Aurora User Guide

Revision 4
July 2008

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

Revision Status

Revision Number	Date	Description
1.0	August 2005	First release
2	July 2007	Title change, content update
3	January 2008	ToolBox information added. Dome volume information added
4	July 2008	Added system accuracy information

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Read Me First

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 Aurora System if any of the hardware components or connectors are damaged. Such damage may affect system functions, and contribute to inaccurate transformations and possible personal injury.
2. Do not track in an untested application environment, as it may contain elements that affect Aurora System functions. For example, the system can be adversely affected by electromagnetic field disturbances from other objects in the room, the close proximity of metal, and the close proximity of another Field Generator. Failure to test for such disturbances will increase the possibility of inaccurate transformations and possible personal injury.
3. When using reply option 0800 with the BX or TX command, you must take appropriate action to detect when a tool is out of volume, and determine whether this situation is detrimental to your application. If a tool is out of volume, reply option 0800 enables the system to return data that may lead to inaccurate conclusions and may cause personal injury.
4. Do not drop the Field Generator or subject it to impact. Physical damage to the Field Generator may alter the Field Generator's calibration and contribute to inaccurate transformations and possible personal injury.
5. Do not place the Field Generator within 10 m of another operating Field Generator. To do so may contribute to inaccurate transformations and possible personal injury.
6. Do not place the SCU or an SIU less than 1 m from the Field Generator. To do so may affect the measurement volume, contributing to inaccurate transformations and possible personal injury.
7. Do not operate the Field Generator within 200 mm of an installed pacemaker. The magnetic field produced by the Field Generator may interfere with the operation of the pacemaker. This interference may result in personal injury.
8. Do not expose sensors to a high magnetic field, such as a Magnetic Resonance Imaging machine, as they may become magnetized. Tracking with a magnetized sensor may result in incorrect transformations and result in possible personal injury.
9. Do not track a tool unless you are sure that its SROM device is programmed correctly, and with the correct settings. Using an incorrectly programmed tool may produce inaccurate transformations and possible personal injury.
10. Do not bend or kink Aurora System cables or tool cables, or use cables that are damaged. Applying transformations from a system with damaged tool cables may result in possible personal injury.

11. Do not place the Field Generator cable inside the measurement volume or wrap it around the Field Generator, as it may create a magnetic interference. This interference can contribute to inaccurate transformations and possible personal injury.
12. Do not place tool cables within 30 mm of the Field Generator cable. If placed this close—particularly if the cables are parallel to each other—the tool cable may become subject to electromagnetic interference. This interference can contribute to inaccurate transformations and possible personal injury.
13. Do not coil the Field Generator cable, as it produces enough electric current that a magnetic field will be created when the cable is placed in a circular formation. This magnetic field may disturb the Field Generator's magnetic field, contributing to inaccurate transformations and possible personal injury.
14. Do not use the Aurora System if the SCU is connected to a non-approved workstation. If the SCU is not connected to IEC 60950 or IEC 60601 approved workstations, you may increase leakage currents beyond safe limits and cause possible personal injury.
15. Do not use the Aurora System in the presence of other magnetic fields. To do so may lead to misleading or inaccurate transformations and possible personal injury.
16. Do not disconnect the Field Generator from the system while tracking. Disconnecting the Field Generator while in tracking mode may result in sparks being generated, and possible personal injury.
17. Do not expose or immerse the Aurora System to liquids, or allow fluid to enter the equipment in any way. Exposing the Aurora System to liquids may result in equipment damage, produce a fire or shock hazard, and result in possible personal injury.
18. Do not block any of the SCU ventilation holes. If the SCU internal electronics overheat, the SCU may perform unpredictably and may damage the system. This may contribute to inaccurate transformations and possible personal injury.
19. Do not use cables or accessories other than those listed in this guide, with the exception of those sold by NDI and NDI-authorized manufacturers. To do so may result in increased emissions and/or decreased immunity of the Aurora System.
20. Make sure that patient auxiliary leakage currents do not exceed allowable limits. Consult both IEC 60601 and applicable national differences and amendments. In addition, give special consideration to insulation materials and thicknesses to ensure the galvanic isolation of multiple tools connected to the Aurora System. Failure to do so may lead to personal injury.
21. Portable and mobile radio frequency (RF) communications equipment can affect the Aurora System. This may contribute to inaccurate transformations and possible personal injury.
22. The Aurora System has not been designed or tested to be used during or following cardiac defibrillation. Cardiac defibrillation may cause inaccurate transformations and result in possible personal injury.
23. Apart from replacing the SCU fuses, there are no user serviceable parts in the Aurora System. All servicing must be done NDI. Unauthorised servicing may result in possible personal injury.
24. Switch off power to the system before cleaning it. Failure to do so may cause personal injury.

25. Do not change either fuse without first disconnecting the SCU from its power source. Failure to disconnect the system may result in personal injury.

Cautions

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

1. To move or ship the Aurora System, repack in the original containers together with all protective packaging to prevent damage.
2. Do not use aerosol sprays near the equipment as these sprays can damage circuitry.
3. Do not use any solvent to clean the Aurora System. Solvents may damage the finish and remove lettering.
4. Do not autoclave any Aurora System component. Autoclaving may damage the system.
5. Do not push or pull connectors in constricted areas. Doing so may damage the connectors.
6. Do not put heavy objects on cable connectors. Doing so may damage the connectors.
7. Do not leave cable connectors where they can be damaged, particularly on the floor, where they can easily be stepped on and damaged.
8. Pull connections apart by gripping the connector. Do not pull them apart by tugging on the cable as this can damage the connecting cable. Never force a connection or a disconnection.

Disclaimers

1. NDI does not guarantee the accuracy of transformations produced from tracking tools outside the characterized measurement volume. Should you choose to enable the tracking of tools located outside of the characterized measurement volume, you will be notified with status flags whenever such a transformation is returned.
2. Due to the nature of the mathematical model that the Aurora System uses to produce transformations, there is a very infrequent occurrence where the system may randomly return a single frame of significantly inaccurate or misleading data. To reduce the impact of this single frame on a measuring task, be aware of the possibility of this occurrence, and take such data into consideration when collecting transformations.
3. All NDI tracking systems are designed to exclusively use NDI specific components. NDI is not responsible for any outcome that should arise from using non-NDI compliant components.
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. This device has been investigated and found to be in compliance with IEC601-1-2:2001, Medical Electrical Equipment, Part 1: General Requirements for Safety - Collateral Standard: Electromagnetic Compatibility - Requirements and Tests. Such compliance does not preclude the case of:

a) this device creating disturbances, which interfere with the operation of other equipment; or

b) other equipment creating emissions, which interfere with the operation of this device.

In the event that either of these cases are suspected, use of this device should be suspended and the appropriate technical personnel consulted.

6. It is not straightforward to interpret the IEC 60601 standard as it applies to tools incorporating sensor, especially when these tools are, in turn, connected to other electro-medical devices such as a surgical microscope or bipolar coagulating forceps. NDI recommends that you involve experts from the necessary safety approval agencies at the onset of the development project. This early involvement will potentially avoid an expensive redesign of the tool in order to comply with requirements of the medical standards.

Questions?

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

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Updates

NDI is committed to continuous improvements in the quality and versatility of its products. To obtain the best results with your NDI system, check the NDI Support Site regularly for update information:

http://support.ndigital.com

1 Aurora System Overview

1.1 Introduction

The Aurora® System is an advanced electromagnetic spatial measurement system designed to calculate the position and orientation of sensors within a defined volume and to a high degree of accuracy. The sensors are typically embedded in tools so that the system can determine the position and orientation of the tools.

A typical system setup is shown in Figure 1-1 on page 2.

The Aurora System comprises three major components:

- Field Generator
- System Control Unit (SCU)
- Sensor Interface Unit (SIU) (4)

A host computer is also required to operate the Aurora System and associated NDI software. The host computer must be approved to IEC60950 or IEC60601 and meet the following minimum specifications:

- RS-232 serial port, or Universal Synchronous Bus (USB) port and USB serial adapter

Note Not all USB serial adapters are of equal quality. NDI has found the Star Tech model ICUSB232 USB to RS-23 Serial DB9 Adapter to be reliable.

- Pentium processor or equivalent (>1 GHz recommended)
- 256 MB Random Access Memory (RAM)
- 75 MB free disc space
- Windows® 2000 (or greater) operating system or Mac OS X 10.4.8 (or greater)
- Screen resolution 1024 x 768 (1280 x 1024 recommended)

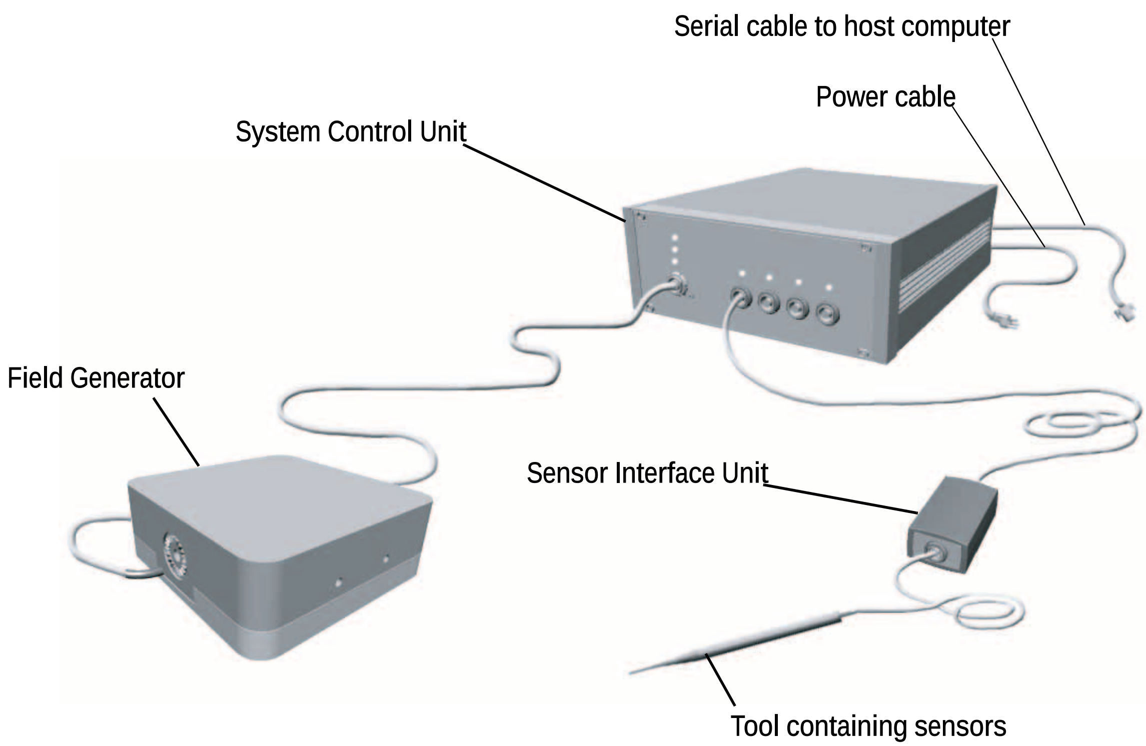


Figure 1-1 Aurora System

1.2 Principles of Operation

The SCU provides power to the Field Generator, which in turn produces a series of varying magnetic fields, creating a known volume of varying magnetic flux. This volume is referred to as the characterized measurement volume. The shape of the characterized measurement volume is either a cube or a dome, dependent on your system configuration. Both volumes are detailed in Figure 1-2. The characterized measurement volume is the volume where data was collected and used to characterize the Field Generator. It is a subset of the detection region. (The detection region is the total volume in which the Field Generator can detect a sensor, regardless of accuracy.)

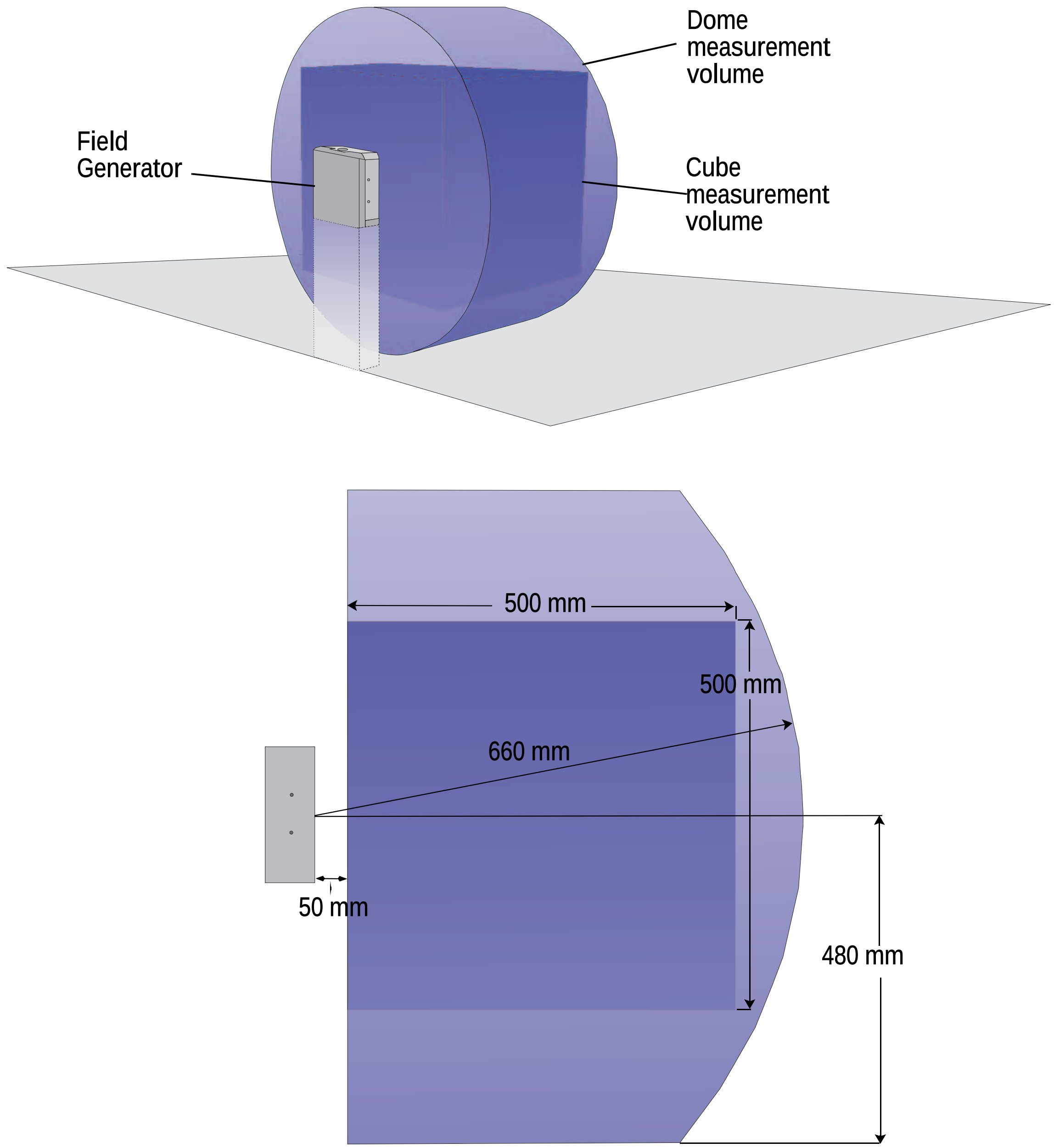


Figure 1-2 Aurora System Measurement Volumes

Sensors, typically embedded in tools, are connected to the SCU, via the SIUs. If these sensors are placed inside the measurement volume, a voltage will be induced in them, caused by the varying magnetic fields produced by the Field Generator. The characteristics of the induced voltage depend on a combination of the sensor position and orientation in the measurement volume, and the strength and phase of the varying magnetic fields.

The SIU converts the voltage, induced in the sensors, into digital data and sends it to the SCU. The SCU analyzes the data and calculates the position and orientation of the sensors. The resultant calculation is sent to the host computer upon request from the API.

