Aurora V3 User Guide

Revision 2
November 2014

IMPORTANT
Please read this entire document before operating the Aurora System

Revision Status

Revision Number	Date	Description
1	February 2014	Initial release
2	November 2014	Update to SCU information, update to PCB integration guide chapters.

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Read Me First

Warnings

Warning!

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

1. Do not use the 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 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.
3. Do not operate the Field Generator within 10 m of another operating Field Generator. To do so may contribute to inaccurate transformations and possible personal injury.
4. 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.
5. Do not coil the Field Generator cable. The cable carries 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.
6. Do not place the SCU or SIU within 1 m of the Field Generator. To do so may affect the measurement volume, contributing to inaccurate transformations and possible personal injury.
7. 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.
8. When using the mounting arm to mount the planar Field Generator, ensure that FG is mounted correctly. The mounting arm segment between the adjustment handle and the plastic segment is ferromagnetic and can adversely affect the Aurora System. The FG must be mounted so that there is a minimum of 20 cm between the FG and this segment. Mounting the FG too close to the ferromagnetic mounting arm segment can increase the possibility of inaccurate transformations and possible personal injury.
9. Do not place Aurora sensors, tools or Sensor Interface Units directly on the Tabletop Field Generator. Doing so will increase the risk of interference of the Tabletop Field Generator magnetic field. Such interference may produce misleading transformations which may result in 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. Ensure that the Aurora System SCU is connected to an IEC 60950 or IEC 60601 approved workstation. If the SCU is not connected to an IEC 60950 or IEC 60601 approved workstation, leakage currents may be increased beyond safe limits and cause possible personal injury.
12. Make sure that the SCU is only connected to a mains supply that has a protective earth. Failure to do so may result in electric shock and personal injury.
13. Make sure that the SCU is positioned so that the operator cannot touch the SCU and patient simultaneously. Failure to do so may result in personal injury.
14. Ensure that the Tabletop Field Generator is placed so that the patient cannot come into direct contact with it. Failure to do so may result in personal injury.
15. Do not move the Field Generator while tracking an object. The system may produce misleading transformations and result in possible personal injury.
16. 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.
17. 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.
18. 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.
19. Do not expose sensors to a high magnetic field, such as a Magnetic Resonance Imaging (MRI) scanner, as they may become magnetized. Tracking with a magnetized sensor may result in incorrect transformations and result in possible personal injury.
20. 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.
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. 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.
23. When using reply option 0800 with the BX or TX API 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.

24. 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.
25. 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.
26. 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.
27. 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.
28. 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.
29. Apart from replacing the SCU fuses, there are no user serviceable parts in the Aurora System. All servicing must be done NDI. Unauthorized servicing may result in possible personal injury.
30. Do not change either fuse without first disconnecting the SCU from its power source. Failure to disconnect the system may result in personal injury.
31. Disconnect power to the Aurora System before cleaning it. Failure to do so may cause personal injury.
32. Do not short-circuit any of the patient isolation circuits on the SCU PCB. If a patient isolation circuit is short-circuited, there is a risk of excessive patient leakage current, which 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.
9. Do not modify the Aurora System equipment without authorization of the manufacturer. Unauthorized modification of the equipment may result in damage to the equipment.
10. When working with SCU or SIU boards as described in "PCB Integration Guide: SCU Board" on page 79 and "PCB Integration Guide: SIU Board" on page 86, the system integrator must handle the boards in an ESD-safe manner. Failure to do so can damage the boards.

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. The embedded computing electronics and the implemented algorithms are not single-fault-safe.
4. 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.
5. This equipment has been investigated with regard to safety from electrical shock and fire hazard. The inspection authority has not investigated other physiological effects.
6. This device has been investigated and found to be in compliance with EN 60601-1-2:2007, 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.
7. 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.
8. Additional equipment connected to medical electrical equipment must comply with the respective IEC or ISO standards (e.g. IEC 60950 for data processing equipment). Furthermore all configurations shall comply with the requirements for medical electrical systems (see IEC

60601-1-1 or clause 16 of the 3Ed. of IEC 60601-1, respectively). Anybody connecting additional equipment to medical electrical equipment configures a medical system and is therefore responsible that the system complies with the requirements for medical electrical systems. Attention is drawn to the fact that local laws take priority over the above mentioned requirements. If in doubt, consult your local representative or the technical service department.

9. The system integrator is responsible for determining and implementing labelling requirements for detachable components.

Contact

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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:

https://support.ndigital.com

Aurora V3 User Guide: Overview

Before using the Aurora system, review the Warnings, Cautions and Disclaimers at the beginning of this guide.

Getting started?

If you're new to the Aurora system, start here:

- Basic introduction to the Aurora system: "Introduction" on page 2
- How the Aurora works: "Principles of Operation" on page 3
- "Software and Drivers Installation" on page 13
- "Setting up the Aurora System Hardware" on page 22
- "Tutorial: Learning to Use the Aurora System (NDI ToolBox)" on page 44

Essential Information

What you need to know to get the most out of the Aurora system:

- Tool types, sensors: "Tool Components" on page 50 and "Tool Types" on page 51
- Tracking data, API, error flags, measurement rate, latency, degrees of freedom (5DOF, 6DOF), coordinate systems: "Aurora System Data" on page 53
- "Field Generator Magnetic Field Strength" on page 61
- How metal and other EM fields affect the Aurora system: "Interference and Distortions" on page 61 and "Effects of Nearby Metal on the Aurora System" on page 62

Integrating Aurora PCBs into your system?

If you have the SCU and SIU in PCB format, you can find the integration information here:

- System Control Unit PCB: "PCB Integration Guide: SCU Board" on page 79
- Sensor Interface Unit PCB: "PCB Integration Guide: SIU Board" on page 86
- Isolation, EMC, shielding: "PCB Integration Guide: Design Considerations" on page 90

Problems with tracking?

For problems with tracking, see the following troubleshooting sections:

- "Data is reported as 'Missing'" on page 93
- "High Indicator Value" on page 94
- "Noisy, inaccurate or unstable data" on page 94.
- "Measurement volume seems too small" on page 94
- "Connection and Hardware problems" on page 96

1 Aurora System Overview

1.1 Introduction

This guide is applicable to the Aurora® V3 System. 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.

The Aurora System comprises the following components:

- Field Generator: one of Planar Field Generator (PFG) or Tabletop Field Generator (TTFG)
- System Control Unit (SCU)
- Sensor Interface Unit (SIU)
- Sensors and/or tools
- Host computer (provided by user)

The Aurora system components are shown in Figure 1-1:

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.

Sensors, typically embedded in tools, are connected to the SIU, which in turn is connected to the SCU. If these sensors are placed inside the Aurora's detection region, 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, and the strength and phase of the varying magnetic fields.

The SIU converts the voltages, 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 application software.

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.) The shape of the characterized measurement volume is dependent on the Field Generator type and how it was characterized. The various volumes are detailed in the following sections:

- "Planar Field Generator Measurement Volume" on page 28
- "Tabletop Field Generator Measurement Volume" on page 37

1.3 Field Generator

The Field Generator generates the electromagnetic field in which sensors and tools can be tracked. For information specific to each Field Generator, please see the appropriate section:

- "Planar Field Generator" on page 28
- "Tabletop Field Generator" on page 36

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 SIU) and calculates sensor positions and orientations. It then sends the position and orientation data to the host computer (if requested).
- Interfaces with the host computer.

Figure 1-2 System Control Unit

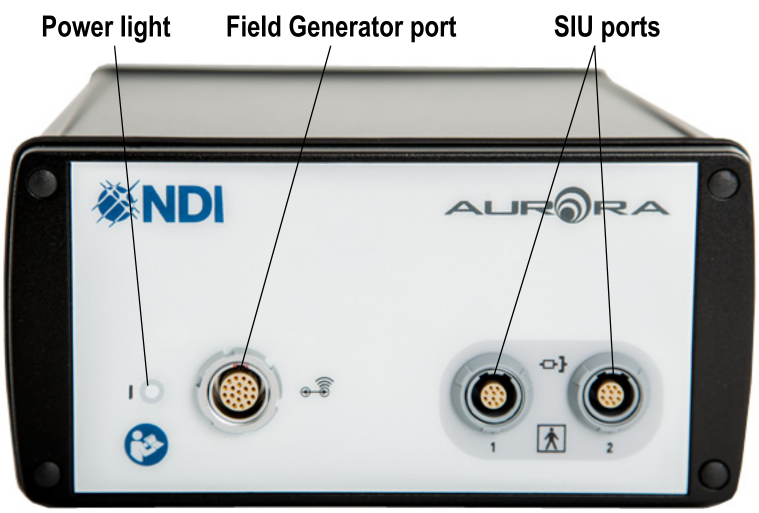
SCU Front Panel

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

Table 1-1 System Control Unit Front Panel

Parts	Description
Power light (green)	Lights when the SCU is powered on.
Field Generator port	Connects the SCU to the Field Generator cable.
SIU ports (2)	Connect SIU(s) to the SCU, allowing communication between the system and connected tools.

Figure 1-3 System Control Unit Front Panel



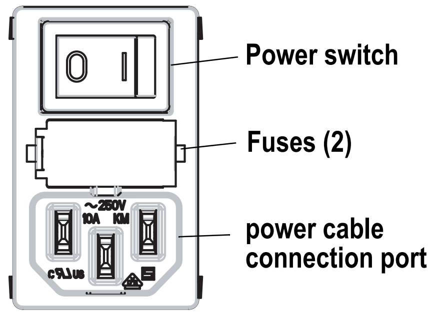
SCU Back Panel

Table 1-2 System Control Unit Back Panel

Part	Description
RS-422 port	A serial communications port used to connect the SCU to the host computer. This is an isolated port with a 9-pin D-shell male connector. For the pinout see “Pinout for RS-422 Connection” on page 7.
Synchronization port	A synchronization port used to synchronize the Aurora System to other equipment or to synchronize two SCUs together. For more information see “External Synchronization” on page 65
USB port	A USB port used to connect the SCU to the host computer.
Power entry module	A sub-assembly that comprises the following components, as illustrated in Figure 1-5: • System power switch for turning the Aurora System on and off **Note: At elevations of over 2000 m above sea level, the SCU must be disconnected from the mains power supply in order to turn the Aurora System off.** • Fuses (for information on changing the fuses, see “Replacing the System Control Unit Fuses” on page 67) • Power cable connection port

Figure 1-4 System Control Unit Back Panel

Figure 1-5 System Control Unit Entry Module



System Control Unit Labels

The SCU type and serial number labels are located on the bottom of the SCU, and show the item ID, model, serial number and manufacture date of the SCU.

Figure 1-6 System Control Unit Labels

System Control Unit Specifications

Table 1-3 System Control Unit Specifications

Dimensions (height x width x depth)	84 mm x 172 mm x 230 mm
Weight	2.0 kg
Host Interface	USB or RS-422
Maximum Data Rate	921 Kbaud (using USB)
Mains Power: AC Input Requirements	110-240 VAC, 50/60 Hz, 40 VA
Maximum Number of Sensor Interface Units	2

1.5 RS-422 Pinout

The SCU incorporates an isolated RS-422 port. NDI does not provide a cable for this port. The connector is a 9-pin D-sub male connector as shown in Figure 1-7 and the pinout is given in Table 1-4.

Figure 1-7 RS-232 Port Connector Pin Arrangement

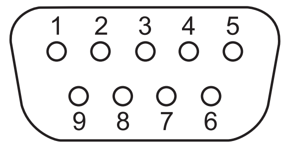


Table 1-4 Pinout for RS-422 Connection

Pin	Pin Function
1	ISO Ground
2	CTS+
3	RTS+
4	RX+
5	RX-
6	CTS-
7	RTS-
8	TX+
9	TX-

1.6 Sensor Interface Unit

The SIU is the interface between the sensors (usually 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. Analog signals in the tool cable (though shielded when using the NDI tool cable) are still susceptible to noise, so the shorter the tool cable, the less noise will appear on the signal from the sensors.

Each SIU can support up to eight 5DOF sensors, four 6DOF sensors, or a combination. The SIU also allows you to interface with sensorless tools, such as a footswitch. For more information about tools, see "Aurora System Tools" on page 50.

Figure 1-8 Sensor Interface Unit

SIU Front Panel

Table 1-5 Sensor Interface Unit Front Panel

Part	Description
Power light (green)	Lights when the SIU is powered on.
Tool port status light (amber/green)	Lights amber when a tool is connected and green when the tool is initialized and ready for tracking.
Tool ports (4)	Connect the tools to the SIU. This tool port is a 10-pin circular plastic connector.

Figure 1-9 Sensor Interface Unit Front Panel

SIU Back Panel

Table 1-6 Sensor Interface Unit Back Panel

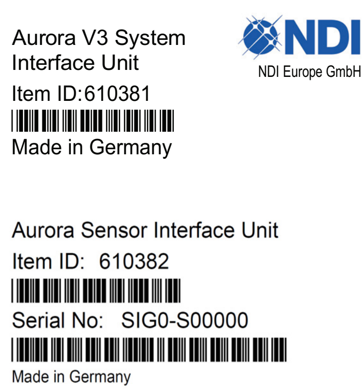
Part	Description
SCU port	Connect SIU to the SCU.

Figure 1-10 Sensor Interface Unit Back Panel

SIU Labels

The SIU type and serial number labels are located on the back of the SIU, and show the item ID, model, serial number and manufacture date of the SIU.

Figure 1-11 Sensor Interface Unit Labels



Sensor Interface Unit Specifications

Table 1-7 Sensor Interface Unit Specifications

Dimensions (height x width x depth)	53 mm x 172 mm x 114 mm
Weight	0.6 kg
Maximum Number of Sensors	8

1.7 Accessories

The following accessories are available for the Aurora System.

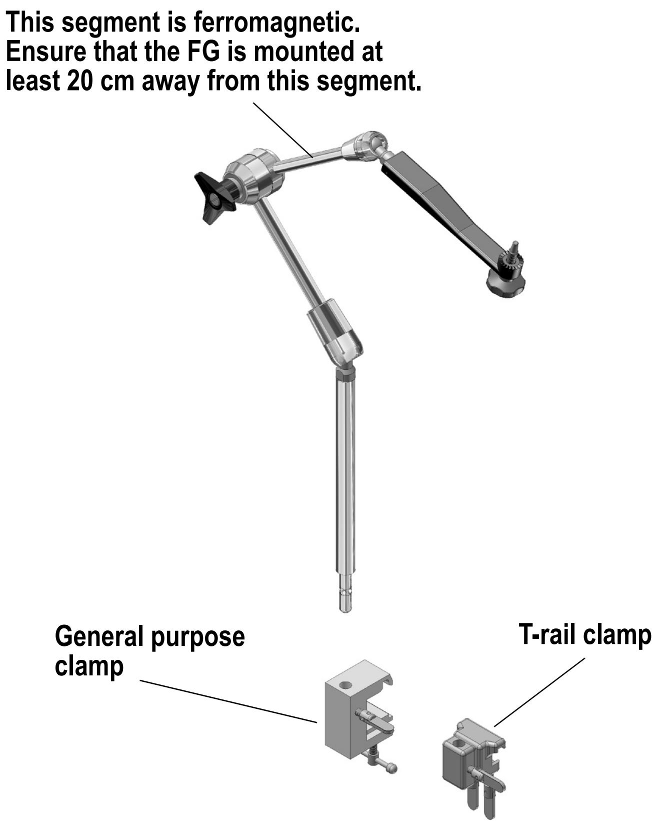
Note **Accessories for the Aurora System are under continual development. For a list of current accessories and applications, contact NDI or visit the NDI website at http://www.ndigital.com/.**

Mounting Arm for Planar Field Generator

The Mounting Arm is designed to help position the Planar Field Generator. This metal arm incorporates several articulated joints that enable you to position the Planar Field Generator at the desired position and angle. The 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 1-12 Field Generator Mounting Arm and Clamps



Warning! **When using the mounting arm to mount the planar Field Generator, ensure that FG is mounted correctly. The mounting arm segment between the adjustment handle and the plastic segment is ferromagnetic and can adversely affect the Aurora System. The FG must be mounted so that there is a minimum of 20 cm between the FG and this segment. Mounting the FG too close to the ferromagnetic mounting arm segment can increase the possibility of inaccurate transformations and possible personal injury.**

Sensors

A variety of miniature 5DOF and 6DOF sensors are available in several different configuration, allowing for many integration options.

(For more information on 5DOF and 6DOF, see "Degrees of Freedom" on page 57.)

Ready-to-Use Tools

NDI offers several ready-to-use tools, which reduce integration efforts and enable rapid application development. These tools incorporate everything required to begin tracking right out-of-the-box, including the sensor, cabling, enclosure, connection, and firmware components.

Accessories for Building Custom Tools

Tool Cable Assembly The tool cable assembly contains everything required to build an Aurora tool. All that is required is to solder the lead wires from one 6DOF sensor (or up to two 5DOF sensors) and program the SROM device.

Tool Cable and Connector Components Tool cable, connectors and SROM devices are also available separately.

6D Architect A software package used to create tool definition files and program them into the SROM device.

1.8 Host Computer Requirements

A host computer is 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:

- Universal Synchronous Bus (USB) port (Alternatively, you can also use a RS-232 serial connection)

Note **Not all USB serial adapters are of equal quality. NDI has found the FTDI model US232R USB to RS-232 adapter cable to be reliable.**

- Intel or Power PC G5 Processor
- 512 MB random access memory (RAM)
- 100 MB free hard drive space
- Windows:
  - Windows XP (32 bit)
  - Windows Vista (32 bit and 64 bit)
  - Windows 7 (64 bit)
  - Windows 8 (64 bit)

- Linux 2.6.35 and 3.x (Previous Linux patches that are supported are included on the CD. (Versions 2.6.33 and 2.6.34 do not work with the USB interface.)
- Mac: a power PC or Intel based Mac with OS X 10.5 and above (NDI ToolBox and the USB driver are Universal Binaries). The Aurora system was tested and verified on version 10.5.8, 10.6 and 10.8, but may work on earlier and later versions.
- Screen resolution 1024 x 768 (1280 x 1024 recommended)

1.9 Service Life/Disposal

The Aurora System's expected service life is approximately eight years. To ensure environmentally responsible disposal after decommissioning, please contact NDI.

2 Software and Drivers Installation

2.1 Aurora Software

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. NDI provides the following software for use with the Aurora system:

NDI Combined API Sample 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.

NDI ToolBox A collection of utilities that allow you to configure, upgrade, troubleshoot, and test the Aurora System.

NDI 6D Architect Used to characterize tools, create tool definition files and program them into the SROM device of custom tools. NDI 6D Architect is not included on the product CD and must be purchased separately, either on its own or as part of the Aurora Tool Developer Kit.

USB Drivers The USB drivers are downloaded as part of the NDI ToolBox installation and are also located on the installation CD.

In addition, you can write your own software application using the Aurora API. See the "*Aurora Application Program Interface Guide*" for details.

2.2 Installing the Software and Drivers: Windows

NDI Combined API Sample

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, browse to Windows\ToolBox\ directory on the product CD and double-click **install.exe**. Follow the on-screen instructions to complete the installation. 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.**

USB Drivers

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

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

Windows XP and Vista

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

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

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

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

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

Windows 7 and Windows 8

Install the USB drivers for Windows 7 and Windows 8 as follows:

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

1. Open the computer's Device Manager (e.g. Windows 7: **Start menu** > **Control Panel** > **Device Manager**; Windows 8: **All Apps > Control panel > Device Manager**)
2. Under **Other Devices**, right-click **NDI Aurora SCU**.
3. Select **Update Driver Software...**, then select **Browse my computer for driver software**.
4. Select **Program Files (x86)\Northern Digital Inc\ToolBox\USB Driver**.
5. In the Windows security dialog, select **Install this driver software anyway** option. The first driver will install.
6. After the first driver is installed, browse to **Other Devices** and right-click **USB Serial Port**.
7. Select **Update Driver Software...**, then select **Browse my computer for driver software**.
8. Select **Program Files (x86)\Northern Digital Inc\ToolBox\USB Driver**. Select **Next**.
9. In the Windows security dialog, select **Install this driver software anyway** option. The second driver will install.

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

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

2.3 Installing the Software and Drivers: Linux

NDI Combined API Sample

To install NDI Combined API Sample, copy the contents of the "CombinedAPISample" folder from the product 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.**

USB Drivers

The USB drivers are included as part of the ToolBox software installation and built on Linux kernel versions 2.6.32 and later. Patching of these kernels is not required. Patches for specific older versions are downloaded as part of the ToolBox installation, and are located in the **~/NDIToolbox/usb-patch** folder. The files are also located on the ToolBox installation CD, in the **Linux > usb-patch** folder.

Connected NDI systems appear as device files /dev/ttyUSBx (where x is enumerated). The driver emulates a standard serial port such that the USB device may be communicated with as a standard RS-232 or RS-422 device.

