Revolution™ Compass
User's Guide

Revisions

November 2002, Rev A, First Release
March 2003, Rev B, New J2 Wiring Instructions
March 2006, Rev C, No PDA instructions
January 2008, Rev D, Revise Mag Calibration

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Introduction

The Revolution compass combines a precision 3-axis solid-state magnetometer and a rugged 2-axis electrolytic tilt sensor 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 compass 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 compass 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 compass is steady and tilt is less than 20°.

Before installing the Revolution, 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 Compass*. After the compass is mounted in-situ, this reference is used to partially compensate for any local permanent magnetism (hard-iron) that may be present.

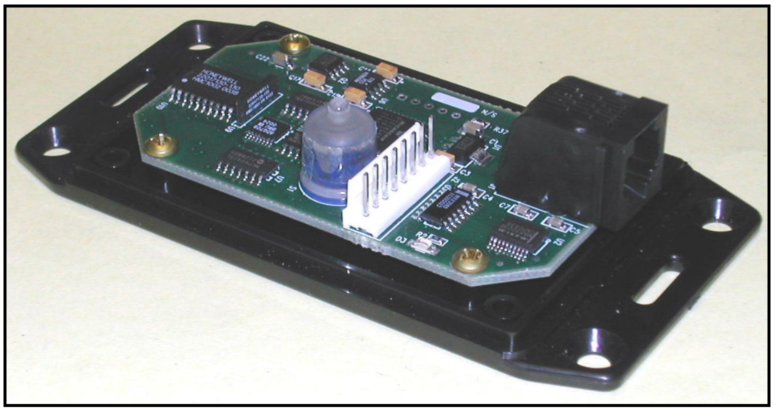
Contents of the E-value-ation compass kit

The Revolution E-value-ation compass kit contains the following primary items described in detail in this section:

- Revolution Compass
- Revolution Software CD
- Serial Cable
- Users Guide

Revolution Compass

The Revolution 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 compass may be made via the RJ12 connector (for the PDA or PC) or by the 8 pin header (for system wiring). See the diagram(s) included with the cable(s).



Compass Features

The Revolution compass 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 1mA. Wake up from standby requires only one millisecond.

Additional features of the compass include:

- Run (continuous) or Sample mode operation
- NMEA 0183 output data format with the following available sentences:
  - ⇒ HDT (True heading – standard sentence)
  - ⇒ HDG (Heading, deviation, and variation – standard sentence)
  - ⇒ XDR (Transducer data: pitch, roll, magX, magY, and magZ – standard sentence)
  - ⇒ HTM (Heading, tilt, and magnetic field – proprietary sentence)
  - ⇒ NCD (Normalized compass data – proprietary sentence)
  - ⇒ CCD (Conditioned compass data – proprietary sentence)
- Output data available:
  - ⇒ Heading, pitch, and roll
  - ⇒ Magnetometer X, Y, Z, and calculated total field
  - ⇒ N, E, H, and V - normalized magnetic field components
  - ⇒ Magnetic inclination (dip angle)

- Angles in degrees (0.0 to 359.9°), mils (0 to 6399), milliradians (0 to 6282), or 16-bit integer (0 – 65535)
- Tunable alarm on H field deviation in Run mode
- Selectable averaging time in Sample mode
- Separate magnetic and tilt IIR single-pole filters in Run mode
- Tunable heading filter in Run mode for quick response in hand-held applications where fast movements should be ignored
- Magnetic field measurement range: ±1.6 G (gain 100)
- Magnetic field measurement sensitivity: 0.3 mG (30 nT, gain 500)
- Serial EEPROM for calibration coefficients and setup parameters

Revolution Software CD

This is a business-card style CD with both the Revolution interface software for a Microsoft Windows PC and software for the (optional) PDA. When the CD is loaded into a CDROM drive, the display shown in Figure 1 will automatically appear if the auto-run feature is enabled.

