



Jewell Instruments  
ECG™ eCompass  
**User's Guide**

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## Introduction

The ECG™ eCompass combines a precision 3-axis solid-state magnetometer, a rugged 2-axis electrolytic tilt sensor, and 2 MEMS gyros that have been factory calibrated to provide accurate heading and tilt measurements. The unit has been verified for accuracy at room temperature in an environment free from magnetic, electrical, and mechanical disturbances. The eCompass can be immediately tested in a location away from any ferrous material and isolated from severe vibration.

A good first test is to hold the eCompass steady at different attitudes (heading, pitch, and roll), take readings, and verify that the horizontal field strength remains roughly the same for different orientations. Expect to see some variation in the horizontal field strength, but it should be less than one or two percent if the eCompass is steady and tilt is less than 20°.

Before installing the eCompass, make note of the dip angle measurement and compare it to the published value for your location. The two values should be very close, usually within 0.5°. It is also a good idea to capture and save a vertical reference as described in the section on *Calibrating the eCompass*. After the eCompass is mounted in-situ, this reference is used to partially compensate for any local permanent magnetism (hard-iron) that may be present.

## Contents of the ECG™ eCompass Evaluation kit

The ECG™ eCompass Evaluation kit contains the following primary items described in detail in this section:

- ECG™ eCompass
- eCompassTest Software CD
- Serial Cable or optional USB cable
- Users Guide

## **ECG™ eCompass**

The ECG™ represents the state of the art in magnetic compassing. It consists of a PC card housed in an ABS enclosure. The base of the enclosure has 4 mounting holes for permanent installation. Only brass or non-magnetic stainless steel screws should be used. Connection to the eCompass may be made via the RJ12 connector or by the 8-pin header (for system wiring). See the diagram(s) included with the cable(s).



### **eCompass Features**

The ECG™ eCompass is a strap-down device that delivers high accuracy for its small size, low cost, and low power consumption. It provides both RS-232 and RS-485 communication links. For battery operation, a low-power standby mode is incorporated to reduce required current to 5mA. Wake up from standby requires only 40 milliseconds.

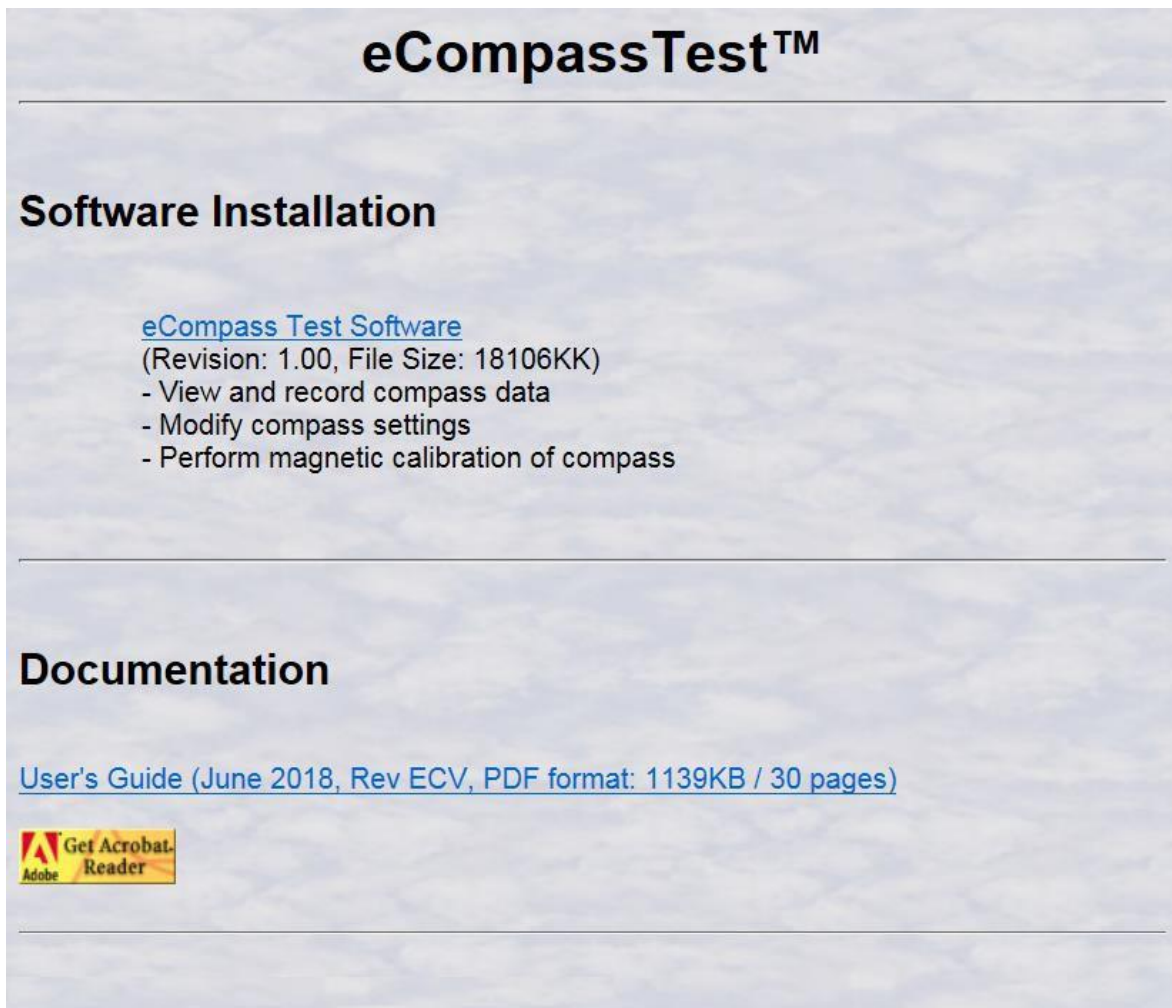
Additional features of the ECG™ eCompass include:

- Exceptional dynamic performance
- High static accuracy
- Wide operating range
- Precise factory calibration
- Fast response
- Single supply operation
- Low power options
- Two independent serial channels
- In-system configuration and test
- Run (continuous) or Sample mode operation
- Wide selection of ASCII or binary output data:
  - ⇒ Heading, pitch and roll
  - ⇒ Magnetometer X, Y, and Z

- ⇒ Temperature, input voltage, and dip angle
- ⇒ Output ASCII or binary
- ⇒ Horizontal X and Y magnetic field strength
- ⇒ Raw and conditioned gyro data

### ***eCompassTest Software CD***

The CD contains the eCompassTest interface software for a Microsoft® Windows™ PC. When the CD is loaded into a CD-ROM drive, a display similar to the one shown in Figure 1 will automatically appear if the auto-run feature is enabled.



**Figure 1**

## ***eCompassTest Software Features***

The eCompassTest application is designed to run on Microsoft Windows XP or newer. There are two main components:

- A VB.NET program (eCompassTest.EXE) that provides the graphical user interface, recording, and logging functions, and
- A windowless DLL (CompassLib.DLL) that implements the eCompass serial interface and calibration functions.

