

Passive Polaris Vega User Guide

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2	30-Sept-2016	Updated volume diagram in section 1.1 Added active wireless tool specification in section 4.6 Removed position sensor chirp signal specification from section 4.6 Added section 2.6: Connecting to a system
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Read Me First!

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

Warnings



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 Vega 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 connect the Polaris Vega System to a host computer or network that is not IEC 60950 and/or IEC 60601 approved. If you connect the system to a non-approved host computer or network you may increase leakage currents beyond safe limits and cause personal injury.
3. 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.
4. Do not protect or shield either the Position Sensor or tools with methods not approved by NDI. Non-approved methods, such as drapes or covers, 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. Inaccurate conclusions may result in personal injury.
5. The Polaris Vega 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 64](#). Failure to do so may result in personal injury.
6. Radio frequency communications equipment, including portable and mobile devices, may affect the Polaris Vega System and result in personal injury.
7. Do not use the Polaris Vega System either adjacent to, or stacked with, other equipment as this may cause the equipment to over heat. Check that the Polaris Vega 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.
8. 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 Vega System and may result in personal injury.
9. Do not incorporate non-NDI sensors with the Polaris Vega System. The accuracy of results produced by applications that incorporate non-NDI sensors with the Polaris Vega System is unknown. Reliance on these results may result in personal injury.

-
10. All user maintenance must be done by appropriately trained personnel. Individual components of the Polaris Vega System contain no user-serviceable parts. Maintenance by untrained personnel may present an electric shock hazard.
 11. 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.
 12. Do not immerse any part of the Polaris Vega 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.
 13. Do not sterilize the Polaris Vega 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. These inaccurate conclusions may result in personal injury.
 14. Do not use the Position Sensor without inspecting it for cleanliness and damage before a procedure. The Position Sensor should also be monitored during the procedure. Reliance on data provided by an unclean or damaged Position Sensor may lead to inaccurate conclusions. Inaccurate conclusions may result in personal injury.
 15. Do not use the Polaris Vega System for absolute measurements; the system is designed for relative measurements only. Treating measurements as absolute may result in an incorrect interpretation of results. These incorrect interpretations may result in personal injury.
 16. 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. Inaccurate conclusions may result in personal injury.
 17. Do not use a wireless tool whose design does not conform to the Polaris Vega System's unique geometry constraints. When a Polaris Vega 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. When two indistinguishable tools are being used, the first tool that is detected will be tracked. If that tool moves out of the measurement volume, the second tool will be tracked. If this is repeated, the tracking data will appear to jump between the two tools. Reliance on data produced by two indistinguishable tools can lead to inaccurate conclusions. These inaccurate conclusions increase the possibility of 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. 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. 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. Inaccurate conclusions may result in personal injury.

21. Do not use the Position Sensor in an MRI environment without first determining the performance, including accuracy, of the Position Sensor in an MRI environment. The Polaris Vega System is conditionally MRI safe, but NDI has not fully validated the 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. Reliance on inaccurate conclusions may result in personal injury.
22. Do not look directly into the laser-emitting aperture. The Class 2 laser module on the Position Sensor emits radiation that is visible and may be harmful to the human eye. Direct viewing of the laser diode emission at close range may cause eye damage.
23. Do not use controls, adjustments, or performance of procedures other than specified in this guide as it may result in hazardous light exposure.
24. Ensure that people with restricted movement or reflexes (for example, patients undergoing medical procedures) do not look directly into the laser-emitting aperture. Patients undergoing medical procedures may be restricted in the availability of adverse-effects reflexes (turning away eyes and/or head, closing eyes) due to pharmaceutical influences and/or mechanical restraints. The Class 2 laser module on the Position Sensor emits radiation that is visible and may be harmful to the human eye. Direct viewing of the laser diode emission at close range may cause eye damage.
25. Position the system components so that they can be easily disconnected from mains power. Failure to do so may result in an electric shock hazard and possible personal injury.
26. The Vega system is classified as Medical Electrical Equipment, intended for use in health care facilities outside of the patient environment. The Vega system can be used in the patient environment as long as it is tested in the final end user configuration.

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 Vega 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 solution and a soft lint-free cloth to remove handling smudges from the enclosure and illuminator covers. 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 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. If using a USB-to-ethernet adapter when connecting the computer to the midspan, always connect the adapter to the “in” port of the midspan (the port that does not provide power). Connecting to the “out port” could cause damage to the adapter.

Disclaimers

1. Read the entire *Passive Polaris Vega User Guide* before attempting to operate the Polaris Vega 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 69 for further information.

3. The user must determine the suitability of the Polaris Vega System for their own application.
4. This equipment has been investigated with regard to safety from electrical shock and fire hazard. The inspection authority has not investigated other physiological effects.
5. The Polaris Vega 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.
6. Northern Digital Inc. has not investigated the implications of incorporating the Polaris Vega Position Sensor with an automatic position device, or any other automated closed loop systems. Using the Polaris Vega System in such an application is solely the responsibility of the user.
7. The Polaris Vega System emits IR light that may interfere with IR-controlled devices, such as operating room tables. It is recommended that you test the Polaris Vega System if you intend to use it in an environment where other IR-controlled devices are in use.
8. Northern Digital Inc. has not validated the Polaris Vega System in the presence of x-ray, gamma ray, proton radiation or other types of radiation. If the Polaris Vega System is used in such an environment, the user is responsible for determining the performance of the system.

Contact Information

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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: <https://support.ndigital.com>

1 Passive Polaris Vega System Overview

1.1 Introduction

This user guide provides information on the Polaris Vega System. The Polaris Vega System is an optical measurement system that uses advanced optical measurement technology to track the 3D position and orientation of markers attached to application-specific tools. The tools are tracked within a specific measurement volume, see [Figure 1-1](#).

This section provides an overview of the system, its components, and how it works. NDI recommends that you read the guide completely before using the system.

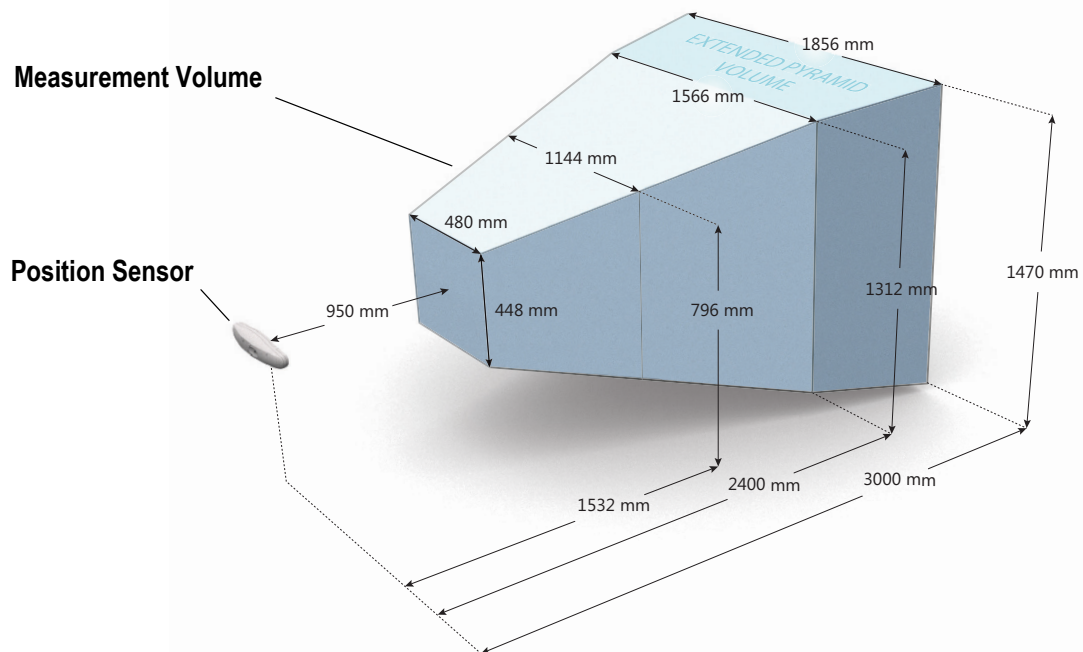


Figure 1-1 Polaris Vega Measurement Volume

Note The back section of the measurement volume, 2400 mm to 3000 mm from the Position Sensor, is only available in the optional extended pyramid volume.

The Polaris Vega System is typically used in research applications, or can be integrated by OEM partners into image guided surgery suites for use in procedures such as neurosurgery, orthopaedics or radiotherapy. The main system component is the Position Sensor, ([page 3](#)). The Position Sensor connects to a host computer via ethernet ([page 2](#)).

An overview of system 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 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.



Figure 1-2 Polaris Vega Position Sensor

1.2 System Connection

The ethernet connection allows multiple Position Sensors to be synchronized and controlled by one host computer. Power for the Position Sensor(s) is supplied via Power over Ethernet (PoE). A block diagram is shown below and for detailed information, see [“Connecting the Hardware” on page 14](#).

Multiple Position Sensors can be connected

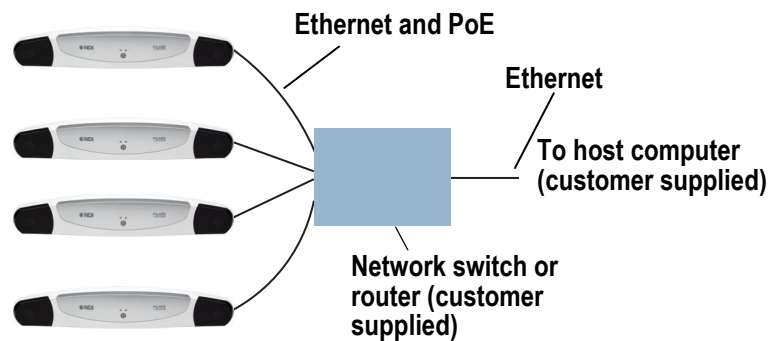


Figure 1-3 Typical System Connection

Note The Vega system is classified as Medical Electrical Equipment, intended for use in health care facilities outside of the patient environment. The Vega system can be used in the patient environment as long as it is tested in the final end user configuration.

1.3 System Configuration Options

The Polaris Vega System is available in a number of configurations and may include the positioning laser, detailed below.



Figure 1-4 Positioning Laser

Positioning Laser

The optional positioning laser, located on the Position Sensor, indicates the general centre of the characterized measurement volume within a tolerance. For details on the positioning laser see [“Positioning Laser” on page 47](#).

1.4 Host Computer Requirements

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

- 1 GHz or faster 32-bit (x86) or 64-bit (X64) processor
- 1 GB RAM (32-bit) or 2GB RAM (64 bit)
- 16 GB available hard disk space (32-bit) or 20 GB (64-bit)
- DirectX 9 graphics device with WDDM 1.0 or higher driver
- Operating system options:
 - Windows 7 (64 bit), 8 and 10
 - 64bit Linux Kernel 2.6.35 and later, and 3.0 and later
 - Mac OS X 10.10 and later
- Screen resolution 1024 x 768 (1280 x 1024 recommended)
- Gigabit network interface is recommended

1.5 Ethernet Switch

A (customer supplied) ethernet switch is required to operate the system. The ethernet switch must be approved to IEC 60950 or IEC 60601 standard and meet the following minimum specifications:

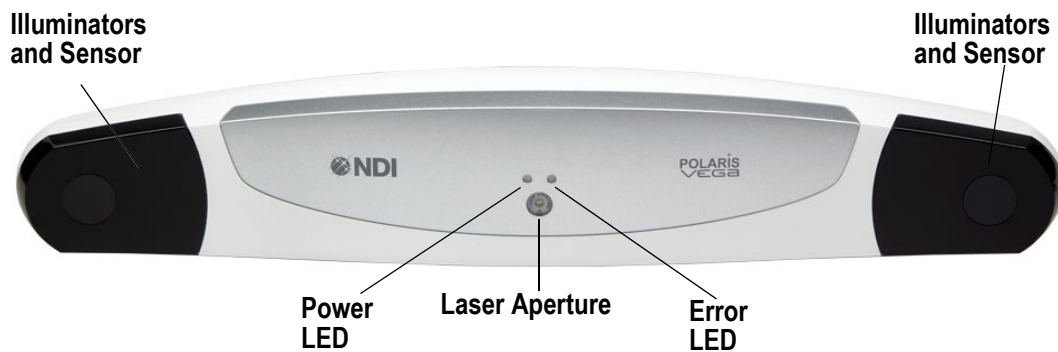
- An IEEE802.3at compliant Power over Ethernet (PoE) type 2 device.

1.6 Position Sensor

The Position Sensor is the main component of the Polaris Vega System. Its main function is to track the position and orientation of markers attached to tools.

- For more information on tools, see [“Passive Polaris Vega System Tools” on page 33](#).
- For a detailed description of how the Position Sensor detects markers, see [“Marker Detection and Tool Tracking” on page 31](#).

Note As an option, the Position Sensor can be branded to custom specifications. For details on this option contact NDI. See [“Contact Information” on page xiii](#).

Front View**Figure 1-5 Position Sensor (with Laser Option) 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 illuminating 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 an image sensor. 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 and error LEDs on the front of the Position Sensor combine as described in [Table 1-1](#) to indicate the status of the Position Sensor:

Table 1-1 Position Sensor Indicator LEDs Summary

Power LED (Green)	Error LED (Amber)	Position Sensor Status
Off	Off	No power
Flashing (4 times per second)	Off	The system is booting up.
Flashing (2 times per second)	Any state	The Position Sensor is warming up. The power LED will stop flashing and light steady green when the Position Sensor is ready for use.
On	Off	The Position Sensor is ready for use; no faults or error conditions
On	On	Minor recoverable error condition (not a fault); can immediately be corrected. If the error condition is not corrected, the system will still be operational, but may requires the application to override the “bad data” filter to receive tracking data.
On	Flashing	Major recoverable fault which prevents operation but can be repaired by the user (for example incompatible firmware).
Off	On	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 Vega Application Program Interface Guide*. for details.)