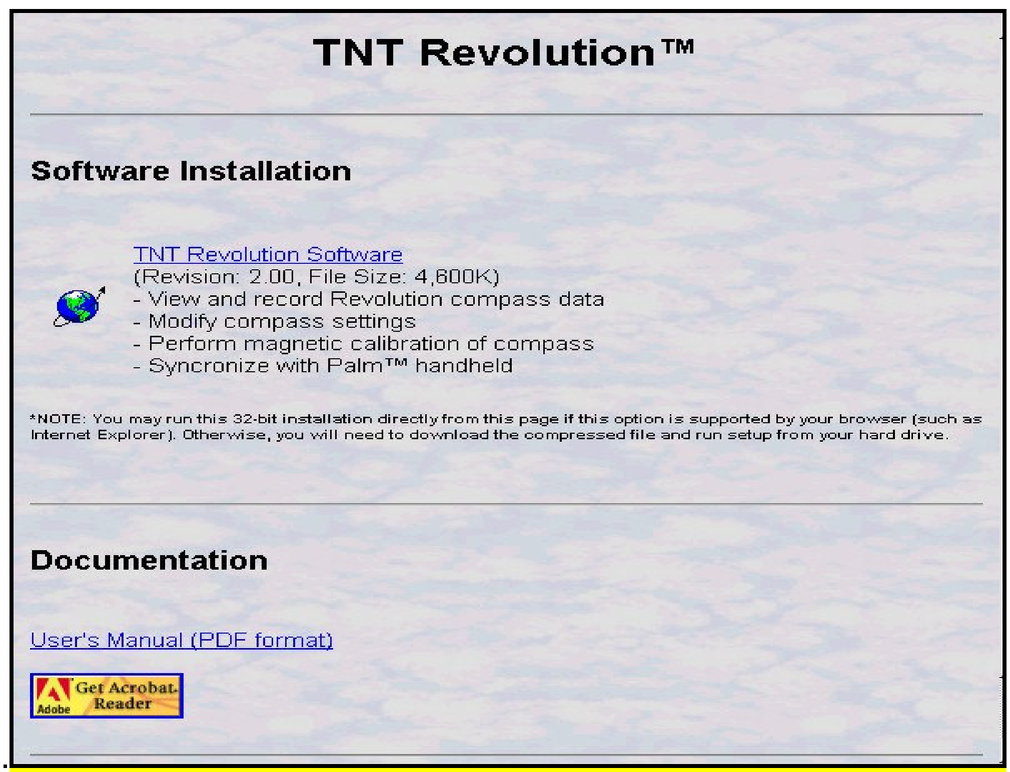


Figure 1

PC Software Features

The Revolution PC program is designed to run on most Microsoft Windows platforms: 95, 98, NT, 2000, ME, and XP. There are two main components:

- A Visual Basic program (Revolution.Exe) that provides the graphical user interface, database, and logging functions, and
- A windowless ActiveX control (Compass.Ocx) that implements the compass serial interface and calibration functions.

The ActiveX control can be used separately from the Revolution PC program to simplify the task of integrating the compass 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 compass that can be read by a host application.

Functions provided by the Revolution PC software are:

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

Getting to Know the PC Software

System Requirements

- PC running Windows 95 or greater
- VGA
- Keyboard
- 5 Mb disk space (more for log files, recorded data files, synchronized files)
- RS-232 serial port

System Recommendations

- PC running Windows 98 or greater
- SVGA 1024 x 768, High Color (16-bit), Large Fonts
- Keyboard and Mouse
- 50 Mb disk space

Revolution Software

The Revolution software allows you to use your PC to communicate with the Revolution compass.

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

During the installation, you may select the directory in which the Revolution software will be installed or accept the default directory of C:\Program Files\True North Technologies\Revolution. Once you run the Revolution software, the LogFiles subdirectory will be created to store log files. Once you record data using the Revolution software, the RecordedData subdirectory will be created to store files of data recorded from the compass.

The following list describes the files placed in the application directory:

- Revolution.exe   TNT Revolution software application
- Revolution.ini   Initialization file for Revolution software
- Revolution.hlp   Help file for Revolution software
- Revolution.cnt   File required by help file
- Revolution.gid   File used by help file

- Compass.ocx   ActiveX control for communicating with Revolution compass

To remove the Revolution software, use the Add/Remove Programs function from the Control Panel, or run the Revolution setup again and chose Remove. Do not simply delete the Revolution directory and files. Please note that any log files, PDA files, or recorded data 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.

Serial Cable

The following cable assembly is included and is shown in Figure 2.