The DLL can be used separately from the eCompassTest application to simplify the task of integrating the eCompass into an end-user system. It provides methods for reading and writing parameters for reading, parsing, and converting NMEA sentence data and for performing hard and soft iron calibration functions. It also maintains a text log of communication between the PC and eCompass that can be read by a host application.

Functions provided by the eCompassTest software are:

- Cockpit attitude display of heading, reciprocal heading, pitch, and roll
- Display and capture NMEA sentence data
- Modify eCompass operating parameters
- Perform hard and soft-iron calibration procedures
- View and maintain communication logs

## ***Serial Cable***

The following cable assembly is included (with evaluation kits) and is shown in Figure 2. An optional USB cable is also available.

4-Wire PC to ECompass: 8 ft. cable with DB9F connector and 9V battery strap going to 6-pin RJ12 plug.



**Figure 2**

# Getting to Know the eCompassTest Software

## System Requirements

- Microsoft® Windows™ XP with .NET Framework 2.0 or greater
- VGA or greater
- Keyboard
- 10 Mb disk space (more for log files and recorded data files)
- RS-232 serial port for serial cable or USB port for USB cable

## System Recommendations

- Microsoft® Windows™ 7 with .NET Framework 2.0 or greater
- SVGA 1024 x 768, High Color (16-bit), Large Fonts or greater
- Keyboard and Mouse
- 50 Mb disk space
- RS-232 serial port for serial cable or USB port for USB cable

## eCompassTest Software

The eCompassTest software allows you to use your PC to communicate with the ECG™ eCompass.

To install the eCompassTest software, insert the CD into the CD-ROM drive of your PC. If the CD does not autorun, run the eCompassTest Setup.exe application from the eCompassTest folder on the CD. The InstallShield® wizard will guide you through the installation process.

During the installation, you may select the folder in which the eCompassTest software will be installed or accept the default folder of C:\Jewell\eCompassTest. Once you run the eCompassTest software, the LogFiles subfolder will be created to store log files. Once you record data using the eCompassTest software, the RecordedData subfolder will be created to store files of data recorded from the eCompass. Once you use the zip files option, a ZipFiles subfolder will be created to store the desired files.

**Is important to note** that starting with Microsoft Windows 7, an application installed in the Program Files or Program Files (x86) folder cannot create or modify folders or files under the Program Files folders. Instead, the subfolders must be stored in the AppData folder structure. For this reason, the eCompassTest installation will default to installing the application in C:\Jewell\eCompassTest. If you do install the application in a Program Files folder, the LogFiles, RecordedData, and ZipFiles folders, their subsequent files, and application INI and XML files will be stored in the appropriate AppData folder automatically.



The following list describes some of the files placed in the application folder:

- eCompassTest.exe eCompassTest software application
- eCompassTest.ini INI file of user-modifiable settings
- eCompassTest Settings.xml XML file of settings changed by software
- eCompassTest.chm Help file for eCompassTest software
  
- CompassLib.dll Dynamic Link Library for communicating with eCompass
- Air.ocx ActiveX control used for attitude display
- Various DLLs Dynamic Link Libraries used to accomplish various tasks
- Readme.txt Readme file explaining installation logic

To remove the eCompassTest software, use the Add/Remove Programs or Uninstall A Program function from the Control Panel, or run the eCompassTest setup again and choose Remove. Do not simply delete the eCompassTest folder and files. Please note that any log files, recorded data files, or other files created since the software was installed will not be deleted by the uninstall process. Once you have properly uninstalled the software, you may freely delete the additional files.

## Preliminary eCompass Evaluation

### ***How the ECG™ eCompass is Prepared***

After factory calibration, test, and verification, the ECG™ is set up as follows:

- 19200 baud serial data rate
- Run mode – no automatic NMEA data output
- 0.2 s magnetometer time constant (Mag TC)
- 0.2 s pitch and roll time constant (Tilt TC)
- 4.0 s tilt complementary filter time constant (GyroTC)
- 4.0 s magnetic field alarm time constant (Alarm TC)
- 2.0 s magnetic field alarm acquire time (Acquire Time)
- 5% magnetic field deviation limit (Alarm Limit)
- 1.5 s sample averaging time (used in Sample mode only)
- 35° pitch and roll warning level
- 44° pitch and roll alarm level (heading blanks above this)

The four time constants are for single pole, low-pass IIR filters that are enabled in Run mode. If you switch to Sample mode, these filters are reset and the magnetic field alarm is disabled.

The magnetometer gain is factory set to accommodate a full-scale range of approximately  $\pm 750$  mG ( $\pm 75$   $\mu$ T). The gain can be reduced to allow more hard-iron, or it can be increased to provide greater sensitivity. A magnetic calibration procedure must be performed after changing the gain.

Prior to factory calibration, the eCompass is demagnetized to eliminate any residual magnetic fields from the circuit components. If the eCompass is exposed to a strong magnetic field of 10 G or more, then it should be demagnetized again before performing a magnetic calibration.

In the Magnetic category of the Settings page, you can see the results of factory calibration of the magnetometer. The X, Y, and Z offsets can only be viewed on this form. X, Y, and Zr are changed automatically after acquiring data using the Calibrate Magnetics option on the Tools menu. The value for Vref will be 32767 if a vertical reference has not been saved. Vref is changed automatically when a good vertical reference is calculated using the “Capture Vertical Reference” option on the Tools menu.

### ***Pitch and Roll Check***

This is a simple test to check pitch and roll accuracy near zero degrees tilt. Place the eCompass on a flat surface and take readings for pitch and roll angles. Now rotate the eCompass precisely 180° and take another set of readings. The second pitch and roll readings should be the same magnitude but opposite signs

of the first, i.e. the sum of the two pitch readings should be zero and the sum of the two roll readings should be zero.

This test is valid even when the flat surface is oriented at a steep angle of 20° to 40°. It does not, however, verify the scale factor accuracy of the tilt sensor. A known angle reference is needed to verify that the scale factor is also correct.

### ***Magnetometer Check***

To verify that the magnetometer is calibrated and operating properly, place the eCompass on a flat surface along the edge of a fixed, non-magnetic straight-edge, like a wooden ruler. Make sure the eCompass environment is magnetically clean (no motors, ferrous materials, etc.). Using the query button on the View NMEA Sentences page in Sample mode, capture CCD samples to see MagX, MagY, and MagZ measurements from the magnetometer.

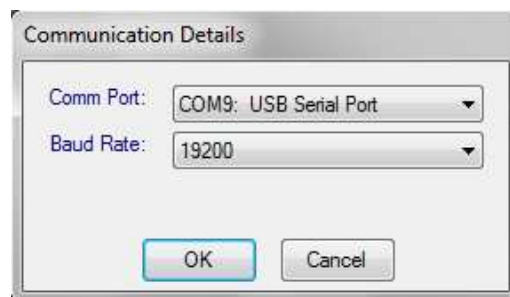
Rotate the eCompass and straight edge until either MagX or MagY approaches zero. Once there, rotate the eCompass exactly 180° by aligning the opposite side with the straight edge, taking care to position the magnetometer end of the eCompass at the same point along the straight edge. Capture additional CCD samples to verify that the measurement that was near zero, MagX or MagY, is still near zero and ideally the opposite sign. Any variation should be within 1% of the magnitude of the other measurement which is near full scale.