1.3 Field Generator

The Field Generator contains a number of large coils that generate known electromagnetic fields as previously described. The measurement volumes are illustrated in Figure 1-2. The volume is projected outwards from the Field Generator’s front face, offset by 50 mm from the Field Generator. The Field Generator is described in the following table and illustrated in Figure 1-3.

Table 1-1 Field Generator

Part	Description
Front face	Origin of the characterized measurement volume. This side is distinguishable from the others as it has both the Aurora logo and NDI logo printed on it.
Mounting point	Designed to attach the Field Generator to the NDI Field Generator Mounting Arm (P/N 8800728), described on page 8.
Field Generator connector	Connects the Field Generator cable to the SCU. The Field Generator connector is a 19 pin circular metal connector.
Field Generator cable	Connects the Field Generator to the SCU.
M8 tapped holes (thread pitch 1.25 mm, depth 13 mm) x 4, 2 per side	Allows the Field Generator to be attached firmly to a fixture.

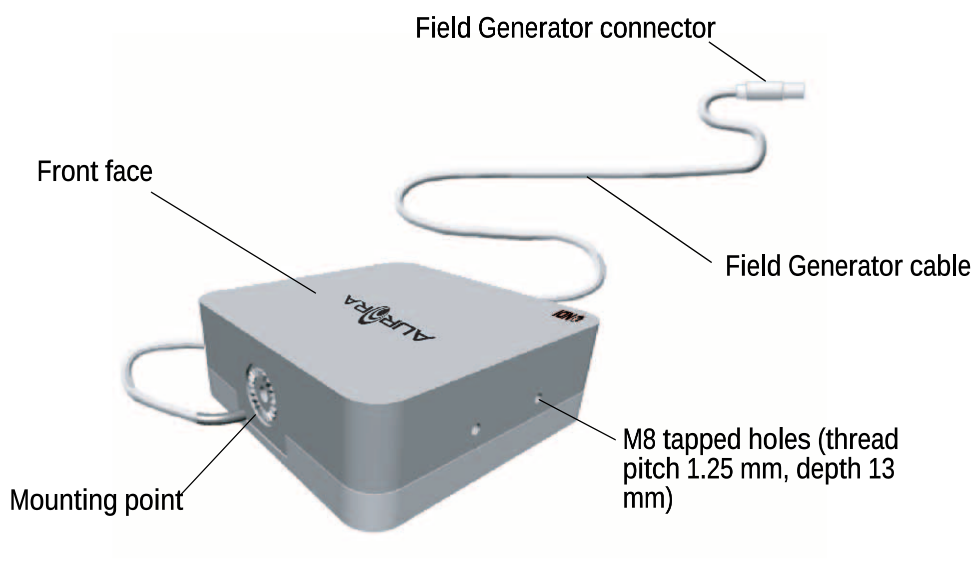


Figure 1-3 Field Generator

1.4 System Control Unit

The SCU controls the operation of the Aurora System. It acts as an interface between the system components and provides visual status indications. A brief overview of the SCU functions is as follows:

- supplies power to the Field Generator and controls the Field Generator’s electromagnetic output.
- collects sensor data (via the SIUs) and calculates sensor positions and orientations. It then sends the position and orientation data to the host computer (if requested).
- provides visual status indications.
- interfaces with the host computer.

SCU Front Panel

The SCU front panel houses the following ports and status indicators:

Table 1-2 System Control Unit Front Panel

Parts	Description
Power light (green)	Lights when the SCU is powered on.
Error light (amber)	The error light is not yet implemented.
Code light (amber)	The code light is not yet implemented.
Field Generator port	Connects the SCU to the Field Generator cable.
SIU ports	Connects SIUs to the SCU, allowing communication between the system and connected tools.
SIU port status lights	Off - No tool is connected to this port. Amber - A tool is connected to this port, but the port has not been initialized for use. Green - A tool is connected to this port, it has been initialized, and it is ready to be used.

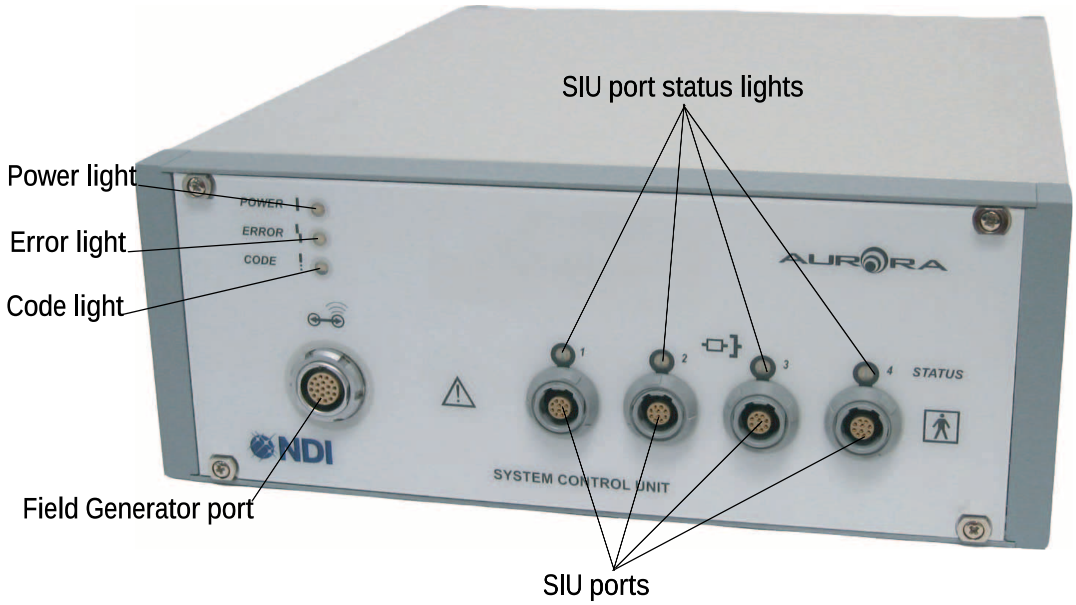


Figure 1-4 System Control Unit Front Panel

SCU Back Panel

The SCU back panel houses the following components:

Table 1-3 System Control Unit Back Panel

Part	Description
Ventilation opening	A fan is installed behind the ventilation opening.
RS-232 port	A serial communications port used to connect the SCU to the host computer.
Power entry module	A sub-assembly that comprises a system power switch, fuse, and power cable connection port. Refer to Figure 1-6.

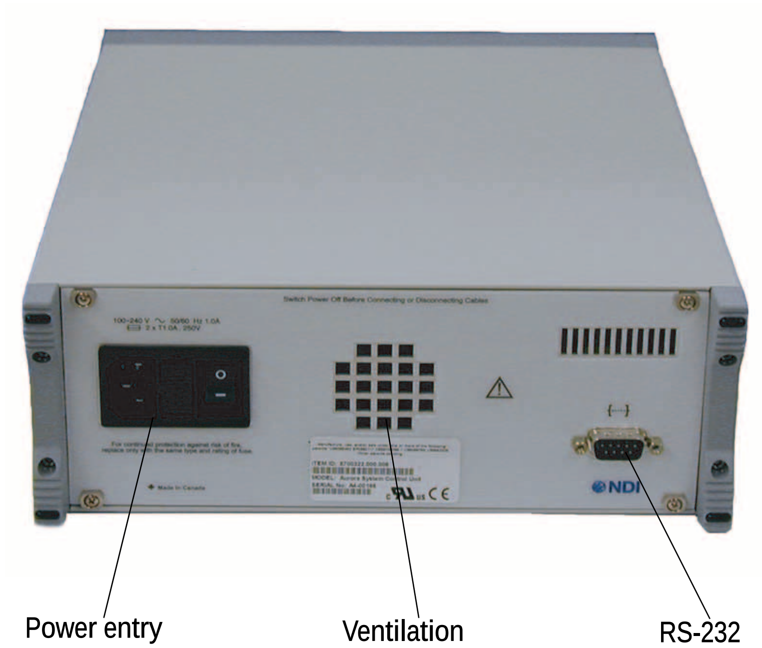


Figure 1-5 System Control Unit Back Panel

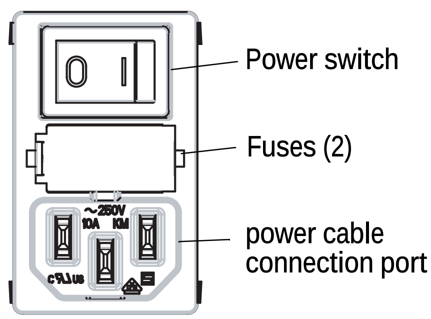


Figure 1-6 System Control Unit Power Entry Module

1.5 Sensor Interface Unit

The SIU is the interface between the sensors (embedded in tools) and the SCU. The main function of the SIU is to convert the analog signals, produced by the sensors, to digital signals. The digital signals are sent to the SCU for processing.

Another function of the SIU is to increase the distance between the SCU and tools, removing the requirement for a long tool cable and keeping bulky system components away from the application space. In addition, the shorter the tool cable, the less noise will appear on the signal from the sensors. Analogue signals in the tool cable (though shielded when using NDI tool cable) are still susceptible to noise, therefore the digital cable is longer than the tool cable.

Each SIU can support up to two sensors. The SIU also allows you to interface with sensorless tools, such as a footswitch. For more information about tools, see “Accessories” on page 8.

Table 1-4 Sensor Interface Unit

Part	Description
Tool port	Connects the SIU to tools. This tool port is a 10-pin circular plastic connector.
SIU connector	Connects the SIU to the SCU.

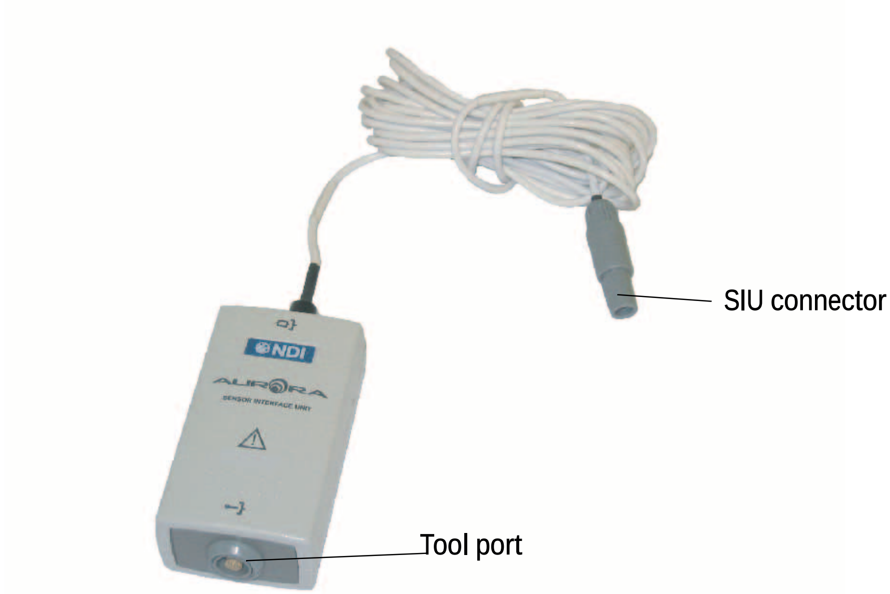


Figure 1-7 Sensor Interface Unit

1.6 Accessories

The following accessories are available for the Aurora System.

Note Accessories for the Aurora System are under continual development. For a list of current accessories and applications, contact NDI.

Field Generator Mounting Arm

The Field Generator Mounting Arm is designed to help position the Field Generator. This metal arm incorporates several articulated joints that enable you to position the Field Generator at the desired position and angle. The Field Generator Mounting Arm can be used with one of two clamps:

- A general purpose clamp that attaches to a table, counter edge or T-rail
- A T-rail clamp, specifically designed to fit onto the edge of a standard operating table. The T-rail clamp provides a robust and stable mounting method.

Figure 1-8 Field Generator Mounting Arm and Clamps

Sensors

These miniature sensors enable you to create your own application specific tools, measuring both 5 degrees of freedom (DOF) and 6DOF. For an explanation of degrees of freedom, refer to “Degrees of Freedom” on page 33.

The 5DOF sensors are available in two sizes; 0.55 mm x 8 mm and 0.8 mm x 8 mm. They are ideal for integration into tools such as needles and guidewires.

The 6DOF sensors are 1.8 mm x 9 mm, cylindrical in shape and can be integrated into small instrumentation.

Tool Cabling

NDI supplied tool cabling is specifically designed for use with Aurora System tools.

Probe

This 6DOF pointing device allows you to identify points in space.

Reference

This 6DOF reference body can be attached to objects for dynamic tracking purposes.

FlexCord Sensor

The FlexCord Sensor consists of a flexible plastic tube with a 5DOF sensor embedded at its end. It can be used for research purposes, for example to illustrate catheter placement.

2 Setting up the Aurora System

2.1 Unpacking the Aurora System

The Aurora System is shipped with:

- Field Generator
- System Control Unit
- Sensor Interface Unit (4)
- Power cord
- Serial cable
- Aurora FlexCord Sensor (2)
- Aurora System Product CD
- Documentation

When unpacking the Aurora System, be sure to handle all system components with care. Keep the packaging in good condition; you will need to use it if the system is ever transported.

Note: See "Return Procedure and Warranty" on page 64 for instructions on returning your system to NDI.

2.2 General Warnings

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

Warning!

1. Do not move the Field Generator while tracking an object. The system may produce misleading transformations which may result in possible personal injury.
2. Do not disconnect the Field Generator from the system while tracking a tool. Disconnecting the Field Generator while in tracking mode will result in the system returning 'MISSING' transformations. This can affect your application and may result in possible personal injury.
3. Do not disconnect the Field Generator while the system is tracking. Disconnecting the Field Generator while in tracking mode may present an electric shock hazard, which may result in possible personal injury.
4. Do not drop the Field Generator or subject it to impact. Physical damage to the Field Generator may alter its calibration and contribute to inaccurate transformations and possible personal injury.
5. Do not place the Field Generator cable inside the measurement volume, as it may create magnetic interference. This interference can contribute to inaccurate transformations and possible personal injury.

6. Do not coil the Field Generator cable. The cable carries enough electric current that a magnetic field will be created when it is placed in a circular formation. This magnetic field may disturb the Field Generator’s magnetic field, contributing to inaccurate transformations and possible personal injury.
7. Do not operate the Field Generator less than 10 m away from another operating Field Generator. To do so may contribute to inaccurate transformations and possible personal injury.
8. Do not operate the Field Generator within 200 mm of an installed pacemaker. The magnetic field produced by the Field Generator may interfere with the operation of the pacemaker. This interference may result in personal injury.
9. Do not block any of the SCU ventilation holes. If the SCU internal electronics overheat, it will perform unpredictably and may damage the system. This may contribute to inaccurate transformations and possible personal injury.
10. Do not immerse any part of the SCU in water, or allow water or any other fluid to enter the equipment in any way. Liquid may damage it and may present a fire or shock hazard.
11. Do not expose the Aurora System circuitry to liquids. Exposing the Aurora System circuitry to liquids may result in equipment damage and possible personal injury.
12. Do not connect the SCU to any host computer that is not IEC60950 and/or IEC60601 approved. If you connect to a non-approved workstation, you may increase leakage currents beyond safe limits and risk personal injury.
13. Do not use the Aurora System if any of the hardware or connectors are damaged. Such damage may affect system functions, and contribute to inaccurate transformations and possible personal injury.
14. Do not kink cables, or use damaged cables. This may cause magnetic interference, or affect system functions. These may contribute to inaccurate transformations and possible personal injury.
15. Always turn the power OFF before connecting or disconnecting the power and Field Generator cables to the SCU. Failure to do so may lead to personal injury.
16. Do not place tool cables within 30 mm of the Field Generator cable. This interference can contribute to inaccurate transformations and possible personal injury.
17. Do not use cables or accessories other than those listed in this guide, with the exception of those sold by NDI and NDI-authorized manufacturers. To do so may result in increased emissions and/or decreased immunity of the Aurora System and may lead to personal injury.
18. Do not immerse any part of the SIU in water, or allow water or any other fluid to enter the equipment in any way. Liquid may damage it and may present a fire or shock hazard.
19. Do not clean the system without first switching power off on all equipment, to avoid personal injury.
20. Do not expose sensors to a high magnetic field, such as a Magnetic Resonance Imaging Machine, as they may become magnetized. Tracking with a magnetized sensor may result in incorrect transformations and possible personal injury.

