Polaris Vega User Guide for ST, VT, and XT Models

10005014 R06
December 2021

Revision Status

Revision Number	Date	Description
01	June 2019	Initial Release
02	November 2019	Updated to include the Vega XT Position Sensor Improved content on the frame rate and tracking rate
03	February 2020	Updated the chapter on sensitivity levels to include the Vega XT Position Sensor
04	February 2020	Added images of revised bilingual laser warning label
05	March 2020	Updated bilingual laser warning label
06	December 2021	Updated for release of Combined Firmware Release 008 (CFR 008)

Part Number:10005014

Published by:

Northern Digital Inc.
103 Randall Dr.
Waterloo, Ontario, Canada N2V 1C5

Telephone:	+ (519) 884-5142
Toll Free:	+ (877) 634-6340
Global:	+ (800) 634 634 00
Facsimile:	+ (519) 884-5184
Website:	www.ndigital.com

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Table of Contents

Read Me First!

This guide provides detailed information about the Polaris Vega ST, VT, and XT Systems. 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 92. 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 overheat. 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. 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. 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 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 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. 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. 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 x-ray, proton radiation, or MRI environment without first determining the performance, including accuracy, of the Position Sensor in these environments. NDI has not validated the Position Sensor in these environments.
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 the external power. Failure to do so may result in an electric shock hazard and possible personal injury.
26. The Polaris Vega System is classified as Medical Electrical Equipment, intended for use in health care facilities outside of the patient environment. The 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 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.

Disclaimers

1. Read the entire *"Polaris Vega User Guide for ST, VT, and XT Models"* 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.

   For more information, see "Radio Frequency Emissions" on page 96.
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 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 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.

Contact Information

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

Head Office
Waterloo, ON Canada
+1 (877) 634-6340
support@ndigital.com
www.ndigital.com

Shelburne, VT USA
+1 (802) 985-1114
support@ndigital.com
www.ndigital.com

Radolfzell, Germany
+49 7732 8234 0
support@ndieurope.com
www.ndieurope.com

Hong Kong, China
+ (852) 2802-2205
support@ndigital.com
www.ndigital.cn

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 Polaris Vega System Overview

1.1 Introduction

The Polaris Vega System is an optical measurement solution that uses near-infrared (IR) light to calculate the 3D positions of markers attached to tools. The Vega Position Sensor can track multiple wireless tools at once within a pre-calibrated measurement volume. Measurement data is captured for integration into tool navigation and visualization applications.

A typical Polaris Vega System includes one or more Position Sensors, one or more wireless tools that are tracked by the Position Sensor(s), and a host computer. The NDI ToolBox software application, page 4, is also available for use with the system.

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

1.2 System Operation

The Polaris Vega System operates as follows:

1. The Position Sensor, Figure 1-1, 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. On passive tools, the IR light reflects off passive markers. On active wireless tools, it triggers markers to activate and emit IR light.
3. Using the reflected or emitted light, the Position Sensor measures the positions of the markers and calculates the transformations (the positions and orientations) of the tools the markers are attached to.
4. The Position Sensor sends the transformation data and status information to the host computer for collection, display, and further manipulation.

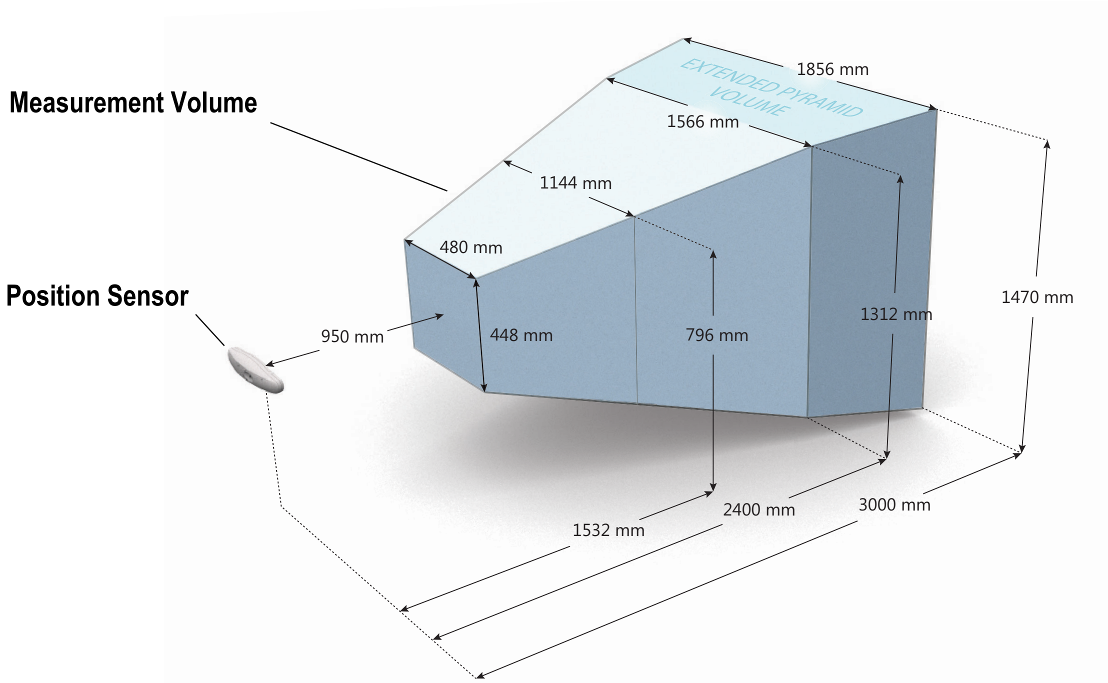
The image below depicts the Polaris Vega VT Position Sensor, equipped with a video camera and positioning laser. For a detailed description of the different Position Sensors, see "Vega Models" on page 9.

Figure 1-1 Polaris Vega VT Position Sensor

1.3 Characterized Measurement Volume

The characterized measurement volume, Figure 1-2, is the volume within the detection region of the Position Sensor where accuracy is within specified limits. NDI cannot guarantee measurement accuracy outside this region. For the Polaris Vega System accuracy specification, see “Polaris Vega System Performance” on page 112.

Figure 1-2 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.**

1.4 Ethernet Communications with the Host

The Polaris Vega System supports a gigabit Ethernet connection between the Position Sensor and host computer. When this connection is used, power to the Position Sensor is supplied via Power over Ethernet (PoE).

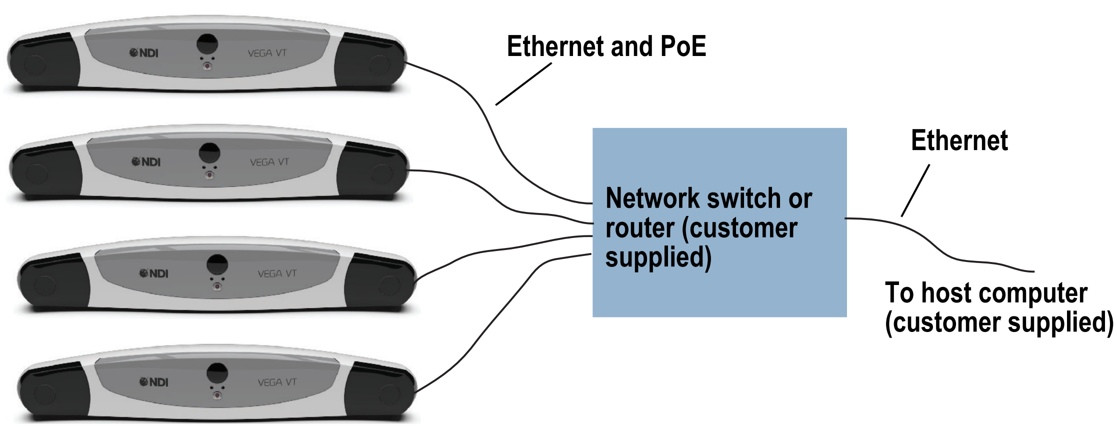
The Position Sensor can be connected directly to the host computer via Ethernet and a PoE midspan. A customer-supplied network switch or router can also be used and is required to connect multiple Position Sensors to the host computer, Figure 1-3.

NDI recommends using a controlled network to ensure the measurement application and communications between the Vega Position Sensor and host computer receive an appropriate quality and level of service.

Note **The customer-supplied Ethernet switch or router must be approved to the IEC 60950 or IEC 60601 standard and meet the following minimum specification: IEEE802.3at compliant Power over Ethernet (PoE) type 2 device, 25.5 W up to 30 W.**

Cat 5e or higher shielded Ethernet cables should be used in any Vega Ethernet configuration.

Figure 1-3 Ethernet Connection



If you install multiple Vega Position Sensors on the same network subnet, tracking is synchronized via the Precision Time Protocol (PTP). Because Vega Position Sensors use PTP, the timestamps from other connected devices on the same network subnet are aligned.

The timestamp for a frame is an item in the Frame Component payload of BX2 API command. For more information, see the *"Polaris Vega Application Programming Interface Guide"*.

When connecting multiple Position Sensors to the same network switch or router, ensure that each port on the switch or router will supply enough power for the connected Position Sensor. If there is insufficient power supplied for tracking, the Position Sensor will raise an alert.

Ethernet Status LEDs

The Ethernet connector houses two LEDs:

- Speed indication (Green):
  - Single flash - 10 Mbps

  - Double flash - 100 Mbps
  - Triple flash - 1000 Mbps
- Link/Activity (Amber):
  - Off - No link
  - On - Link
  - Flash - Activity

1.5 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. To use an NDI-provided host application, such as NDI ToolBox, we recommend a computer with the following specifications or better:

- 1 GHz or faster 64-bit (X64) processor
- 2 GB RAM (64-bit)
- 20 GB available hard disk space (64-bit)
- Operating system options:
  - Windows 7 (64-bit), 8, or 10
  - 64-bit Linux Kernel 2.6.35 or later, or 3.0 or later
  - macOS 10.10 or later
- Screen resolution 1024 x 768 (1280 x 1024 recommended)
- IEEE802.3at compliant Power over Ethernet (PoE) type 2 device, 25.5 W up to 30 W
- Gigabit network interface is recommended

1.6 NDI Software

The following software is available to download 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. For details, see the "*NDI ToolBox online help*".

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.

1.7 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.

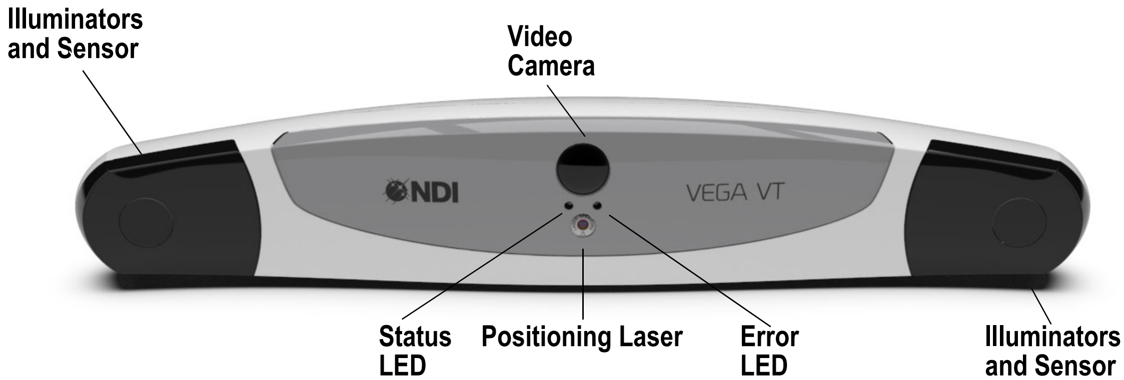
- For more information on tools, see "Polaris Vega System Tools" on page 38.

- For a detailed description of how the Position Sensor detects markers, see "Marker Detection and Tool Tracking" on page 34.
- For a detailed description of the different Position Sensor models that are available, see "Vega Models" on page 9.

Note **The Position Sensor can be branded to custom specifications. For details on this option, contact NDI. See "Contact Information" on page ix.**

Front View

Figure 1-4 Vega VT Position Sensor - Front View



The front of the Position Sensor incorporates the following components:

Illuminators Two arrays of infrared light-emitting diodes (IREDs) that provide IR light for 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.

Video Camera The Polaris Vega VT Position Sensor is equipped with a video camera that is used for capturing a live video stream of the Vega measurement volume.

Positioning Laser The optional positioning laser indicates the general centre of the characterized measurement volume within a tolerance. For details on the positioning laser, see "Positioning Laser" on page 52.

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

Status LED (Green)	Error LED (Amber)	Position Sensor Status
Off	Off	No power.

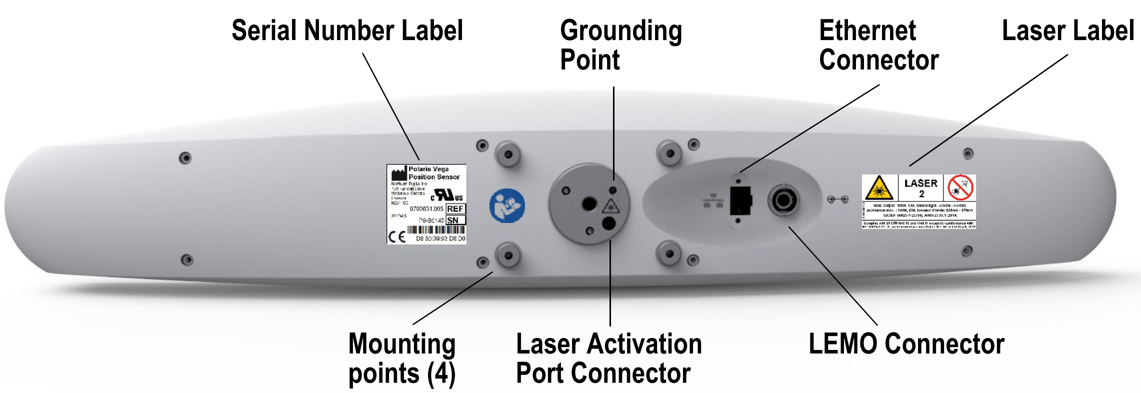
Table 1-1 Position Sensor Indicator LEDs Summary (Continued)

Status LED (Green)	Error LED (Amber)	Position Sensor Status
Flashing (4 Hz)	Off	The system is booting up.
Flashing (2 Hz)	Any state	The Position Sensor is warming up. When the Position Sensor is ready for use, the status LED stops flashing and remains on.
On	Off	The Position Sensor is ready for use with no faults or error conditions.
Flashing (1 Hz with 80% Duty Cycle)	Off	For Vega VT systems only. The video camera is streaming video. Note: Any error condition takes precedence over this streaming indication.
On	On	Minor recoverable error condition. For example, the bump sensor detected a bump. This is not a fault and can immediately be corrected. If not corrected, the system is still operational, but might not be able to receive tracking data until the application overrides the “bad data” filter.
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 in NDI ToolBox or by using the API command GET to read the `Info.Status.Alerts` user parameter. For more details, see the “*Polaris Vega Application Programming Interface Guide*”.

Rear View

Figure 1-5 Vega ST Position Sensor - Rear View



The rear of the Position Sensor incorporates the following components:

Mounting points Four M4 x 0.7 mm pitch x 10 mm deep threaded holes. For mounting details, see “Mounting the Position Sensor” on page 16.

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.

LEMO Connector An option on the Polaris Vega ST Position Sensor for use in integrations that require serial communications with the host. If this option is not included, the connector port will be covered and unusable.

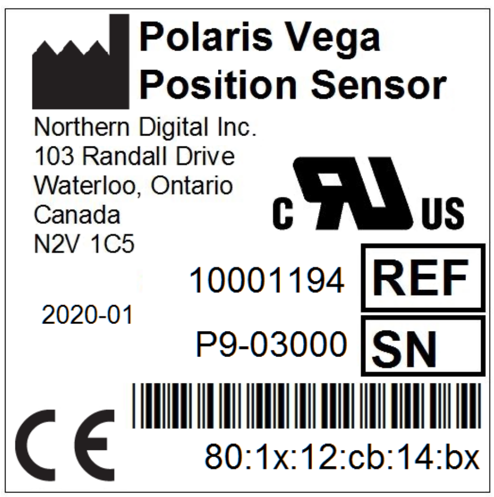
Grounding Point An M3x0.5, 6mm tapped hole to allow for a dedicated ground connection to be fitted to the Position Sensor. (If the system end-use application use requires one.)

Laser Label If the optional positioning laser in included, the laser label is located on the back of the Position Sensor and shows the classification, output, wavelength, standards, and a warning.

Laser Activation Port The laser can be 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 1-5). You can also activate the laser through the user parameters. For details, see the "*Polaris Vega Application Programming Interface Guide*".

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

Figure 1-6 Position Sensor Serial Number Label



Audio Codes

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

- The Position Sensor emits two beeps on reset or when power is applied. 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 Programming Interface Guide"*****.**

1.8 Tools

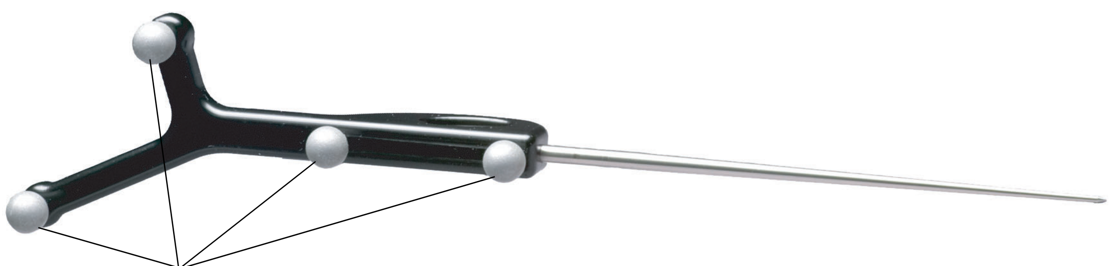
A tool is a rigid structure on which three or more markers are fixed so that there is no relative movement between them. The Polaris Vega System tracks the positions and orientations of tools and can also report the positions of individual markers.

The Polaris Vega System can track passive tools and active wireless tools. Passive tools reflect IR light from the Position Sensor illuminators. Active wireless tools emit IR light in response to pulses of IR light from the Position Sensor illuminators.

Tools are available from NDI for use with the Polaris Vega System. Contact NDI for more details. See "Contact Information" on page ix.

An example of a passive tool is shown in Figure 1-7. The example shows a probe that incorporates four NDI passive sphere markers.

Figure 1-7 Passive Tool with Sphere Markers



Tool Definition Files

The Position Sensor tracks tools based on the geometry of the markers on the tools. A tool definition file describes a tool to the Position Sensor, including the tool's marker geometry. The Position Sensor requires a tool definition file for each tool.