Laser Aperture The (optional) positioning laser beam is emitted from this aperture.



Warning! Do not look directly into the laser-emitting aperture. The Class 2 laser module on the Position Sensor emits radiation that is visible and may be harmful to the human eye. Direct viewing of the laser diode emission at close range may cause eye damage.

Ensure that people with restricted movement or reflexes (for example, patients undergoing medical procedures) do not look directly into the laser-emitting aperture. Patients undergoing medical procedures may be restricted in the availability of adverse-effects reflexes (turning away eyes and/or head, closing eyes) due to pharmaceutical influences and/or mechanical restraints. The Class 2 laser module on the Position Sensor emits radiation that is visible and may be harmful to the human eye. Direct viewing of the laser diode emission at close range may cause eye damage.

Rear View

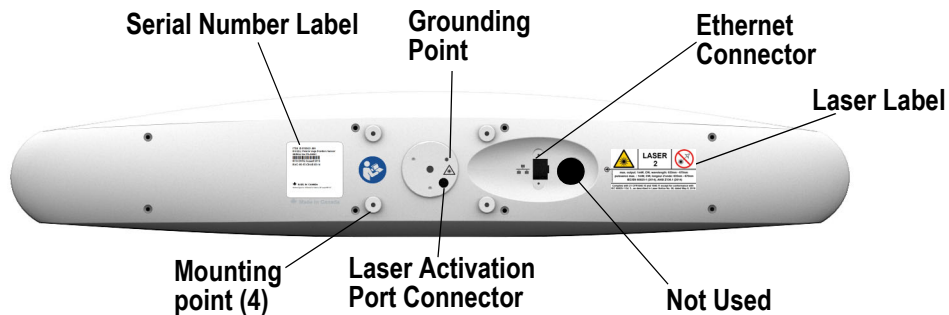


Figure 1-6 Position Sensor Rear View

The rear of the Position Sensor incorporates the following components:

Mount Four M4 x 0.7 mm pitch x 10 mm deep threaded holes. (See [“Mounting the Position Sensor” on page 12](#) for mounting details.)

Ethernet Power and I/O Interface Provides for ethernet communications and Power over Ethernet (PoE). The ethernet port is compatible with the IEEE 802.3at Type 2 PoE standard.

Grounding Point An M3x0.5, 6mm tapped hole to allow for a dedicated ground connection to be fitted to the Position Sensor. (If the system end-use application use requires one.)

Laser Label The laser label is located on the back of the Position Sensor and shows the classification, output, wavelength, standards, and a warning.

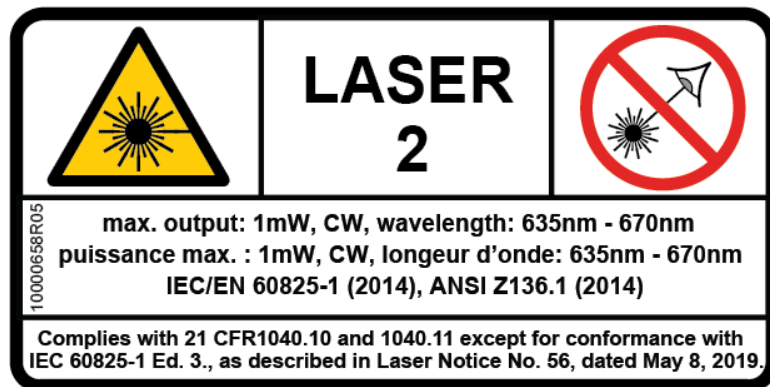


Figure 1-7 Position Sensor Laser Label

Laser Activation Port The laser is activated by means of an external (customer supplied) switch that connects to the rear of the Position Sensor via a 3.5 mm jack socket (see [Figure 1-6](#)). You can also activate the laser through the user parameters, see the *Polaris Vega Application Program Interface Guide* for details.

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.

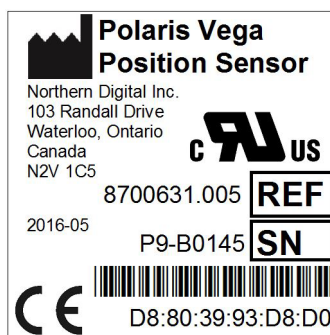


Figure 1-8 Position Sensor Serial Number Label

Audio Codes

In addition to the indicator LEDs, the Position Sensor emits audio tones 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 using NDI ToolBox software, or by setting the value of the user parameter **Param.System Beeper** to 0.)
- 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 Vega 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 Vega 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 46](#).

1.7 Cables and Accessories

The following cables and accessories are required to use the Polaris Vega System.

- A Cat 5e or higher shielded ethernet cable.
- A Power Over Ethernet midspan or endspan that conforms to the IEEE 802.3at standard, Type 2 (25.5 W up to 30 W).

1.8 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](#).

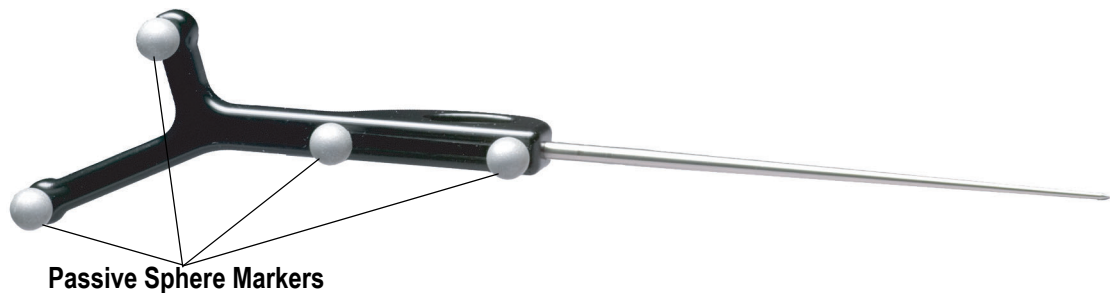


Figure 1-9 Passive Tool

The Polaris Vega System can track passive tools and (optionally) 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

The Polaris Vega System can track the positions and orientations of tools, and can also report the positions of individual markers.

An example of a passive tool is shown in [Figure 1-9](#). The example shows a probe that incorporates four NDI passive sphere markers. For more information on passive tools and passive sphere markers, see [“Passive Tools” on page 33](#).

Passive tools can incorporate two main types of markers; passive marker spheres and Radix lenses. Passive marker spheres are available as follows:

- NDI passive sphere markers have a retro-reflective coating. The coating 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. NDI passive sphere

markers snap-fit to the tool using NDI mounting posts, which are manufactured to firmly hold NDI spheres.

- Radix lenses are retro-reflective markers that can easily be wiped off if they become dirty. In contrast to the NDI passive sphere, the Radix lens cannot be used directly in the form it is supplied. It must first be incorporated into a tool or mounting base (not provided by NDI). For details on Radix lenses, their use and applications, refer to the *Radix User Guide*.

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 activates its illuminators, which emit IR pulses that are detected by an IR receiver in the active wireless tool. The IR receiver triggers the markers in the tool, which emit IR back to the Position Sensor.

For more information on active wireless tools and active markers, see [“Active Wireless Tools” on page 34](#).

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 37](#). 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 37](#). Polaris Vega System tools are described in more detail in [“Passive Polaris Vega System Tools” on page 33](#). For information on tool design and construction, refer to the *Polaris Tool Design Guide*.

Number of Tools

The system can simultaneously track up to 25 passive tools and 6 active wireless tool, but the total number of tools loaded cannot exceed 25. Note that a large number of tools and/or 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 28](#). Stray markers are described on [page 42](#).

1.9 NDI Software

The following software is included on the Polaris Vega installation media. You can also download the software from the NDI Support Site at <https://support.ndigital.com>.

NDI ToolBox A suite of utilities for diagnostics, maintenance, testing, and development support for the Polaris Vega 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 *NDI ToolBox online help* for details.

NDI Combined API Sample (CAPI) A sample program, source code and documentation. This program provides an example of how to write programs to operate the Polaris Vega System.

2 Setting Up the Passive Polaris Vega System

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

- “Unpacking the System” on page 10
- “Operating Environment Requirements” on page 11
- “Mounting the Position Sensor” on page 12
- “Connecting the Hardware” on page 14
- “Application Software” on page 15
- “Connecting to a System” on page 17

2.1 Unpacking the System

The Polaris Vega System is usually shipped to end users with a Position Sensor, cables, and the Polaris Vega installation media (which includes software and end user documentation). OEM partners may receive a different configuration.

Handle all system components with care. Keep the packaging in good condition; you will need to use it if the system needs to be returned to NDI for repair.

Note See “[Return Procedure](#)” on page 75 for instructions on returning the system to NDI.

Network Warning Label

When the Vega Position Sensor is first removed from the packaging, there is a warning label over the ethernet port., [Figure 2-1](#). Review the warning then remove the label using the finger tab on the right.



Figure 2-1 Network Warning Label



Warning!

Do not connect the Polaris Vega System to a host computer or network that is not IEC 60950 and/or IEC 60601 approved. If you connect the system to a non-approved host computer or network you may increase leakage currents beyond safe limits and cause personal injury.

2.2 Operating Environment Requirements



Warning!

Warnings

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

1. **Do not use the Polaris Vega 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, such as drapes or covers, 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. Inaccurate conclusions may result in personal injury.**
3. **The Polaris Vega 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 64. Failure to do so may result in personal injury.**
4. **Do not use the Polaris Vega System either adjacent to, or stacked with, other equipment as this may cause the equipment to over heat. Check that the Polaris Vega 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 Vega System and result in personal injury.**
6. **Do not immerse any part of the Polaris Vega 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. Inaccurate conclusions may result in personal injury.**
8. **Do not use the Position Sensor in an MRI environment without first determining the performance, including accuracy, of the Position Sensor in an MRI environment. The Polaris Vega System is conditionally MRI safe, but NDI has not fully validated the 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. Reliance on inaccurate conclusions may result in personal injury.**
9. **Position the system components so that they can be easily disconnected from mains power. Failure to do so may result in an electric shock hazard and possible personal injury.**

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 29](#) or [Figure 4-3 on page 30](#) for the dimensions of the characterized measurement volume.

- 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 Vega System.
- Make sure that there are no large reflective surfaces within the field of view (described on [page 28](#)). 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 Vega 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.
- The environmental conditions must be as listed in [Figure 11-1 on page 62](#).
- If the system is to be used in an MRI environment, contact NDI for information on response of the system.

2.3 Mounting the Position Sensor

Caution! 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.

Note Before you design a custom enclosure or any attachments (other than mounting) for the Position Sensor, contact NDI for assistance, see [“Contact Information” on page xiii](#).

The Position Sensor is mounted via four M4 x 0.7 mm pitch x 10 mm deep threaded holes. [Figure 2-2](#) shows the Position Sensor dimensions and mounting arrangement.

All dimensions in mm

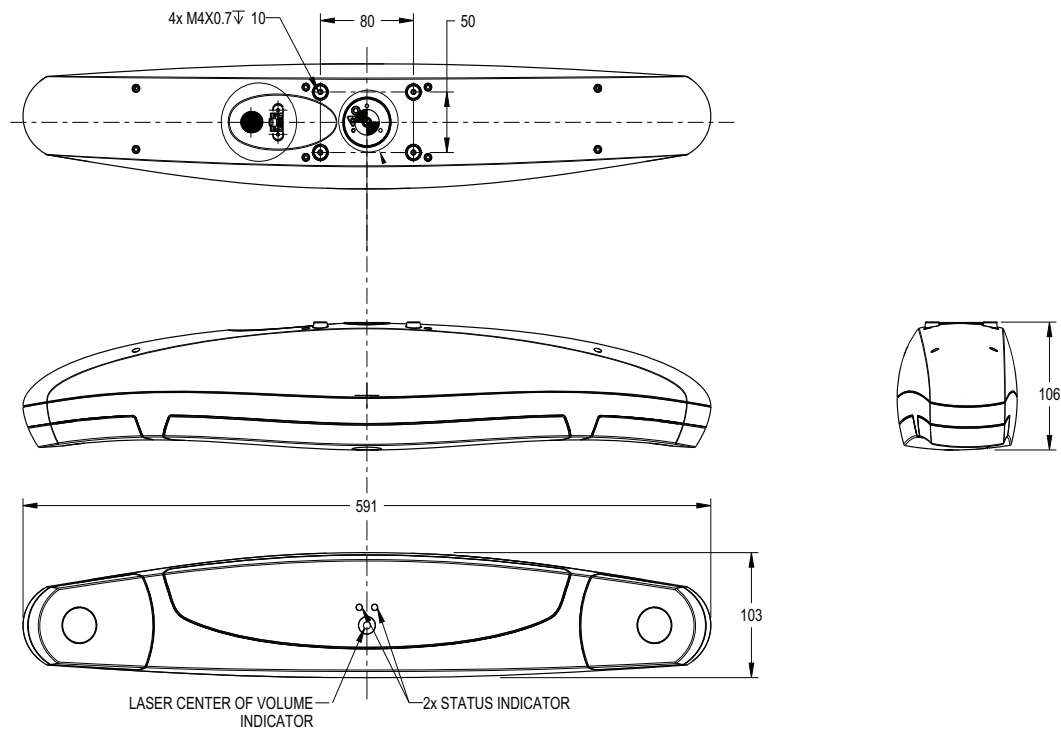


Figure 2-2 Position Sensor Mounting Details

External Laser Trigger Switch

The external laser trigger can be used to connect a switch to trigger the laser. This port is a four-conductor, 3.5-mm audio jack. Only the first two conductors are used, as follows:

Conductor	Signal
1 (tip)	Laser switch contact input
2	Laser switch contact input
3	Not used
4	Not used

If you intend to design and integrate an external laser activation switch, there are certain considerations you should take into account to provide the maximum protection against electrostatic discharge (ESD):

- Design the handle and select a switch that will minimise the possibility of energy flowing into the laser switch circuits in the Position Sensor.
- Electrically isolate the body of the switch from the handle, and provide a good grounding path from the handle to earth ground. This will direct the ESD energy to flow through the

handle and to ground, instead of passing through the laser switch wiring into the Position Sensor.

