Polaris Vicra User Guide

Revision 6
October 2012

IMPORTANT
Please read this entire document
before attempting to operate
the Polaris Vicra System

Revision Status

Revision Number	Date	Description
1	September 2005	Initial release
2	October 2005	Minor updates
3	March 2008	Major updates Removed Bluetooth information. Added Mac OS X user instructions
4	March 2011	Minor updates Revised FTDI driver information Added Windows 7 information
5	April 2012	Revised software installation instructions for Linux Revised serial number label graphics
6	October 2012	Update Power Supply specifications, standards and Declaration of Conformity to comply with IEC 60601-1 3rd Edition

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Read Me First!

This guide provides detailed information about using the Polaris Vicra® Optical Tracking System. Read this section before continuing with the rest of the guide.

Warnings

Warning! In all NDI documentation, warnings are marked by this symbol. Follow the information in the accompanying paragraph to avoid personal injury.

1. Do not use the Polaris Vicra System in the presence of flammable materials such as anaesthetics, solvents, cleaning agents, and endogenous gases. Flammable materials may ignite, causing personal injury or death.
2. Do not transport or store the Position Sensor outside the recommended storage temperature range, as this may cause the system to go out of calibration. Reliance on data provided by an out of calibration Position Sensor may lead to inaccurate conclusions and may cause personal injury. A calibration procedure must be performed before using the Position Sensor after it has been transported or stored outside the recommended storage temperature range.
3. Do not protect or shield either the Position Sensor or tools with methods not approved by NDI. Non-approved methods will interrupt the optical path and degrade the performance of the system. Reliance on data provided by a Position Sensor without an uninterrupted optical path may lead to inaccurate conclusions. If your application involves personal safety, inaccurate conclusions may result in personal injury.
4. The Polaris Vicra System requires special precautions regarding EMC. It must be installed and put into service in accordance with the EMC information detailed in “Electromagnetic Compatibility” on page 72. Failure to do so may result in personal injury.
5. Radio frequency communications equipment, including portable and mobile devices, may affect the Polaris Vicra System and result in personal injury.
6. Do not use the Polaris Vicra System either adjacent to, or stacked with, other equipment. Check that the Polaris Vicra System is operating normally if it is used either adjacent to, or stacked with, other equipment. Failure to do so may result in personal injury.
7. Do not use cables or accessories other than those listed in this guide. The use of other cables or accessories may result in increased emissions and/or decreased immunity of the Polaris Vicra System and may result in personal injury.
8. Do not incorporate non-NDI components with the Polaris Vicra System. The accuracy of results produced by applications that incorporate non-NDI components with the Polaris Vicra System is unknown. If your application involves personal safety, reliance on these results may result in personal injury.
9. All user maintenance must be done by appropriately trained personnel. Individual components of the Polaris Vicra System contain no user-serviceable parts. Maintenance by untrained personnel may present an electric shock hazard.

10. Do not attempt to bypass the grounding prong on the power cord by using a three-prong to two-prong adapter. The system must be properly grounded to ensure safe operation. Failure to do so presents an electric shock hazard.
11. Do not immerse any part of the Polaris Vicra System or allow fluid to enter the equipment. If fluids enter any part of the system they may damage it and present a risk of personal injury.
12. Do not sterilize the Polaris Vicra Position Sensor as this may cause irreversible damage to its components. Reliance on data provided by a damaged Position Sensor may lead to inaccurate conclusions. If your application involves personal safety, these inaccurate conclusions may result in personal injury.
13. Do not use the Position Sensor without inspecting it for cleanliness and damage both before and during a procedure. Reliance on data provided by an unclean or damaged Position Sensor may lead to inaccurate conclusions. If your application involves personal safety, inaccurate conclusions may result in personal injury.
14. Do not use the Polaris Vicra System for absolute measurements; the system is designed for relative measurements only. Treating measurements as absolute may result in an incorrect interpretation of results. If your application involves personal safety, these incorrect interpretations may result in personal injury.
15. Do not rely on unqualified 3D results for stray markers. There are no built-in checks to determine if the 3D results for stray markers represent real markers, phantom markers or IR interference, so the host application must identify and qualify the reported 3D results for stray markers. Reliance on unqualified 3D data may lead to inaccurate conclusions. If your application involves personal safety, inaccurate conclusions may result in personal injury.
16. When using reply option 0x0800 with the BX or TX command, you must take appropriate action to detect the following events: the tool or marker is out of volume, the bump sensor has been tripped, or the system is outside of the optimal operating temperature range. You must determine whether these events are detrimental to your application. If one or more of the events listed occurs, reply option 0800 enables the system to return data that may lead to inaccurate conclusions and may cause personal injury. See the "*Polaris Application Program Interface Guide*" for details.
17. Do not use a wireless tool whose design does not conform to the Polaris Vicra System's unique geometry constraints. When a Polaris Vicra System attempts to track more than one wireless tool in the measurement volume, these unique geometry constraints ensure that they are distinguishable from each other. Reliance on data produced by two indistinguishable tools can lead to inaccurate conclusions. If your application involves personal safety, these inaccurate conclusions may result in personal injury.
18. Do not use a tool with a tip without first verifying the tip offset. Any application that uses a tool with a tip must provide a means to determine the location of the tip. Reliance on data produced by a tool with an inaccurate tip offset may lead to inaccurate conclusions. If your application involves personal safety, these inaccurate conclusions may result in personal injury.
19. Do not use markers without inspecting them for cleanliness and damage both before and during a procedure. Reliance on data produced by unclean or damaged markers may lead to inaccurate conclusions. If your application involves personal safety, inaccurate conclusions may result in personal injury.

20. Do not obstruct the normal flow of air around the Position Sensor (for example, draping or bagging the Position Sensor). Doing so will affect the Position Sensor's operational environment, possibly beyond its recommended thresholds. Reliance on data provided by a Position Sensor that is outside of recommended thresholds may lead to inaccurate conclusions. If your application involves personal safety, inaccurate conclusions may result in personal injury.
21. Do not use the Polaris Vicra Position Sensor in an MRI environment without first determining the performance, including accuracy, of the Position Sensor in an MRI environment. NDI has not fully validated the Polaris Vicra Position Sensor in an MRI environment. It is unknown whether reliance on data provided by a Position Sensor in an MRI environment may lead to inaccurate conclusions. If your application involves personal safety, reliance on inaccurate conclusions may result in personal injury.
22. Do not connect the Polaris Vicra System to a host computer that is not IEC 60950 and/or IEC 60601 approved. If you connect the system to a non-approved host computer you may increase leakage currents beyond safe limits and cause personal injury.

Cautions

Caution! In all NDI documentation, cautions are marked with the word "Caution!". Follow the information in the accompanying paragraph to avoid damage to equipment.

1. To ship the Polaris Vicra System, repack it in the original containers with all protective packaging. The provided packaging is designed to prevent damage to the equipment.
2. Always place the Position Sensor on a rigid support system. If not supported, the Position Sensor may fall, which may affect the calibration and damage the Position Sensor.
3. Use only 70% isopropanol and a lens cleaning solution formulated for multi-coated lenses (for example, AR66) to clean the Position Sensor. Other fluids may cause damage to the illuminator filters. Do not use any paper products for cleaning. Paper products may cause scratches on the illuminator filters.
4. Do not handle the passive sphere markers with bare hands as this will leave residue from skin that affects the marker's reflectivity. Take care not to drop or scuff the markers, as this also affects the reflectivity of the markers.
5. Do not push or pull connectors in constricted areas.
6. Do not put heavy objects on cable connectors
7. Do not leave cable connectors where they can be damaged, particularly on the floor, where they can easily be stepped on
8. Pull connections apart by gripping the connector. Do not pull them apart by tugging on the cable as this can damage the connecting cable. Never force a connection or a disconnection.

Disclaimers

1. Read the entire "*Polaris Vicra User Guide*" before attempting to operate the Polaris Vicra System.
2. This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:

   a) this device may not cause harmful interference, and

   b) this device must accept any interference received, including interference that may cause undesired operation.

   See "Radio Frequency Emissions" on page 77 for further information.
3. The user must determine the suitability of the Polaris Vicra System for their own application.
4. The Underwriters Laboratories Inc. (UL) recognition of the Polaris Vicra System includes the Polaris Vicra Position Sensor, Host USB Converter and the power adapter as follows:

   IEC 60601-1 2nd Edition only - APS APS49ES-24021/Hitron HES49ES-24021 power adapter.
   IEC 60601-1 2nd Edition and 3rd Edition - APS APS49EMG-24021-7/Hitron HEMG49-S240210-7 power adapter.

   This investigation does not include the use of any other power adapter or source with the Polaris Vicra System. Any such configuration will require further investigation. If the Polaris Vicra System is used in a medical application, the final end-use configuration must be independently investigated to the IEC 60601 family of standards and all applicable national differences.
5. The power adapter must be located outside the patient vicinity under all operating conditions. It is the responsibility of the system integrator and/or the end-user to ensure that the system is appropriately configured for the operating conditions.
6. This equipment has been investigated with regard to safety from electrical shock and fire hazard. The inspection authority has not investigated other physiological effects.
7. The Polaris Vicra Position Sensor requires a thermal stabilization period in order to provide reliable measurements. When the Position Sensor is powered on, the power light will flash to indicate that the system is warming up. When the light stops flashing, the system is ready for use as defined by the NDI Accuracy Assessment Kit (AAK) protocol.
8. Northern Digital Inc. has not investigated the implications of incorporating the Polaris Vicra Position Sensor with an automatic position device, or any other automated closed loop systems. Using the Polaris Vicra System in such an application is solely the responsibility of the user.
9. The Polaris Vicra System emits IR light that may interfere with IR-controlled devices, such as operating room tables. It is recommended that you test the Polaris Vicra System if you intend to use it in an environment where other IR-controlled devices are in use.
10. The Polaris Vicra Position Sensor is designed to ingress protection level IP44, but this evaluation was not included in the UL investigation. (Use of unauthorised cleaning fluids may degrade the conformal coating on the Position Sensor screws. This may compromise the IP rating. Refer to "Cleaning the Position Sensor" on page 60.)

Contact Information

If you have any questions regarding the content of this guide or the operation of this product, please contact us:

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Updates

NDI is committed to continuous improvements in the quality and versatility of its software and hardware. To obtain the best results with your NDI system, check the NDI Support Site regularly for update information: http://support.ndigital.com

1 Polaris Vicra System Overview

1.1 Introduction

The Polaris Vicra System is an optical measurement system that measures the 3D positions of either active or passive markers affixed to application-specific tools. Using this information, the Polaris Vicra System is able to determine the position and orientation of tools within a specific measurement volume. A 3D representation of the measurement volume is shown in Figure 1-1.

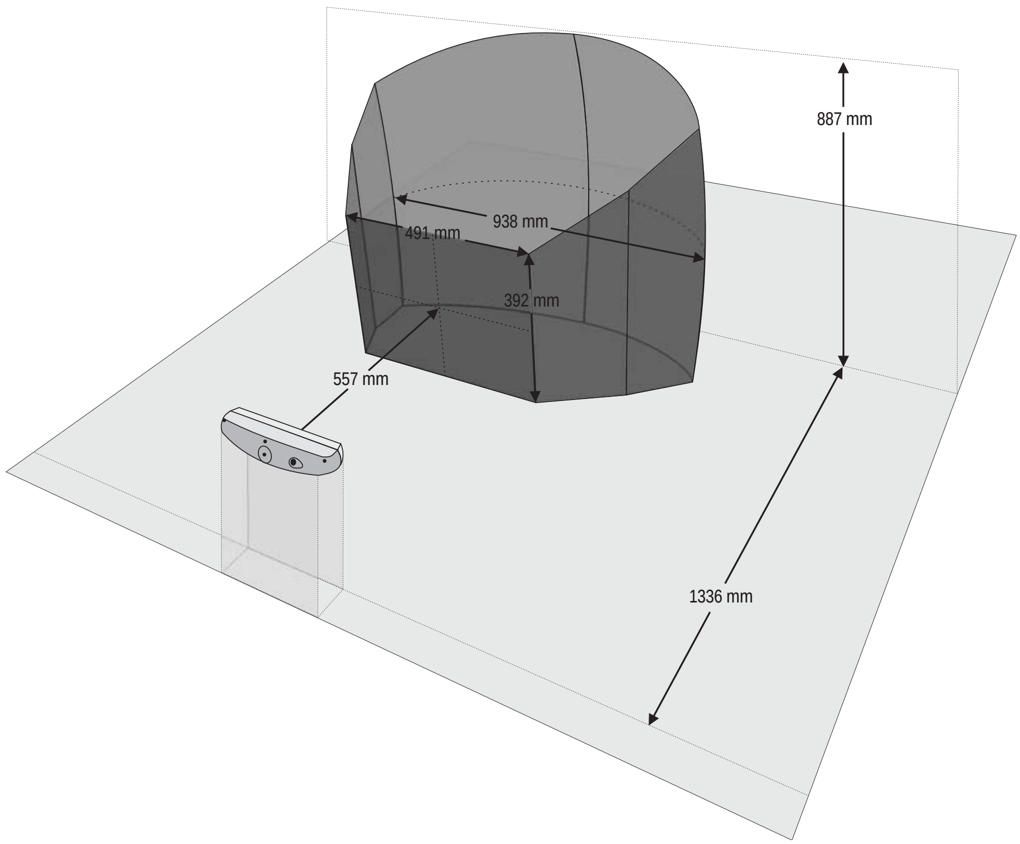


Figure 1-1 Polaris Vicra Measurement Volume

The system has applications in a range of industries, including:

- medical
- dental
- research

The Polaris Vicra System comprises the following components, see Figure 1-2:

- Position Sensor
- Host USB Converter
- Power adapter
- Cables

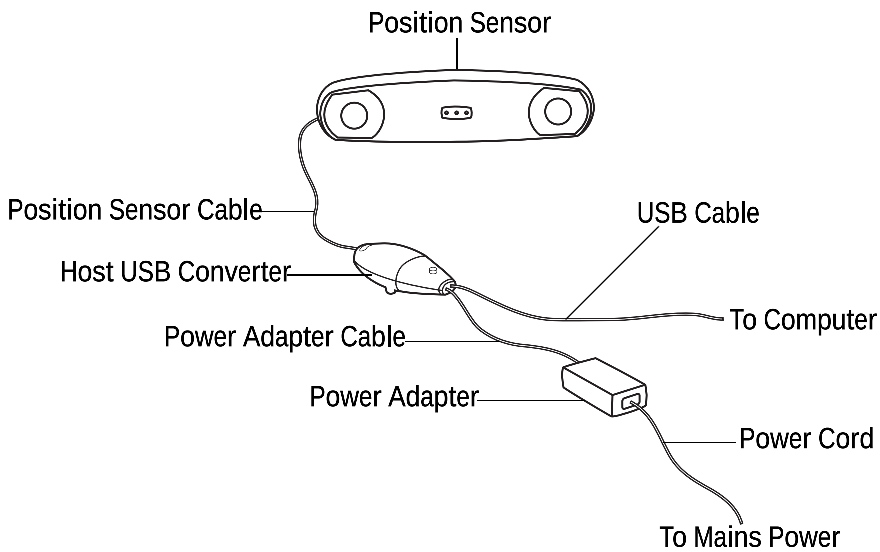


Figure 1-2 Polaris Vicra System Setup

The individual components of the system are described on the following pages:

- "Position Sensor" on page 3
- "Host USB Converter" on page 7
- "Power Adapter" on page 8
- "Cables" on page 9
- "Tools" on page 10
- "Software" on page 12

1.2 Host Computer Requirements

A host computer is also required to operate the system. The host computer must be approved to IEC 60950 or IEC 60601 standard and meet the following minimum specifications:

- Intel or Power PC G5 Processor
- 512 Mb random access memory (RAM)
- 100 Mb free disc space
- Operating system options:
  - Windows XP (32 bit)
  - Windows Vista (32 bit and 64 bit)
  - Windows 7 (64 bit)
  - Linux Kernel 2.6.35 (see "Installing the Software (Linux)" on page 21.)

- Mac OS X (the system was tested and verified on version 10.5.8, but may work on earlier and later versions.)

• Screen resolution 1024 x 768 (1280 x 1024 recommended)

1.3 Position Sensor

The Position Sensor is the main component of the Polaris Vicra System. An overview of its operation is as follows:

1. The Position Sensor emits infrared (IR) light from its illuminators, similar to the flash on a conventional camera.
2. The IR light floods the surrounding area and reflects back to the Position Sensor off passive sphere markers (on passive tools) or triggers markers to activate and emit IR light (on active wireless tools).
3. The Position Sensor then measures the positions of the markers, and calculates the transformations (the positions and orientations) of the tools to which the markers are attached.
4. The Position Sensor transmits the transformation data, along with status information, to the host computer for collection, display, or further manipulation.

Note For a more detailed description of how the Position Sensor detects markers, see "Marker Detection and Tool Tracking" on page 38.

The Position Sensor can track two types of tools: passive tools and active wireless tools. For more information on tools, see "Marker Detection and Tool Tracking" on page 38.

Front View

Figure 1-3 Position Sensor - Front View

The front of the Position Sensor incorporates the following components:

Illuminators Two arrays of infrared light-emitting diodes (IREDs) that provide IR light for the passive sphere markers (on passive tools) and an activation trigger for active markers (on active wireless tools).

Sensors Two sensors that each comprise a lens and a charge coupled device (CCD). The sensors collect IR light that is reflected from passive sphere markers (on passive tools) or emitted from active markers (on active wireless tools).

Indicator LEDs The Power, Status and Error LEDs, on the front of the Position Sensor combine as described in Table 1-1 to indicate Position Sensor status.

Table 1-1 Position Sensor Indicator LEDs Summary

Power LED (Green)	Status LED (Green)	Error LED (Amber)	Position Sensor Status
Flashing	(Any state)	(Any state)	The Position Sensor is warming up. The power LED will stop flashing and light steady green when Position Sensor is ready for use, as defined by the NDI Accuracy Assessment Kit (AAK) protocol. For information on the AAK, contact NDI.
Solid	Solid	Off	The Position Sensor is ready for use; no faults
Solid	Solid	Flashing	Minor recoverable fault; can easily be corrected by a novice user (for example, bump sensor has detected a bump). Does not prevent system operation.
Solid or off	Solid	Solid	Major recoverable fault (for example, firmware update required). The system will not operate until the fault is corrected.
Solid	Off	Solid	Non-recoverable fault. Return the Position Sensor to NDI for service.

You may be able to diagnose the error using the configure utility of NDI ToolBox, or using the API command GET to read the **Info.Status.Alerts** user parameter. (See the "*Polaris Application Program Interface Guide*" for details.)

A minor recoverable fault can usually be quickly corrected by a novice user. A major recoverable fault usually requires more expertise (for example, performing a firmware update). A non-recoverable fault requires that the Position Sensor be returned to NDI for servicing.

Rear View

Figure 1-4 Position Sensor - Rear View

The rear of the Position Sensor incorporates the following components:

Mount 1/4" thread tripod mount, that also incorporates three M3 x 0.5 mm pitch x 8 mm deep threaded holes.

Connector (LEMO) A 14-pin connector that provides power to the Position Sensor and allows communications to and from the Position Sensor. The connector details, internal to the Position Sensor, are shown in Figure 1-5 and Table 1-2.

If you make a custom cable, use LEMO part number FGA.1B.314.CYCD62Z or equivalent LEMO connector to mate to the connector on the Position Sensor.

Cable shield ground connection must be maintained to the shell of the LEMO connector.

Any unused contacts can be left floating.

Note It is good practice to disconnect mains power before connecting or disconnecting cables. Failure to do so may cause damage to the equipment.

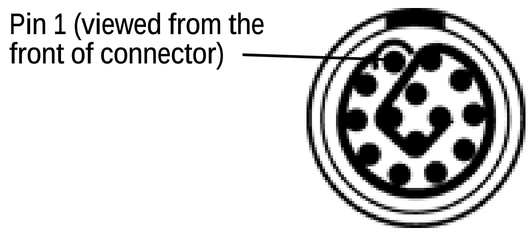


Figure 1-5 Position Sensor Connector Layout

Table 1-2 Position Sensor Connector - Signals

Pin	Signal
1	Power
2	Power
3	Rx +
4	Rx-
5	Ground
6	Ground
7	Ground
8	Tx +
9	Tx -
10	Power
11	RTS +
12	RTS -
13	CTS +
14	CTS -

Serial Number Label The serial number label is located on the back of the Position Sensor and shows the Item ID, model, serial number, and manufacture date of the Position Sensor.

Figure 1-6 Position Sensor - Serial Number Label

Audio Codes

In addition to the indicator LEDs, the Position Sensor emits audio beeps to alert the user to events. The codes are interpreted as follows:

- Two beeps are emitted on reset or when power is applied to the Position Sensor. (This feature can be disabled in NDI ToolBox software, or by setting the value of the user parameter **Param.System Beeper** to 0.)
- If the host computer does not send a command to the system within a given time, the Position Sensor will emit two quick beeps every three seconds. This feature is an application watchdog; the timeout value is the value of the user parameter **Param.Watch Dog Timer**. By default this feature is disabled; to enable it, set the value of the user parameter **Param.Watch Dog Timer** to an non-zero value.
- The API command BEEP can be used to cause the Position Sensor to emit beeps.

Note The user parameters store values for different aspects of the Polaris Vicra System. To set the value of a user parameter, use the API command SET. To retrieve a user parameter value, use the API command GET. For details on user parameters and API commands, see the "*Polaris Application Program Interface Guide*."

Bump Sensor

The Position Sensor contains an internal bump sensor that detects when the Position Sensor has suffered an impact that may affect its calibration. For more information on the bump sensor, see "Bump Sensor" on page 53.

Ingress Protection

The Position Sensor is designed to an ingress protection level of IP 44. The first "4" denotes that the Position Sensor is protected against solids over 1 mm in diameter. The second "4" denotes that the Position Sensor is protected against liquid splashed in all directions. To maintain an ingress protection level of IP 44, the Position Sensor cable (attached to the Host USB Converter) must be plugged in. For details on connecting the system, see "Connecting the Hardware" on page 16.

Note The Polaris Vicra Position Sensor is designed to ingress protection level IP 44, but this evaluation was not included in the UL investigation. (Use of unauthorised cleaning fluids may degrade the conformal coating on the

Position Sensor screws. This may compromise the IP rating. Refer to "Cleaning the Position Sensor" on page 60.)

1.4 Host USB Converter

The Host USB Converter provides the interface between the Position Sensor, the power adapter, and the host computer:

- The attached Position Sensor cable connects the Host USB Converter to the Position Sensor.
- The power adapter and USB cable plugs into the Host USB Converter.
- Modem status bits are provided see "Serial Port Emulation" on page 8.

