

ShotStat Version 2.0

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2nd May 2005

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1 About This Document

This is the User's Manual for ShotStat 2.0, Copyright 2005, DSB Scientific Consulting.

1.1 License

You are free to print, copy or distribute this manual so long as this section appears unmodified.

1.2 Revision History

The documentation for ShotStat 1 was included with the program in the Microsoft Help format (*.hlp). This format was difficult to maintain. With Version 2.0, the Manual was translated to HTML to be viewed with the user's default browser.

The content of the manual was updated as well. In addition to adding information specific to Version 2, the original content was re-written and, we hope, clarified.

Finally, a PDF file is included as well. The user is free to print this PDF if a hard copy manual is desired, so long as the Copyright remains intact.

2 ShotStat Overview

ShotStat was created to provide shooters with a statistics package to help evaluate hand load performance. The idea was to develop a program that allowed shooters to enter data graphically to reduce both time required and technical measurement and calculation for evaluating shot groups.

So, what does ShotStat actually do? The program is basically a statistics calculator for any data set up to 20 elements. You can use this to calculate statistics for shot groups, load velocities, maximum (peak) pressures, case masses, bullet masses, bullet diameters, case expansion, etc. It is up to your imagination the data sets that can be used.

That said, ShotStat is primarily designed to evaluate load performance. With this version, two additional tools have been added: T-test and F-test. The T-test tool is used for deciding if the difference between two averages (such as impact point, velocity, etc.) is statistically significant. The F-test is similarly used to determine if the difference between two variances (such as group size or velocity spread) is statistically significant. These tools extend ShotStat's utility for both load evaluation and firearms training.

For more information, see Section 10.1 Statistics - General Description

3 ShotStat Organization

ShotStat is organized into three pages and numerous windows that each provide a specific function. The three pages are:

The Main Page

The Graphical Entry Page

The Keyboard Entry Page

The Main Page is simply a control page from which the other pages can be accessed. From the Main Page, the user may access the Graphical Entry Page (Section 4), the Keyboard Entry Page (Section 5) and windows for various options, tools, Help, tutorials, etc. There is no data entry actually done on the Main Page.



The graphic on the Main Page is a photo of a Tactical Marksman during a training exercise. Range to Target was a comfortable 175 yards. This sniper provided input for some of the early development of ShotStat.

3.1 Menus Common to the Main, Graphical Entry and Keyboard Entry Pages

3.1.1 File Menu

New Clears any current data and resets all options to default values, prompting to save current data if necessary.

Open Opens the file dialog to open a ShotStat data file; this is not used to import target images. If the opened ShotStat data file was generated using graphical data entry, the Graphical Entry Page is opened and the entered shot graphics are displayed. On the other hand, if the file was generated using keyboard entry, the Keyboard Entry Page is opened. In both cases, the Statistics Output Window is opened and shot statistics displayed.

Save Saves the current data to the currently selected ShotStat data file; if no file name is available to the program, this behaves the same as “Save As.” See Section 11.2 for more details.

Save As Save the current data to a ShotStat data file after providing a file name. See Section 11.2 for more details.

Import Image Opens the file dialog to import a target image file; available file formats are .gif, .jpg and .bmp. After successfully opening a selected image file, ShotStat automatically opens the Graphical Entry Page and

enters Calibration mode.

Note: This Menu Item does not appear on the Keyboard Entry Page.

Export Writes the current data to a formatted text file that can be read using a spreadsheet program, such as Microsoft Excel or OpenOffice.org Calc. This is different than saving the data to a ShotStat data file. See Section 6 for more details.

Print Sends the current data and computed statistics to the default local printer.

Exit/Close For the Graphical Entry and Keyboard Entry Pages, closes the window (and all attached windows) and returns to the Main Page; for the Main Page, exits ShotStat, prompting to save current data if necessary

3.1.2 Help Menu

Manual Opens the ShotStat Manual Contents in the user's default browser

Graphical Entry Tutorial Opens the graphical entry tutorial for learning the ShotStat mouse data entry procedure: calibration, setting aim point, shot entry, shot deletion.

Note: This Menu Item does not appear on the Keyboard Entry Page.

About ShotStat Standard "About" form that displays the running version and access to local System Info.

3.2 Menus Specific to the Main Page

The Main Page has specific menus for the overall configuration and use of ShotStat. These include:

3.2.1 Main Page View Menu

Graphical Data Entry Opens the Graphical Entry Page (See Section 4), displaying current data and statistics if present. If no data is in memory, the Header Entry (Section 4.2) form is displayed before the Graphical Entry Page is actually opened.

Text Data Entry Opens the Keyboard Entry Page (See Section 5), displaying current data and statistics if present. If no data is in memory, the Header Entry (Section 4.2) form is displayed before the Keyboard Entry Page is actually opened.

Show Statistics Opens the Statistics Output Window that displays current data and statistics.

Clear Data This clears all data currently stored in memory; it performs the same function as the Clear button on the Graphical Entry Page Tool Box (Section 4.3).

3.2.2 Main Page Options Menu

Show Header Opens the Enter Header Window so the user can view/edit the header information for the data currently in memory. If no shot data is in memory, any entered header data will be lost when either the Graphical or Keyboard Entry Page is opened. See Section 4.2 for more details.

Default Options Opens a window to set which options are saved into the configuration file. See Section 7.1 for more information.

Default Units Opens a window to set the units (inches, cm or other text entered by the user) displayed for statistics output. This is only a display parameter; it has no effect on the actual calculations.

3.2.3 Main Page Tools Menu

Average Testing Opens a window to enter data needed to perform the T-Test for comparing the averages of two sets of sample data (Section 8.2).

Variance Testing Opens a window to enter data needed to perform the F-Test for comparing the standard deviations of two sets of sample data (Section 8.3).

3.3 Menus Specific to the Graphical Entry Page

3.3.1 Graphical Entry View Menu

Show Tool Box If the Tool Box (Section 4.3) has been closed, it can be re-opened via this menu item. The Tool Box may be closed to unclutter the Graphical Entry Page while working with targets. Note that the Cal, Aimpoint, Enter Shot buttons are automatically selected for “New” target images, so there is no real need to have the Tool Box open for calibration, aimpoint selection and initial shot entry.