2.4 Connecting the Hardware



Warning!

Warnings

Read the following warnings before using the Polaris Vega 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 Vega System and may result in personal injury.**
2. **Do not connect the Polaris Vega System to a host computer or network that is not IEC 60950 and/or IEC 60601 approved. If you connect the system to a non-approved host computer or network you may increase leakage currents beyond safe limits and cause 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 incorporate non-NDI sensors with the Polaris Vega System. The accuracy of results produced by applications that incorporate non-NDI sensors with the Polaris Vega System is unknown. Reliance on these results may result in personal injury.**
5. **Do not use the Position Sensor without inspecting it for cleanliness and damage before a procedure. The Position Sensor should also be monitored during the procedure. Reliance on data provided by an unclean or damaged Position Sensor may lead to inaccurate conclusions. Inaccurate conclusions may result in personal injury.**

To connect the system, follow the procedure detailed below:

1. Connect the ethernet cable to the socket on the Position Sensor.

Caution!

If using a USB-to-ethernet adapter when connecting the computer to the midspan, always connect the adapter to the “in” port of the midspan (the port that does not provide power). Connecting to the “out port” could cause damage to the adapter.

2. There are three ways to connect the PSU:
 - a) Connect the Position Sensor to a switch with embedded PoE.
 - b) Or, to a switch without embedded PoE, connect the switch to PoE and the Position Sensor to the PoE.
 - c) Or, to a router, connect the router to PoE and the Position Sensor to the PoE.
3. Connect the network switch or router to the host computer.
4. It is also possible to connect the Position Sensor to the PoE which is then connected to the host computer with no need for a switch or router.

5. Make sure all the cables are connected firmly, and placed where they will not be stressed, stepped on, or bent.

Note Integrating the Vega Position Sensor into a 10Base-T network is not recommended.

It takes approximately 30 seconds for the Position Sensor to power up after power is applied. The Position Sensor will emit two beeps at the end of its power up cycle, and the power LED will begin to flash.

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.

2.5 Application Software

ToolBox The Polaris Vega System ships with NDI ToolBox application software. ToolBox is a collection of utilities that allow you to configure, upgrade, troubleshoot, and test the Polaris Vega System.

NDI ToolBox is located on the Polaris Vega installation media. You can also download the application from the NDI Support Site at <https://support.ndigital.com>.

Installing NDI ToolBox

To install NDI ToolBox, follow the procedure detailed below:

Windows

The following versions of Windows are supported: Windows 7, 8 and 10.

On the Polaris Vega installation media, browse to Windows 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.

Linux

The following versions of Linux are supported: 64 bit Linux with Kernels 2.6.35 and higher, and 3.0 and higher.

Install NDI ToolBox on a Linux platform as follows:

1. On the Polaris Vega installation media, browse to **Linux/install.sh**.
2. Execution permissions may be required to install ToolBox. Run the following commands in the folder where Linux/install.sh was copied to from the installation media:

```
sudo chmod +x install.sh
./install.sh
```
3. Follow the on-screen instructions to complete the process. The default installation location is **<user_name>/NDIToolBox**.

Silent Install

To execute a silent install of ToolBox, run the installer from the command line with the ‘-q’ option. You can also specify a different directory than the default. For Linux, you would enter:

```
./installer.sh -q -dir /opt/ToolBox
```

If the -dir option is omitted the default install location will be used. On Linux this is **<user home>/NDIToolBox** (or **~/NDIToolBox**)

Mac OS X

The following versions of Mac OS are supported: 10.10 and higher

To install NDI ToolBox on a Mac platform follow the procedure detailed below:

Note 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 Vega installation media, locate, and open, the **MacOSX** folder.
2. Locate and double-click on the **install.dmg** file. Double click on **NDI Installer** and enter your administrator password.
3. Follow the on-screen instructions to complete the NDI ToolBox installation

Note The NDI ToolBox download includes a Java virtual machine (VM). 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.

Uninstalling NDI ToolBox

To uninstall NDI ToolBox, follow the procedure detailed below:

Windows

1. Open the **Windows Start** menu.
2. Select **Northern Digital Inc. > ToolBox**.
3. Select **NDI ToolBox Uninstaller**.
4. Follow the prompts to complete the removal of NDI ToolBox from your system.

Linux

Navigate to the install directory and run `uninstall.sh`.

Mac OS X

Navigate to **Applications>NDI ToolBox** and double click on **Uninstaller.app**. Follow the on-screen instructions.

All related NDI ToolBox files and aliases to NDI ToolBox utilities will be removed from your system.

2.6 Connecting to a System

When you start the ToolBox software, it may automatically connect to a system, depending on the connection options that have been set. Refer to the ToolBox online help for details about connection options. Once ToolBox is running, you can direct it to connect to a different system.

To connect to a system

Select File > Connect to > (Polaris Vega)

ToolBox automatically detects all available Vega Position Sensors and System Control Units and lists them at the top of the **Connect to** menu. You can hover over the menu item to see its IP address. Unless the system configuration was customized, the default host name is the same as the device's serial number, for example P9-12345. If a custom host name was set for the device, that name will represent the device on the network.

Systems are automatically detected using the Bonjour implementation of the “[Zero Configuration Networking](#)” approach. ToolBox uses this protocol to discover the PSUs and SCUs on the network. You can install Apple’s Bonjour software on your host computer to have the ability to discover and connect to the systems from the command prompt.

There are three different networking approaches that can be used to establish the connection:

1. “[Dynamic Host Configuration](#)” on page 17
2. “[Zero Configuration Networking](#)” on page 17
3. “[Static IP Addressing](#)” on page 18

Each approach is detailed below. If you encounter issues with any of these approaches, refer to “[Troubleshooting the connections](#)” on page 19.

Note These instructions use NDI ToolBox to perform the configuration. It is also possible to configure the network using the Vega API. Refer to the *Polaris Vega Application Program Interface Guide* for more information on modifying the connection

Dynamic Host Configuration

DHCP is generally the default network configuration for the Vega System. If there is a DHCP server on the same network as the Vega device, then the server will automatically assign a dynamic IP address to it and the connection to the host can be made.

If there is no response from the DHCP server in three to six seconds, the device will assign it’s own IP parameters using Zero Configuration. (Link Local Addressing)

Zero Configuration Networking

Zero Configuration is the simplest way to network the host computer with the Vega devices. System setup should meet the following requirements to support Zero Configuration:

- The host computer and Vega devices need to be connected to each other or on a local network with no DHCP server.
- The host computer must be configured for zero configuration networking. This is the default for Window and Mac OS. On Linux it may be enabled on a “per interface” basis.

When this criteria is met and you power on the system, the host and devices will be assigned IP addresses on the 169.254.xxx.xxx subnet. Once this is complete, you can connect to the device by selecting **File> Connect To**. The host name for each device will be composed of the device serial number on the .local. domain. For example, P9-12345.local., where P9-12345 is the device serial number.

Static IP Addressing

Static IP Addressing allows you to manually assign an IP address to the Vega device. When you set a static IP address, there are three pieces of information to provide for both the device and host computer:

- the IP address (required)
- the gateway (optional)
- the subnet mask (optional)

Once you set up the Vega device for Static IP addressing, you must set up your host computer network appropriately to enable the connection.

- On Windows, use the Control Panel
- On Mac OS, use Setup
- On Linux use Yast or equivalent

Modifying the connection

Once you are connected to a device, you can change the network connection through the NDI ToolBox Configure utility.

1. Select **Settings and Options> Network**.
2. Select the **IP Method** drop-down and choose the appropriate setting.
 - To configure Static IP networking, select **Static**, then provide an IP address, gateway and subnet mask for the device you are configuring.
 - If you enabled DHCP/ZeroConf there is no additional information to provide.
3. Once complete, select **File > Save Parameters**.
4. Reset the system by selecting **File > Reset System**.

Note To see the IP address of any device in the Connect To menu, hover over it.

Troubleshooting the connections

If you are unable to connect to the Vega device from the host computer, review the following troubleshooting tips.

The device is visible in the Connect To menu but when I try to connect, I get the error message “Failed to Connect.”

Problem: This problem occurs most frequently when static IP addressing is used. In this case, the Vega device may not be configured properly for static IP addressing.

Solution: Configure the host computer and Vega device for static IP addressing as follows:

1. In the ToolBox Configure application, select **File> Connect To**. The Connect menu lists devices found based on DNS-SD and shows the devices by service name and host name.
2. Hover over the device you are trying to connect to. An IP address will be shown in the tool tip. Make note of this IP address.
3. Change the host network interface to be on the same subnet as the Vega device.
4. Select **File > Save Parameters**.
5. Reset the system by selecting **File > Reset System**.
6. In the NDI Configure application, attempt to connect to the Vega device again.

If the problem persists, it is likely due to an issue with the way your hardware is configured. In this case, contact your network administrator.

When I navigate to the Connect To menu, I don’t see the Polaris Vega device I am trying to connect to.

Problem: The Vega system may not be powered on or connected to the network.

Solution: Check the Vega devices and power over ethernet midspan to ensure the devices are both powered on and connected to the network.

If the problem persists, it is likely due to an issue with the way your network is configured. In this case, contact your network administrator.

Connecting to a system using the Polaris API

In addition to using ToolBox to connect to a Vega device, you can also use the Polaris API. To do so, you must connect to the system TCP listening port, which is port 8765 by default. This port is defined as the parameter “Param.Network.Host Port” on the device. An example of connecting to a device and asking its version information is as follows:

```
telnet P9-12345.local 8765
ver 4
```

Where P9-12345 is the device serial number/host name and ver 4 is the command to retrieve the version information for the device.

For more information, refer to the *Polaris Vega Application Program Interface Guide* provided with your system.

3 Tutorial: Learning to Use the Passive Polaris Vega System

This chapter is intended as a tutorial to demonstrate the basic functionality of the Polaris Vega System using NDI ToolBox. For more detailed information on NDI ToolBox, refer to the *NDI ToolBox online help*. 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, and
- pivot a tool to determine the tool tip offset.


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 NDI ToolBox” on page 15](#).
2. Set up and connect the hardware, as described in [“Connecting the Hardware” on page 14](#).
3. Open NDI Track.
4. If NDI Track does not automatically connect to the system, select **File > Connect to**. Select the system from the list, or select **New Connection...** Enter the host name or IP address and select **OK**.

To Track Tools

1. Click  to load the tool definition files for the tools you want to track.
2. In the dialog that appears, browse to the desired tool definition file(s). Hold down **Ctrl** and click to select more than one file.
3. Click **Open**.

Once a tool definition file has been loaded, the Polaris Vega System will automatically attempt to track the tool.

4. 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 20.
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.

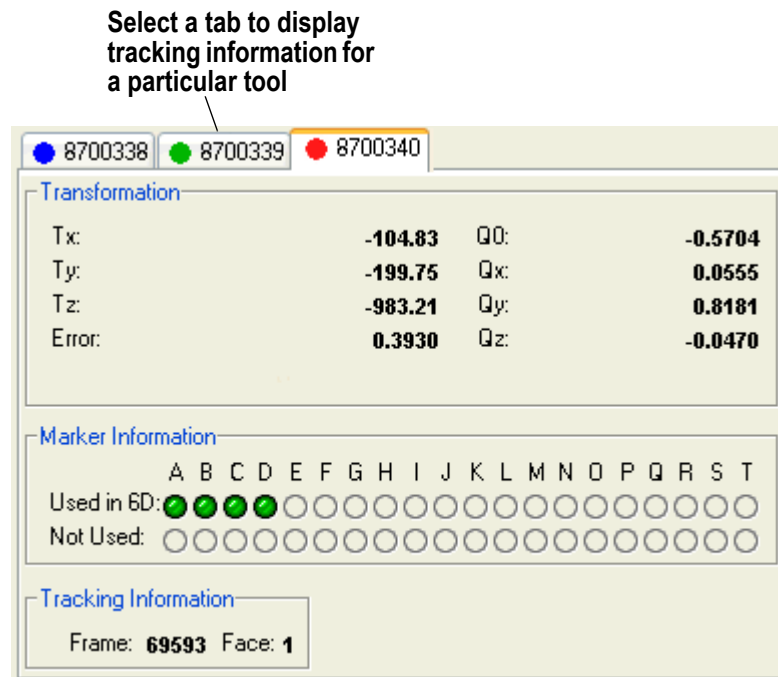


Figure 3-1 Tutorial: NDI ToolBox Tool Tracking Window

“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 all the markers are outside of 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.

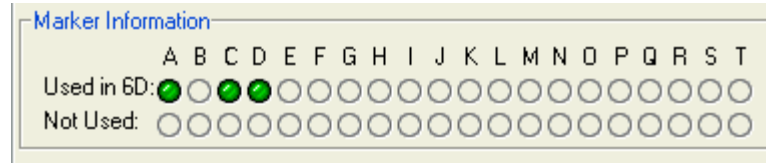


Figure 3-3 Tutorial: Detected Markers Indicator

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.