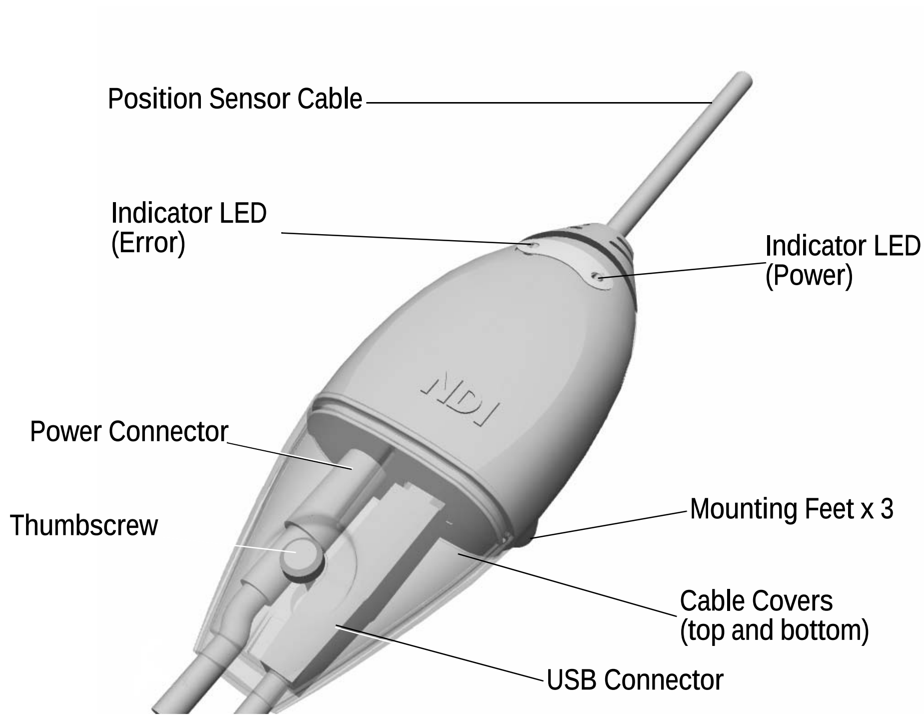


Figure 1-7   Host USB Converter

The Host USB Converter incorporates the following components:

Cable Covers: Two covers (top and bottom) that are secured together by means of a thumbscrew. The covers retain the USB and power adapter cables in place.

Position Sensor Cable: Provides connection for data and power between the Position Sensor and Host USB Converter. This cable is permanently connected to the Host USB Converter and is available in various lengths, to a maximum of 30 m long, depending on the configuration of your system.

Power Indicator: Lights green when power is being supplied to the Host USB Converter.

Error Indicator: Lights amber when the Host USB Converter has detected a fault. (Also flashes briefly when the Host USB Converter is first powered on.)

Mounting Feet: Three feet that incorporate an internal thread (M6 x 1 mm pitch x 4 mm depth) to allow the Host USB Converter to be attached to an external structure (for example, a cart). For free-standing use, rubber inserts are located in the mounting feet.

Serial Number Label The serial number label is located on the bottom of the Host USB Converter and shows the item ID, model, serial number, and manufacture date of the Host USB Converter.

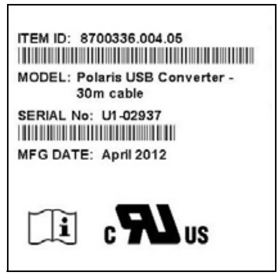


Figure 1-8 Host USB Converter Serial Number label

Serial Port Emulation

Modem Status Bits The Host USB Converter emulates a standard PC serial port, such that the host application may communicate with the Polaris Vicra System as if it was a standard RS-232 device. A feature of this is that the following modem status bits are used as follows:

- The Data Set Ready (DSR) will be set when the Host USB Converter senses that a Position Sensor is connected (power must also be connected to the Host USB converter).
- The Ring Indicator (RI) will be set when a fault condition is showing on the Host USB Converter error indicator.

Communication Rate If your operating system cannot set the serial port rate directly to 1.2 Mbaud, an aliased 19 200 baud rate is provided to enable you to run at the higher speed. Do not set the Polaris Vicra System to 19 200 baud; if the system is set to 19 200 baud, it will be unable to communicate with the host computer, because setting the host application to 19 200 baud will result in the aliased rate of 1.2 Mbaud. (The baud rate of the Polaris Vicra System can be set using the API command COMM. See the "*Polaris Application Program Interface Guide*" for details.)

1.5 Power Adapter

The system is powered by an NDI supplied power adapter. The model of the power adapter is dependent on which Edition of the IEC 60601-1 standard your system is compliant with as follows:

- Advanced Power Systems, part number APS49ES-24021/Hitron, part number HES49ES-24021 - applicable to IEC 60601-1 2nd Edition only.
- Advanced Power Systems, part number APS49EMG-24021-7/Hitron, part number HEMG49-S240210-7 - applicable to IEC 60601-1 2nd Edition and 3rd Edition.

The power adapter connects to the mains supply and provides DC power to the Position Sensor via the Host USB Converter.

Alternatively, power may be supplied by a customer provided power adapter that meets the following criteria:

- medical grade, double insulated (required if end use will be in a medical environment)
- 24 V DC, 1.2 A output (40 W typical)
- Switchcraft part number 760 plug (or equivalent)

Note The Underwriters Laboratories Inc. (UL) recognition of the Polaris Vicra System includes only the Polaris Vicra Position Sensor, Host USB Converter, and the power adapter as follows:

IEC 60601-1 2nd Edition only - APS APS49ES-24021/Hitron HES49ES-24021 power adapter.
IEC 60601-1 2nd Edition and 3rd Edition - APS49EMG-24021-7/Hitron HEMG49-S240210-7 power adapter.

This investigation does not include the use of any other power adapter or source with the Polaris Vicra System. Any such configuration will require further investigation. If the Polaris Vicra System is used in a medical application, the final end-use configuration must be independently investigated to the IEC 60601 family of standards and all applicable national differences.

Note If a non-NDI supplied power adapter is used, it should be chosen to suit the particular use and the resulting system configuration must be verified for electrical safety by an approved test laboratory. For further information contact NDI.

1.6 Cables

NDI supplies the following cables for use with the system:

Position Sensor Cable: Provides connection for data and power between the Position Sensor and Host USB Converter. This cable is permanently connected to the Host USB Converter and is available in various lengths, to a maximum total length of 30 m (approximately 100 feet), depending on the configuration of your system.

The cable used by NDI for the Host USB Converter and the Position Sensor cable has the following characteristics:

- The cable has redundant power and ground lines (three of each) to reduce power loss. A conductor specification of 28 AWG is used for each of these six lines.
- The cable houses four twisted pairs of differential signal lines. A conductor specification of 32 AWG is used for each of these eight lines. These lines are kept as small as possible to reduce cable size.
- To minimise noise interference, the cable is shrouded in a braided shield with 80% to 90% coverage.

NDI has tested communications along a cable with the above specifications up to a length of 30 m (approximately 100 feet).

NDI has also successfully tested a lower cost, but less robust cable. It is available as NDI part number 2600608 (3M™ part number 3600B/14). The details of this cable are as follows:

- 3M Round, Shielded/Jacketed, Discrete Wire Cable, 28 AWG Stranded, PVC/PVC, 3600B/14
- Meets external wiring requirements of National Electrical Code, Article 725 (CL2)

- 28 AWG stranded wire provides flexibility
- Twisted pairs reduce crosstalk for balanced drive applications
- Dual shielding with aluminium film foil and copper braid provides excellent EMI/ESD protection
- Wires are colour coded for easy identification
- 35 db average shielding effectiveness
- RoHS compliant

USB Cable: Provides connection for data between the host computer and Host USB Converter. This cable is a USB, A-B male, double shielded, 5 m cable.

Power Adapter Output Cable: Provides connection for power to the Host USB Converter. This cable is permanently connected to the power adapter and has a plug-in jack connector to connect to the Host USB Converter.

Power Adapter Power Cable: Connects the power adapter to the mains supply. This cable is a medical grade AC line cord.

1.7 Tools

A tool is a rigid structure on which three or more markers are fixed so that there is no relative movement between them. An example of a tool is shown in Figure 1-9.

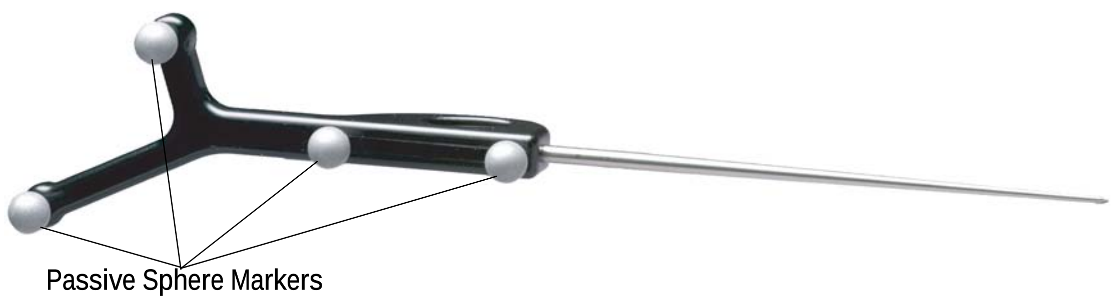


Figure 1-9 Passive Tool

The Polaris Vicra System can track passive tools and active wireless tools. The Position Sensor tracks tools based on the geometry of the markers on the tools. The Position Sensor requires a tool definition file for each tool. A tool definition file describes a tool to the Position Sensor (including the tool's marker geometry).

Passive Tools

Passive tools incorporate NDI passive sphere markers. The passive sphere markers have a retro-reflective coating that reflects IR light back to its source, instead of scattering it. As such, the IR light from the Position Sensor illuminators reflects off the markers directly back to the sensors. The Polaris Vicra System can track the positions and orientations of tools, and can also report the positions of individual passive spheres.

Passive sphere markers must be attached to the tool using NDI mounting posts, which are manufactured to firmly hold NDI spheres.

An example of a passive tool is shown in Figure 1-9. The example shows a probe that incorporates four passive sphere markers. For more information on passive tools and passive sphere markers, see "Passive Tools" on page 40.

Active Wireless Tools

Active wireless tools incorporate active markers, which emit IR light. The tools also house an IR receiver. An active wireless tool draws power from a battery, or from the equipment to which it is attached.

The Position Sensor pulses the illuminators in a way that is recognizable by the IR receiver in the active wireless tool. The active wireless tool detects the IR pulse; the markers then emit IR, which is detected by the Position Sensor.

For more information on active wireless tools and active markers, see "Active Wireless Tools" on page 41.

Tool Definition Files

Each tool has a tool definition file (formatted as .rom) to describe it to the system. A tool definition file must be loaded into the system before the system can track the associated tool. The information stored in the tool definition file includes the geometry of the tool's markers, the tool's manufacturing data, tool face definitions (for a multi-faced tool), and the parameters and settings described in "Tool Tracking Parameters" on page 43. Without this information, the system cannot accurately interpret the data it collects.

Note — For more information on tool definition files, see "Tool Definition File" on page 42. Polaris Vicra System tools are described in more detail in "Polaris Vicra System Tools" on page 40. For information on tool design and construction, refer to the "*Polaris Tool Design Guide*."

Number of Tools

Up to 15 compatible wireless tool definition files can be loaded simultaneously, ready for tracking. The system can simultaneously track up to six passive tools and one active wireless tool, within the following constraint: a maximum of 32 passive and 32 active markers, including stray markers, can simultaneously be in view of the Position Sensor. Additional markers in view may affect the speed of the system and its ability to return transformations.

Note — The field of view of the Position Sensor is described on page 37. Stray markers are described on page 49.

1.8 Software

The following software is included on the Polaris Vicra CD. You can also download the software from the NDI Support Site at: http://support.ndigital.com.

NDI CAPI Sample A sample program written for Windows, and the source code for the program. This program provides an example of how to write programs to operate the Polaris Vicra System.

NDI ToolBox A suite of utilities for diagnostics, maintenance, testing, and development support for the Polaris Vicra System. NDI ToolBox also includes command line functionality, to allow you to embed an NDI ToolBox application (such as upgrading firmware) into your application software. See the ToolBox help for details.

Note NDI 6D Architect application software, which is used to characterize tools and create tool definition files, is located on the CD that accompanies the developer kit.

2 Setting Up the Polaris Vicra System

This chapter provides instructions and information required to set up the Polaris Vicra System for use. This chapter contains the following sections:

2.1 Unpacking the Polaris Vicra System

The Polaris Vicra System is shipped with a Position Sensor, a Host USB Converter, a power adapter, cables, the Polaris Vicra CD, and documentation.

When unpacking the Polaris Vicra System, be sure to handle all system components with care. Keep the packaging in good condition; you will need to use it if the system ever needs to be returned to NDI for repair.

Note: See "Return Procedure" on page 85 for instructions on returning your system to NDI.

2.2 Operating Environment Requirements

Warnings

Warning!

Read the following warnings before using the Polaris Vicra System, to avoid the risk of personal injury.

1. **Do not use the Polaris Vicra System in the presence of flammable materials such as anaesthetics, solvents, cleaning agents, and endogenous gases. Flammable materials may ignite, causing personal injury or death.**
2. **Do not protect or shield either the Position Sensor or tools with methods not approved by NDI. Non-approved methods will interrupt the optical path and degrade the performance of the system. Reliance on data provided by a Position Sensor without an uninterrupted optical path may lead to inaccurate conclusions. If your application involves personal safety, inaccurate conclusions increase the possibility of personal injury**.
3. **The Polaris Vicra System requires special precautions regarding EMC. It must be installed and put into service in accordance with the EMC information detailed in "Electromagnetic Compatibility" on page 72. Failure to do so may result in personal injury.**

4. **Do not use the Polaris Vicra System either adjacent to, or stacked with, other equipment. Check that the Polaris Vicra System is operating normally if it is used either adjacent to, or stacked with, other equipment. Failure to do so may result in personal injury.**
5. **Radio frequency communications equipment, including portable and mobile devices, may affect the Polaris Vicra System and result in personal injury.**
6. **Do not immerse any part of the Polaris Vicra System or allow fluid to enter the equipment. If fluids enter any part of the system they may damage it and present a risk of personal injury.**
7. **Do not obstruct the normal flow of air around the Position Sensor (for example, draping or bagging the Position Sensor). Doing so will affect the Position Sensor's operational environment, possibly beyond its recommended thresholds. Reliance on data provided by a Position Sensor that is outside of recommended thresholds may lead to inaccurate conclusions. If your application involves personal safety, inaccurate conclusions increase the possibility of personal injury.**
8. **Do not use the Polaris Vicra Position Sensor in an MRI environment without first determining the performance, including accuracy, of the Position Sensor in an MRI environment. NDI has not fully validated the Polaris Vicra Position Sensor in an MRI environment. It is unknown whether reliance on data provided by a Position Sensor in an MRI environment may lead to inaccurate conclusions. If your application involves personal safety, reliance on inaccurate conclusions may increase the possibility of personal injury.**

In order for the Polaris Vicra System to operate correctly, the system must be set up in an environment that meets the following criteria:

- There must be a clear line of sight between the Position Sensor and the tools to be tracked. The tools must be inside the characterized measurement volume. Refer to Figure 4-2 on page 37 for the dimensions of the characterized measurement volume.
- The power adapter must be located outside the patient vicinity under all operating conditions. The temperature of the power adapter case can reach +50°C in an ambient temperature of +30°C.
- Make sure that sources of background IR light in the 800 nm to 1100 nm range (e.g. sunlight, some operating room lights) are minimized. The Position Sensor is sensitive to IR light. Since the Position Sensor functions by detecting IR light reflected from, or emitted by, markers, other sources of IR light can interfere with the Polaris Vicra System.
- Make sure that there are no large reflective surfaces within the field of view (described on page 37). For example, the gantry for a magnetic resonance imaging (MRI) machine has a large reflective surface. It can be draped with non-reflective material to eliminate reflections.
- Make sure that the tools do not have flat reflective surfaces. Certain tool shapes and surfaces can cause reflections that may interfere with the Polaris Vicra System. For more information, see the "*Polaris Tool Design Guide*".
- Before using the system, make sure the power LED on the Position Sensor has stopped flashing. The power LED will flash while the Position Sensor warms up; once the LED is

steady, the system is ready for use as defined by the NDI Accuracy Assessment Kit (AAK) protocol. For information on the AAK, contact NDI.

- The environmental conditions must be as listed in Table 12-1 on page 69.
- If the system is to be used in an MRI environment, contact NDI for information on response of the system.

2.3 Mounting the System Units

Caution! Always place the Position Sensor on a rigid support system. If not supported, the Position Sensor may fall which will affect the calibration and damage the Position Sensor.

Position Sensor

The Position Sensor is mounted via a built-in 1/4" thread tripod mount, or 3 (user-supplied) M3 x 0.5 mm pitch x 9 mm screws. Figure 2-1 shows the Position Sensor dimensions and mounting arrangement.

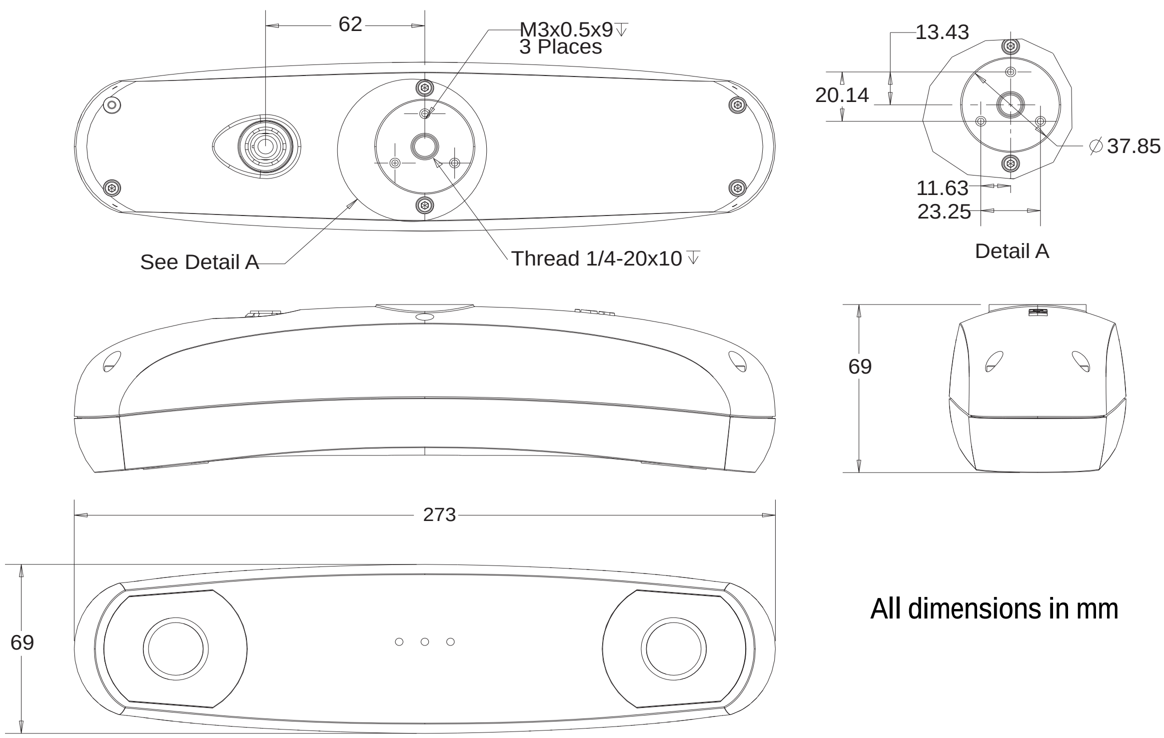


Figure 2-1 Position Sensor Mounting Details

Host USB Converter

The Host USB Converter can be free-standing or may be mounted via M6 x 1 mm pitch x 4 mm deep threaded holes located in the three mounting feet. Figure 2-2 shows the Host USB Converter mounting arrangement, with dimensions.

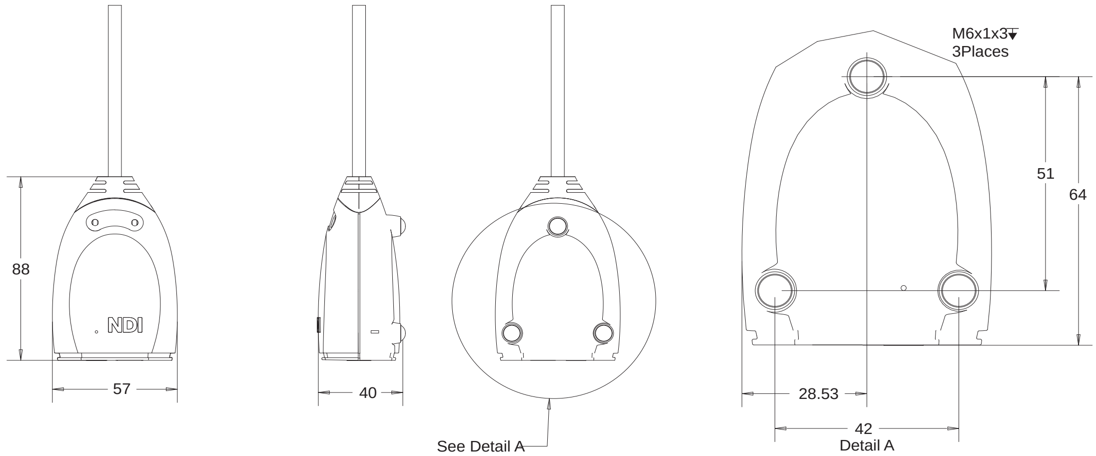


Figure 2-2 Host USB Converter Mounting Details

2.4 Connecting the Hardware

Warnings

Warning!

Read the following warnings before using the Polaris Vicra System, to avoid the risk of personal injury.

1. **Do not use cables or accessories other than those listed in this guide. The use of other cables or accessories may result in increased emissions and/or decreased immunity of the Polaris Vicra System and may result in personal injury.**
2. **Do not incorporate non-NDI components with the Polaris Vicra System. The accuracy of results produced by applications that incorporate non-NDI components with the Polaris Vicra System is unknown. If your application involves personal safety, reliance on these results may result in personal injury.**
3. **Do not attempt to bypass the grounding prong on the power cord by using a three-prong to two-prong adapter. The system must be properly grounded to ensure safe operation. Failure to do so presents an electric shock hazard.**
4. **Do not use the Position Sensor without inspecting it for cleanliness and damage both before and during a procedure. Reliance on data provided by an unclean or damaged Position Sensor may lead to inaccurate conclusions. If your application involves personal safety, inaccurate conclusions may result in personal injury.**
5. **Do not connect the Polaris Vicra System to a host computer that is not IEC 60950 and/or IEC 60601 approved. If you connect the system to a non-approved host computer you may increase leakage currents beyond safe limits and cause personal injury.**

Read the following cautions before you connect the Polaris System components.

Caution! Do not push or pull connectors in constricted areas.

Do not put heavy objects on cable connectors.

Do not leave cable connectors where they can be damaged, particularly on the floor, where they can easily be stepped on.

Pull connections apart by gripping the connector. Do not pull them apart by tugging on the cable as this can damage the connecting cable. Never force a connection or a disconnection.

Note It is good practise to disconnect the mains power before connecting or disconnecting cables.

1. Connect the Position Sensor cable (attached to the Host USB Converter) to the connector located on the back of the Position Sensor. Align the red marking on the Position Sensor connector with the red marking on the cable connector (the double keys of the connectors should be aligned).

   Make sure the Position Sensor cable is securely connected to the Position Sensor. A loose connection may result in partial functionality or unpredictable system behaviour.

2. Connect the USB cable B plug and power adapter cable to the Host USB Converter, as shown in Figure 2-3.

3. Locate the top and bottom cable covers in place on the Host USB Converter. Secure the covers with the thumbscrew, as shown in Figure 2-3.

