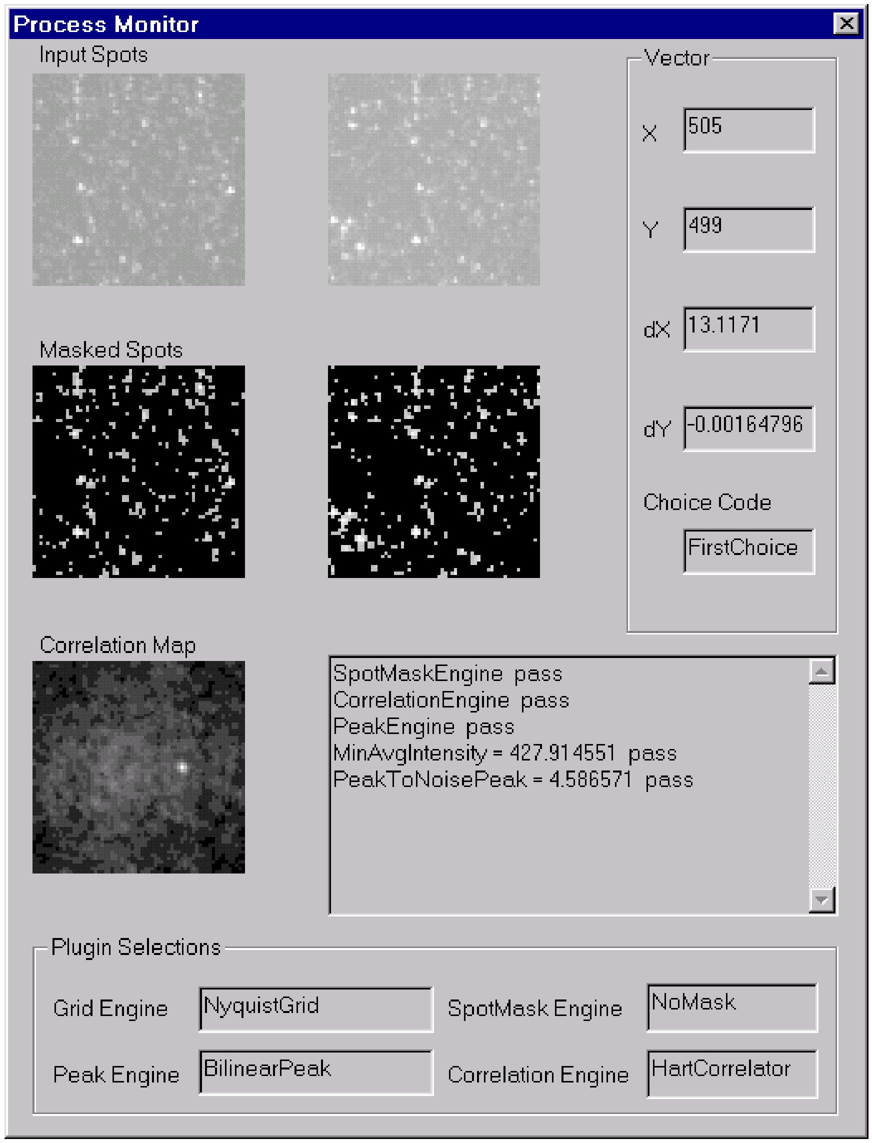
Select a macro in the Final box under Validation in the Processing Setup dialog.

Mapping AOI Between Images (Stereo Only)

With Stereo PIV systems the selected area of interest is mapped from the current view into the other camera. This mapping allows the left and right vector fields to have the same area in the flow and not the same pixel areas. This is quite useful when you wish to process less than the full image in a stereo system with the cameras on both sides of the light sheet. The mapping requires that a calibration file has been present. To map the area of interest between cameras check the Map to check box and then select the area of interest. If whole field is selected, the whole field of both images will be processed.

Process Monitor

When you select Process Monitor on the PIV tab, the Process Monitor dialog is displayed during processing to allow you to see what is happening during the processing. The Process Monitor dialog can be very helpful when trying to understand how the experiment is working, or why it is not working. It can also be helpful debugging tool when you are developing processing plugins.



The Process Monitor shows five image spots. The first two are the Spot A and Spot B images as taken from the input images. The second two images are the Spot A and Spot B images after processing showing changes that may have been made by the SpotMask and CorrelationEngines. For example, if ZeroPadSpotMask is selected, Spot A will have the edges blacked out. If HartCorrelation is selected, it will show which pixels remained after image compression. The bottom spot shows the correlation map. The standard vector information is shown in the Vector area. The PluginData measurements are shown next to the correlation map.

Looking at the number of particles in the spots is helpful in optimizing the spot sizes. Looking at the Masked Spots helps in seeing if the SpotMask and CorrelationEngines are improving the spot image quality.

In the Correlation map look to see if the particle image displacement peak stands out from the background noise. Does the peak move smoothly when an area is processed? Is the peak inside the center ½ of the correlation map or is near the edge? If the peak is too close to the edge you will need to start with a larger spot size, or use a first pass offset.

In the PluginData check to see which parameters are failing. Seeing the values for good vectors and bad vectors will help in choosing an effective threshold value.

Using PTV Processor

INSIGHT 3G allows you to process PIV images using an advanced Particle Tracking Velocimetry (PTV) processor, which implement the particle tracking method that finds the position and velocity of individual particles. The PTV processor can be used in conjunction with the PIV processor to perform the so-called "super-resolution" PIV analysis.

PTV processing can be broken down into these steps:

1. Performing image conditioning (optional).
2. **Particle Identification**: Find particles in the images using particle identification algorithm.
3. **Local Flow Calculation**: Estimate local flow field using PIV processor.
4. **Particle Tracking**: Find particle velocities using particle tracking algorithm.
5. **Velocity Interpolation**: Calculate grid velocities using velocity interpolation algorithm.
6. Performing validation of grid velocities (optional).

The flow chart shows the processing steps of PTV processor, and how to obtain two particle files and a vector file from the input image pair.

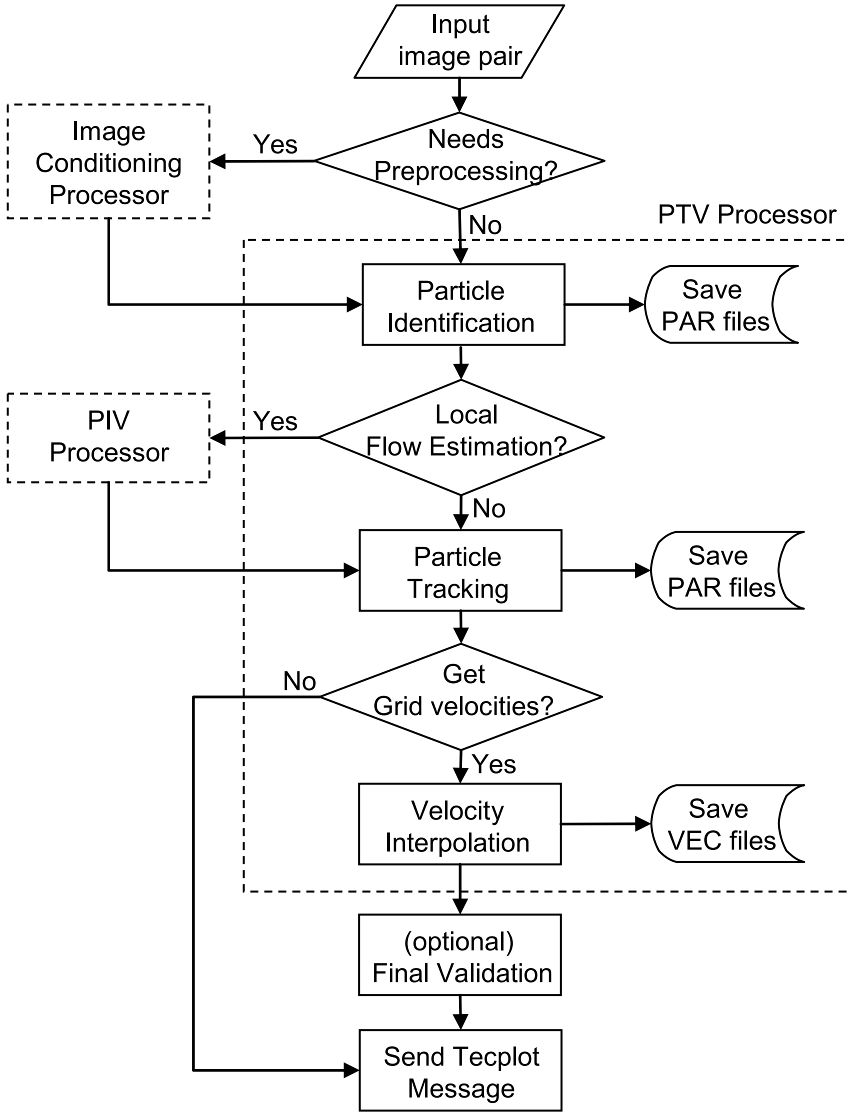


Image Conditioning

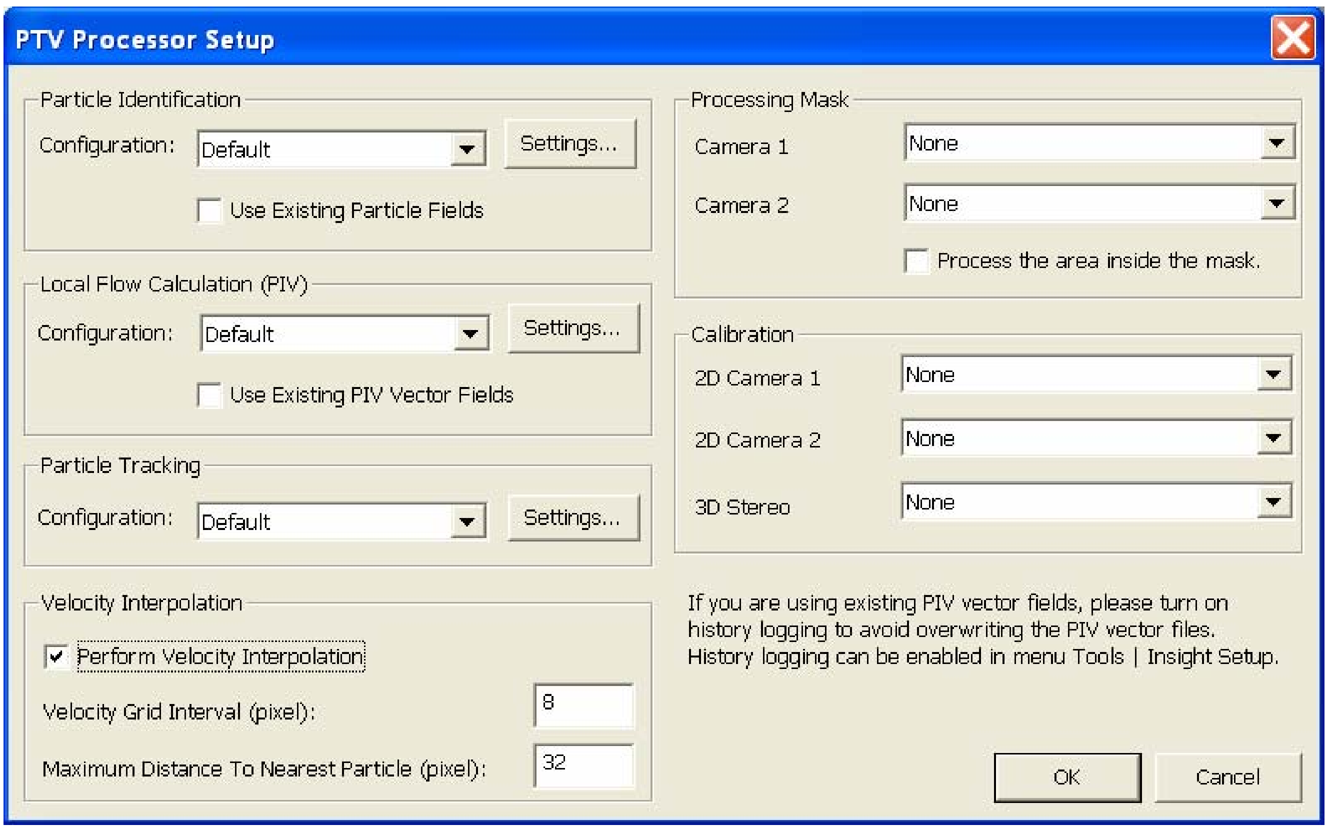
Preprocessing particle images can improve the performance of particle identification. For example, when particles are less than three pixels in the images, particle identification often fails to find the particles. This problem can be solved by applying Gaussian blurring to the raw images. Image preprocessing can also be used to eliminate the background and remove non-uniform illumination. Please see Chapter 7, "Conditioning Images" on how to setup and apply an Image Conditioning Processor.

Setting up a PTV Processor

Before using PTV processor to process PIV images, you need to setup the processing parameters in the PTV Processor Setup dialog.

To open the PTV Processor Setup dialog:

1. Select an image from the Experiment Tree, for which you want to setup the processing parameters. Drag and drop it onto the display panel. See Chapter 16, "Viewing, Enhancing, and Displaying Image Files" for detailed information on how to display and enhance images for processing.
2. Select the PIV tab on the control panel. Click **Process Setup**. The PIV/PTV Processor Setup box opens.
3. Select PTV processor in the drop-down list.
4. Click **Processor Settings**. The PTV Processor Setup dialog opens.



To set up the PTV processor parameters:

1. Select a Particle Identification processor for finding particles in the images. See "Setting up Particle Identification" for detailed information on how to setup a particle identification processor.
2. If there are existing particle files that you want to use, check **Use Existing Particle Fields** to load particles from the most recent particle files (.PAR) of the current image. The processor will skip the particle identification step.
3. Select a PIV processor for calculating local flow field to guide particle tracking. The PIV processor is also used to get the flow

field in super-resolution PIV analysis. See "Setting up Local Flow Estimation" for more information.

4. If there is existing PIV vector file that you want to use, check **Use Existing PIV Vector Fields** to load vectors from the most recent PIV vector files (.VEC) of the current image. The processor will skip the local flow estimation step.

IMPORTANT
You need to turn on the history log in the main menu **Tools	Insight 3G Setup** in order to use existing PIV vector fields. Otherwise, vector files generated by the PIV processor for the same image may be overwritten by the PTV processor.

5. Select a Particle Tracking processor for tracking particles found in the particle identification step. See "Setting up Particle Tracking" for detailed information on how to setup a particle tracking processor.

6. Set up Velocity Interpolation which calculates velocities on a regular grid using the particle tracking results. See "Setting up Velocity Interpolation" for detailed information on how to setup velocity interpolation.

7. Select processing masks for the camera(s) that were defined earlier. Processing masks are defined using the ROI tab. See "Defining a Region of Interest" for details. In the default mode, the defined areas are masked and excluded from being processed. To do the reverse, click **Process the area inside the mask** to have the defined area included in the processing.

8. Select 2D calibration files for the camera(s) that were created earlier. The 2D calibration is used to convert particle position and velocity, as well as grid velocity (if available) from pixel unit to physical unit. See "PIV Calibration Process" for detailed information on how to create a 2D calibration file.

9. For Stereo PIV images, select a 3D calibration file that was created earlier. The 3D calibration is used to combine the two 2D vector fields into a 3D vector field. See "Perspective Calibration" for detailed information on how to create a 3D calibration file for Stereo PIV.

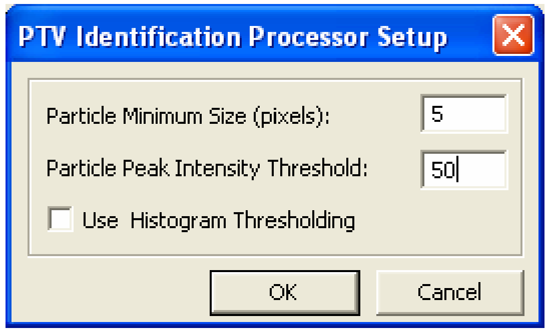
Setting up Particle Identification

Particle Identification processor finds particles and extracts particle position, diameter, and intensity information from the image.

To open the Particle Identification Processor Setup dialog:

1. In the PTV Processor Setup dialog, click **Settings** in the Particle Identification group box. The Identification Setup box opens.

2. Make sure PTVParticleIdentificationProcessor is selected in the processor drop-down list.
3. Click **Processor Settings**. The Particle Identification Processor Setup dialog opens.



Parameters of PTV Particle Identification Processor

Parameter	Description
Particle Minimum Size (pixels)	The minimum size of particles to be found in the image. Objects of smaller size are rejected.
Particle Peak Intensity Threshold	The minimum peak intensity of a particle. Unless adaptive thresholding is used, the threshold entered should be a grayscale value between 1 and 255 for 8-bit image, between 1 and 4095 for 12-bit image, and so on.
Use Histogram Thresholding	Finds the intensity threshold using the intensity histogram of the entire image. The value entered in the particle peak intensity threshold becomes a percentage value *x* between 1 and 99, meaning the intensity of *x* percent of the pixels is lower than the final intensity threshold.

Setting up Local Flow Calculation

PTV processors can use a PIV processor to calculate local flow field and then use it to guide particle tracking. This is commonly known as **Hybrid PTV**. For local flow estimate, the recommended spot size in PIV processor is 64×64. It offers sufficient spatial resolution needed to guide particle tracking.

The local flow field can also be used in **Super-resolution PIV**, which combines the robustness of PIV correlation method and the high spatial resolution of particle tracking method. For super-resolution PIV, you should use the smallest possible spot size supported by the PIV processor

To open the PIV Processor Setup dialog:

1. In the PTV Processor Setup dialog, click **Settings** in the Local Flow Calculation group box. The PIV Processor Setup box opens.
2. Make sure PIVProcessor is selected in the drop-down list.
3. Click **Processor Settings**. The PIV Processor Setup dialog opens.

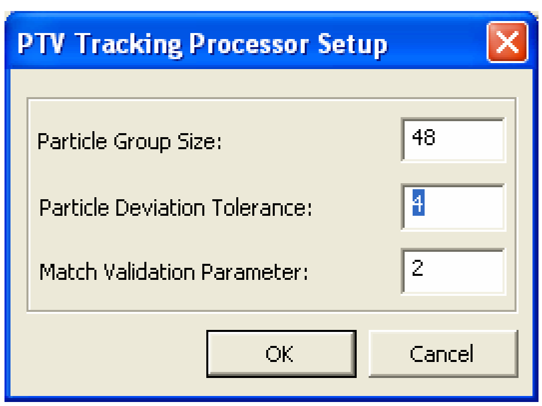
Setting up a PIV processor for use in PTV is the same as setting up a standalone PIV processor. See "Setting up PIV Processing Parameters" for detailed information on how to setup a PIV processor.

Setting up Particle Tracking

Particle Tracking processor matches particles found in two images and calculates the velocity of the matched particles.

To open the Particle Tracking Processor Setup dialog:

1. In the PTV Processor Setup dialog, click **Settings** in the Particle Tracking group box. The Identification Setup box opens.
2. Make sure PTVParticleTrackingProcessor is selected in the drop-down list.
3. Click **Processor Settings**. The Particle Tracking Processor Setup dialog opens.



Parameters of PTV Particle Tracking Processor

Parameter	Description
Particle Group Size	Particle tracking algorithm operates on a group of particles. A minimum of 16 particles per group is required.

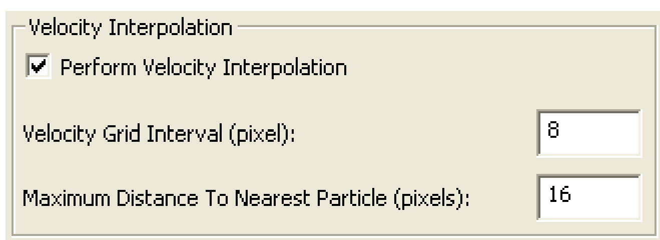
Parameter	Description
Particle Deviation Tolerance	Each particle in a group is shifted according to local flow field, and the distance to its nearest neighbor (called deviation) in the second frame is calculated. A particle pair is matched if its deviation is less than the tolerance times the median deviation of the group.
Match Validation Parameter	The velocity of each matched particle is checked by a median filter using the velocity of its matched neighbors. Match validation parameter defines the median filter tolerance.

Setting up Velocity Interpolation

Velocity Interpolation calculates the velocity on a regular grid so that derivate quantities of velocity such as vorticity and shear stresses can be calculated. Starting with randomly distributed particle velocities, Delaunay Triangulation is first used to find neighbor particles of each grid points, and then the bi-cubic interpolation is used to calculate the velocity at each grid point using the velocity of its neighbor particles. The output is a PTV vector file (.VEC) which is identical to a PIV vector file except for a PTV tag in the header.

To set up Velocity Interpolation parameters:

1. Velocity Interpolation parameters are found in the PTV Processor Setup dialog.



Parameters of PTV Velocity Interpolation

Parameter	Description
Perform Velocity Interpolation	Enable/disable velocity interpolation. No PTV grid vector file is generated if velocity interpolation is skipped.
Velocity Grid Interval (pixels)	The interval between the grid points, which defines the spatial resolution of the grid vector data.
Max Distance to Nearest Particle (pixels)	Each grid point must have at least one neighbor particle within this maximum distance. Otherwise no velocity is calculated at this grid point.

Setting up and Validating Vectors

The processing of PIV images can produce over 95% correct velocity measurements if the guidelines for PIV image capture and processing developed by Keane and Adrian (refer to the PIV Reference manual) are followed. Lost pairs due to in-plane and out-of-plane motion, or low seeding density causing a low correlation signal strength lead to spurious vectors. Spurious vectors happen when the highest correlation peak is not due to pairs of particles moving with the flow, the velocity peak, but when, instead, a random pairing of particle images produce a signal highest correlation peak. Vector field validation functions are designed to filter out the spurious vectors and fill the removed vectors through interpolation.

You can validate vectors in one of two ways:

- Interactive Validation: Soon after processing, you can validate vectors interactively by selecting a set of filters and settings and by validating single vector file or a sequence of vector files.

- Post-Processing Batch Validation: Alternately, you may use the Apply Validation feature to validate a batch of vectors that were processed and saved but not validated. This feature also makes use of the same macro file selected in the PIV Validation box.

Interactive Validation

The following is a typical scenario of how you would validate vectors interactively. Once you get familiar with the process, you may find yourself following your own set of procedures:

1. Capture an image. See "Capturing Images: An Overview" for details.
2. Select an area of interest.
3. Process the image.
4. On the **PIV** tab control panel, click **Validation Setup**. Select left or right camera on the Vector Validation dialog that appears. Click **OK**. The Validation Filters dialog box appears.
5. Select the **Macro** tab and click **Record Validation Macro** button. The Macro Recording dialog appears. Enter a name for the macro and click **OK**.
6. In the Validation filters dialog box, select vector validation filters or option of your choice and set their parameters. The following lists these options:

Filter Option	See Section
Statistics	Checking Velocity Filters
Standard Deviation	Using the Global Standard Deviation Filter
Range	Using the Global Range Filter
Median	Using the Local Median Filter
Mean	Using the Local Mean Filter
Double Correlation	Using the Double Correlation Filter
Smooth	Using the Smooth Filter

7. Select the **Macro** tab and click on the **Stop Recording** button.

Now, you have a validation macro customized for your experiment.

8. Press the 

button to validate your vector files.

CHAPTER 11

Calibrating and Processing PLIF Images

INSIGHT 3G provides a flexible platform for acquiring as well as processing planar laser-induced fluorescence (PLIF) images.

This chapter describes how to:

- Capture PLIF calibration images and,
- Process PLIF images that were captured as described in Chapter 6, "Capturing Images."

Note: *INSIGHT 3G supports only 10-, 12- and 16-bit gray scale images.*

Capturing PLIF Calibration Images

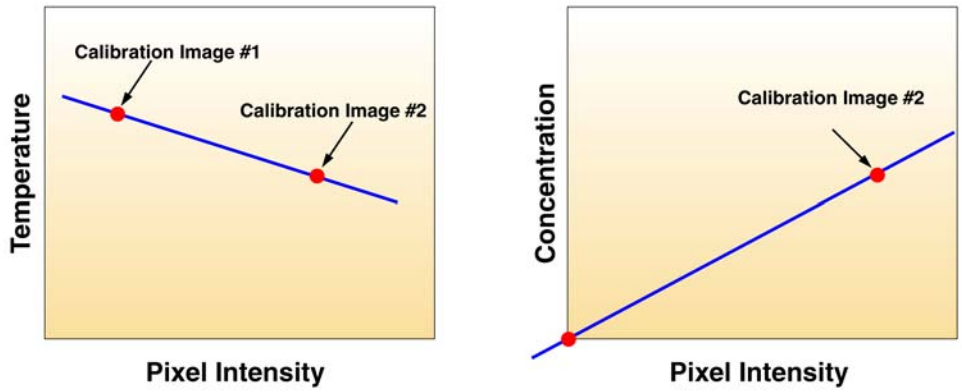
INSIGHT 3G provides the option of capturing PLIF images for calibration purposes.

If you need to quantify intensities, you must capture calibration images at known uniform concentration or temperature conditions with laser and cameras operating with the same settings as in the current experiment or run.

If you are processing PLIF images to determine temperature, you must have two calibration images

If you are processing the image with the intention of determining concentration, a single calibration image using the origin as the location of the second calibration point is sufficient.

These calibration images must be renamed and saved and moved to the settings directory in the current experiment.



To capture calibration images:

1. From *INSIGHT 3G* main menu, click **Tools | Capture Perspective Cal Images**. The Capture Calibration Images box appears.
2. Click **Capture.**

Processing PLIF Images

Processing Using the Ratiometric Method

The ratiometric method of processing PLIF images, corrects images for:

- Spatial variations in laser sheet intensity
- Camera noise
- Unwanted background signals.

Processing these images converts pixel intensity to a specific quantity of interest to you such as concentration or temperature.

Assumptions

Before you start processing images, make sure the following steps have been completed:

- You have raw images captured as described in "Capturing Images."
- You have met the calibration requirements as described in "Capturing PLIF Calibration Images."

❑ If you need to make background correction, you have captured the background image with no fluorescing species present in the flow but with the laser and cameras operating at the same settings as in the experiment, and saved in the settings folder of the current experiment.

Notes:

- *If you are using two calibration images, the background correction is automatic. Under most circumstances a background image is generally not necessary.*
- *If you are using a single calibration image, it is recommended you use a background image and skip the step requiring you to condition images.*

To process the PLIF image:

1. If required, condition the PLIF images as described in "Conditioning Images." See "Assumptions," earlier in this section for additional details.

2. Click 

on the *INSIGHT 3G* Control panel. The PLIF/Spray options become available.

3. Select **PLIF** in the PLIF/Spray tab. The PLIF process option becomes available.

4. Click **Process Setup**... The PLIF Process Setup dialog box appears.

5. Click **Ratiometric.** The parameters for ratiometric processing become available.

6. Perform one of the following two sets of steps:
If using a single calibration image:

A. In the **Calibration Image 1** box, click the down arrow.

B. Select the top blank bar (empty, with no filename).

If using two calibration images:

A. Select the appropriate calibration image from **Calibration Image 1** pull down box.

B. Enter a corresponding value for either the concentration or temperature in **Calibration Value 1**.

C. Repeat Steps A and B by selecting the appropriate calibration image from **Calibration Image 2** pull down box and entering a corresponding value for either the concentration or temperature in **Calibration Value 2** box.

7. Enter a value in **Threshold (%).** Threshold is a user-selected value to set pixels below a given value (determined as a percentage of the maximum pixel value, for example, 65535 for a 16 bit image) to zero (3). This is useful when the laser sheet illuminates only part of the image. Areas outside the laser sheet can be set to zero and be eliminated from the processing.

8. If needed, select a background image from the pull down **Background Image** list.

9. Select **Dynamic** or **Manual** for Intensity Scaling values:

Option	Description
Dynamic	Select to have each processed image examined for the maximum and minimum value of the processed quantity (concentration or temperature). The images are stored in standard TIF format where the pixel intensity is proportional to the quantity of interest. The images are scaled such that the minimum value of the processed quantity is set to a pixel intensity of zero and the maximum processed quantity is set to 65535 (all images are converted to 16-bit during floating point multiplication in the processing algorithm).
Manual	Select to manually specify the maximum and minimum values for displaying the images. Enter the appropriate values for Minimum Value and Maximum Value. Calculated values below what is specified as the Minimum Value, are set to zero, and values above the maximum are set to 65535.

10. Click **Save**. See "Saving/Loading/Deleting a PLIF Process" for details.

Saving/Loading/Deleting a PLIF Process

After you have created a PLIF process as described in "Processing Using the Ratiometric Method" section, you can save these process settings and reapply them to other PLIF images.

To save a PLIF process:

1. Make sure all the settings for the Ratiometric are appropriate and correct.

2. Click **Save**. A window appears asking for the process to be named.

3. Enter an appropriate name and click **OK**. The process is saved in the settings folder, and can subsequently be applied to raw data images.

To load or delete a PLIF process:

1. Highlight the process in **Saved PLIF Processes** list.
2. Click **Load** to load the process. All settings are updated to match the saved values in the process file.

   or

   Click **Del** to delete the process.

To apply a PLIF process:

1. Select **Experiment Tree** tab. Set the appropriate run as the current run. For how to information see "Setting an Experiment or Run as Current."
2. From the experiment tree, drag and drop the desired raw data images from that run to the display. For how to information see "Accessing the Experiment Tree."
3. Select 

tab. Click **PLIF.**
4. Select the appropriate process from the drop-down PLIF process menu.
5. Click **Apply Process**.

   Images are processed sequentially and a status window displays the progress of the processing stage. When processing is complete, the raw images are closed and the processed images are displayed in their place. Processed images are saved in the Analysis folder in the specified run.

   Raw images can be processed multiple times using different process files. For each subsequent processing step, the processed files are given an incremental process number to identify the files and prevent being overwritten. For each process, an html file is created and stored in the run's Analysis folder to record the details of the process that was applied.

Extracting PLIF Data

Currently processed PLIF data can be extracted to a vector file automatically by using the Extract PLIF Data feature. The data in the vector file is displayed automatically in the Tecplot program, if you have the program open.

To extract PILF data:

1: Open Tecplot program.

2: Click 

.

The data is displayed in the Tecplot program.

CHAPTER 12

Processing Spray Images

INSIGHT 3G offers the spray analysis option to help you analyze spray geometry. The spatial distribution of elastically scattered light is used to evaluate spray size, spray angle, spray development, and spray symmetry. These functions help in the development of nozzles, injectors, and spray systems for steady or pulsed sprays.

This chapter provides a general overview of how to setup your hardware and software to capture, process, and analyze spray images.

Hardware Setup for Sprays

Spray analysis is performed using a camera, YAG laser, light sheet optics, and optional traverse (usually providing motion control for the injector). The most common camera used for spray analysis is the Model 630057 TSI POWERVIEW 2MP camera. A TSI Model 610022 Motorized Light Sheet Generator can be used with or without a 610015 series light arm. The Light Sheet Generator can easily be rotated to produce a vertical or horizontal light sheet, with adjustable divergence angle and waist position.

The camera may be mounted at 90-degrees side scatter, viewing a vertical spray cross section perpendicularly (vertical light sheet). In this case, no perspective distortion correction is needed. A relatively large camera can be used here, because the required depth of focus is small. Thus, the laser power can be relatively low.

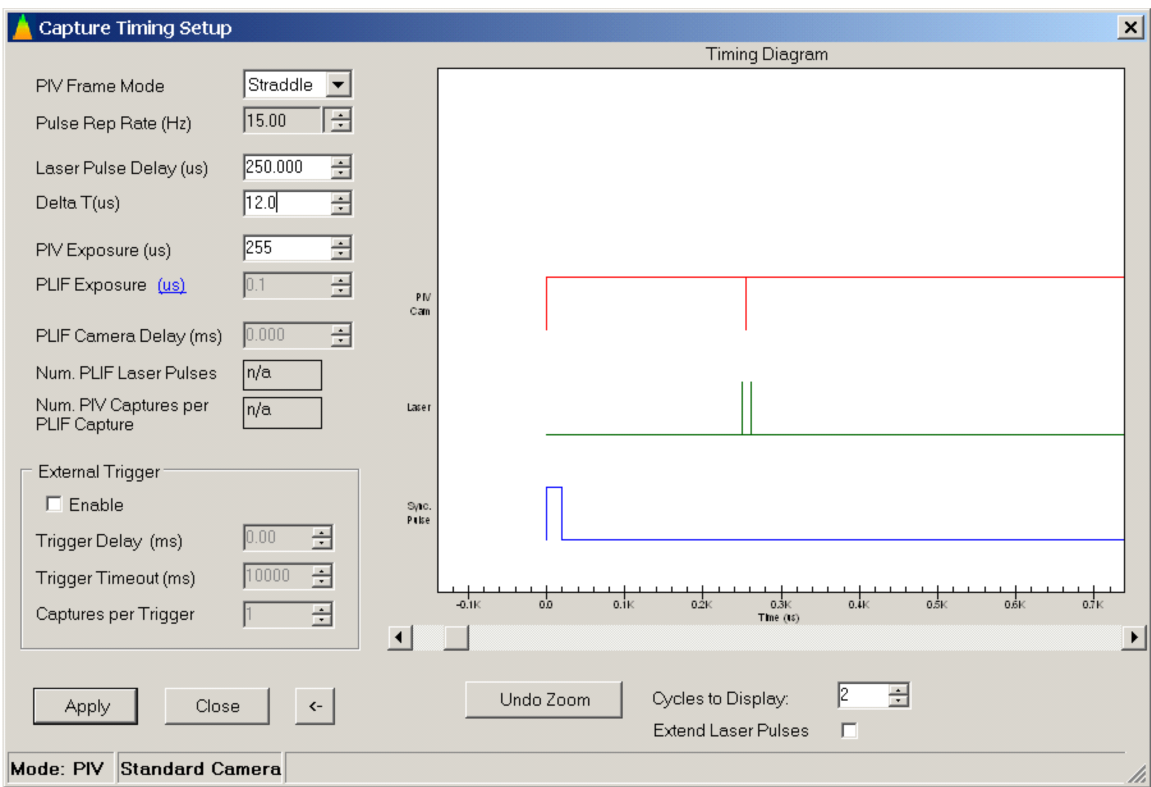
For simplified viewing of both vertical and horizontal spray sections, the camera can be mounted at a 45-degree angle to horizontal. A relatively small camera f# is needed here, because the required depth of focus is large. The laser power must be higher than when the camera is perpendicular. With 45-degree viewing, all images contain perspective distortion, but this is easily corrected by an *INSIGHT 3G* image conditioner. The conditioner's correction factors can be generated within *INSIGHT 3G* using images of a PIV calibration target. Correction factors are supplied with

INSIGHT 3G for 45-degree viewing of a horizontal light sheet and for 45-degree viewing of a vertical light sheet.

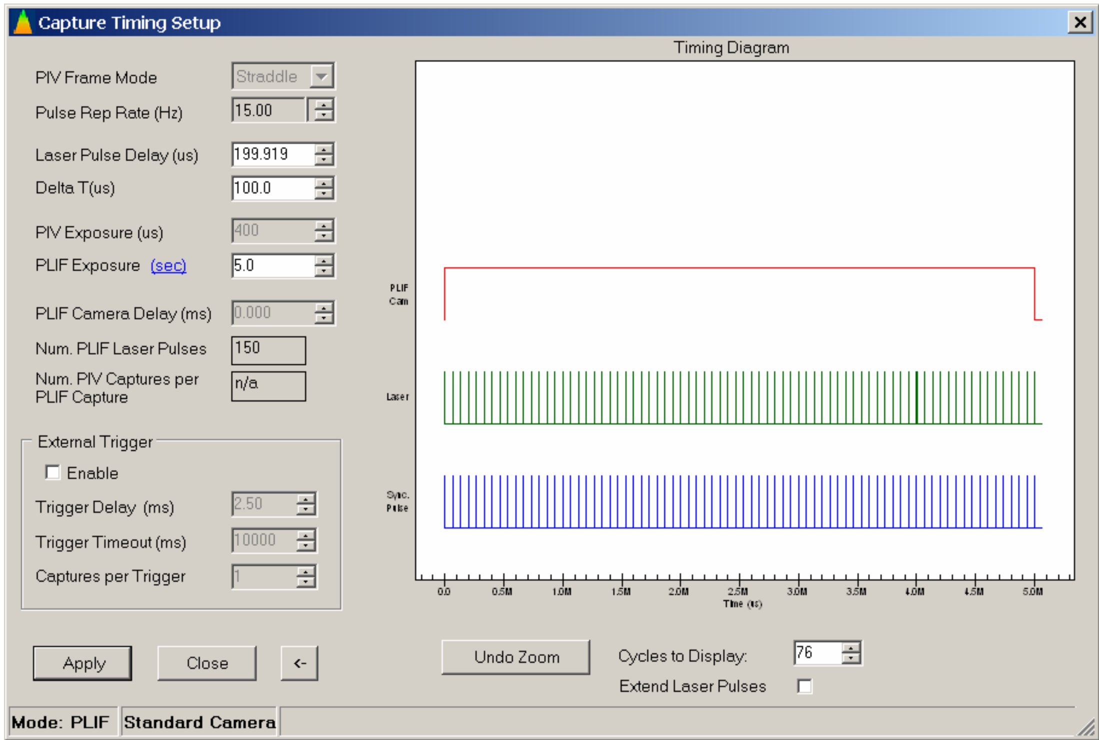
Software Setup for Steady Spray

Steady or "continuous" sprays do not vary with time (beyond the characteristic time of the spray). You can capture images in two ways: with or without accompanying PIV analysis.

When PIV analysis is planned, use a thin, well-aligned light sheet for optimum PIV processing, and to average multiple images for optimum spray analysis. Typically, averaging 10 to 25 images yields a suitably smooth representative image for spray analysis. Steady sprays can be considered 'unchanging with time' only if the analysis time is greater than the characteristic time of the spray, and the 5 to 10 ns YAG laser pulse duration is much shorter than any characteristic time of current sprays.



When accompanying PIV analysis is not planned, images can be acquired in the *INSIGHT 3G* PLIF mode. Typically a thicker light sheet is used and "on-chip" integration is performed by capturing multiple laser pulses with a longer exposure time. The following figure shows an *INSIGHT 3G* timing diagram for a 5 sec exposure time, encompassing 75 laser pulses from a single cavity, or 150 pulses when using both cavities. To reduce background levels, it is helpful to use a 532 nm line filter on the camera lens (TSI P/N 610070).



Software Setup for Pulsed Spray

Pulsed sprays vary greatly with time, typically having a duration of a few milliseconds. Capture images using *INSIGHT 3G*'s External Trigger function and a TTL signal with a transition, some time at or before the start of injection. The *INSIGHT 3G* Trigger Delay setting allows you to acquire an image at any point in the spray development process. The following figure shows a set of three images taken at 1.7 ms, 2.2 ms, and 3.0 ms after the External Trigger was received.

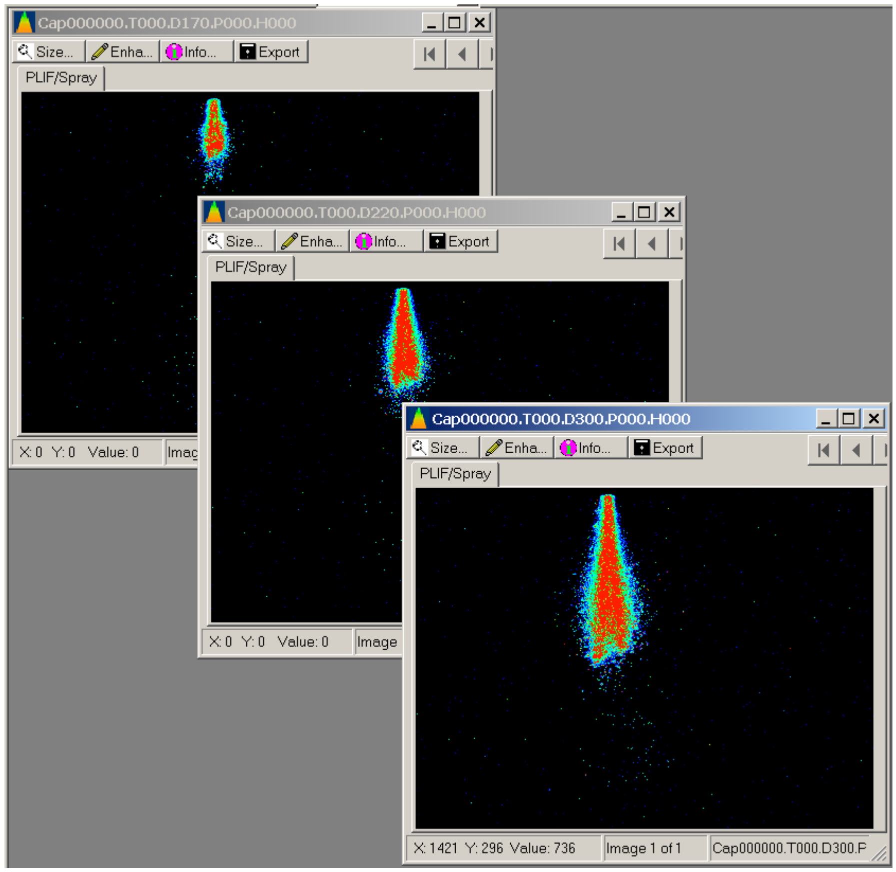


Figure 12-1
Pulsed Spray Images Captured at 1.70 ms, 2.20 ms, and 3.00 ms after the Injector TTL Signal was Received

The full set of 12 images is shown in Figure 12-2. The External Trigger signal usually corresponds to the logic level injector "Command" or "Drive" signal.

When PIV analysis is planned, the strategy is to use a thin, well-aligned light sheet for optimum PIV processing, and to mathematically average multiple images for optimum spray analysis. Typically, averaging 10 to 25 images yields a suitably smooth representative image for spray analysis. A sample INSIGHT 3G Timing Diagram for PIV mode is shown in Figure 12-3.

When accompanying PIV analysis is not planned, images can be acquired using the INSIGHT 3G PLIF mode. Again, a thicker light sheet can be used and "on-chip" integration is performed by capturing multiple laser pulses with a longer exposure time. Images are acquired from successive injections at the same time within the injection process, and the "average" image is built up on the CCD. An averaged image is thus obtained at each point in time during the injection process. The images are identified by their Delay attribute, contained in the filename.

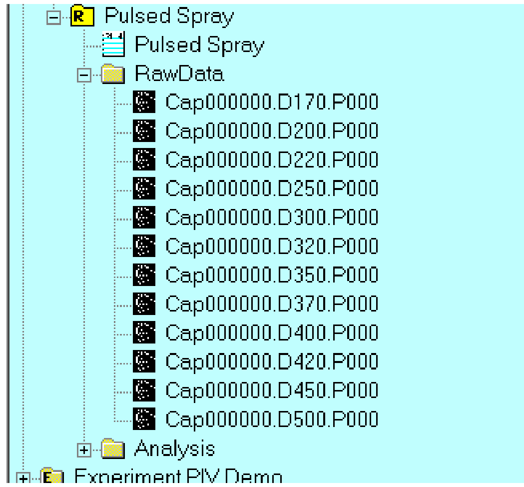


Figure 12-2
INSIGHT 3G Timing Diagram for PIV Mode Acquisition of a Single Steady Spray Image

Figure 12-3 shows the Timing Diagram for PIV Mode acquisition of multiple laser pulses in a pulsed spray image.

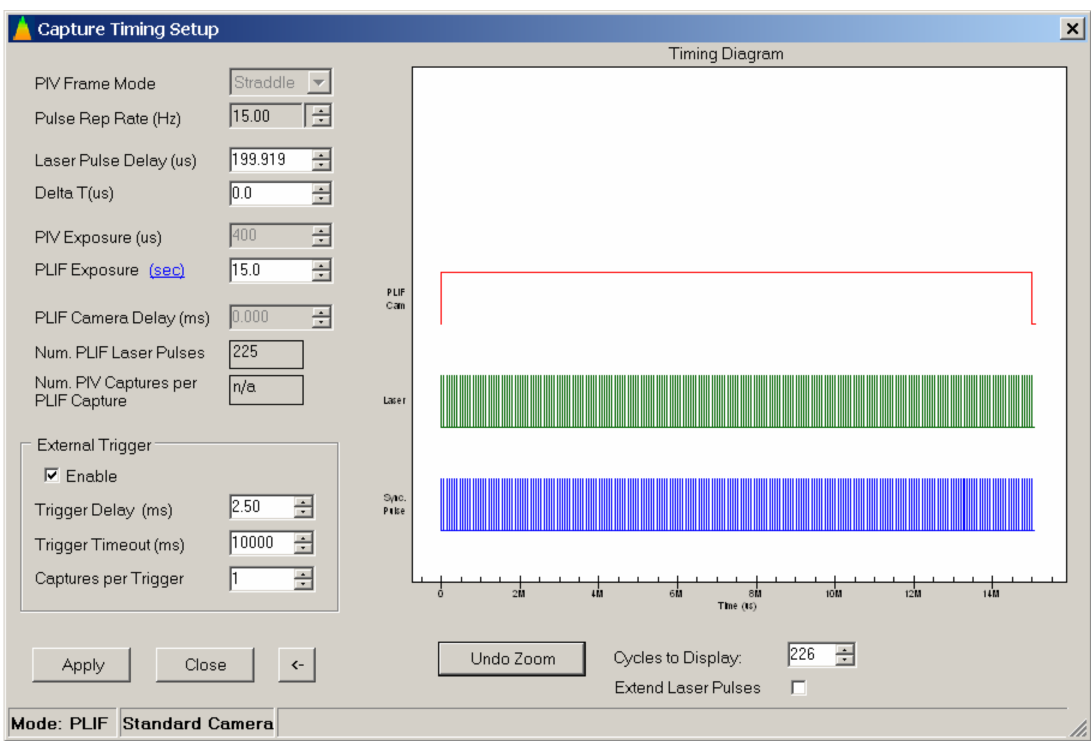


Figure 12-3
INSIGHT 3G Timing Diagram for PLIF Mode Acquisition of Multiple Laser Pulses in a Pulsed Spray Image

Data Analysis

Statistics

INSIGHT 3G provides general analysis of sprays by calculation of statistics for user-specified Regions of Interest (ROIs).

Intensity Profile

INSIGHT 3G provides general analysis of sprays by display of intensity profiles for user-specified locations—horizontal or vertical.

Vertical Spray

INSIGHT 3G provides analysis of spray angle, spray penetration depth, and spray area.

Horizontal Spray

INSIGHT 3G provides analysis of spray symmetry by sector and annulus patternation.

CHAPTER 13

Calibrating, Processing, and Viewing GSV Images

Global Sizing Velocimetry (GSV) is a global imaging technique for simultaneous size and velocity measurement of transparent and spherical particles over a two-dimensional region. A thin laser light sheet illuminates the particles in a plane. A camera records the out-of-focus images of the particles in the light sheet. Particle size is obtained from the oscillation spacing of scattered light recorded in the out-of-focus images. Particle velocity is obtained by matching particles of same size found in two consecutive image frames.

This chapter discusses how to:

- Calibrate a GSV system
- Process GSV images to get particle size and velocity
- View GSV processing results
- View size/velocity statistics using Tecplot

Global Sizing Velocimetry Calibration Process

The only calibration required by GSV is the magnification before defocusing. This is the same as PIV 2D Calibration. The following section describes how to perform the GSV calibration using *INSIGHT* 3G PIV 2D Calibration function. For information on how to capture calibration images, see "Capturing Calibration Images" for details.

GSV Calibration

1. From the main menu of *INSIGHT* 3G, select **Tools | Spatial Calibration**. The PIV 2-D Calibration dialog opens.
2. Select Velocity (m/s) in the Units box.
3. Select Object Measure in the Calibration method box.

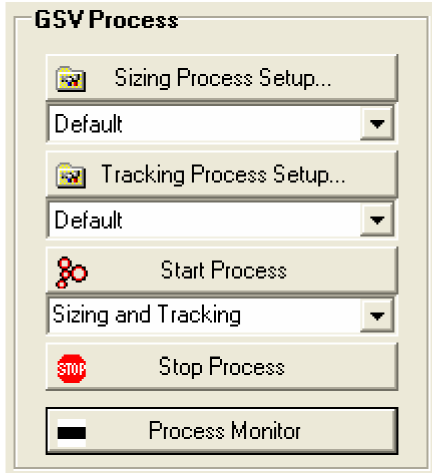
4. Type in the distance between any two dots in the Object size in mm box. The standard GSV calibration target has the grid interval of 2.5 mm.
5. Click **Measure**.
6. Place the cursor in the center of the first dot. Click the left mouse button once.
7. Move the cursor to the center of the second dot. Click the left mouse button once.
8. The result is shown in Calibration Numbers box.
9. If the Object size is changed, click **Calculate** to update the calibration numbers.
10. Click **Save** to save the calibration file for use in GSV sizing process.
11. Click **Close** to close the calibration dialog.

Processing Global Sizing Velocimetry Images

INSIGHT 3G allows you to process GSV images to get particle size, position, and velocity.

Processing GSV Image

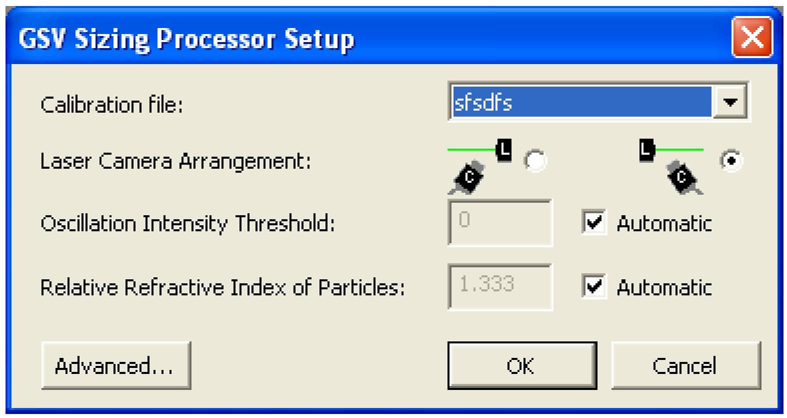
1. Select one or more GSV images from the experiment tree. Drag and drop the image(s) onto the display panel. See "Viewing, Enhancing, and Displaying Image Files" for detailed information on how to display and enhance images for processing.
2. Select the GSV tab on the control panel. The GSV options become available.



3. Click **Sizing Process Setup** to set up the GSV sizing processor. See "Setting up GSV Sizing Processor" for more information.
4. Click **Tracking Process Setup** to set up the GSV tracking processor. See "Setting up GSV Sizing Processor" for more information.
5. Select one of the three types of GSV process:
   - Sizing Only: images are processed to obtain only particle size and position information. This process can be applied to single image or straddled images.
   - Tracking Only: only particle velocity is obtained. This process can only be applied to one or more image pairs which have been processed for sizing.
   - Sizing and Tracking: images are processed to obtain particle size, position, and velocity. This process can only be applied to straddled images. Sizing process is applied to all selected images first, followed by the tracking process.
6. Click **Start Process** to start the selected GSV process.
7. Click **Stop Process** to quit the current GSV process.
8. Click **Process Monitor** to turn on GSV process monitor for sizing process. See "Global Sizing Velocimetry Process Monitor" for more information. Note that the process monitor is only for the sizing process.
9. GSV processing results are automatically saved to the Analysis folder in the experiment tree. The results are also displayed on the display panel immediately after the process. See "Viewing Global Sizing Velocimetry Processing Results" for information on GSV data file format and how to change the display settings.