For more information on tool definition files, see "Tool Definition File" on page 41. Polaris Vega System tools are described in more detail in "Polaris Vega System Tools" on page 38. For information on tool design and construction, see the "*Polaris Tool Design Guide*".

1.9 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 55.

2 Vega Models

There are three Vega Position Sensor models. For a description of each, see the sections below:

- "Vega ST Position Sensor" on page 10
- "Vega VT Position Sensor" on page 10
- "Vega XT Position Sensor" on page 11

2.1 Vega ST Position Sensor

The Vega ST Position Sensor provides high volumetric accuracy at different tracking rates and supports a number of optional features, as described in Table 2-1.

Table 2-1 Vega ST Position Sensor Features and Capabilities

Feature / Capability	
Frame Rate	• 60 Hz fixed
Average Latency*	• < 17ms (typical)
Supported Tool Types	• Passive Spheres • Radix Lenses • One-Way Active Wireless Tools For more information on tools and markers, see "Polaris Vega System Tools" on page 38.
Communication Interface	• Ethernet
Other Configuration Options	• Positioning Laser • Extended Pyramid Volume • Gamma Radiation Hardening • Serial Communications

*Latency is scene and context dependent. Individual frames, especially during the lock-on stage (beginning of tracking), may exhibit longer latency.

Figure 2-1 Vega ST Position Sensor with Positioning Laser

2.2 Vega VT Position Sensor

The Vega VT Position Sensor is similar to the Vega ST but is equipped with a video camera and supports a different set of features.

Table 2-2 Vega VT Position Sensor Features and Capabilities

Feature / Capability	
Frame Rate	• 60 Hz fixed
Average Latency*	• < 17ms (typical)

Table 2-2 Vega VT Position Sensor (Continued)Features and Capabilities

Feature / Capability	
Supported Tool Types	• Passive Spheres • Radix Lenses • One-Way Active Wireless Tools For more information on tools and markers, see "Polaris Vega System Tools" on page 38.
Communication Interface	• Ethernet
Other Configuration Options	• Positioning Laser • Extended Pyramid Volume

*Latency is scene and context dependent. Individual frames, especially during the lock-on stage (beginning of tracking), may exhibit longer latency.

Figure 2-2 Vega VT Position Sensor

2.3 Vega XT Position Sensor

The Vega XT Position Sensor provides a higher tracking rate and lower latency than the Vega ST and VT Position Sensors.

Table 2-3 Vega XT Position Sensor Features and Capabilities

Feature / Capability	
Frame Rate	• Configurable up to 400 Hz
Average Latency*	• < 3 ms (typical) at 400 Hz Frame Rate
Supported Tool Types	• Passive Spheres • Radix Lenses For more information on tools and markers, see "Polaris Vega System Tools" on page 38.
Communication Interface	• Ethernet
Other Configuration Options	• Positioning Laser • Extended Pyramid Volume

*Latency is scene and context dependent. Individual frames, especially during the lock-on stage (beginning of tracking), may exhibit longer latency.

Figure 2-3 Vega XT Position Sensor with Positioning Laser

3 Setting Up the 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:

3.1 Unpacking the System

The Polaris Vega System is usually shipped to end users with a Position Sensor and cables. OEM partners may receive a different configuration.

To download the latest software and end user documentation, visit the NDI Support Site at https://support.ndigital.com.

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

Note **For instructions on returning the system to NDI, see “Return Procedure” on page 102.**

Remove the Network Warning Label

When the Vega Position Sensor is first removed from the packaging, there is a warning label, as show in Figure 3-1, over the Ethernet port. Review the warning, then remove the label using the finger tab on the right.

Figure 3-1 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.**

Power the Position Sensor and Check the Bump Sensor

NDI recommends applying power to the Position Sensor for approximately 12 hours upon receipt of the unit. This charges the bump sensor battery and provides the opportunity to determine if the unit experienced a potentially damaging impact during shipping and handling.

For instructions on determining if the bump sensor has been triggered and how to reset the sensor, see “Bump Sensor” on page 55.

If the bump sensor has not been triggered, a fully charged battery will power the bump sensor and real-time clock for approximately two years. If the bump sensor has been triggered, the battery will power the sensor and clock for approximately two months. For instructions on what to do if the battery is fully drained, see “Bump Sensor Battery” on page 56.

3.2 Operating Environment Requirements

Warnings

To avoid the risk of personal injury, read the following warnings before using the Polaris Vega System.

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 92. 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 overheat. 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 use the Position Sensor in an x-ray, proton radiation, or MRI environment without first determining the performance, including accuracy, of the Position Sensor in these environments. NDI has not validated the Position Sensor in these environments.
8. Position the system components so that they can be easily disconnected from the external 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. For the dimensions of the characterized measurement volume, see Figure 5-2 on page 32 or Figure 5-3 on page 33.
- Ensure that the environment you place the Position Sensor in meets the operating conditions outlined in Table 14-1 on page 90.
- 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.
- In a setup where two Position Sensors face each other, the exposure timing of one of them should be shifted so the two do not illuminate the measurement volume at the same time. For more information, see the `Param.Exposure.Time Slot.Passive` information in the *“Polaris Vega Application Programming Interface Guide”*.
- Make sure that there are no large reflective surfaces within the field of view (described on page 31).
- 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 status LED on the Position Sensor has stopped flashing. The status LED will flash while the Position Sensor warms up. When the LED is steady, the system is ready for use.

3.3 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.**

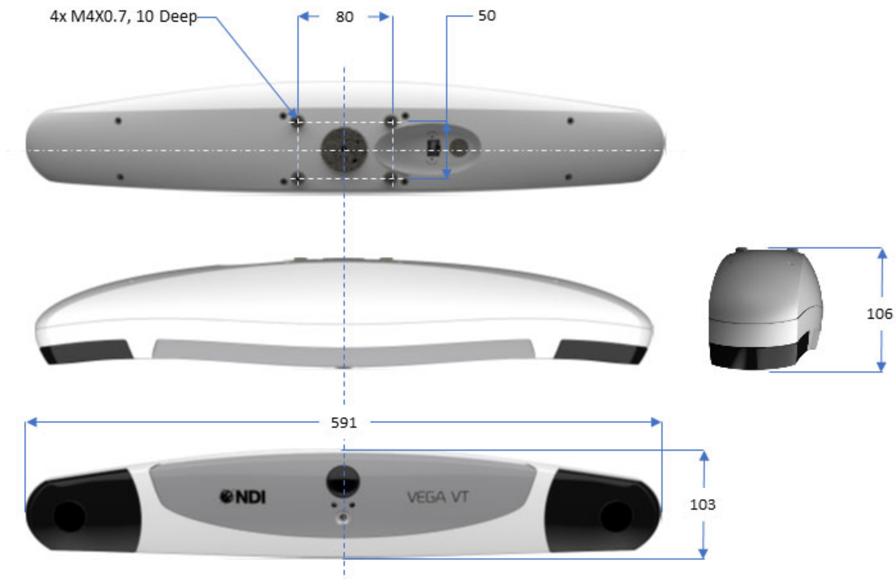
Note **Before you design a custom enclosure or any attachments for the Position Sensor, contact NDI for assistance. See “Contact Information” on page ix.**

Figure 3-2 on page 16 is provided for information purposes only and dimensions are subject to change without notice.

The Position Sensor is mounted via four M4 x 0.7 mm pitch x 10 mm deep threaded holes. Figure 3-2 shows the Position Sensor dimensions and mounting arrangement.

Figure 3-2 Position Sensor Mounting Details

All dimensions in mm



3.4 Connecting the Hardware

Warnings

To avoid the risk of personal injury, read the following warnings before using the Polaris Vega System.

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 one of the procedures below:

- "Setting up the Ethernet Connection" on page 17
- "Setting up for Serial Communications" on page 75

Setting up the Ethernet Connection

You can also connect the Position Sensor to the PoE and the PoE to the host computer with no need for a switch or router.

1. Connect the Ethernet cable to the port on the Position Sensor.
2. To connect the Position Sensor, perform one of the following actions:
   - For a switch with embedded PoE, connect the Position Sensor to the switch.
   - For a switch without embedded PoE, connect the switch to PoE and the Position Sensor to the PoE.
   - For 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. 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.**

The internal Position Sensor-to-Video Camera network is 192.168.184.xxx. This means the Position Sensor will not work correctly if it is connected to a 192.168.184.xxx network.

Power Up and Warm Up

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 status LED will begin to flash.

The Position Sensor requires a warm-up time every time it is powered on. The status LED will flash while the Position Sensor warms up; when the LED is steady, the system is ready for use.

3.5 Installing Application Software

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

The ToolBox video client utility uses GStreamer to handle the video stream from the Vega video camera. You can install GStreamer as part of the ToolBox installation or install your own version of GStreamer separately from the ToolBox installation.

You can download NDI ToolBox from the NDI Support Site at https://support.ndigital.com. For instructions on using ToolBox, see the *"ToolBox online help"*.

Install NDI ToolBox

Install on Windows

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

1. Navigate to where you saved the NDI ToolBox installer.
1. Double-click **install.exe**.
2. Follow the on-screen instructions.

Install on Linux

The following versions of Linux are supported: 64-bit Linux with Kernels 2.6.35 and higher, and 3.0 and higher. The default installation location is **<user_name>/NDIToolBox** or **~/NDIToolBox**.

Execution permissions may be required to install ToolBox.

1. Navigate to where you saved the NDI ToolBox installer.
2. Run the following commands:

```
sudo chmod +x install.sh
./install.sh
```

3. Follow the on-screen instructions.

Tip: To silently install ToolBox, run the installer from the command line with the '-q" option. You can also specify a different directory than the default. For example, `./installer.sh -q -dir /opt/ToolBox`. If you omit the `-dir` option, the default install location is used.

Install on macOS

The following versions of macOS are supported: 10.10 and higher

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

1. Navigate to where you saved the NDI ToolBox installer.
2. Double-click the **install.dmg** file.
3. Double-click **NDI Installer** and enter your administrator password.

4. Follow the on-screen instructions.

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

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

Uninstall on Windows

1. Open the **Windows Start** menu.
2. Select **Northern Digital Inc. > ToolBox**.
3. Select **NDI ToolBox Uninstaller**.
4. Follow the on-screen instructions.

Uninstall on Linux

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

Uninstall on macOS

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

3.6 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. For details about connection options, see the *"ToolBox online help"*. After ToolBox is running, you can direct it to connect to a different system.

Connect to a System Using Ethernet Communications

1. Select **File > Connect to > (Polaris Vega)**

ToolBox automatically detects all available Vega Position Sensors 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 multicast DNS (mDNS). ToolBox uses this protocol to discover the Position Sensors on the network. On Windows computers, you can install Apple's Bonjour software. On Linux computers, you can enable Avahi.

If direct connection to the video camera is enabled, any connected video cameras (VCUs) will also be displayed in the **Connect to** menu. For information on this setting, see "Connecting to the Video Camera" on page 64.

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

- “Dynamic Host Configuration” on page 20
- “Link-local Addressing (zeroconf)” on page 20
- “Static IP Addressing” on page 20

Each approach is detailed below. If you encounter issues with any of these approaches, see “Troubleshooting the connections” on page 21.

Note **These instructions use NDI ToolBox to perform the configuration. You can also configure the network using the Vega API. For more information on modifying the connection, see the** *“Polaris Vega Application Programming Interface Guide”*.

Dynamic Host Configuration

DHCP is generally the default network configuration for the Polaris Vega System. If there is a DHCP server on the same network as the Vega device, 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 its own IP parameters using Link-local Addressing (zeroconf).

Link-local Addressing (zeroconf)

Zero Configuration or Link-local Addressing 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 must 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 macOS. On Linux it may be enabled on a “per interface” basis.

When these criteria are 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)

After 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 Linux, use **Yast** or equivalent.
- On macOS, use **Setup**.

Modifying the connection

After 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. Select **File > Save Parameters**.
4. To reset the system, select **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. 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 Position Sensor 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, see the *“Polaris Vega Application Programming Interface Guide”* provided with your system.

4 Tutorial: Learning to Use the 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, see 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.

4.1 Getting Started: Tracking Tools

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

Set Up the System

1. Install NDI ToolBox, as described in "Install NDI ToolBox" on page 18.
2. Set up and connect the hardware, as described in "Connecting the Hardware" on page 16.
3. Open the NDI Track Toolbox Utility.
4. If NDI Track does not automatically connect to the system, perform the following actions:
    a) Select **File > Connect to.**
    a) Select the system from the list or select **New Connection...**
    a) Enter the host name or IP address and select **OK**.

Track Tools

1. Click  to load the tool definition files for the tools you want to track.
2. In the dialog, navigate to the desired tool definition file(s).
3. Select one or more files.
4. Click **Open**.

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

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

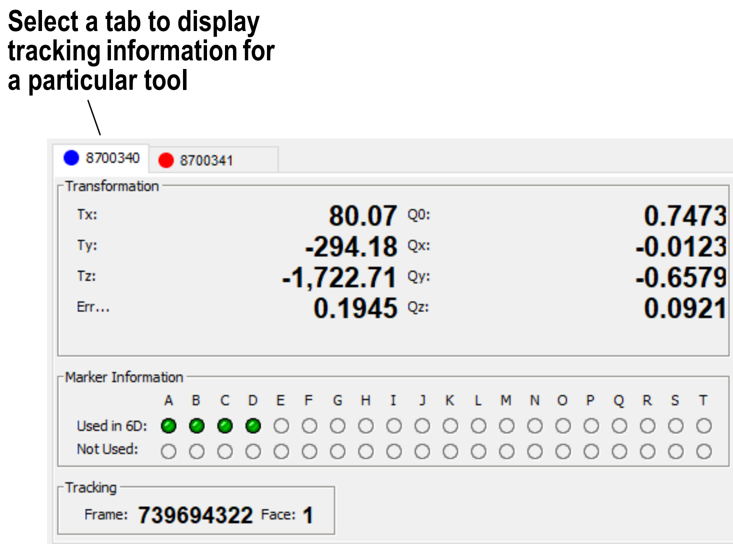
4.2 Triggering Information and Error Flags

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.

View Information and Error Flags

1. Set up the system to track tools, as described in "Getting Started: Tracking Tools" on page 23.
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 4-1 Tutorial: NDI ToolBox Tool Tracking Window

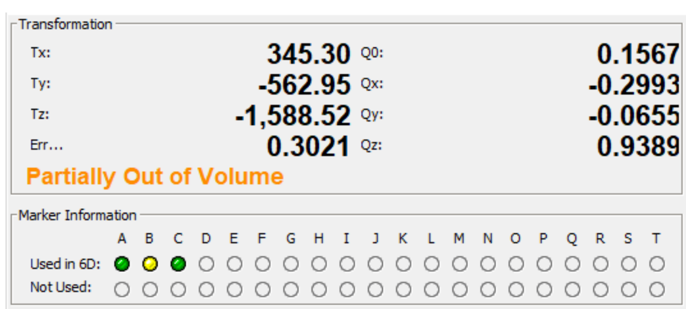


"Partially Out of Volume" and "Out of Volume" flags:

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 4-2 Tutorial: "Partially Out of Volume" Flag

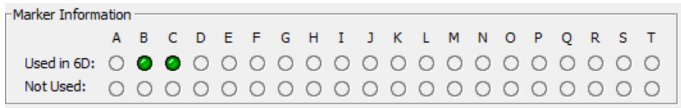


"Too Few Markers" flag:

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.

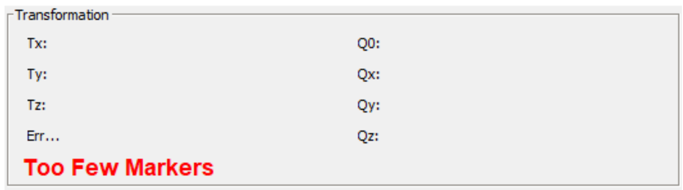
The Position Sensor will no longer be able to detect the covered markers.

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

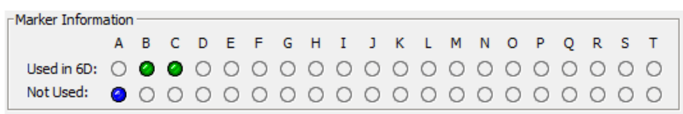


“Exceeded Maximum Marker Angle” flag:

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 4-5 Tutorial: “Exceeded Max Marker Angle” Indicator



4.3 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 47.

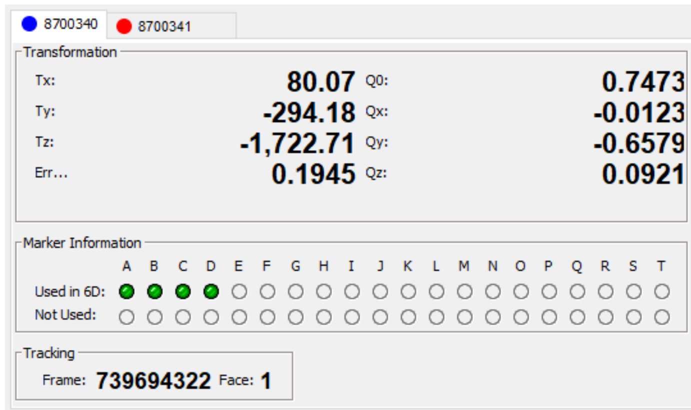
Set a Tool as Reference

1. Set up the system to track tools, as described in “Getting Started: Tracking Tools” on page 23.
2. Click  to load tool definition files for at least two tools.

3. For each loaded tool definition file, there is a tab in the bottom right section of the tool tracking utility. Select the tab corresponding to the tool you want to set as reference.

Figure 4-6 Tutorial: Selecting a Reference Tool

Select the tab for the tool you want to set as reference.



4. Right-click 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.**

4.4 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. For more details, see "Tool Tip Offset" on page 45.

Set Up the System to Pivot

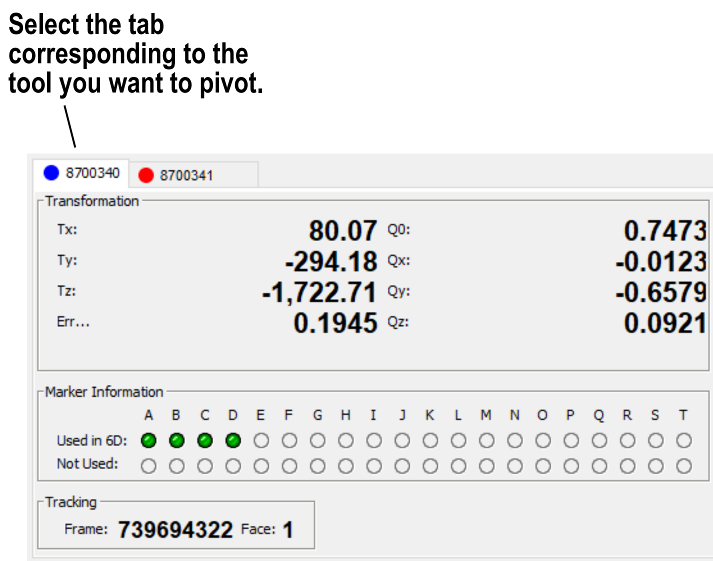
You will need a divot in which to rest the tool tip while you pivot the tool. The size and shape of the divot must match the tool tip, to ensure that the tip does not move. For example, a probe with a 1-mm ball tip requires a hemispherical divot with a 1-mm diameter in which to pivot.

