First Principles User Guide

Revision 3
May 2010

IMPORTANT
Please read this entire document
before using First Principles

Revision Status

Revision Number	Date	Description
1	June 06	Initial issue
2	April 08	Added new calculation types; added setup for Certus using Smart Markers; added new Raw Data View error code; updated screen captures and defined new options.
3	May 10	Added video integration information.

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Published by:

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

Telephone:	+1 (519) 884-5142
Toll Free:	+1 (877) 634 634 0
Global:	++ (800) 634 634 00
Facsimile:	+1 (519) 884-5184
Website:	www.ndigital.com

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Read Me First

Read this section before continuing with the rest of the guide.

Warnings

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

For a complete list of warnings, refer to the documentation that accompanied your system.

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.

For a complete list of cautions, refer to the documentation that accompanied your system.

Contact Information

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

INTERNATIONAL HEADQUARTERS:
NORTHERN DIGITAL INC.
103 Randall Drive
Waterloo, ON, Canada N2V 1C5

Phone: + 1 (519) 884-5142
Toll Free: + 1 (877) 634-6340
Global: + (800) 634-634-00
Fax: + 1 (519) 884-5184

Email: support@ndigital.com
Website: www.ndigital.com

EUROPEAN OFFICE:
NDI EUROPE GmbH
Fritz-Reichle-Ring 2
D-78315 Radolfzell
Germany

Phone: + 49 (77 32) 939 19 00
Global: + (800) 634 634 00
Fax: + 49 (77 32) 939 19 09

Email: support@ndieurope.com
Website: www.ndieurope.com

ASIA PACIFIC OFFICE:
NDI ASIA PACIFIC
Unit 301, 3/F Core Building 1
No. 1 Science Park East Avenue,
Hong Kong Science Park,
Shatin, New Territories,
Hong Kong

Phone: + (852) 2802 2205
Fax: + (852) 2802 0060
Email: APsupport@ndigital.com
Website: www.ndigital.com

Updates

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

http://support.ndigital.com

About This Guide

Introduction

This guide is intended for users of the Optotrak® or Optotrak Certus® measurement system who wish to use First Principles™ software to collect and manipulate the data produced by experiments.

Assumptions

It is assumed that you are familiar with the Microsoft® Windows® environment. It is also assumed that you are familiar with the Optotrak System, in particular:

- you know what markers, rigid bodies, and tools are
- you know what strobers are
- you know the difference between global and local coordinate systems
- you understand what a tool definition file is
- if you are using an ODAU II, you understand how it works

Related Documentation

Refer to the documentation that was delivered with your system for detailed information on the use of the Optotrak System.

1 What is First Principles?

First Principles is an application software package that provides you with an easy way to observe, record, play back and manipulate the data produced by an experiment.

Note An *experiment* is a specific Optotrak System setup that uses markers, rigid bodies, tools, and/or ODAU II units to measure the movement and/or location of a subject/object.

Record and play back data Use First Principles to observe and record the data that your experiment produces. The software includes a simple interface to enable you to play back recorded data. You can save and export a collection at any time during (or after) an experiment. In addition, you can open previously collected data to review and analyze.

Manipulate data First Principles provides you with the power to manipulate data at any time. You can change the physical setup of the experiment and observe the effects of these changes on the experiment without having to re-initialize the Optotrak System or stop tracking. You can also apply calculations to the collected data in real time or when playing back the data.

Manage the system First Principles provides you with the ability to test specific elements of an experiment, before performing the experiment itself. For example, you can check that markers are being measured properly, that the current registration is accurate, and that the software is communicating with the Optotrak System correctly.

1.1 Working with Experiments

A First Principles experiment may comprise a number of sessions, which in turn may comprise a number of collections. For example, consider an experiment named “Gait Analysis”. On day one, you take a number of “collections” from subject A and save those collections as “Session 1”. On day two, you open the “Gait Analysis” experiment and take a number of “collections” from subject B and save those collections as “Session 2”.

The following paragraphs provide an overview of the process for working with experiments. With First Principles you can create a new experiment, or open an existing one. Figure 1-1 shows a flowchart of the process.

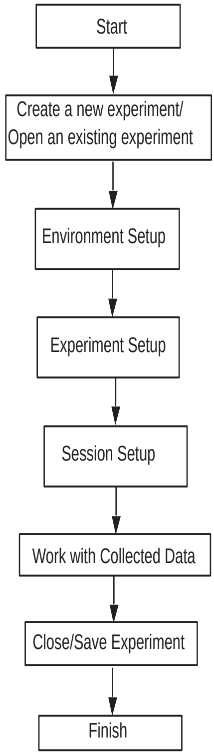


Figure 1-1 Experiment Process Overview

1. Start

   a) Connect and power on the Optotrak hardware components.

   b) Open First Principles.

2. Create/Open an Experiment

   Choose either to create a new experiment, or to open and continue work on an existing experiment.

Note The experiment file extension is .exp.

---

3. Environment Setup

a) If you have multiple Position Sensors connected to your system, you must perform a registration, if it was not done recently.

b) If you want to move the global coordinate system to a new location, you can perform an alignment.

First Principles provides an easy-to-use wizard to perform both these steps.

4. Experiment Setup

If you are working with an existing experiment, you can either make changes to the experiment setup already created for it, or you can skip over this step and proceed directly to step 5.

a) Connect the hardware components of the experiment — strobers, markers, rigid bodies, and/or tools.

b) In the Experiment Setup window, describe the components being used, so that your system can track them properly.

5. Session Setup

a) Choose a file location for saving collections.

b) If you chose to create temporary imaginary markers, digitize these points using the simple procedure provided with First Principles.

6. Work with Data

- View the data produced by the experiment in real time.
- Perform collections of produced data. If you choose to do so, data is automatically exported to predefined file formats.
- Manipulate your experiment both by changing your setup or by adding calculations to the data produced.
- Save and/or export data collections for future analysis.

7. Save Experiment

Save the experiment setup for future sessions.

8. Finish

1.2 Working with Collected Data

To open and work with previously collected data, First Principles provides the following process:

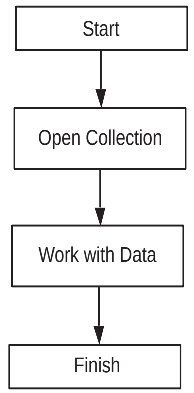


Figure 1-2 Reviewing Data Overview

1. Start

    Open First Principles.

2. Open Data Collections

    Browse to and select data collections made in a previous experiment.

Note The data collection file extension is .nco.

---

3. Work with Data

    a) Use the view settings to customize the main window to display your selected data collections in a manner useful to your particular analysis.

    b) Review the data collections using playback functionality.

    c) Manipulate the data collections by adding or removing calculations.

d) Export data collections for future analysis.

e) Save new view settings and calculations by saving the collection.

4. Finish

1.3 Installing First Principles

System Requirements

To run First Principles, you *must* have the following:

- ❒ Windows XP/Vista/7 (32 or 64 Bit)
- ❒ Internet Explorer 5.0 or above
- ❒ video card with Open GL support
- ❒ monitor that supports a resolution of 1024 x 768
- ❒ Pentium 4 Processor or better
- ❒ 256 MB RAM

To run First Principles, NDI also *recommends* having the following:

- ❒ 2 GB RAM or more
- ❒ 300 GB or more free hard drive space
- ❒ monitor that supports a resolution of 1600 x 1200
- ❒ wheel mouse
- ❒ 17-inch monitor or larger

Installation Procedure

1. Close all other programs before installing First Principles; once the installation is complete, you will be prompted to restart your computer.
2. Insert the First Principles CD into the computer’s CD drive.
3. Follow the steps as directed by the automatic installation wizard.

By default, this wizard stores all program files on **C:\Program Files\Northern Digital Inc\NDI First Principles**. You must be able to read and write to this location.

Some NDI data files used and created by First Principles are stored in the ‘ndigital’ directory. This directory is defined by the ND_DIR environment variable, and can typically be found in **C:\ndigital**. You must be able to read and write to this location.

Note NDI recommends that this directory not be changed during installation.

4. If prompted, restart the computer.
5. Start First Principles. The licence update dialog will appear. Refer to the following section for details on licences.

About Licences

First Principles is distributed free for a trial period of 120 days from the day you install it. During the trial period, all product features are available. You may purchase the full version or activate a free version at any time during the trial period. The free version provides only playback functionality.

When you start First Principles for the first time, the licence update dialog appears:

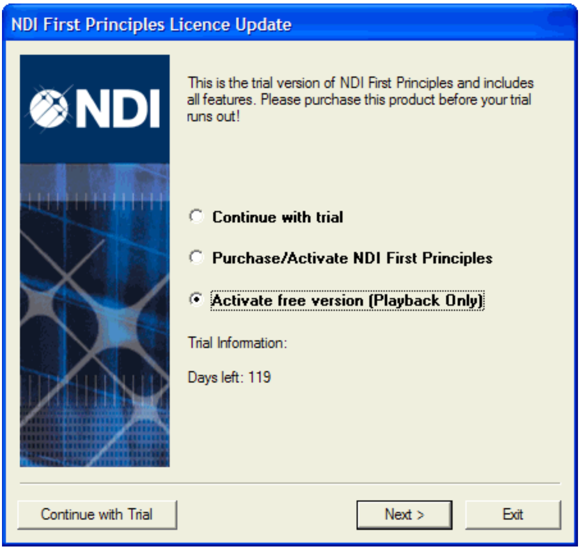


Figure 1-3 Licence Update

This dialog displays the number of days left in your free trial and presents three options as follows:

1. **Continue with Trial**. This option provides access to all features, providing the trial period has not expired. Once the trial period expires, this option is not available.

2. **Purchase/Activate NDI First Principles**. This option guides you through the purchase and activation procedure.

3. **Activate free version (Playback Only)**.This option activates the free, playback only, version. (If you activate the free version, you still have the option to purchase the full version at any time.)

Note You may select Continue with Trial at any time from any licence dialog.

Select the desired option and click **Next**. If you select **Continue with trial** or **Activate free version**, the dialog will close and First Principles will start. If you select Purchase/Activate NDI First Principles, the activate dialog appears:

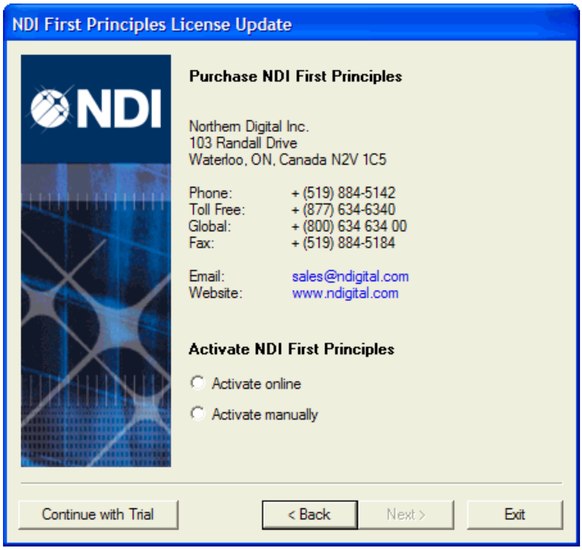


Figure 1-4 Activate Dialog

This dialog displays NDI contact information and two activation options, online and manual. Select the desired option and click **Next**. Proceed to online activation or manual activation as appropriate.

Note NDI contact information is also listed under "Contact Information" on page iv. You will need to contact NDI to purchase First Principles and to obtain the necessary activation information.

Online Activation

If you select Online Activation, the following dialog appears:

Figure 1-5 Online Activation

1. Make sure that your computer is connected to the internet. Enter the **Licence ID** and **Password** as supplied by NDI.
2. Click **Finish**. If activation is successful, the dialog closes and First Principles starts.

Manual Activation

If you select Manual Activation, the following dialog appears:

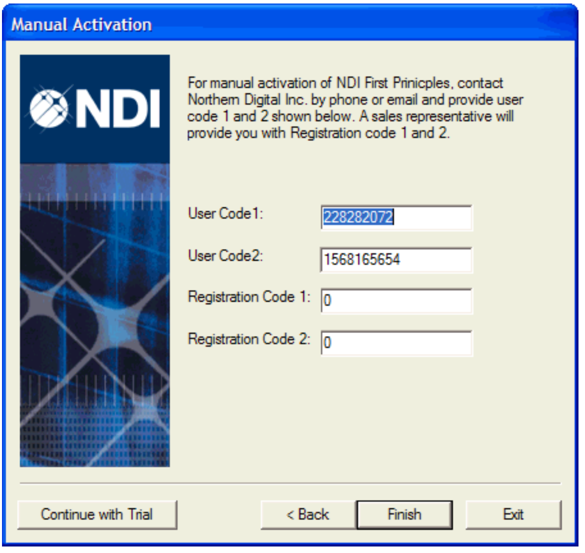


Figure 1-6 Manual Activation

1. Contact NDI and provide **user code 1** and **user code 2**. NDI will supply you with **registration code 1** and **registration code 2**.
2. Enter the information supplied by NDI in the appropriate fields. Click **Finish**. If activation is successful, the dialog closes and First Principles starts.

Licence Management

Licence status information and update options are also accessible when First Principles is running. To view the current licence status, select **Help > Licencing Info**. The following dialog appears:

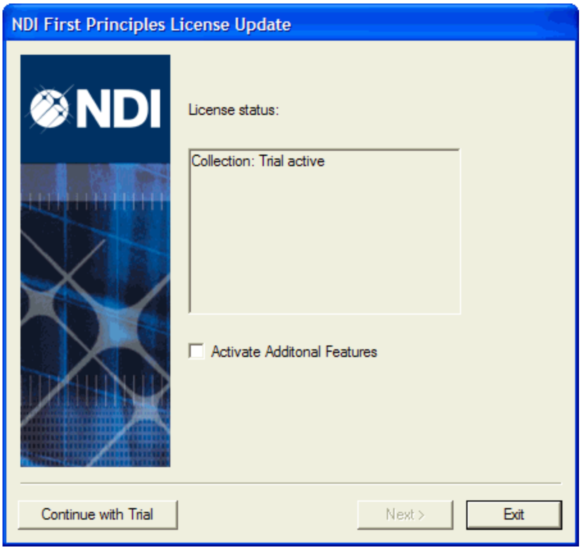


Figure 1-7 Licence Status

The **Licence status** box displays the current status. To **Activate additional features**, select the associated checkbox and click **Next**. The Activate dialog appears as previously described, refer to "Activate Dialog" on page 8.

2 Getting Started

To start using First Principles, complete the following tasks:

1. Set up hardware and start software
2. Adjust communication settings

Note If you are only going to open and review existing data collections, you do not need to be connected to an Optotrak System or be concerned with communication settings.

2.1 Set Up Hardware and Start Software

1. Refer to the system documentation and place and connect the main hardware components of your Optotrak System:
   - ❒ SCU
   - ❒ Position Sensor(s)
   - ❒ link cables
   - ❒ power cables
   - ❒ communication cables to host computer
2. Power on the system.
3. Start First Principles.

When you start First Principles, the software automatically attempts to connect to the Optotrak System, establish communication, and determine what hardware components are being used in your setup.

2.2 Adjust Communication Settings

Check the communication settings to ensure that they are correctly assigned. From the main menu, select **Settings > Communication Settings**. The Communication Settings Dialog appears:

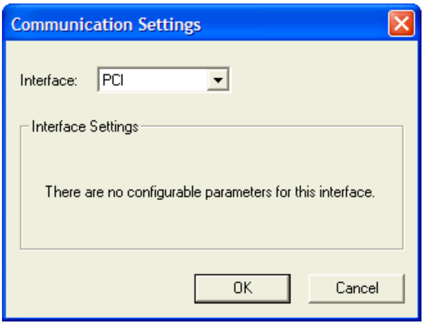


Figure 2-1 Communication Settings Dialog

If you are you using a PCI card:

1. From the **Connection Type** drop-down list, select **PCI**.
2. Click **OK** (no other input required).

If you are using a SCSI card:

1. From the **Connection Type** drop-down list, select **SCSI**. The SCSI Settings Dialog appears:

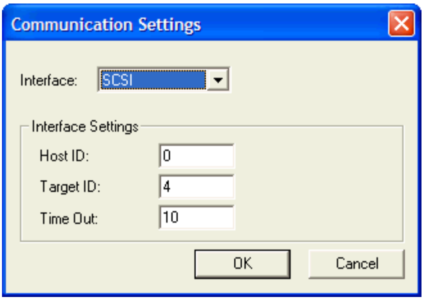


Figure 2-2 SCSI Settings Dialog

2. Enter the **Host ID**. You can determine the Host ID using the program NDI SCSI Check. This program is available from NDI Technical Support.

3. Enter the **Target ID** found on the back of the SCSI box. SCSI IDs are numbered from 0 though 7, and are used by the workstation to distinguish between the devices connected to the SCSI bus.
4. Enter the **Time Out**. Set this value to the time that the system will wait for communication until it times out. A recommended default value is 10 (seconds).

If you are using an Ethernet connection:

Note For detailed information about using Ethernet to communicate with an Optotrak System, refer to the documentation delivered with your system.

1. From the **Connection Type** drop-down list, select **Ethernet**. The Ethernet Settings Dialog appears:

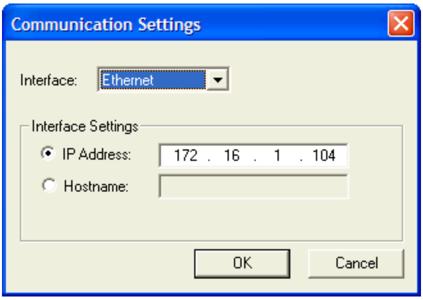


Figure 2-3 Ethernet Settings Dialog

2. If you are using a static IP address, set the **IP Address** to that of the SCU. If you are using DHCP, set the **Hostname** instead of **IP Address**. (The **Hostname** is SCU's serial number string without a dash "-".)

Note Depending on your facility setup, a network using DHCP may automatically assign an IP address to the SCU. Please consult your network administrator for information specific to your facility setup.

3. Click **OK**.

2.3 Query System

If you decide to change your hardware setup after starting First Principles, use the Query System utility to ensure that the software is aware of your changes. This function is also useful to check that the software is communicating correctly with the system and that all devices are correctly connected.

After making your changes, select **Utilities > Query System**. The software re-initializes the connected Optotrak System and attempts to determine its new hardware configuration. The Sample Query System Results Dialog appears:

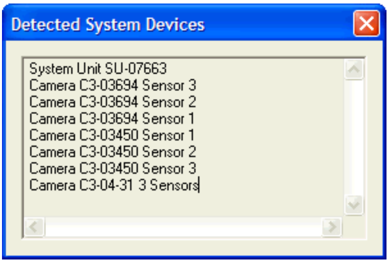


Figure 2-4 Sample Query System Results Dialog

3 Environment Setup

Before performing an experiment, you must set up the global coordinate system in which the experiment will be tracked. This process can be as simple as deciding to use the default global coordinate system of a single Position Sensor. Alternatively, this process can be as complicated as using several Position Sensors to track a marker using a common global coordinate system that, in addition, has been moved to a customized location.

First Principles provides you with an easy-to-use wizard that walks you through an environment setup and automatically saves your choices for future sessions.

3.1 Understanding the Environment Setup Wizard

The environment setup wizard allows you to review the current global coordinate system setup before using the system. Environment setup involves two possible processes; registration and alignment.

What is Registration?

If the software detects two or more Position Sensors connected to the system, you must perform a registration procedure. *Registration* is the process of aligning all the Position Sensors' coordinate systems to that of one of the Position Sensors, producing a single global coordinate system against which the position and orientation of rigid bodies, tools, and markers are measured.

For more information about registration, refer to the system user guide.

What is Alignment?

Alignment is the process of changing the default global coordinate system (placed at a Position Sensor) to the location of either a rigid body's coordinate system, or that produced by a combination of digitized points.

For more information about alignment, refer to the system user guide.

Note If you choose to perform both a registration and an alignment, remember that registration always comes first and that it invalidates any previous alignment.

What is the Environment Setup Process?

The Environment Setup wizard walks you through both registration and alignment using the following process:

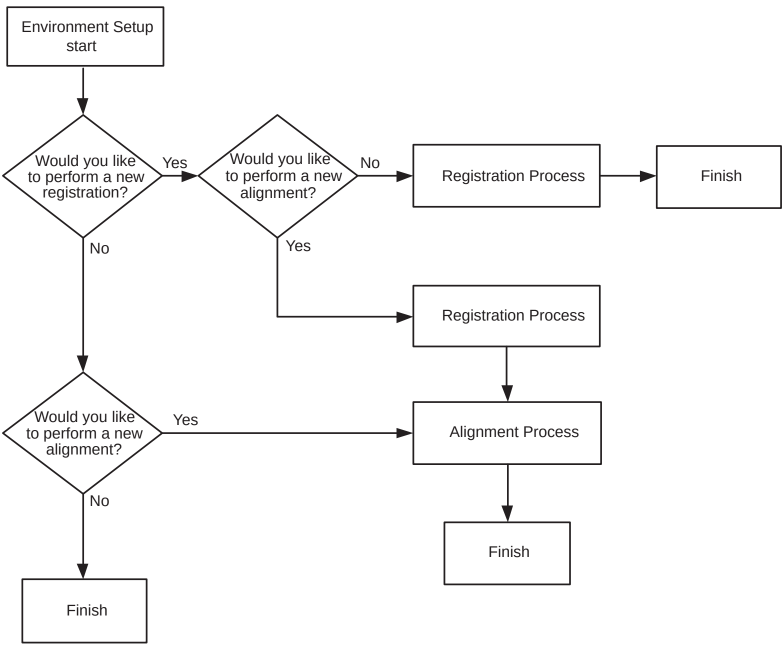


Figure 3-1 Environment Setup Process

3.2 Accessing the Environment Setup Wizard

There are two ways to access the Environment Setup wizard:

1. Select **Settings** > **Coordinate System Details** or,
2. Create either a new experiment or open an existing experiment:

- Select **File** > **New Experiment** to create an entirely new experiment.
- Select **File** > **Open Experiment** to browse to and open an existing experiment (.exp).

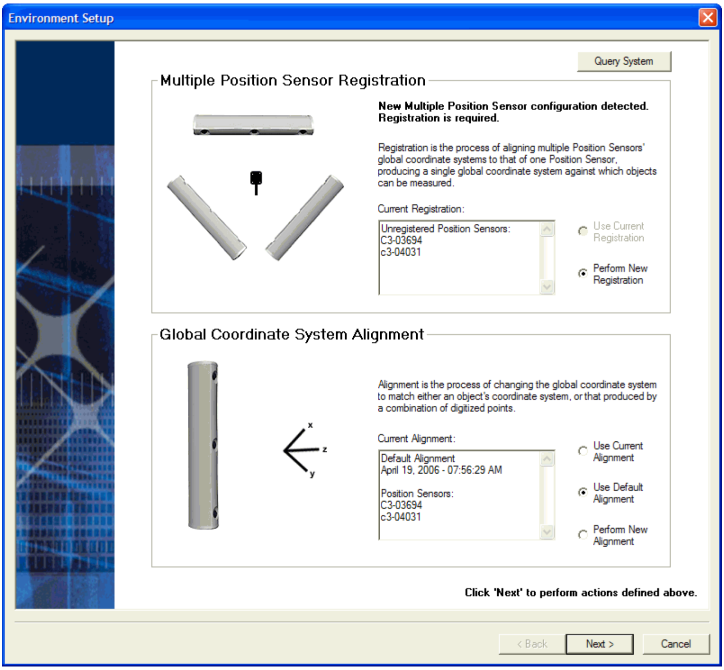


Figure 3-2 Environment Setup Window

3.3 Choosing to Perform a Registration

If the system has detected two or more Position Sensors connected to the system, the Environment Setup window enables the Position Sensor Registration dialog:

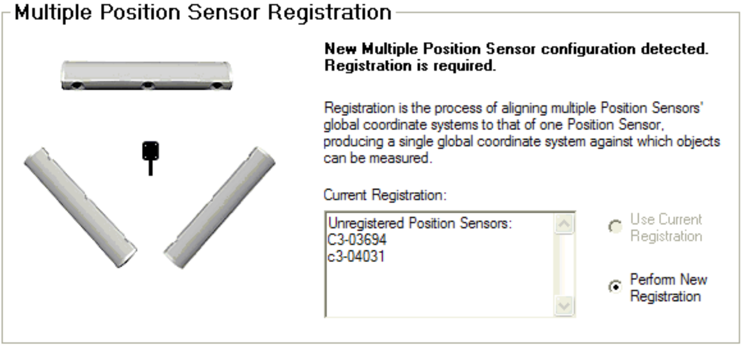


Figure 3-3 Position Sensor Registration Dialog

The Position Sensor Registration dialog provides the following information and options:

- It confirms that you have multiple Position Sensors connected to your system.
- It displays the details of the last time the detected Position Sensors were registered and their serial numbers.
- It offers you the option of reusing the current registration. For example, select this option if you are performing an experiment in which you are certain that the Position Sensors have not been moved since the last registration. You will not need to re-register.