Show Statistics If the Statistics Output Window (Section 4.5) has been closed, it can be re-opened via this menu item. The Statistics Output Window may be closed to unclutter the Graphical Entry Page while working with targets. Output is rendered to the Output Window dynamically, so there is no need to have this Window open during calibration or shot entry. If the user does not need to watch the statistics being updated as shots are entered, there is no need to have it open during Shot Entry, either. Statistics can be checked at any time by opening the Statistics Output Window, then closing it to get it out of the way.

Note: the Statistics Output Window can alternately be Minimized rather than Closed if you prefer; it will remain on the Windows Task Bar. It can then be Restored by clicking it's block on the Task Bar.

3.3.2 Graphical Entry Options Menu

Set Background Color Opens a dialog to select the background color for the Picture Box of the Graphical Entry Page. Use this to increase contrast if taping targets to the screen or to help define the limits of the imported target image.

Full Screen Cursor Toggles the full cursor cross hairs extending to the limits of the Graphic Entry Page Picture Box. This can be useful for locating the mouse cursor location if taping targets to the screen.

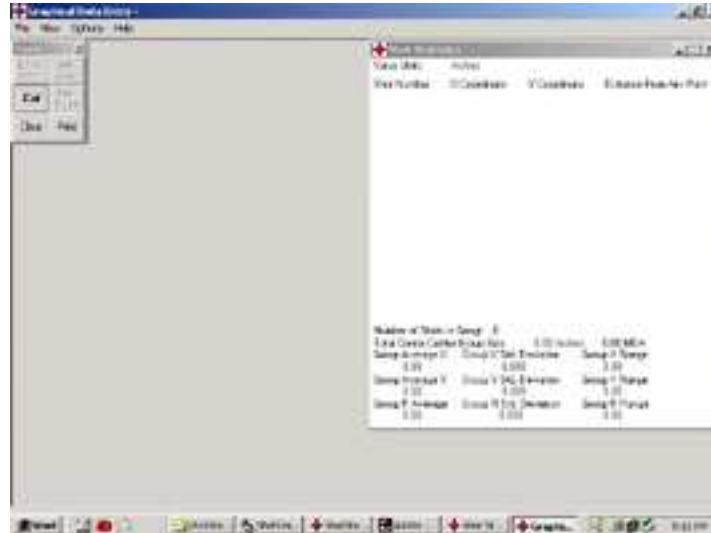
Show Centroid Toggles drawing of the group centroid, which is the average group center as computed from the shot data. The centroid is plotted as a square in a different color from the circular shot data markers. The centroid may help troubleshoot site alignment problems (by comparing to the shooter's aim point), non-zero sites, etc.

Axes Through Aimpoint Toggles drawing a full screen cross hair intersecting at the entered aim point. This divides the target into quadrants with the aim point at the origin.

3.4 Menus Specific to the Keyboard Entry Page

There are currently no menu items on the keyboard entry page that are not common to the Main Page and Graphical Entry Page.

4 The Graphical Entry Page



4.1 Overview

The Graphical Entry Page is the heart of target analysis with ShotStat. With this page, you can quickly and easily obtain shot group statistics without measuring the target. How the Graphical Entry Page behaves depends on several option settings and if data is in memory when the page is opened.

To open the Graphical Entry Page, do one of the following:

1. To open the Graphical Entry Page with new target image: on the Main Page, click File/Import Image, browse to find the desired image file and double click to open it.
2. To open the Graphical Entry Page either without a target image or with the desired target image previously selected: on the Main Page, click View/Graphical Data Entry.

If there is no data in memory when the Graphical Entry Page is opened, the Header Entry Window (Section 4.2) is displayed before the Graphical Entry Page is actually opened.

To use the Graphical Entry, a specific procedure must be followed. The Tutorial outlines how to do this (Help/Tutorial), or see Section 4.6.

4.2 The Header Entry Window

Each shot group can have descriptive information attached called the “header” in ShotStat.

Enter Header Information

Range to Target: yds (required if you want MOA)

Shooter's Name:

Date Fired:

Firearm:

Caliber:

Lot Number:

General Comments:

Ok Cancel

The following information can be stored for each shot group:

Range-To-Target in yards, this value is “required” if you want ShotStat to compute the group center-to-center Minutes of Angle (MOA); the default is 100 yards, which can be changed in the configuration file.

Shooter Name a text description of 30 characters or less; there is no default, but a default can be saved in the configuration file.

Date Fired a text description of 20 characters or less; there is no default and no default can be set.

Firearm Description a text description of 30 characters or less; there is no default, but a default can be saved in the configuration file.

Caliber Description a text description of 30 characters or less; there is no default, but a default can be saved in the configuration file.

General Comments a text description; there is no default, and no default can be set.

The ShotStat configuration file can be modified as follows: on the Main Page, click Options/Default Options. See Section 7.1.

4.3 Graphical Entry Tool Box

The Tool Box contains buttons that control either the function of the mouse in the Picture Box (Calibrate, Set Aim Point, Enter Shot, Delete Shot) or performs an immediate action (Clear, Print). If a button is 'greyed,' it's function is not available (for example, the Enter Shot button cannot be used if no Aim Point has not been entered).



The Tool Box is “smart” in that it will set the mode according to the options available to the user:

When no calibration is done, neither the aim point can be set nor shots entered; therefore, Calibrate is selected. The calibration procedure is described in Section 4.6

After calibration, Set Aim Point is selected, but Enter Shot and Remove Shot remain unavailable. Calibrate is available, since the user may re-calibrate if wished.

After the Aim Point is entered, ShotStat goes into Enter Shot mode.

4.4 Graphical Entry Picture Box

The picture box is where the target image is actually displayed and shot data actually entered. While in the picture box region, the mouse cursor is a cross hair, a normal mouse cursor otherwise. The picture box is nearly as large as a fully maximized window on the user's screen.

Please note that all shot data of interest must lie within the picture box. In ShotStat Version 2, there are no scroll bars to handle larger images, so target images must be slightly smaller than the user's screen resolution. For example, if your screen is 800x600 pixels, you would not want to use a target image larger than about 540x680 pixels (roughly). If you tape your targets to the screen for graphical entry, make sure all relevant shot data lie within the picture box. Setting the background color may be useful for defining the actual size of the picture box.