Setting up GSV Sizing Processor

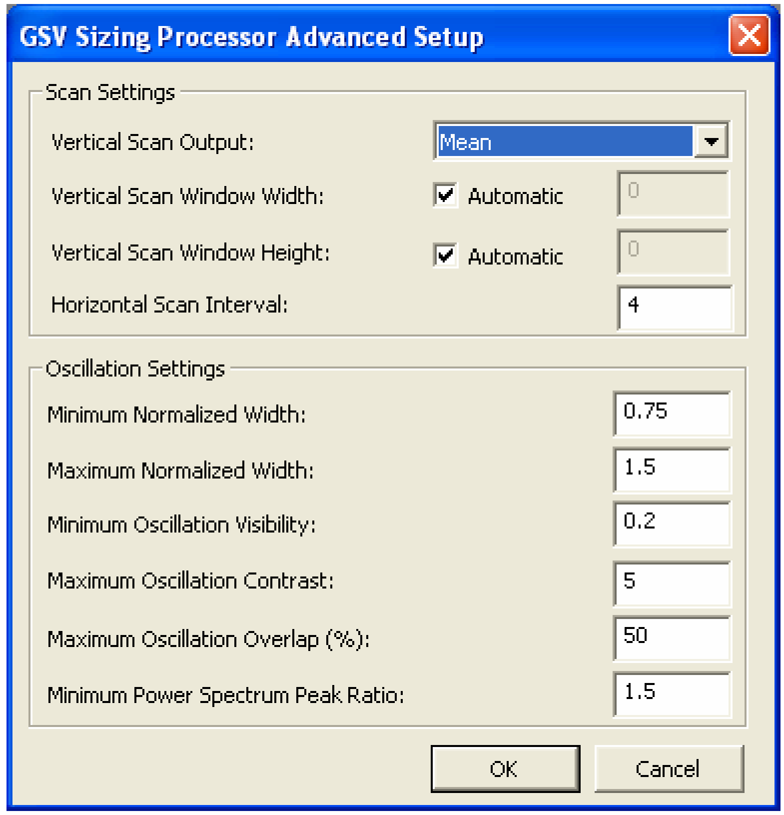
1. Click **Sizing Process Setup**. The GSV Particle Processor setup dialog appears.
2. Select a processor configuration from the list.
3. Click **Processor Settings**. The GSV Sizing Processor setup dialog appears.



4. The parameters in the sizing processor setup dialog are:

Parameters	Description
Calibration file	Use the calibration file created in GSV calibration process.
Laser Camera Arrangement	Select the laser-camera arrangement you are using: a) laser on the left and camera on the right; or b) laser on the right and camera on the left.
Oscillation Intensity Threshold	Set the minimum of mean intensity of an oscillation pattern. You may check **Automatic** box to use the default value chosen by the program, or enter the threshold (after uncheck the Automatic box).
Relative Refractive Index of Particles	GSV does not require the refractive index for size measurement. However, if the refractive index is known, you may enter it here (after uncheck the **Automatic** box) to get the most accurate size measurement.

6. (Optional) Click **Advanced** to open GSV Sizing Processor Advanced Setup dialog.



6. (Optional) There are two groups of parameters in the sizing processor advanced setup dialog: scan settings and oscillation settings.

Scan Settings	**Description**
Vertical scan output	Select the output of vertical scans, which can be mean, median, or maximum of the rows included in each vertical scan. Mean is the default choice. Median may be a good choice if the scan window height is large. Maximum gives the best sensitivity but it is also the most sensitive to noises.
Vertical scan window width	Set the window width of windowed FFT. Check the **Automatic** box to let the program choose the optimum value.
Vertical scan window height	Set the number of rows in each vertical scan. Check the **Automatic** box if the height of oscillation patterns is between 8 and 24 pixels. Otherwise, uncheck the box and enter a value that is about half of the pattern height.
Horizontal scan interval	Set the steps for windowed FFT. Larger steps results in less number of windowed FFT to be calculated for each scan, and thus faster processing. The rule of thumb is using a value closer to the minimum oscillation spacing you want to resolve in the images.

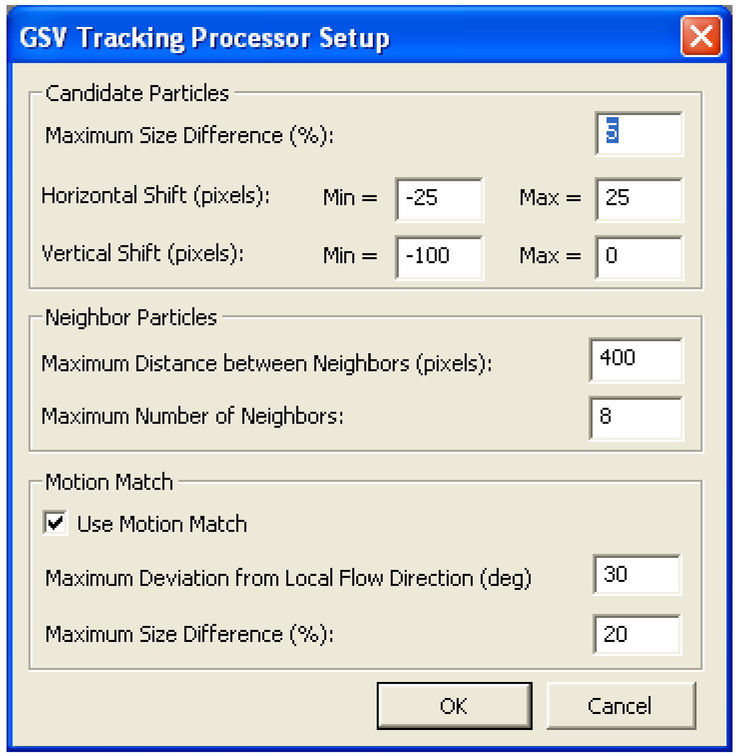
Oscillation Settings	Description
Minimum normalized width	Set the minimum width of oscillation patterns relative to the nominal width estimated by geometric optics. The typical range is between 0.5 and 1. Oscillation patterns shorter than the minimum width will be rejected.
Maximum normalized width	Set the maximum width of oscillation patterns relative to the nominal width estimated by geometric optics. The typical range is between 1 and 1.5. Patterns longer than the maximum width will be checked to see if they are formed by the overlapped oscillation patterns.
Minimum oscillation visibility	Set the minimum visibility of oscillation patterns. The visibility is calculated by $\frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}$, where minimum and maximum are found within each scan window.
Maximum oscillation contrast	Set the maximum contrast of oscillation patterns. The contrast is calculated by $\frac{I_{\max}}{I_{mean}}$, where mean and maximum are found within each scan window.
Maximum oscillation overlap	Set the maximum overlap percentage allowed for oscillation patterns found in adjacent vertical scans. The overlap percentage is defined as the length of common section over the length of whole oscillation pattern. It is used to detect the oscillation patterns that are processed multiple times by adjacent vertical scans.
Minimum power spectrum peak ratio	Set the minimum ratio between the highest peak and the second highest peak in the power spectrum of an identified oscillation pattern. This parameter is effective in rejecting bad patterns such as those caused by interference of nearby particles.

7. (Optional) Click **OK** to close the GSV Sizing Processor Advanced Setup dialog.
8. Click **OK** to close the GSV Sizing Processor setup dialog.
9. Click **Save** to save the new settings.
10. Click **Close** to close the GSV Particle Processor Setup dialog.

IMPORTANT
You must save the settings before you close the dialog box. The new settings are not automatically saved when you click **Close**.

Setting GSV Tracking Processor

1. Click **Tracking Process Setup**. The GSV Particle Processor setup dialog appears.
2. Select a processor configuration from the list.
3. Click **Processor Settings**. The GSV Tracking Processor setup dialog appears.



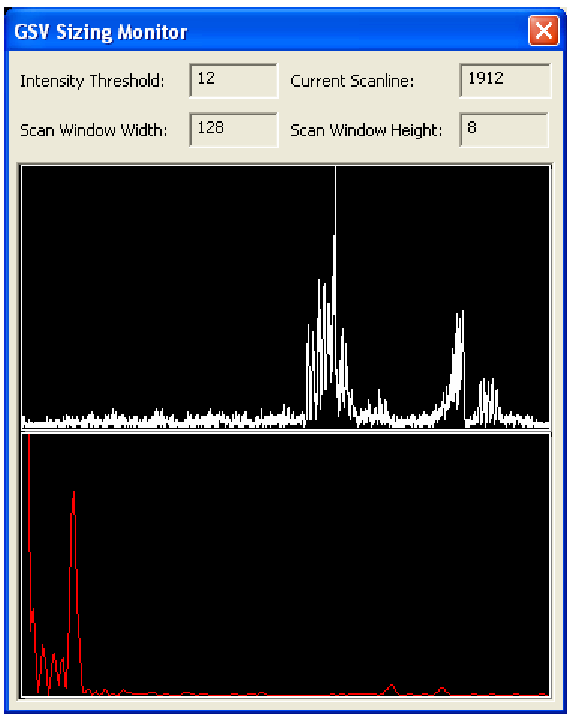
4. The parameters in the tracking processor setup dialog are:

Parameters	Description
Maximum size difference	The maximum relative size difference, in percentage, allowed between two pair particles.
Minimum and maximum horizontal shift	The minimum and maximum horizontal shift, in pixels, between two paired particles. Moving left in the images is negative shift and moving right is positive shift.
Minimum and maximum vertical shift	The minimum and maximum vertical shift, in pixels, between two paired particles. Moving down in the images is negative shift and moving up is positive shift.
Maximum distance between neighbor particles	The maximum distance, in pixels, between neighbor particles. The neighbor particles are those with similar motion and are used primarily in the motion match.

Parameters	Description
Maximum number of neighbors	The maximum number of particles selected within the maximum neighbor distance.
Use motion match	Check the box to enable motion match, which runs after the size match.
Maximum deviation from local flow direction	Particles paired by motion match should have similar shift direction to those paired by size match. The deviation must be within the maximum deviation defined here.
Maximum size difference (for motion match)	Particles paired by motion match can have larger size difference than the *Acceptable size difference*, but they should still have similar size and the maximum size difference allowed in motion match is defined here.

GSV Process Monitor

When you click **Process Monitor** button on the GSV tab, the GSV Process Monitor dialog is displayed during processing to allow you to see what is happening during the processing.



The GSV process monitor has two graph panels:

1. The top panel shows the horizontal intensity profile obtained in the current vertical scan. Depending on the output type selected in the sizing processor setup, it can be mean, median, or maximum of the rows included in the vertical scan.
2. The bottom panel shows the power spectrum of individual oscillation patterns found in current scan. The power spectra of

all oscillation patterns are normalized by their peak power and then added up to get the one shown in the graph.

The GSV process monitor also displays the values of oscillation intensity threshold and scan window size. It is useful when you select **Automatic** for these settings in the processor setup but still want to know the actual values used by the program.

Viewing Global Sizing Velocimetry Processing Results

Global Sizing Velocimetry (GSV) automatically saves the processing results in the Analysis folder of the experiment tree. GSV also automatically displays the results on top of raw images after processing. The saved results can be viewed in a spreadsheet, or displayed on top of the raw images. If straddled image frames are processed, the results are displayed in both A and B frames.

Opening GSV Data File as a Table

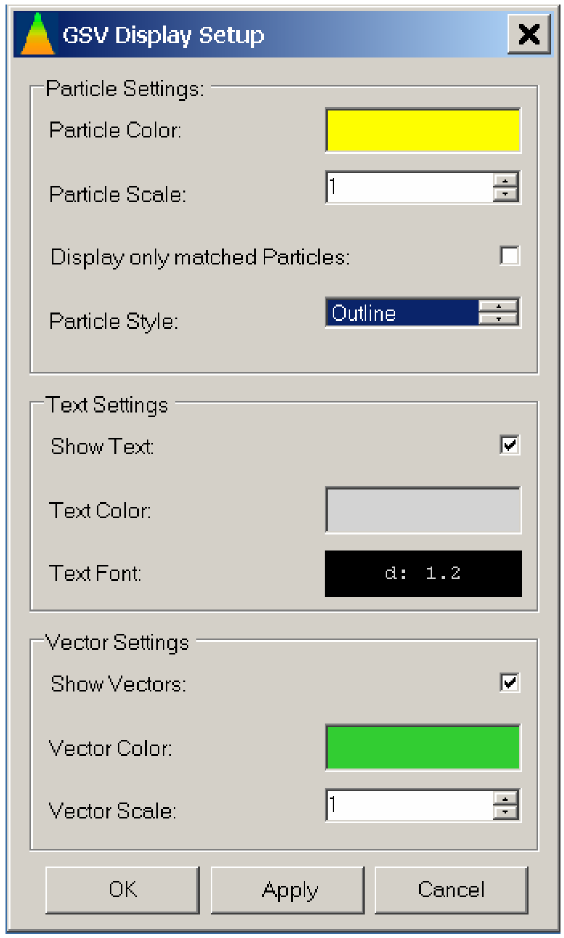
1. Close any images opened in the display panel.
2. Select one or more GSV data file in the Analysis folder of the experiment tree. Drag and drop the files on the display panel. Or right click the mouse and select **Open As Table** from the menu.
3. The selected data file(s) is opened as a table with captions. For particles without velocity data (unmatched or no tracking is done), a very large number is shown in the velocity cells.

Viewing GSV Data File on Top of the Raw Image

1. Have a raw image open in the display panel.
2. Select the corresponding GSV data file in the Analysis folder of the experiment tree. Drag and drop the files on the display panel.
3. The selected data file(s) is shown on top of the raw image. Particles are represented by circles centered at their positions, and velocity vectors are drawn if available.

Changing Display Settings for Particles

1. Click **Tools** in the toolbar menu of the display panel. Select **Tools | Particle | Setup**. The GSV Particle Display Settings dialog opens.



2. There are three groups of settings: particle settings for circles representing particles, text settings for particle size text, and velocity settings for particle velocity vectors.

Particle Settings	Description
Particle Color	Set the color of circles representing particles found in the image.
Particle Scale	Set the scale of circle size with respect to actual particle diameter in pixels.
Display only matched particles	Check the box to display only particles matched in tracking process. Otherwise, all particles found in the sizing process are shown.
Particle Style	Select Outline or Filled for circles representing particles.

Text Settings	Description
Show Text	Check the box to display a text next to particle showing the particle diameter.
Text Color	Set the color of text
Text Font	Set the font of text

Vector Settings	Description
Show Vectors	Check the box to display vectors
Vector Color	Set the color of vectors
Vector Scale	Set the scale of vectors with respect to actual particles displacement in pixels.

3. (Optional) Click **Apply** to apply new settings.

4. Click **Ok** to apply new settings and close the dialog.

CHAPTER 14

Presenting Data with Tecplot®

INSIGHT 3G provides Tecplot®, a third-party software to display and manage PIV data. TSI Tecplot Add-On is an add-on software used to view INSIGHT 3G 2-D and 3-D vector files and compute flow properties, it is also used to view INSIGHT 3G GSV particle files and compute diameter statistics. Tecplot is a general-purpose data viewing package, with an emphasis on fluid flow data. It offers comprehensive fluid flow data visualization with many options. It provides the most frequently-used PIV and GSV flow field viewing controls in a single tabbed dialog. The combination of common PIV and GSV data viewing using TSI Tecplot Add-On and the ability to customize the graphs to meet your requirements using Tecplot makes this feature a powerful tool for analyzing your PIV and GSV data.

Installing Tecplot

TSI Tecplot Add-On is installed with INSIGHT 3G. However, Tecplot has to be installed separately. Follow the installation instructions provided with the Tecplot manual.

If you have not installed INSIGHT 3G into the default folder C:\Program Files\TSI\Insight 3G\, you would need to set the INSIGHT 3G folder using the **Msg** tab option. See "Message Folder."

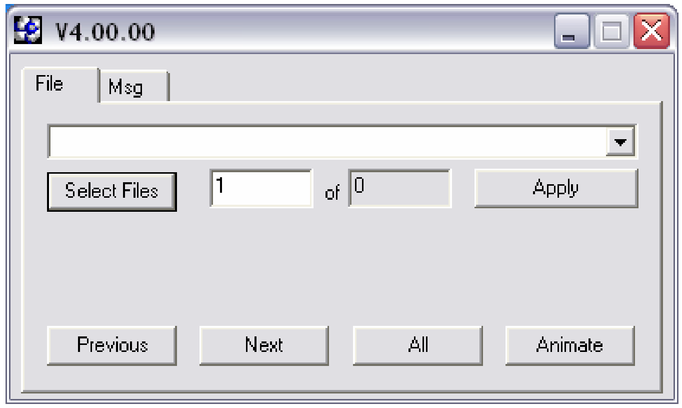
Accessing and Using TecPIV and Tecplot

To open Tecplot:

Click **Tecplot** on the INSIGHT 3G Toolbar. The Tecplot program opens and the TecPIV dialog becomes available. The following screen shows the different options available to display and manipulate the 2D, 3D, and particle data generated by

®Tecplot is a registered trademark of Tecplot, Inc.

INSIGHT 3G. Following are descriptions of the tasks you can perform with each of the TecPIV display features and options. You can also configure Tecplot to directly open a processed image by configuring the Msg tab option.



Selecting and Reading Files into Tecplot

Use the File tab options in the TSI Tecplot Add-On dialog to select and read vector and particle files into Tecplot.

To select and open vector files:

1. From the TSI Tecplot Add-On dialog, click **File | Select Files**.
2. The Select Vector File(s) dialog opens. Use the Look In scroll box to navigate to your vectors folder. Select **All Vector Files** in the File of type box to view the vector files, or select “All Particle Files” in the File of type box to view the particle files.
3. Select the desired vector files and click **Open.** The group of files is checked for compatibility when the files are read into Tecplot. To be compatible, the vector files must be the same type, have the same number of vectors, and the vectors must be at the same locations. If this is not true, an error message explaining why the files are not compatible is displayed. If you try to work with incompatible files, the results are unpredictable and a crash is likely.

   To open a single vector or particle file:

   - Double-click the filename, or highlight the file and click **Open**.
   - The number of files selected is displayed in Total Number of files of box. This number of files increases by 1 if you create a vector field average.

To select more than one file:

1. Hold the **Control** key down and click on all the filenames.

2. Click **Open**.

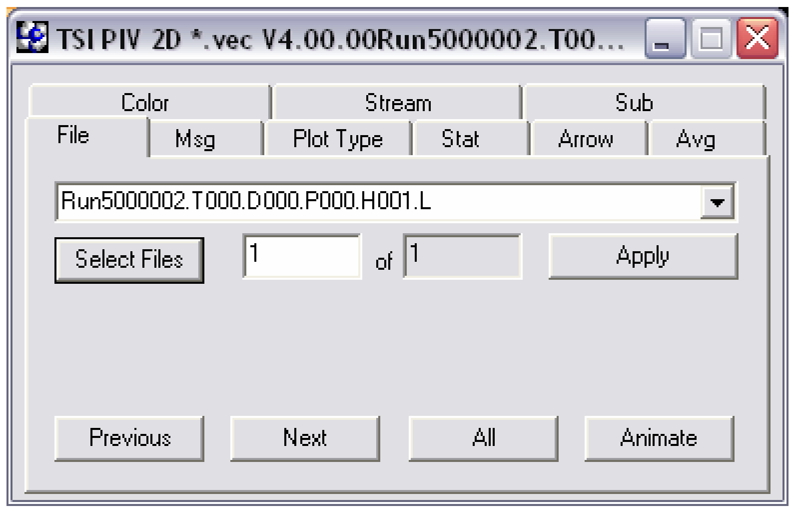
or

1. Select a group of files, highlight the first filename.

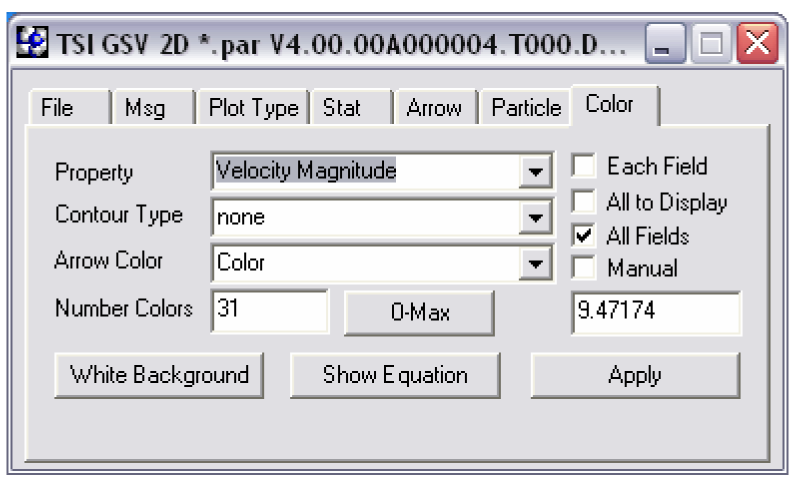
2. Hold <**Ctrl>**+**<Shift**> and click on the last filename.

3. Click **Open**.

The following dialog box will show if you choose vector files:



The following dialog box will show if you choose particle files:

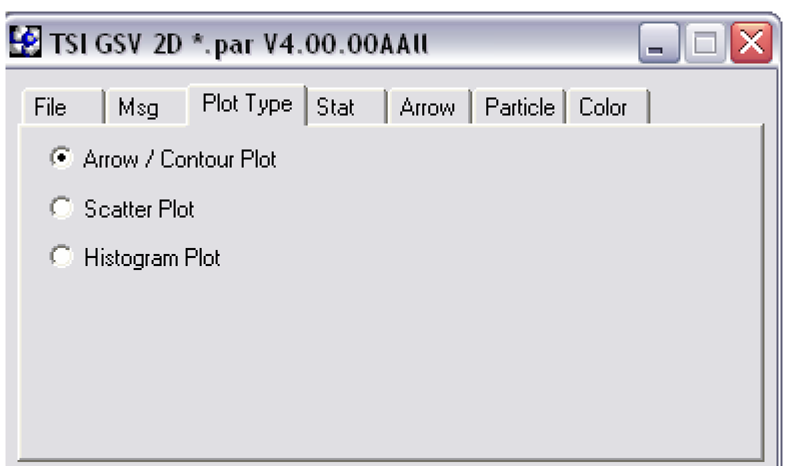


The following are other options available to open and display vector files.

Option	Description
Previous, Next	Use **Next** and **Previous** to change the displayed file by one in the file list. If you are already at the end of the list, the display file is not changed. To go directly to a specific file, open the File pull down list and select the file or type in a new number in the file number edit box. The display file number is updated when you change display file.
All	Use to display all open vector or particle fields together. Seeing all of the vectors or particles at a location shows the range of velocities at that point. When All is selected, the filename displayed on the graph changes to the experiment family name. When the All option is selected, the statistics page shows the statistics for all open vector or particle fields, including the average field if it has been created. Showing contours as colored arrows generally gives a better result with All selected. Reducing the number of displayed vectors with the Arrows page skip vectors may improve the display
Animate	Select to show all of the vector or particle fields in order. Display starts with the first field and stops when the last field is displayed. This Animate command updates the filename on the graph; the standard Tecplot Animate command does not. To record animations use the Tecplot Main Menu | Tools | Animate | Zones dialog.

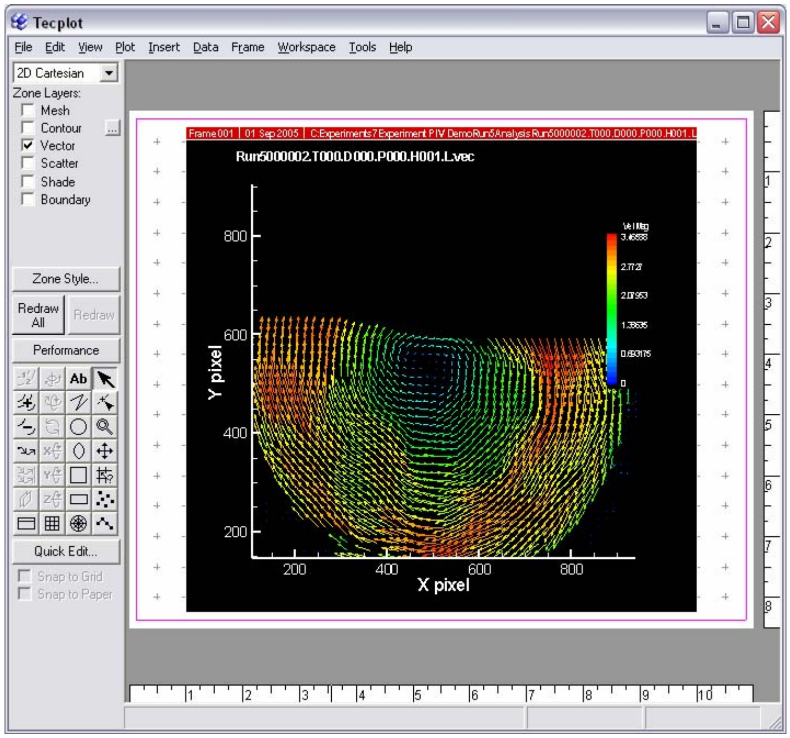
Selecting the Plot Types

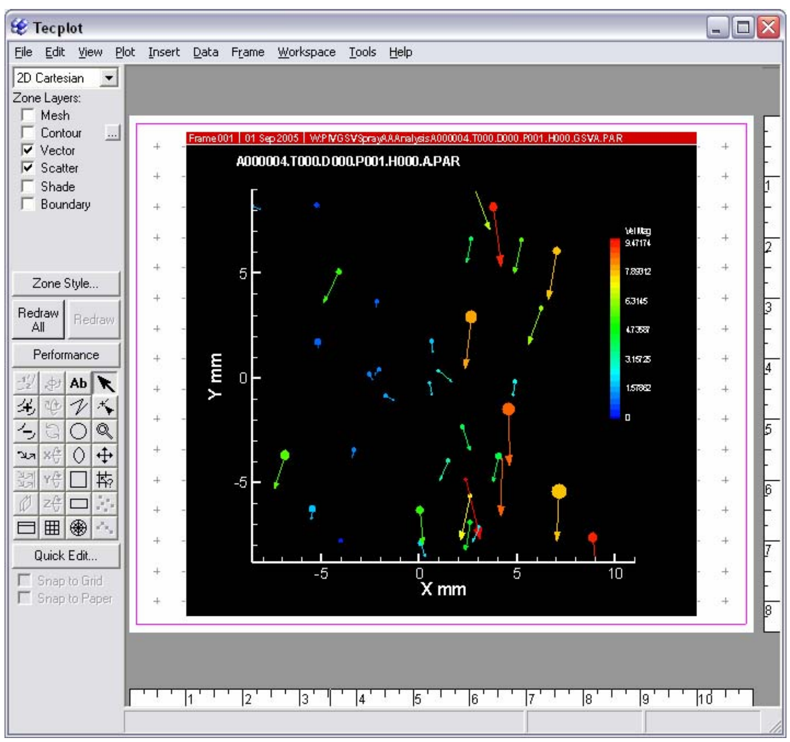
The Plot Type option is used to select the type of plot to display vectors and particles.



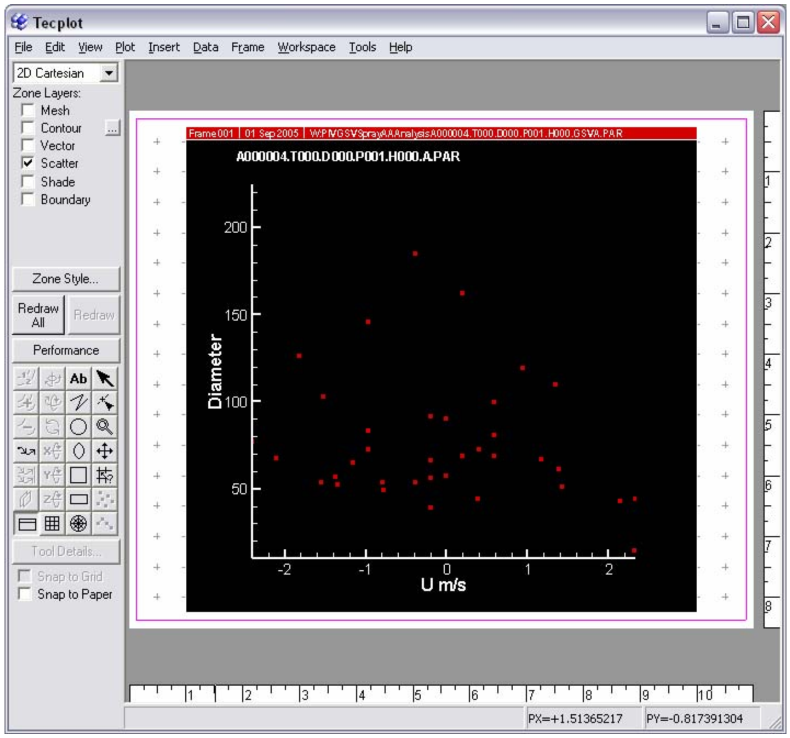
Examples of Different Plots

Arrow/contour plot for vector and particle files:

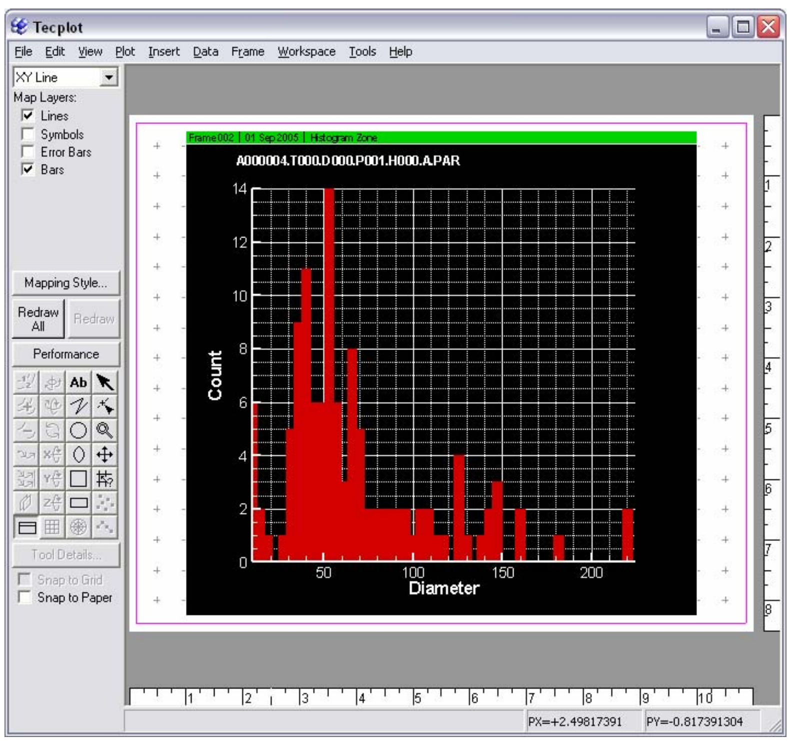




Scatter plot for vector and particle files:

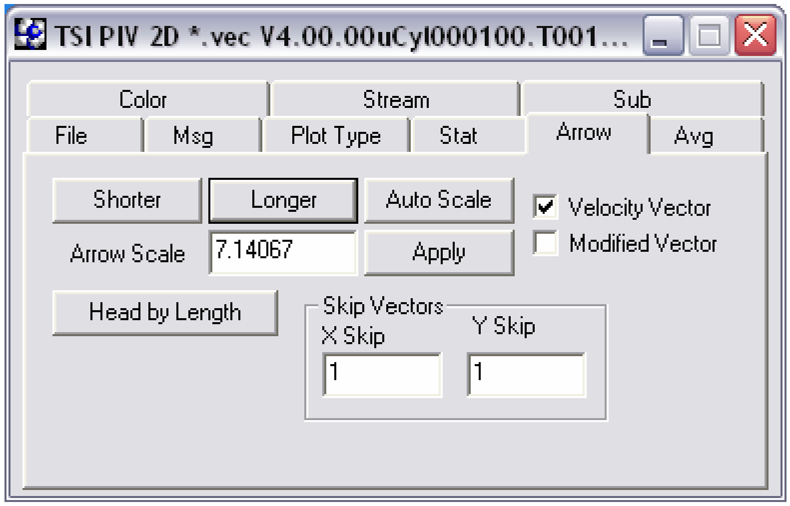


Histogram plot for vector and particle files:



Changing the Shape and Size of Arrows

The Arrow options are used to manipulate the shape and size of the arrows representing the velocity vectors.



To change the length of the arrows:

1. Click **Arrow** in the TSI Tecplot Add-On dialog box.
2. Use any of the following options:
    - Click **Shorter** or **Longer** to make the arrows shorter or longer than what is displayed. The arrow scale factor increases or decreases by √2.
    - Type in a scale factor directly into the Arrow Scale box.
    - Click **Auto Scale** to set the arrow scale to an optimized arrow scale based on the number of vectors and the maximum velocity.

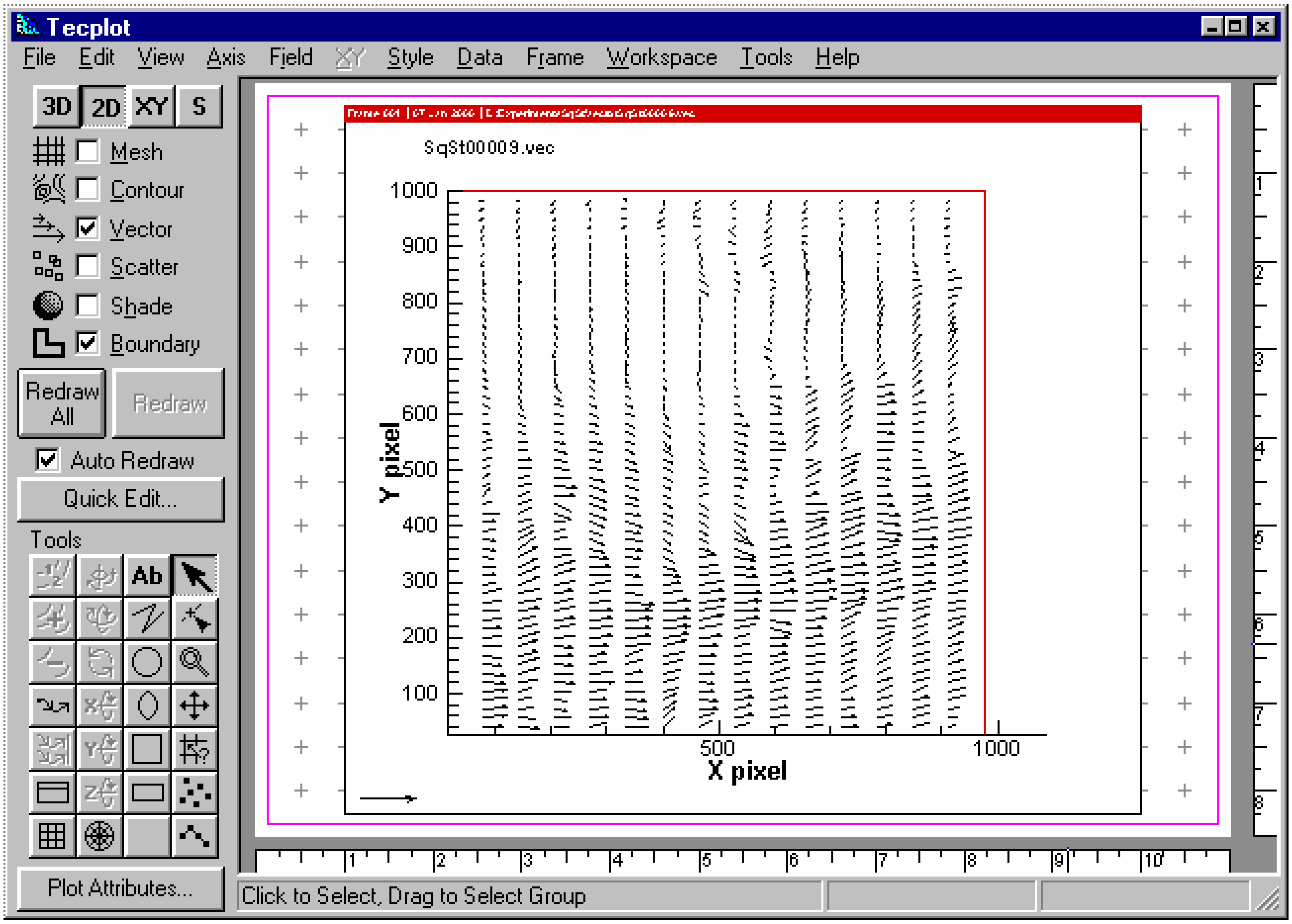
To toggle arrowhead length from fixed to a scale proportionate to arrow length:

- Click **Head by Length** or **Fixed Head**.

To control number of vectors to be displayed:

- Provide numbers in the Skip Vectors box. A skip value of 1 means show every vector, skip 2 means show every other vector.

  To improve visualization you may want to show a reduced vector field overlaid on flood contour field, like vorticity. When you do this, the contour values are computed at full resolution, but only some of the velocity vectors are shown. Using a vector skip in the direction of the flow may enhance your ability to see changes in the flow profile as shown in the following figure. The following figure shows the Vector field display using X Skip = 4, Y Skip = 1 to enhance the visualization of the flow profile with x position.



Selecting Velocity Vectors and Modified Vectors

Modified vectors are velocity vectors that have been modified in some way. If you have subtracted the mean velocity from the flow field, by toggling between the velocity vector and modified vectors, you may view the flow field from two perspectives. A modified vector field must have been computed to view the modified vectors. See "Subtract Options" for details.

To have velocity values read from the vector file:

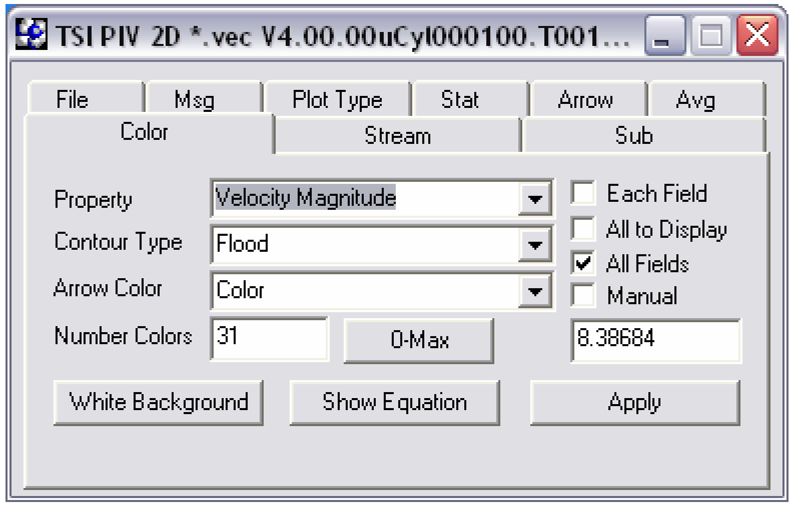
❑ Select **Velocity Vectors**.

To have modified velocity values read:

❑ Select **Modified Vectors**.

Setting and Changing Contour Properties and Color

The color tab options in TSI Tecplot Add-On allow you to control contour parameters and to set the color of the arrow displays. The following provides detailed descriptions of the color options.



Selecting Contour Property

This option allows you to select a contour parameter to be displayed. The properties lists are different for 2-D and 3-D vector fields. This property is the variable that is used for contour values and arrow color.

To select a contour property:

1. Click **Color** tab in the TSI Tecplot Add-On dialog box.
2. From the Property pull-down list, select a property. See "Table of Flow Properties" for a list of properties.

Table of Flow Properties

Property	File Type	Description
U	All	U velocity component
V	All	V velocity component
W	3-D	W velocity component
CHC/Count	All	Vector choice code for a single vector field, the number valid vectors at the node for an Avg field.
Velocity Magnitude	All	Flow velocity
Vorticity	All	Formula
DU/DY	All	Formula
DV/DX	All	Formula

Property	File Type	Description
DU/DX	All	Formula
DV_DY	All	Formula
-u'v' Reynolds Stress	Sequence	See Average Page | Compute Reynolds Stress/Density button
-u'w' Reynolds Stress	3-D Sequence	See Average Page | Compute Reynolds Stress/Density button
-v'w' Reynolds Stress	3-D Sequence	See Average Page | Compute Reynolds Stress/Density button
Residual	3-D	Residual error when computing the 3-D velocity from the left and right vectors using least squares fit. The error is the square root of the X, and Y errors, in pixels
Total Turbulence	Sequence Turbulence Computed	Velocity magnitude turbulence
U Turbulence	Sequence Turbulence Computed	U velocity component turbulence
V Turbulence	Sequence Turbulence Computed	U velocity component turbulence
V Turbulence	Sequence Turbulences Computed	U velocity component turbulence

Selecting Contour Type

This option allows you to select background contour.

To select a contour type:

1. Click **Color** in the TSI Tecplot Add-On box.
2. Select a property from the pull-down list. See Table of Contour Types for a list of contour types.

Table of Contour Types

Contour Type	Files	Description
None	All	Background contour off
Flood	All	Contour shown as filled colors
Color Line	All	Color coded lines show the divisions between contour thresholds
Flood + Line	All	Flood contour with the contour divisions highlighted with black lines
Black Line	All	Contour shown as black lines, good for laser printing
Carpet Plot	3-D	Mesh connecting the vector heads. Shows a surface with 3-D deformation of the flow. To turn off the mesh using the Tecplot Mesh check box, under File on the main menu.

Selecting Arrow Colors

You can select color codes to go with contour parameter values for the arrows. Using colored arrows is effective for showing a flow parameter with high-resolution vector fields, where adding a background contour makes the graph too cluttered.

Use black arrows to show the velocity field overlaid on a contour background.

To select arrow colors:

1. Click **Color** tab in the TSI Tecplot Add-On box.
2. Select a color from the Arrow Color pull-down list. Select **Off** to turn off the arrow display. This is a useful setting for viewing the contour background.

Selecting Number of Colors

You can select number of colors to represent the number of contour threshold values in the graph. Using a high number-up to 151, gives the smoothest flood contour plots and colored arrows. Using few contours gives better-looking line contour plots. The display speed slows down with more colors.

To select number of colors:

1. Click **Color** tab in the TSI Tecplot Add-On dialog box.
2. Type in a number in the Number of Colors box.
3. Click **Color Scale** to select the range of colors used in the plot. The range options change with the parameter shown. Properties that can be either positive or negative, like U, V, W, Vorticity, dU/dy, …can be scaled with Symmetric where the maximum value = -1 x minimum value. With symmetric, the contours are symmetric about 0 and 0 is always green. Range sets the minimum and maximum contour values to the minimum and maximum values in the data. 0 is not always in the center of the graph.

   Properties that are always positive like Velocity Magnitude and Turbulence can be shown with a color scale from 0 to maximum, or the actual velocity range.

   CHC/Count is an integer field and does not allow scaling options.

Selecting Contour Color Range

The contour color range can be selected by choosing one of four options.

Note: *For Each Field, All to Display, All Fields settings, the contour levels are automatically set according the contour parameter range for one or all vector fields.*

To select the contour color range:

1. Click **Color** tab in the TSI Tecplot Add-On dialog box.
2. Select one of the following check boxes:

Field	Description
Each Field	Select to set the contours for each vector field as it is displayed. When you animate a sequence of vector fields, the colors are set so that each vector field has the full range of colors. This is helpful in seeing the pattern in each vector field, but makes comparing the values between vector fields more difficult.
All to Display	Select to set the contour levels according to the range of current display field. The same range is used for all vector fields during animate.
All Fields	Select to set the contour range to the range of all open vector fields. The same range is used for all vector fields during animate.
Manual	Enter a value for setting the contour levels in the box below.

Selecting a Background

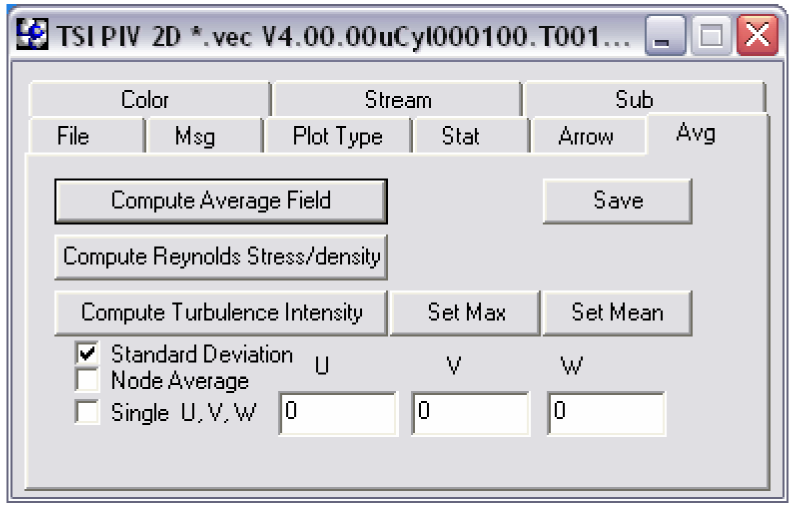
Use this option to toggle the display background color between black and white. The black background is usually preferable when displaying on the computer monitor while the white background works well for printing

To toggle background color:

1. Click **Color** in the TSI Tecplot Add-On box.
2. Click **Black Bkgrnd** or **White**.

Computing Average Fields and Other Quantities

The Average set of options are used when average vector field and other quantities from the *INSIGHT 3G* vector files need to be calculated. The following describe the features available in this set.



Computing Average Fields

This option allows you to compute the average field which is the mean of the valid velocity vectors at each point. The number of valid vectors is stored in the CHC (choice) data column. (See "*INSIGHT 3G* Data Files"). The average contour field is the average of the contour values at each location. This is not the contour of the average vector field. The average field can be subtracted from each individual vector field provided in the subtract tab option. See "Average Vector (*AVG.VEC) File" for more information.

To compute average fields:

1. Open all vector fields to be included. See "Selecting and Reading Files into Tecplot."
2. Click **Avg.** tab in the TSI Tecplot Add-On dialog box.
3. Select **Compute Average Field**.
4. Click **Save**.

Computing Reynolds Stress/Density

This option allow you to compute the Reynolds Stress for a 2-D vector field, the average velocity field is computed and appended to the vector field list. The average only includes the valid vectors so each node may have a different number of vectors. This gives the average u and v velocity at each vector node. The average velocity field is subtracted from each of the instantaneous vectors giving u' and v' for each vector. The -u' and v' components for each instantaneous velocity vector are multiplied giving -u'v'. The -u'v' values are averaged at each node giving the Reynolds Stress for the sequence of vector fields. When the Reynolds Stress is shown as the contour parameter, the sequence Reynolds Stress is shown as the contour parameter for each of the instantaneous vector fields.

When 3-D vector fields are used, the average W and w' are also computed and the Reynolds Stress values -u'w' and -v'w' are computed.

Reynolds Stress includes a density term that is not included in the Tecplot equation. To compute the actual numerical value of Reynolds Stress, multiply the compute value of Reynolds Stress/Density by the density.

Note: *The Reynolds Stress -u'v', -u'w' and -v'w' values are not normalized.*

To compute Reynolds Stress/Density:

1. Open all vector fields to be included. See "Selecting and Reading Files into Tecplot."
2. Click **Avg.** tab in the TSI Tecplot Add-On dialog box.
3. Select **Compute Reynolds Stress/Density.**
4. Click **Save**.

Computing Turbulence Intensity

This option allows you to make turbulence computations. If it does not already exist, it creates an average velocity field, then computes the turbulence intensity using the formula specified. The Total Turbulence intensity is displayed when the computations are complete.

To compute Turbulence Intensity:

1. Open all vector fields to be included. See "Selecting and Reading Files into Tecplot."
2. Click **Avg.** tab in the TSI Tecplot Add-On dialog box.
3. Make the following selections:

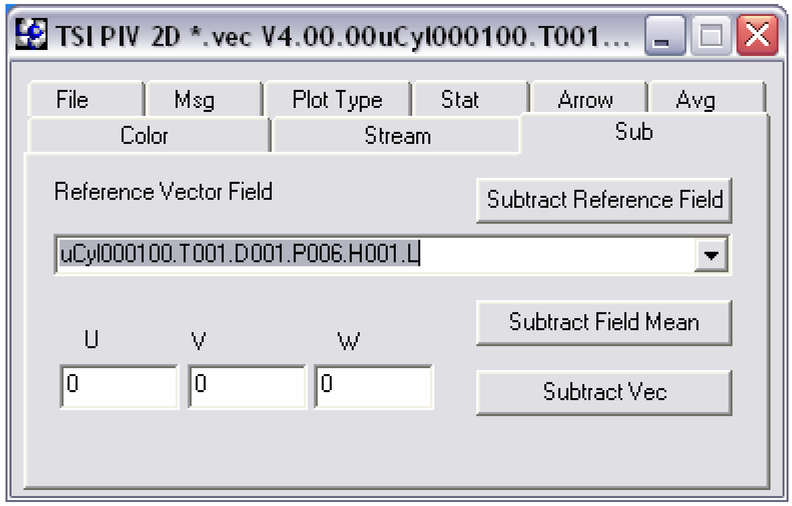
Option	Description
Standard Deviation	Select this check box if the turbulence is to be computed by the standard deviation of the velocity vectors at the vector node location. The Standard deviation is divided by a velocity value in the other two turbulence formulas.

Option	Description
Node Average	Select this check box if the standard deviation of the velocity values is divided by the average velocity at the node. Each vector uses the local average velocity with node average. With Node Average a high turbulence reading may be caused by either a wide range of velocity values at the point or by a low average velocity value. The Max Turbulence is used to clip the maximum turbulence computed.
Single U, V, W	With Single U, V, W, the velocity standard deviation at each node is divided by the same velocity value. You may set this velocity to divide by any positive value you want. The velocity used is shown to the right of the Single U, V, W Check box. **U, V, W** The velocity value used for Single U, V, W Turbulence. Enter velocity values by editing the numbers, or by clicking **Set Mean** or **Set Max**. The velocity components must be positive. You may only edit the W velocity component with 3-D vector fields. The turbulence values are clipped to this maximum value. This is most useful with Node Average Turbulence where the divisor may be near zero. **Set Mean** Fills in the mean U, V, W (for 3-D vector fields), of the Average vector field into the Velocity U, V, W boxes in the Single U, V, W Turbulence computation. **Set Max** Fills in the maximum U, V, W (for 3-D vector fields) of the average vector field and not the velocity U, V, W edit boxes used in the Single U, V, W Turbulence computation.