If you plan to access the system from a non-root user account, you will need to add the account to the "lock" and "dialout" groups. On some older systems it may also be necessary to add the account to the "tty" and "uucp" groups. You can add the account the required groups using the following command in Terminal and then restarting the machine:

```
sudo usermod -G lock,dialout <account name>
```

To install and run ToolBox on a 64-bit system, the 32-bit libraries will need to be installed first. You can do this using the following sequence of commands in Terminal (the first two commands in italics are only required on Debian systems):

`sudo dpkg --add-architecture i386`

`sudo apt-get update`

`sudo apt-get install ia32-libs`

On Debian systems, permissions may be required to install ToolBox. You can grant these permisions by mapping to the location of the install.sh file and using the following command in Terminal: `sudo chmod a+x install.sh`

To Install the USB Patches:

The instructions below are based on the Linux 2.6.x kernel, where 2.6.x is the kernel version number. The following changes are captured in the ftdi.patch file. The patch file is located in the **<user_account>/usb-patch/** directory after ToolBox has been installed.

Note **These instructions and the supplied patches have been tested with specific kernel versions. If you are using a different kernel version, the patch file may not work. Only apply the patch appropriate to your kernel version. Do not apply the patch more than once. Patches are available for 2.6.8, 2.6.20, 2.6.23 and 2.6.28. (Version 2.6.28 will also work on version 2.6.30.)**

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

ftdi_sio.c - added Polaris Spectra/Vicra SCU/Host USB Converter product ID to supported devices tables, added aliasing of 19.2KBd for the Polaris Spectra or Polaris Vicra System to use 1.2 MBd, and optimized transmit latency setting.

ftdi_sio.h - added the define for the USB product ID for the Polaris Spectra/Vicra SCU/Host USB Converter.

1. Apply the patch to an unmodified kernel as follows:
   a) Log on as root user.
   b) Execute the command `cd /usr/src/linux-2.6.x`
   c) Create backups of the files **./drivers/usb/serial/ftdi_sio.c** and **./drivers/usb/serial/ftdi_sio.h**
   d) Execute the command `patch -p1 < ftdi-usb-patch-kernel-2.6.x.patch`
2. If the driver is a kernel-loadable module, apply the patch as follows:
   a) Execute the command `make modules`
   b) Execute the command `make modules_install`
   c) Restart the computer.
3. If the driver is not a kernel-loadable module, rebuild the kernel following the instructions specific to the kernel. If you are unfamiliar with kernel rebuilding, refer to the instructions usually located in the source directory or at www.kernel.org.

4. The SCU or Host USB Converter when connected will appear as /dev/ttyUSBx (where x is enumerated).

SCUs are interchangeable on the same USB port, without having to re-install drivers or losing the device file enumeration previously established, as long as all serial converters (NDI or other FTDI-based converters) are plugged in and enumerated in the same order.

2.4 Installing the Software and Drivers: Mac OS X

Additional System Requirements

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

- 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

To install NDI Combined API Sample, copy the contents of the “CombinedAPISample” folder from the product 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.dmg** file. Double click on **NDI ToolBox Installer** and enter your administrator password.
4. Follow the on-screen instructions to complete the installation procedure**.**

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 the Aurora System. 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 (`).

USB Driver

Install the USB driver as follows:

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

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

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

Activating the VCP

Activate the VCP as follows:

1. Restart the Mac host computer. (If you have been following the previous installation procedures, the computer will have already restarted.)
2. Connect the Aurora System to one of the Mac host computer USB ports.
3. From the **Apple** menu, select **System Preferences...**, then select the Network icon. Select **OK** on the resulting dialog box.
4. If necessary, “unlock” the lock icon (located in the lower left of the dialog box) and enter your password.
   a) **Mac OS X 10.5 and above:** Click the **Apply** button. (This will activate the VCP.) Quit the System Preferences application.
   b) **Mac OS X 10.4:** Proceed with steps 5 and 6 below.
5. From the **Show** drop-down menu, select **Network Port Configurations**. The newly created VCP for the Aurora System will be shown at the top of the list.
6. Click the check box next to usbserialxxxxxxxx and click the **Apply Now** button. This will activate the VCP. Quit the System Preferences application.

Note **A unique VCP will be assigned to each USB port to which the Aurora System has been connected. This means that, if in the future, you connect the Aurora System to a different USB port you will have to perform this activation procedure again.**

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

Uninstalling Software

NDI ToolBox

Uninstall NDI ToolBox as follows:

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

USB Driver

Remove the USB driver as follows:

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

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

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

Additional Information

The following sections provide additional Mac OS X specific information.

Modified FTDI USB to Serial Driver

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

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

and/or

2. Possibly disable access to your other devices.

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

Additional Installation Files

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

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

Lock Files and Groups

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

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

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

1. Launch the **NetInfo Manager** application (normally found in the Applications folder in the Utilities sub-folder).
2. Use the hierarchical navigator to select **groups>uucp**.
3. Click the lock icon and authenticate (using a userid with administrator privileges).
4. Select the **users** property in the bottom panel.
5. Select the **Directory>New Value** menu. Enter the userid of the user account you wish to enter.
6. Click the lock icon and confirm that you wish the modification to become permanent.
7. Quit the **NetInfo Manager** application. This will allow the alternate user account to run the 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 states 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 Image Capture utility is not applicable to the Aurora System). 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 has a USB interface. However, if you wish to use the RS-232 serial interface, you will have to use a USB to serial adapter.

Note **Not all USB serial adapters are of equal quality. NDI has found the FTDI model US232R USB to RS-232 adapter cable 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 NDI ToolBox uses to communicate to these devices may have compatibility issues.

3 Setting up the Aurora System Hardware

3.1 Unpacking the Aurora System

The Aurora System is shipped with:

- Field Generator (Planar FG with attached cable or Tabletop FG with separate cable)
- System Control Unit (SCU)
- Sensor Interface Unit (SIU)
- SCU-SIU communications cable
- Power cord
- USB cable
- Aurora System Product CD

When you unpack 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, Repairs and Warranty" on page 100 for instructions on returning your system to NDI.**

3.2 Mounting the Components

Field Generator

For specific mounting instructions for your Field Generator, please refer to the appropriate section:

- "Planar Field Generator Mounting" on page 29
- "Tabletop Field Generator Mounting" on page 38

Warning!

Do not operate the Field Generator within 10 m of another operating Field Generator. To do so may contribute to inaccurate transformations and possible personal injury.

SCU and SIU

Place the SCU and the SIU on a flat surface. It is important to position the Aurora System components and cables correctly to minimize interference and avoid inaccurate transformations. Follow these warnings when setting up the Aurora System hardware components:

Warning!

Do not place the SCU or SIU within 1 m of the Field Generator. To do so may affect the measurement volume, contributing to inaccurate transformations and possible personal injury.

Do not place Aurora sensors, tools or Sensor Interface Units directly on the Tabletop Field Generator. Doing so will increase the risk of interference of the Tabletop Field Generator magnetic field. Such interference may produce misleading transformations which may result in possible personal injury.

Make sure that the SCU is positioned so that the operator cannot touch the SCU and patient simultaneously. Failure to do so may result in personal injury.

See also "Cable Management" on page 23.

3.3 Cable Management

It is important to position the Aurora System components and cables correctly to minimize interference and avoid inaccurate transformations. Follow these warnings when setting up the Aurora System:

Warning!

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.

Do not coil the Field Generator cable. The cable carries 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.

Do not place the SCU or SIU within 1 m of the Field Generator. To do so may affect the measurement volume, contributing to inaccurate transformations and possible personal injury.

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.

Make sure that the cable connecting the SCU to the host computer (USB or RS-422 cable) does not come close to other cables in the Aurora System.

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.

See also “Mounting the Components” on page 22.

3.4 Operating Environment Considerations

The Aurora System can be affected by certain metals and by other electromagnetic field sources in the operating environment. When setting up the Aurora System, read the following warnings, to minimize the possible sources of interference:

Warning!

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.

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.

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

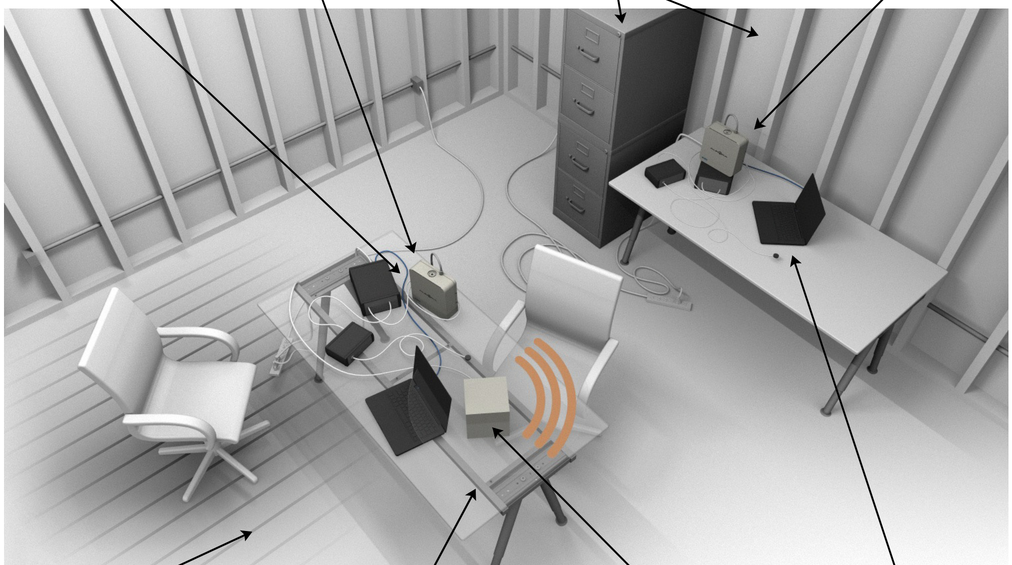
Do not use the Aurora System in the presence of other magnetic fields. To do so may lead to misleading or inaccurate transformations and possible personal injury.

Portable and mobile radio frequency (RF) communications equipment can affect the Aurora System. This may contribute to inaccurate transformations and possible personal injury.

Do not operate the Field Generator within 10 m of another operating Field Generator. To do so may contribute to inaccurate transformations and possible personal injury.

Figure 3-1 shows common sources of disturbances, which you should try to avoid or minimize in your setup. For more information on how environmental factors affect the Aurora System, see “Interference and Distortions” on page 61 and “Effects of Nearby Metal on the Aurora System” on page 62.

Figure 3-1 Environmental Disturbances



3.5 Connecting the Components

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

Caution! **Do not push or pull connectors in constricted areas. Doing so may damage the connectors.**

Do not put heavy objects on cable connectors. Doing so may damage the connectors.

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

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.

Warning! **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.**

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). If your system includes a Tabletop FG, connect the Field Generator cable to the FG, making sure that the red alignment marks on the cable and FG are aligned. See Figure 3-2.

Figure 3-2 TTFG Connector

2. Use the SCU-SIU communications cable to connect each SIU to the SCU.
3. Plug each tool into a tool port on the SIU.

Warning! **Ensure that the Aurora System SCU is connected to an IEC 60950 or IEC 60601 approved workstation. If the SCU is not connected to an IEC 60950 or IEC 60601 approved workstation, leakage currents may be increased beyond safe limits and cause possible personal injury.**

4. Use the USB cable to connect the SCU to the host computer. (Alternatively, you can use the RS-422 port with a null-modem cable.)
5. Plug the power cable into the power entry module on the SCU.

Warning! **Make sure that the SCU is only connected to a mains supply that has a protective earth. Failure to do so may result in electric shock and personal injury.**

6. Turn on the system using the power switch on the SCU.

If the Aurora System is operating correctly, the following occurs:

- The SCU will beep twice.
- The SCU and SIU power light LEDs will be lit green.
- The tool port status lights on the SIU will be lit amber if a tool is connected.

Note **If the system does not operate correctly refer to** **"Troubleshooting" on page 93****.**

3.6 Using the Aurora System

Read the following warnings before using the Aurora System:

Warning!

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.

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.

Do not move the Field Generator while tracking an object. The system may produce misleading transformations and result in possible personal injury.

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.

Hot-Plugging Components

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.

Warning!

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.

4 Planar Field Generator

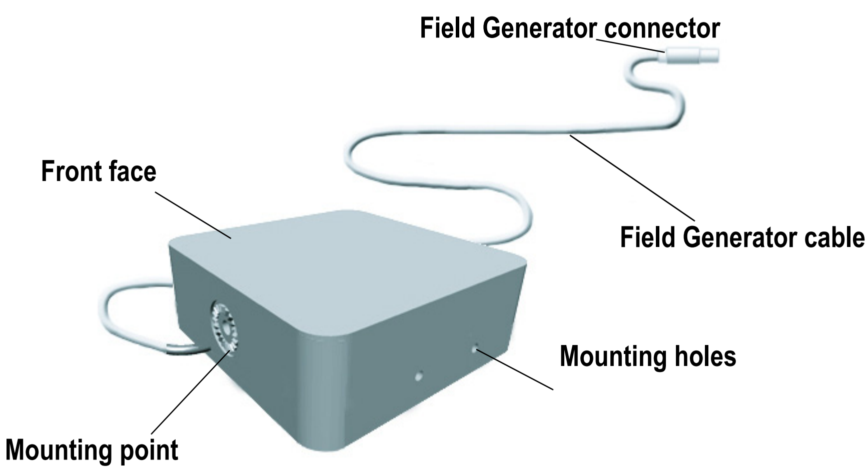
4.1 Description

The Planar Field Generator is described in the following table and illustrated in Figure 4-1.

Table 4-1 Planar 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 Aurora Field Generator Mounting Arm, described on page 10.
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.
4 mounting holes, 2 per side	M8 tapped holes (thread pitch 1.25 mm, depth 13 mm). Allows the Field Generator to be attached firmly to a fixture.

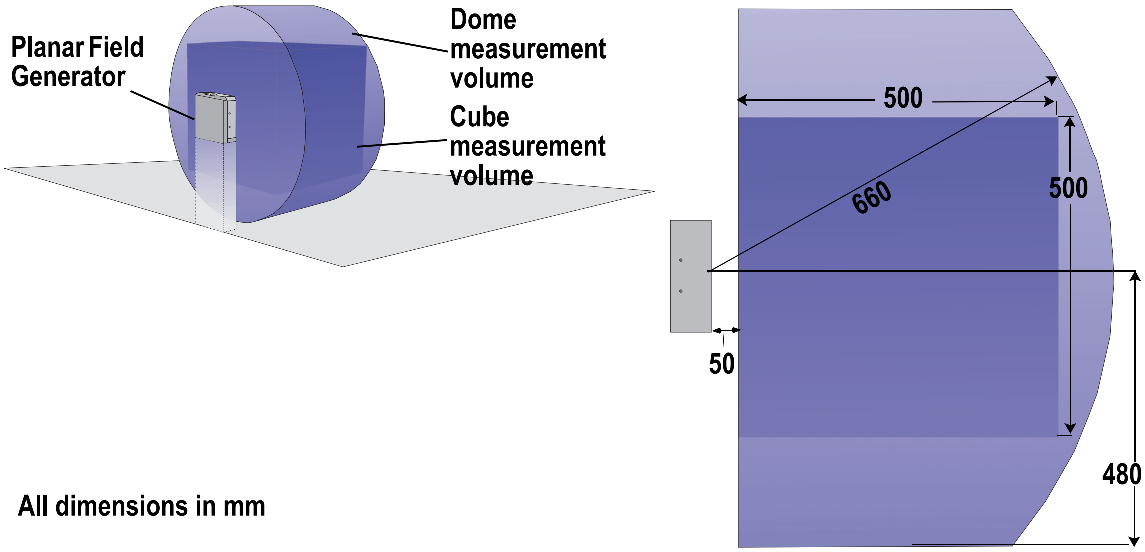
Figure 4-1 Planar Field Generator



4.2 Planar Field Generator Measurement Volume

The Planar Field Generator contains a number of large coils that generate known electromagnetic fields as previously described. The measurement volumes are illustrated in Figure 4-2. The volume is projected outwards from the Field Generator's front face, offset by 50 mm from the Field Generator.

Figure 4-2 Planar Field Generator Measurement Volume



4.3 Planar Field Generator Labels

The Field Generator type and serial number labels are located on the back of the Field Generator. They show the item ID, model and serial number of the Field Generator. Figure 4-3 shows an example of the Planar Field Generator labels.

Figure 4-3 Planar Field Generator Labels

4.4 Planar Field Generator Mounting

To mount the Planar Field Generator, proceed as follows:

1. Make sure the remainder of the Aurora System is set up as described in "Mounting the Components" on page 22, "Cable Management" on page 23 and "Operating Environment Considerations" on page 24.
2. 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.

- Make sure that the Field Generator cable is not wrapped around the Field Generator or looped anywhere along its length.
- Make sure that the Field Generator is not within a radius of 1.0 m of any metal equipment, electric motors, or sources of power (with the Field Generator as the centre of this sphere). Take into account the possibility of metal in the following:

  - Tables, benches or worktops
  - Metal reinforcing rods in the floor
  - Computer equipment (eg monitors)
  - Metal struts or electrical wiring in nearby walls

Note **If the nature of your application environment is such that the presence of metal cannot be avoided, see "Effects of Nearby Metal on the Aurora System" on page 62 for guidance.**

3. 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 (2.6 kg). The support system must also be designed to mini mize vibrations, as vibrations may introduce measurement errors. The Field Generator may be mounted in two ways (refer to Figure 4-4 and Figure 4-5):
   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, to position the Field Generator in any direction, in a manner that helps reduce its proximity to metal disturbances. For more information, contact NDI.

Warning!

When using the mounting arm to mount the planar Field Generator, ensure that FG is mounted correctly. The mounting arm segment between the adjustment handle and the plastic segment is ferromagnetic and can adversely affect the Aurora System. The FG must be mounted so that there is a minimum of 20 cm between the FG and this segment. Mounting the FG too close to the ferromagnetic mounting arm segment can increase the possibility of inaccurate transformations and possible personal injury. See the illustration in "Field Generator Mounting Arm and Clamps" on page 10.)