True North P/N 1540: 4-Wire PC to Compass: 8 ft. cable with DB9F connector and 9V battery strap going to 6-pin RJ12 plug.

Figure 2

Preliminary Compass Evaluation

How the Revolution Compass is Prepared

After factory calibration, test, and verification, the Revolution is setup as follows:

- 19200 baud serial data rate
- Run mode – no automatic NMEA data output
- 0.4 s magnetometer time constant (Mag TC)
- 0.8 s pitch and roll time constant (Tilt TC)
- 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 three 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 ± 750 mG (± 75 µT). 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 compass is demagnetized to eliminate any residual magnetic fields from the circuit components. If the compass 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 page. 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 "Vertical Reference" category of the Calibrate page.

Pitch and Roll Check

This is a simple test to check pitch and roll accuracy near zero degrees tilt. Place the compass on a flat surface and take readings for pitch and roll angles. Now rotate the compass 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 compass on a flat surface along the edge of a fixed, non-magnetic straight-edge, like a wooden ruler. Make sure the compass environment is magnetically clean (no motors, ferrous materials, etc.). Using the Sample mode on the Capture page, capture CCD samples to see MagX, MagY, and MagZ measurements from the magnetometer.

Rotate the compass and straight edge until either MagX or MagY approaches zero. Once there, hold the straight edge and rotate the compass exactly 180° by aligning the opposite side with 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 PC Revolution Program

Running the Revolution Software for the First Time

The first time you run the Revolution software, you will see the dialog 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 compass when it is shipped. Once you have established communication with the compass, you will not be prompted in this way unless the software is unable to communicate with the compass.

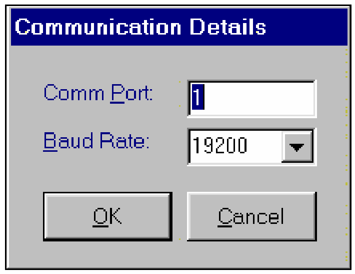


Figure 3

If the software cannot communicate with the compass, you will receive the dialog in Figure 4:

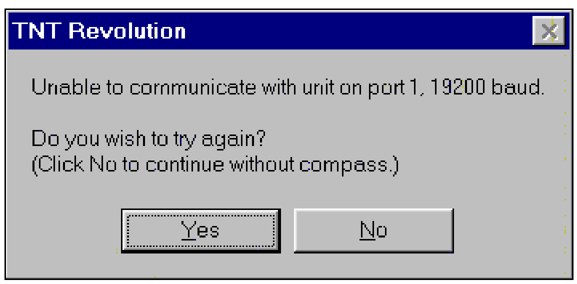


Figure 4

Click Yes from the dialog in Figure to try again. You will be prompted to enter the communication port and baud rate as in Figure 5. Clicking No allows you to proceed without connecting a compass.

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

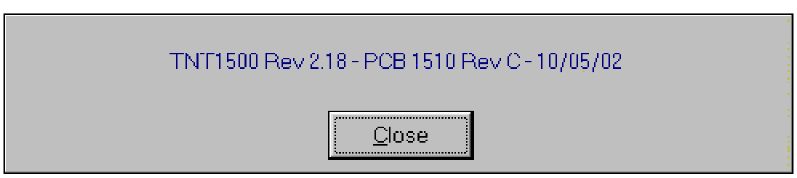


Figure 5

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

Figure 6

Any menu items and toolbar buttons requiring a compass 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 compass
- Test communication with the compass
- View help

Description of the Software Main Screen

The Revolution 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 Compass ID, Port, Baud rate, unique Unit ID, and Angles value. The Main Screen appears as shown in Figure 7.

