InertiaCube BT™

User Guide for InertiaCube BT

700 Technology Park Drive
Suite 102
Billerica, MA 01821
Phone +1 781.541.6330 • Fax +1 781.541.6329
www.intersense.com

User Manual for InertiaCube BT
DLL Version 4.19 and higher

Contacting InterSense

Please do not hesitate to contact us for any reason. We are here to help and we value your business.

700 Technology Park Drive
Suite 102
Billerica, MA 01821
USA

Telephone:	+1 (781) 541-6330	email:	ISinfo@intersense.com
Fax:	+1 (781) 541-6329	Internet:	www.intersense.com
Technical Support:	+1 (781) 541-7624	email:	techsupport@intersense.com

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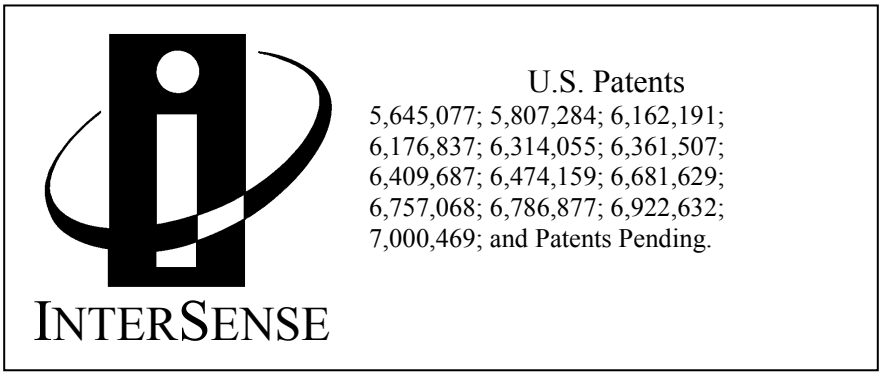

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Regulatory Statements and Approvals

Precautionary Statements

Any changes or modifications to the InertiaCube BT not expressly approved by Thales Visionix, Inc. will void the warranty and any regulatory compliance issued for the system.

Do not drop or otherwise shock the tracking devices for they can be permanently damaged.

Do not bend, twist, pull strongly or tamper in any way with any part of the cabling.

Take care to avoid electric shocks. Do not plug-in or unplug the power cable with wet hands.

Please see Appendix C for Health and Safety warnings and guidelines

Compliance information for the Bluetooth Module

Category	Country	Standard
Radio	**USA**	FCC CFR47 Part 15 C, para 15.247
	FCC ID:	T9J-R41-1
	EUROPE	EN 300 328-1
		EN 300 328-2 2.4GHz
	CANADA	IC RSS-210 low power comm. device
	IC Canada ID:	6514A-RN411
EMC	**USA**	FCC CFR47 Part 15 subclass B
	EUROPE	EN 55022 Class B radiated
		EN61000-4-2 ESD immunity
		EN61000-4-3 radiated field
		EN61000-4-6 RF immunity
		EN61000-4-8 power magnetic immunity
Bluetooth	**LISTED**	B013180
Environmental	**RoHS**	RoHS compliant

Responsible party (contact for FCC matters):
Thales Visionix, Inc.
700 Technology Park Drive
Suite 102
Billerica, MA 01821
USA

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1 Theory of Operations

This technology offers you several advantages:

- Long range wireless tracking
- Smooth, jitter-free tracking
- Fast update rate
- Convenience of utilizing Blutetooth® wireless communication

The InertiaCube BT is a wireless inertial 3-DOF (Degree of Freedom) orientation tracking system. It obtains its motion sensing using a miniature solid-state inertial measurement unit, which senses angular rate of rotation, gravity and earth magnetic field along three perpendicular axes. The angular rates are integrated to obtain the orientation (yaw, pitch, and roll) of the sensor. Gravitometer and compass measurements are used to prevent the accumulation of gyroscopic drift. The wireless communication is Class 1 Bluetooth.

1.1 InertiaCube BT™ integrated inertial instrument

The InertiaCube BT is a monolithic part based on micro-electro-mechanical systems (MEMS) technology involving no spinning wheels that might generate noise, inertial forces and mechanical failures. The InertiaCube BT simultaneously measures 9 physical properties, namely angular rates, linear accelerations, and magnetic field components along all 3 axes. Micro-miniature vibrating elements are employed to measure all the angular rate components and linear accelerations, with integral electronics and solid-state magnetometers. The magnetometers permit optional yaw drift correction. The geometry and composition of these elements are proprietary, but the functional performance of the multisensor unit can be understood sufficiently by reference to the equivalent diagram in Figure 1.

Figure 2 illustrates the basic physical principal underlying all Coriolis vibratory gyros. Suppose that the tines of the tuning fork are driven by an electrostatic, electromagnetic or piezoelectric drive to oscillate in the plane of the fork. When the whole fork is rotated about its axis, the tines will experience a Coriolis force $\underline{F} = \underline{\omega} \times \underline{v}$ pushing them to vibrate perpendicular to the plane of the fork. The amplitude of this out-of-plane vibration is proportional to the input angular rate, and is sensed by capacitive, inductive, or piezoelectric means to measure the angular rate.

By way of comparison, a conventional inertial measurement unit (IMU) senses 6 of these properties using 6 separate instruments (3 rate gyros and 3 linear accelerometers) each of which by itself would typically be larger, heavier, and more expensive than an InertiaCube BT sesnsor. Unlike conventional rate gyro and accelerometer instruments, which must be carefully aligned on a precision machined tri-axial mounting block, the InertiaCube BT is a monolithic device with its orthogonal outputs factory calibrated to precise alignment.

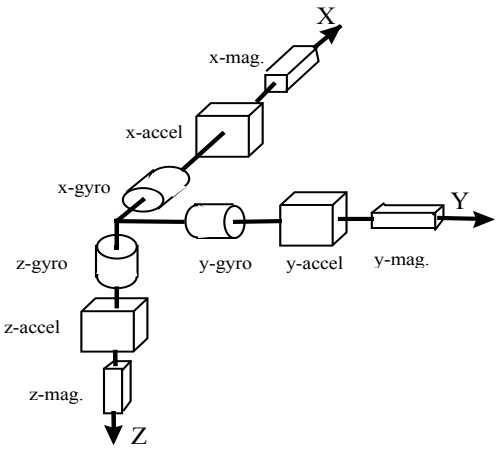


Figure 1: Functional diagram of InertiaCube BT

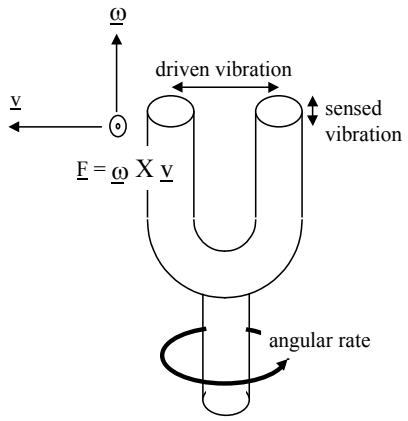


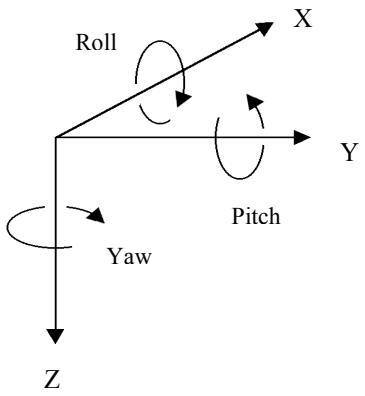
Figure 2: Principle of Coriolis vibratory Gyroscope

Figure 3: InertiaCube BT

1.2 3-DOF Gyroscopic Earth-stabilized Orientation Sensing (GEOS™) algorithms

Figure 4 shows the processing which is used to compute orientation using this sensor configuration. The basic computation of orientation from gyroscopic angular rates (in the top line of boxes) provides the very rapid dynamic response and high resolution of the system. The accelerometers and magnetometers are used to stabilize the orientation to the earth's gravitational and magnetic fields, thus eliminating the gradual but unbounded accumulation of gyroscopic drift errors. The Kalman filter uses an ever-evolving adaptive algorithm to discard the portion of the accelerometer measurements, which are due to actual motion instead of gravity. This is a very important step, because otherwise horizontal accelerations would result in very large transient pitch and roll errors known as "slosh". The low cost sourceless trackers used in early consumer HMDs are inclinometer/compass devices, and are thus intrinsically slosh-prone to the point of being uncomfortable to use.

In the default operating GEOS mode, the reference frame (hereafter referred to as Navigation frame or Nav frame or N frame) is the locally-level geographic frame with its x-axis pointing north, y-axis east, and z-axis down. The Euler angles reported by the tracker can be described as a sequence of rotations applied to the InertiaCube BT starting with its body axes initially aligned with the Nav frame axes and resulting in the current orientation. The sequence starts with a rotation by (+yaw) about the Z axis, followed by a rotation by (+pitch) about the new Y axis (i.e. body frame axis), followed by a rotation by (+roll) about the new X axis (i.e. body frame x axis)



The line from the magnetic field sensor outputs of the InertiaCube BT to the Kalman filter is a dotted line to indicate that the use of the magnetometers may optionally be disabled (completely, or partially if using the environmental compass calibration tool). The accelerometer measurements are sufficient to correct all of the drift in pitch and roll, and the geomagnetic compassing function is only used to correct drift in yaw. It may be desirable to turn magnetic yaw compensation off if there are large variations in the direction of magnetic north over the tracking area. With the compassing turned off, the yaw value will drift a few degrees per minute. This drift is too slow to notice while it is happening, but the cumulative yaw error may eventually become noticeable and it may be necessary to apply a Heading Boresight. When yaw compensation mode is disabled, the Nav frame axes are aligned instead to pseudo-north, pseudo-east, and down, where pseudo-north is simply the direction the InertiaCube BT x-axis was facing on power-up or after application of a Heading Boresight command.

2 Specifications and Performance Characteristics

2.1 Performance Specifications

Degrees of Freedom	3 (Yaw, Pitch, and Roll)
Angular Range	Full 360º - All Axes
Maximum Angular Rate	1200º per second
Minimum Angular Rate	0º per second
Accuracy (RMS)	1º in yaw, 0.50º in pitch & roll at 25º C
Angular Resolution	0.01º RMS
Update Rate	180 Hz
Range*	100 ft. (30 meters) with Class 1 Receiver typical 10 ft. (3 meters) with Class 2 Receiver typical
Typical Average Latency*	40 ms (Bluetooth® dependent)
Wireless Interface	Bluetooth Class 1
Size	2.38 in. x 2.00 in. x 1.25 in. (60 mm x 54 mm x 32 mm)
Weight	2.40 ounces (67 grams)
Charging Power Supply	5V DC, 2A (included - specify country)
Operating Temp. Range	0º to 50º C
O/S Compatibility	.dll for Windows 7/Vista/XP .dylib for Mac OS X .so for Linux
Software Support	SDK with full InterSense API

** Performance may vary depending on wireless environment, operating system and Bluetooth adapter.*

2.2 Connection Scheme

The InertiaCube BT connects via Bluetooth through a virtual COM port. The Bluetooth adapter/software must support the Serial Port Profile (SPP) to enable this connectivity.

2.3 Compatibility

The InterSense InertiaCube BT is PC compatible with Windows 7, Vista, and XP. Third party software using the standard InterSense .dll (isense.dll) is also supported. Please check with third party software providers or InterSense (techsupport@intersense.com) about specific software compatibility and support.

InterSense provides support for Linux operating systems (using glibc 2.3.6 and higher) with a shared object library (.so) file included on the InterSense product CD.

InterSense provides support for Mac OS X operating systems (10.4 and higher) with a dynamic library (.dylib) file included on the InterSense product CD.

2.4 Software

Test software and the InterSense Software Development Kit (SDK) delivered with the InertiaCube BT are provided on the InterSense Support CD with the system. Use the auto install tool to extract and install the software.

The following software and drivers are installed from the InterSense Support CD:

1. In the core of all InterSense software is isense.dll which is installed in the Windows system directory.

2. Isdemo32.exe is installed in the InterSense\Programs folder. It provides a convenient graphical interface for testing and configuring the tracker.
3. InterSense Server Application (IServer.exe) provides multiple services to applications requiring tracker data. IServer runs in the system tray, reading the data from the connected devices at the maximum speed allowed by the operating system. That data is then made available to other applications that use the InterSense DLL to communicate with the tracker. This allows multiple applications running at the same time to read data from the same tracking device. IServer can also provide mouse emulation, allowing the InertiaCube BT to be interfaced with other applications that can be driven by the mouse.
4. InterSense SDK sample programs and instructions. The SDK folder contains InterSense libraries for Window, Linux and Mac OS X. Sample code is provided to demonstrate the SDK use with the C/C++, C#, and Visual Basic languages (all languages use the standard C-based DLL/library).

Please see the documentation on the InterSense Support CD for details.