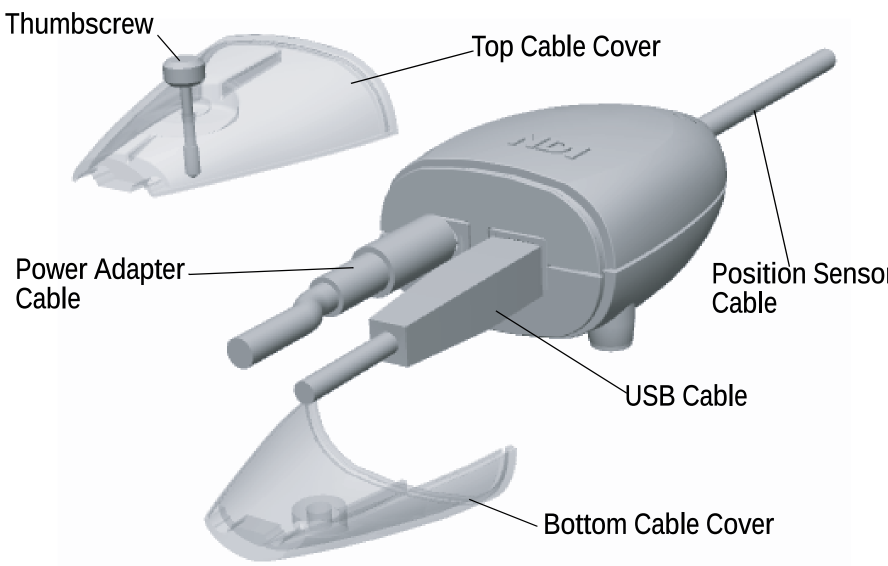


Figure 2-3 Connecting Cables to the Host USB Converter

4. Plug the USB cable A plug into the host computer.

5. Make sure all the cables are connected firmly, and placed where they will not be stressed, stepped on, or bent.
6. Plug the power cable into the power adapter.
7. Plug the power cable into the power mains and turn on the mains.

The Polaris Vicra System will begin a diagnostic evaluation. During this evaluation, the LEDs on the Position Sensor will flash. When the diagnostic evaluation is complete, the Position Sensor will emit two beeps and the power LED on the Position Sensor will light.

The Position Sensor requires a warm-up time every time it is powered on. The power LED will flash while the Position Sensor warms up; once the LED is steady, the system is ready for use as defined by the NDI Accuracy Assessment Kit (AAK) protocol. For information on the AAK, contact NDI.

Note: The Position Sensor initially communicates to the host computer at 9600 baud. If you are using the NDI ToolBox application it will increase the baud rate as high as possible. If you are using your own application, the baud rate can be set using the "COMM" API command. Refer to the "*Polaris Application Program Interface Guide"*.

2.5 Installing the Software (Windows)

The NDI software is located on the Polaris Vicra CD. You can also download the software from the NDI Support Site at http://support.ndigital.com.

Note: NDI 6D Architect application software, which is used to characterize tools and create tool definition files, is located on the CD that accompanies the developer kit.

NDI Combined API Sample

To install NDI Combined API Sample, copy the contents of the "CombinedAPISample" folder from the Polaris Vicra CD onto the host computer.

NDI ToolBox

To install NDI ToolBox, follow the on-screen instructions from the auto-run window that appears when you insert the Polaris Vicra CD into the drive. Alternatively, on the Polaris Vicra CD, browse to Windows\ToolBox\ directory and double-click **install.exe**.

Once you start the installation from the install page, a wizard appears. Follow the on-screen instructions to complete the process. The default installation location is
C:\Program Files\Northern Digital Inc.\ToolBox

The installation of NDI ToolBox also includes installing the drivers for the Host USB Converter.

Note: The NDI ToolBox installation includes a Java virtual machine (VM) for Windows and Linux systems. The Java VM included in the NDI ToolBox installation is fully compatible with NDI ToolBox. Other versions of Java VM may cause NDI ToolBox to exhibit unusual or unpredictable behaviour.

Host USB Drivers

The Windows driver model consists of two parts; low-level USB and high-level virtual serial port. It appears as a Windows serial port, COMx (where x is enumerated) and emulates a standard PC serial port such that the Host USB Converter may be communicated with as a standard RS-232 device.

When you first connect the NDI Host USB Converter to the host computer, you will need to install drivers for the Host USB Converter. There are two sets of drivers for the Host USB Converter:

- the first set of drivers enables the Host USB converter to work with the host computer
- the second set of drivers sets up the USB port where the Host USB Converter is connected to emulate a serial port

Driver Location

If you have already installed NDI ToolBox, the USB drivers were installed as part of that installation. By default, the drivers are located at C:\Program Files\Northern Digital Inc\ToolBox\USB Driver. (See "NDI ToolBox" on page 18.)

The drivers are also located on the Polaris Vicra CD in the USB Driver folder.

Windows XP and Vista

Install the USB drivers for Windows XP and Vista as follows:

1. When you first connect the Host USB Converter to the host computer, the **Found New Hardware** wizard will begin automatically.
2. When prompted, select the option that allows you to specify the drivers' location.
3. Browse to the folder containing the drivers, either on the host computer or on the Polaris Vicra CD. Windows will automatically select the correct drivers from the folder.
4. Click **Next** and **Finish** as required to complete the installation.

Note: After you have selected the folder containing the USB drivers, a warning may appear, indicating that the drivers have not passed Windows Logo testing. Click "Continue Anyway".

5. Once the first set of drivers is installed, the **Found New Hardware Wizard** will launch a second time. Follow steps 2 to 4 above to install the second set of drivers.
6. The system will now appear to be connected through a virtual COM port.

Host USB Converters are interchangeable on the same USB port, without having to re-install drivers or losing the COM port previously established.

Windows 7

Install the USBdrivers for Windows 7 as follows:

Note: When you first connect the Host USB Converter to the host computer, an error message may appear over the task bar. Ignore the message and complete the following steps to install the USB drivers

1. From the Windows menu, select **Control Panel**.
2. In the top right hand corner of the Control Panel window, select **View by: Small Icons**.
3. From the Control panel, select **Device Manager**.
4. Under **Other Devices**, right click **NDI Host USB Converter**.
5. Select **Update Driver Software...**, then select **Browse my computer for driver software**.
6. Select **Program Files (x86)\Northern Digital Inc\ToolBox\USB Driver**. Select **Next**.
7. In the Windows security dialog, select **Install this driver software anyway** option. The first set of drivers will install.
8. After the first set of drivers are installed, browse to **Other Devices** and right click **USB Serial Port**.
9. Select **Update Driver Software...**, then select **Browse my computer for driver software**.
10. Select **Program Files (x86)\Northern Digital Inc\ToolBox\USB Driver**. Select **Next**.
11. In the Windows security dialog, select **Install this driver software anyway** option. The second set of drivers will install.

Driver installation is complete and the system will now appear to be connected through a virtual COM port.

Host USB Converters are interchangeable on the same USB port, without having to re-install drivers or losing the COM port previously established.

Reassigning the Windows COM Number

After the Host USB Converter drivers have been installed, you can reassign the Windows COM number as follows:

1. Launch **Device Manager**.
2. Navigate to **Ports (COM & LPT)**.
3. Right-click on the Host USB Converter.
4. Select the **Properties** pop-up menu.
5. Select the **Port Settings** tab.
6. Click on the **Advanced Settings** button.
7. From the dialog box that is displayed, select the **Com Port Number** drop-down field.
8. Reassign the COM port as necessary.
9. Select **OK** to save the changes.

Windows will remember this mapping even if the Host USB Converter is unplugged from the USB port. When the Host USB Converter is reconnected to the host computer, the COM port mapping will be re-established (if it is plugged into the same USB port).

2.6 Installing the Software (Linux)

The NDI software is located on the Polaris Vicra CD. You can also download the software from the NDI Support Site at http://support.ndigital.com.

Note NDI 6D Architect application software, which is used to characterize tools and create tool definition files, is located on the CD that accompanies the developer kit. NDI 6D Architect is written to run on a Windows operating system.

NDI Combined API Sample

To install NDI Combined API Sample, copy the contents of the “CombinedAPISample” folder from the Polaris Vicra CD onto the host computer.

Note The NDI Combined API Sample contains an application and source code. The application is written to run on a Windows operating system; however, you can still view the source code on a Linux system.

NDI ToolBox

Install NDI ToolBox as follows:

1. On the Polaris Vicra CD, browse to Linux/ToolBox/install.bin.
2. Follow the on-screen instructions to complete the process. The default installation location is <user_account>/ToolBox.
3. Installing NDI ToolBox also downloads the kernel patch file to apply to drivers for the Host USB Converter. The default download location is <user_account>/ToolBox/usb-patch.

Note The NDI ToolBox installation includes a Java virtual machine (VM) for Windows and Linux systems. The Java VM included in the NDI ToolBox download is fully compatible with NDI ToolBox. Other versions of Java VM may cause NDI ToolBox to exhibit unusual or unpredictable behaviour.

Host USB Drivers

On Linux kernel versions 2.6 and later USB serial devices appear as driver files "/dev/ttyUSBx" (where x is the port number). These drivers emulate a standard tty serial port and allow applications to communicate through the USB device as if it were an RS-232 or RS-422 port.

For Linux kernel versions 2.6.8 through 2.6.30 NDI has supplied a patch to allow the kernel to recognize and configure the NDI Host USB Converter. (The patch files are located in the <ToolBox_install_dir>/usb-patch/ directory after ToolBox has been installed.) Kernel versions 2.6.32 and later automatically recognize the NDI devices and no patching is required; but you must execute step 7 below.

Note These instructions and the supplied patches have been tested with specific kernel versions. If you are using a different kernel version, the patch file may not work.

Note Only apply the patch appropriate to your kernel version. Do not apply the patch more than once. Patches are available for 2.6.8, 2.6.20, 2.6.23 and 2.6.28. (Version 2.6.28 will also work on version 2.6.30.) Kernel versions 2.6.33 and 2.6.34 do not work with Polaris Vicra device drivers.

The patch modifies the files ftdi_sio.c and ftdi_sio.h in the directory /usr/src/linux-2.6.x/drivers/usb/serial. The modifications are:

1. ftdi_sio.h - added the define for the USB product ID for the Polaris Spectra SCU and NDI Host USB Converter.
2. ftdi_sio.c - alias baud rate 19.2Kbs to 1.2Mbs and set default USB latency to 1ms.

Apply the patch to an unmodified kernel as follows:

1. Log on as root user.

Note Steps 2 to 5 are not required if you are using Linux kernel 2.6.32 or higher.

2. Open a command shell and cd to the kernel source directory, usually /usr/src/linux.
3. Create backups of the files ./drivers/usb/serial/ftdi_sio.c and ./drivers/usb/serial/ftdi_sio.h.
4. patch -p1 < ftdi-usb-patch-kernel-2.6.x.patch.
5. If the driver is a kernel-loadable module, apply the patch as follows:
   a) make modules
   b) make modules_install
   c) Restart the computer.

   If the driver is not a kernel-loadable module, rebuild the kernel following the instructions specific to the kernel. If you are unfamiliar with kernel rebuilding, refer to the instructions usually located in the source directory or at http://www.kernel.org/.
6. The Host USB Converter when connected will appear as "/dev/ttyUSBx", where x is the port number.
7. If you plan to access the Polaris Vicra from a non-root user account, you will need to add the user account to the "lock" group. It may also be necessary to add the user account to the following groups:
   - uucp
   - tty
   - dialout

   This can be done only as root user with the command "usermod –G <group> <account name>". (You will need to logout and login for the changes to take effect.)

These drivers can be used for both the Host USB Converter and SCU (a component of the hybrid Polaris Spectra System). SCUs and Host USB Converters are interchangeable on the same USB port, without having to re-install drivers or losing the device file enumeration previously established, as long as all serial converters (NDI or other FTDI-based converters) are plugged in and enumerated in the same order.

2.7 Installing the Software (Mac)

The NDI software is located on the Polaris Vicra CD. You can also download the software from the NDI Support Site at http://support.ndigital.com.

Note NDI 6D Architect application software, which is used to characterize tools and create tool definition files, is located on the CD that accompanies the developer kit. NDI 6D Architect is written to run on a Windows operating system.

System Requirements

The system requirements for the Mac OS X as follows:

Hardware

- A Power PC or Intel based Mac (NDI ToolBox and the USB driver are Universal Binaries).
- 512 MB minimum installed memory
- 15 MB free hard drive space

Mac OS X Version

- Mac OS X 10.5.8 The system was tested and verified on version 10.5.8, but may work with earlier and later versions. (To determine which version of Mac OS X you have, select **Apple**>**About This Mac**.)

Java Version

- Minimum: Java 2 Platform Standard Edition 5.0 (J2SE 5.0 build 1.5.0_xx). (If you have an older version of Java you will need to download an update from the Apple website.)

To determine which version of Java you have, launch the Terminal application and at the command prompt, enter:

```
java -version.
```

Account Permissions

To manage NDI software on a Mac platform you will need administrator account privileges.

Installing and Running NDI ToolBox

Install NDI ToolBox as follows:

1. On the Polaris Vicra CD, open the **MacOSX** folder.
2. In the **MacOSX** folder, open the **ToolBox** sub-folder

3. In the **ToolBox** folder, locate and double-click on **install.dmg** file. Double click on **NDI Installer** and enter your administrator password.
4. Follow the on-screen instructions to complete the NDI ToolBox installation

To run NDI ToolBox you can connect to the system using either:

- /dev/cu.usbserial-xxxxxxxx

or

- /dev/tty.usbserial-xxxxxxxx

The USB driver creates two possible Virtual COM Ports (VCP) connection methods to each NDI device. This is for backwards compatibility with access via BSD UNIX-style device methods. The tty methods were traditionally meant to be used for call-in connections and the cu methods for call-out connections. NDI ToolBox will work correctly when either of the connections is chosen.

Each NDI ToolBox Utility (Configure, Tool Tracker, Image Capture, Terminal Window, Console) runs in its own window. To switch between them, select the keystroke combination: Command-Accent (`).

Host USB Driver

Install the host USB driver as follows:

1. On the Polaris Vicra CD, locate, and open, the **MacOSX** folder.
2. In the **MacOSX** folder, locate and open the **USB Driver** sub-folder.
3. Double-click on **FTDIUSBSerialDriver (NDI).pkg**. (This file is also placed in the ToolBox installation folder during ToolBox installation.)

Follow the on-screen instructions to complete the installation procedure.

Note: The driver supplied with NDI ToolBox is necessary for the creation of a VCP software interface to a NDI device with a USB interface. The driver is a Mac OS X kernel extension provided by FTDI and configured by NDI to support NDI devices.

Activating the VCP for a NDI Device

Activate the VCP for an NDI device as follows:

1. Restart the Mac host computer. (If you have been following the previous installation procedures, the computer will have already restarted.)
2. Connect the NDI device to one of the Mac host computer USB ports.
3. From the **Apple** menu, select **System Preferences...**, then select the Network preferences icon. Select **OK** on the resulting dialog box.
4. If necessary, “unlock” the lock icon (located in the lower left of the dialog box) and enter your password.

5. From the **Show** drop-down menu, select **Network Port Configurations**. The newly created VCP for the NDI device will be shown at the top of the list.
6. Click the check box next to usbserialxxxxxxxx and click the **Apply Now** button. This will activate the VCP. Quit the System Preference application.

Note A unique VCP will be assigned to each USB port to which NDI devices have been connected irrespective of which NDI device you connected. This means that, if in the future, you connect the NDI device to a different USB port on your Mac you will have to go through this activation procedure again if an NDI device has never been connected to that port.

To verify that the NDI device is recognized by the VCP driver, launch the System Profiler application (normally found in the Utilities sub-folder within the Applications folder). Expand the Hardware tree in the left-hand Contents pane and click on the USB branch. The USB device tree will appear in the right-hand pane. The NDI device should appear under the applicable USB Bus branch.

Uninstalling Software

NDI ToolBox

Uninstall NDI ToolBox as follows:

Navigate to **Applications>NDI ToolBox** and double click on **NDI ToolBox Uninstaller** application and follow the on-screen instructions. All related NDI ToolBox files and aliases to NDI ToolBox utilities will be removed from your system.

Host USB Driver

Remove the host USB driver as follows:

1. Launch the Terminal application (normally found in the Applications folder in the Utilities sub-folder) At the command prompt, enter the following commands:

```
cd /System/Library/Extensions
sudo rm -r FTDIUSBSerialDriver.kext
cd /Library/Receipts
sudo rm -r “FTDIUSBSerialDriver (NDI).pkg”
```

2. To remove the deactivated VCPs (usbserial-xxxxxxxx) from the system:
   a) Unplug any NDI devices from the USB ports.
   b) Select **Apple**>**System Preferences...**> **Network**.
   c) From the **Show** drop down menu, select the **Network Port Configurations**. The menu will display a deactivated port as greyed out. Select the port and click **Delete**. Confirm the deletion to remove the port.

Additional Information

The following sections provide additional Mac OS X specific information.

Modified FTDI USB to Serial Driver

If you have other devices (such as a USB to serial port converter) that also use a FTDI VCP driver then installing the driver that is included on the Polaris Vicra CD may:

1. Result in a change to the version of the driver previously installed

and/or

2. Possibly disable access to your other devices.

The NDI configured version of the driver is based on v2.2.7 of the original FTDI VCP driver. If your device is not recognized by this version of the driver, access to your device will be disabled. Please contact NDI for assistance.

Additional Installation Files

During NDI ToolBox installation additional support files are placed outside the selected destination folder. The following files are placed in the /Library/Java/Extensions folder:

- jai_imageio.jar
- jh.jar
- libpivot.jnilib
- librxtxSerial.jnilib
- RXTXcomm.jar

Lock Files and Groups

NDI ToolBox uses lock files to manage requests to access the VCP connections to NDI devices. These lock files are kept in the folder /var/lock (hidden from the Finder but accessible via the Terminal application). Access to this folder is available to members of the uucp group. The user account that ran the NDI ToolBox installer was added as a member of the uucp group and the /var/lock folder was created at that time.

If an alternate user account (different from the one that was used to install NDI ToolBox) runs the NDI ToolBox utilities, then make this account a member of the uucp group as follows:

Note The following procedure is only applicable to Mac OS 10.4.X. For information on Mac OS 10.5 and higher, contact NDI. See page xiii for contact details.

1. Launch the NetInfo Manager application (normally found in the Applications folder in the Utilities sub-folder).
2. Use the hierarchical navigator to select **groups>uucp**.
3. Click the lock icon and authenticate (using a userid with administrator privileges).

4. Select the **users** property in the bottom panel.
5. Select the **Directory**>**New Value** menu. Enter the userid of the user account you wish to enter.
6. Click the lock icon and confirm that you wish the modification to become permanent.
7. Quit the NetInfo Manager application. This will allow the alternate user account to run the ToolBox utilities.

Note Uninstalling NDI ToolBox does not remove the lock file folder or membership to the uucp group.

NDI ToolBox Preferences

When you exit NDI ToolBox, the state of each utility (window sizes, VCP last connected to, etc.) are saved to the user's home folder. These preference files are hidden from viewing in the Finder. They have names of the form *.[*]Properties* and can be viewed using the Terminal application. Launch the Terminal application (normally found in the Applications>Utilities sub-folder) and enter the following commands:

```
cd ~
ls -la
```

Moving NDI ToolBox Files

The NDI ToolBox utility applications (configure, track, capture) all have to reside in a single folder (default is NDI ToolBox). Within this directory is a Java file named toolbox.jar. It contains supporting code for the utilities and as such has to be located with the utilities. NDI recommends that you do not manually move the folder from where NDI ToolBox has been installed, otherwise the uninstall application will not operate correctly. If you wish to move where NDI ToolBox is installed you should first uninstall it and then re-install.

3 Tutorial: Learning to Use the Polaris Vicra System

This chapter is intended as a tutorial to demonstrate the basic functionality of the Polaris Vicra System using NDI ToolBox. The tutorial is designed for first time users of the system to:

- set up the system to track tools
- observe error and information flags while tracking tools
- track using a reference tool
- pivot a tool to determine the tool tip offset

For more detailed information on NDI ToolBox, refer to the NDI ToolBox online help.

3.1 Getting Started: Tracking Tools

This section describes how to set the system up to track tools.

To Set Up the System

1. Install NDI ToolBox as described in “Installing the Software (Windows)” on page 18, “Installing the Software (Linux)” on page 21 or “Installing the Software (Mac)” on page 23
2. Set up and connect the hardware, as described in “Connecting the Hardware” on page 16.
3. Install the drivers for the Host USB Converter, as described in “Host USB Drivers” on page 19 (Windows), “Host USB Drivers” on page 21 (Linux) or “Host USB Driver” on page 24 (Mac).
4. Open NDI ToolBox.
5. If NDI ToolBox does not automatically connect to the system, select **File** > **Connect to** > **(COMx)** (Windows) or **File** > **Connect to** > **(/dev/ttyUSBx)** (Linux). If you are using a Mac, refer to “Installing the Software (Mac)” on page 23.

To Track Tools

1. If the tool tracking utility is not open, click  to open it.
2. Click  to load the tool definition files for the tools you want to track.
3. In the dialog that appears, browse to the desired tool definition file(s). Hold down **Ctrl** and click to select more than one file.
4. Click **Open**.

   Once a tool definition file has been loaded, the Polaris Vicra System will automatically attempt to track the tool.
5. Move the tool throughout the characterized measurement volume, making sure the markers on the tool face the Position Sensor.

As you move the tool, the symbol representing the tool in the graphical representation will move to reflect the tool's position.

3.2 Triggering Information and Error Flags

This section describes how to trigger some of the most common flags. errors, warnings, and marker information for each tool are displayed in the bottom right section of the tool tracking utility.

To View Information and Error Flags

1. Set up the system to track tools, as described in "Getting Started: Tracking Tools" on page 28.
2. For each loaded tool definition file, there is a tab in the bottom right section of the tool tracking utility. Select a tab to display tracking information for a particular tool.

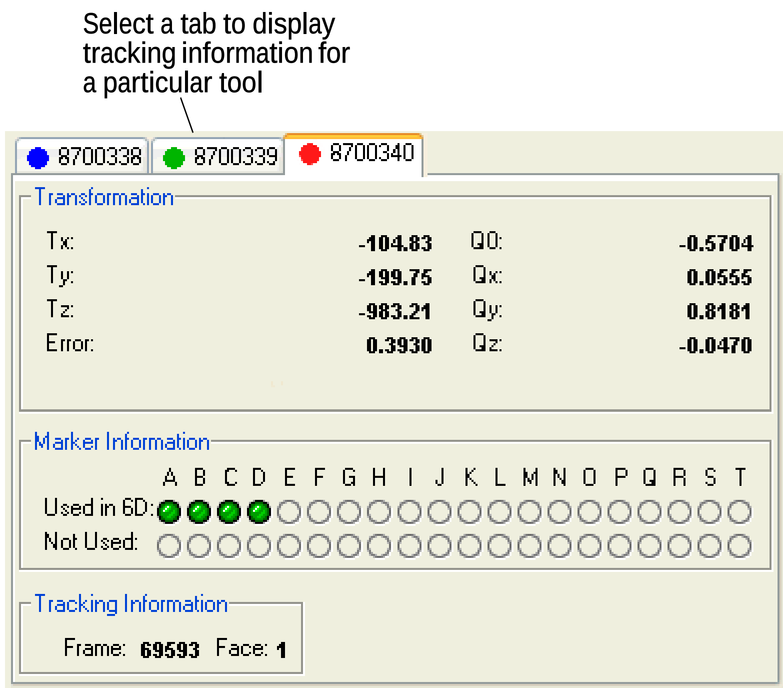


Figure 3-1 Tutorial: NDI ToolBox - Tool Tracking Window

"Partially Out of Volume" and "Out of Volume" flags:

Move the tool to the edge of the characterized measurement volume.

As you move the tool to the edge of the volume (some markers are in the volume and some out), NDI ToolBox will display the message "Partially Out of Volume." Once the tool is completely outside of the volume (all markers are outside the volume), NDI ToolBox will display the message "Out of Volume."

Figure 3-2 Tutorial: "Partially Out of Volume" Flag

"Too Few Markers" flag:

1. Position the tool inside the characterized measurement volume, with the markers facing the Position Sensor.
2. Cover one or more markers, without touching them.

   The Position Sensor will no longer be able to detect the covered markers.