21. Sensors must be mounted securely within the tool body. If a sensor moves out of position, accuracy is affected. This may contribute to inaccurate transformations and possible personal injury.

2.3 Mounting the Field Generator

To mount the Field Generator, proceed as follows:

1. Choose a location that minimizes interference:
   - If an Aurora System is being set up within 10 m of another Aurora System, there is a potential for interference when in tracking mode. For more information, contact NDI.
   - Ensure that the Field Generator cable is not wrapped around the Field Generator or looped anywhere along its length.
   - The Field Generator should not be in the vicinity of any metal equipment or sources of power within a radius of 1.0 m (with the Field Generator as the centre of this sphere).

Note If the nature of your application environment is such that the presence of metal cannot be avoided, see “Metal Resistance” on page 40 for guidance.

2. Place or mount the Field Generator on a rigid support system that can carry the full weight of the Field Generator and the Field Generator cable (2.8 kg). The support system must also be designed to minimize vibrations, as vibrations may introduce measurement errors. The Field Generator may be mounted in two ways (refer to Figure 2-1 and Figure 2-2):
   a) By means of four mounting holes, two on either side of the Field Generator. The holes are M8 tapped, thread pitch 1.25 mm, depth 13 mm.
   b) By means of a mounting point. The mounting point allows you to use an NDI-supplied Field Generator Mounting Arm (P/N 8800728), to position the Field Generator in any direction, in a manner that helps reduce its proximity to metal disturbances. For more information, contact NDI.

Note The drawing shown in Figure 2-2 is available for download from the NDI Support Site.

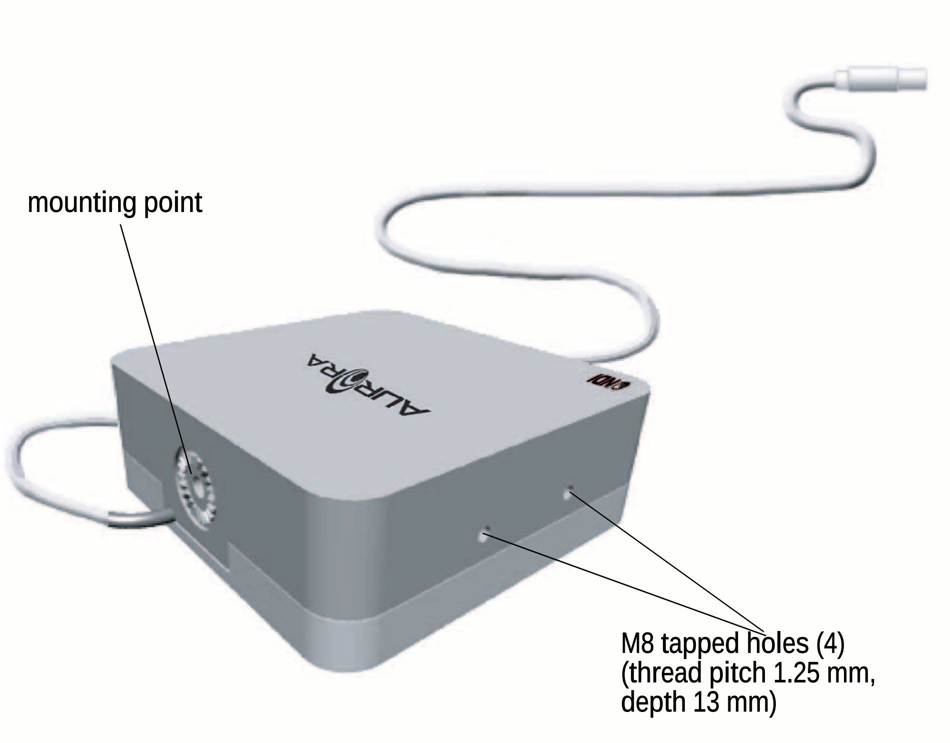


Figure 2-1 Field Generator - Mounting Options

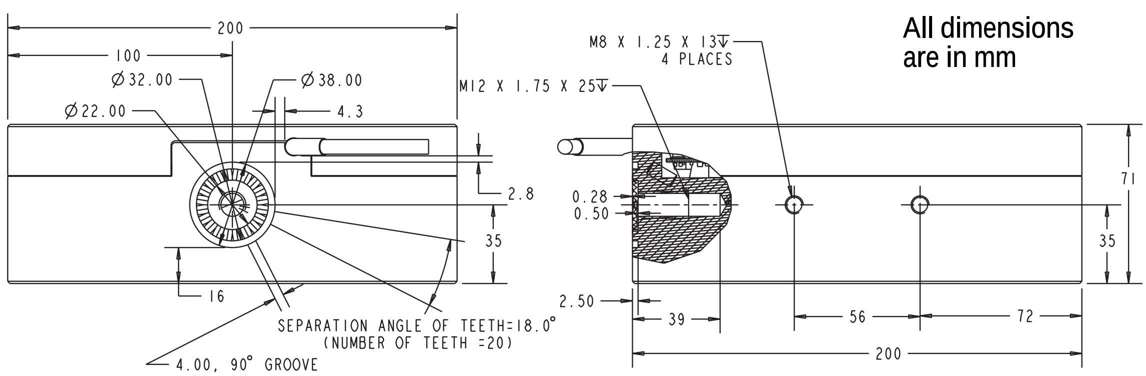


Figure 2-2 Field Generator - Mounting Details

3. Orient the Field Generator so that the measurement volume encompasses the area of interest (area where the tools will be tracked; refer to Figure 1-2 on page 3).
4. The Field Generator may be bagged or draped to fulfil sterility requirements.

System Control Unit

1. Remove the SCU from the box.
2. Place the SCU on a flat surface and make sure its ventilation port is not blocked.

3. Make sure that the cable connecting the SCU to the host computer does not come close to other cables in the Aurora System, such as the Field Generator cable.

Note The power entry module, located at the back of the SCU, has a switching power supply with universal input voltage of 100 to 240 VAC. As such, the voltage need not be manually changed.

Sensor Interface Unit

1. Remove the SIUs from the box.
2. Place each SIU on a flat surface and make sure that each tool cable can reach an SIU, but that tool cables do not lie close to the Field Generator cable.

2.4 Connecting the Components

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

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

Do not put heavy objects on cable connectors.

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

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

Connect the Aurora System components as follows:

1. Insert the Field Generator cable connector into the Field Generator port (located on the front of the SCU).
2. Insert each SIU connector into one of the SIU ports (located on the front of the SCU).
3. Plug each tool into its respective tool port (located on the front end of the SIU).
4. Check that the tool cables are at least 30 mm from the Field Generator cable.
5. Attach one end of the serial communications cable to the RS-232 port at the back of the SCU.
6. Attach the other end of the cable to the RS-232 port on the back of the host computer.
7. Plug the power cable into the power entry module on the back of the SCU.

Note Tools can be disconnected and reconnected into any SIU while the system is still running (hot-plugging). SIUs can also be hot-plugged into the SIU ports on the SCU.

3 Using the Aurora System

3.1 Introduction

This chapter provides information on operating the Aurora System. The information is listed under the following topics:

- Powering on the Aurora System
- Installing the Software
- Using the Aurora System
- Aurora System Tools

3.2 Powering on the Aurora System

Before applying power to the Aurora System, make sure the system is correctly connected. Refer to "Setting up the Aurora System" on page 11. When you have connected the system, proceed as follows:

1. Plug the SCU power cable into a power outlet.
2. Turn the power on using the switch located on the back of the SCU.
3. If the Aurora System is operating correctly, the following occurs:
    - The SCU will beep three times. The first beep is followed by two quick beeps.
    - The SCU power light will be lit green; the SCU error and code lights are off.
    - The SIU port status lights on the SCU will be lit amber if a tool is connected.

Note — If the system does not operate correctly refer to "Troubleshooting" on page 62.

3.3 Installing the Software (Windows)

The NDI software is located on the product CD that was delivered with the system. You can also download the software from the NDI Support Site at http://support.ndigital.com.

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

NDI Combined API Sample

This application is a sample of source code to help you better understand the API commands designed specifically for NDI measurement systems. Use this application along with the "*Aurora Application Program Interface Guide*" when designing your own software application.

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

NDI ToolBox

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

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

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

3.4 Installing the Software (Linux)

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

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

NDI Combined API Sample

This application is a sample of source code to help you better understand the API commands designed specifically for NDI measurement systems. Use this application along with the “*Aurora Application Program Interface Guide*” when designing your own software application.

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

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

NDI ToolBox

Install NDI ToolBox as follows:

1. On the product CD, browse to Linux/ToolBox/install.bin.
2. Follow the on-screen instructions to complete the process. The default installation location is <user_account>/ToolBox.

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

3.5 Installing the Software (Mac)

Note Ignore any references to USB drivers during the install procedure.

The NDI software is located on the product CD that was delivered with the system. You can also download the software from the NDI Support Site at http://support.ndigital.com.

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

System Requirements

The system requirements for the Mac OS X are as follows:

Hardware

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

Mac OS X Version

- Minimum version: Mac OS X 10.4.8. (To determine which version of Mac OS X you have, select **Apple**>**About This Mac**.)

Java Version

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

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

```
java -version.
```

Account Permissions

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

NDI Combined API Sample

This application is a sample of source code to help you better understand the API commands designed specifically for NDI measurement systems. Use this application along with the "*Aurora Application Program Interface Guide"* when designing your own software application.

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

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

Installing and Running NDI ToolBox

Install NDI ToolBox as follows:

1. On the product CD, locate, and open, the **MacOSX** folder.
2. In the **MacOSX** folder, locate and open the **ToolBox** sub-folder.
3. In the **ToolBox** folder, locate and double-click on the **install.zip** file. This will create the installer application **install** on the desktop.
4. Double-click on **install.**
5. Click on the "lock" icon and follow the on-screen instructions to complete the NDI ToolBox installation.

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

- /dev/cu.usbserial-xxxxxxxx

or

- /dev/tty.usbserial-xxxxxxxx

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

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

Installing Firmware Update Packages

Install the firmware update packages as follows:

1. On the product CD, locate, and open, the **Firmware** folder.
2. Double-click on **install.htm.**
3. Click the **Download Installer for Mac OS X...** button. You will be directed to the appropriate **install.zip** file in the **Finder**.

4. Double-click on the **install.zip** file. This will create the installer application **Install** on the desktop. (If an instance of **Install** is already present on the desktop, a number will be appended to the application name.)
5. Double-click on **install.**
6. Click on the “lock” icon and follow the on-screen instructions to complete the installation procedure.

Uninstalling Software

NDI ToolBox

Uninstall NDI ToolBox as follows:

Double click on the **uninstall** application and follow the on-screen instructions. (The **uninstall** application is normally located in the NDI ToolBox folder in the Uninstall sub-folder.) All related NDI ToolBox files and aliases to NDI ToolBox utilities will be removed from your system.

Additional Information

The following sections provide additional Mac OS X specific information.

Additional Installation Files

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

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

Lock Files and Groups

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

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

1. Launch the **NetInfo Manager** application (normally found in the Applications folder in the Utilities sub-folder).
2. Use the hierarchical navigator to select **groups>uucp**.

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

Manager application and the alternate user account will be able to run the NDI ToolBox utilities.

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

NDI ToolBox Preferences

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

```
cd ~
ls -la
```

Moving NDI ToolBox Files

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

USB to Serial Adapter

The Aurora System does not have a USB interface. You will have to use a USB to serial adapter for a Mac host computer to communicate with the Aurora SCU.

Note Not all USB serial adapters are of equal quality. NDI has found the Star Tech model ICUSB232 USB to RS-232 Serial DB9 Adapter to be reliable.

You must be aware of two scenarios that may occur:

1. If the USB to serial adapter you are using is also FTDI-based and you install the NDI USB driver by mistake, you may overwrite your existing driver.
2. NDI has not tested non-FTDI-based USB to serial adapters and consequently, the serial library that ToolBox uses to communicate to these devices may have compatibility issues.

3.6 Aurora System Tools

All Aurora System tools consist of a combination of up to seven basic components:

Table 3-1 Tool Components

Component	Description
Sensors	The sensor comprises a wire wound around a small metal core. The winding may be connected to a twisted pair of lead wires. A tool can contain up to two (0, 1, or 2) sensors.
SROM device	The SROM device stores tool specific information and characterization data. An SROM device is hardware that can be programmed only once. It is normally located inside the tool connector.
Tool connector	The connector houses the SROM device and provides the means to connect the tool to the SIU.
Tool cable	A custom conductor shielded cable that connects the sensors, switches, and LEDs to the tool connector.
LEDs and switches (optional)	Single input/output devices that indicate or initiate a tool function. Each tool can support up to three input/output devices.
Tool body	The tool body houses the sensors, LEDs and switches.

Note NDI supplies sensors specifically designed and tested for use with the Aurora System. If you use sensors supplied by any other source, be aware that NDI does not guarantee the accuracy of measurements made with those sensors. Figure 3-1 shows a typical NDI sensor. (Other sensor configurations are available, contact NDI for details.)

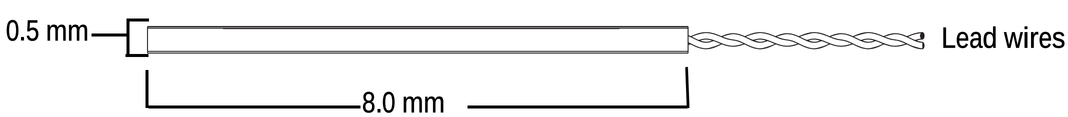


Figure 3-1 A Typical Sensor

Figure 3-2 shows an example of a tool incorporating each basic tool component:

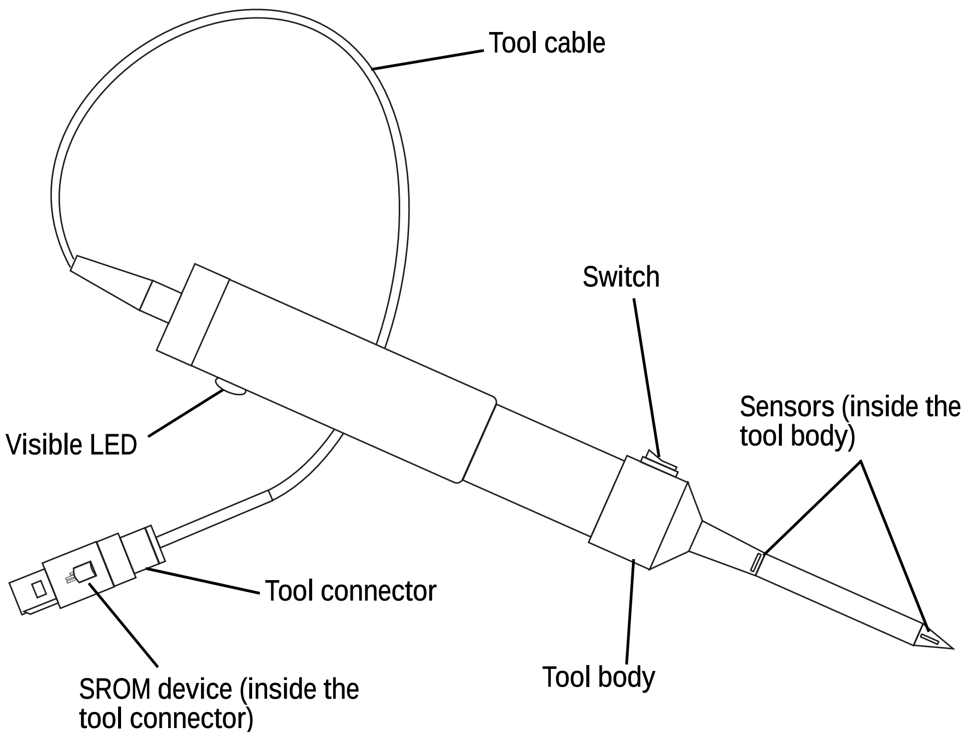


Figure 3-2 Basic Tool Components

Tool Types

A tool can be categorized as one of several basic types, depending on the number of sensors embedded in it:

Table 3-2 Categorizing Tool Types

Sensors	Tool Type	Sensor Placement	5DOF/6DOF
0	sensorless tool (such as a foot switch)	not applicable	not applicable
1	single sensor tool	anywhere	5DOF
2	dual sensor tool	not fixed relative to each other	5DOF (2)
	6DOF tool	fixed relative to each other	6DOF
	collinear sensor tool	fixed relative to each other in a collinear fashion	5DOF
	parallel sensor tool	fixed relative to each other in a parallel fashion	5DOF

Note For more information about tool design and how to build your own tools to use with the Aurora System, refer to the ***"Aurora Tool Design Guide"***.