1. Set up the system to track tools, as described in "Getting Started: Tracking Tools" on page 23.

2. Click  to load a tool definition file for the probe or pointer tool.

3. For each loaded tool definition file, there is a tab in the bottom right section of the tool tracking utility. Select the tab corresponding to the tool you want to pivot.

Figure 4-7 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.

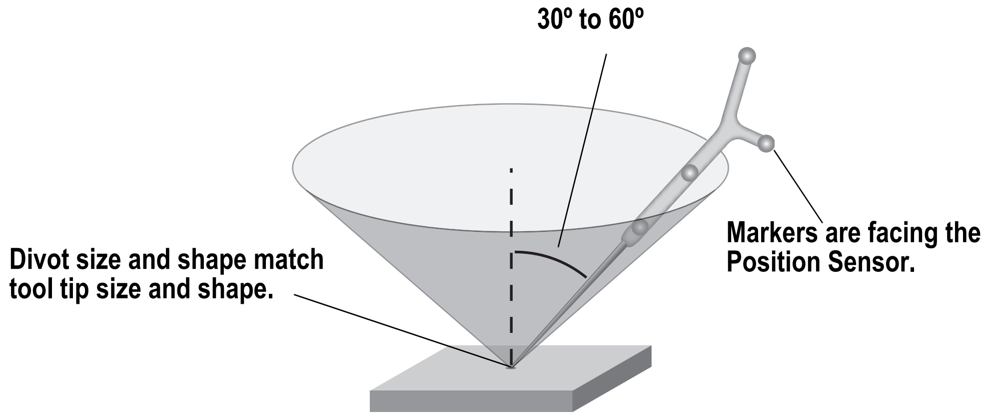
Pivot the Tool

1. Place the tool tip in the divot.
2. Ensure that the tool is within the characterized measurement volume and will remain within the volume throughout the pivoting procedure.
3. Click **Start Collection** in the **Pivot tool** dialog.
4. Pivot the tool in a cone shape, at an angle of 30º to 60º from the vertical.

a) Keep the tool tip stationary and ensure that there is a line of sight between the markers on the tool and the Position Sensor throughout the pivoting procedure.

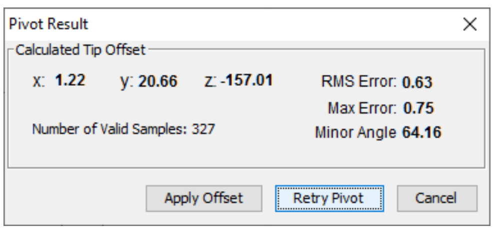
b) Pivot the tool slowly until the specified pivot duration time has elapsed.

Figure 4-8 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 4-9 NDI ToolBox Software: Pivot Result Dialog



5 How the 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 required to use the system. To learn how to use the system, see “Tutorial: Learning to Use the Polaris Vega System” on page 23.

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

This chapter contains the following information:

5.1 Communicating with the Polaris Vega System

The Polaris Vega System is controlled using an application programming 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 Programming Interface Guide*”.

5.2 Information Returned by the Polaris Vega System

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. 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 31.
- **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 Programming Interface Guide".*
- **the frame number** for each tool transformation. The frame number is incremented by 1 at the frame rate. 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.

Note **Transformations with respect to a reference tool (described on page 47) and transformations for a probe with a tool tip offset (described on page 45) are calculated using application software such as NDI ToolBox.**

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.

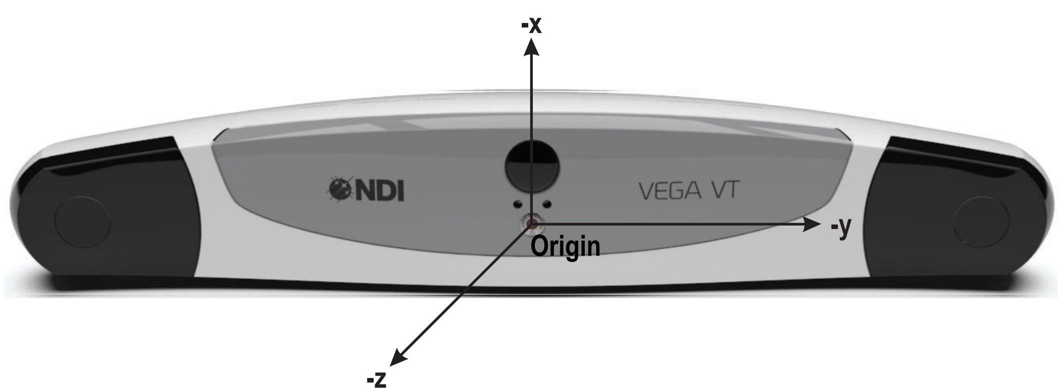
Note For information on the API commands used to request tracking information from the Polaris Vega System, see the BX, BX2, or TX command in the *"Polaris Vega Application Programming Interface Guide"*.

5.3 Global Coordinate System and Measurement Volume

Global Coordinate System

The Vega Position Sensor uses a coordinate system with an origin located at the Position Sensor and axes aligned as shown in Figure 5-1. This global coordinate system is defined during manufacturing and cannot be changed. The origin of the coordinate system is not tied to a physical feature of the Position Sensor enclosure and can vary from system to system by up to 50mm along all axes. This means that two different position sensors may report different transformation even when the physical setup is the same.

Figure 5-1 Global Coordinate System



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. 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 47.

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 Vega Position Sensor. There are two characterized measurement volumes available for the Polaris Vega System: the pyramid volume, illustrated in Figure 5-2 on page 32, and the extended pyramid volume, illustrated in Figure 5-3 on page 33.

The Position Sensor's performance is determined using the calibration methodology described in Appendix A on page 112.

Figure 5-2 Pyramid Volume

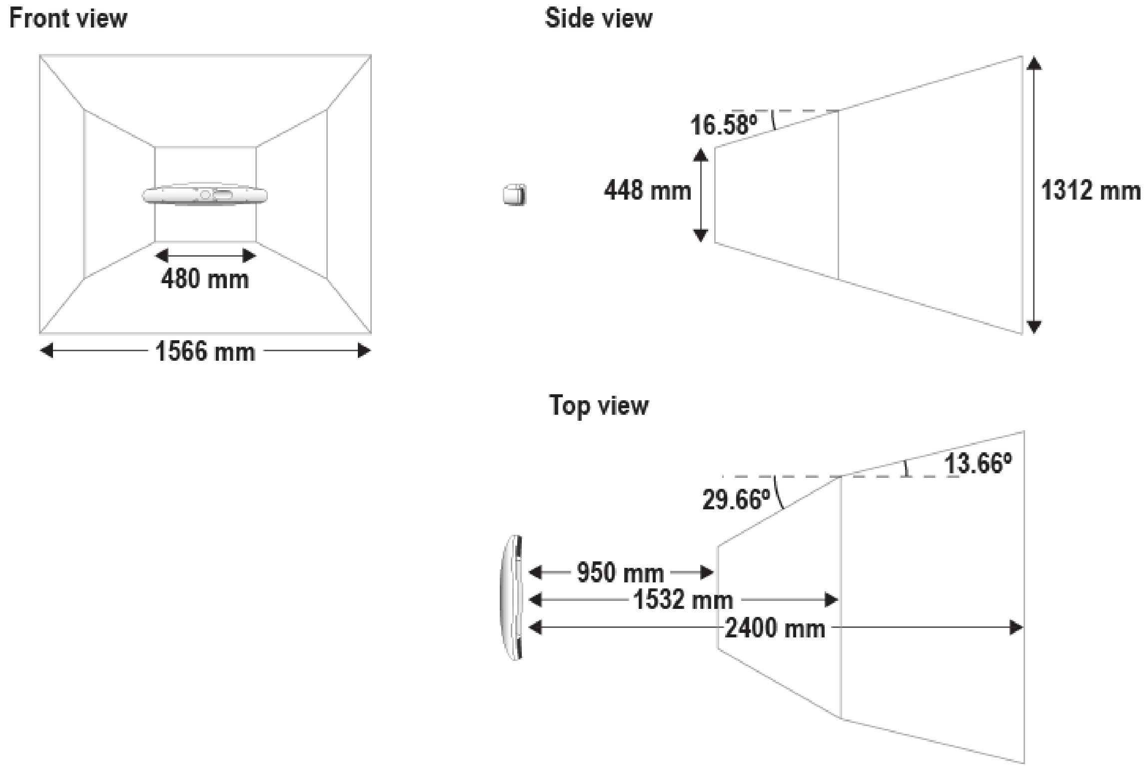
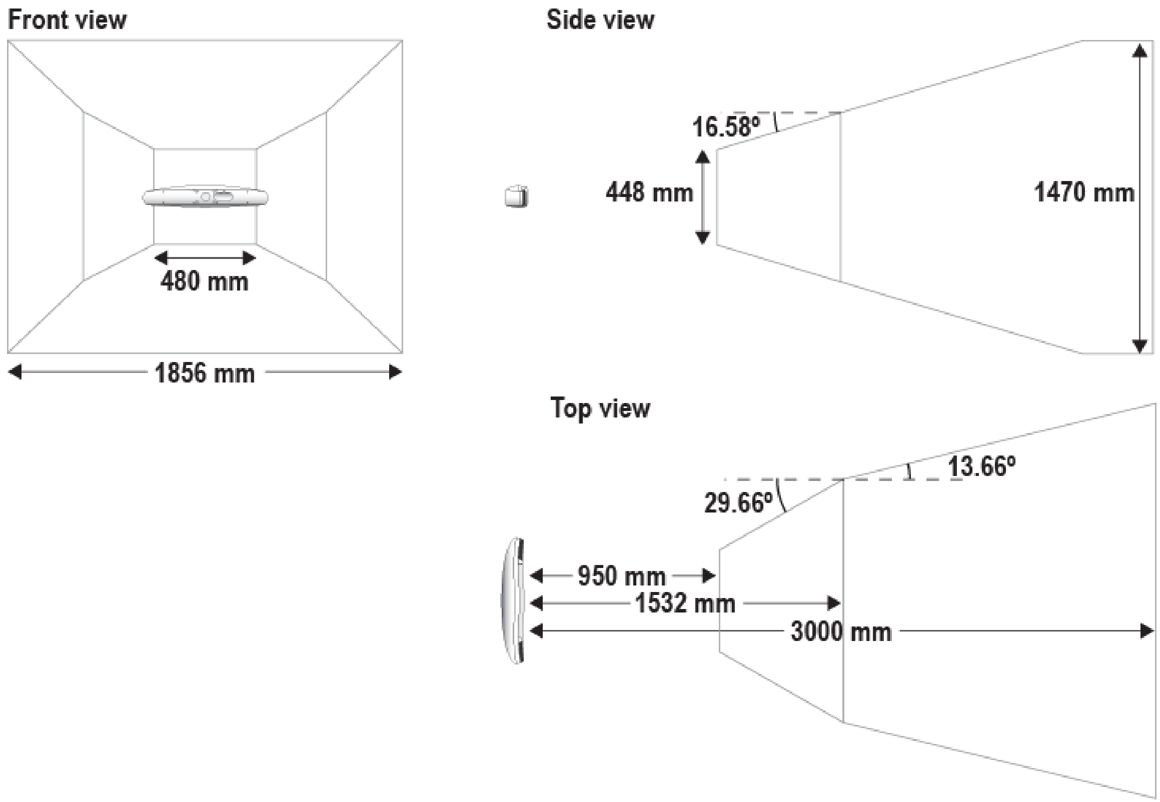


Figure 5-3 Extended Pyramid Volume



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 regardless of whether 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.

For details, see the "*Polaris Vega Application Programming Interface Guide*".

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. For details, see page 44.

5.4 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 infrared "chirp" signal emitted by the Position Sensor just before exposure starts (see "Chirp Signal Specification" on page 40). The infrared receiver on the active wireless tool detects the chirp and activates the IREDs for the duration of the exposure time.

For both active and passive markers, the Position Sensor collects IR for a period of time called the **exposure time**. This acts like an electronic shutter. The system makes automatic adjustments to the exposure 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 exposure time; see "Setting the Infrared Light Sensitivity" on page 81 for more details.

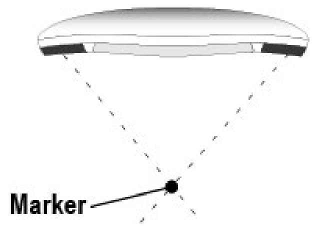
Acquiring and Tracking Tools

When the Polaris Vega System first begins tracking a tool, or if 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 5-4. 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 5-4 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. For details about unique geometry requirements, see the “*Polaris Tool Design Guide*”.

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).

For more details, see “Stray Marker Reporting” on page 47 and “Phantom Markers” on page 48.

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 acquires and tracks 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 three 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*”.**

5.5 Tracking Rate and Frame Rate

The frame rate is the rate at which the system takes images of the measurement volume. The tracking rate is the rate at which the system reports transformations for all the tools being tracked. The tracking rate cannot exceed the frame rate.

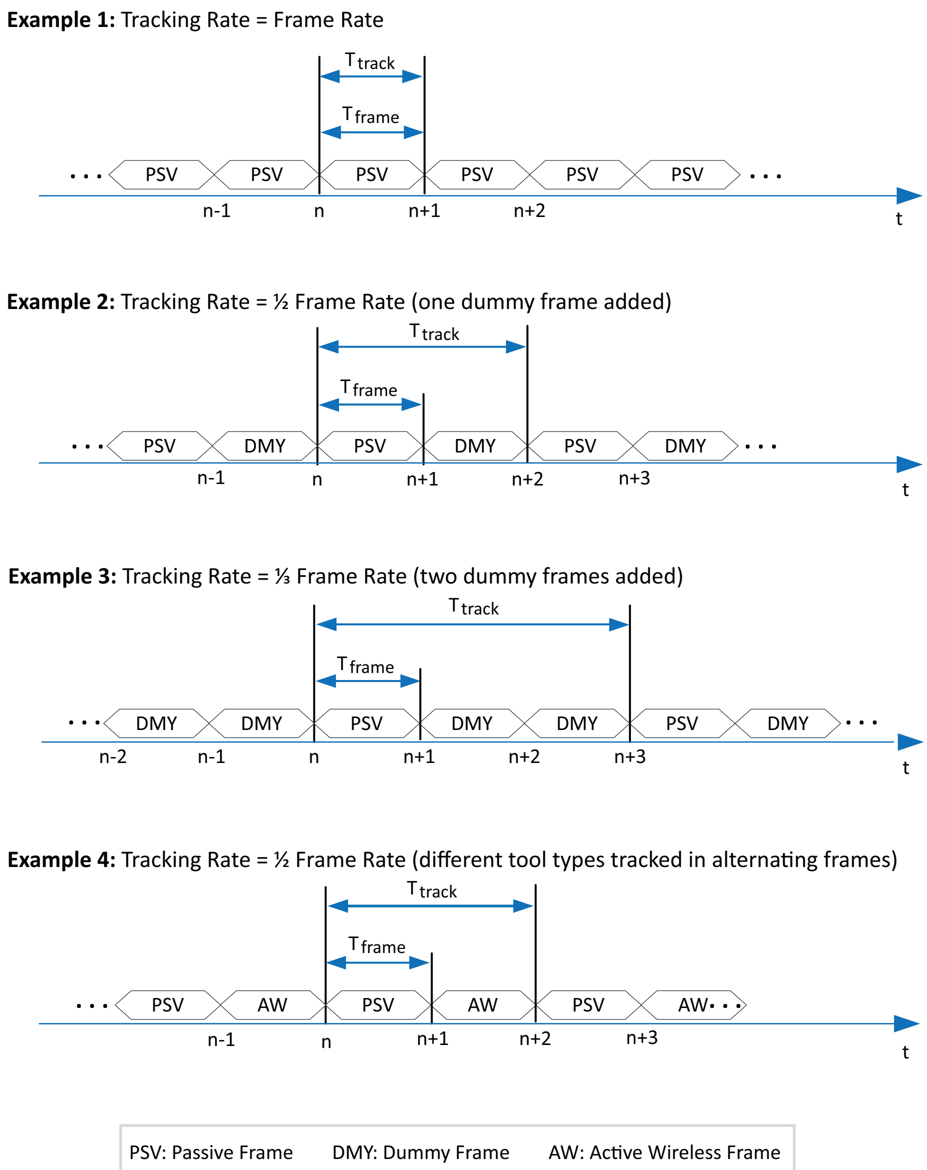
The default frame rate is 60 Hz and the default tracking rate is 20 Hz (1/3 the frame rate). These defaults can be changed using the Polaris Vega API or ToolBox.

The number and type of tools being tracked affect the tracking rate. The tracking rate decreases as more frames are needed to track all the tools. The number and type 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 tracking rate is the frame rate. It is possible to slow the tracking rate down to ½ or ⅓ of the frame rate.
- All active wireless tools are tracked in the same frame. If only active wireless tools are tracked, the maximum tracking rate is the frame rate. It is possible to slow the tracking rate down to ½ or ⅓ of the frame rate.
- Active wireless tools and passive tools are tracked in alternating frames. The maximum tracking rate for each tool type is ½ the frame rate. It can be further slowed down to ⅓ of the frame rate. At ½ frame rate, active wireless and passive tools are tracked in alternating frames. At ⅓ frame rate, active wireless and passive tools are tracked in two subsequent frames followed by a “dummy frame”.

Figure 5-5 illustrates the relationship between the tracking rate and frame rate.

Figure 5-5 Tracking Rate and Frame Rate Relationship



Tracking Rate and Frame Rate Measurements:

$$\text{Tracking Rate} = \frac{1}{T_{track}}, \text{ Frame Rate} = \frac{1}{T_{frame}}.$$

5.6 Polaris Vega System Tools

A tool is a rigid structure on which three or more spherical markers, Radix lenses, or active markers are fixed so that there is no relative movement between them. Polaris Vega tools can be either passive or active wireless.

You can enable up to 25 tools. However, 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.

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.

Do not use a 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 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. Inaccurate conclusions increase the possibility of personal injury.

For more information, see “Passive Tools” on page 38 and “One-Way Active Wireless Tools” on page 39.

Passive Tools

An example of a passive tool is shown in Figure 1-7. 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 Spheres 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. For detailed information on passive sphere markers, see the “*Polaris Tool Design Guide*”.