4. Click **Compute Turbulence Intensity**.
5. Click **Save**. This saves the average vector field both with and without turbulence information to disk. A sequence of vector fields must be open for the averaging to work. If 2-D *.vec files are open, familyAvg.vec and familyAvg.std are stored to disk. If 3-D *.v3d vector files are open, the average fields are saved as familyAvg.v3d and familyAvg.v3s, when “family” is the name entered in a file save dialog. The average *.vec and *.v3d files have the same file format as the individual vector files so they may be opened as part of sequence with individual vector files. The *.std and *.v3s include the velocity standard deviation for each vector node. This allows you to view the turbulence information without having to open up the full sequence of files. Since the file formats are different, the *.std and *.v3s files may not be opened with a sequence of *.vec or *.v3d files.

Subtracting Vector Files

The Subtract tab options allow you to manipulate the vector fields.



The following provides detailed descriptions of these options.

Subtracting Reference Field

The **Subtract Reference Field** button subtracts the selected reference vector field from each open vector field. If you have computed an average vector field, it is used as the default reference field. You can select any open vector field as the reference field by selecting it from the pull-down list. The subtract reference field subtracts the reference velocity from the vector field velocity on a vector node by vector node basis.

Subtracting the average velocity field breaks the vector fields up into the average velocity, average velocity value, and fluctuating velocity, the individual vector field—the average vector field.

The graph title shows the name of the reference vector field that has been subtracted.

To subtract reference field:

1. Open all vector fields to be included. See "Selecting and Reading Files into Tecplot."
2. Click **Sub.** tab in the TSI Tecplot Add-On dialog box.

3. Select:

Subtract Mean Velocity

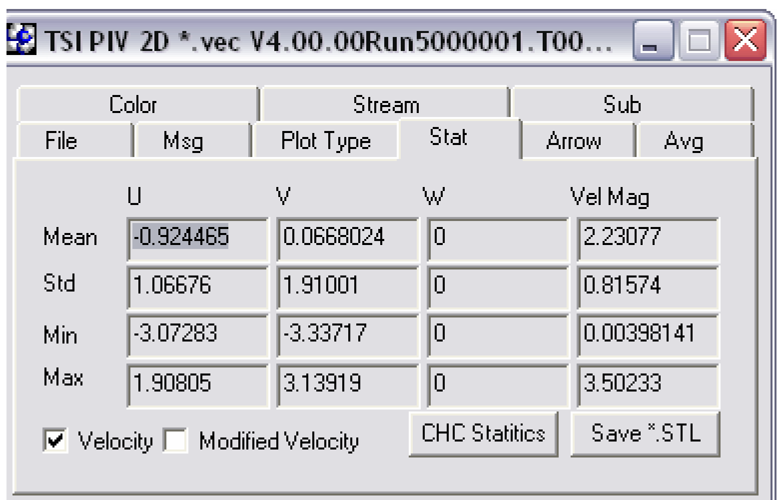
Computes the mean velocity of the currently displayed vector field and subtracts that velocity vector from each vector in each vector field. The graph title shows the velocity value subtracted.

Subtract Vec

Subtracts the user input U, V, W vector from each vector in each open vector field.

Statistics Options

The Statistics tab has options to show the velocity component and contour parameter mean, standard deviation, minimum and maximum values of the currently displayed vector field. If all fields are being displayed, the statistics are for all of the open vector fields. The contour statistics are shown for the currently displayed contour parameter.



Velocity/Modified Velocity Check

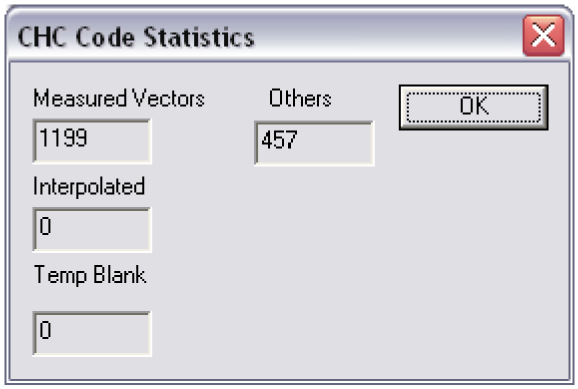
You can look at the statistics of either the actual velocity values or the modified velocity values. You may want to look at the statistics of the modified vectors if you have subtracted the mean vector field, then the modified vector field gives information about the variations from the mean.

CHC Statistics Button

Opens the vector editing statistics dialog box.

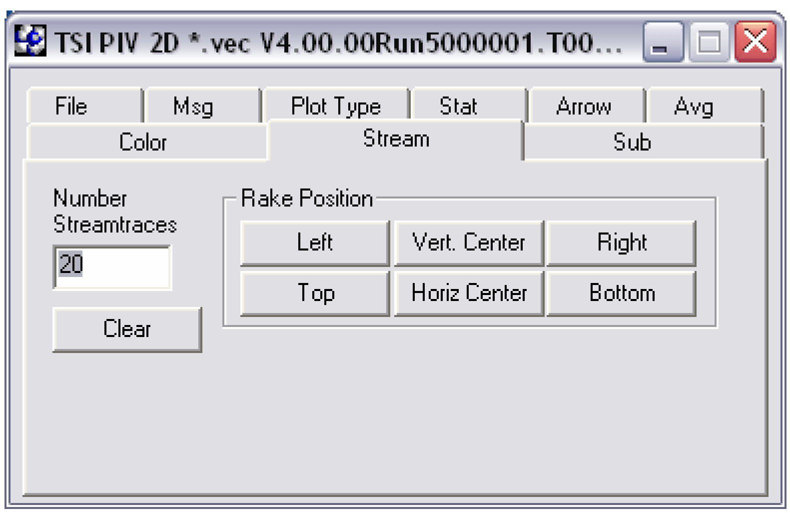
CHC Choice Code Statistics Dialog

The Choice Code Statistics show the source of the velocity vectors. Measured vectors are vectors directly from the processing of the image. Interpolated vectors are places where the surrounding vectors were interpolated to fill in the holes. Temp Blank means the vector has been removed by vector editing and could be filled in with an interpolated vector. Other includes points removed from the vector field by Polygon Edit, SNR failure vectors and Smoothed vectors. The Choice Code Statistics Dialog screen is shown below.



Stream Option

A stream trace shows the hypothetical path of a particle in the vector field assuming the velocity at each point remained constant. The figure below shows the Stream trace tab options.



Number of Stream Traces

Each time a rake position button is pressed, that many stream traces are added to the display. If 30 stream traces are selected and you press Left and then Right, a total of 60 stream traces are shown.

Clear

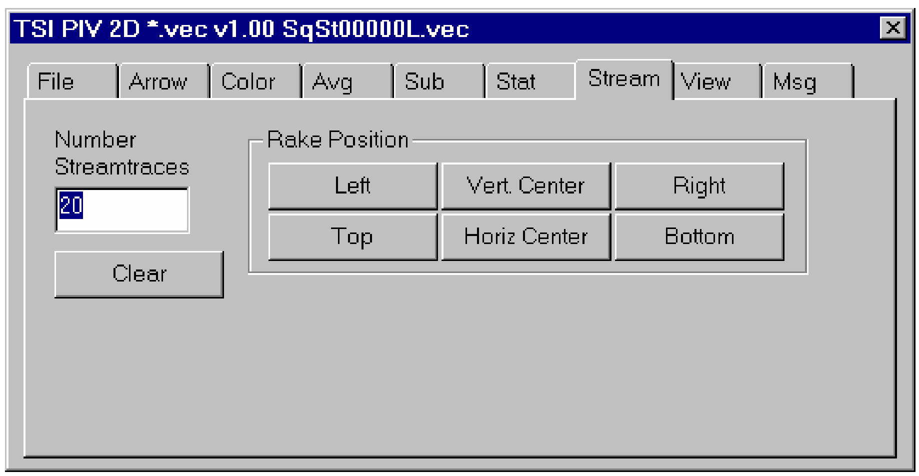
Erases the stream traces from the graph.

Rake Position

The rake is a line divided with the Number of Stream traces that are the starting position of the stream traces. The stream traces are equally spaced at the rake position. The stream traces are computing in both forward and reverse directions. By selecting a rake position you can see how the flow moves relative to the location. The left, right, bottom, and top rakes are positioned a small distance from the edges.

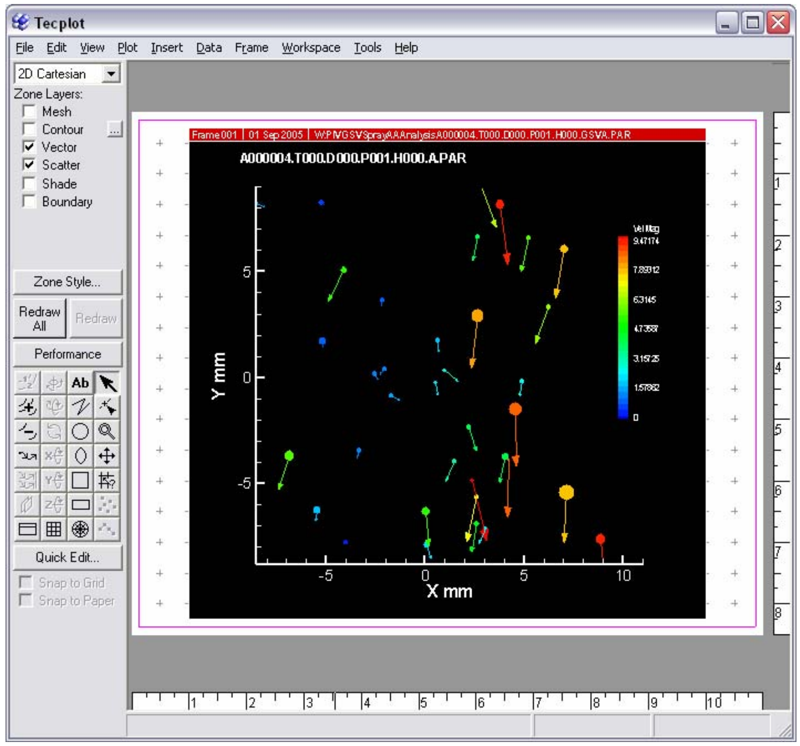
View Option

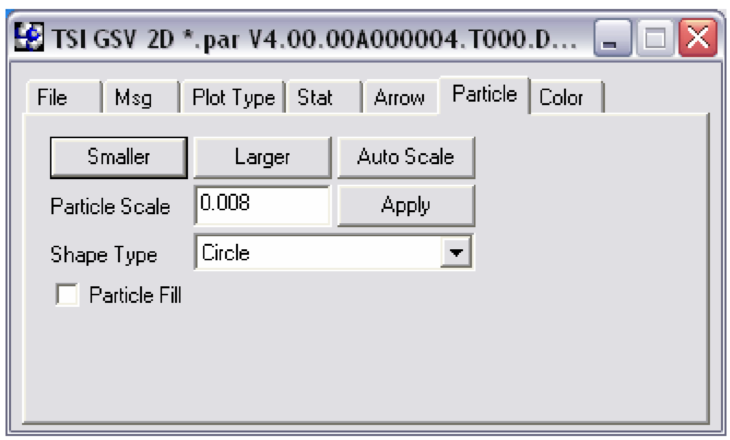
The view page is used with 3-D vector fields only. It has a set of seven preset viewing angles. Switching view positions can help in visualizing the third velocity component. The **Tecplot Main Menu | View | 3D Rotate** dialog can be used for full control of the viewing perspective. The View Page screen is shown below.



Changing the Shape and Size of Particles

The particle options are used to manipulate the shape and size of the points representing the particle sizes.





To change the size of the points:

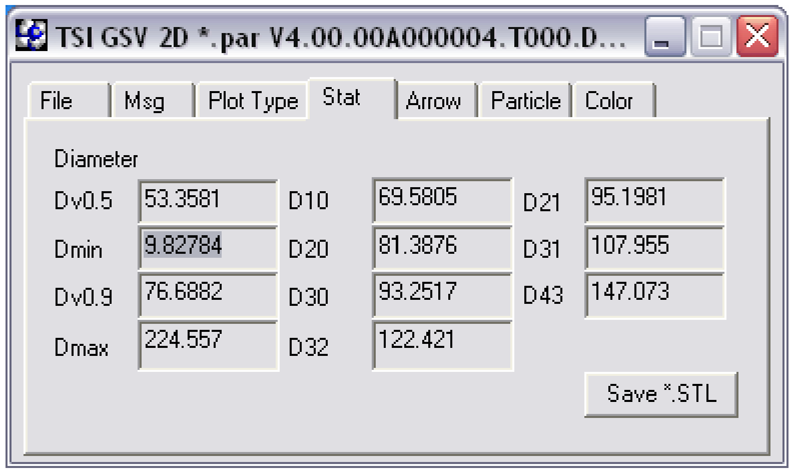
1. Click **Particle** in the TSI Tecplot Add-On dialog box.
2. Use any of the following options:
   - ❑ Click **Shorter** or **Longer** to make the arrows shorter or longer than what is displayed. The arrow scale factor increases or decreases by √2.
   - ❑ Type in a scale factor directly into the Arrow Scale box.
   - ❑ Click **Auto Scale** to set the arrow scale to an optimized arrow scale based on the number of vectors and the maximum velocity.

To change the shape of the points:

1. Click **Particle** in the TSI Tecplot Add-On dialog box.
   - Select the shape from the Shape Type list. Check Particle Fill to fill colors within the shape.

Viewing the Statistics of Particles

The Stat options are used to display the statistics of particle sizes.

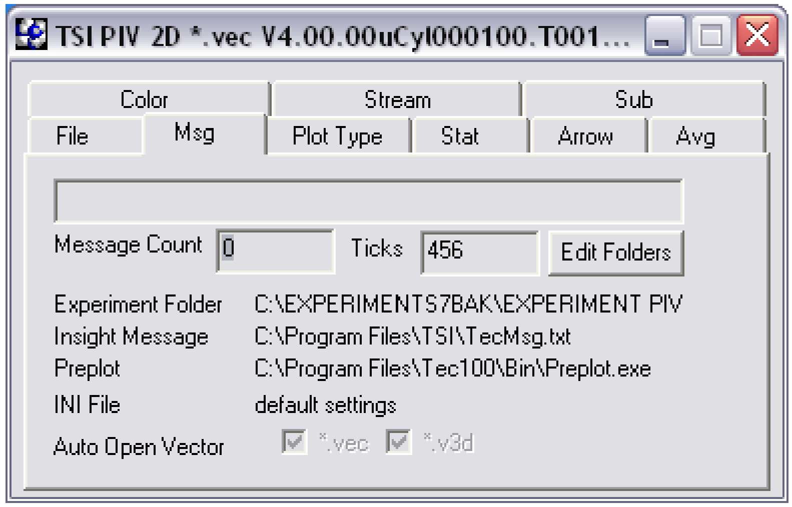


To view the statistics of particle statistics:

1. Click **Stat** in the TSI Tecplot Add-On dialog box.

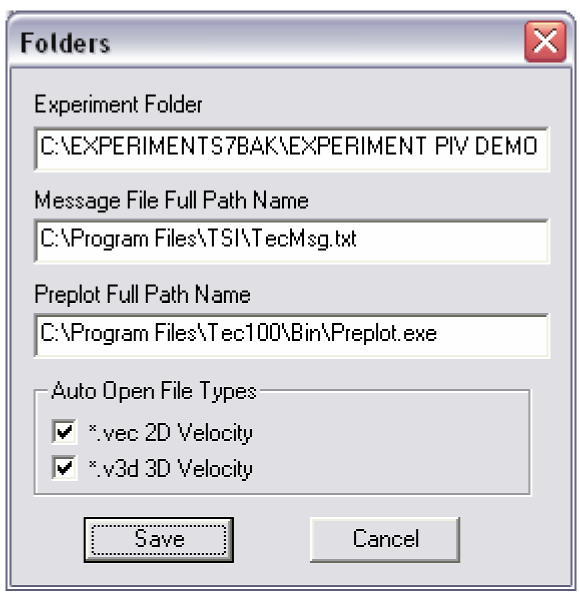
Message Option

The Message page shows the folders of the programs that TecPIV communicates with. To change from the default folders, press the **Edit Folders** button. The Message Count shows how many messages from *INSIGHT 3G* have been received, the Ticks field increments each time TecPIV checks for a new message from *INSIGHT 3G*. When a message is received, it is shown in the box above the message count. The figure below shows the Message Page screen.



Auto Open Vector Files Check Boxes

Use these check boxes to turn on or off the types of files Tecplot automatically displays from INSIGHT 3G. Use the Edit Folders button to have Tecplot remember the selections. To view V3D stereo 3-D vector fields but not the 2-D *.VEC files, uncheck the *.VEC box and check the *.V3D then Tecplot will only auto display the 3-D fields. To temporarily turn off the auto display so that you can change the display parameters without being interrupted by reading new vector fields, uncheck the boxes, go to the other pages and set the display parameters you want, then check the boxes and have the new vector fields displayed with your desired view.



Edit Folders Dialog

The Edit folders dialog shows the locations where TecPIV will look for files.

Experiment Folder

The Experiment Folder is the directory that is the starting point the first time you press the Select Files Button in the file page. When this is the root folder where your PIV vector files are located, you will have less navigation to do to open vector files. When a file has been opened it that folder, it becomes the starting location for the next Select Files.

Message Folder

INSIGHT 3G communicates with TecPIV by writing a file named Message.txt into this folder. This folder must be set to the location that *INSIGHT* 3G is writing messages into for the messages to be received.

Preplot Path Name

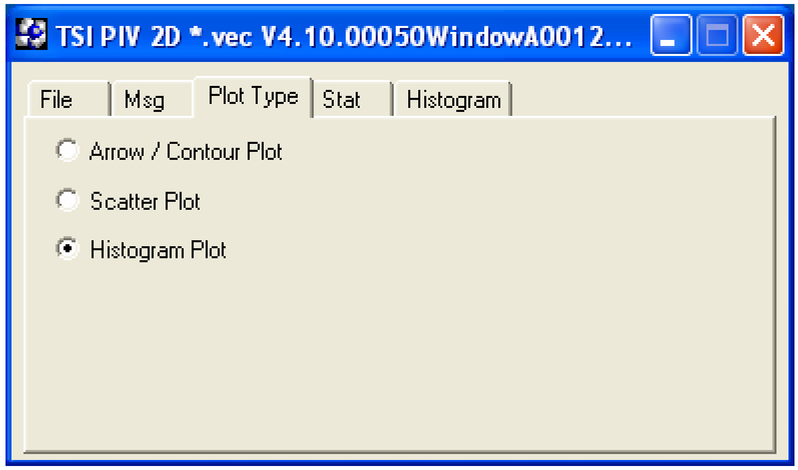
This is the full path name to the file Preplot.exe. Preplot is part of the Tecplot package and is usually in the Tecplot\Bin\ folder. If you are not using the latest version of Tecplot you will probably have to change this to your Tecplot\Bin folder. Preplot is used to convert *INSIGHT* 3G ASCII files into binary files that can be opened faster by Tecplot.

Save Button

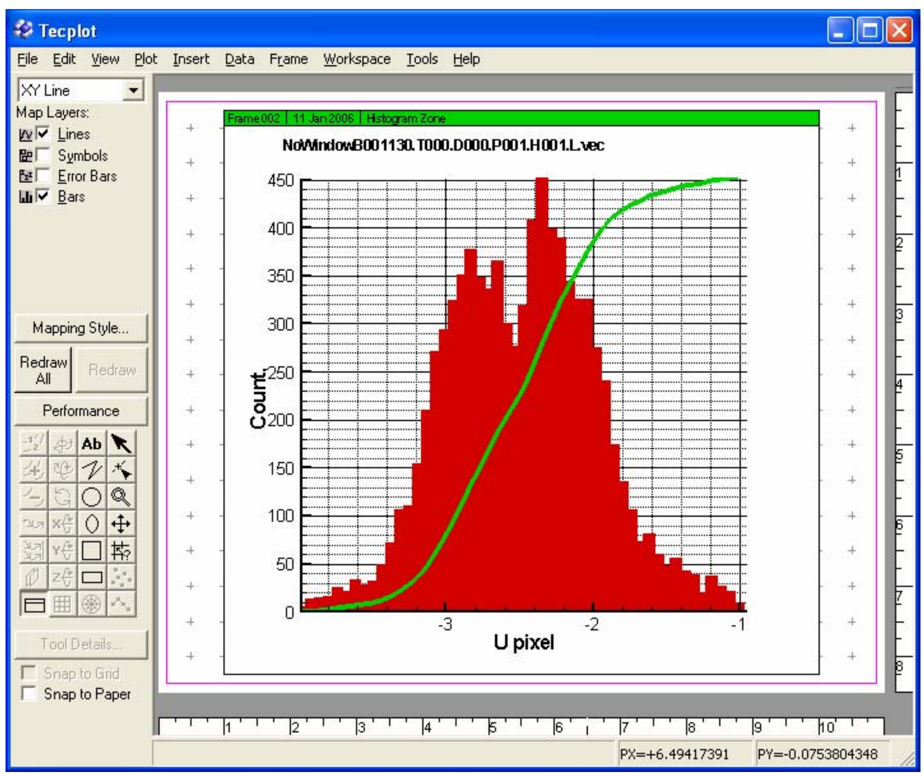
The Save button writes the folder information into a TecPIV.INI initialization file. Each time TecPIV is launched, it checks to see if TecPIV.INI is available. If it is, your stored values are automatically loaded. If TecPIV.INI is not found, the default values are shown. If the TecPIV.INI file format has changed since you saved it, a warning box showing the default values will be used. The Edit Folders Dialog screen is shown below.

Histogram Plot

The data can be displayed as a histogram by selecting the Histogram Plot radio button in the Plot Type Page. A data file must be open for the Plot Type Tab to be displayed. The plot files are selected on the file page. To view the histogram from a single data file, select the file with the **Forward** and **Next** buttons. The histogram of multiple data files can viewed by selecting the **All** button. The following screen shows the plot type page with histogram plot selected.

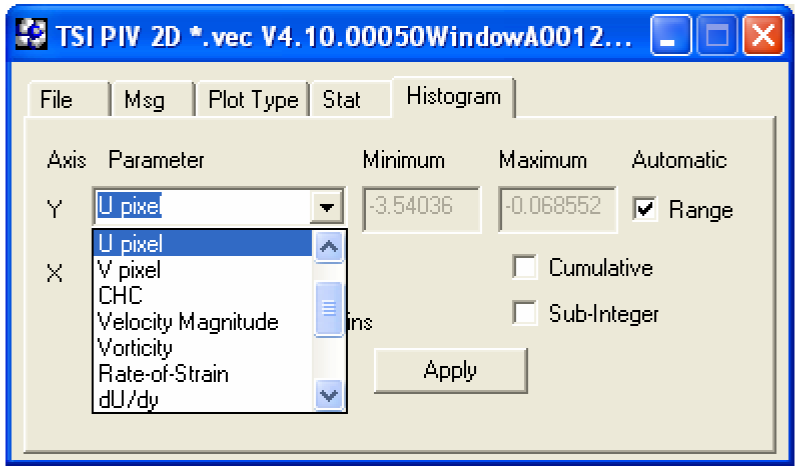


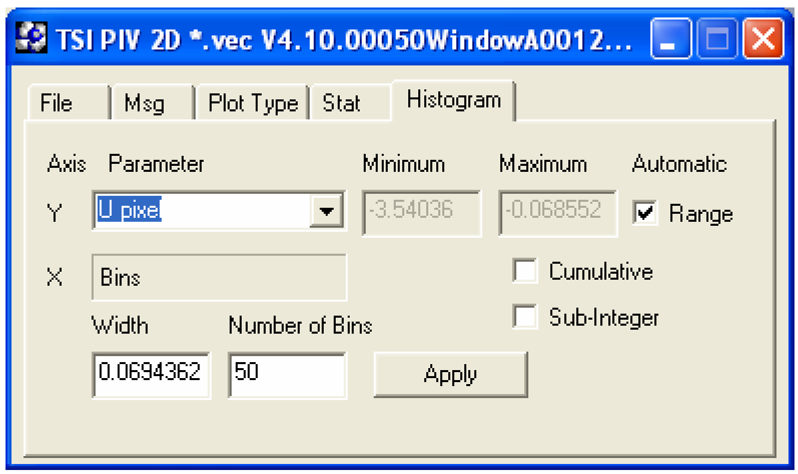
The histogram is only displayed when the Histogram page is selected. When another page is selected, the display goes back to the Arrow and Contour or Scatter plot. Selecting the Histogram page again returns the histogram graph. The following screen shows a histogram plot with cumulator enabled.



Y-Axis Parameter Selection

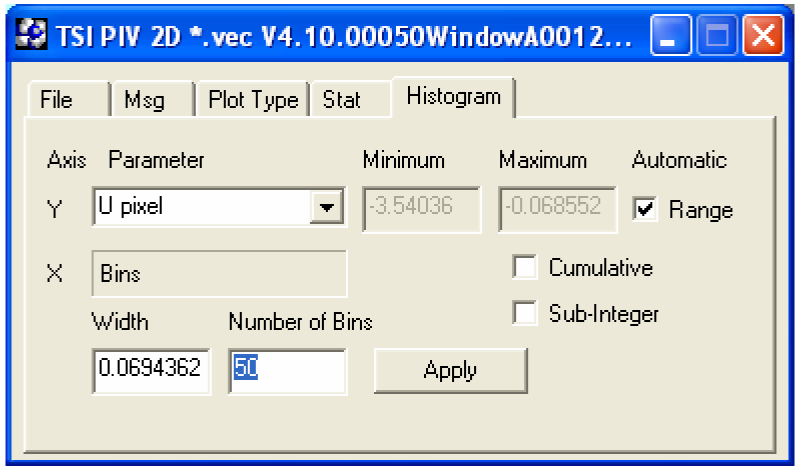
The parameter to plot is selected from the Y-Axis Parameter pull down menu.





Bin Width and Number of Bins

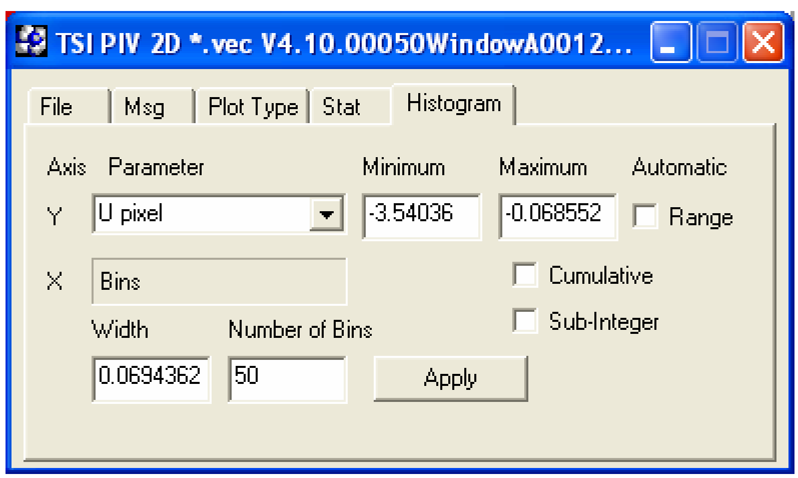
The histogram Bin Width and Number of bins are edited by entering a value in the edit boxes. The entered value takes affect when you select another parameter to edit or press the **Apply** button. When a Bin Width or Number of Bins value is changed, the other value is recomputed so that the bins fill the range from Minimum to Maximum.



Range

The histogram is plotted with X-Axis values from the range minimum to maximum.

When the Automatic Range box is checked, the minimum and maximum range values are set to the minimum and maximum values from the data files. The range is recomputed each time the Y-Axis Parameter or display data file is changed. cted parameter.



When the Automatic Range is not checked, you may enter the minimum and maximum X-axis values to plot. The values you enter will take affect when you select another edit field or press the **Apply** button.

The manual range values will remain the same when a different Y-Axis Parameter or data file selected. If the histogram is blank, try switching to Automatic Range to see the actual data range and use this information to help in resetting the manual range.

Cumulative

When the Cumulative box is checked, a line representing the percentage of counts less than each bin is plotted with the histogram. The cumulative line is scaled from 0% at the bottom of the graph to 100% at the graph top.

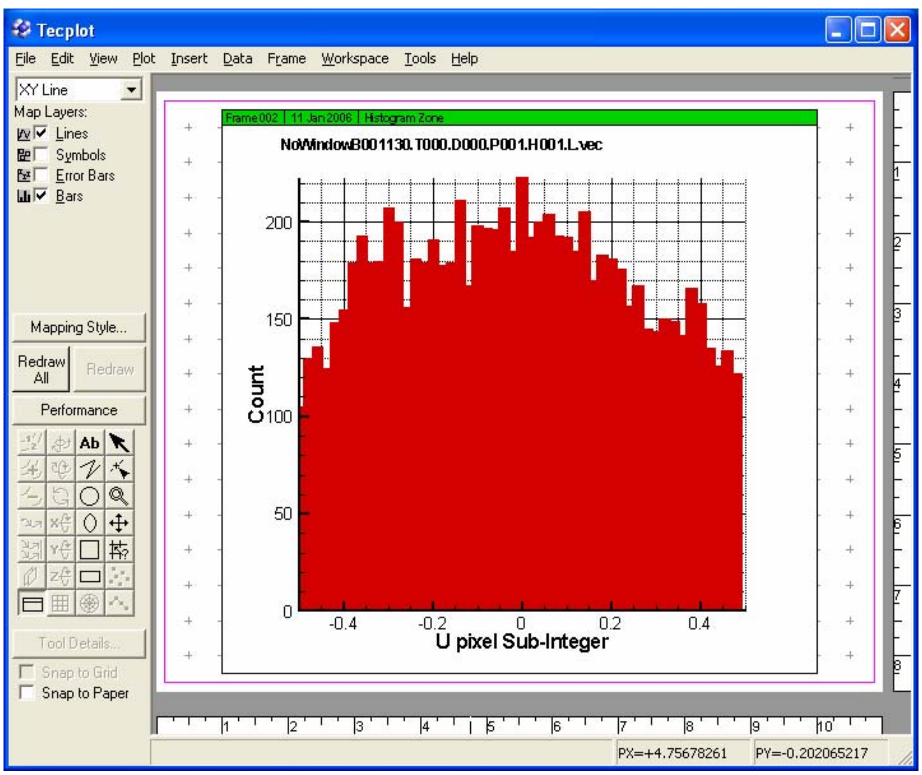
Sub-Integer Plot

The Sub-Integer check box was designed to give a "Peak Locking" display. Peak Locking is a bias that gives more readings near integer pixel displacements and fewer readings near integer +0.5 locations. When the sub-integer box is checked, the value plotted in the histogram is:

Parameter Value – round(Parameter Value)

This formula gives a value from –0.5 to +0.5. The sub-integer minimum and maximum X-axis range is fixed to –0.5 to +0.5. When the histogram has a high number of counts in the center (integer displacement) and few counts at the edges (integer –0.5 and integer +0.5), peak locking may be the reason.

The following screen shows a Sub-Integer Histogram Plot.



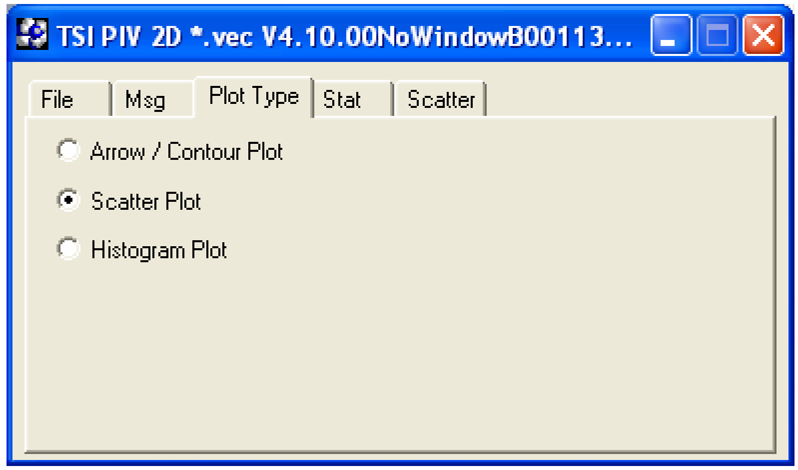
The histogram from a single vector file may not have enough data points to give a clear view of the pattern. To fill in the histogram you can select multiple files in the file page, and then select **All** on the file page before switching to the histogram view.

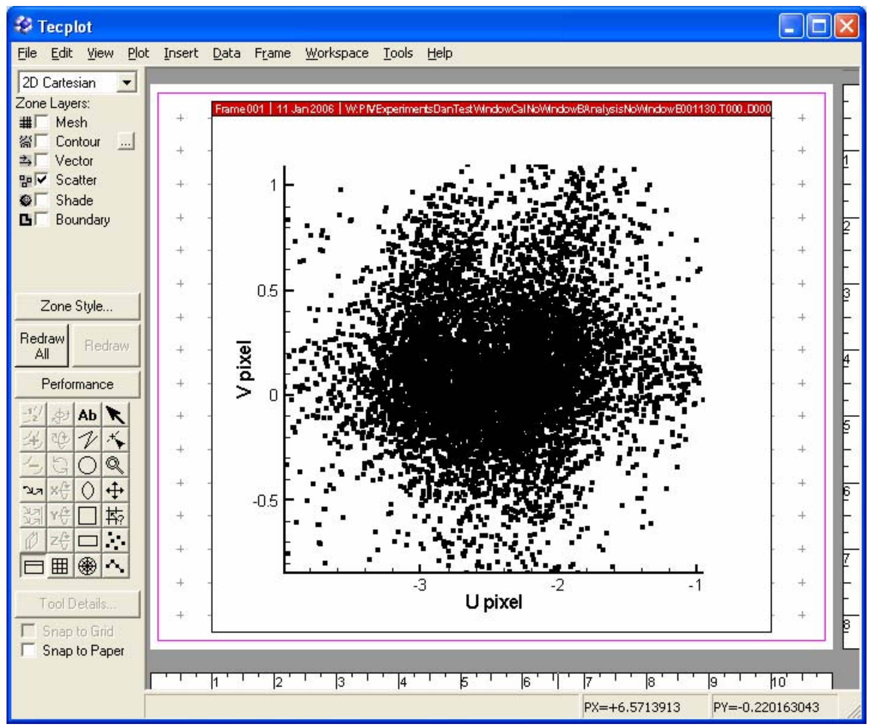
Some care needs to be exercised in interpreting the peak locking graph. If the velocity range is small (l pixel range less), the graph may look like it has peak locking, when it is really a reflection of a small displacement range. Increasing the time between laser pulses (dT) will increase the displacement range and may make the measurements more accurate. A flow may happen to have more displacements at integer pixel values than half integer values. You can test for this by changing the time between pulses (dT) by a small amount checking if the most counts are still at the integer location.

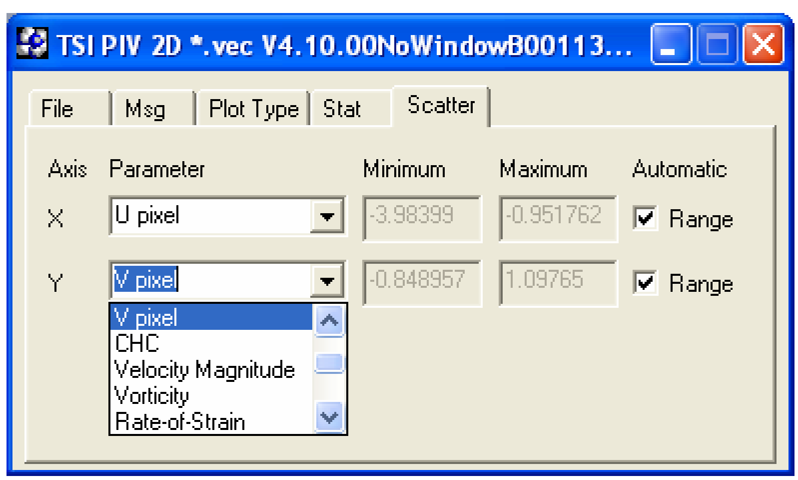
The degree of peak locking is a function of both the images and the processing. When the particles are imaged as single pixel in size, the processing will be peak locked because the image does not contain enough information in the neighboring pixels to locate the particle to sub-pixel accuracy. Displacement peak locating algorithms are typically optimized for 3-pixel diameter particle images, so the imaging should also be optimized to capture 3-pixel diameter particle images. In processing, the general rule is that Hart correlation has more peak locking than FFT correlation, and deformation grid processing reduces peak locking over Nyquist, Recursive Nyquist, or Rectangular grids.

Scatter Plot

The Scatter Plot graphs the data points on two axes. You can select any parameter for the X- and Y-axis for plotting. To create a scatter plot, first open a data file using the File page controls. Go to the Plot Type page and select the **Scatter Plot** option. And the graph will switch to a scatter plot.


TSI PIV 2D *.vec V4.10.00NoWindowB00113...
File
Msg
Plot Type
Stat
Scatter
Arrow / Contour Plot
Scatter Plot
Histogram Plot


Tecplot
File Edit View Plot Insert Data Frame Workspace Tools Help
2D Cartesian
Zone Layers:
Mesh
Contour
Vector
Scatter
Shade
Boundary
Zone Style...
Redraw All
Redraw
Performance
Tool Details...
Snap to Grid
Snap to Paper
V pixel
U pixel
PX=+6.5713913
PY=-0.220163043


TSI PIV 2D *.vec V4.10.00NoWindowB00113...
File
Msg
Plot Type
Stat
Scatter
Axis
Parameter
Minimum
Maximum
Automatic
X
U pixel
-3.98399
-0.951762
Range
Y
V pixel
-0.848957
1.09765
Range
V pixel
CHC
Velocity Magnitude
Vorticity
Rate-of-Strain

With the Scatter page you can select the parameters for plotting on the X- and Y-axis. Any pair of parameters can be plotted together. Seeing pattern of the two parameters may give some insight into the flow behavior. To set the parameter for the X- or Y-axis select it from the pull down list. The graph range can either be set to Automatic ranging which set the limits to display all of the data points or manual where you can enter the display limits. To manually set the graph limits, deselect the Range and then you can enter the Minimum and Maximum range value. The change takes affect when you leave the text field by selecting a different edit field.

Troubleshooting

Normally TecPIV is installed with the INSIGHT 3G software.

If you are having trouble launching TecPIV for Tecplot, you need to make sure that the following dlls are located in the Tecplot\Bin folder.

- For Tecplot version 10 or higher: PIVPlot.dll
- For Tecplot versions 7.5 through 9: TecPIV.dll

Note: *These instructions use TEC\ for the Tecplot folder. This could be C:\TEC75\, C:\TEC80\, C:\PROGRAM FILES|TEC90, or other folder on your computer.*

To use the add-on as a replacement for the Quick Macro Panels, you just need to follow the following steps.

Copy TecPIV.dll or PIVPlot.dll to TEC\Bin Folder

Copy the file from C:\Program Files\TSI\Insight 3G to your TEC\Bin. Tecplot looks in this folder for Add-On dlls.

If you cannot see the dll files using Windows Explorer, change your Explorer setting by selecting **View | Options** to open the view options and select **Show All Files**, be sure **Hide** files is not selected.

Edit TEC\Tecplot.Add

The TSI Tecplot Add-On will be run when Tecplot is launched if the LoadAddon command for the PIV Add-On is included. Open your **TEC \Tecplot.Add** using Notepad (**Start | Programs | Accessories | Notepad**). Go to the end of the file and add this line:

```
$! LoadAddon "TecPIV"
```

or

```
$! LoadAddon "PIVPlot"
```

Save the file using the Notepad **File | Save** command.

Verify that the Add-On Starts

Verify that the add-on works by starting Tecplot. The TSI Tecplot Add-On will open up if it has been installed properly and if the add-on is in the correct folder. If the TSI add-on does not open with Tecplot, verify that the dll is in the TEC \BIN folder and that the LoadAddOn “TecPIV” has been saved in TEC\Tecplot.Add.

For Further Information

For further information, contact:

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WWW:	http://www.tecplot.com

CHAPTER 15

Programming Macros

INSIGHT 3G provides an easy and visual interface to program your capture and experiment settings and automate it for subsequent use through macros. Using built-in macros you can automate the capture process to compare results with multiple schemes, validate results using different criteria, and process data using different conditions.

Each time you save the settings for the following tasks, the settings are also saved and available in the macro programmer interface. Later, you can use one or more of these settings in an experiment or series of runs by programming them into a macro. This chapter describes how to create and use macros.

In addition, you can use batch files to run macros on sets of images or other data. After creating the macros and data sets you wish to analyze using those macros, you can create a batch file that will perform these actions sequentially.

Working with Macros

The following describes how to create macros and perform other tasks with macros.

To create a macro:

1. Click **Tools | Visual Macro Programmer.** The Visual Macro Programmer window opens. Assuming you have saved settings for various tasks, you would see the icons under the appropriate box.
2. Click and drag each setting in the order in which you want the task to run when the macro is executed. Choices include: Capture, Condition Image, Apply ROI, Processes, Final Vector Validation.
3. Click **Save**.
4. Enter a name for the macro. The macro is saved in the Saved Macro box.

Other tasks:

Tasks	Description
Run a macro	Click  on the tool bar, or in the **Tools** ǀ **Visual Macro Programmer** window.
Stop a macro	Click  on the tool bar.
Load a macro	In the **Visual Macro Programmer** window, select a macro and click **Load**.
Delete a macro	In the **Visual Macro Programmer** window, select a macro you wish to delete and click **Delete.**

Working with Batch Files

Batch files provide a way to run multiple macros sequentially. Since macros are limited to analysis of a set of images within one experiment, batch files provide a way to work across experiments. It is still the case that one macro can only analyze images that are located within the same experiment, but with batch files one can create multiple associations between macros and data sets.

To create a batch file:

1. First create the macros in each experiment in which you wish to analyze data. Refer to the previous section for instructions on how to do this.
2. Create data lists that represent the images or data that you want to analyze. First select the data or images that you want to create a list from, and then right-click on the selected items and choose **Create Image List**.
3. Select an appropriate name for your list. The new list will be placed in the Settings folder. Note that the images will not be copied, so you must ***not*** delete the images. Once created, you cannot change data lists, so to make any changes, just create a new one.
4. Now that you have a macro and an image list, you can begin the creation of your batch file. In order to create an empty batch file, right-click in the experiment tree at the bottom, beneath all files in the tree. Select **Create Batch File**.
5. Enter an appropriate name for the batch file. A new, empty batch file will be created and displayed at the end of the experiment tree, outside of all experiments.
6. In order to add macro/datalist associations to the batch file, simply drag macros or datalists to the batch file. You will be

prompted to choose a matching datalist or macro from the same experiment.

To run a batch file:

1. Right-click on a batch file and select **Run**.
2. When you are ready, click **Run** in the form. The form will display the currently open data list and the currently selected macro. Hitting stop will prevent the next datalist from being analyzed.
3. When analysis is complete, "BATCH COMPLETE" will appear on the form.

CHAPTER 16

Viewing, Enhancing, and Displaying Image Files

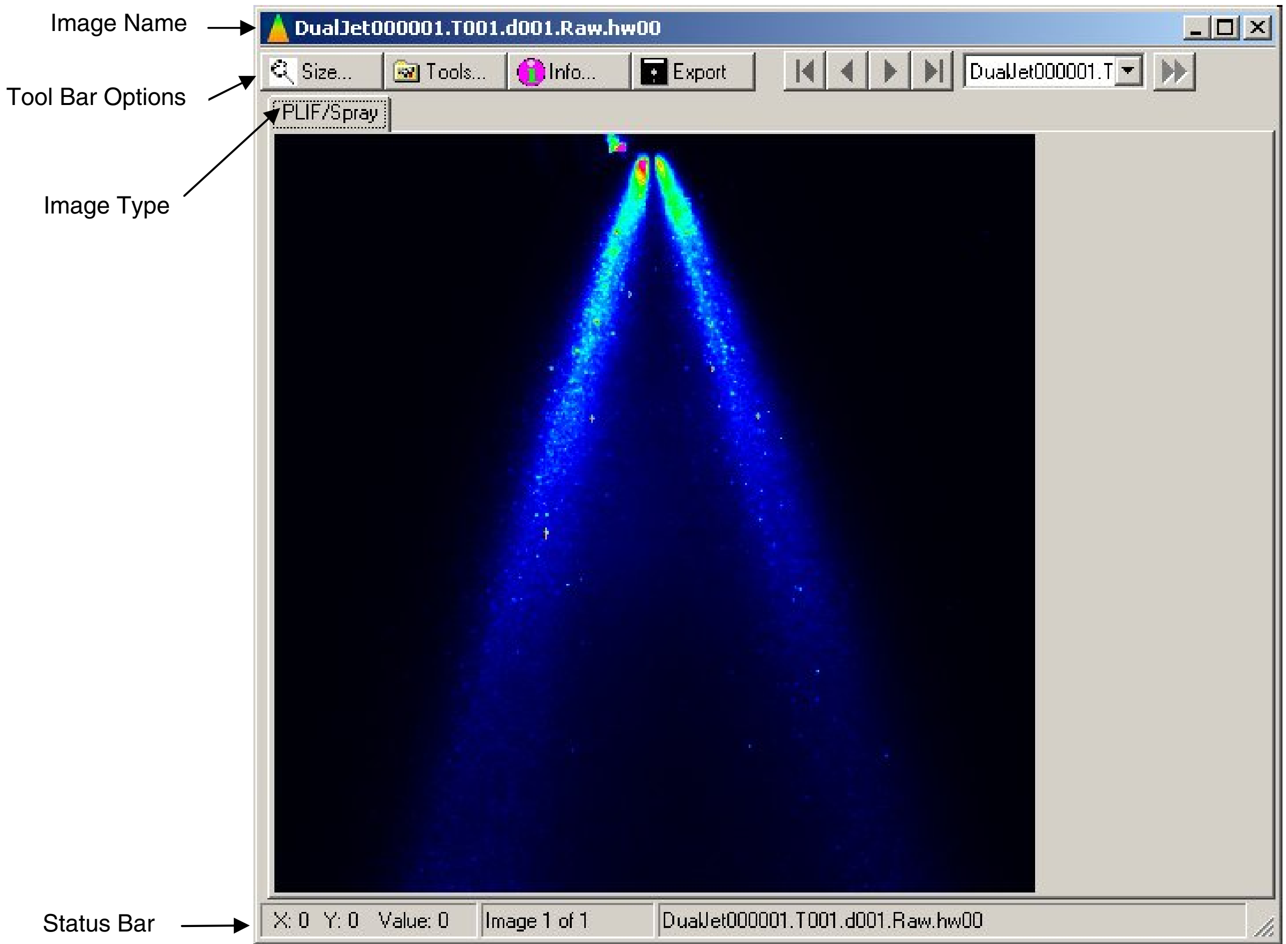
The display panel in *INSIGHT 3G* allows you to drag and drop images from the Experiment tree and then using the many features available in the display panel, enhance the images so that you can process them, view them or select a certain region of interest. *INSIGHT 3G* also provides you with image information, controls to scroll through or animate the data, and the means to export images in different formats.

This chapter describes the display panel features and how to do the following:

- Zoom in or out of an image for optimal viewing.
- Select entire images or use cross-hair marks to help with processing and calibration.
- Modify output lookup tables to enhance images for optimal viewing.
- Edit and change the appearance of vectors, remove, apply, and view vectors.
- Get statistical information on images and vectors, display image information bar and make changes to the display.
- Export images.
- Animate images.

Display Panel Features

The following figure illustrates *INSIGHT 3G*'s features.



The following describe these display features:

Zooming In and Out of Image Files

When you open a data file, *INSIGHT 3G* brings up the image at full resolution—each pixel is mapped to a pixel on the screen and often the image is too large to be seen in its entirety. To view the entire image you may have to zoom in or out.

To resize, zoom in or out of image files:

1. Open and drag an image file on to the display panel. The display window opens and the display features become available.
2. From the Tool Bar, click **Size.** The following options are available.

Option	Description
Fit in Window	Sizes the image to fit in the display window.
Full Size 1:1	Displays image at actual or full resolution.
Zoom In 2:1, 3:1 4:1	Zooms in to provide a closer look at the image file.
Zoom Out 2:1, 3:1, 4:1	Zooms out to provide a larger or entire view of the image file.

Note: *You can also zoom into the image by right-clicking and dragging the mouse.*

Applying Crosshairs

Applying crosshairs shows the center of the image and is useful for aligning cameras when you are performing calibration in a PIV experiment. See "PIV Calibration Process" for details.

To turn on crosshairs:

From the main menu bar of the display panel select **Tools | Cross hairs**. A check mark appears on the Crosshairs option and crosshair marks appear on the images.

To turn off crosshairs:

From the main menu bar of the display panel select **Tools | Cross hairs**. The check mark from the Crosshairs option and the crosshair marks on the images are removed.

Selecting Entire Images

The Select Entire Image option is useful when you are processing captured images and want to make sure the entire image has been selected.

To select the entire image:

From the main menu bar of the display panel select **Tools | Select Entire Image**. A check mark appears on the Select Entire Image option and the entire image is selected. Also see "Defining a Region of Interest."

Enhancing Image Displays by Modifying Look Up Tables (LUT)

INSIGHT 3G allows you to manipulate and display the Look Up Tables (LUT) of the graphics board in your computer to enhance the image display. Although the LUT manipulates the pixel intensity values displayed on your computer monitor, it does not affect the values in the stored image file.

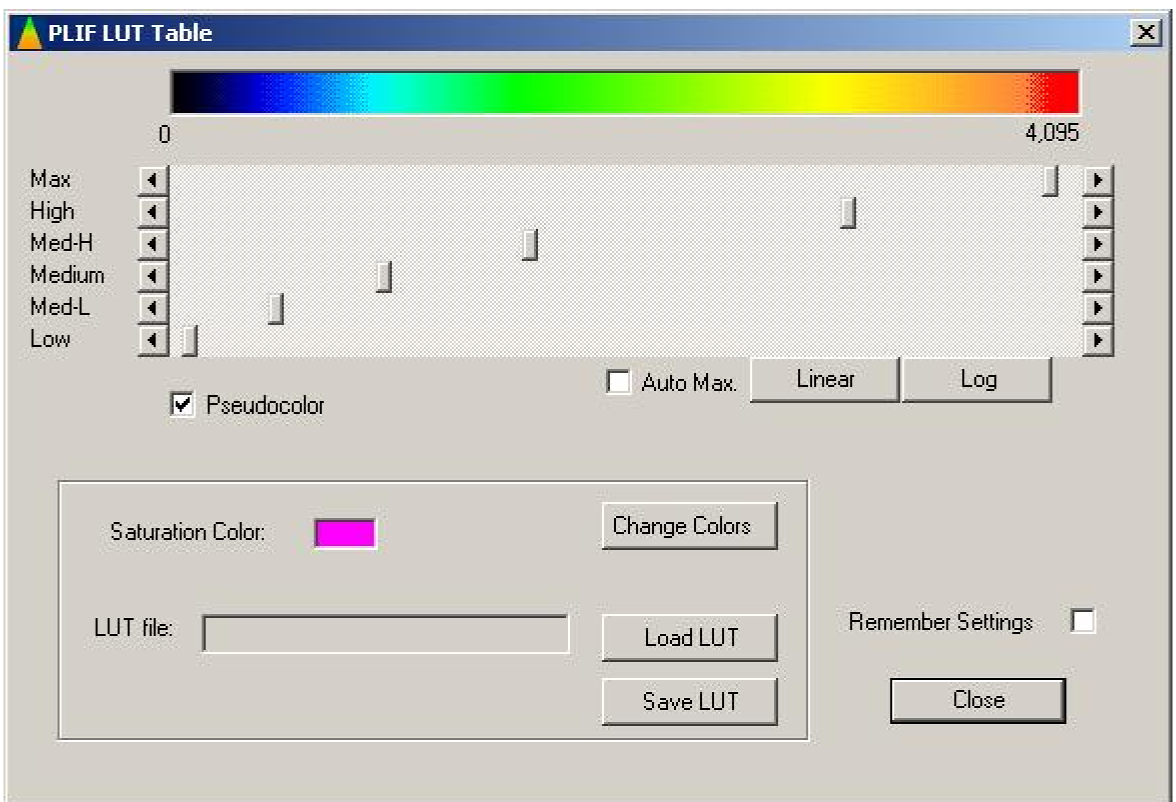
Two look-up table options are available. One for PIV images and the other for PLIF images, as the latter tend to be darker.