Figure 4-4 Planar Field Generator - Mounting Options

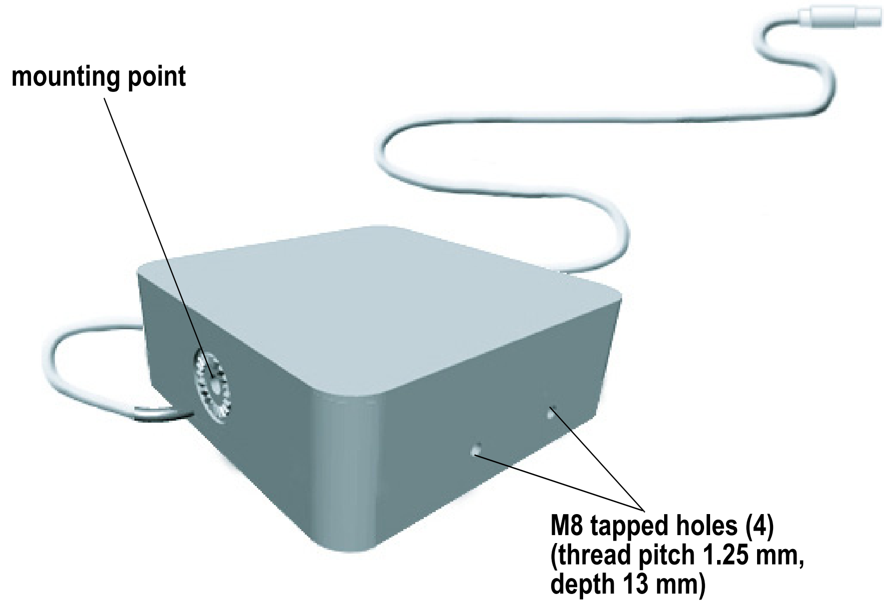
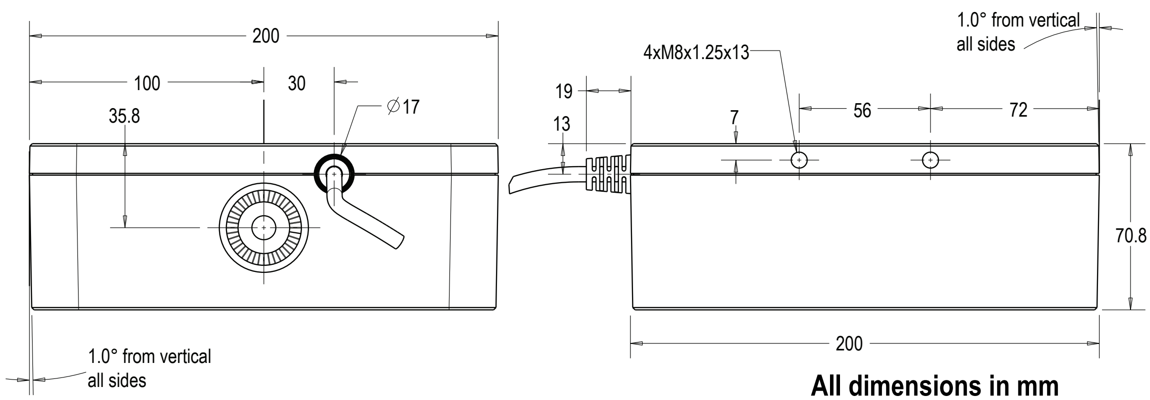


Figure 4-5 Planar Field Generator - Mounting Details

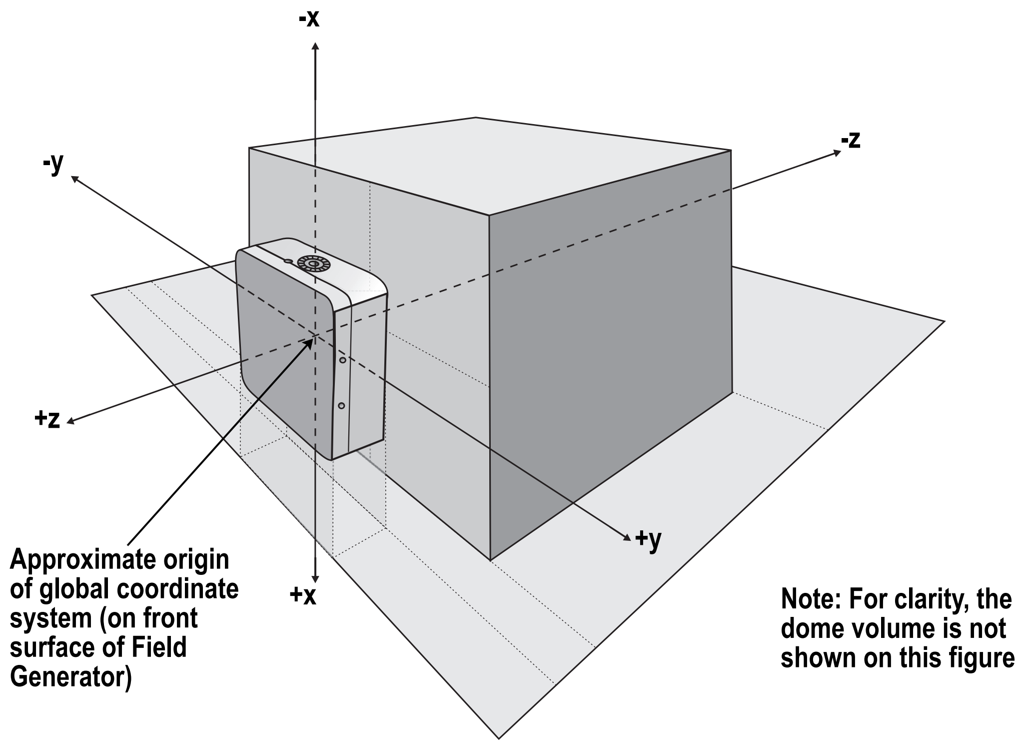


Note **The drawing shown in Figure 4-5 is available for download from the NDI Support Site.**

4. Orient the Field Generator so that the measurement volume encompasses the area of interest (area where the tools will be tracked; refer to Figure 4-2 on page 29).
5. The Field Generator may be bagged or draped to fulfil sterility requirements.

4.5 Planar Field Generator Global Coordinate System

Figure 4-6 Global Coordinate System (Planar Field Generator)



4.6 Aurora System Accuracy (Planar Field Generator)

Aurora System accuracy for the Planar Field Generator 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.**

Table 4-2 Cube Volume (Planar Field Generator) - Position Errors

	5DOF		6DOF	
Position Errors	**RMS (mm)**	**95% CI (mm)**	**RMS (mm)**	**95% CI (mm)**
Position Accuracy	0.70	1.40	0.48	0.88
Position Precision	0.48	1.00	0.30	0.70
Position Trueness	0.50	1.00	0.40	0.70

Table 4-3 Cube Volume (Planar Field Generator) - Orientation Errors

Orientation Errors	5DOF RMS (°)	5DOF 95% CI (°)	6DOF RMS (°)	6DOF 95% CI (°)
Orientation Accuracy	0.20	0.35	0.30	0.48
Orientation Precision	0.07	0.15	0.20	0.40
Orientation Trueness	0.20	0.32	0.25	0.45

Table 4-4 Dome Volume (Planar Field Generator) - Position Errors

Position Errors	5DOF RMS (mm)	5DOF 95% CI (mm)	6DOF RMS (mm)	6DOF 95% CI (mm)
Position Accuracy	1.10	2.00	0.70	1.40
Position Precision	0.80	1.68	0.56	1.20
Position Trueness	0.80	1.50	0.50	0.90

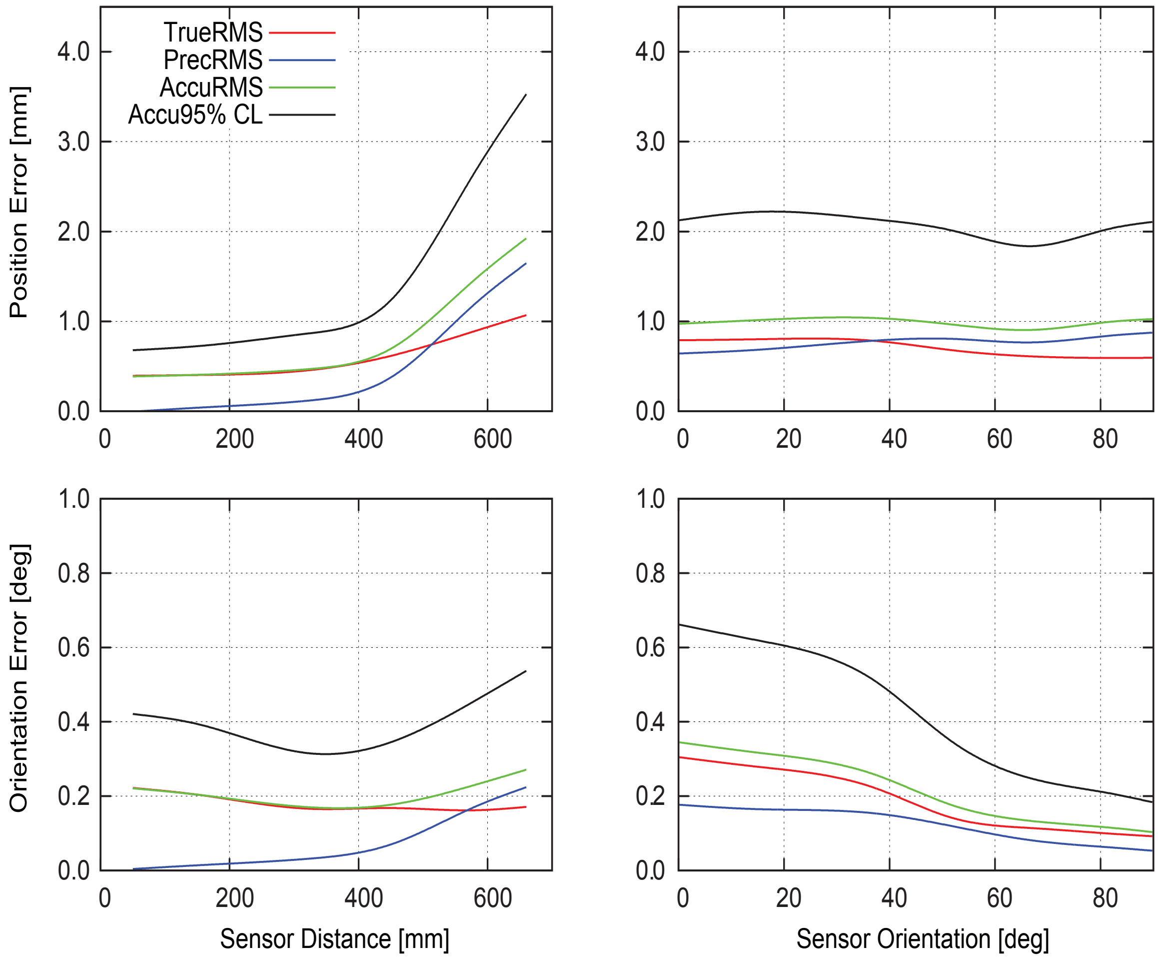
Table 4-5 Dome Volume (Planar Field Generator) - Orientation Errors

Orientation Errors	5DOF RMS (°)	5DOF 95% CI (°)	6DOF RMS (°)	6DOF 95% CI (°)
Orientation Accuracy	0.20	0.40	0.30	0.55
Orientation Precision	0.15	0.25	0.22	0.40
Orientation Trueness	0.18	0.32	0.25	0.45

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 are applicable to both the cube and dome volumes.**

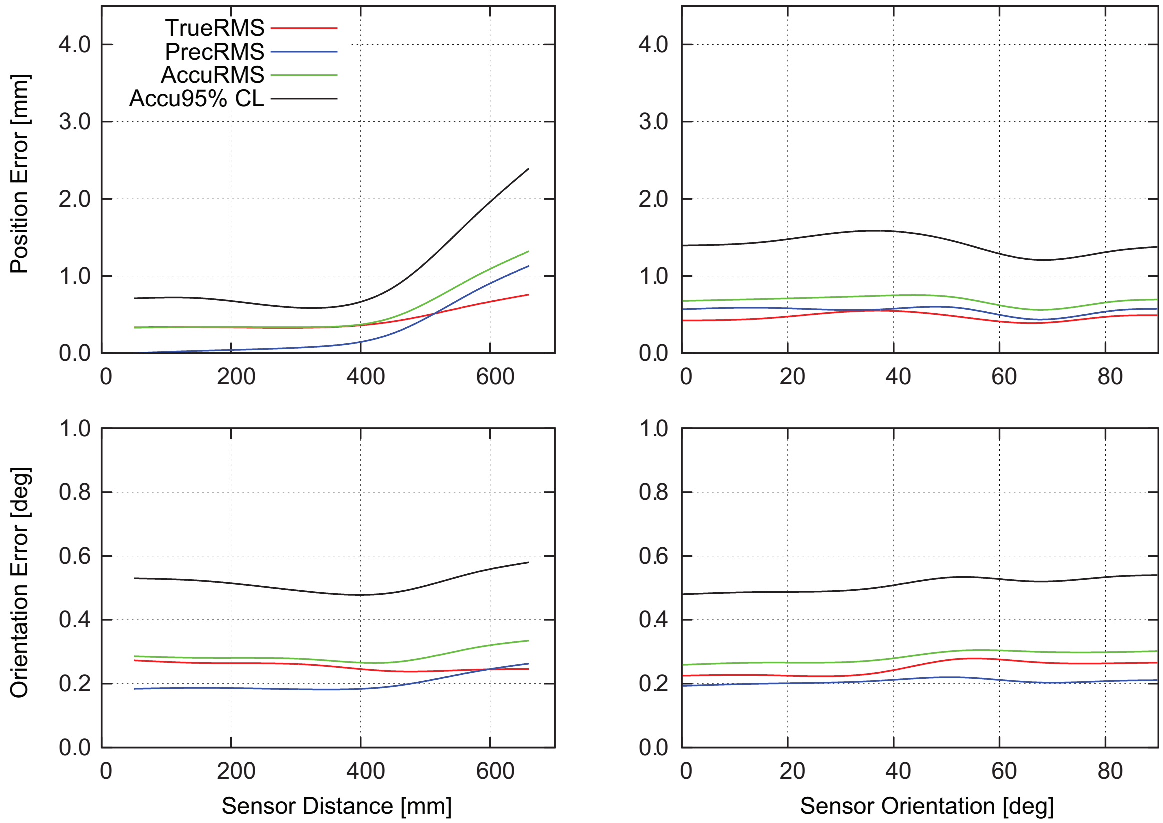
Figure 4-7 System Accuracy with Planar Field Generator (5DOF Sensor)



Note: The plots show qualitative data to indicate trends. Do not use the plots to extract accuracy

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 4-8 System Accuracy with Planar Field Generator (6DOF Sensor)



Note: The plots show qualitative data to indicate trends. Do not use the plots to extract accuracy

4.7 Planar Field Generator Specifications

Table 4-6 Planar Field Generator Specifications

Dimensions (height x width x depth)	200 mm x 200 mm x 71 mm
Weight	2.6 kg

5 Tabletop Field Generator

5.1 Description

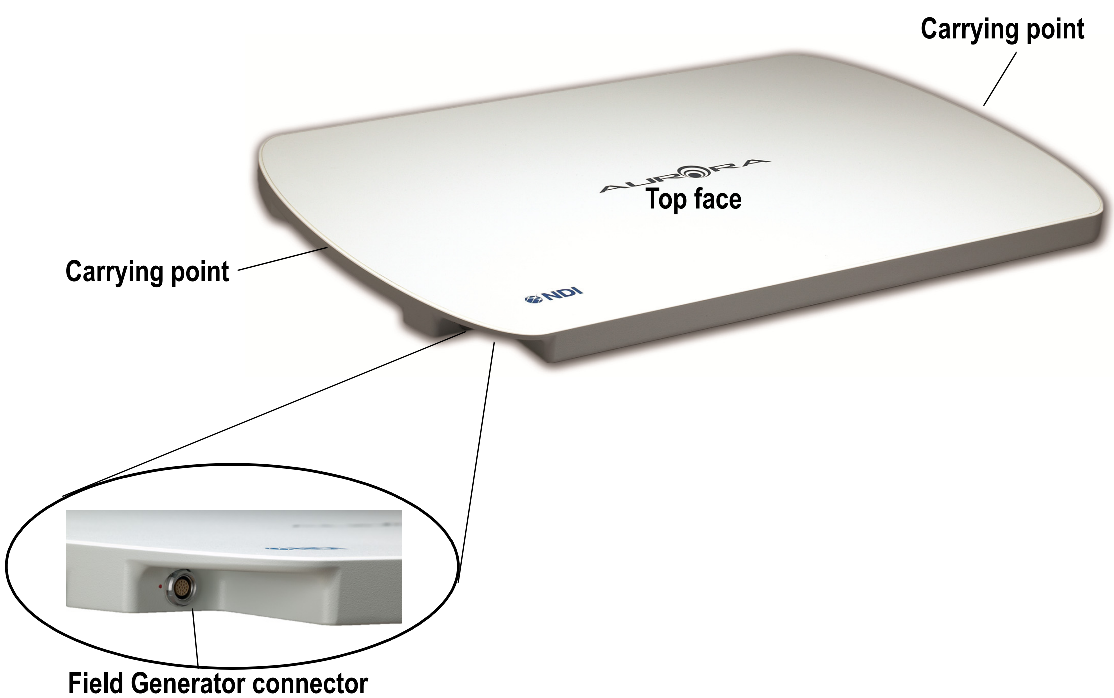
The Tabletop Field Generator (TTFG) is designed to be placed on a patient table, between the patient and the table. The TTFG incorporates a thin barrier that minimizes any tracking distortions caused by conductive or ferromagnetic materials located below the TTFG.

The TTFG is described in the following table and illustrated in Figure 5-1.

Table 5-1 Tabletop Field Generator

Part	Description
Top face	Origin of the characterized measurement volume. The top face has both the Aurora logo and NDI logo printed on it.
Carrying points	Two carrying points are moulded into the TTFG case, as shown below.
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 (not shown)	Connects the Field Generator to the SCU, via a 19 pin, 4.5 m cable.

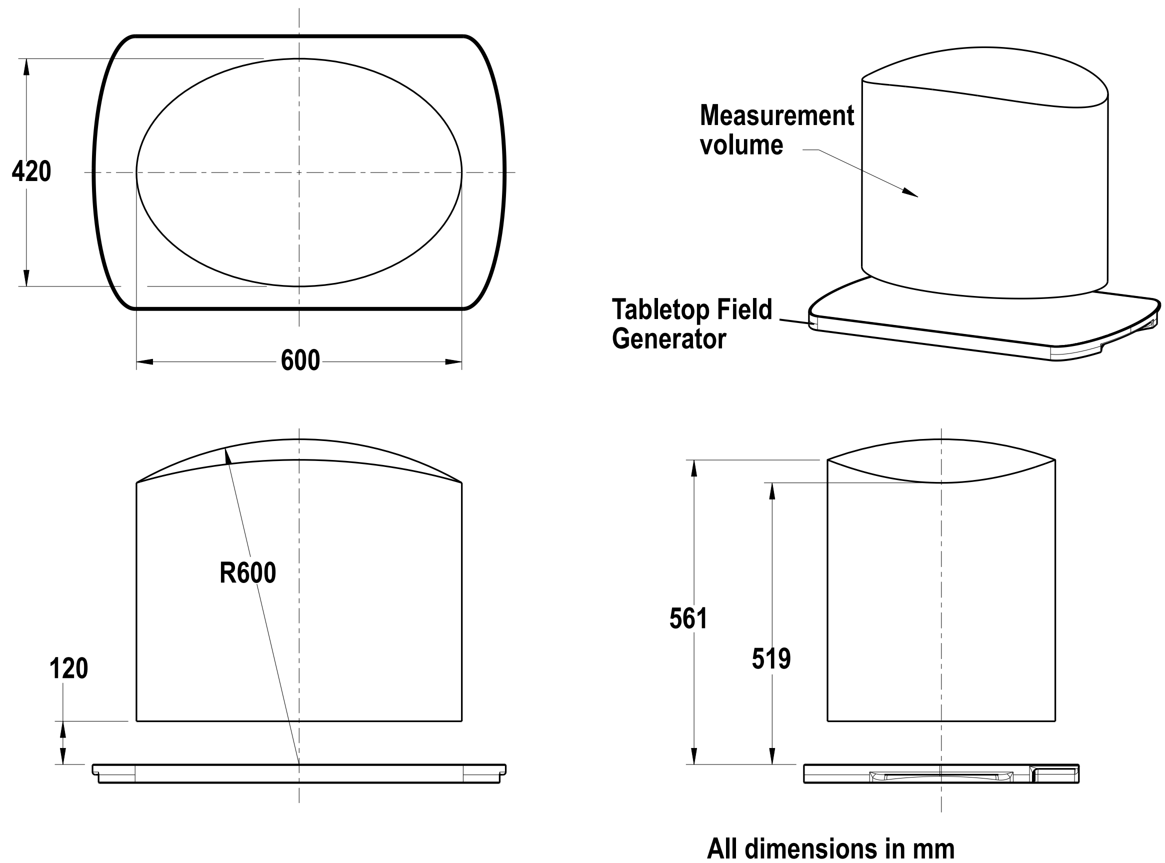
Figure 5-1 Tabletop Field Generator



5.2 Tabletop Field Generator Measurement Volume

The Tabletop Field Generator contains a number of large coils that generate known electromagnetic fields as previously described. The measurement volume is illustrated in Figure 5-2. The volume is projected outwards from the Field Generator's top face, offset by 120 mm from the Field Generator.

Figure 5-2 Tabletop Field Generator Measurement Volume



5.3 Tabletop Field Generator Field Generator Labels

The Field Generator type and serial number labels are located on the bottom of the Field Generator. They show the item ID, model and serial number of the Field Generator. Figure 5-3 shows an example of the Tabletop Field Generator labels.

Figure 5-3 Tabletop Field Generator Labels

5.4 Tabletop Field Generator Mounting

The Tabletop Field Generator (TTFG) is designed to be placed on a patient table, between the patient and the table. The TTFG incorporates a thin barrier that minimizes any tracking distortions caused by conductive or ferromagnetic materials located below the TTFG.

Warning!

Ensure that the Tabletop Field Generator is placed so that the patient cannot come into direct contact with it. Failure to do so may result in personal injury.