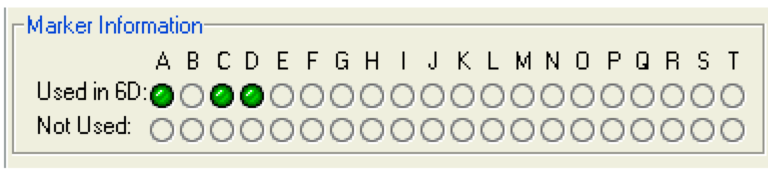


Figure 3-3 Tutorial: Detected Markers Indicator

   If the Position Sensor cannot detect the minimum number of markers, NDI ToolBox will display the message "Too Few Markers" and will not report a transformation.

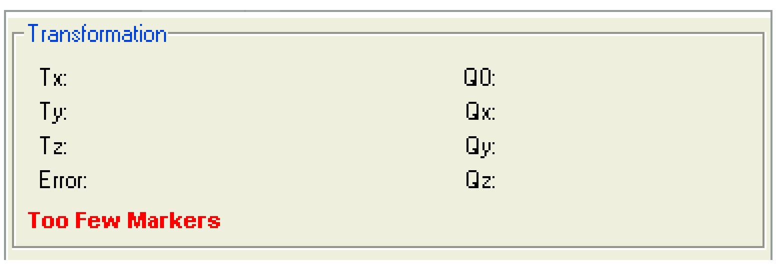


Figure 3-4 Tutorial: "Too Few Markers" Flag

"Exceeded Maximum Marker Angle" flag:

1. Position the tool inside the characterized measurement volume, with the markers facing the Position Sensor.
2. Turn the tool gradually until the markers are no longer facing the Position Sensor.

   Once a marker has exceeded the maximum marker angle, NDI ToolBox will display a blue indicator in the Not Used section of the marker information.

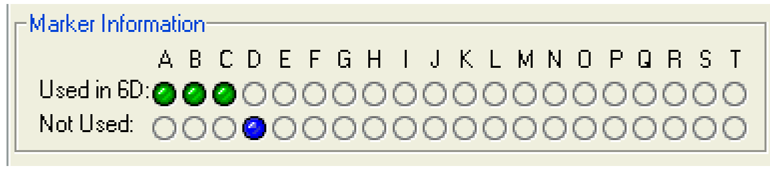


Figure 3-5 Tutorial: "Exceeded Max Marker Angle" Indicator

3.3 Setting a Tool as Reference

This section describes how to set a tool as reference. When you set a tool as reference, all the other tools will be tracked with respect to the reference tool. For more information on reference tools, see "Reference Tools" on page 48.

To Set a Tool as Reference

1. Set up the system to track tools, as described in "Getting Started: Tracking Tools" on page 28.
2. Click  to load tool definition files for at least two tools.
3. For each loaded tool definition file, there is a tab in the bottom right section of the tool tracking utility. Select the tab corresponding to the tool you want to set as reference.

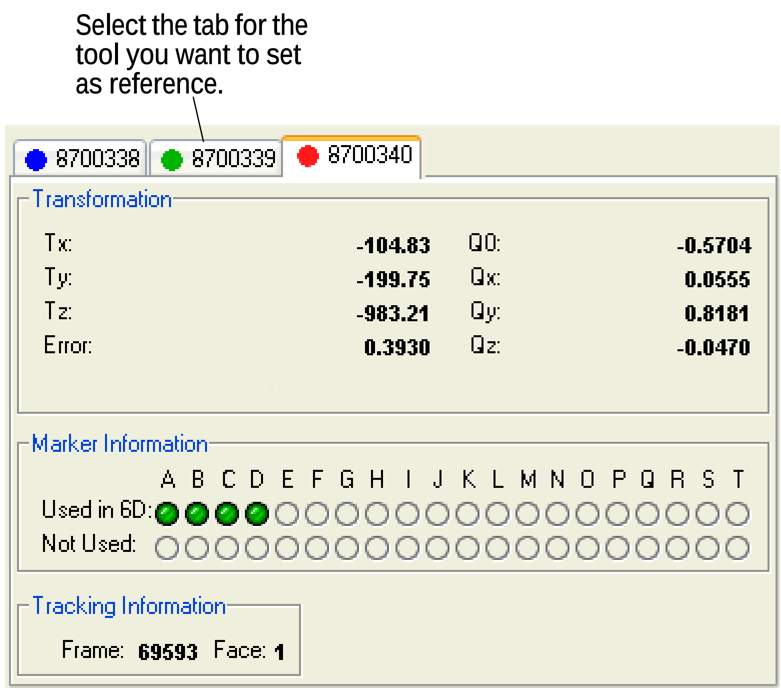


Figure 3-6 Tutorial: Selecting a Reference Tool

4. Right click on the tool tab, then select **Global Reference**.

   The reference tool will appear as a square in the graphical display. The other tools will be displayed inside a square, that is the colour of the reference tool. The positions and orientations of other tools will now be reported in the local coordinate system of the reference tool.

Note The Polaris Vicra System still calculates the tool transformations in the coordinate system of the Position Sensor. The NDI ToolBox software then calculates and reports the tool transformations with respect to the reference tool.

3.4 Determining the Tool Tip Offset

This section describes how to determine the tool tip offset of a probe or pointer tool by pivoting. Once NDI ToolBox has calculated the tool tip offset, it can report the position of the tip of the tool, instead of the position of the origin of the tool. See “Tool Tip Offset” on page 47 for more details.

To Set Up the System to Pivot

You will need a divot in which to rest the tool tip while you pivot the tool. The size and shape of the divot must match the tool tip, to ensure that the tip does not move. For example, a probe with a 1 mm ball tip requires a hemispherical divot with a 1 mm diameter in which to pivot.

1. Set up the system to track tools, as described in “Getting Started: Tracking Tools” on page 28.
2. Click to load a tool definition file for the probe or pointer tool.
3. For each loaded tool definition file, there is a tab in the bottom right section of the tool tracking utility. Select the tab corresponding to the tool you want to pivot.

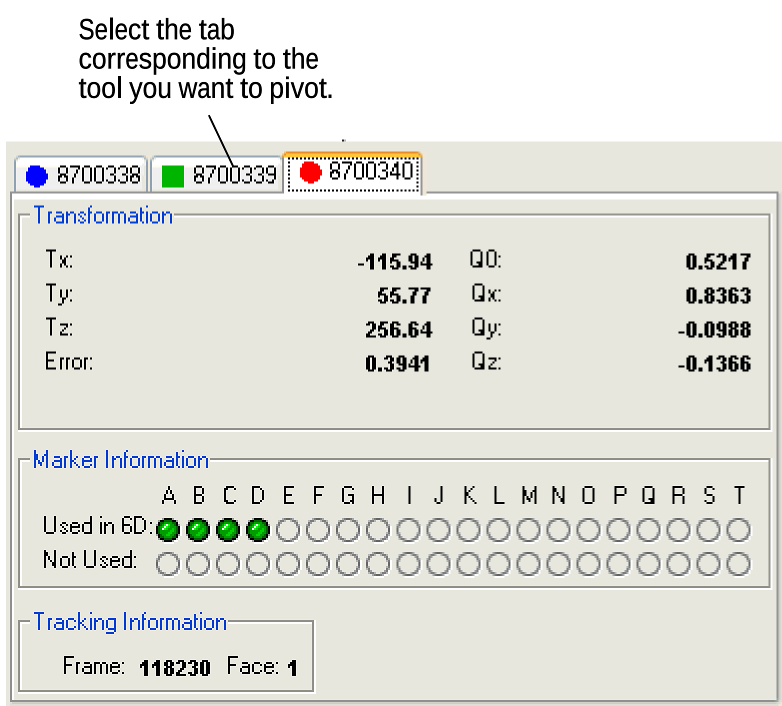


Figure 3-7 Tutorial: Selecting a Tool to Pivot

4. Click to open the **Pivot** dialog.
5. Select a start delay of about 5 seconds and a duration of about 20 seconds.

To Pivot the Tool

1. Place the tool tip in the divot.
2. Ensure that the tool is within the characterized measurement volume, and will remain within the volume throughout the pivoting procedure.
3. Click **Start Collection** in the **Pivot tool** dialog.
4. Pivot the tool in a cone shape, at an angle of 30º to 60º from the vertical.
   a) Keep the tool tip stationary, and ensure that there is a line of sight between the markers on the tool and the Position Sensor throughout the pivoting procedure.
   b) Pivot the tool slowly until the specified pivot duration time has elapsed.

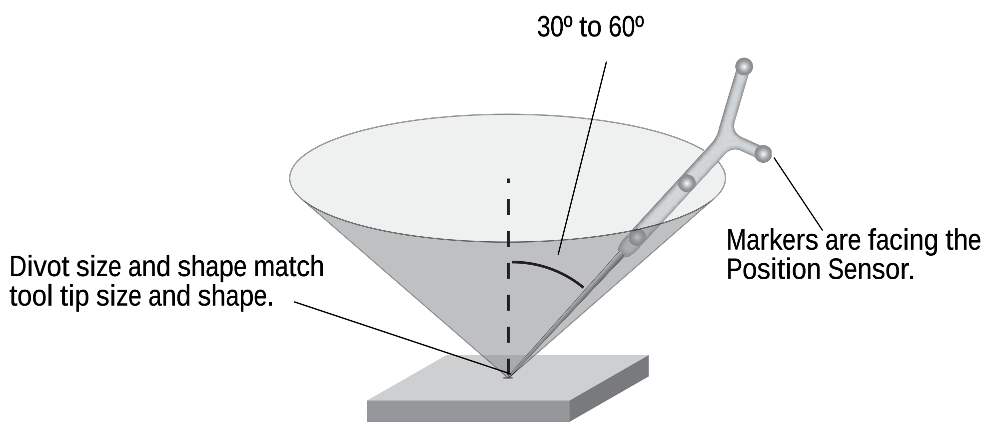


Figure 3-8 Tutorial: Pivoting Technique

When the pivot is complete, the **Pivot Result** dialog appears. Click **Apply Offset** to report the position of the tip of the tool.

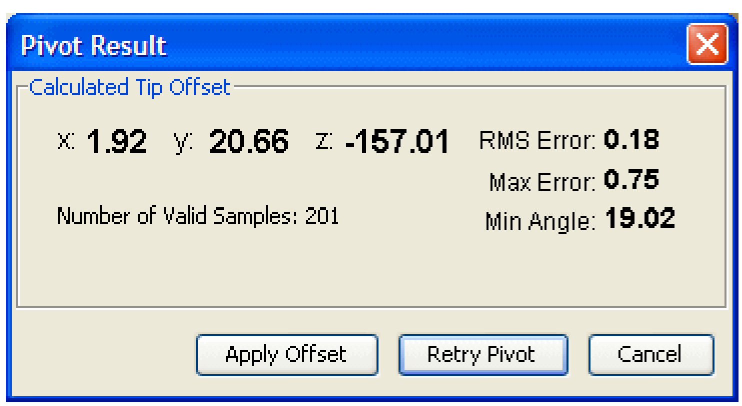


Figure 3-9 Tutorial: Pivot Result Dialog

4 How the Polaris Vicra System Works

This chapter provides details on how the Polaris Vicra System works. The information can help increase your technical understanding of the system, but is not absolutely necessary in order to use the system. To learn how to use the system, refer to "Tutorial: Learning to Use the Polaris Vicra System" on page 28.

This chapter contains the following information:

4.1 Communicating with the Polaris Vicra System

The Polaris Vicra System is controlled using an application program interface (API). The API is a set of commands and parameters that allow you to configure and request information from the system.

Values for different aspects of the Polaris Vicra System are stored in user parameters. Some user parameters store values for the full system configuration (for example, the combined firmware revision); others store values pertaining to a particular hardware device in the system (for example, the illuminator rate on the Position Sensor). Some user parameters are read-only parameters that store useful information about the system; some user parameter values can be changed, to allow you to configure the system. You can read and change user parameter values using API commands.

NDI Combined API Sample and NDI ToolBox both allow you to view the communications stream of API commands and responses between the application and the Polaris Vicra System.

For details on API commands and user parameters, see the "*Polaris Application Program Interface Guide*."

4.2 Information Returned by the Polaris Vicra System

Warning! Do not use the Polaris Vicra System for absolute measurements; the system is designed for relative measurements only. Treating measurements as absolute may result in an incorrect interpretation of results. If your application involves personal safety, these incorrect interpretations may result in personal injury.

When the Polaris Vicra System is tracking tools, it returns information about those tools to the host computer. The system by default returns:

- **the position of each tool's origin**, given in mm, in the coordinate system of the Position Sensor (see "Global Coordinate System" on page 36)

Note Transformations with respect to a reference tool (described on page 48), and transformations for a probe with a tool tip offset (described on page 47) are calculated using application software such as NDI ToolBox.

- **the orientation of each tool**, given in quaternion format. The quaternion values are rounded off, so the returned values may not be normalized.
- **an error value** for each tool transformation. This RMS value, given in mm, is the result of the least squares minimization between the marker geometry in the tool definition file and the tool's measured marker positions.
- **the status of each tool**, indicating whether the tool is out-of-volume, partially out-of-volume, or missing. It also indicates whether the port handle corresponding to each tool is enabled and initialized. For more information on port handles, see the "*Polaris Application Program Interface Guide*".
- **the frame number** for each tool transformation. The frame number is incremented by 1 at a constant rate of 60 Hz. The frame counter starts as soon as the system is powered on, and can be reset using API commands (see the "*Polaris Application Program Interface Guide*" for details). The frame number returned with a transformation corresponds to the frame in which the data used to calculate that transformation was collected.
- **the system status**, which includes some of the system errors described in "Tracking Errors and Flags" on page 57.

If requested, the system can also return:

- tracking errors and flags (described in "Tracking Errors and Flags" on page 57). (Some tracking errors and flags are returned by default.)
- marker status information, such as whether a particular marker was used to calculate a tool transformation.
- positions of stray passive markers.
- transformations for tools that are outside of the characterized measurement volume.

- transformations for tools when the system has detected one of the following error conditions:
  - the bump sensor has been triggered,
  - the system is outside of operating temperature range,
  - the bump sensor battery power is low,
  - the temperature sensors are outside of functional range, or
  - the input voltage is out of range.

The tool tracking utility of NDI ToolBox displays most of this returned information (except for the port handle information).

Note For information on the API commands used to request tracking information from the Polaris Vicra System, see the "*Polaris Application Program Interface Guide*".

4.3 Global Coordinate System and Measurement Volume

Global Coordinate System

The Polaris Vicra Position Sensor uses a coordinate system with an origin located at the Position Sensor and axes aligned as shown in Figure 4-1. This global coordinate system is defined during manufacturing and cannot be changed.

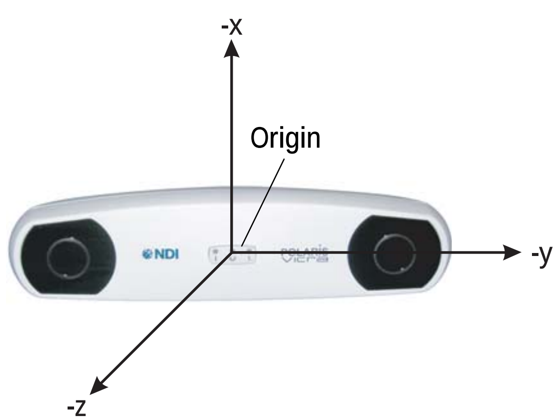


Figure 4-1 Position Sensor Global Coordinate System

Warning! Do not use the Polaris Vicra System for absolute measurements; the system is designed for relative measurements only. Treating measurements as absolute may result in an incorrect interpretation of results. If your application involves personal safety, these incorrect interpretations may result in personal injury.

The Polaris Vicra System will report the transformations of tools in the global coordinate system. However, if you are using a reference tool, software can calculate and report transformations in the local coordinate system of the reference tool. For more information on reference tools, see "Reference Tools" on page 48.

Field of View and Characterized Measurement Volume

The **field of view** is the total volume in which the Polaris Vicra System can detect a marker, regardless of accuracy.

The **characterized measurement volume** is a subset of the field of view. It is the volume where data was collected and used to characterize the Polaris Vicra System Position Sensor. The dimensions of the characterized measurement volume are illustrated in Figure 4-2.

Within the characterized measurement volume, the Polaris Vicra System can measure a single marker with an accuracy of 0.25 mm RMS. The accuracy of measurements reported outside the Polaris Vicra characterized measurement volume is unknown. The Position Sensor's performance is determined using the calibration methodology described in Appendix A on page 94.

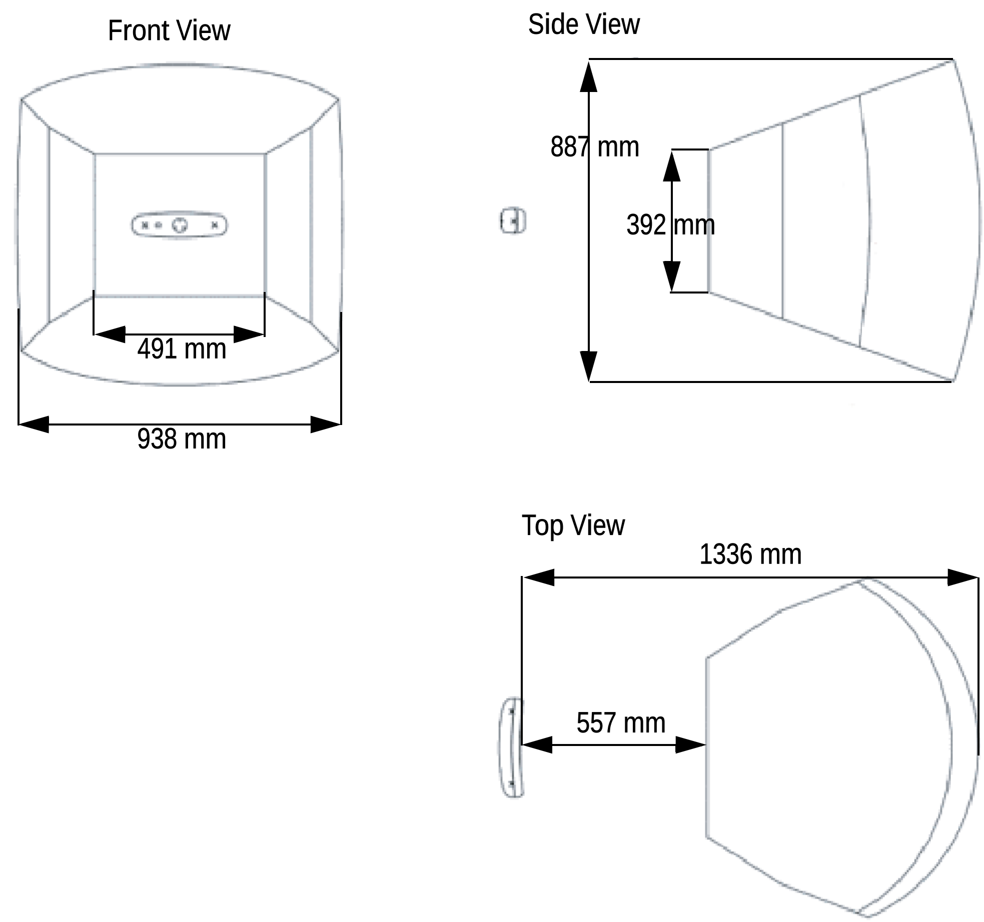


Figure 4-2 Characterized Measurement Volume

Out of Volume and Partially Out of Volume

A tool is flagged as **out of volume** if all of its markers are outside of the characterized measurement volume, but the system can still detect the tool.

The Polaris Vicra System is specifically designed to NOT report measurements for tools or markers that are out of volume. By default, the Polaris Vicra System reports tools with markers that are outside of the characterized measurement volume as missing. You can request measurements for these tools by using reply option 0x0800 with the BX or TX command. You enable this additional functionality at your own discretion. See the "*Polaris Application Program Interface Guide*" for details.

A tool is flagged as **partially out of volume** if:

- fewer than the minimum number of markers (a parameter in the tool definition file) are inside the characterized measurement volume, and
- at least one marker on the tool is inside the characterized measurement volume

For example, consider a five-marker tool, with three markers inside the characterized measurement volume and two markers outside the volume. If the minimum number of markers is set to 3, the tool is considered to be inside the volume. If the minimum number of markers is set to 4 or 5, the tool will be flagged as partially out of volume. (The minimum number of markers parameter specifies the minimum number of markers that the system must use in the calculation of a tool transformation. See page 44 for details.)

4.4 Marker Detection and Tool Tracking

Detecting Markers

The Position Sensor detects active and passive markers using different methods. Active markers are triggered by a 20 Hz "chirp" signal emitted by the Position Sensor illuminators, which causes the active markers to emit IR for the integration time. (The chirp signal is only a trigger.)

To detect passive markers, the Position Sensor's illuminators flood the surrounding area with IR for the whole integration time by flashing at 20 Hz (similar to the flash on a camera). The passive sphere markers have a retro-reflective coating that reflects the IR directly back to the Position Sensor instead of scattering it.

For both active and passive markers, the Position Sensor collects IR for a period of time called the **integration time**. This acts like an electronic shutter. The system makes automatic adjustments to the integration time so that the intensity of the brightest IR detected is set to a maximum value, and the intensity of all other IR detected falls below this value. This process is called **dynamic range control**.

The system distinguishes between potential marker data and background IR using a value called the **trigger level**. The trigger level is the minimum IR intensity considered to be valid marker data. Background IR that falls below the trigger level is rejected by the Position Sensor. The trigger level generally increases with integration time; see "Setting the Infrared Light Sensitivity" on page 62 for more details.

Acquiring and Tracking Tools

When the Polaris Vicra System first begins tracking a tool, or whenever a tool goes missing, it must "acquire" the tool. (For information on why a tool goes missing, see "Missing and Disabled Transformations" on page 56.) To acquire tools, the Polaris Vicra System first measures the positions of all the visible markers.

IR light hits the Charge Coupled Devices (CCDs) in the Position Sensor. If the system is unable to detect individual IR sources, or has detected more IR sources than it can process, it will report an error, see “Tracking Errors and Flags” on page 57. Otherwise, the system will calculate the position of the IR sources.

To determine the position of an IR source, the Position Sensor calculates a line between the source of IR and each sensor (displayed as dotted lines in Figure 4-3). Where the lines cross each other, the Polaris Vicra System calculates the **line separation**. (The distance between the lines.) (In a theoretical case the lines will intersect exactly, but in the modelled “real world” case they will be apart.) If the line separation at this point is less than a pre-defined limit, the Polaris Vicra System considers the point to be a possible marker position. Otherwise, the point is discarded.

Figure 4-3 Determining a Marker Position

Once the system has measured the positions of all the markers, it calculates the segment length (the distance between two markers) for each pair of markers, and the angle between each segment. It compares this data with the marker geometry data in each tool definition file (described on page 42), to determine which markers belong to which tool. The unique geometry requirements, described in the “*Polaris Tool Design Guide*”, allow the Polaris Vicra System to distinguish between tools. Any markers that are not part of a tool are considered stray markers (this may include phantom markers). See “Stray Marker Reporting” on page 49 for more details on stray markers and phantom markers.

The Polaris Vicra System has “acquired” a tool once it has matched the **minimum number of markers** (a parameter in the tool definition file) for the tool and can calculate a transformation for the tool. Once a tool has been acquired, the Position Sensor tracks it using a predictive algorithm.

Three-Marker Lock-On

If the “three-marker lock-on” option is enabled in the tool definition file, the Polaris Vicra System will acquire and track the tool as long as it can detect at least three markers. The system will not report the transformations unless the minimum number of markers is used to calculate the transformation.