This technique works with a flat surface at any orientation; it doesn't have to be perfectly level. The test verifies that the magnetometer offset is null. Additional steps can be performed to verify that the full-scale readings for MagX and MagY are the same.

## **Using the eCompassTest Program**

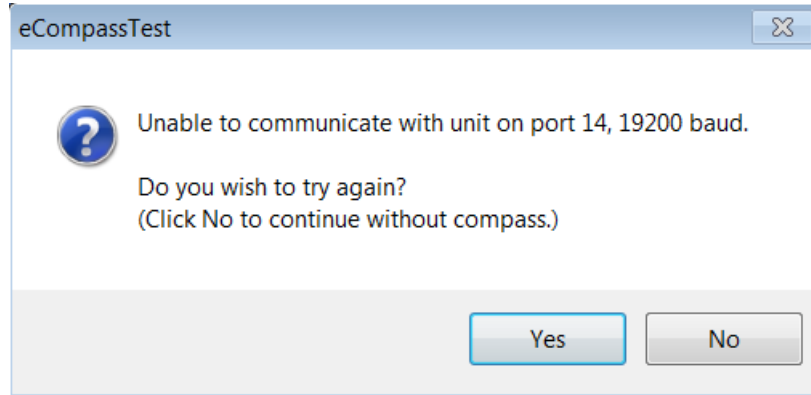
### ***Running the eCompassTest Software for the First Time***

The first time you run the eCompassTest software, you will see a dialog similar to the one in Figure 3 prompting you to enter the serial communication port and baud rate. The baud rate defaults to 19200 which is the rate used by the eCompass when it is shipped. Once you have established communication with the eCompass, you will not be prompted in this way unless the software is unable to communicate with the eCompass.



**Figure 3**

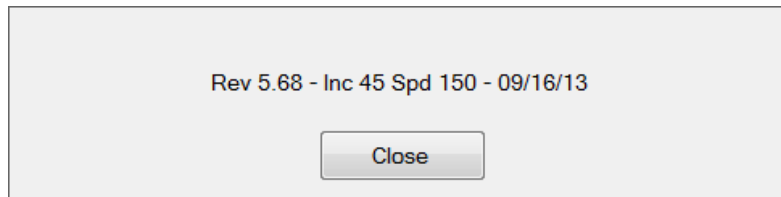
If the software cannot communicate with the eCompass, you will receive a dialog similar to the one in Figure 4:



**Figure 4**

Click Yes from the dialog in Figure 4 to try again. You will be prompted to enter the communication port and baud rate as in Figure 3. Clicking No allows you to proceed without connecting the eCompass.

If the software is able to communicate with the eCompass, a window similar to the one in Figure 5 (showing correct version information for the eCompass) will appear centered in the application's main window.



**Figure 5**

If you choose to proceed without connecting an eCompass, the window in Figure 6 will appear centered in the application's main window.



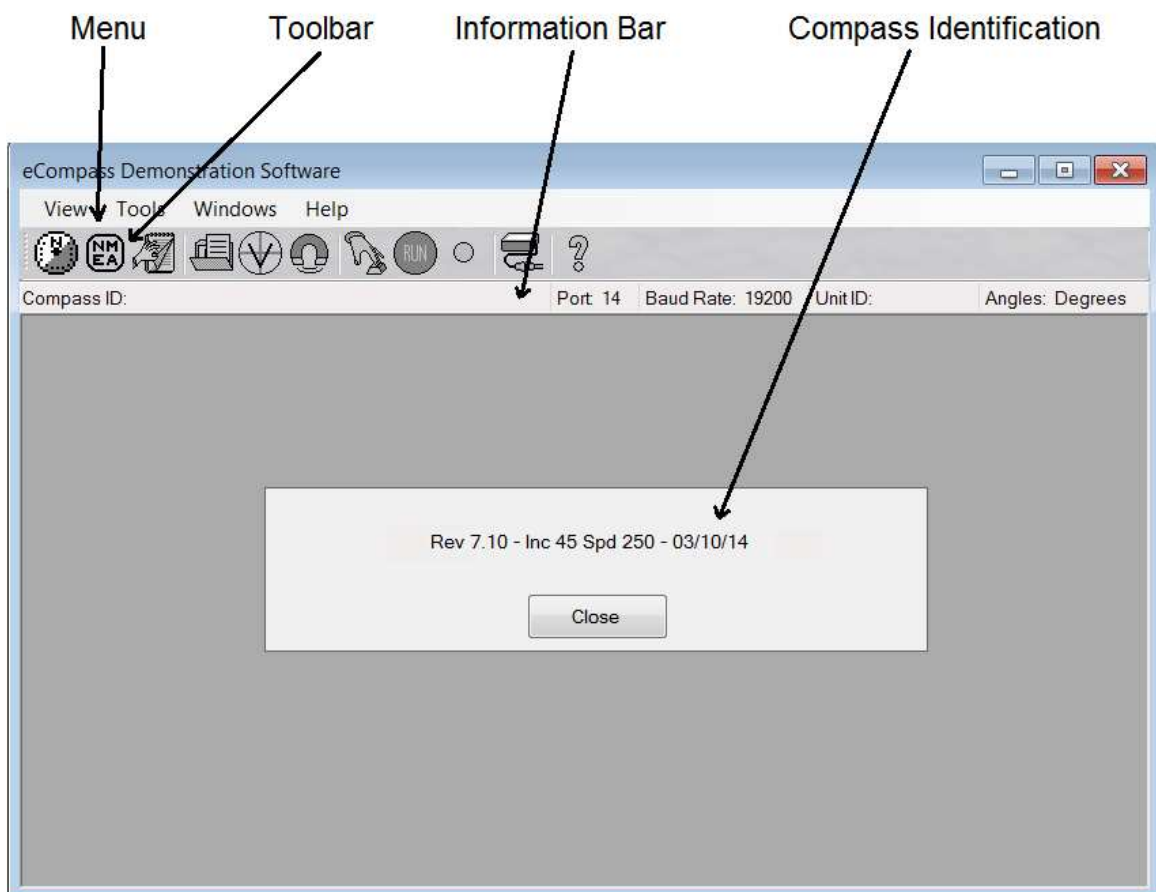
**Figure 6**

Any menu items and toolbar buttons requiring an eCompass will be disabled, but you will still be able to do the following functions:

- View log information
- View settings log information
- Modify software options
- Reconnect to the eCompass
- Create zip file to be sent to Jewell Instruments for debugging purposes
- View help

### ***Description of the Software Main Screen***

The eCompassTest Software Main Screen contains a menu, toolbar, information bar, and a scrollable area to hold application dialogs and windows. The toolbar allows easy access to a subset of the menu items. The information bar shows the ECompass ID, Port, Baud rate, unique Unit ID, and Angles value. The Main Screen appears as shown in Figure 7.