To mount the Field Generator, proceed as follows:

1. Make sure the remainder of the Aurora System is set up as described in “Mounting the Components” on page 22, “Cable Management” on page 23 and “Operating Environment Considerations” on page 24.
2. Carry the Field Generator by the molded grips, located at either side of the Field Generator, see Figure 5-1 on page 36.
3. Choose a location that minimizes interference from above the Field Generator:
   - 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.
   - Make sure that the Field Generator cable is not lying across the Field Generator or looped anywhere along its length.
   - Make sure that there are no metal objects, electric motors or power sources within a 1.0 m hemisphere above the Field Generator. Take into account the possibility of metal in the following:

     - Tables, benches or worktops

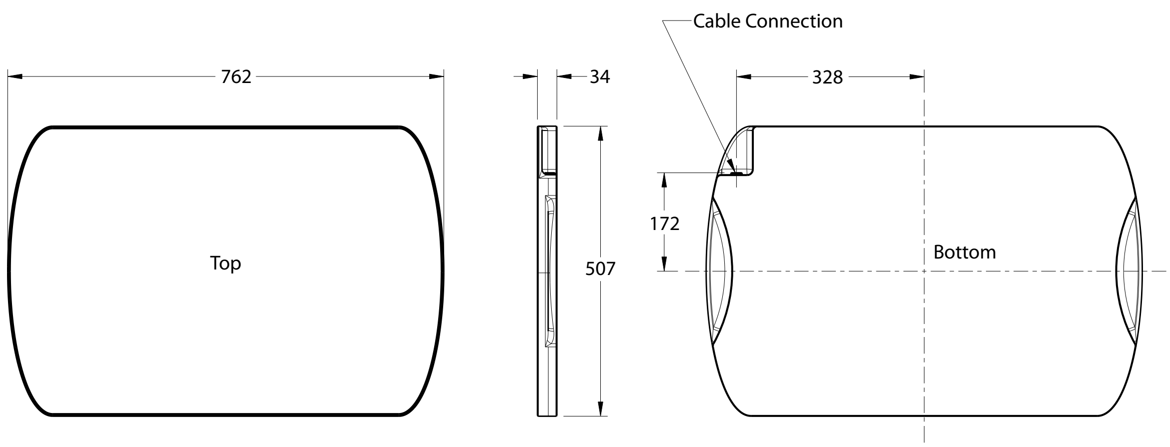
- Computer equipment (eg monitors)
- Metal struts or electrical wiring in nearby walls

Note **If the nature of your application environment is such that the presence of metal cannot be avoided above, inside or outside the measurement volume, see “Effects of Nearby Metal on the Aurora System” on page 62 for guidance.**

4. Place the Field Generator, taking into account the following requirements:
   - Make sure the Field Generator is placed in a horizontal position. If this is not possible the Field Generator must be secured, so it does not slide out of position.
   - Make sure the Field Generator is supported over its full surface area. This will prevent any deformation of the Field Generator caused by a patient’s weight. Deformation will damage the Field Generator and may result in accuracy degradation.

Note **The drawing shown in Figure 5-4 is available for download from the NDI Support Site.**

Figure 5-4 Tabletop Field Generator - Mounting Details

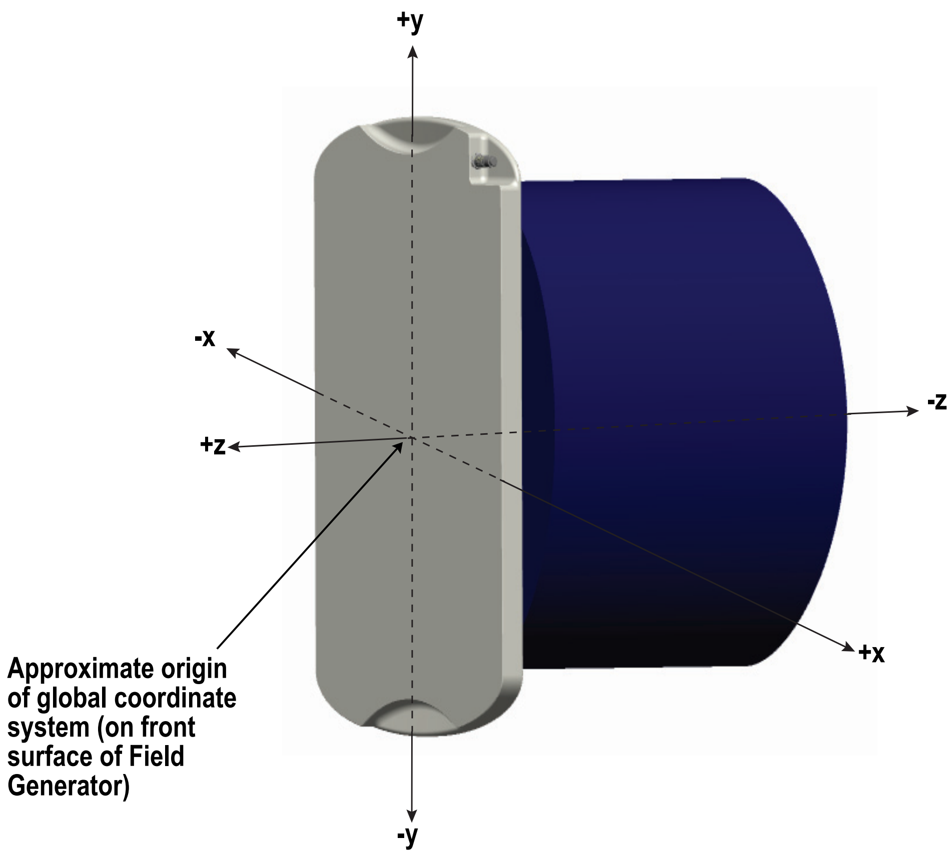


All dimensions in mm

5. Orient the Field Generator so that the measurement volume encompasses the area of interest (area where the tools will be tracked; refer to Figure 5-2 on page 37).
6. The Field Generator may be bagged or draped to fulfil sterility requirements.

5.5 Tabletop Field Generator Global Coordinate System

Figure 5-5 Global Coordinate System (Tabletop Field Generator)



5.6 Aurora System Accuracy (Tabletop Field Generator)

Aurora System accuracy for the Tabletop Field Generator dome volume 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.**

Table 5-2 Dome Volume (Tabletop Field Generator) - Position Errors

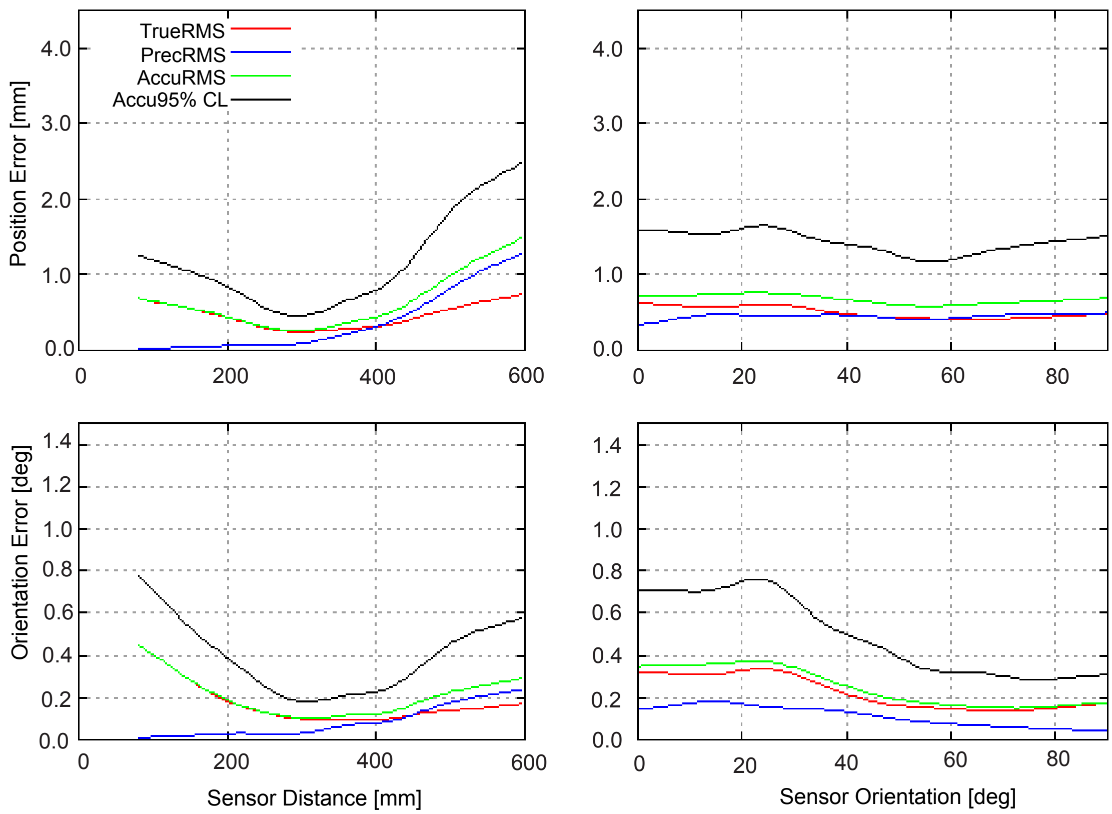
	5DOF		6DOF	
Position Errors	**RMS (mm)**	**95% CI (mm)**	**RMS (mm)**	**95% CI (mm)**
Position Accuracy	1.2	1.8	0.8	1.2
Position Precision	0.7	1.3	0.4	0.9
Position Trueness	1.0	1.3	0.7	0.9

Table 5-3 Dome Volume (Tabletop Field Generator) - Orientation Errors

	5DOF		6DOF	
Orientation Errors	**RMS (°)**	**95% CI (°)**	**RMS (°)**	**95% CI (°)**
Orientation Accuracy	0.5	0.7	0.7	0.8
Orientation Precision	0.2	0.3	0.3	0.5
Orientation Trueness	0.5	0.6	0.7	0.8

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

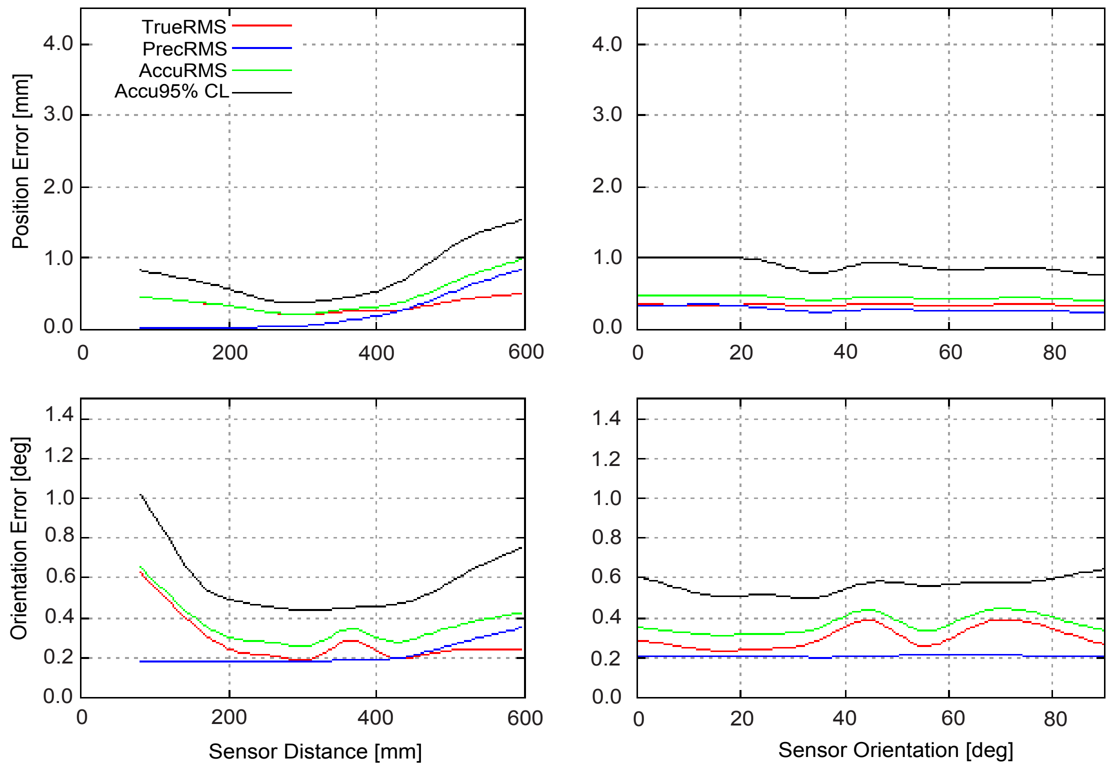
Figure 5-6 System Accuracy with TTFG (5DOF Sensor)



Note: The plots show qualitative data to indicate trends. Do not use the plots to extract accuracy

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 5-7 System Accuracy with TTFG (6DOF Sensor)



Note: The plots show qualitative data to indicate trends. Do not use the plots to extract accuracy

5.7 Tabletop Field Generator Specifications

Table 5-4 Tabletop Field Generator Specifications

Dimensions (height x width x depth)	507 mm x 762 mm x 34mm
Weight	13.3 kg (without cable)

6 Tutorial: Learning to Use the Aurora System (NDI ToolBox)

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.

6.1 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 and Drivers: Windows" on page 13, "Installing the Software and Drivers: Linux" on page 15 or "Installing the Software and Drivers: Mac OS X" on page 17.
2. Set up and connect the hardware, as described in "Connecting the Components" on page 25.
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 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.

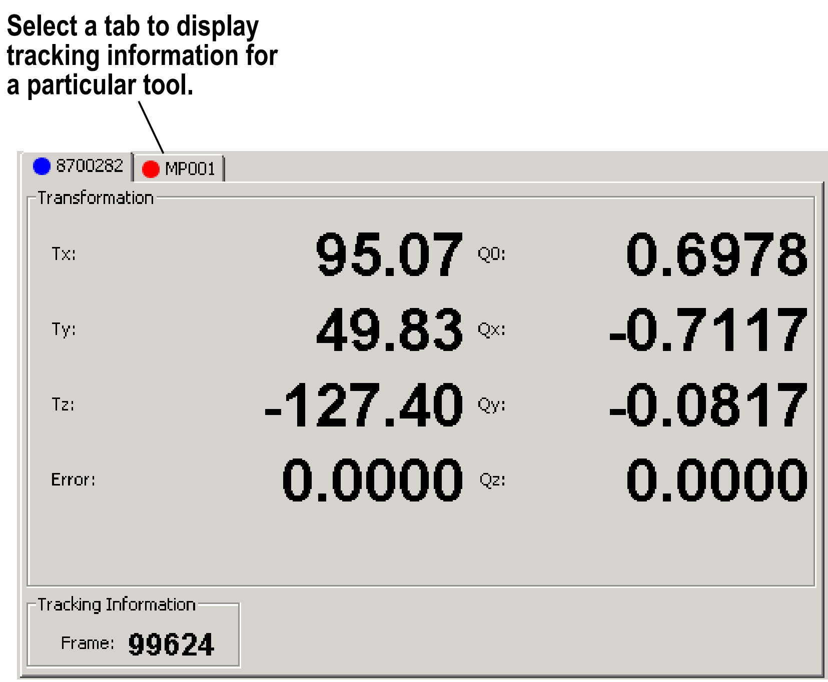
6.2 Information and Error Flags

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 44.
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 6-1 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, NDI 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, NDI 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, NDI ToolBox will display the message "Bad Fit" (the transformation data remains blank).

Figure 6-2 Tutorial: "Partially Out of Volume" Flag

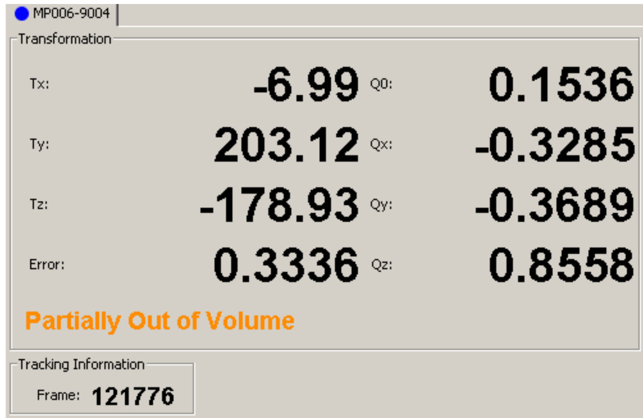
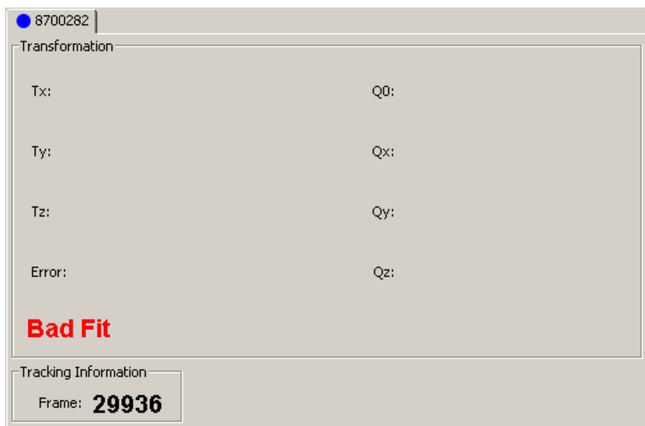


Figure 6-3 Tutorial: "Bad Fit" Flag



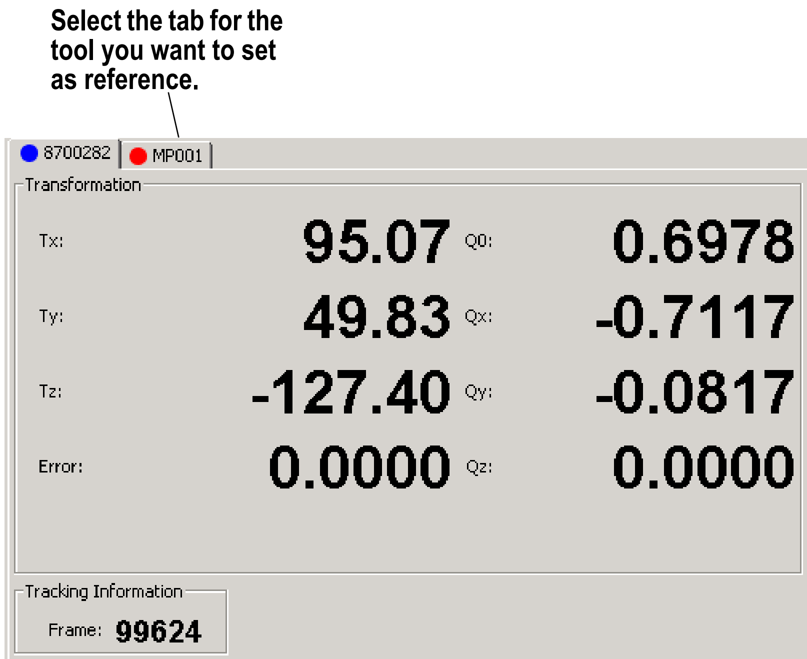
6.3 Setting a Tool as Reference

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 52.

To Set a Tool as Reference

1. Set up the system to track tools, as described in "Getting Started: Tracking Tools" on page 44.
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. (The reference tool should be a 6DOF tool.)

Figure 6-4 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.**

6.4 Determining the Tool Tip Offset

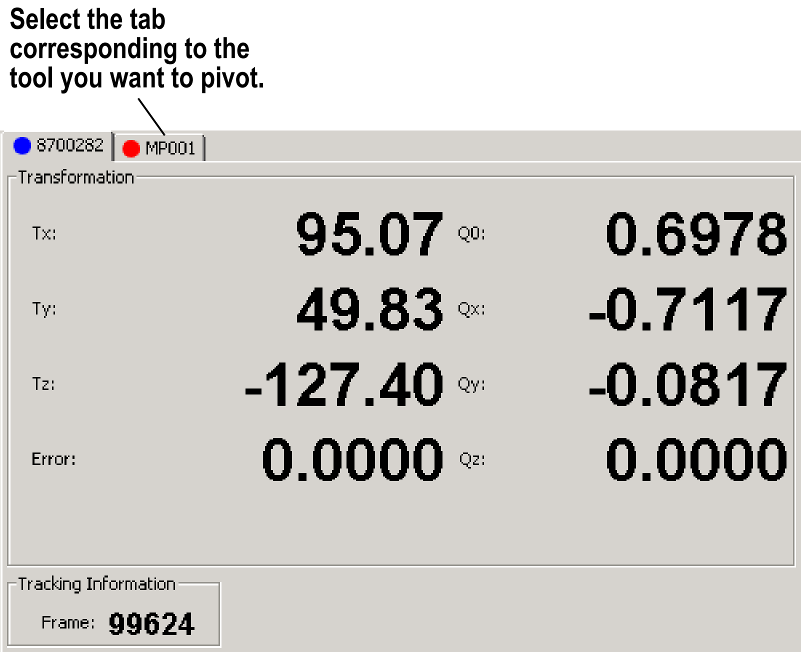
This section describes how to determine the tool tip offset of a probe or pointer tool by pivoting. Once NDI ToolBox has calculated the tool tip offset, it can report the position of the tip of the tool, instead of the position of the origin of the tool.