Note NDI recommends that you perform a registration daily and each time you move the Position Sensor(s), or change the physical setup of the Position Sensor(s).

Using the information provided in this section, choose one of the following actions:

- Choose **Use Current Registration** if you do not wish to make any change from the last settings. If you select this option, the previous registration information will be applied to the global coordinate system, and you are moved on to Experiment Setup.

- Choose **Perform New Registration** if you wish to perform a new registration. See “Performing a Registration” on page 23.

3.4 Choosing to Perform an Alignment

The Global Coordinate System Alignment dialog offers you the opportunity to perform an alignment before collecting any experiment data:

Note Make sure you perform an alignment before you collect data. Unlike previous versions of NDI software, you will not be able to re-align the coordinate system once data has been collected.

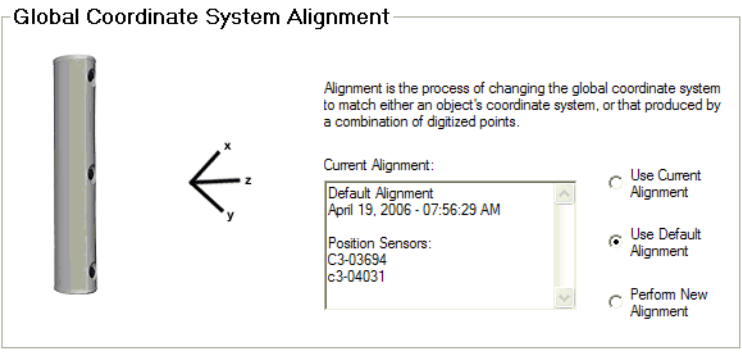


Figure 3-4 Global Coordinate System Alignment Dialog

The Global Coordinate System Alignment dialog provides the following information and options:

- It shows you the details of the last time an alignment was performed.
- It offers you the option of reusing the current alignment.
- It offers you the option of resetting the alignment to the default global coordinate system (the Position Sensor).

Using the information provided in the dialog, choose one of the following actions:

- Choose **Use Current Alignment** if you do not wish to make any changes from the last settings. If you choose this option, the previous alignment information will be applied to the global coordinate system, and you are moved on to the next step.
- Choose **Use Default Alignment** if you want to change the alignment to the global coordinate system, with its origin in the Position Sensor.
- Choose **Perform New Alignment** to perform a new alignment procedure. See “Performing an Alignment” on page 31.

3.5 What Next?

Performing a new registration? Go to “Performing a Registration” on page 23.

Performing a new alignment? Go to “Performing an Alignment” on page 31.

Using existing alignment/registration information (either customized or default)? Go to either “Experiment Setup for an Optotrak 3020” on page 41, or “Experiment Setup for an Optotrak Certus” on page 53.

4 Performing a Registration

Registration is the process of aligning multiple Positions Sensors' coordinate systems to that of one Position Sensor, producing a single global coordinate system against which rigid bodies, tools, and markers can be measured.

The registration process consists of the following:

1. Multiple Position Sensors track markers on the same rigid body or tool (known as a *registration object*) throughout a shared measurement volume area. "Shared" can mean any of the following:
   - Multiple measurement volumes overlapping a common area.
   - If two measurement volumes do not overlap a common area, they must both overlap in areas with a third measurement volume.
   - For a string of Position Sensors, a common link must exist between their measurement volumes in order to be considered sharing. For example, for an environment setup involved four Position Sensors, measurement volume 1 must overlap measurement volume 2, which must overlap measurement volume 3, which must overlap measurement volume 4. In this manner, measurement volume 4 is sharing with measurement volume 1.
2. Using the tracking information returned from each Position Sensor, the software calculates the location of each Position Sensor's coordinate system with respect to each other.
3. The software calculates and applies the transformations required to shift all coordinate systems to that of only one of the Position Sensors thus creating one global coordinate system. (The Position Sensor will be the furthest one physically connected to the SCU)

Note For more information about registration and rigid bodies/tools, refer to the system documentation.

4.1 Registration Procedure

The Environment Setup wizard provides you with the following registration procedure:

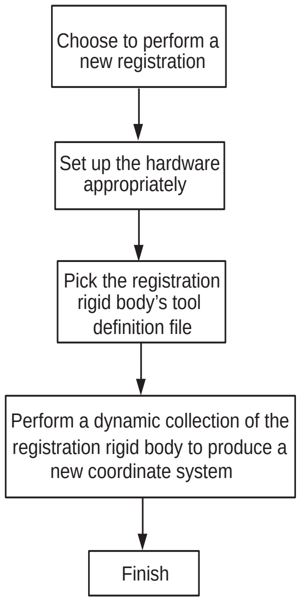


Figure 4-1 First Principles Registration Procedure

Once you have chosen to perform a new registration, the Environment Setup wizard begins. Refer to "Registration Welcome Window" on page 25:

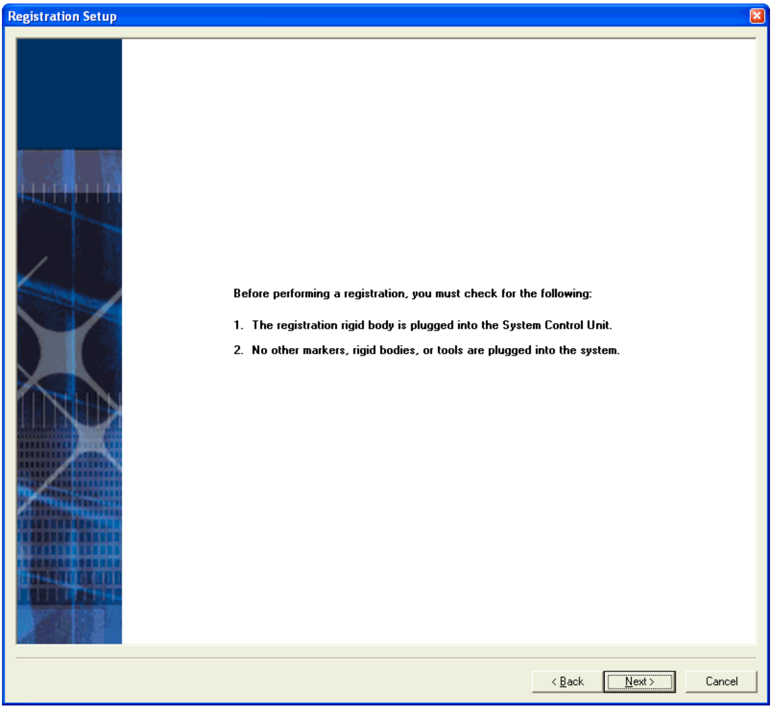


Figure 4-2 Registration Welcome Window

1. Following the on-screen instructions, connect the registration rigid body or tool to the SCU. (If you are using an Optotrak 3020 system, connect the rigid body or tool to Port 1 on the SCU.) Make sure that there are no other tools, rigid bodies, or markers plugged into the system.
2. Click **Next**. The following window appears:

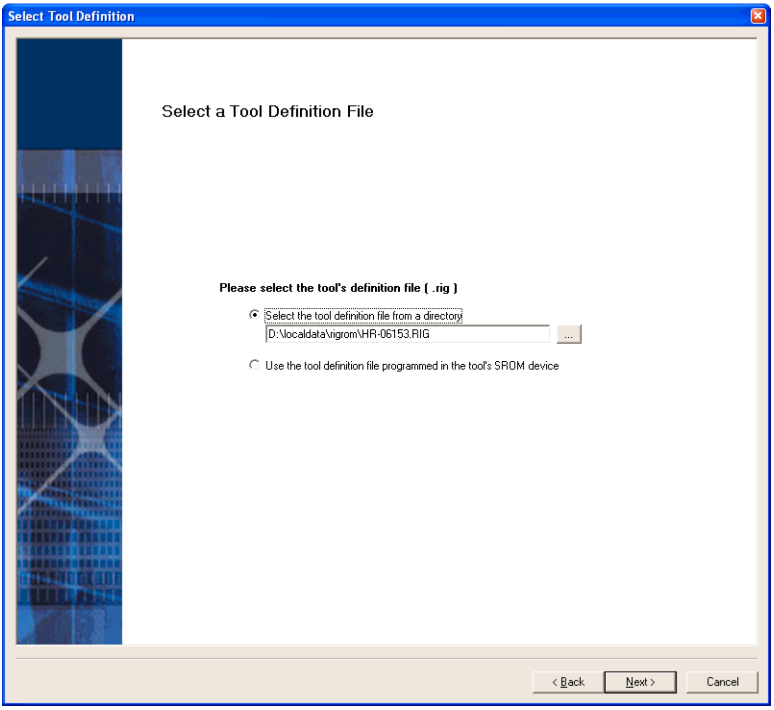


Figure 4-3 Registration Procedure — Select a Tool Definition File

3. Choose from the options provided:
    - If you are using a registration *rigid body*, choose **Select the tool definition file from a directory** and browse to the desired tool definition file (.rig).
    - If you are using a registration *tool* with a programmed SROM device, select **Use the tool definition file programmed in the tool's SROM device**. This option is not available for Optotrak 3020 systems, as they do not support SROM devices.

Note If you wish to use a tool definition file other than that programmed in the SROM device of a connected tool, select the tool definition file from a directory.

4. Click **Next**. The following window appears:

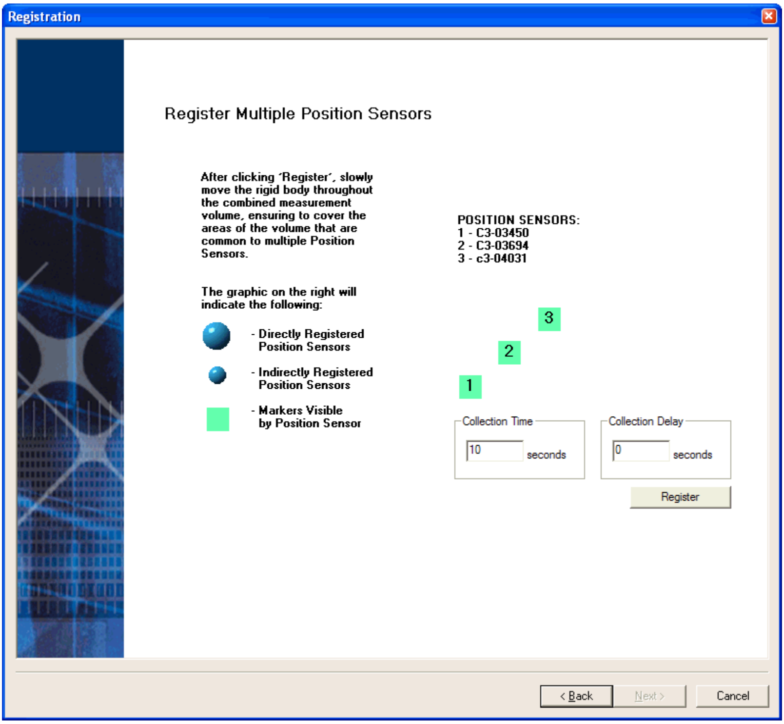


Figure 4-4 Registration Procedure — Collect Registration Data

5. **Pre-registration check**. The Position Sensors are numbered and listed by serial number at the right side of the display. They are also represented graphically by their number. Slowly move the registration object throughout the combined volume and notice that, as each Position Sensor sees at least three markers of the object, a green background appears behind the Position Sensor number. Using this method you can determine the limits of the combined volume that you will cover during the actual registration procedure.

6. Enter a **Collection Time** in seconds. Enter a time that will allow you to cover the combined volume during the registration process.

7. (Optional) Enter a **Collection Delay**, in seconds. Enter a time that will allow you time to position the registration object before the collection begins.
8. Click **Register** and begin to slowly move the registration object throughout the combined volumes, as determined in step 5. As the overlapping volumes of two Position Sensors are registered, a “blue sphere” icon appears between the two applicable Position Sensors. If two Position Sensors are registered because they share a common volume with a third Position Sensor, a small “blue sphere” icon appears.

   Move the registration object throughout the combined volume, making sure that all combinations of overlap contain either large or small “blue sphere” icons.
9. At the end of the collection, a Registration Results section appears at the bottom of the window, displaying either “Registration Successful” or “Registration Failed”.
   - If your registration failed, click **Register** to try again. Also see “Registration Hints” on page 29.
   - If your registration is successful and you are satisfied with the resulting RMS Error, click **Finish**. If you wish to review the result details, click **View Log.**

An example of a successful registration is shown in “Successful Registration” on page 29.

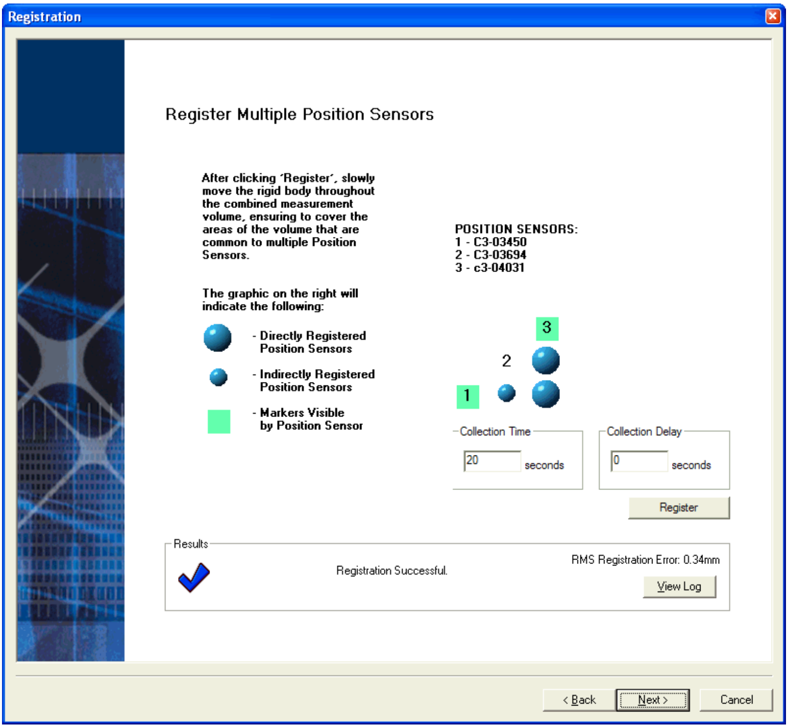


Figure 4-5 Successful Registration

What Next?

Performing an Alignment? Continue on with "Performing an Alignment" on page 31.

Not performing an Alignment? The Environment Wizard closes and the Experiment Setup window appears. Go to either "Experiment Setup for an Optotrak 3020" on page 41, or "Experiment Setup for an Optotrak Certus" on page 53.

4.2 Registration Hints

- Be sure that each Position Sensor has some overlapping measurement volume with at least one other Position Sensor in the setup.

- Be sure that the markers on the registration object are plugged into the SCU, can be seen by the Position Sensors, and are in the shared measurement volume area.
- Be sure that you selected the proper tool definition file for the registration object.
- When moving the registration object throughout the shared measurement volumes, be sure that a) you are moving it SLOWLY, and b) you have moved it at least 500 mm in each direction (up, down, and sideways).

5 Performing an Alignment

Alignment is the process of transforming the global coordinate system to a new location that is more meaningful to your experiment.

There are two ways to perform an alignment:

- **Align to digitized points:** Collect snapshots of specific points in the measurement volume using a digitizing probe. Use the location of these points to calculate a new global coordinate system.
- **Align to a rigid body or tool's coordinate system:** Perform a collection of a static rigid body/tool (also known as an *alignment object*). Use the resulting transformations to calculate the alignment object's local coordinate system, and then transform the global coordinate system to this location.

Note For more information about alignment objects, refer to the system user guide.

5.1 Alignment Procedure

The Environment Setup wizard provides you with the following alignment procedure:

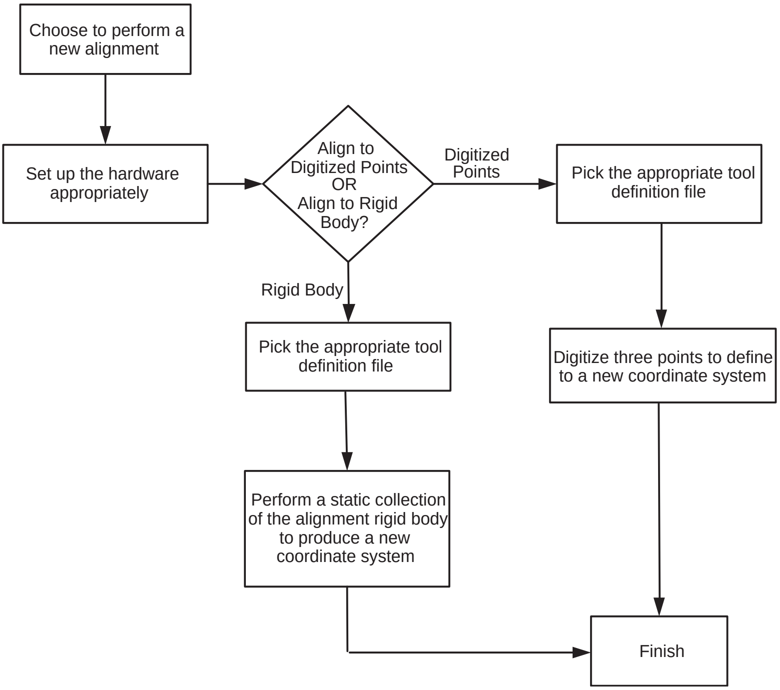


Figure 5-1 First Principles Alignment Procedure

Once you have chosen to perform a new alignment, the Alignment wizard begins, as shown in “Alignment — Welcome Window” on page 33:

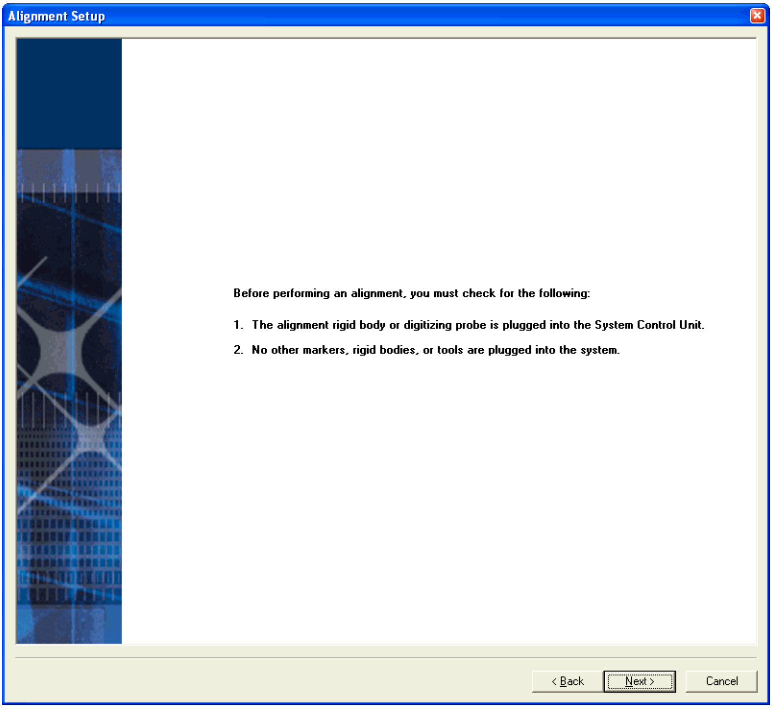


Figure 5-2 Alignment — Welcome Window

1. Connect either the alignment object or the digitizing probe to the SCU. (If you are using an Optotrak 3020 system, connect the alignment object of digitizing probe to Strober Port 1 on the SCU.) As instructed, make sure that there are no other tools, rigid bodies, or markers plugged into the system.
2. Click **Next**. The following window appears:

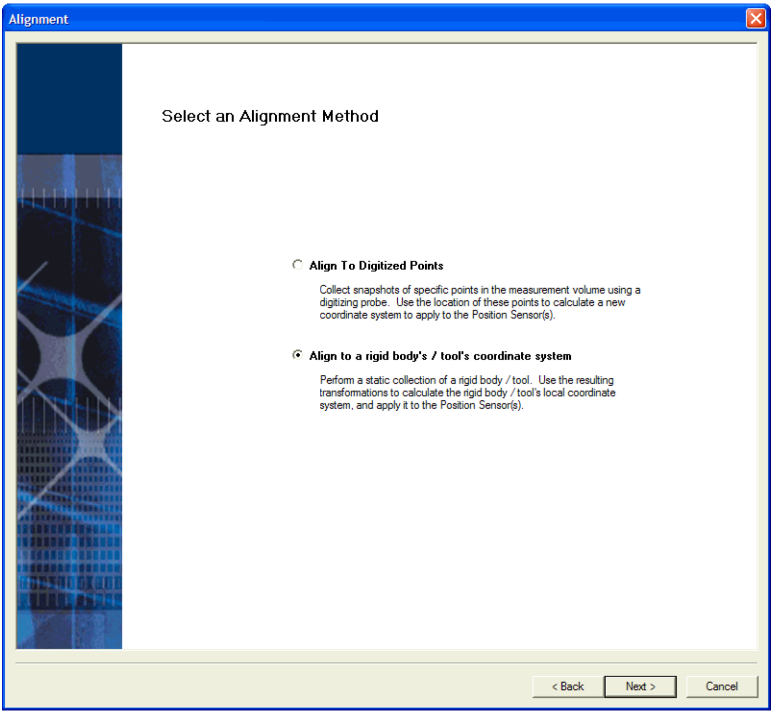


Figure 5-3 Alignment — Select an Alignment Method

3. Select how you wish to perform the alignment:
   - **Align to digitized points**: Collect snapshots of specific points in the measurement volume using a digitizing probe.
   - **Align to a rigid body or tool's coordinate system**: Perform a static collection of an alignment object.
4. Click **Next**.
   - **If you chose to use digitized points**, go to "Using Digitized Points" on page 35.
   - **If you chose to use an alignment rigid body/tool**, go to "Using an Alignment Object" on page 37.

5.2 Using Digitized Points

If you have chosen to perform an alignment using digitizing points, the following appears:

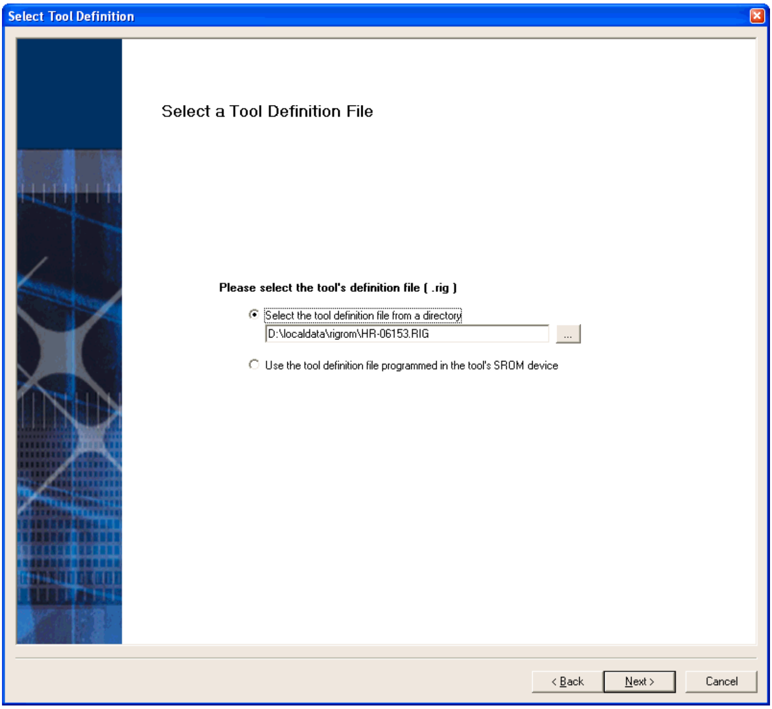


Figure 5-4 Alignment — Select a Tool Definition File

1. Choose from the options provided:

   - If you are using a digitizing *rigid body*, choose **Select the tool definition file from a directory** and browse to the desired tool definition file.

   - If you are using a digitizing *tool* with a programmed SROM device, select **Use the tool definition file programmed in the tool's SROM device**. This option is not available for Optotrak 3020 systems, as they do not support SROM devices.

Note If you wish to use a tool definition file other than that programmed to a connected probe, select the tool definition file from a directory.