**Figure 7**

## **eCompass Installation**

Before installing the eCompass, consider the following:

- Verify that the eCompass performs as expected in a test location free from magnetic interference and mechanical vibration.
- If the target location is free of local magnetic fields (permanent and induced), then the magnetic calibration procedure should not be necessary.
- If a magnetic calibration will be needed, you will need to capture a vertical reference in a magnetically clean location. Refer to section on Capturing a Vertical Reference.
- The reference is used to determine the magnetometer Z-axis offset during calibration.
- If the J2 connector is going to be used, install the cable before permanently mounting the eCompass.

### ***Location***

Choose a location with as little magnetic interference as possible. If there is a lot of ferrous metal, it may be necessary to decrease magnetometer gain to keep the X, Y, and Z signals from saturating. In this case, heading accuracy will decrease. The magnetization of the disturbing material may also change over time, which will require repeated calibrations to maintain eCompass accuracy.

Magnetic fields that arise from 50 or 60 Hz AC currents are significantly compensated, because the eCompass averages magnetometer signals over 18.2 milliseconds, which corresponds to 55 Hz. However, intermittent magnetic fields generated by motors or solenoids may not be compensated. Also, nearby wires carrying DC current can affect the magnetometer. If the generated field is static, it can be compensated. Otherwise, the field may affect the eCompass reading.

Finally, consider mechanical vibration to minimize its effect on the tilt sensor. Most of the noise caused by a piston engine can be compensated by tuning algorithms in the eCompass firmware. However, it may be desirable to orient the eCompass on an axis that is not aligned with the vehicle so that engine noise affects pitch and roll equally.

### ***Mounting***

Use brass or stainless-steel screws to secure the eCompass in place. The label on the eCompass enclosure indicates directions for positive pitch, roll, and magnetometer readings. The eCompass indicates North when the magnetic field is maximum in the positive X direction, and null in Y.

If the mounting platform is not level, pitch and roll offsets can be zeroed without affecting eCompass accuracy. An auto-zero function is provided on the tilt settings page in the eCompassTest software. Although it can be mounted in any orientation within range, the best eCompass accuracy is achieved for small tilt angles because scale factor errors do not affect the tilt readings near zero.

### ***Wiring to the Internal Connector (J2)***

Perform the following sequence of steps to install the system wiring cable provided in the ECG™ eCompass kit. If a cover is not required, it can be removed and the MTA connector can simply be plugged into J2 as shown in Figure 8. In this case, the connector will not be retained in place by the cover.



**Figure 8**

1. Remove the eCompass cover by unscrewing the 4 stainless steel screws from the bottom of the case. If the screws are lost, replace with 10mm, M3-05, flat, Philips-head, non-magnetic #316 stainless. With the screws out, lift the cover first from the end opposite the connectors to remove.

**TAKE CARE. DO NOT DISTURB THE POSITION OF U9.**

This is a vertical, thru-hole IC (HMC1001). Bending this sensor from its factory-set position will invalidate the magnetometer factory calibration.

2. Remove the black, snap-in plug from the 5/16" hole in the cover.
3. Insert a grommet into the hole. Make sure it is properly seated on both sides and that the opening for the wire is uniformly circular.
4. Feed cable (4-pair, #24 AWG, CAT5, non-plenum) through the grommet starting from inside the cover. The entire length of the wire will have to be fed through the grommet.

5. Rotate the wire to align the connector so that it can be plugged into the header on the card. Pin 1 will line up naturally so there is little chance of reversing the connection.
6. Plug the connector onto the 8 J2 header pins, making sure all 8 pins are inside the body of the connector. Also make sure that the connector is fully seated onto the pins.
7. If there will be any tension on the wire, it may be desirable to clamp a plastic cable tie or non-magnetic clamp around the wire on the inside edge of the grommet to relieve strain. Otherwise, cable stress will be transferred directly to the connector.
8. Pitch the cover down at the connector end and work it back over the RJ12 connector until it is properly seated.
9. Turn the eCompass over and replace the 4 stainless steel screws.

## Calibrating the eCompass

Once the eCompass is mounted in its target location, the detrimental effects of local magnetic fields, both permanent and induced, can be largely compensated. An advantage of an electronic eCompass over its mechanical predecessor is that the compensation can be performed without additional hardware. A strap-down electronic compass can be compensated more precisely than a mechanically gimballed compass because the magnetometer remains fixed in its surroundings.

Compensation for permanent and induced fields is generally separated and referred to as hard-iron and soft iron calibration. Hard-iron errors are usually most severe and have the effect of shifting the center of a sphere from the origin within a 3-dimensional coordinate system. The purpose of a hard-iron calibration procedure is to determine where the center of the sphere lies so that appropriate X, Y, and Z offsets can be subtracted from the corresponding magnetometer signals to return the center to the origin. In algebraic form, hard-iron is represented by the a, b, and c coefficients in:

$$(x - a)^2 + (y - b)^2 + (z - c)^2 = r^2,$$

where x, y, and z are orthogonal components of the earth's magnetic field and r is the total field strength, which is an unknown constant.

Soft iron effects distort the shape of the sphere into an ellipsoid. The purpose of a soft-iron calibration procedure is to determine parameters of the ellipsoid, such as the relative lengths of the 3 axes and their orientation in space, so that an appropriate transformation can be generated that will reshape the ellipsoid into a sphere.

In both cases, it can be difficult or impossible to get good calibration data. The eCompass must remain fixed in its environment (vehicle, robot, boat, etc.) and both must be rotated together in the earth's magnetic field, ideally in all three dimensions. Since the effects of local magnetic fields remain fixed relative to the magnetometer as it rotates, they can be determined and compensated.



Since a boat or vehicle of any size cannot be inverted, Jewell Instruments offers a two-step calibration that relies on first acquiring a vertical reference outside the influence of the vehicle, then performing a simple, two-dimensional rotation while roughly level to determine all three components of hard iron. The rotation can be performed continuously, or individual samples can be captured. In both cases, the data collection algorithms are designed to ensure that in-range data from a complete rotation is collected before being analyzed.

The ECG™ eCompass has an onboard calibration capability embedded in the firmware that implements a least squares algorithm to compute hard-iron offsets that optimize accuracy. Either 2D or 3D data can be collected. For 2D collection, the firmware supports an option to use a previously stored vertical reference to estimate the Z-axis offset.

Calibration coefficients can also be calculated externally, using more powerful algorithms implemented in the eCompassTest PC software. These algorithms determine both hard-iron and soft-iron compensation coefficients. For 2D data collection, a minimum of 7 sampled data points or one complete rotation is required. After data is collected and new coefficients are calculated, the variation in total magnetic field is calculated using both old and new coefficients to determine which are best. Results are presented with suggested best choices for the user to accept or override.

For the case where it is possible to collect good 3D data, the eCompassTest software also offers an option for 3D hard and soft iron compensation. After collecting 3D data, the software calculates a set of 9 independent coefficients that best compensate for both sources of error. The iterative algorithm works to find the ellipsoid that best fits the collected data by minimizing the sum of the squared geometric distances between the collected data and the parametric ellipsoid.