For example, consider a four-marker tool with the “three-marker lock-on” option enabled. If the system can only detect three of the markers on the tool, it will continue to track that tool but will only report transformations if the minimum number of markers is set to 3. If the minimum number of markers is set to 4, the system will continue to track the tool in the background, but will report the tool as MISSING. Selecting three-marker lock-on in this case will result in the tool transformations being reported faster, once the minimum number of markers becomes visible, because the system does not have to spend time re-acquiring the tool.

Note For more details on the “three-marker lock-on” option, see the “*Polaris Tool Design Guide*”.

4.5 Sampling Rate

The sampling rate is the rate at which the system reports information for all the tools. The illuminator rate is limited to 20 Hz to track passive tools. Therefore, the Polaris Vicra System returns transformations at 20 Hz. (Tracking an active wireless tool does not affect the sampling rate of the system.)

4.6 Polaris Vicra System Tools

A tool is a rigid structure on which three or more markers are fixed so that there is no relative movement between them. Polaris Vicra tools can be either passive or active wireless. See “Passive Tools” on page 40 and “Active Wireless Tools” on page 41 for further information.

Up to 15 compatible tool definition files can be loaded simultaneously, ready for tracking. The system can simultaneously track up to six passive tools and one active wireless tool within the following constraint: a maximum of 32 passive and 32 active markers, including stray markers, can simultaneously be in view of the Position Sensor, regardless of whether or not they are being tracked. Additional markers in view may affect the speed of the system and its ability to return transformations.

The Position Sensor tracks tools based on marker geometry, which is specified in the tool definition file for each tool. A tool definition file must be loaded before the Polaris Vicra System can track its associated tool. For more information on tool definition files, see “Tool Definition File” on page 42.

Tools are available from NDI for use with the Polaris Vicra System. Contact NDI for more details.

Passive Tools

Passive tools are wireless, and incorporate NDI passive sphere markers. The passive sphere markers have a retro-reflective coating that reflects IR light back to its source, instead of scattering it. To track passive tools, the Position Sensor flashes IR from its illuminators, similar to the flash on a camera. The IR floods the surrounding area and reflects off the passive markers back to the Position Sensor, where it is detected by the sensors.

The Polaris Vicra System can report the positions of passive markers individually, and calculate the position and orientation of tools that incorporate them. The measured position is the centre of the marker. When a passive sphere marker is attached to an NDI mounting post, the centre of the sphere is located at the top of the mounting post.

The Position Sensor recognizes passive tools solely by marker geometry. The marker geometry is specified in the tool definition file, which must be loaded into the system before the tool can be tracked. See “Tool Definition File” on page 42 for details.

Warning! Do not use a wireless tool whose design does not conform to the Polaris Vicra System's unique geometry constraints. When a Polaris Vicra System attempts to track more than one wireless tool in the measurement volume, these unique geometry constraints ensure that they are distinguishable from each other. Reliance on data produced by two indistinguishable tools can lead to inaccurate conclusions. If your application involves personal safety, these inaccurate conclusions increase the possibility of personal injury.

The passive markers can only be sterilized one time. NDI does not recommend that a passive marker be used if it has been sterilized more than once, as multiple cycles of sterilization may adversely affect the marker's performance. Testing has shown that there is no significant degradation in the performance of these markers after one cycle of ETO, STERRAD 100S, or STERIS SYSTEM 1 sterilization. The passive markers cannot be autoclaved. Pre-sterilized passive sphere markers are also available; contact NDI for details.

Warning! Do not use markers without inspecting them for cleanliness and damage both before and during a procedure. Reliance on data produced by unclean or damaged markers may lead to inaccurate conclusions. If your application involves personal safety, inaccurate conclusions increase the possibility of personal injury.

Caution! Do not handle the passive sphere markers with bare hands as this will leave residue from skin that affects the marker's reflectivity. Take care not to drop or scuff the markers, as this also affects the reflectivity of the markers.

For detailed information on passive sphere markers, see the "*Polaris Tool Design Guide*."

Active Wireless Tools

Active wireless tools are not connected to the system, and incorporate active markers. Active wireless tools are powered by battery or by the equipment to which they are attached. To track active wireless tools, the Position Sensor pulses the illuminators in a way that is recognizable by an IR receiver in the active wireless tool. The active wireless tool detects the IR pulse; the markers then emit IR, which is detected by the Position Sensor.

The Position Sensor recognizes active wireless tools solely by marker geometry. The marker geometry is specified in the tool definition file, which must be loaded into the system before the tool can be tracked. See "Tool Definition File" on page 42 for details.

Warning! Do not use a wireless tool whose design does not conform to the Polaris Vicra System's unique geometry constraints. When a Polaris Vicra System attempts to track more than one wireless tool in the measurement volume, these unique geometry constraints ensure that they are distinguishable from each other. Reliance on data produced by two indistinguishable tools can lead to inaccurate conclusions. If your application involves personal safety, these inaccurate conclusions increase the possibility of personal injury.

Active markers are physically smaller than passive sphere markers. They consist of an infrared light-emitting diode (IRED) mounted on a ceramic base. The ceramic base allows the markers to be sterilized by auto-claving.

Warning! Do not use markers without inspecting them for cleanliness and damage both before and during a procedure. Reliance on data produced by unclean or damaged markers may lead to inaccurate conclusions. If your application involves personal safety, inaccurate conclusions increase the possibility of personal injury.

Tool Characteristics

Tools used with the Polaris Vicra System have the following characteristics:

- A 5DOF (five degrees of freedom) tool has between three and six markers. All the markers on a 5DOF tool are collinear. The Polaris Vicra System will report the 3D position and 2D orientation of a 5DOF tool.
- A 6DOF (six degrees of freedom) tool has between three and six markers that are not collinear. The Polaris Vicra System will report the 3D position and 3D orientation of a 6DOF tool.
- The geometry of each tool must follow the unique geometry constraints. Tools must have different marker geometries from one another, so the Position Sensor can distinguish between them. A marker geometry that is the mirror image of another tool's marker geometry is not considered unique. For more details on unique geometry constraints and marker geometry, see the "*Polaris Tool Design Guide*".
- A multi-faced tool (which is also 6DOF) can have up to six faces, totalling a maximum of 20 markers. Each face on a tool is treated as a separate rigid body which complies with the following constraints:
    - It has a maximum of six markers
    - It complies with the unique geometry constraints
    - It has a different marker geometry from the other faces on the tool.
- Each tool has its own local coordinate system This is defined during the tool characterization process, and is often dependent on the tool's intended use.

Multi-Faced Tool Tracking

When the Polaris Vicra System is tracking a multi-faced tool, it tracks only one face at a time. The face being tracked is returned with reply option 0x0002 of the BX and TX commands, and is reported in NDI ToolBox (see the online help in NDI ToolBox for more details).

Each face is assigned a face normal in the tool definition file (described below). The face normal is a vector pointing in the same direction as the tool face, to let the Polaris Vicra System know the direction each tool face is facing. The system will track the face most directly oriented to the Position Sensor (i.e. the face with the smallest angle between the face normal and the sensors in the Position Sensor). If the minimum number of markers are not visible on the face most directly oriented to the Position Sensor, the system will attempt to track another face.

The system has a hysteresis of 2° when determining whether to switch faces. The system will determine the angle between the sensors and each face of the tool. If the face with the smallest angle is 2° smaller than the current face's angle, the system will switch to the new face.

4.7 Tool Definition File

A **tool definition file** (formatted as .rom) describes a tool to the Position Sensor. The information stored in the tool definition file includes the geometry of the tool's markers, the tool's manufacturing data, information on marker and face normals, face definitions, and the parameters used to track tools. For more information on the parameters used to track tools, see Tool Tracking Parameters below.

A tool definition file must be loaded into the system (by the host computer) before the Polaris Vicra System can track its associated tool. If the Polaris Vicra System is measuring the positions of stray markers (described in "Stray Marker Reporting" on page 49), at least one tool definition file must be loaded in order for the Position Sensor illuminators to emit IR light.

Tool definition files can be created in NDI 6D Architect. The procedure used to create a tool definition file is called **tool characterization**. For more information on tool characterization, see the "*Polaris Tool Design Guide*" and the "*NDI 6D Architect User Guide*".

4.8 Tool Tracking Parameters

The tool tracking parameters (described below) are the **maximum 3D error**, the **maximum marker angle**, the **minimum number of markers**, and the **minimum spread**. They are specified in the tool definition file (described on page 42). The flow chart on page 46 describes how the Polaris Vicra System uses the tool tracking parameters to determine which markers to use to calculate a tool transformation, and when to return a transformation.

For information on how to change the tool tracking parameters and what values to use, see the "*Polaris Tool Design Guide*" and the "*NDI 6D Architect User Guide*".

Maximum 3D Error

The **maximum 3D error** parameter specifies the maximum allowable 3D error for each marker on the tool. The maximum 3D error is the difference between the measured and expected location of a marker on a tool. The expected location of a marker on a tool is specified in the tool definition file (described on page 42).

If the 3D error for a particular marker is greater than the specified maximum 3D error value, the data from that marker will be not be used to determine the tool transformation.

Maximum Marker Angle

The **maximum marker angle** parameter specifies the maximum allowable angle between a marker and each sensor on the Position Sensor. The default maximum marker angle for passive sphere markers is 90º and for active markers it is 60°. Each marker has an associated normal vector, which is defined in the tool definition file. A marker normal is a vector of length 1, and points in the same direction as the marker, as illustrated in Figure 4-4.

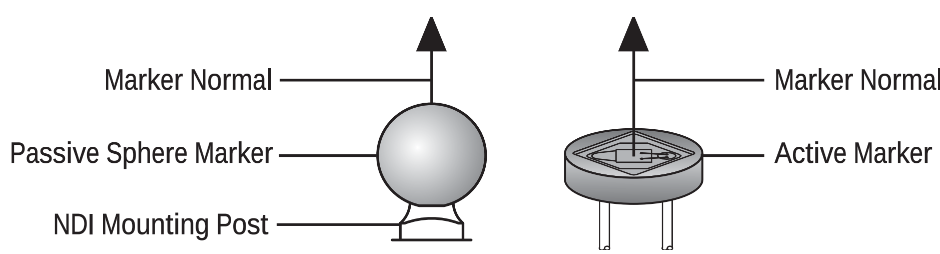
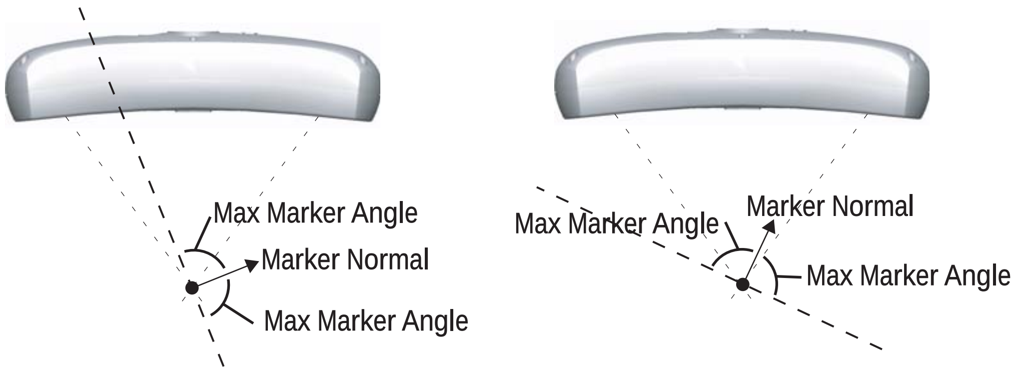


Figure 4-4 Marker With Marker Normal

The Polaris Vicra System uses the marker normal to determine which direction the marker is facing. The system measures the angle between the marker normal and each sensor, in both the Position Sensor's *xy*- and *yz*-planes. (The Position Sensor's coordinate system is described in "Global Coordinate System" on page 36.) The Position Sensor then compares these measured angles to the maximum marker angle, as illustrated in Figure 4-5.



The angle between the marker normal and the left sensor is greater than the maximum marker angle.

The angle between the marker normal and each sensor is less than the maximum marker angle.

Figure 4-5 Maximum Marker Angle

If the angle between a marker normal and either sensor is greater than the specified maximum marker angle, the system will not use the data from that marker to determine the tool transformation.

The further a marker is from the Position Sensor, the smaller the angle it can be turned and still be within the maximum marker angle.

Minimum Number of Markers

The **minimum number of markers** parameter specifies the minimum number of markers that the Position Sensor must use in the calculation of a tool transformation in order to return the transformation. If the system cannot calculate a transformation using the minimum number of markers, it will report the tool as MISSING.

For example, consider a four-marker tool that has three markers inside the characterized measurement volume, and one marker outside of the characterized measurement volume. If the minimum number of markers parameter is set to 3, the Polaris Vicra System will report transformations for the tool (as long as the other tool tracking parameters are satisfied). If the minimum number of markers parameter is set to 4, the Polaris Vicra System will report the tool as MISSING.

Note You can tell the Polaris Vicra System to report the positions of tools that have fewer than the minimum number of markers inside the characterized measurement volume by using reply option 0x0800 with the TX or BX command. This may reduce the accuracy of the transformations. See the "*Polaris Application Program Interface Guide*" for details.

Minimum Spread

The **minimum spread** parameters specify the minimum size 3D box that must contain all the markers used in the calculation of a tool transformation. The length, width, and height of this box must be greater than the specified Minimum Spread 1, Minimum Spread 2 and Minimum Spread 3 parameters, respectively, or else the system will not return a transformation.

This setting is optional. For more details on the minimum spread parameter, see the "*Polaris Tool Design Guide*".

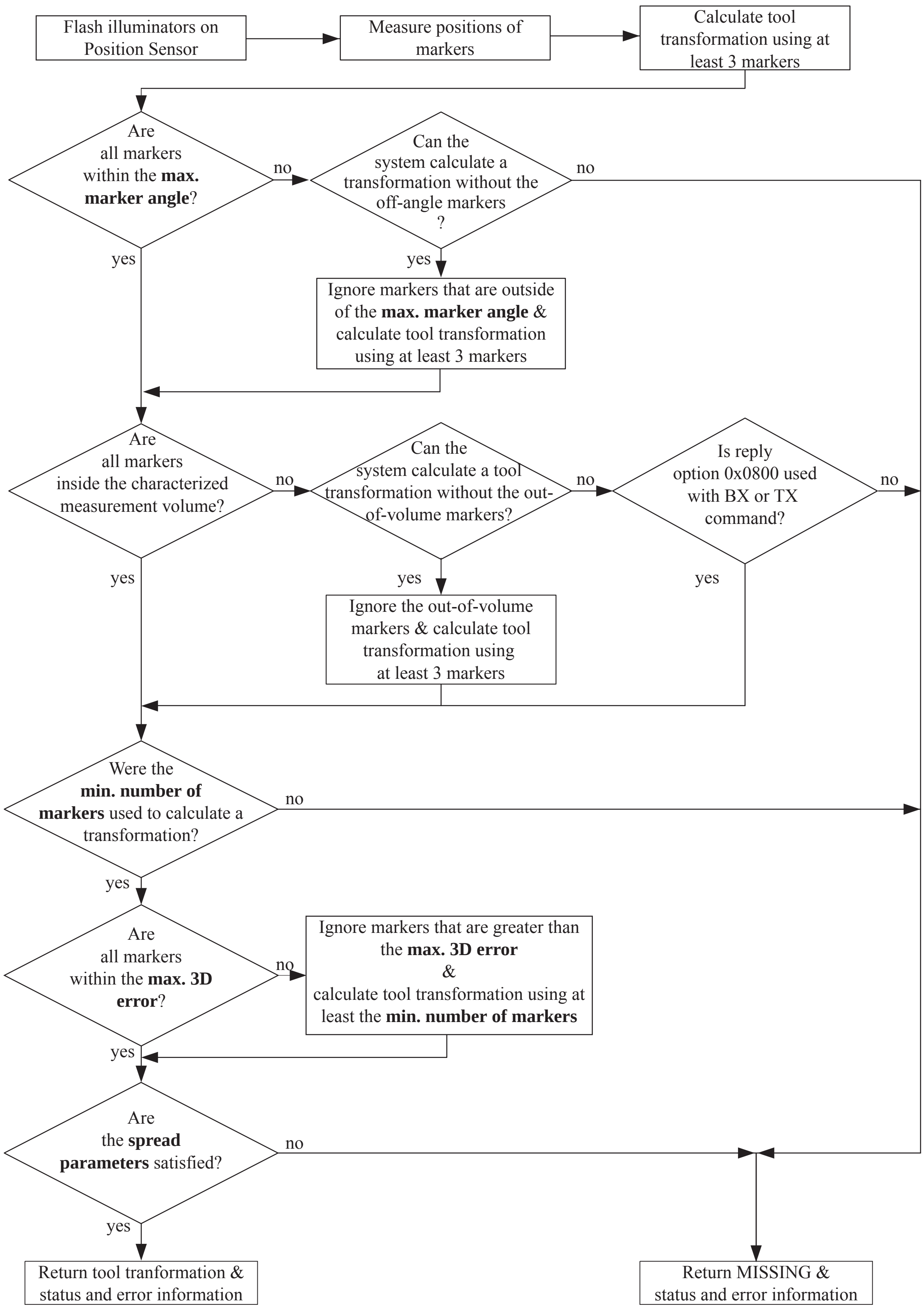


Figure 4-6 Flowchart of Tool Tracking Parameters

4.9 Tool Tip Offset

Warning! Do not use a tool with a tip without first performing a pivot procedure to verify the tip offset. Reliance on data produced by a tool with an inaccurate tip offset may lead to inaccurate conclusions. If your application involves personal safety, these inaccurate conclusions increase the possibility of personal injury.

The **origin** of a tool is defined as part of the tool's local coordinate system in the tool definition file. When the Position Sensor tracks a tool, it reports the transformations of the origin of the tool.

In certain circumstances, it is useful to track a point on the tool other than the tool's origin. In particular, it is useful to track the location of the tip of a probe. It is possible to define the tool's origin at the tip of the probe; however, if the tool is later bent, the origin will no longer be located at the tip.

NDI recommends determining the **tool tip offset** of the tool, prior to each use. The tool tip offset is the vector between the tip of the tool and the origin of the tool. Application software can apply the tool transformations reported by the Polaris Vicra System to the tool tip offset, in order to determine the location of the tool tip.

Note: The Polaris Vicra System always tracks the origin of the tool. It is the application software, not the Polaris Vicra System, that calculates the location of the tool tip.

Determining the tool tip offset prior to each use ensures that the location of the tool tip is known as accurately as possible.The tool tip offset can be determined either by using a calibrator, or by performing a pivoting procedure.

Using a Calibrator

A calibrator is a rigid body that incorporates three or more markers and a clamping mechanism. The clamping mechanism allows another tool (usually a probe) to be clamped into place. An example of a calibrator is illustrated in Figure 4-7. To use a calibrator to determine the tool tip offset of a probe, clamp the probe in place on the calibrator. The origin of the calibrator is defined at the point where the tool tip will rest. The Polaris Vicra System can then measure the positions of the probe's origin and the calibrator's origin. The application software compares these measurements to determine the tool tip offset of the probe.

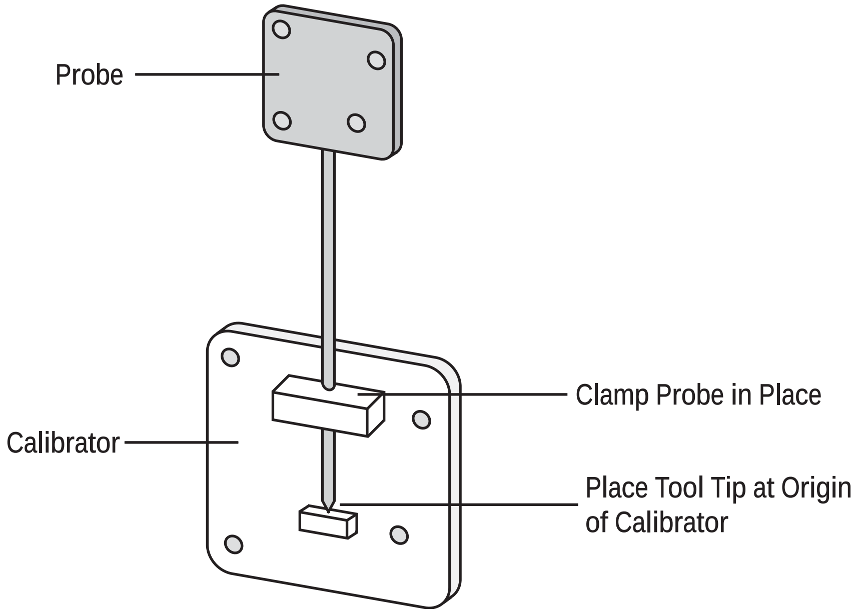


Figure 4-7 Sample Calibrator

Pivoting

You can also determine the tool tip offset using a process called pivoting, using either NDI ToolBox or NDI 6D Architect software. During the pivoting procedure, the Polaris Vicra System will measure the positions of the markers while you pivot the tool. The software collects this data, and uses it to determine the tool tip offset. Instructions on how to pivot a tool are detailed in "Determining the Tool Tip Offset" on page 32. In addition the procedure is also detailed in the "*NDI 6D Architect User Guide*" and online help, and in the NDI ToolBox online help.

4.10 Reference Tools

A reference tool is a tool whose local coordinate system is used as the global coordinate system in which other tools are tracked. The Polaris Vicra System tracks all the tools, including the reference tool, and reports the transformations in the coordinate system of the Position Sensor (described on page 36). Software (such as NDI ToolBox) then calculates and reports the positions and orientations of all other tools with respect to the position and orientation of the reference tool.

Note Use a reference tool to ensure minimal drift in the measurements produced; specifically, drift caused by time, settling and/or temperature.

It is the application software, not the Polaris Vicra System, that calculates the tool transformations with respect to the reference tool.

For example, in neurosurgery the reference tool can be attached to the patient's head. Then a registration procedure is performed that defines the reference tool's position relative to the patient's head. From then on, if either the patient's head or the Position Sensor shifts, the measurements are not affected since they are reported with respect to the patient's head (the reference tool) and not with respect to the Position Sensor.

If the Polaris Vicra cannot track the reference tool (for example, if the reference tool is occluded), then the software will not be able to calculate the transformations of other tools with respect to the reference tool.

4.11 Stray Marker Reporting

A stray marker is a marker that is not part of a rigid body. For example, by placing stray markers on a patient's chest, the markers may be used to gate/track the patient's breathing in order to time radiation therapy.

If the stray marker reporting functionality is enabled, the Polaris Vicra System will report tool transformations, as well as 3D data (position only, no orientation information) for up to 50 markers that are not used in tool transformations (including phantom markers, described below). It is then necessary to eliminate phantom markers within the application software, and verify that the stray markers are within the characterized measurement volume.

It is important to be aware of the potential hazards associated with using the stray marker reporting functionality. The hazards are as follows:

- An external IR source, for example, an IR transmitter or incandescent light, may be identified as a stray marker.
- No marker identification is possible from frame to frame. It is therefore the user's responsibility to devise a method to keep track of which 3D position belongs to which marker in which they are interested.
- A stray marker does not have a marker normal, so there is no way to know if the marker orientation is exceeding a particular angle.
- There are no built in checks to determine if the 3D result is a real marker or a phantom marker, generated by other IR sources or markers in view of the Position Sensor. The system tries to reject markers by the use of the line separation qualifier, but if several markers are in a line parallel to the horizontal plane of the Position Sensor, phantom markers may still be generated that are within the line separation qualifier. (Phantom markers are explained on page 50.)
- Partial occlusion of markers cannot be detected, or compensated for by the Position Sensor. The user may be able to detect the apparent shift if the marker position can be constrained in the application software. For example, the marker position has to be constrained along a vector and its position relative to another marker is supposed to be fixed within some tolerance.