2. Click **Next**. The following window appears:

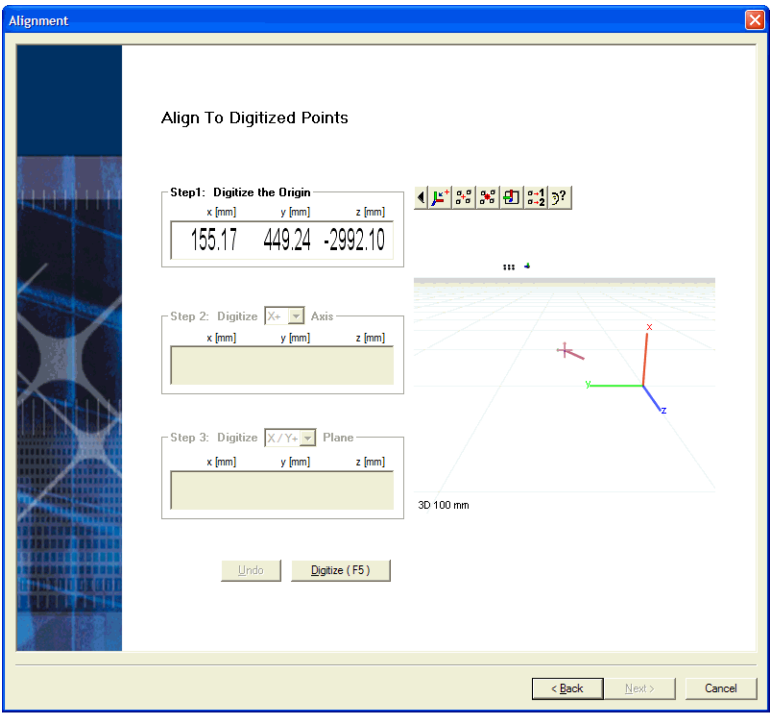


Figure 5-5 Alignment — Align to Digitized Points

3. **Step 1: Digitize the Origin**:

   a) Place the digitizing probe's tip at the new origin of the desired global coordinate system.

   b) Click **Digitize** or press **F5**. The software collects a single frame of data to determine the location of that point. This location will serve as the new origin of the global coordinate system.

4. **Step 2: Digitize an Axis**:
   a) Select an axis from the drop-down list provided.
   b) Place the digitizing probe’s tip on this new axis of the global coordinate system.
   c) Click **Digitize** or press **F5**. The software collects a single frame of data to determine the location of that point. The software uses this location to determine the selected axis of the new global coordinate system.
5. **Step 3: Digitize a Plane**:
   a) Select a plane from the drop-down list provided. Notice that the options provided are automatically limited to planes that extend from the selected axis determined in the previous step.
   b) Place the digitizing probe’s tip on this new plane of the global coordinate system.
   c) Click **Digitize** or press **F5**. The software collects a single frame of data to determine the location of that point. The software uses this location to determine the plane of the new global coordinate system.
6. Once you have completed the three steps in the Alignment dialog, the software calculates a new global coordinate system based on the location of the digitized origin, axis and plane. Click **Finish.**

What Next?

Go to either “Experiment Setup for an Optotrak 3020” on page 41, or “Experiment Setup for an Optotrak Certus” on page 53.

5.3 Using an Alignment Object

If you have chosen to perform an alignment using an alignment object, the following windows appears:

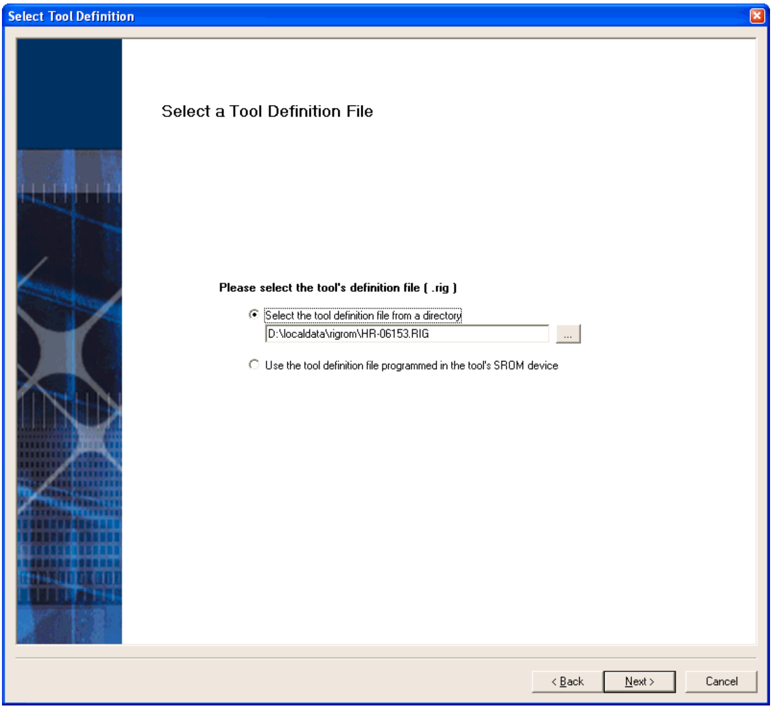


Figure 5-6 Alignment — Select a Tool Definition File

1. Choose from the options provided:

   - If you are using an alignment *rigid body*, choose **Select the tool definition file from a directory** and browse to the desired tool definition file.
   - If you are using an alignment *tool*, select **Use the tool definition file programmed in the tool's SROM device**. Note that this option is not available for Optotrak 3020 systems, as they do not support SROM devices.

Note If you wish to use a tool definition file other than that programmed to an alignment tool, select the tool definition file from a directory.

2. Click **Next**. The following window appears:

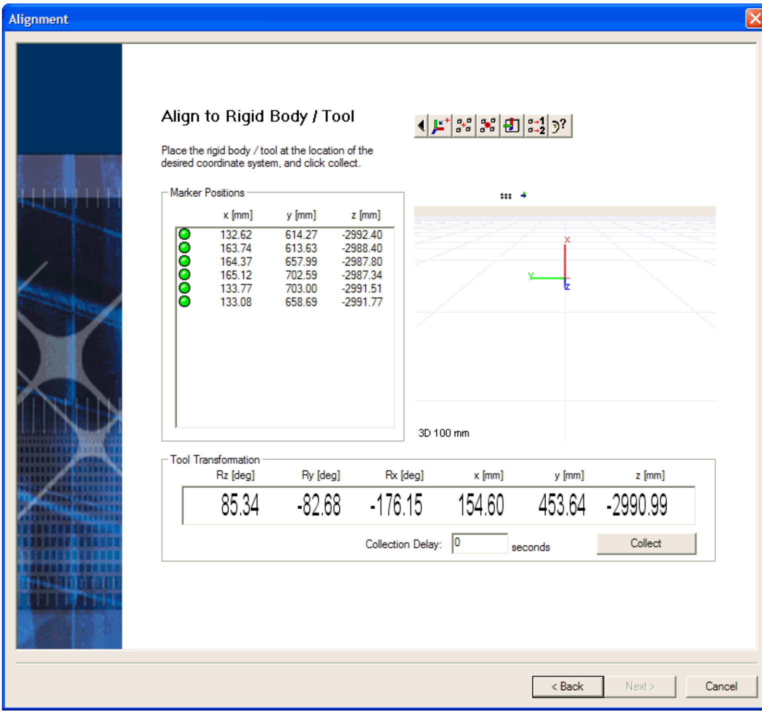


Figure 5-7 Alignment — Collect Alignment Object Data

3. Using both the real-time **Marker Positions** table and spatial view provided for guidance, place the alignment object in the measurement volume so that the rigid body/tool’s transformation can be seen.
4. Move the alignment object to the location of the new global coordinate system, so that its own origin matches the origin of the desired new global coordinate system.
5. Rotate the alignment object until its own coordinate system is in the orientation of the desired new global coordinate system.
6. Click **Collect**.

Note Do not move the alignment object during the collection, or the alignment will fail.

7. At the end of the collection, an alignment results section appears at the bottom of the window, displaying either “Alignment Successful” or “Alignment Failed”.
   - If your alignment failed, click **Collect** to try again. Also see “Alignment Hints” on page 40 to learn more about possible reasons why it was not successful.
   - If your alignment is successful and you are satisfied with the resulting RMS Error, click **Finish**.

What Next?

Go to either “Experiment Setup for an Optotrak 3020” on page 41, or “Experiment Setup for an Optotrak Certus” on page 53.

5.4 Alignment Hints

Be sure the alignment object's markers are plugged in, and in view of the Position Sensor(s) and in the measurement volume.

Be sure you select the correct tool definition file.

Be sure the alignment object is completely stationary when the system is collecting the alignment data file.

6 Experiment Setup for an Optotrak 3020

This section details the procedure required to set up an experiment using an Optotrak 3020 System. (For details on setting up an experiment using an Optotrak Certus System, refer to "Experiment Setup for an Optotrak Certus" on page 53.)

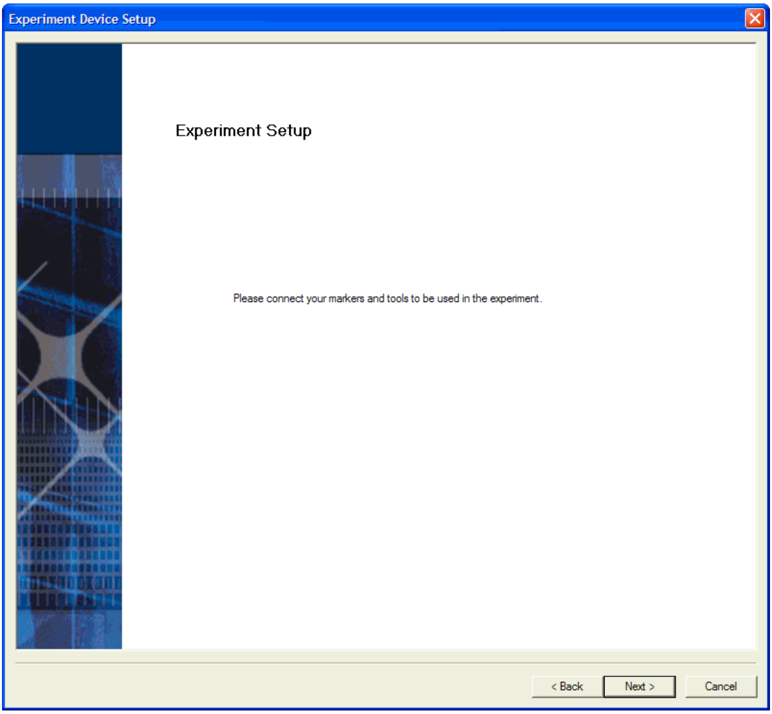


Figure 6-1 Experiment Setup Initial Window

1. As directed by the initial window, set up your experiment by plugging in all markers, rigid bodies, and/or ODAU IIs required for your experiment.
2. Click **Next** when you are ready. The Experiment Setup window appears. This window provides three tabs that allow you to set up:
   - markers
   - rigid bodies

- ODAU IIs

Note If you have opened a previously created experiment, its setup information will be loaded and the software will provide you with a list of expected rigid bodies and/or markers. Check against this list before clicking Next.

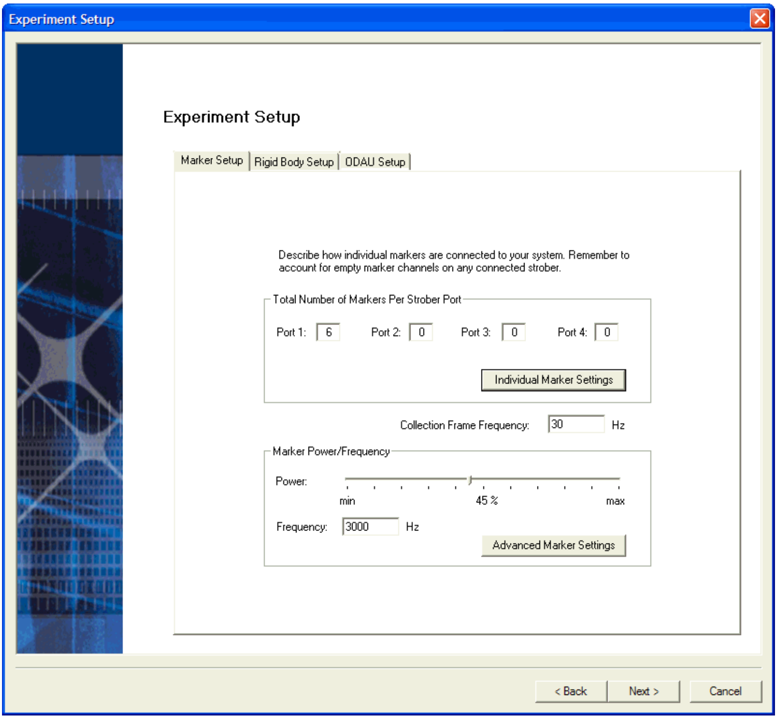


Figure 6-2 Experiment Setup Window

6.1 Marker Setup

Describe the markers connected to your system—both individual markers and those attached to a rigid body.

1. Click the **Marker Setup** tab.

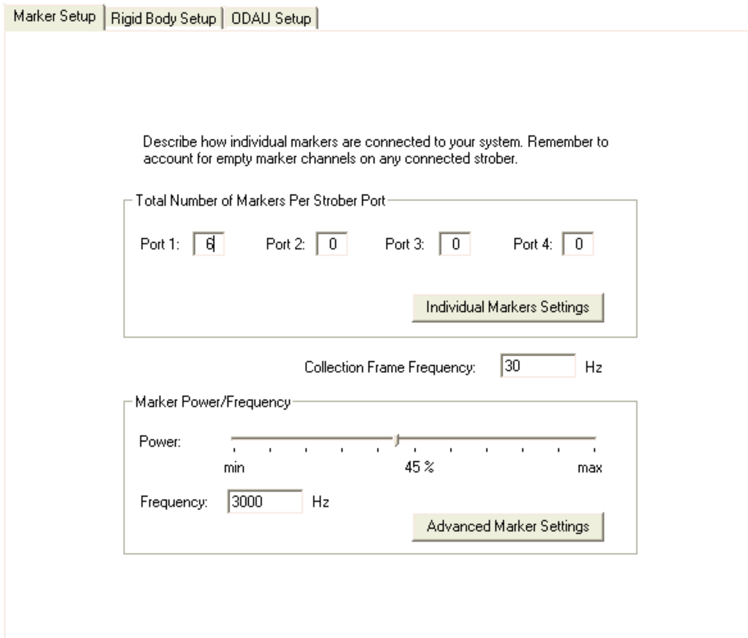


Figure 6-3 Optotrak 3020 Marker Setup Tab

2. Enter the **Total Number of Markers Per Strober Port**. For example, if you have two rigid bodies with six markers each plugged into strober port 1, you would assign the value **12** to **Port 1**.

   Make sure that you account for empty channels on any connected strober. For instance, if you have two 6-channel strobers daisy chained on Port 1 and you have connected three markers on the first strober and five markers on the second strober, you should specify 11 (6+5) as the total number of markers on Port 1.

3. (Optional) To rename markers, or to apply a frame of reference to a particular marker that is different than that of the global coordinate system, click **Individual Marker Settings**. The following dialog appears:

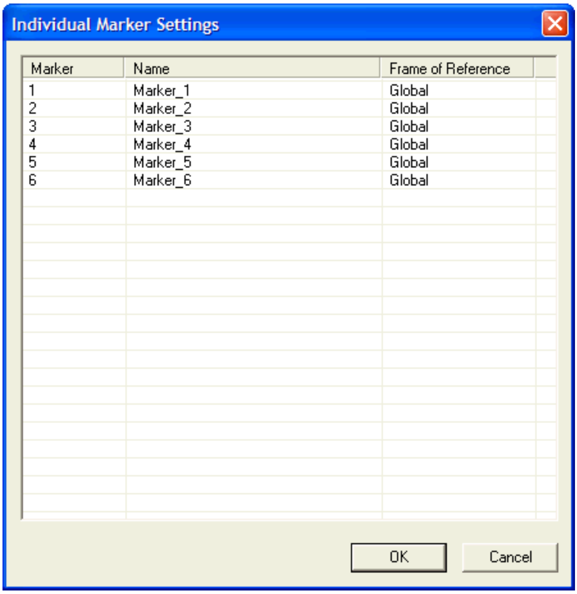


Figure 6-4 Individual Marker Settings

This dialog is automatically populated with all the markers entered for each strober port. To change a marker's frame of reference, select a new **Frame of Reference** from the drop-down list (if this option is available). Click **OK** when you are finished.

What is a frame of reference? Frame of reference refers to the coordinate system within which a marker is being tracked and measured. By default, markers are measured relative to the global coordinate system; however, you can change this if you want to know the location of a marker relative to another object, typically another rigid body or tool already defined in the experiment. (A marker will be reported as missing if its reference object goes missing.) All markers belonging to a rigid body will be changed if that rigid body has its frame of reference changed to that of another rigid body.

Note You can rename markers in this window by double-clicking on a marker and typing in its new name.

4. Set the **Marker Power** using the slider provided.

   What is marker power? Marker power is the overall “brightness” of a marker. The marker power value represents the combination of both marker voltage and duty cycle. The minimum marker power value (0%) represents 7.0 V at a 10% duty cycle. The maximum marker power value (100%) represents 12.0 V at an 85% duty cycle.

   If marker power is set too low, the Position Sensor may not be able to detect a marker in the measurement volume. For example, marker power may need to be higher if the markers are at the back of the measurement volume. Inversely, if a marker is at the front of the measurement volume, the marker power must be lower so as not to saturate the Position Sensor. The Raw Data view can be used to check if the marker emits sufficient IR signal; refer to “Raw Data View” on page 87 for details.

5. Set the **Marker Frequency**.

   What is marker frequency? Marker frequency is the rate at which markers are activated within a frame. Increasing marker frequency increases the rate at which marker positions are measured within a frame. This may be useful when tracking fast moving objects. However, a high marker frequency reduces the effectiveness of marker power (making it more difficult for the Position Sensor to detect markers at the back of the measurement volume). If you must use a high marker frequency, you should also increase the duty cycle.

6. (Optional) Click **Advanced Marker Settings** to adjust marker voltage and duty cycle directly (instead of simply applying a combined **Marker Power** value):

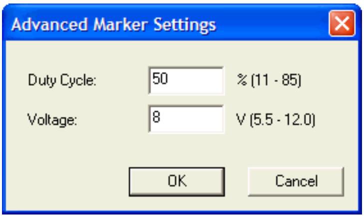


Figure 6-5 Advanced Marker Settings Dialog

   What is duty cycle? Duty cycle is the percentage of the marker period (time between two markers being activated) during which a marker is activated. If this value is set too high, the life span of the marker may be diminished; an activated marker in your hand should not feel hot.

What is marker voltage? Marker voltage is the voltage that strobers use to activate markers. If this value is too high, the life span of the marker may be diminished. If this value is too low, there may not be enough marker power for the Position Sensor to be able to detect the marker in the measurement volume.

6.2 Rigid Body Setup

Some of the markers you have assigned to a strober may be part of a rigid body:

Note You must define all the rigid bodies in your experiment before you collect any data. Otherwise, you will not be able to use First Principles to perform rigid body calculations.

1. Click the **Rigid Body Setup** tab.

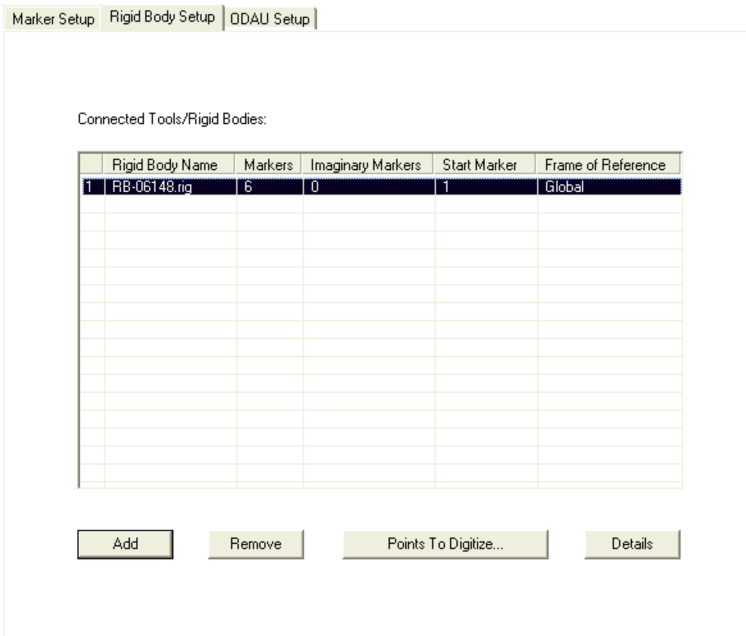


Figure 6-6 Optotrak 3020 Rigid Body Setup Tab

2. To assign a rigid body, click **Add**. Browse to and select the appropriate tool definition file (.rig) that represents the rigid body plugged into the system. The software adds the rigid body and its relevant tool definition file name to the Connected Tools/Rigid Bodies list.

3. Enter the **Start Marker** — the marker location of the first marker on the rigid body, relative to all markers connected to the system. Notice that the software provides you with a suggested value.

Note You can remove rigid bodies from this list by selecting a rigid body and clicking Remove. You can also view the contents of a rigid body's tool definition file (.rig) by selecting it from the list and clicking Details.

How to Add Imaginary Markers to a Rigid Body

Imaginary markers are points assigned to a rigid body where it is difficult or undesirable to attach an actual marker. Their locations are appended to the rigid body's tool definition file and are tracked as if they were real markers.

Some rigid bodies include imaginary markers in their tool definition file. These markers are "permanent" as their positions are recorded in the tool definition file and cannot be edited. These markers are created using NDI 6D Architect software, as part of the characterization process.

Some situations call for "temporary" imaginary markers — imaginary markers that are associated with a rigid body's design but that may change in location, for instance segment endpoints associated with a segment rigid body attached to different subjects. Use First Principles to create these temporary points and save them as part of your experiment setup.

1. Select a rigid body from the **Connected Tools/Rigid Bodies** list.
2. Click **Points to Digitize**. The following window appears:

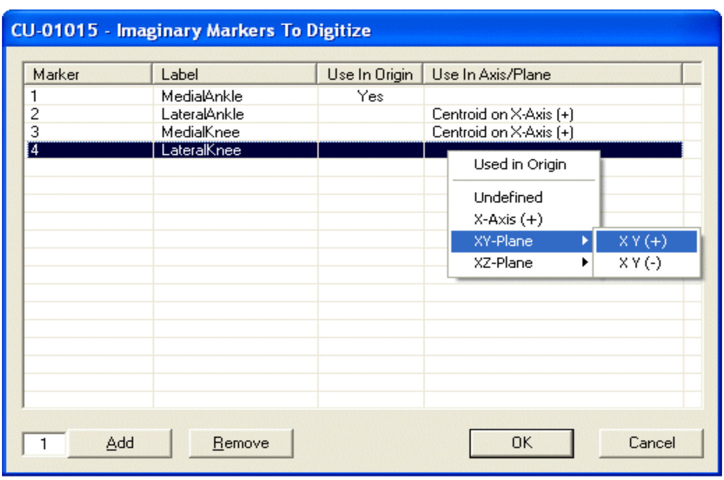


Figure 6-7 Adding Imaginary Markers

3. Click **Add** to add placeholders for each imaginary marker your experiment requires.

4. Double-click each label in turn and rename the imaginary markers as desired for your experiment.
5. In the **Use In Origin** column, select **Yes** for each marker you want to include when determining the origin. The origin will move to the centroid of all selected markers. If no markers are selected in this column, the origin will remain unchanged. (Markers may also be selected by right-clicking and selecting **Use in Origin** from the drop-down list.)
6. In the **Use In Axis/Plane** column, select the marker(s) you want to define as the new X-axis, followed by the marker(s) you want to define as the XY plane and XZ plane. If no markers are selected in this column, the tool coordinate system orientation will remain unchanged.
7. Click **OK**. The Imaginary Markers to Digitize dialog closes. If your experiment includes an ODAU II, proceed with ODAU II setup below, otherwise click **Next** to continue and complete the session setup procedure. (Refer to “Session Setup” on page 68 to complete the session setup.)

6.3 ODAU II Setup

You might also have Optotrak Data Acquisition Units II (ODAU IIs) connected to the Optotrak System, to record additional data about your experiment, in conjunction with marker data. For example, your experiment may involve capturing marker data attached to a subject’s legs. At the same time, your experiment might also employ a force plate to record analog signals created when the subject walks across it.

Note These instructions assume that you understand the concepts and terminology used in the operation of ODAU II devices. For more information, see the “*Data Acquisition Unit II Guide”*.