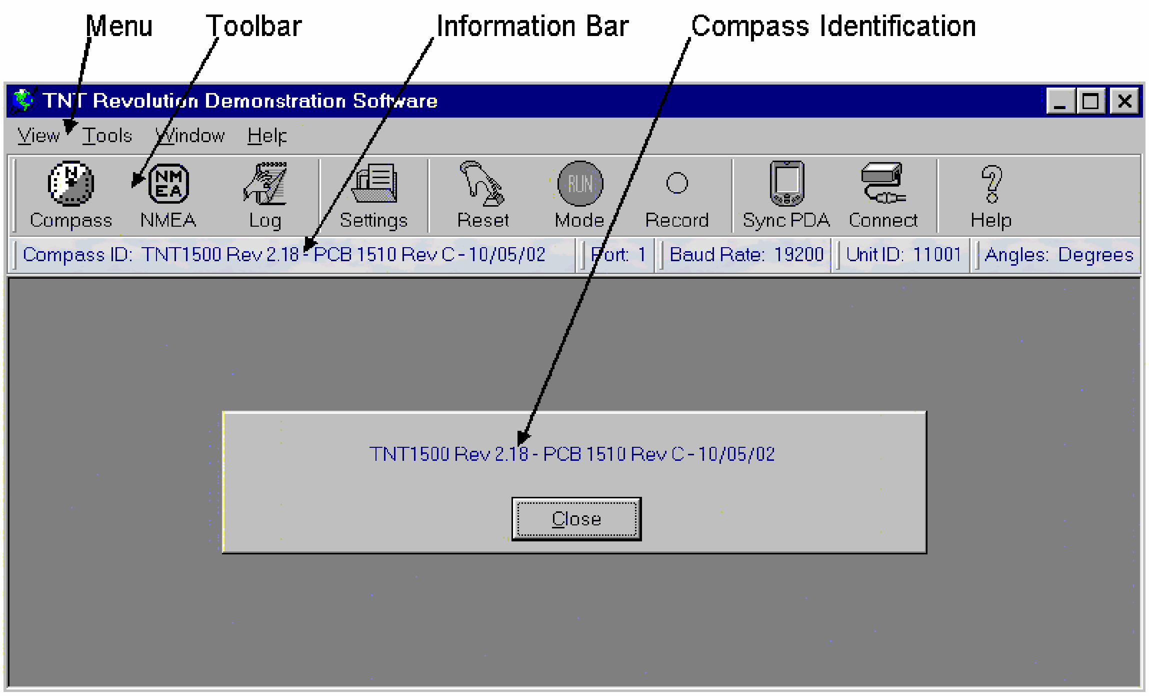


Figure 7

Compass Installation

Before installing the compass, consider the following:

- Verify that the compass 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 system wiring is going to be used, install the cable before permanently mounting the compass.

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 compass accuracy.

Magnetic fields that arise from 50 or 60 Hz AC currents are significantly attenuated, because the compass averages magnetometer signals over 18.2 milliseconds, which corresponds to 55 Hz. However, intermittent magnetic fields generated by motors or solenoids being turned on and off 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 compass reading.

Since horizontal components of acceleration affect compass accuracy and cannot be compensated, choosing a location near the center of a vehicle is best. For example, mounting the compass on a mast to get it away from a ship's steel hull may result in acceptable accuracy only in calm seas. A compromise location that minimizes both influences may yield the best overall performance.

Finally, consider mechanical vibration to minimize its affect on the tilt sensor. Most of the noise caused by a piston engine can be compensated by tuning algorithms in the compass firmware. However, it may be desirable to orient the compass on an axis that is not aligned with the vehicle so that engine noise affects pitch and roll equally. Use the Deviation setting to electronically shift the heading into alignment with the vehicle.

Mounting

Use brass or stainless steel screws to secure the compass in place. The label on the Revolution enclosure indicates directions for positive pitch, roll, and magnetometer readings. The compass 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 compass accuracy. An auto-zero function is provided on the tilt settings page in both the PDA and PC Revolution software. Although it can be mounted in any orientation within range, the best compass 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 Revolution compass 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. Contact True North about supplying a locking header and connector instead.