4.5 Statistics Output Window

As shots are entered (or removed), the shot data and statistics are displayed on the Statistics Output Window.

Shot Statistics			
Value Units:		Inches	
Shot Number	X Coordinate	Y Coordinate	Distance From Aim Point
01	-0.27	0.14	0.30
02	0.22	0.14	0.26
03	0.21	-0.11	0.24
04	-0.22	-0.13	0.26
05	-0.05	-0.30	0.30
06	0.21	-0.06	0.22
07	0.02	0.14	0.15
08	-0.19	0.08	0.20
09	0.08	-0.14	0.16
10	0.04	0.26	0.26
11	-0.10	0.23	0.25
12	0.18	0.09	0.20
13	0.21	0.22	0.30
14	-0.09	-0.03	0.10
Number of Shots in Group 14			
Total Center-Center Group Size		0.57 Inches	0.54 MOA
Group Average X	Group X Std. Deviation	Group X Range	
0.02	0.174	0.48	
Group Average Y	Group Y Std. Deviation	Group Y Range	
0.04	0.169	0.56	
Group R Average	Group R Std. Deviation	Group R Range	
0.23	0.062	0.21	

In the top section of the window, the shot data are displayed: x and y coordinates and distance from point of aim for each shot in the order entered. The bottom section displays the computed statistics: number of shots in the group, center-to-center group size (in both units and MOA, if the Range-to-Target parameter was set) and the average, standard deviation and range for x, y and distance. Note that the distance from point of aim is labeled "R" in ShotStat.

The Statistics Output Window can be moved, minimized or closed completely while entering (or removing) shot data. If closed, the Statistics Output Window can be opened by clicking View/Show Statistics.

4.6 The Calibration and Aim Point Procedure

Before the Graphical Entry Page can be used to enter shot data, the screen must be 'calibrated' and an aim point set. Calibration in this sense means that there needs to be a correspondence between distances on the screen (the target image) and distances on the real target. In other words, ShotStat does not require images to be 1:1, so you can zoom your target images as needed.

4.6.1 Calibration

To calibrate the screen image, you must have something on the target of known real length. This can be an aiming square or circle or a mark you place on the target for calibration. In a pinch, you can use the bullet diameter if the holes are cut cleanly.

Calibration is easy, only takes a couple of seconds and only needs to be done once per target. When the Graphical Entry Page is first opened with a new target image, the "Cal" tool button is automatically selected and ShotStat is in calibration mode. To calibrate:

1. Place the mouse cursor on one end of the known distance mark on the target and Left Click.
2. As the mouse is moved, the 'calibration line' follows the mouse cursor. Move the mouse to the other end of the known distance mark.
3. Left click the mouse; the length of the line on the screen should be the same as the known distance on the target image. If not, simply start over at Step 1.
4. When the calibration length is entered (Step 3), ShotStat opens an Input Box so you can enter the real length, in inches, that the calibration line represents. The initial default is 1 inch, but the user can save an alternative default value. See Section 7.1.

Note: The Real Length has to be entered as a decimal value, not a fraction. See Section 9, Decimal Equivalents.

4.6.2 Setting the Aim Point

ShotStat uses the Aim Point as the theoretical 'zero' (or origin) for the target image. The aim point should be set to that point on the target at which the shooter was aiming. After calibration, the "Aim Point" tool button is automatically selected and ShotStat is in Aim Point mode. To set the Aim Point:

1. Place the cursor at the aim point and Left Click. The aim point is indicated on the image as a small colored hollow cross. After the aim point is set, ShotStat automatically goes into Enter Shot mode.
2. If you make an error setting the aim point, simply select the “Aim Point” tool button and re-enter the aim point.

Note: In ShotStat Version 2, you should only enter one aim point per shot group. You *can* enter a different aim point for each shot, but you will not have any way to know the aim points for individual shots, and this may be prone to errors in the statistical calculations. We highly recommend that you enter only one aim point per shot group.

4.6.3 Graphical Entry Tutorial

To help new users become familiar with the calibration/aim point procedure, a tutorial is included. You can access the tutorial by clicking Graphical Entry Tutorial on the Help menu on either the Main Page or the Graphical Entry Page.

The tutorial includes a sample target image file, so the user can practice while reading the tutorial.

4.7 Entering and Removing Shot Data

Shots are entered simply by clicking the shots on the target image when the “Enter Shot” tool button is selected. Entered shots are indicated by a small circle. In ShotStat Version 2, you can enter up to 20 shots per group.

Note: The shot statistics on the Output Window are updated as shots are entered or removed, but no statistics are shown for the *FIRST* shot.

Shots are removed by clicking the small indicator circle while the “Del Shot” tool button is selected. If you miss the indicator circle, ShotStat will display a message essentially saying that it could not find the shot you are trying to delete. If you try to delete a shot that overlaps with another, you may have to delete both and re-enter the one you want to keep.

4.8 Clearing All Data

The entire data set can be cleared (as opposed to deleting individual shots) by one of three methods:

1. clicking the “Clear” tool button
2. selecting Clear Data in the View Menu on the Graphical Entry Page
3. selecting Clear Data in the View Menu on the Main Page

Regardless of the method used to clear data, ShotStat will prompt you to save the file if it has not been saved.

4.9 Printing Statistics

The information displayed in the Statistics Output Window can be sent to the user's default printer by

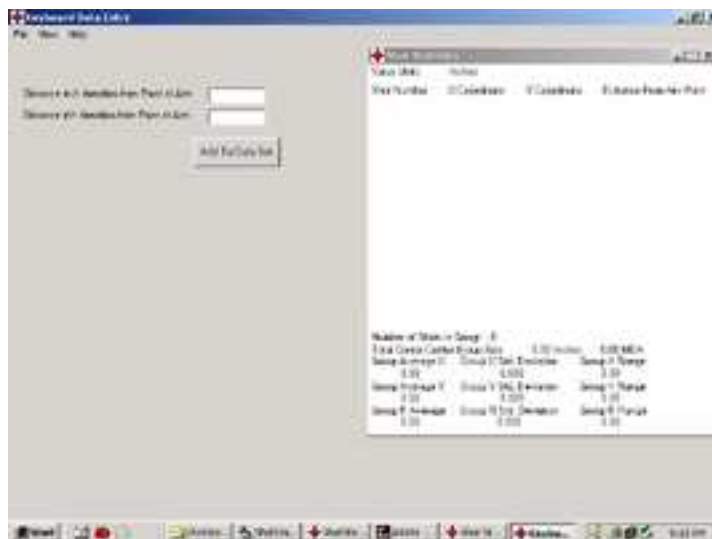
1. clicking the "Print" tool button.
2. clicking Print on the File Menu on either the Main Page, the Graphical Entry Page, or the Keyboard Entry Page.