1. Click the **ODAU Setup** tab.

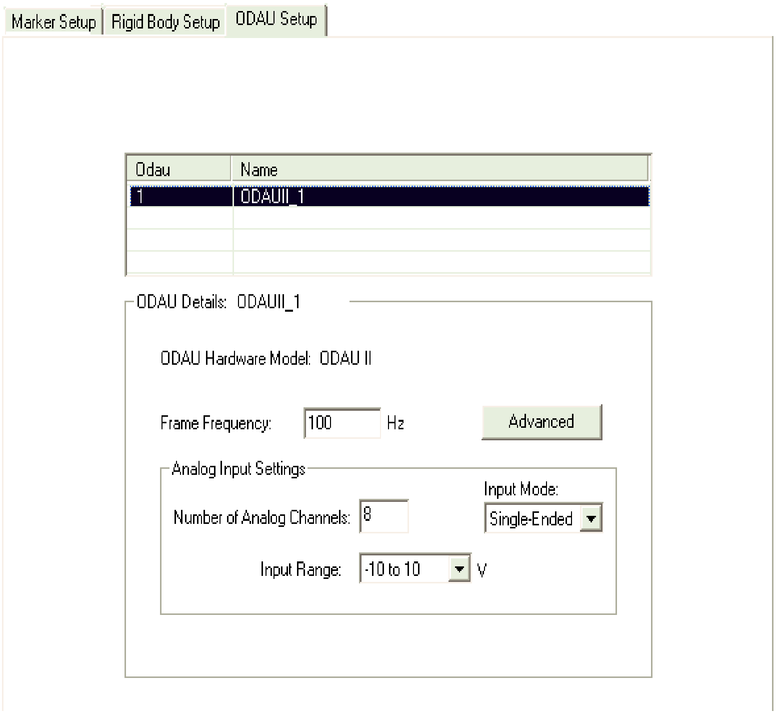


Figure 6-8 ODAU Setup Tab

2. From the list of **ODAU Units Detected**, select an ODAU unit. Its information is loaded into the fields provided.

3. Set the **Frame Frequency** to the frequency at which the ODAU II will record frames of data. By default, this value is set at 100 Hz.

4. In the Analog Input Settings section:

   - from the drop-down list, indicate whether the **Input Mode** is differential or single-ended.

   - indicate the **Number of Analog Channels** that the ODAU II will be recording data from. Without multiplexer boards, the maximum value for single-ended connections is 16; the maximum value for differential connections 8.

- from the drop-down list, set the **Input Range** to the voltage range the ODAU II should sample.

5. (Optional) Click Advanced to access additional settings. The following dialog appears:

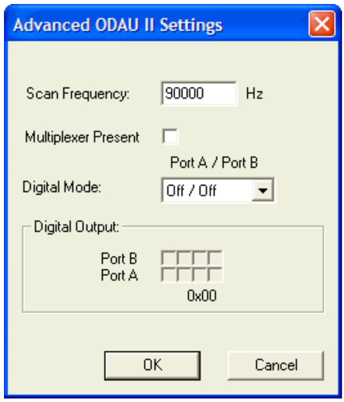


Figure 6-9 Advanced ODAU II Settings

a) Enter a **Scan Frequency**. The maximum scan rates vary with the **Input Range** that you have selected:

Table 6-1 Scan Frequency Chart

Input Range (V)	Max Recommended Scan Rate (Hz)
-10 to 10	90 000
-2 to 2	90 000
-1 to 1	70 000
-0.1 to 0.1	20 000

b) Indicate whether or not there is a **Multiplexer Present**. (Selecting this option changes the **Digital Mode** options.)

c) **Digital Mode:** Select the **Digital Mode** for **Port A/Port B** from the following list of options.

Note The options available depend on whether the Multiplexer Present option is selected. The multiplexer uses the first 4 digitized channels.

Table 6-2 Digital Mode - Selection Options

Multiplexer Present Port A/Port B	No Multiplexer Present Port A/Port B
Mux/Off	Off/Off
Mux/In	In/In
Mux/Out	In/Out
	Out/Out
	In Out/In Out

d) **Digital Output:** Select the **Digital Output** channels for **Port A** and/or **Port B**. The corresponding hexadecimal code is displayed as selections are made. (These options are only accessible if the applicable port has been selected as an output from the **Digital Mode** drop-down list.)

e) Click **OK** to apply these settings and close the dialog.

6.4 Setup Completion

When you have entered all applicable settings for your experiment, click **Next**. The Session Setup wizard appears. Refer to “Session Setup” on page 68 to complete the session setup.

7 Experiment Setup for an Optotrak Certus

This section details the procedure required to set up an experiment using an Optotrak Certus System. (For details on setting up an experiment using an Optotrak 3020 System, refer to “Experiment Setup for an Optotrak 3020” on page 41.)

1. As directed by the initial window, set up your experiment by plugging in all markers, rigid bodies, tools, and/or ODAU IIs required for your experiment.

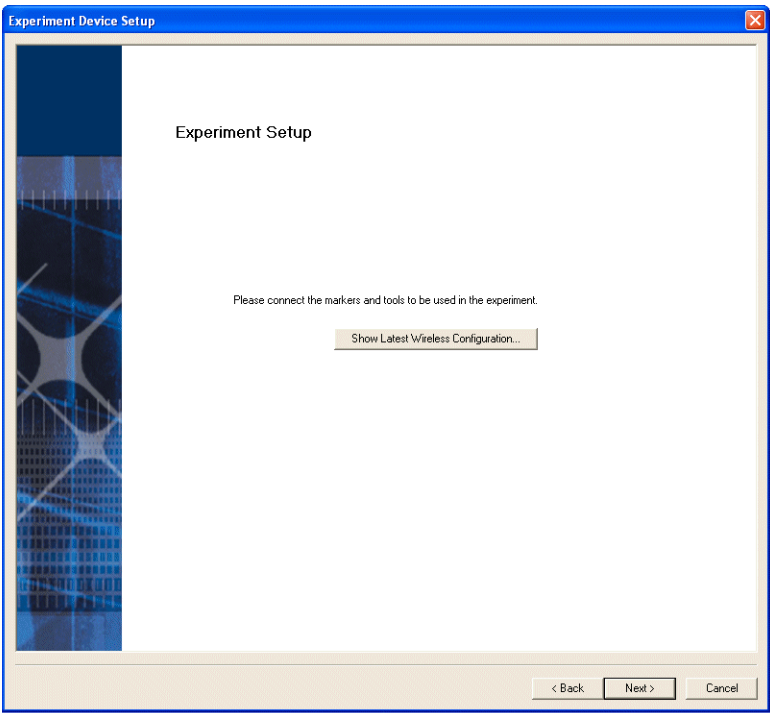


Figure 7-1 Experiment Setup Initial Window

Note If you have opened a previously created experiment, the software will provide you with a list of expected tools, rigid bodies and markers. Check your setup against this list before clicking Next.

2. Click **Next** when you are ready. The following window appears:

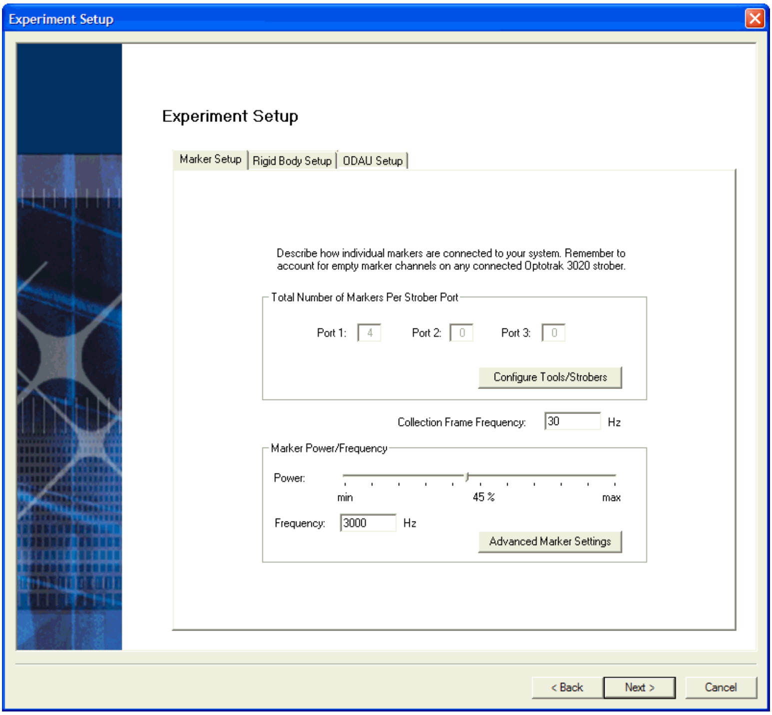


Figure 7-2 Experiment Setup Window

Use this window to describe to the software the details of each item connected to the system.

Note If you have opened a previously created experiment, and have not changed the setup that was listed in the previous step, you can click Next to skip past this window. Alternatively, you can use this window to describe changes that you *have* made.

If you disconnect and then reconnect tool(s) while the system is tracking, select File > Edit Experiment and update the experiment setup to detect the tool(s).

7.1 Marker Setup

Describe the strobers, markers and tools connected to your system:

1. Click the **Marker Setup** tab.

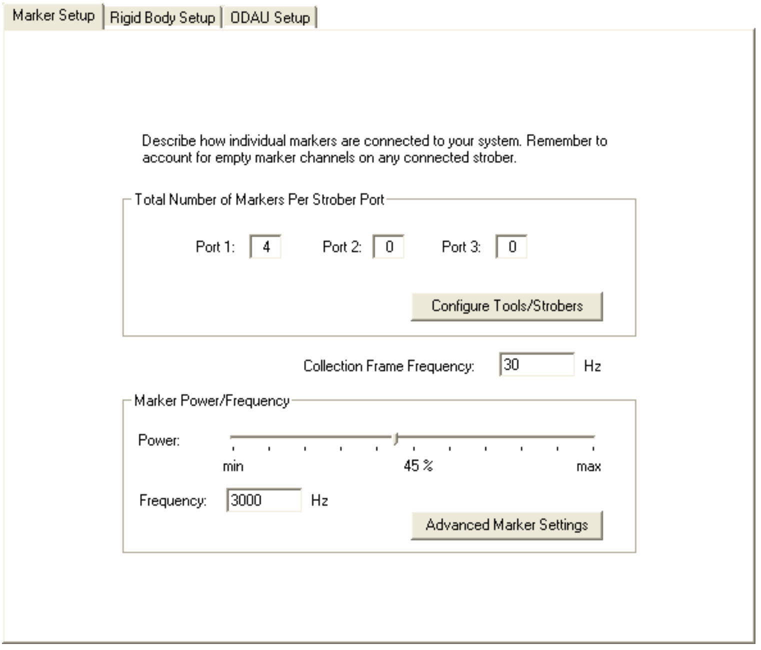


Figure 7-3 Optotrak Certus Marker Setup Tab

The software automatically determines the **Total Number of Markers Per Strober Port** based on the tools plugged into the system. Smart Marker configurations are automatically detected. Note that the software does not automatically detect any connected rigid bodies or individual markers connected to marker strobers, or those connected to Optotrak 3020 strober adapters. These must be added manually by clicking on **Configure Tools/Strobers**, as described below.

2. Click **Configure Tools/Strobers**. The following window appears:

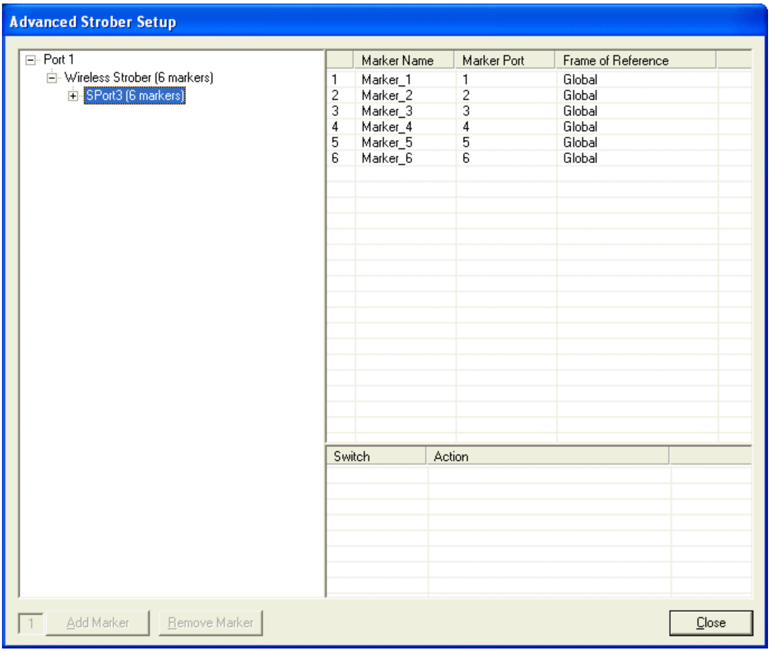


Figure 7-4 Advanced Strober Setup

The software retrieves and displays how the following are connected to the system:

- strobers
- tools
- markers

Wireless strober setups are displayed in a configuration tree:

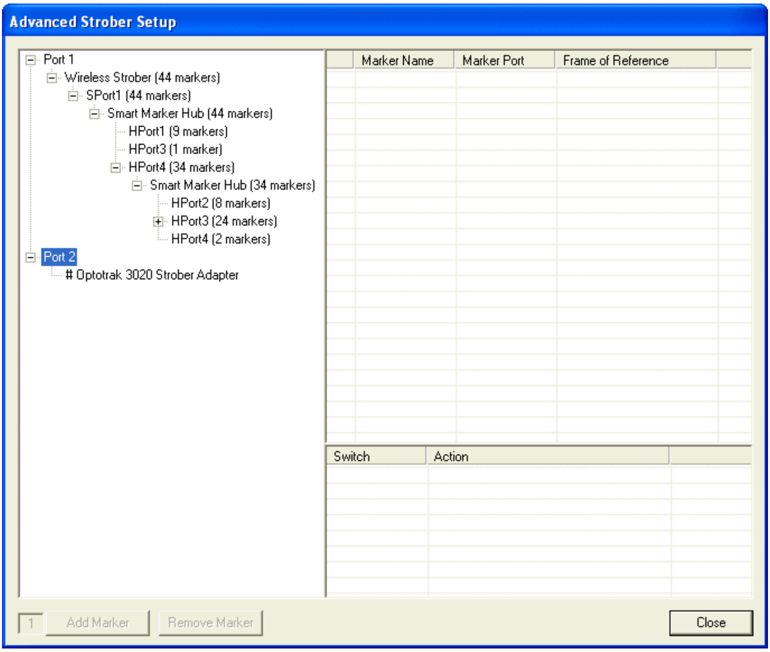


Figure 7-5 Wireless Strober Setup

Note Make sure that the devices listed reflect your experiment setup. Unplug any device not listed, wait two seconds and then plug in the device and reconfigure the tool/strober. (Close the Setup window, click Back, then click Configure Tools/Strobers.)

Note that the software does not automatically detect any connected rigid bodies or individual markers connected to marker strobers, or those connected to Optotrak 3020 strober adapters. You must manually add these to the setup.

a) Select a strober that has individual markers or a rigid body attached to it, and click **Add Marker** to add the total number of markers connected to it—both individual markers and those that are part of a rigid body. To quickly add a number of markers, select the **Alt-A** keys.

b) To remove markers, highlight them and select **Remove Marker** or the **Alt-R** keys. Alternatively, press the **Delete** key.

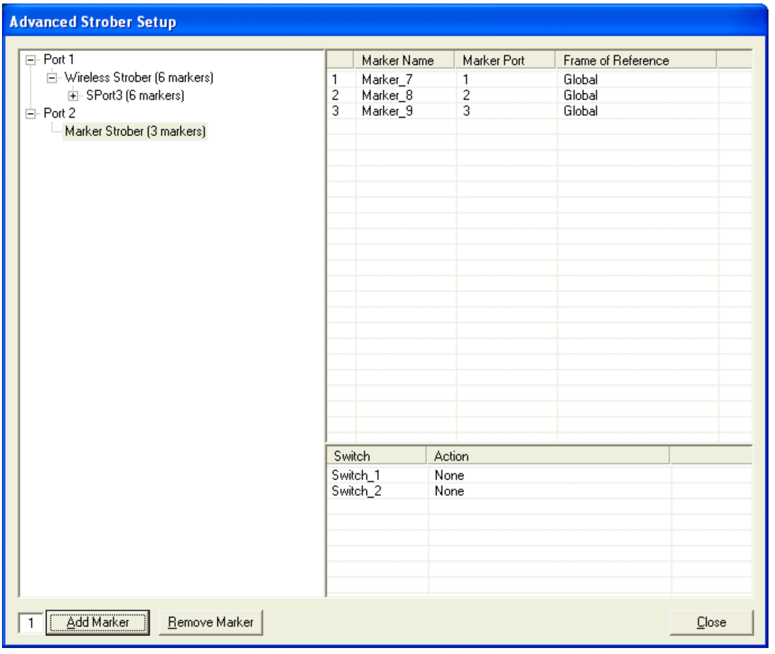


Figure 7-6 Adding Markers to a Marker Strober Setup

3. (Optional) You can rename a marker by double-clicking on its name and typing in a new one.

4. (Optional) You can change a marker's Frame of Reference. To change a marker's reference, select a new **Frame of Reference** from the drop-down list provided.

   What is a frame of reference? Frame of reference refers to the coordinate system within which a marker is being tracked and measured. By default, markers are measured relative to the global coordinate system; however, you can change this if you want to know the location of a marker relative to another object, typically another rigid body or tool already defined in the experiment. (A marker will be reported as missing if its reference object goes missing.) All markers belonging to a rigid body will be changed if that rigid body has its frame of reference changed to that of another rigid body.

Changing Marker Firing Sequences

Markers are fired in the order they are listed. You can indirectly change this order by changing the Marker Port address of the markers in question.

Individual Markers

1. Double-click an individual marker's Marker Port entry.
2. Type in a new number to change that marker's Marker Port.

Note Only change the Marker Port entry on markers that are associated with a Marker Strober. Changing the Marker Port entry on any other markers may prevent the markers from firing.

Rigid Body Markers

All markers associated with a rigid body must be fired consecutively; you should not change their firing sequence.

Smart Markers

Smart Markers are automatically assigned Marker Port numbers and they cannot be changed.

Tool Markers

Tool markers are automatically assigned Marker Port numbers according to their placement in the tool's internal wiring.

Note Do not change the port order on tool markers, as the tools will go missing.

Changing Marker Power/Frequency

On the Marker Setup tab:

1. Set the **Marker Power** using the slider provided.

   What is marker power? Marker power is the overall “brightness” of a marker. The marker power value represents the combination of both marker voltage and duty cycle. The minimum marker power value (0%) represents 7.0 V at a 10% duty cycle. The maximum marker power value (100%) represents 12.0 V at an 85% duty cycle.

   If marker power is set too low, the Position Sensor may not be able to detect a marker in the measurement volume. For example, marker power may need to be higher if the markers are at the back of the measurement volume. Inversely, if a marker is at the front of the measurement volume, the marker power must be lower so as not to saturate the Position Sensor. The Raw Data view can be used to check if the marker emits sufficient IR signal; refer to “Raw Data View” on page 87 for details.

2. Set the **Marker Frequency**.

   What is marker frequency? Marker frequency is the rate at which markers are activated within a frame. Increasing marker frequency increases the rate at which marker positions are measured within a frame. This may be useful when tracking fast moving objects. However, a high marker frequency reduces the effectiveness of marker power (making it more difficult for the Position Sensor to detect markers at the back of the measurement volume). If you must use a high marker frequency, you should also increase the duty cycle.

3. (Optional) Click **Advanced Marker Settings** to adjust marker voltage and duty cycle directly (instead of simply applying a combined **Marker Power** value):

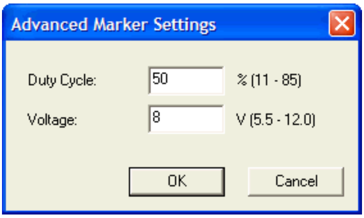


Figure 7-7 Advanced Marker Settings Dialog

What is duty cycle? Duty cycle is the percentage of the marker period (time between two markers being activated) during which a marker is activated. If this value is set too high, the life span of the marker may be diminished; an activated marker in your hand should not feel hot.

What is marker voltage? Marker voltage is the voltage strobers use to activate markers. If this value is too high, the life span of the marker may be diminished. If this value is too low, there may not be enough marker power for the Position Sensor to be able to detect the marker in the measurement volume.

7.2 Rigid Body Setup

.rig files are automatically created and added for any connected/detected tools (.rom). However, you must add .rig files for any connected rigid body attached to a strober that does not automatically detect tools (such as the Optotrak 3020 strober adapter or marker strober), as the system cannot automatically detect these.

Note If you are planning to incorporate an Optotrak 3020 digitizing probe in your experiment, you must add it at this stage. This is to enable the correct option during Digitize Probe setup.

1. Click the Rigid Body Setup tab. The following window appears:

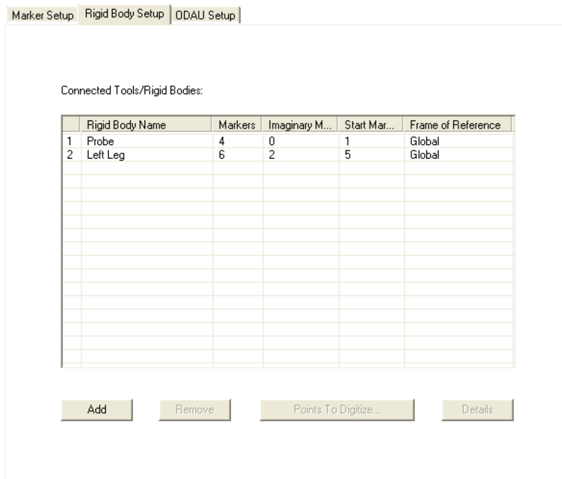


Figure 7-8 Optotrak Certus Rigid Body Setup Tab

2. To assign a rigid body, click **Add**. Browse to and select the appropriate tool definition file (.rig) that represents the rigid body plugged into the system. The software adds the rigid body and its information to the Connected Tools/Rigid Bodies list.

3. Enter the **Start Marker**—the marker location of the first marker on the rigid body, relative to all markers connected to the system. Notice that the software provides you with a suggested value.

Note You can remove rigid bodies from this list by selecting a rigid body and clicking Remove. You can also view the contents of a rigid body's tool definition file (.rig) by selecting it from the list and clicking Details.

How to Add Imaginary Markers to a Rigid Body

Imaginary markers are points assigned to a rigid body where it is difficult or undesirable to attach an actual marker. Their locations are appended to the rigid body's tool definition file and are tracked as if they were real markers.

Some rigid bodies include imaginary markers in their tool definition file. These markers are "permanent" as their positions are recorded in the tool definition file and cannot be edited. These markers are created using NDI 6D Architect, as part of the characterization process.

Some situations call for "temporary" imaginary markers — imaginary markers that are associated with a rigid body's design but that may change in location, for instance segment endpoints associated with a segment rigid body attached to different subjects. Use First Principles to create these temporary points and save them as part of your experiment setup.

1. Select a rigid body from the **Connected Tools/Rigid Bodies** list.
2. Click **Points to Digitize**. The following window appears:

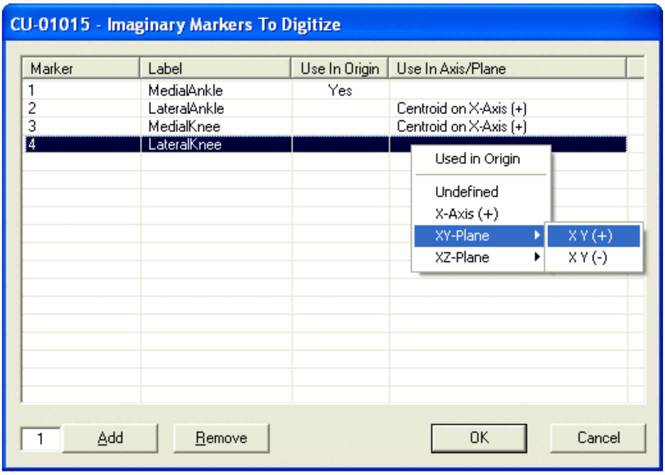


Figure 7-9 Adding Imaginary Markers

3. Click **Add** to add placeholders for each imaginary marker your experiment requires.
4. Double-click each label in turn and rename the imaginary markers as desired for your experiment.
5. In the **Use In Origin** column, select **Yes** for each marker you want to include when determining the origin. The origin will move to the centroid of all selected markers. If no markers are selected in this column, the origin will remain unchanged. (A marker may also be

selected by right clicking and selecting **Use in Origin** from the drop-down list.)

6. In the **Use In Axis/Plane** column, select the marker(s) you want to define as the new X-axis, followed by the marker(s) you want to define as the XY plane and XZ plane. If no markers are selected in this column, the tool coordinate system orientation will remain unchanged.
7. Click **OK**. The Imaginary Markers to Digitize dialog closes. If your experiment includes an ODAU II, proceed with ODAU II setup below; otherwise, click **Next** to continue and complete the session setup procedure. (Refer to “Session Setup” on page 68 to complete the session setup.)