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 44.
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 6-5 Tutorial: Selecting a Tool to Pivot



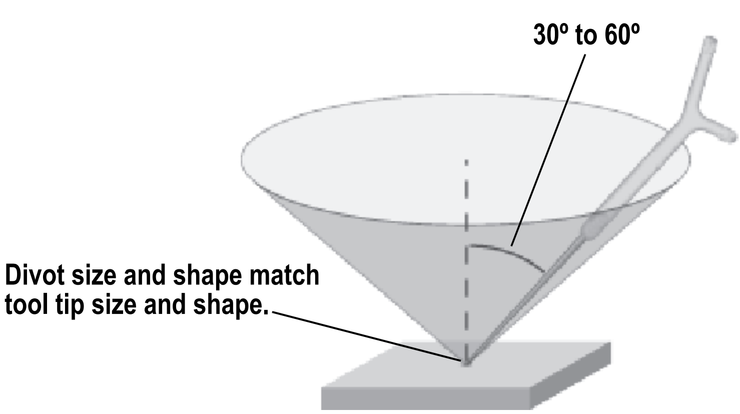
3. Click  to open the **Pivot** dialog.

4. Select an appropriate start delay (e.g. about 5 seconds) and duration, e.g. about 60 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.
5. Keeping the tool tip stationary, slowly pivot the tool until the specified pivot duration time has elapsed.

Figure 6-6 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 6-7. If the tool is a 6DOF tool, the dialog is as shown in Figure 6-8.

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

Figure 6-7 NDI ToolBox Software: Pivot Result (5DOF) Dialog

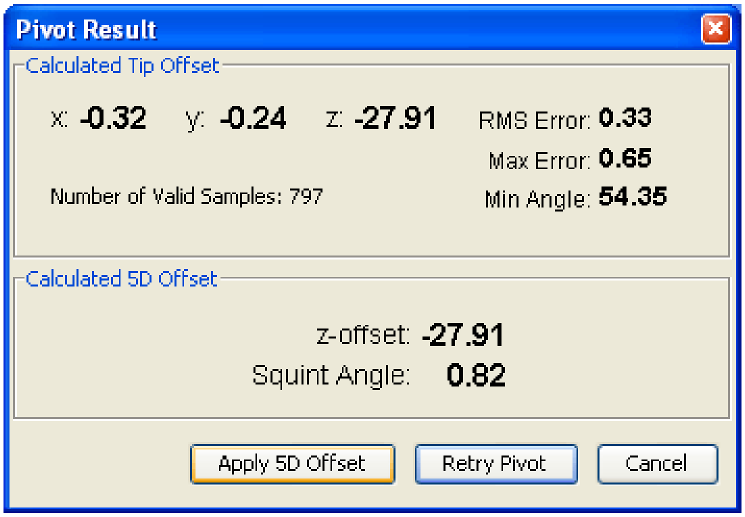
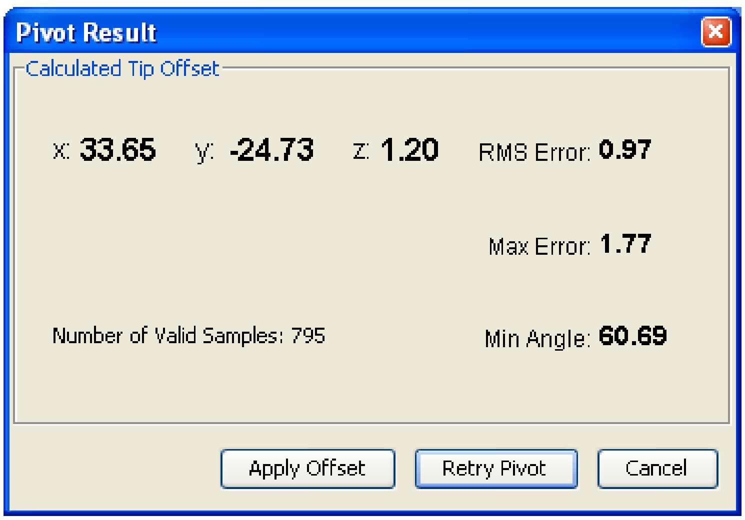


Figure 6-8 NDI ToolBox Software: Pivot Result (6DOF) Dialog



7 Aurora System Tools

7.1 Tool Components

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

Table 7-1 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 7-1 shows a typical NDI sensor. (Other sensor designs are available, visit the NDI Web site at http://www.ndigital.com/medical/aurora-sensors.php, or contact NDI for details.)**

Figure 7-1 A Typical Sensor

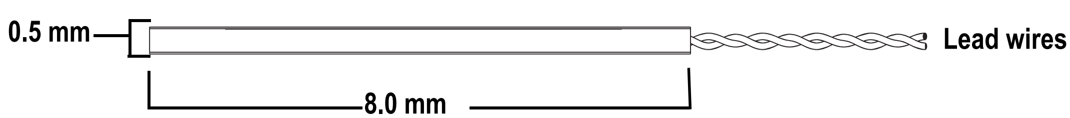
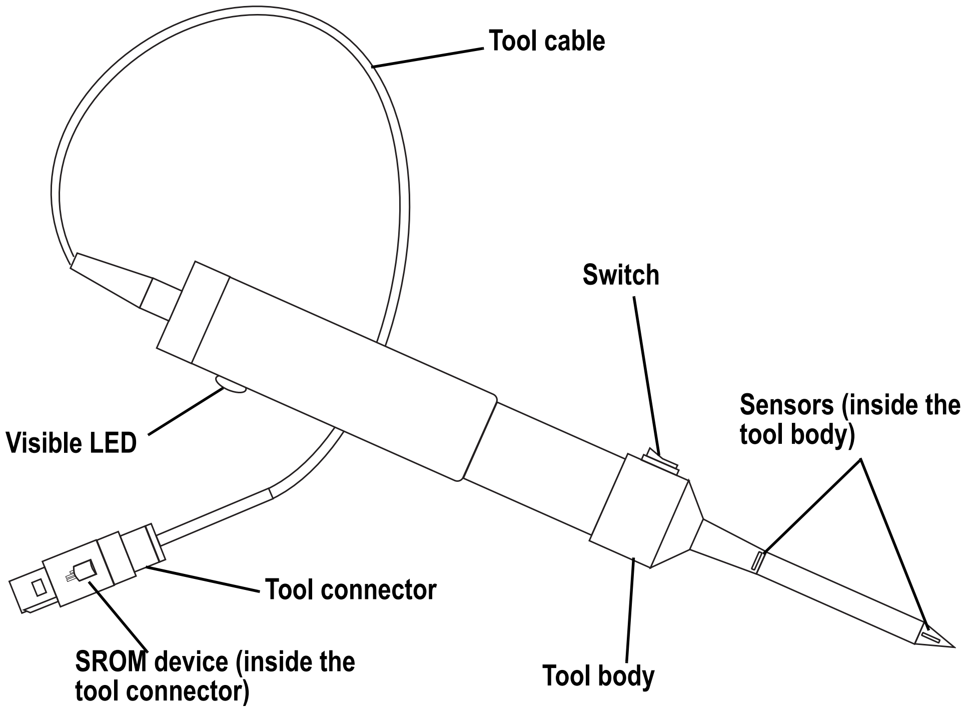


Figure 7-2 shows an example of a tool incorporating each basic tool component:

Figure 7-2 Basic Tool Components



Warning!

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.

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.

7.2 Tool Types

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

Table 7-2 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

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"*.**

7.3 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.**

8 Aurora System Data

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
- Transformations
- Indicator Value
- Error Flags and Codes
- Measurement Rate
- Latency
- Degrees of Freedom
- Global and Local Coordinate Systems

8.1 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*."

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 58).
- **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 55.)
- **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 "Transformations" on page 54.)

- **the system status**, which includes some of the system errors described in "Error Flags and Codes" on page 55.

8.2 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.**

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.

Note **Sensorless tools do not produce transformations.**

8.3 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 scaled to fall 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."*

8.4 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 API 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.)

8.5 Measurement Rate

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 and fixed; 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, using the TSTART API command. For details on API commands, see the "*Aurora Application Program Interface Guide*.".**

8.6 Latency

The latency of the Aurora System can be defined as the answer to the question, "How old are these 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.

8.7 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 8-1) 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 have a very small angle between them. 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."*

8.8 Global and Local 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 fixed relative to the Field Generator. The global coordinate system for each Field Generator is illustrated in the appropriate section:

- "Planar Field Generator Global Coordinate System" on page 32
- "Tabletop Field Generator Global Coordinate System" on page 40

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 52.

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.

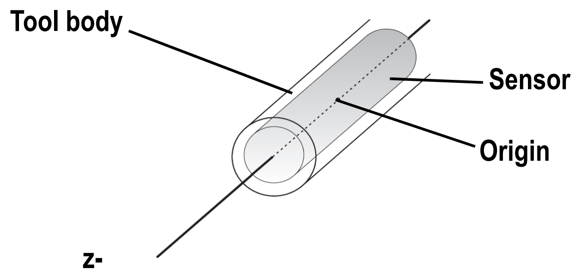
The following sections describe typical arrangements of local coordinate systems.

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 8-1 Sample Single Sensor Tool

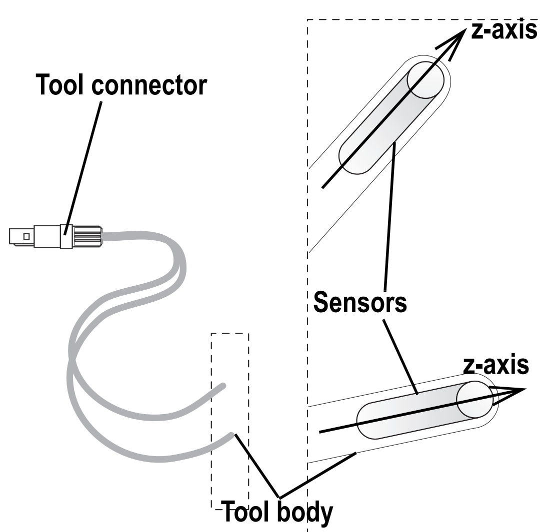


Note **Single sensor tools do not return an indicator value. For more information about indicator values, see** **"Indicator Value" on page 55****.**

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.

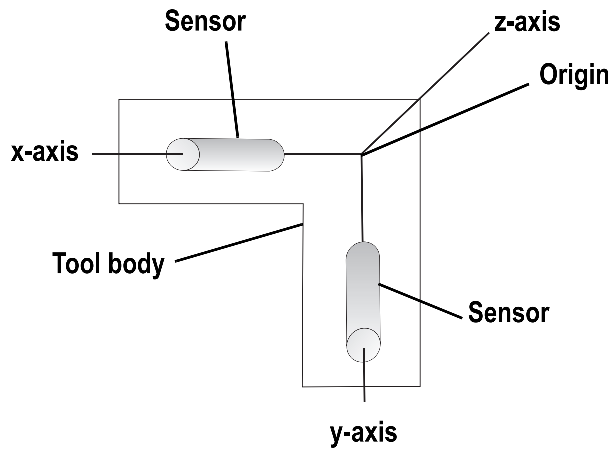
Figure 8-2 Sample Dual 5DOF Tool



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 8-3 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 8-3 Sample 6DOF Tool



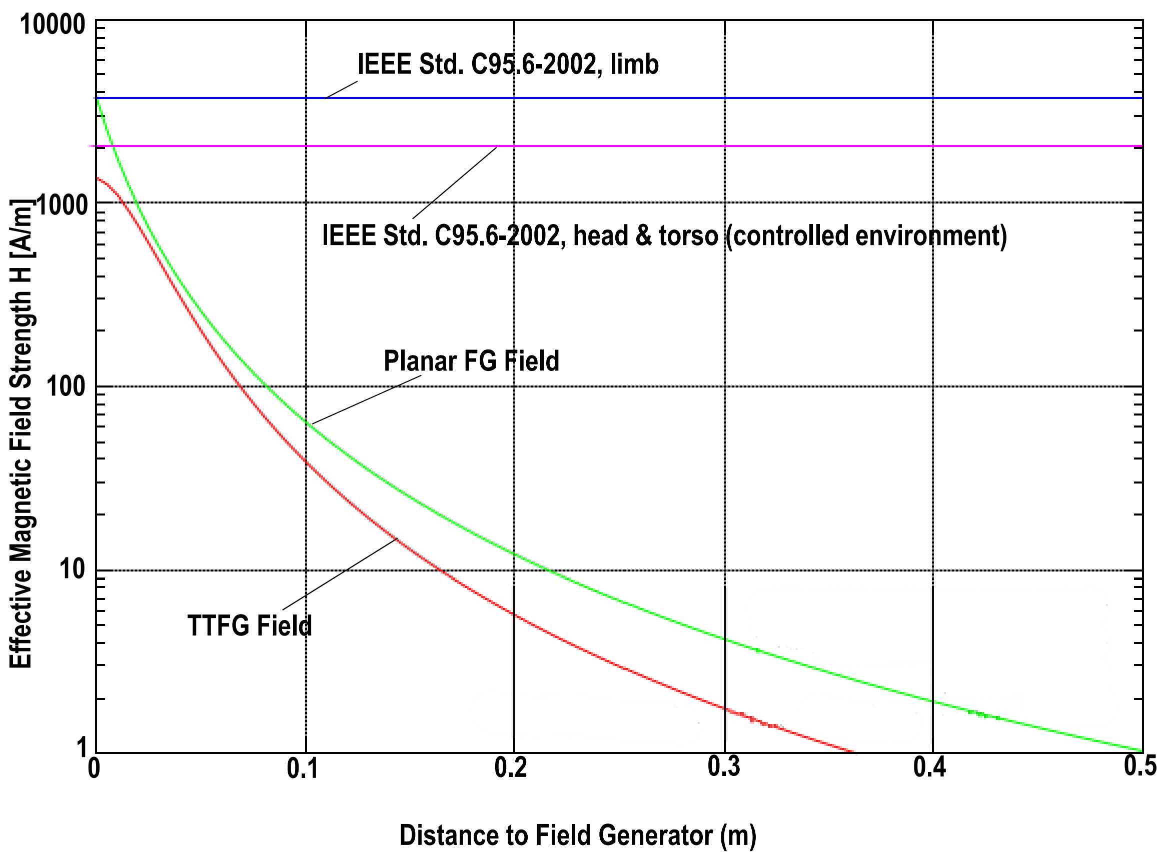
9 Electromagnetic Fields, Distortion and Metal

9.1 Field Generator Magnetic Field Strength

Figure 9-1 shows the magnetic field plot of the Field Generator coils, for the Planar and Tabletop Field Generators. The plot shows the magnetic field strength of the coils as a function of distance to the exterior of the Field Generator.

The plot also shows the recommended safety thresholds defined by the Institute for Electrical and Electronic Engineers (IEEE) Std. C95.6-2002 for both limb and head and torso (controlled environment). ("IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0-3 kHz.")

Figure 9-1 Field Generators Magnetic Field Plots



9.2 Interference and Distortions

Distortion may be caused by emissions from other electrical equipment or by nearby metal. To minimize distortions to the Aurora's electromagnetic field follow the advice given in the following sections:

- "Mounting the Components" on page 22
- "Cable Management" on page 23
- "Operating Environment Considerations" on page 24

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.

9.3 Effects of Nearby Metal on the Aurora System

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 metals which don't cause problems when used near the Aurora System, as well as the problems caused by placing problematic metal near the Aurora System.

Metals which can be used with Aurora

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.**

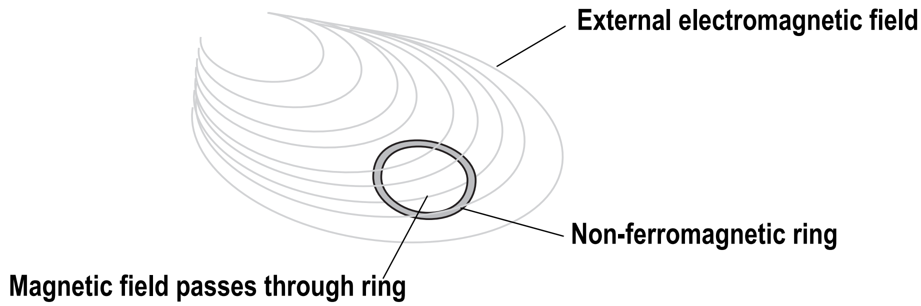
Ferromagnetic Metals

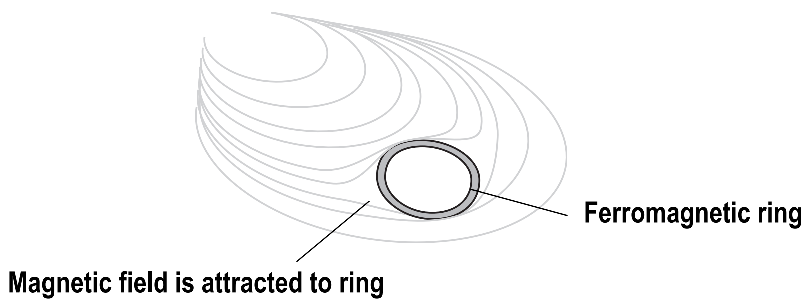
Ferromagnetic material should be avoided near the Aurora system.

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 9-2 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

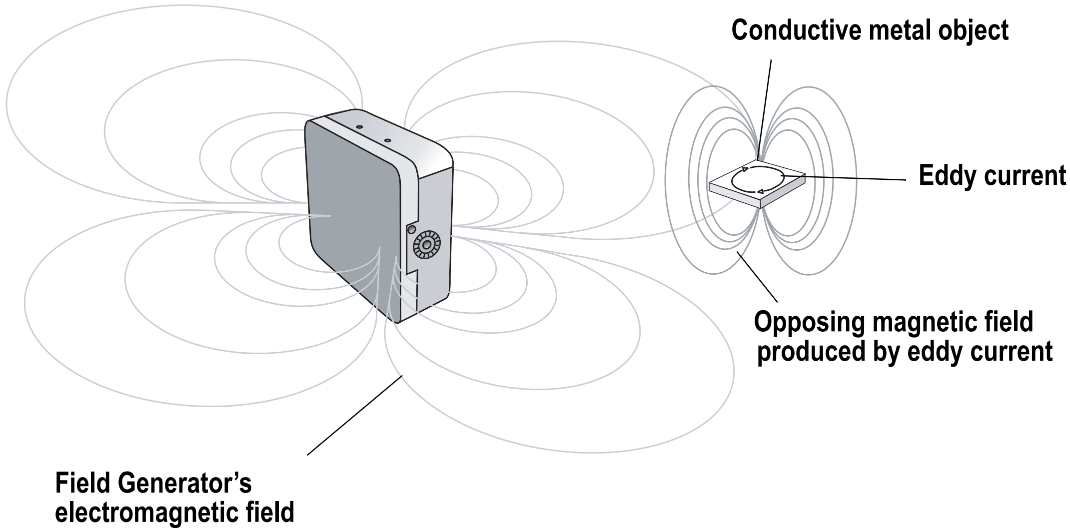
Eddy Currents

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 9-3 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.

Metal Loops

Another situation to consider is the effect of eddy currents in metallic loops. Loops may occur in structures like metallic table frames, or concrete reinforcement bars. Cutting the loops will reduce the effect of eddy currents. If cutting the loops is not an option, then locate the system to minimize the effects of the loops.

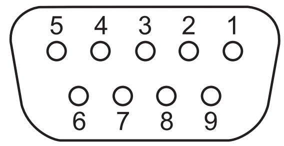
9.4 Metal Resistance Research

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.

10 External Synchronization

The SCU may be used to trigger external devices and it can also be synchronized to another Aurora SCU. The SCU external synchronization port is a 9-pin D-sub female connector.

Figure 10-1 Synchronization Port Connector Pin Arrangement



This port uses open collector output signals. The connector pin designations are detailed in Table 10-1.

Table 10-1 Pin Definition for the System Control Unit Synchronization Port

Pin Number	Value	Description
1	+3.3	SCU provides up to 200 mA, +3.3 V
2	Viso	Optocoupler Anode
3	FR IN	Clock input at frame rate (high to low edge triggered)
4	HF IN	Clock signal input
5	GND	Ground
6	HF OUT	Clock signal output
7	reserved	reserved
8	reserved	reserved
9	FR OUT	Clock output at frame rate (active low)

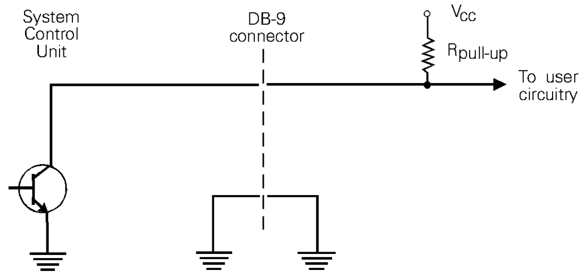
10.1 Output Signals

The output signals FR OUT and HF OUT are active low, open collector outputs. Each output is capable of sinking a maximum of 150 mA through an external pull-up resistor, tied to V_{cc} (Refer to Figure 10-2). V_{cc} must not exceed 15 V.