Reference Tools

A reference tool is used to allow relative measurement, rather than absolute measurement. Measuring a tool’s position and orientation is fairly straightforward as long as the following are true:

1. The Field Generator does not accidentally shift. If it does shift, the global coordinate system also shifts. This change affects the perceived location of a tool within the global coordinate system, producing misleading measurement data.
2. The object of interest does not accidentally shift. If you are using the Aurora System to place a tool at a specific point on the object of interest, it is very important that the object does not move with respect to the Field Generator, while you are trying to place the tool. There is no way for the system to perceive such movement, and you may end up placing the tool in the wrong location.

In many application environments, shifted objects and bumped Field Generators are not uncommon occurrences. As such, the two above requirements are often difficult to meet.

A *reference tool* is designed to be fixed to an object of interest. Once fixed, if the object moves, the reference tool will also move. Other tools can be measured relative to the reference tool, in the reference tool’s local coordinate system.

The Aurora System measures the reference tool’s movement as well as the tracking tool’s movement, producing two sets of measurements. You can design your application to interpret these measurements in the following way:

1. Calculate the reference tool’s movements to capture any (accidental or intentional) shifting.
2. Apply these movements to the tracking tool’s position and orientation data, to correct for any accidental shifting.

For a reference tool to accurately compensate movement, you should locate the reference tool close to the tracking tool’s path through the measurement volume.

For more information about reference tools, see the *“Aurora Tool Design Guide.”*

Note Reference tools are available for purchase from NDI.

4 Tutorial: Learning to Use the Aurora System

This chapter is intended as a tutorial to demonstrate the basic functionality of the Aurora System using NDI ToolBox. For more detailed information on NDI ToolBox, refer to the NDI ToolBox online help. The tutorial is designed for first time users of the system to:

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

4.1 Getting Started: Tracking Tools

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

To Set Up the System

1. Install NDI ToolBox, as described in “Installing the Software (Windows)” on page 16, “Installing the Software (Linux)” on page 17 or “Installing the Software (Mac)” on page 18.
2. Set up and connect the hardware, as described in “Connecting the Components” on page 15.
3. Open NDI ToolBox.
4. If NDI ToolBox does not automatically connect to the system, select either:

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

   or

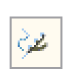
   File > **Connect to** > **(/dev/ttySx)** (Linux)

   or

   File > **Connect to** > **(/dev/cu.usbserial-xxxxxxxx)** or **(/dev/tty.usbserial-xxxxxxxx)** (Mac)

Note There are two possible connection methods for Mac users. This is to allow for backwards compatibility, with access via BSD UNIX-style device methods. The tty methods were traditionally meant to be used for call-in connections and the cu methods for call-out connections. NDI ToolBox will work correctly with either connection method.

To Track Tools

1. If the tool tracking utility is not open, click  to open it.
2. Connect the tool to the appropriate SIU. The system will automatically attempt to track the tool.

3. Move the tool throughout the characterized measurement volume. As you move the tool, the symbol representing the tool in the graphical representation will move to reflect the tool’s position.

4.2 Information and Error Flags

This section describes how to trigger the most common flags. Error and warning information for each connected tool is displayed in the bottom right section of the tool tracking utility.

To View Information and Error Flags

1. Set up the system to track tools, as described in “Getting Started: Tracking Tools” on page 25.
2. For each tool, 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.

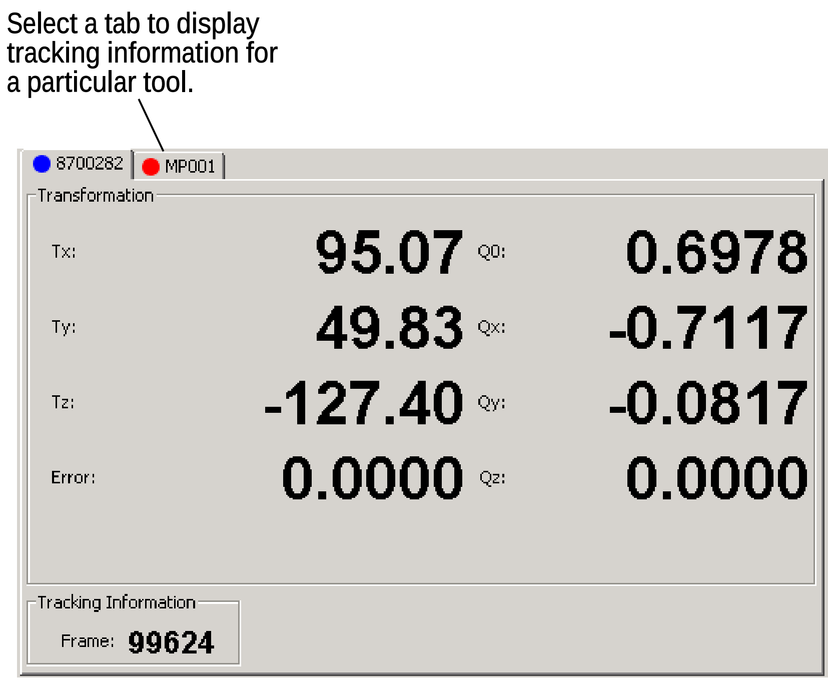


Figure 4-1 Tutorial: NDI ToolBox Tool Tracking Window

“Out of Volume” and “Bad Fit” flags:

Move the tool to the edge of the characterized measurement volume. As you move the tool to just outside the edge of the volume, ToolBox will display the message “Out of Volume.” Notice that at this position, the transformation data is still displayed.

Note If you are using a 6DOF tool and you place the tool such that one sensor is in the volume and other is outside the volume, ToolBox will display the message “Partially Out of Volume”.

Continue to move the tool outside the volume, but keep it within the detection region. Notice that the transformation data goes blank.

Once the tool is completely outside of the detection region, ToolBox will display the message "Bad Fit" (the transformation data remains blank).

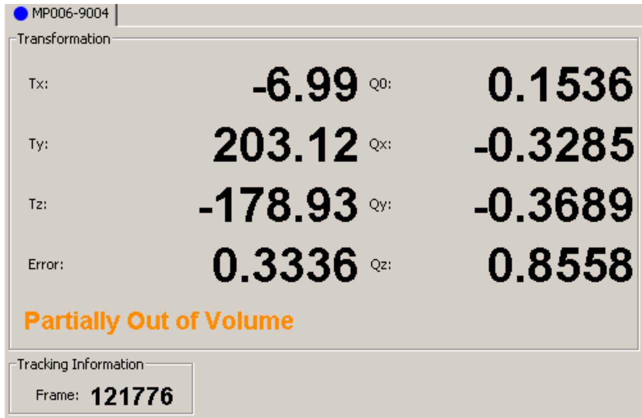


Figure 4-2 Tutorial: "Partially Out of Volume" Flag

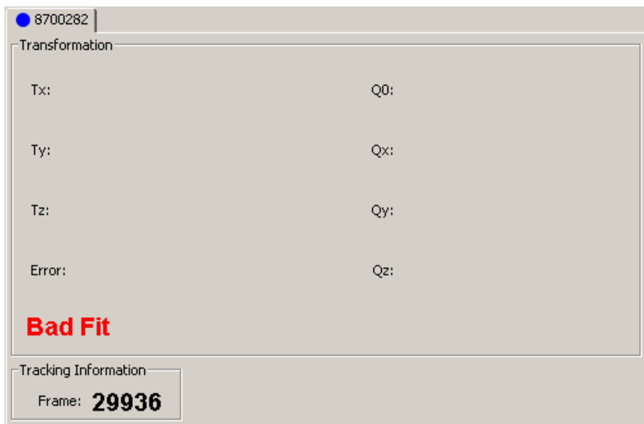


Figure 4-3 Tutorial: "Bad Fit" Flag

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 24.

To Set a Tool as Reference

1. Set up the system to track tools, as described in "Getting Started: Tracking Tools" on page 25.
2. Connect at least two tools.
3. For each connected tool, 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.

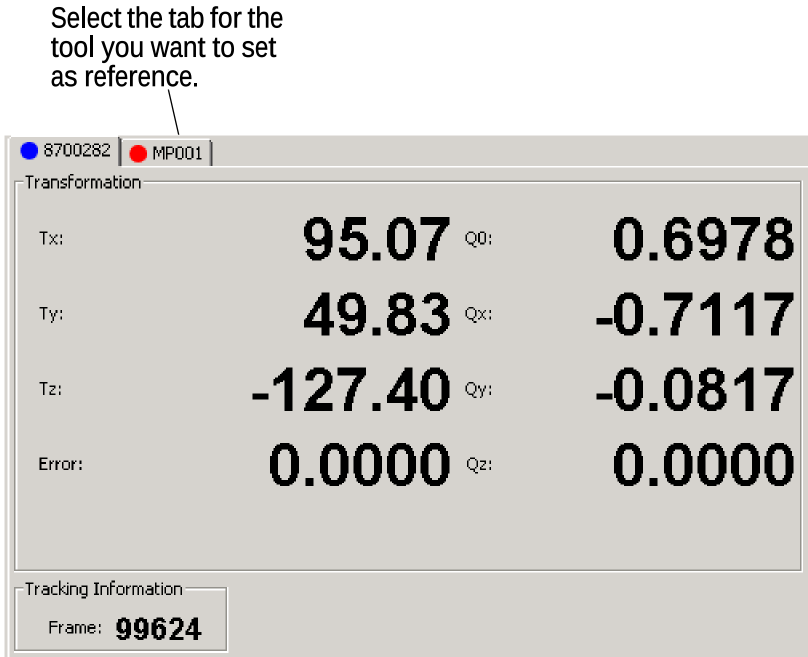


Figure 4-4 Tutorial: Selecting a Reference Tool

4. Select **Track>Global Reference** (or right-click on the tool tab, then select **Global Reference**).

   The reference tool will appear as a square in the graphical display. The other tool(s) 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 Aurora System still calculates the tool transformations in the coordinate system of the Field Generator. 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.

To Set Up the System to Pivot

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

1. Set up the system to track tools, as described in “Getting Started: Tracking Tools” on page 25.
2. For each connected tool 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.

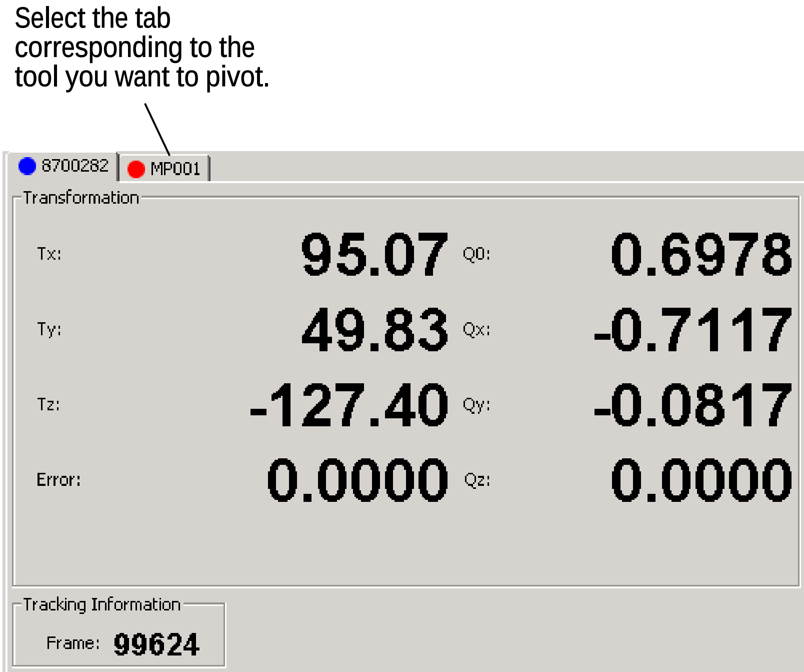


Figure 4-5 Tutorial: Selecting a Tool to Pivot

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

To Pivot the Tool

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

a) Keep the tool tip stationary, slowly pivot the tool until the specified pivot duration time has elapsed.

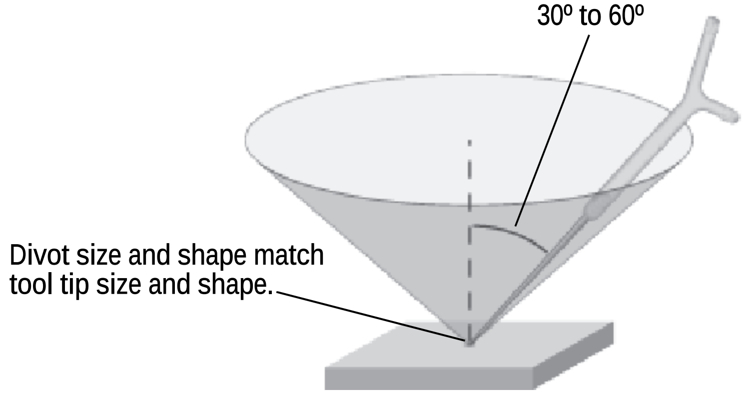


Figure 4-6 Tutorial: Pivoting Technique

When the pivot is complete, the **Pivot Result** dialog appears. If the tool is a 5DOF tool, the dialog is as shown in Figure 4-7. If the tool is a 6DOF tool, the dialog is as shown in Figure 4-8.

Click **Apply 5D Offset** or **Apply Offset** as appropriate, to report the position of the tip of the tool.

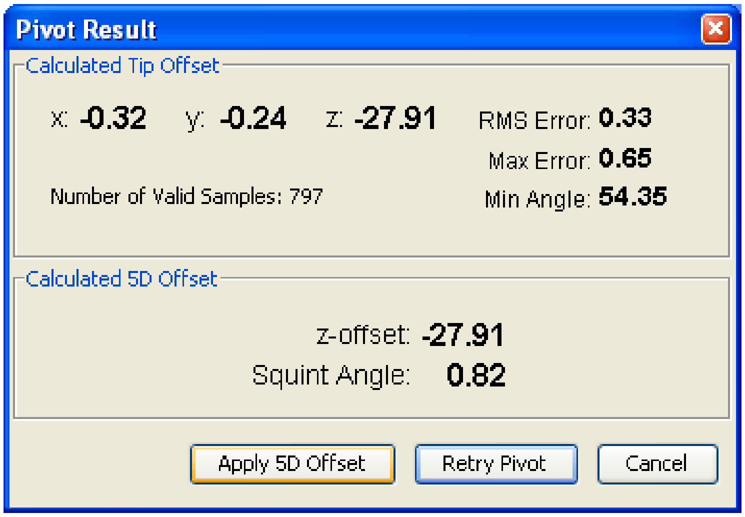


Figure 4-7 NDI ToolBox Software: Pivot Result (5DOF) Dialog

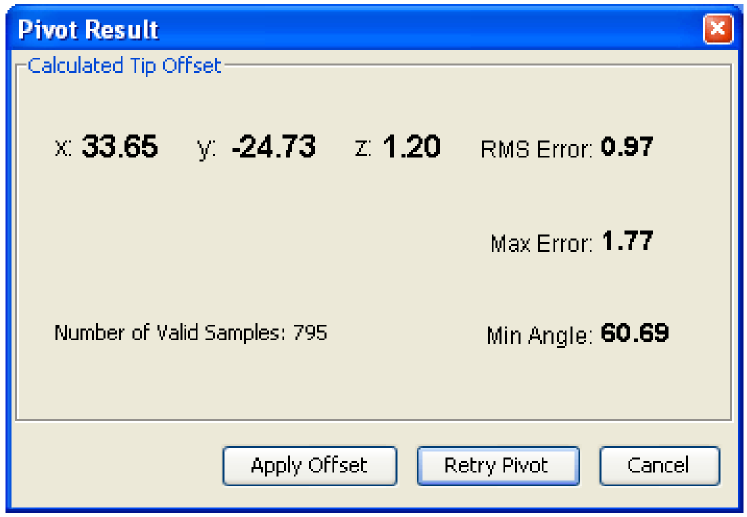


Figure 4-8 NDI ToolBox Software: Pivot Result (6DOF) Dialog

5 How the Aurora System Works

5.1 Introduction

This chapter provides details on how the Aurora System works. The information can help increase your technical understanding of the system, but it is not absolutely necessary in order to use the system. This chapter provides information on the following topics:

- Communicating with the Aurora System
- Information Returned by the Aurora System
- Degrees of Freedom
- Coordinate Systems
- Transformations
- Measurement Rates
- Metal Resistance
- Field Generator Coils Magnetic Fields
- Distortion
- Error Flags and Codes

5.2 Communicating with the Aurora System

The Aurora System is controlled using an application program interface (API). The API is a set of commands that allow you to configure and request information from the system. The Aurora System returns information only when requested by the host computer.