Warning! Do not rely on unqualified 3D results for stray markers. There are no built-in checks to determine if the 3D results for stray markers represent real markers, phantom markers or IR interference, so the host application must identify and qualify the reported 3D results for stray markers. Reliance on unqualified 3D data may lead to inaccurate conclusions. If your application involves personal safety, inaccurate conclusions may result in personal injury.

To enable the stray marker reporting functionality, use the 0x1000 reply option with the BX or TX command. This reply option returns out-of-volume information along with the 3D data. See the "*Polaris Application Program Interface Guide*" for details.

In order for the Position Sensor to measure stray markers, a tool definition file must be loaded, and the associated port handle must be initialized and enabled, even if no tools are being tracked. The Position Sensor illuminators emit IR light only when a tool definition file is loaded.

4.12 Phantom Markers

Phantom markers are the result of the calculation that the Polaris Vicra System uses to determine the position of a source of IR. They appear, and are reported as, markers but they do not actually exist; they are phantom markers.

To determine the position of a source of IR, the Position Sensor calculates a line between the source of IR and each sensor (displayed as dotted lines in Figure 4-8). Where the lines cross each other, the Polaris Vicra System calculates the **line separation** (the distance between the lines). If the line separation at this point is less than a pre-defined limit, the Polaris Vicra System considers the point to be a possible marker position.

Phantom markers are reported when the imaginary lines calculated from the sensors intersect in more than one place with a line separation less than a pre-defined limit. This generally occurs when two or more markers are in the same plane as the sensors. For example, in the case of two coplanar markers, there will be four mathematical solutions, as illustrated in Figure 4-8. Two are the actual marker locations and two are the phantom marker locations. In the example shown, one phantom marker is closer to the Position Sensor than the actual markers and the other phantom marker is further farther away from the Position Sensor than the actual markers, but this is not the only possible scenario.

The number of phantom markers increases with the number of coplanar markers. When there are *n* coplanar markers, there will be up to $n \bullet (n - 1)$ phantom markers.

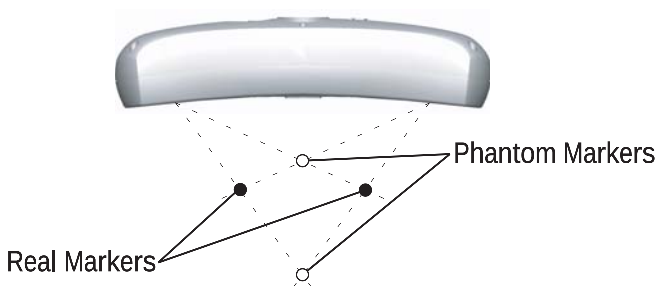


Figure 4-8 Phantom Markers

When you request stray marker data from the Polaris Vicra System, the system will report data for both phantom markers and stray markers. The system cannot distinguish which solutions are phantom markers; it is necessary to eliminate the reported phantom markers using application software.

If you do not request stray marker data from the Polaris Vicra System, the system will not return any phantom marker data.

4.13 Passive Sphere Markers

NDI passive sphere markers have a retro-reflective coating that reflects IR light back to its source instead of scattering it. The IR light from the Position Sensor illuminators reflects off the passive markers directly back to the sensors.

The Polaris Vicra System can report the positions of passive markers individually, and calculate the position and orientation of tools that incorporate them. The measured position is the centre of the marker. When a passive sphere marker is attached to an NDI mounting post, the centre of the sphere is located at the top of the mounting post.

The passive markers can only be sterilized one time. NDI does not recommend that a passive marker be used if it has been sterilized more than once, as multiple cycles of sterilization may adversely affect the marker's performance. Testing has shown that there is no significant degradation in the performance of these markers after one cycle of ETO, STERRAD 100S, or STERIS SYSTEM 1 sterilization. The passive markers cannot be autoclaved. Pre-sterilized passive sphere markers are also available; contact NDI for details.

Warning! Do not use markers without inspecting them for cleanliness and damage both before and during a procedure. Reliance on data produced by unclean or damaged markers may lead to inaccurate conclusions. If your application involves personal safety, inaccurate conclusions increase the possibility of personal injury.

Caution! Do not handle the passive sphere markers with bare hands as this will leave residue from skin that affects the marker's reflectivity. Take care not to drop or scuff the markers, as this also affects the reflectivity of the markers.

4.14 Active Markers

Note The active wireless tool tracking feature is an option that you must order at time of purchase.

Active markers are physically smaller than passive sphere markers. They consist of an Infrared Light Emitting Diode (IRED) mounted on a ceramic base. The Position Sensor codes (“chirps”) the IR pulses emitted from its illuminators. These coded IR pulses are received by the IR receiver on the tool which then activates the IREDs. The Position Sensor receives the IR emitted by the IREDs and processes it in the same manner as passive markers.

Active markers are mounted in active wireless tools. The ceramic base allows them to be sterilised by auto-claving as required. The power for active wireless tools is supplied by battery. For detailed information on active markers and active wireless tools, refer to the *“Polaris Tool Design Guide”*.

4.15 Filter Spectral Response

The lenses on the Position Sensor filter out visible light, allowing only certain amounts of light at specific frequencies to pass through to the CCDs. The CCDs are sensitive only to light below certain frequencies. The result is a band pass filter from 800 nm to 1100 nm. Environmental light in this range can affect the performance of the Polaris Vicra System. The more intense the environmental light in this range, the higher the probability that it will interfere with the system.

Note It is important to reduce environmental IR, to prevent interference with the system. Some operating room lights may emit IR.

The amount of light at various frequencies that passes through the lenses to the CCDs, and then is detected by the CCDs, as illustrated in Figure 4-9.

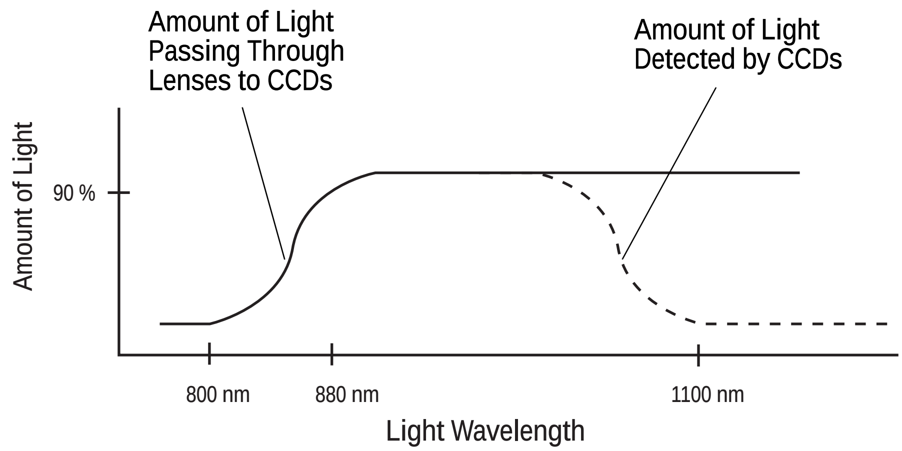


Figure 4-9 Filter Spectral Response

4.16 Data Transmission Rate

The Polaris Vicra System can achieve an internal tool transformation update rate of 20 Hz. The host update rate (the rate at which the host computer receives data) is dependent on the following factors:

Baud Rate The baud rate specifies how fast data is transferred from the system to the host computer. At lower baud rates, the host computer may not receive tool transformations at 20 Hz.

API command reply length The more data the system must return with every transformation, the slower the host update rate. The amount of data returned with each transformation increases as you track more tools and select more options.

Application speed The host transmission rate can vary according to how often the application asks for data, and how often the graphical user interface (in particular, graphics) need to be updated.

5 Additional System Features

This chapter provides details about additional features of the Polaris Vicra System. This chapter contains the following information:

- "Bump Sensor" on page 53
- "Keyed Features" on page 54

5.1 Bump Sensor

The Position Sensor contains an internal bump sensor that detects when the Position Sensor has suffered an impact. Although each instance is different, it is NDI's expectation that a representative trigger threshold is equivalent to a 250 mm to 300 mm drop onto a vinyl tiled concrete surface.

When a bump is detected:

- The error LED on the Position Sensor flashes, indicating that a non-critical error has been detected. The flashing will persist until the bump is cleared.
- The "bump detected" bit in the **Info.Status.Alerts** user parameter is set. This bit will persist until the bump is cleared.
- The "bump detected" bit in the **Info.Status.New Alerts** user parameter is set. This bit will be cleared as soon as the user parameter is read. (When the bit is set in **Info.Status.New Alerts**, the "diagnostic pending" bit in the TX and BX responses will also be set to indicate a new alert.)
- The **Info.Status.Bump Detected** and **Param.Bump Detector.Bumped** user parameters are set to "1". These user parameter values persist until the bump is cleared.
- The API commands TX and BX will not report transformations unless reply option 0x0800 is used. This behaviour persists until the bump is cleared. Because a bump can affect the calibration of the Position Sensor, the system is designed not to report transformations if it has detected a bump.

Note: See the "*Polaris Application Program Interface Guide*" for details on user parameters and API commands.

If a bump has been detected, NDI recommends that you perform an accuracy assessment procedure with the NDI Accuracy Assessment Kit (AAK), to ensure that the Position Sensor is still calibrated. For information on the accuracy assessment procedure and AAK, contact NDI or visit the support site at http://support.ndigital.com.

A Position Sensor whose bump sensor has been triggered may no longer be covered under warranty, as the impact required to trigger the bump sensor is greater than that expected to occur through proper use and handling of the Position Sensor.

Clearing the Bump Sensor

You can clear a bump using the following methods:

- Use the configure utility of NDI ToolBox. See the NDI ToolBox help for more details.

- Use the API command SET to set the value of the user parameter **Param.Bump Detector.Clear** to “1”. This clears all bumps detected up to this point. The system will automatically reset this user parameter to “0”. See the “*Polaris Application Program Interface Guide*” for details.

Bump Sensor Battery

The bump sensor is functional whether the Polaris Vicra System is powered on or off. When the system is powered on, the bump sensor circuit draws its power, through the system, from the mains supply. When the system is not powered on, the bump sensor derives its power from an internal battery that has an operational life of approximately 10 years. If the bump sensor battery in your system needs to be replaced, contact NDI.

5.2 Keyed Features

In addition to the base configuration, certain options are available from NDI as keyed features for the Polaris Vicra System. Currently available keyed features are:

- Multi Firmware: allows the system to be simultaneously programmed with more than one combined firmware revision.
- Password Protect: provides security against changes to the system configuration.

For information on the latest keyed features and how to purchase them, contact NDI.

Installing a Keyed Feature

To install a keyed feature, use the configure utility of NDI ToolBox. For information on using NDI ToolBox, see the NDI ToolBox online help.

Disabling and Enabling Keyed Features

Disabling a feature makes that feature unavailable. Enabling a feature makes the feature available. A feature is enabled upon installation. You can disable or enable features using the configure utility of NDI ToolBox, or using API commands. For details on API commands, see the “*Polaris Application Program Interface Guide*.”

Available Features

Multi Firmware Feature

The multi firmware feature allows the system to house more than one combined firmware revision. When the multi firmware feature is enabled, you can specify which combined firmware revision the system will use on its next reset or power up.

You can install new combined firmware revisions using NDI ToolBox. You can specify which combined firmware revision the system will use in NDI ToolBox or using API commands. For details on API commands, see the “*Polaris Application Program Interface Guide*.”

Password Protect Feature

The password protect feature provides security against changes to the system configuration. When the password feature is enabled, you must enter the correct password before you can:

- save user parameter values,
- update the firmware, or
- install, disable, or enable a keyed feature.

If the correct password is not entered, user parameter values can be changed but not saved (they will return to their previous values upon system reset or initialization).

To enter the password, use NDI ToolBox or use the API command SET to set the value of the user parameter **Config.Password** to the correct password. If the system is subsequently reset or initialized, you will have to re-enter the password before you can make changes to the system configuration. For details on API commands, see the "*Polaris Application Program Interface Guide*."

The password is obtained from NDI.

6 Error Flags and Codes

This chapter explains the error flags and codes that the Polaris Vicra System may return. This chapter contains the following information:

- "Missing and Disabled Transformations" on page 56
- "Tracking Errors and Flags" on page 57

6.1 Missing and Disabled Transformations

Normally, the Polaris Vicra System reports a position, orientation, and error value for every transformation. If the system cannot return a transformation, it will report the tool as MISSING or DISABLED.

Missing Transformations

The system reports a tool as MISSING if it cannot calculate a transformation for the tool. The system may be unable to calculate a transformation if:

- The system cannot detect the minimum number of markers.
- Fewer than the minimum number of markers are inside the characterized measurement volume. By default, the Polaris Vicra System only reports the transformation of markers and tools inside the characterized measurement volume. You can tell the Polaris Vicra System to report the positions of markers outside the characterized measurement volume, using reply option 0x0800 with the TX or BX command. See the "*Polaris Application Program Interface Guide*" for details. See "Tool Tracking Parameters" on page 43 for a description of this parameter.
- Fewer than the minimum number of markers are within the maximum marker angle or the maximum 3D error.
- The spread parameters are not satisfied.
- There is a system error (described on page 57).

By default, the system will report a tool as MISSING (even when it has calculated a transformation for the tool) if one of the following conditions is present:

- Fewer than the minimum number of markers are inside the measurement volume.
- The bump sensor has been triggered.
- The system is outside of the operating temperature range.
- The bump sensor battery power is low, the temperature sensors are out of functional range, or the input voltage is out of range.

The Polaris Vicra System is specifically designed to NOT report measurements in these conditions. You can request measurements in these conditions by using reply option 0x0800 with the BX or TX command. You enable this additional functionality at your own discretion.

Warning! When using reply option 0x0800 with the BX or TX command, you must take appropriate action to detect the following events: the tool or marker is out of volume, the bump sensor has been tripped, or the system is outside of the optimal operating temperature range. You must determine whether these events are detrimental to your application. If one or more of the events listed occurs, reply option 0800 enables the system to return data that may lead to inaccurate conclusions and may cause personal injury. See the “*Polaris Application Program Interface Guide*” for details.

Disabled Transformations

The system reports a tool as DISABLED if the port handle corresponding to the tool was not enabled, has been disabled, or is unoccupied. A port handle is unoccupied if it has been allocated, but you have not yet associated a tool definition file with that port handle. See the “*Polaris Application Program Interface Guide*” for more details on port handles.

6.2 Tracking Errors and Flags

Many of the following errors and flags are displayed in NDI ToolBox. They are all returned with the TX and BX commands (using reply options 0x0001 and 0x0002).

System status flags

System Communication Synchronization Error Indicates communication problems between internal sub-components of the system.

Diagnostic Pending Indicates a change in any of the alerts flags. The flag persists until the **Info.Status.New.Alerts** parameter is read. Reading the new alerts user parameter automatically clears the flag.

Temperature Indicates that the system is out of specified operating temperature range or not yet warmed up. By default transformation data is not returned when this flag is set. The flag will automatically be cleared as soon as the system is back in the specified operating temperature range.

Port status flags

Out of Volume The out of volume flag is set for a marker or tool that is completely outside of the characterized measurement volume, but can still be detected by the system. The flag is set regardless of whether the reply option 0x0800 for the TX or BX command is used. (Reply option 0x0800 enables the reporting of the positions of tools and markers that are outside of the characterized measurement volume. See the “*Polaris Application Program Interface Guide*” for details.)

Partially Out of Volume The partially out of volume flag is set for a tool if less than the minimum number of markers are inside the characterized measurement volume, and at least one marker on the tool is inside the characterized measurement volume. See “Tool Tracking Parameters” on page 43 for a description of the minimum number of markers parameter.

Algorithm Limitations Indicates that during parts of the algorithm used for 2D/3D/6D calculations a limitation has been detected (for example buffer full). This does not mean that an error occurred or that the tools will not track properly.

- If the flag is transient, i.e. it comes on for only a few frames during the beginning of tracking or during a disruption of the scene (blocking/unblocking), no actions need to be taken.
- If the flag persists and the tool does not track, changing the scene (removing tools and/or markers) or simply re-arranging the scene should resolve the problem.

IR Interference Indicates that one of the sensors has detected an object that is bright enough to be considered a marker but is too large. (For example, this flag can be triggered by two passive sphere markers being close together.) This may not affect tracking in which case it can be ignored. If one or more tools do not track and the flag persists the scene should be examined for the root cause of the flag (for example by taking a video capture with NDI ToolBox).

Processing Exception Indicates that an exception has been detected in the firmware. Transformation data will be invalid as long as the flag persists. The system may self-recover from this condition, depending on the scene. The flag typically comes on when the system is overloaded, ie it cannot handle the scene. Remove some tools and/or markers from the scene to prevent this flag from being triggered.

Fell Behind While Processing Indicates that the system cannot keep up with processing the data. This flag comes on when the system is overloaded. Remove some tools and/or markers from the scene to prevent this flag from being triggered.

Data Buffer Limitations The system's internal data buffers cannot hold all incoming data. This flag comes on when the scene is overloaded or, in rare cases, if the scene is arranged in an unfavourable way (many markers lined up in a horizontal line).

Re-arranging the scene or removing tools/markers will remove this flag.

Note This flag is different from "Algorithm limitations" as "Data buffer limitations" means that real raw data is lost. In the case of the "Algorithm limitations" flag the system has all raw data, but does not have enough buffer to process it. Both flags are very scene dependent and are independent of each other, however both typically only come on in heavily loaded scenes.

Tool information flags

Bad Transformation Fit Indicates that although enough markers are visible, the tool transformation could not be calculated due to fit constraints.

Not Enough Acceptable Markers for Transformation The system does not have enough "good" markers (inside the characterized measurement volume, within the tool tracking parameter values defined in the tool definition file) to calculate a transformation for this tool.

IR Interference This flag is a combination of the "IR interference" and "Data buffer limitation" flags in the port status flags. It is kept for backward compatibility with Polaris. NDI recommends that instead you use the port status flags.

Fell Behind While Processing This is a copy of the flag "Fell behind while processing" in the port status flags. It is kept for backward compatibility with Polaris. NDI recommends that instead you use the port status flags.

Processing exception This is a copy of the flag "Processing exception" in the port status flags. It is kept for backward compatibility with Polaris. NDI recommends that instead you use the port status flags.

Marker Information

The marker information returned with option 0x0002 of the TX and BX commands are 4-bit numbers that indicate if and how a marker was used in the tool transformation or, if it was not used, it provides an indication why it was rejected for the tool transformation. For a detailed explanation of the marker information see the *"Polaris Application Program Interface Guide"* (TX and BX commands).

Note If option 0x0008 (3D position of markers on tools) is used, NDI recommends that you use the 3D information only in combination with the marker information reported in option 0x0002. Option 0x0008 will report all markers associated with a tool, regardless of individual marker status. The marker information can provide further indication about the "quality" of the reported 3D position.

7 Maintenance

User maintenance of the Polaris Vicra System is limited to the following procedures:

- Cleaning the Position Sensor
- Disposal of equipment

The Position Sensor is the only system unit that requires special consideration. The power adapter and Host USB Converter can be cleaned by following standard procedures.

Note Do not open any component of the Polaris Vicra System. Doing so will void the warranty.

Warning!

Maintenance Warnings

Before doing any maintenance on the Polaris Vicra System, read the following warnings:

1. **All user maintenance must be done by appropriately trained personnel. Individual components of the Polaris Vicra System contain no user-serviceable parts. Maintenance by untrained personnel may present an electric shock hazard.**
2. **Do not use the Position Sensor without inspecting it for cleanliness and damage both before and during a procedure. Reliance on data provided by an unclean or damaged Position Sensor may lead to inaccurate conclusions. If your application involves personal safety, inaccurate conclusions may result in personal injury.**
3. **Do not immerse any part of the Polaris Vicra System or allow fluid to enter the equipment. If fluids enter any part of the system they may damage it and present a risk of personal injury.**
4. **Do not sterilize the Polaris Vicra Position Sensor as this may cause irreversible damage to its components. Reliance on data provided by a damaged Position Sensor may lead to inaccurate conclusions. If your application involves personal safety, these inaccurate conclusions may result in personal injury.**

7.1 Cleaning the Position Sensor

Regularly inspect the Position Sensor for cleanliness. The Position Sensor and particularly the illuminator filters and lenses, should be cleaned only when necessary. The frequency of cleaning must be determined by the user. This may include “in-use” cleaning.

Caution! Use only 70% isopropanol and a lens cleaning solution formulated for multi-coated lenses (for example, AR66) to clean the Position Sensor. Other fluids may cause damage to the illuminator filters. Do not use any paper products for cleaning. Paper products may cause scratches on the illuminator filters.

To clean the Position Sensor, follow the procedure detailed below:

1. Remove dust from each illuminator filter and lens, using a photographic lens duster (brush). Gently wipe the surface in one direction only, by pulling the brush across the surface.

2. Gently wipe the illuminator filters and lenses with disinfectant wipes containing 70% isopropanol. Continue cleaning the remainder of the Position Sensor, taking care not to wipe debris from the Position Sensor case onto the illuminator filters or lenses. Avoid prolonged contact between the wipes and the Position Sensor.
3. Clean the illuminator filters and lenses, using a commercial lens cleaning solution formulated for multi-coated lenses (for example, AR66) and a clean knitted microfibre optical cleaning cloth (for example, Hitecloth). Avoid prolonged contact between the lens cleaner and the illuminator filters and lenses.

Note Use of unauthorised cleaning fluids may degrade the conformal coating on the Position Sensor screws. This may compromise the IP rating.

7.2 Disposal of Equipment

To ensure environmentally responsible disposal after the equipment is decommissioned, please contact NDI. See "Contact Information" on page xiii.

8 Setting the Infrared Light Sensitivity

8.1 IR Light Sensitivity Levels

The IR light sensitivity level determines how sensitive the Polaris Vicra System is to IR light.

Background IR Light

Background IR light is IR light that is not reflected (passive) or emitted (active) from a marker, but is detected by the Polaris Vicra Position Sensor. Background IR light can be direct (light bulbs, sunlight) or indirect (reflections off shiny surfaces or draping). In particular, IR light in the 800 nm to 1100 nm range can interfere with the Polaris Vicra System's ability to track tools. For example, some types of operating room lights emit IR light that is detected as background IR.

The **IR light sensitivity level** controls the Polaris Vicra System's ability to tolerate background IR light.

Trigger Level and Integration Time

The **integration time** is the time in which the Polaris Vicra Position Sensor collects IR light.

The **trigger level** is the minimum IR light intensity considered to be valid marker data. The Polaris Vicra System uses the trigger level to distinguish between marker data and background IR light. IR light that falls below the trigger level is rejected by the Position Sensor. The trigger level increases with the integration time. In general, as the sensitivity level increases, so does the trigger level.

During operation, the Polaris Vicra System makes adjustments to the integration time so that the intensity of the brightest IR light detected is set to a maximum value, and the intensity of all other IR light detected falls below this value. Changing the sensitivity level does not change this maximum value. Thus, when the sensitivity level changes, the integration time does not change but the trigger level does.

The relationship between trigger level and integration time for each sensitivity level is illustrated in Figure 8-1.