2.5 Setting up the Hardware

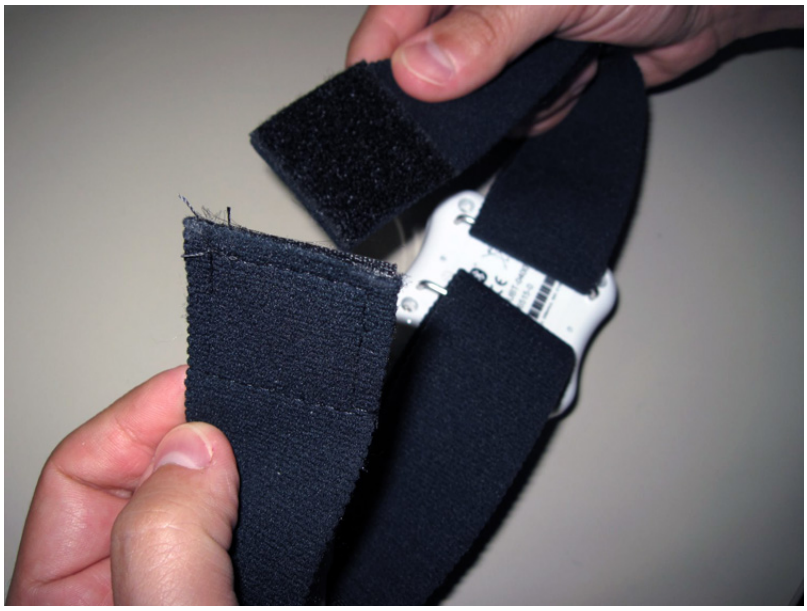
2.5.1 InertiaCube BT placement

The shape of the InertiaCube BT is designed for mounting to a lower or upper extremity (arm/leg). The (2) fabric straps included with the sensor allow you to attach the sensor to the body segment you wish to analyze.

Attach each fabric strap to the metal bracket on the underside of the sensor. You can determine the length of the strap by adjusting accordingly.

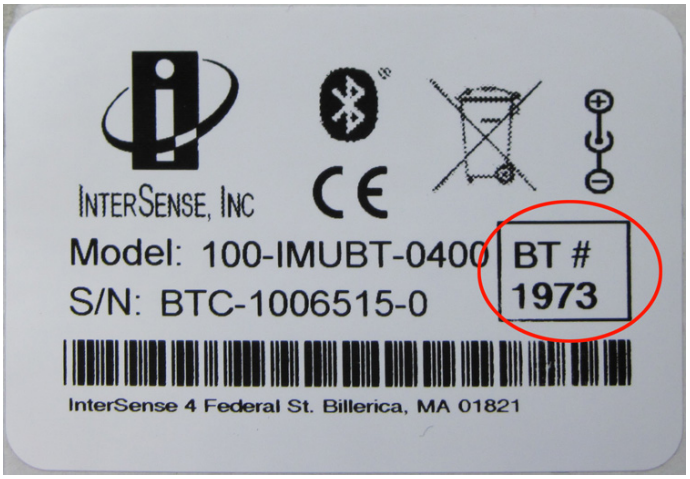
Below is an image with both straps attached.

To secure to a body segment, attach the Velcro as pictured.



2.5.2 Connecting InertiaCube BT to Bluetooth receiver

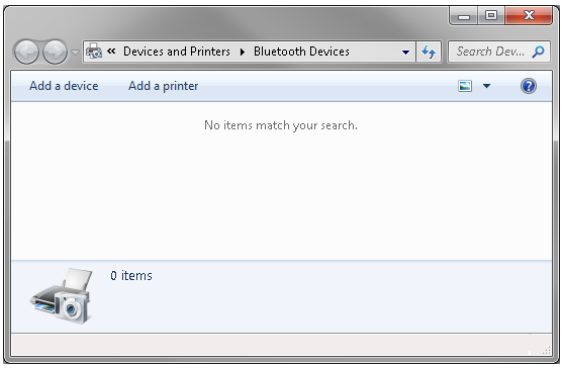
Note the "BT #" identification number on the InertiaCube BT label. You can refer to this number to easily identify the sensor when associating and working with their configurations in the operating system. The number is encoded into the hardware ID and readable name of the InertiaCube BT (in the example below, "InertiaCubeBT-1973").



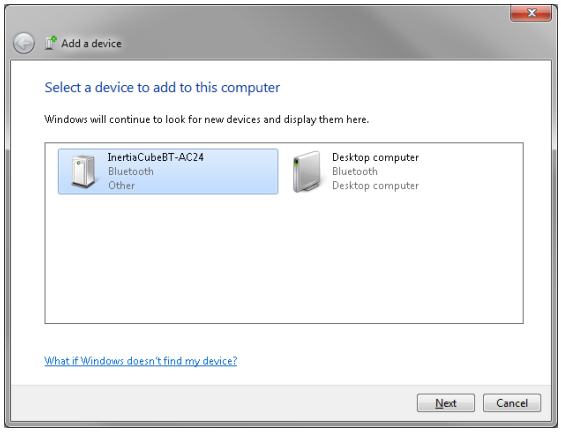
2.5.2.1 Windows 7 Bluetooth Connection

Bluetooth system tray icon:

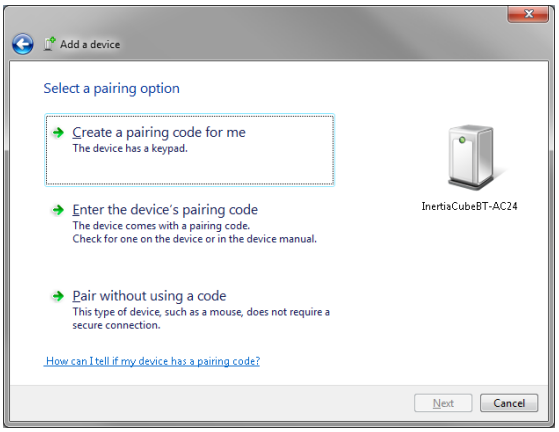
1) After double-clicking on system tray icon:



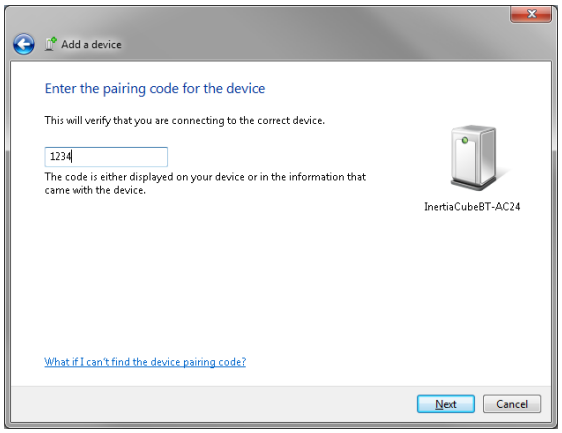
2) Clicking ‘Add a device’



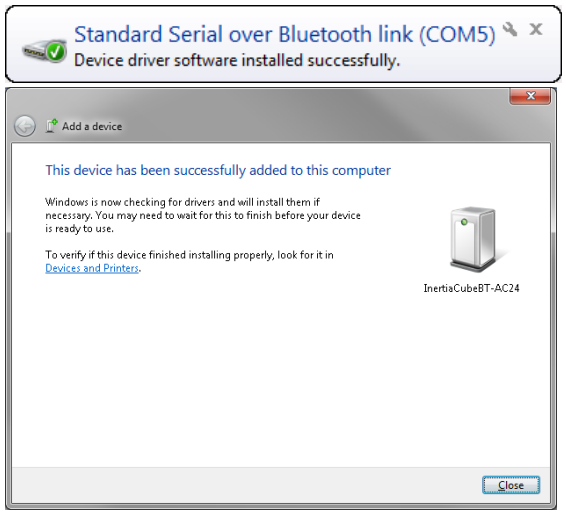
3) Clicking ‘Next’:



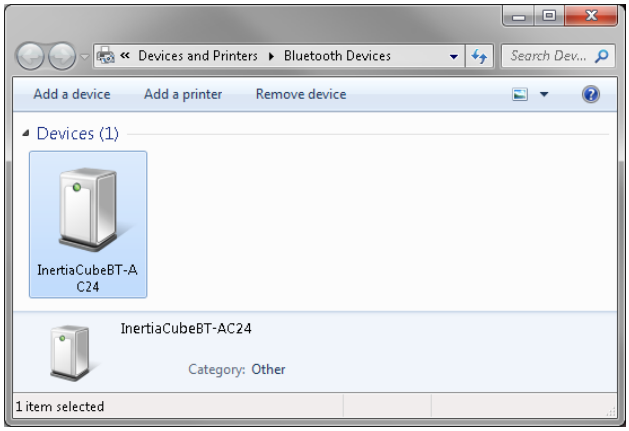
4) After selecting ‘Enter the device’s pairing code’ and clicking ‘Next’, with the default 1234 code entered (needs to be entered within 60 seconds or you’ll get a failure and need to retry):



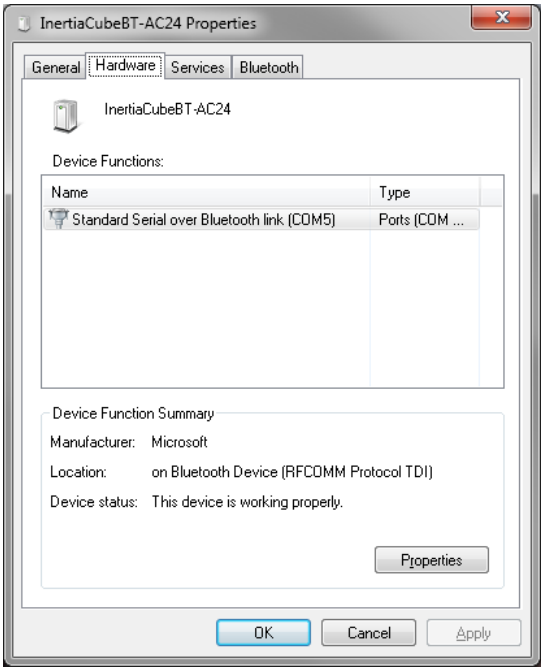
Success balloon showing COM port assigned (lower right corner), and result dialog:



5) Double-click icon once installed.



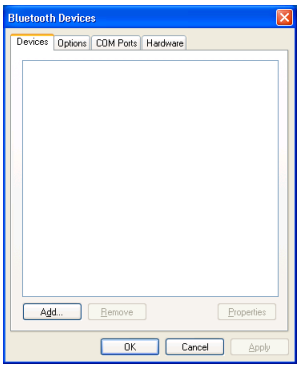
6) Right-click to show properties. Choose the 'Hardware' tab to show COM port.



2.5.2.2 Windows XP Bluetooth Connection

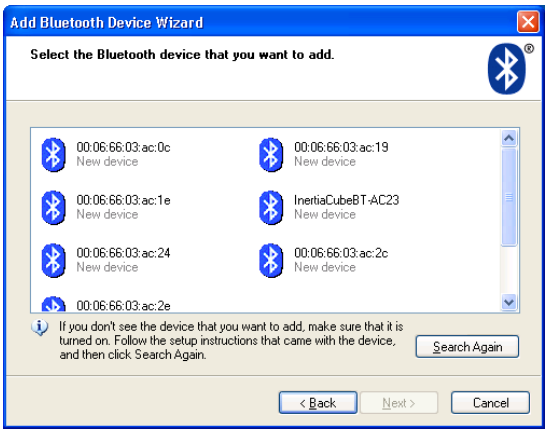
Bluetooth system tray icon:

7) After double-clicking on system tray icon:

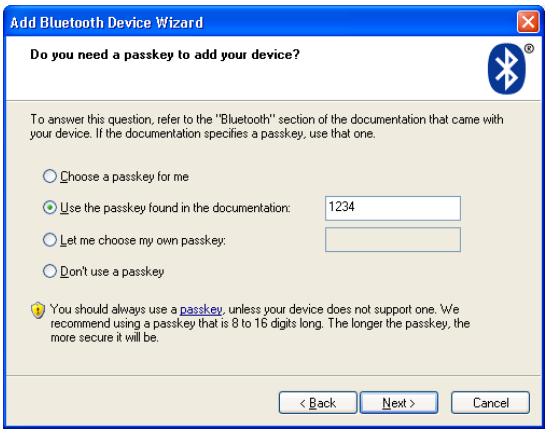


8) Click 'Add…'

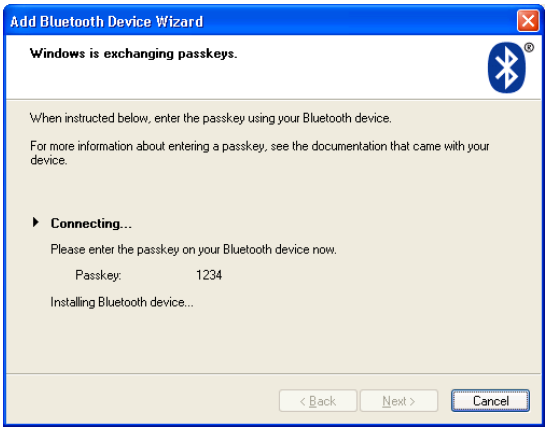
9) Clicking 'Next':



10) Select the desired device and click ‘Next’. You will need to ‘Use the passkey found in the documentation’, input the default code 1 2 3 4 and choose ‘Next’. This needs to be entered within 60 seconds or you’ll get a failure and need to retry.