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

For details on API commands, see the "*Aurora Application Program Interface Guide*."

5.3 Information Returned by the Aurora System

When the Aurora System is tracking tools, it returns information about those tools to the host computer (if requested). By default, the system returns:

- **the position of each tool's origin**, given in mm, in the coordinate system of the Field Generator (see "Global Coordinate System" on page 34).
- **the orientation of each tool**, given in quaternion format. The quaternion values are rounded off, so the returned values may not be normalized.
- **an indicator value**, between 0 and 9.9 (where 0 is the absence of error and 9.9 is the highest indication of error). (See "Indicator Value" on page 38.)
- **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 “*Aurora Application Program Interface Guide*.”

- **the frame number** for each tool transformation. The frame counter starts as soon as the system is powered on, and can be reset using API commands (see the “*Aurora Application Program Interface Guide*” for details). The frame number returned with a transformation corresponds to the frame in which the data used to calculate that transformation was collected. (See “Measurement Rates” on page 39.)
- **the system status**, which includes some of the system errors described in “Error Flags and Codes” on page 43.

5.4 Degrees of Freedom

Aurora tools are defined as either 5DOF or 6DOF, where DOF means degrees of freedom. 5DOF and 6DOF are defined as follows:

- 5DOF: Five of the six degrees of freedom. Three translation values on the x, y and z-axes and any two of the three rotation values - roll, pitch and yaw.
- 6DOF: Six degrees of freedom. The three translation values on the x, y and z-axes; and the three rotation values roll, pitch and yaw.

The number, and placement, of sensors incorporated in a tool determines whether the tool is 5DOF or 6DOF and consequently the kind of measurements the Aurora System can perform.

5DOF

If a tool incorporates only one sensor, the rotation around the sensor’s z-axis (Rz) (see Figure 5-2) cannot be determined. As such, only five degrees of freedom (5DOF) can be determined for single sensor tools.

For example, how much a needle physically rolls is not as important as where it is pointing and where the tip is located; as such, a needle can be a 5DOF tool, with only one sensor incorporated into its design.

6DOF

If a tool incorporates two sensors fixed relative to each other and ideally orthogonal, the system can determine six degrees of freedom (6DOF) for the tool. First, the system determines 5DOF information for each sensor. Next, the system combines and compares this information, applies the tool description data, and determines six degrees of freedom (6DOF) for the entire tool.

For example, an ultrasound technician needs to know the location of the ultrasound probe as it moves over a subject, in order to match its findings to actual physical locations on that subject. Incorporating two sensors into the ultrasound probe produces 6DOF measurements and ensures that all translation and rotation values of the probe are captured.

Note: If the tool’s two sensors are fixed relative to each other in a co-linear or parallel fashion, the system will provide 6DOF information for the tool, but it will not be as accurate. This is because the two sensors are not orthogonal. As such, this tool should be considered a 5DOF tool that returns an indicator value.

For more information about how the two sensors must be arranged to correctly produce 6DOF transformations for the entire tool, see the *"Aurora Tool Design Guide."*

Rotation

The Aurora System calculates rotation as a quaternion, q0, qx, qy and qz, which represent the rotation vector and the rotation around that vector. The Aurora System uses quaternions as they are a mathematically efficient method of presenting transformations, see "Explaining Transformations" on page 38.

5.5 Coordinate Systems

This section explains the different coordinate systems that are used by the Aurora System to calculate the positions and orientations of tools. It is important to understand the nature of both global and local coordinate systems.

Global Coordinate System

The Field Generator uses a coordinate system with the origin located approximately on the surface of the Field Generator and the axes aligned as shown in Figure 5-1. This global coordinate system is defined during manufacture and cannot be changed.

The Aurora 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. See "Reference Tools" on page 24.

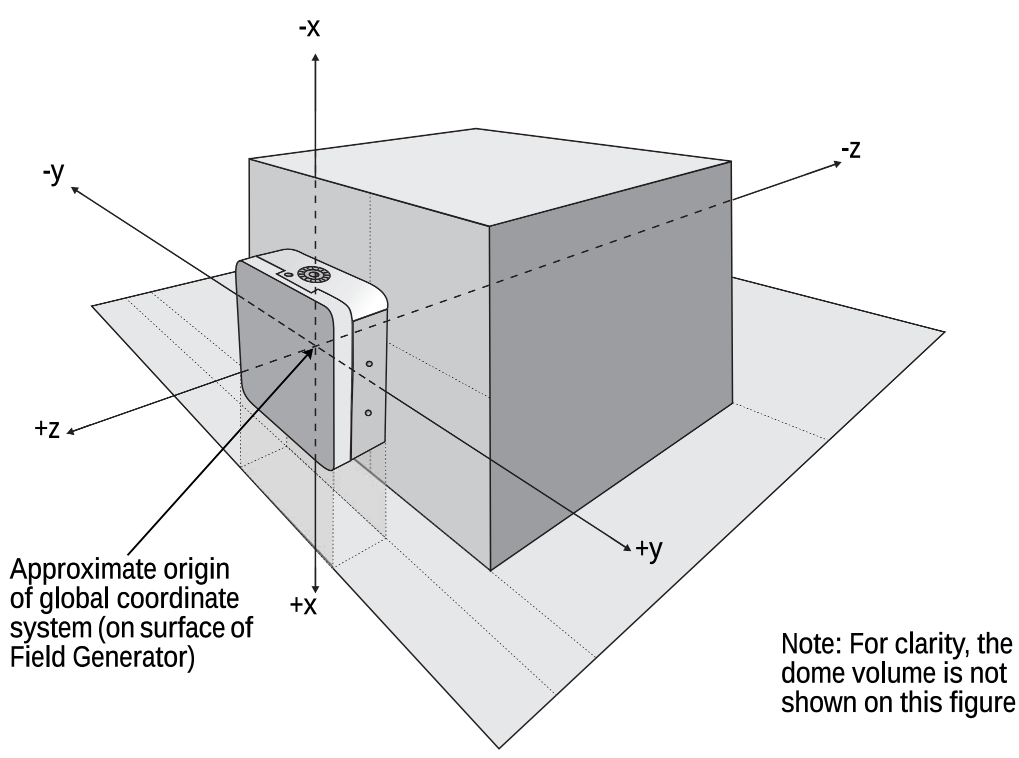


Figure 5-1 Global Coordinate System

Local Coordinate System

Each tool has its own local coordinate system that is defined by an origin and three axes. Local coordinate systems are an integral part of the measurement process, and the Aurora System cannot calculate a tool's position or orientation without them.

The following sections describe typical arrangements of local coordinate systems.

Note For more detailed information about local coordinate systems and different tool designs, see the ***"Aurora Tool Design Guide."***

Single Sensor Tools

The single sensor tool's local coordinate system is based directly on that of its sensor. By default, the system assigns the z-axis along the sensor's length, with an origin at the sensor's centre. It is possible to move the origin along the z-axis. The x and y axes are not fixed, due to the inability to determine rotation about the z-axis.

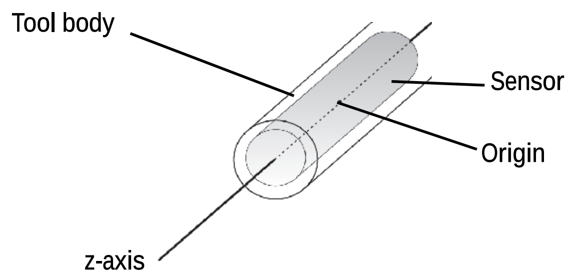


Figure 5-2 Sample Single Sensor Tool

Note Single sensor tools do not return an indicator value. For more information about indicator values, see "Indicator Value" on page 38.

Dual Sensor Tools

Dual 5DOF Tools A dual 5DOF tool is essentially two single sensor tools joined to the same tool connector. As such, the tool actually has two local coordinate systems, each based on one of the sensors incorporated into its design. These local coordinate systems are determined in the same way as that of a single sensor tool.

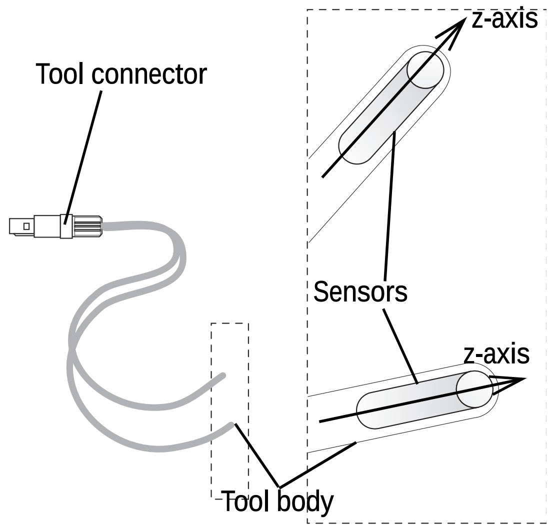


Figure 5-3 Sample Dual 5DOF Tool

6DOF Tools A 6DOF tool incorporates two sensors fixed relative to each other. 6DOF tools are assigned their *own* coordinate system, independent of their sensors. Each tool includes a tool definition file programmed onto the tool's SROM device. This file defines the tool's local coordinate system.

Figure 5-4 shows a sample 6DOF tool with a coordinate system independent of its sensors. When the Aurora System calculates this tool's position and orientation, it will return only one transformation and indicator value.

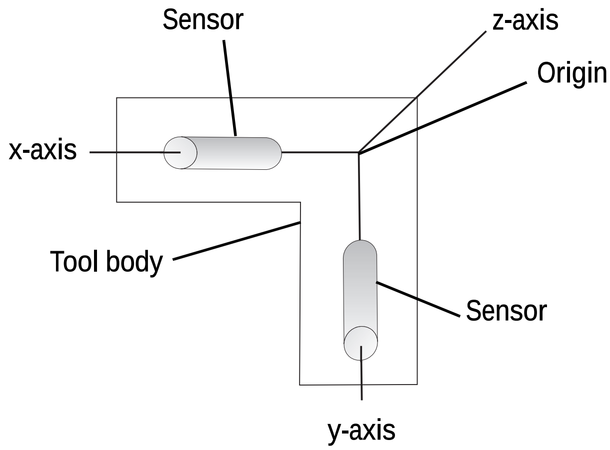


Figure 5-4 Sample 6DOF Tool

Collinear Sensor Tools When two sensors are fixed in a collinear fashion, the system will calculate 6DOF, but the rotation about the common axis will not be accurate. This is because the two sensors are collinear rather than orthogonal. As such, this tool is considered a 5DOF tool.

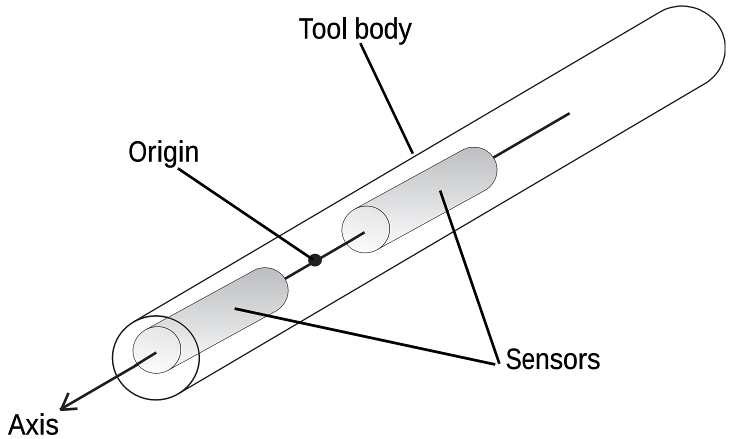


Figure 5-5 Sample Collinear Sensor Tool

One advantage of a collinear sensor tool is that, unlike single sensor tools, you can define the axis running the length of the two sensors as something other than the z-axis. You can also assign the tool's point of origin, as long as it falls upon this axis. In general, it will also be slightly more accurate than a single sensor tool. Another advantage is that it provides indicator values. For further information on indicator values see "Indicator Value" on page 38.

Parallel Sensor Tools When two sensors are fixed parallel to each other, the system will calculate 6DOF, but the rotation about the common axis will not be accurate. This is because the two sensors are parallel rather than orthogonal. As such, this tool is considered a 5DOF tool.

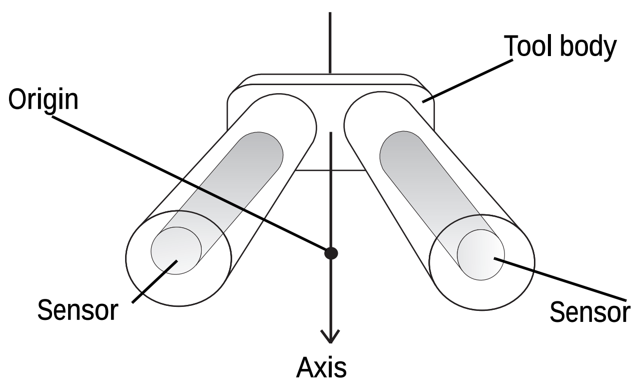


Figure 5-6 Sample Parallel Sensor Tool

As shown in Figure 5-6, you can assign the axis running lengthwise between the two sensors. You can also assign the tool's origin, as long as it falls upon this axis. The axis must be parallel to the two sensors and exactly half way between them

5.6 Transformations

This section describes how the Aurora System produces tool transformations.

Explaining Transformations

A transformation is a combination of translation and rotation values that describes the tool's position and orientation.

Once the Aurora System has calculated the position and orientation of a tool, it returns a *transformation*, representing the results. Transformations are returned in the following format:

q0 qx qy qz Tx Ty Tz indicator_value

Where:

1. **q0 qx qy qz** represents the tool's orientation (in quaternion format),
2. **Tx Ty Tz** represents the tool's position in the measurement volume (in mm) and
3. **indicator_value** represents the transformation's indicator value.

Note The Aurora System calculates a tool's rotation in quaternion format (q0 qx qy qz), but Aurora documentation explains a tool's rotation in Euler format (Rx, Ry and Rz), as it is easier to visualize. NDI ToolBox software is capable of displaying a tool's rotation using either format.

Indicator Value

With each transformation calculated, the Aurora System returns an *indicator value*. The indicator value is an estimate of how well the system calculated that particular transformation. Indicator value is formatted as a unitless value falling between 0 and 9.9 (where 0 is the absence of error and 9.9 is the highest indication of error).

For 6DOF tools, the indicator value compares sensor measurements to the tool's design (as described by its SROM device or tool definition file). The greater the difference between the calculated sensor positions and the known locations of the sensors within the tool, the higher the indicator value. Such discrepancies are often an indication that magnetic field disturbances are affecting the collected data.

For 5DOF transformations, the indicator value is always zero.