## Capturing a Vertical Reference

Select Capture Vertical Reference from the Tools menu to see a dialog (Figure 9) that instructs you on obtaining a vertical reference.

You may adjust the number of units per division on the vertical scale of the graph, the number of readings to be taken, and whether or not the graph will update automatically; however, you cannot modify these values while collecting data. If you notice that the PC cannot keep up with the incoming data (on slower computers) and that you cannot stop the data collection, turn off the automatic update option. In this case, the PC will not be bogged down with updating the graph during data collection, and the graph will be drawn once after all data has been collected.

Locate the eCompass in an open place away from large metallic objects or structures, position the eCompass approximately level, and click the Read Data button. As valid readings are taken, the graph will plot the value (if automatic update is enabled), and the status bar will show progress. Once the specified number of readings have been taken, the Vertical Reference is calculated based on the data. You may then choose to apply the new value.

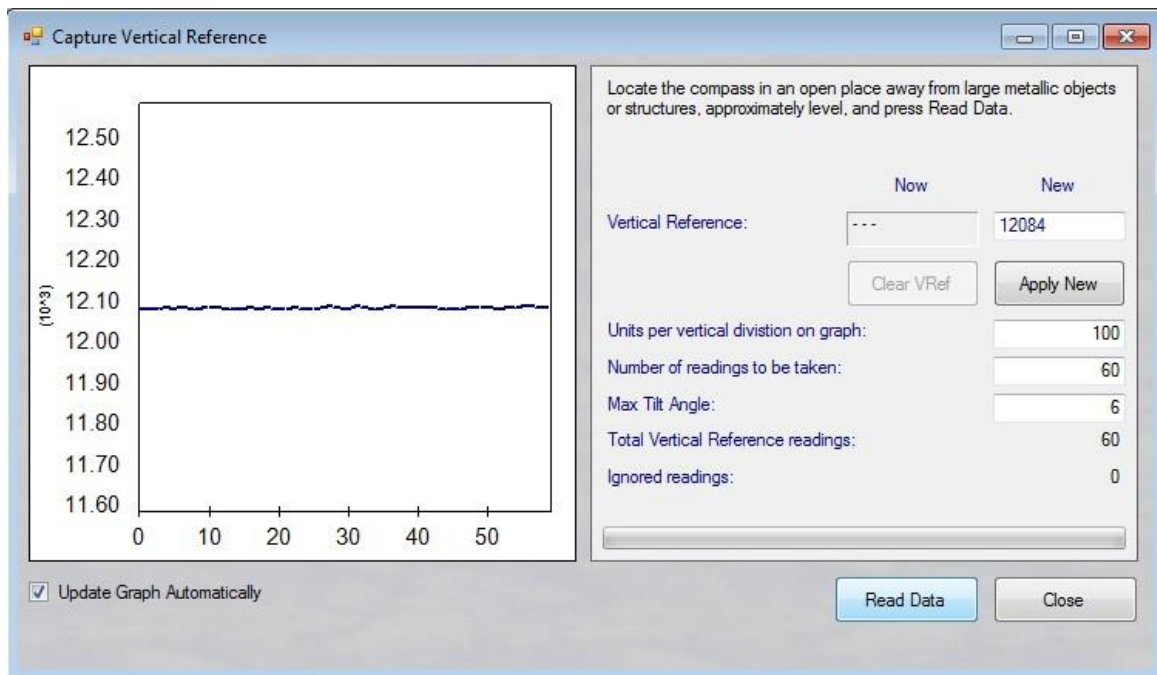


Figure 9

## **External Magnetic Calibration**

Select Calibrate Magnetics from the Tools menu to perform magnetic calibration using the software algorithm residing on the computer being used. You may select 3D data geometry where sample points are not coplanar or 2D where sample points are in an approximate horizontal plane. Use 3D only when large tilt angles can be achieved to generate enough variation in Z-axis data to produce a reliable offset. Use 2D if the eCompass is mounted in a boat, truck, RV, or other vehicle that only operates near level. If you have captured a vertical reference, you may select 2D with Vertical Reference where Vref is used in combination with a measured component to estimate the Z Offset.

Once you have selected the data geometry option, select the data collection option: Capture Every [n] Readings, Capture Readings Every [n] Degrees of Rotation (2D only), or Multi-step Samples Triggered Manually. Based on the selected option, you may specify various values such as the number of readings to take, the number of degrees between captures, the number of readings to average for each captured sample, etc.

The relationship between “Readings [n] to skip between captures” and “Number of readings to take” is important for timed data collection. The reading rate is 825 per minute and the maximum number of readings to take is 3000. If n=0 (no skipping) and the number of readings to take is 850 (default value), then the capture sequence will complete in a little over a minute. During this time, the eCompass carrier must be maneuvered through at least one rotation to collect a complete set of magnetic data. If the maneuvering will take longer, either n or the total number of readings to take can be increased.

The software will record three files in the LogFiles subfolder:

1. a data file containing the data that was collected, CalData
2. a results file containing the results of the calibration, CalResults
3. an intermediate file containing progress data, CalProgress

These files contain information that can help to diagnose calibration issues.

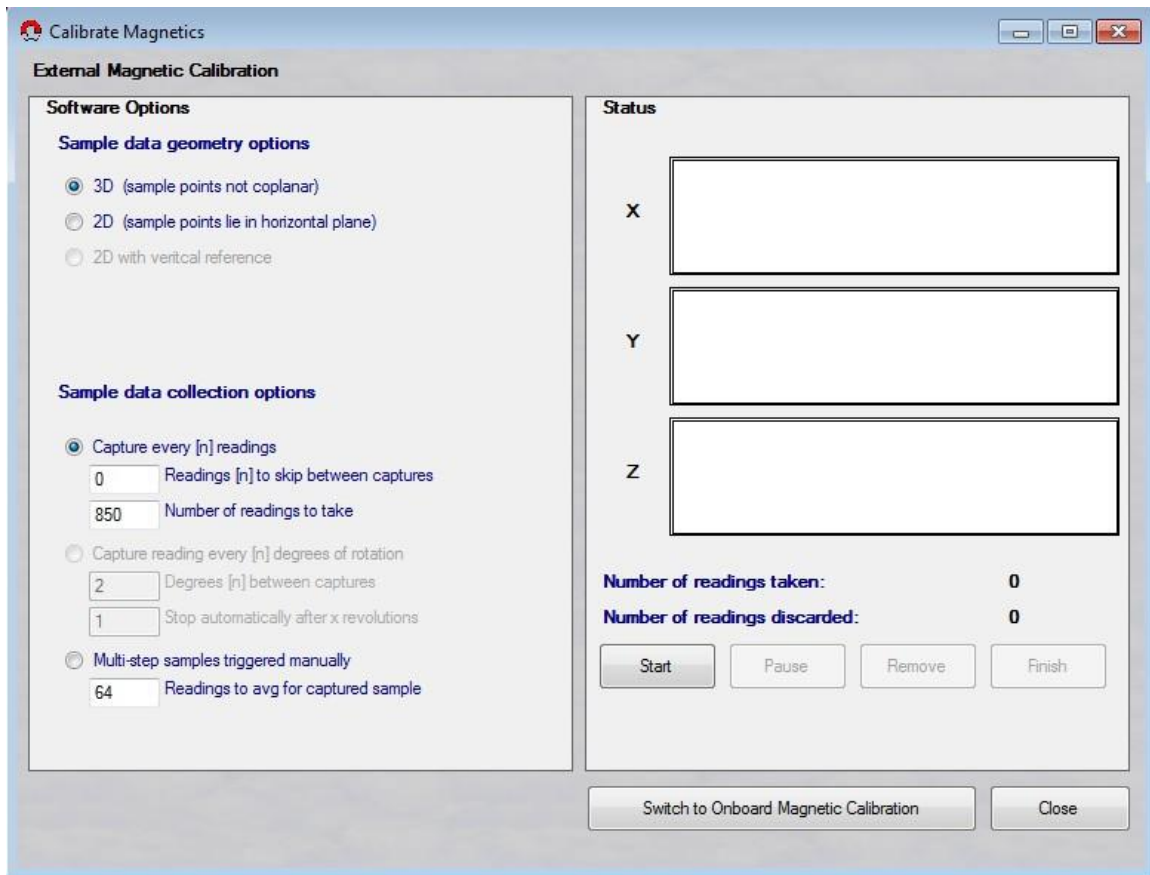
For the ECG™ eCompass, a Switch to Onboard Magnetic Calibration button will be visible at the bottom of the window. While not collecting data, click this button to switch to onboard magnetic calibration.