7.3 ODAU II Setup

You might also have Optotrak Data Acquisition Units II (ODAU IIs) connected to the Optotrak System, to record additional data about your experiment, in conjunction with marker data. For example, your experiment may involve capturing marker data attached to a subject’s legs. At the same time, your experiment might also employ a force plate to record analog signals created when the subject walks across it.

Note These instructions assume that you understand the concepts and terminology used in the operation of ODAU II devices. For more information, see the *“Data Acquisition Unit II Guide”*.

1. Click the **ODAU Setup** tab.

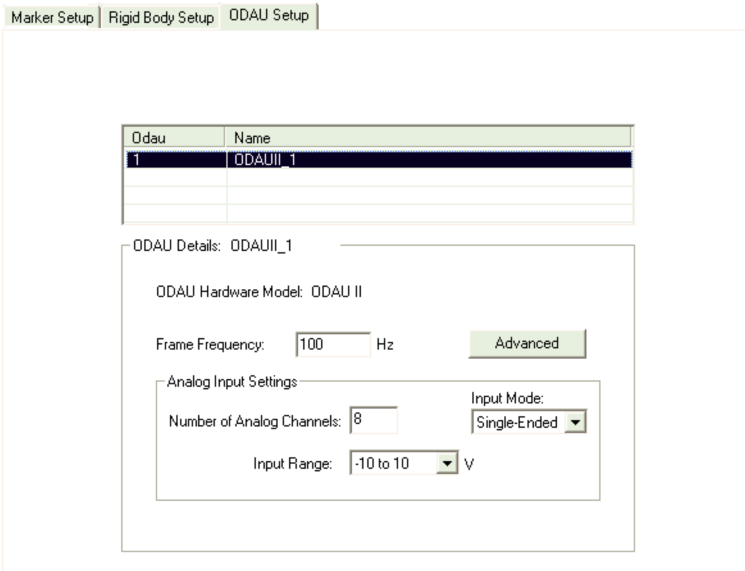


Figure 7-10 ODAU Setup Tab

2. From the list of **ODAU Units Detected**, select an ODAU II unit. Its information is loaded into the fields provided.
3. Set the **Frame Frequency** to the frequency at which the ODAU II will record frames of data. By default, this value is set at 100 Hz.
4. In the Analog Input Settings section:
   - from the drop-down list, indicate whether the **Input Mode** is differential or single-ended.
   - indicate the **Number of Analog Channels** that the ODAU II will be recording data from. Without multiplexer boards, the maximum value for single-ended connections is 16; the maximum value for differential connections 8.
   - from the drop-down list, set the **Input Range** to the voltage range the ODAU II should sample.
5. (Optional) Click Advanced to access additional settings. The following dialog appears:

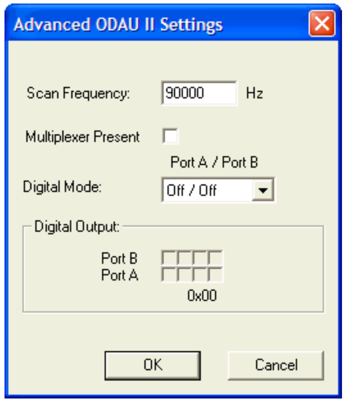


Figure 7-11 Advanced ODAU II Settings

a) Enter a **Scan Frequency**. The maximum scan rates vary with the **Input Range** that you have selected:

Table 7-1 Scan Frequency Chart

Input Range (V)	Max Recommended Scan Rate (Hz)
-10 to 10	90 000
-2 to 2	90 000
-1 to 1	70 000
-0.1 to 0.1	20 000

b) Indicate whether or not there is a **Multiplexer Present**. (Selecting this option changes the **Digital Mode** options.)

c) **Digital Mode:** Select the **Digital Mode** for **Port A/Port B** from the following list of options.

Note The options available depend on whether the Multiplexer Present option is selected. The multiplexer uses the first 4 digitized channels.

Table 7-2 Digital Mode — Selection Options

Multiplexer Present Port A/Port B	No Multiplexer Present Port A/Port B
Mux/Off	Off/Off
Mux/In	In/In
Mux/Out	In/Out
	Out/Out
	In Out/In Out

d) **Digital Output:** Select the **Digital Output** channels for **Port A** and/or **Port B**. The corresponding hexadecimal code is displayed as selections are made. (These options are only accessible if the applicable port has been selected as an output from the **Digital Mode** drop-down list.)

e) Click **OK** to apply these settings and close the dialog.

7.4 Setup Completion

When you have entered all applicable settings for your experiment, click **Next**. The Session Setup wizard appears. Refer to “Session Setup” on page 68 to complete the session setup.

8 Session Setup

The final step in the experiment setup is session setup. The **Session Setup** wizard appears when you select **Next** from **Experiment Setup**. Session setup consists of:

- Specifying the collected data location
- Digitizing imaginary markers (If any points to be digitized have been defined in the rigid body part of the Experiment Setup wizard.)

These steps are detailed in the following paragraphs.

8.1 Collected Data Location

The **Collected Data Location** window allows you to name the session and specify the directory location.

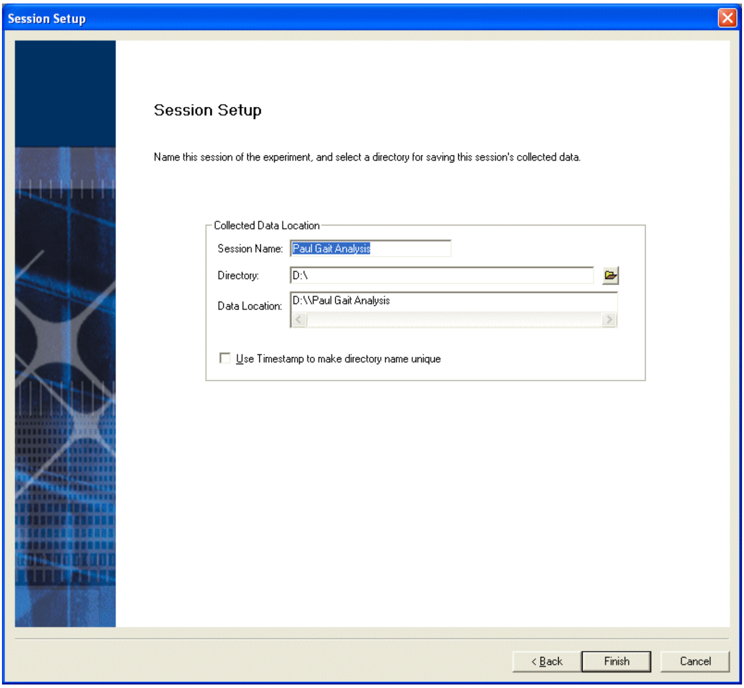


Figure 8-1 Collected Data Location

1. Browse to the desired directory.
2. Type in a name for the session.

   The data location line is automatically filled in to show the data location.

   Check **Use Timestamp to make directory name unique** to add the time to the directory name.
3. Click **Next**. If any points to be digitized have been defined in the rigid body part of the Experiment Setup wizard, the **Digitizing Probe Setup** window appears. (See “Digitizing Imaginary Markers” on page 70.). Otherwise, the Session Setup is complete and the application opens in Text View displaying the real-time data measured by the system. Refer to “Viewing Experiment Data” on page 82.

8.2 Digitizing Imaginary Markers

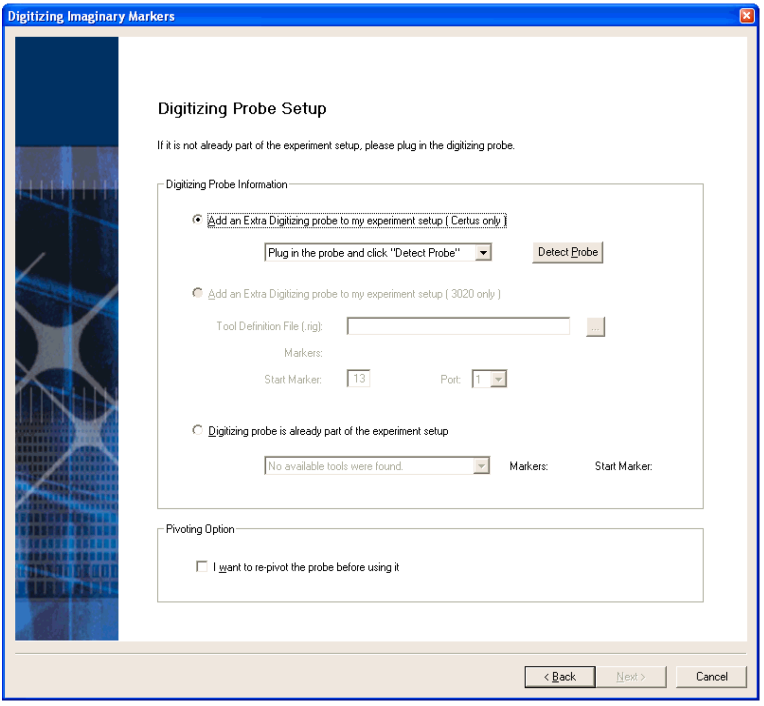


Figure 8-2 Digitizing Probe Setup

To digitize imaginary markers, follow the procedure detailed below:

1. Select the Digitizing probe information from one of the following three options:

   - (Certus only) Select the **Add an extra digitizing probe to my experiment setup (Certus only)** option.

   a) Plug in the probe to any free tool strober port. (If there is no tool strober port available, add another tool strober with a probe attached anywhere in the configuration.)

   b) Click **Detect Tools** to identify the probe you have just plugged in. (It will always find this probe.)

- (Optotrak 3020 only) Select the **Add an extra digitizing probe to my experiment setup (3020 only)** option to select a tool definition that matches the probe:

a) Plug in the probe to the port that is pre-selected by the application, as indicated in the **Port** drop down list. (If you did not connect the tool to the SCU port pre-selected by the application, select the appropriate **Port** from the drop down list.)

b) Browse to, and select, the appropriate rigid body file for the chosen digitizing probe.

c) The **Marker** field displays the number of markers associated with the selected rigid body file.

d) The **Start Marker** field displays the next available marker position.

- Check the **Digitizing probe is already part of the experiment setup** option. From the drop down list, select the tool that you will use as the digitizing probe. (This list contains only rigid bodies that do not contain imaginary markers to be digitized.) If this option is "greyed out" and you are using a Certus system, make sure that you added the probe during the Rigid Body Setup procedure. Refer to "Rigid Body Setup" on page 61.

2. Check the **I want to re-pivot the probe before using it** option if you want to re-pivot the probe.
3. Select **Next**.
   - If you checked the pivoting option, the pivot collection dialog will open. Refer to "Pivot Procedure" on page 74. Complete the pivot procedure and then continue with Step 4.
   - If you did not check the pivoting option, the following dialog appears. Continue with digitizing the imaginary markers in Step 4.

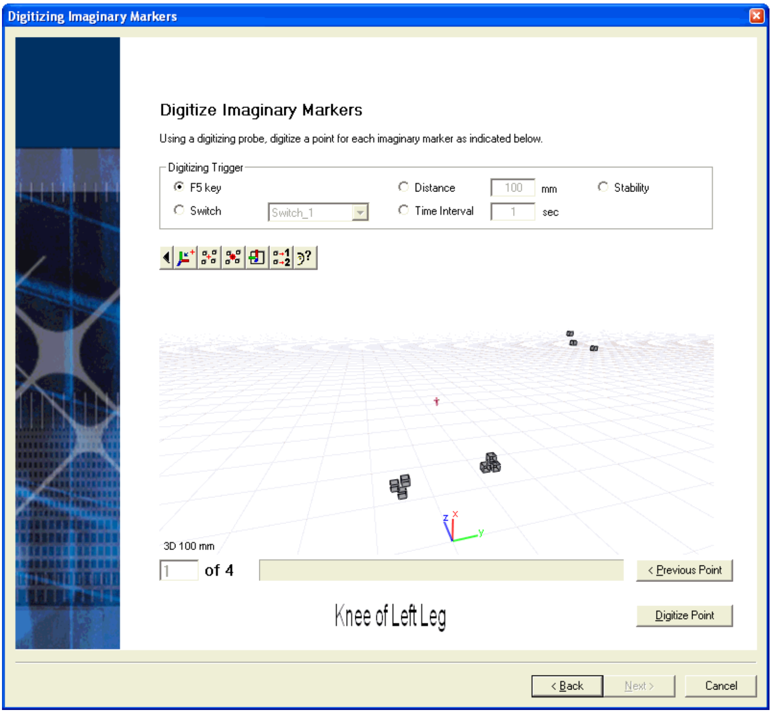


Figure 8-3 Digitizing Imaginary Markers

4. Select a **Digitizing Method**:
   - Select **F5** if you want to use either First Principles' **Digitize Point** button or the **F5** shortcut key to initiate a collection.
   - Select **Switch** if your digitizing tool/rigid body design includes a switch that when activated, initiates a collection.
   - Select **Distance** if you wish to simply move the digitizing probe and have the software automatically collect a point at specific distance intervals. Enter the desired interval in millimetres.
   - Select **Time Interval** if you wish to simply move the digitizing tool/rigid body and have the software automatically collect a point at specific time intervals. Enter the desired interval in seconds.

- Select **Stability** if you want First Principles to initiate a collection when the tool or rigid body has stopped moving for about two seconds, relative to the digitized tool/rigid body.

5. At this point, the system is producing realtime data of the digitizing probe and the tool containing the marker being digitized. Notice the spatial view showing the markers in the measurement volume.

   Using the spatial view for guidance, move the probe into the measurement volume and place its tip at the first point.

6. Using whatever digitizing method you selected, collect a snapshot of that point. An imaginary marker is created and added to the spatial view (in a different colour than existing markers).

   The bottom of the dialog displays a progress bar that increments each time you digitize a point. Below the progress bar, a prompt displays the name of the point you are digitizing. This is the name you specified when you set up the experiment.

   The counter at the left of the progress bar shows the current point number out of the total number.

   If necessary, select **< Previous Point** to go back one point.

7. Repeat this process until you have finished creating all desired imaginary markers. The **Next** button will now be enabled. After all points have been digitized, you can highlight and change the current point by selecting the sequence number field and entering the required point. For instance, you may wish to re-digitize a specific point because the subject moved.

8. Click **Next**. The dialog closes and the experiment starts with a default text view displaying real-time data.

8.3 What Next?

Now that you are collecting data, you will want to customize the views. Refer to “Viewing Experiment Data” on page 82.

9 Pivot Procedure

First Principles provides a stand-alone pivot utility that enables you to calculate a tool tip offset without having to run or start an experiment. One example of use would be if a tool or rigid body is dropped and you want to quickly apply a new tool tip offset.

The pivot procedure is as follows:

1. From the main menu, select **Utilities** > **Pivot Tool/Rigid Body**. The following appears:

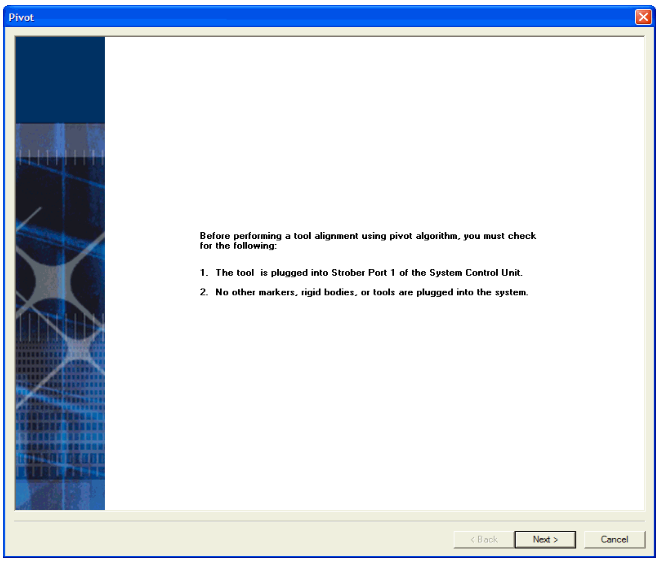


Figure 9-1 Pivot Procedure - Initial Dialog

2. Following the on-screen instructions, make sure that the tool or rigid body is connected to port 1 on the SCU and that no other markers, tool, or rigid bodies are connected to the system.
3. Click **Next**. The following window appears:

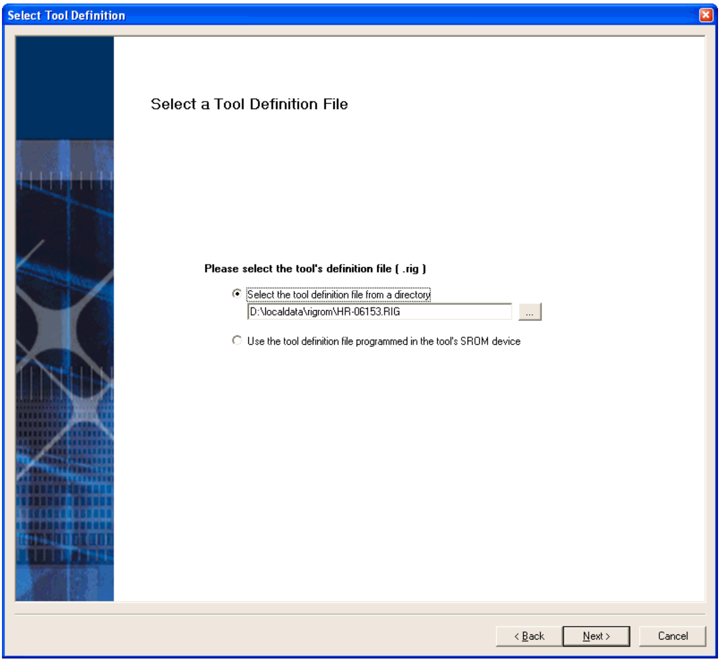


Figure 9-2 Pivot Procedure - File Location

4. Browse to, and select, the appropriate tool definition file.
5. Click **Next**. The following dialog appears:

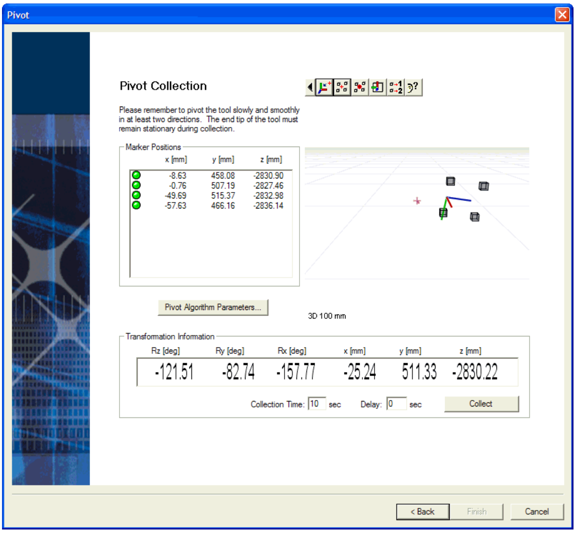


Figure 9-3 Pivot Collection Dialog

The pivot collection dialog displays a 3D spatial view that allows you to visualize the tool or rigid body as you perform the pivot procedure.

Note You can manipulate the spatial view with the toolbar located on the dialog. For further information, refer to "Using the Spatial View" on page 91.

The marker *x*, *y* and *z* positions are shown on the left of the dialog. The indicators in the left column show green when the associated marker is visible to the Position Sensor and red when not in view. Transformation data for the tool or rigid body is displayed at the bottom of the dialog.

6. (Optional.) To adjust the pivot algorithm parameters, complete this step; otherwise, proceed to step 8. Click **Pivot Algorithm Parameters...**. The following dialog appears:

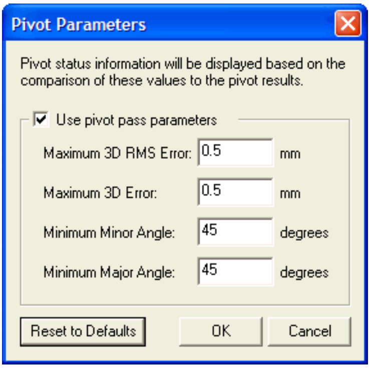


Figure 9-4 Pivot Parameters Dialog

7. Select the **Use pivot pass parameters** checkbox to use the pivot pass parameters. If this option is not checked, the pass parameters will not be used when the pivot results are calculated. Refer to Table 9-1 and set the parameters as desired. (Selecting **Reset to Defaults** will reset the parameters to default values.)

Table 9-1 Pivot Parameters

Pivot Parameter	Description
Maximum 3D RMS Error	This field defines the acceptable threshold for 3D RMS Error values produced by a pivot. The 3D RMS Error is produced by applying the result of the pivot procedure to each frame of the pivot procedure, and calculating an overall RMS error for the collection.
Maximum 3D Error	This field defines the acceptable threshold for 3D error values produced by a pivot. The 3D Error is produced by applying the result of the pivot procedure to each frame of the pivot procedure, and calculating an error for that frame.
Minimum Major Angle	This field defines the acceptable threshold for a major angle produced during a pivot. The major angle is the greatest angle the tool was moved during the pivot procedure.

Pivot Parameter	Description
Minimum Minor Angle	This field defines the acceptable threshold for a minor angle produced during a pivot. The minor angle is defined as being orthogonal to the plane of the major angle.

8. Set a Collection Time of between 5 s and 60 s and a Delay of sufficient time (between 0 s and 60 s) to allow you to correctly position the tool or rigid body and begin the collection.
9. Position the tool or rigid body in the measurement volume with its tool-tip placed on a fixed point (such as a divot in a pivot block). Ensure that the markers are visible and that the software is reporting valid transformation of the tool.
10. Click Collect to begin the data collection trial.
11. As the system collects the data, continuously pivot the tool or rigid body back and forth and side to side, with its tip remaining stationary at the fixed point. Ideally, the angles of the pivot movements should be between 30° and 60°.

Note It is very important that the tip remains stationary while the tool or rigid body is being pivoted. The design of the pivot block should take into account the shape of the tool's end-tip. For more information about designing a pivot block, contact NDI.

12. At the end of the collection period, the Pivot Collection dialog will show either a pass or a fail. An example of a successful pivot is shown on page 79:

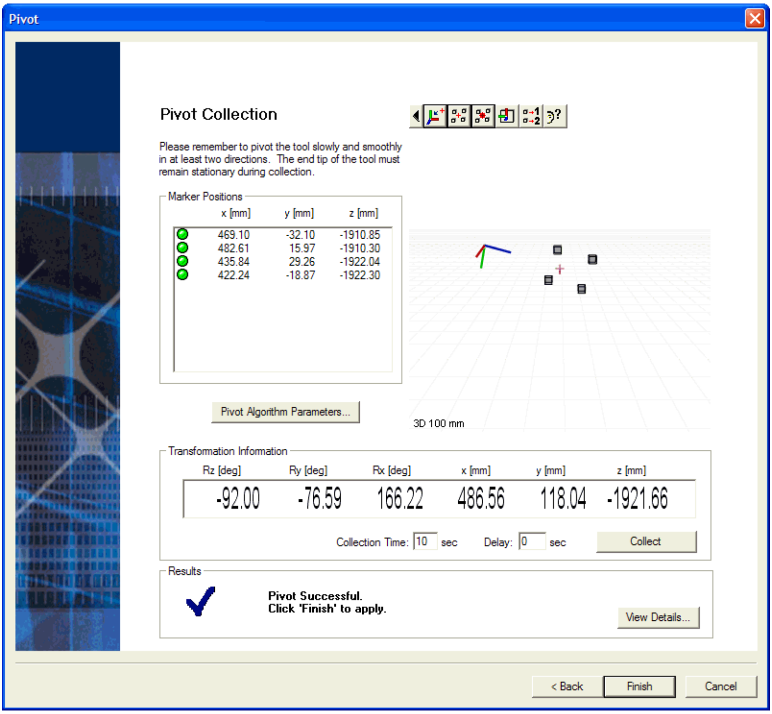


Figure 9-5 Successful Pivot Dialog

13. To view the pivot results click **View Details**. The following dialog appears:

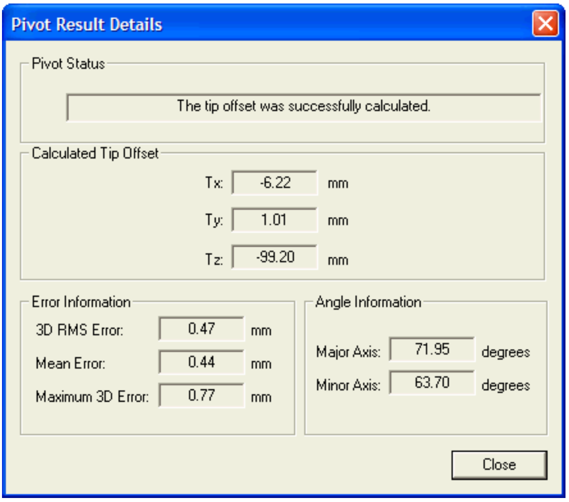


Figure 9-6 Pivot Results Dialog

Note If the pivot failed, the results dialog will appear by default and any errors or angle information that is outside parameters is displayed in yellow.