Indicator values less than 1.0 are typically considered acceptable. You should set your own thresholds, depending on the nature of your application needs.

Note The indicator value is not an absolute indication of overall error, but simply an indication that your measurement may be compromised, or that you have a mismatched tool definition file.

For more information about the indicator value and how to use it with your applications, see the *"Aurora Application Program Interface Guide."*

Producing Transformations

The following procedure describes how the Aurora System produces transformations:

1. When a tool is placed in the measurement volume, its sensor(s) produce data.
2. The system receives the sensor data via the tool's SIU.

3. The system processes the sensor data and calculates a 5DOF transformation for each sensor that is producing information.
4. The system reads the tool description data previously uploaded from the tool's SROM device, or in a tool definition file previously uploaded from the host computer.
5. The following list describes the next step the system must perform, depending on the type of tool the SROM settings describe:

Single Sensor and Dual 5DOF Tools The system does not need to perform any additional steps. The 5DOF transformation produced in step 3 is the final transformation for the entire tool. No indicator value is produced.

6DOF Tool The system takes the two 5DOF transformations produced in step 3 and processes them using a mathematical model and the tool description data. The result is a single 6DOF transformation that reflects the position and orientation of the entire tool. Accompanying this 6DOF transformation is an indicator value.

Collinear Sensor Tool/Parallel Sensor Tool The system takes the two 5DOF transformations produced in step 3 and processes them using a mathematical model and the tool description data. The result is a single 6DOF transformation but, for practical purposes, a tool of this type must be considered a 5DOF tool, as the full 6DOF transformation is not accurate. This is because the sensors are not orthogonal. In addition, the indicator value produced is not as representative as those produced with 6DOF tools, and may not be useful for your application's purposes.

Note Sensorless tools do not produce transformations.

5.7 Measurement Rates

Measurement rate is the rate at which the Aurora System calculates transformations. The maximum measurement rate, or frame rate, is 40 Hz.

Note The measurement rate is internal to the Aurora System; how fast your application receives and processes measurements from the Aurora System is also dependent on external factors, such as serial baud rate, API command used (TX or BX), host computer performance and software application design.

When a tracking tool passes outside of the Field Generator's measurement volume, the system may take extra time trying to find it before reporting it back as 'MISSING'.

Note It is possible to obtain faster measurement rates than those listed above. Contact NDI for assistance.

Latency

The latency of the Aurora System can be defined as the answer to the question, "How old is this data?" The latency of the Aurora System is not strictly defined, because there are too many variables. It is typically 75 ms, (three frames) but can be higher.

5.8 Metal Resistance

Most applications that require the technology made available by the Aurora System also require metal objects: tables, tools, braces, and so forth.

Although the Aurora System's technology revolves around electromagnetic activity—activity that is affected by the presence of metal—NDI has developed ways to make the Aurora System resistant to certain metals.

The following sections describe the problems caused by placing metal near an electromagnetic measurement system.

About Eddy Currents

An eddy current is caused when a conductive material is exposed to a dynamic magnetic field. The changing magnetic field induces a circulating flow of electrons within the conductive material, resulting in an electric current.

These circulating currents (sometimes known as eddy currents) produce an electromagnetic effect of their own, creating magnetic fields that oppose the original, external magnetic field. The greater the electrical conductivity of the conductor, the greater the eddy current developed (and the greater the opposing magnetic field produced).

When using an Aurora System, if a conductive metal intersects the Aurora System's electromagnetic field, the opposing magnetic field created by resulting eddy currents disrupts that field and affects the transformation data produced.

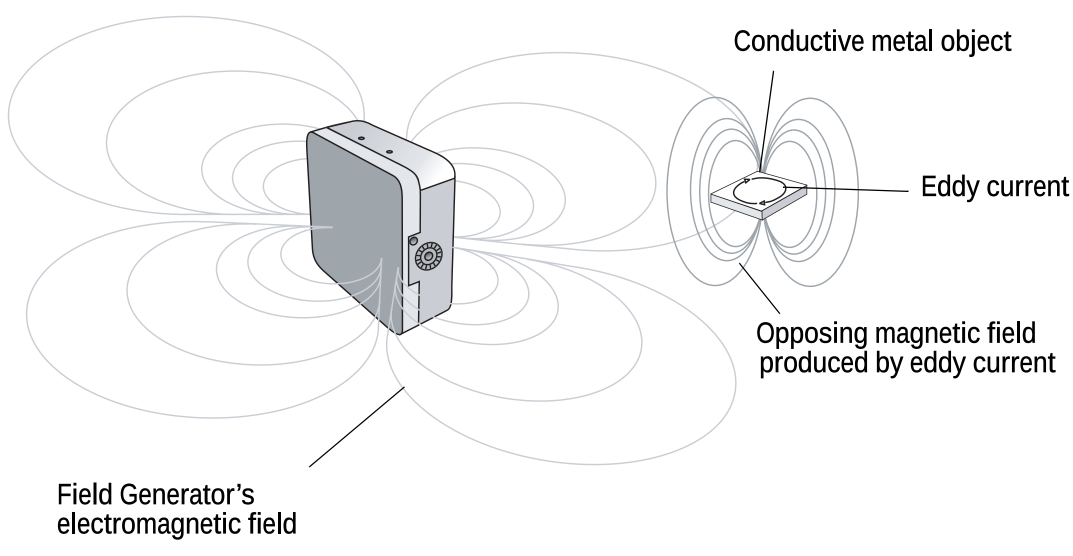


Figure 5-7   Visualizing the Effects of Eddy Currents

One method of reducing this effect is to adjust the placement of both the tool being measured and the object producing the eddy currents. Moving the tool so that the distance between its sensors and the Field Generator is smaller than its proximity to the object creating eddy currents, may decrease the effects of the eddy currents on tool measurements.

The Aurora System uses special technology to take into account such effects as eddy currents. The following metal alloys work well with the Aurora System when applied in amounts similar to that used in medical tool construction:

- cobalt-chrome alloy
- steel DIN 1.441
- titanium (TiA16V4)
- 300 series stainless steel

Note Tests have also shown that the Aurora System produces reasonable results with a steel DIN 1.4301 plate measuring 500 mm x 500 mm.

About Ferromagnetic Metals

Ferromagnetic material generally has little or no net magnetic property. However, if it is placed in a magnetic field, its domains will re-orient in parallel with that field, and may even remain re-oriented when the field is turned off. Even metals with only small amounts of ferrous material in them may have these reactions.

The magnetic field produced in a ferromagnetic object attracts the external magnetic field, resulting in the external magnetic field bending towards the object itself. As such, introducing a ferromagnetic object into the Aurora Field Generator’s electromagnetic field will cause a distortion that can affect the transformation data produced. All ferrous materials will have an effect, in varying degrees, on the Aurora System’s ability to produce measurement data.

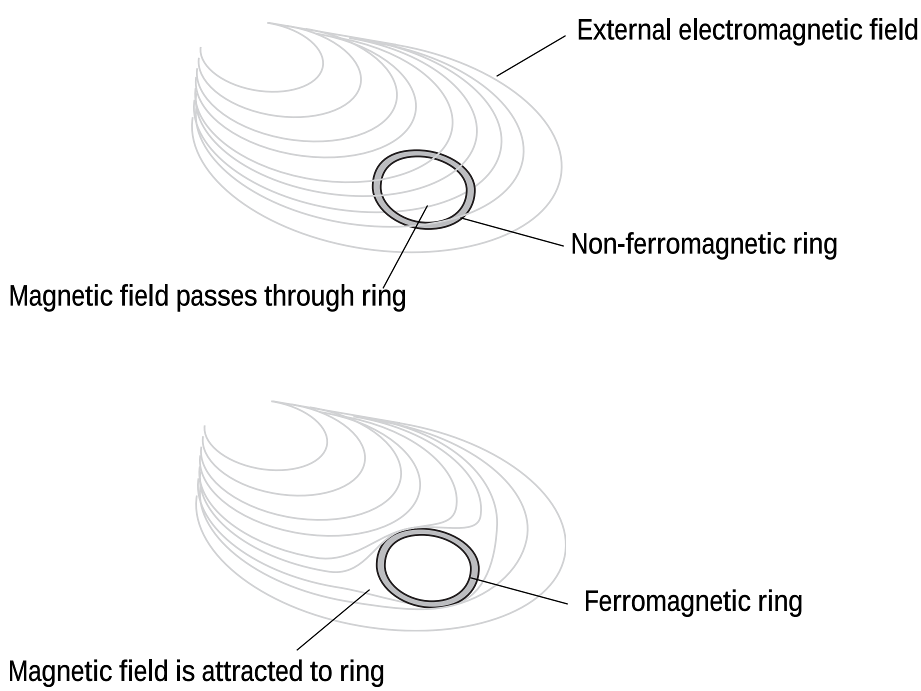


Figure 5-8 Visualizing the Effects of Ferromagnetic Material

The following metal alloys are examples of ferromagnetic metal that do not work well with the Aurora System:

- steel DIN 1.4034
- steel DIN 1.4021

Metal Resistance Research

NDI has developed and integrated a metal resistance technology into the Aurora System. For more information about the protocols used to test this resistance (and the results of these tests for different metals), refer to the "*Accuracy Protocol to Assess the Influence of Metallic Objects on the Performances of an Electromagnetic System*" research paper, available on the NDI Support Site:

http://support.ndigital.com

5.9 Field Generator Coils Magnetic Fields

Figure 5-9 shows the magnetic field plot of the Field Generator coils. The plot shows the magnetic flux density and magnetic field of the coils as a function of distance and the values inside the coil. The coil field line represents the min/max values of the field at a given distance.

The plot also shows the Institute for Electrical and Electronic Engineers (IEEE) Std. C95.1 safety limit in the frequency range 0.1 Hz to 3 kHz at 163 A/m.

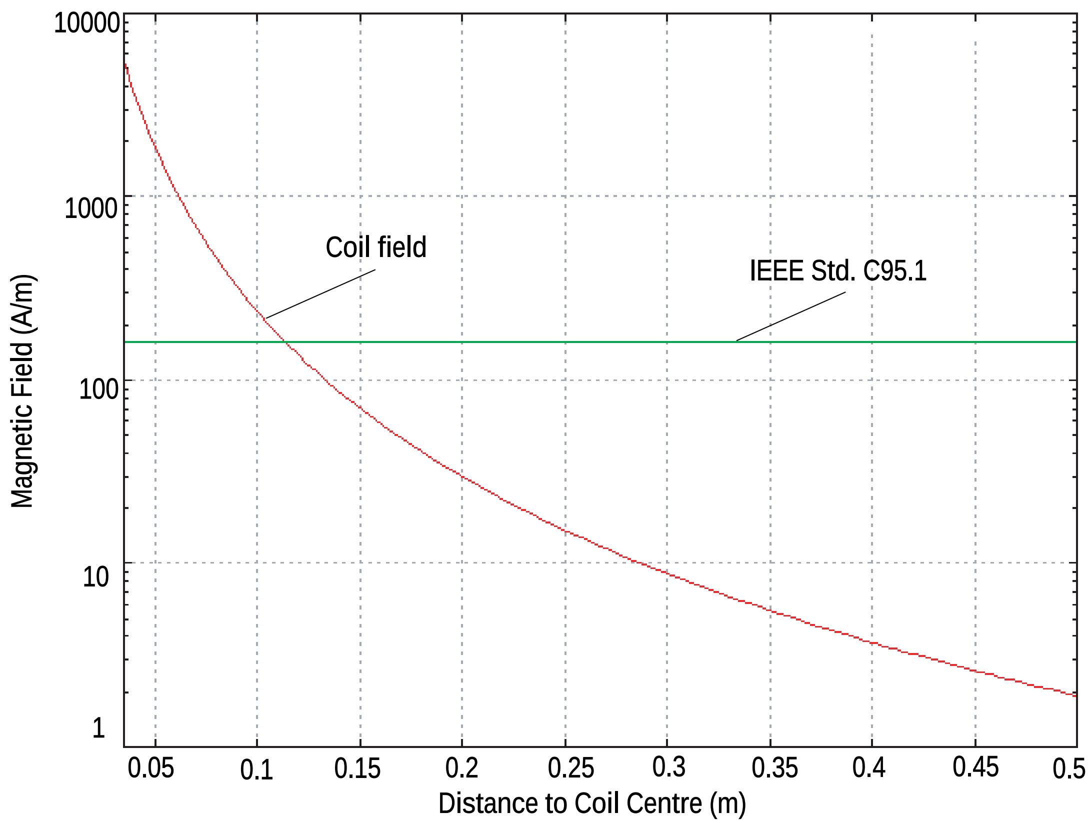


Figure 5-9 Field Generator Magnetic Field Plot

5.10 Distortion

The Aurora System is susceptible to interference that may cause distortion of the magnetic field, resulting in inaccurate measurements. For example, interference from adjacent electrical equipment may cause distortion. To determine if other equipment is causing distortion, switch the equipment on and off while monitoring the Aurora System.

Consider factors such as the magnetic properties of adjacent materials and placement of the Field Generator when determining where the system will be used.

5.11 Error Flags and Codes

This section explains the error flags and codes that the Aurora System may return. For comprehensive information on error flags and codes, refer to *"The Aurora Application Program Interface Guide"*.

Missing and Disabled Transformations

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

Missing Transformations

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

- The tool is moving too fast
- There is severe interference
- There is a system error (described below).
- The tool is not in the detection region.

By default, the system will report a tool as MISSING (even when it has calculated a transformation for the tool) if the tool is out of volume. The Aurora System is specifically designed to NOT report measurements when the tool is out of volume. You can request out of volume measurements by using reply option 0800 with the BX or TX command. You enable this additional functionality at your own discretion.

Warning! When using reply option 0800 with the BX or TX command, you must take appropriate action to detect when a tool is out of volume, and determine whether this situation is detrimental to your application. If a tool is out of volume, reply option 0800 enables the system to return data that may lead to inaccurate conclusions and may cause personal injury.

Disabled Transformations

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

Tracking Errors and Flags

Many of the following errors and flags are displayed in NDI ToolBox. They are all returned with the TX and BX commands.

System Status Flags

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

Hardware Failure Indicates that a system hardware failure has been detected.

Hardware Change Indicates that the Field Generator has been disconnected from the System Control Unit.

Port Status Flags

Bad Fit The bad fit flag is set if the system is unable to determine the tool position, typically because the tool is not within the detection region.

Out of Volume The out of volume flag is set if a tool is completely outside the characterized measurement volume, but is still within the detection region. The flag is set regardless of whether the reply option 0800 for the TX or BX command is used. (Reply option 0800 enables the reporting of the positions of tools that are outside of the characterized measurement volume. See the “*Aurora Application Program Interface Guide*” for details.)

Partially Out of Volume The partially out of volume flag is only applicable to 6DOF tools. The partially out of volume flag will be set if one of the tool’s sensors is inside the characterized measurement volume and the other sensor is outside the characterized measurement volume, but still within the detection region.

Processing Exception Indicates that a rare exception has been detected due to corrupt firmware. In this situation, please contact NDI.

Broken Sensor Indicates that a sensor lead wire is broken, either along its length or at a connection point. (This bit may not always be set when a sensor lead wire breaks.)

6 Maintenance

User maintenance of the Aurora System is limited to:

- cleaning
- replacing the SCU fuses

Warning! Apart from replacing the SCU fuses, there are no user serviceable parts in the Aurora System. All servicing must be done by NDI. Unauthorised servicing may result in possible personal injury.

6.1 Cleaning

Warning! Do not expose or immerse the Aurora System to liquids, or allow fluid to enter the equipment in any way. Exposing the Aurora System to liquids may result in equipment damage, produce a fire or shock hazard, or contribute to possible personal injury.

Switch off power to the system before cleaning it. Failure to do so may cause personal injury.

Caution! Do not use aerosol sprays near the equipment as these sprays can damage circuitry.

Do not use any solvent to clean the Aurora System. Solvents may damage the finish and remove lettering.

Do not autoclave any Aurora System component. Autoclaving may damage the system.