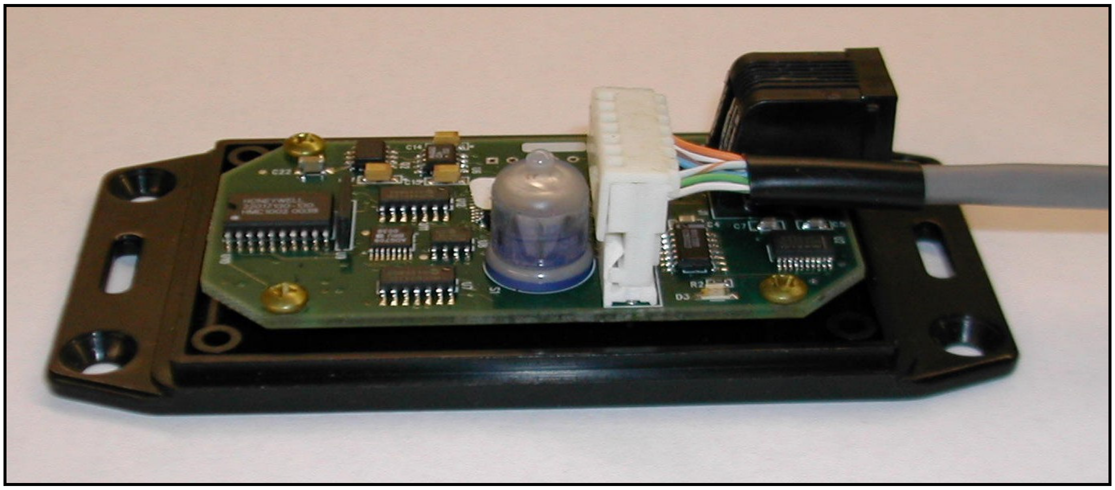


Figure 8

1. Remove the Revolution 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 (HMC1002). 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) thorough 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 compass over and replace the 4 stainless steel screws.

Calibrating the Compass

Once the compass 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 compass over its mechanical predecessor is that the compensation can be performed without additional hardware. A strap-down electronic compass like the Revolution can be compensated more precisely than a mechanically gimbaled 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 compass 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, True North 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 PC software also implements “least squares” algorithms that 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 PC 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 readings to be taken, the amount of units per division on the vertical scale of the graph, 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 compass in an open place away from large metallic objects or structures, position the compass approximately level, and click the Read Data. 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.

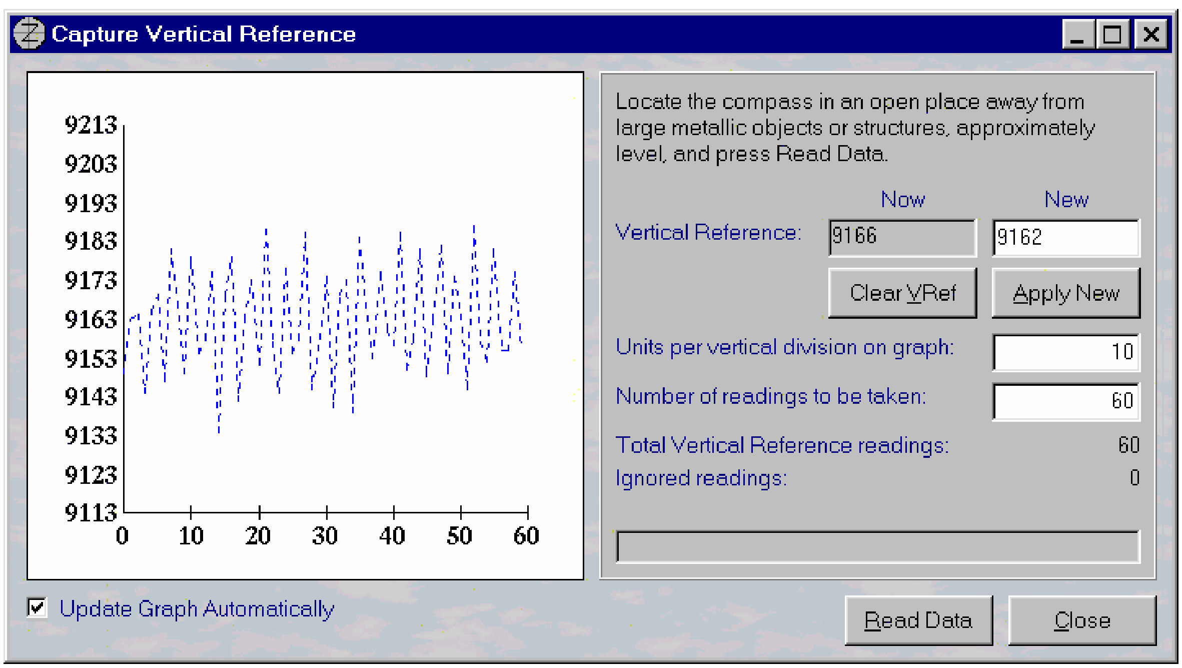


Figure 9

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 compass 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 software can optionally record three files:

1. a data file containing the data that was collected
2. a results file containing the results of the calibration
3. an intermediate file containing progress data from the collection process

Use the Magnetic Calibration Tab of the Options Dialog to modify these file specifications.