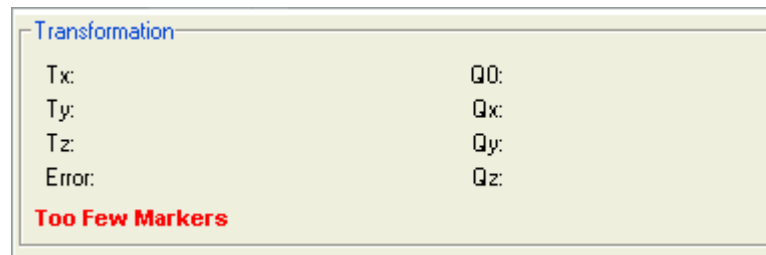


Figure 3-4 Tutorial: “Too Few Markers” Flag

“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.

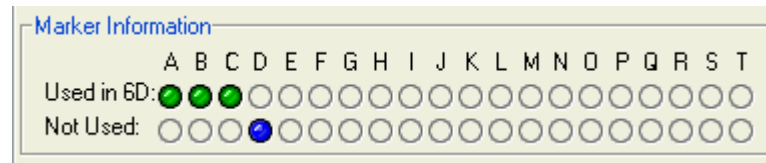



Figure 3-5 Tutorial: “Exceeded Max Marker Angle” Indicator

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 42](#).

To Set a Tool as Reference

1. Set up the system to track tools, as described in [“Getting Started: Tracking Tools” on page 20](#).

- Click  to load tool definition files for at least two tools.
- 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.

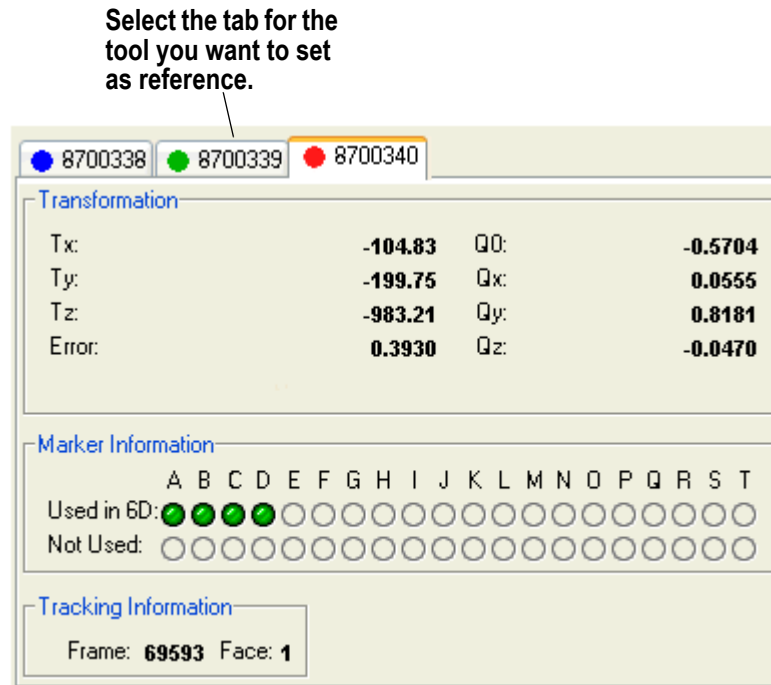


Figure 3-6 Tutorial: Selecting a Reference Tool

- 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 Vega 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 40](#) 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 20.
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.

Select the tab
corresponding to the
tool you want to pivot.

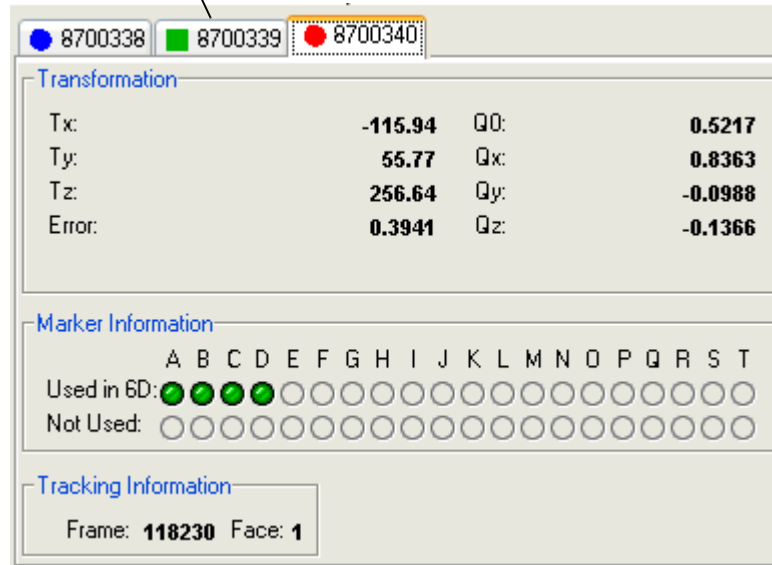



Figure 3-7 Tutorial: Selecting a Tool to Pivot

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 30° to 60° 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.

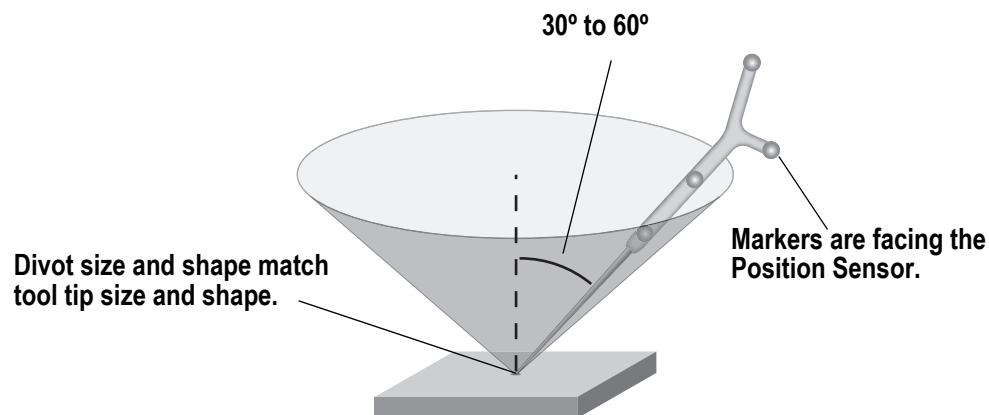


Figure 3-8 Tutorial: Pivoting Technique

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

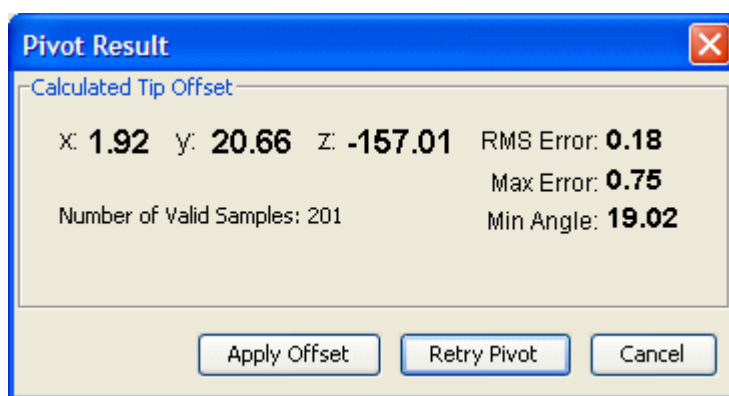


Figure 3-9 NDI ToolBox Software: Pivot Result Dialog

4 How the Passive Polaris Vega System Works

This chapter provides details on how the Polaris Vega 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 Passive Polaris Vega System” on page 20](#).

Note References to active tools are applicable only for active wireless systems.

This chapter contains the following information:

- [“Communicating with the Passive Polaris Vega System” on page 26](#)
- [“Information Returned by the Passive Polaris Vega System” on page 27](#)
- [“Global Coordinate System and Measurement Volume” on page 28](#)
- [“Marker Detection and Tool Tracking” on page 31](#)
- [“Sampling Rate” on page 32](#)
- [“Passive Polaris Vega System Tools” on page 33](#)
- [“Tool Definition File” on page 37](#)
- [“Tool Tracking Parameters” on page 37](#)
- [“Tool Tip Offset” on page 40](#)
- [“Reference Tools” on page 42](#)
- [“Stray Marker Reporting” on page 42](#)
- [“Phantom Markers” on page 43](#)
- [“System Spectral Response” on page 44](#)
- [“Data Transmission Rate” on page 44](#)

4.1 Communicating with the Passive Polaris Vega System

The Polaris Vega 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 Vega 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.

For details on user parameters, see the *Polaris Vega Application Program Interface Guide*.

4.2 Information Returned by the Passive Polaris Vega System



Warning!

Do not use the Polaris Vega System for absolute measurements; the system is designed for relative measurements only. Treating measurements as absolute may result in an incorrect interpretation of results. These incorrect interpretations may result in personal injury.

When the Polaris Vega System is tracking tools, it returns information about those tools to the host computer. By default, the system 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 28](#)).

Note Transformations with respect to a reference tool (described on [page 42](#)), and transformations for a probe with a tool tip offset (described on [page 40](#)) 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 Vega Application Program Interface Guide*.
- **the frame number** for each tool transformation. The frame number is incremented by 1 at the base frame rate (typically 60Hz). 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.

If requested, the system can also return:

- tracking errors and flags. (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 (3D positions not associated with any tool)
- 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.

Note For information on the API commands used to request tracking information from the Polaris Vega System, see the BX, BX2 or TX command in the *Polaris Vega Application Program Interface Guide*.

4.3 Global Coordinate System and Measurement Volume

Global Coordinate System

The Polaris Vega 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.

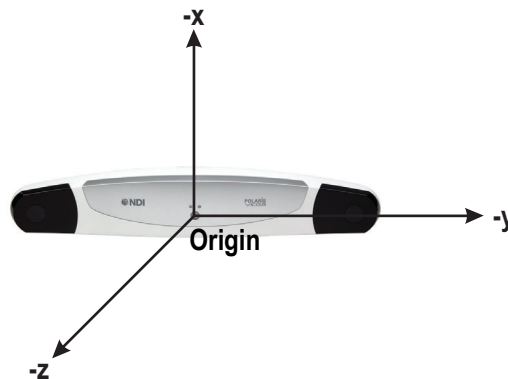


Figure 4-1 Global Coordinate System



Warning! Do not use the Polaris Vega System for absolute measurements; the system is designed for relative measurements only. Treating measurements as absolute may result in an incorrect interpretation of results. These incorrect interpretations may result in personal injury.

The Polaris Vega 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 42](#).

Field of View and Characterized Measurement Volume

The **field of view** is the total volume in which the Polaris Vega 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 Vega System Position Sensor. There are two

characterized measurement volumes available for the Polaris Vega System: the pyramid volume, illustrated in [Figure 4-2](#), and the extended pyramid volume, illustrated in [Figure 4-3](#).

The Position Sensor's performance is determined using the calibration methodology described in [Appendix A on page 85](#).