11) Windows will now attempt to validate the connection.



12) When complete you will see the following Window display the COM port assignments. The OUTGOING COM port is what will be needed for the 'isports.ini' to communication to the InertiaCube BT.

2.5.2.3 Linux Bluetooth Connection

These instructions apply to Fedora 12, and should be fairly similar for all distributions.

(1) Turn on your InertiaCube BT device(s)

(2) Plug in USB adapter, verify it was detected using **lsusb** or similar (if you have a built in adapter, it may be listed by **lspci** instead)

(3) Run: **hcitool scan**, and you will get results such as:

```
Scanning ...
    00:06:66:03:AC:44       InertiaCubeBT-AC44
    00:06:66:03:AC:0C       InertiaCubeBT-AC0C
    00:06:66:03:AC:23       InertiaCubeBT-AC23
    00:06:66:03:AC:19       InertiaCubeBT-AC19
```

These results list the hardware addresses and names of any InertiaCube BT sensors found. Note that the last 4 digits will match a label on the InertiaCube BT.

(4) Run: **rfcomm bind <dev> [bdaddr]** (as root), for example:
   a. **sudo rfcomm bind rfcomm0 00:06:66:03:AC:0C**

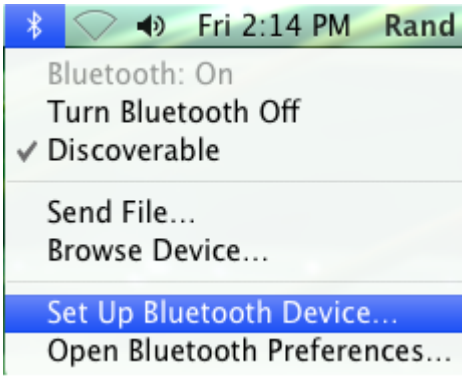
(5) Verify permissions on the created device (your user must be in the group or otherwise have "rw" permissions to the device, which will be created in /dev)

(6) Add the newly bound device to the **isports.ini** file with ":bluetooth" appended, for example:
    a. **Port1 = /dev/rfcomm0:bluetooth**

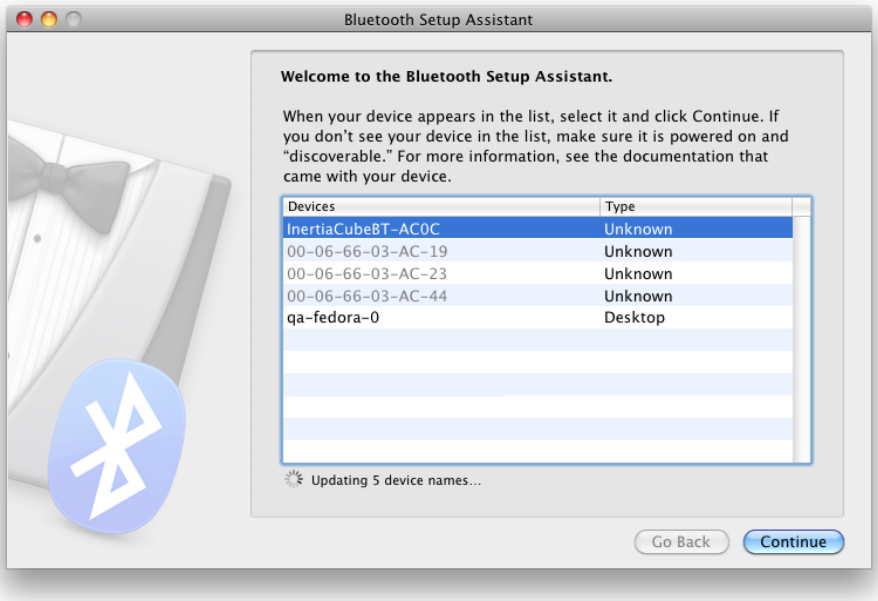
(7) Your device is now ready to use.

2.5.2.4 Mac OS X Bluetooth Connection

(1) With a Bluetooth adapter attached to your Mac or using the internal adapter, and Bluetooth enabled, choose **Set Up Bluetooth Device…** from the Bluetooth symbol on the top right of your screen. If Bluetooth is disabled, you need to turn it on from this menu before proceeding.

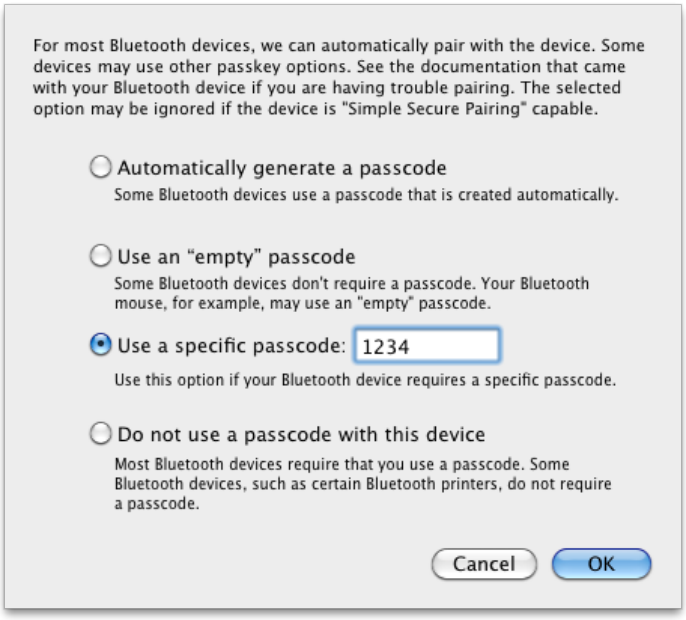


(2) A dialog will open showing the Bluetooth devices. These will initially appear as hardware addresses (numeric, in gray), but will then be updated with the actual device names (such as "InertiaCubeBT-AC0C" as they are discovered. The last 4 digits will match a label on the corresponding InertiaCube BT:



(3) With one of the devices selected, choose **Continue**, at which point it will prompt you for a passcode (if it does not, please power-cycle the InertiaCube BT and try again):

(4) Choose **Passcode Options…** and on the dialog that appears, enter **1234** as the code, under **Use a specific passcode:**



(5) Press **OK**, then **Continue** on the *Bluetooth Setup Assistant* dialog, and the Assistant will connect to the InertiaCube BT:

(6) Successful pairing should look like this:

(7) Add the newly bound device to the **isports.ini** file with ":bluetooth" appended, for example. The device will be created in /dev and will be named **tty.[btname]-SPP** where *btname* is derived from the sensor name; for example:

   a. **Port1 = /dev/tty.InertiaCubeBT-AC0C-SPP:bluetooth**

(8) Your device is now ready to use.

2.5.3 'ISPORTS.INI' File

The InertiaCube BT requires a configuration file called **isports.ini** in order to be detected by the InterSense DLL (library). A sample file has been provided in the Programs directory and will be used by the *InterSense Server* and *ISDEMO* applications. This file contains entries such as:

```
Port1=COM1:bluetooth
Port2=COM2:bluetooth
…
```

For optimal detection speed, you should modify this file to contain only the *outgoing* COM ports used on your system associated with the InertiaCube BT sensors, a process known as "pairing". Outgoing COM ports are the ports used by Bluetooth to initiate communication from the PC to the device. Failure to perform this step may result in much slower detection, or no detection if the COM ports assigned by Windows (or your Bluetooth stack) are higher than COM32 (the maximum COM port listed in the file and recognized by ISDEMO). With a properly configured file, detection times should generally be in the range of 4-6 seconds per sensor.

For developing your own applications, or running an application outside of the Programs directory, you can either copy the **isports.ini** file or place it in a more general location. In addition to searching the current working directory for **isports.ini**, the DLL also searches:

(1) The **ISPORTS_INI_DIR** environment variable (all platforms)
    a. May require a restart or logout to take effect depending on OS and how it is set
(2) **The application's working directory** (all platforms)
(3) **C:\dev** (Windows only)
(4) **C:** (Windows only)

These paths are searched in that order.

Additionally, if the InertiaCube BT sensors are paired with one PC or adapter, they must be paired again when used with another PC or another adapter, even if the operating system seems to indicate they are already authenticated. Failure to perform this step may result in failure to detect the InertiaCube BT sensors.

3 ISDEMO: Testing the InertiaCube BT

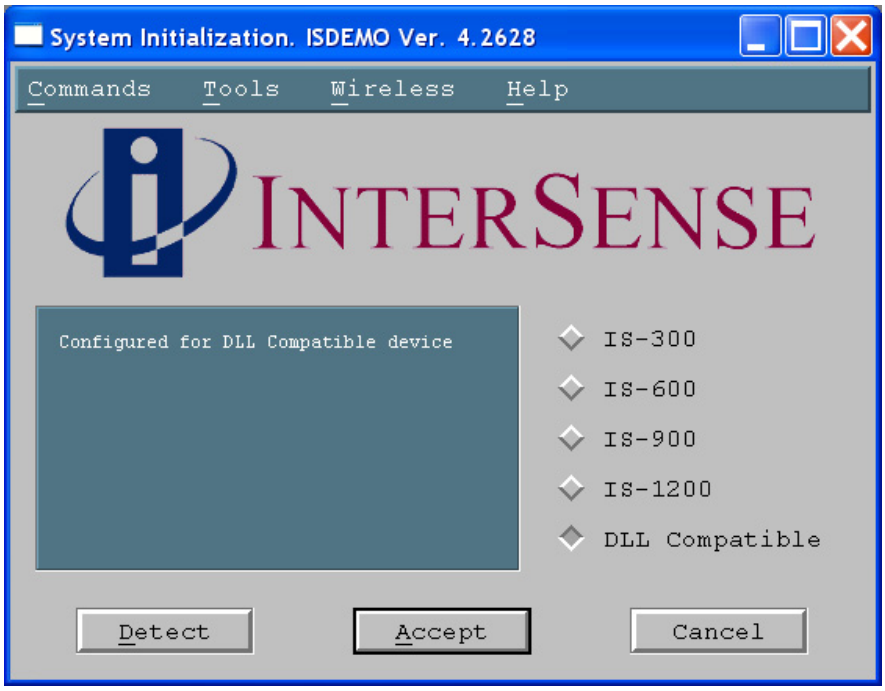
ISDEMO is included as a test and diagnostics tool. With it you can test all the features of your tracker. At the time of this publication, the latest release of ISDEMO is version 4.2628. Please check with www.intersense.com/support to keep your version of ISDEMO up to date.

ISDEMO provides a convenient graphical interface to validate the communication of the InertiaCube BT to the PC and test performance through the standard InterSense DLL. See Section 4, Developers Instructions, to learn how to interface the InertiaCube BT to software applications.

3.1 Using ISDEMO

The first screen you'll see is the hardware selection window (shown below). The program creates a different interface depending on the tracker model selected. Select the *DLL Compatible* option and click *ACCEPT*.

Note: You must select DLL Compatible, or ISDEMO will not be able to correctly configure your tracker.



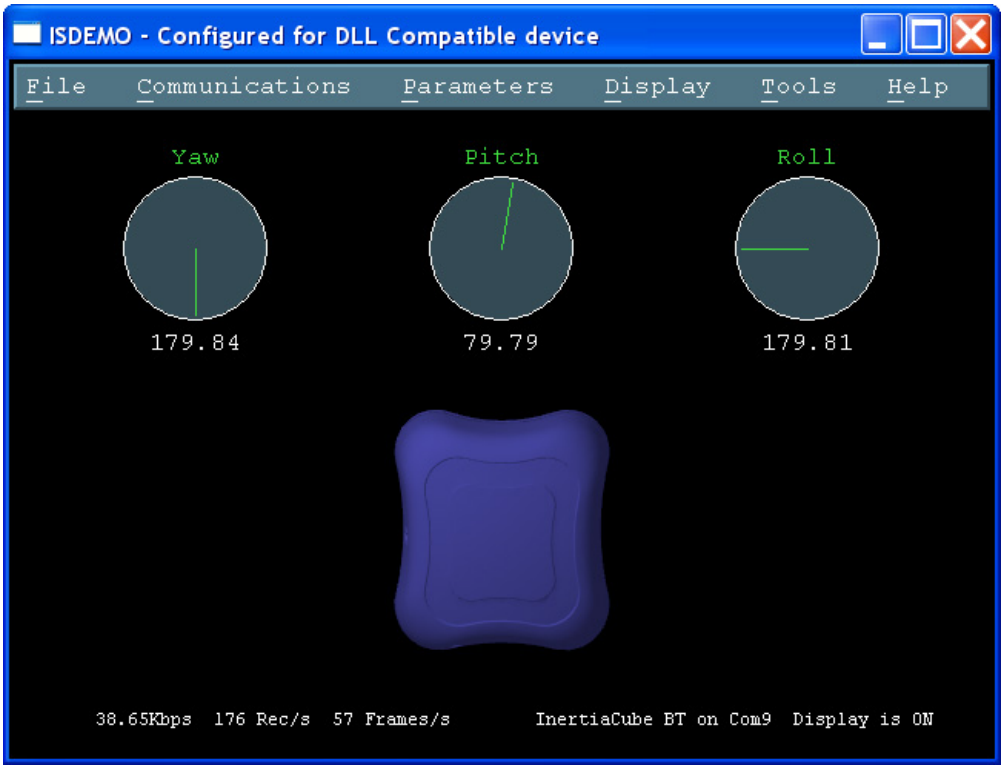
DLL Compatible

DLL compatible trackers include all of InterSense's tracking systems that use software applications programmed to the InterSense API which call functions through the InterSense DLL. Some InterSense trackers, like the InertiaCube BT, are only DLL compatible. The InterSense precision line of trackers (IS-900, IS-1200) can interface either directly through a serial port or via the DLL.