Passive sphere markers cannot be re-sterilized. NDI does not recommend that a passive sphere 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.

Radix Lenses 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, see the *“Radix Lens Integration Guide”*.

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. For details, see "Tool Definition File" on page 41.

Caution! **Do not handle 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.**

One-Way Active Wireless Tools

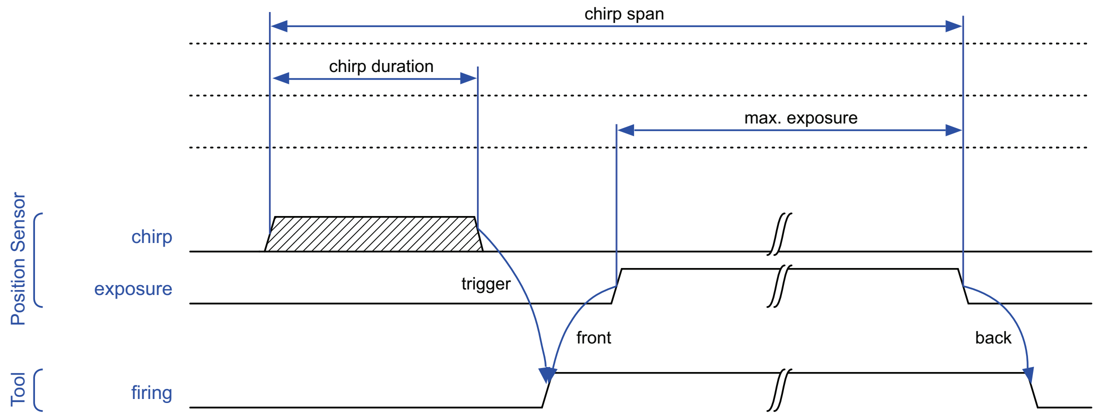
All Polaris Vega systems support one-way active wireless tools. These tools are equipped with an IR receiver and IREDs that are activated by a chirp signal emitted by the Position Sensor.

To track active wireless tools, the Position Sensor pulses (chirps) its illuminators in a way recognized by the tool's IR receiver. When the receiver detects the end of a valid chirp signal, the tool activates its IREDs, which are then seen by the Position Sensor.

These tools can be powered by a battery or an external source.

Figure 5-6 illustrates the interaction between the active wireless tool and the Vega Position Sensor.

Figure 5-6 Active Wireless Tool Timing Diagram



At time *chirp span* before the end of exposure, the Position Sensor starts chirping its illuminators for *chirp duration*.

When the tool detects the end of the chirp signal, it starts firing the IREDs for a time that is slightly longer than the maximum exposure time of the Position Sensor. This ensures minimal overlap on both ends of the exposure period where the IREDs are active before exposure starts and after exposure ends.

Table 5-1 Chirp Signal Specification

Parameter	Vega ST/VT	Vega XT	Comment
Chirp Frequency	107.3 kHz	143.0 kHz	
Chirp Duty Cycle	50%	50%	
Chirp Span	2400 µs	450 µs	relative to end of exposure
Chirp Duration	345 µs	105 µs	
max. Exposure	2000 µs	300 µs	relative to end of exposure
Front Overlap	>= 0	>= 0	firing must start at or before start of exposure
Back Overlap	>= 0	>= 0	firing must not stop before end of exposure
Irradiance	0.02 – 70 W/m^2	0.02 – 70 W/m^2	Signal strength of the chirp signal throughout the measurement volume.
Wavelength	800 – 900 nm	800 – 900 nm	Wavelength of illuminator signal

Note **Vega ST/VT systems have a different chirp frequency and timing than Vega XT systems.**

Since there is no data communication between the Position Sensor and the tool (other than the chirp signal for synchronization), they act in the same manner as passive tools. This means:

- The host application must provide tool definition files (rom files) that describe the tool geometry to the system.
- The tool geometry must follow the Unique Geometry Rules
- Active wireless tools and passive tools are tracked in separate frames. This means active wireless tool can have the same tool geometry as a passive tool that is used at the same time.
- If active and passive tools are tracked at the same time, the track frequency will be at most ½ of the frame frequency (alternating tracking of active wireless and passive tools)

For customers interested in implementing one-way active wireless tracking, NDI provides an evaluation kit (part number 10007019) that includes a reference design (schematic and source code). For details, contact NDI Customer Support through the support site at https://support.ndigital.com.

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.

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. For more details, see the *"NDI ToolBox online help"*.

Each face is assigned a face normal in the tool definition file (described on page 41). 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 tracks the face most directly oriented to the Position Sensor, measured as 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 attempts to track another face.

When determining whether to switch faces, the system has a hysteresis of 2°. The system determines 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 switches to the new face.

5.7 Tool Definition File

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.

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, tool face definitions (for a multi-faced tool), and the parameters and settings described in "Tool Tracking Parameters" on page 42. A tool definition file must be loaded into the system before the system can track the associated tool. Without this information, the system cannot accurately interpret the data it collects.

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, for each tool type you want the system to track, you must load at least one "dummy" tool 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. For details, see the "*Polaris Vega Application Programming Interface Guide*".

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*”.

5.8 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 41). The flow chart on page 45 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

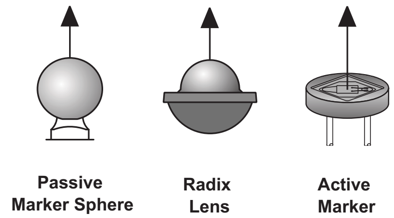
The **maximum 3D error** parameter specifies the maximum allowable 3D error for each marker on the tool. The 3D error is the difference between the measured and expected location of a marker on a tool. The expected location of a marker on a tool is specified in the tool definition file (described on page 41).

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 of the two sensors in the Position Sensor. Each marker in the tool definition file has an associated normal vector. A marker normal is a unit vector which indicates the direction the marker is facing. See Figure 5-7.

Figure 5-7 Markers with Marker Normals

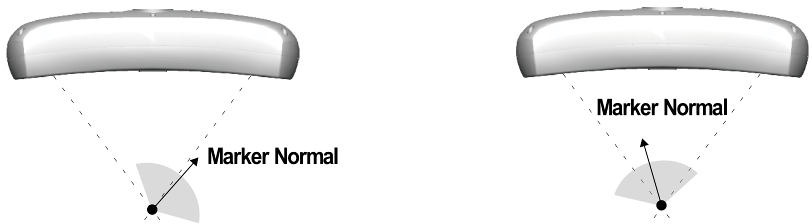


The system measures the angle between the marker normal and the vectors directed from the marker position to each sensor. If the angle between the marker normal and either sensor is greater than the specified maximum marker angle value, the system will not use the data from that marker to determine the tool transformation.

In the diagram on the left side of Figure 5-8, the angle between the marker normal and the left sensor is greater than the maximum marker angle of 60 ° (highlighted region). Therefore, the system would not use this marker to calculate a transformation.

In the diagram on the right side of Figure 5-8, the angle between the marker normal and each sensor is less than the maximum marker angle of 60 °. Therefore, the system could use this marker to calculate a transformation.

Figure 5-8 Maximum Marker Angle



How the maximum marker angle improves tool accuracy: Markers (particularly active markers) do not behave as a perfect point source of light. As markers are viewed off-axis, the apparent centre of emission shifts. The amount of shift increases as the off-axis viewing angle increases. This apparent shift in the markers' 3D locations can introduce significant errors in the tool transformations. Setting a maximum marker angle causes the system to stop using the marker data when the off-axis viewing angle reaches a certain level, reducing the possibility that the system will calculate inaccurate transformations.

Setting the maximum marker angle: When setting the maximum marker angle, consider whether markers might occlude each other. Often, a tool will stop tracking due to partial marker occlusion before the markers exceed the maximum marker angle.

The maximum marker angle can be set in NDI Cygna-6D. The default maximum marker angle is ±90º for an NDI Passive Sphere and ±60º for an active marker or Radix lens. The value in NDI Cygna-6D is the half-range. For example, a value of 90º in NDI Cygna-6D is actually ±90º.

Checking the Marker Angles

The closer a marker is to the Position Sensor, the smaller the angle it can be turned and still be within the maximum marker angle. The following equation can be used to check whether a marker will be visible for a given position and orientation.

Let $\hat{n}$ be the marker normal, $\vec{m}$ be the marker position, and $\vec{s}$ be the sensor's position in the Position Sensor's coordinate system. The system will not use a marker to calculate the tool transformation if the absolute marker angle (θ) for either sensor is greater than the maximum marker angle.

$$\theta = \arccos\left(\frac{\hat{n} \bullet (\vec{s} - \vec{m})}{||\vec{s} - \vec{m}||}\right)$$

For Polaris Vega systems, the positions of the sensors are approximately [0, -250, 0] and [0, 250,0].

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 reports the tool as MISSING.

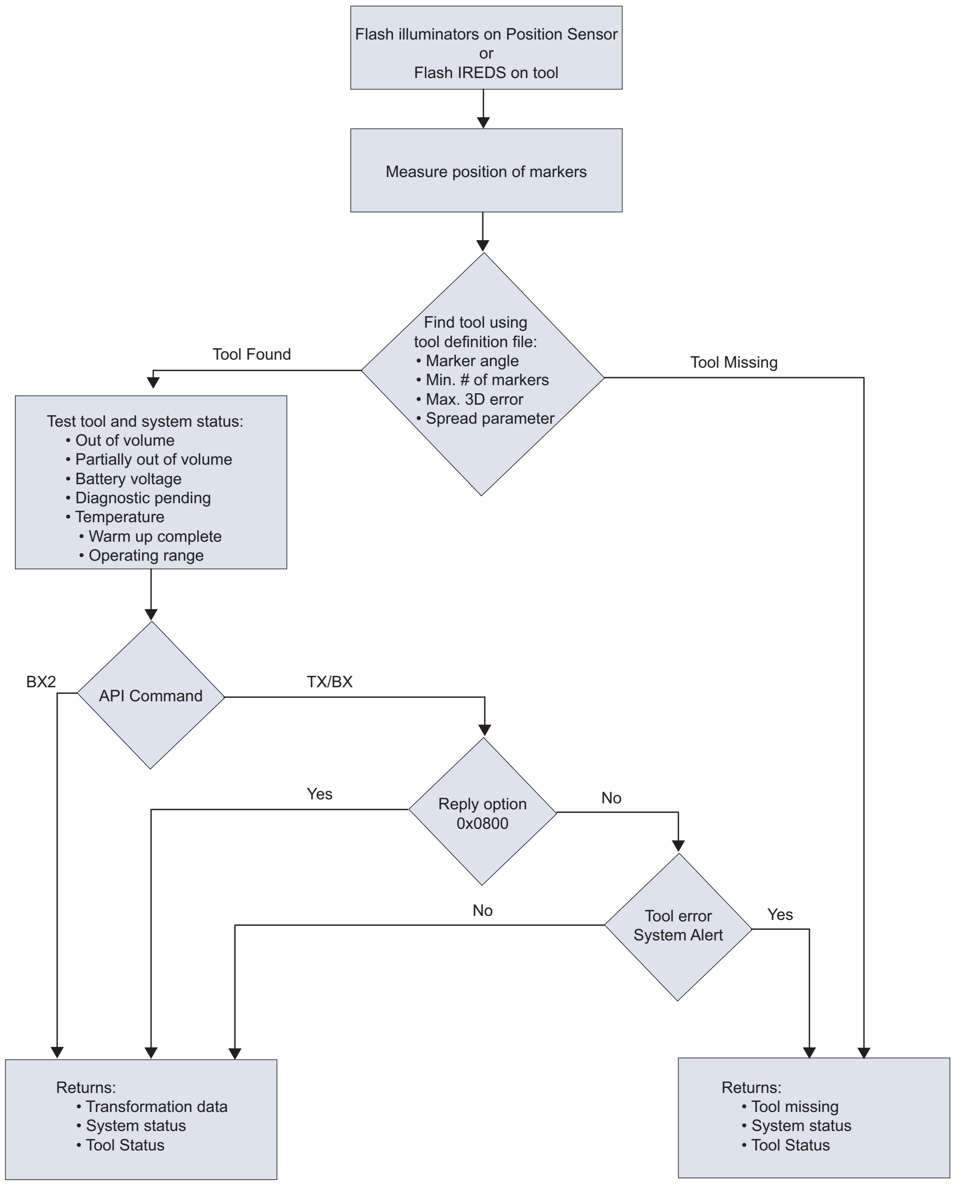
For example, consider a four-marker tool that has three markers inside the characterized measurement volume and one marker outside of the characterized measurement volume. If the minimum number of markers parameter is set to 3, the Polaris Vega System will report transformations for the tool, as long 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 more information on the minimum spread parameters, see the "*Polaris Tool Design Guide".*

Figure 5-9 Flowchart of Tool Tracking Parameters



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

5.9 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. 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. For example, 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 is no longer 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. To determine the location of the tool tip, application software can apply the tool transformations reported by the Polaris Vega System to the tool tip offset.

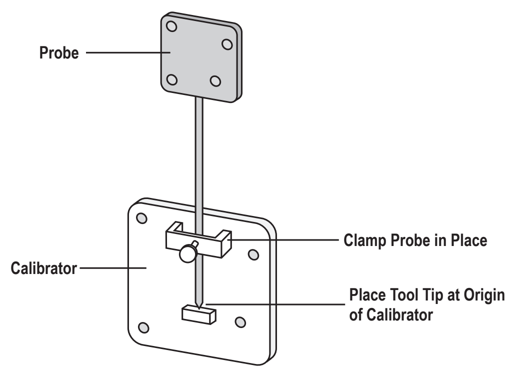
Note **The Polaris Vega System always tracks the origin of the tool. It is the application software, not the Polaris Vega System, that calculates the location of the tool tip.**

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 5-10. 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 5-10 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 26. The procedure is also detailed in the *"ToolBox online help*".

5.10 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 31). 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 Vega Position Sensor 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.

5.11 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 reports tool transformations, 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 48). The application software must eliminate phantom markers and verify that the stray markers are within the characterized measurement volume.

It is important to be aware of the following potential hazards associated with using the stray marker reporting functionality:

- An external IR source, may be reported as a stray marker. For example, an IR transmitter or incandescent light.
- Marker identification is not possible from frame to frame. Users must 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 using 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 48.)

- 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 must be constrained along a vector and its position relative to another marker is supposed to be fixed within some tolerance.

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. For details, see the *“Polaris Vega Application Programming Interface Guide*”.

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.

5.12 Phantom Markers

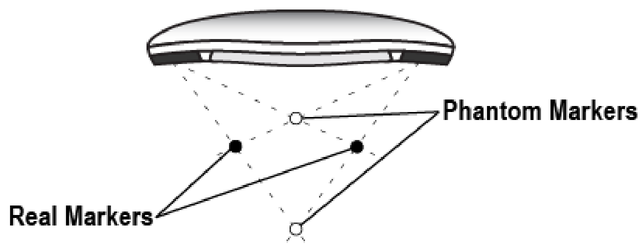
Phantom markers are the result of the calculation that the Polaris Vega System uses to determine the position of a source of IR. They appear and are reported as markers, but are not actual markers.

To determine the position of a source of IR, the Position Sensor calculates a line between the source of IR and each sensor (displayed as dotted lines in Figure 5-11). 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 5-11. 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 5-11 Phantom Markers



When you request stray marker data from the Polaris Vega System, the system reports data for both phantom markers and stray markers. If you do not request stray marker data from the Polaris Vega System, the system will not return any phantom marker data.

Note **The system cannot distinguish which solutions are phantom markers; you must eliminate the reported phantom markers using application software.**

5.13 System Spectral Response

The Polaris Vega System uses near infrared light for tracking. The system responds to wavelengths in the 800 nm to 1100 nm 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.**

5.14 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) must be updated.

6 Vega System Features

This chapter provides details about additional features of the Polaris Vega System, including the following:

6.1 Video Camera - Vega VT Systems Only

Polaris Vega VT Position Sensors include a video camera that provides a live, colour video stream of the Vega measurement volume. The video camera is integrated into the Position Sensor and is located centrally between the two image sensors with a small vertical offset. See Figure 2-2 on page 11.

Important points about the video camera are as follows:

- The video camera is not used for tracking tools.
- Streaming from the video camera is via port 554.
- Control of the video camera is either via the Position Sensor (proxying) or through a direct connection to the video camera. See “Connecting to the Video Camera” on page 64.

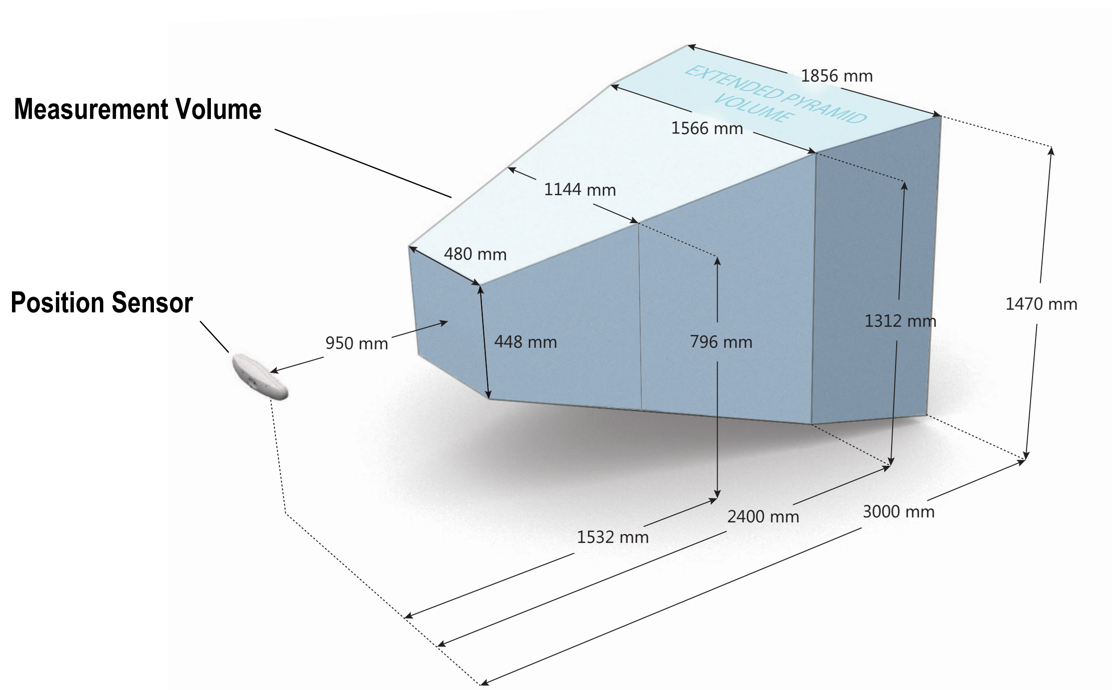
It is possible to project the Position Sensor’s tool tracking data stream onto the live video stream. This feature can be used for augmented reality overlays. For more information, see the “*Polaris Vega Application Programming Interface Guide*”.