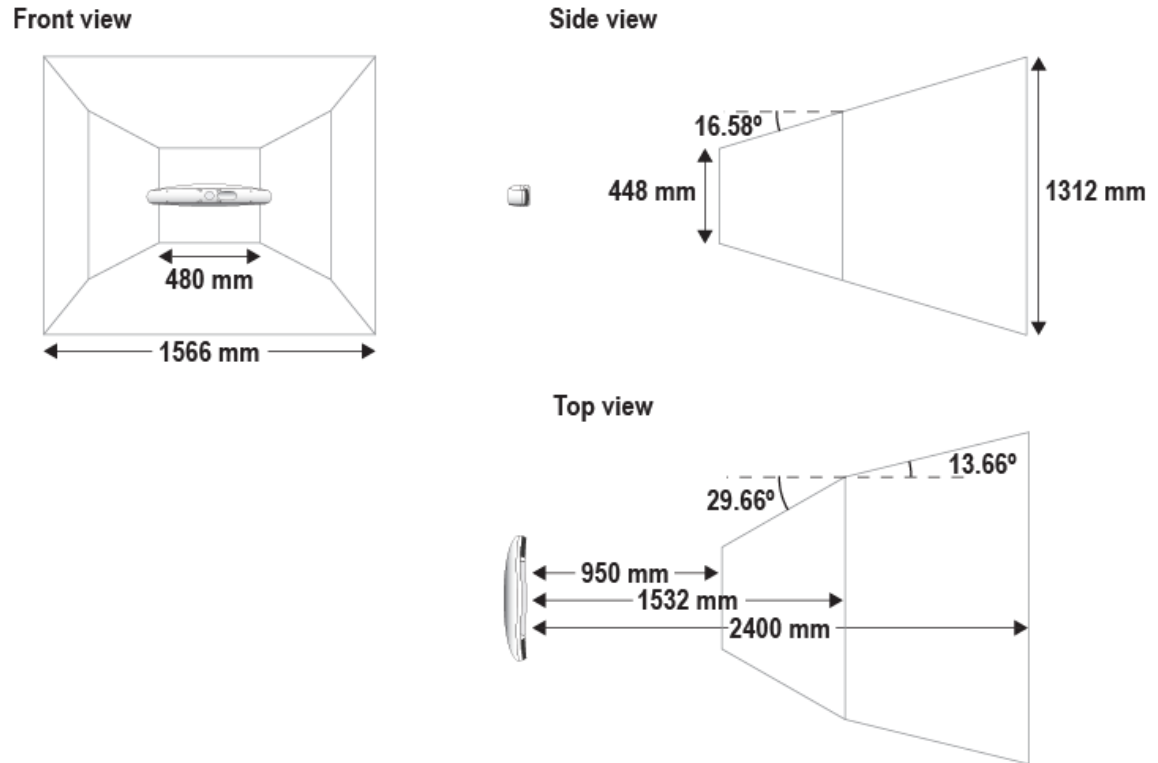


Figure 4-2 Pyramid Volume

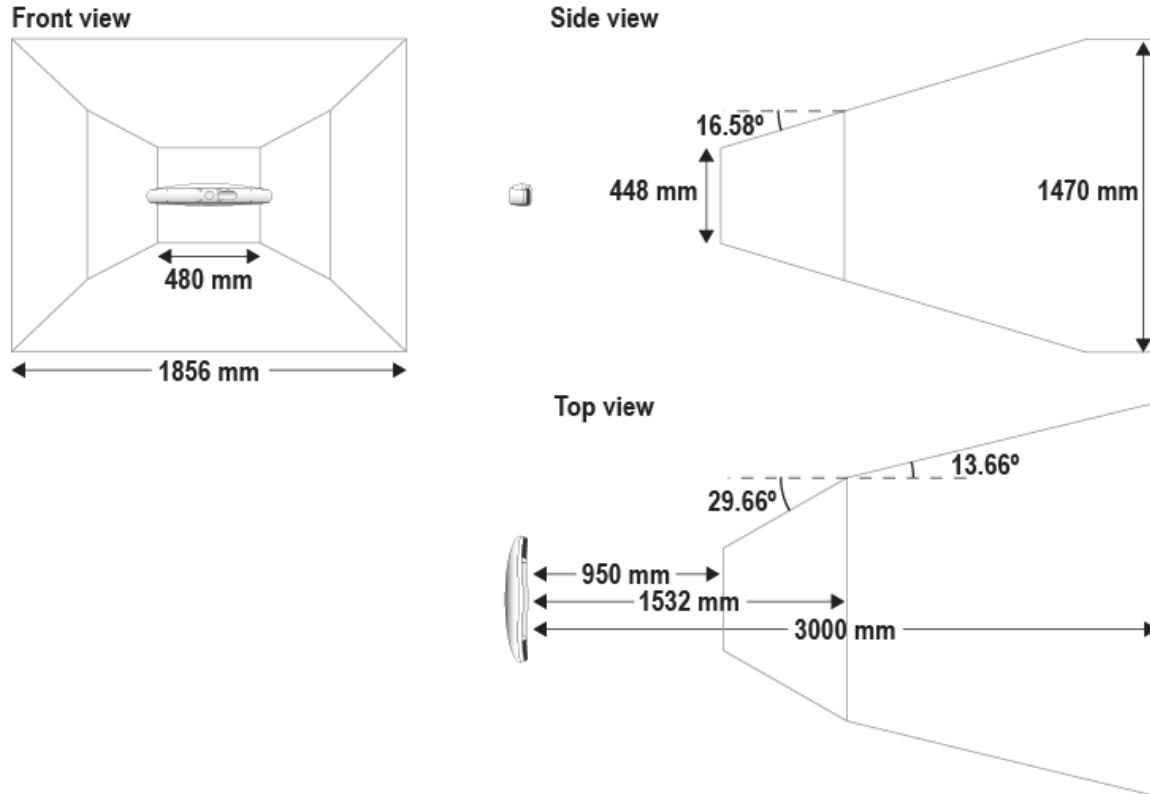


Figure 4-3 Extended Pyramid Volume

Out of Volume and Partially Out of Volume Flags

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.

With the BX2 command, measurements are reported whether or not the tools or markers are inside the characterized measurement volume. You must check the accompanying status code to determine whether the measurements are inside the volume, partially out of volume, or completely out of volume.

With the BX or TX commands, tools or markers outside the characterized measurement volume are by default reported as missing. You can request these measurements by using reply option 0x0800.

See the *Polaris Vega 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 39](#) for details.)

4.4 Marker Detection and Tool Tracking

Detecting Markers

The Position Sensor detects active and passive markers using different methods. To detect passive markers, the Position Sensor's illuminators flood the field of view with IR. The passive markers are designed to be retro-reflective, directing the IR back to the Position Sensor instead of scattering it.

Active wireless tools are triggered by a high frequency (107.3kHz) infrared “chirp” signal emitted by the Position Sensor just before integration starts. The infrared receiver on the active wireless tool detects the chirp and activates the IREDs for the duration of the integration time.

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 54](#) for more details.

Acquiring and Tracking Tools

When the Polaris Vega System first begins tracking a tool, or whenever a tool goes missing, it must “acquire” the tool. To acquire tools, the Polaris Vega System first measures the positions of all the visible markers.

IR light hits the sensors 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. Otherwise, the system will calculate the position of the IR sources.

To determine the position of a marker, the Position Sensor calculates virtual lines emanating from the measured center of the images of the marker on each sensor through the optics into 3D space. These lines are called the lines of sight. In a perfect (error-free) system, a pair of lines of sight intersect exactly at the location of the marker in 3D-space as shown in [Figure 4-4](#). In a real system the lines of sight do not intersect exactly, but will pass by each other at a very small distance. The shortest distance between the two lines of sight is called the line separation. If the line separation at this point is less than a predefined limit, the Polaris Vega System considers the point to be a possible marker position. Otherwise, the point is discarded.

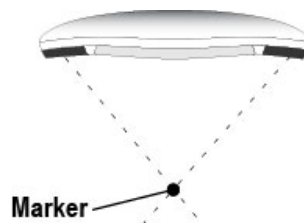


Figure 4-4 Determining a Marker Position

At this point the system has a set of (un-associated) 3D coordinates. The next step is to associate the 3D positions with markers on the tool. For this step the unique geometry algorithm is used. This involves determining the segment length (the distance between any pair of two 3D positions) and the segment angles (the angle between any pair of segments). These measured segments and segment angles will then be compared to the “nominal” segments and segment angles as calculated from the tool definition. If the measured and nominal data are within predefined tolerances of each other, the measured data will be considered a “match” and the corresponding markers will be associated with the tool. Refer to the *Polaris Tool Design Guide* for details about unique geometry requirements.

Any measured 3D position that cannot be matched to a tool is considered a stray marker and will be reported as such. Stray markers can be real (physically present markers not associated with any tool), they can be caused by reflections or they can be phantom markers (mathematically valid solution for co-planar arrangements of real makers).

See [“Stray Marker Reporting” on page 42](#) and [“Phantom Markers” on page 43](#) for more details.

The Polaris Vega 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 Vega 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 sooner, once the minimum number of markers becomes visible, because the system does not have to spend time re-acquiring the tool.

In general it is recommended to use the three-marker lock-on flag. The only exception is if 3 of the markers on the tool are co-linear. In this case three-marker lock-on cannot be used.

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 transformations for all the tools. The number and classification of tools being tracked affects the sampling rate.

The maximum internal sampling rate is the base frame rate. The default base frame rate is 60Hz. The sampling rate decreases as more frames are needed to track all the tools. The number and classification of tools have the following effects on the number of frames needed:

- All passive tools are tracked in the same frame. If only passive tools are tracked, the maximum sampling rate is the base frame rate. If the base frame rate is 60Hz, it is possible to slow the sampling rate down to $\frac{1}{2}$ or $\frac{1}{3}$ of the base frame rate.
- All active wireless tools are tracked in the same frame. If only active wireless tools are tracked, the maximum sampling rate is the base frame rate. It is possible to slow the sampling rate down to $\frac{1}{2}$ or $\frac{1}{3}$ of the base frame rate.

Note NDI's active wireless tool reference kit only allows tracking of active wireless tools at 20Hz. This is a restriction of the tool kit and not of the Polaris Vega System. Custom designs can make use of the full 60Hz tracking rate if the tool design allows.

- Active wireless tools and passive tools are tracked in separate frames. The maximum sampling rate for each tool type is $\frac{1}{2}$ the base frame rate. It can be further slowed down to $\frac{1}{3}$ of the base frame rate. At $\frac{1}{2}$ base frame rate, active wireless and passive tools will be tracked alternating. At $\frac{1}{3}$ base frame rate, active wireless and passive tools will be tracked in two subsequent frames followed by a “dummy frame”.

4.6 Passive Polaris Vega System Tools

A tool is a rigid structure on which three or more spherical markers or Radix lenses are fixed so that there is no relative movement between them. Polaris Vega tools can be either passive or active wireless. See [“Passive Tools” on page 33](#) and [“Active Wireless Tools” on page 34](#) for further information.

Up to 25 tools total can be loaded simultaneously. Of these up to 6 can be active wireless. It should be noted that a large number of tools in view or a large number of extraneous 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 Vega System can track its associated tool. For more information on tool definition files, see [“Tool Definition File” on page 37](#).

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

Passive Tools

Passive tools have no active (light-emitting) components and do not require power from a cable or battery. NDI offers two types of markers for passive tools:

- Passive Sphere – a sphere with a retro-reflective surface
- Radix Lens – a retro-reflective plastic lens

In either case, light from the illuminators around the sensors of the Position Sensor is reflected back to the sensors, making the markers appear bright compared to the rest of the scene. To identify individual markers and associate them with a specific tool, the system uses geometrical properties like lengths and angles of the marker constellation derived from the tool definition file. See [“Tool Definition File” on page 37](#) for details.



Warning!

Passive sphere markers cannot be re-sterilized. NDI does not recommend that a passive marker be used if it has been sterilized a second time, 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. Passive sphere markers cannot be autoclaved.



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. Inaccurate conclusions may result in personal injury.

Caution!

Do not handle the passive 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 physically connected to the Vega system. They incorporate active markers and an IR receiver. These tools are powered by battery or by the equipment to which they are attached. To track active wireless tools, the Position Sensor pulses its illuminators (chirps) in a way that is recognizable by the tool's IR receiver. When the receiver on the tool detects the chirp signal, the tool activates its infrared light-emitting diodes (IREDs), which in turn are seen by the Position Sensor.

Active wireless tool specification

The Active Wireless tool must detect the Position Sensor chirp with the following specification:

- Wavelength range: 800 – 900 nm (850nm center)
- Frequency: 105.0 - 110 kHz (107.3 kHz center)
- Duration: 200 - 2000 μ s, (344 μ s default)
- Duty cycle: 10% - 90% (50% center)
- Irradiance: 0.02 - 70 W/m²

Active Wireless Tool Timing

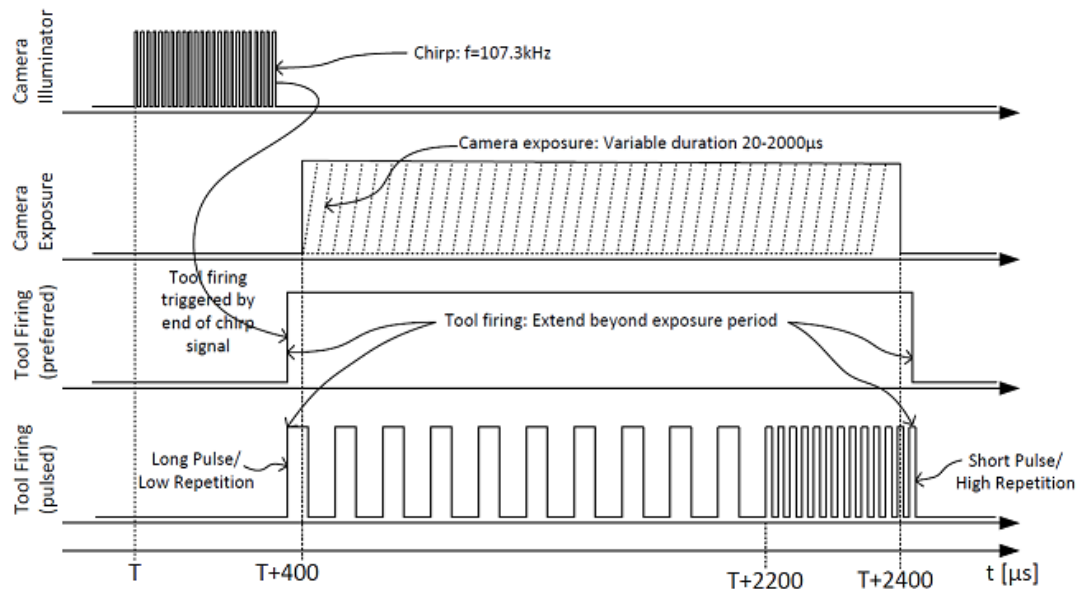


Figure 4-5 Active Wireless Tool Timing Diagram

Figure 4-5 illustrates the interaction between the active wireless tool and Vega. At T, Vega starts the chirp signal (the default duration is 344 μ s). The end of the chirp signal triggers the start of the active wireless tool IRED marker activation. The IRED firing period must extend beyond T+2400 μ s to ensure the markers are firing during the Vega exposure period.

NDI recommends that the IREDs are fired solid for the complete activation duration.

An alternate way of firing the IREDs is the pulsed method. If this method is implemented, the pulse width should not exceed 16 μ s and the minimum repetition rate should be 64 μ s. From T+2200 μ s to at least T+2400 μ s, the pulse width must be shortened to 2 μ s and the repetition rate increased to 4 μ s. This ensures that a missed pulse has minimal impact on the overall signal.

Note The tool needs to function with a refresh rate of at least 20Hz.

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 37](#) for details.



Warning!

Do not use a wireless tool whose design does not conform to the Polaris Vega System's unique geometry constraints. When a Polaris Vega 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. When two indistinguishable tools are being used, the first tool that is detected will be tracked. If that tool moves out of the measurement volume, the second tool will be tracked. If this is repeated, the tracking data will appear to jump between the two tools. Reliance on data produced by two indistinguishable tools can lead to inaccurate conclusions. 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.



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. Inaccurate conclusions may result in personal injury.

Tool Characteristics

Tools used with the Polaris Vega 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 Vega 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 Vega 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 tool can be multi-faced, with up to 8 faces. Only one face is selected at any given time. The system automatically selects the face with the best alignment to the Position Sensor, based on face normals. Each face must comply with the unique geometry rules as if it were a standalone 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 Vega 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, is included in the Port/Tool Status field of the BX2 6D Data component, 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 on [page 37](#)). The face normal is a vector pointing in the same direction as the tool face, to let the Polaris Vega 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.