With ShotStat Version 2, no printer settings can be changed; the data are sent directly to the printer.

5 The Keyboard Entry Page

5.1 Introduction

If you manually measure your targets or wish to use ShotStat to compute statistics for other metrics (case weights, bullet diameters, etc), you will need to input the data using the keyboard. ShotStat does not use a 'spreadsheet' style input format. Rather, text input boxes for x and y data are used.



Since the same statistics engine is used regardless of input style (graphical or keyboard) or what type of analysis you wish to use, you must always input both x and y values. If you are working with one dimensional data (such as case weights, muzzle velocities, etc), enter your data as x and enter 1 for y. In this case, the only meaningful output is for x.

Alternately, if you have two groups of data (say two brands of brass), you can enter one as x and the other as y. This will save some work; in this case, read only x and y output, and ignore the rest.

Statistics are computed and displayed as for Graphical Entry. Please see Section 4.5 for specific information about the Statistics Output Window. Like the Graphical Entry Page, if the Keyboard Entry Page is opened for new data (no data in memory), the Header Entry Window (Section 4.2) is displayed first and must be closed before Keyboard Entry can begin.

To open the Keyboard Entry Page: on the Main Page, click Data/Keyboard Entry.

5.2 How to Measure Targets and Using the Text Entry Page

To use the ShotStat, you should measure targets by a procedure similar that used by ShotStat for Graphical Entry. The Calibration step is not needed, however.

1. Mark an 'origin on the target;' preferably, this is the aim point used by the shooter.
2. Draw a horizontal line through the aim point; this is called the horizontal (x) axis. Shots 'above' this line have positive y-values; those 'below' the line have negative y-values.
3. Draw a vertical line through the aim point; this is called the vertical (y) axis. Shots to the 'right' of this line have positive x-values; those to the 'left' of the line have negative x-values.
4. From a shot, draw a vertical line to the horizontal axis. Measure the distance from the origin to where the vertical line from the shot crosses the horizontal axis; this distance is the x-value for that shot. The x-value is positive or negative as described in Step 3.
5. From that same shot, draw a horizontal line to the vertical axis. Measure the distance from the origin to where the horizontal line from the shot crosses the vertical axis. this distance is the y-value for that shot. The y-value is positive or negative as described in Step 2.
6. Enter the x,y data pair (the distances measured in Steps 4 and 5) for the shot into ShotStat's Text Entry Page text boxes for x and y.
7. Click "Enter Shot" to enter the shot.
8. There is no need to measure the straight-line distance from the origin to the shot position; this distance is computed by ShotStat.
9. To Remove a shot, click the "Remove Shot" button; you will be prompted for the "Shot Number" of the shot to remove. The Shot Number is the Shot Number as listed in the Statistics Output Window.

6 Exporting Data

The ShotStat data files are not very convenient for using ShotStat shot data or computed statistics in other programs (such as spreadsheets). Therefore, ShotStat has an export function that writes a comma delimited text data file of the shot data and computed statistics; unlike the ShotStat data file, no program control variables are written to an Export File.

ShotStat requires the data set and computed statistics be saved to a ShotStat data file before an Export can be done. If the data has not been saved, ShotStat displays a message, *but does not save the data*. The user must save the data, then try the Export again.

When the Export function is selected, ShotStat attempts to write the text file with the same base name as the current ShotStat data file but with the extension '.txt'. If a file with that name exists in the user's data file path, ShotStat will prompt for a file name. Note that an ASCII text file is written no matter what extension the user gives the Export file; use of other extensions may 'confuse' Windows, since file associations are based on extension rather than data in the file.

To use the Export file with a spreadsheet, it is important to note that the data in the file is comma delimited. Spreadsheets, such as MS Excel, can import text data files, so long as the user can inform the program how the data are separated. When importing into Excel, you must therefore be sure the 'comma' box is checked when Excel prompts for how the data in the file is separated into columns.