INSIGHT 3G captures 8-bit, 12-bit and 16-bit images, depending on the camera that was used for the image capture. For 8-bit images, each pixel in these images has a grayscale assigned to it, ranging from 0 to 255, with 0=black and 255=white. You can also use pseudo colors and assign a color ranging from 0-255 with 0=black and 255=red. When an image is initially displayed on your computer screen, the graphics board in your computer displays this image based on that number. Using the LUT option, you can modify each pixel intensity—for example, alter image brightness or the contrast or both to bring up the details.

For 12-bit images, there are a total of 4096 intensity levels, hence it is better to show the images in pseudocolor so that the contrast of the images can be seen more easily.

To use the LUT option:

1. From the display panel menu bar, select **Tools | PIV LUT** or **Tools | PLIF LUT.** The PIV LUT or PLIF LUT dialog opens.



2. Use the following LUT options and controls to manipulate the image displays:

Option	Description
	Displays the current settings. You can also use this to preview the effect of changes made through controls and options available in this dialog box.
	Slide these tabs for each color or grayscale value to make gross changes. Use the bar to preview the settings.
	Use these controls to make minute changes to the color or gray-scale values.
Pseudocolor	Select this check box to display colors instead of grayscale values.
Auto Max	Use for extremely dark images. INSIGHT 3G automatically finds the highest intensity level in the bit map and assigns a top intensity value to it.
Linear	Click to apply the linear function on the color range to spread the color or grayscale range linearly.
Log	Click to apply the logarithmic function on the color range.
Change Colors	Click to change text labels or color for the color bands or saturation color. The Change Colors dialog appears.
Remember Settings	Check box to save the settings and reload them next time this image is opened.
Load LUT	Click to browse for and load a LUT file containing color values, text labels for bands, and slider settings.
Save LUT	Click to save the current slider settings, color values, and text labels to a LUT file.
Saturation color	Displays the color selected to indicate saturation levels.

Editing, Displaying, and Clearing Vectors

INSIGHT 3G's vector editing options allow you to setup and change vector appearance, to apply vectors automatically and to clear vectors on your PIV images.

To setup vectors:

1. Click on **Tools | Vector Setup**. The Vector setup dialog box opens.

2. Select the appropriate option or options. The following table describes the Vector options that affect the appearance of vector files:

Option	Description
Vector Color	Changes the color of the vector arrows. **To change the color:** **1.** Right-click on box. A color palette is displayed **2.** Select a new color to represent vector arrows. **3.** Click **OK**.
Scale	Changes the length and width of the vectors. Use the arrows to scroll up and down to select the desired scale.
Default Delta T (us)	Displays the default delta T setting that was embedded during image capture. For images captured with previous version of INSIGHT, you can specify a value in this box for processing your PIV vectors in Velocity mode.
Screen Updating	Select the number of vectors to display from the following selections. Draw All: Displays all the vectors. Draw 1/2: Displays half of all the vectors. Draw 1/4: Displays a fourth of all the vectors Draw 1/8: Displays an eighth of all the vectors.

3. Click **Apply** to see the effect of the change and **OK** to save the changes. **Cancel** discards the changes.

Getting Information on Images

INSIGHT 3G also provides intensity levels in the form of statistics and a histogram. It also provides additional information on the images. Following describes how to access and use these features.

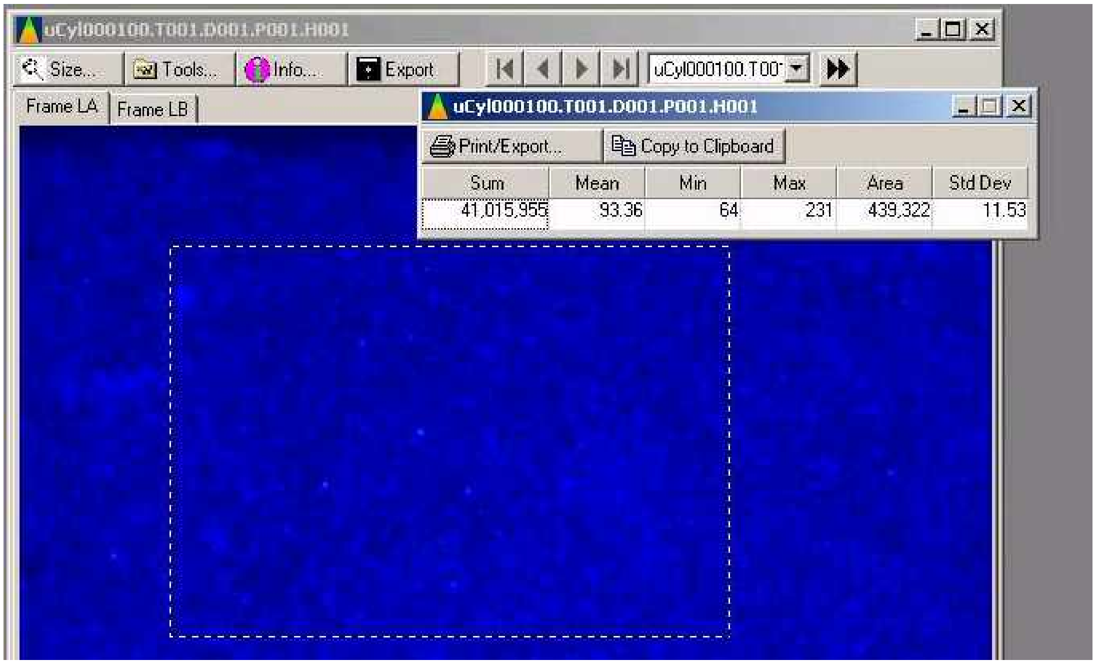
Image Statistics

The Image Statistics feature provides a table displaying intensity levels. These statistics can be printed and exported to other applications, copied to a clipboard to be inserted into another application such as Microsoft® Word.

To display image statistics:

1. Drag and drop or double-click the desired image file from the Experiment tree to the display panel.

2. From the main menu of the display panel, select  | **Image Statistics**. The statistics table, as shown in the following figure, is displayed.



To export image statistics:

1. Select **Print/Export** from the statistical table menu bar. The Table Print/Export dialog opens.
2. Make your selections from the following export options:

Option	Description
CSV	Select if you wish to export the table in comma separated value format.
Excel	Select if you wish to export the table into a Microsoft Excel spreadsheet format.
For MATLAB	Select if you wish to export the table into MATLAB. See Using MATLAB for details.

3. Specify where you wish to send the exported file. Click  to browse to the appropriate drive.
4. Click **OK**.

To print image statistics:

1. Click **Print/Export** from the statistical table menu bar. The Table Print/Export dialog opens.
2. *(optional)* Select the Print Setup box if you would like to specify your printing preferences before printing.

3. Click **Print.** If you selected Print Setup, checked your printer dialog opens. Specify your printing preferences and click **OK.**

To send the image statistics table to a clipboard:

1. Click **Copy to Clipboard** from the statistical table menu bar.

Image Histogram

Image histogram feature provides a histogram displaying intensity levels.

To display the image histogram:

1. Drag and drop or double-click the desired image file from the Experiment tree to the display panel.

2. From the main menu of the display panel, select 

| **Image Histogram**. The image histogram, as shown in the following figure, is displayed.

3. Click Y-Axis Label button to change the text of the Y-Axis label.

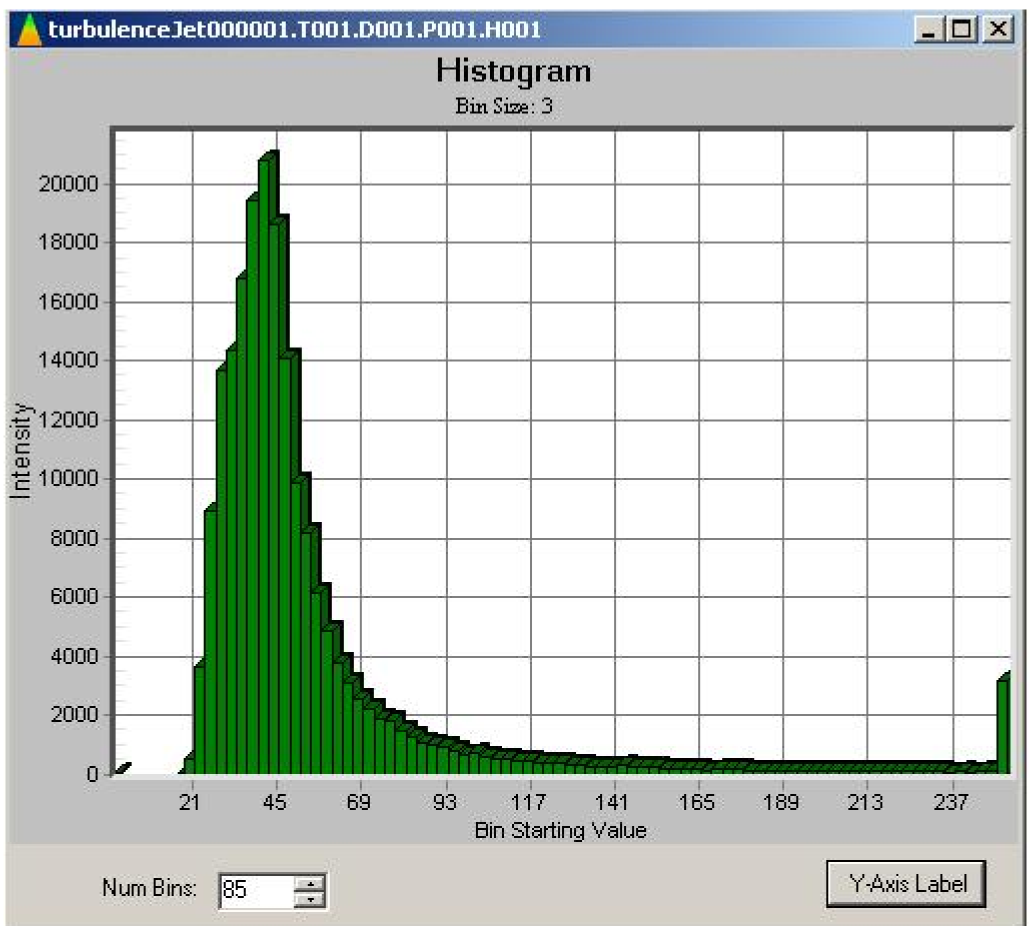


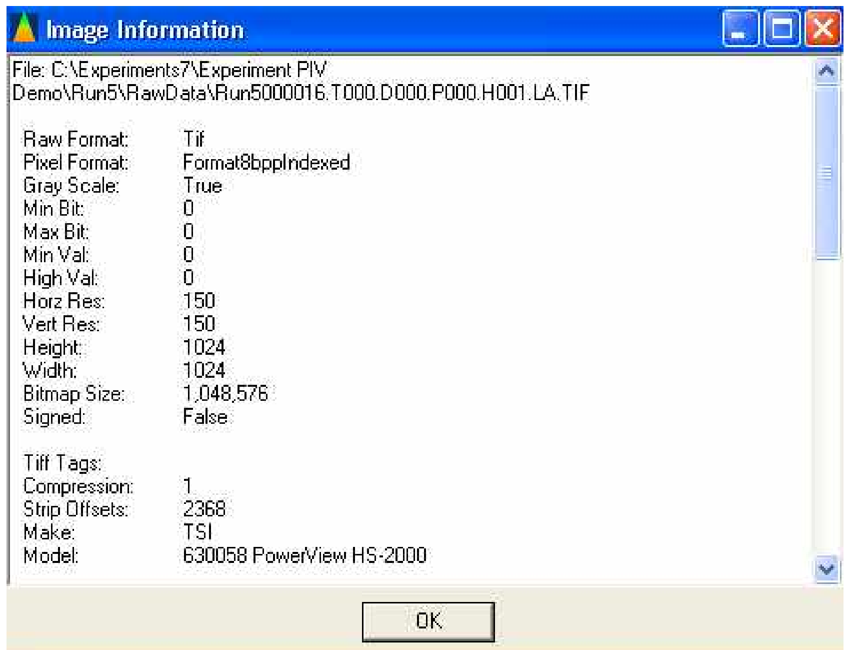
Image Information

Image information provides a histogram displaying intensity levels.

To display the image information:

1. Drag and drop or double-click the desired image file from the Experiment tree to the display panel.
2. From the main menu of the display panel, select 

 | **Image Information**. The image histogram, as shown in the following figure, is displayed.



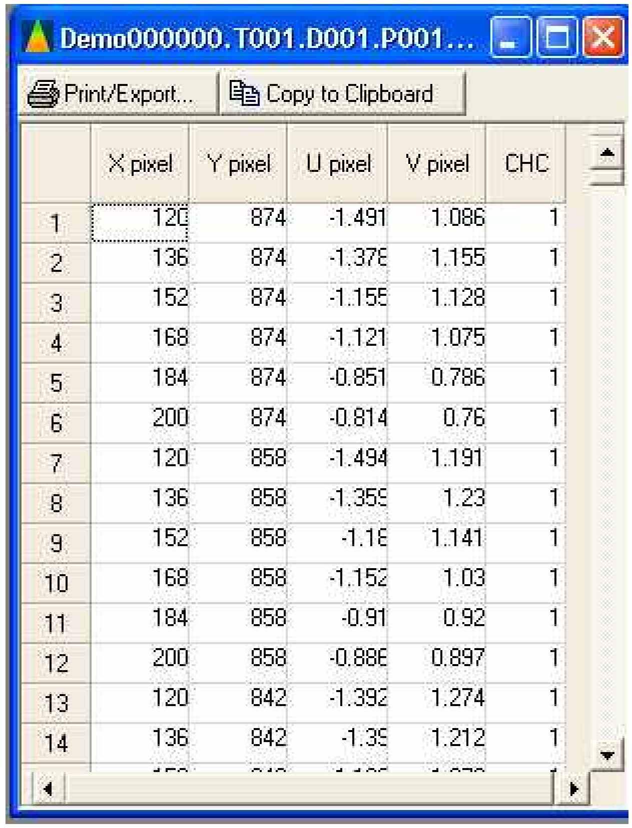
Vector Information

You can get additional vector information in the form of detailed statistical table or a histogram.

To display the vector statistics:

1. Drag and drop or double-click the desired image file from the Experiment tree on to the display panel.
2. From the main menu of the display panel, select 

 | **Vectors | Open Left Vector Table** or **Open Right Vector Table**. The vector statistical table, as shown in the following figure, is displayed:



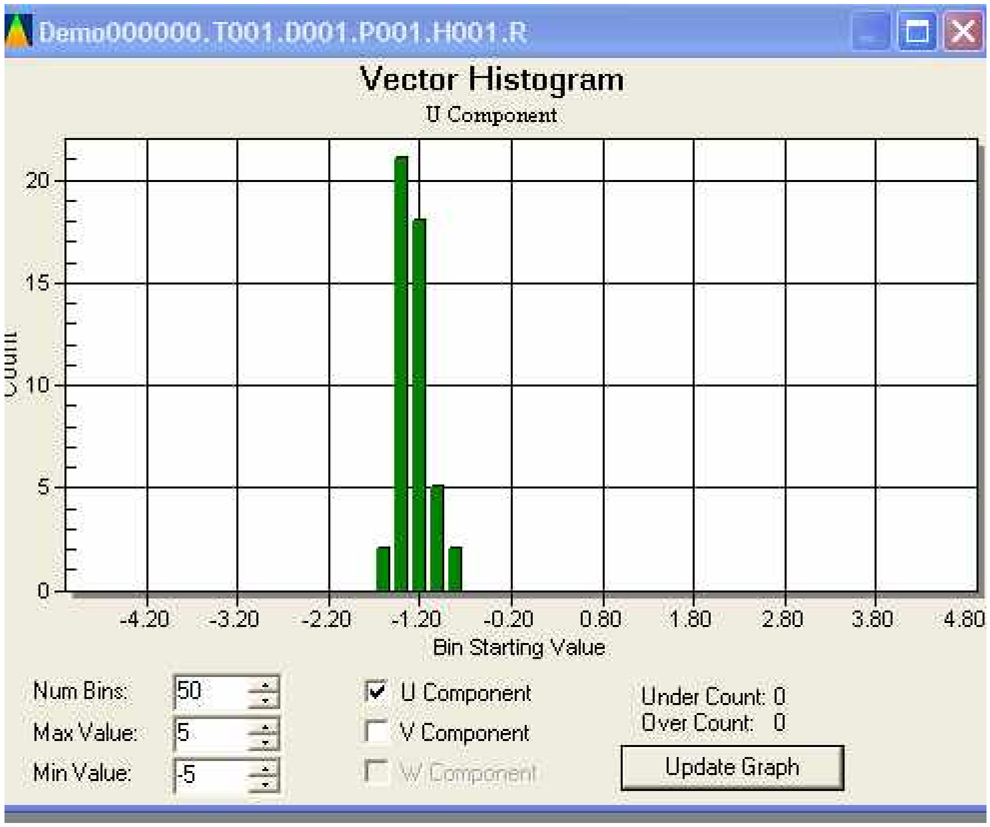
	X pixel	Y pixel	U pixel	V pixel	CHC
1	120	874	-1.491	1.086	1
2	136	874	-1.378	1.155	1
3	152	874	-1.155	1.128	1
4	168	874	-1.121	1.075	1
5	184	874	-0.851	0.786	1
6	200	874	-0.814	0.76	1
7	120	858	-1.494	1.191	1
8	136	858	-1.359	1.23	1
9	152	858	-1.18	1.141	1
10	168	858	-1.152	1.03	1
11	184	858	-0.91	0.92	1
12	200	858	-0.888	0.897	1
13	120	842	-1.392	1.274	1
14	136	842	-1.39	1.212	1

To display the vector histogram:

1. Drag and drop or double-click the desired image file from the Experiment tree on to the display panel.

2. From the main menu of the display panel, select 

| **Vectors | Open Left Vector Histogram** or **Open Right Vector Histogram**. The vector histogram, as shown in the following figure, is displayed.



Exporting Images

The Export option available on the display panel allows you to export images from *INSIGHT 3G* into other applications. These images can be exported in three formats: .JPG, TIF, and BMP. Exported files can be viewed using any imaging software application.

To export images:

1. Drag and drop or double-click the desired image files from the Experiment tree on to the display panel.
2. From the main menu of the display panel, click 

. The Export Images dialog box is displayed.
3. In the Images Loaded box, select the images you wish to export. Use the Select All or Select None buttons to make quick selections.
4. Select the format in which you wish to export. Choices include: BMP, JPG, or TIF.
5. Select the Data Mode option:

Option	Description
Preserve Data	Export the raw data as it is captured.
Apply LUT	Check to use values from the current LUT and export it exactly as it is displayed.
Include PIV vectors	Select to have the vectors displayed on the images to be exported on top of the images.

6. Specify where you wish to send the exported file. Click ... to browse to the appropriate drive.

7. Click **Export**.

Animating Images

The animation feature available on the display panel menu bar, allows you can view all the loaded files in the form of an animation.

To animate images:

1. Drag and drop or double-click the desired image files from the Experiment tree on to the display panel.

2. From the main menu of the display panel, click . Each loaded image file is displayed in the form of an animation.

CHAPTER 17

Developing and Using Plugin Dynamic Link Libraries (PIV Only)

INSIGHT 3G comes with several algorithms to choose from for processing PIV images. These algorithms produce good results for the majority of experiments. However, to provide measurements in flows with special challenges and research, user-created algorithms can be plugged into one of these processing points.

Note: *The plugins provided in INSIGHT 3G were developed using Microsoft Visual C++ Version 6. TSI assumes that you have C++ skills to develop these plugins. The example plugins are Win32 Dynamic-Link Libraries and do not use MFC (Microsoft Foundation Class). Other C++ compliers should also work, but TSI has not tested them.*

Plugin Definition and Structure

A plugin is a DLL that implements a Plugin Interface. Each plugin point has an interface that defines the methods that plugin must implement. Standardizing the inputs and outputs of each plugin point with a DLL interface allows *INSIGHT 3G* to call plugin methods without having to know anything about the algorithm used to implement the method. This standardization allows the algorithms to be mixed and matched to optimize processing.

The plugin structure allows you to have control of the few most critical points in the PIV processing. The plugin author does not have to search through large amounts of code looking for the parts that are of interest. By isolating plugin methods, the testing and debugging of the new code is simplified.

To create plugins quickly and easily, a set of plugin wizards has been developed. The plugin wizards work with Visual C++ to automate the creation of a new plugin project. The wizard-created plugins take care of the overhead of data transfer and communication with *INSIGHT 3G* allowing you to concentrate on implementing your algorithm.

PluginData and Dynamic Link Libraries (DLL) Plugin Parameters

Features of the plugins include PluginParameters and PluginData.

Plugin Parameters

Plugin parameters are used to control the processing algorithm. A plugin parameter may be of type boolean, integer, floating point, or string. The DefaultPeakEngine Correlation Engine parameter is an example of a string Plugin Parameter, the Rectangular grid uses a boolean Plugin parameter to control if recursive processing is to be used, integer Plugin parameters set the first pass spot offsets, and a float Plugin parameter sets the spot size reduction between passes. With plugin parameters you can develop one plugin that can be optimized depending on the circumstances.

Plugin Data

The Plugin data feature is used to make user-defined measurements during processing. Data is created for each vector. This data can be used as a signal-to-noise ratio for validation, exported to the vector file, and viewed in the process monitor. The plugin data class holds the following information: measured value, and if it passed or failed the SNR test, data name, plugin name, export on, SNR filter, SNR threshold, SNR greater than or less than test.

SNR Vector Validation

SNR vector validation is used to eliminate vectors that have poor signal-to-noise ratio during processing. Filtering out bad vectors during processing by measuring input spot or correlation values produces a vector field with less need for validation based on the velocity. SNR validation can measure and use any parameter. Two common SNR tests are Minimum Average Spot Intensity and the Correlation Displacement Peak Height to highest noise-to- peak-ratio. The average spot intensity is measured in the Base Spot Mask. The Peak To Noise Ratio is measured in the Base Peak Mask. Other SNR measurements may be added by plugins.

Plugin Development Kit

INSIGHT 3G during installation installs the files you need to create your own plugins and example plugin code in the TSI\Insight 3G\PluginSDK folder. The following lists the contents of this folder:

Folder	Contents
BaseEngine	Contains base classes for deriving your plugin.
Interface	Contains interfaces that are used in exchanging data between *INSIGHT 3G* and the plugin.
ExampleCode	Contains example source code showing an example implementation for each plugin point. ExampleCode DLLs can be used as the starting point for developing your own plugin

Installing TSI Plugin Wizards into Visual C++

The following plugin wizards are installed in the Insight 3G\PluginSDK\Wizard folder:

- TSI Grid Wizard.awx
- TSI Spot Mask Wizard.awx
- TSI Correlation Wizard.awx
- TSI Peak Wizard.awx

To use the wizards for Visual C++, copy them from the PluginSDK\Wizard folder into your Visual C++ Template folder default location:

C:\Program Files\Microsoft Visual Studio\Common\MSDev98\Template.

Plugin Coordinates and Units

The plugin processing is done in pixel units. The world units of m/s and mm are not used in the plugins. Velocity measurement in m/s are made by computing all of the particle image displacements and vector locations in pixel units, and then converting to mm location and m/s velocity units as the vector file is saved to disk.

The plugin image, spot and correlation map coordinates have the (0, 0) pixel in the lower left corner and (Width, Height) in the upper right corner. This is different from the standard image coordinate system with the (0, 0) pixel in the upper left corner and the (Width, Height) pixel in the lower right corner. Using the Y increasing up coordinates better matches standard world coordinates and simplifies the conversion from pixels to mm and m/s.

TSI Plugin Wizard Generated Code

The code that the TSI Plugin Wizards generate have two sections—DLL export methods that communicate with INSIGHT 3G and a C++ Class where the real work of the plugin is done. The DLL export methods simply call a class method with the same parameter list, with the exception of InterfaceImplemented() that returns the interface version number. This structure gives you all of the advantages of programming in C++ without having to program the overhead of DLL communication.

When creating a plugin, first derive and compile the plugin using the wizard generated code to verify that the plugin is functioning and connected to INSIGHT 3G. Then you can edit or delete the wizard methods and data as you implement your algorithm.

The classes are named CustomGridClass, CustomSpotMaskClass, CustomCorrelationClass, and CustomPeakClass.

Plugin	Bass Class	Class	Output Folder Insight 3G\
Grid	BaseGrid	CustomGridClass	GridEngine
SpotMask	BaseSpotMask	CustomSpotMask	SpotMask-Engine
Correlation	BaseCorrelator	Custom-CorrelationClass	Correlation-Engine
Peak	BasePeak	CustomPeakClass	PeakEngine

ExampleCode

Each ExampleCode subfolder contains a plugin implementation. The folder includes the plugin CPP and H source code files. StdAfx.cpp and StdAfx.h files are used by Visual C++ for precompiled headers. A Visual C++ project workspace *.DSW and a Visual C++ project *.DSP are also included.

Plugin	Description
GaussianMask	Applies a Gaussian filter to the input Spot A reducing the pixel intensity away from the center of the spot. The GaussianMask decreases the relative strength of spot edge particles. The correlation of edge particles where different amounts of the particle are included in Spot A and Spot B increases the correlation peak location error. GaussianMask demonstrates the use of PluginData with a minimum *average spot intensity measurement.*
RectangularGrid	An example that shows the use of float, integer and boolean PluginParameters. It has float PluginParameters to set the grid spacing based on the width and height of Spot A. It has a boolean PluginParameter to turn recursive processing on or off. It has a float PluginParameter to set the spot size reduction between processing passes. It has a boolean PluginParameter to set central-difference or forward-difference offset. And it has integer PluginParameters to set the first processing pass offset distance.
DirectCorrelator	Implements the direct correlation. This is the code that the TSI correlation wizard creates without any modifications.
GaussianPeak	Locates the displacement peak by doing a 3-point Gaussian fit in the X and Y directions around the highest correlation map pixel. This the TSI Peak Wizard code without any modifications.

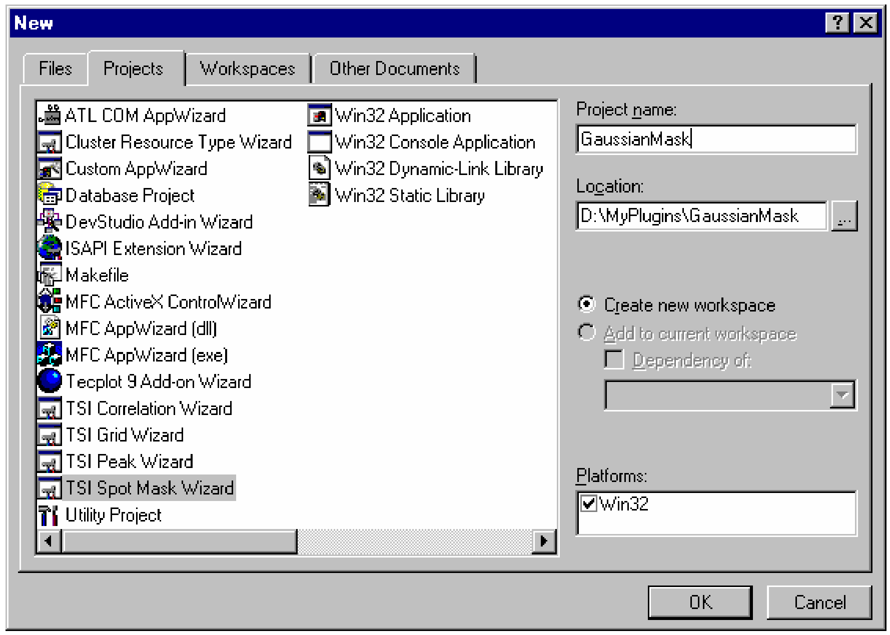
Creating a Plugin Using a Wizard

You can start a plugin project with Microsoft Visual C++ 6 using one of the TSI-provided wizards.

A plugin wizard has been created for each plugin point. The plugin wizard generates a project that is linked to the PluginSDK folder so that it can simply be built and run with *INSIGHT 3G*. Each of the wizards implements an algorithm so that the default wizard code is a valid plugin. The generated code can then be modified to implement your algorithm.

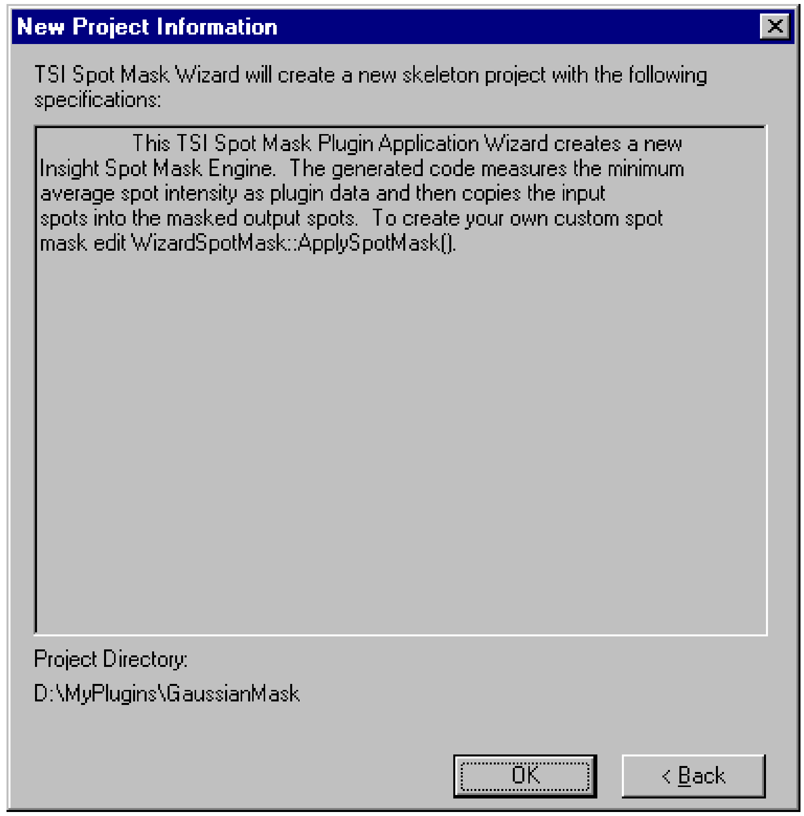
The creation of a plugin for any of the plugin points is the same, with the exception of choosing the TSI Wizard in the New Project dialog, and setting the output file path to the correct engine folder in the project settings dialog. The following steps illustrate how to create the plugin project using the Gaussian Spot Mask Plugin, as an example. The code is included in your Insight 3G\PluginSDK\ExampleCode\GaussianMask folder.

1. From the Visual C++ main menu select **File | New | Projects** and select **TSI Spot Mask Wizard.** The other wizards included are: **TSI Correlation Wizard**, **TSI Grid Wizard** or **TSI Peak Wizard**.



2. Enter the name in the Project name box and location in the Location box.

3. Click **OK**. If you do not see the TSI Plugin Wizards, see "Installing TSI Plugin Wizards into Visual C++" section of this chapter. The New Project Information dialog appears describing the plugin being created.

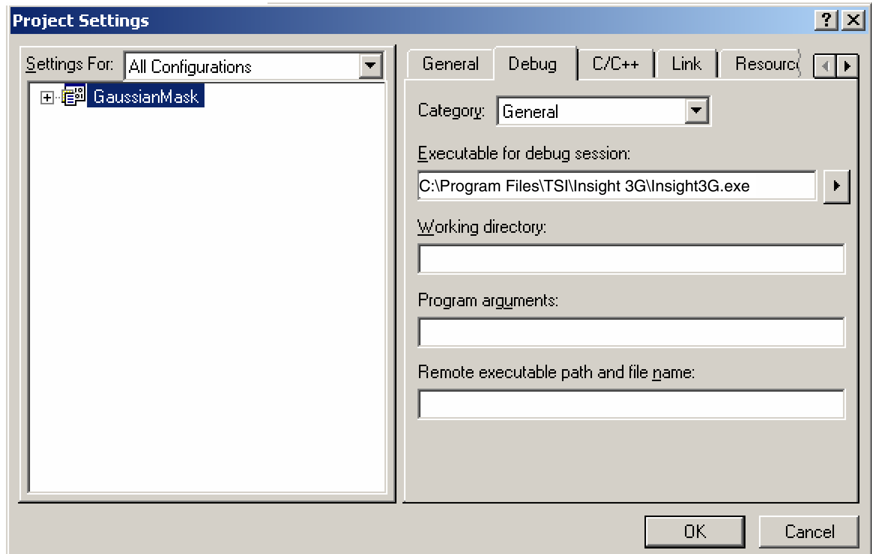


4. Click **OK**.
   If *INSIGHT 3G* was installed in the default folder you are prompted to specify if the plugin should be created in that folder. If you wish to create the plugin in the default folder, click **Yes**.

   If *INSIGHT 3G* was not installed in the default folder or if you wish to select a different folder to create the plugin in, navigate to the folder where the executable file for *INSIGHT 3G* and the PluginSDK folder are installed.

   After the project files are created, perform the following step.

5. From the Visual C++ main menu, select **Project | Settings | Debug**. The following dialog box appears.

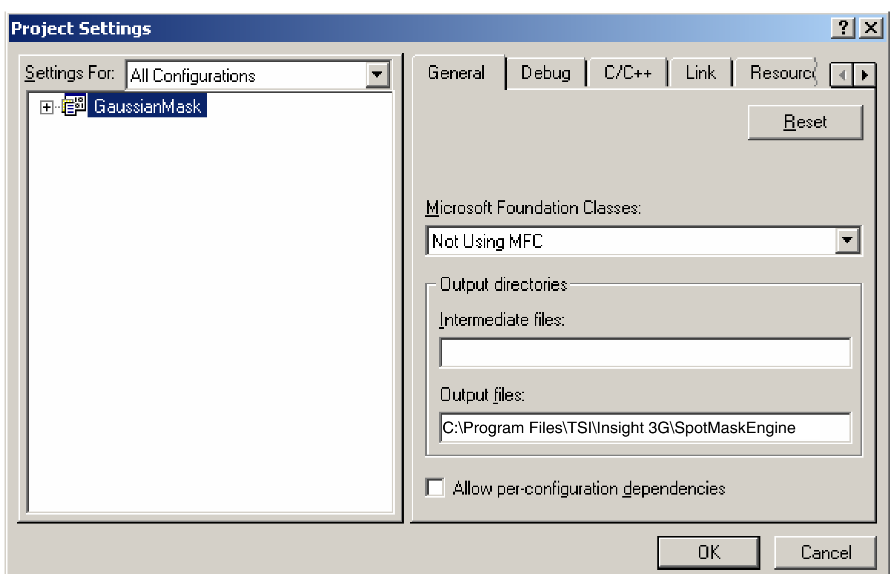


6. Make the following selections:

Field	**Selection**
Settings For	All Configurations.
Executable for debug session:	Enter the full path to Insight3G.exe

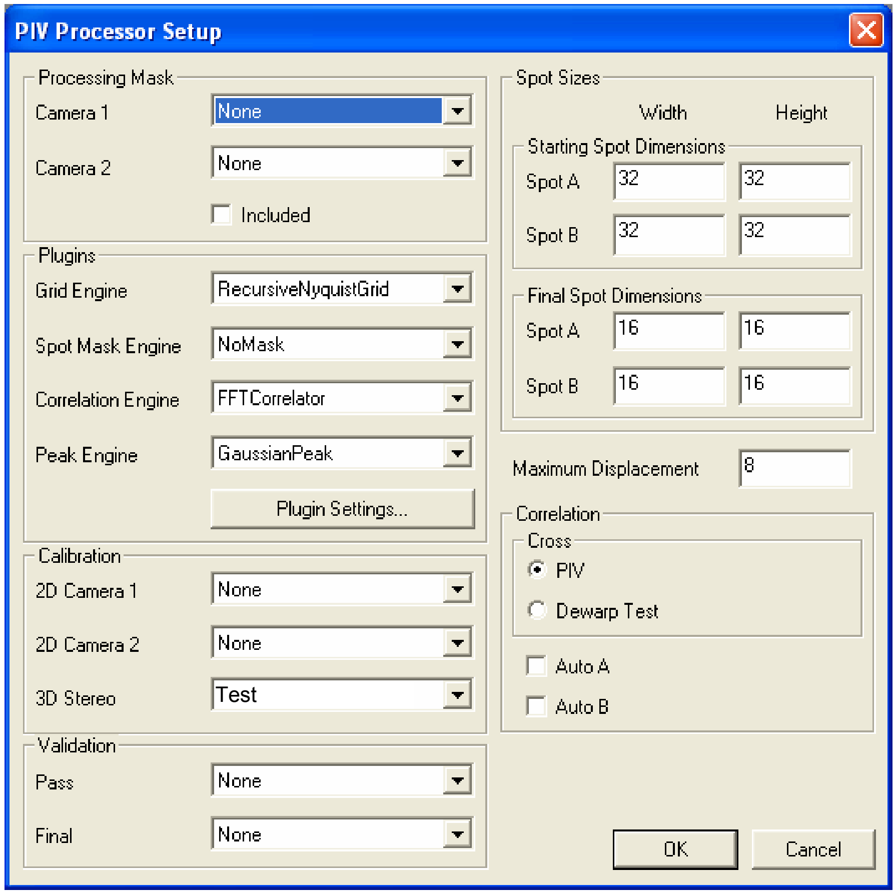
7. Click **General** tab and in the Output files box, specify the path to the plugin engine folder. In our example, C:\Program Files\Insight 3G\TSI\SpotMaskEngine. The default plugin engine folders are:

C:\Program Files\TSI\Insight 3G\GridEngine
C:\Program Files\TSI\Insight 3G\SpotMaskEngine
C:\Program Files\TSI\Insight 3G \CorrelationEngine
C:\Program Files\TSI\Insight 3G \PeakEngine



8. Click **OK**. The plugin DLL compiles and builds. If there are errors, verify that the output DLL file is in the correct folder and the PluginSDK files are being located by doing the following:

Click the **Visual C++ Execute Program** <**Ctrl**>+<**F5**> button or the **Go <F5>** button to start *INSIGHT 3G*. If *INSIGHT 3G* does not start, verify the **Project | Settings | Debug | Executable** for debug session value.



In *INSIGHT 3G*, select the PIV Tab and choose **Processor Setup | Processor Settings, | Spot Mask Engine** drop down list. The new Spot Mask should be listed, if not, verify that the path: Visual C++ Project | Settings | General | Output values is C:\Program Files\TSI\Insight 3G\SpotMaskEngine.

9. Select the new plugin and process an image to verify that the plugin is working.

You are now ready to start customizing the files to implement your own algorithm.

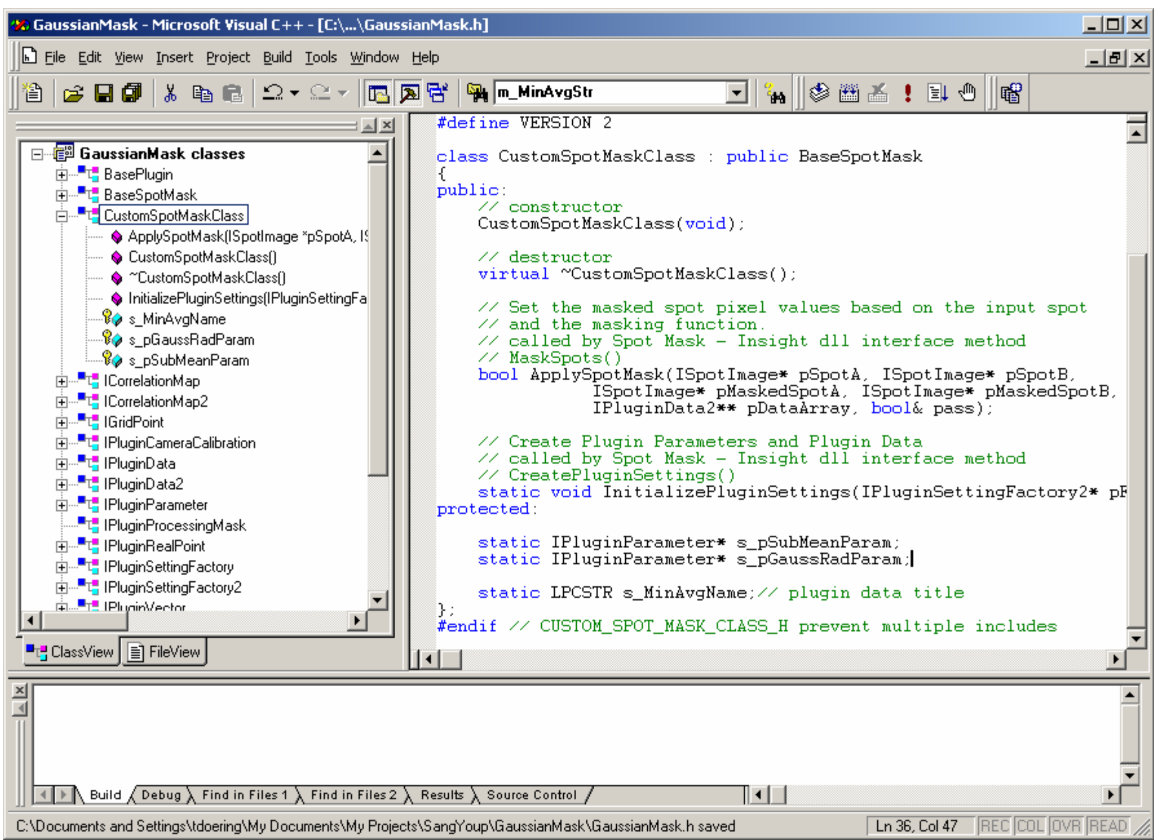
You can debug or trace through the code by setting a break point at the line of code where you want to start debugging. Then with Visual C++ set for Win32 Debug launch *INSIGHT 3G* using the **Go** <**F5**> button. When the line of code with the break point is executed, *INSIGHT 3G* pauses as you trace through the code and use the debugger. When you click the **Go** <**F5**> button again, *INSIGHT 3G* continues processing until the next break point.

Customizing the Gaussian Spot Mask Engine

Two Plugin Parameters are used in this plugin; a float parameter that controls the Gaussian mask radius, and a bool parameter that turns mean subtraction on or off.

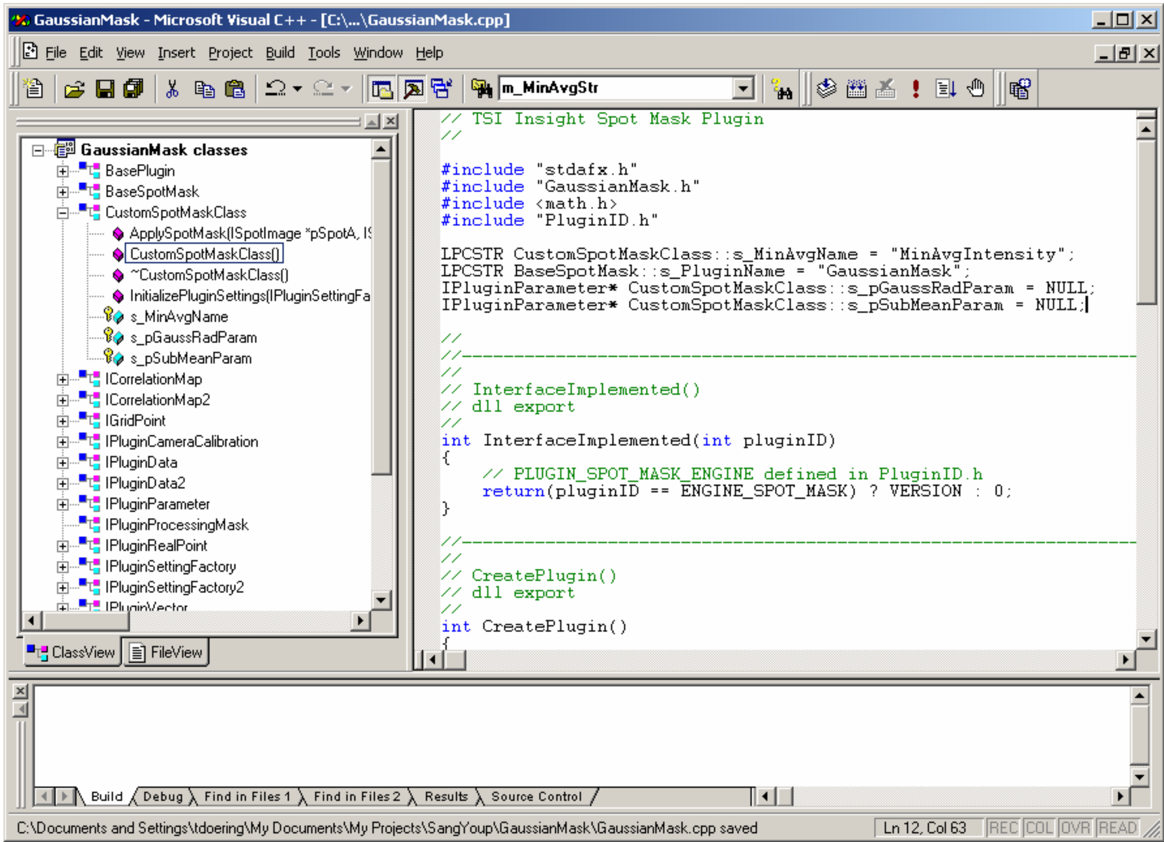
To customize the Gaussian Spot Mask:

1. Open the GaussianMask.h file.



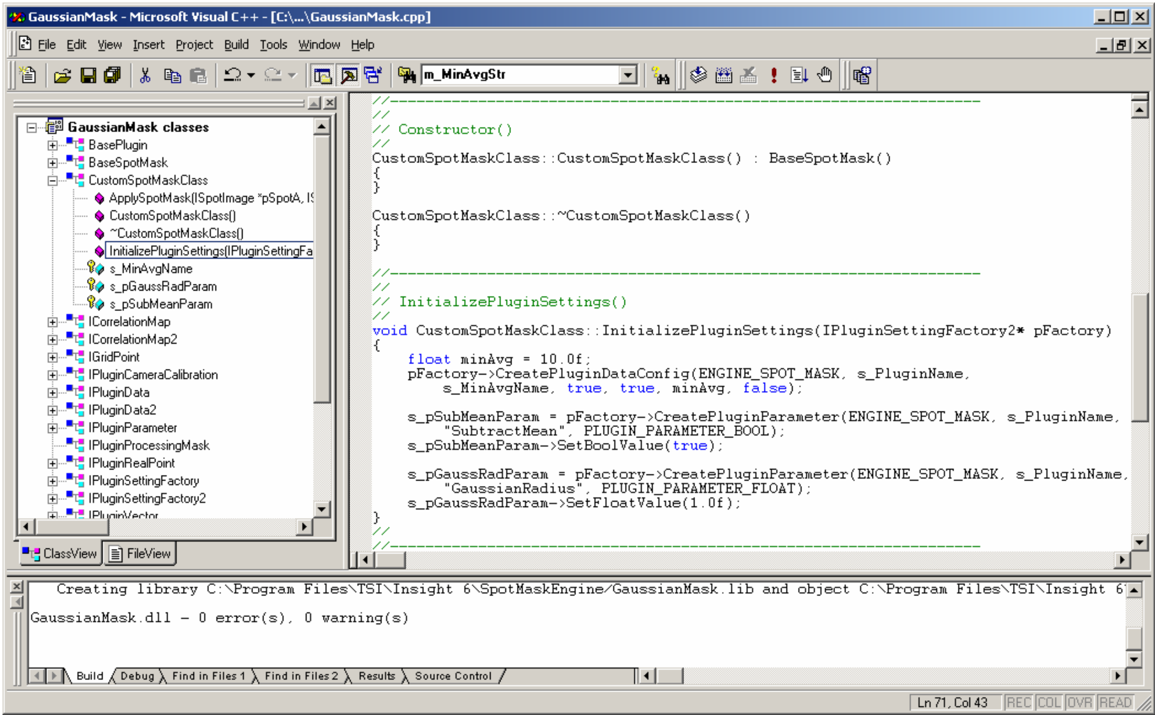
2. Declare two static variables of type IPluginParameter* s_pSubMeanParam and s_pGaussRadParam, and one method ApplyGaussianMask() inside the CustomSpotMaskClass.

3. Open the GaussianMask.cpp file.



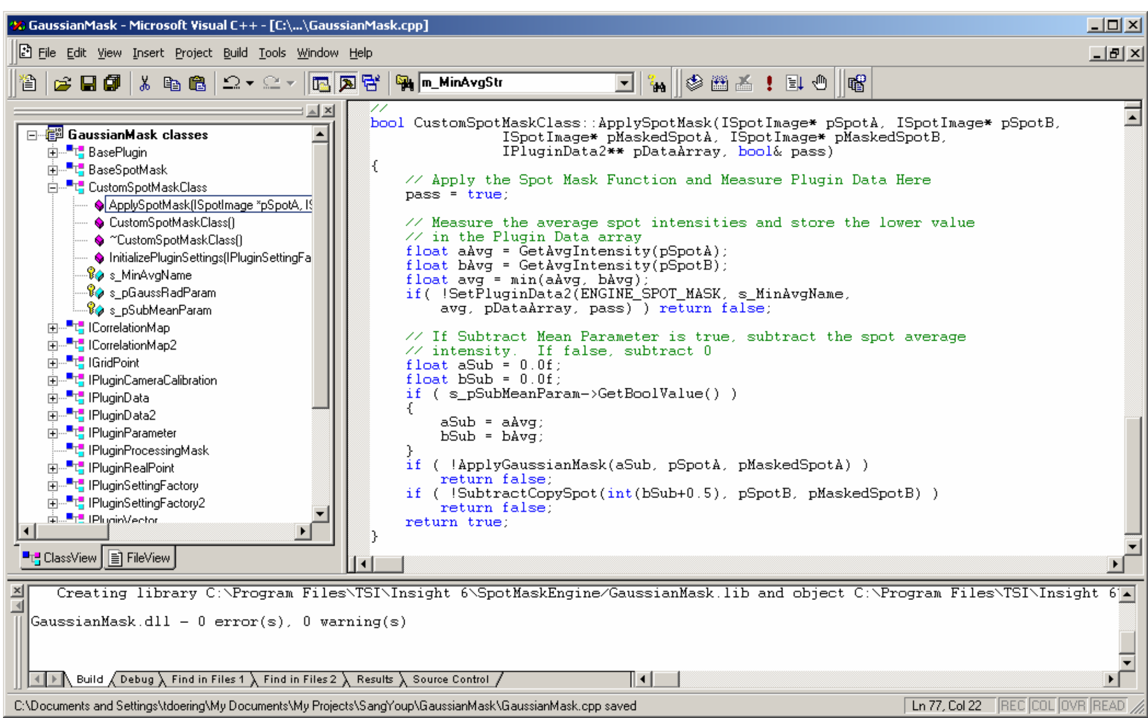
4. Add #include <math.h> at the top of the file. It is required for the exponential (exp) function.