### **3D (Figure 10)**

To collect continuous 3D data where sample points are not coplanar, select the “Capture every [n] readings” option, begin rotating, pivoting, and rolling the unit, and click the Start button. Three histogram style graphs show the X, Y, and Z data distribution as it is being captured. During data collection, use the Pause/Resume button to suspend/resume taking readings. Once you have collected the specified number of readings, data collection will stop and results

will be calculated. The Finish button is enabled after ten readings have been collected, but it may be necessary to collect many more than this minimum number to produce accurate results.

To manually collect 3D data, select the “Multi-step samples triggered manually” option and specify the number of readings to average for each captured sample. After clicking the Start button, position the eCompass at different fixed positions and click the Sample button to take each sample. Three histogram style graphs show X, Y, and Z data distribution as it is being captured. The Finish button is enabled after ten samples have been collected, but it may be necessary to collect many more than this minimum number to produce accurate results.



**Figure 10**

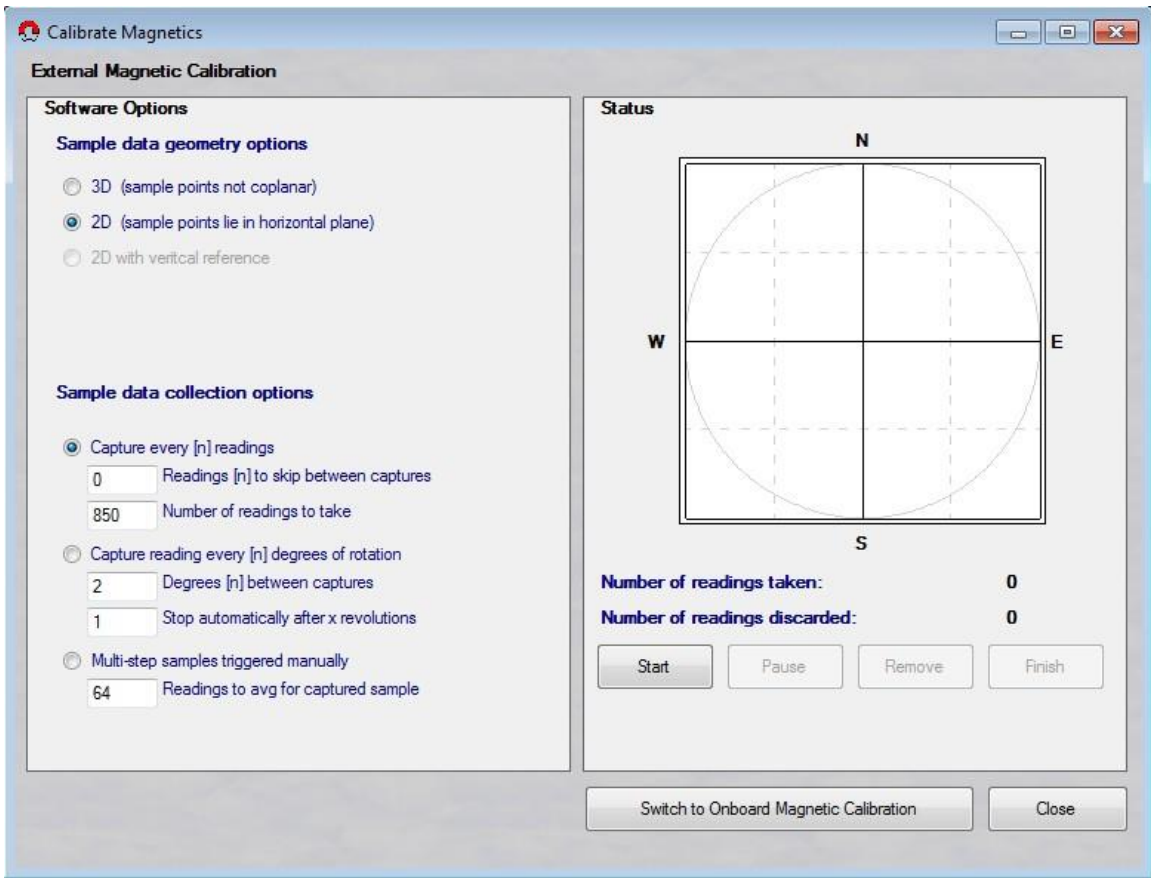
Please note that the Switch to Onboard Magnetic Calibration button is available only with ECG™ eCompasses with a Firmware Revision greater than 5.60. When not collecting data, you may click this button to switch to onboard magnetic calibration.

## ***2D or 2D With Vertical Reference (Figure 11)***

To collect 2D data continuously in a circle, select the “Capture every [n] readings” option and specify the number of readings to take and the number of readings to skip between captures. Begin rotating the eCompass and click the Start button. A series of blue dots will be drawn on the circular graph to plot the data points. During data collection, use the Pause/Resume button to suspend/resume taking readings. Once you have collected the specified number of readings, data collection will stop and results will be calculated. The Finish button is enabled after six readings have been collected, but it may be necessary to collect many more than this minimum number to produce accurate results.

To collect 2D data based on angle, select the “Capture reading every [n] degrees of rotation” option and specify the number of degrees between captures and the maximum number of rotations. Begin rotating the eCompass and click the Start button. A series of blue dots will be drawn on the circular graph to plot the data points. Once you have completed the specified number of rotations, data collection will stop and results will be calculated. The Finish button is enabled after six readings have been collected, but it may be necessary to collect many more than this minimum number to produce accurate results.