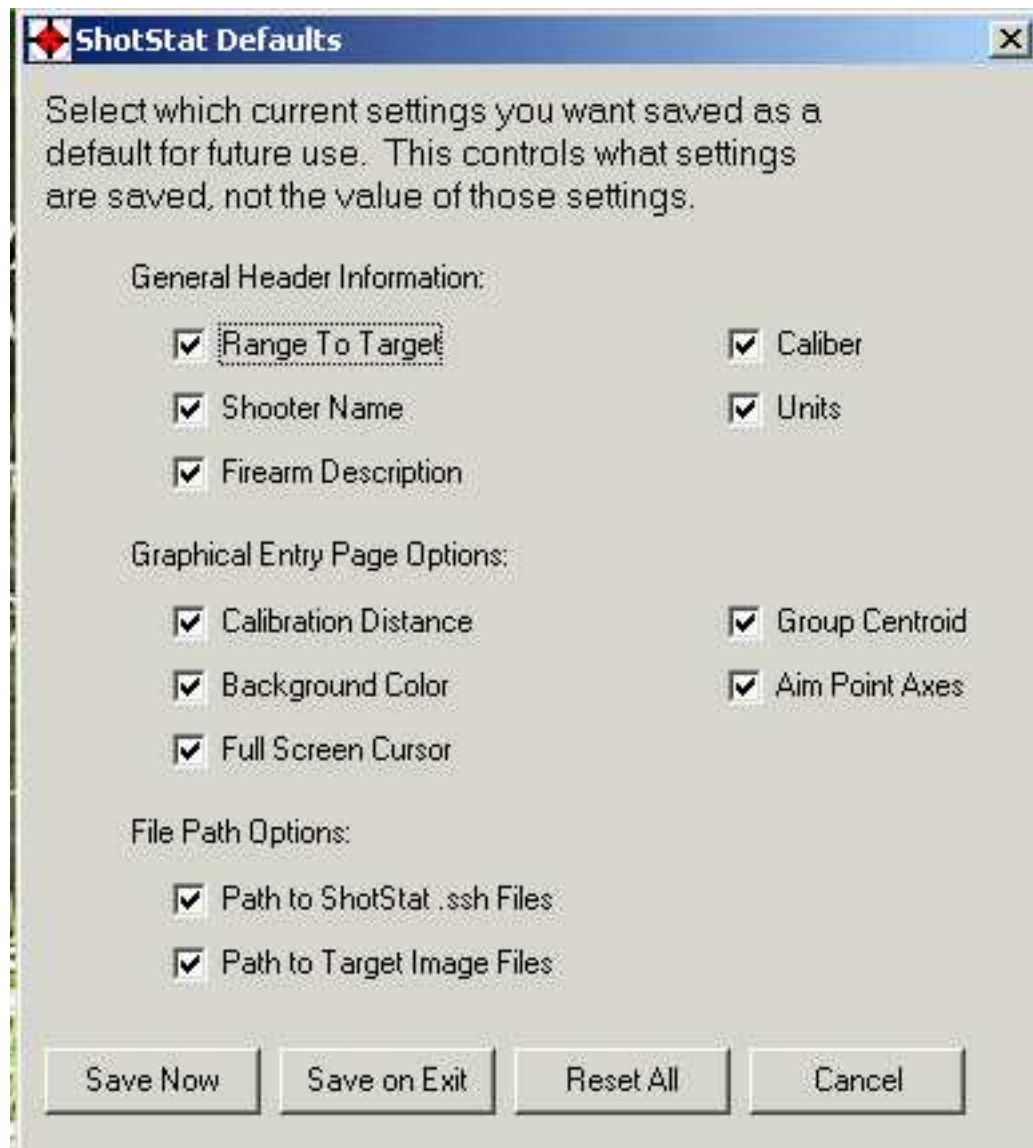
7 Options

7.1 Default Behavior of ShotStat

To avoid users having to configure ShotStat each use, ShotStat stores default values for user and control parameters in a configuration file. For multi-user systems (such as Windows 2000 and Windows XP), there is a separate configuration file for each user. This means users can configure ShotStat for their own preferences. For single user systems (such as Windows 98 and Windows ME), there is only one configuration file. For more technical detail regarding the configuration file, see Section 11.1.

The Default Options Window has a series of check boxes that control what program parameters are saved to the configuration file. This does not select values for these items; rather, the values are whatever the current program values are. For example, checking "Full Cursor" means that the current state of the Full Cursor Option is written, not that a setting of Full Cursor is written. Any items *not* checked are kept as whatever settings currently in the file.

To Open the Default Options Window: on the Main Page, click Options/Default Options.



The Default Options Window has four buttons:

Save Now Writes the configuration file immediately; it is still written when ShotStat exits

Save On Exit The configuration file is not written immediately, but will be written when ShotStat exits.

Cancel any changes to the options on the Default Options Window are discarded, and the window is closed.

Reset Restores ShotStat to the install configuration. The configuration is not written until ShotStat exits.

To temporarily return to the install configuration but to keep the saved configuration for future uses, click Reset and then uncheck all options in the Default Options Window.

To return to the install configuration and write the configuration file, check all options in the Default Options Window, click Reset and click Save Now.

7.2 Behavior of the Graphical Entry Page

The information on the Graphical Entry page is organized as follows:

Mouse Cursor Indicated by a cross hair.

Calibration Points Indicated by circles connected by a straight line.

Aim Point Indicated by a 'hollow cross;' the precise location of the selected aim point is the center of the cross.

Entered Shots Indicated by solid circles

Group Centroid Indicated by a colored square

In addition, several features of the Graphical Entry Page can be configured according the user's taste or usefulness for a particular target/group. These include:

Set Background Color Opens a dialog to select the background color for the Picture Box of the Graphical Entry Page. Use this to increase contrast if taping targets to the screen or to define the limits of the imported target image. If the Background Color box is checked in the Default Options Window, this color will be stored as the ShotStat default when ShotStat exits.

Full Screen Cursor Toggles the full cursor cross hairs extending to the limits of the Graphic Entry Page Picture Box. This can be useful for locating the mouse cursor location if taping targets to the screen. If the Full Cursor box is checked in the Default Options Window, this setting (yes/no) will be stored as the ShotStat default when ShotStat exits.

Show Centroid Toggles drawing of the group centroid, which is the average group center as computed from the shot data. The centroid is plotting as a square in a different color from the circular shot data markers. The centroid may help troubleshoot site alignment problems (by comparing to the shooter's aim point), non-zero sites, etc. If the Group Centroid box is checked in the Default Options Window, this setting (yes/no) will be stored as the ShotStat default when ShotStat exits.

Axes Through Aim Point Toggles drawing a full screen cross hair intersecting at the entered aim point. This divides the target into quadrants with the aim point at the origin. If the Aim Point Axes box is checked in the Default Options Window, this setting (yes/no) will be stored as the ShotStat default when ShotStat exits.

8 Statistics Tools

8.1 Introduction

ShotStat provides two tools for statistical hypothesis testing: the T-Test and the F-Test. “Statistical Hypothesis Testing” is a fancy way of saying you may wish to know if two sets of data are different or not, within the framework of the random errors in each set. For example, the T-Test (10.3) is used to determine if two averages are significantly different. The averages you may wish to test may be average point of impact for two shot groups, average case weight for two lots (or brands) of cases, etc. The Null Hypothesis (10.3) that you are testing in a T-Test can be stated as “the sample averages are not significantly different.”

The F-Test (10.3) is used similarly to evaluate if the standard deviations or variances of two samples are the same. If you wish to know if the group size for two Lots of ammunition are significantly different, you should use the F-Test. In this case, the Null Hypothesis being tested can likewise be worded: “the sample standard deviations are not significantly different.”