For each tool used, the client application must provide the system with a tool definition file. If the application is only interested in 3D data (stray markers), no tool definition file is required. However, at least one “dummy tool” must be loaded for each tool-type of which 3D data is supposed to be tracked in order to tell the system to add a frame for this tool type. Dummy tools can be added via optional parameters in the “Port Handle Request” command. See the *Polaris Vega Application Program Interface Guide* for details.

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*.

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 37](#)). The flow chart on [page 40](#) describes how the Polaris Vega 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*.

Maximum 3D Error

The **maximum 3D error** parameter specifies the maximum allowable 3D error for each marker on the tool. The 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 37](#)).

If the 3D error for a particular marker is greater than the specified maximum 3D error value, the system will not use data from that marker 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 90° 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 4-6](#).

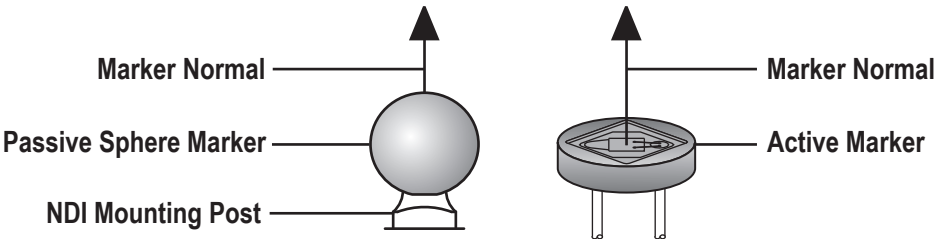


Figure 4-6 Markers Normal

The Polaris Vega 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 28.](#)) If the angle between the marker normal and either sensor is greater than the specified maximum marker angle value, the system will not use the data from that marker to determine the tool transformation.

The actual range of use of a marker depends on the marker’s location in the characterized measurement volume. The closer a marker is to the Position Sensor, the smaller its range of use. This is illustrated in [Figure 4-7](#) for a maximum marker angle value of 60°.

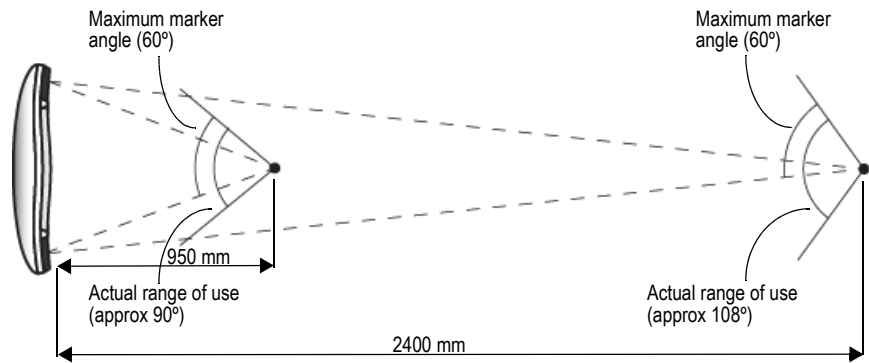


Figure 4-7 Actual Range of Use

[Figure 4-1](#) lists some examples of the actual range of use of a marker at different places in the characterized measurement volume. The calculations use the default maximum marker angle values of $\pm 90^\circ$ for passive sphere markers and $\pm 60^\circ$ for active markers.

Table 4-1 Actual Range of Use

Distance From Position Sensor (along z-axis)	Actual Range of Use	
	Passive Marker	Active Marker
950 mm (front of volume)	150.5°	90.51°
2400 mm (back of pyramid volume)	168.1°	108.1°
3000 mm (back of extended pyramid volume)	170.5°	110.5°

Minimum Number of Markers

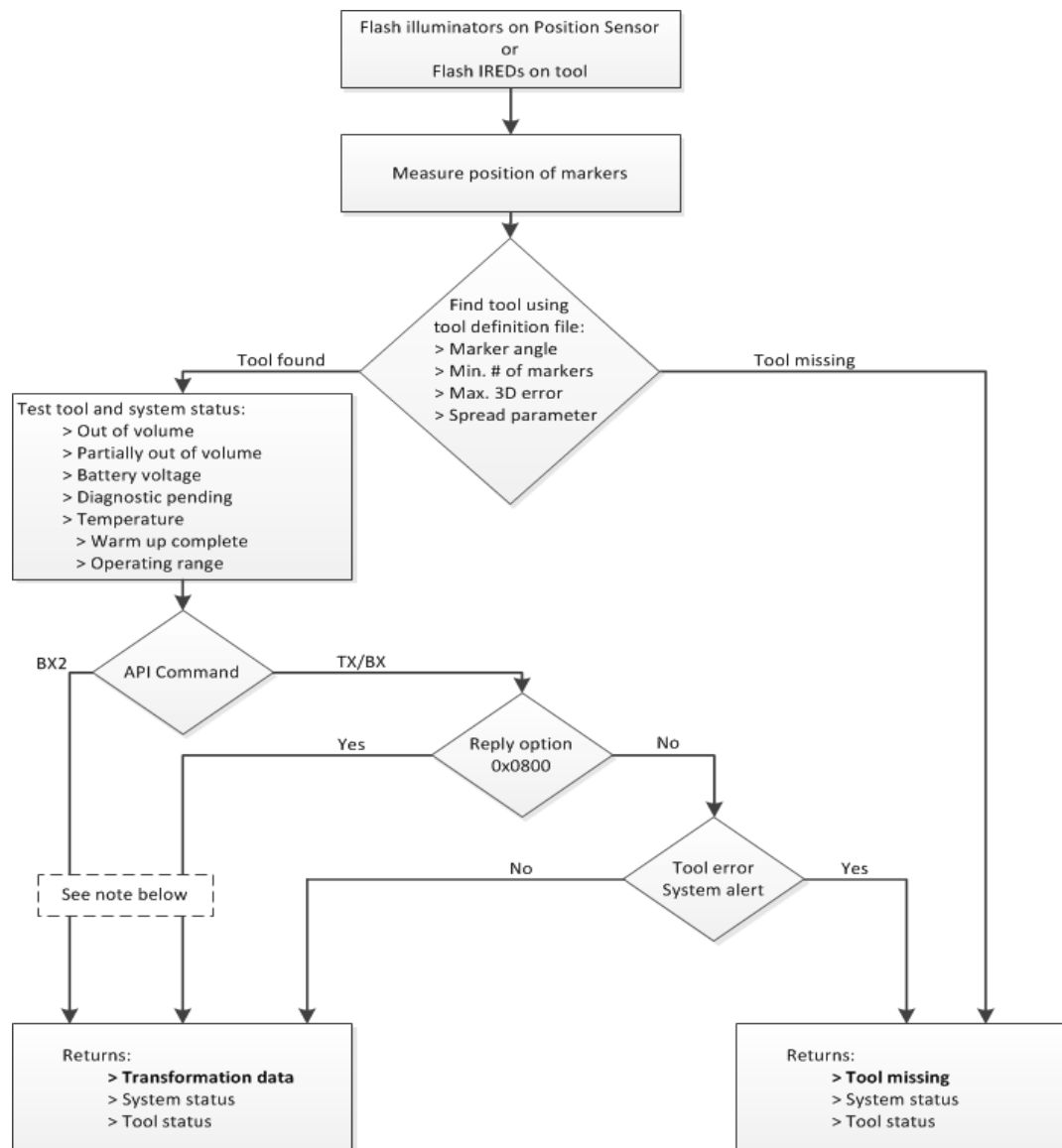
The **minimum number of markers** parameter specifies the minimum number of markers that the Position Sensor must use in the calculation of a tool transformation. If the system cannot calculate a transformation using the minimum number of markers, it will report the tool as MISSING.

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 Vega 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 Vega System will report the tool as MISSING.

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 further information on the minimum spread parameters, see the *Polaris Tool Design Guide*.



Note: The application must take appropriate action to detect the events listed above, and determine whether they are detrimental to the application.

Figure 4-8 Flowchart of Tool Tracking Parameters

4.9 Tool Tip Offset



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. These inaccurate conclusions may result in 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 Vega System to the tool tip offset, in order to determine the location of the tool tip.

Note The Polaris Vega System always tracks the origin of the tool. It is the application software, not the Polaris Vega 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 4-9](#). 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 Vega 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.

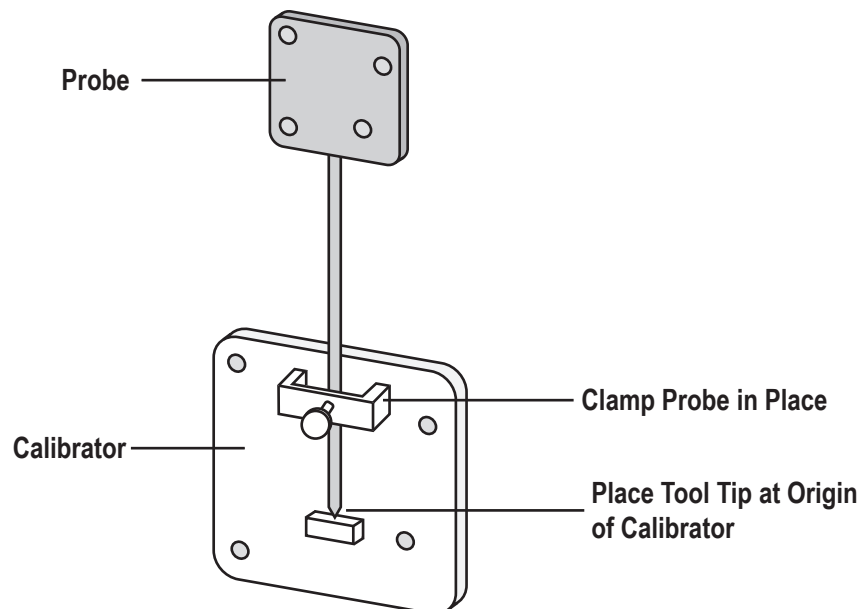


Figure 4-9 Sample Calibrator

Pivoting

You can also determine the tool tip offset using a process called pivoting, using the NDI ToolBox. During the pivoting procedure, the Polaris Vega 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 23](#). The procedure is also detailed 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 Vega System tracks all the tools, including the reference tool, and reports the transformations in the coordinate system of the Position Sensor (described on [page 28](#)). 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 Vega 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 Vega 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 or tool. 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.

When you request stray marker data from the Polaris Vega System, the Polaris Vega System will report tool transformations, as well as 3D data (position only, no orientation information) and out-of-volume information for markers that are not used in tool transformations (including phantom markers, described on [page 43](#)). 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 reported 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.
- 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 43](#).)
- 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. Inaccurate conclusions may result in personal injury.

To request stray marker data, use the 0x1000 reply option with the API command BX or TX. The BX2 option --3d=strays can also be used. These reply options return out-of-volume information along with the 3D data. See the *Polaris Vega Application Program Interface Guide* for details.

In order for the Position Sensor to measure stray passive 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 Vega System uses to determine the position of a source of IR. They appear and are reported as markers but they do not actually exist.

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 4-10](#)). Where the lines cross each other, the Polaris Vega System calculates the **line separation** (the distance between the lines). If the line separation at this point is within a predefined limit, the Polaris Vega 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 within a predefined 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 4-10](#). 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 will be

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 $n \cdot (n - 1)$ phantom markers.

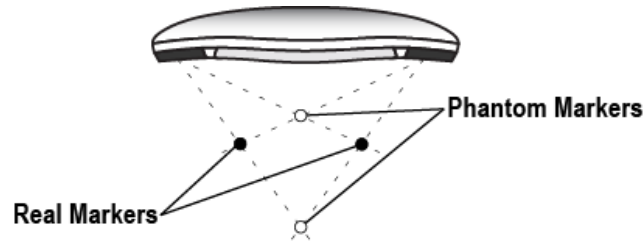


Figure 4-10 Phantom Markers

When you request stray marker data from the Polaris Vega 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 Vega System, the system will not return any phantom marker data.

4.13 System Spectral Response

The Polaris Vega System uses near infrared light for tracking. The system responds to wavelengths in the 800nm to 1100nm range. Light sources with spectral content in this wavelength range may cause interference with tracking. Examples include sunlight, halogen lamps and other incandescent light-bulbs. The system will signal the presence of extraneous light sources by setting the “Interference” flag. Whether or not the interference impacts tracking depends on the actual scene, but it is generally advisable to remove the source of interference before using the system in critical applications. Taking video captures of the scene with the interference present is the easiest way to identify the location and source of the interference.

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

4.14 Data Transmission Rate

The host computer update rate (the rate at which the host computer receives data) is dependent on the following factors:

Network Utilization If the system is operated on a busy shared network, the transmission may slow down due to bandwidth limitations. If the system is operated on a separate network, this issue will not be significant.

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. The slower update rate is not significant, unless a large amount of data is being transferred, for example, image data.

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 Vega System. This chapter contains the following information:

- “Bump Sensor” on page 46
- “Positioning Laser” on page 47
- “Keyed Features” on page 49

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 255 mm to 400 mm (depending on orientation) drop onto a vinyl tiled concrete surface.

When a bump is detected:

- The error LED on the Position Sensor is on, indicating that a potentially minor recoverable fault has been detected. The on-state 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 condition will also be reported as an alert code in the System Alerts component of the BX2 response.
- 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.
- The API command BX2 will report transformations but will also include a System Alert component with data to indicate the cause of the alert.

Note See the *Polaris Vega 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 <https://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 online 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 Vega Application Program Interface Guide* for details.

Bump Sensor Battery

The bump sensor is functional whether the Polaris Vega 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 7 years. At that point the system will report a low-battery status. Note that once the battery is no longer able to power the bump sensor, the system will report a bump every time it is taken off mains power. This behavior cannot be prevented unless the battery is replaced. If the bump sensor battery in your system needs to be replaced, contact NDI. See [“Contact Information” on page xiii](#).