To clean the Aurora System proceed as follows:

1. Wipe off dust with a dry, soft cloth.
2. Remove dirt or finger marks using a damp cloth and dry immediately with a clean cloth.

6.2 Replacing the System Control Unit Fuses

Warning! Do not change either fuse without first disconnecting the SCU from its power source. Failure to disconnect the system may result in personal injury.

1. Disconnect the SCU from the power supply.
2. Release the two fuse holder tabs simultaneously with the aid of a tool (such as a screwdriver), and pull upwards. The tabs are marked with arrows for identification.

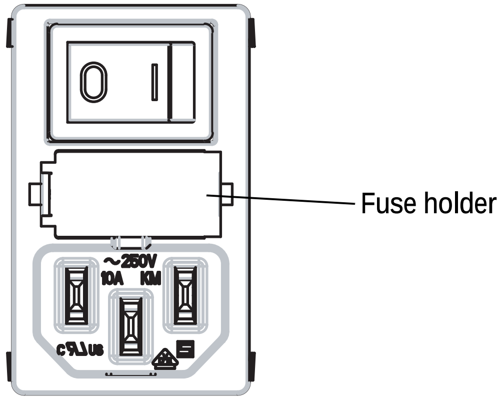


Figure 6-1 System Control Unit Power Entry Module

3. Remove the fuses from the fuse drawer and verify the filament is intact.
4. Replace the fuse(s) as required, with the correct type and rating (1.00 A, 250 V, Time Delay, 5 mm x 20 mm).
5. Press the fuse holder downwards, ensuring that it latches correctly.

7 Calibration and Verification

7.1 System Calibration

As with all measurement and testing instruments, industry practice dictates that the Aurora System should be periodically calibrated to ensure it is operating within tolerances acceptable to the user. You must establish the system's calibration interval on the basis of your system's stability, purpose, and degree of usage.

If, at any time, any concern regarding accuracy about the Aurora System arises, you should:

1. Calibrate the Aurora System immediately.
2. Analyze the system's usual calibration interval and adjust it if necessary.
3. Take all other corrective measures deemed necessary by the user in the circumstances.

Note: The Aurora System is highly specialized instrumentation developed by NDI. It is recommended that the Aurora Field Generator be returned to the NDI facility for calibration procedures. This practice ensures that all calibrations are conducted in accordance with procedures established specifically for the Aurora System.

7.2 System Verification

Determining how to use the Aurora System to best suit your specific requirements should be done carefully, with much of the testing and evaluation closely tailored to your anticipated usage.

For example, users often want to know the "maximum error" of the Aurora System when evaluating best practices. However, the maximum error obtained from a particular data set is not a sufficiently robust measure. The spatial detail that is lost in condensed statistical summaries is often crucial, since most measurement systems have operational regions where errors tend to be considerably lower and other regions where errors tend to be substantially higher.

To learn about more valuable methods of evaluating and planning the use of the Aurora System, refer to the research paper entitled "*Accuracy Assessment Protocols of Electromagnetic Tracking Systems.*" You can find this document on the NDI Support Site at http://support.ndigital.com.

7.3 Environment Verification

1. Establish a baseline for the system's performance. This may include testing in a local environment with minimal electromagnetic field disturbances.
2. Introduce each object that might disturb the characterized electromagnetic field, and objects that would be typical of the environment used in your particular application.
3. Establish an indicator value threshold reflective of your particular application requirements. For more information about what an indicator value is, see "Indicator Value" on page 38.
4. Placement of the Field Generator may affect the system's performance. Consider changing the placement of the Field Generator within the environment.
5. Adjust the local environment in order to simulate your system's particular application.

8 Approvals and Classifications

8.1 Electrical Safety Approvals

Table 8-1 Electrical Safety Approvals

Standard	Title
UL 60601-1, First Edition (2003)	Medical Electrical Equipment, Part 1: General requirements for safety
CAN/CSA C22.2 No. 601.1 - M90 (R2001)	Medical Electrical Equipment, Part 1: General Requirements For Safety
CAN/CSA C22.2 No. 601.1.S1-94 (R1999)	Supplement No. 1-94 to CAN/CSA C22.2 No. 601.1 - M90
CAN/CSA C22.2 No. 601.1B-90 (R2002)	Amendment 2 to CAN/CSA C22.2 No. 601.1 - M90
IEC 60601-1:1988+A1:1991+A2:1995	Medical Electrical Equipment, Part 1: General Requirements for safety w/ amendments

8.2 EMC/EMI Approvals

Table 8-2 EMC/EMI Approvals

Standard	Title
FCC CFR47, Part 15, Subpart B	Class B, Unintentional Radiators
CISPR11/EN55011	Class B, Industrial, Scientific and Medical Equipment
EN60601-1-2:2001 (2nd. Edition)	Medical Electrical Equipment, Part 1: General requirements for safety - Collateral standard: Electromagnetic Compatibility - Requirements and tests

8.3 Classifications

Table 8-3 Classifications

Type	Classification
Electric Shock Protection	Class I - protectively earthed with power from supply mains.
Degree of Protection from Electric Shock	Type BF equipment.
Degree of Protection Against Ingress of Liquids	Ordinary equipment.
Method of Sterilization or Disinfection	Not suitable for sterilization.
Flammable Atmosphere	Not suitable for use in the presence of a flammable anaesthetic mixture with air, oxygen, or nitrous oxide.
Mode of Operation	Continuous.

9 Technical Specifications

9.1 Aurora System Accuracy

Aurora System accuracy for cube and dome volumes is detailed in the following tables. (ISO 5725-1: 1994 (E) (Accuracy (Trueness and Precision) of Measurement Methods and Results)).

Note The following system accuracy results were derived using two 5DOF sensors. For the 6DOF result, the two 5DOF sensors were combined and positioned 90° to each other, with the centres of the sensors 14 mm apart. The tests were conducted using 10 Field Generators.

Table 9-1 Cube Volume - Position Errors

	5DOF		6DOF	
Position Errors	RMS (mm)	95% CI (mm)	RMS (mm)	95% CI (mm)
Position Accuracy	0.9	1.8	0.6	1.1
Position Precision	0.6	1.3	0.4	0.9
Position Trueness	0.7	1.3	0.5	0.9

Table 9-2 Cube Volume - Orientation Errors

	5DOF		6DOF	
Orientation Errors	RMS (°)	95% CI (°)	RMS (°)	95% CI (°)
Orientation Accuracy	0.3	0.5	0.4	0.6
Orientation Precision	0.1	0.2	0.2	0.4
Orientation Trueness	0.3	0.5	0.4	0.6

Table 9-3 Dome Volume - Position Errors

	5DOF		6DOF	
Position Errors	RMS (mm)	95% CI (mm)	RMS (mm)	95% CI (mm)
Position Accuracy	1.4	2.6	0.9	1.8
Position Precision	1.1	2.1	0.7	1.4
Position Trueness	1.0	1.9	0.7	1.2

Table 9-4 Dome Volume - Orientation Errors

Orientation Errors	5DOF RMS (°)	5DOF 95% CI (°)	6DOF RMS (°)	6DOF 95% CI (°)
Orientation Accuracy	0.3	0.6	0.4	0.6
Orientation Precision	0.2	0.3	0.3	0.5
Orientation Trueness	0.3	0.5	0.3	0.5

The graphs below illustrate that system accuracy varies relative to the distance and orientation of the (5DOF or 6DOF) sensor to the Field Generator.

Note The data in both graphs is applicable to both the cube and dome volumes.

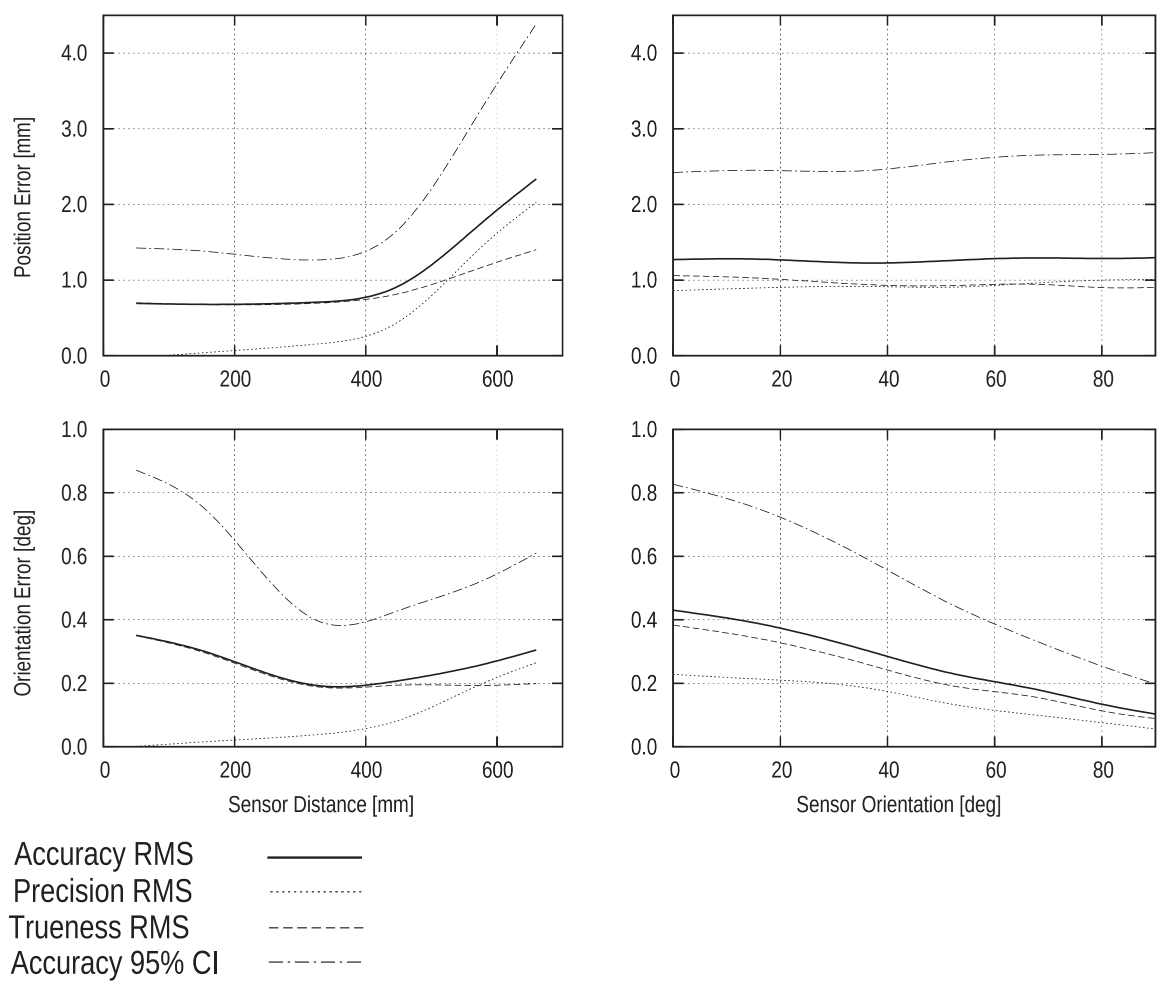


Figure 9-1 System Accuracy (5DOF Sensor)

Note 'Distance' is defined as the length of the position vector between the origin of the Field Generator coordinate system and centre of the sensor. 'Orientation' is defined as the angle between the sensor axis and the position vector. (Due to symmetry, the orientation value can only vary between 0° and 90°.)

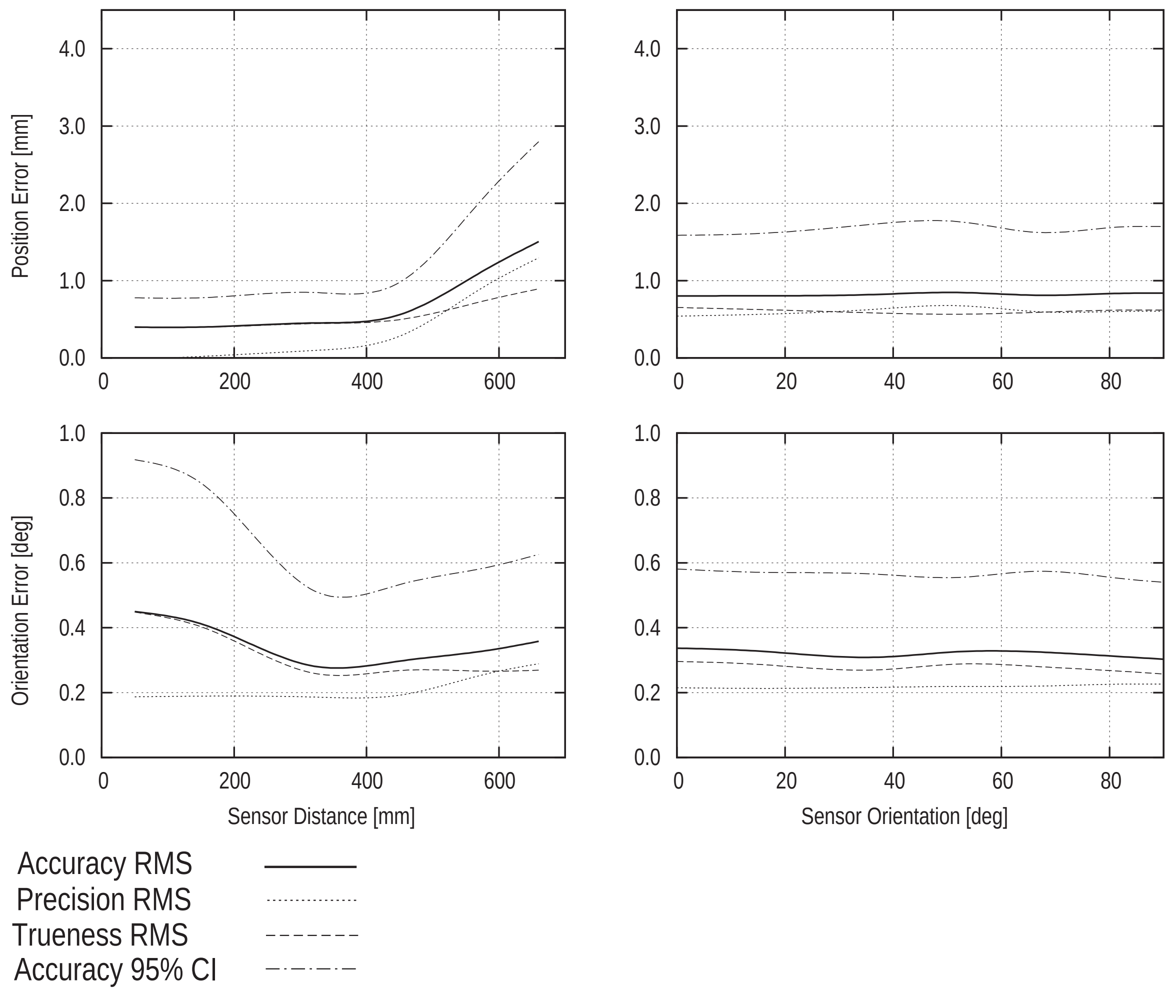


Figure 9-2 System Accuracy (6DOF Sensor)

9.2 Field Generator

Table 9-5 Field Generator Specifications

Dimensions (height x width x depth)	200 mm x 200 mm x 70 mm
Weight	2.8 kg

Table 9-6 Field Generator Operating Environmental Conditions

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

Table 9-7 Field Generator Transportation and Storage Conditions

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

9.3 System Control Unit

Table 9-8 System Control Unit Specifications

Dimensions (height x width x depth)	88 mm x 235 mm x 295 mm
Weight	3.4 kg
Host Interface	RS-232
Maximum Data Rate	115 Kbaud
Mains Power: AC Input Requirements	100 -240 V ~ (Universal input) 50/60 Hz 1.0 A
Fuses	2 x T1.00, 250 V (time-delay, 5 mm x 20 mm 1.00 A, 250 V)
Maximum Number of Sensor Interface Units	Four

Table 9-9 System Control Unit Operating Environmental Conditions

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

Table 9-10 System Control Unit Transportation and Storage Conditions

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

9.4 Sensor Interface Unit

Table 9-11 Sensor Interface Unit Specifications

Dimensions (height x width x depth)	32 mm x 50 mm x 90 mm
Weight	0.250 kg
Maximum Number of Sensors	Two

Table 9-12 Sensor Interface Unit Operating Environmental Conditions

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

Table 9-13 Sensor Interface Unit Transportation and Storage Conditions

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

10 Electromagnetic Compatibility

10.1 ESD Precautionary Measures

Care should be taken to mitigate the production of electrostatic charges. These measures can include, but are not limited to, air conditioning, humidification, conductive floor coverings, attire, etc.