It is important to understand what these tests can tell you. Essentially, you want a good guess as to whether the *populations* for each sample are different. The Null Hypothesis says these populations are the same. This means that your samples are two samples from the same population if the Null Hypothesis is true. In other words, any difference in the averages (or standard deviation) is due to the errors in measurement, not due to the samples being representative of populations that are different. With this kind of test, the handloader can put a quantitative value to the statement Load A is better than Load B. This quantitative value is the Significance Level (See 10.3).

For both types of test, the user needs to decide the Significance Level *before* the test is conducted. The Significance Level is the chance of incorrectly rejecting the Null Hypothesis. Typical values are 10%, 5% and 2.5%, though you can select any value between 0.001% and 45% using ShotStat.

8.2 Sample Average Comparisons with the T-Test

The T-Test is used to compare two averages to determine if they are significantly different. The T-Test Window in ShotStat displays input boxes for Samples A and B:

T-Test: Testing Averages

Lot Numbers are Optional. All other fields are required.

Sample A	Sample B
Lot #: <input type="text"/>	Lot #: <input type="text"/>
Average: <input type="text"/>	Average: <input type="text"/>
Standard Deviation: <input type="text"/>	Standard Deviation: <input type="text"/>
Number in Sample: <input type="text"/>	Number in Sample: <input type="text"/>

Level of Significance: %

Lot Number (optional) Free format description the user may wish to use to identify the sample(s)

Average (required) mean for each sample

Standard Deviation (required) standard deviation (square root of variance) for each sample

Number (required) the number of items/measurements made for each sample; for example, a five round group has a Number of 5. Larger numbers result in more reliable tests.

Under the Sample A and Sample B areas, ShotStat displays an input box for:

Significance Level (required) entered as a percentage, the desired acceptable chance for ShotStat reporting that the samples are different when they are actually, in fact, the same. This must be between 0.001 and 45, but generally, a value of 10, 5 or 2.5 will be used. The default is 5%.

There are three command options available to the user:

Compute performs the test; upon completion of the test, ShotStat displays a message stating when the samples are probably the same or probably different.

Cancel cancels the T-Test Tool and closes the T-Test Window; all entered data are lost

Print after a test is performed, the option to print the current data and results exists. ShotStat sends the output to the default printer for the local computer. The “Print” command button is not visible until a test is performed that can be printed.

8.3 Sample Standard Deviation Comparisons with the F-Test

The F-Test is used to compare two variances to determine if they are significantly different. The way ShotStat is written, the values to be compared are the standard deviations, which are internally converted to the variances. The F-Test Window in ShotStat displays input boxes for Samples A and B:

F-Test: Variance Testing

Lot Numbers are Optional. All other fields are required.

Sample A	Sample B
Lot #: <input type="text"/>	Lot #: <input type="text"/>
Standard Deviation: <input type="text"/>	Standard Deviation: <input type="text"/>
Number in Sample: <input type="text"/>	Number in Sample: <input type="text"/>

Level of Significance: %

Lot Number (optional) Free format description the user may wish to use to identify the sample(s)

Standard Deviation (required) standard deviation (square root of variance) for each sample

Number (required) the number of items/measurements made for each sample; for example, a five round group has a Number of 5. Larger numbers result in more reliable tests.

Under the Sample A and Sample B areas, ShotStat displays an input box for:

Significance Level (required) entered as a percentage, the desired acceptable chance for ShotStat reporting that the samples are different when they are actually, in fact, the same. This must be between 0.001 and 45, but generally, a value of 10, 5 or 2.5 will be used. The default is 5%.

There are three command options available to the user:

Compute performs the test; upon completion of the test, ShotStat displays a message stating when the samples are probably the same or probably different.

Cancel cancels the F-Test Tool and closes the F-Test Window; all entered data are lost

Print after a test is performed, the option to print the current data and results exists. ShotStat sends the output to the default printer for the local computer. The “Print” command button is not visible until a test is performed that can be printed.

9 Decimal Equivalents

If you manually measure your targets (for text data entry) in fraction of an inch, you will need to convert the fractions to decimals. The following table may be helpful.

1/16	0.062	9/16	0.562
1/8	0.125	5/8	0.625
3/16	0.188	11/16	0.688
1/4	0.250	3/4	0.750
5/16	0.312	13/16	0.812
3/8	0.375	7/8	0.875
7/16	0.438	15/16	0.938
1/2	0.500	1	1.000

10 Statistics

10.1 Statistics - General Description

It is often said that statistics can be used to “prove” anything. Properly used and interpreted, this simply is not true. Rather, statistics uses mathematical analysis for two related purposes: analysis of error and estimation of the quality of predicted values. Analyzed correctly and objectively, statistics cannot “prove” erroneous theories, at least with the quality of the data. Errors in “proof” arise from errors in the data, but careful researchers do not extrapolate conclusions beyond those supported by data.

Let’s take a shooting example to show how ridiculous the “prove anything” idea of statistics really is. Suppose you shot a ten round group at 100 yards; you shot well with a good load and printed a 1/2 inch group. Using this shot group data, you make a prediction that you have a 90% chance of the next shot hitting twelve feet behind you. Clearly a mistake in the analysis has been made. This shows how blindly following a number, simply because it appears on a calculator display or computer print-out, can lead to erroneous conclusions.

The key to properly using a statistical analysis of measured data is to:

1. Understand the particular measurement being made (analysis of errors)
2. Interpret the measurements for a *particular set of data*

Oversimplification of either of these steps is what leads to false conclusions. This is done all the time with popular political polling and advertising, where purposeful misrepresentation of the data may have a political or financial motivation. Further, one cannot ‘throw out’ measured data simply to improve the statistical result. Oversimplification and omitting data are two of the tricks used when statistics is wrongfully used to “prove” a point. Manipulators get away with these tricks because of the mathematical nature of statistics and the seeming complexity of the field.

10.2 Avoiding Bias in Statistical Analysis

Pretend for a moment you are asked by a person conducting a survey:

“Would you rather pay higher taxes or go hungry?”

It is probably fair to say that in response to this question, most would reply “pay higher taxes,” and the surveyor might then report “Most respondents support paying higher taxes.”