5. Define the static members s_pSubMeanParam and s_pGaussRadParam.



6. In the CustomSpotMask::InitalizePluginSettings() method, initialize the two IPluginParameter* variables s_pSubMeanParam and s_pGaussRadParam and set the default values.

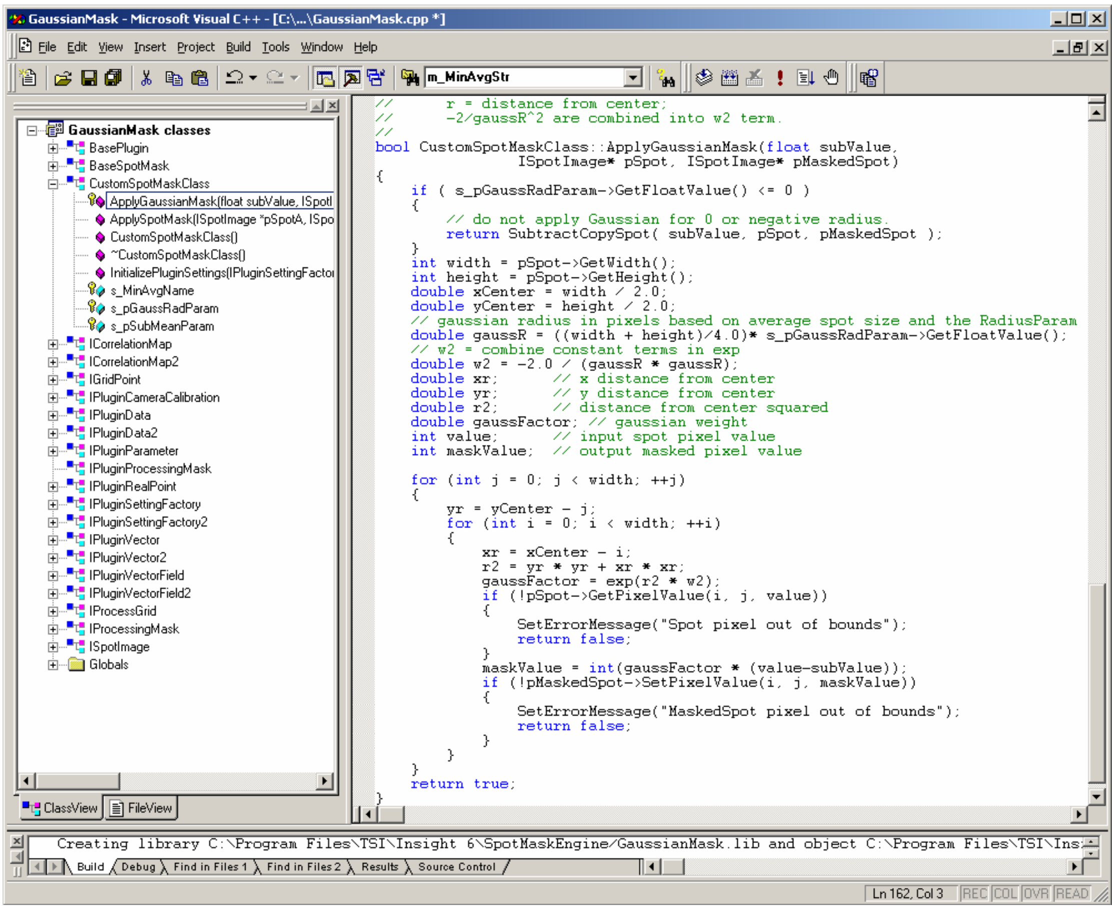
7. In the GaussianMask.cpp file, edit the ApplySpotMask() method.



8. Create two float variables aSub and bSub and initialize to 0. Check the s_pSubMeanParam value and if true, set aSub and bSub to the average spot intensities.

9. Change the SpotA CopySpot() method to ApplyGaussianMask(), and change the SpotB CopySpot() method to SubtractCopySpot(). The ApplyGaussianMask method will be entered in the next step, the SubtractCopySpot subtracts the input value, bSub, from each pixel.

10. Type in the CustomSpotMaskClass::ApplyGaussianMask() method.



This method first checks that a valid Gaussian radius was entered and if not uses SubtractCopySpot(). The Gaussian equation parameters are then computed and each pixel value is multiplied by a Gaussian weighting factor.

You can debug your plugin by setting break point and then running *INSIGHT* 3G from Visual C++ in debug mode by launching *INSIGHT* 3G with the **Go <F5>** button.

Plugin SDK Files and Classes

The following lists the files in the PluginSDK folder and their classes:

BaseEngine Folder

The BaseEngine folder contains the following plugins:

BasePlugin

This is the base class for all plugins. It implements the following methods common to all plugins.

INSIGHT 3G DLL Interface Methods	
`LPCSTR GetErrorMessage(int handle);`	Returns the error message string.
`int InterfaceImplemented(int pluginID);`	Returns true if the DLL implements the specified pluginID.
`int CreatePlugin();`	Returns the plugin's handle 0 if unsuccessful.
`void CreatePluginSettings(IPluginSettingFactory2* pFactory);`	
`bool DestroyPlugin(int handle);`	Destroys a previously created plugin using the plugin's handle. Returns true if successful.
Useful Plugin Methods	
`bool SetPluginData(LPCSTR pluginName, LPCSTR dataName, float value, IPluginData** pDataArray, bool& pass)`	Finds the measured plugin name and data name to the PluginData array, sets and validates the value. SNR pass or fail is returned in pass. Returns false if it could not find a match between input names to the PluginData Array. (Deprecated)
`bool SetPluginData2(int pluginID, LPCSTR dataName, float value, IPluginData2** pDataArray, bool& pass)`	Finds the measured pluginID and data name to the PluginData array, sets and validates the value. SNR pass or fail is returned in pass. Returns false if it could not find a match between input names to the PluginData Array.
`LPCSTR GetErrorMessage(void)`	Returns the error message.

BaseGrid

This is the base class for GridEngines, derived from the BasePlugin. It implements the following common grid methods and computations:

INSIGHT 3G DLL Interface Methods	

bool SetGridParameters(
  int handle,
  const int aStartSpotWidth,
  const int aStartSpotHeight,
  const int bStartSpotWidth,
  const int bStartSpotHeight,
  const int aFinalSpotWidth,
  const int aFinalSpotHeight,
  const int bFinalSpotWidth,
  const int bFinalSpotHeight,
  const RECT aoi,
  const int imageWidth, const int imageHeight);
	Stores the processing setup parameters

bool GetGridSize(int handle, int& vecColumns, int& vecRows, int& spotColumns, int& spotRows, bool& isFinalPass);	Computes and returns the grid size for the current pass along with the spot columns, spot rows and whether this is the final pass or not.
bool FillInGrids(int handle, IProcessGrid* pProcessGrid, IPluginVectorField2* pVF, IPluginVectorField2* PreviousPassVF, IPluginProcessingMask* GridMask)	Fills the grids using the passed in grid mask. (Deprecated)
bool FillInGrids2(int handle, IProcessGrid* pProcessGrid, IPluginVectorField2* pVF, IPluginVectorField2* PreviousPassVF, IPluginProcessingMask* pGridMask, bool invertedGridMask)	Fills the grids using the passed in grid mask.
bool GetIsMultipass(int handle)	Returns true if grid engine is multipass.
Useful Plugin Methods	

bool GridSizeUniformSpacing(
  const int xSpacing, const int ySpacing,
  const int aSpotWidth, const int aSpotHeight,
  const int bSpotWidth, const int bSpotHeight,
  const RECT aoi, int& columns, int& rows);
	Calculates the number of vectors that fit with the input parameters.

INSIGHT 3G DLL Interface Methods	
`Bool FillUniformSpacingGrid(IprocessGrid* pProcessGrid, IpluginVectorField* pVF, IpluginVectorField* pPreviousPassVF, IpluginProcessingMask* pGridMask, const int xSpacing, const int ySpacing, const int aSpotW, const int aSpotH, const int bSpotW, const int bSpotH, const RECT aoi, const int imageWidth, const int imageHeight, bool isCentralDifferenceOffset);`	Sets the Spot A and Spot B dimensions and locations and stores in the Process Grid using the Previous Pass Vector field to offset the spots. Initializes the vector field.
`RECT GetVectorArea(const int spotWidth, const int SpotHeight, const RECT aoi);`	Calculates the image range for vectors. The vectors can not be closer than ½ spot from the edge of the area of interest.
`Void ComputeOffsets(float xVec, float yVec, IgridPoint* pGridPt, int& aXOffset, int& aYOffset, int& bXOffset, int& bYOffset, int& offsetChoiceCode);`	Calculates the spot offsets base on a vector from the Previous Pass Vector field.
`Void ReduceSpotSize(float factor, bool& isFinalSize);`	Calculates the spot sizes for the next processing pass. If the spots are at the final size returns isFinalSize = true.

BaseSpotMask

The Base class for SpotMaskEngines is derived from BasePlugin. It implements the following common SpotMask methods:

INSIGHT 3G DLL Interface Methods	Description
`bool MaskSpots(int handle, ISpotImage* pSpotA, ISpotImage* pSpotB, ISpotImage* pMaskedSpotA, ISpotImage* pMaskedSpotB, IPluginData2** pDataArray, bool& pass)`	Applies masking to the input spots. (Deprecated)
`bool MaskSpots2(int handle, ISpotImage2* pSpotA, ISpotImage2* pSpotB, ISpotImage2* pMaskedSpotA, ISpotImage2* pMaskedSpotB, IPluginData2** pDataArray, bool& pass)`	Applies masking to the input spots.

INSIGHT 3G DLL Interface Methods	Description
Useful Plugin Methods	**Description**
`Bool CopySpot(ISpotImage* srcSpot, ISpotImage* destSpot);`	Copies the pixel values from the source spot the destination spot. Returns false if the spots are different sizes.
`float GetAvgIntensity(ISpotImage* pSpot);`	Returns the average pixel intensity for the spot.

BaseCorrelator

The Base class for CorrelationEngines, derived from BasePlugin. Implements the following common correlation methods.

INSIGHT 3G DLL Interface Methods	Description
`bool Correlate(int handle, ISpotImage* pSpotA, ISpotImage* pSpotB, ICorrelationMap2* pCorrelationMap, const int dxMax, const int dyMax, float& xZero, float& yZero, bool& pass)`	Correlates input spots into correlation map.
`bool GetMapSize(int handle, ISpotImage* pSpotA, ISpotImage* pSpotB, int& dxMax, int& dyMax, int& mapWidth, int& mapHeight)`	
Useful Plugin Methods	
`bool ComputeMinimumMapSize( ISpotImage* pSpotA, ISpotImage* pSpotB, int& dxMax, int& dyMax, int & mapWidth, int & mapHeight);`	Calculates the smallest correlation map that will hold the range of displacements in the correlation. Returns the map size by reference. Returns false if there is an error computing the map size.

BasePeak

The Base class for PeakEngines, derived from BasePlugin. It implements common peak search methods.

INSIGHT 3G DLL Interface Methods	Description
`bool LocatePeak(int handle, ICorrelationMap2* pCorrelationMap, IPluginData2** pDataArray, const float xZero, const float yZero, const int dxMax, const int dyMax, float& dx, float& dy, bool& pass)`	(Deprecated)

INSIGHT 3G DLL Interface Methods	Description

`bool LocatePeak2(int handle,`
`ICorrelationMap2* pCorrelationMap, ICorrelationMap2* pAutoCorrelationMapA, ICorrelationMap2* pAutoCorrelationMapB, IPluginData2** pDataArray,`
`const float xZero, const float yZero, const int dxMax, const int dyMax, float& dx, float& dy, bool& pass)`	

Useful Plugin Methods	

`Bool FindPeakPixel(ICorrelationMap2* pMap,`
`const float xZero, const float yZero,`
`const int dxMax, const int dyMax,`
`int& x, int& y);`
	Finds the highest intensity correlation map pixel in the search area. If no peaks found x and y are –1. Returns false if error.

`Bool GetPeakNeighborhood5(`
`ICorrelationMap2* pMap,`
`const float xZero, const float yZero,`
`const int dxMax, const int dyMax,`
`float& vPeak, float& vLeft, float& vRight,`
`float& vUp, float &vDown, int& x, int& y);`
	Finds the highest intensity pixel in the correlation map search area and returns it and the four nearest neighbors, the pixel used for 3-point curve fitting. If no peak was found x and y = -1. Returns false if error.

`Void SetOutOfBoundsErrorMsg(int x, int y,` `LPCSTR methodName);`	A common error in peak search is looking outside the bound of the correlation map. This method is used to generate a formatted error showing the out-of-bounds location you tried to access.
`Float MeasurePeakToNoiseSNR(void);`	Computes the peak pixel intensity divided by the highest noise peak pixel intensity. A common SNR test for filtering out bad vectors. Returns the ratio.

`void SetSearchArea(ICorrelationMap2* pMap,`
`const float xZero, const float yZero,`
`const int dxMax, const int dyMax);`
	Use to calculate the range of correlation map pixel to search for the peak.

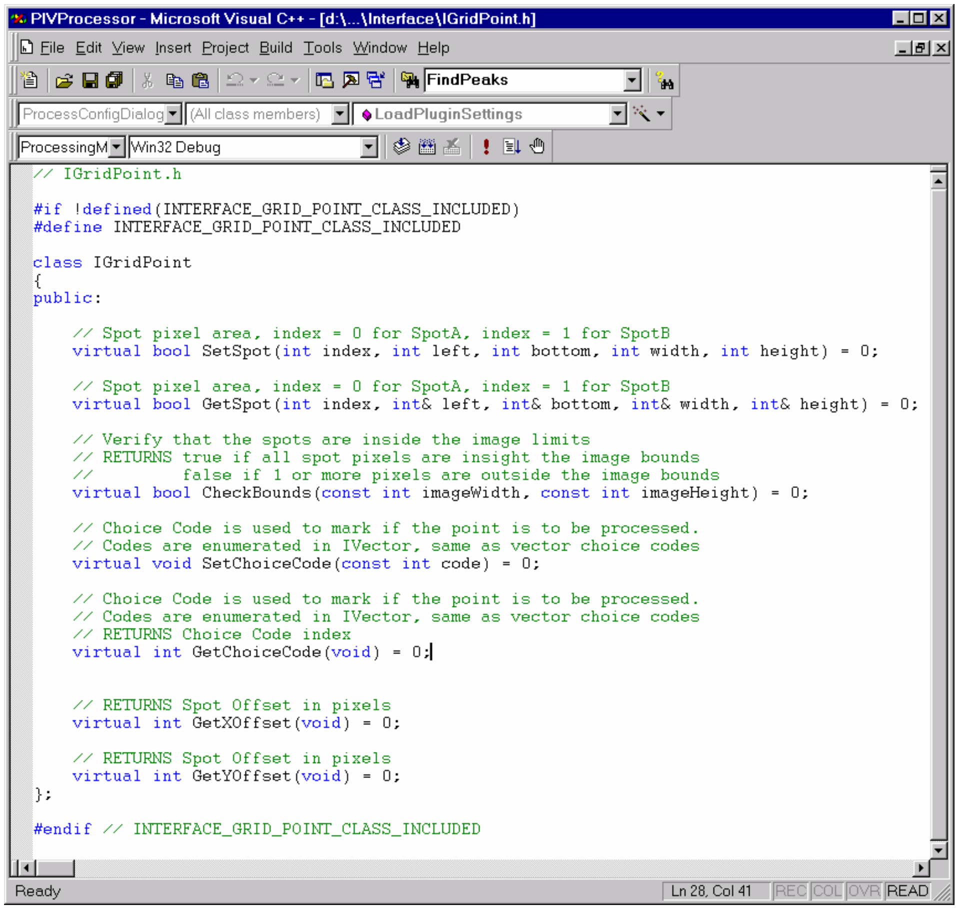
INSIGHT 3G DLL Interface Methods	Description
`bool FindPeaks(ICorrelationMap2* pMap);`	Scans the image and finds the local peaks, storing the parameters of the four largest peaks. Returns false for error.
`bool IsLocalPeak(ICorrelationMap2* pMap, int x, int y, float v, float& sum);`	Returns true if the pixel is higher than all of its neighbors. Sum is the sum of the pixel and its neighbors, use as a tie-breaker if two peaks have the same height.
`void StorePeak(int x, int y, float peakValue, float sum);`	Store the peak location in the peaks array.
`void ClearPeakArray();`	Resets the peak array
`void ShuffleDown(int i);`	Use to sort peaks in the array.
`class PeakRecord`	Use for the peak array.

Interface Classes

The following interface classes and class methods are described. For detailed information, including comments on the use of these methods, refer to the *.H files in the *INSIGHT 3G* \PluginSDK\Interface folder.

- ICorrelationMap2
- IGridPoint
- IPluginData2
- IPluginParameter
- IPluginSettingFactory2
- IPluginVector2
- IPluginVectorField2
- IProcessGrid
- IProcessingMask
- ISpotImage
- PluginID

The following shows an example of a *.H file view with Visual C++.



Class	Description
ICorrelationMap2	The correlation map is the output from the CorrelationEngine and the input to the PeakEngine. The correlation map is a 2D-array of floating point pixels. The particle image displacement is distance from the zero pixel to the particle image displacement peak plus the offset.

Class	Description
ICorrelationMap2 Methods:	
`void SetSize(int width, int height);`	
`bool SetPixelValue(int x, int y, float value);`	
`bool AddToPixelValue(int x, int y, float value);`	
`bool GetPixelValue(int x, int y, float& value);`	
`int GetWidth(void);`	
`int GetHeight(void);`	
`void SetZeroPixel(const float xZero, const float yZero);`	
`bool GetZeroPixel(float& xZero, float& yZero);`	
`void SetMaxDisplacement(const int dxMax, const int dyMax);`	
`bool GetMaxDisplacement(int& dxMax, int& dyMax);`	
`void SetSpotOffset(const int xOffset, const int yOffset);`	
`bool GetSpotOffset(int& xOffset, int& yOffset);`	
`ICorrelationMap2& operator +=(ICorrelationMap2& correlationMap);`	

Class	Description
`IGridPoint`	A grid point is a definition of a pair of spots to be processed. Each spot has a width, height and x, y location. Translating the spots x, y locations sets offsets. The choice code is used to show if a grid point should be processed. CheckBound is used to find out if one of the spots has been offset beyond the image bounds and its choice code should be set to CC_BOUNDS.
GridPointMethods:	
`.Bool SetSpot(int index, int left, int bottom, int width, int height);`	
`bool GetSpot(int index, int& left, int& bottom, int& width, int& height);`	
`bool CheckBounds(const int imageWidth, const int imageHeight;`	
`void SetChoiceCode(const int code);`	
`int GetChoiceCode(void);`	
`int GetXOffset(void);`	
`int GetYOffset(void);`	

Class	Description
`IPluginData2`	A measured value from one of the plugins. Stored in the IpluginVector.
IPluginData2 Methods	
`Void SetValue(float value);`	
`float GetValue(void);`	
`void SetExport(bool writeToFile);`	
`bool GetExport(void);`	
`void SetSnrFilter(bool snrValidate);`	
`bool GetSnrFilter(void);`	
`void SetSnrThreshold(float thresholdValue);`	
`float GetSnrThreshold(void);`	
`void SetSnrGreaterOrLessThan(bool isGreaterThan);`	
`bool GetIsGreaterOrLessThan(void);`	
`void SetDataName(LPCSTR dataName);`	
`LPSTR GetDataName(void);`	
`void SetPluginName(LPCSTR pluginName);`	
`LPSTR GetPluginName(void);`	
`bool Validate(void);`	
`bool ValidateValue(float value);`	
`int GetPluginID(void);`	
`IPluginData2& operator =(IPluginData& pluginData);`	
`IPluginData2& operator +=(IPluginData& pluginData);`	

Class	Description
IPluginParameter	PluginParameters are used to give you control over plugin settings. PluginParameters may be Boolean, float, integer or string variables.

IPluginParameter Methods

```
enum ParameterType
{
       PLUGIN_PARAMETER_BOOL,
       PLUGIN_PARAMETER_FLOAT,
       PLUGIN_PARAMETER_INT,
       PLUGIN_PARAMETER_STRING
};
LPCSTR GetParameterName(void);
LPCSTR GetPluginName(void);
int GetParameterType(void);
bool SetBoolValue(bool b);
bool GetBoolValue(void);
bool SetFloatValue(float f);
float GetFloatValue(void);
bool SetIntValue(int i);
int GetIntValue(void);
bool SetStringValue(LPCSTR string);
LPCSTR GetStringValue(void);
```

Class	Description
IPluginSettingFactory2	Used by a plugin to create IPluginDataConfig and IPluginDataConfiguration objects.

IPluginSettingFactory2 Method

```
void CreatePluginDataConfig(
  int pluginID,
  LPCSTR pluginName,LPCSTR dataName,
  bool isSnrFilter, bool isGreaterThan,
  float snrThreshold, bool exportToFile);

IPluginParameter* CreatePluginParameter(
  int pluginID,
  LPCSTR pluginName,
  LPCSTR ParameterName,
  int parameterType);

IPluginDataConfigurationArray* GetPluginDataConfigArray();
```

Class	Description
IPluginVector2	The vector during processing. The IPluginVector contains the location, velocity, choice code, ICorrelation Map and IPluginData. The ICorrelationMap is only available during processing until the next image is loaded. The IPluginData2 is also only available during processing until the next image is loaded if Export is false.

IPluginVector2 Method

```
typedef enum
{
      CC_BOUNDS = -4,
      CC_NOT_SET,
      CC_REMOVED,
      CC_SNR,
      CC_BLANK,
      CC_1,
      CC_2,
      CC_3,
      CC_INTERPOLATED,
      CC_SMOOTHED,
      CC_MAX
} ChoiceCode;

int getChoiceCode();

LPCSTR getChoiceCodeString(void);

float getU();
Float getV();

float getX();

float getY();

IPluginVector& operator = (IPluginVector& vector);

void setChoiceCode(int choiceCode);

void setU(float u);

void setV(float v);

bool isHole();

void setX(float x);

void setY(float y);

int getPluginDataArraySize(void);

bool getPluginDataArray(
  IPluginData** pDataArray,
  int capacity);

void setPluginData(LPCSTR pluginName,
 LPCSTR dataName, float value);

ICorrelationMap* getCorrelationMap(void);

void setSpotOffset(const int xOffset,
  const int yOffset);
```

Class	Description

`bool getSpotOffset(int& xOffset, int & yOffset);`
 	
`ICorrelationMap2* getCorrelationMap2();`
 	
`bool getPluginDataArray2(IPluginData2** pDataArray, int capacity);`
 	
`ICorrelationMap2* getAutoCorrelationMapA();`
 	
`ICorrelationMap2* getAutoCorrelationMapB();`	

(continued on next page)

Class	Description
`IPluginVectorField2`	2D array of IPluginVector objects.
`IPluginVectorField2 Methods`	

`int getGridColumns();`
`int getGridRows();`
`int getImageHeight();`
`int getImageWidth();`
`void setImageDimensions(int width, int height);`
`IPluginVector& getNearest( float imageX, float imageY);`
`IPluginVector& get(int gridX, int gridY);`
`IPluginVectorField& operator = (IPluginVectorField& vectorField);`
`void set(int gridX, int gridY, IPluginVector& vector);`
`void write(const char* fileName) throw();`
`IPluginVector2& getVector2(int gridX, int gridY);`
`IPluginVectorField2& operator = (IPluginVectorField2& vectorField);`
`void setVector2(int gridX, int gridY, IPluginVector2& vector);`
`IPluginVector2& getNearestVector2(float imageX, float imageY);`	

`IProcessGrid`	2D array of IGridPoints.
IProcessGrid Methods	

`bool SetGridDimensions(int columns, int rows);`
`bool GetGridDimensions(int& columns, int& rows);`
`IGridPoint* GetGridPoint(int column, int row);`
`int GetNumberGridPoints(void);`
`IGridPoint* GetGridPoint(int index);`	

Class	Description
`IProcessingMask`	The processing mask is created using the ROI tab and specified in the Processor Setup dialog. Refer to Defining a Region of Interest and Processing PIV Images. Points with masked pixels are removed or included from the vector field.
IProcessingMask Methods	

`bool getContainsMaskedPixel(int x, int y);`
 	
`bool getContainsMaskedPixel(int left, int bottom, int width, int height);`	

Class	Description
ISpotImage2	The pixel values of one of the spots being processed. ISpotImage is used for both the raw image spots and the masked spots. The pixel are stored as int with a range of -2^{16} to 2^{16} for all image bit depths.
SpotImage Methods	

```
void SetSize(int width, int height,
  int bitsPerPixel);

bool SetPixelValue(int x, int y, int value);

bool GetPixelValue(int x, int y, int& value);

int GetWidth(void);

int GetHeight(void);

int GetBitsPerPixel(void);
int GetGrayScaleMax(void);

void ZeroPixels();

void SetXSpotMaskOffset(float xShift);
void SetYSpotMaskOffset(float yShift);

float GetXSpotMaskOffset();

float GetYSpotMaskOffset();
```

Class	Description
PluginID	Enumerates the ID numbers for the plugin points.
PluginID Methods	

`#define ENGINE_GRID        0x0001`
`#define ENGINE_SPOT_MASK   0x0002`
`#define ENGINE_CORRELATION 0x0004`
`#define ENGINE_PEAK        0x0008`	

Data Files

The following lists the different types of data files and settings stored in INSIGHT 3G.

File	Description
user_defined_name.pivproc	Saves PIV processor settings in these files.
user_defined_name.plifproc	Saves PLIF and spray processor settings in these files.
user_defined_name.pivcond	Saves PIV image conditioning settings in these files.
user_defined_name.plifcond	Saves PLIF image conditioning settings in these files.
user_defined_name.pivval	Saves PIV validation settings in these files.

APPENDIX A

INSIGHT 3G Data Files

This appendix describes the file naming convention and lists all the data files generated in *INSIGHT* 3G.

INSIGHT 3G Filenaming

INSIGHT 3G uses a filenaming system to help organize the many files generated in an experiment. The filenaming system allows many filenames to be derived from the image filenames, so that you do not have to enter filenames for each process. A typical full filename for an image is listed in Table A-1 below.

Table A-1
Filename Components

C:*Experiments7* \Demo000000.T001.D001.P001. H001.La.tif	Full filename
C:*Experiments7*	Directory where the files are stored. This is the name specified when *INSIGHT* 3G is setup. In this example, Experiments 7 is the directory where these image files are stored
Cap000000.T001.D001.P001.H00 1.Ra.tif	Filename
Filename Components	
Cap	RunName
000000	Sequence Number All images that are processed to create a vector field have the same frame number.
T0001	Traverse.
D0001	Delay
P001	Process
H001	Hardware configuration

Table A-1
Filename Components

R	Camera Identifier used for two camera systems. A camera ID is added to the filename if two-camera image capture is being used. L is used for the left camera and R is used for the right camera. If you have a two-camera system but are capturing a sequence using only the left or only the right camera, no Camera ID character is used. If you have a single camera system, no Camera ID character is added to the filename.
a	Frame Straddle Frame Identifier. If Frame Straddle Image capture mode is selected, a Frame ID character is added to the filename. The character A designates the first frame and B designates the second frame of a frame straddle image pair. If Frame Straddle mode is not selected, no Frame ID character is used in the filename.
.tif	File extension

Table A-2
Number of Images with Same Sequence Number for Image Capture Modes

Number Cameras	Frame Straddle Capture	Number of Images with same Sequence Number
1	no	1
1	yes	2
2	no	2
2	yes	4

Note: Do Not End Family Name with a Number
The sequence number is determined by reading the filename backwards. It does not assume a fixed number of digits for the sequence number. If the family name ends with a digit, that character is interpreted as part of the sequence number, not the family name. This may not be desired.

INSIGHT 3G Files

The following table lists all the files that are generated and used by *INSIGHT* 3G. Some of these files are described in detail in this appendix.

File Extension	Description
Tif	Standard image file.
Mac	A macro, listing a number of commands or instructions programmed by you that can be executed with a single mouse click. See "Programming Macros" for details.
Vec	2D Vectors: a set of vectors produced by PIV processing. It may also include summarized PLIF data extracted from a PLIF processed image. See "Vector (*.VEC) File" in this appendix.
Par	Particles: a set of particles produced by PTV or GSV processing.
V3d	3D Vectors: a set of 3D vectors produced by PIV processing. See "3-D Vector Files."
Exp	Notes and settings of an Experiment.
Run	Notes and settings of a Run.
ROI	Region of Interest. A rectangle, line or polygon region of interest. They can be saved and re-used.
PIV2dCal	PIV 2d Calibration File.
PLIFPerCal	PLIF Perspective Calibration File. See "Perspective Calibration (*.PIVPERCAL) (*.PIVPLIFCAL) Files."
PIVPerCal	PIV Perspective Calibration File. See "Perspective Calibration (*.PIVPERCAL) (*.PIVPLIFCAL) Files."
PLIFProc	PLIF Process Settings File.
PIVCond	PIV Conditioner Settings File. A typical conditioner would be background subtraction.
PLIFCond	PLIF Conditioner Settings File.
PIVProc	PIV Process Settings File.
PIVVal	PIV Validation File.
Capture	Capture Settings File. All timings and settings required to execute a capture are in this file.
PIProc	Particle Identification Settings File.
PTProc	Particle Tracking Settings File.
PTVProc	Particle Tracking Velocimetry Settings Files.
GSVCond	GSV Conditioner Settings File.
GSVSProc	GSV Sizing Settings File.
GSVTProc	GSV Tracking Settings File.

The following describes the format and contents of some of the files listed in the above table.

Vector (*.VEC) Files

The vector file is created by INSIGHT 3G when an image is processed, or when vector fields are averaged together. The vector files may be in units of mm and m/s, or in pixels depending on the calibration mode selected. The file header line labels the data columns and shows which measurement units were used. In addition to the vector location, a vector choice code value is recorded in the vector record. This choice code shows where the vector came from and if it should be considered a good vector. If the vector should not be used, the velocity value is stored as 9.9e9. This very large velocity value was chosen to create obvious errors should you mistakenly include it in any calculations.

Choice (CHC) Codes

The choice code in the velocity record identifies some information about the vector. Only vectors with positive CHC codes should be accepted in velocity field computations. The number of vectors with each choice code can be found in INSIGHT 3G by using the **PIV Validation | Statistics** dialog, or the Statistics List File. Refer to "Setting up and Validating Vectors" for details. The following lists the choice codes.

Table A-3
Choice Codes

CHC	Description
1	Highest correlation peak used for vector
2	2nd highest correlation peak used for vector
3	3rd highest correlation peak used for vector
4	Interpolated vector
5	Smoothed Measured Vector, was a code 1, 2 or 3 before smoothing
0	Temporally Blank. Vector did not pass a validation criteria and is waiting to be filled with an interpolated vector
-1	SNR Fail. The vector was removed because the correlation did not pass the SNR validation criteria defined in the Process | Setup | Signal Levels dialog
-2	Removed point. The point has been disabled by the Process | Polynomial Grid, or other removed point from grid.
-3	Bounds, 3-D Vector outside 2-D vector field overlap range. *.V3D file, or the 2D vector is out of the image bounds after spot offset.
-4	Vector has not been set.

Error Vectors

Velocity values of 9.9e9, indicate an error velocity. This is not a valid velocity value. Following shows an error vector record:

```
5.200000, 49.600002, 9999899648.000000, 9999899648.000000, -1
```

X Position mm	5.200000
Y Position mm	49.600002
U Velocity m/s	9999899648.000000 (9.9e9)
V Velocity m/s	9999899648.000000 (9.9e9)
Choice Code	-1 Non-positive choice code indicates error vector.

Pixel *.VEC Files

A pixel displacement *.VEC vector file is created by INSIGHT 3G when an image is processed in the Pixel Measurement mode. In this mode, the vector locations are in pixels, with the lower left image corner being pixel (0, 0) and the upper right corner being the image size in pixels (width, height). The U and V velocities are pixel displacements. The dT time between laser pulses is not used in the Pixel*VEC file.

A graph of the pixel VEC field looks the same as velocity VEC graphics, except for the axis labels in Tecplot. Using pixel displacements is recommend during experiment setup when you are changing the image field of view and finding the optimum dT. Once the experiment is configured, you should measure the field of view and make velocity measurements.

For Stereoscopic PIV, the left and right images must be processed in pixel units. The vector field combination converts from pixel to velocity.

Pixel *.VEC Header Line

The following shows the header line information.

TITLE="\D:\Experiments\Deg\Vector\Deg00000L.vec"	Filename
VARIABLES= "X pixel", "Y pixel", "U pixel", "V pixel", "CHC"	Data Column names. Note that the locations and displacements are in pixels
ZONE T="Pixel, Height=1016, Width=1000 "	File type and image size
I=5, J=5,	Number of data columns and rows
F=POINT	Data record format

Pixel *.VEC File Listing

The following lists the information in the vector file.

```
TITLE="\D:\Experiments\NoFlame\Vector\NoFlame00000.vec”
VARIABLES= "X pixel", "Y pixel", "U pixel", "V pixel", "CHC”
ZONE T="Pixel, Height=1016, Width=1008 “ I=5, J=5, F=POINT
178.000000, 740.000000, 0.491974, 6.357293, 1
220.000000, 740.000000, -0.018176, 6.074150, 1
262.000000, 740.000000, -0.909887, 3.350246, 1
304.000000, 740.000000, -0.556065, 2.236705, 1
346.000000, 740.000000, 0.936499, 2.503492, 1
178.000000, 697.000000, 0.926384, 6.084085, 1
220.000000, 697.000000, 1.048864, 5.355914, 1
262.000000, 697.000000, 0.184813, 2.561666, 1
304.000000, 697.000000, 0.097759, 1.811634, 1
346.000000, 697.000000, 1.062590, 1.723937, 1
178.000000, 654.000000, 2.140738, 6.097198, 1
220.000000, 654.000000, 2.681501, 5.165774, 1
262.000000, 654.000000, 3.058857, 4.093365, 1
304.000000, 654.000000, 2.807137, 2.704170, 1
346.000000, 654.000000, 1.884373, 0.276705, 1
178.000000, 611.000000, 2.914146, 6.338531, 1
220.000000, 611.000000, 3.954605, 5.376866, 1
262.000000, 611.000000, 4.598196, 3.926779, 1
304.000000, 611.000000, 4.705809, 2.075917, 1
346.000000, 611.000000, 2.659779, -2.413448, 1
178.000000, 568.000000, 3.367159, 7.807587, 1
220.000000, 568.000000, 4.726717, 5.827351, 1
262.000000, 568.000000, 5.950926, 3.602065, 1
304.000000, 568.000000, 6.672514, 2.030572, 1
346.000000, 568.000000, 4.341700, 1.140477, 1
```

Velocity *.VEC File

A velocity *.VEC vector file is created by INSIGHT 3G when an image is processed in Velocity measurement mode. In this mode, the image field of view is calibrated to convert from pixels to mm and m/s.

Velocity *.VEC Header Line

The following lists the information in the vector header file.

TITLE="\D:\Experiments\NoFlame\Vector\NoFlame 00000.vec"	Filename
VARIABLES= "X mm", "Y mm", "U m/s", "V m/s", "CHC"	Data Columns Titles. Note that the vector positions are in mm and the vectors are m/s.
ZONE T="50.000000um/p, 50.000000um/p, 500.000000us, Height=1016, Width=1008 "	File calibration data. The X and Y pixel size in the fluid µm/pixel, dT time between laser pulses in µs, and the image size in pixels.
I=5, J=5,	Number of vector columns and rows
F=POINT	Data Record Format

Velocity *.VEC File Listing

The following lists the information in the vector file.

```
TITLE="\D:\Experiments\NoFlame\Vector\NoFlame00000.vec"
VARIABLES= "X mm", "Y mm", "U m/s", "V m/s", "CHC" ZONE
T="50.000000um/p, 50.000000um/p, 500.000000us, Height=1016,
Width=1008 " I=5, J=5, F=POINT
8.400000, 40.600002, -0.065474, 0.692784, 1
11.500001, 40.600002, -0.122179, 0.831409, 1
14.600001, 40.600002, -0.192558, 0.146732, 1
17.700001, 40.600002, -0.008696, 0.036004, 1
20.800001, 40.600002, -0.048741, 0.013533, 1
8.400000, 37.200002, 0.031781, 0.640250, 1
11.500001, 37.200002, -0.032186, 0.611632, 1
14.600001, 37.200002, -0.119164, 0.262560, 1
17.700001, 37.200002, 0.116347, 0.216588, 1
20.800001, 37.200002, -0.190743, -0.126673, 1
8.400000, 33.800002, 0.143111, 0.632801, 1
11.500001, 33.800002, 0.176790, 0.492490, 1
14.600001, 33.800002, 0.196977, 0.289668, 1
17.700001, 33.800002, 0.186416, 0.113515, 1
20.800001, 33.800002, -0.032692, -0.095980, 1
8.400000, 30.400001, 0.247513, 0.716288, 1
11.500001, 30.400001, 0.414715, 0.510695, 1
14.600001, 30.400001, 0.487097, 0.284305, 1
17.700001, 30.400001, 0.242056, -0.261369, 1
20.800001, 30.400001, 0.539581, -0.269433, 1
8.400000, 27.000001, 0.159128, 0.942642, 1
11.500001, 27.000001, 0.618935, 0.649365, 1
14.600001, 27.000001, -0.790643, -0.561989, 1
17.700001, 27.000001, 0.014077, -0.599571, 1
20.800001, 27.000001, 0.383812, -0.353321, 1
```

Average Vector (*AVG.VEC) File

The Average vector field file is created with Tecplot by averaging a sequence of vector fields at each measurement location. This file format is similar to the standard VEC file format. The changes are the velocity is Mean Velocity and the fifth column is Count instead of Choice. The Average Vector file can be included as part of an animation sequence in Tecplot so that the animation can show a sequence of instantaneous vector fields followed by the average vector field.

The count is the number of valid vectors (vectors with a positive choice code) at each location. The maximum count is the number of vector fields averaged together. If some vectors at a location were not valid, the count at that point is reduced. Only valid points are included in the average.

The vector grid for all of the vector fields in the average must be the same. Having a different number of vector columns and rows, or different vector locations in some of the VEC files used in the average will give incorrect results.

The units of the *AVG.VEC file may be in either pixels or mm and m/s depending on the units of the VEC files used in computing the average.

(continued on next page)

Average Vector File Listing

The following shows an Average Vector file listing:

```
TITLE="\D:\Experiments\Deg\Vector\DegL” VARIABLES= "X pixel",
"Y pixel", "U Mean pixel", "V Mean pixel", "Count” ZONE
T="Pixel, Height=1016, Width=1000 “ I=5, J=5, F=POINT
138.000000, 908.000000, 0.194089, 0.241566, 8
261.000000, 908.000000, 0.233431, 0.205879, 8
384.000000, 908.000000, 0.267045, 0.153003, 8
507.000000, 908.000000, 0.358548, 0.153543, 8
630.000000, 908.000000, 0.431884, 0.111491, 8
138.000000, 827.000000, 0.159519, 0.154415, 8
261.000000, 827.000000, 0.226142, 0.126557, 8
384.000000, 827.000000, 0.266780, 0.096698, 8
507.000000, 827.000000, 0.359502, 0.111918, 8
630.000000, 827.000000, 0.419891, 0.055146, 8
138.000000, 746.000000, 0.162204, 0.104445, 8
261.000000, 746.000000, 0.228636, 0.103401, 8
384.000000, 746.000000, 0.276518, 0.079071, 8
507.000000, 746.000000, 0.360926, 0.077221, 8
630.000000, 746.000000, 0.452794, 0.069008, 8
138.000000, 665.000000, 0.155498, 0.070431, 8
261.000000, 665.000000, 0.217330, 0.035222, 8
384.000000, 665.000000, 0.275173, 0.032714, 8
507.000000, 665.000000, 0.353082, -0.035741, 8
630.000000, 665.000000, 0.436182, 0.020788, 8
138.000000, 584.000000, 0.166035, 0.034134, 8
261.000000, 584.000000, 0.224729, 0.041150, 8
384.000000, 584.000000, 0.282870, 0.002764, 8
507.000000, 584.000000, 0.359145, 0.008448, 8
630.000000, 584.000000, 0.415600, -0.017352, 8
```

Mean and Standard Deviation (*.STD) Vector File

The mean and standard deviation file is computed by Tecplot from a sequence of vector fields. The *.STD contains all of the data in the *AVG.VEC file plus the standard deviation of the valid velocity measurements at each location.

The *.STD file has two more data columns than the *AVG.VEC file and so cannot be opened with a sequence of VEC files in Tecplot to create an animation.

The units of the *.STD file may be in either pixels or mm and m/s depending on the units of the VEC files used in computing the average.

Mean and Standard Deviation File Header

The following lists the information in the Mean and Standard Deviation File header:

TITLE="D:\Experiments\Deg\Vector\DegLAvg.std"	Filename
VARIABLES= "X pixel", "Y pixel", "U Mean pixel", "V Mean pixel", "Count", "U StdDev", "V StdDev"	Data Column Titles
ZONE T="Pixel, Height=1016, Width=1000 "	Calibration data
I=5, J=5	Number of vector Columns and Rows
F=POINT	Data Record Format

Mean and Standard Deviation File Listing

The following is a listing of the Mean and Standard Deviation file:

```
TITLE="D:\Experiments\Deg\Vector\DegLAvg.std” VARIABLES= "X pixel",
"Y pixel", "U Mean pixel", "V Mean pixel", "Count", "U StdDev", "V
StdDev” ZONE T="Pixel, Height=1016, Width=1000 “ I=5, J=5, F=POINT
138.000000, 908.000000, 0.194089, 0.241566, 8, 0.009636, 0.006454
261.000000, 908.000000, 0.233431, 0.205879, 8, 0.010775, 0.006944
384.000000, 908.000000, 0.267045, 0.153003, 8, 0.009808, 0.005208
507.000000, 908.000000, 0.358548, 0.153543, 8, 0.017558, 0.009246
630.000000, 908.000000, 0.431884, 0.111491, 8, 0.020065, 0.018837
138.000000, 827.000000, 0.159519, 0.154415, 8, 0.008751, 0.005492
261.000000, 827.000000, 0.226142, 0.126557, 8, 0.024162, 0.008655
384.000000, 827.000000, 0.266780, 0.096698, 8, 0.019269, 0.009730
507.000000, 827.000000, 0.359502, 0.111918, 8, 0.028638, 0.010139
630.000000, 827.000000, 0.419891, 0.055146, 8, 0.013219, 0.011245
138.000000, 746.000000, 0.162204, 0.104445, 8, 0.009589, 0.007419
261.000000, 746.000000, 0.228636, 0.103401, 8, 0.006463, 0.007079
384.000000, 746.000000, 0.276518, 0.079071, 8, 0.016142, 0.007830
507.000000, 746.000000, 0.360926, 0.077221, 8, 0.016967, 0.006335
630.000000, 746.000000, 0.452794, 0.069008, 8, 0.017017, 0.003942
138.000000, 665.000000, 0.155498, 0.070431, 8, 0.008919, 0.002538
261.000000, 665.000000, 0.217330, 0.035222, 8, 0.017503, 0.004883
384.000000, 665.000000, 0.275173, 0.032714, 8, 0.032399, 0.007115
507.000000, 665.000000, 0.353082, -0.035741, 8, 0.010044, 0.008536
630.000000, 665.000000, 0.436182, 0.020788, 8, 0.012876, 0.006777
138.000000, 584.000000, 0.166035, 0.034134, 8, 0.010848, 0.004685
261.000000, 584.000000, 0.224729, 0.041150, 8, 0.013074, 0.002998
384.000000, 584.000000, 0.282870, 0.002764, 8, 0.015167, 0.004134
507.000000, 584.000000, 0.359145, 0.008448, 8, 0.021311, 0.002282
630.000000, 584.000000, 0.415600, -0.017352, 8, 0.030514, 0.005010
```

Particle (*.PAR) Files

The Particle file is created by *INSIGHT* 3G when an image is processed with PTV processor (.PAR) or GSV sizing processor (.GSVX.PAR). Particle files may be in units of mm and m/s, or in pixels depending on the calibration mode selected. The file header line labels the data columns and shows which measurement units were used. In addition to the particle position, velocity and size information, a particle choice code value is recorded in the particle record to show the status of the particle.

Choice (CHC) Codes

The choice code in the particle record identifies some information about the particle. Only particles with non-negative CHC codes should be included in the final particle field, and only particles with positive CHC codes should be accepted in velocity field computations. The following lists the choice codes.

Table A-4
Choice Codes

CHC	Description
1	Particles with a valid velocity vector
0	Particles obtained without velocity processing
-3	Particles with an invalid velocity vector
-4	Particles without velocity vector

Velocity Not Set

Velocity values of 9.9e9 indicate the particle velocity has not been set. It can happen when no velocity processing has been done for the particles. For example, only particle identification is done in PTV processor, or only GSV sizing is done in GSV. The choice code 0 is used in these cases. Velocity Not Set can also happen when no velocity is found for some particles in the velocity processing. The choice code -4 is used for those particles.

Statistics List (*STL) File

The Statistics List File gives a summary of the vector file data for a sequence of vector fields. The first line is the header that labels the data columns. The Statistics List File can be read into a spreadsheet program. Viewing this file can show how a sequence of vector fields are changing. For example, did some vector fields require more editing than the others, how are the mean velocity values changing over time.

To read the Statistics file into Microsoft Excel Spreadsheet program:

1. Click **File | Open** to get the file selection dialog box.
2. Change the Files of Type to All Files (*.*).
3. Select the Statistics (*STL) file.
4. Using the Text Import Wizard dialog, select **Delimited.**
5. Click **Next**.
6. On the next page select **Comma.**
7. Click **Finished**. The data is read into an Excel spreadsheet with the column titles in Row A, and one line for each file in the list.

Statistics File Header

Following table shows the header of the Statistics file.

File	Filename
Velocity Statistics	
U Mean	Average U velocity values in vector field
V Mean	Average V velocity values in vector field
U StdDev	Standard Deviation of U velocity
V StdDev	Standard Deviation of V velocity values in vector field
Velocity Range	
U Max	Largest U velocity value
U Min	Minimum U velocity value
V Max	Largest V velocity value
V Min	Minimum V Velocity value
Choice Code Counts	
1st Choice	Number of first peak vectors, choice code 1
2nd Choice	Number of second peak vectors, choice code 2
3rd Choice	Number of third peak vectors, choice code 3
Smoothed	Number of measured smoothed vectors, choice code 5
Interpolated	Number of interpolated vectors, choice code 4
Temp Blank	Number of temporally blank vectors, choice code 0
SNR Fail	Number of vectors where correlation failed SNR criteria , choice code -1
Removed	Number of vectors removed by polygon edit, choice code -2
Vector Units	
Velocity Unit	Vector field units either Pixels or m/s

Statistics File Listing

The following is an example listing of a statistics file:

```
File, U Mean, V Mean, U StdDev, V StdDev, U Max, U Min, V
Max, V Min, 1st Choice, 2nd Choice, 3rd Choice, Smoothed,
Interpolated, Temp Blank, SNR Fail, Removed, Velocity Unit
d:\experiments\deg\vector\deg00001.vec, 0.284133, 0.081017,
0.098876, 0.067917, 0.460182, 0.150314, 0.236902, -0.025677,
25, 0, 0, 0, 0, 0, 0, 0, pixel
d:\experiments\deg\vector\deg00021.vec, 0.293000, 0.079595,
0.098131, 0.067056, 0.456886, 0.156136, 0.231293, -0.030029,
25, 0, 0, 0, 0, 0, 0, 0, pixel
d:\experiments\deg\vector\deg00041.vec, 0.284765, 0.079688,
0.097722, 0.067306, 0.436539, 0.142189, 0.240892, -0.042515,
25, 0, 0, 0, 0, 0, 0, 0, pixel
d:\experiments\deg\vector\deg00061.vec, 0.304321, 0.082242,
0.098571, 0.068352, 0.462822, 0.161285, 0.243132, -0.049000,
25, 0, 0, 0, 0, 0, 0, 0, pixel
d:\experiments\deg\vector\deg00006r.vec, -0.292504, 0.135428,
0.120730, 0.070908, -0.123068, -0.507261, 0.273191, 0.013832,
25, 0, 0, 0, 0, 0, 0, 0, pixel
d:\experiments\deg\vector\deg00008r.vec, -0.294194, 0.130916,
0.106345, 0.073018, -0.133028, -0.478882, 0.272966, 0.011860,
25, 0, 0, 0, 0, 0, 0, 0, pixel
d:\experiments\deg\vector\deg00010r.vec, -0.289989, 0.128955,
0.110417, 0.069614, -0.129911, -0.468920, 0.264456, 0.009594,
25, 0, 0, 0, 0, 0, 0, 0, pixel
d:\experiments\deg\vector\deg00012r.vec, -0.296084, 0.132140,
0.109434, 0.070635, -0.133997, -0.477514, 0.267853, 0.017067,
25, 0, 0, 0, 0, 0, 0, 0, pixel
d:\experiments\deg\vector\deg00014l.vec, 0.276679, 0.084987,
0.091532, 0.068646, 0.433334, 0.149426, 0.241810, -0.029633,
25, 0, 0, 0, 0, 0, 0, 0, pixel
d:\experiments\deg\vector\deglavg.vec, 0.056147, 0.101641,
0.101377, 0.065080, 0.207377, -0.099389, 0.232638, 0.008464,
25, 0, 0, 0, 0, 0, 0, 0, pixel
d:\experiments\deg\vector\deglAVG.vec, 0.032628, 0.103661,
0.101940, 0.065097, 0.183320, -0.125280, 0.231745, 0.011045,
25, 0, 0, 0, 0, 0, 0, 0, pixel
```

Image Capture Timing (*.TXT) File

When a sequence of images is captured to RAM, a timing file is stored in the experiment folder showing the times when the images were captured. All times recorded in this file are in milliseconds.

The first line is the time and date of the opening of the log file.

The image filename is shown in the first column.

The second column is the elapsed time since the beginning of the capture. Note that the elapsed time between the beginning of the capture and the first actual capture will always be larger than the time between subsequent captures. This is due to various startup activities (memory allocation, synchronizer communication, etc.) that take place during this time.

The third column shows the time since the last frame captured and can be analyzed to look for missed triggers. To get the frame rate in frames per second, use 1/time/1000.

The fourth column shows the time spent solely in the frame grabber. In certain cases this can be used to determine if other processes are affecting the capture rate.