3.2 ISDEMO: Main window

ISDEMO has six primary menus in its main window:

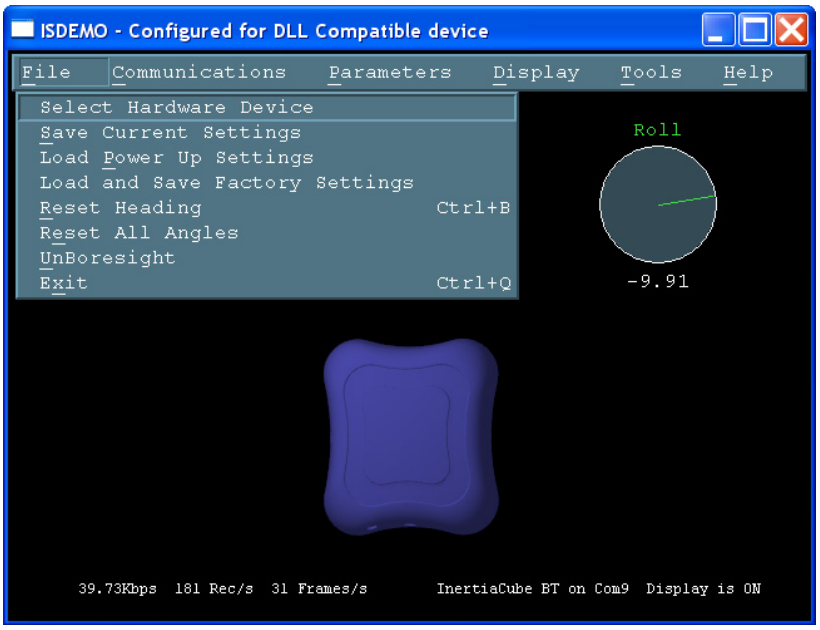
File
Communications
Parameters
Display
Tools
Help



3.3 File options

The *File* menu provides you with the following options:

Select Hardware Device
Save Current Settings
Load Power Up Settings
Load and Save Factory Settings
Reset Heading (Ctrl+B)
Reset All Angles
UnBoresight
Exit (Ctrl+Q)



Select Hardware Device — *System Initialization* window (also seen at initial start-up) is shown when *Select Hardware Device* is selected. Use this window to select or detect the tracker model connected to your computer.

Save Current Settings — Saves current settings to a file in the windows directory. The next time the tracker is turned on these settings will be restored.

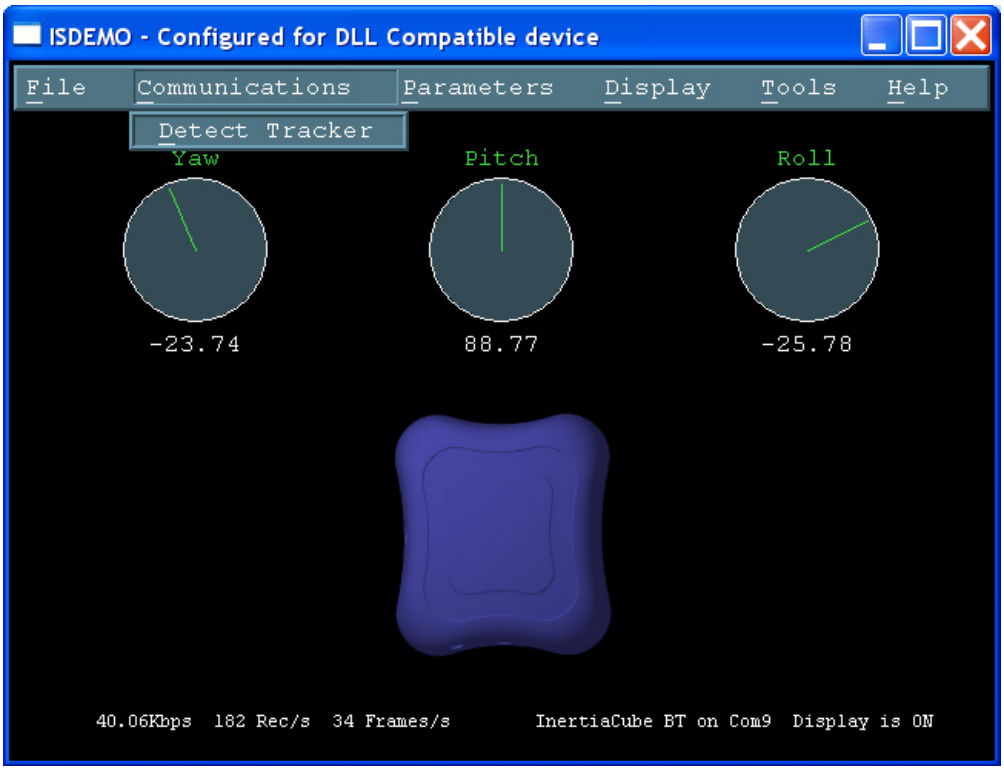
Load Power Up Settings — Restores the InertiaCube settings to those present when you first powered up the tracker. All changes made to the settings since power up are lost.

Load and Save Factory Settings
This restores the system settings to the factory defaults.

Reset Heading	Resets the current heading to zero. Also known as a heading boresight.
Reset All Angles	Resets all three angles to zero. Also known as full boresight.
UnBoresight	Sets all boresight settings to factory default.
Exit	Exits ISDEMO

3.4 Communications options

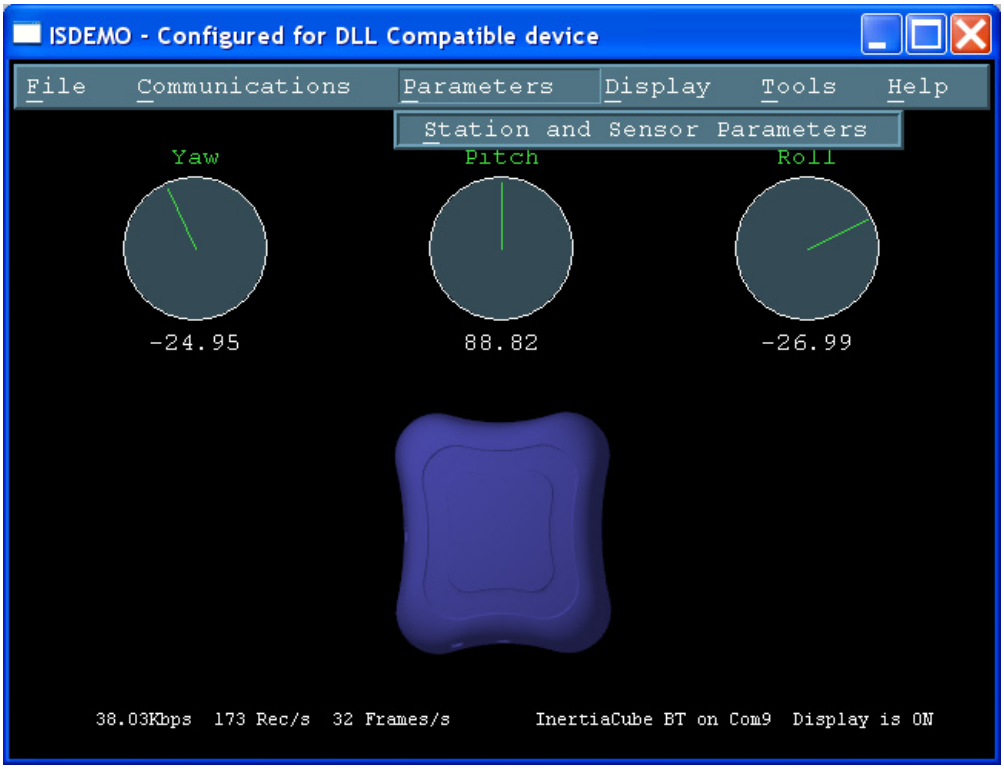
This menu item will connect the tracker through the DLL. The DLL will automatically detect an InterSense tracker connect to COM ports 1 through 32 on the PC. The baud rate of the InertiaCube BT is fixed at 115,200 baud. The first two rates (kbps and records/s) displayed at the bottom of the window show the InertiaCube BT update rates. The third rate (frames/s) shows the graphics update rate based on the PC's hardware configuration.



Detect Tracker Will reinitialize the DLL and detect the connected tracking device(s).

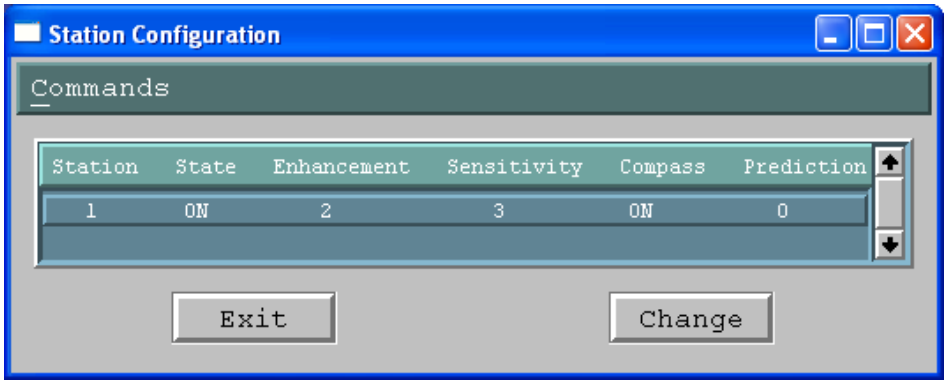
3.5 Parameter options

Parameters menu gives you access to the tracker configuration controls.



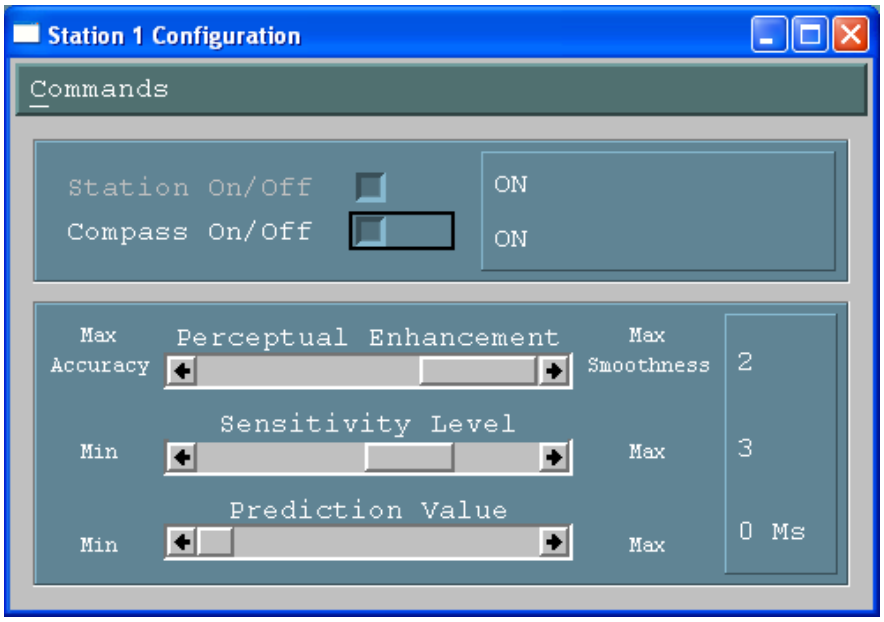
Station and Sensor Parameters

The window shown below allows you to configure the InertiaCube BT.



Double clicking on the Station line or clicking the Change button will bring up the Station Configuration window where changes can be made.

Station Configuration window



Station ON/OFF The station is always ON and data records will be sent continuously. The InertiaCube BT can not be turned off.

Compass This controls the state of the compass component of the InertiaCube BT. When compass is ON, the readings produced by the magnetometers inside the InertiaCube BT are used as the absolute reference orientation for yaw. Metallic objects and electronic equipment in close proximity to the InertiaCube can affect the magnetometers. If compass is OFF, no heading compensation is applied.

Perceptual Enhancement Level

In order to provide the best performance for a large range of applications, three levels of perceptual enhancement are available. None of the modes introduce any additional latency.

Mode 0 provides the best accuracy. The InertiaCube BT uses gyros to measure angular rotation rates for computing the sensor's orientation. To compensate for the drift, the tracker uses accelerometers to measure the actual physical position and orientation of the sensor. That data is then used to compute the necessary correction. In Mode 0 correction adjustments are made immediately, no jitter reduction algorithms are used. This results in most accurate output (not recommended for head tracking) with lower RMS error. Use this mode for accuracy testing or for any application that requires best accuracy.