The problem is that these two choices are presented as an *or* choice, but they are not mutually exclusive. It is possible to *neither* pay higher taxes *nor* go hungry, but this is not given as a choice. In this case, the surveyor has introduced a *bias* by (1) neglecting to list reasonable alternatives and (2) by equating the severity of not paying higher taxes and not eating.

Statistical analysis of measured data such as shot positions on a target are a bit more objective, but the danger of introducing bias remains. The researcher must be vigilant to remain objective and must constantly review the numbers from the point of view that they prove the *opposite* of what one really intends to 'prove.' This idea is so important in statistics that a special construct exists to aid the mathematical analysis: the Null Hypothesis (Section 10.3).

For example, suppose you shoot two five-shot groups, one from Load A and one from Load B, and these represent optimized loads using bullets by two manufacturers. You believe Bullet A is 'better,' but wish to test this using statistics (and ShotStat). In this case, your Null Hypothesis is that Loads A and B are the *same*, and it is the *Null Hypothesis that you test*. That is, you assume that A and B are the same, then set out to 'prove' your assumption 'correct.' Only when an analysis of the data suggests your assumption is incorrect do you safely conclude that A really is better than B (here 'better' means smaller group). This approach helps to lower the tendency to introduce your own bias into the analysis.

10.3 Statistics - Terminology

Before jumping into the kinds of analyses useful for shooting and load evaluation that ShotStat can provide, it is helpful to define some terms so that their meaning in the following discussions is precise.

Average there are several statistical averages, such as the mean, the mode, the median, etc. In this discussion, average is the mean, which is the common definition of average.

Chaos Often, the terms chaos and random are used interchangeably or together. However, these terms have very different meanings. Understanding the difference is essential to proper data analysis. Statistics typically addresses measurements involving random errors; chaos implies a dynamical dependence, such as the fifth value depending on the fourth (which depended on the third, etc).

Confidence Interval the range of values between which an estimation is made with a stated certainty. For example, one may speak of a 90% confidence interval. One standard deviation represents the 68.3% confidence interval, and 3 times the standard deviation represents the 99.7% confidence interval.

F-Test an analytical test used to determine if the difference between the variances of two sets of measured data is significant, given a stated Significance Level.

Hypothesis a statement to be tested by measurement; for using statistics, the hypothesis is actually a mathematical expression (such as "the standard deviation of muzzle velocity for Load A is less than the standard deviation

of muzzle velocity for Load B”). In general, statistics can be used to reject a special hypothesis called the Null Hypothesis (rejecting the Null Hypothesis implies an Alternate Hypothesis may be true) to within a stated Significance Level.

Population the entire “true” data set under consideration. For example, you may wish to measure the average point of impact (relative to point of aim) for a Lot of ammunition. Because the test is destructive, you probably do not want to test the entire Lot, but that would be the only way to actually measure the average point of impact. In this case, you would select a Sample to test, and use the analysis of the sample data to draw conclusions about the entire Population.

Random Error errors in measurement in a population or sample that follow no pattern. Random errors are assumed to occur in a Gaussian distribution (also called a normal distribution); this means small errors occur more frequently than larger errors.

Range in a set of data, the maximum value minus the minimum value.

Sample the portion of a population that is selected to actually test. ShotStat can be used with samples of twenty or smaller. Larger samples result in more meaningful analyses. Note that an average or standard deviation only represents an *approximation* to the true, population average or standard deviation. An F-Test or T-Test gives an idea of how close is this approximation.

Significance Level the probability of rejecting a Null Hypothesis that is actually true; for example, a 5% Significance Level means one has a 5% chance of rejecting the Null Hypothesis that is actually true. A smaller Significance Level implies more certainty in rejecting the Null Hypothesis.

Standard Deviation the average difference between the sample average and the individual measurements. It is the square root of variance.

Statistic a value computed from a set of measurements, such as mean, variance or standard deviation

Systematic Error errors in measurement that follow a pattern; these tend to be constant within one set of measurements, but they can be very hard to discover. An example of a systematic error might be using a ruler that is cut-off at 1/4 inch to measure targets; all measurements will be 1/4 inch too short.

T-Test an analytical test used to determine if the difference between the averages of two sets of measured data is significant, given a stated Significance Level.

Variance the average of the squared differences of measured values from the average value.

10.4 Interpretation of Data

Once statistics are calculated, the meaning of the result is subject to interpretation. The value of this interpretation will depend largely on the experience of the analyst, as well as the understanding of the measurement made. The meanings of each value computed by ShotStat may not be so great by themselves, but are best used together to give an overall impression of the data.

For this discussion, and the brief examples given in the General Examples section, it is assumed that all variations of bullet impact from true theoretical point of aim are described by the following physical properties:

1. side wind effect between muzzle and target
2. bullet stabilization characteristics (for example, distance from muzzle that stabilization occurs, time or distance that it takes during stabilization, degree of stabilization, etc)
3. barrel vibrations, either planer or torsional
4. muzzle velocity variations
5. deceleration characteristics (drag, head or tail wind, etc)
6. optics (refraction, mirage, parallax, etc)

In this discussion, we further assume that there is a true point of aim, defined by the bore of the firearm and not by site alignment. If we know the drag parameters of the bullet and its muzzle velocity and assume there are no optical effects, a perfect bullet (stabilized completely at the muzzle), no wind and a perfectly stiff barrel, we can calculate the impact point for a certain site picture. Further, if the sites are parallel to the bore axis in both windage and elevation directions, this calculated impact point would match the true theoretical impact point. For the case that the true point of aim is the same as that given by the actual site picture, we will say that the sites are neutral. Neutral sites are those whose site picture gives the true, theoretical point of impact. All of the General Examples assume neutral sites.

Data collected as a function of range-to-target can be extremely informative. A tiny group, artificially adjusted to zero at 100 yards, does not necessarily mean accurate shot placement at 300 yards. Plotting the standard deviations or averages calculated with ShotStat as a function of range-to-target can show a tremendous amount about actual load performance.

If a strain gauge is available, interesting correlations may exist between pressure-time curve parameter statistics (peak pressures, distribution width, etc). ShotStat can be used to compute these statistics using the Keyboard Entry function.

10.4.1 General Examples

In this Section, some general examples of data interpretation are given.