Timing File Listing

The following is an example of a timing (*.TXT) file listing the camera timing information.

timestampLeftPIV.txt - Notepad

File Edit Format View Help

```
Timing Log Opened: 10/21/2004 11:23:36 AM
Capture Name                           Elapsed Time (ms)   Time Since Last Frame (ms)FrameGrabber time (ms)
begin capture                          0                   0                   0
AOI run000001.T000.D000.P000.H001      9143                9143                586
AOI run000002.T000.D000.P000.H001      9744                601                 600
AOI run000003.T000.D000.P000.H001      10345               601                 601
AOI run000004.T000.D000.P000.H001      10945               600                 601
AOI run000005.T000.D000.P000.H001      11556               611                 611
AOI run000006.T000.D000.P000.H001      12147               591                 591
AOI run000007.T000.D000.P000.H001      12748               601                 600
AOI run000008.T000.D000.P000.H001      13349               601                 601
AOI run000009.T000.D000.P000.H001      13950               601                 600
AOI run000010.T000.D000.P000.H001      14551               601                 603
AOI run000011.T000.D000.P000.H001      15161               610                 609
AOI run000012.T000.D000.P000.H001      15782               621                 620
AOI run000013.T000.D000.P000.H001      16383               601                 600
AOI run000014.T000.D000.P000.H001      16984               601                 600
AOI run000015.T000.D000.P000.H001      17585               601                 600
AOI run000016.T000.D000.P000.H001      18186               601                 601
AOI run000017.T000.D000.P000.H001      18787               601                 601
AOI run000018.T000.D000.P000.H001      19388               601                 601
AOI run000019.T000.D000.P000.H001      19988               600                 601
AOI run000020.T000.D000.P000.H001      20589               601                 601
```

3-D Vector Files

The following lists the files created and processed in the INSIGHT 3G Stereo PIV version and their formats:

Extension	Description	Format
V3D	3-D vector file.	ASCII & Tecplot
*.PIVPERCAL *.PIVPLIFCAL	Calibration File. Contains the polynomial equations for mapping points from the fluid to the cameras and from the cameras to the fluid.	ASCII
.CPT	Calibration Points File. Lists the location of the calibration markers in the image and fluid for one calibration image.	ASCII
.GRD	Calibration Gradient. Lists the 12 displacement gradients for each point.	ASCII & Tecplot

3-D Vector (*.V3D) File

The 3-D vector file is created by combining two, 2-D vector files into one 3-D vector file. The file contains a header line and one record for each vector.

The U, V, and W velocity components are computed using a least-squares fit of the left vector and right vector. The residual error found by plugging the least-squares solution back into the equations. The total residual error is the square root of the component residual errors squared. The units of the residual error are in pixels. For example if the residual error is 1.0 pixel, the left and right vectors did not match by one pixel. In typical PIV configurations this indicates that the two V velocity measurements differed by 1 pixel. The residual can be used as a check to make sure that the two 2-D vector can be from the same 3-D vector.

The choice codes are listed in the VEC file format definition. Non-positive choice codes indicate errors and must not be used in velocity field statistics.

3-D Vector Header Line

Following shows a 3-D vector file header:

TITLE="D:\Experiments\Deg\Vector\Deg00000.v3D"	filename
VARIABLES="X mm", "Y mm", "Z mm", "U m/s", "V m/s", "W m/s", "CHC", "Residual pixels"	Data Column Titles
ZONE T="3D Velocity"	Title
I=4, J=4, K=1	Columns, Rows, Planes, K is always 1 for stereo PIV
F=POINT	Record Format

Note: *The V3D file units are always in mm and m/s, not pixels.*

3-D Vector (*.V3D) File Listing

The following is a 3-D Vector file listing:

```
TITLE="D:\Experiments\Deg\Vector\Deg00000.v3D" VARIABLES="X mm", "Y mm", "Z
mm", "U m/s", "V m/s", "W m/s", "CHC", "Residual pixels", ZONE T="3D
Velocity" I=4, J=4, K=1, F=POINT
-9.60459, -15.9296, 0, -0.000524411, 0.00414582, -0.461622, 1, 0.0314854
-6.20357, -15.9296, 0, 0.000194652, 0.00430889, -0.442992, 1, 0.0159115
-2.80255, -15.9296, 0, -0.000152724, 0.00397104, -0.420229, 1, 0.0291489
0.598478, -15.9296, 0, 4.18488e-005, 0.00395065, -0.440376, 1, 0.0357319
-9.60459, -12.5285, 0, 9.20153e-005, 0.00487148, -0.453866, 1, 0.00915304
-6.20357, -12.5285, 0, -3.58881e-005, 0.0044658, -0.45274, 1, 0.0157696
-2.80255, -12.5285, 0, 0.000419979, 0.0045025, -0.419085, 1, 0.0297433
0.598478, -12.5285, 0, 0.000382887, 0.00470845, -0.427999, 1, 0.00732069
-9.60459, -9.12751, 0, 0.000157937, 0.00271535, -0.46542, 1, 0.0158749
-6.20357, -9.12751, 0, -0.000528862, 0.00380699, -0.42884, 1, 0.034495
-2.80255, -9.12751, 0, -0.0016384, 0.00325252, -0.385416, 1, 0.0543617
0.598478, -9.12751, 0, -0.000608029, 0.00317918, -0.405632, 1, 0.0737102
-9.60459, -5.72648, 0, -0.000905317, 0.00278981, -0.476492, 1, 0.0034331
-6.20357, -5.72648, 0, -0.0002381, 0.00213592, -0.430195, 1, 0.0281619
-2.80255, -5.72648, 0, 0.000811252, 0.00254835, -0.450617, 1, 0.00909315
0.598478, -5.72648, 0, 0.00182587, 0.00309806, -0.413516, 1, 0.0262402
```

Perspective Calibration (*.PIVPERCAL) (*.PIVPLIFCAL) Files

The perspective calibration file contains header information about the number of cameras and equation orders, a set of four polynomial equations for each camera and the list of calibration points files that were used as the input data.

Perspective Calibration File: Header Information

The following shows the header information which contains the file format version, number of cameras, the equation orders, and the number of terms in each polynomial equation and the image size:

```
TSI_CAL_VERSION 2.000000
2, Cameras
2, X Polynomial Order
2, Y Polynomial Order
2, Z Polynomial Order
10 Polynomial Terms
1000 x 1016 Pixels
```

Perspective Calibration File: Equations for Each Camera

Each camera has four polynomial equations that map locations between the image and the fluid. The first two equations map a (x, y, z) location in the fluid to an image (X, Y) pixel. The next two equations map image X, Y pixel locations into the fluid at z location into a fluid (x, y) location.

1: X pixel = f(x, y, z) in the fluid

2: Y pixel = f(x, y, z) in the fluid

3: x in Fluid = f(X, Y, z) X, Y pixel location and fluid z

4: y in Fluid = f(X, Y, z) X, Y pixel location and fluid z

The first two equations that map from a point in the fluid to a camera pixel are used in the actual stereo PIV processing equations. The two equations that map from a camera pixel and z depth, to a point in the fluid are used as part of the user interface. These functions allow the camera field of view to be seen in the fluid space for example.

Each line of the polynomial is one equation term. The first column is the coefficient, the second is the X exponent, the third column is the Y exponent and the last column is the Z exponent. An example polynomial equation from the sample file is shown below:

```
Left Camera X pixel = f(x mm, y mm, z mm)
498.28, 0, 0, 0
15.9418, 1, 0, 0
0.0746178, 0, 1, 0
7.20318, 0, 0, 1
-0.0217225, 2, 0, 0
-0.00269723, 1, 1, 0
0.00207929, 0, 2, 0
0.0543614, 1, 0, 1
-0.00117683, 0, 1, 1
1.96596, 0, 0, 2
```

For an input (x, y, z) location, the image is mapped to the camera X pixel :

$$X \text{ pixel} = 499.28 + (15.9418\ x) + (0.0746178\ y) + (7.20318\ z) + (-0.0217225\ x^2) + (-0.00269723\ xy) + 0.00207929\ y^2) + (0.0543614\ xz) + (-0.00117683\ yz) + (1.96596\ z^2)$$

Perspective Calibration File: Listing of Calibration Points

As shown below, this section of the Perspective Calibration file starts with header line Calibration Files, followed by the path to the files and then a list of all calibration points files used in the calibration. Perspective Calibration reads in these calibration files and draws the calibration points in the fluid and camera views to show the calibration data.

```
Calibration Files
D:\Experiments\MyExperiment\Settings\CalMyExperiment000000.T0
000.D0000.P0000.H0000.LA.TIF\
cal00L.cpt
cal01L.cpt
cal02L.cpt
cal03L.cpt
cal04L.cpt
cal00R.cpt
cal01R.cpt
cal02R.cpt
cal03R.cpt
cal04R.cpt
```

The following is a listing of the Perspective Calibration File:

```
TSI_CAL_VERSION 2.000000
2, Cameras
2, X Polynomial Order
2, Y Polynomial Order
2, Z Polynomial Order
10 Polynomial Terms
1000 x 1016 Pixels
Left Camera X pixel = f(x mm, y mm, z mm)
498.28, 0, 0, 0
15.9418, 1, 0, 0
0.0746178, 0, 1, 0
7.20318, 0, 0, 1
-0.0217225, 2, 0, 0
-0.00269723, 1, 1, 0
0.00207929, 0, 2, 0
0.0543614, 1, 0, 1
-0.00117683, 0, 1, 1
1.96596, 0, 0, 2
Left Camera Y pixel = f(x mm, y mm, z mm)
509.441, 0, 0, 0
-0.224836, 1, 0, 0
16.8926, 0, 1, 0
1.02466, 0, 0, 1
0.000430078, 2, 0, 0
-0.0251999, 1, 1, 0
```

```
-0.00244276, 0, 2, 0
-0.00426572, 1, 0, 1
0.0722038, 0, 1, 1
-0.401407, 0, 0, 2
Left Camera x mm = f(X pixel, Y pixel, z mm)
-29.8091, 0, 0, 0
0.0571186, 1, 0, 0
-5.01267e-005, 0, 1, 0
-0.305822, 0, 0, 1
5.4566e-006, 2, 0, 0
5.58161e-007, 1, 1, 0
-4.82353e-007, 0, 2, 0
-0.000306184, 1, 0, 1
2.45321e-007, 0, 1, 1
-0.124284, 0, 0, 2
Left Camera y mm = f(X pixel, Y pixel, z mm)
-29.0498, 0, 0, 0
-0.00207564, 1, 0, 0
0.0559703, 0, 1, 0
0.0881426, 0, 0, 1
5.90531e-008, 2, 0, 0
5.62622e-006, 1, 1, 0
4.86601e-007, 0, 2, 0
-1.09743e-006, 1, 0, 1
-0.000302387, 0, 1, 1
0.0235868, 0, 0, 2
Right Camera X pixel = f(x mm, y mm, z mm)
503.33, 0, 0, 0
16.8737, 1, 0, 0
-0.0190635, 0, 1, 0
-3.83467, 0, 0, 1
0.016045, 2, 0, 0
-0.00290465, 1, 1, 0
-0.00206668, 0, 2, 0
0.073668, 1, 0, 1
0.000886864, 0, 1, 1
2.76027, 0, 0, 2
Right Camera Y pixel = f(x mm, y mm, z mm)
505.766, 0, 0, 0
0.0991513, 1, 0, 0
17.2623, 0, 1, 0
0.948321, 0, 0, 1
0.000272029, 2, 0, 0
0.0183154, 1, 1, 0
-0.00264331, 0, 2, 0
0.00150064, 1, 0, 1
0.0799081, 0, 1, 1
-0.438243, 0, 0, 2
Right Camera x mm = f(X pixel, Y pixel, z mm)
-30.4821, 0, 0, 0
```

```
0.0624117, 1, 0, 0
-0.000655091, 0, 1, 0
0.376267, 0, 0, 1
-3.3662e-006, 2, 0, 0
5.79788e-007, 1, 1, 0
4.13933e-007, 0, 2, 0
-0.000286715, 1, 0, 1
-2.27159e-006, 0, 1, 1
-0.165112, 0, 0, 2
Right Camera y mm = f(X pixel, Y pixel, z mm)
-29.9476, 0, 0, 0
0.00151859, 1, 0, 0
0.0592945, 0, 1, 0
0.0861381, 0, 0, 1
-1.1882e-008, 2, 0, 0
-3.67467e-006, 1, 1, 0
5.15634e-007, 0, 2, 0
1.73821e-006, 1, 0, 1
-0.000284645, 0, 1, 1
0.0267127, 0, 0, 2
Calibration Files
D:\Experiments\MyExperiment\Setting\
CalMyExperiment000000.T0000.D0000.P0000.H0000.LA.TIF\
cal00L.cpt
cal01L.cpt
cal02L.cpt
cal03L.cpt
cal04L.cpt
cal00R.cpt
cal01R.cpt
cal02R.cpt
cal03R.cpt
cal04R.cpt
```

Calibration Points (*.CPT) File

The calibration points file is the results of the image analysis. This file is created by analyzing a calibration image to identify the calibration markers. After the markers have been validated with the grid definition, each valid calibration point is stored as one line in this file. Some calibration points may be missing because they are too close to an image edge or the marker image included a bad pixel. The file is an ASCII text file.

With Optical Configuration Calibration, CPT files are created from the camera configuration data. These CPT files are named Virt_L.CPT, and Virt_R.CPT.

The file header section shows the file version number, image size, camera Z-axis sign, target type, data column headers, fiducial mark location, and calibration data points.

The camera Z sign shows if the camera is looking at the front or back of the laser light sheet. If the camera has a negative Z sign, the image locations are flipped left to right in mapping. This sign is set by the Calibration Target Type Same Side, Both Sides check.

The fiducial mark is the anchor point of the calibration grid. Identifying the fiducial mark allows you to verify that the coordinate system has the proper origin. Because the fiducial mark has a different shape that might affect its measured centroid, the fiducial mark is not used as a calibration data point.

The line before the first point, fiducial or calibration, labels the columns. The X_Image and Y_Image columns are the measured marker image location in the image in pixels. The x_Target, y_Target, z_Target columns are the calibration marker locations in the fluid from the calibration grid dialog. Each record shows the calibration marker locations from two perspectives, the camera and the fluid. These data points are used to create the calibration mapping functions.

Calibration Points *.CPT File Listing

The following shows the calibration points file listing:

```
TSI_CPT_VERSION 2.000000
1000 x 1016 pixels
+ Camera_z_Sign
1 Target_z_Planes
Fiducial_Mark_Grid
X_Image, Y_Image, x_Target, y_Target, z_Target
Fiducial_Point
501.694794, 510.284943, 0.000000, 0.000000, 0.500000
Calibration_Points
698.812683, 7.119034, 12.500000, -30.000000, 0.500000
737.436829, 7.853043, 15.000000, -30.000000, 0.500000
775.698853, 9.770273, 17.500000, -30.000000, 0.500000
813.875916, 11.073089, 20.000000, -30.000000, 0.500000
851.545837, 12.356258, 22.500000, -30.000000, 0.500000
889.036560, 13.406416, 25.000000, -30.000000, 0.500000
926.532898, 14.457169, 27.500000, -30.000000, 0.500000
963.340149, 16.263405, 30.000000, -30.000000, 0.500000
44.005566, 29.467993, -27.500000, -27.500000, 0.500000
87.068901, 30.605194, -25.000000, -27.500000, 0.500000
129.820099, 31.986855, -22.500000, -27.500000, 0.500000
172.344864, 33.085751, -20.000000, -27.500000, 0.500000
```

```
214.478226, 34.300846, -17.500000, -27.500000, 0.500000
256.457275, 35.414383, -15.000000, -27.500000, 0.500000
297.774567, 36.298954, -12.500000, -27.500000, 0.500000
339.203949, 37.955029, -10.000000, -27.500000, 0.500000
380.281281, 39.142319, -7.500000, -27.500000, 0.500000
421.078430, 40.416878, -5.000000, -27.500000, 0.500000
461.641479, 41.608162, -2.500000, -27.500000, 0.500000
501.850037, 42.719612, 0.000000, -27.500000, 0.500000
541.713318, 43.921734, 2.500000, -27.500000, 0.500000
581.478760, 45.094425, 5.000000, -27.500000, 0.500000
620.779724, 46.289745, 7.500000, -27.500000, 0.500000
659.901794, 47.597660, 10.000000, -27.500000, 0.500000
698.682617, 48.251602, 12.500000, -27.500000, 0.500000
737.358459, 50.163517, 15.000000, -27.500000, 0.500000
775.636902, 51.024551, 17.500000, -27.500000, 0.500000
813.855591, 52.270443, 20.000000, -27.500000, 0.500000
851.402771, 53.591816, 22.500000, -27.500000, 0.500000
888.728149, 53.977837, 25.000000, -27.500000, 0.500000
926.237671, 55.496765, 27.500000, -27.500000, 0.500000
963.032837, 56.787159, 30.000000, -27.500000, 0.500000
43.870770, 73.715363, -27.500000, -25.000000, 0.500000
```

Calibration Gradient File (*.GRD)

The Calibration Gradients file is a list of the 12 calibration gradients at each point in the points file. A gradient file is created on the first 3-D vector field combination of a processing sequence. It has the same name as one of the image files with a *.grd extension. It is saved to the same directory as the image files. In the sample file listing each line covers several lines of the page. The first line is the header describing the data in the file so that Tecplot software can read it. Each record has 15 numbers

Location in the Fluid in mm	x, y, z
Left Camera X image displacement factors (pixel/mm)	L dX/dx, L dX/dy, L dX/dz
Left Camera Y image displacement factors (pixel/mm)	L dY/dx, L dY/dy, L dY/dz
Right Camera X image displacement factors (pixel/mm)	R dX/dx, R dX/dy, R dX/dz
Right Camera Y image displacement factors (pixel/mm)	R dY/dx, R dY/dy, R dY/dz

Calibration Gradients (*.GRD) File Listing

The following shows the Calibration Gradients file listing:

```
TITLE="D:\Experiments\Deg\Calibration\Deg.grd” VARIABLES="X mm", "Y mm", "Z mm", "L dX/dx",
"L dX/dy", "L dX/dz", "L dY/dx", "L dY/dy", "L dY/dz", "R dX/dx", "R dX/dy", "R dX/dz", "R
dY/dx", "R dY/dy", "R dY/dz", ZONE T="Gradient Coefficients” I=5, J=4, K=1, F=POINT
-10.346, -8.63154, 0, 35.6012, 0.348786, -0.654915, -0.434829, 35.678, -0.148478, 34.0861,
0.194181, 1.90171, -0.0835734, 34.7652, -0.136183
-7.42508, -8.63154, 0, 35.3224, 0.343625, -0.932701, -0.429991, 35.5305, -0.143046,
34.3748, 0.185409, 1.67908, -0.0892958, 34.9007, -0.0857261
-4.50417, -8.63154, 0, 35.0246, 0.33877, -1.20414, -0.427367, 35.3776, -0.13889, 34.6421,
0.176206, 1.43908, -0.0946377, 35.0284, -0.0552818
-1.58326, -8.63154, 0, 34.7078, 0.334223, -1.46923, -0.426955, 35.2193, -0.136009, 34.8881,
0.166573, 1.18171, -0.0995992, 35.1481, -0.0448499
1.33766, -8.63154, 0, 34.3719, 0.329981, -1.72798, -0.428757, 35.0556, -0.134404, 35.1126,
0.156508, 0.906975, -0.10418, 35.2601, -0.0544303
-10.346, -5.71063, 0, 35.5924, 0.36548, -0.662029, -0.580014, 35.6561, -0.429254, 34.0741,
0.219085, 1.88053, 0.0561764, 34.7236, -0.443604
-7.42508, -5.71063, 0, 35.3139, 0.353246, -0.940316, -0.580578, 35.5078, -0.421148,
34.3624, 0.203394, 1.66391, 0.0426059, 34.8597, -0.383856
-4.50417, -5.71063, 0, 35.0164, 0.341319, -1.21226, -0.583356, 35.3541, -0.414318, 34.6293,
0.187273, 1.42992, 0.029416, 34.9881, -0.34412
-1.58326, -5.71063, 0, 34.6998, 0.329698, -1.47785, -0.588346, 35.1951, -0.408763, 34.8747,
0.170721, 1.17856, 0.0166065, 35.1085, -0.324397
1.33766, -5.71063, 0, 34.3643, 0.318384, -1.7371, -0.59555, 35.0306, -0.404483, 35.0988,
0.153737, 0.909836, 0.00417747, 35.2212, -0.324686
-10.346, -2.78971, 0, 35.5764, 0.382377, -0.668352, -0.726004, 35.6105, -0.71337, 34.0552,
0.24326, 1.85043, 0.196616, 34.6559, -0.768979
-7.42508, -2.78971, 0, 35.2983, 0.36307, -0.947141, -0.731971, 35.4614, -0.70259, 34.343,
0.220651, 1.63981, 0.175197, 34.7927, -0.699939
-4.50417, -2.78971, 0, 35.001, 0.34407, -1.21958, -0.74015, 35.3069, -0.693086, 34.6095,
0.197611, 1.41183, 0.154159, 34.9217, -0.650912
-1.58326, -2.78971, 0, 34.6848, 0.325376, -1.48568, -0.750543, 35.147, -0.684857, 34.8545,
0.17414, 1.16648, 0.133502, 35.0429, -0.621897
1.33766, -2.78971, 0, 34.3496, 0.306989, -1.74543, -0.763149, 34.9817, -0.677903, 35.0782,
0.150238, 0.903765, 0.113225, 35.1562, -0.612895
-10.346, 0.131198, 0, 35.5534, 0.399476, -0.673884, -0.8728, 35.541, -1.00083, 34.0293,
0.266706, 1.81139, 0.337744, 34.5621, -1.11231
-7.42508, 0.131198, 0, 35.2756, 0.373096, -0.953175, -0.884168, 35.3911, -0.987372,
34.3167, 0.237179, 1.60678, 0.308478, 34.6996, -1.03397
-4.50417, 0.131198, 0, 34.9787, 0.347023, -1.22612, -0.89775, 35.2358, -0.975194, 34.5827,
0.20722, 1.38481, 0.279592, 34.8293, -0.975656
-1.58326, 0.131198, 0, 34.6627, 0.321257, -1.49272, -0.913545, 35.0751, -0.964291, 34.8274,
0.17683, 1.14547, 0.251086, 34.9512, -0.93735
1.33766, 0.131198, 0, 34.3278, 0.295797, -1.75297, -0.931553, 34.909, -0.954663, 35.0506,
0.14601, 0.888763, 0.222961, 35.0652, -0.919056
```

History Log Files

The following shows example of processing and capture log files when history logging is enabled. See "Enabling Distributed Processing (PIV Only)."

```
Insight 3G
Log File: P000
Processing Log
Date/Time: 8/23/2004 12:08:09 PM
User Name: pivlab
Notes: No notes
Settings File:
C:\Experiments7\Troolin\Settings\new1.PIVProc
Settings File Contents: (on the Date/Time)
[/]
RealizationPIVProcessor=PIV Processor
[RealizationPIVProcessor]
FinalValidationMacro=New1
PassValidationMacro=New1
3DCalibration=
MaximumDisplacement=8
GridEngine=DeformationGrid
ProcessingMask0=
2DCalibration0=
ProcessingMask1=
2DCalibration1=
SpotSizes=32 32 32 32 16 16 16 16
PIVCrossCorrelation=1
AutoCorrelationA=0
AutoCorrelationB=0
SpotMaskEngine=DeformationMask
CorrelationEngine=FFTCorrelator
PeakEngine=GaussianPeak
[RealizationPIVProcessor!GridEngine]
xOffsetPass1=0
yOffsetPass1=0
xSpacing=2.000000
ySpacing=2.000000
CenterOffset=1
Primary Iteration=3
Secondary Iteration=2
XSpotOffsetPixelExport=0
XSpotOffsetPixelSNRValidate=0
XSpotOffsetPixelSNRGreater=0
XSpotOffsetPixelSNRThreshold=0.000000
YSpotOffsetPixelExport=0
YSpotOffsetPixelSNRValidate=0
YSpotOffsetPixelSNRGreater=0
```

```
Insight 3G
Log File: H002
Capture Log

Date/Time: 10/2/2004 8:01:30 PM
User Name: preeti
Notes: No notes
Settings File: C:\Experiments7\Experiment
PLIF Demo\Uniform Temperature
Test\RawData\H002
Settings File Contents: (on the Date/Time)
[Capture]
Capture Type=PIV
PIV Frame Mode=Straddle
Capture Mode=Single
Exposure Mode=Free
Save Mode=To RAM
[Timings]
Pulse Rep Rate=20
Q Switch Divide=1
Delta T=9
Laser Pulse Delay=0
PIV Cam. Exposure Time=7
PLIF Cam. Exposure Time=6
PLIF Exposure Units=
External Trigger=1
Trigger Delay=1
PLIF Cam. Trigger Delay=4
Trigger Timeout=3
Captures Per Trigger=2
Number Laser Pulses=1
Pulses per PLIF Cap=2
[Sequence Mode]
Number to Capture=1
Starting Number=1
[Laser Power]
LaserA Low=100
LaserA Medium=125
LaserA High=175
LaserB Low=100
LaserB Medium=125
LaserB High=175
LaserA=100
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YSpotOffsetPixelSNRThreshold=0.000000
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dXCenterVectorSNRValidate=0
dXCenterVectorSNRGreater=0
dXCenterVectorSNRThreshold=0.000000
dYCenterVectorExport=0
dYCenterVectorSNRValidate=0
dYCenterVectorSNRGreater=0
dYCenterVectorSNRThreshold=0.000000
dXLeftTopVectorExport=0
dXLeftTopVectorSNRValidate=0
dXLeftTopVectorSNRGreater=0
dXLeftTopVectorSNRThreshold=0.000000
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dYLeftTopVectorSNRGreater=0
dYLeftTopVectorSNRThreshold=0.000000
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dXRightTopVectorSNRValidate=0
dXRightTopVectorSNRGreater=0
dXRightTopVectorSNRThreshold=0.000000
dYRightTopVectorExport=0
dYRightTopVectorSNRValidate=0
dYRightTopVectorSNRGreater=0
dYRightTopVectorSNRThreshold=0.000000
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dXLeftBottomVectorSNRGreater=0
dXLeftBottomVectorSNRThreshold=0.000000
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dYLeftBottomVectorSNRGreater=0
dYLeftBottomVectorSNRThreshold=0.000000
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dXRightBottomVectorSNRValidate=0
dXRightBottomVectorSNRGreater=0
dXRightBottomVectorSNRThreshold=0.000000
dYRightBottomVectorExport=0
dYRightBottomVectorSNRValidate=0
dYRightBottomVectorSNRGreater=0
dYRightBottomVectorSNRThreshold=0.000000
xGridSpacingExport=0
xGridSpacingSNRValidate=0
xGridSpacingSNRGreater=0
xGridSpacingSNRThreshold=0.000000
yGridSpacingExport=0
yGridSpacingSNRValidate=0
yGridSpacingSNRGreater=0
yGridSpacingSNRThreshold=0.000000
LaserB=100
[Capture Name]
Traverse Number=0
Delay Number=0
[GUI Traverse]
Auto Mode=0
X=0
Y=0
Z=0
[GUI Capture AOI]
PIV Enabled=0
PIV X=0
PIV Y=0
PIV Width=100
PIV Height=100
PLIF Enabled=0
PLIF X=0
PLIF Y=0
PLIF Width=100
PLIF Height=100
[Component]
CaptureMode=1
[Synchronizer]
Yag1Power=1
Yag2Power=1
CameraType=3
VectorFrames=2
TriggerMode=1
LaserType=1
PulseType=0
Polarity=512
Timeout=100
NumberOfPulses=0
External Trigger In Timeout=0
VideoType=0
QSwitchDivide=1
YAGFrequency=100
CameraDelay=10000
DeltaTime=90
PulseDelay=0
QSwitch1=1000
QSwitch2=1000
ShutterOpenTime=2550
[Camera Camera Simulator#1]
ShutterOpenDelay=0.000000
ExposureDuration=7.000000
AreaOfInterestLeft=0
AreaOfInterestTop=0
AreaOfInterestRight=2047
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InterpolateExport=0
InterpolateSNRValidate=0
InterpolateSNRGreater=0
InterpolateSNRThreshold=0.000000
[RealizationPIVProcessor!SpotMask]
MinAvgIntensityExport=0
MinAvgIntensitySNRValidate=1
MinAvgIntensitySNRGreater=1
MinAvgIntensitySNRThreshold=0.100000
[RealizationPIVProcessor!CorrelationEngine]
DefaultPeakEngine=GaussianPeak
IsSpotZeroPadded?=0
[RealizationPIVProcessor!PeakEngine]
PeakToNoisePeakExport=0
PeakToNoisePeakSNRValidate=0
PeakToNoisePeakSNRGreater=1
PeakToNoisePeakSNRThreshold=1.500000
AreaOfInterestBottom=2047
width=2048
height=2048
flipImage=0
[DataSource]
ExposeMode=0
[Camera Camera Simulator#2]
ShutterOpenDelay=0.000000
ExposureDuration=7.000000
AreaOfInterestLeft=0
AreaOfInterestTop=0
AreaOfInterestRight=2047
AreaOfInterestBottom=2047
width=2048
height=2048
flipImage=0
[Camera Camera Simulator#3]
ShutterOpenDelay=0.000000
ExposureDuration=6.000000
AreaOfInterestLeft=0
AreaOfInterestTop=0
AreaOfInterestRight=2047
AreaOfInterestBottom=2047
width=2048
height=2048
flipImage=0
[Camera Camera Simulator#4]
ShutterOpenDelay=0.000000
ExposureDuration=6.000000
AreaOfInterestLeft=0
AreaOfInterestTop=0
AreaOfInterestRight=2047
AreaOfInterestBottom=2047
width=2048
height=2048
flipImage=0
[Frame Grab Frame Grabber Simulator#0]
AreaOfInterestLeft=0
AreaOfInterestTop=0
AreaOfInterestRight=2047
AreaOfInterestBottom=2047
Timeout=5000
[Frame Grab Frame Grabber Simulator#1]
AreaOfInterestLeft=0
AreaOfInterestTop=0
AreaOfInterestRight=2047
AreaOfInterestBottom=2047
Timeout=5000
[Traverse]
```