Mode 1 provides accuracy similar to that of mode 0, with the

addition of a jitter reduction algorithm. This algorithm reduces the accuracy by only a small amount and does not add any latency to the measurements. Mode 1 is recommended for augmented reality applications (i.e. overlaying or mixing both virtual and real objects in a visualization system.)

Mode 2 is recommended for use with HMD or other immersive applications. The drift correction adjustments are made smoothly and only while the sensor is moving, so as to be transparent to the user. Very slow rotational movements may not be detected when using this mode, depending on the Sensitivity level.

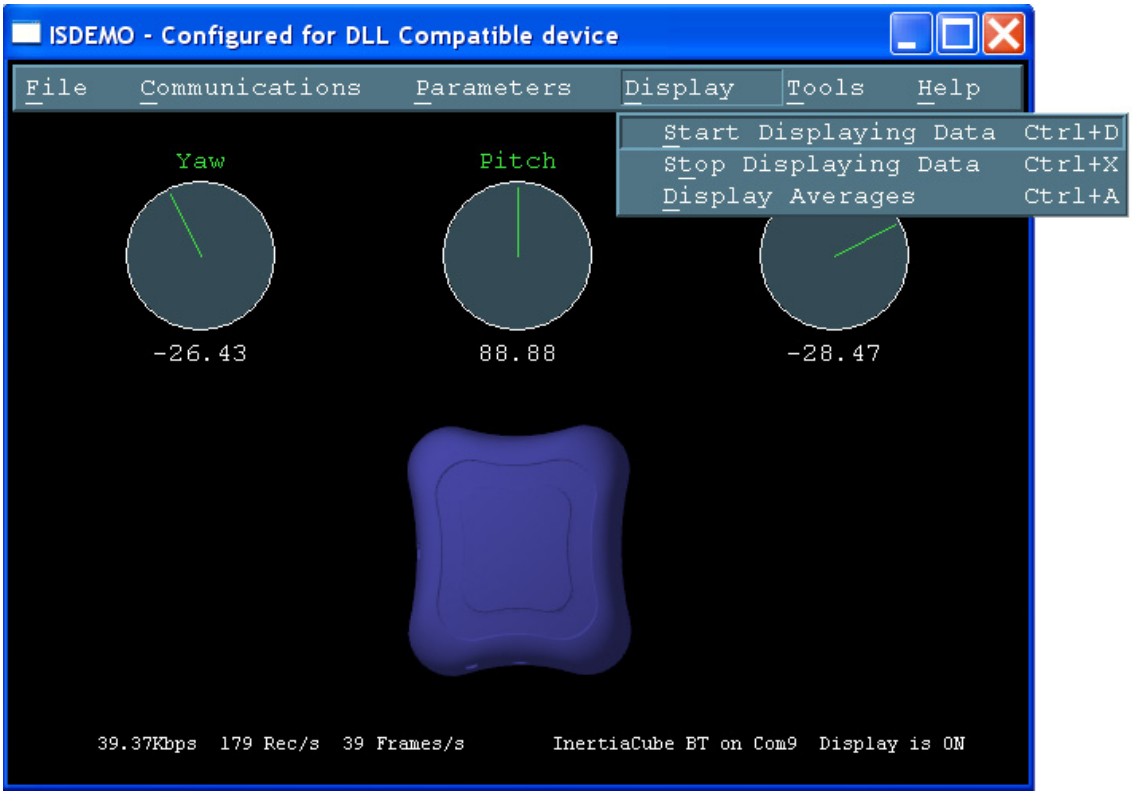
Sensitivity Level

This setting applies when Perceptual Enhancement Level is set to 1 or 2. It controls the minimum angular rotation rate picked up by the InertiaCube. Default is level 3. Increasing sensitivity does not increase latency during normal movements. It may, however, result in some small residual movements for a couple of seconds after the sensor has stopped. If your application requires sensitivity greater than the maximum provided by this control, you must use Perceptual Enhancement level 0 or 1 instead.

Prediction Value

The InertiaCube BT can predict motion up to 50 ms into the future, which compensates for graphics rendering delays and further contributes to eliminating simulator lag.

3.6 Display Options



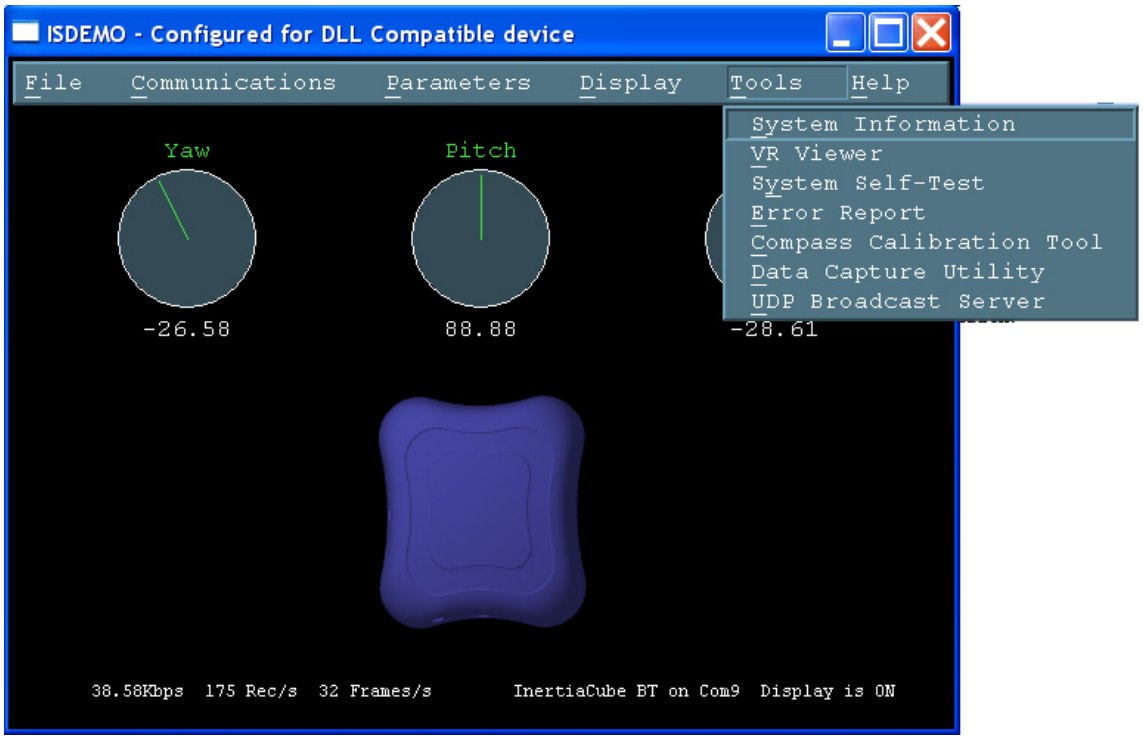
Start (and Stop) Displaying Data

To display orientation data being received from the tracker, use the *Start Displaying Data* option in the *Display* menu or press Ctrl-D.

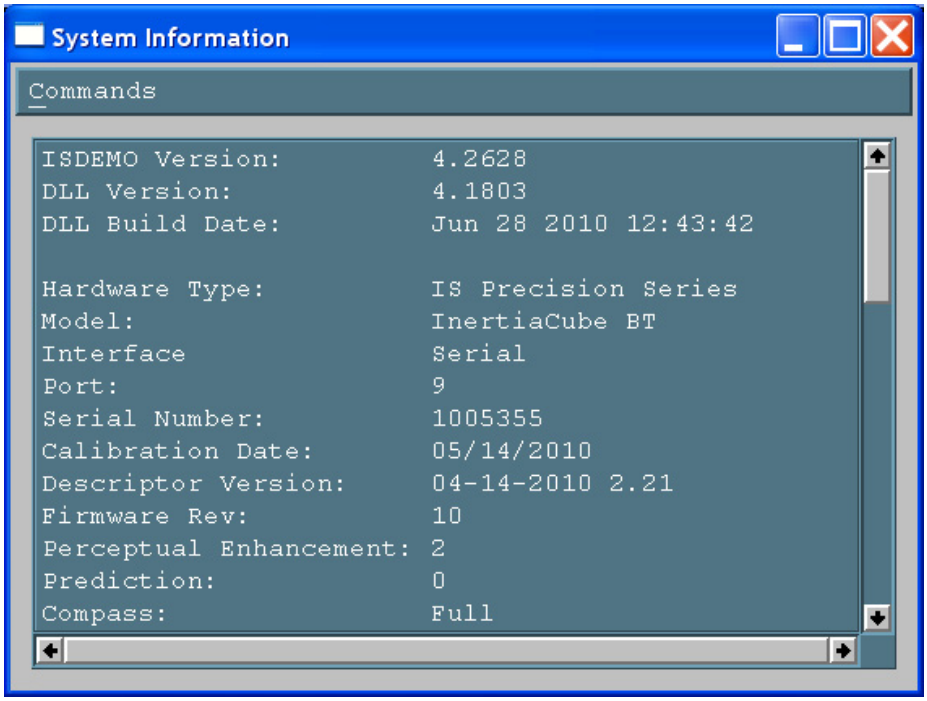
Display Averages

This will display average data collected after the display is turned on, in parentheses after the current values. To reset, stop and start displaying data or press the Space bar on the keyboard.

3.7 Tools Options

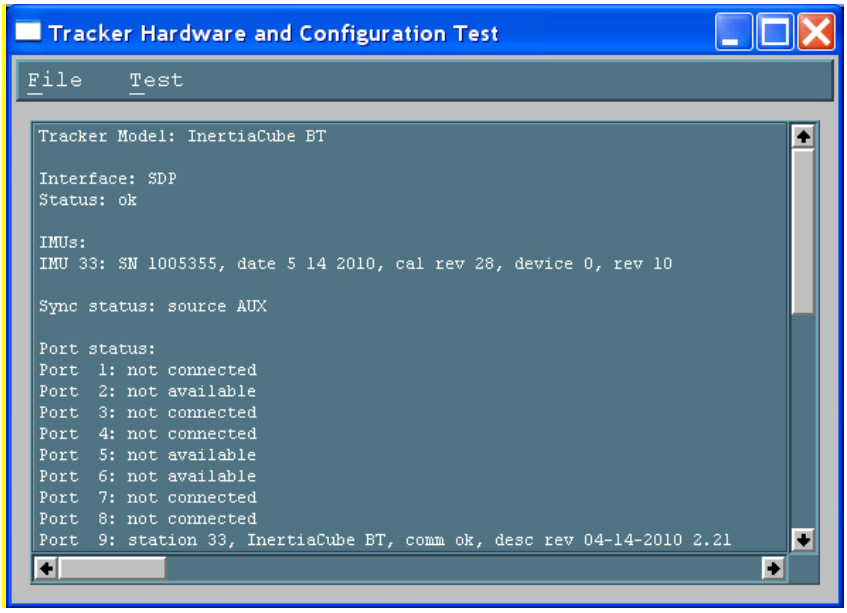


System Information This window provides a summary of the InterSense tracker hardware and software configuration



VR Viewer The VR Viewer is an example that provides a view of the sensor's orientation from the origin looking out.

System Self Test Its purpose is to detect and display information on all the connected hardware and compare it to the user configuration to evaluate it for errors. This tool was primarily designed for troubleshooting the system when hardware failure is suspected.

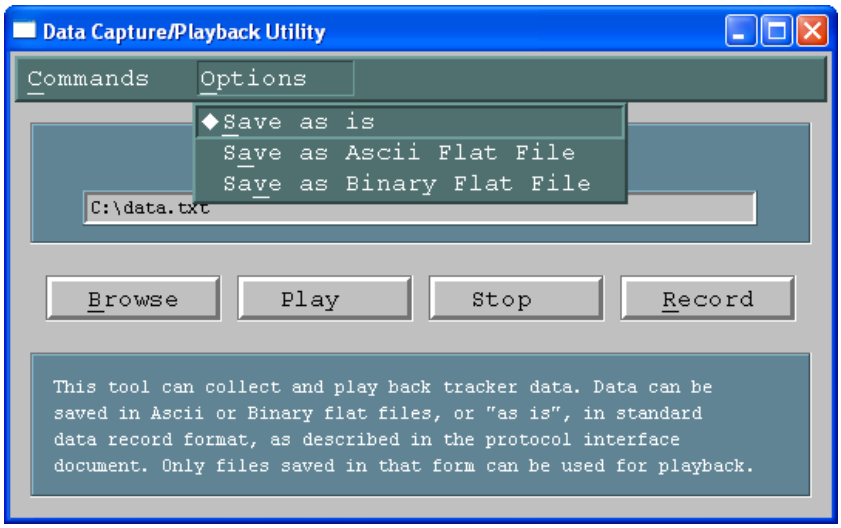


Error Report

Compass Calibration Tool See Section 3.8 for detailed explanation of this tool.