To manually collect 2D data, select the “Multi-step samples triggered manually” option and specify the number of readings to average for each captured sample. After clicking the Start button, position the eCompass at different fixed positions and click the Sample button to take each sample. On the circular graph, discarded readings will appear as gray dots, and each collected sample is drawn as a blue X. The Finish button is enabled after six samples have been collected, but it may be necessary to collect many more than this minimum number to produce accurate results.



**Figure 11**

If you have trouble performing a magnetic calibration on the eCompass, this may mean that the magnetic settings have been corrupted. In this case, you can Reset the Magnetic Calibration to restore the factory default magnetic settings. You will then need to successfully perform a magnetic calibration. Use this option with caution!

## External Magnetic Calibration Results

If the new results produce less variation in total magnetic field strength than the old, then the new offsets will be shown in boldface, and the Use New button will be highlighted in Figure 12. Likewise, if the application of soft-iron gains produces the least variation, the Use Soft Iron Gains checkbox is checked. Either or both of these can be overridden. You can toggle between using the old and new values by clicking the Use Old and Use New buttons, respectively.

The value labeled Mag Total 3 Sigma in the dialog is a percentage that means that 97% of the calculated total field magnitudes fell within a range centered on the average, plus or minus the indicated percent of average. It indicates the calculated variation with and without soft-iron, depending on whether the Use Soft Iron Gains checkbox is checked.

The value labeled Ellipticity is the percentage difference between the major and minor axes of the calculated ellipse that best fits the data. The value shown is 100 times the ratio of the major axis divided by the minor axis. For 3D soft iron, the ratio is between the longest and shortest of the three axes. Using soft-iron compensation will not be suggested if the two axes differ by less than 0.5%.

The screenshot shows the 'Calibrate Magnetics' dialog box with the 'External Magnetic Calibration' tab selected. The dialog is divided into two main sections: 'Software Options' and 'Results'.

**Software Options:**

- Sample data geometry options:**
  - 3D (sample points not coplanar)
  - 2D (sample points lie in horizontal plane)
  - 2D with vertical reference
- Sample data collection options:**
  - Capture every [n] readings
    - Readings [n] to skip between captures: 0
    - Number of readings to take: 850
  - Capture reading every [n] degrees of rotation
    - Degrees [n] between captures: 2
    - Stop automatically after x revolutions: 1
  - Multi-step samples triggered manually
    - Readings to avg for captured sample: 64

**Results:**

	Old	New
X Offset:	-79	<b>77</b>
Y Offset:	16	<b>12</b>
Z Offset:	111	<b>37</b>
<input checked="" type="checkbox"/> Use Soft Iron Gains		
Mag Total 3 sigma:	11.5 %	10.9 %
Ellipticity:		0.0 %

Buttons: Use Old, Use New (highlighted), Restart magnetic calibration, Switch to Onboard Magnetic Calibration, Close.

Figure 12

## ***External Magnetic Calibration Settings***

The CalMag section of the eCompassTest.INI file contains various settings that affect external magnetic calibration. Most of these settings correspond to the data geometry and data collection options on the external magnetic calibration screen. However, the following settings are configurable only in the INI file:

### CalMagTC

Smoothing time constant for calculated magH

### CalNumAvg2DTilt

Number of tilt readings to average on both sides of each data point

### CalSoft3DMaxIter

Number of iterations before aborting soft-iron algorithm

### CalBeforePauseIgnoreCount

Number of CCD sentences to discard before pausing data collection

### CallgnoreCount

Number of CCD sentences to ignore when data collection starts initially or resumes after being paused

### CalTimeoutCount

Number of CCD sentences to capture before terminating automatically

### CalVrefMaxTilt

Maximum tilt angle for averaging calculated vertical magnetic component to determine Z hard iron



## Onboard Magnetic Calibration

Embedded in the firmware (Revision 5.61 or higher) of the ECG™ eCompass are routines to collect and analyze magnetic calibration data.

Select Calibrate Magnetics from the Tools menu to perform magnetic calibration. If the external magnetic calibration dialog appears, use the Switch to Onboard Magnetic Calibration button to switch the eCompass from external to onboard calibration mode. Also, you may specify onboard or external calibration from the Magnetic Tab of the Settings dialog.

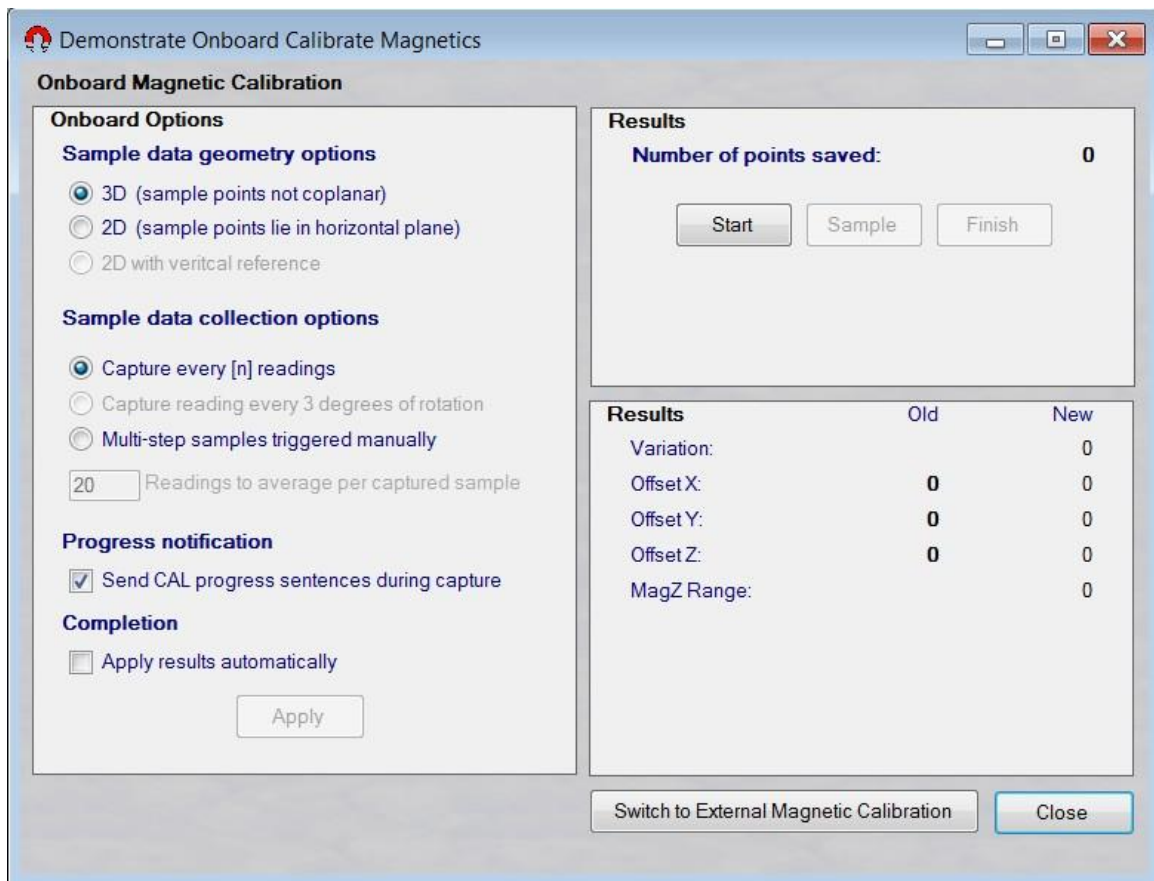


Figure 13

Select 3D data geometry if sample points are not coplanar or 2D when sample points are in an approximate horizontal plane. If you have captured a vertical reference, you may also select 2D with Vertical Reference where Vref is used to estimate the Z Offset.