For information about configuring the video camera and connecting to the streaming output, see “Video Camera” on page 58.

6.2 Extended Pyramid Volume

The optional extended pyramid volume provides a larger characterized measurement volume. As shown in Figure 6-1, the extended pyramid volume is the back section of the measurement volume, 2400 mm to 3000 mm from the Position Sensor.

Figure 6-1 Polaris Vega Extended Pyramid Volume



For the accuracy specification for the extended pyramid volume, see “Polaris Vega System Performance” on page 112.

6.3 Positioning Laser

The positioning laser is an optional component of the system. It is located in the Position Sensor and indicates the general center 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. An aperture on the front of the Position Sensor emits the laser beam and directs it along the *z*-axis of the Position Sensor’s global coordinate system (described on page 31).

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

Laser Use

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 ToolBox Configure utility. The **Laser** option is available under the **Position Sensor Settings and Options** node. Once activated, the laser will automatically turn off after 35 seconds.
- 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 and a value of 0 turns the laser off. The laser automatically turns off after 35 seconds.
- You can connect a switch to the external laser trigger connector. For details, see "External Laser Trigger Switch" on page 54.

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

Laser Specifications and Standards

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

Table 6-1 Laser Characteristics

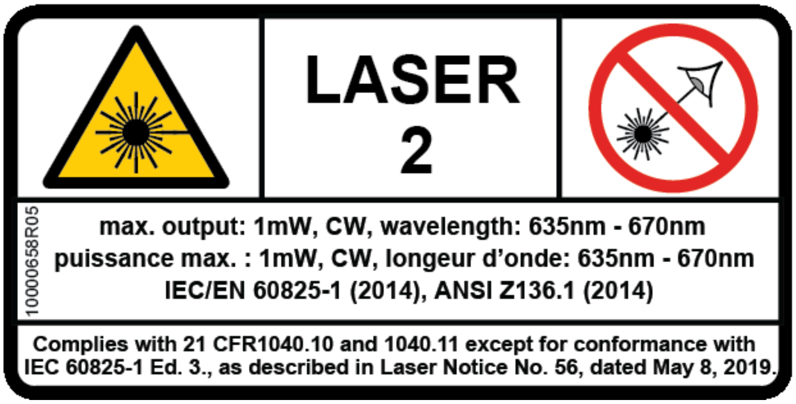
Wavelength	635 nm to 670 nm
Maximum Output	1 mW
Divergence (Half Angle)	0.7 mRad

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 6-2 is located on the back of the Position Sensor and lists the laser specifications and safety information.

Figure 6-2 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.**

External Laser Trigger Switch

The Laser Activation Port Connector 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, to provide the maximum protection against electrostatic discharge (ESD), you should consider the following:

- 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.

6.4 Gamma Radiation Hardening

The Vega ST model is available in a radiation robust variant that is suited for use in radiation oncology environments. Hardening of the Vega ST Position Sensor against gamma and neutron radiation is achieved by a shielded processor and modified memory management.

Do not use the Position Sensor in an x-ray, proton radiation, or MRI environment without first determining the performance, including accuracy, of the Position Sensor in these environments. NDI has not validated the Position Sensor in these environments.

6.5 Serial Interface

The Vega ST Position Sensor is available with an optional LEMO connector to support serial communications between the Position Sensor and host computer.

For detailed information about the serial interface, see “Serial Communications” on page 70.

6.6 Bump Sensor

All Vega Position Sensors contain 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 50 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 persists until the bump is cleared.
- The “bump detected” bit in the `Info.Status.Alerts` user parameter is set. This bit persists until the bump is cleared.
- The “bump detected” bit in the `Info.Status.New Alerts` user parameter and the “diagnostic pending” bit in the TX and BX responses are set to indicate a new alert. When the `Info.Status.New Alerts` parameter is read, the “bump detected” bit is cleared.
- The API command BX2 will report transformations but will also include a System Alert component with data to indicate the cause of the alert.
- By default, the API commands TX and BX will not report transformations if a bump is detected. Use the reply option 0x0800 to over-ride this behaviour.
- 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.

Note **For details on user parameters and API commands, see the “*Polaris Vega Application Programming Interface Guide*”.**

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. For instructions, see the "*NDI ToolBox online help"*.
- 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". For details, see the *"Polaris Vega Application Programming Interface Guide*".

Bump Sensor Battery

The bump sensor functions even when the Polaris Vega System is powered off. When the system is powered on, the bump sensor circuit draws its power, through the system, from the external power supply. When the system is not powered on, the bump sensor draws its power from an internal, rechargeable battery. The battery also powers the system's real-time clock.

- If the bump sensor has not been triggered, a fully charged battery will power the bump sensor and real-time clock for approximately two years.
- If the bump sensor has been triggered, the battery will power the sensor and clock for approximately two months.
- The battery reaches full charge when the Position Sensor is powered on for more than 12 hours.

When the battery is drained where it is unable to power the bump detector and real-time clock, the bump detector no longer functions, the real-time clock loses its setting, and the system reports a low-battery status.

If the battery can no longer power the bump sensor, the system will report a bump every time it disconnected from the external power. This persists until the battery is recharged and the bump is cleared.

After the battery is recharged, NDI recommends that you perform an accuracy assessment with the NDI Accuracy Assessment Kit (AAK) to ensure that the Position Sensor is still calibrated. If the system passes the AAK threshold, you can clear the bump alert.

To reset the real-time clock after the battery is charged, use one of the following methods:

- Use the ToolBox Configure utility to enter to correct date and time. The **Clock** option is available under the **Position Sensor Settings and Options** node.
- Use the API command SET to set the value of the user parameter `Param.Clock.Date Time`.

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

6.7 System Watchdog

The Polaris Vega Position Sensor is equipped with a system watchdog that monitors its operation. In the case of a system malfunction (hardware or firmware), the system watchdog will force the Position Sensor to restart. After restarting, the system will need to be reconfigured (tool definition files loaded, etc.) before tracking can resume. It is up to the host application to reconfigure the system automatically.

The system watchdog will write an entry to the event log before restarting the system.

Repeated restarts initiated by the system watchdog indicate there is an issue within the system that should be investigated. The exception to this rule is if the system is used in an environment that has a high level of gamma and neutron radiation. In such an environment, radiation-induced bit-flips (soft-errors) can cause the system to temporarily malfunction. The restart ensures the system is returned to a known ‘good state’.

For a description of the option available for Position Sensors that will be used in gamma and neutron radiation environments, see “Gamma Radiation Hardening” on page 54. This option reduces the risk of restarts during use.

6.8 Multi Firmware

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 more information on user parameters and API commands, see the “*Polaris Vega Application Programming Interface Guide*”.

6.9 Data Averaging

Data averaging is available in combination with the BX2 command. Data averaging allows the user to trade data reporting frequency for a reduction in position jitter (noise). Data averaging is available for all Vega systems, but is most useful with the higher frame rate available on Vega XT.

Data averaging is disabled by default, but can be enabled and configured through user parameters. For more information, see the “*Polaris Vega Application Programming Interface Guide*”.

7 Video Camera

The “live view” video camera that is integrated into the Vega VT Position Sensor is used for capturing a video stream of the Vega measurement volume.

The video camera streams data using the RTSP protocol. As such, any third-party media player that supports this protocol can be used to display the stream from the video camera.

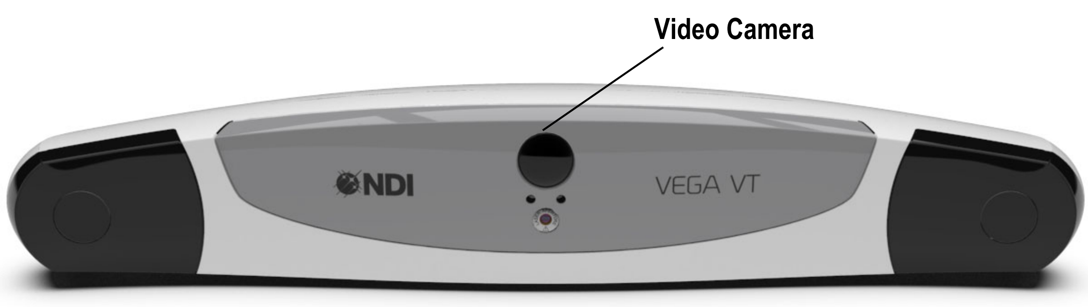
The video camera is fixed focus, with the point of focus being 2.5 m from the center of the Position Sensor. The focal length of the camera is 4.35 mm. For details on the field of view for each resolution supported by the camera, see Table 7-1.

The video output from the camera is provided in standard video format. The lowest available resolution is 1024 x 768 at 47fps (maximum) and the maximum resolution is 2048 x 1536 at 20fps (maximum).

Table 7-1 Video Camera Field of View

Resolution	Horizontal Field of View	Vertical Field of View
2048 x 1536, 1024 x 768	54.8°	42.5°
1920 x 1088	51.8°	30.6°

Figure 7-1 Vega Video Camera - Front View



7.1 Getting Started with the Video Camera

The simplest way to view and configure the stream from the Vega video camera is to use the NDI ToolBox Video Client utility. Follow the steps below to view the video stream:

1. Install NDI ToolBox, as described in “Install NDI ToolBox” on page 18. During the installation, select the option to install GStreamer.
2. Set up and connect the hardware, as described in “Connecting the Hardware” on page 16.
3. Open the NDI ToolBox Video Client utility.
4. To connect to the Position Sensor that contains the video camera you wish to stream from, select **File> Connect to**, then select the Vega Position Sensor of interest from the list.

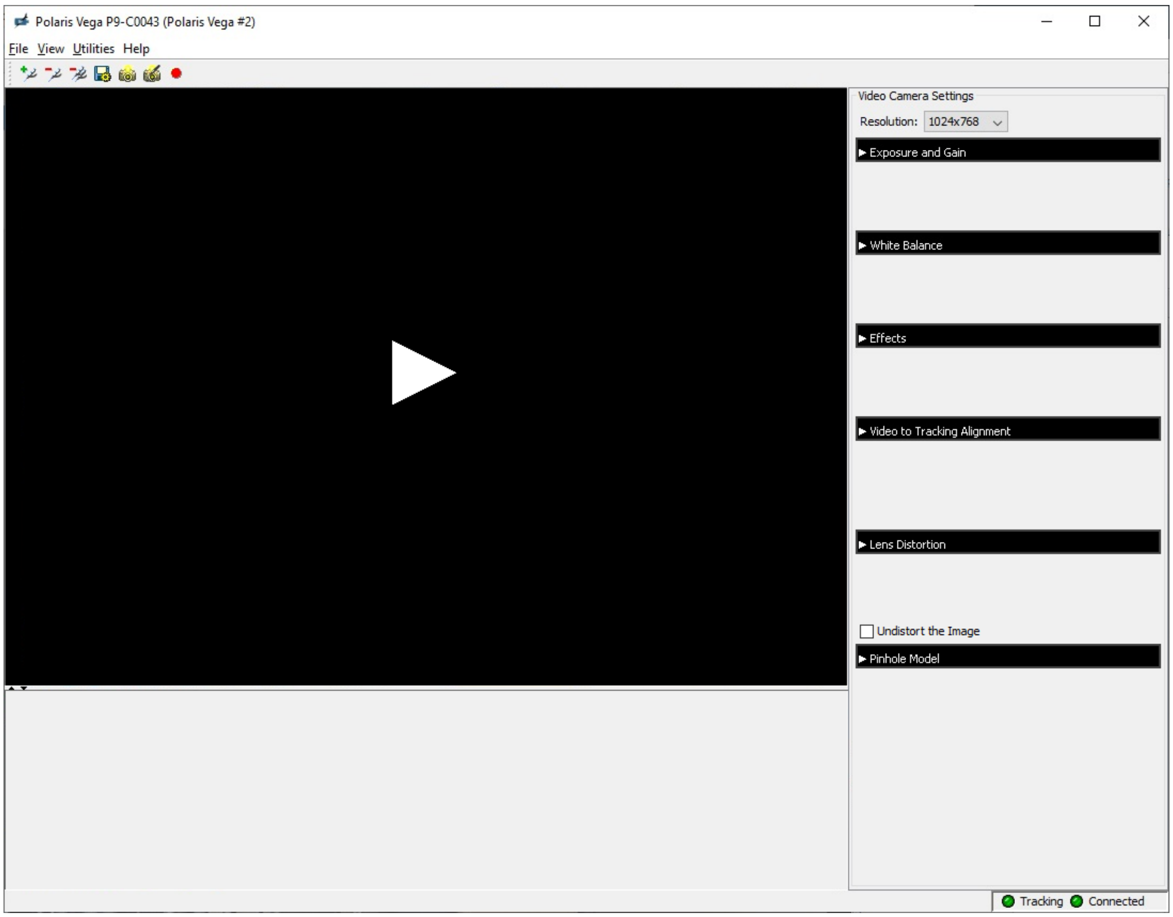
The Video Client utility will display the stream from the video camera.

- To pause streaming, hover the mouse over the video stream display area and click the **Pause** button that is displayed.

- To resume streaming, hover over the same area and press the **Play** button that is displayed.

Figure 7-2 below shows the main window of the Video Client utility when streaming is paused. Any tools that are being tracked will be displayed under the video stream display area.

Figure 7-2 ToolBox Video Client Utility - Main Window



You can use the **Video Camera Settings** panel on the right side of the utility to adjust different aspects of the video stream. For information on the video camera settings you might want to adjust when first using the video camera in your environment, see "Common Adjustments" on page 59.

The toolbar above the video stream display area allows you to perform different functions, such as taking a snapshot of the video stream and recording the video stream to a file. For more information on these and other functions available in the Video Client utility toolbar, see the *"ToolBox online help*".

7.2 Common Adjustments

This section describes some common adjustments you might use to optimize the appearance of the video camera output in your environment, including the following:

- "Resolution" on page 60
- "Frame Rate" on page 60
- "Image Brightness" on page 60

- "Saturation" on page 61
- "White Balance" on page 61
- "Streaming Latency" on page 61

Resolution

The video camera supports three different resolutions. The higher the resolution, the lower the frames per second. Supported resolutions are as follows:

- 1024 x 768 at 14 to 47 fps
- 1920 x 1088 at 11 to 30 fps
- 2048 x 1536 at 10 to 20 fps

Select the **Resolution** drop-down and choose a resolution. You can only change the resolution when not streaming.

Frame Rate

The frame rate can be adjusted within the range specified by the resolution. This setting can reduce flicker caused by lighting. For example, if the light source is running at 50 Hz, and the exposure time is short (as it usually would be in a bright scene), you may notice that the image will flicker at a constant rate. Adjusting the frame rate from 30 Hz to 25 Hz will mitigate this issue because 50 is an even multiple of 25.

Additionally, lowering the frame rate allows for longer exposure times, which can produce better images of static scenes - they are typically less noisy than those that rely on the gain.

To change the frame rate for the video camera, you can use the NDI ToolBox Configure utility, or you can use the Polaris Vega API to set the value for the `Param.Frame Rate` video camera user parameter. For more information, see "Using the ToolBox Configure Utility" on page 62 or "Using the Polaris Vega Application Programming Interface" on page 63.

Image Brightness

The **Exposure and Gain** settings allow you to adjust image brightness.

1. Start streaming from the video camera so you can see the effects of your adjustments.
2. Expand the **Exposure and Gain** menu.
3. Enable **Automatic Exposure and Gain**.
4. Adjust the **Brightness Target** slider to achieve optimal brightness.

You can also select a different **Metering** mode depending on your environment.

- General scenes can usually use the **Center Weighted** mode.
- Backlit scenes should use the **Segmented** mode.
- Spotlighted scenes such as an operating room with a particularly bright area should use the **Spotlight** mode.

- The **Weighted ROI** mode uses a selected zone in the image area to adjust the brightness. To view the zone, select the **Display ROI** option. To select a different zone, click **Define ROI** then click and drag a rectangle over the desired zone in the video stream display area.

5. Adjust the **Maximum Exposure** slider to the highest setting to prevent motion blur.

Saturation

High contrast, highly saturated images can be improved by increasing the gamma correction value.

1. Start streaming from the video camera so you can see the effects of your adjustments.
2. Expand the **Effects** menu.
3. In the **Gamma Mode** drop-down, select **User Defined** or **User Defined - Enhanced**.
4. Use the **Gamma** slider to increase the gamma correction value. This will reduce the amount of saturation in the image.

White Balance

The White Balance settings adjust the colour gains and offset to achieve a realistic colour video. When **Automatic White Balance** is enabled, the algorithm adjusts the red and blue gains to try to maintain an image with equal amounts of red, green and blue.

To adjust the colour balance:

1. Start streaming from the video camera so you can see the effects of your adjustments.
2. Expand the **White Balance** menu.
3. Select the **Automatic** option.
4. Adjust the **Blue Green Factor** and **Red Green Factor** sliders to achieve optimal colour balance.

Streaming Latency

There are several steps that can be taken to reduce the latency of the video stream.

On the computer running the streaming client,

- Install a high quality, high-speed (gigabit) network interface card.
- Install a high-speed video card.
- Increase the CPU power.
- Increase the priority of the application that is processing the video. In Windows, for example, this is done in the Task Manager.
- Select a lower image resolution. A resolution of 1024x768 offers the lowest latency.
- Increase noise filtering to reduce the amount of transmitted image data (at the expense of fine detail).

The network setup can also affect the latency of the video stream. The lowest latency configuration is a direct connection between the Vega Position Sensor and the client computer. Connecting the

Position Sensor to the client computer via network switch or hub may increase latency, depending on the amount of traffic on the network.

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

Performance of the video camera is highly dependent on network throughput. Devices that can reduce this throughput (e.g. Ethernet to USB converter) should be avoided.