5.2 Positioning Laser

The positioning laser is an optional component of the system. It is located in the Position Sensor, and indicates the general centre of the characterized measurement volume. This feature allows you to properly position the Position Sensor, or position objects in the measurement volume, relative to the measurement volume. The laser beam is emitted from an aperture on the front of the Position Sensor, and is directed along the z-axis of the Position Sensor’s global coordinate system (described on [page 28](#)).

Note The laser spot will diverge with increasing distance from the Position Sensor.

Laser Use



Warning!

Do not look directly into the laser-emitting aperture. The Class 2 laser module on the Position Sensor emits radiation that is visible and may be harmful to the human eye. Direct viewing of the laser diode emission at close range may cause eye damage.

Ensure that people with restricted movement or reflexes (for example, patients undergoing medical procedures) do not look directly into the laser-emitting aperture. Patients undergoing medical procedures may be restricted in the availability of adverse-effects reflexes (turning away eyes and/or head, closing eyes) due to pharmaceutical influences and/or mechanical restraints. The Class 2 laser module on the Position Sensor emits radiation that is

visible and may be harmful to the human eye. Direct viewing of the laser diode emission at close range may cause eye damage.

Do not use controls, adjustments, or performance of procedures other than specified in this guide as it may result in hazardous light exposure.

You can activate the laser using the following methods:

- Use the API command SET to set the value of the user parameter **Param.Laser.Laser Status**. A value of 1 turns the laser on; a value of 0 turns the laser off. The laser will automatically turn off after 35 seconds.
- You can connect a switch to the external laser trigger connector. See [“Mounting the Position Sensor” on page 12](#) for details.

Note For more information on user parameters and API commands, see the *Polaris Vega Application Program Interface Guide*.

Laser Specifications and Standards

The positioning laser is a Class 2 laser with the following characteristics:

Table 5-1 Laser Characteristics

Wavelength	635 nm to 670 nm
Maximum Output	1 mW
Divergence (Half Angle)	0.7 mrad

The Polaris Vega System containing a positioning laser conforms to the following standards:

- ANSI Z136.1 (2014)
- IEC 60825-1 (2014) and IEC 60825-1 (2007)
- FDA/CDRH 21 CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice No. 56, dated May 08, 2019

The label shown in [Figure 5-1](#) is located on the back of the Position Sensor, and lists the laser specifications and safety information.

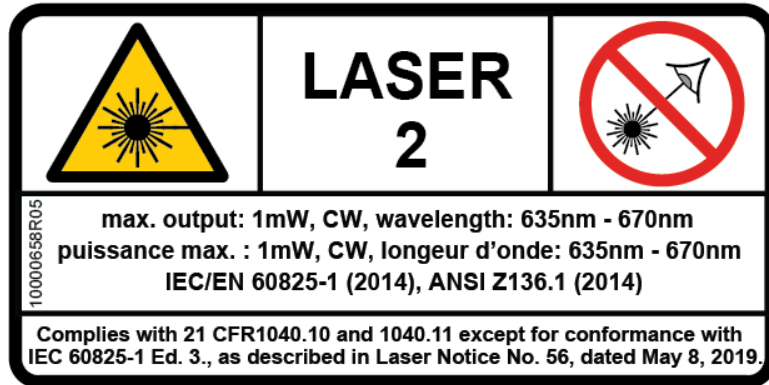


Figure 5-1 Position Sensor Laser Label

Note If the Polaris Vega System is incorporated into another product, the laser safety information must be included in the product manual.

5.3 Keyed Features

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

- **Multi Firmware:** allows the system to be simultaneously programmed with more than one combined firmware revision. This feature is referred to as “MultiFirmware” in the ToolBox user interface and Polaris Vega API.
- **Password Protect:** provides security against changes to the system configuration. This feature is referred to as “Password” in the ToolBox user interface and Polaris Vega API.
- **Positioning Laser:** indicates the centre of the characterized measurement volume. This feature is referred to as “PositioningLaser” in the ToolBox user interface and Polaris Vega API.
- **MR250:** allows the Vega System to operate at a base frame rate of 250Hz. In the ToolBox user interface and Polaris Vega API, this feature is referred to as “MR250_X.X”, where X.X is the version number of the feature.

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 Vega 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 Vega 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 Vega Application Program Interface Guide*.

The password is obtained from NDI.

Positioning Laser Feature

The positioning laser is located in the Position Sensor, and indicates the general centre of the characterized measurement volume. This feature allows you to properly position the Position Sensor, or position objects in the measurement volume relative to the characterized measurement volume. The positioning laser cannot be purchased after you obtain the system; it must be installed when the system is manufactured. For full details on the positioning laser, see [“Positioning Laser” on page 47](#).

MR250 Feature

The MR250 feature key changes the base frame rate of the Polaris Vega system to 250Hz. The following table specifies the performance characteristics for standard Polaris Vega systems and for Polaris Vega systems with the MR250 feature enabled.

Table 5-2 Polaris Vega Performance Characteristics

Performance Characteristic	Polaris Vega (Standard)	Polaris Vega with MR250
Measurement Rate	20, 30, or 60Hz	250Hz
Data Latency	18 ms (typical)	8 ms (typical)
Supported Measurement Volumes	Pyramid Extended Pyramid	Pyramid Extended Pyramid
Supported Tool Types	Passive Active Wireless Radix	Passive
Accuracy: RMS	0.12 mm (Pyramid) 0.15 mm (Extended Pyramid)	0.25 mm (Pyramid) 0.30 mm (Extended Pyramid)
Accuracy: 95% Confidence Interval	0.2 mm (Pyramid) 0.3 mm (Extended Pyramid)	0.5 mm (Pyramid) 0.6 mm (Extended Pyramid)

6 Maintenance

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

- Cleaning the Position Sensor
- Disposal of equipment

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



Maintenance Warnings

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

1. **All user maintenance must be done by appropriately trained personnel. Individual components of the Polaris Vega 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 before a procedure. The Position Sensor should also be monitored during the procedure. Reliance on data provided by an unclean or damaged Position Sensor may lead to inaccurate conclusions. Inaccurate conclusions may result in personal injury.**
3. **Do not immerse any part of the Polaris Vega 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 Vega 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. These inaccurate conclusions may result in personal injury.**

6.1 Cleaning the Position Sensor

Regularly inspect the Position Sensor for cleanliness. The Position Sensor, 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 solution and a soft lint-free cloth to remove handling smudges from the enclosure and illuminator covers. 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. 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.

6.2 Disposal of Equipment

To ensure environmentally responsible disposal after the equipment is decommissioned, please contact NDI. See [“Contact Information” on page xiii](#).

7 Setting the Infrared Light Sensitivity

7.1 Infrared Light Sensitivity Levels

The IR light sensitivity level determines how sensitive the Polaris Vega 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 Vega 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 Vega 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 Vega System's ability to tolerate background IR light.

Trigger Level and Integration Time

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

The **trigger level** is the minimum IR light intensity considered to be valid marker data. The Polaris Vega 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 integration time ([Figure 7-1](#)).

During operation, the Polaris Vega System makes adjustments to the integration time so that the intensity of the brightest IR light detected settles at a maximum value and the intensity of all other IR light falls below this value. It is generally the case that markers are the brightest IR source in the scene. However, IR light reflected from surgical tools or draping material may be detected by the Position Sensor and interfere with the identification of markers.

The goal of the sensitivity level is to allow IR light from tool markers to be detected while eliminating IR light from other sources. Changing the sensitivity level does not change the integration time; therefore the maximum IR light value does not change. However, changing the sensitivity level does change the trigger level, which in turn allows the Polaris Vega Position Sensor to ignore background IR light of different levels. The relationship between trigger levels and integration time for each sensitivity level is shown in [Figure 7-1](#).

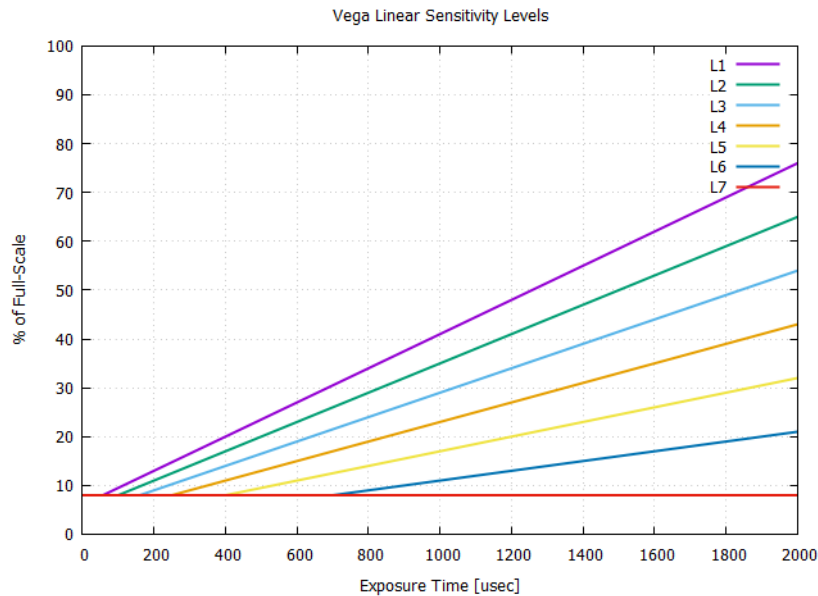


Figure 7-1 Vega Linear Sensitivity Levels

Sensitivity Levels

There are seven sensitivity levels. Level 1 is the least sensitive; that is the Position Sensor is least affected by background IR light because the trigger threshold is high. With increasing sensitivity levels, the system becomes more sensitive to IR light. This means that at higher sensitivity levels the Position Sensor can detect fainter IR light levels but will include IR light from background sources, making it more susceptible to background IR interference.

If you experience a large amount of background interference that causes the system to not track properly, try decreasing the sensitivity level; this will eliminate more background IR light. However, setting the level too low may cause tools to stop tracking.

If you are having trouble tracking tools with low IR intensity (e.g., because some tools are far from the Position Sensor), try increasing the sensitivity level; this will allow the Position Sensor to detect fainter IR light. Setting the level too high may cause an increase in background interference, which in turn may prevent the system from performing optimally.

Note If you have experience with Polaris Spectra systems, be aware that the meaning of the levels has changed. Higher levels in Vega mean higher sensitivity whereas for Spectra a higher level means lower sensitivity.

7.2 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, BX2 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.

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 user 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 Vega Application Program Interface Guide* for details.

8 Calibration and Firmware

8.1 Checking the Calibration of the Passive Polaris Vega 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 Vega 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 31](#) 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 Vega Position Sensor. See “[Return Procedure](#)” on [page 75](#) for instructions on returning equipment to NDI.

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 255 mm to 400 mm (depending on orientation) 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 <https://support.ndigital.com>.

For full details on the bump sensor, see “[Bump Sensor](#)” on [page 46](#).

8.2 Updating the Firmware

The Polaris Vega System’s firmware is stored in flash memory devices in the Position Sensor. The latest firmware can be downloaded from the NDI Support Site at <https://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 Vega 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 online 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 online help* explains how to use NDI ToolBox to select which combined firmware revision the system will use. The *Polaris Vega Application Program Interface Guide* explains how to select a combined firmware revision using API commands.

9 Approvals

9.1 Electrical Safety and Electromagnetic Compatibility

The Polaris Vega System, consisting of a Position Sensor (model P9), is listed in the [“Declaration of Conformity” on page 77](#).

9.2 Optical Radiation Safety

Position Sensor Illuminators

The Polaris System Position Sensor illuminators emit invisible infrared radiation with a pulsed duration of up to 2.2 ms and 4.4% duty cycle resulting in a maximum average measured power of 127 μ W. The Position Sensor has been assessed against the standards listed in the [“Declaration of Conformity” on page 77](#) and found not to pose a potential hazard to the eye under any foreseeable viewing condition.

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

The Polaris Vega System conforms to the IEC 62471:2006 and EN 62471:2008.

Positioning Laser



Do not use controls, adjustments, or performance of procedures other than specified in this guide as it may result in hazardous light exposure.

The positioning laser is a Class 2 laser, with a wavelength of 635 nm to 670 nm and a maximum output of 1 mW. The Polaris Vega System containing a positioning laser conforms to the following standards:

- ANSI Z136.1 (2014)
- IEC 60825-1 (2014) and IEC 60825-1 (2007)
- FDA/CDRH 21 CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice No. 56, dated May 08, 2019

Note For information on laser operation, see [“Positioning Laser” on page 47](#).

9.3 IEC 60601-1 recommendations for the Passive Polaris Vega System

The Polaris Vega System is classified as Medical Electrical Equipment, intended for use in Health Care Facilities outside of the patient environment. The reason for use outside of the patient environment is that the system was tested using an IEC 60950 certified power supply. It should be possible to certify the system for use in the patient environment if the power supply given to the certification house passes IEC 60601-1.

When installed in an end product, the following recommendations should be considered:

- The maximum investigated branch circuit rating is 20 A.
- The investigated Pollution Degree is 2.
- The following tests shall be performed by the system integrator in the end product application:
 - a) Marking Legibility after installation
 - b) Touch Current (Leakage Test)
- Complete evaluation of risk management requirements must be conducted by the system integrator in the end product investigation.
- NDI has not considered Essential Performance.
- The end-product evaluation shall ensure that the requirements related to Accompanying Documents, Clause 7.9 of IEC 60601-1 v3.1 are met.
- Suitability of the power source shall be verified by the respective certification body.
- The system was tested together with a personal computer. Since, in final application the product may be used with any certified personal computer, a leakage current test shall be conducted to verify suitability of the final system configuration. End product investigation shall consider compliance with enclosure leakage current test with the personal computer's protective earth disconnected.
- The optional external switch intended to be connected to the laser activation port in any end-use application must be separated from live parts by at least 2MOOPs (Means of Operator Protection).