Small x-standard deviation, large y-standard deviation this is a vertically strung group; If both x and y averages are small, the group is centered around the point of aim, and is most likely strung due to a velocity or deceleration effect (such as fairly large shot-to-shot velocity variations). Barrel vibrations and bullet stabilization effects cannot be ruled out based on a single range-to-target experiment.

Small standard deviation, large range this data set may contain 'bad data,' but care must be exercised. There may be simply a bad shot (shooter error), but DSB Scientific has seen handloads that gave a 4 tight shot, one bad shot pattern very reproducibly.

This may indicate a very subtle barrel vibration or bullet stabilization effect. Perhaps you can check for such an effect by a slight change in powder charge, both larger and smaller, or a small change in bullet weight (keeping the manufacturer and type/style bullet the same), changing neck tension slightly, etc. Bullet run-out should be checked, since there may be high run-out loads only intermittently. Carefully assessing the cause of this type of group gets into the guts of handloading and into fine tuning load development.

In order to assess whether or not a given shot is kept or thrown out, the criterion we use is: if the shot was called BAD at the moment of shooting (BEFORE the target is examined), the shot can be thrown out; if not, the shot is kept, no matter how 'wild' it appears to be. In other words, if the shooter knows he made an error, we don't keep the shot if testing load performance.

Large x average, small r standard deviation this group may simply be due to a constant side wind effect; however, there may also be a barrel vibration or bullet stabilization effect. Adjustment of the sites to "zero" the firearm may only correct the symptom, not the cause. That is, you may obtain a zero at one range-to-target, but find the group impacts right or left at other ranges. Such zero-ing is fine for fixed range target shooters, but may not be acceptable when variable ranges are possible. If multiple range precision is important, it is far better to properly tune the load than merely move the sites around to give the false sense of a zero'd rifle.

Large y average, small r standard deviation the velocity or deceleration characteristics may not be their theoretical values. See comments under 'large x average, small r standard deviation' for additional discussion.

r range this is a very interesting statistic that contains much information about the combined barrel vibrations and bullet stabilization effects. For small

such effects, the r range should be approximately $1/2$ the center-to-center group size, average r will be approximately zero and all x and y statistics will be nearly the same. If you draw a circle with the center at the point of aim and radius of r range, shot impacts will be randomly scattered within the circle.

On the other hand, either a large barrel vibration or bullet stabilization effect may cause the r range to be small while the center-to-center group size is large.

In order to see these effects, larger groups and data sets are necessary. For example, you may wish to shoot 10-20 round groups at a range that gives about a six inch pattern. If the groups result in a small r range (relative to the center-to-center group size), there may be a vibration or stabilization effect, and the groups might appear as a 'donut' around the point of aim.

multiple range-to-target experiments as a final general example, the graph of standard deviation (x, y and r should all be examined separately) versus range-to-target should be a straight line. A sharp change in the slope of the line may indicate the approximate range a stabilization effect becomes important. It should be noted that the graph will never intercept the standard deviation axis at a value smaller than the offset from linearity caused by the duration of instability.

11 Technical Information

This section is provided for computer administrators and developers that may wish to access the data stored in the ShotStat data and default files.

11.1 Configuration File

On multiuser Windows systems, ShotStat stores per user configuration information in a text file called ShotStat.ini. For Windows 2000 and XP, this file is stored in the '%userprofile%\Application Data\ShotStat\20' folder, so each local user can store their own configuration data. Upon start-up, ShotStat looks for this file; if it is missing, a standard set of defaults is used. The configuration information includes:

- paths to image and data files
- options for the Graphical Entry Page (full screen cursor, background color, etc)
- What options to store in the configuration file upon ShotStat exit
- Header information such as Shooter Name, Firearm, Caliber, etc.

This file must be stored on the local machine, even if ShotStat is being accessed over a network.

These files are written in ASCII format, and hence are plain text readable.

The format of the ShotStat.ini file, in the order the data is saved, is:

Default Range to Target	single precision float
Default Shooter Name	string[30]
Default Firearm Description	string[30]
Default Caliber Description	string[30]
Default Units	string[30]
Default Real Calibration Distance	single precision float
Default Graphic Entry Background Color	long integer
Default Setting for Full Screen Cursor	boolean
Default Setting for Show Centroid	boolean
Default Setting for Show Aimpoint Axes	boolean
Default Data File Path	variable length string
Default Image File Path	variable length string

11.2 ShotStat Data Files

The format of the ShotStat data files (extension .ssh) is:

Version	variable length string
Shooter Name	string[30]
Date	string[20]
Firearm Description	string[30]
Caliber Description	string[30]
Lot Number	string[30]
General Comments	string[]
Range to Target	single precision float
Number of Shots (N)	single precision float
x coordinate of Shot #1	single precision float
y coordinate of Shot #1	single precision float
...	single precision float
...	single precision float
x coordinate of Shot #N	single precision float
y coordinate of Shot #N	single precision float
Calibration Value	single precision float
Calibration Start x coordinate	single precision float
Calibration Start y coordinate	single precision float
Calibration Stop x coordinate	single precision float
Calibration Stop y coordinate	single precision float
Calibration Real Distance	single precision float
Aim Point x coordinate	single precision float
Aim Point y coordinate	single precision float
Image File Name	variable length string
Units	variable length string
Graph Entry	boolean
Are Full Axes On	boolean
Is Centroid On	boolean
Draw Full Screen Cursor	boolean
Graphical Page Background Color	long cursor

12 Further Assistance

DSB Scientific Consulting provides free technical support to registered users of ShotStat. If you purchased either a CD or Download version of ShotStat 2.0, you are automatically a registered user. This support covers usability and bugs in the program. User's requests for additional features for future versions are welcome. To request ShotStat Technical Assistance, visit the web page: <http://www.dsbscience.com/contactdsb>. Be sure to include your return contact information and state your issue as specifically as possible.

DSB can also help you analyze and interpret your data. From the data you provide, we may suggest additional experiments in your load development. In addition, DSB works closely with personnel of Precision Crafted Ammunition conducting both experimental and theoretical ballistics research. Fees for tech-

nical assistance are set for individual situations. Precision Crafted Ammunition provides custom loading and ballistic services.