Once you have selected the data geometry option, select the data collection option: Capture every [n] readings, Capture readings every 3 degrees of rotation (2D only), or Multi-step samples triggered manually. Based on the selected

option, specify either “Readings [n] to skip between captures” or “Readings to average per captured sample.”

The relationship between “Readings [n] to skip between captures” and the fixed number of readings to take is important for timed data collection. The reading rate is 825 per minute and the number of readings to take is 120. If  $n=0$  (no skipping), then the capture sequence will complete in less than 9 seconds. Set  $n=6$  to complete the capture sequence in a little over a minute ( $825 / 7 = 118$ ). During this time, the eCompass carrier must be maneuvered through at least one rotation to collect a complete set of magnetic data. If the maneuvering will take longer, increase  $n$  up to a maximum of 255 (roughly 37 minutes of capture time).

You may also specify whether the eCompass should send the CAL calibration NMEA sentences during capture and whether the eCompass should apply results automatically.

### **3D**

To collect continuous 3D data, select the “Capture every [n] readings” option, begin rotating, pivoting, and rolling the eCompass, and click the Start button. Once you have collected the specified number of readings, data collection will stop and results will be calculated. Also, after enough readings have been collected, you may click the Finish button to calculate the results.

To manually collect 3D data, select the “Multi-step samples triggered manually” option and specify the number of readings to average for each captured sample. Click the Start button, begin rotating, pivoting, and rolling the eCompass, and click the Sample button to take each sample. Once you have collected at least six samples, you may click the Finish button to calculate the results.

### **2D or 2D With Vertical Reference**

Select the 2D sample data geometry option or you may select 2D With Vertical Reference if you have captured a vertical reference.

To collect 2D data continuously in a circle, select the “Capture every [n] readings” option and specify the number of readings to take. Begin rotating the eCompass and click the Start button. After enough readings have been collected, you may click the Finish button to calculate the results.

To collect 2D data based on angle, select the “Capture reading every 3 degrees of rotation” option. Begin rotating the eCompass and click the Start button. After enough readings have been collected, you may click the Finish button to calculate the results.

To manually collect 2D data, select the “Multi-step samples triggered manually” option and specify the number of readings to average for each captured sample. Click the Start button, begin rotating the eCompass, and click the Sample button

to take each sample. Once you have collected at least six samples, you may click the Finish button to calculate the results.

## Onboard Magnetic Calibration Results

If you did not check the Apply Results Automatically checkbox, the suggested offsets will be displayed in boldface and the Use New or Use Old button will be highlighted appropriately.

The Old and New Variation values provide quantitative measures of how well the new and old offsets compensate for hard-iron. Accuracy is improved as variation decreases. If new offsets are not calculated, a message on the screen will provide an explanation.

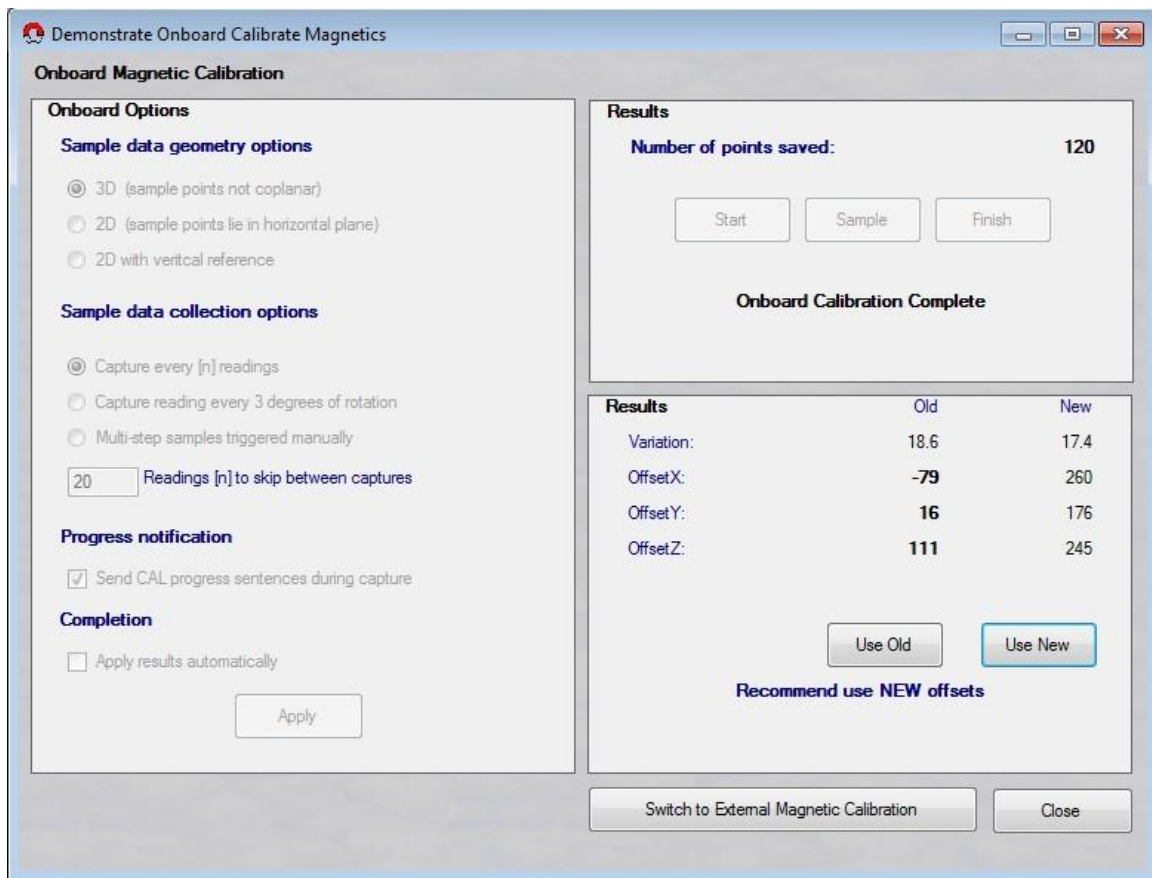


Figure 14

If you have trouble performing a magnetic calibration on the eCompass, this may mean that the magnetic settings have been corrupted. In this case, you can Reset the Magnetic Calibration to restore the factory default magnetic settings. You will then need to successfully perform a magnetic calibration. Use this option with caution!