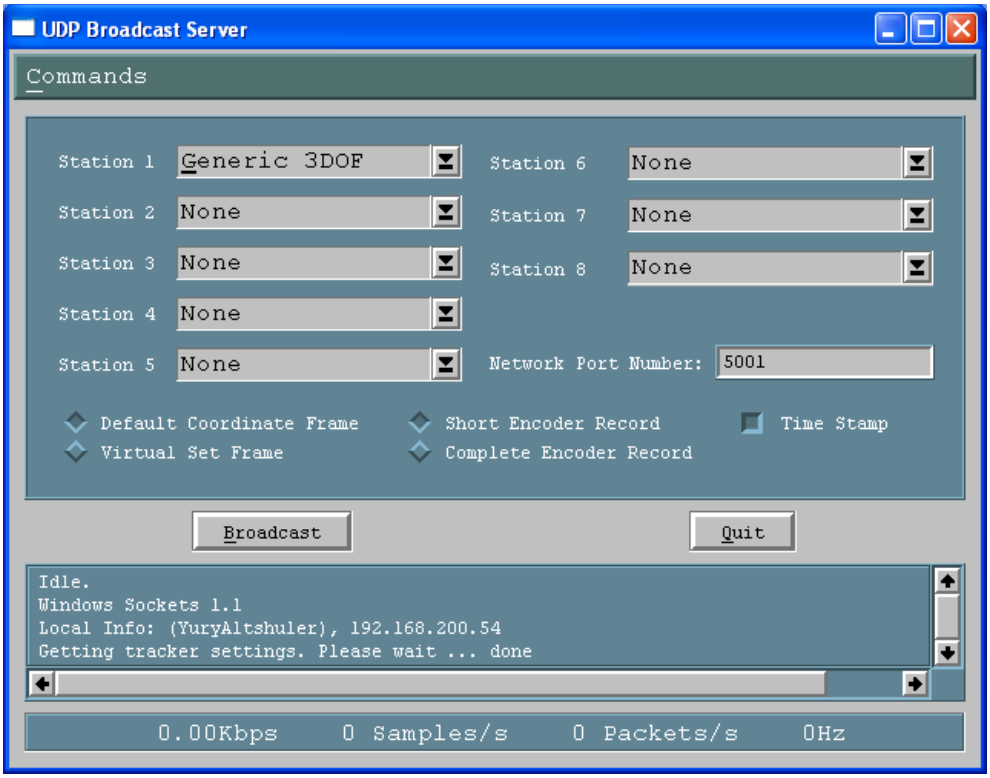
Data Capture/Playback Utility

ISDEMO has the ability to write the data it receives from the tracker to a file. To utilize this feature you must first specify the name and location of the output file. To start data collection, select *Record*. Data can be saved *As Is*, or in an ASCII or binary flat file. When Flat File option is selected, only tracker data is saved, one line per update cycle. To import data to Excel or Matlab the output format must be set to ASCII or the *ASCII Flat file* option must be used. Previously recorded data can be displayed through ISDEMO by selecting *Play*. Playback option will only work on files saved with the *As Is* option.



UDP Broadcast Server

This tool is used to broadcast tracker data over the network using UDP packets. Other machines on the network can run client software that receives this data, using the InterSense library. Please contact technical support for assistance in decoding the UDP data packets in 3rd party software that does not use the InterSense library.



Client software can only receive data, so stations and output records have to be configured here. Depending on

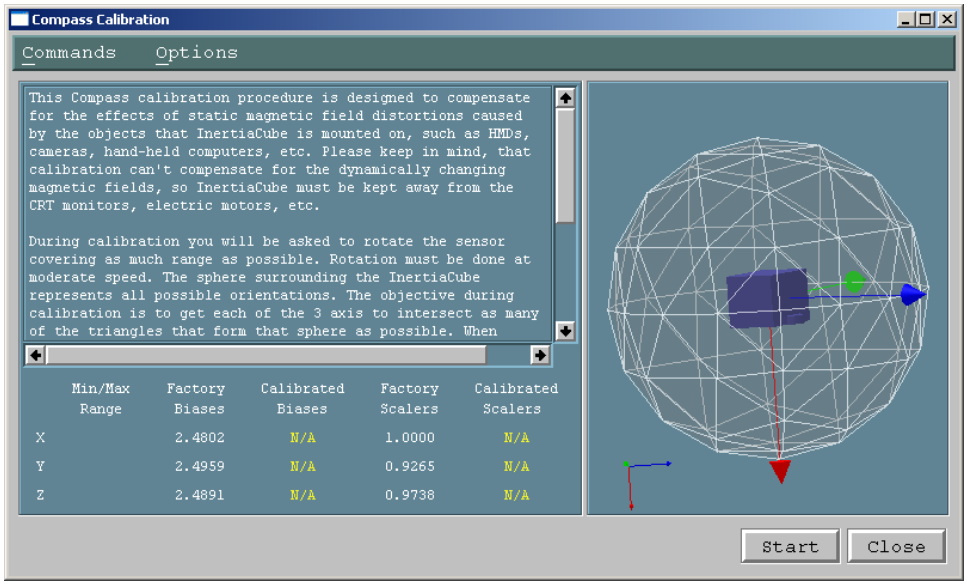
available hardware, select one of the 4 available options for each of the stations:

None	Station is OFF and no data will be received from it.
Generic 3DOF	Only position and orientation data is available. Use this option with the InertiaCube BT
Stylus/Wand	This option is not for use with the InertiaCube BT.
Camera Tracker	This option is not for use with the InertiaCube BT.

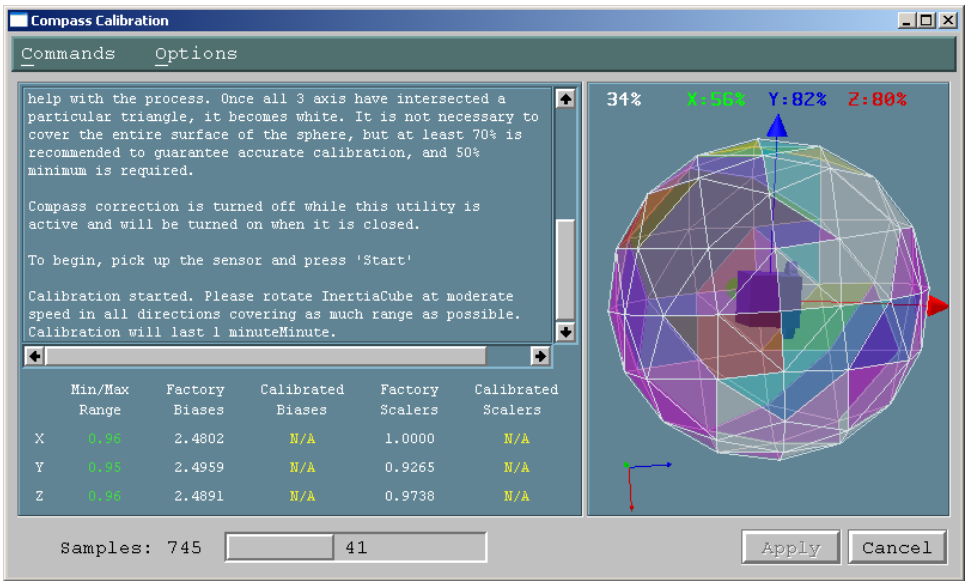
NOTE: A unique Network Port number, not used by any other computer on the network, should be assigned to the server. All client applications, including the ISDEMO, should use that number to receive UDP data. Default is 5001, and should not be changed unless there is a conflict. The InterSense library will automatically detect any data on this port. Also, remember to allow this port through any firewalls that may block outgoing connections on the PC running ISDEMO, or any incoming connections on PCs that will be receiving the data.

3.8 Compass Calibration Tool

Use the compass calibration procedure to compensate for the effects of static magnetic field distortions caused by objects that the InertiaCube BT is mounted on. ***Please keep in mind that this calibration can't compensate for dynamically changing magnetic fields***, so the InertiaCube BT must be kept away from CRT monitors, electric motors, and anything that has a moderate to strong electric current flowing through it.

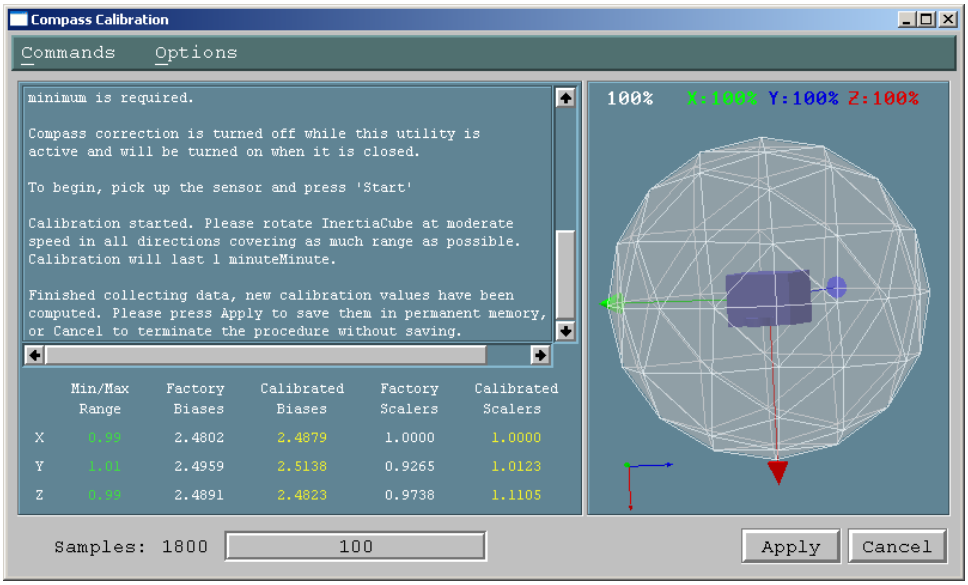


During calibration, you will be asked to rotate the sensor covering as much range as possible. Rotation must be done at moderate speed. The sphere surrounding the InertiaCube BT represents all possible orientations. The objective during calibration is to get each of the 3 axes to intersect as many of the triangles that form that sphere as possible. When a surface triangle in this sphere is intersected, it acquires the color component of the intersecting axis, providing a visual cue to help with the process. Once all 3 axes have intersected a particular surface triangle, it becomes white. It is not necessary to cover the entire surface of the sphere with white during calibration, but at least 70% is recommended to guarantee accurate calibration, and 50% minimum is required. Saving the calibration with less than this will require a confirmation, and may cause your InertiaCube BT to output invalid data until the factory calibration has been restored.



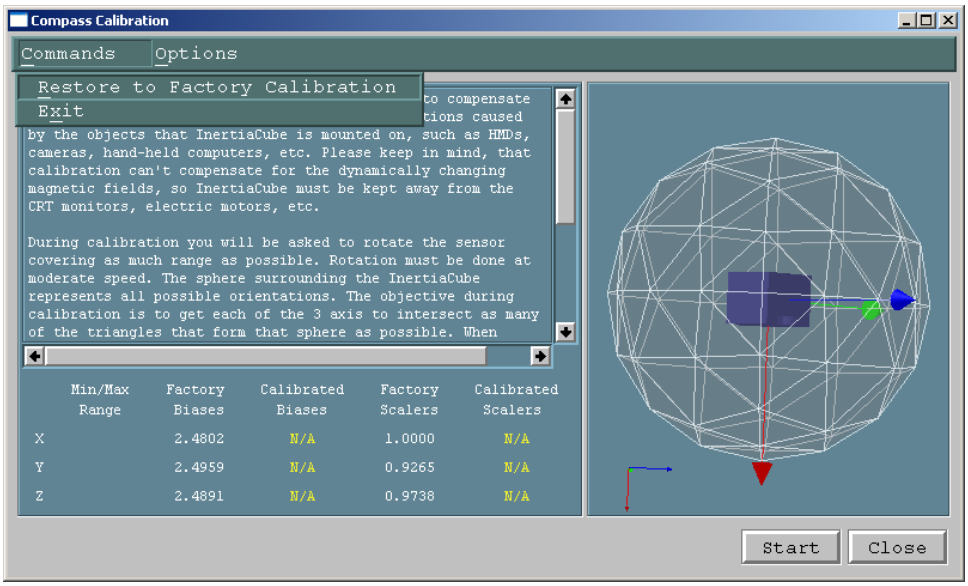
Compass correction is turned off while this utility is active and will be turned on when it is closed.

To begin the compass calibration, pick up the sensor and press 'Start' button. When the calibration is complete, the ‘Start’ button becomes an ‘Apply’ button. The new computed calibrated values are displayed in the window and are applied to the Flash RAM when the ‘Apply’ button is pressed. Press the ‘Cancel’ button to abort the calibration procedure without saving any new values to the Flash RAM in the InertiaCube BT. Once the values are applied, the ‘Apply’ button is replaced with the ‘Start’ button the ‘Cancel’ button is replaced with the ‘Close’ button. ‘Close’ closes the calibration window.