The pivot results dialog provides the following information:

Table 9-2 Pivot Results

Results	Description
Calculated Tip Offset	This section displays the *x*, *y*, and *z* position of the tool tip, relative to the origin of the tool's local coordinate system.
Error Information	This section displays the 3D RMS, mean, and maximum 3D errors of the collection, in millimetres.
Angle Information	This section displays the maximum and minimum angles of the pivot you performed. The maximum angle is the greatest angle created by the pivot movements; the minimum angle is defined as being orthogonal to the plane of the maximum angle.

Note If the Use pivot pass parameters option was not checked, the pivot procedure will pass, but any error or angle information that is outside parameters will be highlighted in yellow.

14. Click **Finish** to apply the calculated tip offset and close the dialog.

10 Viewing Experiment Data

First Principles provides a comprehensive list of options for viewing experiment data. **A *view* is a window that allows you to see data in real time, as it is produced by the Optotrak System and the experiment setup.** To add a new view, simply select it from the **View** menu. You can customize views in several ways:

- select the type of view to display
- select how many views are open
- select the type of data to display in each view

When you collect a set of data, your customized view settings will be recorded along with the data they display. You may play back data collections using the same views in which they were originally displayed. (For information on data collection and playback, refer to "Data Collection and Playback" on page 106.)

An example of the main experiment window is shown in "Main Experiment Window" on page 83 below. In this example three views have been selected; two text views and one spatial view. You may view as many different views as desired. The following view options are provided:

- text view
- missing data view
- raw data view
- spatial view
- strip chart view
- probe view
- video view

Each view is described in detail in the following paragraphs.

To increase viewing area, the toolbar and control bar may be toggled as desired. Select **View** > **Toolbar** or **View** > **Control Bar** and click to toggle on and off.

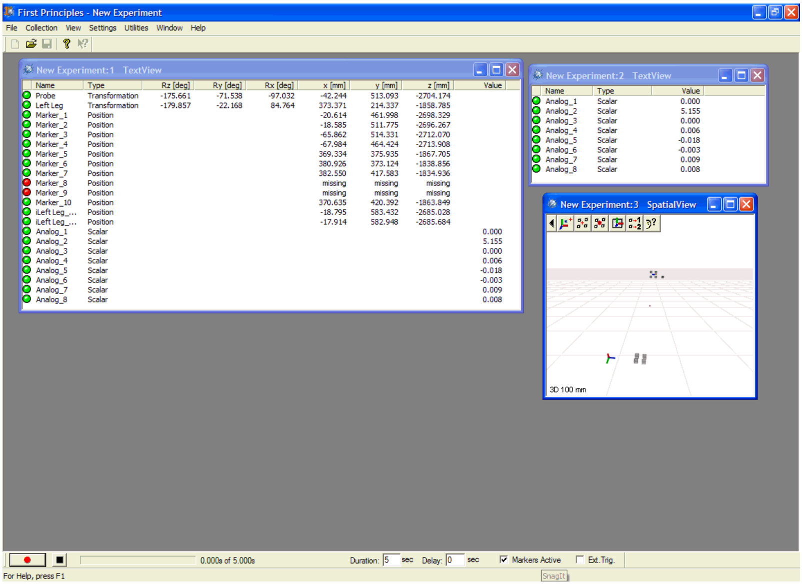
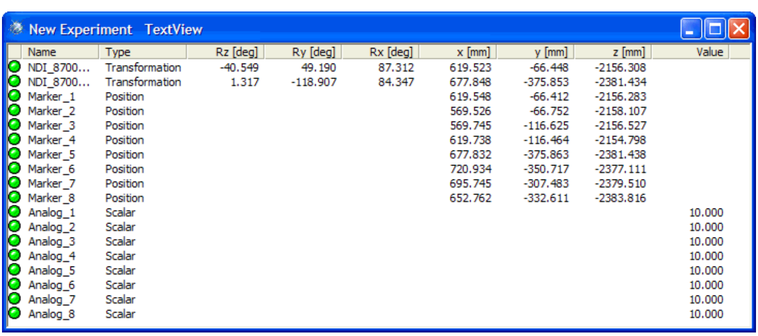


Figure 10-1 Main Experiment Window

10.1 Text View

Select **View** > **Text View** from the main menu bar. The text view provides a table listing data and their corresponding realtime values as their sources are tracked in the measurement volume. An example of a text view is shown in Figure 10-2.



New Experiment TextView

Name	Type	Rz [deg]	Ry [deg]	Rx [deg]	x [mm]	y [mm]	z [mm]	Value
NDI_8700...	Transformation	-40.549	49.190	87.312	619.523	-66.448	-2156.308	
NDI_8700...	Transformation	1.317	-118.907	84.347	677.848	-375.853	-2381.434	
Marker_1	Position				619.548	-66.412	-2156.283	
Marker_2	Position				569.526	-66.752	-2158.107	
Marker_3	Position				569.745	-116.625	-2156.527	
Marker_4	Position				619.738	-116.464	-2154.798	
Marker_5	Position				677.832	-375.863	-2381.438	
Marker_6	Position				720.934	-350.717	-2377.111	
Marker_7	Position				695.745	-307.483	-2379.510	
Marker_8	Position				652.762	-332.611	-2383.816	
Analog_1	Scalar							10.000
Analog_2	Scalar							10.000
Analog_3	Scalar							10.000
Analog_4	Scalar							10.000
Analog_5	Scalar							10.000
Analog_6	Scalar							10.000
Analog_7	Scalar							10.000
Analog_8	Scalar							10.000

Figure 10-2 Text View

You can choose to display markers, rigid bodies and tools, the results of calculations, and ODAU II output. In the example (“Text View” on page 83), the view displays tools, markers and ODAU II data. To select the data to display, right-click within the view window. The following menu appears:

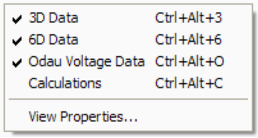


Figure 10-3 Text View Options

Click the data types filter to toggle them on and off. Alternatively you can select the desired data types filter options from the **View** option on the main menu bar.

You can also define the way that data is displayed. Click either **View Properties** from the Text View Options dialog or **View** > **View Properties** from the main menu bar. The following dialog appears:

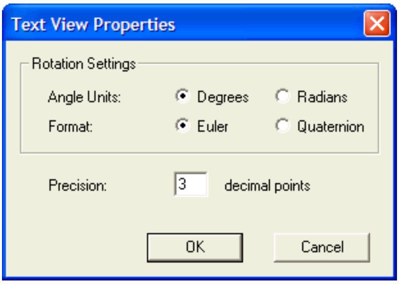


Figure 10-4 Text View Properties Dialog

Use the radio buttons to select the desired rotation settings and set the decimal point precision as desired within the range 0-16.

10.2 Missing Data View

Select **View** > **MissingData View** from the main menu bar. The missing data view provides a strip chart-like display of markers being tracked in real time, flagging those that go missing. This facility is useful in identifying any component of the system that is not collecting data. An example of a missing data view is shown in Figure 10-5:

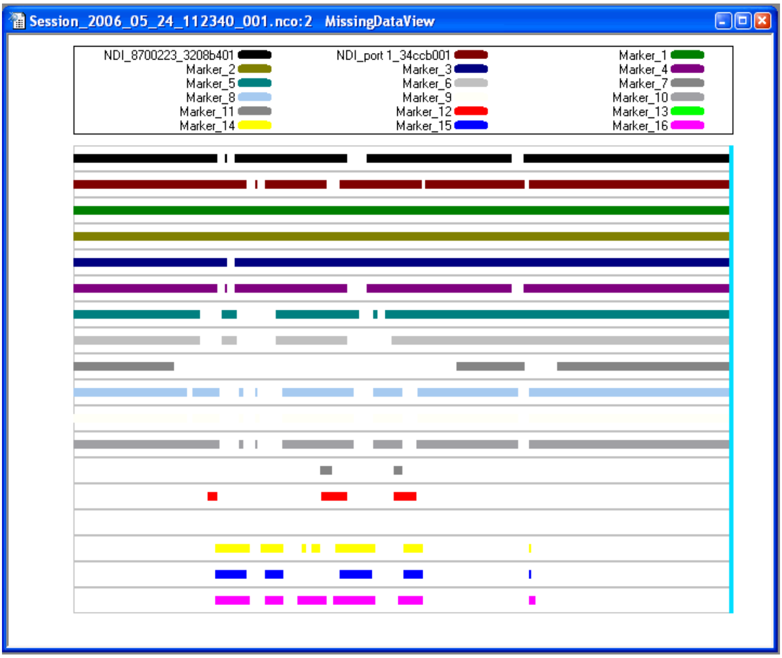


Figure 10-5 Missing Data View

In the example, two tools and sixteen markers are selected. The legend at the top of the window relates to the data on the chart. It can be seen that both tools and all but markers one and two had periods when data was missing, denoted by the gaps in the data lines.

You can define the way that data is displayed. Right-click within the missing data view and select **View Properties** or select **View** > **View Properties** from the main menu bar. The following window appears:

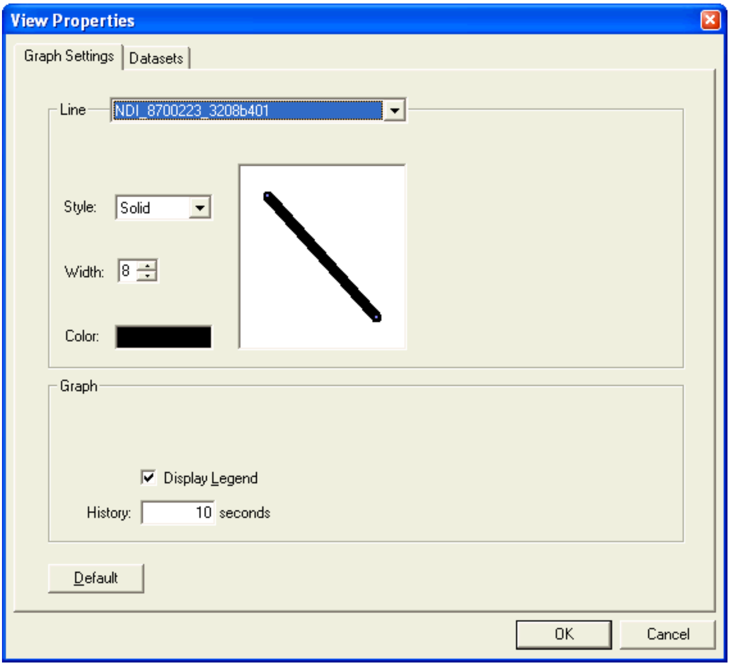


Figure 10-6 Missing Data View Properties — Graph Settings Tab

Graph Settings

The missing data view default settings are adequate for most situations, but they may be configured as follows:

1. From the **Line** drop-down list, select the object whose graph view properties you want to edit. (For example, the object may be a marker, a tool, or an ODAU II channel.)
2. From the **Style** drop-down list, select the desired line style. (Notice that the adjacent representative graphic view changes to reflect your selection.)
3. From the **Width** options, select the desired width, in pixels.
4. From the **Colour** drop-down list, select the desired line colour.
5. In the **Graph** section, select the **Display Legend** and **History** options as desired. (History is set in seconds from 1 s to 3600 s.)

6. Select the **Datasets** tab. The following window appears:

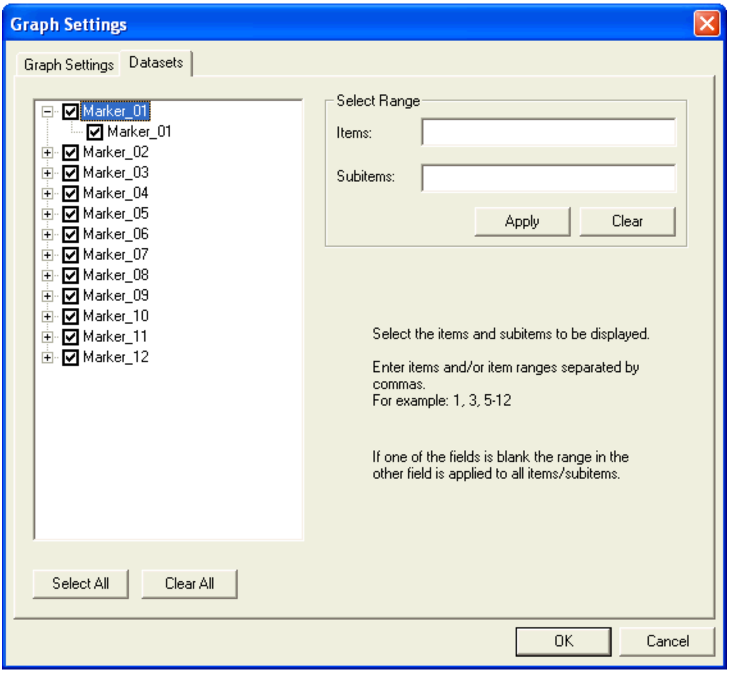


Figure 10-7 Missing Data View Properties — Dataset Tab

The **Datasets** tab allows you to select which data to monitor. You can select data in two ways:

1. Select the check box directly next to the desired data source. (You can also use the default **Select All** and **Clear All** buttons as desired.)
2. Follow the on-screen instructions and type the item numbers in the **Items** line. Click **Apply.**

When you have made your selections, click **OK** to close the window and return to the missing data view.

10.3 Raw Data View

The raw data view provides a text view of the full raw data being produced by the system, before it is processed into 3D and 6D data. The software can report, in real time, the following data for each sensor on the Position Sensor:

Centroid (0 to 2047) is the centre point of an imagined three-dimensional volume created by the selected markers. The mean position of the infrared light emitted by a marker across an Optotrak sensor.

Peak (0 to 100) represents the strength of a marker's signal received by the sensor.

Amplification represents the amount of "boost" required to obtain a marker reading. A value of 0% indicates that a minimum amount of amplification was required for sensor to detect the marker, while a value of 100% indicates that the maximum amount of amplification was required. If markers have amplification levels close to 100%, these markers may be too dim for the Position Sensors to determine their positions. If markers have amplification levels close to 0%, these markers may be too bright for the Position Sensors to determine their positions. You can adjust marker power in **Settings** > **Marker Settings/Frequency**.

Code indicates the status of the signal being received from a marker. For example, if a marker is missing, the code for that marker will indicate the reason that the Position Sensor cannot determine its position. The following table lists these codes:

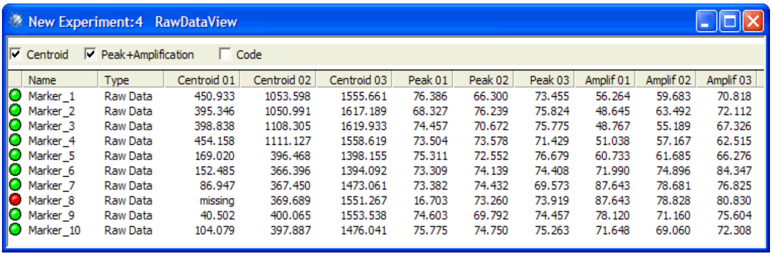
Table 10-1 Raw Data View — Code Definitions

Error	Definition
Centroid acceptable	The sensor successfully calculated the marker centroid.
Waveform too wide	The amount of light visible is above the noise threshold for the system to determine the marker centroid. The marker is too close to the Position Sensor. Move the marker farther away from the Position Sensor to correct this problem.
Peak too small	The marker signal is too weak. This may be due to the marker being obscured or the marker having insufficient power. Increase the strober voltage and/or duty cycle to strengthen the marker signal. For further information, refer to "Experiment Setup for an Optotrak 3020" on page 41 or "Experiment Setup for an Optotrak Certus" on page 53 as appropriate.

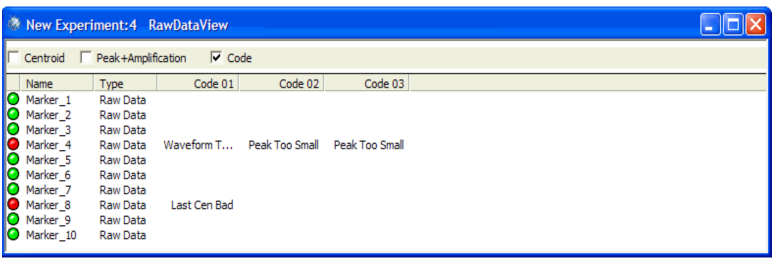
Table 10-1 Raw Data View — Code Definitions (Continued)

Error	Definition
Peak too large	The marker signal is too strong. Decrease the strober voltage and/or duty cycle to weaken the marker signal. For further information, refer to "Experiment Setup for an Optotrak 3020" on page 41 or "Experiment Setup for an Optotrak Certus" on page 53 as appropriate.
Waveform out of volume	The marker waveform is partially out of the field of view of the sensor. Check the measurement volume of the Position Sensor on the name plate located at the back. (See the system user guide for details.) Relocate the marker so that the marker waveform is within the measurement volume.
Fell behind	The sensor fails to process the current marker's signal before required to process the next marker's signals. Lower the marker frequency to correct this problem. For further information, refer to "Experiment Setup for an Optotrak 3020" on page 41 or "Experiment Setup for an Optotrak Certus" on page 53 as appropriate.
Bad last centroid	Interpolation cannot be carried out because a marker was not visible in the previous frame. This would only occur if the collection was configured to perform interpolation on the raw sensor values.
Buffer full	The internal centroid data buffer on the sensor is full and the sensor fails to store the current marker data. Lower the frame rate to correct this condition. For further information, refer to "Experiment Setup for an Optotrak 3020" on page 41 or "Experiment Setup for an Optotrak Certus" on page 53 as appropriate.
Missed sensor	The sensor has determined that it has missed a time control signal from the Optotrak System Control Unit, probably because of a communication error.
Corrupted data	The sensor failed to process the marker data due to an internal communication error.
Has reflection	Multiple centroids were detected. This is usually the result of reflection caused by a highly reflective surface, which was detected by the sensor as an IR source. Other sources of IR in the room can also cause this.

Two examples of the raw data view are shown in "Raw Data View" on page 90. In the top example, **Centroid** and **Peak + Amplification** are selected. In the lower example, **Code** is selected. Also, in the lower example markers were obscured to produce the **Peak too small** error. Use the check-boxes at the top of the window to select the data you wish to view.



Name	Type	Centroid 01	Centroid 02	Centroid 03	Peak 01	Peak 02	Peak 03	Amplif 01	Amplif 02	Amplif 03
Marker_1	Raw Data	450.933	1053.598	1555.661	76.386	66.300	73.455	56.264	59.683	70.818
Marker_2	Raw Data	395.346	1050.991	1617.189	68.327	76.239	75.824	48.645	63.492	72.112
Marker_3	Raw Data	398.838	1108.305	1619.933	74.457	70.672	75.775	48.767	55.189	67.326
Marker_4	Raw Data	454.158	1111.127	1558.619	73.504	73.578	71.429	51.038	57.167	62.515
Marker_5	Raw Data	169.020	396.468	1398.155	75.311	72.552	76.679	60.733	61.685	66.276
Marker_6	Raw Data	152.485	366.396	1394.092	73.309	74.139	74.408	71.990	74.896	84.347
Marker_7	Raw Data	86.947	367.450	1473.061	73.382	74.432	69.573	87.643	78.681	76.825
Marker_8	Raw Data	missing	369.689	1551.267	16.703	73.260	73.919	87.643	78.828	80.830
Marker_9	Raw Data	40.502	400.065	1553.538	74.603	69.792	74.457	78.120	71.160	75.604
Marker_10	Raw Data	104.079	397.887	1476.041	75.775	74.750	75.263	71.648	69.060	72.308



Name	Type	Code 01	Code 02	Code 03
Marker_1	Raw Data			
Marker_2	Raw Data			
Marker_3	Raw Data			
Marker_4	Raw Data	Waveform T...	Peak Too Small	Peak Too Small
Marker_5	Raw Data			
Marker_6	Raw Data			
Marker_7	Raw Data			
Marker_8	Raw Data	Last Cen Bad		
Marker_9	Raw Data			
Marker_10	Raw Data			

Figure 10-8 Raw Data View

10.4 Spatial View

The spatial view provides the functionality to visualize experiments by means of 3D and 2D graphical panes, showing views of the markers in the measurement volume. The default spatial view is the 3D pane. An example of the 3D pane is shown below:

Note If you experience any problems with the graphical panes, review the Windows settings related to your graphics card. Changing these settings may solve the problem.

Note Selecting View>Video View overlays real-time video over the spatial view. For details on the video view, see “Video View” on page 102.

This view can display only 3D and 6D data, including calculations. It cannot display scalar values such as ODAU II voltages and scalar calculations.

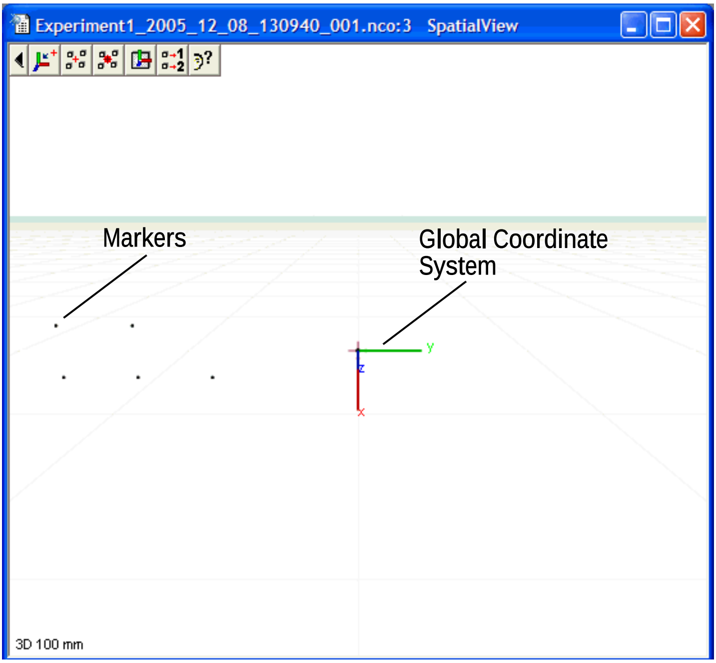
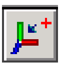
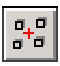
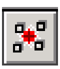
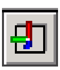
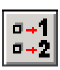


Figure 10-9 Spatial View — 3D Pane

Using the Spatial View

The spatial view window incorporates a toolbar. This toolbar allows you to control the major functionality of the view with a single mouse click on the appropriate icon. You can toggle the toolbar with the arrow button on the left of the toolbar. Refer to Table 10-2 for a description of each icon.

Table 10-2 Spatial View Toolbar Icons

Icon	Description
	Toggles the menu display
	Resets the view back to the coordinate system origin
	Moves the view to the marker centroid (the geometric centre of the markers)
	Locks or unlocks the view to the marker centroid
	Toggles the coordinate system frame of reference in 90° steps
	Toggles between different marker display types
	Launches the navigation help

Marker Views

The spatial view can display markers in a number of different formats.

The formats are toggled with the  icon as described above. The various formats are as follows:

- displays as a point
- displays as a number, representing the marker number, as defined in the experiment setup
- displays as the marker label defined in the experiment setup. This option will also display any 3D or 6D information that is displayed in the text view

- displays as large 3D boxes. This option is useful for viewing the spatial view from a distance.
- makes markers invisible, which may be useful if lines are drawn between markers.

The markers can be selected and de-selected by clicking. The marker will change colour when it is selected. This feature is useful in designating markers of particular interest.

3D and 2D Views

When it is first selected, the spatial view defaults to a 3D pane. Double-click that pane to display the three corresponding 2D panes, in addition to the 3D pane. Double-click any pane to maximize that pane in the window. Another double-click will again display all panes. An example of the spatial view with both 3D and 2D panes is shown in Figure 10-10.

The 2D panes show the top, bottom and side views of the markers. The coordinate system is also displayed and this can be useful for orientation. The coordinates and scale of each pane are displayed in the bottom left hand corner of each pane.