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U-Axis=0.000000
V-Axis=0.000000
W-Axis=0.000000
X-Axis=0.000000
Y-Axis=0.000000
Z-Axis=0.000000
```

APPENDIX B

Using MATLAB®

MATLAB®, a technical computing program combining computation, programming and visualization, is integrated into *INSIGHT 3G*. Specifically, the Spatial Tool, Time Series Analysis Toolbox, and Proper Orthogonal Decomposition (POD) features can be accessed and used from within *INSIGHT 3G* to perform PIV data analysis and to display PIV results such as advanced statistical properties in time and space domains.

Getting Started

To access these features, click 

icon on the *INSIGHT 3G* tool bar. The Toolbox launch window opens (Figure B-1).

Figure B-1
INSIGHT 3G Toolbar Window

Space and Time Analysis toolbox and POD toolbox can be selected from the drop-down list. Click **Go** button to launch the toolbox. The following screen (Figure B-2) is an example of the Space and Time Analysis toolbox when it is launched.

MATLAB® is a registered trademark of The MathWorks, Inc.

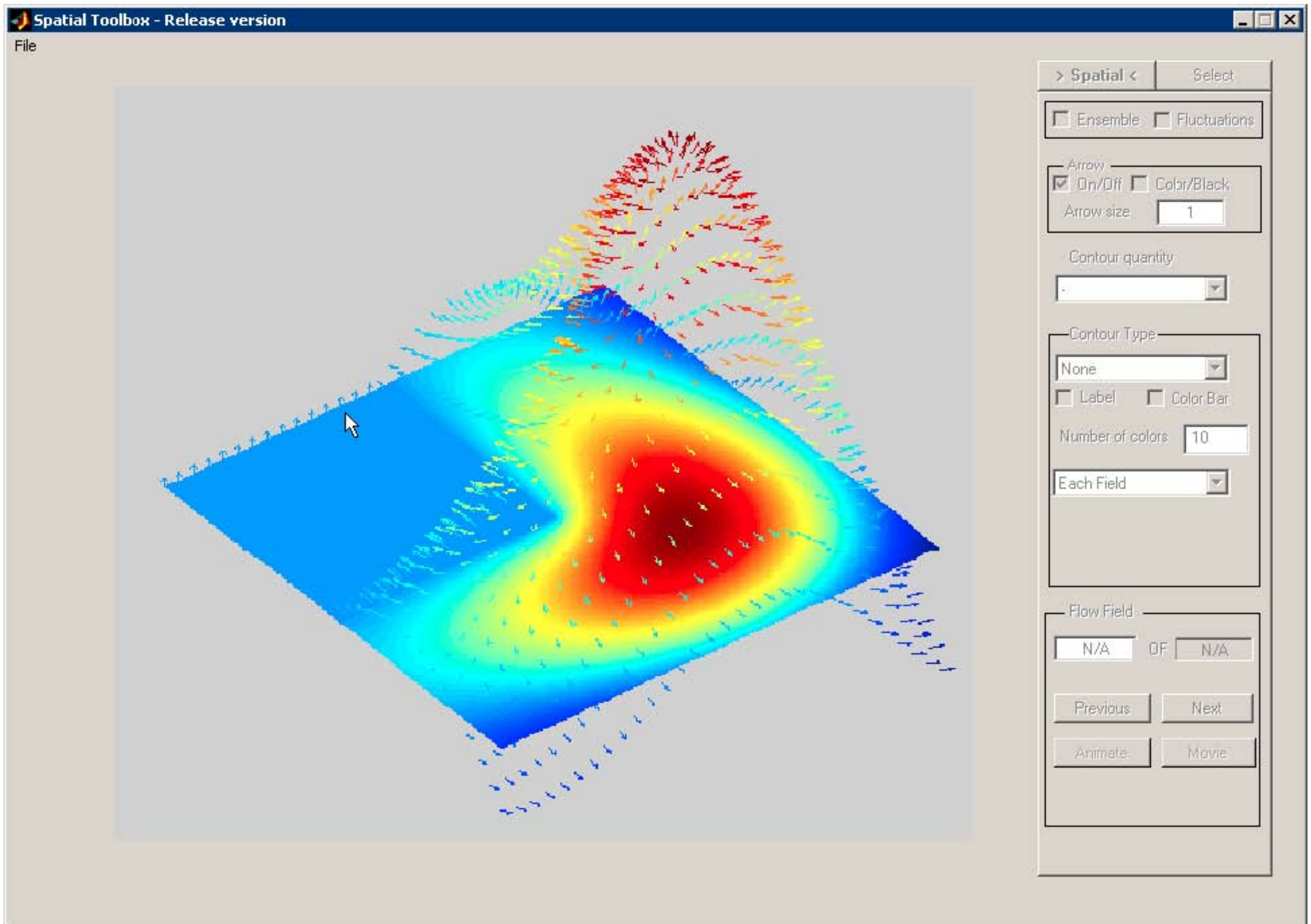


Figure B-2
Spatial Toolbox Window

Loading *INSIGHT 3G*™ Files

INSIGHT 3G data, vector files with *.vec or *.v3d extensions can be loaded into this program.

To load *INSIGHT 3G* data files:

1. From the main menu bar of the Spatial Toolbox screen, click **File | Load Vector Files**. A dialog box to select vector files opens.

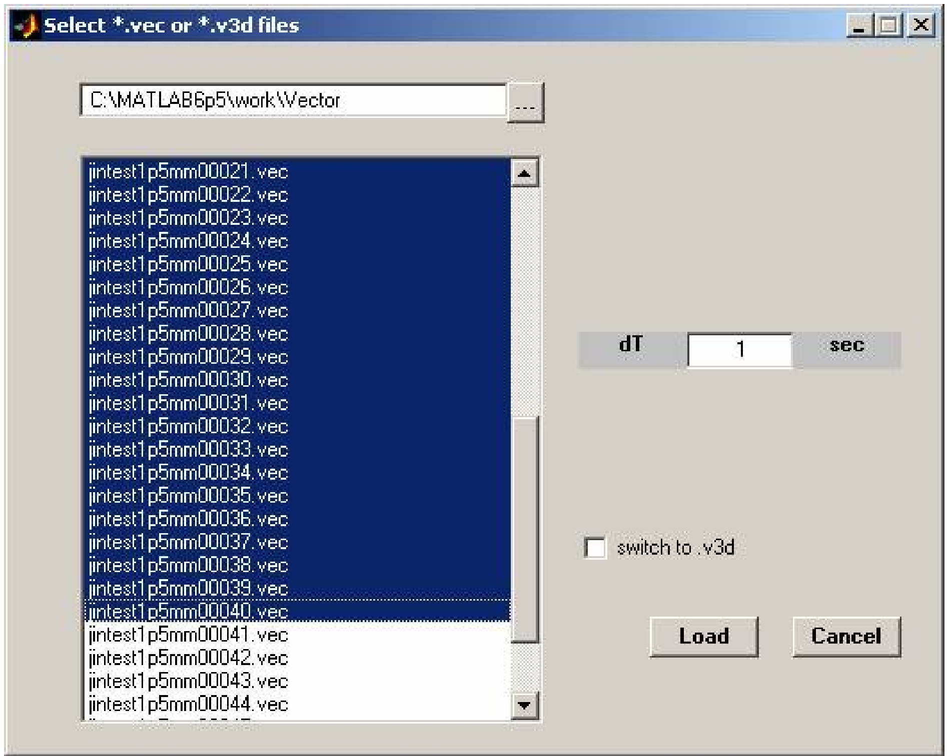


Figure B-3
Select Vector Files

2. Use of the following methods to select and load the files:

    - Click ... to browse to the appropriate folder and select the folder that includes the data files.
    - If you know directly type in the name of the folder.
    - Double-click the .. in the list of files box, or double-click the name of the directory within the list to get the files in the subfolders. *.vec files are listed as a default. Check **Switch to .v3d** to see the list of *.v3d files.

    Note: *The order in which files are selected is not important. You can pick the last file first, and the first file last. During the loading procedure, the files are automatically sorted in the ascending order of their filenames.*

    - Set dT for the time interval between two vector files.

3. Click **Load**. The Spatial Toolbox reads the vector files, initializes the toolbox default variables and calculates several flow quantities. This part may take from several seconds to a few minutes, depending on the length of the selected series and the size of each vector map.

Using the Spatial Toolbox

When you select at least one vector file in the Spatial Toolbox, the default window looks like the one shown in Figure B-4:

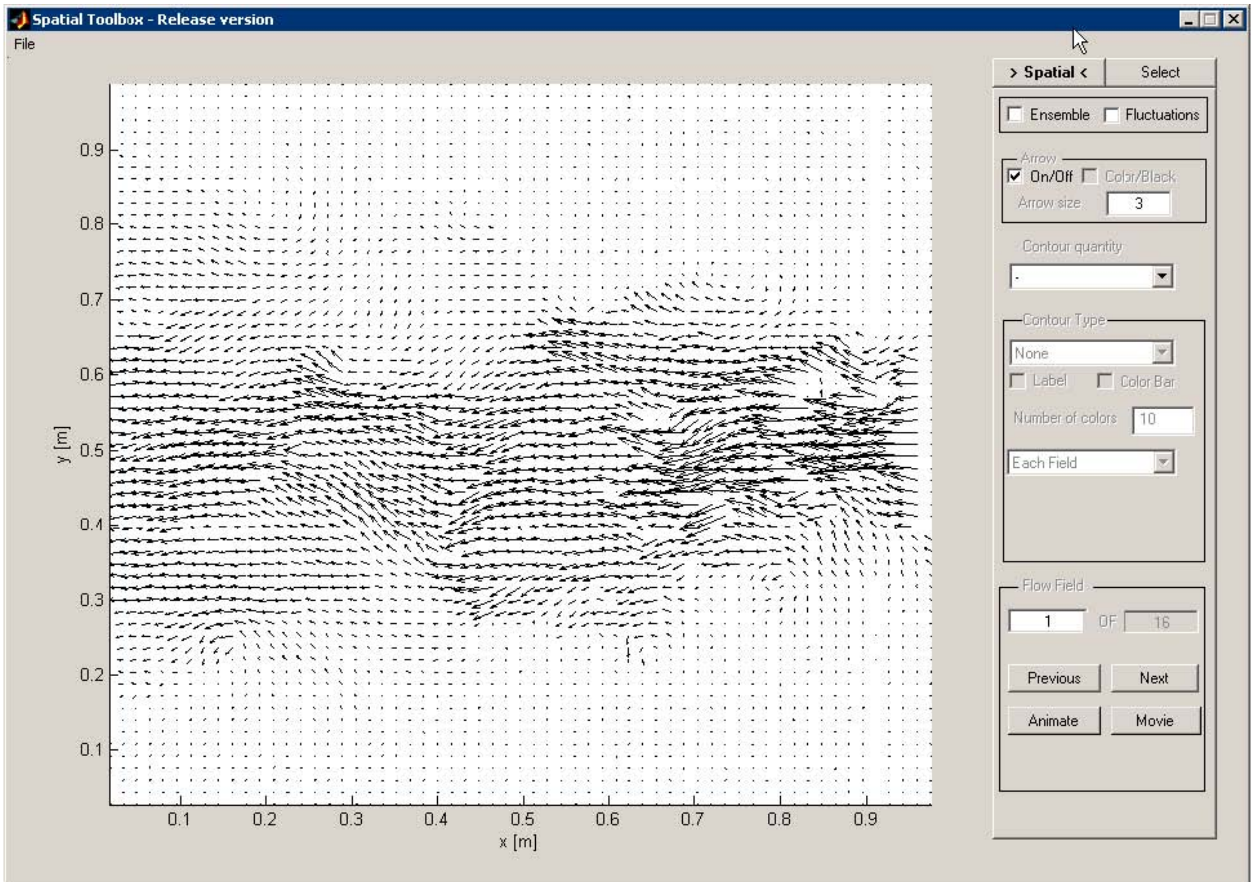
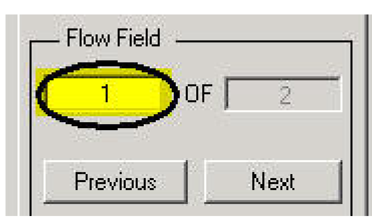


Figure B-4
Vector File Selected

Navigating the Spatial Toolbox

- Use **Next** or **Previous** to display flow fields maps. The appropriate map number is also displayed.
- To jump to specific map, enter the number of the map in the edit box and click **Enter**.



Spatial Toolbox Options

You can choose to display data using one large set of options with various combinations and choose arrows either in black or in color. The color of arrows could represent any one of the available quantities for that particular mode. The arrows could be on top of the contour map of the selected quantity, and contour could be displayed as color patterns, bounded, or unbounded (smooth view), color or black contour lines. The following lists the control options available in the Spatial Toolbox.

Arrow Options

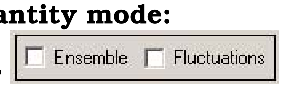
The following arrow choices are available:

Option	Description
On/Off	Select **On** to display and **Off** to hide the arrows.
Color/Black	Available only if arrows are turned on. ***Color***: Displays arrows according to the current quantity.
Arrow Size	Specify arrow size.

Contour Quantity Modes

Use this option to choose the quantity that will be displayed. There are four main sets of quantities or modes.

To choose contour quantity mode:

Use the two checkboxes 

to switch between the following modes:

Instantaneous Mode

Leave both checkboxes unselected to choose Instantaneous mode The list of quantities is:

$$u, v, \sqrt{u^2 + v^2}, \omega = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}, s_{xx} = \frac{\partial u}{\partial x}, \frac{\partial u}{\partial y}, \frac{\partial v}{\partial x}, s_{yy} = \frac{\partial v}{\partial y}, \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}, s_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}$$

Ensemble Averaged Mode

Select the Ensemble checkbox to choose Ensemble Average mode. This gives the ensemble averages of the instantaneous quantities. The list is:

$$U, V, \sqrt{U^2 + V^2}, \Omega = \frac{\partial V}{\partial x} - \frac{\partial U}{\partial y}, S_{xx} = \frac{\partial U}{\partial x}, \frac{\partial U}{\partial y}, \frac{\partial V}{\partial x}, S_{yy} = \frac{\partial V}{\partial y}, \frac{\partial U}{\partial x} + \frac{\partial V}{\partial y}, S_{xy} = \frac{\partial U}{\partial y} + \frac{\partial V}{\partial x}$$

Fluctuations Mode

Select the Fluctuations checkbox for this mode. The list is:

$$u', v', \sqrt{u'^2+v'^2}, \omega' = \frac{\partial v'}{\partial x} - \frac{\partial u'}{\partial y}, s'_{xx} = \frac{\partial u'}{\partial x}, \frac{\partial u'}{\partial y}, \frac{\partial v'}{\partial x}, s'_{yy} = \frac{\partial v'}{\partial y}, \frac{\partial u'}{\partial x} + \frac{\partial v'}{\partial y}, s'_{xy} = \frac{\partial u'}{\partial y} + \frac{\partial v'}{\partial x}$$

Turbulent Mode

Select both checkboxes for Turbulent quantities mode. The list is:

$$\langle u'^2 \rangle, \langle v'^2 \rangle, -\langle u'v' \rangle, T_u = \frac{\sqrt{\langle u'^2 \rangle}}{\langle U \rangle}, T_u = \frac{\sqrt{\langle v'^2 \rangle}}{\langle V \rangle}, \varepsilon \approx \langle s_{xx}^2 + s_{yy}^2 + 2s_{xy}^2 \rangle, P = -\langle u'v' \rangle S_{xy}$$

Contour Types

To specify a contour type, choose one of the following options in the Contour Type box:

Option	Description
Flood	Displays smooth color patches with no sharp boundaries.
Color Line	Displays only color boundaries, according to the color map of the selected quantity.
Flood + Line	Displays color patches, with sharp boundaries.
Black Line	Displays only boundaries of the contours.

Defining Contours

Setting the number of colors, using either default settings or by specifying them manually, defines the number of contour levels of a selected quantity, in one of the following four contour modes:

Mode	Description
Each Field	Select to automatically update the contour level to each presented map limits (min and max) and distributed evenly into number of contour levels, that is number of colors.
All to Display	Select to have the currently presented map define the contour levels for all following maps, unless another option is selected. If you change the quantity, the limits are updated, but remain constant for all forthcoming views.

Mode	Description
All Fields	Select to define the contour levels by the maximum and minimum values of the selected quantity from the whole selected dataset. This is a powerful option allowing you to compare the values visually, with not a single value out of the defined color set (which can happen in the Manual or All to Display modes). However, to determine the absolute maximum and minimum values, the entire dataset has to be calculated at least once. For example, All Fields of the vorticity demands the calculating gradients in both directions of the selected dataset. This could be time-intensive for the time-resolved PIV images).
Manual	Specify the maximum and minimum level of the color to be shown, the selection could be symmetric by entering the same positive and negative values or anti-symmetric, if different values are used. **To specify number of colors (contour levels):** **1:** Enter the desired number in Number of Colors edit box: **2:** Click **Enter.**

Figure B-5 shows the instantaneous velocity field (arrows) and the instantaneous vorticity field in color-line contour mode. Color bar is added and the number of contour levels is set to 25.

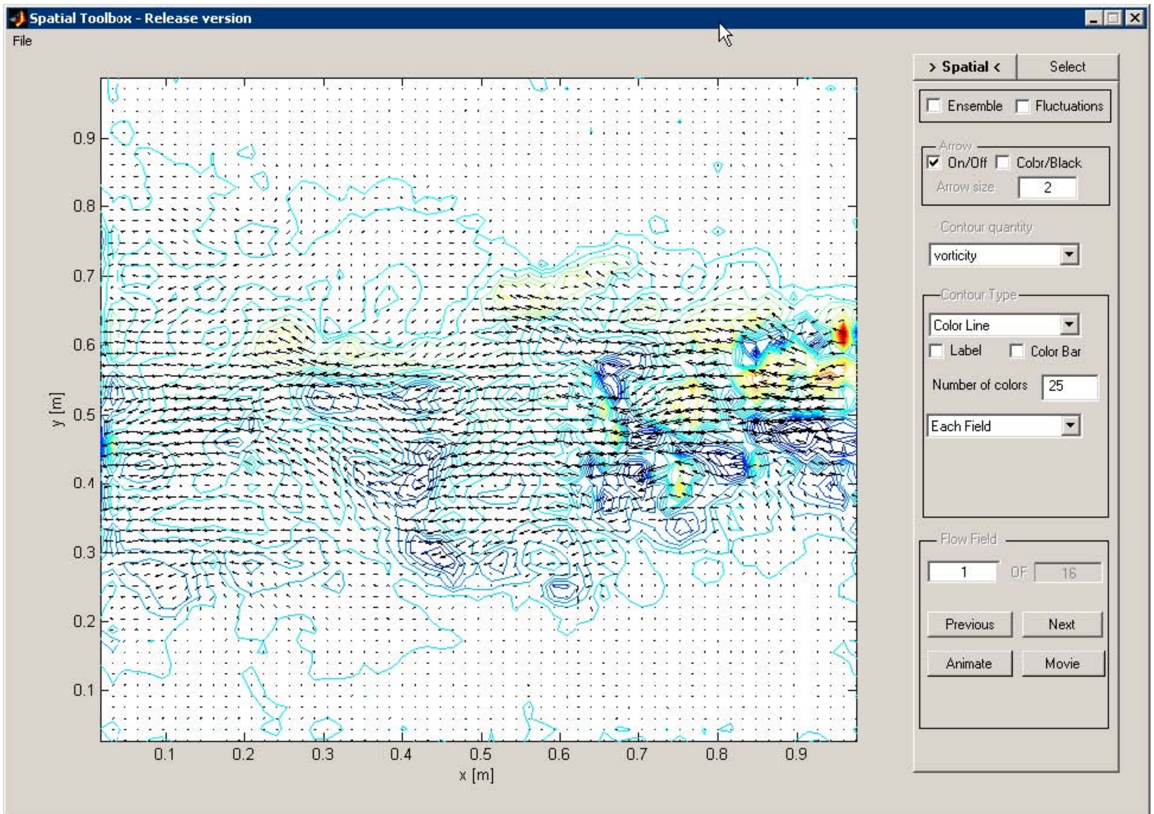


Figure B-5
Instantaneous Velocity Field (Arrows) and the Instantaneous Vorticity Field in Color-Line Contour Mode

Figure B-6 shows an instantaneous velocity field with longer arrows, set to 3. Flood contour type is of the rate-of-strain component, the number of contour levels are set to 3 to emphasize strong positive and negative regions.

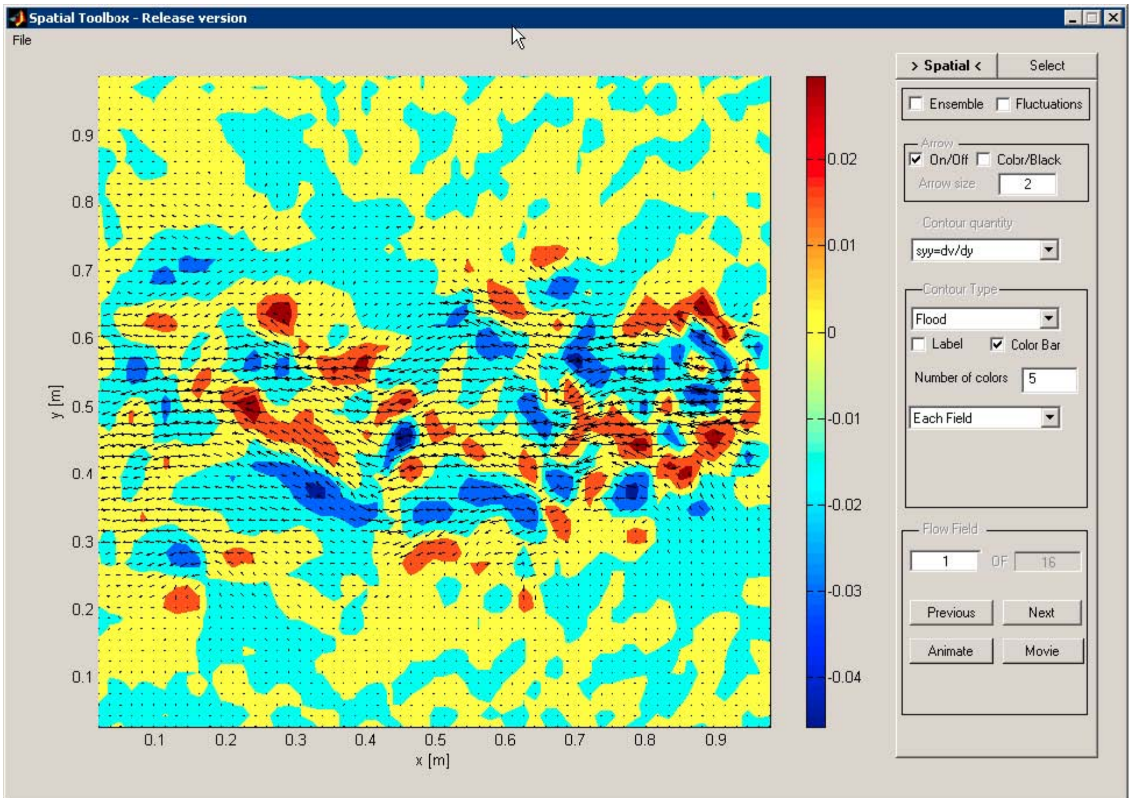


Figure B-6
Instantaneous Velocity Field with Longer Arrows

Figure B-7 shows an ensemble averaged velocity field displayed with arrows. The color of the arrows and the sharp boundaries are of the average vorticity field, the number of contour levels is set to 5, and the color is distributed symmetrically by manual set of contour levels between –0.04 and 0.04 [1/sec].

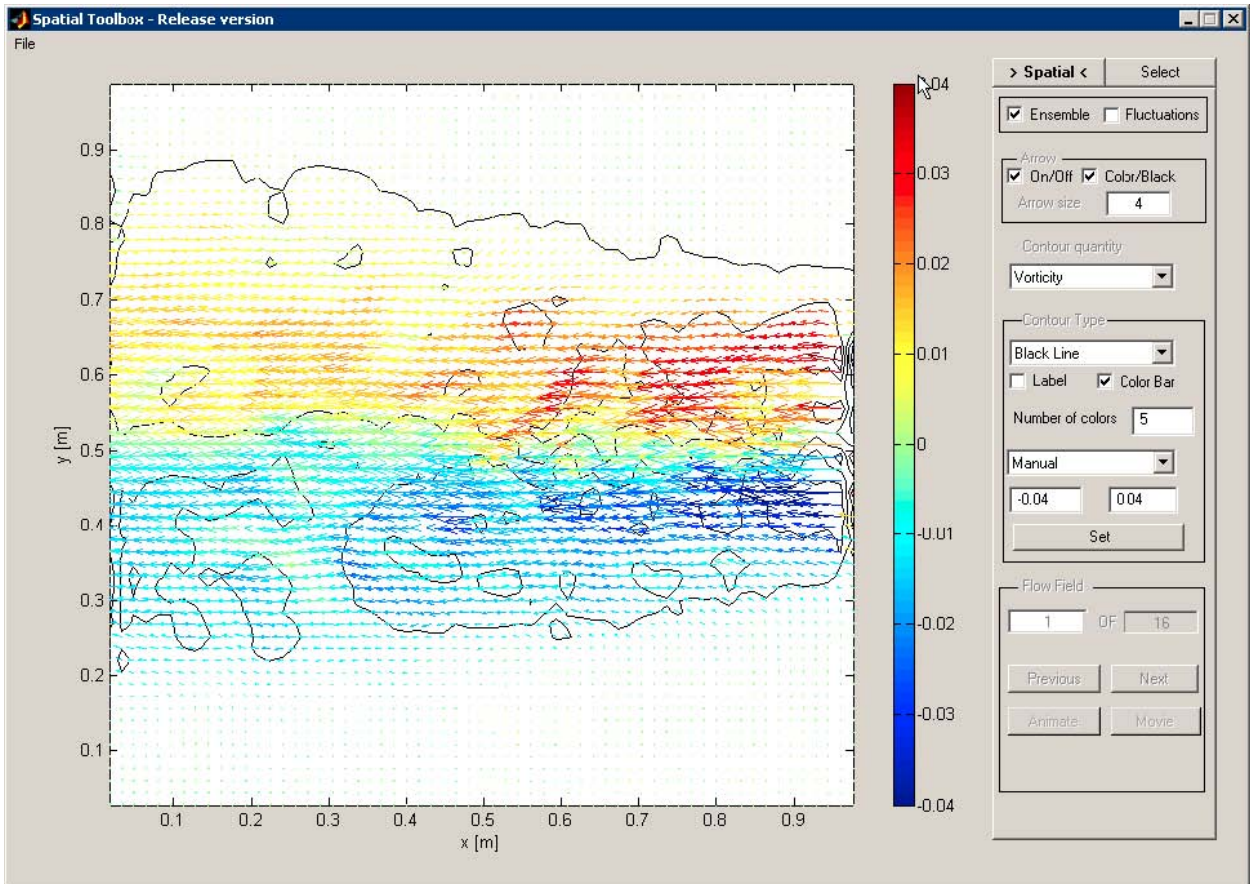


Figure B-7
Ensemble Averaged Velocity Field Displayed with Arrows

Animating Displays

You can run the animation of the successive maps, with all the visualization properties that were selected before, using the animation feature of the Spatial Toolbox.

Note: *During animation, the movie is not stored in the memory, you need to explicitly save it using the Movie option. See "[Creating Movies](#)."*

To start animation:

Click **Animate**. The first map is the current map (that could be manually entered in the edit box).

To stop animation:

Click **Animate** again. The animation stops at any map when the action was performed. If you do not stop, the animation continues until the last map is displayed.

Creating Movies

The movie option allows you to save your animated maps in the form of an .avi file.

To create a movie:

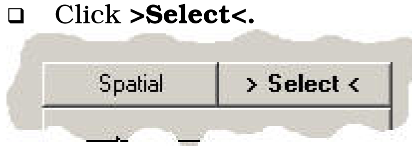
1. Click **Movie**.
2. Enter a name for the .AVI file. The Windows AVI video file (uncompressed, default frame-per-second rate of 15 fps) is saved in the *INSIGHT 3G* directory, when the last map is reached, or when the Movie button is clicked again.

Using the Time Series Analysis Toolbox

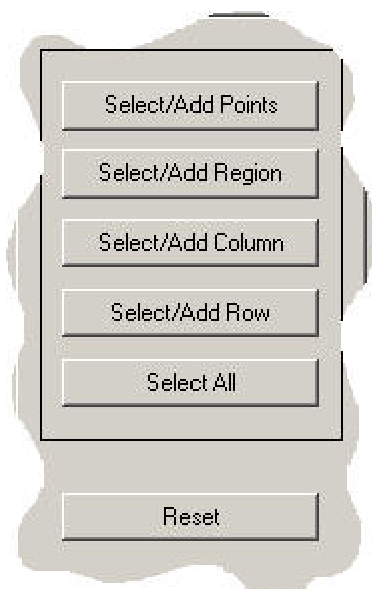
You can also use the Time Series Analysis Toolbox feature of MATLAB to make selections such as points or regions in the images and then use various options to get a profile or time distribution analysis.

To access the Time Toolbox:

- Click **>Select<.**



A collection of selection tools become available.



To make a selection:

- ❑ Click the appropriate selection. These are described later in this section.

Note: *You can select only one type of selection. For example Add Points cannot be selected with Add Region.*

To quit after making a selection:

- ❑ After region/points are selected, click the middle mouse button.

To reset a selection:

- ❑ Click **Reset.** All selections are cleared. Also when you click **Spatial,** all selections are cleared.

Selecting Options for Analysis

The following describe each of the selection options that are available.

Selecting Points

This selection allows you to select single/multiple points from the map as shown in Figure B-8.

To select points:

- ❑ Drag and select a region and then click **Select/Add Points**.

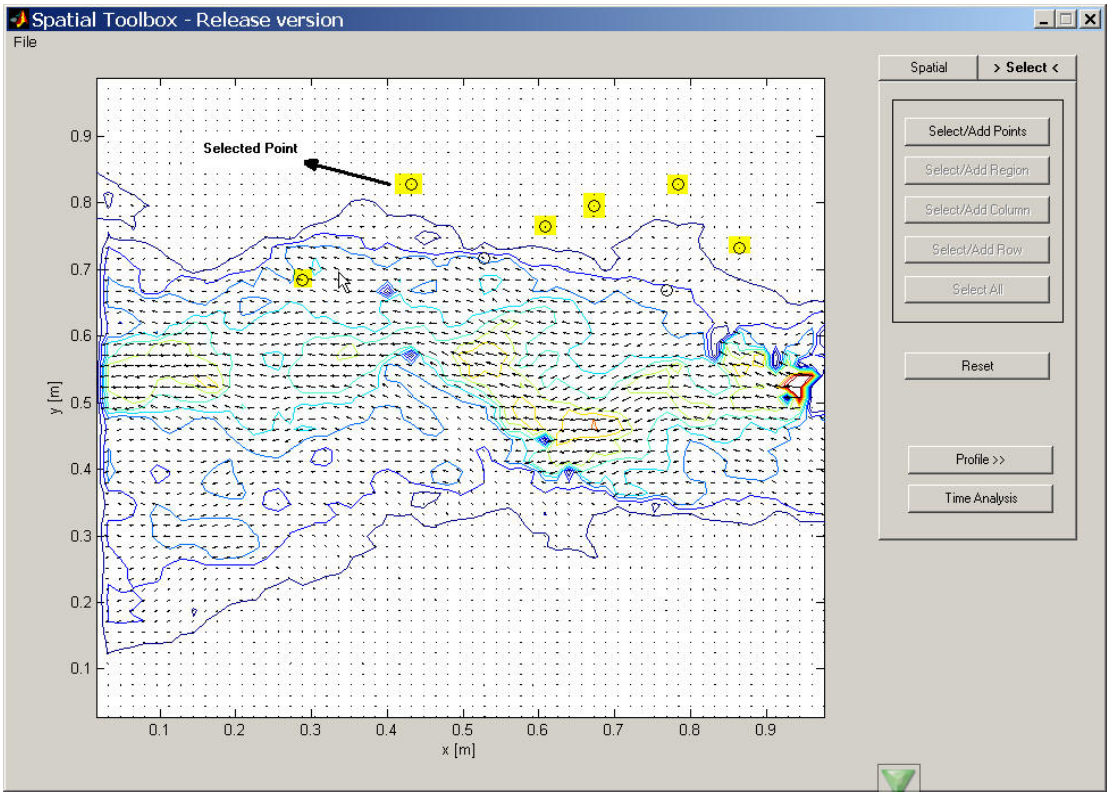


Figure B-8
Select Single/Multiple Points from the Map

Selecting Regions

This selection allows you to select particular regions in your map for analysis.

Note: *When adding two or more regions, you can select only regions that have at least one side equal, and ends of the side that lie on the same line.*

To select regions:

- ❑ Drag the mouse and select a region and then click **Select/Add Regions.**

Figure B-9 shows two regions selected.

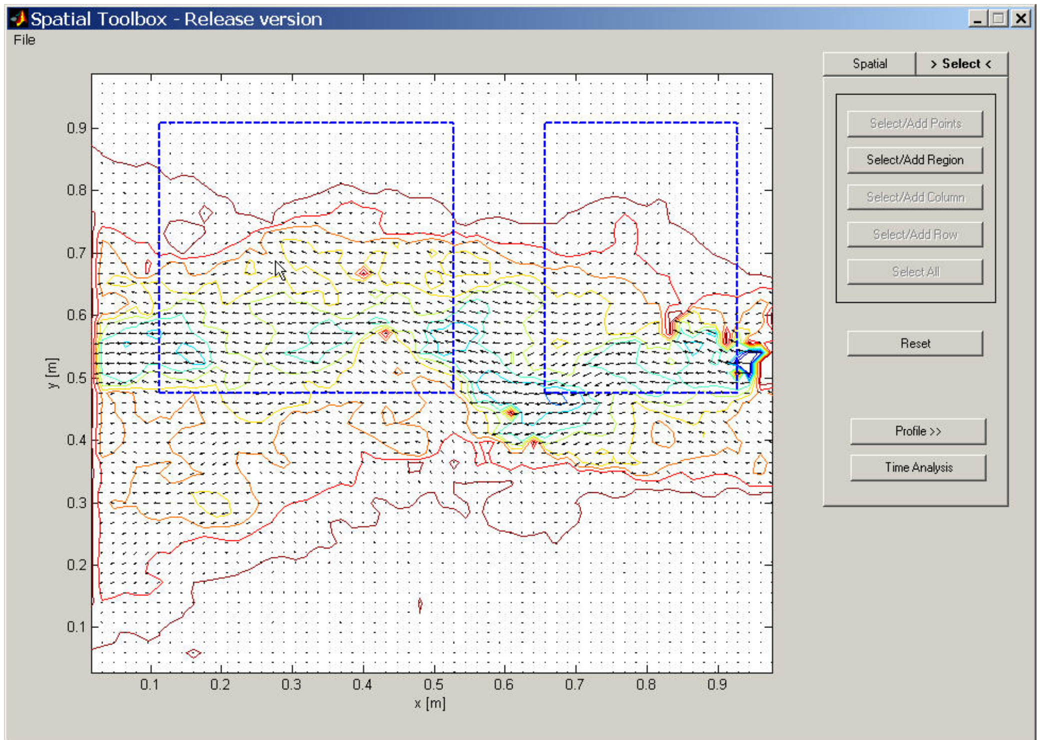


Figure B-9
Two Regions Selected

Selecting Rows or Columns

These options allow you to select rows and columns on the map (Figure B-10).

To select rows or columns:

- ❑ Click **Select/Add Row** to select the entire row.
- ❑ Click **Select/Add Column** to select the entire column.

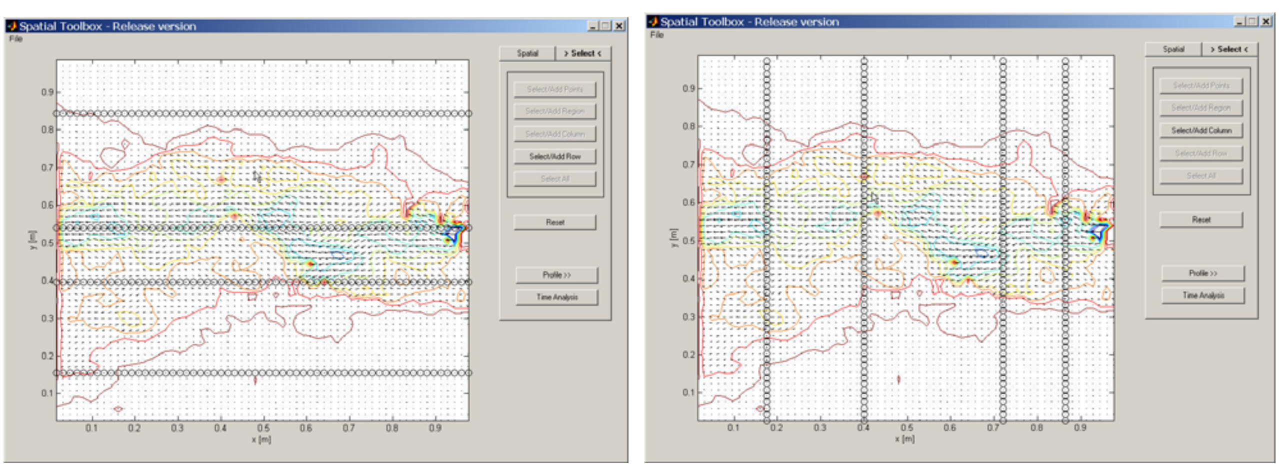


Figure B-10
Selecting Rows (left) or Columns (right)

Selecting the Entire Map

This selection allows you to select the entire map.

To select the entire map:

- Click **Select All** to select the entire row, as shown in Figure B-11.

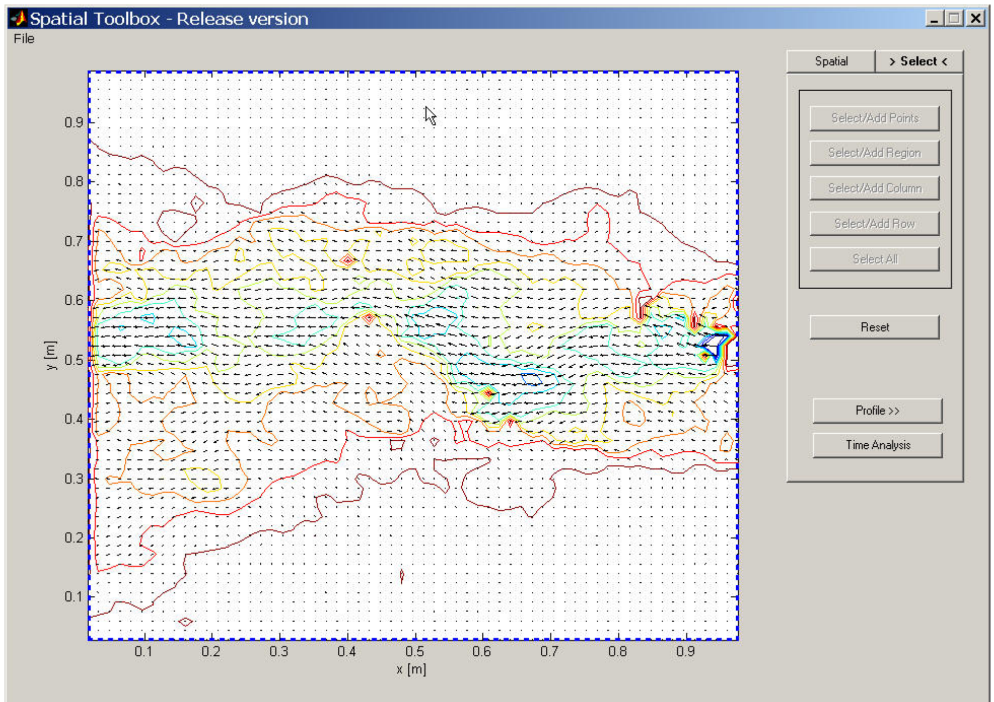


Figure B-11
Select All to Select Entire Row

Performing Profile Analysis

After selecting areas of interest in the display, you can perform Profile analysis.

To perform a Profile analysis:

1. Select an area or point.
2. Click **Profile**. The distribution window opens.
3. Use the following options to view the display or export the information.

Option	Description
Direction (Rows/Columns	Changes one of the axis to x or y, respectively.
Swap X-Y	Changes between axes.

Option	Description
Single	Displays all the data in the selected region of interest (rows or columns or regions or all) in spatial distribution along rows or along columns (X or Y profile per row or column).
Average	Displays red line presenting average of quantities.
Export	***Figure***: Allows you to use the Plot Edit options of MATLAB. ***CSV:*** Allows you to export the selected filename, for saving data in CSV format.

Examples

This section provides screen shots illustrating the outputs of the various options you may perform.

Figure B-12 shows a distribution window, with the Average distribution added to the plot (thick red line) and displaying two disconnected regions.

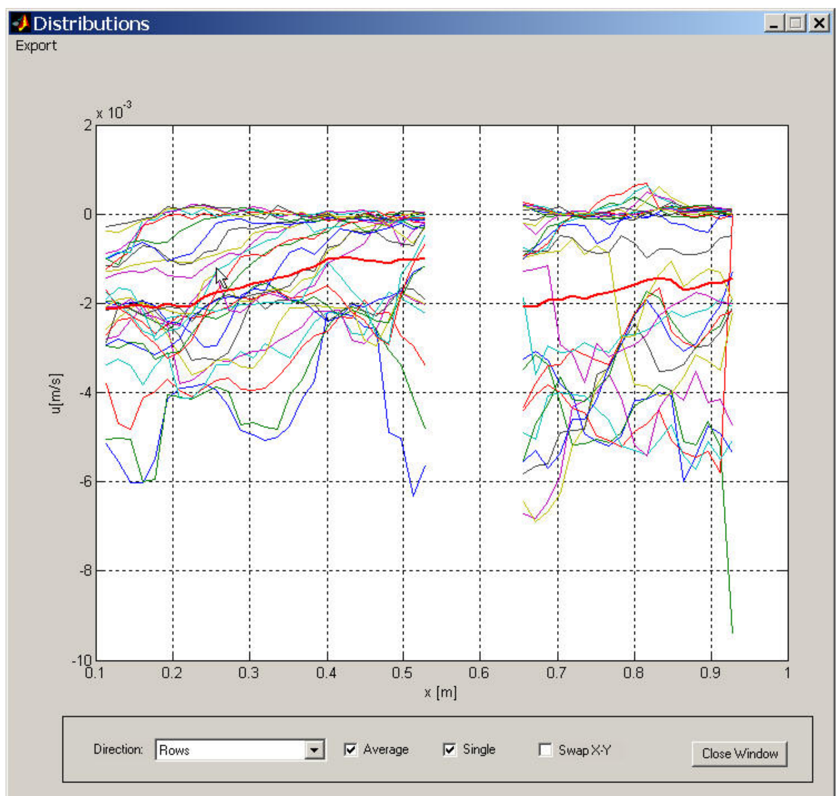


Figure B-12
Distribution Window with Average Distribution Added to Plot and Displaying Two Disconnect Regions

Figure B-13 shows distribution with axes swapped (rotated 90 degrees) by checking the Swap X-Y option.

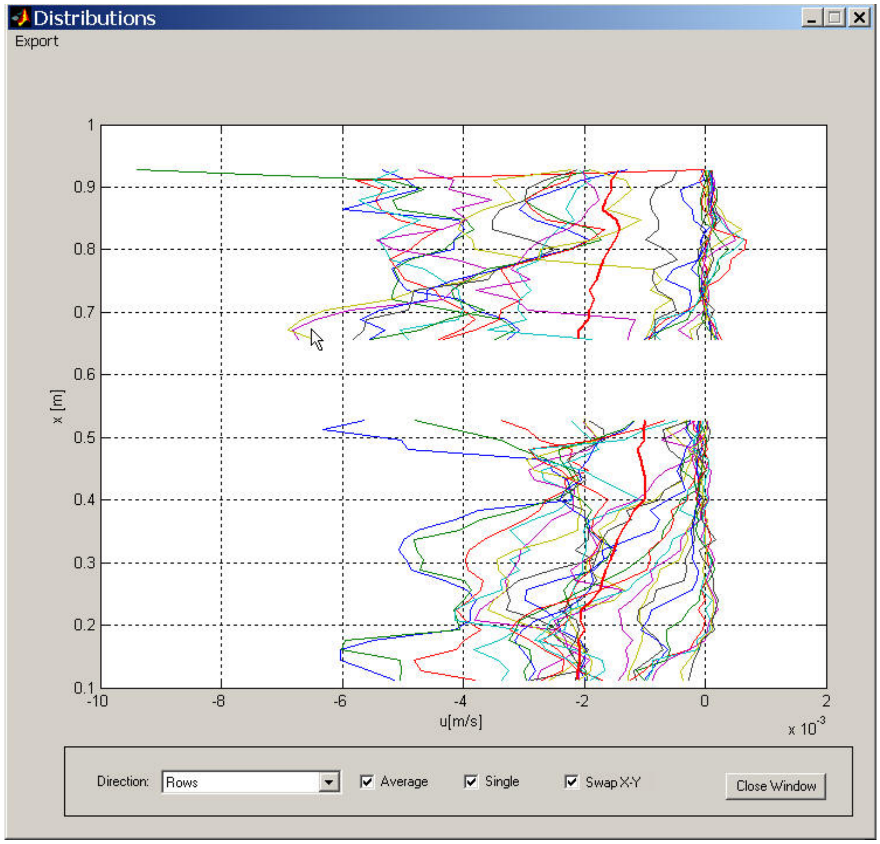


Figure B-13
Distribution with Axes Swapped

Figure B-14 shows the output of using the Export to Figure option.

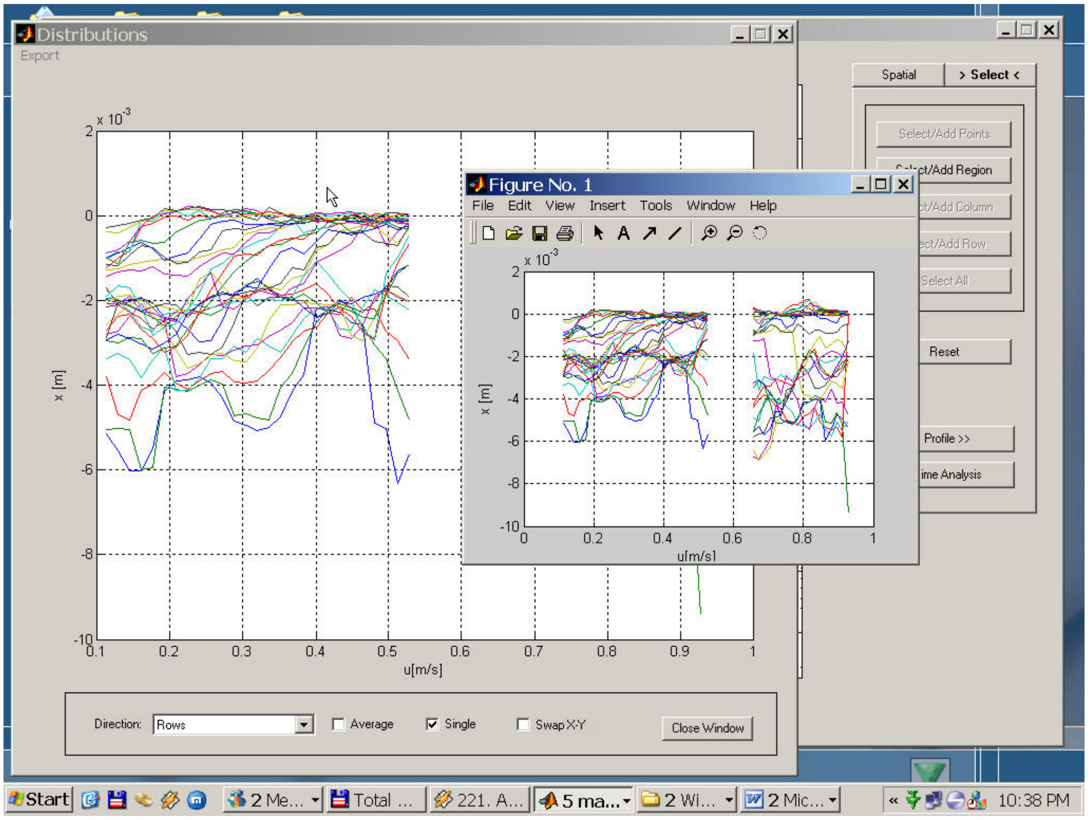


Figure B-14
Output Using the Export to Figure Option

The Export to Figure allows you to copy one curve from the figure into another, add text, arrows, etc. and change the visual style of the figure, as shown in Figure B-15.

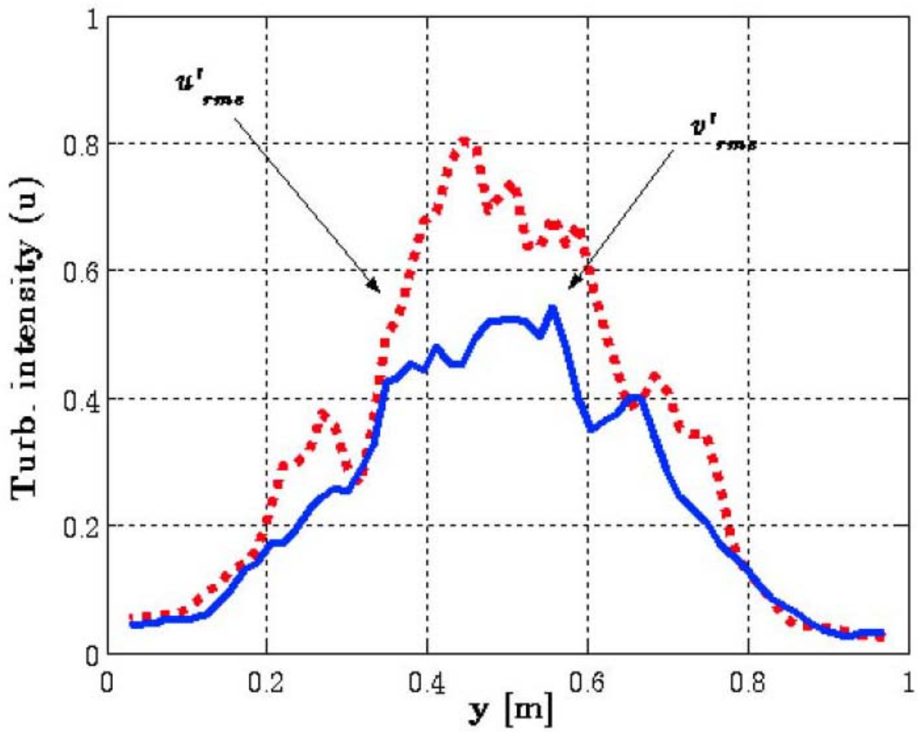


Figure B-15
Change the Visual Style of the Figure

Performing the Time Series Analysis

You can use the Time Series tools to analyze high frame rate PIV images in the same way as the other images.

To perform time series analysis:

1. Select a region as described in "Selecting Options for Analysis" and shown in Figure B-16. You could select a set of points, rows, columns, regions or the entire map.

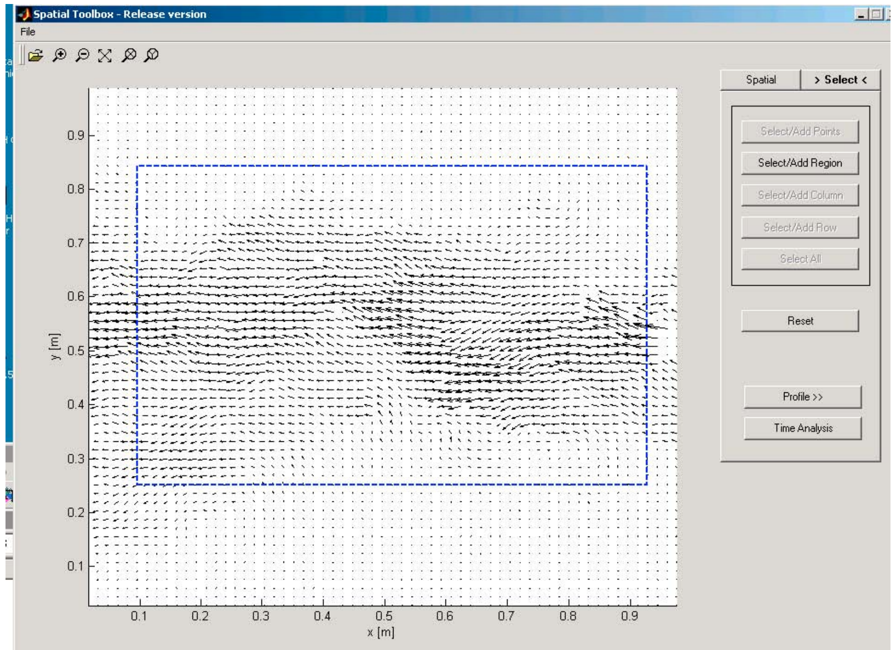


Figure B-16
Select a Region

2. Click **Time Analysis**.

Figure B-17 shows the first window of the Time Series Toolbox. The default plot is spatial averaged time history of the u velocity (from left to right).

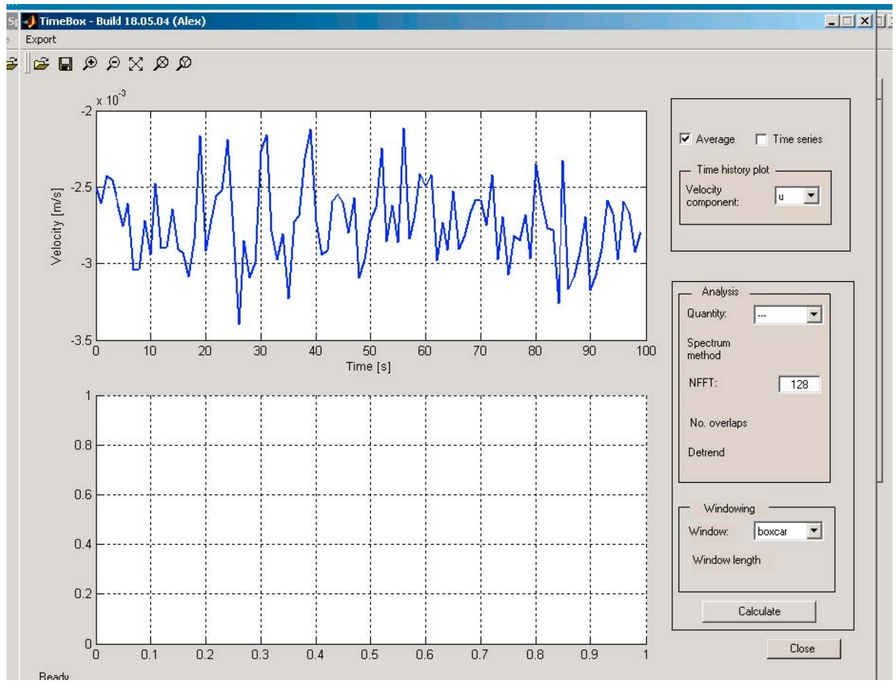


Figure B-17
First Window of the Time Series Toolbox

You could use other possible selections for velocity components such as instantaneous and fluctuating velocity components from the left to right (u), from the top to bottom (v) and in the case of stereoscopic PIV data, the out-of-plane component (w).

Figure B-18 shows the time history of a selected point, with the Time Series option checked.

Note: *The Average option is checked too, and it is emphasized by the thick blue line on the display.*

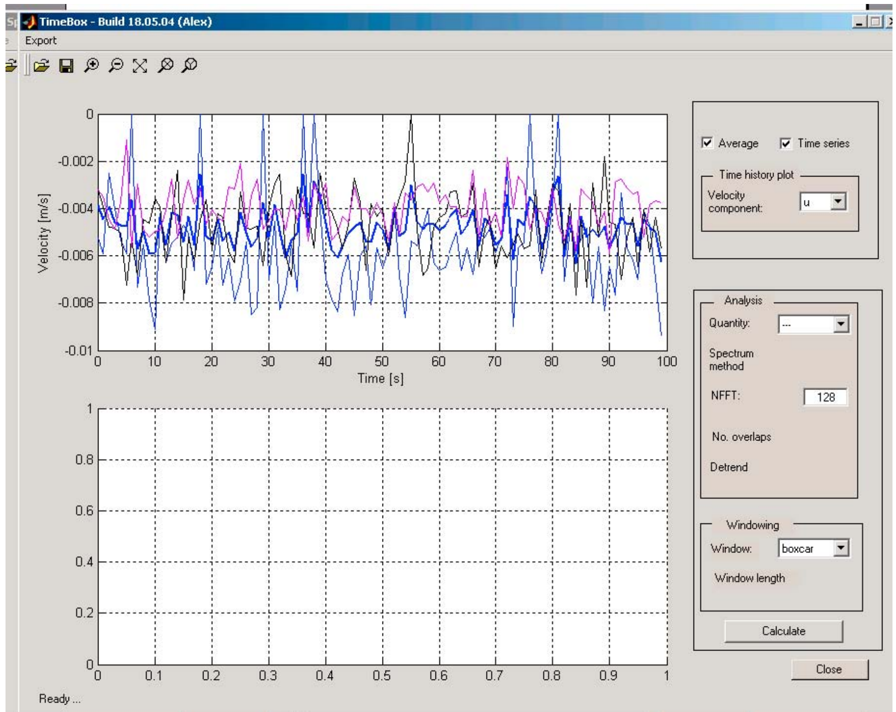


Figure B-18
Time History of a Selected Point

Depending on the two checkboxes, you may choose to see only pointwise time history and/or its spatial average. In addition, you can plot the time history of the fluctuation velocities, same as the instantaneous for the three components.

Figure B-19 shows an example of the lateral correlation. Rii relates to the selected velocity component (that is if u is selected it is Ruu, from the left to the right) and k1 refers to the rows direction (from the top to the bottom).

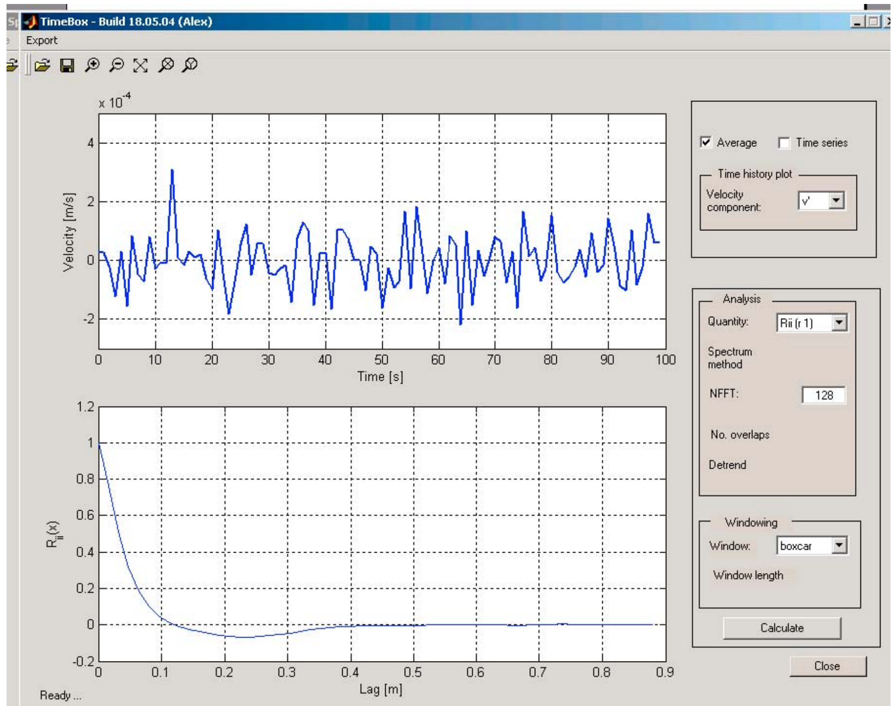


Figure B-19
Example of the Lateral Correlation

Figure B-20 shows an example of the longitudinal correlation function, in this case it is Rvv in k2 direction.

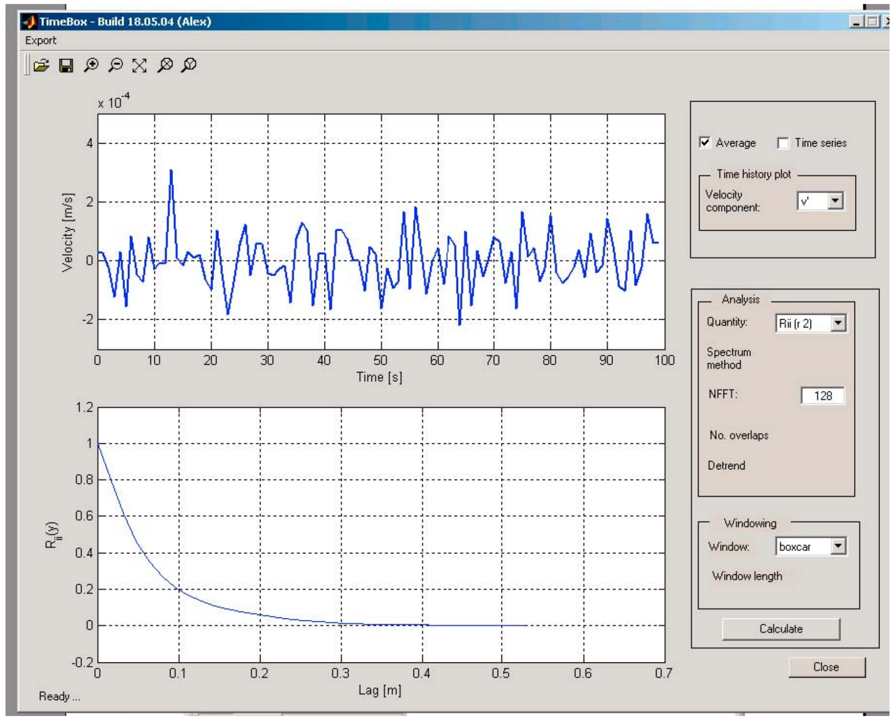


Figure B-20
Example of the Longitudinal Correlation Function

Figure B-21 shows an example of the wave-number spectra.

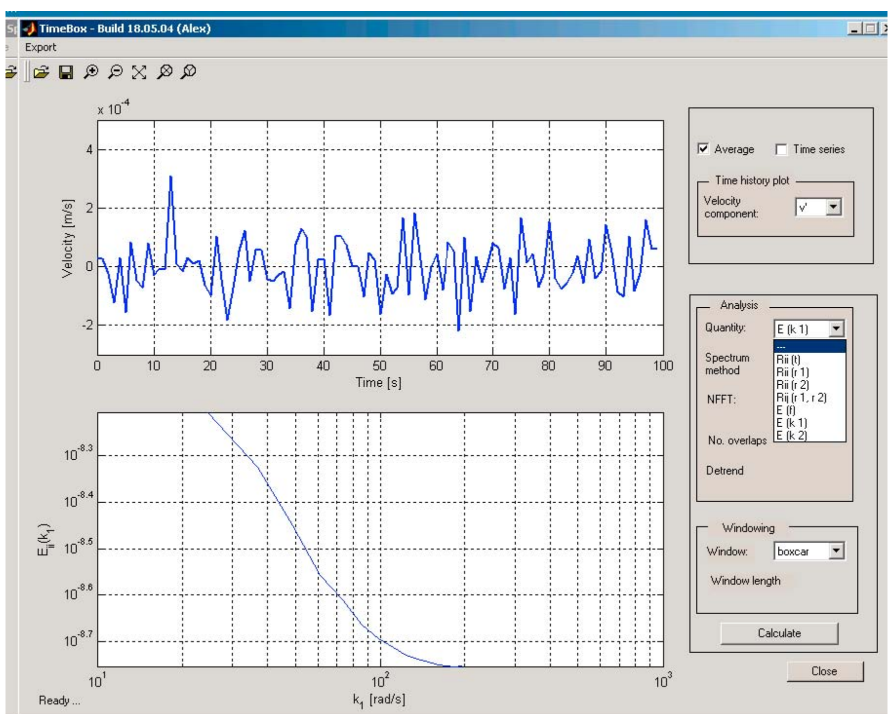


Figure B-21
Example of the Wave Number Spectra

Figure B-22 shows how each one of the axes could be independently exported or saved into MATLAB figure or comma separated file.

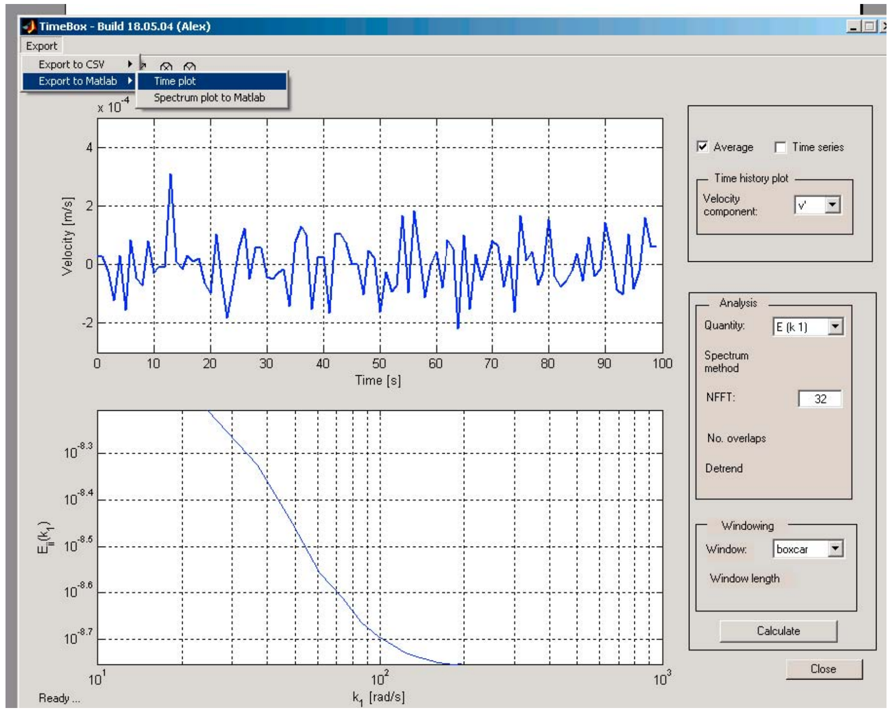


Figure B-22
Export to MATLAB