Select the pull-up resistor such that:

$$R_{pull-up} > \frac{V_{cc}}{0,15}$$

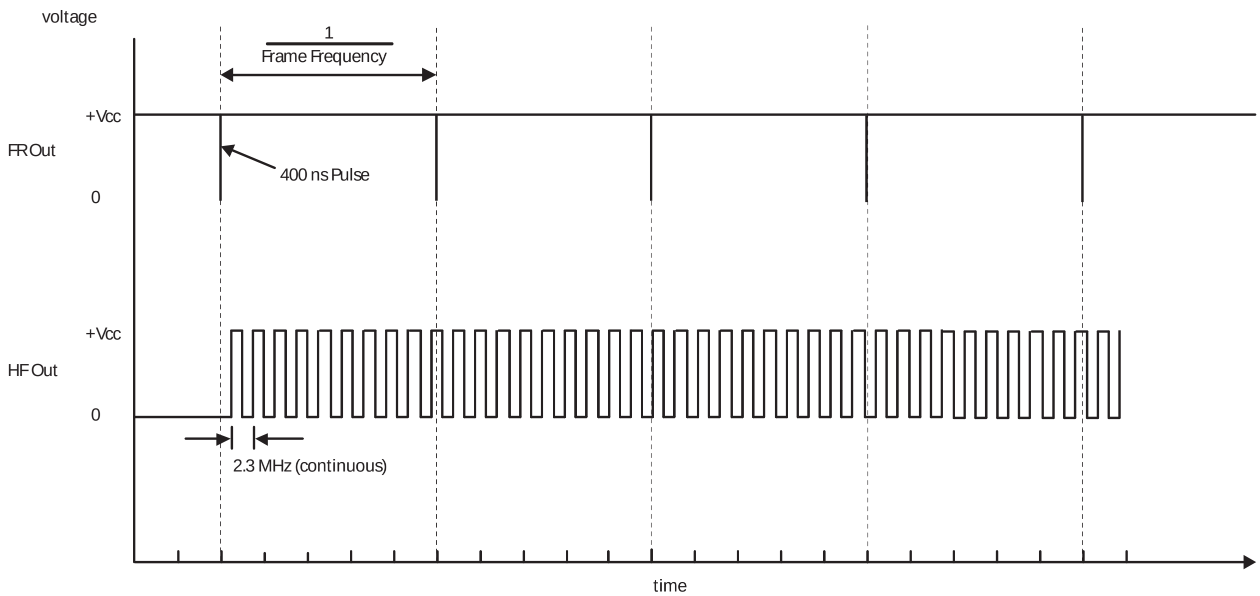
Figure 10-2 Output Signal Connection



The FR OUT signal goes low for 400 ns at the start of each frame.

Figure 10-3 shows a timing diagram of both output signals, FR OUT and HF OUT.

Figure 10-3 External Sync Port Output Signals (With External Pull-up Resistor)



10.2 Input Signals

The input signals FR IN and HF IN are galvanic isolated from the rest of the SCU electronics. They can be used to synchronize two Aurora systems. Please contact NDI technical support for details. See page xvii for contact information.

11 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 NDI. Unauthorized servicing may result in possible personal injury.

11.1 Cleaning

Warning!

Disconnect power to the Aurora System before cleaning it. Failure to do so may cause personal injury.

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.

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.

11.2 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 outwards. The tabs are marked with arrows for identification.

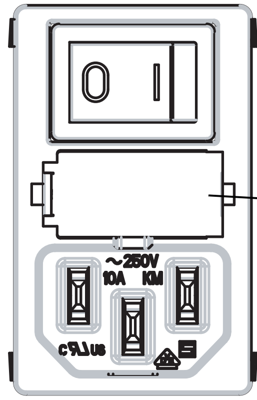


Figure 11-1 System Control Unit Power Entry Module

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, Breaking Capacity - High, 5 mm x 20 mm).
5. Press the fuse holder inwards, ensuring that it latches correctly.

11.3 Recurrent Safety Tests

NDI recommends periodic safety tests performed at an interval of two years or less, depending on application and use. The exact test interval must be determined by the system integrator. During the safety test, the following parameters should be tested:

Table 11-1 Recurrent Safety Tests

Test Item	Acceptance Criteria
Visual inspection	Device has no obvious damage
Protective Earth resistance	< 0.20 Ohm
Isolation resistance	> 2000 MOhm
Earth leakage current NC	< 5.0 mA
Earth leakage current SFC	< 10 mA
Touch current NC	< 0.1 mA
Touch current SFC	< 0.5 mA
Patient leakage current AC NC	< 0.1 mA
Patient leakage current AC SFC	< 0.5 mA
Patient leakage current DC NC	< 10.0 µA
Patient leakage current DC SFC	< 50.0 µA

Alternatively, recurrent tests according to IEC 62353 can be performed.

12 Calibration and Verification

12.1 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.**

12.2 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.

12.3 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 55.
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.

12.4 Field Accuracy Verification

NDI recommends that you establish a field accuracy verification procedure, to monitor and confirm the system performance. You should establish a method and schedule that reflects the end use of the system.

13 Approvals and Classifications

The following approvals and classifications apply to the Aurora V3 System as described in "Aurora System Overview" on page 2.

13.1 Electrical Safety Approvals

Table 13-1 Electrical Safety Approvals

Standard	Title
IEC 60601-1:2005 +Cor.:2006 +Cor.:2007 +A1:2012	Medical Electrical Equipment, Part 1: General requirements for basic safety and essential performance
NRTL mark	TÜV Süd Product Service

13.2 EMC/EMI Approvals

Table 13-2 EMC/EMI Approvals

Standard	Title
EN60601-1-2:2007	Medical Electrical Equipment, Part 1: General requirements for safety - Collateral standard: Electromagnetic Compatibility - Requirements and tests

13.3 Classifications

Table 13-3 Classifications

Type	Classification
Electric Shock Protection	Class I - protectively earthed with power from supply mains
Degree of Protection from Electric Shock	Type BF (Tools and Sensors, planar FG) Type B (TTFG)
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

14 Aurora System Technical Specifications

This chapter includes technical specifications valid for the entire Aurora System. For technical specifications for a specific Field Generator, including accuracy specifications, dimensions, and weight, see the appropriate chapter:

- "Planar Field Generator" on page 28
- "Tabletop Field Generator" on page 36

14.1 Operating Environmental Conditions

The operating environmental conditions listed in Table 14-1 are valid for all components of the Aurora System.

Table 14-1 Aurora System Operating Environmental Conditions

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

14.2 Transportation and Storage Conditions

The transport and storage conditions listed in Table 14-2 are valid for all components of the Aurora System.

Table 14-2 Aurora System Transportation and Storage Conditions

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

15 Electromagnetic Compatibility

15.1 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.

Caution! **When working with SCU or SIU boards as described in "PCB Integration Guide: SCU Board" on page 79 and "PCB Integration Guide: SIU Board" on page 86, the system integrator must handle the boards in an ESD-safe manner. Failure to do so can damage the boards.**

15.2 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 IEC60601-1-2:2007

Table 15-1 Cables, Transducers and Accessories

Cable Name	NDI P/N	Type	Shielded	Notes
USB Cable	7500624.001	USB A-B Cable, 5 m	Yes	
SIU Cable	610101	Communication cable between SCU and SIU, 4.5 m	No	
Tabletop Field Generator Cable	610348	19-Conductor Lemo-Lemo Cable, 4.5 m	Yes	The Tabletop Field Generator cable is detachable.
Power Cord, AC (North America)	7500010	3- Conductor Medical Grade	No	

Warning!

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.

15.3 Guidance and Manufacturer's Declaration - Electromagnetic Emissions

The Aurora System is intended for use in the electromagnetic environment listed in Table 15-2. The customer or the user of the Aurora System should make sure that it is used in such an environment.

Table 15-2 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 A	The Aurora System is suitable for use in all establishments, other than 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	

15.4 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.

Warning!

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.

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.

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

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.

Portable and mobile radio frequency (RF) communications equipment can affect the Aurora System. This may contribute to inaccurate transformations and possible personal injury.

Do not operate the Field Generator within 10 m of another operating Field Generator. To do so may contribute to inaccurate transformations and possible personal injury.

Table 15-3 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	The USB interface on the Aurora V3 SCU is sensitive to electrical fast transients. NDI recommends using the RS-422 instead.

Table 15-3 Electromagnetic Immunity

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.
Conducted RF IEC 61000-4-6	3Vrms 150 kHz to 80 MHz	3Vrms 150 kHz to 80 MHz	Recommended separation distance: $d = \left(\frac{3,5}{3}\right)\sqrt{P}$ External RF sources can distort Aurora measurements indirectly because of imperfect filtering and demodulation effects in the amplification circuits. If the Aurora firmware detects such a distortion, the Aurora returns MISSING instead of an incorrect reading.

Table 15-3 Electromagnetic Immunity

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:  External RF sources can distort Aurora measurements indirectly because of imperfect filtering and demodulation effects in the amplification circuits. If the Aurora firmware detects such a distortion, the Aurora returns MISSING instead of an incorrect reading.

* 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.

15.5 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 15-4 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.

16 PCB Integration Guide: SCU Board

This chapter describes the Aurora V3 System Control Unit board. The board can be purchased separately for integration into a custom enclosure. When designing your own enclosure, see also: "PCB Integration Guide: SIU Board" on page 86 and "PCB Integration Guide: Design Considerations" on page 90.

16.1 SCU Board Dimensions and Layout

Board size 206 mm x 135 mm x 23 mm. The following connectors extend past the end of the board:

- FG connector: 15 mm past end of board (with centre axis 8.3 mm past top of board)
- SIU Redel connector (if populated): 14.3 mm past end of board
- USB Connector: 7.1 mm past end of board
- Synchronization port: 11.2 mm past end of board

Figure 16-1 SCU Board Dimensions

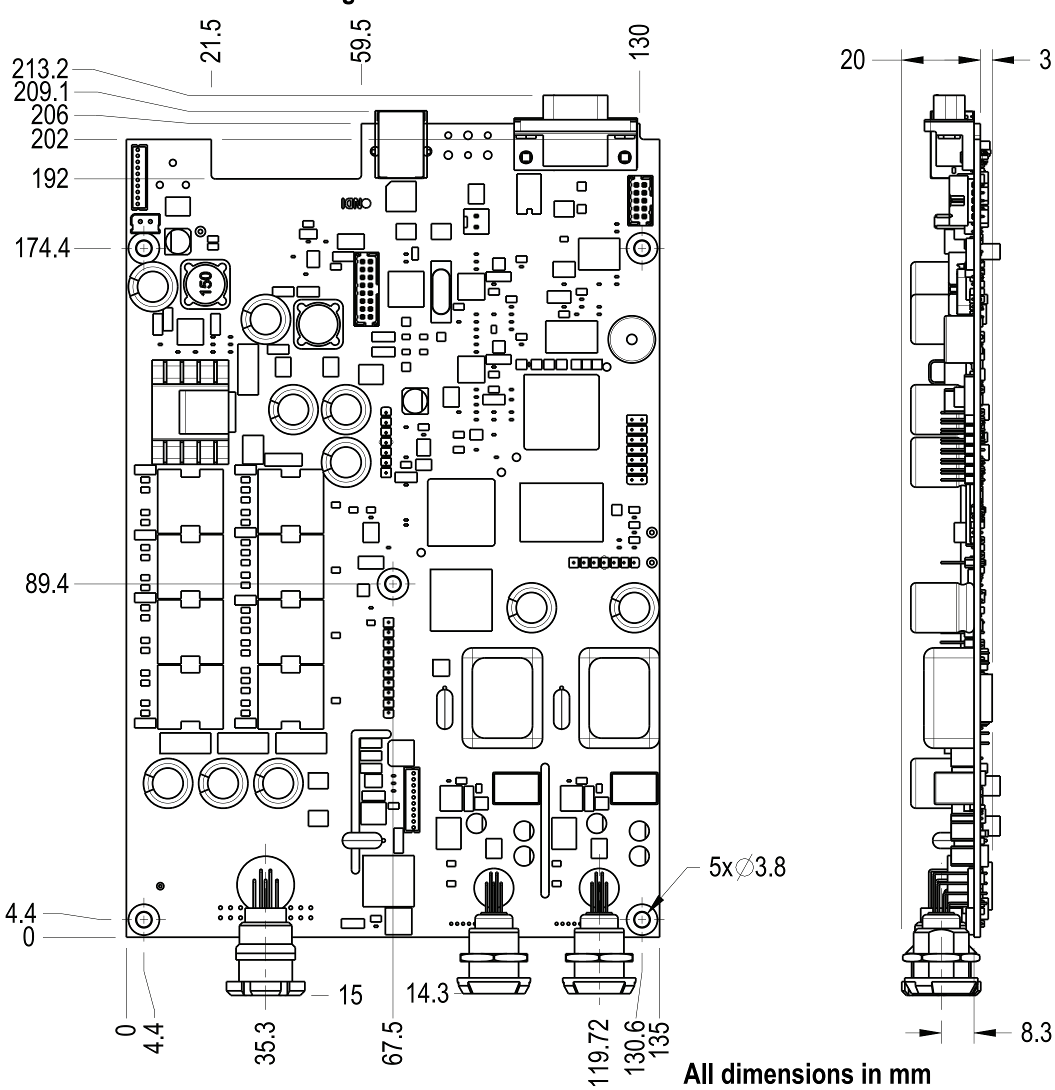
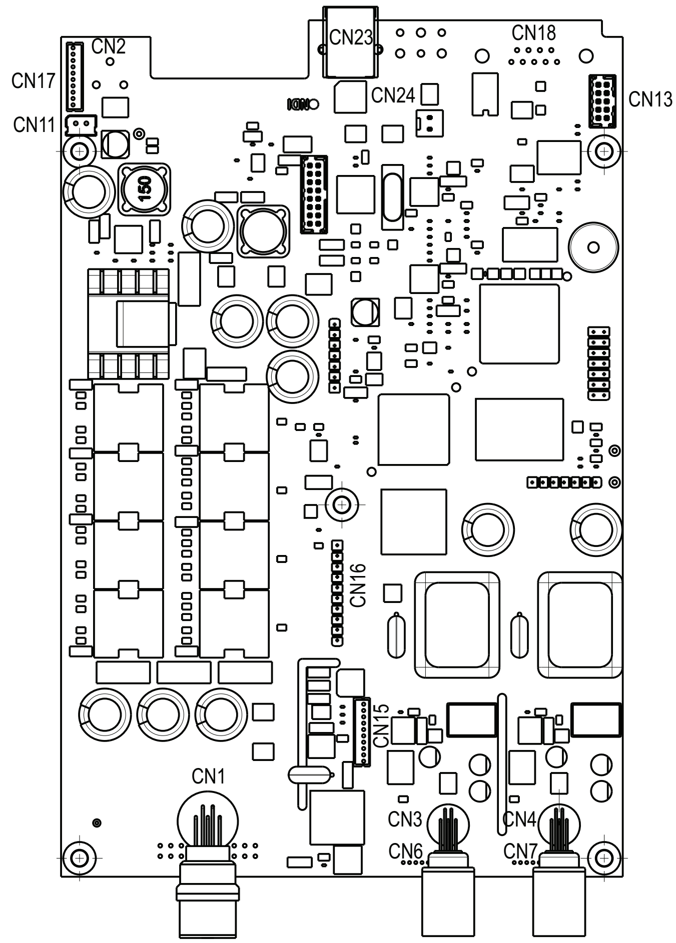


Figure 16-2 SCU Board Layout



Note **See "ESD Precautionary Measures" on page 73 for information on the correct handling of the SCU and SIU boards.**

Mounting There are five mounting holes that are connected to ground. Use these mounting holes to connect the board to the earth ground of the enclosure.

Populated Connectors The following connectors are always populated on the SCU board:

- FG connector located at CN1 (see "SCU Board Connection to SIU" on page 85 for details).
- USB type B connector located at CN23 (see "SCU Board Host Communication" on page 83 for details).

Optional Connectors The following connection options can be specified upon ordering the SCU board from NDI:

- SIU connector: 10-pin Redel connectors located at CN3 and CN4 (as shown in Figure 16-2), or 10-pin JST headers located at CN6 and CN7 (see "SCU Board Connection to SIU" on page 85 for details).
- Synchronization port: female 9-pin D-type connector located at CN18 (see "SCU Board Synchronization Port" on page 85 for details).

- Power jack: 2.1/5.5 mm power jack located at CN2 (see "SCU Board Connection to Power" on page 81 for details).

Headers The following connection options are always provided as a header on the board:

- RS-232 port located at CN13 (see "Pinout for CN13: Molex header for RS-232 Host Communication" on page 83 for details).
- RS 422 port located at CN15 (see "Pinout for CN15: 10-pin JST Header for RS-422 Host Communication" on page 84 for details).

Board weight 0.3 kg

16.2 SCU Board Connection to Power

The SCU can be powered by either of the following two connections:

- 10-pin JST header B10B-ZR (located at CN17)
- 2.1/5.5 mm power jack (located at CN2)

Only one power connector can be used at a time. The pinouts are described in Table 16-1 and Table 16-2.

Note **The Aurora V3 boards do not provide an input protection.**

Power Header

Figure 16-3 Pin Arrangement for CN17: 10-pin JST Header for Power Connection

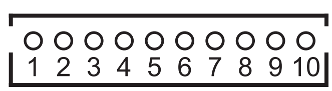


Table 16-1 Pinout for CN17: 10-pin JST Header for Power Connection

Pin	Pin Function
1 to 4	Ground
7 to 10	V in
5 and 6	Not connected

Power Jack

Table 16-2 Pinout for CN2: 2.1/5.5 mm Power Jack for Power Connection

Pin	Pin Function
1 (inner pin)	V in
2 and 3	Ground

The centre pin provides +24V DC, the 0 V should be connected to ground.

Power Supply

A medical power supply suitable to the application must be used. NDI recommends a 24V, minimum 60W supply with a 60601-1 approval. The power supply should offer a protection of 2 MOPP (Means of Patient Protection) input to output and 1 MOPP input to ground.

Power Switch

A power switch can be added at location CN11. Connect an external power switch or short if this switch is not used. (CN11 is by default already shorted when the SCU board is purchased.) If CN11 is left open, the board cannot be powered.

Protective Earth

The SCU board must be connected to protective Earth. This can be done using the five mounting holes on the board.

16.3 SCU Board Connection to Field Generator

The Field Generator connector is Lemo EEG.2B.319.CLV and is located at CN1. This connector is always populated on the SCU board. To ensure the quality of the signal, it is not possible to have an FG header connection on the SCU board.

Ideally, the SCU board can be mounted such that the FG connector penetrates the enclosure. If this cannot be achieved, it is possible to extend the cable length by up to one metre by adding a bulkhead cable. This cable is available from NDI. The FG cable should not be placed in close proximity to an unshielded SIU board.

For optimal performance, the FG connector must be connected to the Earth ground of the enclosure. This connects the cable shield of the FG to ground. An ungrounded or poorly-grounded shield cable might create noise.

16.4 SCU Board Host Communication

There are three possible communication interfaces to the Aurora System:

- RS-232: Molex male header, 2 mm pitch, series 87831 (header located at CN13)
- USB (located at CN23 or CN24). By default, the SCU board is populated with a USB connector at CN23.
- Isolated RS-422: 10-pin JST header B10B-ZR (header located at CN15)

The communication protocol is independent of the communication interface used and is backwards-compatible with previous Aurora Systems.

Upon power-up, the Aurora System sends a RESET message along all interfaces. The first interface to send a valid command that is received by the Aurora System becomes the active interface. The other interfaces are disabled until the next reset.

The pinouts are described in the following sections:

RS-232 Host Communication

Figure 16-4 Pin Arrangement for Molex header for RS-232 Host Communication

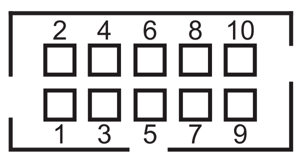


Table 16-3 Pinout for CN13: Molex header for RS-232 Host Communication

Pin	Pin Function
1, 7, 8	Not connected
2	DTR
3	TX
4	CTS
5	RX
6	RTS
9 and 10	Ground

USB Host Communication

Table 16-4 Pinout for CN23: USB Type B for Host Communication

Pin	Pin Function
1 to 4	Connect to a USB host using a standard USB cable.