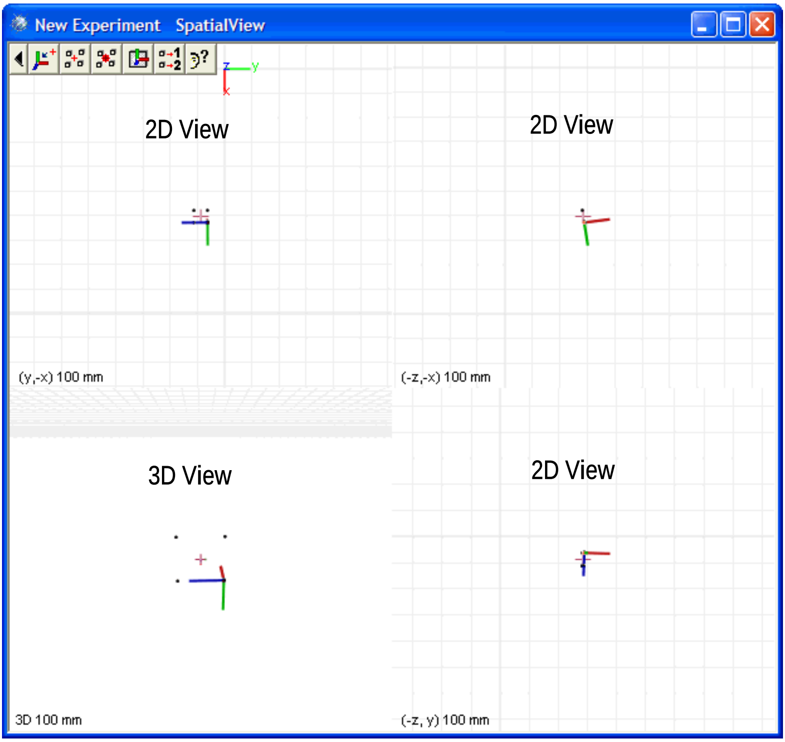


Figure 10-10 Spatial View — 3D and 2D Views

Manipulating Views

There is considerable flexibility provided to allow you to manipulate the spatial view to best meet your requirements. Each 3D and 2D pane can be manipulated independently, and easily, by means of mouse and keyboard shortcuts.

The following table describes the keyboard and mouse shortcuts you can use to manipulate the 3D and 2D panes:

Table 10-3 Spatial View — Keyboard and Mouse Shortcuts

To:	Do this:
Zoom in/out	Use the mouse scroll wheel, or hold ‘Z’ + left mouse button + drag
Move view	Hold left mouse button + drag
Rotate view	Hold ‘Ctrl’ + left mouse button + drag (This control is not applicable in the 2D views.)
Reset view to the tool origin	Press ‘O’
Reset view to geometric centre of markers	Press ‘C’
Lock/unlock the view to geometric centre of markers	Press ‘L’
Maximize/minimize a pane	Double-click the pane
Toggle anti-aliasing	Press ‘~’
Toggle grid	Press ‘G’

Drawing Lines Between Markers

The spatial view also provides the functionality for you to draw lines between markers. This feature can be useful if you want to visualize the relationship between markers. For instance, if markers are placed on a limb, then joining the markers along the limb at the joints will aid in visualizing movement of the limb. An example of a 3D pane with lines between markers is shown in Figure 10-11.

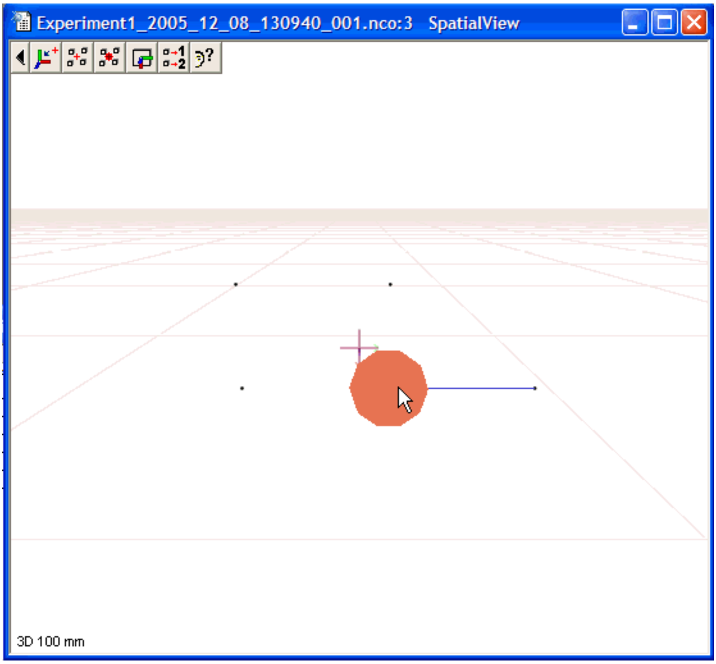


Figure 10-11 Spatial View — Drawing Lines Between Markers

To draw lines between markers:

1. Hold the ‘Shift’ key and click the first marker. The marker will “flash” to show it is selected.
2. Move to the second marker and click to select. A line will appear between the two markers. Continue selecting the desired markers in this way.
3. After the final selection, hold down the ‘Shift’ key and click in the pane away from the markers. The “flashing” marker will become deselected.

To change the colour of the lines between markers, right-click the line and select the desired colour from the palette that appears. (It is possible to define custom colours in this palette using normal Windows conventions.) The current line and all subsequent lines will be drawn in the latest selected colour.

To delete a line, select it and press the 'Delete' key

10.5 Strip Chart View

The strip chart view provides a graphical representation of several traces of data, to which you can add or remove as desired. You can customize colours, names, and ranges. An example of a strip chart view is shown in Figure 10-12. In this example the *x*, *y*, and *z* positions are displayed for each of four markers.

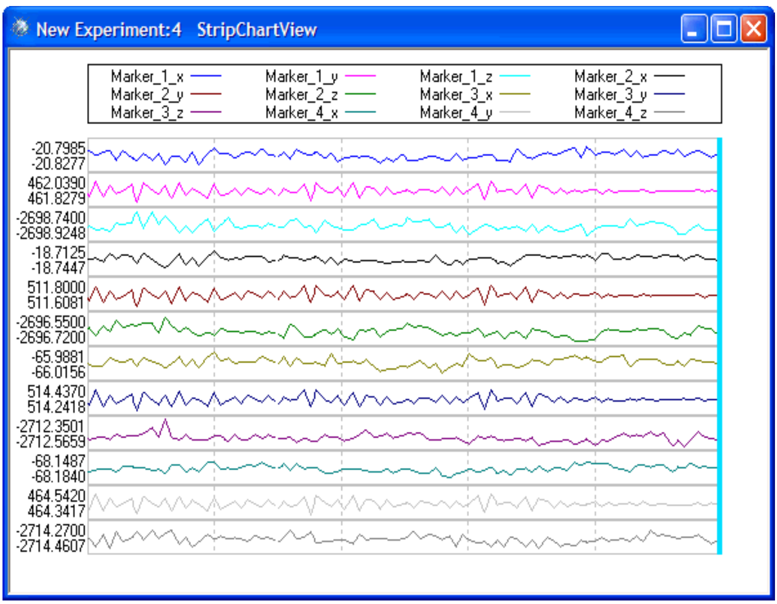


Figure 10-12 Strip Chart View

Similar to the other views, you can configure the strip chart view to display various forms of data. Right-click and, from the list of options, select the data to display. The list of view options can also be accessed from **View** on the main menu bar. The view options can be further defined from the **View Properties** option, described in the following paragraphs.

Strip Chart Options

To set the view options for the strip chart view:

1. Right-click the strip chart view and select **View Properties**. Alternatively select **View** > **View Properties** from the main menu bar. The following dialog appears:

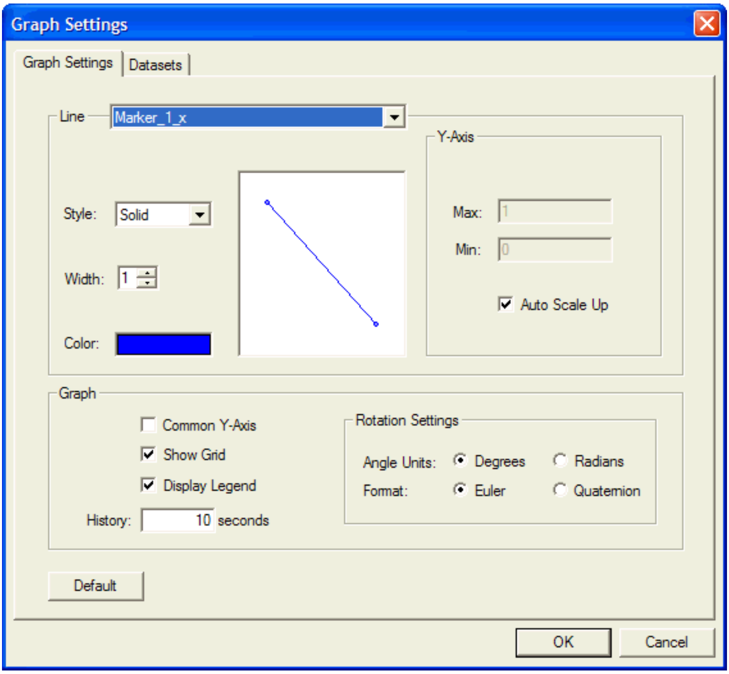


Figure 10-13 Strip Chart View — Graph Settings

2. Select the data line that you want to edit from the **Line** drop-down list.

3. Select the line **Style**, **Width** and **Colour** as desired. Your revised settings are displayed in the preview window.

4. In the **Y-Axis** section, select **Auto Scale Up** as desired. With this selection checked, all data lines are auto-scaled upwards (it does not scale down). If it is de-selected, you must set the Y-axis scale, in the **Max** and **Min** fields, for each data line.

5. In the **Graph** section, select **Common Y-Axis**, **Show Grid** and **Display Legend** as desired. If you select **Common Y-Axis**, all data lines will be set to a common Y-axis. This feature is useful if you want to compare relative measurements between two or more data lines. In **History**, select the time that you want to display, within the range 1 s to 3600 s (1 hour).

6. In the **Rotation Settings** section, select the **Angle Units** and **Format** as desired.

7. Click **OK** to apply your settings and return to the strip chart view, or click **Datasets** to edit the data. If you choose to edit the datasets, the following window appears:

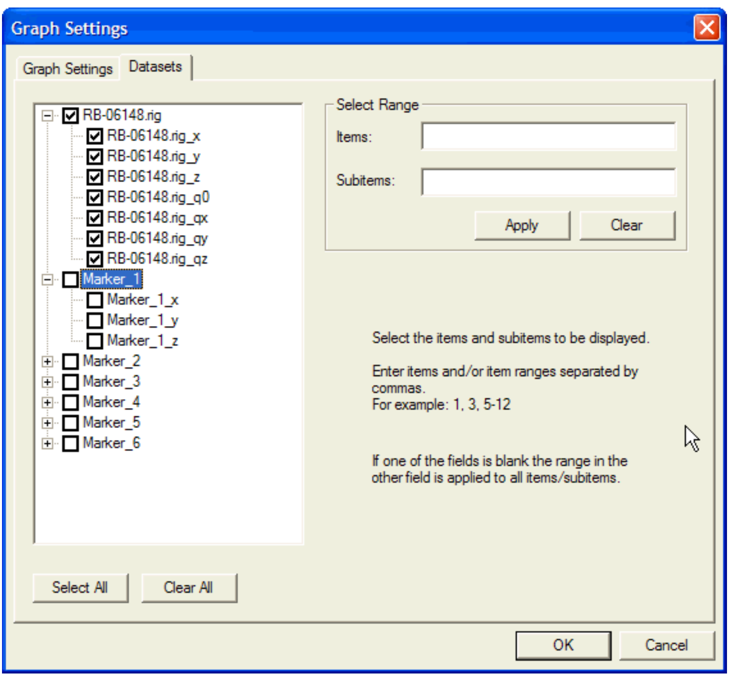


Figure 10-14 Strip Chart View — Datasets

The **Datasets** window allows you to select what items and what data from those items, to display on the strip chart. In the example above, it can be seen that a rigid body position (x, y, z) and transformation (q0, qx, qy, qz) is selected and that individual markers are de-selected. You can select data in a number of ways:

- Use the **Select All** and **Clear All** buttons to select or clear all items.
- Click an item or sub-item to select/deselect it.
- Enter the item and sub-item numbers in the appropriate field and click **Apply**. (The items and subitems are numbered from the top of the list.) For example:

To select items 1, 2, 3, 4, 10 and their third subitems enter:

Items: 1-4, 10

Subitems: 3

To select the first and third subitems of all items, enter:

Items: (leave empty)

Subitems: 1, 3

Note Any changes you make in the Dataset window are also applied to the View menu.

When you have completed your changes, click **OK** to apply the changes and return to the strip chart view.

10.6 Probe View

Select **View>Probe View** from the menu bar. The probe view allows you to “capture” or “digitize” random points using any tool. You can then copy and paste the points into your desired application, for example, Excel, Word, Notepad. You can also add the captured (digitized) points as imaginary markers into a rigid body file. The probe can be measured in the global frame of reference, or relative to any other tool. An example of a probe view is shown below.

Note The probe view is a general utility that allows you to use the system as a 3D “rule”. It has no function as part of the experiment process.

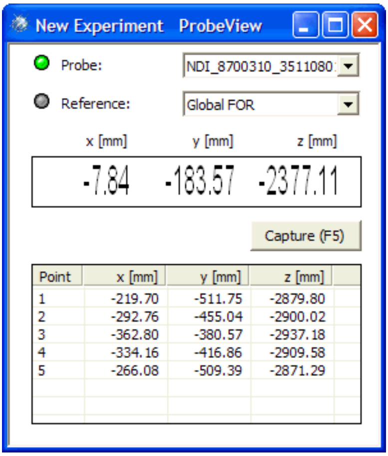


Figure 10-15 Probe View

The probe view is configured and manipulated as follows:

1. Select the probe that you will use to collect data points, from the **Probe** drop-down list. The **Probe** indicator will “light” as follows:
    - Green - The selected probe is in view and tracking correctly
    - Red - The selected probe is not in view, or at least one of its markers is obscured. The associated x y z coordinates will display --- --- ---
    - Grey - no probe has been selected
2. Select a reference in which to measure the probe, from the **Reference** drop-down list. The probe can be measured in the global frame of reference, or relative to any other (loaded) tool.

    The **Reference** indicator will “light” as follows:
    - Green - Another tool is selected as the frame of reference and is tracking correctly
    - Red - Another tool is selected as the frame of reference and that tool is not in view, or one or more of its markers are obscured
    - Grey - (Default) Global frame of reference is selected

3. The main x, y, z field displays the current coordinates of the probe. Select the **Capture** button or press **F5** as required to add the current coordinates to the **Point** list. To delete individual points, select them with the left mouse button and press **Delete**.

To define the capture trigger select **View>Options** and select the capture trigger as follows:

- Select **F5** if you want to use either First Principles' **Capture** button or the **F5** shortcut key to initiate a collection.
- Select **Distance** if you wish to simply move the probe and have the software automatically collect a point at specific distance intervals. Enter the desired interval in millimetres.
- Select **Time Interval** if you wish to simply move the probe and have the software automatically collect a point at specific time intervals. Enter the desired interval in seconds.
- Select **Stability** if you want First Principles to initiate a collection when the probe has stopped moving for about two seconds, relative to the reference.

10.7 Video View

The video view provides the functionality to overlay video with the motion data, allowing you to see the video of the experiment run synchronized with the motion data. If video recording is not included as standard on your system (video playback is free), you will need to purchase this feature. A prompt will appear during tracking if a key is required to activate the feature.

The synchronization of video and motion data can be either simple start/stop or frame by frame. Start/stop synchronization only requires a "webcam" and is sufficient for a visual indication of markers overlaid with video. Frame by frame synchronization requires a high specification camera and custom cable. Frame by frame synchronization provides very precise synchronization of markers and video. Refer to your system user guide for details on hardware selection and setup.

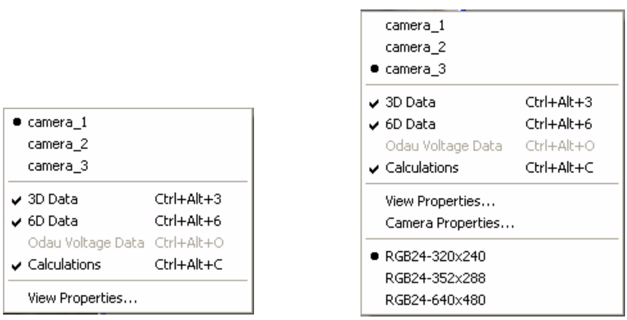
Using Video View

Note All the controls and features used in video view are identical to those used in spatial view. See “Spatial View” on page 90.

Select **View>Video View** from the menu bar. A video view appears. In the example shown in Figure 10-17 there are three video sources, two recorded video sources and one camera source. You can select any of the available video sources.

Each time you select **View>Video View**, a new video view will open. Right click on the video view and select the required source from the pop up menu.

Figure 10-16 illustrates an example of a recorded video menu and a camera video menu. The camera video menu displays resolution settings specific to the camera. In addition, right click on **Camera Properties...** to access camera specific settings.



Recorded Video   Camera Video

Figure 10-16 Video Source Menus

If First Principles detects any camera(s) that supports the DirectShow interface, they will automatically record video, in addition to motion data. To prevent the video from being recorded, disconnect any camera connected to the host computer. In this case, the video view content will be empty.

In the example shown in Figure 10-17, the controls have been set to illustrate varying degrees of video opacity. To adjust video opacity, press "t" on the keyboard, select and hold the left mouse button and move the mouse vertically. Video opacity can also be adjusted from the video view properties, see below.

As video opacity is increased beyond a certain threshold the spatial control buttons become unavailable and "greyed out". This is to prevent the inadvertent movement of the spatial view settings, relative to the video. See Video View Properties below for detailed information on this feature.

To save your settings for collections or experiments, select Ctrl-s or **File>Save Experiment** or **Save Collection**.

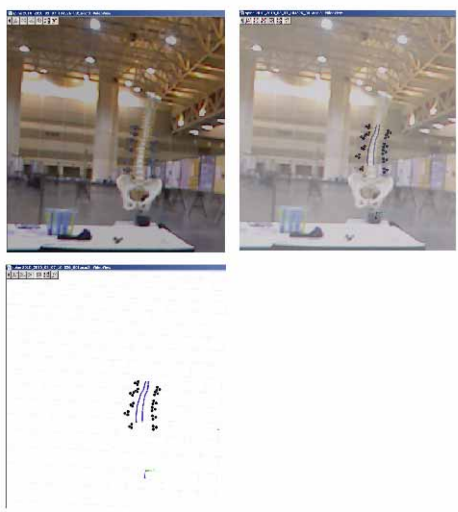


Figure 10-17 Video View

Video View Properties

To view the video view properties, right click in the required video view and select **View Properties...**. The video view properties dialog appears, see Figure 10-18. The first two settings, **Default Line Thickness** and **Default Point Size** relate to markers in the spatial view, see "Spatial View" on page 90.

Set the **Default Refresh Rate** as required. This setting will be applied to all subsequent video views that you open. Higher refresh rates will require more host computer processing power.

Set the **Video Opacity** slider as required. Video opacity can also be adjusted by pressing the “t” key, clicking and holding the left mouse button and moving the mouse vertically.

Check the **Unlock 3D View Manipulation** to access the spatial view control buttons. This check box is only available at settings below 90% opacity. This is to prevent the inadvertent movement of spatial view settings.

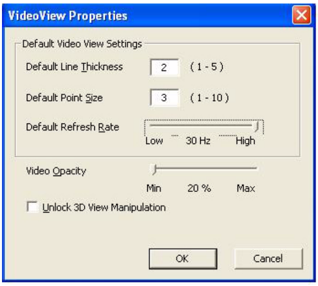


Figure 10-18 Video View Properties

10.8 What Next?

Now you have your experiment set up and running, with the views set as desired you will want to record and play back data collections. Refer to “Data Collection and Playback” on page 106.

11 Data Collection and Playback

First Principles enables you to record and play back the data you collect during experiments.

The record and playback interfaces are very simple and intuitive. The toolbars for both record and playback are context-sensitive and use universal controls.

The record and playback functions are detailed in the following sections.

11.1 Data Collection

First Principles allows you to record all the real-time data with one mouse click. The record toolbar is located at the bottom of the main window and is active whenever a view of the real-time data is active.

Figure 11-1 Record Toolbar

To set collection properties, follow the procedure detailed below:

1. Open the view(s) that you want to record. (Refer to “Viewing Experiment Data” on page 82.)
2. Right-click the record toolbar and select **Collection Properties...**. The following dialog appears. (Collection properties can also be accessed from the main menu bar. Select **Collection** > **Collection Properties**.)

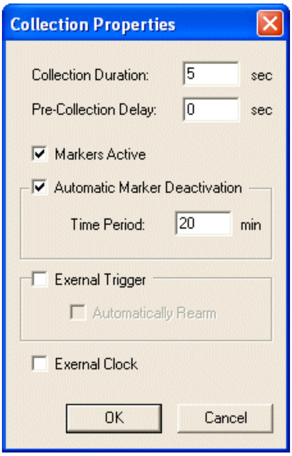


Figure 11-2 Collection Properties

3. Set the **Collection Duration**, within the range 0 s to 99999 s.
4. Set the **Pre-Collection Delay**, within the range 0 s to 60 s. (This feature can be used to allow time to position the experiment before recording begins.)
5. Make sure the **Markers Active** option is checked. This feature can be used to switch markers off when not required. This will maximize their life. (This option can also be selected from the record toolbar. When the markers are deactivated, the toolbar option will be highlighted.)
6. Select **Automatic Marker Deactivation** as desired. Set the **Time Period**. This option is automatically selected for Smart Markers in wireless mode.
7. Select **External Trigger** as desired. If you select this option, the record button is greyed out and the record function is controlled by the SCU. Refer to the system documentation for information on how to use the external trigger function.

   The external trigger option allows you to define a specific event, for example a door opening, to trigger recording. Additionally, when this option is selected, you can select **Automatically Rearm**. This will set the system to again trigger recording when the same external event occurs.

8. Select **External Clock** if you have applied an external clock to the SCU. If you select this option, the application will not respond until the SCU receives the clock signal.
9. Select the record button to initiate the data collection and recording. The data will be recorded for the selected time period. Select the stop button at any time to stop recording.
10. The recorded data will be stored with the name and at the location defined during the session setup. The collections will also save all views and view settings, so that playback of this collection will look the same as when it was recorded. Refer to “Collected Data Location” on page 68. The recorded data is stored with a .nco extension and automatically exported to the file formats defined in **Settings** > **Auto Export**. Refer to “Exporting Data” on page 129.

Note The record functionality can also be accessed from the Collection drop-down menu.

The first time in each session that you record data, a Session Summary dialog will appear. This dialog displays data and the name and location of each file you record and the dialog increments as the session progresses. This information is useful as a reference for the current session. Double-click a collection to open that collection. An example of a Session Summary is shown below:

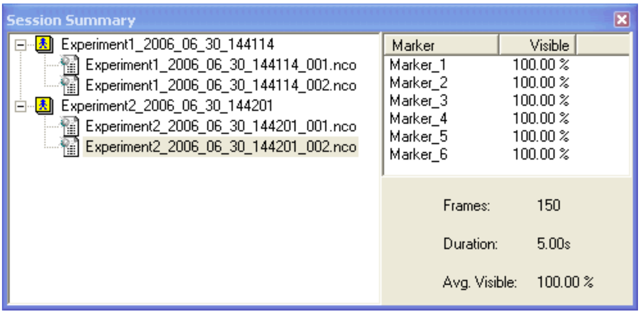


Figure 11-3 Session Summary

11.2 Data Playback

To play back previously recorded data, follow the procedure detailed below.

1. Select **File > Open Collection...**.
2. Browse to and select the desired data collection (.nco extension). The recorded collection(s) will open and the playback bar appears.

Figure 11-4 Playback Bar

3. From the drop down box, select the desired playback option:

real time	plays data back in seconds If the frame frequency is high, some frames may be skipped during playback.
marker frames	plays data back in frames according to the marker frame rate

Collections containing ODAU data have two more options:

ODAU frames	plays data back in frames according to the ODAU frame rate
fastest frames	picks the data file (marker data file or voltage data file) with the highest frame rate and plays back all its frames

4. Right-click the playback bar and select **Playback Properties...** . The following dialog appears.

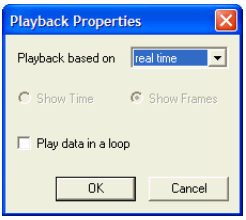


Figure 11-5 Playback Properties

5. Select playback based on **real time** or **frames**. If frames is selected, the **Show Time** and **Show Frames** buttons are active. Select the desired option.
6. If desired, check **Play data in a loop**.
7. Select **OK**. The Playback Properties dialog closes and the playback bar updates to reflect the edits you have made.

Note Apart from the Show Time and Show Frames options, all playback properties can be set directly on the playback bar or from the Playback option on the main menu bar.

8. Data playback is controlled using the standard control buttons on the playback bar. The following keyboard shortcuts may also be used during playback:
   - Up arrow — play data
   - Down arrow — pause data
   - Left arrow — move back (in pause mode only)
   - Right arrow — move forward (in pause mode only)
   - Home — move to beginning of data
   - End — move to end of data

Notes If you are playing a strip chart view, you can click anywhere along any data line to move the progress bar to that position.
If you are playing spatial view, the spatial view toolbar is available and fully functional.