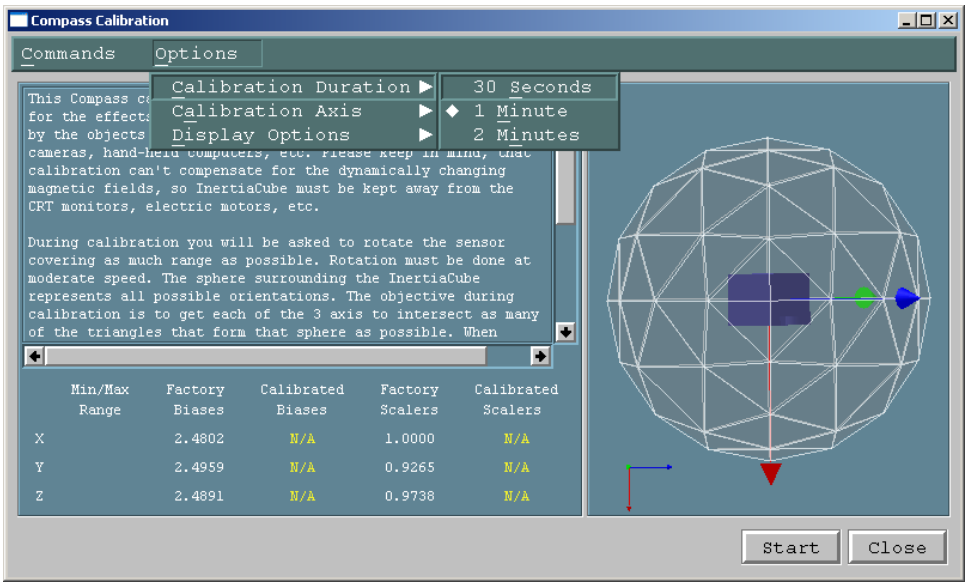
Compass Calibration → Commands

The *Commands → Restore to Factory Calibration* menu provides a way to restore the original factory calibration to the InertiaCube BT. The factory calibrated biases and scalar data, which is stored in Flash RAM, is displayed for each axis in the Compass Calibration window.



Compass Calibration → Options → Calibration Duration

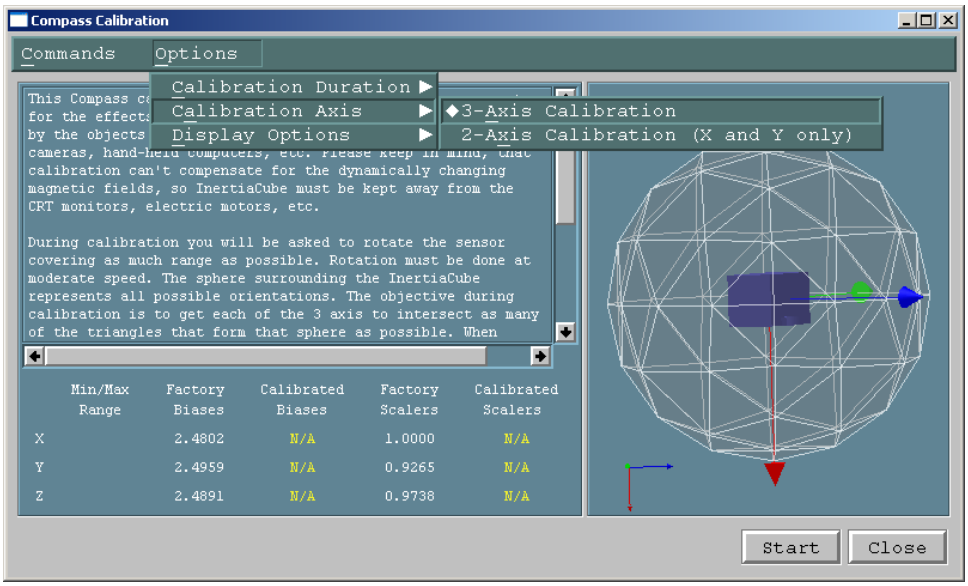
The default calibration process duration is 1 minute, but a longer (2 minutes) or shorter (30 seconds) can be selected.



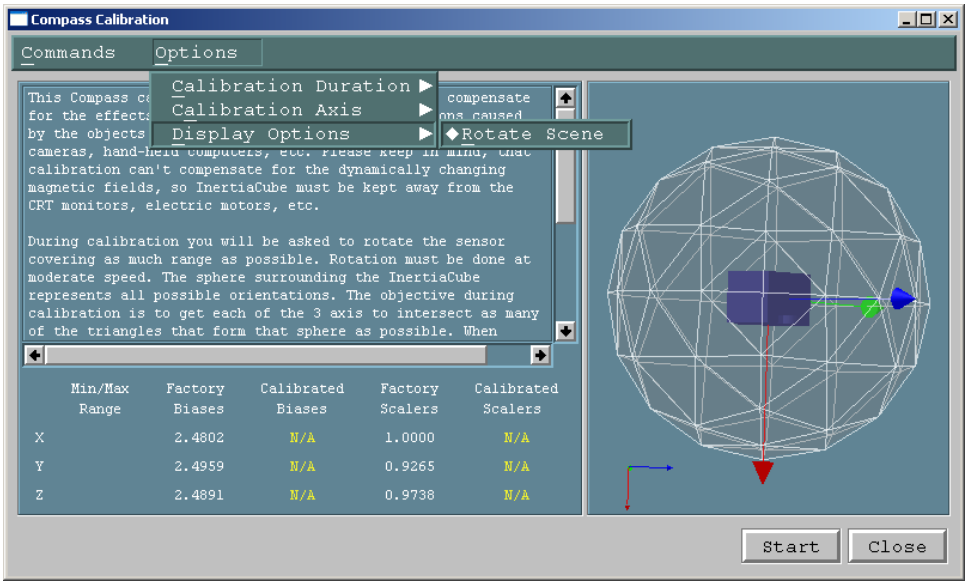
Compass Calibration → Options → Calibration Axis

By default, a full 3-axis magnetometer calibration is performed when selecting the 'Start' button. For special cases where the

mounted InertiaCube BT will only rotate about the z-axis (i.e. on a vehicle) a 2-axis magnetic calibration can be selected.



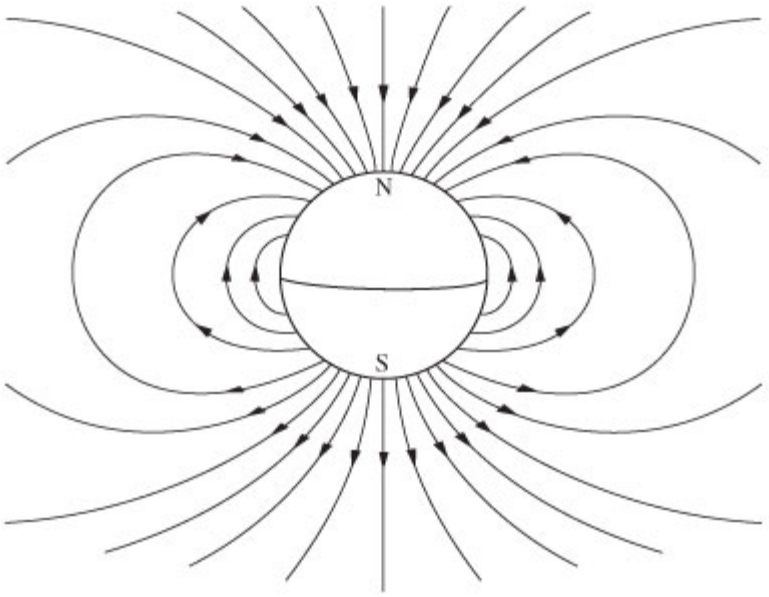
Compass Calibration → Options → Display Options
The *Rotate Scene* display option is selected by default. It keeps the sphere in the window moving with a slight oscillation to allow all of the triangles to be seen during the calibration process.



3.9 Magnetic Environment Calibration Tool

3.9.1 Theory of Operation

The InterSense InertiaCube BT sensors measure the Earth's magnetic field along three perpendicular axes to calculate the direction of magnetic north. This data is used as reference for yaw (heading), and prevents any drift accumulation in the inertial system. As with any compass, local disturbances of the Earth's magnetic field can corrupt data and cause errors in the sensor output. By characterizing and storing normal magnetic field values it is possible to detect such disturbances and prevent them from negatively affecting tracking performance. The Magnetic Environment Calibration Tool was developed to measure the normal magnetic inclination and field strength for a particular environment, store it in permanent sensor memory, and tune how it affects integration of compass data in tracking algorithms.



The Earth's field is closely approximated by the field of a dipole magnet positioned at the centre of the Earth. Magnetic inclination (dip angle) is the angle that the geomagnetic field is tilted with respect to the surface of the earth. Magnetic inclination varies from 90° at the magnetic poles (perpendicular to the surface) to 0° at the magnetic equator (parallel to the surface). The strength of the field at the Earth's surface ranges from less than 0.3 gauss to over 0.6 gauss, depending on the location. Both dip angle and field strength can also be affected by building materials and other sources, therefore calibration will only be valid at the specific location where it was performed.

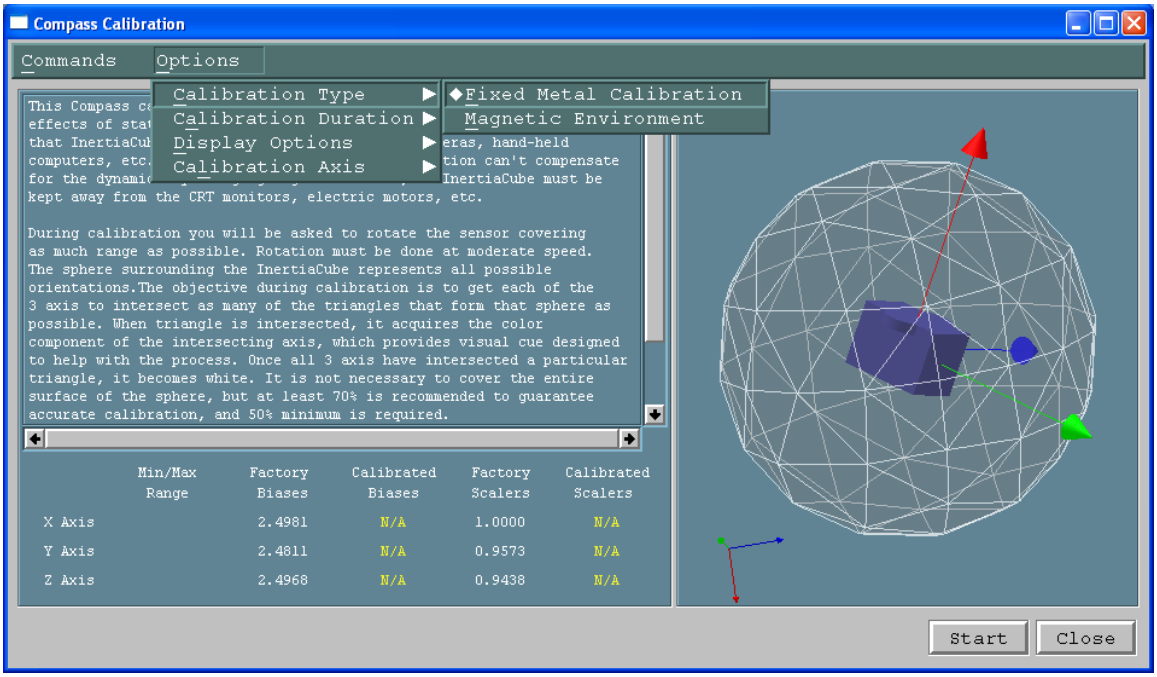
3.9.2 Algorithm

The InterSense 3-DOF tracking algorithm uses Kalman filters to estimate and correct drift and errors based on data from the reference sensors, in this case the magnetometer. The Kalman filters assign "noise" values to the inputs based on the known sensor characteristics and other parameters; discounting the affect of the compass on the output. When nominal values for magnetic field inclination and strength are known it will use them to calculate "quality" of the magnetometer data. This calculation uses tuning parameters and is based on how much the compass data deviates from the calibrated values. When the input falls outside of the range

allowed by the tuning parameters no compass data is used. The system can continue to accurately track orientation using only gyro data until magnetic interference is removed and the compass data can be used again.