7.3 Configuring the Video Camera

In addition to using the NDI ToolBox Video Client utility to configure the video camera, you can use the NDI Toolbox Configure utility or the Polaris Vega Application Programming Interface. See the following sections:

- "Using the ToolBox Configure Utility" on page 62
- "Using the Polaris Vega Application Programming Interface" on page 63

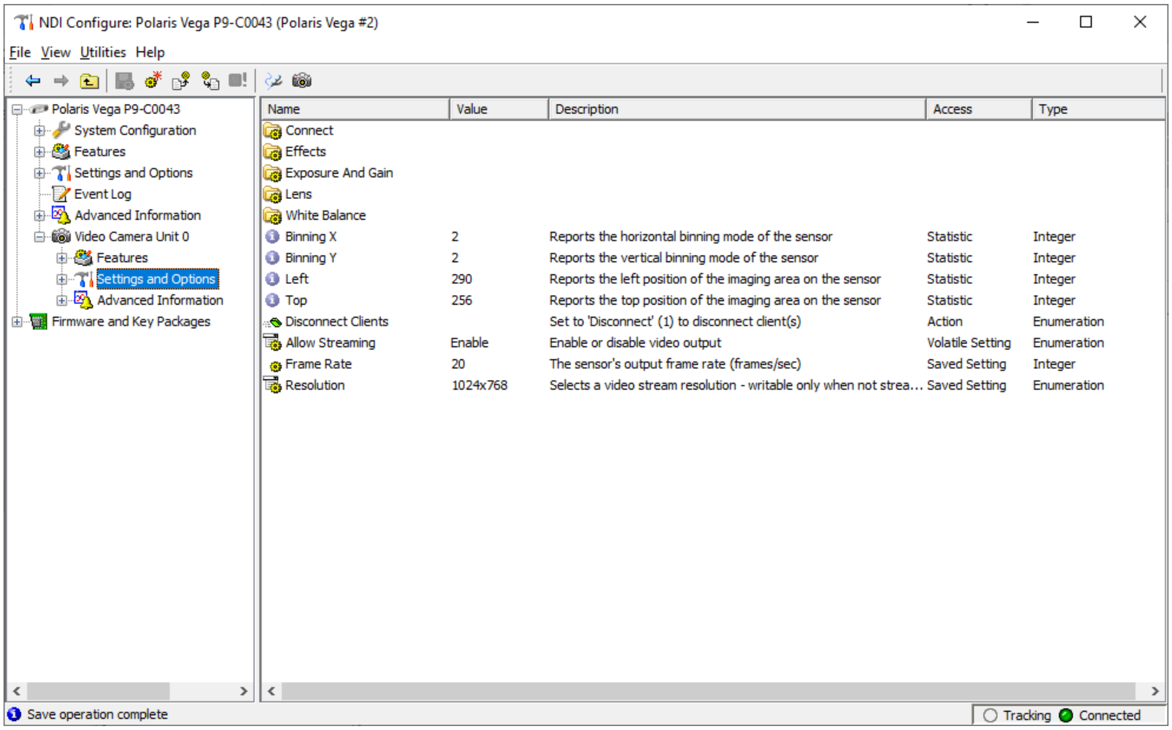
Using the ToolBox Configure Utility

The NDI ToolBox Configure utility displays system information and controls the setting of video camera parameters and options.

1. Open the NDI ToolBox Configure utility.
2. To connect to the Position Sensor that contains the video camera you wish to work with, select **File> Connect to**, then select the Vega Position Sensor of interest from the list.
3. In the panel on the left of the Configure utility, expand the **Polaris Vega** node, then the **Video Camera** node**.**
4. Select **Settings and Options**.

5. In the panel on the right, use the various settings to adjust the configuration of the video camera for your environment. See Figure 7-3.

Figure 7-3 Video Camera Settings in the ToolBox Configure Utility



Using the Polaris Vega Application Programming Interface

The Polaris Vega Application Programming Interface (API) allows you to configure the Vega video camera parameters.

The method for setting and getting parameters for the video camera depends on whether the communication with the video camera is performed through the Position Sensor (proxying) or via a direct connection to the video camera. For information on changing this setting, see “Connecting to the Video Camera” on page 64.

If the connection is through the Position Sensor, prefix all parameter names with "VCU-0.". If a direct connection is used, this prefix can be omitted.

Table 7-2 Video Camera API Commands

Action	API Command
Set a parameter via the Position Sensor	`SET VCU-0.<parameter name>`
Get a parameter via the Position Sensor	`GET VCU-0.<parameter name>`

Table 7-2 Video Camera API Commands

Action	API Command
Retrieve all video camera parameters via the Position Sensor, including details	`GETINFO VCU-0.*`
Default all video camera parameters via the Position Sensor	`DFLT VCU-0.*`

Note **If you have adjusted video camera parameters, you can use the INIT command to reset the parameters to their saved values. This will also close any currently streaming video connections.**

For detailed information on the video camera parameters, see the *"Polaris Vega Application Programming Interface Guide"*.

7.4 Connecting to the Video Camera

There are two ways to connect to the video camera, through the Position Sensor or directly to the video camera. When you connect through the Position Sensor, only one connected application can change parameter values for the video camera. If you want to change the parameter values for the video camera with a different application, then you need to enable the direct connection to the video camera and use that connection for setting video camera parameter values.

- When Direct Connection is **Disabled**, connection to the video camera is through the Position Sensor via port 8765. This is the default setting.
- When Direct Connection is **Enabled**, the connection is directly to the video camera, via port 8766.
- Streaming is always via port 554.

Note **The instructions in this guide assume the connection to the video camera is through the Position Sensor. If you connect directly to the video camera instead, you will need to adjust the instructions accordingly.**

You can use the ToolBox Configure utility or Polaris Vega API to change the Direct Connection setting.

1. In the ToolBox Configure utility, connect to the desired Position Sensor.
2. In the panel on the left of the Configure utility, expand the **Polaris Vega** node, then select **Settings and Options**.
3. Click the **Video Camera** folder.
4. In the panel on the right, change the value for **Direct Connection** to **Enabled** or **Disabled**.
5. Save the change, restart the system, then reconnect to the video camera.

For information on changing the value of the parameter `Param.Video Camera.Direct Connection` via the API, see the *"Polaris Vega Application Programming Interface Guide"*.

When you configure the video camera for a direct connection, it is listed as a separate device in the **Connect to** menu of the NDI ToolBox utilities and is identified by its serial number and the suffix "VCU", for "Video Camera Unit".

7.5 Using Different Streaming Clients

The video camera streams data using the RTSP protocol. As such, any third-party media player that supports this protocol can be used to display the stream from the video camera.

Note **The Vega video camera can support one streaming connection at a time.**

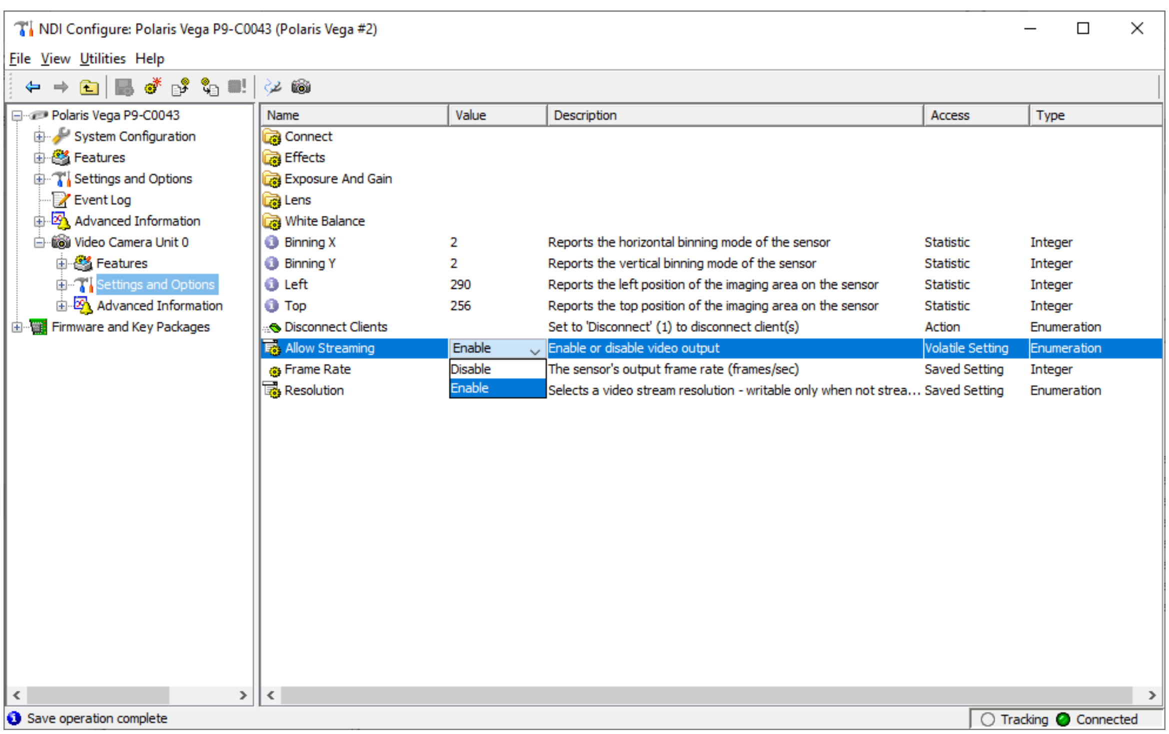
Enable Streaming

The ToolBox Video Client utility automatically enables streaming from the video camera. In order to prevent unauthorized access to video data from third parties, streaming must be explicitly enabled when using any other client. Without streaming enabled any connection attempt to port 554 will fail.

Use ToolBox to enable streaming as follows:

1. Start the NDI ToolBox Configure utility.
2. In the panel on the left of the Configure utility, expand the **Polaris Vega** node, then the **Video Camera** node**.**
3. Select **Settings and Options**.
4. Set the **Allow Streaming** option to **Enabled**. See Figure 7-4.

Figure 7-4 Enable Video Streaming with ToolBox



Find the Video Stream URL

To establish a connection between the video camera and the media player, you usually provide a URL of the following structure: rtsp://hostname.local:554/video or rtsp://IP Address:554/video.

To retrieve the IP address for use in the URL, follow the procedure detailed below.

1. In the NDI ToolBox Configure utility, navigate to **File> Connect to**.
2. Hover over the Vega Position Sensor in the list and make note of the IP address that is displayed.

Note **To allow video streaming to the computer running the media player, you may need to configure the computer's firewall to allow UDP traffic on ports 30000-30500 and TCP/UDP traffic on port 554. Contact your network administrator for details.**

Stream with GStreamer

GStreamer is a framework for creating streaming media applications that is freely available and recommended by NDI because it does not introduce significant latency.

Note **The Vega video camera was tested by NDI with GStreamer version 1.12.1 with the libav wrapper installed.**

GStreamer provides a library that can be used to process the video coming from the Vega video camera. To use the library from the command line, you must use the gst-launch-1.0.exe application and construct command line arguments that can communicate with the video camera (rtspsrc), decode and decompress the video data (rtph264depay, avdec_h264) and display it on the screen (autovideosink). Each processing element is delimited by an exclamation point (!) and can be configured using its available properties (e.g. latency is a property of rtspsrc).

The line below is the structure to use to display live video on your screen:

```
gst-launch-1.0.exe rtspsrc location=rtsp://[IP Address/hostname.local or IP
address of Position Sensor]:554/video latency=1 protocols=1 drop-on-latency=true
do-retransmission=false udp-reconnect=false ! rtph264depay ! avdec_h264 ! queue !
autovideosink sync=false
```

Following is specific example of the command:

```
gst-launch-1.0.exe rtspsrc location=rtsp://192.168.1.186:554/video latency=1
protocols=1 drop-on-latency=true do-retransmission=false udp-reconnect=false !
rtph264depay! avdec_h264 ! queue ! autovideosink sync=false
```

Note **This example uses the IP address of the Position Sensor (192.168.1.186:554). You can use the host name instead. For example, P9-C0043.local:554.**

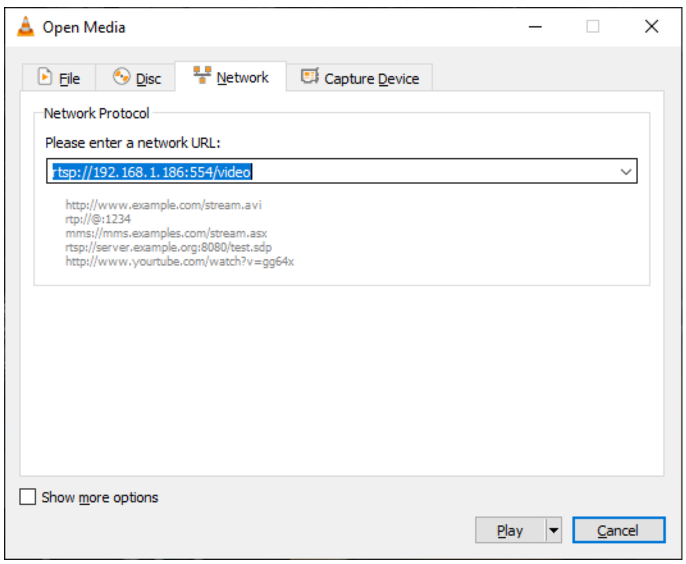
Stream with VLC

VLC is a simple, freely-available media player. However, it internally buffers the video data before displaying it on the screen, which adds significant latency to the video display. NDI recommends GStreamer or the NDI ToolBox Video Client utility over VLC.

After you have downloaded and installed VLC, establish streaming as follows:

1. In the VLC main window, select **Media> Open Network Stream**.
2. In the **Open Media** dialog, on the **Network** tab, type the URL as described on page 66. See the example in Figure 7-5.
3. Click **Play**.

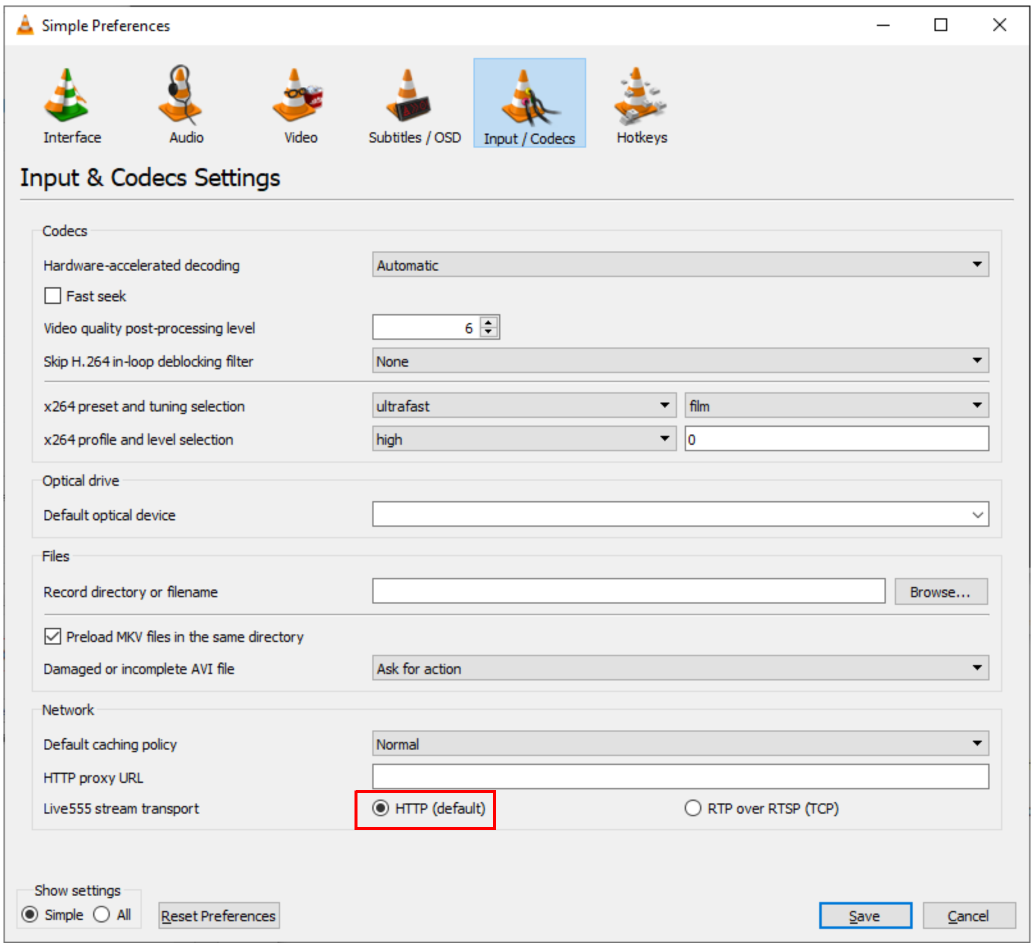
Figure 7-5 VLC Open Media Dialog



If you encounter errors when trying to stream to the VLC media player, you may need to configure VLC as follows.

1. In the VLC main window, select **Tools> Preferences** then click **Input/Codecs**.
2. At the bottom of the screen, choose the **HTTP** option. See Figure 7-6.

Figure 7-6 VLC Configuration

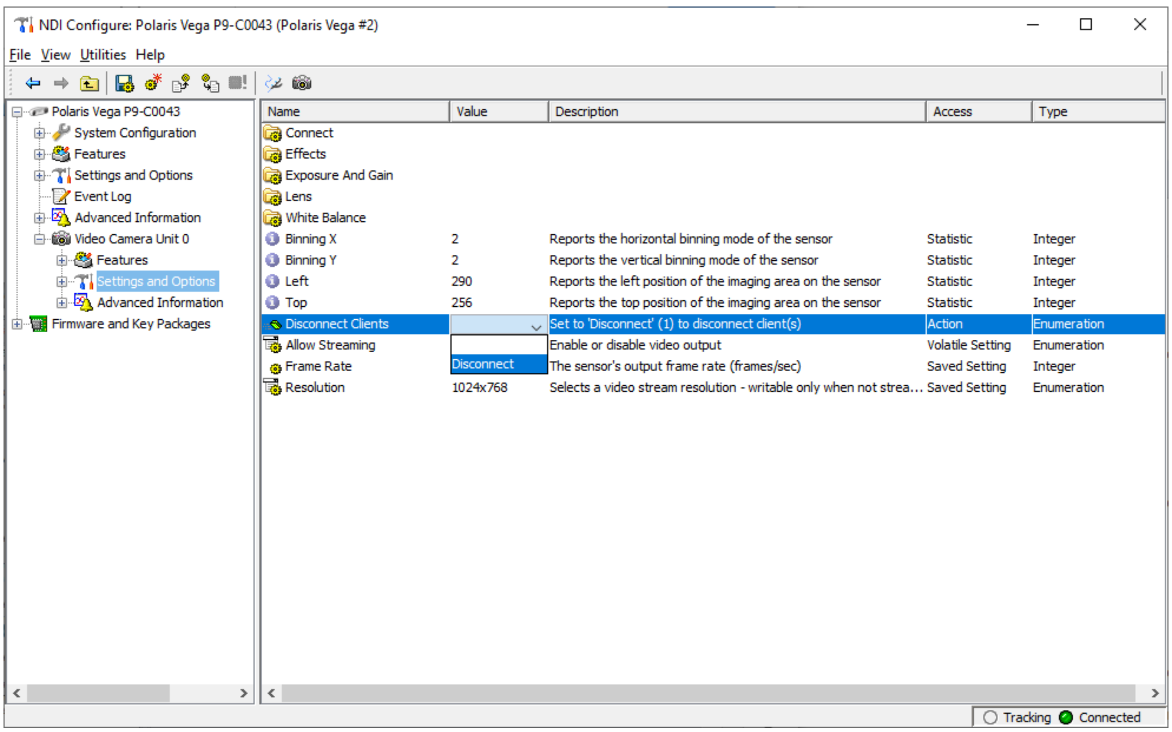


Disconnect Streaming Clients

To force a streaming client to disconnect from the video stream, use the **Disconnect Clients** setting.