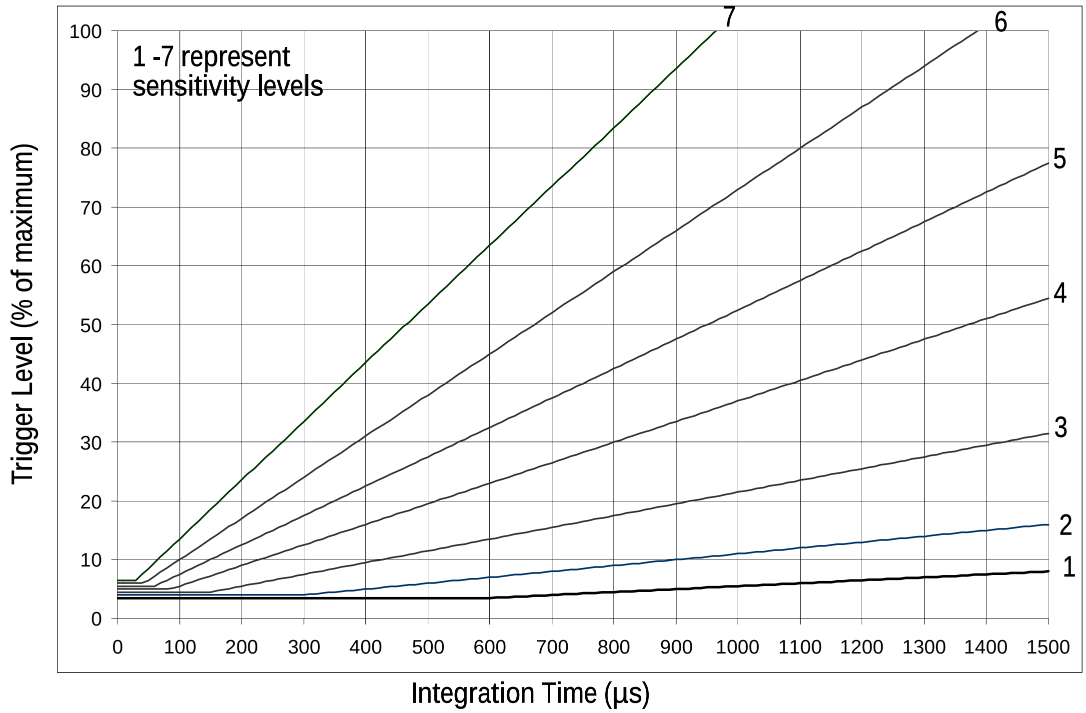


Figure 8-1 Infrared Light Sensitivity Levels

Sensitivity Levels

There are seven sensitivity levels; with each increasing level number, the ability of the system to tolerate background IR light increases. Increasing the sensitivity level makes the system performance more robust in the presence of background IR light; however, it increases the chance that a tool cannot be tracked properly because it may have a marker that is not bright enough. Low marker brightness can be caused by, for example, the surface of a marker becoming partially occluded by fluids or other materials, thus reducing the reflectivity of the marker.

Level 4 is the default sensitivity level for the Polaris Vicra System and should work well in most situations.

8.2 Changing the Sensitivity Level

Checking for Background IR Light

If a tool is tracking intermittently or not tracking at all, check the **IR interference** flag in the port status and in the tool information returned with the BX or TX command. If the IR interference flag is intermittently or constantly on for any of the tools, there may be background IR present. Alternatively, you can check for the “Interference” flag in the tool tracking utility of NDI ToolBox, or use the image capture utility in NDI ToolBox to capture images of the IR detected by the system.

Choosing a Sensitivity Level

Choose a sensitivity level of 5, 6 or 7 if:

- the "IR Interference" flag in the Port Status flags is on persistently

  AND

- tools don't track

  AND

- re-arranging the scene doesn't help.

Choose a sensitivity level of 3, 2 or 1 if:

- a tool doesn't track

  AND

- all markers are clearly in view AND clean

  AND

- no other error flags are giving any indication for why the tool is not tracking

(NDI experience shows that there should not be any reason for going to a level lower than 4.)

Note Changing the sensitivity level may reduce tracking problems only when the tools are in a different physical location from the background IR. The sensitivity level cannot reduce tracking problems when the tools are embedded in background IR.

Use the default sensitivity level 4 unless the system is experiencing interference from background IR light. If the system is experiencing such interference, check the environment for causes (for example, reflections). If it is not possible to eliminate the source of the background IR light, then start with a low sensitivity level and increase the level until the tools track reliably.

The system may actually be tracking a tool even when the tool's IR interference flag is on. You should still increase the sensitivity level, since the behaviour of the system in this case is dependent on the setup. (For example, moving the tool to another part of the measurement volume may prevent it from being tracked properly.)

Changing the Sensitivity Level

You can change the IR sensitivity using the following methods:

- Use the configure utility of NDI ToolBox to select a sensitivity level, and to program a sensitivity level as the default setting in the Position Sensor memory.
- Use the API command SET to change the value of the parameter Param.Tracking.Sensitivity. The changed value will persist until the system is reset or initialized. To save the changed value (program it as the default setting in the Position Sensor memory), use the API command SAVE. See the "*Polaris Application Program Interface Guide*" for details.

9 Calibration and Firmware

9.1 Checking the Calibration of the Polaris Vicra System

The Position Sensor is calibrated at NDI, using the methodology described in Appendix A. Over time, it is possible for the Position Sensor to lose calibration. A periodic calibration check should be performed on the Position Sensor. The frequency of the calibration check depends on the specific application and environment in which the Position Sensor is used.

If the Position Sensor begins to lose calibration, it may lose the ability to track some tools before others. This is due to the various constraints used by the Polaris Vicra System, which make certain tool designs more sensitive to loss of calibration than others. For example, consider a tool that has several similar segment lengths or similar angles between segments, or has segment lengths similar to those of another tool. An out-of-calibration Position Sensor may not be able to determine which markers belong to which tool, because the segment lengths will be measured less accurately. In this case, the system will report the tools as missing. (See “Marker Detection and Tool Tracking” on page 38 and the “*Polaris Tool Design Guide*” for details on segment lengths and angles.)

NDI’s Accuracy Assessment Kit can be used as an aid in determining whether a Position Sensor is performing acceptably for the user’s application. For all calibration procedures, return the Position Sensor to NDI. This practice ensures that all calibrations are conducted in accordance with procedures established specifically for the Polaris Vicra Position Sensor. See “Return Procedure” on page 85 for instructions on returning equipment to NDI.

Line Separation and Calibration

The Position Sensor line separation (described on page 38) can sometimes be an indication that a Position Sensor is out of calibration, but is not necessarily the best indicator and cannot always detect calibration loss. For example, suppose one of the sensors was to shift towards the centre of the Position Sensor while maintaining its horizontal alignment. In this case, the Position Sensor would be out of calibration without any change in line separation, and the reported position of the tool would be shifted.

If the Position Sensor is measuring high line separation values, it may be an indication of loss of calibration. Line separation alone should not, however, be used as a test for calibration loss.

Bump Sensor

The Position Sensor contains an internal bump sensor that detects when the Position Sensor has suffered an impact. Although each instance is different, it is NDI’s expectation that a representative trigger threshold is equivalent to a 250 mm to 300 mm drop onto a vinyl tiled concrete surface.

If a bump has been detected, NDI recommends that you perform an accuracy assessment procedure with the NDI Accuracy Assessment Kit (AAK), to ensure that the Position Sensor is still calibrated. For information on the accuracy assessment procedure and AAK, contact NDI or visit the support site at http://support.ndigital.com.

For full details on the bump sensor, see “Bump Sensor” on page 53.

9.2 Updating the Firmware

The Polaris Vicra System's firmware is stored in EEPROM flash memory devices in the Position Sensor. The latest firmware can be downloaded from the NDI Support Site at:

http://support.ndigital.com.

The Position Sensor incorporates a safe boot loader that will perform verification of the control firmware prior to loading and executing it. The safe boot loader has been included to provide a fallback if a future control firmware upgrade fails. A communication fault or power fault could cause a field firmware upgrade to fail. In these cases, the Position Sensor will still be able to start up by running the safe boot loader. This will provide minimal support, to allow you to retry the control firmware upgrade.

Updating Firmware

Update the Polaris Vicra System's firmware using the configure utility in NDI ToolBox. NDI ToolBox also includes command line functionality, to allow you to embed an NDI ToolBox application (such as upgrading firmware) into your application software. See the ToolBox help for details.

Multi Firmware Feature

The multi firmware feature is a keyed feature available for purchase from NDI. This feature allows the system to be simultaneously programmed with more than one combined firmware revision. When the multi firmware feature is enabled, you can specify which combined firmware revision the system will use on its next reset or power up.

You can install new combined firmware revisions using NDI ToolBox.

The NDI ToolBox help explains how to use NDI ToolBox to select which combined firmware revision the system will use. The "*Polaris Application Program Interface Guide*" explains how to select a combined firmware revision using API commands.

10 Approvals

10.1 Electrical Safety and Electromagnetic Compatibility

The approvals for the Polaris Vicra System (consisting of a Position Sensor, Model P6, power adapter and a Host USB Converter), are listed in the Declaration of Conformity on page 87.

10.2 Optical Radiation Safety

Position Sensor Illuminators

The Polaris Vicra Position Sensor illuminators emit invisible LED radiation. The Position Sensor has been assessed against the standards listed in the Declaration of Conformity on page 87 and found not to pose a potential hazard to the eye under any foreseeable viewing condition.

Note The Polaris Vicra System emits IR light that may interfere with IR controlled devices, such as operating room tables. It is recommended that you test the Polaris Vicra System if you intend to use it in an environment where other IR controlled devices are in use.

11 Classifications

Table 11-1 Classifications

Classification	Description
Electric shock protection	Class I - no applied parts
Degree of protection from electric shock	Not classified
Degree of protection against ingress of solids and liquids	Ordinary equipment (Position Sensor designed to IP44)
Flammable atmosphere	Not suitable for use in the presence of a flammable anaesthetic mixture with air, oxygen or nitrous oxide
Mode of operation	Continuous when supplied by mains
Method of sterilization or disinfection	Not suitable for sterilization
IRED illuminators risk group	Exempt

12 Technical Specifications

12.1 Operating Environmental Conditions

The Polaris Vicra System (Position Sensor, Host USB Converter, power adapter, and cables) has been tested to function in the conditions listed in Table 12-1.

Table 12-1 Operating Environmental Conditions

Environmental Condition	Value
Atmospheric Pressure	70 kPa to 106 kPa
Relative Humidity	30% to 75%
Temperature	$+10^{o}C$ to $+30^{o}C$

Warning! The power adapter must be located outside the patient vicinity under all operating conditions. It is the responsibility of the system integrator and/or the end-user to ensure that the system is appropriately configured for the operating conditions.

The Position Sensor requires a warm-up time every time it is powered on. The warm-up time is typically two minutes; if the Position Sensor is stored at low temperatures, the warm-up time may be longer. The power LED will flash while the Position Sensor warms up; once the LED is steady, the system is ready for use as defined by the NDI Accuracy Assessment Kit (AAK) protocol. For information on the AAK, contact NDI.

12.2 Transportation and Storage Environmental Conditions

The Polaris Vicra System (Position Sensor, Host USB Converter, power adapter, and cables) has been tested to be stored and transported in the conditions listed in Table 12-2.

Warning! Do not transport or store the Position Sensor outside the recommended storage temperature range, as this may cause the system to go out of calibration. Reliance on data provided by an out of calibration Position Sensor may lead to inaccurate conclusions and may cause personal injury. A calibration procedure must be performed before using the Position Sensor after it has been transported or stored outside the recommended storage temperature range.

Caution! To ship the Polaris Vicra System, repack it in the original containers with all the supplied protective packaging. The provided packaging is designed to prevent damage to the equipment.

Table 12-2 Transportation and Storage Environmental Conditions

Specification	Value
Atmospheric Pressure	50 kPa to 106 kPa
Relative Humidity	10% to 90% non-condensing
Temperature	-10°C to +50°C

12.3 Unit Technical Specifications

Table 12-3 Position Sensor - Technical Specifications

Specification	Value
Dimensions	273 mm x 69 mm x 69 mm
Weight	<1 kg
Mounting	1/4" thread tripod mount, or 3 M3 x 0.5 mm x 9 mm screws
Maximum Update Rate	20 Hz
Input Voltage	18-32 VDC
Power Consumption	13.5 W (approx.)

Table 12-4 Host USB Converter - Technical Specifications

Specification	Value
Dimensions	88 mm x 57 mm x 39 mm
Weight	0.35 kg
Mounting	Free standing or secured via internal threads (M6 x 1mm pitch 3 mm depth) in (three) mounting feet
Host Interface	USB (1.1 and 2.0 compatible)
Input Voltage	24 VDC
Output Voltage	26 VDC
Power Consumption	<2 W

Table 12-5 Power Adapter Technical Specifications
(Part number APS49ES-24021/Hitron HES49ES-24021
applicable to IEC 60601-1 2nd Edition only)

Specification	Value
Dimensions	125.00 mm x 61.78 mm x 32.00 mm
Weight	0.37 kg
Mounting	Free standing
Input Voltage	100 VAC to 240 VAC
Input Frequency	60/50 Hz
Input Power	1.0 A
Power Output	24 VDC @ 2.1 A

Table 12-6 Power Adapter Technical Specifications
(Part Number APS49EMG-24021-7/Hitron HEMG49-S240210-7
applicable to IEC 60601-1 2nd and 3rd Editions)

Specification	Value
Dimensions	125.00 mm x 61.78 mm x 32.50 mm
Weight	0.37 kg
Mounting	Free standing
Input Voltage	100 VAC to 240 VAC
Input Frequency	60/50 Hz
Input Power	1.20 to 0.63 A
Power Output	24 VDC @ 2.1 A

13 Electromagnetic Compatibility

Warning!

The Polaris Vicra System requires special precautions regarding EMC. It must be installed and put into service in accordance with the EMC information, detailed in this chapter. Failure to do so may result in personal injury.

Radio frequency communications equipment, including portable and mobile devices, may affect the Polaris Vicra System and result in personal injury.

Do not use the Polaris Vicra System either adjacent to, or stacked with, other equipment. Check that the Polaris Vicra System is operating normally if it is used either adjacent to, or stacked with, other equipment. Failure to do so may result in personal injury.

This chapter contains the following information about the electromagnetic compatibility of the system:

- "Cables and Accessories" on page 72
- "Guidance and Manufacturer's Declaration: Electromagnetic Emissions" on page 73
- "Guidance and Manufacturer's Declaration: Electromagnetic Immunity" on page 73
- "Recommended Separation Distances" on page 76
- "Radio Frequency Emissions" on page 77

13.1 Cables and Accessories

The following table lists the cables and accessories that may be used with the Polaris Vicra System while still maintaining compliance to the emissions and immunity requirements of IEC 60601-1-2:2007.

Warning!

Use of cables or accessories other than those listed in the following table may result in increased emissions and/or decreased immunity of the Polaris Vicra System and may result in personal injury.

Table 13-1 Cables and Accessories that Maintain Emissions and Immunity Compliance

Name	NDI P/N	Type	Shield	Notes
Cable AC Line Cord, Medical Grade	7500010	North American	No	Mains to Power Adapter, for 120 VAC testing
Cable AC Line Cord	7500012	France/Belgium/ Germany	No	Mains to Power Adapter, for 230 VAC testing
USB cable	2600596	USB, A-B male, double shielded, 5 m	Yes	Computer to Host USB Converter

Table 13-1 Cables and Accessories that Maintain Emissions and Immunity Compliance

Name	NDI P/N	Type	Shield	Notes
Power Adapter	8001088	Switch Mode, 100-240 VAC input, 24 VDC, 2.1 A output	N/A	Applicable to IEC 60601-1 2nd Edition only
Power Adapter	8001260	Switch Mode, 100-240 VAC input, 24 VDC, 2.1 A output	N/A	Applicable to IEC 60601-1 2nd and 3rd Editions

13.2 Guidance and Manufacturer's Declaration: Electromagnetic Emissions

The Polaris Vicra System is intended for use in the electromagnetic environment specified below. The customer or the user of the Polaris Vicra System should assure that it is used in such an environment.

Table 13-2 Manufacturer's Declaration for Electromagnetic Emissions

Emissions Test	Compliance	Electromagnetic Environment Guidance
RF emissions CISPR11	Group 1	The Polaris Vicra System uses RF energy only for its internal function. Therefore, its RF emissions are very low and are not likely to cause any interference in nearby electronic equipment.
RF emissions CISPR11	Class B	The Polaris Vicra System is suitable for use in all establishments, including domestic establishments and those directly connected to the public low-voltage power supply network that supplies buildings used for domestic purposes.
Harmonic emissions IEC61000 3-2	Class A	
Voltage fluctuations/ flicker emissions IEC61000-3-3	Complies	

13.3 Guidance and Manufacturer's Declaration: Electromagnetic Immunity

The Polaris Vicra System is intended for use in the electromagnetic environment specified below. The customer or the user of the Polaris Vicra System should assure that it is used in such an environment.

Table 13-3 Electromagnetic Immunity

Immunity Test	IEC 60601 Test Level	Compliance Level	Electromagnetic Environment - Guidance
Electrostatic discharge (ESD) IEC 61000-4-2	±6 kV contact ±8 kV air	±6 kV contact ±8 kV air	Floors should be wood, concrete or ceramic tile. If floors are covered with synthetic material, the relative humidity should be at least 30%.

Table 13-3 Electromagnetic Immunity (Continued)

Immunity Test	IEC 60601 Test Level	Compliance Level	Electromagnetic Environment - Guidance
Electrical fast transient/burst IEC 61000-4-4	±2 kV for power supply lines. ±1 kV for input/ output lines	±2 kV for power supply lines. ±1 kV for input/ output lines	Mains power quality should be that of a typical commercial or hospital environment.
Surge IEC 61000-4-5	±1 kV line(s) to line(s)	±1 kV differential mode	Mains power quality should be that of a typical commercial or hospital environment.
	±2 kV line(s) to earth	±2 kV common mode	
Voltage dips, short interruptions and voltage variations on power supply input lines IEC 61000-4-11	<5% U_T (>95% dip in U_T) for 0.5 cycles	<5% U_T (>95% dip in U_T) for 0.5 cycles	Mains power quality should be that of a typical commercial or hospital environment. If the user of the Polaris Vicra System requires continued operation during power mains interruptions, it is recommended that the Polaris Vicra System be powered from an uninterruptible power supply or a battery.
	40% U_T (60% dip in U_T) for 5 cycles	40% U_T (60% dip in U_T) for 5 cycles	
	70% U_T (30% dip in U_T) for 25 cycles	70% U_T (30% dip in U_T) for 25 cycles	
	<5% U_T (>95% dip in U_T) for 5 s	<5% U_T (>95% dip in U_T) for 5 s	
Power frequency (50/60Hz) magnetic field IEC 61000-4-8	3 A/m	3 A/m	Power frequency magnetic fields should be at levels characteristic of a typical location in a typical commercial or hospital environment.

Note U_T is the a.c. mains voltage prior to application of the test level.

Table 13-4 Electromagnetic Immunity—Not Life Supporting

Immunity Test	IEC 60601 Test Level	Compliance Level	Electromagnetic Environment - Guidance
Conducted RF IEC 61000-4-6	3 Vrms 150 kHz to 80 MHz	3 V	Portable and mobile RF communications equipment should be used no closer to any part of the Polaris Vicra System, including cables, than the recommended separation distance calculated from the equation applicable to the frequency of the transmitter. **Recommended separation distance:** $d = 1,2\sqrt{P}$ See Table 13-5 on page 76.
Radiated RF IEC 61000-4-3	3 V/m 80 MHz to 2,5 GHz	3 V/m	$d = 1,2\sqrt{P}$ 80 MHz to 800 MHz $d = 2,3\sqrt{P}$ 800 MHz to 2,5 GHz See Table 13-5 on page 76. Where 'P' is the maximum output power rating of the transmitter in watts (W) according to the transmitter manufacturer and 'd' is the recommended separation distance in metres. Field strengths from fixed RF transmitters, as determined by an electromagnetic site survey[a], should be less than the compliance level in each frequency range[b]. Interference may occur in the vicinity of equipment marked with the following symbol: 

Note At 80 MHz and 800 MHz, the higher frequency range applies.

These guidelines may not apply to all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects, and people.

a - Field strengths from fixed transmitters, such as base stations for radio (cellular/cordless) telephones and land mobile radios, amateur radio, AM and FM radio broadcast and TV broadcast, cannot be predicted theoretically with accuracy. To assess the electromagnetic environment due to fixed RF transmitters, an electromagnetic site survey should be considered. If the measured field strength in the location where the Polaris Vicra System is used exceeds the applicable RF compliance level above, observe the Polaris Vicra System to verify normal operation. If abnormal performance is observed, additional measures may be necessary, such as re-orienting or relocating the Polaris Vicra System.

b - Over the frequency range of 150 kHz to 80 MHz, field strengths should be less than 3 V/m.

13.4 Recommended Separation Distances

The Polaris Vicra System is intended for use in an electromagnetic environment in which radiated RF disturbances are controlled. The customer or the user of the Polaris Vicra System can help prevent electromagnetic interference by maintaining a minimum distance between portable and mobile RF communications equipment (transmitters) and the Polaris Vicra System, as recommended below, according to the maximum output power of the communications equipment.

Table 13-5 Recommended Separation Distances between Portable and Mobile RF Communications Equipment and the Polaris Vicra System

Rated maximum output power of transmitter (watts)	Separation distance according to frequency of transmitter (metres)		
	150 kHz to 80 MHz $d = 1{,}2\sqrt{P}$	80 MHz to 800 MHz $d = 1{,}2\sqrt{P}$	800 MHz to 2.5 GHz $d = 2{,}3\sqrt{P}$
0,01	0,12	0,12	0,23
0,1	0,38	0,38	0,73
1	1,2	1,2	2,3
10	3,8	3,8	7,3
100	12	12	23

For transmitters rated at a maximum output power not listed above, the recommended separation distance (d) in metres (m) can be estimated using the equation applicable to the frequency of the transmitter, where P is the maximum output power rating of the transmitter in watts (W) according to the transmitter manufacturer.

Note At 80 MHz and 800 MHz, the higher frequency range applies.

These guidelines may not apply to all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects, and people.

13.5 Radio Frequency Emissions

FCC

This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions:

1. This device may not cause harmful interference and,
2. This device must accept any interference received, including interference that may cause undesired operation.

Note This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:
— Reorient or relocate the receiving antenna.
— Increase the separation between the equipment and receiver.
— Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
— Consult the dealer or an experienced radio/TV technician for help.

Changes or modifications not expressly approved by Northern Digital Inc. could void the user’s authority to operate the equipment.

CE Mark

CE Mark: This is a Class B product. In a domestic environment, this product may cause radio interference, in which case the user may be required to take adequate measures.

Industry Canada

Industry Canada Compliance Statement: This ISM device complies with Canadian ICES-001.

Avis de Conformité à la réglementation d’Industrie Canada: Cet appareil ISM est conforme à la norme NMB-001 du Canada.

14 Troubleshooting

14.1 Introduction

This section provides possible solutions to common problems and answers some frequently asked questions. For further information regularly check the NDI Support Site at:

http://support.ndigital.com

If you cannot find the answer to your question here or on the support site, contact NDI at the address shown at the front of this guide.

The majority of problems that may occur with the Polaris Vicra System can be grouped into one of the following categories:

- A system hardware failure (for example a faulty Position Sensor or cable)
- A tool error (for example, dirty markers)
- Environmental conditions (for example, incidental IR light)
- User error (for example, obscuring the optical path)

Most faults are indicated by system LEDs or audio codes, as detailed in "LEDs" on page 79 and "Audio Codes" on page 82. You can diagnose the fault by using the GET command to read the **Info.Status.Alerts** user parameters, or by observing the error message in the configure utility of NDI ToolBox. For details on the **Info.Status.Alerts** user parameters, see the "*Polaris Application Program Interface Guide*."