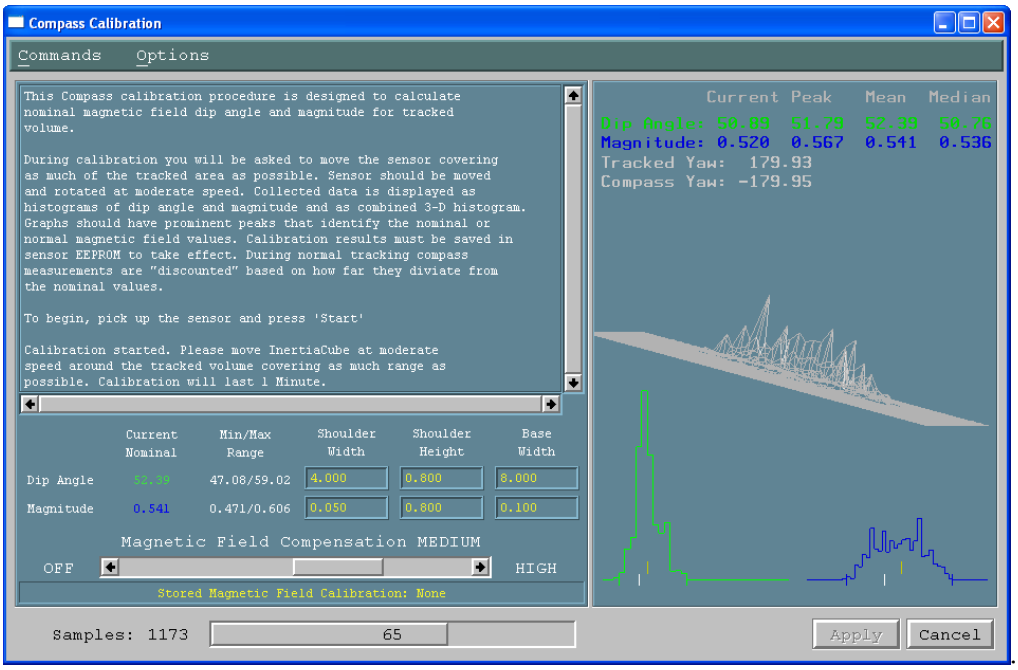
3.9.3 Starting Calibration Procedure

The Calibration Tool is located in the Tools menu of the main ISDemo window. The type of calibration can be selected in from the Options Menu.



3.9.4 Calibration Procedure

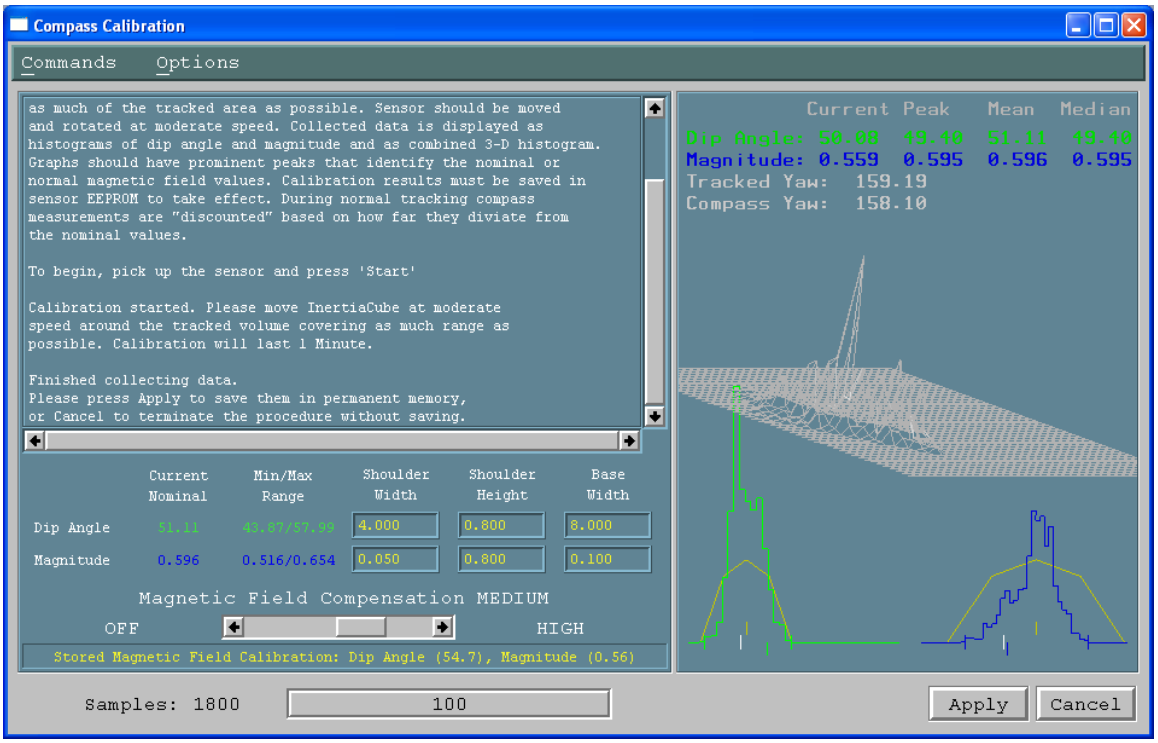
During the calibration procedure, the system collects magnetic field data and displays it in the form of histograms for inclination (dip angle) and field strength (magnitude). A third 3-dimentional histogram is a combination of both data sets, and provides additional visual feedback. The Dip Angle data is displayed in green throughout the interface; Magnitude data is in blue. Tuning parameters and graphs are in yellow.



You can select calibration duration from the Options menu, default is 1 minute. During calibration, the sensor should be moved and rotated at a moderate speed, covering as much of the tracked volume as possible. It should be kept away from any potential sources of magnetic interference, such as metal furniture, electronics, etc. Histograms should have pronounced peaks in order to provide a meaningful calibration; if you have very broad peaks or multiple peaks, you may not have covered a sufficient amount of the area, or you may have strayed near a source of magnetic interference, such as a filing cabinet or steel beam.

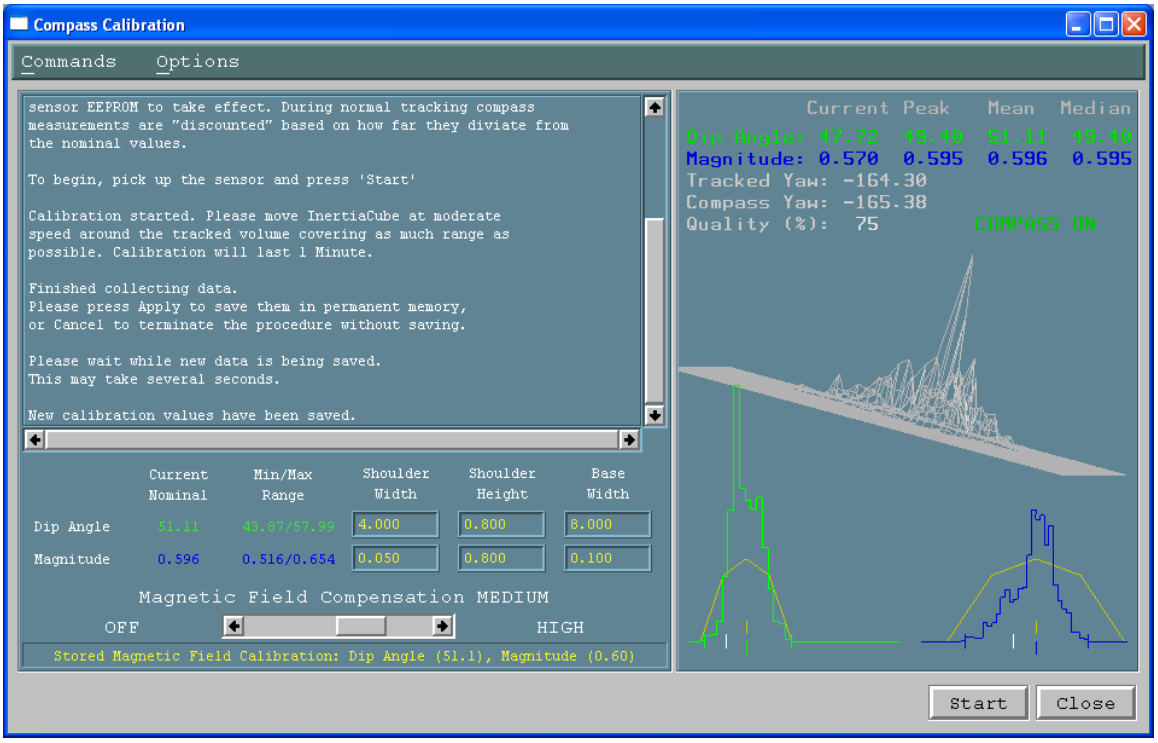
3.9.5 Calibration Results

After the end of the calibration period a new Dip Angle and Magnitude are calculated and can be store in the sensor's EEPROM by pressing the Apply button. The interface is updated and the tuning parameters are displayed in the form of a yellow line, covering what is now considered usable compass data. To adjust the tuning parameters, use the Magnetic Field Compensation slider control at the bottom of the screen.



3.9.6 Testing and Tuning

After calibration data is stored in the sensor's EEPROM, the system will be able to start calculating compass data quality and display it on the screen. It also displays 2 different Yaw values, first is the normal output of the sensor, second is the pure compass yaw as reported by the sensor. By comparing the values when magnetic interference is introduced you can determine the effectiveness of the calibration and select the appropriate Magnetic Field Compensation factor. In a very clean magnetic environment a higher level of compensation may be appropriate. This will guarantee that compass data is heavily discounted whenever data diverges from the stored nominal values. If you expect a lot of interference, a lower value of compensation may be appropriate, allowing for more compass data to be used. The system can track well without the use of compass for some time before any significant drift accumulation. However, it is important to allow the Kalman filter algorithm to use enough compass data to maintain stability and accuracy. The default value is Medium and it works well under most conditions.



4 Developer's Instructions

For InterSense SDK Version 4.0 or higher.

Please refer to the document 'dll_api.pdf' located in the SDK folder for further details, functions, and sample code. This document describes the interface to be used by the application software to initialize and retrieve data from the InterSense devices using the ISENSE.DLL. This dynamic link library is provided to simplify communications with all models of InterSense tracking devices. It can detect, configure, and get data from up to 32 trackers. The DLL maintains compatibility with existing devices, and also makes the applications forward compatible with all future InterSense products (new DLLs may be required, but the application will not need to be recompiled).

4.1 Sample Program

The DLL is distributed with sample programs written in C and C# (for Windows) to demonstrate usage. It includes a header file with data structure definitions and function prototypes. Most of the API description below can also be obtained from the header file.

main.c	Main loop of the program. All API calls are made from here.
isense.c	DLL import procedures. This file is included instead of an import library to provide compatibility with all compilers.
isense.h	Header file containing function prototypes and definitions. This file should not be modified.
types.h	Header file containing data type definitions.

Appendix A – Frequently Asked Questions

Q1. What type of battery is used inside of the InertiaCube BT? How often do they have to be changed?

The InertiaCube BT contains a Lithium Ion battery. A new unit is expected to provide ~8 hours of continuous use. If the battery is no longer holding a charge the unit must be returned to InterSense for repair as opening the sensor will necessitate recalibration.

Q4. What is the MTBF of each component separately?

Based on supplier data, the MTBF for the InertiaCube BT is estimated at 5 years.

Q5. What type of shock can the InertiaCube BT sustain?

These InertiaCube is designed to withstand a maximum acceleration of 500 g. This means that a direct impact on the devices is not recommended. The InertiaCube BTs can withstand a higher level of shock if installed on the inside of an object, or mounted on rubber.

Q7. Do you have any advice about working with software packages?

Consult with the software vendor or contact InterSense techsupport@intersense.com.

Q8. How do I know whether I have the latest release of ISDEMO?

Check our web site, the URL is http://www.intersense.com/downloads.aspx.

Appendix B – Troubleshooting

Problem	Reason/Solution
ISDEMO doesn't work!	Most common reasons (not in any order): 1) Incorrect port settings – verify the correct Bluetooth COM port is listed in the isport.ini file, and includes ":bluetooth" appended to the port name. 2) Not using *Start Displaying Data*. It may be necessary to select *Stop Displaying Data* first. 3) IServer may be running; if IServer is running and the InertiaCube BT sensor(s) was/were turned on after it started, you will need to re-detect them in order to use them in ISDEMO or other DLL-based applications. Alternately, you may exit IServer.
Poor yaw accuracy	Check for the following: 1) Placement directly on top of metal. You should place the InertiaCube an inch or two away, or use the compass calibration tool described in section 3.8. 2) Is the sensor being used near large ferromagnetic objects or near dynamic magnetic fields? The InertiaCube BT cannot function properly with the compass enabled in the presence of significant magnetic field distortions. The environmental calibration can help with temporary positioning near such fields, but the only solution for permanent use near such fields is to disable the compass and use some other method to deal with the accumulated yaw drift over time.
Orientation is drifting uncontrollably	1) Keep InertiaCube BT still for 10 seconds after connecting with ISDEMO or DLL. 2) Compass is turned off in ISDEMO. 3) Hardware may be damaged. Contact technical support. You will be asked to run the tests provided by the Hardware Diagnostics application from our Support / Downloads webpage to gather more information; gathering this information and emailing it to technical support is helpful.

Appendix C – Care and Maintenance

Care and Cleaning

Recommended cleaning materials are the same as those for computers. Antistatic cloths can clean the components and reduce static electricity. Cleaning solutions should be applied to the cloth and not directly on any part of the system components.

Phone & email support

Any questions regarding the care and maintenance of your InertiaCube BT can be handled by phone (781) 541-7624 or by email techsupport@intersense.com.

Returns to InterSense

If you need to return a component to InterSense for replacement or repair, contact InterSense prior to shipment to obtain a Return Authorization (RA) number. When calling, please look on the back of IS-900 Processor to provide the serial number and the serial number of any devices you need to return to help us complete the RA process. To request an RMA please use the link below and follow the instructions:

http://www.intersense.com/rma

Please note that Thales Visionix, Inc. will not be responsible for materials returned without an RMA number clearly marked on the outside of the shipping package.

Battery

Lithium Polymer (internal)