Table 16-5 Pinout for CN24: USB Header for Host Communication

Pin	Pin Function
1	USB_VCC
2	D-
3	D+
4	Ground

Isolated RS-422 Host Communication

Figure 16-5 Pin Arrangement for CN15: 10-pin JST Header for RS-422 Host Communication

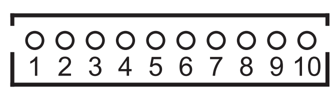


Table 16-6 Pinout for CN15: 10-pin JST Header for RS-422 Host Communication

Pin	Pin Function
1	RX+
2	RX-
3	TX+
4	TX-
5	Reserved
6	ISO Ground
7	RTS+
8	RTS-
9	CTS+
10	CTS-

16.5 SCU Board Connection to SIU

The SCU supports connections for up to two SIUs. The SIUs can be connected the following ways:

- 10-pin JST header B10B-ZR (located at CN6 and CN7), using a 1:1 (straight through) cable to the SIU. This cable is 205 mm long and is provided by NDI.
- 10-pin Redel connector PKB.M1.0GL.VG (located on CN3 and CN4), connecting via cable to Redel connectors on the SIU. The maximum cable length for this cable is 4.5 m. For more details on this option, contact NDI.

Only one of each header/connector pair can be used, i.e. one of CN3 or CN6, and one of CN4 or CN7.

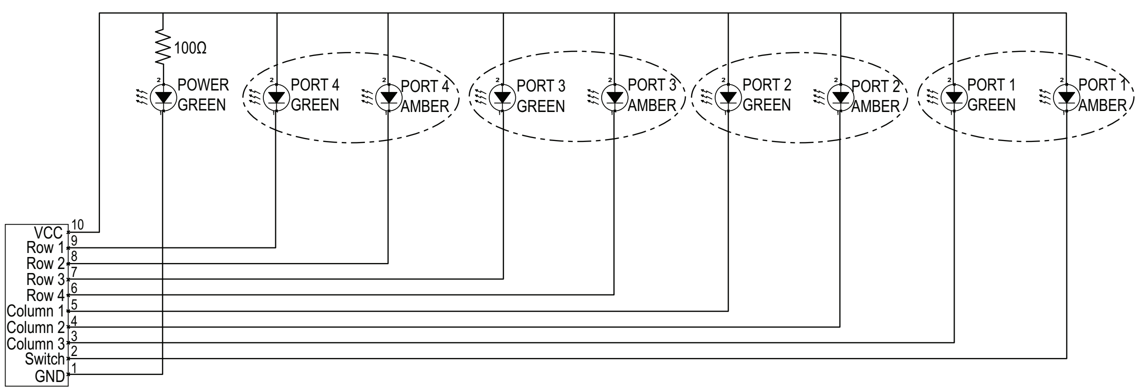
16.6 SCU Board Synchronization Port

The synchronization port located at CN18 can be used to synchronize one Aurora System with another. It can be populated using a female 9-pin D-type connector. For complete details on the synchronization port, see "External Synchronization" on page 65

16.7 SCU Board Power LED and Tool Port Status LEDs for the SIU

The SCU board incorporates a simple 10-pin header with 2.54 mm between the pins, located at CN16. This header provides a signal for a power LED, as well as signals for tool port status LEDs for the SIU board connected to SIU port 1 (i.e. connected to CN3 or CN6) on the SCU board. The signals are illustrated in Figure 16-6.

Figure 16-6 Power LED and Tool Port Status LED Signals on SCU Board



For other options for tool port status LEDs on the SIU, see "SIU Board LEDs" on page 89.

For details on LED behaviour, see "Sensor Interface Unit Front Panel" on page 8.

16.8 SCU Board Unused Connections

CN8, CN10, CN12, CN14 and CN20 are for internal use only.

17 PCB Integration Guide: SIU Board

This chapter describes the Aurora V3 Sensor Interface Unit board. The board can be purchased separately for integration into a custom enclosure. When designing your own enclosure, see also "PCB Integration Guide: SCU Board" on page 79 and "PCB Integration Guide: Design Considerations" on page 90.

17.1 SIU Board Dimensions and Layout

The SIU board is available in two different versions: with Redel plastic tool connectors, or with Odu metal tool connectors. The tool port connector type can be specified upon ordering the SIU board.

Board Size 135 mm x 89.1 mm. The following connectors extend past the end of the board:

- Redel plastic tool connectors: 11.6 mm past the end of the board
- Odu metal tool connectors: 13.6 mm past end of board

Distance from Redel or Odu tool connectors (centre axis) to top of board: 8.0 mm

Board weight 0.1 kg

Figure 17-1 SIU Board Dimensions - With Redel Connectors

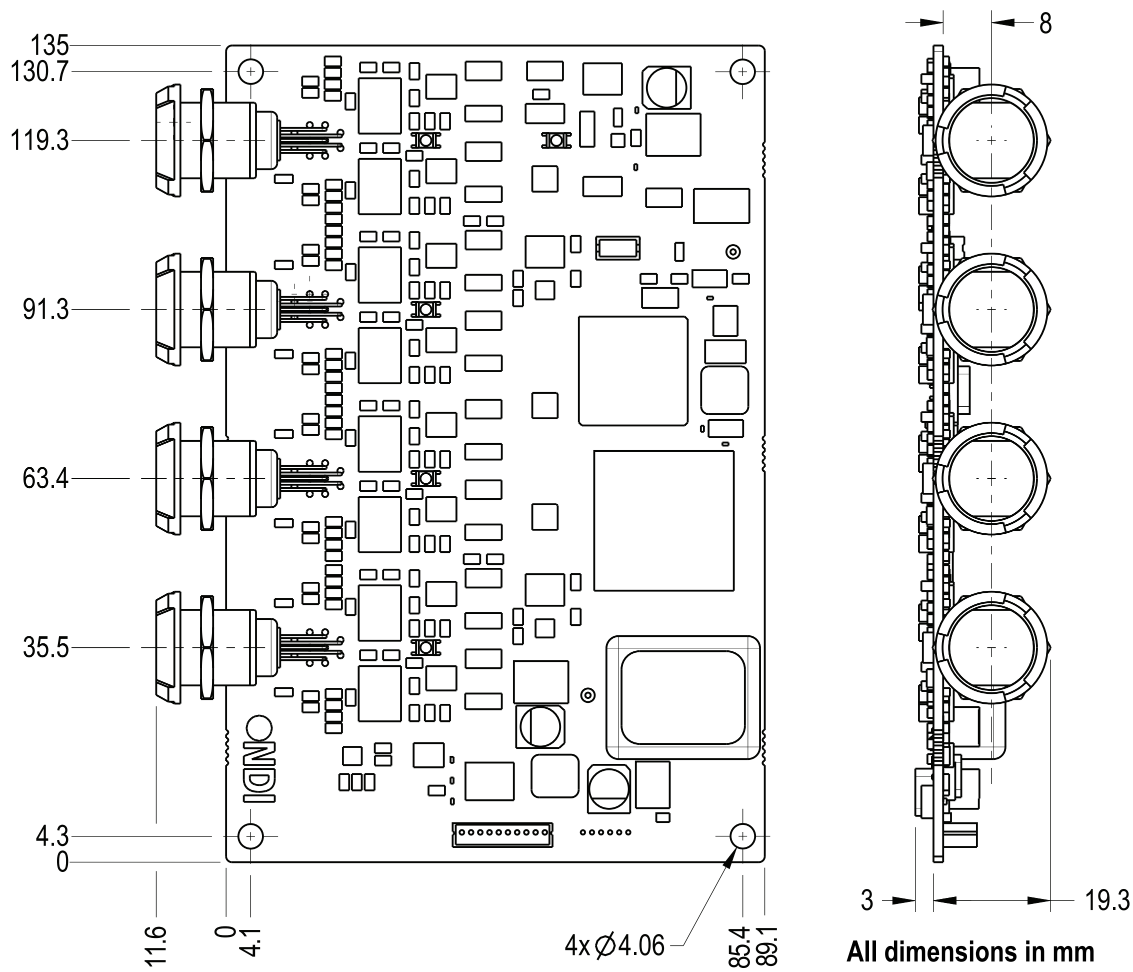


Figure 17-2 SIU Board Dimensions - With Odu Connectors

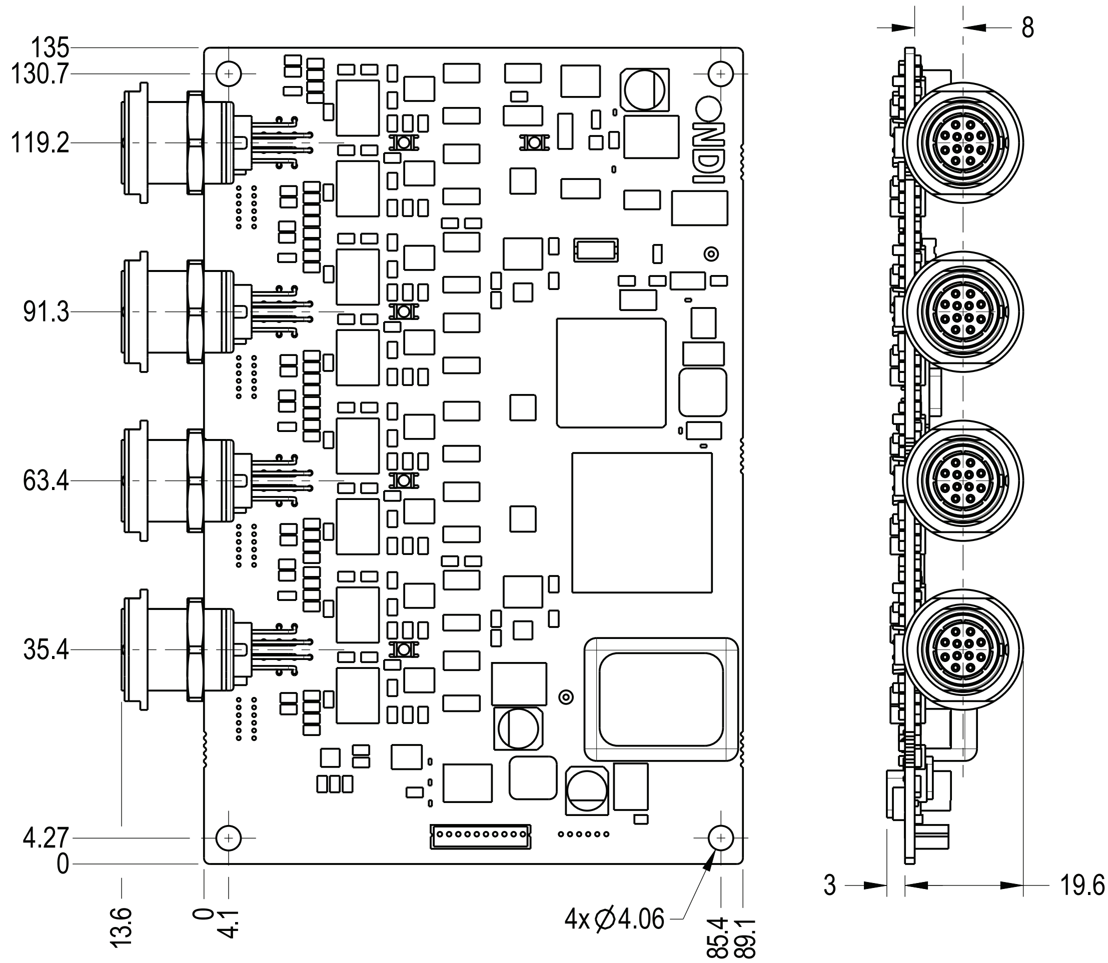
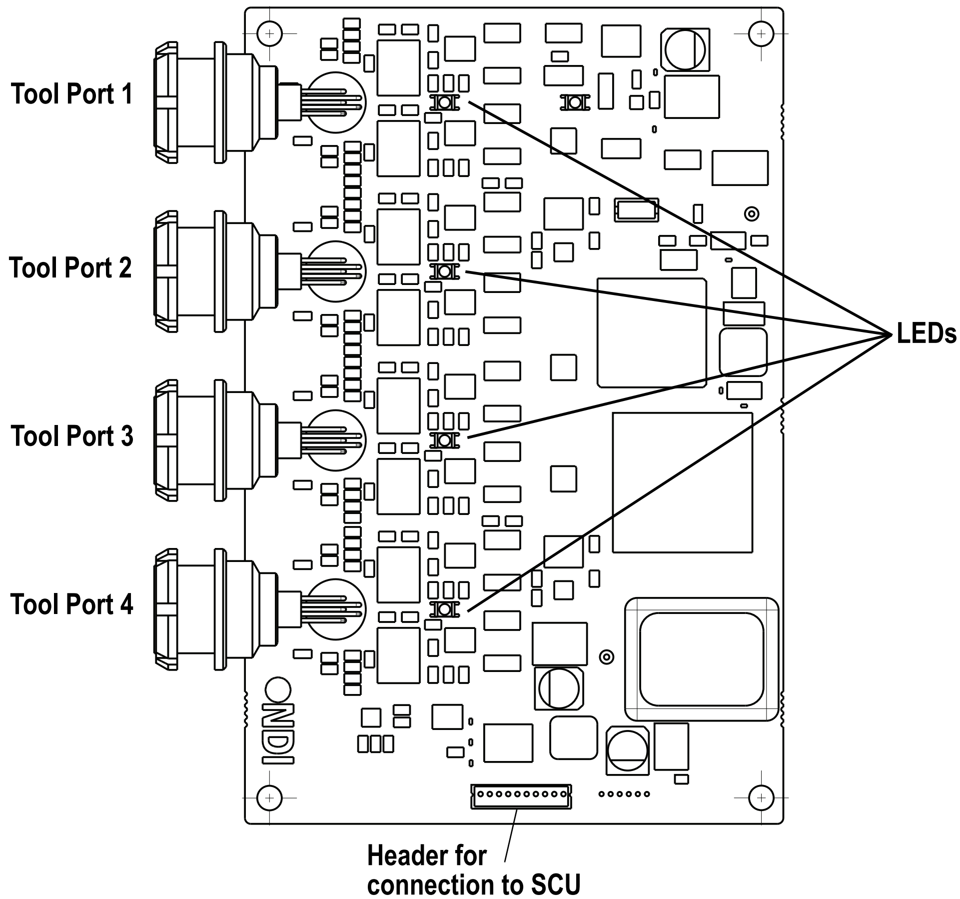


Figure 17-3 SIU Board Layout



Note See "ESD Precautionary Measures" on page 73 for information on the correct handling of the SCU and SIU boards.

17.2 SIU Board Connection to SCU

SIU and SCU Boards in the Same Enclosure

The SIU can be connected to the SCU by via 10-in JST header B10B-ZR, using a short 1:1 (straight through) cable to the SCU. This cable is provided by NDI.

SIU in a Separate Enclosure

For an external SIU in its own enclosure, a cable is needed to connect the header on the board to a Redel connector on the enclosure. A 340-mm long cable can be purchased from NDI, or you can build your own cable using the pinout described in Table 17-1.

Table 17-1 Pinout for Header to Redel Extension Cable Inside SIU Enclosure

Pin on SIU Board (JST B10B-ZR)	Pin on Enclosure Connector (Redel PKB.M1.0GL.VG)	Pin Function
1	4	TXD
2	3	RXD
3	5	ADC+
4	6	ADC-
5	10	SYNC+
6	9	SYNC-
7	2	+5V
8	1	+12V
9	7	-12V
10	8	GND

17.3 SIU Board Tool Port Connectors

There are two possibilities for the tool port connectors:

- Redel PKA.M1.0NL.VN
- Odu G52LFC-P12QF00-A00

If the Odu connectors are used, the SIU board is considered as having a type B classification. To provide BF type isolation when using tools with Odu connectors, care must be taken to isolate sensors and electronics in each individual tool. A tool should provide isolation of 1500 V against its connector pins, the connector enclosure, and the SCU enclosure.

Note For the tool connector pinout, see the "*Aurora Tool Design Guide*."

17.4 SIU Board LEDs

Tool port status LEDs are available for the SIU via the following methods:

- The SCU board incorporates 10-pin header which provides the signals for the LEDs on the SIU board connected to SIU port 1 (i.e. connected to CN3 or CN6) on the SCU board. See "SCU Board Power LED and Tool Port Status LEDs for the SIU" on page 85 for details.
- The LEDs are also located directly on the SIU board as illustrated in Figure 17-3 on page 88. These LEDs can be conveyed to another location via a light pipe.
- It is possible to use an I2C-bus for the LEDs on the SIU. This would require electronics on the patient side and would need special consideration regarding isolation. Please contact NDI for more details on this option.

18 PCB Integration Guide: Design Considerations

Note **The approvals and classifications listed in** **"Approvals and Classifications" on page 71** **apply to the Aurora V3 System as described in** **"Aurora System Overview" on page 2****.**

18.1 Patient Isolation

Patient isolation is implemented on the SCU board. The SCU board contains an isolated section for each SIU interface. Each circuit contains an isolated DC-DC converter and an isolated signal converter. The SCU board is constructed with an air clearance of $\geq$2.5 mm and a creepage distance of $\geq$4.0 mm.

Warning!

Do not short-circuit any of the patient isolation circuits on the SCU PCB. If a patient isolation circuit is short-circuited, there is a risk of excessive patient leakage current, which may result in personal injury.

The following parts bridge these barriers and are considered critical components:

Port 1:

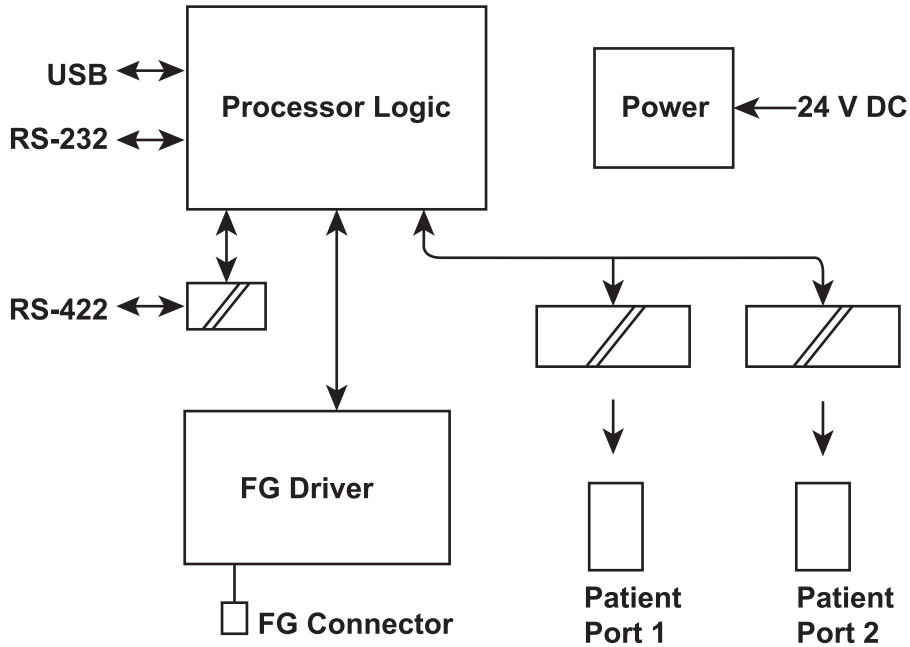
- U3 XP Power JHM1024D12
- U8 Analog devices ADUM2402BRWZ
- C8 (various vendors) X1/Y1 Capacitor 100 pF

Port 2:

- U32 XP Power JHM1024D12
- U18 Analog devices ADUM2402BRWZ
- C11 (various vendors) X1/Y1 Capacitor 100 pF

A block diagram illustration isolation is shown in Figure 18-1.

Figure 18-1 SCU Isolation Diagram



To provide type BF isolation when using tools with Odu connectors, care must be taken to isolate sensors and electronics in each individual tool. A tool should provide isolation of 1500 V against its connector pins, the connector enclosure, and the SCU enclosure.

The capacitors on the SCU board allow leakage currents below type CF isolation level to be achieved.

Note **The system integrator must ensure that none of the insulation barriers on the SCU board are bypassed or shorted during integration. The system integrator must test the insulation barriers in the final system.**

18.2 RS-422 isolation

This section on the SCU board is constructed with the same air clearance and creepage distances of 2.5 mm and 4.0 mm respectively.

The following parts bridge these barriers and are considered critical components:

- U33 Recom R0.25S-3.33.3/H
- U20 Analog devices ADUM2402BRWZ
- C36 (various vendors) X1/Y1 Capacitor 100 pF

Note **The system integrator must ensure that none of the insulation barriers on the SCU board are bypassed or shorted during integration. The system integrator must test the insulation barriers in the final system.**

18.3 EMC Considerations

The system integrator is responsible for adequate EMC shielding.

NDI recommends using a metal enclosure with a good connection to ground for the SCU. All metal connectors should have a low-impedance path to ground. An ungrounded or poorly-grounded FG shield cable might create a noise source visible in an EMC scan.

The SIU board is not a major source of noise and can be embedded into a plastic enclosure.

18.4 SCU-SIU Shielding

If the SCU and SIU boards are placed in the same enclosure, a high signal separation of the FG electronics on the SCU and the measurement electronics on the SIU is necessary to provide optimal performance. If the two boards are stacked on top of one another in close proximity, a ferro-magnetic shield should be placed between the SCU and SIU boards. This shield should be at least as large as the SIU board and approximately 1 mm thick.