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 compass 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.

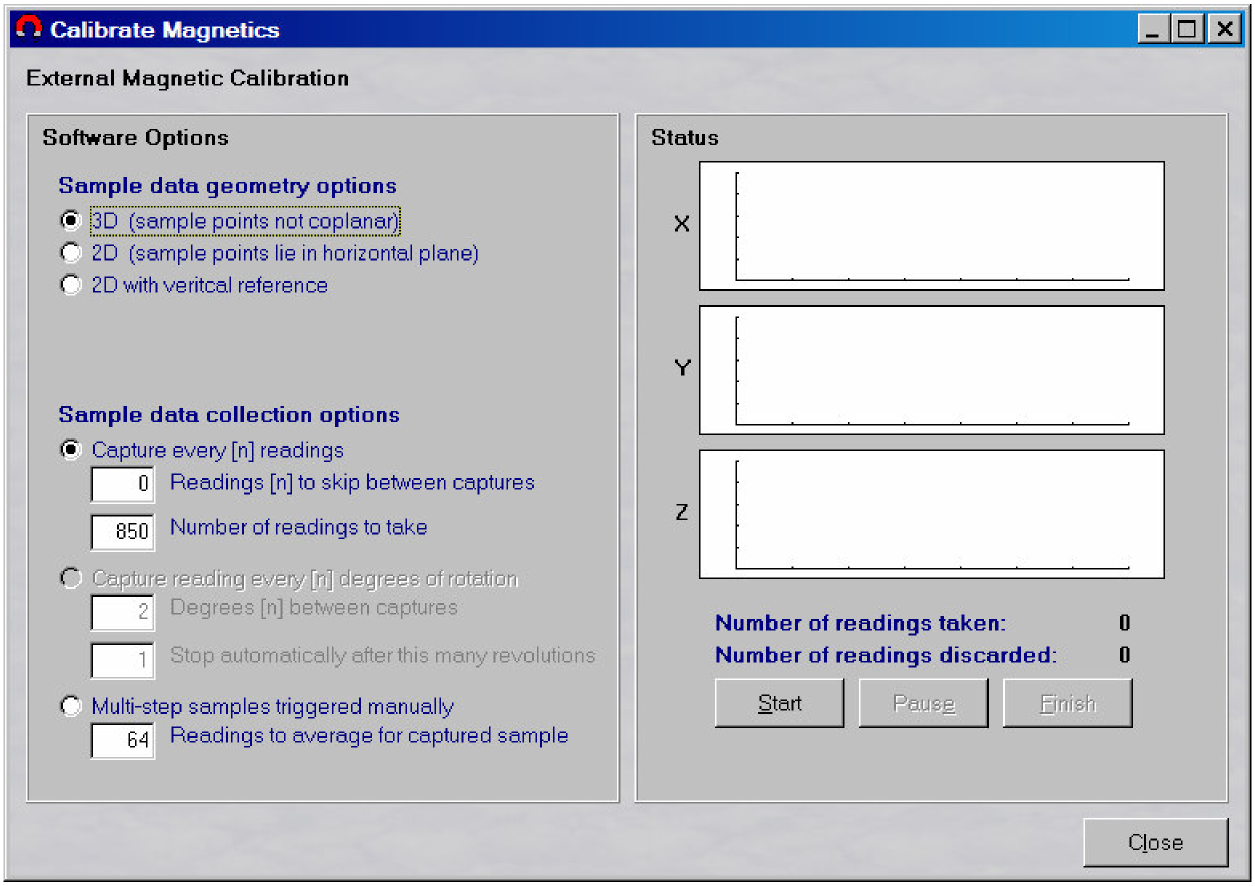

Calibrate Magnetics
External Magnetic Calibration
Software Options
Sample data geometry options
3D (sample points not coplanar)
2D (sample points lie in horizontal plane)
2D with veritcal reference
Sample data collection options
Capture every [n] readings
0
Readings [n] to skip between captures
850
Number of readings to take
Capture reading every [n] degrees of rotation
2
Degrees [n] between captures
1
Stop automatically after this many revolutions
Multi-step samples triggered manually
64
Readings to average for captured sample
Status
X
Y
Z
Number of readings taken: 0
Number of readings discarded: 0
Start
Pause
Finish
Close

Figure 10

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 compass 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 compass 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 compass 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.