1. Start the NDI ToolBox Configure utility.
2. In the panel on the left of the Configure utility, expand the **Polaris Vega** node, then the **Video Camera** node**.**
3. Select **Settings and Options**.
4. Set the **Disconnect Clients** option to **Disconnect**. See Figure 7-7.

Figure 7-7 Toolbox Setting: Disconnect Clients

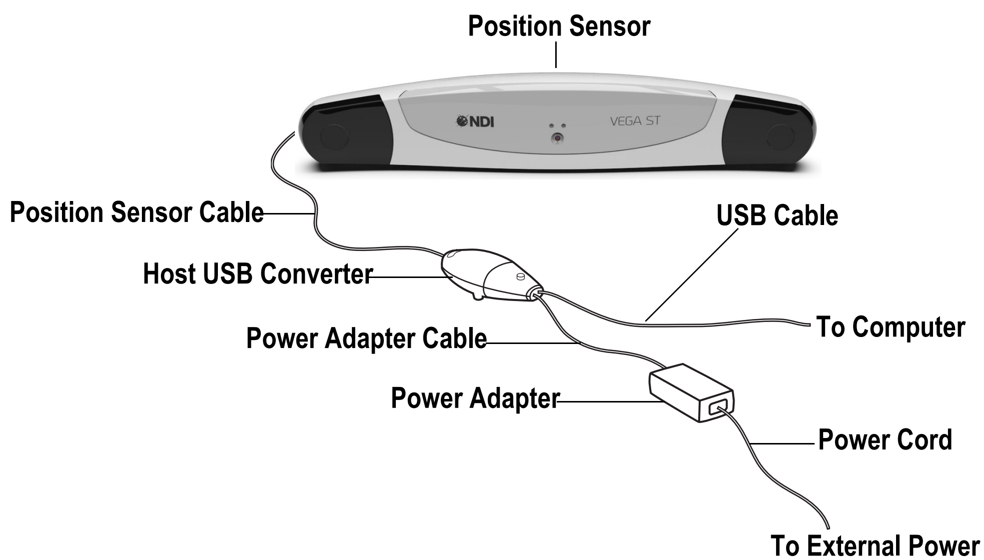


8 Serial Communications

The Vega ST Position Sensor is available with an optional LEMO connector to support serial communications between the Position Sensor and host computer. This option is only recommended for customers that are migrating from Polaris Spectra to Polaris Vega. It is not recommended for new designs.

Contact NDI if you have questions regarding communication interfaces. See “Contact Information” on page ix.

Figure 8-1 Serial Connection



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

LEMO Connector

The LEMO connector is a 14-pin connector that provides power to the Position Sensor and allows communications to and from the Position Sensor. The LEMO connector is located on the back of the Position Sensor. The connector details, internal to the Position Sensor, are shown in Figure 8-2 and Table 8-1.

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

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

Any unused contacts can be left floating.

Figure 8-2 Position Sensor Connector Layout

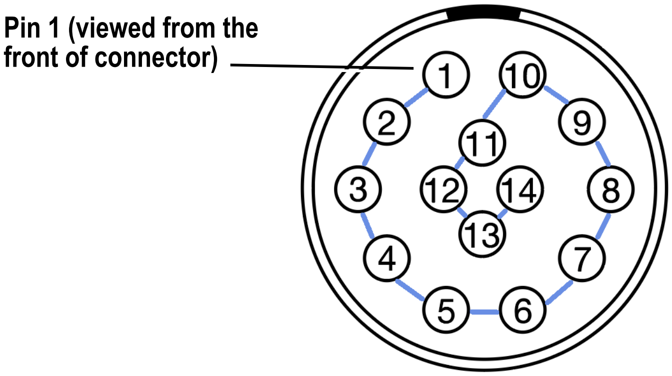


Table 8-1 Position Sensor Connector - Signals

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

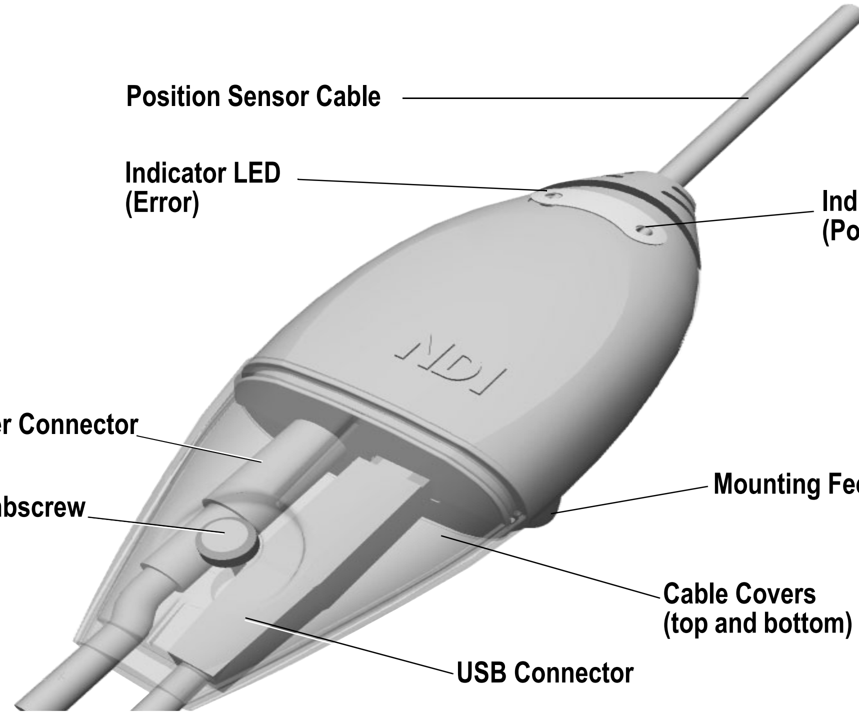
Host USB Converter

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

- The attached Position Sensor cable connects the Host USB Converter to the Position Sensor.
- The power adapter and USB cable plug into the Host USB Converter.

- Modem status bits are provided (see “Serial Port Emulation” on page 74).

Figure 8-3 Host USB Converter



The Host USB Converter incorporates the following components:

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

Position Sensor Cable: Provides connection for data and power between the Position Sensor and Host USB Converter. This cable is permanently connected to the Host USB Converter and is available in various lengths to a maximum of 15 m, depending on the configuration of your system.

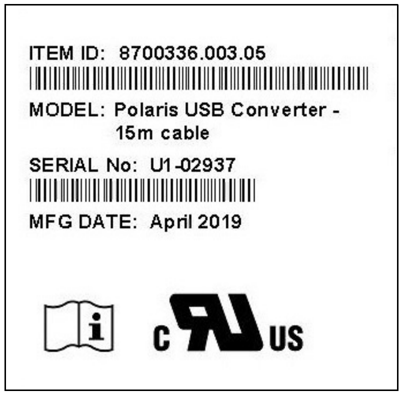
Power Indicator: Lights green when power is being supplied to the Host USB Converter.

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

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

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

Figure 8-4 Host USB Converter Serial Number Label

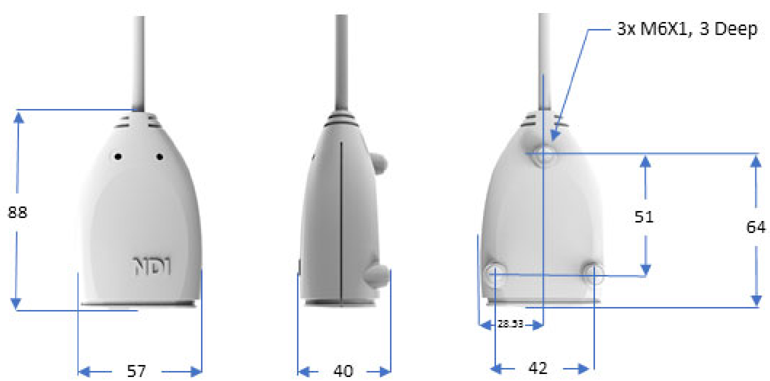


The Host USB Converter can be free-standing or can be mounted via M6 x 1 mm pitch x 3 mm deep threaded holes located in the three mounting feet. Figure 8-5 shows the Host USB Converter dimensions and mounting arrangement.

Note **Before you design a custom enclosure or any attachments for the Host USB Converter, contact NDI for assistance. See "Contact Information" on page ix.**

Figure 8-5 below is provided for information purposes only and dimensions are subject to change without notice.

Figure 8-5 Host USB Converter Mounting Details



All dimensions in mm

If the Host USB Converter is located within the patient vicinity where it may be touched by the patient, the operating ambient temperature range is +10°C to +30°C. If the Host USB Converter is located outside this patient vicinity, the operating ambient temperature range permitted for the system is +10°C to +40°C.

Serial Port Emulation

Modem Status Bits The Host USB Converter emulates a standard PC serial port, such that the host application may communicate with the Polaris Vega System as if it was a standard RS-422 device. A feature of this is that the following modem status bits are used as follows:

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

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

Power Adapter

The system is powered by an NDI-supplied power adapter: Advanced Power Systems, part number APS49EMG-24021-7/Hitron, part number HEMG49-S240210-7 - applicable to IEC 60601-1 2nd Edition and 3rd Edition.

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

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

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

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

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

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

If a non-NDI supplied power adapter is used, it should be chosen to suit the particular use and the resulting system configuration must be verified for electrical safety by an approved test laboratory. For more information, contact NDI. See **"Contact Information" on page ix****.**

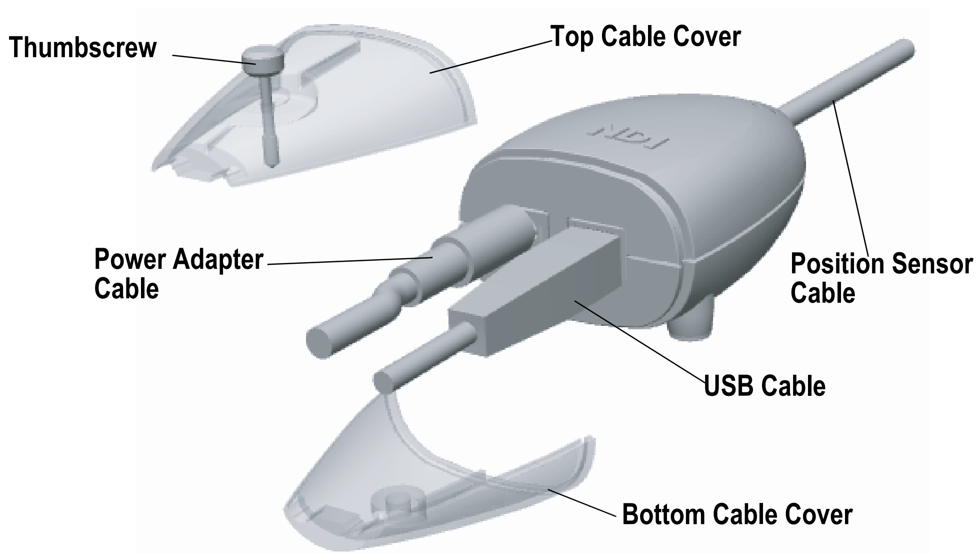
8.1 Setting up for Serial Communications

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

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

2. Connect the USB cable B plug and power adapter cable to the Host USB Converter, as shown in Figure 8-6.
3. Locate the top and bottom cable covers in place on the Host USB Converter. Secure the covers with the thumbscrew, as shown in Figure 8-6.

Figure 8-6 Host USB Converter Connecting the Cables



4. Plug the USB cable A plug into the host computer.
5. Make sure all the cables are connected firmly, and placed where they will not be stressed, stepped on, or bent.
6. Plug the power cable into the power adapter.
7. Plug the power cable into the external power supply and turn on the power.

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

8.2 Installing Host USB Drivers

If you are using the Host USB Converter for serial communications between the Position Sensor and host computer, you must install USB drivers on the host computer.

Follow one of the operating-system specific procedures below to install the drivers:

- "Install on Windows" on page 76
- "Install on Linux" on page 77
- "Install on macOS" on page 78

Install on Windows

About the Drivers

The Windows driver model consists of two parts: low-level USB and high-level virtual serial port. It appears as a Windows serial port, COMx (where x is enumerated), and emulates a standard PC serial port such that the Host USB Converter may be communicated with as a standard RS-422 device.

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

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

Driver Location

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

You can also download the drivers from the NDI Support Site at https://support.ndigital.com.

Installation

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

1. Start the **Device Manager**. In Windows 10, click the **Search** icon in the Windows task bar and begin typing "Device Manager". When it appears in the list of matches to your search term, select the **Device Manager (Control Panel)** item.
2. Under **Other Devices**, right-click **NDI Host USB Converter**.
3. Select **Update Driver Software...**, then select **Browse my computer for driver software**.
4. Perform one of the following actions:
    - Navigate to where you saved the downloaded driver.
    - Navigate to **Program Files\Northern Digital Inc\ToolBox\USB Driver**.
5. Click **Next**.
6. In the Windows security dialog, select **Install this driver software anyway**. The first set of drivers will install.

7. After the first set of drivers are installed, browse to **Other Devices** and right-click **USB Serial Port**.
8. Select **Update Driver Software...**, then select **Browse my computer for driver software**.
9. Select **Program Files\Northern Digital Inc\ToolBox\USB Driver**. Select **Next**.
10. In the Windows security dialog, select **Install this driver software anyway**. The second set of drivers will install.

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

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

Reassign the Windows COM Number

If necessary, after the Host USB Converter drivers have been installed, you can reassign the Windows COM number.

1. Start the **Device Manager**.
2. Navigate to **Ports (COM & LPT)**.
3. Right-click the Host USB Converter.
4. Click **Properties**.
5. Click the **Port Settings** tab.
6. Click the **Advanced Settings** button.
7. In the dialog, select the **Com Port Number** drop-down field.
8. Reassign the COM port as necessary.
9. Click **OK**.

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

Install on Linux

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

Kernel versions 2.6.32 and later automatically recognize the NDI devices.

Note **The Host USB Converter, when connected, will appear as "/dev/ttyUSBx", where x is the port number.**

If you plan to access the Polaris Vega from a non-root user account, you must add the user account to the "lock" group. It may also be necessary to add the user account to the following groups:

- uucp
- tty

- dialout

This can be done only as root user with the command “usermod –G <group> <account name>”. For the changes to take effect, log out and log in again.

Install on macOS

This file is also placed in the ToolBox installation folder during ToolBox installation.

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

1. Perform one of the following actions:
   - Navigate to where you saved the downloaded driver.
   - Navigate to the Toolbox folder.
2. Double-click **FTDIUSBSerialDriver (NDI).pkg**.
3. Follow the on-screen instructions.

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

Modified FTDI USB to Serial Driver

If you have other devices, such as a USB to serial port converter, that also use a FTDI VCP driver, if you install the driver from NDI, you may:

- change the version of the driver previously installed
- possibly disable access to your other devices

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

8.3 Connecting to a System Using Serial Communications

Windows Select **File > Connect to > (COMx)**

Linux Select **File > Connect to > (/dev/ttyUSBx)**

Mac connect to the system using either:

/dev/cu.usbserial-xxxxxxxx

or

/dev/tty.usbserial-xxxxxxxx

9 Maintenance

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

- Cleaning the Position Sensor
- Cleaning the Video Camera
- Disposal of equipment

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

Maintenance Warnings

Before performing 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. Inaccurate conclusions may result in personal injury.

9.1 Cleaning the Position Sensor

Inspect the Position Sensor regularly 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 isopropanol solution and the Position Sensor.

9.2 Cleaning the Video Camera

To clean the video camera window, follow the procedure detailed below:

1. Use a photographic lens duster brush or an air puffing lens cleaner to gently remove any dust and particles from the window. Do not use pressurized air.
2. Use a clean, dry, microfibre lens cleaning cloth to remove fingerprints or other marks from the window. Wipe gently in a circular motion over the window.
3. If necessary, wipe the window with 70% isopropanol solution and a lens cleaning cloth. Standard lens cleaning solution can also be used. The cloth should only be slightly damp, not wet.

Note **When wiping the window with a cloth or duster brush, use a circular motion and sweep up and away from the window to draw dust and debris out of the enclosure. Do not wipe dust, debris, or cleaning solution towards the edges of the window. An accumulation around the edges of the window can impact the quality of the image from the video camera. An air puffing lens cleaner is useful for removing dust and debris from the edges of the window.**

9.3 Disposal of Equipment

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

10 Setting the Infrared Light Sensitivity

10.1 Infrared Light Sensitivity Levels

The IR light sensitivity level determines how sensitive the Polaris Vega System is to IR light. There are three important terms that relate to Vega sensitivity levels:

- The **exposure time** is the time in which the Vega Position Sensor collects IR light.
- The **trigger threshold** is the minimum pixel intensity required for the system to detect a marker. To detect a marker, one or more pixels in the marker image must have intensities above this threshold.
- **Background IR light** is IR light that is not reflected (passive) or emitted (active) from a marker, but is detected by the 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 goal of the sensitivity level is to allow IR light from tool markers to be detected while eliminating background IR light. Changing the sensitivity level does not change the exposure time; therefore, the maximum IR light value does not change. However, changing the sensitivity level changes the trigger threshold and allows the Polaris Vega Position Sensor to ignore background IR light of lower intensity (as long as the background IR intensity is significantly lower than the marker intensity).

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.

For instructions on increasing and decreasing the sensitivity level, see "Changing the Sensitivity Level" on page 84.