The FG cable (including a bulkhead cable inside the enclosure, as described in "SCU Board Connection to Field Generator" on page 82) should not be placed in close proximity to an unshielded SIU board.

18.5 Thermal Design

The SCU board has the following input voltage and power consumption:

Table 18-1 SCU Power Input Information

Input Voltage	24 V DC
Power Consumption: Setup Mode	~10 W
Power Consumption: Tracking Mode	~35 W

The SCU board's total power consumption of ~35W splits into the FG and SIU. The SIU power consumption is approximately 5 W.

The maximum operating ambient temperature for the SCU and SIU boards is 50ºC.

18.6 Mean Time Between Failures

Mean time between failures (MTBF) is calculated for an environmental temperature of 50ºC. The MTBF drops by half for every 10ºC increased in environmental temperature. A fan is recommended for higher temperatures. The MTBF are as follows:

SCU: >250 000 hours
SIU: >250 000 hours

19 Troubleshooting

The troubleshooting section highlights the most common difficulties with the Aurora system. If you have a different problem, or if your problem persists after trying the suggestions below, please contact NDI technical support.

19.1 Data is reported as 'Missing'

There are several possibilities why a tool or sensor may be reported as MISSING:

The tool or sensor is outside of the measurement volume.

- Make sure the tools and sensors are located inside the characterized measurement volume. The various volumes are detailed in the following sections:
  "Planar Field Generator Measurement Volume" on page 28
  "Tabletop Field Generator Measurement Volume" on page 37
- Make sure the desired measurement volume is selected. In the ToolBox Track software, you can select the volume using the menu option **Track > Volumes**.

The Aurora's EM field is being disturbed by outside sources

The Aurora system is sensitive to disturbances in its electromagnetic field, which can be caused by other nearby electromagnetic fields or by sources of metal. If the interference is too strong, the Aurora system will be unable to track the sensors, and the tools and sensors will be reported as missing. See "Reducing Interference" on page 94 for advice on minimizing interference.

Problem with the tool definition file

If you are loading a tool definition file (.rom file) as a virtual SROM in the software, you may be using a tool definition file that is either mismatched to the tool, or one that contains a wrong setting.

- NDI provides tool definition files for all the sensors we sell. You can download the tool definition files on our support site at https://support.ndigital.com. The name of the tool definition file contains the sensor part number. If you cannot find the tool definition file for your tool, contact NDI technical support.
- If you have made or modified the .rom file using the 6D Architect software, you may have changed a setting incorrectly so that the tool no longer tracks. Try using the default tool definition file located on the NDI support site. If the tool is able to track with the default tool definition file, contact NDI technical support for help finding the problem with your customized tool definition file.

The tool is moving too quickly

The Aurora system may have trouble tracking the tool if it is moved too quickly.

19.2 High Indicator Value

There are several possibilities why the system is returning a high error value for the 6DOF transformations:

- 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. See "Problem with the tool definition file" on page 93.
- Disturbances are influencing the system's calculations of how the sensors are positioned. Such disturbances include magnetic sources, metal placed too close to the system, or the system setup itself is causing interference. See "Reducing Interference" on page 94.
- The tool is too far away from the Field Generator. The farther away from the Field Generator the tool is placed, the more susceptible it is to measurement noise. Try moving the tool closer to the centre of the measurement volume. In particular, 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.
- The tool has been dropped or changed in some way physically, so that the positions of the sensors within the tool have been shifted. In this case, the physically positions and/or orientations of the sensors within the tool no longer match the tool definition file, and the tool will not track properly.

19.3 Noisy, inaccurate or unstable data

The Aurora system is sensitive to disturbances in its electromagnetic field, which can be caused by other nearby electromagnetic fields or by sources of metal. Disturbances to the Aurora's EM field can cause the data to be noisy, inaccurate or unstable. See "Reducing Interference" on page 94 for advice on minimizing disturbances to the Aurora's EM field.

19.4 Measurement volume seems too small

If the measurement volume seems to be smaller than expected, check the following:

- The environment may have elements that are interfering with the Aurora System's electromagnetic field. For example, metal and other electromagnetic fields can distort the measurement volume and interfere with measurements. See "Reducing Interference" on page 94 for advice on minimizing interference.
- Make sure the desired measurement volume is selected. In the NDI ToolBox Track software, you can select the volume using the menu option **Track > Volumes**.

19.5 Reducing Interference

The Aurora System is susceptible to interference that may cause distortion of the electromagnetic field, resulting in inaccurate measurements or other tracking problems. If the Aurora system is not tracking properly or the tracking data quality is poor, check for sources of interference:

Metal interference

The Aurora system is sensitive to some metals, in particular ferro-magnetic metals.

- Check for metals in the setup, e.g. on the tools used, in or under the table or patient bed, or in other nearby objects. If it is not possible to completely remove the metal objects, try increasing the distance between the Field Generator and the metal, and between the sensors and the metal.
- If the Aurora system is placed close to a wall or floor, be aware that there can be metal interference from inside the wall or under the floor. Try moving the Aurora system to a different location.

If certain metals are placed too close to the Aurora FG or to the sensors, the measurements will be affected, usually resulting in inaccurate data or inability to track. For more information, see "Effects of Nearby Metal on the Aurora System" on page 62.

Electromagnetic interference from another Aurora system

If using multiple Aurora systems in proximity to one another (including in adjacent rooms), make sure to leave at least 10 m between Aurora Field Generators.

Electromagnetic interference from other EM-emitting devices

The Aurora system's electromagnetic field can be affected by nearby EM fields emitted from other electronic devices. If the Aurora's EM field is disturbed by other EM fields, the measurements will be affected, usually resulting in noisy data, high indicator values, or inability to track.

- Check for other devices emitting EM fields, including a RF emissions. To determine if other equipment is causing distortion, switch the equipment on and off while monitoring the Aurora system.
- If the Aurora system is placed in a small room or near a wall, check for potentially interfering devices in the adjacent room.

Interference on the sensor cables

The Aurora system is susceptible to picking up noise along its cables. The cables between the sensors and the SIU are particularly sensitive to noise.

- Make sure the cables are not very close to other electrical or electronic equipment and are not tangled up with or lying parallel to cables from other equipment.
- To minimize the possibility of the cables picking up additional noise from the Aurora system itself, set up the system as described in "Cable Management" on page 23.

Interference caused by the Aurora system setup

The setup of the Aurora system may cause interference due to e.g. the proximity of the SCU to the Field Generator, or various cables to one another. To minimize the possibility of the Aurora system components interfering with each other, set the system up as described in "Mounting the Components" on page 22 and "Cable Management" on page 23.

19.6 Connection and Hardware problems

If you are unable to establish communication with the Aurora System, check your communication settings using NDI ToolBox.

The following flowcharts detail a work flow for troubleshooting hardware problems with the Aurora Systems. If you are not sure which flowchart applies to your problem, start with the first one and follow them in order.

Figure 19-1 Troubleshooting Flowchart: Connection Problems

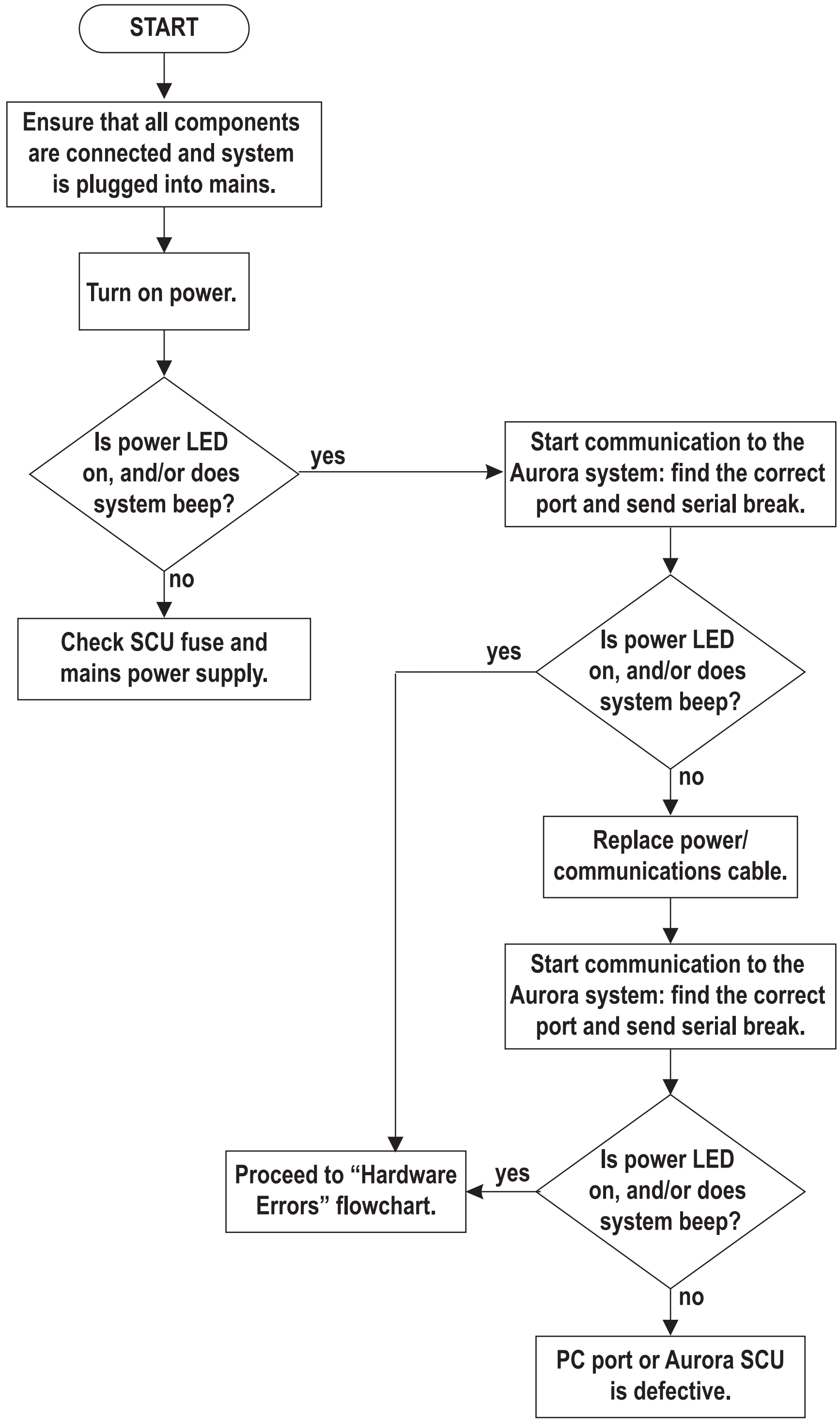


Figure 19-2 Troubleshooting Flowchart: Hardware Errors

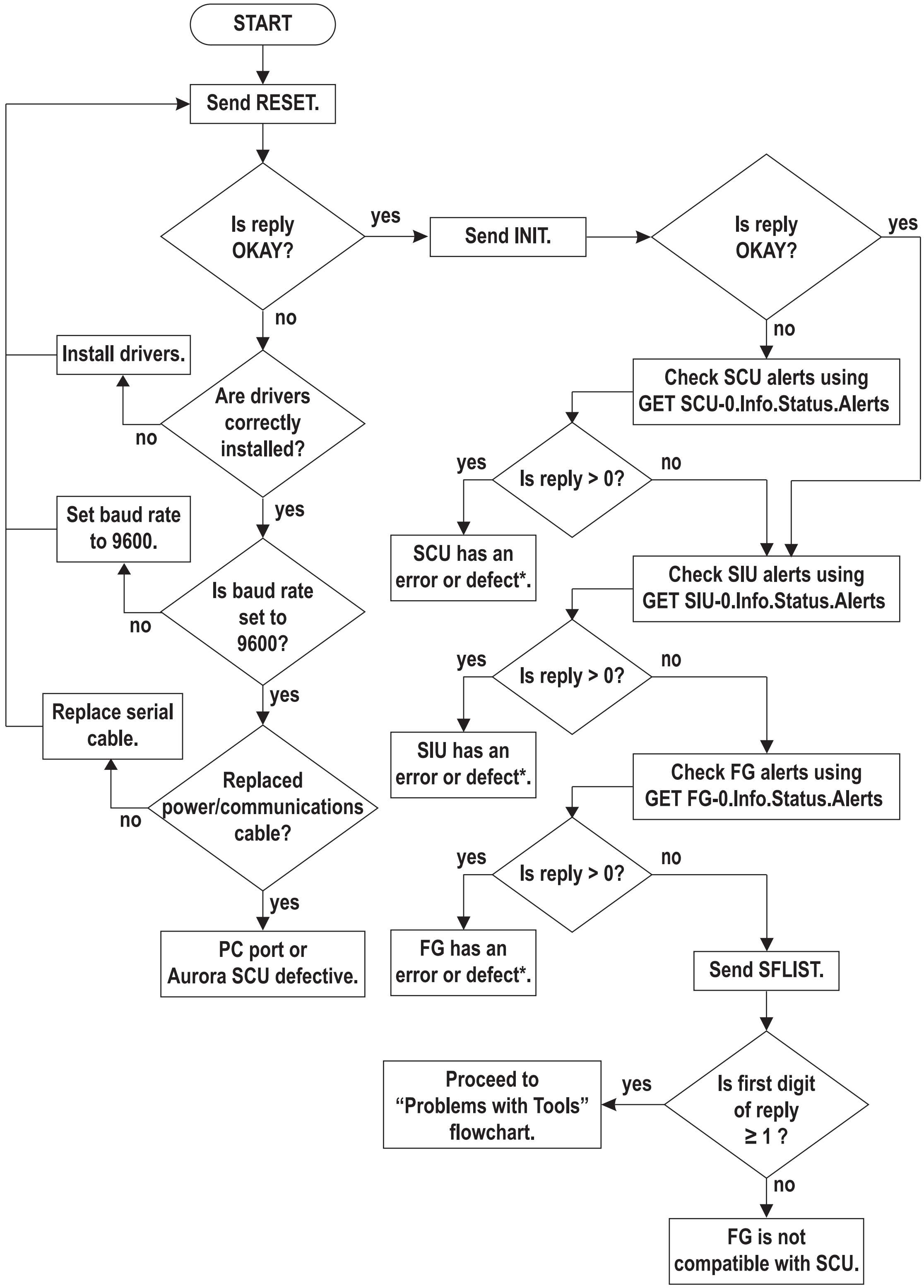
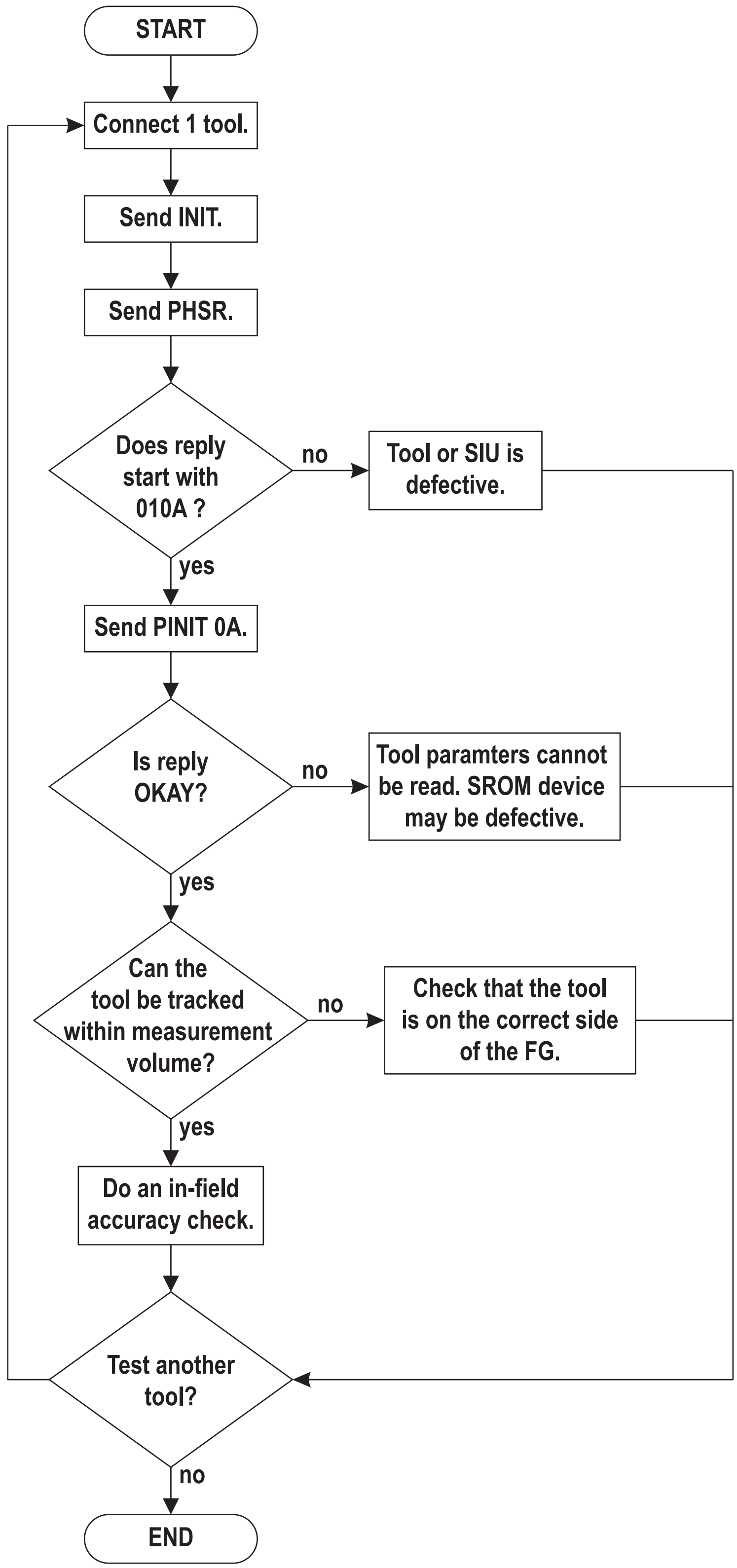


Figure 19-3 Troubleshooting Flowchart: Problems with Tools



20 Return, Repairs and Warranty

20.1 Returns and Repairs

Before returning equipment to NDI, you must either fill out a Returned Materials Authorization (RMA) request form at the NDI Support Site, or contact your account manager at NDI. NDI will then provide you with RMA information, shipping instructions, and the estimated repair cost.

Caution! **To move or ship the Aurora System, repack in the original containers together with all protective packaging to prevent damage.**

20.2 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 https://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
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).

21 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
CI	Confidence Interval
DIN	Deutsches Institut für Normung (German Institute for Standardization)
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
FCC	Federal Communications Commission
FG	Field Generator
FM	Frequency Modulation
IEEE	Institute of Electrical and Electronic Engineers
LED	Light Emitting Diode
MOPP	Means of Patient Protection
MRI	Magnetic Resonance Imaging
MTBF	Mean Time Between Failures
NC	Normal Case
NDI	Northern Digital Inc.
PFG	Planar Field Generator
RAM	Random Access Memory
RF	Radio Frequency
RMA	Returned Materials Authorization
RMS	Root Mean Square
SCU	System Control Unit
SFC	Single Fault Condition
SIU	Sensor Interface Unit
SROM	Serial Read Only Memory
TTFG	Tabletop Field Generator
UL	Underwriters Laboratories Inc.
USB	Universal Synchronous Bus

22 Equipment Symbols

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

Table 22-1 Equipment Symbols

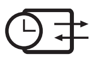
Symbol	Meaning	Location
	Warning (To avoid personal injury, consult accompanying documentation)	Planar FG, TTFG
	Read accompanying documentation	SCU, SIU
	Possible interference to the operation of, or damage to active implanted cardiac devices	Planar FG, TTFG
	Power LED	SCU, SIU
	RS-422 serial communication port	SCU
	Synchronization port	SCU
	USB port	SCU
	Direct current	SCU
	Indicates polarity of power jack	SCU
	Field Generator cable port	SCU
	Connection port between SCU and SIU	SCU, SIU
	Type BF equipment	SCU, SIU, Planar FG
	Type B equipment	TTFG
	Fragile	Packaging
	Keep away from rain	Packaging
	Recyclable (corrugated fibre board)	Packaging
	Humidity limit	Packaging

Table 22-1 Equipment Symbols (Continued)

Symbol	Meaning	Location
	Atmospheric pressure limit	Packaging
	Temperature limit	Packaging
	Certification Mark - National Registered Testing Laboratory	TTFG, SCU

23 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.

characterization (Field Generator)

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

characterization (tool)

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

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 cable

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

Field Generator port

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

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 transformation

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 recognized 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 transformation*, *quaternion transformation.*

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