14.2 LEDs

Position Sensor

The power, status, and error LEDs on the Position Sensor combine to indicate the status of the component. These LEDs behave as described in 14-1:

Table 14-1 Power, Status, and Error LEDs Summary

Power (Green)	Status (Green)	Error (Amber)	Meaning and Action Required
Flashing	(Any state)	(Any state)	The power LED will stop flashing and light steady green when system is ready for use as defined by the NDI Accuracy Assessment Kit (AAK) protocol. For information on the AAK, contact NDI.
Solid	Solid	Off	The Position Sensor is ready for use; no faults
Solid	Solid	Flashing	Minor recoverable fault that can easily be corrected by a novice user. **NDI ToolBox response**: The fault is indicated in the configure utility of NDI ToolBox. **API response**: The “diagnostic pending” bit is set in the BX or TX response. To determine what the fault is, read the alerts parameters as described in the “*Polaris Application Program Interface Guide*.”
Solid or off	Solid	Solid	Major recoverable fault. This type of fault requires more expertise to correct than a minor recoverable fault. **NDI ToolBox response**: The fault is indicated in the configure utility of NDI ToolBox. **API response**: One of the following responses occurs: • The “diagnostic pending” bit is set in the BX or TX response. To determine what the fault is, read the alerts parameters as described in the “*Polaris Application Program Interface Guide*.” • An error is returned. The error code indicates the nature of the error. Error codes are listed in the “*Polaris Application Program Interface Guide*.”

Table 14-1 Power, Status, and Error LEDs Summary (Continued)

Power (Green)	Status (Green)	Error (Amber)	Meaning and Action Required
Solid	Off	Solid	Non-recoverable fault. Return the Position Sensor to NDI for service. **NDI ToolBox response**: The fault is indicated in the configure utility of NDI ToolBox. **API response**: One of the following responses occurs: • The “diagnostic pending” bit is set in the BX or TX response. To determine what the fault is, read the alerts parameters as described in the “*Polaris Application Program Interface Guide*.” • An error is returned. The error code indicates the nature of the error. Error codes are listed in the “*Polaris Application Program Interface Guide*.”
Off	Off	Off	Voltage is out of range. Check/replace the Position Sensor, Host USB Converter, or cables.

Host USB Converter

- **Power**:
  Lights green when power is being supplied to the Host USB Converter.
- **Error**:
  Lights amber when the Host USB Converter has detected a fault.

If the Host USB Converter Error LED is lit, follow the flow chart below to help diagnose the fault.

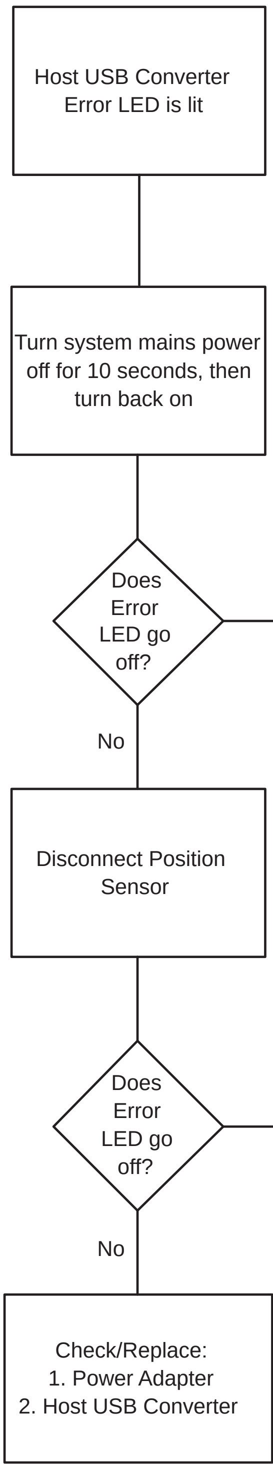


Figure 14-1 Host USB Converter - Error LED Fault Chart

14.3 Audio Codes

The Position Sensor emits audio beeps that provide an audible indication of system status, as listed in 14-2.

Table 14-2 Audio Codes

Indication	Meaning	Action
Two beeps emitted	Normal indication when power is initially applied to the system or the system is reset.	No action required.
Two beeps emitted every three seconds	The host computer has not sent a command to the system within the amount of time specified by the user parameter **Param.Watch Dog Timer**. By default this feature is disabled; to enable it, set the value of the user parameter **Param.Watch Dog Timer** to an non-zero value.	Check the host computer application to make sure it is functioning as desired.

14.4 Common Problems

The following paragraphs lists specific problems and a possible solution.

The tool is inside the measurement volume, but the software reports that the tool is partially out of volume

This may mean that less than the **minimum number of markers** (a parameter in the tool definition file) are inside the characterized measurement volume, but at least one marker on the tool is outside the characterized measurement volume.

For example, consider a four-marker tool, whose minimum number of markers parameter is set to 4. If three of the tool's markers are inside the characterized measurement volume, and the other marker is outside the characterized measurement volume, the Polaris Vicra System will continue to track the tool, but the accuracy is unknown, and the tool will be reported as partially out of volume.

The system doesn't track tools at the back of the characterized measurement volume

If the system will track at the front of the measurement volume but not at the back, the Position Sensor may be damaged, or calculating high line separation values. For more details on line separation, see "Marker Detection and Tool Tracking" on page 38. You can check the line separation values using the 3D command. See the "*Polaris Application Program Interface Guide*" for details.

Other IR-based devices are not working properly

Using the Polaris Vicra System in the same room as other IR-based devices may cause these other devices to malfunction. The Position Sensor's illuminators flood the surrounding area with IR light, which could saturate other IR receiving devices, preventing them from properly receiving other IR signals.

It may be possible to synchronize other devices with the Polaris Vicra System, so that IR signals from the other devices are not being emitted at the same time as the illuminators emit IR. Contact NDI Technical Support for details or visit the support site at http://support.ndigital.com.

The Polaris Vicra System is tracking some tools, but not others

As the Position Sensor begins to lose calibration, it may lose the ability to track some tools before others. This is due to the various algorithm constraints used by the Polaris Vicra System, which make certain tool designs more sensitive to loss of calibration than others. Consider, for example, a tool that has several similar segment lengths or similar angles between segments, or has segment lengths similar to those of another tool. The out-of-calibration Position Sensor may not be able to determine which markers belong to which tool, and so will report the tools as missing. (See “Marker Detection and Tool Tracking” on page 38 and the “*Polaris Tool Design Guide*” for details on segment lengths and angles.)

See “Checking the Calibration of the Polaris Vicra System” on page 65 for more details about calibration.

Reflections and other IR Sources

Reflections and other IR sources may cause markers to become “lost” in the background IR light. These reflections and sources should be eliminated or minimised as much as possible. Reflections occur when IR light from the illuminators is reflected off surfaces such as:

- surgical drapes - ensure that drapes are placed such that reflections are minimised
- reflective surfaces - minimise reflective surfaces in the environment
- tools - design and manufacture tools in non-reflective materials. Refer to the *“Polaris Tool Design Guide”* for further information.

Other sources of IR light, such as operating room lights, should be considered when positioning the system in order to minimise interference from such devices.

What happens if the markers are partially blocked from the view of the Position Sensor?

The Polaris Vicra System requires a clear line-of-sight to the markers. Anything that interferes with the line-of-sight can reduce the measurement accuracy. The magnitude of the errors that are caused by partial occlusion of the markers depends on the number of markers, the geometry of the tool, and the severity of the occlusion. Errors caused by partial occlusion can have exactly the same magnitude for active and passive tools. However, there is more opportunity to partially occlude the passive markers because they are larger than active markers.When designing a new tool, it is important to consider the effect of partial occlusion on its accuracy. The values used for these parameters will also depend on the design of the tool. The best value is usually determined through experimentation. See the *“Polaris Tool Design Guide”* for further information on tool design.

Why is the tool reported as missing?

A tool may be reported as missing if:

- it has been rotated so that too few markers are visible to the Position Sensor

- the tool is no longer in the field of view
- the tool is damaged (for instance, if it is bent)
- the condition of the makers has deteriorated (for instance, the markers are scuffed, or occluded with foreign matter)

The Position Sensor seems too warm

The Position Sensor will be warm to the touch during normal use. If the temperature goes out of range, the temperature bit in the system status section of the BX/TX response will be set. An error message will be shown in NDI ToolBox application software.

The Virtual Serial Port cannot be opened

If you cannot open the virtual serial port, check the system connections, the Host USB Converter and the host PC USB port.

The Polaris Vicra System does not have full functionality, or is behaving intermittently

Check the connection between the Position Sensor cable and the Position Sensor. A loose connection may result in partial functionality or unpredictable system behaviour.

15 Return Procedure and Warranty

15.1 Return Procedure

In the event that you need to return equipment to NDI for repairs, you will need to fill out a Return Materials Authorization (RMA) request form at the NDI Support Site at http://support.ndigital.com. NDI will contact you with RMA information and shipping instructions. Any materials you are returning to NDI should be shipped in their original packaging.

You are responsible for the shipping costs of returning equipment to NDI, whether or not the equipment is covered under warranty. When the equipment is received at NDI, it will be inspected to determine whether the required repair is covered under warranty. NDI can provide you with a quote of repair costs either before or after repairs have been made. If the equipment is covered under warranty, NDI will pay the return shipping costs. If the equipment is not covered under warranty, you are required to pay the return shipping costs.

15.2 Warranty

Unless otherwise agreed to in writing by NDI, the warranty is as follows, and applies only to the original purchaser.

Note: This warranty is also posted on the NDI Support Site at http://support.ndigital.com.

Note: This warranty is void if you open the case of any system component.

Hardware

NDI warrants to the Buyer that NDI's hardware product(s) will be free from defects in material and workmanship only for a period twelve (12) months from the date such product(s) is/are shipped from NDI to the Buyer.

This warranty does not apply to product(s) normally consumed in Buyer's operations or which have a normal life inherently shorter than the above-stated warranty period. Without limiting the generality of the foregoing, the following products shall have the following warranty periods:

product or components thereof which are re-chargeable batteries . . .	90 days from shipment
infrared emitting diode (IRED) markers or product(s) which contain IRED markers (other than illuminators on Position Sensors)	90 days from shipment
single use, disposable reflective (passive-type) markers	prior to first use but no more than 90 days from shipment

Software

NDI's software product(s) is/are licensed and provided "as is, where is" without warranty of any kind. NDI makes no warranties, express or implied, that the functions contained in the software product(s) will meet the Buyer's requirements or that the operation of the programs contained therein will be error free.

General Provisions Applicable to Warranty

NDI's obligations under this warranty shall be limited to repairing or replacing (at NDI's option) the product(s), EXW (Incoterms 2000) NDI's plant (Waterloo, Ontario, Canada). Any original parts removed and/or replaced during any repair process shall become the property of NDI. This warranty shall apply only to the original Buyer [being that person or legal entity which has contracted directly with NDI for the supply of the product(s)]. Repair work shall be warranted on the same terms as stated herein except such warranty shall be for a period of sixty (60) days or for the remainder of the unexpired warranty period, whichever is longer. In respect of any product(s) supplied hereunder which are manufactured by others, NDI gives no warranty whatsoever, and the warranty given by such manufacturers, if any, shall apply.

The obligations of NDI set forth in this warranty are conditional upon proper transportation, shipping, handling, storage, installation, use, maintenance and compliance with any applicable recommendations of NDI. Without limiting the generality of the foregoing, this warranty shall not apply to defects or damage resulting from: fire; misuse; abuse; accident; neglect; improper installation; improper care and/or maintenance; lack of care and/or maintenance; customer supplied software interfacing; modification or repair which is not authorized by NDI; power fluctuations; operation of hardware product(s) outside of environmental specifications; improper site preparation and maintenance; permitting any substance whatsoever to contaminate or otherwise interfere with optics; and any other cause beyond the control of NDI. The obligations set forth in this warranty are further conditional upon the Buyer promptly notifying NDI of any defect and, if required, promptly making the product(s) available for correction. NDI shall be given reasonable opportunity to investigate all claims and no product(s) shall be returned to NDI without NDI first providing the Buyer with a return material authorization number and shipping instructions. All product(s) returned to NDI shall be packaged in the containers originally used by NDI to ship the product(s) to the Buyer.

NDI, for itself, its agents, contractors, employees, providers, and for any parent or subsidiary of NDI, expressly disclaims all warranties, express or implied, including, without limitation, of merchantability or fitness for a particular purpose.

The foregoing warranty is the entire warranty of NDI. NDI neither assumes nor authorizes any person, purporting to act on its behalf, to modify or to change this warranty, or any other warranty or liability concerning the product(s).

16 Declaration of Conformity

Figure 16-1 and 16-2 is a copy of The EC Declaration of Conformity for the Polaris Vicra System.

NDI

EC DECLARATION OF CONFORMITY

Manufacturer: NORTHERN DIGITAL INC.

Address: 103 Randall Drive
Waterloo, Ontario
Canada N2V 1C5

Equipment Type: Opto-Electronic Spatial Measurement System

Trade Name: Polaris Vicra®

We, NDI, hereby declare that the product listed above adheres to the European Directives below and is in conformity with the Standards listed.

Council Directive(s):
2006/95/EC, Low Voltage Directive (LVD)
2004/108/EC, Electromagnetic Compatibility Directive (EMC)

Standards Applied:
See attachment

Year Mark First Applied:
2005

Dated at Waterloo, Ontario, Canada this 24 day of October, 2012.

NORTHERN DIGITAL INC.
per:

David Rath
President

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Figure 16-1 EC Declaration of Conformity Page 1

NDI

Attachment to EC DECLARATION OF CONFORMITY
Polaris Vicra®

	Standards Applied	Additional Information
Safety:	EN 60601-1:2006 +AC:2010 / IEC 60601-1:2005 +C1:2006 +C2:2007 ANSI/AAMI ES60601-1:2005 +C1:2009 +A2:2010 CAN/CSA-C22.2 No. 60601-1-08	Excluding Risk Management
	EN 62471:2008 / IEC 62471:2006 (Modified)	Exempt Risk Group for Infrared Illuminators
EMC:	EN 55011:2009 +A1:2010 / CISPR 11:2009 +A1:2010 FCC Title 47 CFR, Part 15 (2010) ICES-001, Issue 4 (2006)	Class B, Group 1 - ISM Class B - Unintentional Radiators Class B, Group 1 – ISM Radio Frequency Generators
	EN 60601-1-2:2007 / IEC 60601-1-2:2007 (Modified) EN 61000-3-2:2006 +A1:2009 +A2:2009 / IEC 61000-3-2:2005 +A1:2008 + A2:2009 EN 61000-3-3:2008 / IEC 61000-3-3:2008 EN 61000-4-2:2009 / IEC 61000-4-2:2008 EN 61000-4-3:2006 +A1:2008 +A2:2010 / IEC 61000-4-3:2006 +A1:2007 +A2:2010 EN 61000-4-4:2004 +A1:2010 / IEC 61000-4-4:2004 +A1:2010 EN 61000-4-5:2006 / IEC 61000-4-5:2005 EN 61000-4-6:2009 / IEC 61000-4-6:2008 EN 61000-4-8:2010 / IEC 61000-4-8:2009 EN 61000-4-11:2004 / IEC 61000-4-11:2004 JIS T 0601-1-2:2002	 Harmonic Current Emissions Voltage Fluctuations & Flicker ESD Immunity Electric Field Immunity EFT/Burst Immunity Surge Immunity Conducted Immunity Magnetic Field Immunity Dips, Interruptions & Variations Immunity

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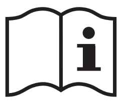
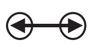
Figure 16-2 EC Declaration of Conformity Page 2

17 Abbreviations and Acronyms

Acronym or Abbreviation	Definition
5DOF	5 Degrees Of Freedom
6DOF	6 Degrees Of Freedom
AAK	Accuracy Assessment Kit
API	Application Program Interface
CAPI	Combined Application Program Interface
CCD	Charge Coupled Device
CD	Compact Disk
CRC	Cyclic Redundancy Check
DSR	Data Set Ready
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EEPROM	Electrically Erasable Programmable Read Only Memory
ESD	Electrostatic Discharge
FCC	Federal Communications Commission
IC	Industry Canada
IR	Infrared Light
IRED	InfraRed Light Emitting Diode
LED	Light Emitting Diode
MRI	Magnetic Resonance Imaging
NDI	Northern Digital Inc.
RF	Radio Frequency
RI	Ring Indicator
RMA	Return Materials Authorization
RMS	Root Mean Square
UL	Underwriters Laboratories Inc.
USB	Universal Serial Bus
VCP	Virtual COM Port
VM	Virtual Machine

18 Equipment Symbols

Symbol	Meaning	System Components
	Caution (To avoid personal injury, consult accompanying documents.)	Position Sensor Host USB Converter
	Consult accompanying documents.	Position Sensor Host USB Converter
	On (power: connection to the mains supply)	Position Sensor Host USB Converter
	Status	Position Sensor
	Error	Position Sensor Host USB Converter
	Direct Current	Host USB Converter
	USB Port	Host USB Converter
	Connection Port	Position Sensor
	Keep away from rain	Packaging
	Fragile	Packaging
	This way up	Packaging

19 Glossary

3D RMS Error

The RMS error is the square root of the sum of the squares of the measurement errors. This can be approximated by the square root of the mean square added to the standard deviation squared of the errors.

Calibration

Calibration is the process of establishing, under specified conditions, the relationship between values produced by an NDI measurement system and corresponding known values established by a device that is traceable to a national standard.

Characterized Measurement Volume

The characterized measurement volume is the volume within the detection region where accuracy is within specified limits. NDI cannot guarantee measurement accuracy outside this region.

Faces

Tool faces are separate rigid bodies that make up a tool.

Field of View

The field of view is the total volume in which the Polaris Vicra System can track a marker, regardless of accuracy.

Firmware

Firmware is a computer program stored in an NDI hardware device and controls the Polaris Vicra System.

Flash EEPROM

Flash Electrically Erasable Programmable Read Only Memory (EEPROM) stores control parameters and system information within the Position Sensor. The information programmed to the Flash EEPROM is retained even after the system is turned off.

Frame

A frame contains the measured positions of the markers in the field of view at a particular point in time.

Global Coordinate System

The global coordinate system is the Polaris Vicra coordinate system. The global coordinate system is used by the Polaris Vicra as a frame of reference against which tool transformations are reported. By default, the global coordinate system's origin is set at the Position Sensor

Illuminator

The illuminator is an array of IR light-emitting diodes that surround the sensor lenses on the Position Sensor. These flood the area in front of the Position Sensor with IR light, which is reflected back to the Position Sensor by the passive markers.

Line Separation

To determine the position of an IR source, the Position Sensor calculates a line between the source of IR and each sensor. The line separation is the distance between these two lines where they cross.

Local Coordinate System

A local coordinate system is a coordinate system assigned to a specific tool or rigid body.

Maximum 3D Error

Maximum 3D error applies to individual markers. It specifies, in the tool definition file, the maximum allowable difference between the measured and expected location of a marker on a tool or rigid body.

Maximum Marker Angle

Maximum marker angle is used to determine if a marker will be used in the calculation of a rigid body or tool. If the marker is determined to be farther off-angle to the Position Sensor than the maximum marker angle, this data is not used to determine the rigid body or tool.

Passive Marker

A passive marker is a retro-reflective passive sphere that reflects IR light emitted by the Position Sensor.

Pivoting

Pivoting is a procedure (of rotating a tool about its tip) used to determine the tool tip offset.

Position Sensor

The Position Sensor is the component of the Polaris Vicra System that provides a source of IR light for passive markers, collects marker position data from both active and passive markers, calculates tool transformations, and sends the results to the host computer.

Quaternion

A quaternion is a compact representation of rotations, or correspondingly, orientations in 3D space (rather than having to use orthogonal matrices).

Reference Tool

A reference tool is a tool or rigid body whose local coordinate system is used as a frame of reference in which other tools are reported/measured.

Rigid Body

A rigid body is an object on which three or more markers are fixed relative to one another.

Tool Definition File

A tool definition file stores information about a tool or rigid body. This includes information such as the placement of the tool's markers, the location of its origin, and its manufacturing data. A tool definition file is formatted as .rom for tools.

Tool Tip Offset

The tool tip offset is the vector between the tip of the tool and the tool origin.

Transformation

A transformation is a combination of translation and rotation values that describe a change of the tool or rigid body in position and orientation.

Unique Geometry Tool

Unique geometry tools incorporate markers positioned in such a way that, when detected in the measurement volume, the tool can be uniquely identified from other tools.

Appendix A Polaris Vicra Calibration Performance and Methodology

Standard industry practice dictates that all measurement and testing instruments should be periodically calibrated to ensure they are operating within tolerances acceptable to the user and/or the user's customers.

The user must establish a calibration procedure and interval that is appropriate for the accuracy requirements of their application.

The Position Sensor is a highly specialized instrument developed exclusively by NDI. For all calibration procedures, return the Position Sensor to NDI. This practice ensures that all calibrations are conducted in accordance with procedures established specifically for the Polaris Vicra Position Sensor.

Note The NDI Accuracy Assessment Kit (AAK) can be used in the field as an aid to determine whether a Position Sensor is performing acceptably for the user's application.

If, at any time, a concern should arise that the Position Sensor is not measuring accurately, it should be returned to NDI.

Note The calibration procedure at NDI applies to single markers and cannot be directly applied to an application that uses tools with several markers.

A.1 Polaris Vicra Performance

The Polaris Vicra System performance is determined by a statistical analysis of the 3D Euclidean distance error between the reported position of an NDI marker and its true position, based on measurements taken throughout the entire Polaris Vicra System's measurement volume. Acceptance criteria for the Polaris Vicra System's performance are based on the RMS values of the accuracy and repeatability.

The **3D RMS volumetric accuracy acceptance criterion** is less than or equal to 0.25 mm, based on an NDI marker stepped through a statistically representative set of positions throughout the measurement volume, using the mean of 30 samples at each position at 20°C.

The **3D RMS repeatability acceptance criterion** is less than or equal to 0.20 mm, based on total samples of an NDI marker stepped through a statistically representative set of positions throughout the measurement volume, using 30 samples per position at 20°C.

A.2 Calibration Method

The following method is used to calculate the Polaris Vicra System's accuracy and repeatability:

An NDI marker is accurately moved to each of n locations (X_i, Y_i, Z_i) spread throughout the measurement volume. The mechanism that moves the marker is assumed to have an accuracy that is at least 10 times better than the measured accuracy of the Polaris Vicra System. This assumption allows the errors in the marker positioning to be ignored.

At each of the n locations, the Polaris Vicra System takes m readings of the marker's 3D position (x_{ij}, y_{ij}, z_{ij}).

The **accuracy of the Polaris Vicra System** is calculated as the RMS variation of the mean of *m* readings about the true 3D location calculated across all *n* locations throughout the measurement volume.

The **repeatability of the Polaris Vicra System** is calculated as the RMS variation of the *m* readings about the average of the 3D readings at each location *n*. This RMS variation is calculated across all *n* locations throughout the measurement volume.

3D average measurements:

$$x_{i_{\text{average}}} = \frac{\sum_{j=1}^{m} x_{i,j}}{m}, \quad y_{i_{\text{average}}} = \frac{\sum_{j=1}^{m} y_{i,j}}{m}, \quad z_{i_{\text{average}}} = \frac{\sum_{j=1}^{m} z_{i,j}}{m}$$

$$\textbf{3D RMS accuracy} = \sqrt{\frac{\sum_{i=1}^{n}\left[(x_{i_{\text{average}}} - X_i)^2 + (y_{i_{\text{average}}} - Y_i)^2 + (z_{i_{\text{average}}} - Z_i)^2\right]}{n}}$$

$$\textbf{3D RMS repeatability} = \sqrt{\frac{\sum_{i=1}^{n}\left[\sum_{j=1}^{m}\left[(x_{i,j} - x_{i_{\text{average}}})^2 + (y_{i,j} - y_{i_{\text{average}}})^2 + (z_{i,j} - z_{i_{\text{average}}})^2\right]\right]}{n \cdot m}}$$

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