10 Classifications

Table 10-1 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	IP20 (Protection against solid objects over 12 mm. No protection against liquids.)
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
Laser classification	Class 2
IRED illuminators risk group	Exempt

11 Technical Specifications

11.1 Operating Environmental Conditions

The Polaris Vega System (Position Sensor and cables) has been tested to function in the conditions listed in [Table 11-1](#).

Table 11-1 Operating Environmental Conditions

Environmental Condition	Value
Atmospheric Pressure	70 kPa to 106 kPa
Relative Humidity	30% to 75%
Temperature	+10°C to +35°C (see warning below)

The Position Sensor requires a warm-up time every time it is powered on. The warm-up time is typically 30 seconds; 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.

11.2 Transportation and Storage Environmental Conditions

The Polaris Vega System (Position Sensor and cables) has been tested to be stored and transported in the conditions listed in [Table 11-2](#).



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 Vega System, repack it in the original containers with all protective packaging. The provided packaging is designed to prevent damage to the equipment..

Table 11-2 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

11.3 Technical Specifications

Table 11-3 Position Sensor Technical Specifications

Specification	Value
Dimensions	591 mm x 103 mm x 106 mm
Weight	1.7 kg +/- 0.1 kg
Mounting	via four M4 x 0.7 mm pitch x 10 mm deep threaded holes, rear mount
Update Rate	default is 60Hz
Power Requirement	compatible with IEEE 802.3at Type 2*

*For IEC 60601-1 testing, the power injector used was Power Dsine (Microsemi Corp.), PD-9001GR/AC (PD-6561G300).

12 Electromagnetic Compatibility



The Polaris Vega 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 64. Failure to do so may result in personal injury.

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

Do not use the Polaris Vega System either adjacent to, or stacked with, other equipment as this may cause the equipment to over heat. Check that the Polaris Vega 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 64](#)
- [“Guidance and Manufacturer's Declaration: Electromagnetic Emissions” on page 64](#)
- [“Guidance and Manufacturer’s Declaration: Electromagnetic Immunity” on page 65](#)
- [“Recommended Separation Distances” on page 67](#)
- [“Radio Frequency Emissions” on page 69](#)

12.1 Cables and Accessories

No cables or accessories are delivered with the Polaris Vega System. A customer supplied ethernet cable is required to connect the system units. The cable must be at least Cat 5e shielded to maintain compliance to the emissions and immunity requirements of IEC 60601-1-2:2014.



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 Vega System and may result in personal injury.

12.2 Guidance and Manufacturer's Declaration: Electromagnetic Emissions

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

Table 12-1 Manufacturer's Declaration for Electromagnetic Emissions

Emissions Test	Compliance	Electromagnetic Environment Guidance
RF emissions CISPR11	Group 1	The Polaris Vega 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 Vega 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	

12.3 Guidance and Manufacturer's Declaration: Electromagnetic Immunity

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

Table 12-2 Electromagnetic Immunity

Immunity Test	IEC 60601 Test Level	Compliance Level	Electromagnetic Environment - Guidance
Electrostatic discharge (ESD) IEC 61000-4-2	±8 kV contact ±2, ±4, ±8, ±15 kV air	±8 kV contact ±2, ±4, ±8, ±15 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%.
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	

Table 12-2 Electromagnetic Immunity (Continued)


Immunity Test	IEC 60601 Test Level	Compliance Level	Electromagnetic Environment - Guidance
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 Vega System requires continued operation during power mains interruptions, it is recommended that the Polaris Vega 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 12-3 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	<p>Portable and mobile RF communications equipment should be used no closer to any part of the Polaris Vega System, including cables, than the recommended separation distance calculated from the equation applicable to the frequency of the transmitter.</p> <p>Recommended separation distance:</p> $d = 1,2\sqrt{P}$ <p>See Table 12-4 on page 68.</p>

Table 12-3 Electromagnetic Immunity—Not Life Supporting (Continued)

Immunity Test	IEC 60601 Test Level	Compliance Level	Electromagnetic Environment - Guidance
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 12-4 on page 68 . 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 Vega System is used exceeds the applicable RF compliance level above, observe the Polaris Vega System to verify normal operation. If abnormal performance is observed, additional measures may be necessary, such as re-orienting or relocating the Polaris Vega System.

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

12.4 Recommended Separation Distances

The Polaris Vega System is intended for use in an electromagnetic environment in which radiated RF disturbances are controlled. The customer or the user of the Polaris Vega System can help prevent electromagnetic interference by maintaining a minimum distance between portable and

mobile RF communications equipment (transmitters) and the Polaris Vega System, as recommended below, according to the maximum output power of the communications equipment.

Table 12-4 Recommended Separation Distances between Portable and Mobile RF Communications Equipment and the Vega 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.

12.5 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

CISPR 11: Class B

Industry Canada

Industry Canada Compliance Statement: This ISM device complies with Canadian ICES-003.

Avis de Conformité à la réglementation d'Industrie Canada: Cet appareil ISM est conforme à la norme NMB-003 du Canada.

13 Troubleshooting

13.1 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:

<https://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 Vega 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 71 and “[Audio Codes](#)” on page 72. 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 Vega Application Program Interface Guide*.

13.2 LEDs

Position Sensor

The power and error LEDs on the Position Sensor combine to indicate Position Sensor status. The LEDs behave as described in Table 13-1

Table 13-1 Position Sensor Indicator LEDs Summary

Power LED (Green)	Error LED (Amber)	Position Sensor Status
Off	Off	No power
Flashing (4 times per second)	Off	The system is booting up.
Flashing (2 times per second)	Any state	The Position Sensor is warming up. The power LED will stop flashing and light steady green when the Position Sensor is ready for use.
On	Off	The Position Sensor is ready for use; no faults or error conditions
On	On	Minor recoverable error condition (not a fault); can easily be corrected by a novice user (for example, bump sensor has detected a bump). Does not prevent system operation if the application provides the appropriate override. NDI ToolBox response: The fault is indicated in the Configure utility of NDI ToolBox.
On	Flashing	Major recoverable fault which prevents operation but can be repaired by the user (for example incompatible firmware). NDI ToolBox response: The fault is indicated in the Configure utility of NDI ToolBox. API response: One of the following responses occurs: <ul style="list-style-type: none"> The “diagnostic pending” bit is set in the BX, BX2 or TX response. To determine what the fault is, read the alerts parameters as described in the <i>Polaris Vega Application Program Interface Guide</i>. An error is returned. The error code indicates the nature of the error. Error codes are listed in the <i>Polaris Vega Application Program Interface Guide</i> .
Off	On	Non-recoverable fault. Return the Position Sensor to NDI for service.

13.3 Audio Codes

The Position Sensor emits audio tones that provide an audible indication of system status, as listed in Table 13-2.

Table 13-2 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.

13.4 Common Problems

The following paragraphs lists specific problems and possible solutions.

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

This may mean that fewer 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 Vega 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 31. You can check the line separation values using the 3D command. See the *Polaris Vega Application Program Interface Guide* for details.

Other IR-based devices are not working properly

Using the Polaris Vega 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 Vega 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 <https://support.ndigital.com>.

The Passive Polaris Vega 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 Vega 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 31](#) and the *Polaris Tool Design Guide* for details on segment lengths and angles.)

See [“Checking the Calibration of the Passive Polaris Vega System” on page 57](#) 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 minimized as much as possible. Reflections occur when IR light from the illuminators is reflected off surfaces such as:

- surgical drapes: ensure the drapes are placed such the reflections are minimized
- reflective surfaces: minimize 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 minimize interference from such devices.

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

The Polaris Vega 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. 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, it is bent)

- the condition of the markers 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, an error message will be shown in NDI ToolBox application software.

The Polaris Vega 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.

14 Return Procedure and Warranty

14.1 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 <https://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.

14.2 Warranty

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

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.

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).

15 Declaration of Conformity



EC DECLARATION OF CONFORMITY

Manufacturer: Northern Digital Inc.

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

Equipment Type: Opto-Electronic Spatial Measurement System

Trade Name: Passive Polaris Vega™

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):

2014/35/EU Low Voltage Directive
2014/30/EU EMC Directive
2011/65/EU RoHS Directive

Standards Applied:

See attachment

Year Mark First Applied:

2016

Dated at Waterloo, Ontario, Canada this 28 day of June, 2016.

Northern Digital Inc.

per:

David Rath
President

FM-10311 Rev 001

Attachment to EC DECLARATION OF CONFORMITY
Passive Polaris Vega™

	Standards Applied	Additional Information
Safety:	EN 60601-1:2006/A1:2013 IEC 60601-1 Edition 3.1 (2012) ANSI/AAMI ES60601-1:2005/(R)2012 CAN/CSA-C22.2 NO. 60601-1:14	Biocompatibility, PESS
	EN 60825-1:2014/ IEC 60825-1(ed.3)	Class 2 Laser Product
	EN 60825-1:2007 IEC 60825-1(ed.2)	Class 2 Laser Product
	EN 62471:2008 / IEC 62471(ed.1)	Exempt Risk Group for Infrared Illuminators
EMC:	EN 55011:2009 +A1:2010 / CISPR 11:2009 +A1:2010 FCC Title 47 CFR, Part 15 (2013) ICES-003, Issue 6 (2016)	Class B, Group 1 - Industrial, Scientific and Medical Equipment. Class B - Unintentional Radiators Class B - Information Technology Equipment (Including Digital Apparatus)
	EN 60601-1-2:2015 / IEC 60601-1-2:2014 EN 61000-3-2:2006 +A1:2009 +A2:2009 / IEC 61000-3-2:2005 +A1:2008 + A2:2009 EN 61000-3-3:2013 / IEC 61000-3-3:2013 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 61000-4-4:2012 / IEC 61000-4-4:2012 EN 61000-4-5:2006 / IEC 61000-4-5:2005 EN 61000-4-6:2013 / IEC 61000-4-6:2014 EN 61000-4-8:2010 / IEC 61000-4-8:2009 EN 61000-4-11:2004 / IEC 61000-4-11:2004 JIS 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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16 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
CMOS	Complementary metal–oxide–semiconductor
CRC	Cyclic Redundancy Check
DSR	Data Set Ready
EEPROM	Electrically Erasable Programmable Read Only Memory
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Immunity
ESD	Electrostatic Discharge
FCC	Federal Communications Commission
FPS	Frames Per Second
IC	Industry Canada
I/O	Input/Output
IR	Infrared Light
IREM	Infrared Light-Emitting Diode
LED	Light-Emitting Diode
LPS	Limited Power Source
MOOP	Means of Operator Protection
MRI	Magnetic Resonance Imaging
NDI	Northern Digital Inc.
PoE	Power Over Ethernet
RAM	Random Access Memory
RF	Radio Frequency
RGB	Red Green Blue
RI	Ring Indicator
RMA	Return Materials Authorization
RMS	Root Mean Square
UL	Underwriters Laboratories Inc.

17 Equipment Symbols

Table 17-1 Equipment Symbols










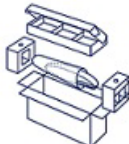
Symbol	Meaning	System Components
	Consult accompanying documents.	Position Sensor
	Laser Warning (To avoid personal injury, consult accompanying documents.)	Position Sensor
	Laser Aperture Caution (To avoid personal injury, consult accompanying documents.)	Position Sensor
	On (power: connection to the mains supply)	Position Sensor
	Error	Position Sensor
	Ethernet	Position Sensor
	Unused communication port	Position Sensor
	Keep away from rain	Packaging
	Fragile	Packaging
	Retain packaging	Packaging

Table 17-1 Equipment Symbols (Continued)

Symbol	Meaning	System Components
	Acceptable pressure during shipping	Packaging
	Acceptable humidity during shipping	Packaging
	Acceptable temperature during shipping	Packaging
	Cardboard recycling indicator (Chinese)	Packaging
	Cardboard recycling indicator (German)	Packaging
	Paper recycling indicator (German)	Packaging
	Cut packaging here	Packaging
	Do not cut packaging here	Packaging

18 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.

Absolute Measurements

Absolute measurements are measurements taken directly in the Position Sensor's coordinate system, i.e. measurements reported by the system. NDI recommends not to use the system for absolute measurements. NDI does not guarantee the stability of absolute measurements. Any movement of the position sensor or changes in the environmental conditions (ambient temperature, warmup, etc.) may cause the absolute measurement to change, even though the observed tool is physically not moving. NDI recommends to use relative (or referenced) measurements.

Calibration

Calibration is the process of establishing, under specified conditions, the relationship between values produced by the Polaris Vega 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 Vega System can track a marker, regardless of accuracy.

Firmware

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

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 Vega coordinate system. The global coordinate system is used by the Polaris Vega 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.

Passive Polaris Vega System

Passive refers to the fact that the system is intended to be used with passive tools, i.e. retro-reflective spheres. The Vega system also supports the tracking of active wireless tools.

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 Vega 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.

Relative Measurements

Relative measurements, or referenced measurements, require the use of at least two tools, one of which is the reference. For relative measurements, all tool transformations are transformed into the coordinate system of the reference tool. When the system is used in this way, movements of the position sensor itself are cancelled out. NDI recommends using the system in this way.

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 Passive Polaris Vega 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 Vega 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 Passive Polaris Vega Performance

The Polaris Vega 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 Vega System's measurement volume. Acceptance criteria for the Polaris Vega 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 0.12 mm within the pyramid volume, and less than or equal to 0.15 mm within the extended pyramid volume. This criterion is based on a statistically representative set of positions distributed uniformly 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 0.06 mm within the pyramid volume, and less than or equal to 0.08 mm within the extended pyramid volume. This criterion is based on a statistically representative set of positions distributed uniformly 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 Vega 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 Vega System. This assumption allows the errors in the marker positioning to be ignored.

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

The **accuracy of the Polaris Vega 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 Vega 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:

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

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

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

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