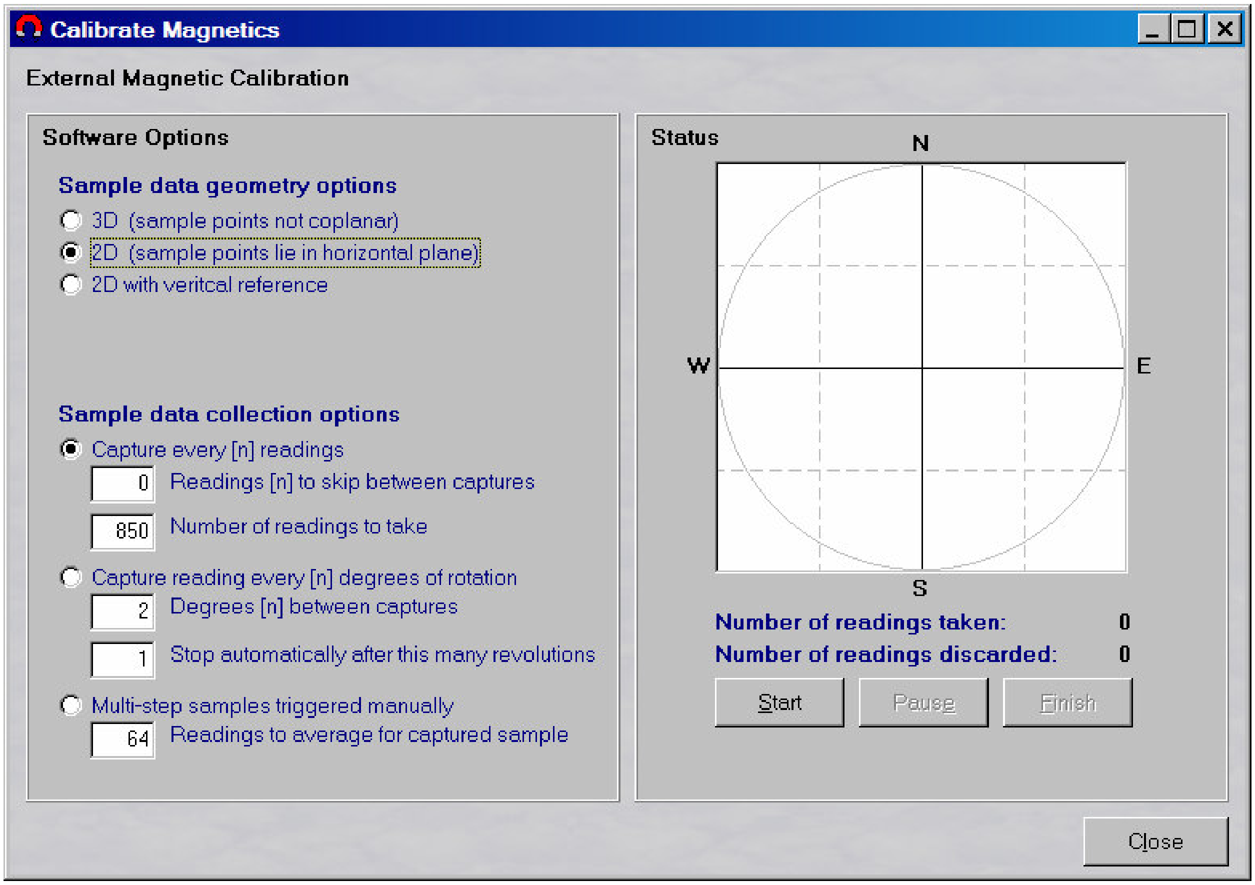


Figure 11

If you have trouble performing a magnetic calibration on the compass, 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 (Figure 12)

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%.