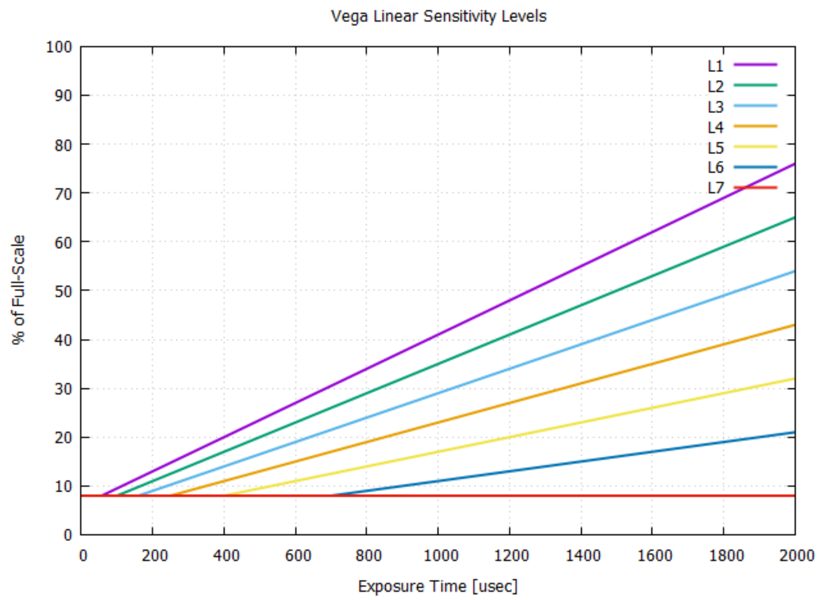
Note **If you have experience with Polaris Spectra systems, be aware that the meaning of the levels has changed. Higher levels in Vega mean higher sensitivity whereas for Spectra a higher level means lower sensitivity.**

Vega ST and VT Sensitivity Levels

The Vega ST and Vega VT Position Sensors implement variable exposure time. In these systems, the trigger threshold is implemented as a piecewise-linear function of exposure time, as shown in Figure 10-1. The Polaris Vega ST and VT Position Sensors continuously adjust the exposure time so that the intensities of the marker images are close to a predefined target value. Generally, markers are the brightest IR source in the scene. However, the Position Sensor may detect background IR light reflected from surgical tools or draping material which may interfere with the identification of markers.

The relationship between trigger threshold and exposure time for each sensitivity level is shown in Figure 10-1.

Figure 10-1 Vega ST and VT Sensitivity Levels



Vega XT Sensitivity Levels

Vega XT uses a fixed exposure time. Because of this, the trigger thresholds are constant for each sensitivity level. The relationship between trigger threshold and exposure time for each sensitivity level is shown in Table 10-1 on page 83.

Table 10-1 Vega XT Sensitivity Levels

Sensitivity Level	% of Full Scale
L1	55
L2	50
L3	45
L4	40
L5	35
L6	30
L7	25

10.2 Changing the Sensitivity Level

For most Vega applications and environments, there will be no need to change the sensitivity level from the default settings. If you experience IR interference problems, the first step is to attempt to remove the cause of the interference. You can use the NDI Capture ToolBox Utility to take images of the scene and identify sources of interference. If the interference cannot be removed from the scene, the NDI Capture ToolBox Utility can still be helpful to assess if changing the sensitivity level will yield a more reliable result. In general, changing the sensitivity level to a less sensitive level will only help in situations where the intensity of the interference is lower than that of the markers. If the intensity of the interference is similar to or higher in intensity than the markers, changing sensitivity levels cannot resolve the problem.

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 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. For details, see the "*Polaris Vega Application Programming Interface Guide*".

11 Calibration and Firmware

11.1 Checking the Calibration of the Polaris Vega System

The Position Sensor is calibrated at NDI using the methodology described in Appendix A. However, over time, the Position Sensor can 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 the Position Sensor is used in.

If the Position Sensor begins to lose calibration, it may lose the ability to track some tools before others. The various constraints used by the Polaris Vega System make certain tool designs more sensitive to loss of calibration than others. For example, if a tool has several similar segment lengths, similar angles between segments, or segment lengths similar to those of another tool, an out-of-calibration Position Sensor may not measure segment lengths as accurately and may not be able to determine which markers belong to which tool. In this case, the system reports the tools as missing. For details on segment lengths and angles, see “Marker Detection and Tool Tracking” on page 34.

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. For instructions on returning equipment to NDI, see “Return Procedure” on page 102.

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 50 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 55.

11.2 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 provides a fall-back if the main control firmware becomes unusable. For example, due to a failed firmware upgrade. 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. For details, see the *"ToolBox online help*".

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 Programming Interface Guide"* explains how to select a combined firmware revision using API commands.

12 Approvals

12.1 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 104.

12.2 Optical Radiation Safety

Position Sensor Illuminators

The Position Sensor has been assessed against the standards listed in the "Declaration of Conformity" on page 104 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 52.**

12.3 IEC 60601-1 recommendations for the 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.

The Polaris Vega System is a component intended to be used as a part of an end product Medical Electrical System. 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)

- Two (2) MOOP (Means of Operator Protection) are provided from AC input to output of the Power Injector, and one (1) MOOP is provided from AC input to Protective Earth (per Power Injector Certification).
- 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).
- The product is not suitable for use in the presence of a flammable anaesthetics mixture with air or oxygen or with nitrous oxide.

13 Classifications

Table 13-1 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 external power
Method of sterilization or disinfection	Not suitable for sterilization
Laser classification	Class 2
IRED illuminators risk group	Exempt

14 Technical Specifications

14.1 Operating Environmental Conditions

The Polaris Vega System (Position Sensor and cables) has been tested to function in the conditions listed in Table 14-1.

Table 14-1 Operating Environmental Conditions

Environmental Condition	Value
Atmospheric Pressure	70 kPa to 106 kPa
Relative Humidity	30% to 75%
Temperature	+10^{o}C to +35^{o}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 status LED will flash while the Position Sensor warms up; once the LED is steady, the system is ready for use.

14.2 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 14-2.

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

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 14-2 Transportation and Storage Environmental Conditions

Specification	Value
Atmospheric Pressure	50 kPa to 106 kPa
Relative Humidity	10% to 90% non-condensing
Temperature	-10^{o}C to +50^{o}C

14.3 Technical Specifications

Table 14-3 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
Power Requirement	Compatible with IEEE 802.3at Type 2**

*The weight of the Position Sensor when equipped with the radiation hardening feature is 2.15 kg +/- 0.15kg.

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

14.4 Mean Time Between Failures

The mean time between failures (MTBF) for the Polaris Vega Position Sensor is calculated at >100,000 hours. The MTBF drops by half for every l0°C increase in environmental temperature. Therefore, care must be taken to use the Polaris Vega Position Sensor within the recommended operating environmental conditions defined in this guide.

14.5 Shelf Life

The Vega Position Sensor contains a rechargeable battery that powers the bump sensor and real-time clock when the Position Sensor is not powered on. The Position Sensor cannot be used when the battery is drained.

- If a bump is triggered, a fully charged battery will power the bump sensor and clock for approximately two months before the battery is completely drained.
- If a bump is not triggered, a fully charged battery will power the bump sensor and clock for approximately two years before the battery is completely drained.

For details, see “Bump Sensor Battery” on page 56.

15 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 92. 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 overheat. 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 92
- “Guidance and Manufacturer's Declaration: Electromagnetic Emissions” on page 92
- “Guidance and Manufacturer’s Declaration: Electromagnetic Immunity” on page 93
- “Recommended Separation Distances” on page 95
- “Radio Frequency Emissions” on page 96

15.1 Cables and Accessories

Ethernet cables 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.

15.2 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 15-1 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.

Table 15-1 Manufacturer's Declaration for Electromagnetic Emissions

RF emissions CISPR11	Class A	The Polaris Vega System is suitable for use in all establishments other than domestic 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	

15.3 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 ensure that it is used in such an environment.

Table 15-2 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	External 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	External power quality should be that of a typical commercial or hospital environment.
	±2 kV line(s) to earth	±2 kV common mode	
Voltage dips (3), short interruptions (1), and voltage variations on power supply input lines (1) IEC 61000-4-11	0% U_T for 0.5 cycles (0º, 45º, 90º, 135º, 180º, 225º, 270º, 315º)	0% U_T for 0.5 cycles (0º, 45º, 90º, 135º, 180º, 225º, 270º, 315º)	External power quality should be that of a typical commercial or hospital environment. If the user of the Polaris Vega System requires continued operation during external power interruptions, it is recommended that the Polaris Vega System be powered from an uninterruptible power supply or a battery. U_T is the external power voltage prior to application of the test level.
	0% U_T for 1 cycle (0º)	0% U_T for 1 cycle (0º)	
	70% U_T (30% dip in U_T) for 25/30 cycles(0º)	70% U_T (30% dip in U_T) for 25/30 cycles(0º)	
	0% U_T for 250/300 cycles(0º)	0% U_T for 250/300 cycles(0º)	
	49 Hz & 61 Hz	49 Hz & 61 Hz	
Power frequency (50/60 Hz) magnetic field IEC 61000-4-8	30 A/m	30 A/m	Power frequency magnetic fields should be at levels characteristic of a typical location in a typical commercial or hospital environment.

Table 15-3 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	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. Recommended separation distance: $d = 1{,}2\sqrt{P}$ See Table 15-4 on page 95.
Radiated RF IEC 61000-4-3	3V/m, 80 - 2700 MHz, 1 kHz , 80% AM modulation	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 15-4 on page 95. 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.

15.4 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 15-4 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.

15.5 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 A

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.

16 Troubleshooting

16.1 Introduction

This section provides possible solutions to common problems and answers some frequently asked questions. For more 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. See “Contact Information” on page ix.

Most 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 be indicated by system LEDs or audio codes, as detailed in “LEDs” on page 98 and “Audio Codes” on page 99. 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 Programming Interface Guide*”.

16.2 LEDs

Position Sensor

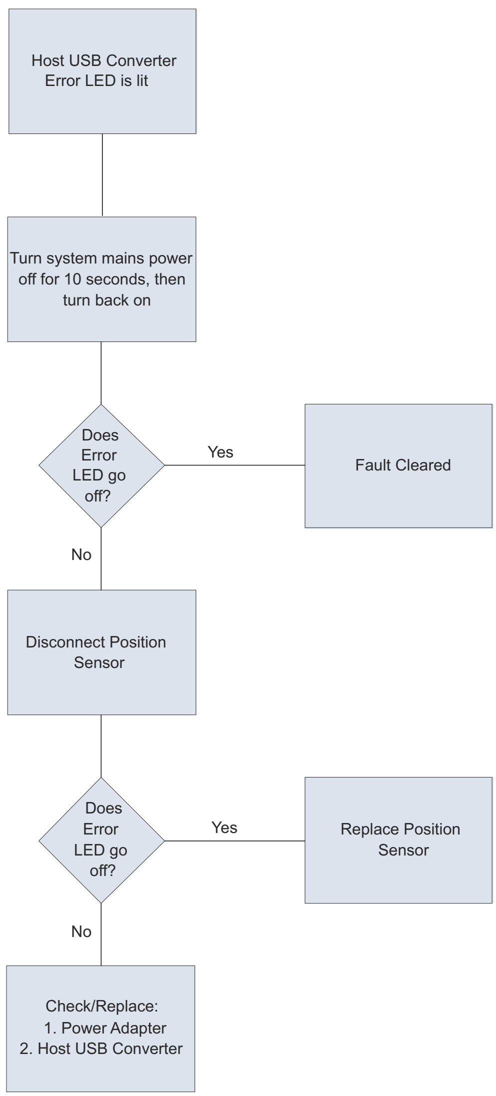
The power and error LEDs on the Position Sensor combine to indicate Position Sensor status. For more information on each status, see Table 1-1 on page 5.

Host USB Converter

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

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

Figure 16-1 Host USB Converter: Error LED Fault Chart



16.3 Audio Codes

The Position Sensor emits audio tones that provide an audible indication of system status, as listed in Table 16-1.

Table 16-1 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.

16.4 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, if a four-marker tool with its minimum number of markers parameter set to 4 has three markers inside the characterized measurement volume and one marker 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 tracks at the front of the measurement volume but not at the back, the Position Sensor may be damaged or may be calculating high line separation values. For more details on line separation, see “Marker Detection and Tool Tracking” on page 34. You can check the line separation values using the 3D command. For details, see the “*Polaris Vega Application Programming Interface Guide”*.

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. For details, contact NDI Technical Support or visit the support site at https://support.ndigital.com.

The 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. The various constraints used by the Polaris Vega System make certain tool designs more sensitive to loss of calibration than others.

For example, if a tool has several similar segment lengths, similar angles between segments, or 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 and will report the tools as missing. For details on segment lengths and angles, see “Marker Detection and Tool Tracking” on page 34. For more details about calibration, see “Checking the Calibration of the Polaris Vega System” on page 85.

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. For more information, see the “*Polaris Tool Design Guide*”.

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 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. For more details on tool design, see the “*Polaris Tool Design Guide*”.

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 makers has deteriorated (for instance, the markers are scuffed or occluded with foreign matter).

The Position Sensor seems too warm

The Position Sensor will be warm to the touch during normal use. If the temperature goes out of range, 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.

The Virtual Serial Port cannot be opened

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

17 Return Procedure and Warranty

17.1 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.

17.2 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).

18 Declaration of Conformity

NDI

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 7 day of June, 2019.

Northern Digital Inc.
per:

David Rath
President

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	
	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	Class A, Group 1 - Industrial, Scientific and Medical Equipment.
	FCC Title 47 CFR, Part 15	Class A - Unintentional Radiators
	ICES-003, Issue 6 (2016)	Class A - 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	Harmonic Current Emissions
	EN 61000-3-3:2013 / IEC 61000-3-3:2013	Voltage Fluctuations & Flicker
	EN 61000-4-2:2009 / IEC 61000-4-2:2008	ESD Immunity
	EN 61000-4-3:2006 +A1:2008 +A2:2010 / IEC 61000-4-3:2006 +A1:2007 +A2:2010	Electric Field Immunity
	EN 61000-4-4:2012 / IEC 61000-4-4:2012	EFT/Burst Immunity
	EN 61000-4-5:2006 / IEC 61000-4-5:2005	Surge Immunity
	EN 61000-4-6:2013 / IEC 61000-4-6:2014	Conducted Immunity
	EN 61000-4-8:2010 / IEC 61000-4-8:2009	Magnetic Field Immunity
	EN 61000-4-11:2004 / IEC 61000-4-11:2004	Dips, Interruptions & Variations Immunity
	JIS 0601-1-2:2002	

19 Abbreviations and Acronyms

Acronym or Abbreviation	Definition
5DOF	5 Degrees Of Freedom
6DOF	6 Degrees Of Freedom
AAK	Accuracy Assessment Kit
API	Application Programming Interface
CAPI	Combined Application Programming 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
IRED	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
PSU	Position Sensor Unit
PTP	Precision Time Protocol
RAM	Random Access Memory
RF	Radio Frequency
RGB	Red Green Blue
RI	Ring Indicator
RMA	Return Materials Authorization
RMS	Root Mean Square
UDP	User Datagram Protocol
UL	Underwriters Laboratories Inc.
VCU	Video Camera Unit

20 Equipment Symbols

Table 20-1 Equipment Symbols

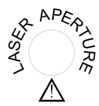
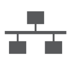
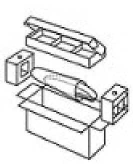
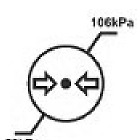
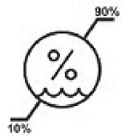
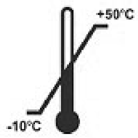
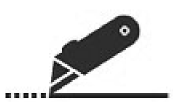
Symbol	Meaning	System Components
	Consult accompanying documents.	Position Sensor
	Laser Warning (To avoid personal injury, consult accompanying documents.)	Position Sensor
	Laser Aperture Caution (To avoid personal injury, consult accompanying documents.)	Position Sensor
I	On (power: connection to the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

Table 20-1 Equipment Symbols (Continued)

Symbol	Meaning	System Components
	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

21 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, warm-up, etc.) may cause the absolute measurement to change, even though the observed tool is physically not moving. NDI recommends using 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.

Frame Rate

The frame rate is the rate at which the system takes images of the measurement volume.

Global Coordinate System

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

Latency

Latency is the time between when the Position Sensor collects data and when that data is available to the host application. The Vega XT Position Sensor offers the lowest latency. Latency is measured in milliseconds.

Line Separation

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

Local Coordinate System

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

Maximum 3D Error

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

Maximum Marker Angle

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

Passive Marker

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

Pivoting

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

Position Sensor

The Position Sensor is the component of the Polaris 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.

Tracking Rate

The tracking rate is the rate at which the system reports transformations for all the tools being tracked. The tracking rate cannot exceed the frame rate.

Transformation

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

Unique Geometry Tool

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

Appendix A Polaris Vega System 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 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 Polaris Vega System 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. Performance specifications are detailed in Table A-1.

This criteria is based on a statistically representative set of positions distributed uniformly throughout the measurement volume, using 30 samples per position at 20°C.

Table A-1 Polaris Vega System Performance

	Vega ST/VT		Vega XT	
	Pyramid Volume	Extended Pyramid Volume	Pyramid Volume	Extended Pyramid Volume
Volumetric Specification				
3D RMS Accuracy[1]	0.12 mm	0.15 mm	0.12 mm	0.15 mm
3D RMS Repeatability[2]	0.06 mm	0.08 mm	0.06 mm	0.08 mm
Infield Accuracy Test				
AAK Result (RMS)	0.25 mm	0.25 mm	0.25 mm	0.25 mm

[1] The 3D RMS volumetric accuracy error is determined as the best-fit error of a statistically representative set of measured positions distributed uniformly throughout the measurement volume when compared to the nominal positions, as reported by a NIST-traceable CMM.

For each measured position the mean of 30 samples is used. The data is collected with the system at thermal equilibrium, at an ambient temperature of 20.0 ± 0.5 °C.

[2] The 3D RMS repeatability error is determined as from the same data set as the 3D RMS volumetric accuracy error. For each measured position the mean position is calculated.

The local repeatability error is then calculated as the standard deviation of the distance of each of the 30 samples, relative to the mean position.

The volumetric 3D RMS repeatability error is the RMS error of all local repeatability errors.

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:

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

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

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

Appendix B Deprecated Features

B.1 Password Protection

The current password protection feature is deprecated. NDI is developing a more comprehensive version of this feature to be released with a future firmware revision.

If you choose to enable the current password protection feature, it provides the following security against changes to the system configuration:

- 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 you do not enter the correct password, you can change user parameter values but cannot save them. Upon system reset or initialization, the parameters return to their previous values.
- If the system is reset or initialized after you enter the password, you must re-enter the password before you can make changes to the system configuration.

To enter the password, use NDI ToolBox or the API command `SET Config.Password=<password>`, where <password> is the correct password. Obtain the password from NDI.

In the ToolBox user interface and Vega API, this feature is referred to as “Password”.

B.2 250 Hz Tracking Rate (MR250)

Previously, the Vega ST Position Sensor supported the option of tracking at 250 Hz with lower latency. This option has been discontinued and is no longer available. The replacement option is the Vega XT. For more information about the Vega XT, see “Vega XT Position Sensor” on page 11.

For historical reference, system capabilities associated with the 250 Hz tracking rate are described in Table 21-1.

Table 21-1 System Capabilities at 250 Hz

Feature / Capability	
Volumetric Accuracy, Pyramid	0.25 mm
Volumetric Accuracy, Extended Pyramid (Optional)	0.30 mm
Tracking Rate	250 Hz
Latency (when tracking two tools)	<8 ms
Supported Tool Types	• Passive Spheres • Radix Lenses
Communication Interface	• Ethernet
Other Configuration Options	• Positioning Laser • Extended Pyramid Volume