You should discharge any built-up static before connecting or disconnecting any cables marked with the electrostatic discharge (ESD) warning symbol shown here. To discharge any built up static, touch either the SCU metal enclosure or a large metallic object.

Avoid touching accessible pins on connectors marked with the ESD symbol. You should also use an anti-static mat and bond yourself to either the SCU metal enclosure or to earth by means of an anti-static wrist strap.

All staff using the Aurora System should receive instructions on the ESD warning symbol and training in basic ESD precautionary procedures. This training should include an introduction to the physics of ESD, the voltage levels that can occur in normal circumstances, and the damage caused to electronic components on contact with an electrostatically charged operator. In addition, users should be provided with an explanation of the methods used to prevent the build-up of electrostatic charges.

10.2 Cables, Transducers and Accessories

The following table shows the cables, transducers and accessories that may be used with the Aurora System and still maintain compliance to the emissions and immunity requirements of IEC60601-1-2:2001

Table 10-1 Cables, Transducers and Accessories

Cable Name	NDI P/N	Type	Shielded	Notes
Host Cable	120056	RS-232 Cable, F/F	No	The SIU and Field Generator cables are attached to the respective component and hence the NDI P/N refers to the component part number, not the cable part number.
SIU Cable	8700301.000.002	-	N/A	
Field Generator Cable	8700343.000.001	-	N/A	
Power Cord, AC	7500010	3- Conductor Medical Grade	No	

Warning!

Do not use cables, transducers or accessories other than those listed in the table above, with the exception of those sold by NDI or by NDI-authorized manufacturers. To do so may result in increased emissions and/or decreased immunity of the Aurora System.

10.3 Guidance and Manufacturer's Declaration - Electromagnetic Emissions

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

Table 10-2 Manufacturer’s Declaration for Electromagnetic Emissions

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

Warning!

Warnings

Do not use the Aurora System in the presence of other magnetic fields. To do so may lead to misleading or inaccurate transformations and possible personal injury.

Do not expose sensors to a high magnetic field, such as a Magnetic Resonance Imaging Machine, as they may become magnetized. Tracking with a magnetized sensor may result in incorrect transformations and possible personal injury.

Caution! The Aurora System has not been designed or tested to be used during or following cardiac defibrillation. Cardiac defibrillation may cause system errors and/or equipment damage.

10.4 Guidance and Manufacturer's Declaration - Electromagnetic Immunity

The Aurora System is intended for use in the electromagnetic environment listed below. The customer and/or the user of the Aurora System should ensure that it is used in such an environment.

Table 10-3 Electromagnetic Immunity

Immunity Test	IEC 60601 Test Level	Compliance Level	Electromagnetic Environment-Guidance
Electrostatic discharge (ESD)IEC 61000-4-2	±6kV contact ±8kV air	±6kV contact ±8kV air	Observe precautions when connecting or disconnecting cables at ports identified with the ESD warning symbol.
Electrical Fast Transient (EFT)/burst IEC 61000-4-4	±2kV for power supply lines ±1kV for I/O lines	±2kV for power supply lines ±1kV for I/O lines	
Surge IEC 61000-4-5	±1kV differential mode	±1kV differential mode	
	±2kV common mode	±2kV common mode	
	< 5% U_t for 0.5-cycle	< 5% U_t for 0.5-cycle	
Dips / Interruptions /Variations on power supply input IEC 61000-4-11	40% U_t for 5-cycles	40% U_t for 5-cycles	
	70% U_t for 25-cycles	70% U_t for 25-cycles	
	<5% U_t for 5-sec	<5% U_t for 5-sec	
Immunity Test	IEC 60601 Test Level	Compliance Level	Electromagnetic Environment-Guidance
Power frequency (50/60Hz) magnetic field IEC 61000-4-8	3A/m	3A/m	Ensure the ambient magnetic fields are low enough not to interfere with the operation of the Aurora System. Portable and mobile RF communications equipment should be used no closer to any part of the Aurora System, including cables, than the recommended separation distance calculated from the equation applicable to the frequency of the transmitter.

Table 10-3 Electromagnetic Immunity

Conducted RF IEC 61000-4-6	3Vrms 150 kHZ to 80 MHz	3Vrms 150 kHZ to 80 MHz	Recommended separation distance: $d = \left(\frac{3.5}{3}\right)\sqrt{P}$
Radiated RF IEC 61000-4-3	3 V/m 80 MHz to 2.5 GHz	3 V/m 80 MHz to 2.5 GHz	$d = \left(\frac{3.5}{3}\right)\sqrt{P}$ 80 MHz to 800 MHz $d = \left(\frac{7}{3}\right)\sqrt{P}$ 800 MHz to 2.5 GHz 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 meters. Field strengths from fixed RF transmitters, as determined by an electromagnetic site survey* should be less than the compliance level in each frequency range.** Interference may occur in the vicinity of equipment marked with the following symbol: 

* Field strengths from fixed transmitters, such as base stations for radio, cellular/cordless telephones, 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 in which the Aurora System is used exceeds the applicable RF compliance level above, the Aurora System should be observed to verify normal operation. If abnormal performance is observed, additional measures may be necessary, such as re-orienting or relocating the Aurora System.

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

Note
1. U_t is the AC mains voltage prior to the application of the test level.
2. These guidelines may not apply to all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects, and people.
3. At 80 MHz and 800 MHz, the higher frequency range applies.

10.5 Recommended Separation Distances

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

Table 10-4 Separation Distance - Communications Equipment and Aurora System

Rated maximum output power of transmitter (watts)	Separation distance according to frequency of transmitter (meters)		
	150 kHz to 80 MHz d = (3.5 / 3) sqrt (P)	80 MHz to 800 MHz d = (3.5 / 3) sqrt (P)	800 MHz to 2.5 GHz d = (7 / 3) sqrt (P)
0.01	0.117 m	0.117 m	0.233 m
0.1	0.369 m	0.369 m	0.737 m
1.0	1.17 m	1.17 m	2.33 m
10	3.69 m	3.69 m	7.38 m
100	11.67 m	11.67 m	23.33 m

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

1. At 80 MHz and 800 MHz, the higher frequency range applies.
2. These guidelines may not apply to all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects, and people.

11 Troubleshooting

When I begin tracking a tool, my application reports it as ‘Missing’.

There are several possibilities why a tool reports as missing:

1. The tool has passed out of the measurement volume.
2. Electromagnetic disturbances are so large that they completely interfere with the tool’s readings. Such disturbances include magnetic sources, or metal placed too close to the system.
3. If you are using a tool definition file, you may be applying one that is either mismatched to the tool, or one that contains a wrong setting.
4. You are moving the tool too quickly.
5. Make sure that the tool cable is not parallel to the SCU power cable or the Field Generator cable.

Contact NDI Technical Support if the problem persists.

I am unable to initialize the Aurora System.

Check your communication settings using NDI ToolBox. For more information, see the NDI ToolBox Online Help.

Contact NDI Technical Support if the problem persists.

The power light does not turn on after turning on my Aurora System.

There are a number possibilities why your system does not power up:

1. The SCU’s power cable is not properly connected to either the SCU itself, or the power source.
2. The SCU fuse is blown. For information on how to check the fuse, see "Replacing the System Control Unit Fuses" on page 46.

Contact NDI Technical Support if the problem persists.

The transformations being returned have a very high indicator value.

There are several possibilities why the system is returning a high error value:

1. If you are using a tool definition file, you may be applying one that is either mismatched to the tool, or one that contains a wrong setting.
2. Disturbances are influencing the system’s calculations of how the sensors are positioned. Such disturbances include magnetic sources, or metal placed too close to the system.
3. The tool has been dropped or changed in some way physically, so that the positions of the sensors within the tool have been shifted.
4. Make sure that the tool cable is not parallel to the SCU power cable or the Field Generator cable.
5. Move the tool closer to the centre of the measurement volume; the father away from the Field Generator the tool is placed, the more susceptible it is to measurement noise. This is especially true if you are tracking a tool with respect to a reference tool. If the reference tool is placed too

far back in the measurement volume, not only will its own transformations be affected by measurement noise, but the original tool's transformations being reported against the reference tool will also be affected.

Contact NDI Technical Support if the problem persists.

My Aurora System's measurement volume seems to be smaller than it should be. My tools keep going 'missing' before they reach the edges.

If your measurement volume seems to be smaller than expected (i.e.smaller than a 500 mm cube), your application environment may have elements that are interfering with the Aurora System's electromagnetic field. For example, sources of metal can distort the measurement volume and interfere with measurements. Check your environment and test different adjustments until the measurement volume is restored.

Contact NDI Technical Support if the problem persists.

How do I return my Aurora System?

If you ever need to return your Aurora System, you will need to obtain a Returned Materials Authorization (RMA) from NDI. See “Return Procedure and Warranty” on page 64.

12 Return Procedure and Warranty

12.1 Return Procedure

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

You are responsible for the shipping costs of returning equipment to NDI, whether or not the equipment is covered under warranty. When the equipment is received at NDI, it will be inspected to determine whether the required repair is covered under warranty. NDI can provide you with a quotation 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.

12.2 Warranty

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

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

Hardware

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

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

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

Software

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

General Provisions Applicable to Warranty

NDI’s obligations under this warranty shall be limited to repairing or replacing (at NDI’s option) the product(s), EXW (Incoterms 2000) NDI’s point of origin. 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 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).

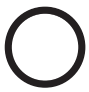
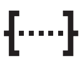
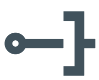
13 Abbreviations and Acronyms

Abbreviation or Acronym	Definition
5DOF	5 Degrees Of Freedom
6DOF	6 Degrees Of Freedom
AC	Alternating Current
AM	Amplitude Modulation
API	Application Program Interface
CD	Compact Disc
CI	Confidence Interval
DIN	Deutsches Institut für Normung
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
FCC	Federal Communications Commission
FM	Frequency Modulation
IEEE	Institute of Electrical and Electronic Engineers
LED	Light Emitting Diode
MRI	Magnetic Resonance Imaging
NDI	Northern Digital Inc.
RAM	Random Access Memory
RF	Radio Frequency
RMA	Returned Materials Authorization
RMS	Root Mean Square
SCU	System Control Unit
SIU	Sensor Interface Unit
SROM	Serial Read Only Memory
UL	Underwriters Laboratories Inc.
USB	Universal Synchronous Bus

14 Equipment Symbols

The following table explains the symbols found on Aurora System hardware:

Table 14-1 Equipment Symbols

Symbol	Meaning	Location
	Warning (to avoid personal injury, consult accompanying documentation)	SCU, SIU
	Power On	SCU (Switch)
	Power Off	SCU (Switch)
	Fuse	SCU
	Alternating current	SCU
	RS-232 serial communication port	SCU
	Field Generator cable port	SCU
	Sensor Interface Unit cable port	SIU
	Tool cable port	SCU, SIU
	Type BF equipment	SCU

15 Declaration of Conformity

EC DECLARATION OF CONFORMITY

Manufacturer:	NORTHERN DIGITAL INC.
Address:	103 Randall Drive Waterloo, Ontario Canada N2V 1C5
Equipment Type:	Electromagnetic Spatial Measurement System
Trade Name:	Aurora®
EEC Directive(s):	The above mentioned products conform with the requirements of the following European Council Directive(s): **89/336/EEC – EMC Directive** **73/23/EEC – Low Voltage Directive**

Dated at Waterloo, Ontario, Canada this 30th day of September 2003.

NORTHERN DIGITAL INC.
per:

David G. Crouch
President

FM-10030 Rev 001

16 Glossary

5DOF

Five of the six degrees of freedom needed to uniquely define the position and orientation of a rigid body in space. Three translation values on the x, y and z-axes and any two of the three rotation values, in general - roll, pitch and yaw.

6DOF

Six degrees of freedom needed to uniquely define the position and orientation of a rigid body in space. The three translation values on the x, y, and z-axes; and the three rotation values roll, pitch and yaw.

calibration

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

centroid

The centroid is the centre point of an imagined three-dimensional volume created by the selected sensors.

characterization (tool)

Characterizing a tool is the process of creating its tool definition file (.rom).

characterization (Field Generator)

Characterizing a Field Generator is a manufacturing process used to determine and define the specific physical parameters of each Field Generator.

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.

detection region

The detection region is the total volume in which an NDI measurement system can detect a marker/sensor, regardless of accuracy.

dual sensor tool

A dual sensor tool contains two sensors. If the sensors are affixed relative to each other inside this tool, the system is able to measure the transformations of the tool in 6DOF.

Electromagnetic Compatibility (EMC)

Electromagnetic Compatibility (EMC) is the extent to which a piece of hardware will both interfere with other equipment and tolerate electrical interference from other equipment.

Electromagnetic Interference (EMI)

Electromagnetic Interference (EMI) are electromagnetic waves that emit from natural sources or electrical and electronic devices.

Euler rotation

An Euler rotation is a mathematical method of describing a rotation in three dimensions: the rotation of the object around each axis (Rx, Ry, and Rz), applied in a specific order.

Euler transformation

An Euler transformation is a mathematical method of describing translations and rotations in three dimensions. Six values are reported for an Euler transformation: the three translational values in the x, y, and z-axes; and rotations around each of the axes, Rx, Ry, and Rz.

Field Generator

The Field Generator is the component of the Aurora System that generates the electromagnetic field.

Field Generator port

The Field Generator port connects the System Control Unit to the Field Generator.

Field Generator cable

The Field Generator cable connects the Field Generator to the System Control Unit.

global coordinate system

The global coordinate system is an NDI measurement system's coordinate system. The global coordinate system is used by the measurement system as a frame of reference against which tool transformations are reported. By default, the global coordinate system's origin is set at the Field Generator.

indicator value

The indicator value is a unitless estimate of how well the system calculated a particular transformation.

local coordinate system

A local coordinate system is a coordinate system assigned to a specific tool.

local frame of reference

A local frame of reference is a reference tool's local coordinate system.

measurement volume

See characterized measurement volume.

missing

If the system cannot determine the location of a sensor or a transformation of a rigid body/tool, that sensor or rigid body/tool is considered missing.

quaternion transformations

A quaternion transformation is a mathematical method of describing a change in position and orientation in three dimensions. Seven values are reported for a quaternion transformation: the three translational values in the x, y, and z axes; qx, qy and qz form a vector and q0 indicates the amount of rotation about that vector.

reference tool

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

Rx, Ry, Rz

The terms Rx, Ry, and Rz refer to angles of rotation around the x, y and z-axes respectively.

sensor

A sensor is a coil of wire with two lead wires whose position can be determined in 5DOF by the Aurora System.

Sensor Interface Unit (SIU)

The SIU is the component of the Aurora System that connects tools to the System Control Unit (SCU).

sensorless tools

Tools that have no sensors, and cannot have their position determined. For example, a foot switch. Sensorless tools have GPIO lines that need to be recognised by the system.

single sensor tool

A single sensor tool contains one sensor. This tool can only provide 5DOF position information.

SROM device

An SROM device is a memory device located inside a wired tool. A tool definition file can be programmed into the SROM device so that the tool can carry its own information for automatic retrieval by an NDI measurement system.

SROM Image file

see *tool definition file*

System Control Unit (SCU)

The System Control Unit (SCU) controls the Aurora System. The SCU powers and directs the Field Generator's output, collects measurement data from tools, and calculates transformations. It also communicates with the host computer.

tool definition file

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

tool origin

The tool origin is the origin of the tool's local coordinate system.

transformation

A transformation is a combination of translation and rotation values that describe the location of the tool in position and orientation. See also *Euler transformations, quaternion transformations.*

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Numerics

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