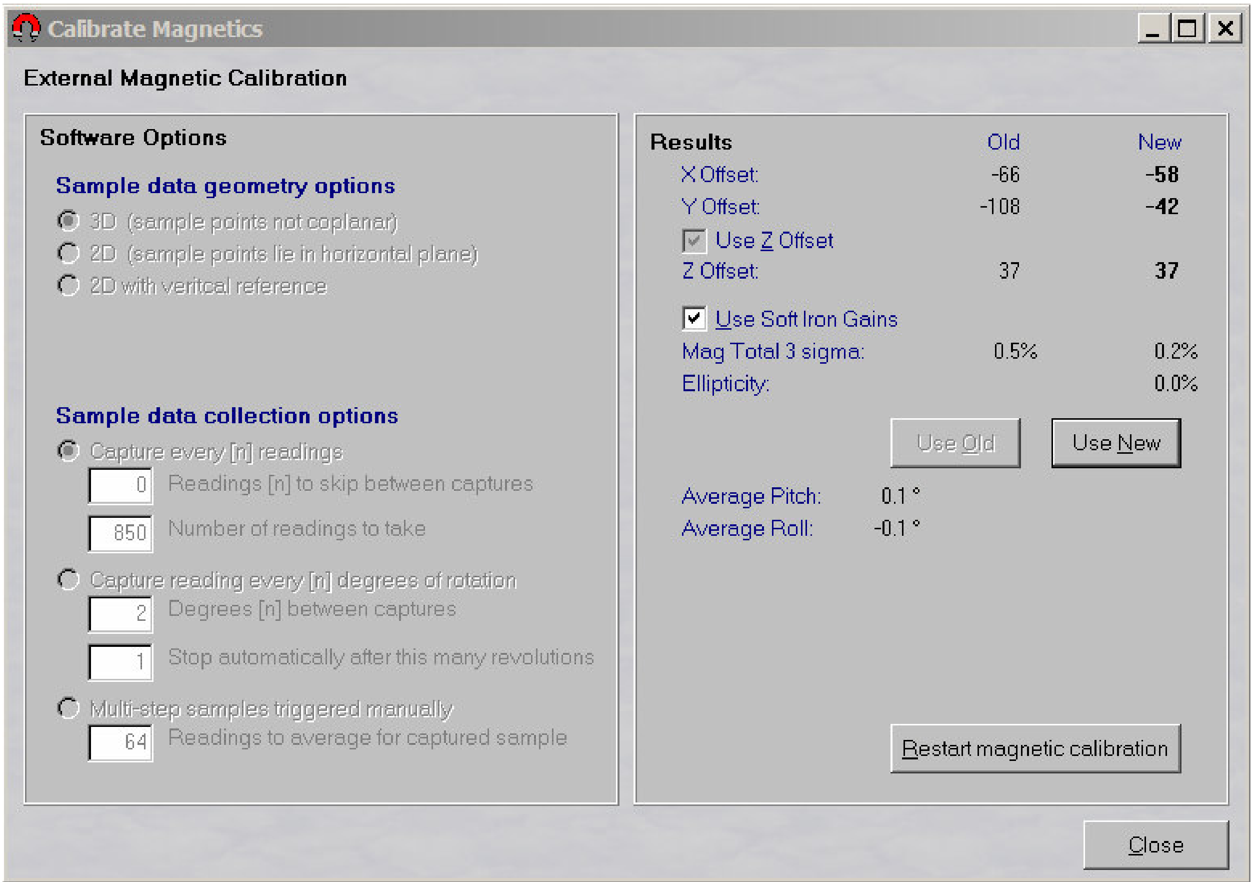


Figure 12

External Magnetic Calibration Settings

The CalMag section of the Revolution.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:

<u>CalMagTC</u>

Smoothing time constant for calculated magH

<u>CalNumAvg2DTilt</u>

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

<u>CalSoft3DMaxIter</u>

Number of iterations before aborting soft-iron algorithm

<u>CalBeforePauseIgnoreCount</u>

Number of CCD sentences to discard before pausing data collection

<u>CalIgnoreCount</u>

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

<u>CalTimeoutCount</u>

Number of CCD sentences to capture before terminating automatically

<u>CalVrefMaxTilt</u>

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