Figure B-23 shows the Export to Figure option used. This option allows you to use Plot Edit options of MATLAB.

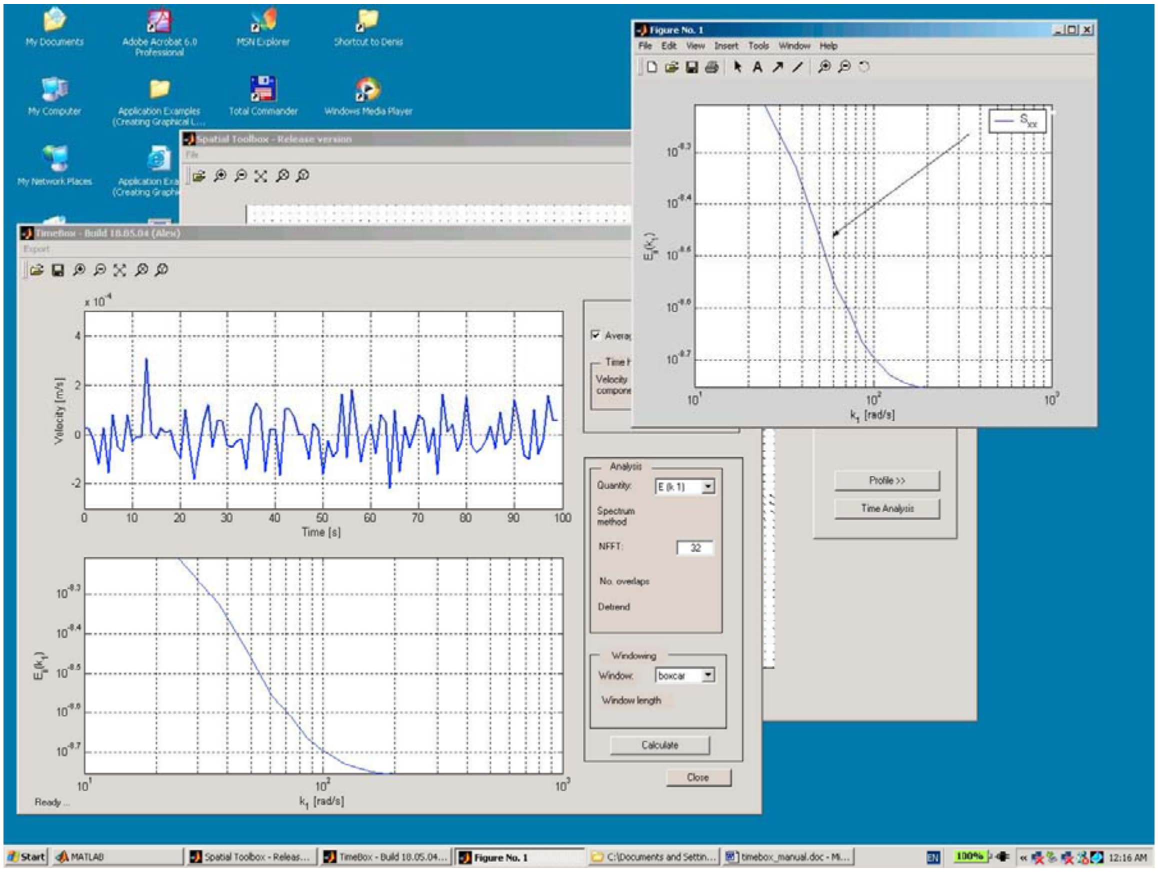


Figure B-23
Export to Figure Option

For each comma separated file, a unique filename is used.

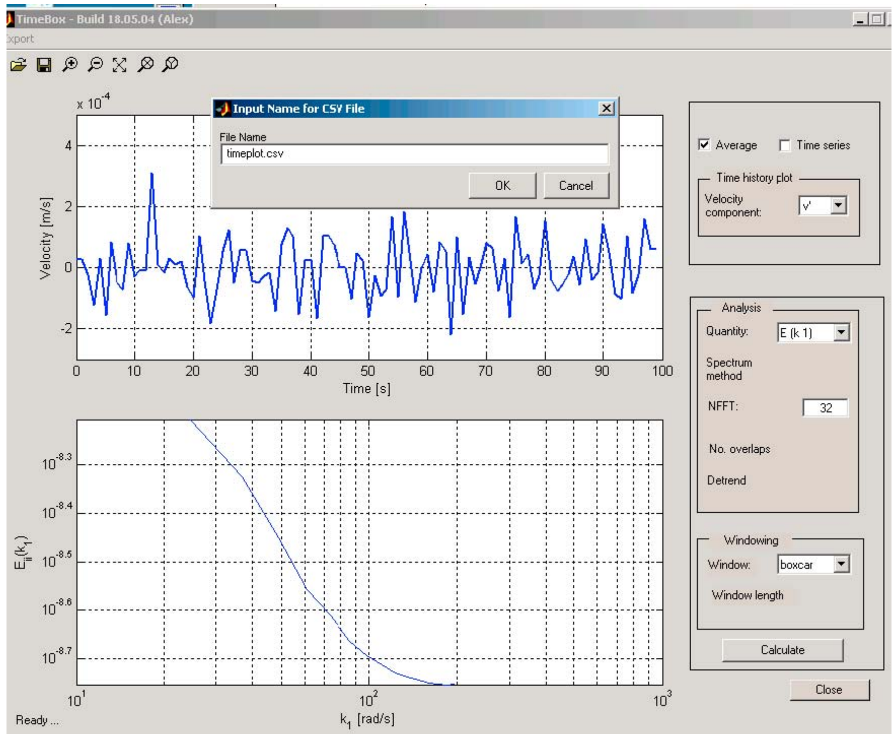


Figure B-24
Input Name for CSV File

Using the Proper Orthogonal Decomposition (POD) Toolbox

When at least one vector file is selected, the select window appears allowing you to select region of interest.

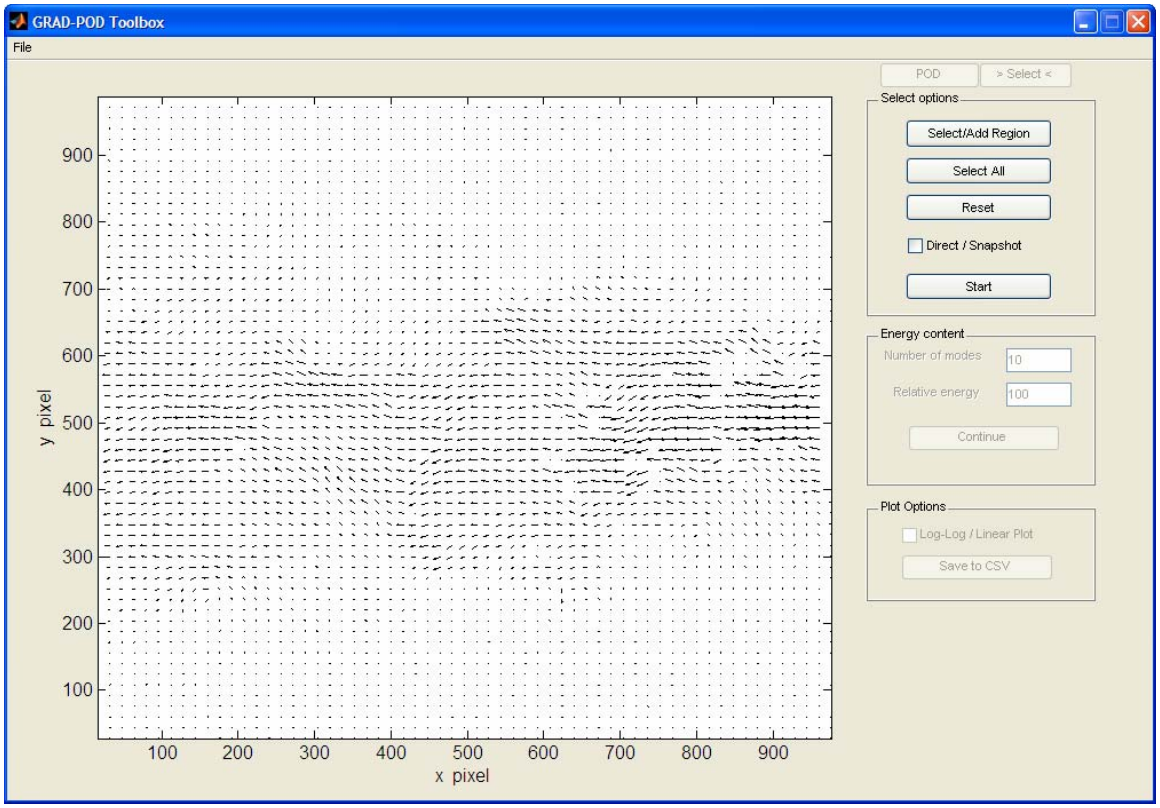


Figure B-25
Default Selection Window

Select Options

In selection tab, the following selection tools are present (see Figure B-26)

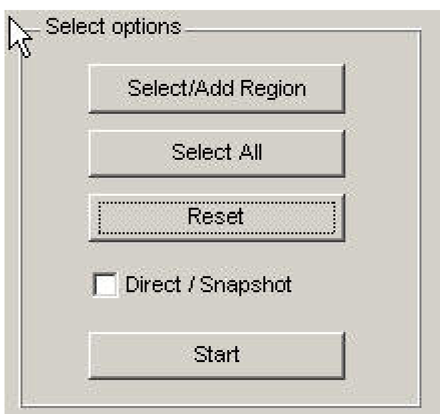


Figure B-26
Select Options

Select/Add Region

Allows you to select a single region from the map (see Figure B-27).

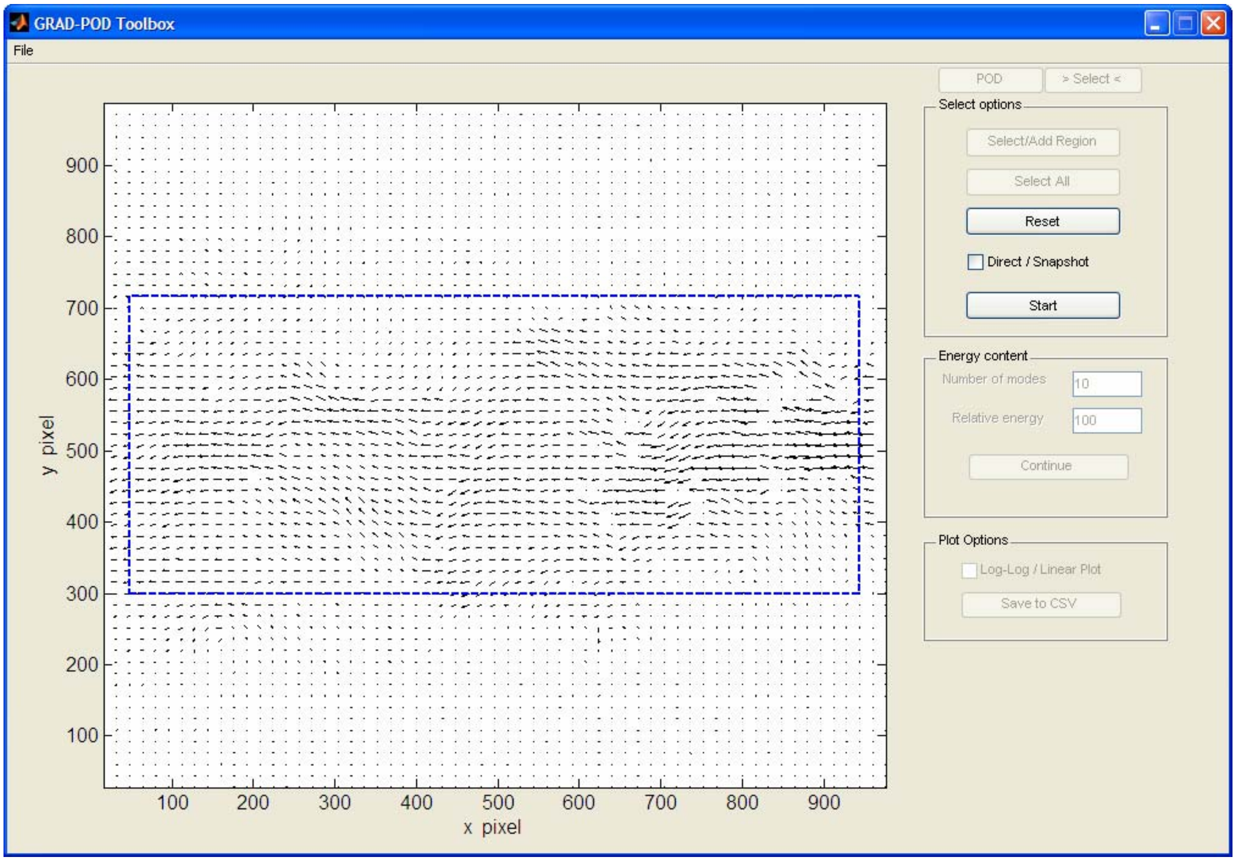


Figure B-27
Selecting Regions

Select All

Pressing **Select All** will select the entire map (see Figure B-28)

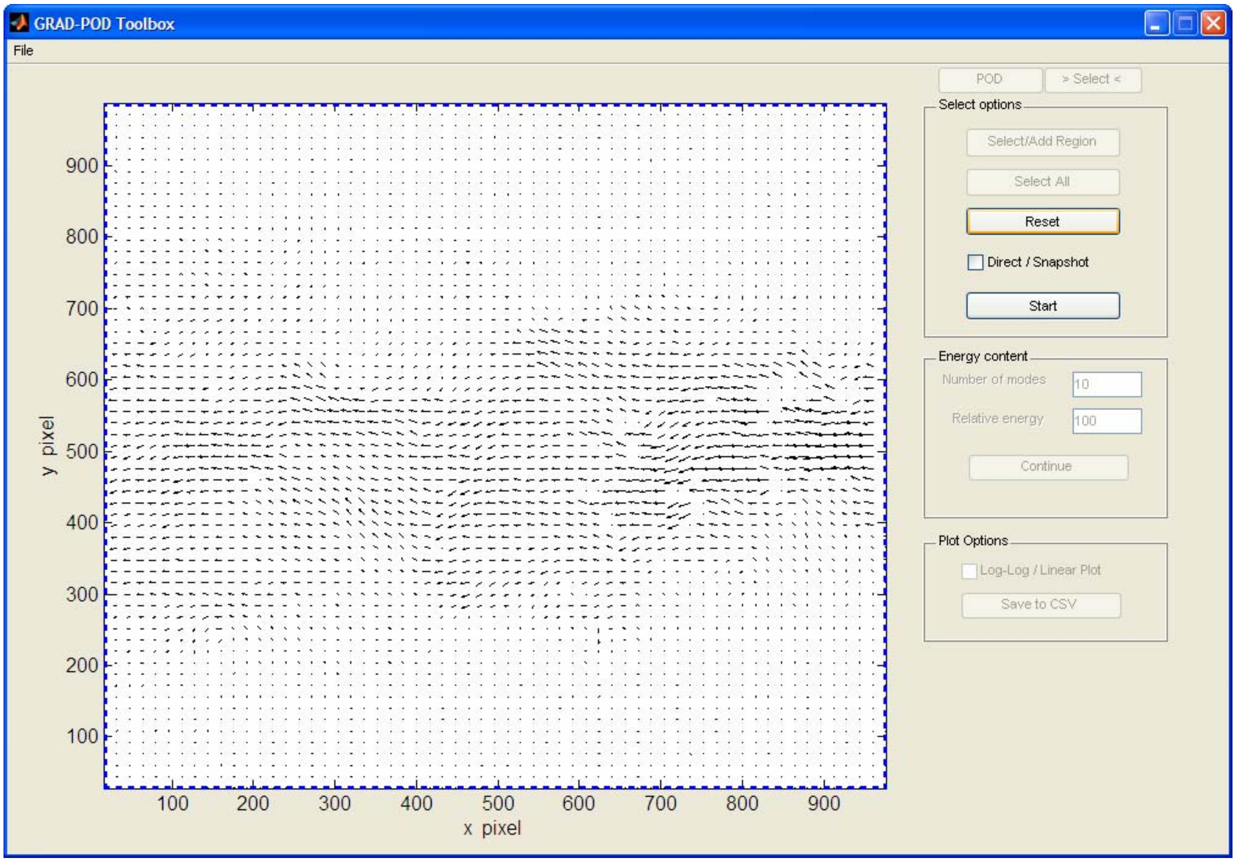


Figure B-28
Selecting the Entire Map

When selection of region or selection of entire map is done, the only choice is to reset current selection and to do another selection, or to continue with the current.

Resetting of the current selection can be done by pressing the **Reset** button

Direct/Snapshot

This checkbox is checked and unchecked *automatically* by the software. There is still an option for the user to change the selection; however, the performance of the toolbox will be strongly altered. There are two methods to calculate the POD modes, as it is explained in details in theoretical and computational background: the direct method and the method of snapshots. The selection is done according to the minimal size of the input matrix, i.e., if the number of vectors is less than the number of the velocity vector fields, then the computationally efficient method is the direct method. Otherwise, the most efficient method is the method of snapshots. The recommendation is **not** to change the default selection of the software. Both methods lead, obviously, to the identical result.

After selection region of interest, you may proceed to choose the energy content by pressing the **Start** button.

Or to adjust the selection, press **Reset** button

Choosing Energy Content

After pressing the start button, plot of relative energy versus number of modes is shown in Figure B-29.

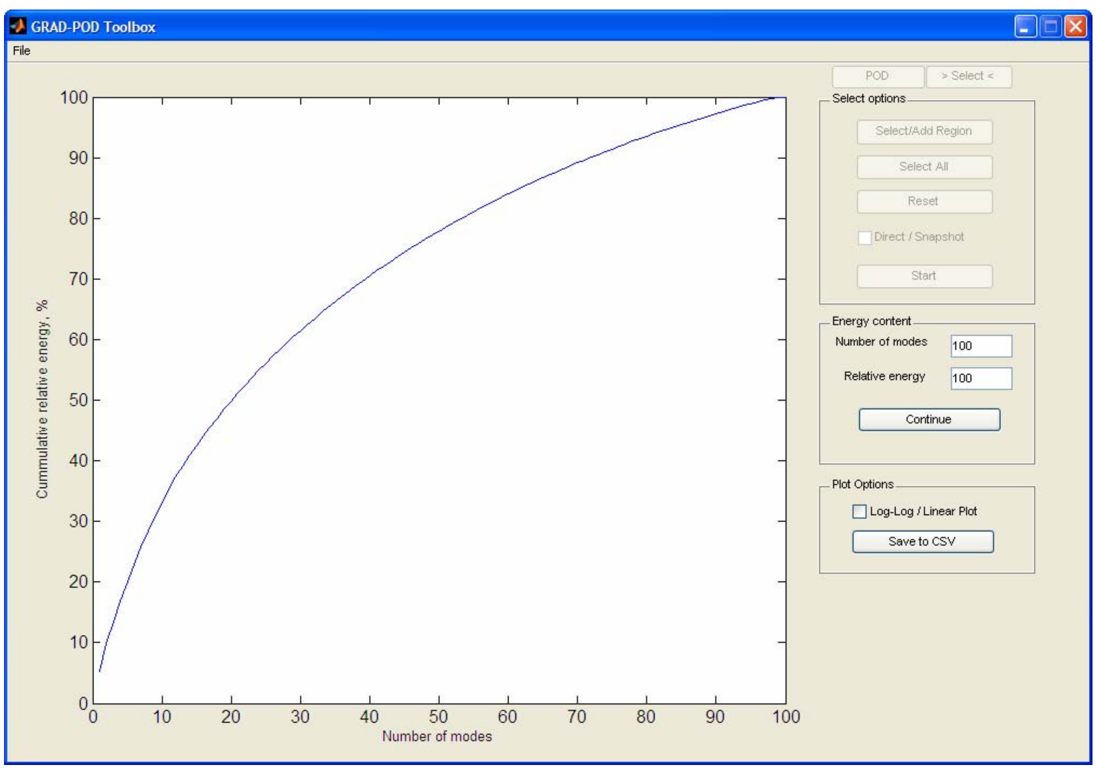


Figure B-29
Plot of Relative Energy Versus Number of Modes

The following controls are enabled (Figure B-30) to let you choose number of modes or relative energy percent .There are two choices:

- Enter number of modes (minimum is 1, maximum is number of maps loaded) and press **Continue** button. Related energy percent will be automatically calculated.
- Enter energy percent (1..100%) and press the **Continue** button. Related number of modes will be automatically calculated.

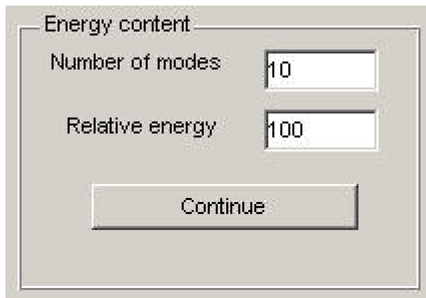


Figure B-30
Energy Content Controls

Energy Content Controls

Energy plot can be switched to log-log (Figure B-31) notation using the checkbox in plot options field (Figure B-32).

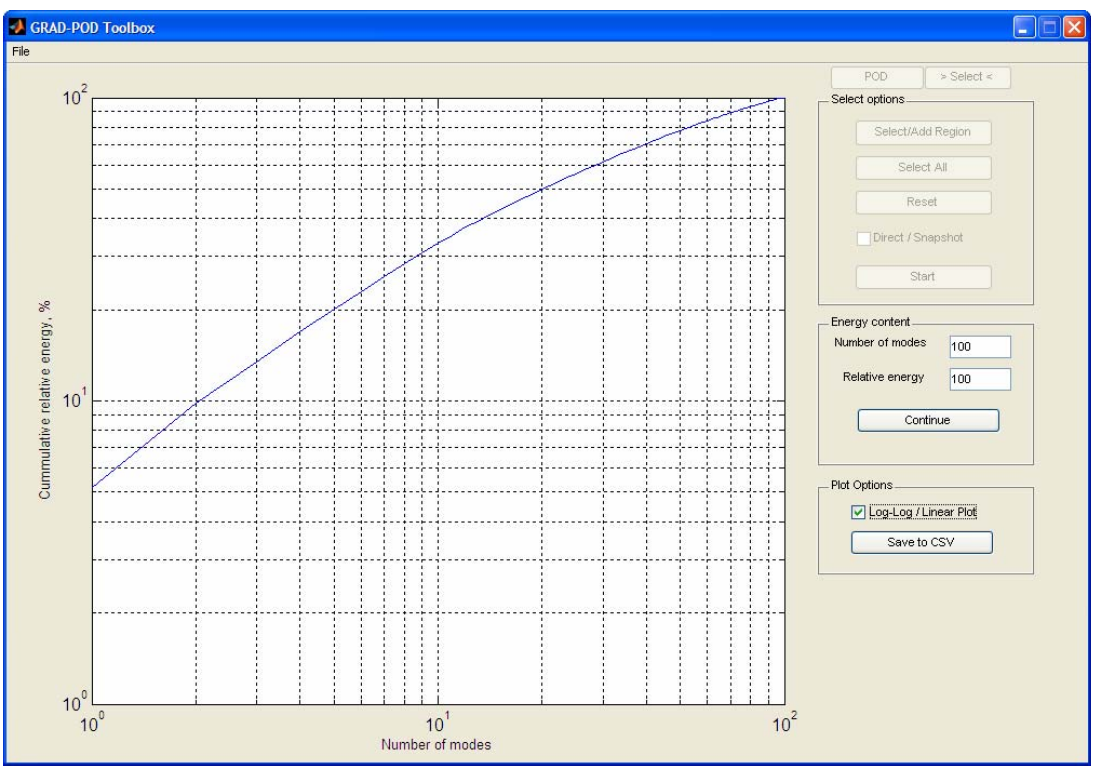


Figure B-31
Energy Plot Using Log-Log Notation

Energy plot can be saved to CSV file using **Save to CSV** button (Figure B-32). When pressed, you will be asked for the filename to save.

Figure B-32
Plot Options Field and File Name Dialog

After pressing the **Continue** button, default window looks like Figure B-33.

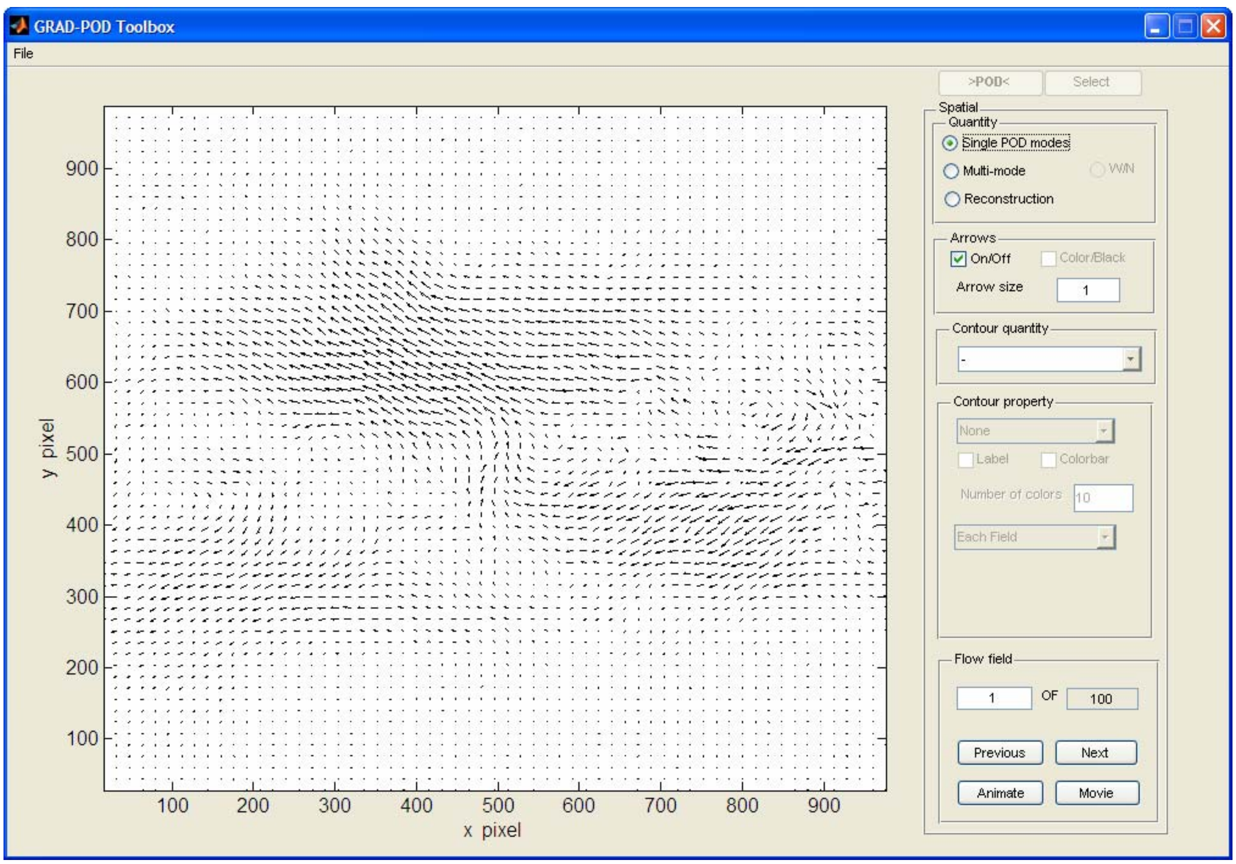
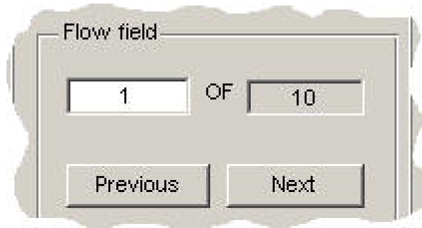


Figure B-33
Default Window, Arrows, GUI Controls, and Main Axes

Navigation

Navigation is done by using the **Next/Previous** buttons, which display next/previous maps accordingly.

To jump to a specific map, enter the number of the map in the edit box followed by **Enter.**



Available Options

You can choose between one of the large set of various combinations to present its data: arrows in black or in color. The color of arrows could represent any one of the available quantities for that particular mode. The arrows could be on top of the contour map of the selected quantity, and contour could be as color patterns, bounded, or unbounded (smooth view), color or black contour lines. Below, in the working example, we show some of the combinations.

Arrow Options

The following arrow choices are available:

Option	Description
On/Off	Select **On** to display and **Off** to hide the arrows.
Color/Black	Available only if arrows are turned on. ***Color***: Displays arrows according to the current quantity.

Contour Quantity Modes

Use this option to choose the quantity that will be displayed (see Figure B-34).

The list of quantities is:

$$u, v, \sqrt{u^2 + v^2}, \omega = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}, s_{xx} = \frac{\partial u}{\partial x}, \frac{\partial u}{\partial y}, \frac{\partial v}{\partial x}, s_{yy} = \frac{\partial v}{\partial y}, \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}, s_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}$$

And in the same order they appear in the toolbox:

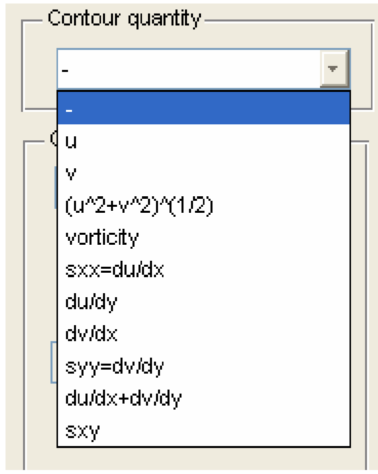


Figure B-34
List of Available Quantities to Use for a Contour- or Color-Coding of an Output

Output Options

The results can be presented in Single POD modes, Multi-mode, or Reconstruction of fields (Figure B-35).

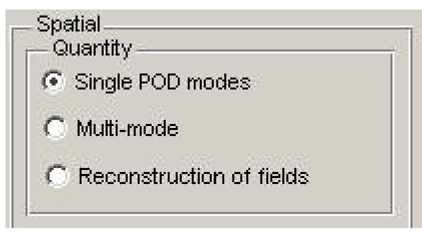


Figure B-35
List of Available Ways to Show the Output

Single POD Modes

Every POD mode of velocity vector fields could be shown as a vector field, by arrows, and with derived quantities as the background contours. The derived quantities are calculated instantaneously from each POD mode, as it has been a regular flow snapshot. Navigation and animation/movie options are: Next/Previous (from one to the number of modes, selected before) and Animation/Movie from the current mode towards the last.

Multi-Mode

The result is a linear combination of POD modes, defined by the user in the vector of indices of modes. The combination could be of consequent or randomly selected modes (i.e., from 1 to 5 or 1,2,5, for example). In addition, the toolbox allows calculating the sum of the selected modes or their linear combination by using their respective eigenvalues. The latter option is called weighted version and realized by checking the radio-button 

(the short version of Weighted/Non-Weighted). The default is a regular sum (Non-weighted version) and checking the radio-button will show the weighted version. When working in Multi-mode, the control shown in Figure B-36 is available.

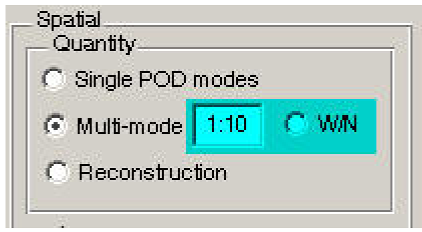


Figure B-36
Multi-Mode Controls

The 

edit-box allows you to choose modes that will be used to calculate quantities in multi-mode.

The software allows you to use any index notation of a vector in MATLAB and gives lot of flexibility, allowing to choose single modes, group of modes, group of modes with given step, etc. For example:

- 1:10—Choose all modes from 1 to 10.
- 1:2:10—Choose all modes with step of 2, i.e., 1,3,5,7,9 will be chosen.
- 1, 3, 5 or 1 3 5—modes 1, 3, and 5 will be chosen and any other combination, like 1:2:5,10 will also work

Note: *Minimum allowed value to enter is 1 and maximum allowed value is maximum number of modes.*

Reconstruction of Fields

Every one of the selected vector fields could be reconstructed by using all the modes or some of the modes. The reconstruction with all the modes gives the exact original vector field, while the reconstruction with lower number of modes will provide you with the low-order reconstructed model of the vector field. You are advised to understand more about the low-order representation from additional documentation providing a theoretical and computational background.

When working in Reconstruction mode, the option shown in Figure B-37 becomes available.

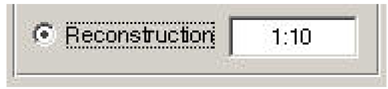


Figure B-37
Reconstruction Mode

You can make custom selection of modes to use in reconstruction, similarly to the way explained in the multi-mode section.

***Note**: A default selection for reconstruction and multi-mode is a vector of [1:maximum number of modes].*

Contour Types

Available contour types are:

- Flood—smooth color patches, no sharp boundaries.
- Color Line—only color boundaries, according to the color map of the selected quantity.
- Flood + Line—color patches, with sharp boundaries.
- Black Line—only boundaries of the contours.

There are several examples given below to show some of the available arrow and contour combinations.

(continued on next page)

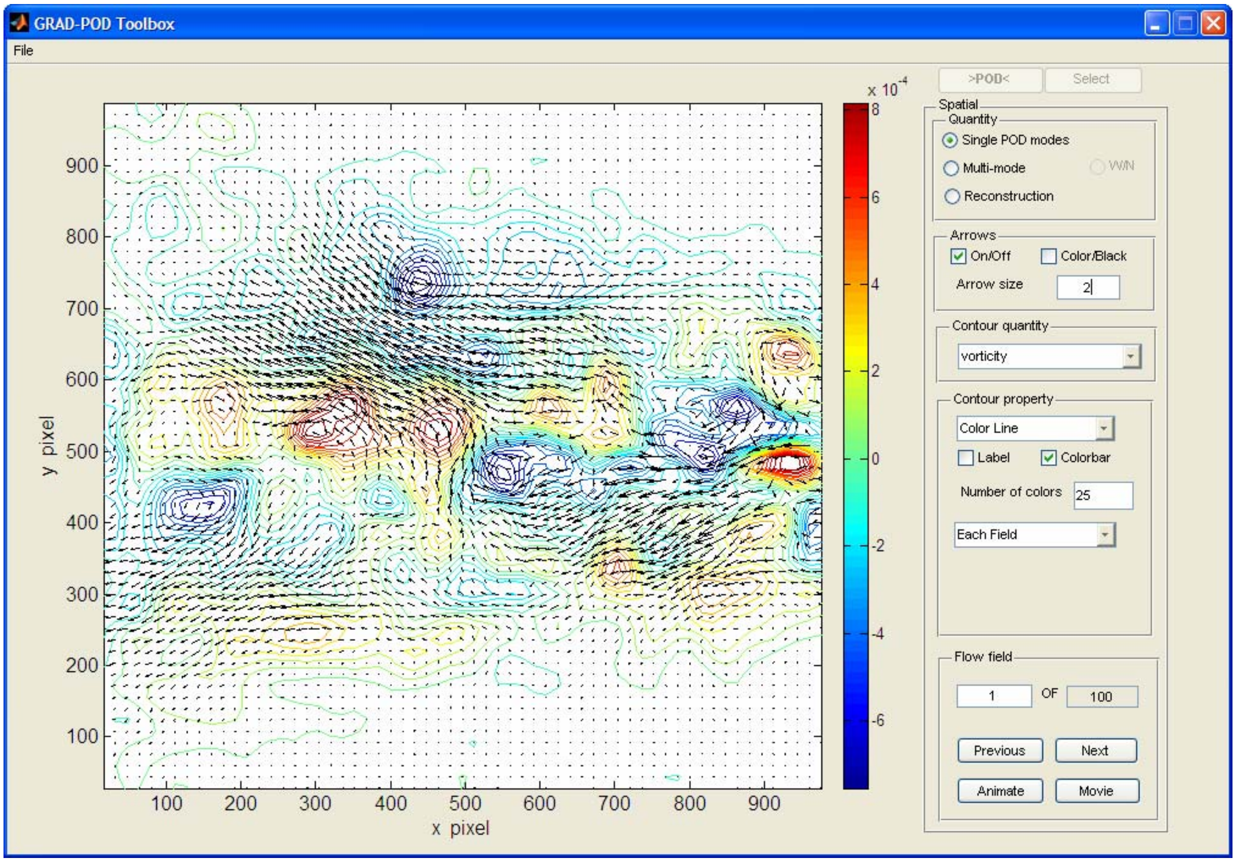


Figure B-38
Single Modes Velocity Field (Arrows) and the Instantaneous Vorticity Field in Color-Line Contour Mode. Note that a number of contour levels are set to 25

Control of Contour Levels and Colors

You can manually enter the number of contour levels (or number of colors), by entering the desired number in the edit box

and pressing **Enter**.

The number of colors (default or manually set) defines the number of contour levels of the selected quantity, but in one of four modes (contour modes):

Each Field The contour is automatically updated to each presented map limits (min and max) and distributed evenly into number of contour levels (i.e., number of colors)

All to Display The currently presented map defines the contour levels for all forthcoming maps, unless other option is selected. If you change the quantity, the limits are updated, but still will be constant for all forthcoming views.

All Fields The contour levels are defined by the maximum and minimum values of the selected quantity from the whole selected dataset. This is a very powerful option that allows you to compare the values visually, when not even one value will be out of the defined color set (which is possible to happen in manual or All to Display modes). However, you should realize that in order to determine the absolute maximum and minimum values, the whole dataset has to be calculated at least once. For example, All Fields of the vorticity demands the calculation of gradients in both directions of the selected dataset

Manual You can select the maximum and minimum level of the color to be shown, the selection could be symmetric by entering the same positive and negative values or anti-symmetric, if different values are used.

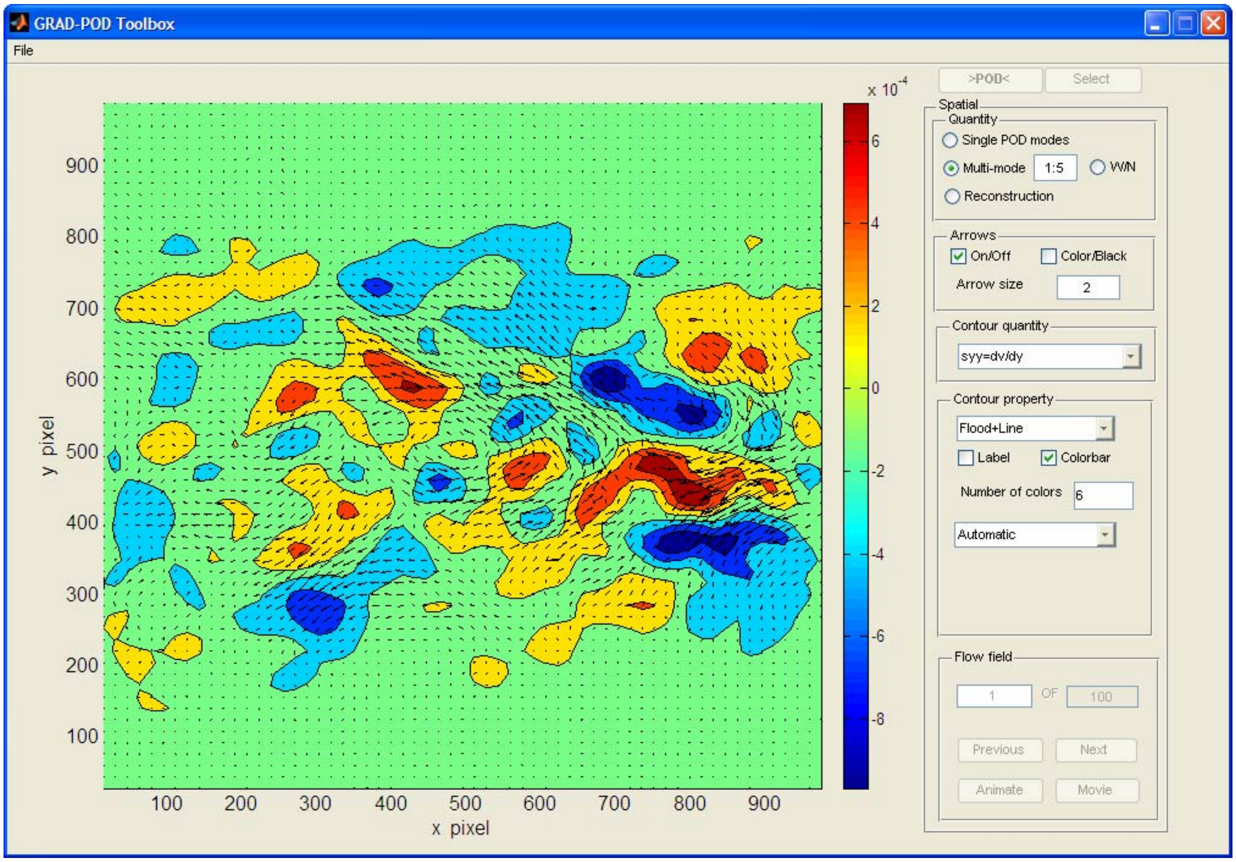


Figure B-39
Multi-Mode Output, Non-Weighted Sum of the First 5 POD Modes. Contour is set to flood+line type of the rate-of-strain component s_{yy}, number of contour levels set to 6 to emphasize strong positive and negative regions.

Animation and Movie Options

You can run the animation of the successive maps, with all the visualization properties that were selected before, by pressing **Animation** button. The first map is the current map (that could be manually entered in the edit box) and pressing again the Animation button stops the animation at any map. Otherwise, the animation will continue up to the last map.

During the animation, the movie is **not** stored in the memory. You should operate the Movie button in the same way as the Animation button. But in addition, you will be prompted to type in the file name of the AVI file. The Windows AVI video file (uncompressed, default rate is 15 frames-per-second) is saved when the last map is reached, or the Movie button is pressed again (i.e., released).

Note: *The POD Toolbox window must be in the front while the movie is recorded. The movie is recorded by using MATLAB standard function* `getframe()` *that captures the screen. Therefore, if* *another window pops up in front of the POD Toolbox, it might be captured and it may corrupt the movie.*

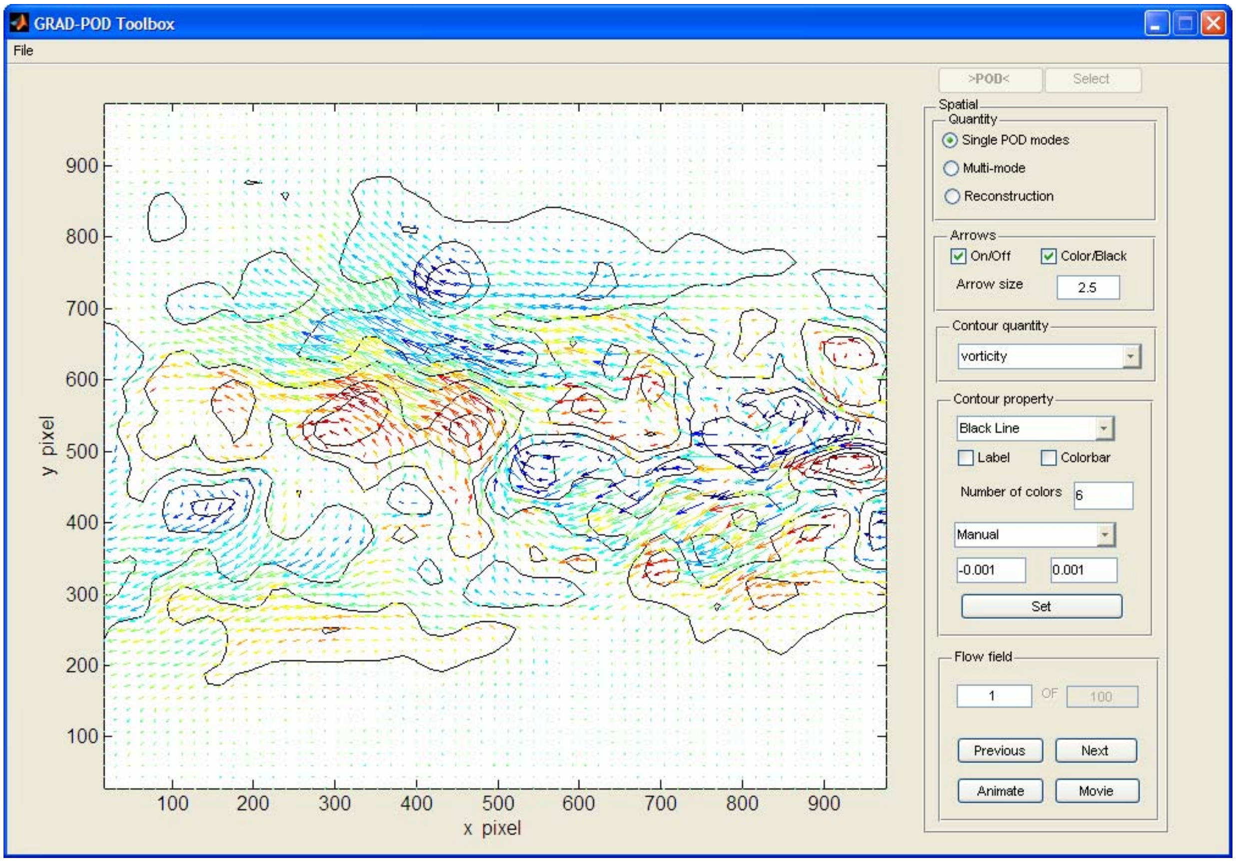


Figure B-40
The Color of the Arrows and the Contour Lines Correspond to Vorticity, the Number of Contour Levels is set to 6, and the Color is Distributed Symmetrically by Manual Set of Contour Levels Between –0.001 and 0.001

APPENDIX C

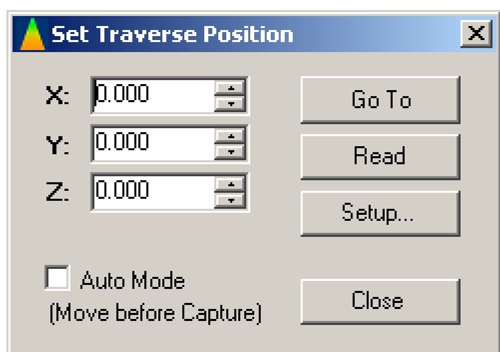
Enabling and Setting the Traverse

This appendix describes how to enable and setup a traverse, if you are using one in your experiment.

The traverse manager is used to control the position of the laser/camera. It has two modes:

- **Manual Move Mode** in which the motion of the laser or camera is controlled manually and not by *INSIGHT* 3G.
- **Traverse Manager Move Mode** in which motion is controlled by the traverse manager).

Traverse control can be enabled by selecting **Tools | Hardware Setup | Traverse Installed**. The position values can be displayed by clicking **Traverse Setup**.



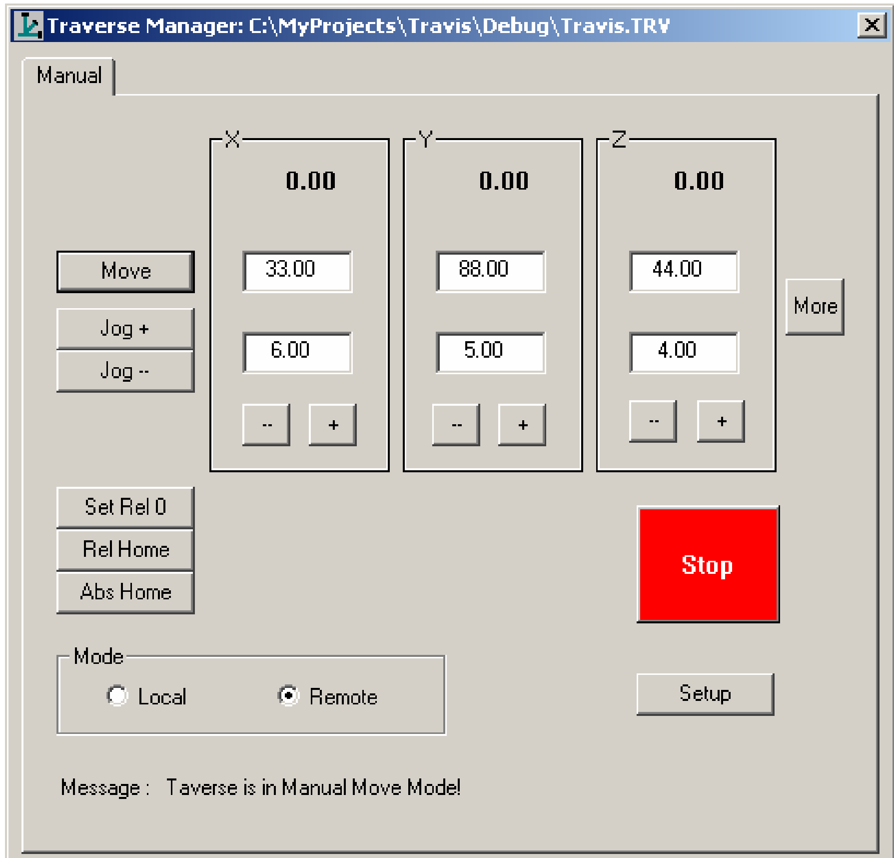
To access the Traverse Manager click the Setup button under Traverse Setup.

Enabling and Setting up the Traverse

To enable and setup the traverse:

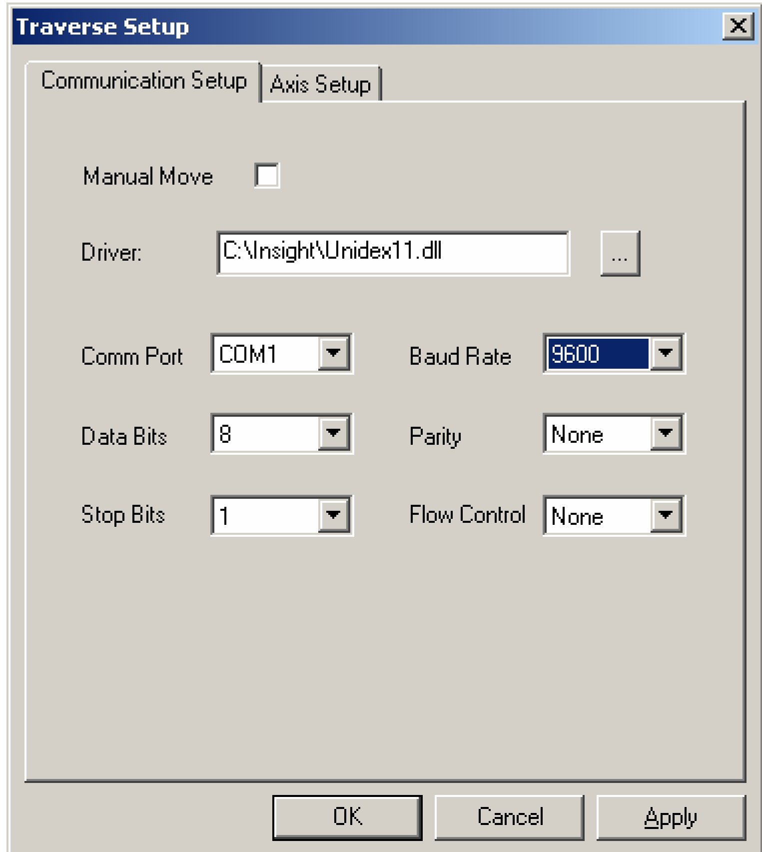
1. From the Capture tab, click **Component Setup**. Select the **Traverse Manager** tab in the dialog box.
2. Click **OK.**

3. From the Capture tab, click **Traverse Setup.** The traverse setup box appears.



To change to Manual Move mode:

1. Click **Setup** in the Traverse Manager dialog box. The Traverse Setup Dialog appears.



2. Select the **Manual Move** box. When Manual Move is selected, all other settings are unavailable.

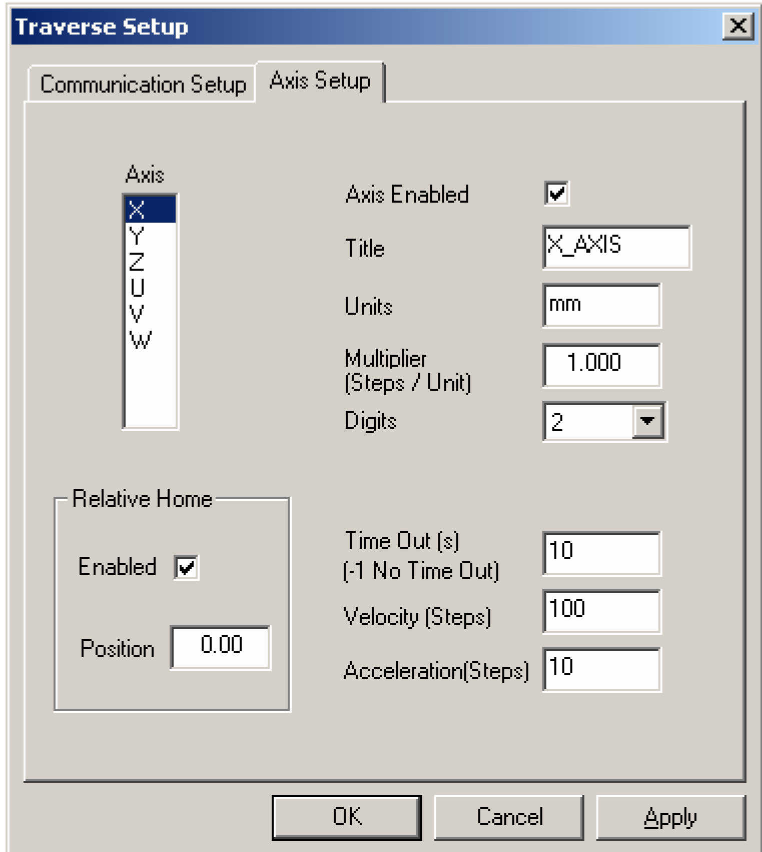
To change to Traverse Manager control:

1. Click **Setup** in the Traverse Manager dialog box. The Traverse Setup Dialog appears.
2. Unselect the **Manual Move** box.

   When Manual Move option is unselected, the driver, used to communicate with a specific motion controller and the communications port setting can be changed. The **OK** and **Apply** buttons apply the changes made in the Communication Setup. The **Cancel** button discards all changes made in that session.

To set up and configure axis:

1. From the Traverse Setup dialog box, click **Axis Setup** tab. The Axis Setup dialog appears:



2. Select an axis.

3. To enable the axis select the Axis Enable box. The following options become available. Make your selections based on the following descriptions.

Option	**Description**
Title	Title of the axis to be displayed.
Units	Set the unit of traverse move.
Multiplier	Set the multiplier of the steps per unit.
Digits	Set the total number of floating point digits to be displayed.
Time Out	Set the timeout of each axis for traversing. The software will stop the move and give a timeout
Velocity (Steps)	Set the velocity setting of the axis.
Acceleration (Steps)	Set the acceleration setting of the axis.

4. Select **Enabled** under Relative Home to enter a number to denote a home position relative to the hardware home position in the Position box.

5. Click **Apply** and then **OK.**

To use the Traverse Manager:

Option	Description
Move	Sets the Move positions. The Move button moves all enabled axis to the location specified in the edit box.
Jog	The Jog positions of the X, Y, Z, U, V, and W axis. Moves relative to the current position in the specified number of steps.
+ -	The + and - buttons within each axis group, jogs only that axis
Mode	Switches communications mode with the motion controller. ***Local:*** Changes the positions outside of the application usually through an external motion controller interface (that is, joystick or front panel keypad). ***Remote***: Commands are sent through the serial port to the motion controller.

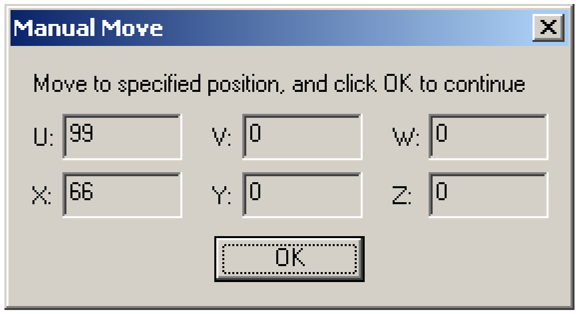
An example of switching between communications mode may be that in the current setup, the laser/camera position is off of the "home" position needed:

- You select local mode and move the laser/camera using a joystick through the motion controller.
- When you have the position needed, click the **SetRel0** button to set the relative home.
- Reselect remote mode.

The **Rel Home** button moves the laser/camera to the set relative home position. The **Abs Home** button moves the laser/camera to the hardware home position.

When an experiment is saved, the current location of the laser/camera is saved. When an experiment is reloaded and run, the traverse will move to the positions previously saved in the experiment file and the experiment will continue.

If the experiment is run in Manual mode, a dialog box requesting you to move to specified position is displayed.


Manual Move
Move to specified position, and click OK to continue
U: 99
V: 0
W: 0
X: 66
Y: 0
Z: 0
OK

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2. Was there any incorrect or missing information? (please explain) ____________________

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   ____

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Organization (finding what you need)	❑	❑	❑
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