12 Calculations

As you are producing or reviewing data, First Principles provides you with the power to manipulate that data with *calculations*. Calculations are user-defined operations that use collection data to produce additional information in real time. The available calculations are as follows:

- Angle
- ASL EyeTracker
- Constants (3D and 6D and constant float)
- Distance
- Transform
- Inverse Transformation
- Relative
- Force Plate 6
- Force Plate 8
- Force Plate 8 Hall
- Centre of Pressure

12.1 About the Calculations Dialog

You can apply a calculation at any time during the experiment or during playback:

1. From the main menu, select **Collection/Playback** > **Calculations**. The Calculations dialog appears:

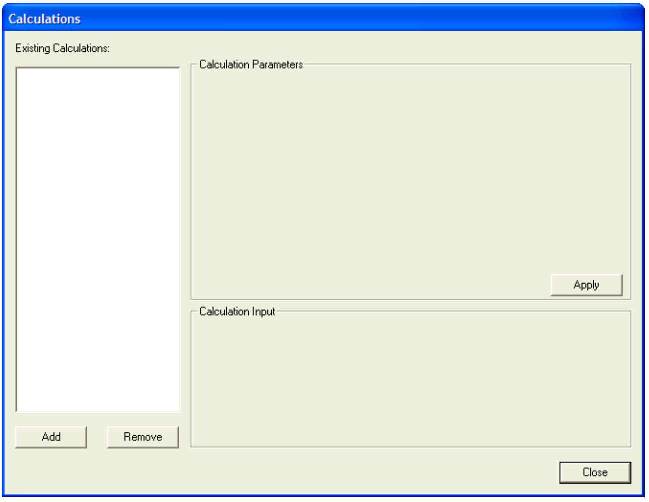


Figure 12-1 Calculations Dialog

2. Click **Add**, and from the list that appears, select a calculation type. For more information about each type, see "Calculation Types" on page 114.
3. Click **OK**. A new calculation is created and added to the list in the Calculation dialog and activated in the current views, when the calculation dialog is closed. The background colour of each calculation in the list denotes its status as follows:
    - Black — Currently selected calculation
    - White — All inputs have been defined
    - Yellow — Not all inputs have been defined

Note To rename the new calculation with a more relevant title, double-click it and type in a new name. Press Enter when you have finished, to save your changes.

4. Select the new calculation. The Calculation Dialog updates to provide you with appropriate fields for this calculation type:

    - Calculation Parameters
    - Calculation Input

    An example of the Calculations Dialog with a Transform calculation selected is shown in "Calculation Dialog — Transform Example" on page 113.

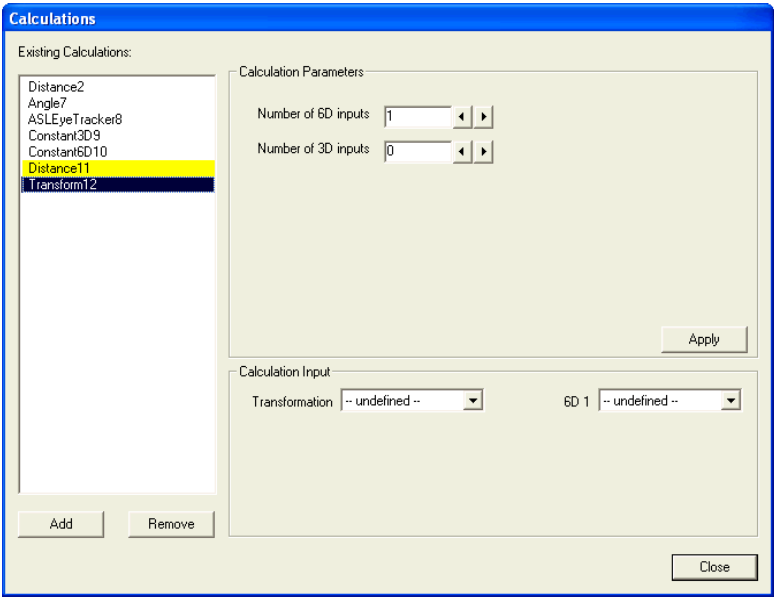


Figure 12-2 Calculation Dialog — Transform Example

5. Use the descriptions provided in "Calculation Types" on page 114 to modify the Calculation Parameters available for your chosen calculation type.
6. Click **Apply** to update the desired Calculation Input fields so that they reflect the chosen Calculation Parameters.
7. Enter the desired Calculation Input.
8. Click **Close** to close the Calculations dialog and add the calculation to the experiment.

12.2 Calculation Types

Angle

Angle calculates the angle between two vectors. These vectors are defined using 3D points in the measurement volume (for example, markers). For example, a biomedical researcher might apply the Angle calculation to the experiment data to calculate the angle of rotation of a specific joint on a person's body.

Angle calculations include the following calculation parameters:

Table 12-1 Angle Calculation Parameters

Parameter	Description
Units	Angle can be represented as either degrees or radians.
Angle Type	Angle Type dictates the way the angle is calculated: • Angle between 2, 3D vectors • Angle between 2, 2D vectors, created by projecting 3D vectors onto a selected plane.

Angle calculations requires that you create two vectors using the following calculation input:

Table 12-2 Angle Calculation Input

Input	Description
Head	Head is a 3D point in the measurement volume that represents the head of a vector.
Tail	Tail is the 3D point in the measurement volume that represents the tail of a vector.

ASLEyeTracker

ASLEyeTracker calculations include the following calculation parameters:

Table 12-3 ASLEyeTracker Calculation Parameters

Parameter	Description
COM port	COM port defines which COM port on the host computer the eye tracker is plugged into. (Default 1)
Baud Rate	Baud Rate is the communication rate between the eye tracker and the host computer. (Default 19200)
Stop Bits	Stop Bits are bits set for each byte of data transmitted. (Default 1)
Data Bits	Data Bits dictate the number of bits that create a byte. (Default 8)
Parity	Parity enables parity checking: the use of parity bits to check that data has been transmitted accurately. The parity bit is added to every data unit (typically seven or eight bits) that are transmitted. The parity bit for each unit is set so that all bytes have either an odd number or an even number of set bits. (Default No)
HW Handshaking	Hardware flow control. If **No** is selected, software flow control is used (Default No)

ASLEyeTracker calculations require the following calculation input:

Table 12-4 ASLEyeTracker Calculation Input

Input	Description
Transform01	Transform01 is the transformation produced by a tool/rigid body attached to the subject’s head. This transformation is transmitted to the ASLEyeTracker using the communication parameters set listed in Table 12-3. ASLEyeTracker will then use this data, in combination with the movement of the subject’s eye, to calculate the location of the subject’s gaze.

Constants

Constant is a value placeholder that you can apply in other calculations. It does not perform a calculation. First Principles provides three different formats for constants:

Constant3D Constant3D value consists of an *x*, *y* and *z* value. This can included in any calculation that manipulates 3D data.

Constant6D Constant 6D value consists of an *x*, *y*, *z*, Rx, Ry, and Rz value. This can be included in any calculation that manipulates 6D data.

ConstantFloat ConstantFloat value is an integer that can be included in any calculation that manipulates scalar values.

Distance

Distance calculates the distance (in mm) between two points in the measurement volume.

Distance calculations include the following calculation parameters:

Table 12-5 Distance Calculation Parameters

Parameter	Description
Input Type	Input Type dictates the kind of points you will be selecting. The software can calculate the distance between any combination of 3D and 6D points.

The calculation input required reflects the Input Type you selected. If you change the Input Type, click **Apply** to update the calculation inputs

Transform

Transform applies a transformation to an existing value. For example, Transform could be used to apply one rigid body's transformation to another rigid body in the experiment.

Transform calculations include the following calculation parameters:

Table 12-6 Transform Calculation Parameters

Parameter	Description
Number of 6D Inputs	An integer between 0-7
Number of 3D Inputs	An integer between 0-7

The calculation input required reflects the number of 3D and 6D inputs you selected. These represent the number of 3D (markers) or 6D (rigid bodies) to which you wish to apply the transformation. If you change the number of 3D or 6D inputs, click **Apply** to update the calculation inputs.

Table 12-7 Transform Calculation Input

Input	Description
Transformation	From the **Transformation** drop-down list, select the transform you want to apply to the remaining calculation inputs. The remaining calculation inputs reflect the number of 3D and 6D inputs you select. Select each input from the corresponding drop-down list.

Inverse Transformation

Inverse transformation calculates the inverse of the selected transformation input.

Inverse transformation calculations require the following calculation input:

Table 12-8 Inverse Transform Calculation Input

Input	Description
Transformation	From the **Transformation** drop-down list, select the transformation for which you want to calculate the inverse.

Relative

Relative calculation calculates a new position or transformation in a coordinate system of another reference transformation. It can also calculate a new position relative to reference position.

Relative calculations include the following calculation parameters:

Table 12-9 Relative Calculation Parameters

Parameter	Description
Input Type	Input Type dictates the kind of points you will be selecting. The software can calculate a relative position or transformation between any combination of 3D and 6D points. Click **Apply** whenever you change this setting to appropriately update the calculation inputs.

Relative calculations require the following calculation inputs:

Table 12-10 Relative Calculation Input Type 6D-6D)

Input	Description
Reference Transformation	From the **Ref Transform** drop-down list, select the transformation to be used as reference.
Transformation	From the **Transform** drop-down list, select the transformation to be calculated, relative to the reference.

Table 12-11 Relative Calculation Input Type 6D-3D

Input	Description
Reference Transformation	From the **Ref Transform** drop-down list, select the required transformation to be used as reference.
Position	From the **Position** drop-down list, select the position to be calculated, relative to the reference.

Table 12-12 Relative Calculation Input Type 3D-3D

Input	Description
Reference Position	From the **Ref Position** drop-down list, select the required position to be used as reference.
Position	From the **Position** drop-down list, select the position to be calculated, relative to the reference.

Force Plate 6

Force plate 6 calculation re-interprets the force plate output analog signals to force and moment vectors. This calculation is meant for use on force plates with six analog output channels (for example, Bertec, AMTI). The outputs of this calculation consist of force and moment vectors in the force plate local coordinate system and the force plate transformation in the global coordinate system.

Input: six voltage values representing Fx, Fy, Fz, Mx, My, Mz outputs from the force plate.

Output: (Fx, Fy, Fz, Mx’, My’, Mz, Transformation); [N, Nm, mm]

Force and Moment Vector Part of the Output

Force and moment vector values are calculated from analog inputs using the following formula:

$\overline{FM} = \mathbf{Cal} * \overline{A} / (1000000 * Vexc * G)$

where:

$\overline{FM}$ is the resulting 6 element force and moment vector, (Fx, Fy, Fz, Mx, My, Mz)

Cal is the 6x6 calibration matrix provided by the plate manufacturer. Top half of the matrix is assumed to be in [VN/μV] and the bottom half in [VNm/μV] units,

$\overline{A}$ is the input 6 element analog signal vector measured and provided by the force plate (Fxv, Fyv, Fzv, Mxv, Myv, Mzv) [V]

V exc is the amplifier excitation voltage

G is the amplifier gain setting

The resultant moment vector represents moment above the surface of the force plate and is calculated as follows:

Mx' = Mx - Fy * Zoffset

My' = My + Fx * Zoffset

where Zoffset is the user supplied vertical offset from the top plane to the origin of the force platform. (It is the z coordinate of the user supplied **Centre Offset** (mm) calculation parameter.) The calculation automatically adjusts the **Centre Offset** such that the z value is always positive, as assumed by all equations.

The resulting force and moment output vector is then (Fx, Fy, Fz, Mx’, My’, Mz) [N, Nm].

Transformation Part of the Output

Transformation output provides the information of where the force plate is in the Optotrak measurement volume

The transformation value is important only in the following two circumstances:

- The SpatialView (see page 90) is required to show the real orientation of the force plate in the measurement volume

or

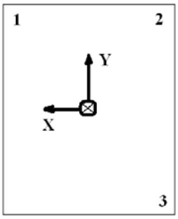
- The multiple force plates are inputs into another calculation where their relative position information is important (for example Centre of pressure calculation).

Note The information below is only applicable if you need this calculation to provide the correct transformation value.

The transformation value provided by this calculation is based on three force plate corner coordinates, measured on the plate surface and corrected by the Centre Offset value supplied by the manufacturers.

Set the correct transformation output of the force plate as follows:

1. Enter the manufacturer supplied Centre Offset (in mm) in the force plate coordinate system.
2. Enter 3D coordinates of corners 1, 2 and 3 on the top plane of the plate (refer to Figure 12-3) in that order, measured in the Optotrak coordinate system. The corners can be measured by using the digitizing probe and ProbeView (see page 100). The corners description in the force plate coordinate space are:
1:(X+,Y+); 2:(X-,Y+); 3:(X-, Y-).



Corners to be digitized

Figure 12-3 Force Plate Coordinate Space

Centre Offset value is supplied by the manufacturer, and is the result of the calibration procedure. It represents the offset of the force plate coordinate space from the physical centre of its sensors.

Note The Centre Offset value is sometimes reported from the real centre to the top of the plate, and not from the top to the centre, as assumed by the application. First Principles automatically recognizes the right orientation of the offset vector, based on the value of the Z coordinate of the offset.

Force Plate 8

Force plate 8 calculation re-interprets force plate output analog signals to force and moment vectors. This calculation is meant for use on piezo-electric force plates with eight analog output channels (for example Kistler). The outputs of this calculation are force and moment vectors in the force plate local coordinate system and the force plate transformation in the global coordinate system.

Input: Eight analog values Vx12, Vx34, Vy14, Vy23, Vz1, Vz2, Vz3, Vz4 representing Fx12, Fx34, Fy14, Fy23, Fz1, Fz2, Fz3, Fz4 outputs from the force plate.

Output: (Fx, Fy, Fz, Mx', My', Mz, Transformation); [N, Nm, mm].

Force and Moment Vector Part of the Output

Force and moment vector values are calculated from analog inputs using the following formulae:

Fx12 = Vx12 / Sx * XYRange / 5

Fx34 = Vx34 / Sx * XYRange / 5

Fy14 = Vy14 / Sy * XYRange / 5

Fy23 = Vy23 / Sy * XYRange / 5

Fz1 = Vz1 / Sz * ZRange / 5

Fz2 = Vz2 / Sz * ZRange / 5

Fz3 = Vz3 / Sz * ZRange / 5

Fz4 = Vz4 / Sz * ZRange / 5

where **Vx, Vy, Vz** [V] are voltage outputs from the force plate, **Sx, Sy, Sz** [pC/N] are sensitivity values for respective channels and **XYRange, ZRange** [pC/5V] are the force plate output ranges for particular channels.

Measured forces at sensors are then used to produce the overall force and moment vectors as follows:

Fx = Fx12 + Fx34

Fy = Fy14 + Fy23

Fz = Fz1 + Fz2 + Fz3 + Fz4

Mx = b * (Fz1 + Fz2 - Fz3 - Fx4)

My = a * (-Fz1 + Fz2 + Fz3 - Fz4)

Mz = b * (-Fx12 + Fx34) + a * (Fy14 - Fy23)

where **a** is the half of the sensor’s X distance [m] and **b** is the half of the sensor’s Y distance [m], in the plate coordinate system.

The moment vector represents moment above the surface of the force plate and is calculated as follows:

Mx' = Mx - Fy * Zoffset

My' = My + Fx * Zoffset

where Zoffset is the user supplied vertical offset from the top plane to the origin of the force platform. (It is the z coordinate of the user supplied **Centre Offset** (mm) calculation parameter.) The calculation automatically adjusts the **Centre Offset** such that the z value is always positive, as assumed by all equations.

The resulting force and moment output vector is then:

(Fx, Fy, Fz, Mx’, My’, Mz) [N, Nm].

Transformation Part of the Output

Transformation output provides the information of where the force plate is in the Optotrak measurement volume

The transformation value is important only in the following two circumstances:

- The SpatialView (see page 90) is required to show the real orientation of the force plate in the measurement volume

or

- The multiple force plates are inputs into another calculation where their relative position information is important (for example Centre of pressure calculation).

Note The information below is only applicable if you need this calculation to provide the correct transformation value.

The transformation value provided by this calculation is based on three force plate corner coordinates, measured on the plate surface and corrected by the Centre Offset value supplied by the manufacturers.

Set the correct transformation output of the force plate as follows:

1. Enter the manufacturer supplied Centre Offset (in mm) in the force plate coordinate system.
2. Enter 3D coordinates of corners 1, 2 and 3 on the top plane of the plate (refer to Figure 12-3) in that order, measured in the Optotrak coordinate system. The corners can be measured by using the digitizing probe and ProbeView (see page 100). The corners description in the force plate coordinate space are: 1:(X+,Y+); 2:(X-,Y+); 3:(X-, Y-).

Centre Offset value is supplied by the manufacturer, and is the result of the calibration procedure. It represents the offset of the force plate coordinate space from the physical centre of its sensors.

Note The Centre Offset value is sometimes reported from the real centre to the top of the plate, and not from the top to the centre, as assumed by the application. First Principles automatically recognizes the right orientation of the offset vector, based on the value of the Z coordinate of the offset.

Force Plate 8 Hall

Force plate 8 Hall calculation re-interprets the force plate output analog signals to force and moment vectors. This calculation is meant for AMTI Hall-effect force plate, using the 8-channel analog output. It is applicable to AMTI's AccuSwayPlus, AccuGait, HE6x6, and other AMTI Hall-effect based force plates with analog voltage outputs.

The outputs of this calculation consist of force and moment vectors in the force plate local coordinate system and the force plate transformation in the global coordinate system.

Input: eight voltage values representing FzC, FzD, FzA, FzB, FyAC, FxDC, FxAB, FyBD outputs from the force plate.

Output: (Fx, Fy, Fz, Mx', My', Mz, Transformation); [N, Nm, mm]

Force and Moment Vector Part of the Output

Measured force and moment vector values are calculated from analog inputs using the following formula:

$\overline{FM} = \mathbf{Cal} * \overline{A}$

where:

$\overline{FM}$ is the resulting 6 element force and moment vector, (Fx, Fy, Fz, Mx, My, Mz)

Cal is the 6x8 calibration matrix provided by the plate manufacturer. Top half of the matrix is assumed to be in [N/V] and the bottom half in [Nm/V] units,

$\overline{A}$ is the input 8 element analog signal vector measured and provided by the force plate (FzC, FzD, FzA, FzB, FyAC, FxDC, FxAB, FyBD) [V]

The resultant moment vector represents moment above the surface of the force plate and is calculated as follows:

Mx' = Mx - Fy * Zoffset

My' = My + Fx * Zoffset

where Zoffset is the user supplied vertical offset from the top plane to the origin of the force platform. (It is the z coordinate of the user supplied **Centre Offset** (mm) calculation parameter.) The calculation automatically adjusts the **Centre Offset** such that the z value is always positive, as assumed by all equations.

The resulting force and moment output vector is then (Fx, Fy, Fz, Mx', My', Mz) [N, Nm].

Transformation Part of the Output

Transformation output provides the information of where the force plate is in the Optotrak measurement volume

The transformation value is important only in the following two circumstances:

- The SpatialView (see page 90) is required to show the real orientation of the force plate in the measurement volume

or

- The multiple force plates are inputs into another calculation where their relative position information is important (for example Centre of pressure calculation).

Note The information below is only applicable if you need this calculation to provide the correct transformation value.

The transformation value provided by this calculation is based on three force plate corner coordinates, measured on the plate surface and corrected by the Centre Offset value supplied by the manufacturers.

Set the correct transformation output of the force plate as follows:

1. Enter the manufacturer supplied Centre Offset (in mm) in the force plate coordinate system.
2. Enter 3D coordinates of corners 1, 2 and 3 on the top plane of the plate (refer to Figure 12-3) in that order, measured in the Optotrak coordinate system. The corners can be measured by using the digitizing probe and ProbeView (see page 100). The corners description in the force plate coordinate space are: 1:(X+,Y+); 2:(X-,Y+); 3:(X-, Y-).

Centre Offset value is supplied by the manufacturer, and is the result of the calibration procedure. It represents the offset of the force plate coordinate space from the physical centre of its sensors.

Note The Centre Offset value is sometimes reported from the real centre to the top of the plate, and not from the top to the centre, as assumed by the application. First Principles automatically recognizes the right orientation of the offset vector, based on the value of the Z coordinate of the offset.

Centre of Pressure

Centre of pressure calculation calculates the position of the centre of pressure from the outputs of force plate calculations. It can take up to eight force plates as the input and calculate the total centre of pressure in the global coordinate system using transformations of each force plate and their force and moment outputs.

Centre of pressure calculations include the following calculation parameters:

Table 12-13 Relative Calculation Parameters

Parameter	Description
Number of plates	An integer of 1 to 8. Click **Apply** whenever you change this setting to appropriately update the calculation inputs.
Fz Threshold [N]	Sets the Fz threshold that the force plate has to exceed, in order to be included in the calculation. This avoids extraneous noise, for example from an unloaded force plate, being included in calculations. (If the force plate does not exceed the Fz threshold, it will be reported as missing.)

Input: force plate data

Output: 3D point in the Optotrak coordinate system

The centre of pressure of one force plate in the force plate local coordinate system is calculated as

COPx = -My' / Fz

COPy = Mx' / Fz

COPz = 0,

where **My'** is the y coordinate of the moment above the surface of the force plate, **Mx'** is the x coordinate of the moment above the surface of the force plate (see force plate 6 or force plate 8 calculations for information on how Mx', My' are calculated).

Centre of pressure in the Optotrak coordinate system, calculated from multiple force plate data, is calculated as a weighted average of centres of pressure of participating force plates:

$COPx = (\Sigma\ (COP_{xi}^{g} * |Fzi|)\ )\ /\ \Sigma|Fzi|$

$COPy = (\Sigma\ (COP_{yi}^{g} * |Fzi|)\ )\ /\ \Sigma|Fzi|$

$COPz = (\Sigma\ (COP_{zi}{}^{g} * |Fzi|)\ )\ \ /\ \ \Sigma|Fzi|$

where **Fzi** is the z coordinate of the force vector in the force plate coordinate system, $\mathbf{COP}_i{}^{g}$ is the 3D location of the centre of pressure of the force plate 'i' in the Optotrak coordinate system calculated as

$\overline{COP}_i{}^{g} = T(\overline{COP}_i)$,

where $\overline{COP}_{\mathbf{i}}$ is the 3D location of the centre of pressure of the force plate in the force plate local coordinate system, **T** is the transformation from force plate coordinate system to the Optotrak coordinate system.

13 Exporting Data

First Principles provides the functionality for you to export data in a variety of file formats. The file export interface allows you to:

- quickly select source files and destination folders
- select applicable export file formats
- define export subsets by time or frame

First Principles can export data in two ways: via the export dialog, or using the auto export feature. For further information, refer to "Exporting Data" on page 130

13.1 First Principles File Formats

First Principles produces the following file formats:

- collection file (.nco)
- experiment file (.exp)
- tool definition file (rig)
- raw data file (.nrw, .nor) (Optotrak and ODAU II raw data files)

First Principles can open and play the following file formats:

- collection file (.nco)
- 3D data file (.n3d)
- 6D data file (.n6d)
- raw data file (.nrw, .nor) (Optotrak and ODAU II raw data files)

13.2 Exported Data File Formats

First Principles can convert data and export it in the following file formats:

- 3D data file (.n3d) in NDI floating point format
- 6D data file (.n6d) in NDI floating point format
- ODAU II data file (.nov) ODAU II voltage in NDI floating point format

- c3d (.c3d)
- ASCII data files (.txt)
- Comma Separated Value files (.csv)
- tab separated value files (.xls)

13.3 Exporting Data

First principles can export data in two ways; using an auto export feature that exports data as soon as recording has finished and manually using the export dialog. Both methods are described below.

Auto Export

To automatically export data from First Principles, follow the procedure detailed below:

1. From the main menu, select **Settings** > **Auto Export**. The following dialog appears:

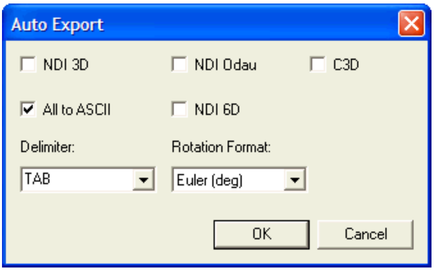


Figure 13-1 Auto Export Dialog

2. Check the file types you want to export and select the delimiter from the drop-down options. If you select either the **NDI 6D**, or **All to ASCII** option, select a **Rotation Format** from the drop-down options.

Notes NDI 6D files always contain Euler data in radians, even if Euler (deg) is selected.
To export a collection file to C3D, the ODAU frame frequency must be an integer multiple of the marker frame frequency.

3. Select **OK**. The dialog closes. When you next stop a recording session, the data will be exported to the same directory defined during session setup and in the formats defined above.

Manual Export

To manually export data from First Principles, using the export dialog, follow the procedure detailed below:

1. From the main menu, select **File** > **Export Data**. The following dialog appears:

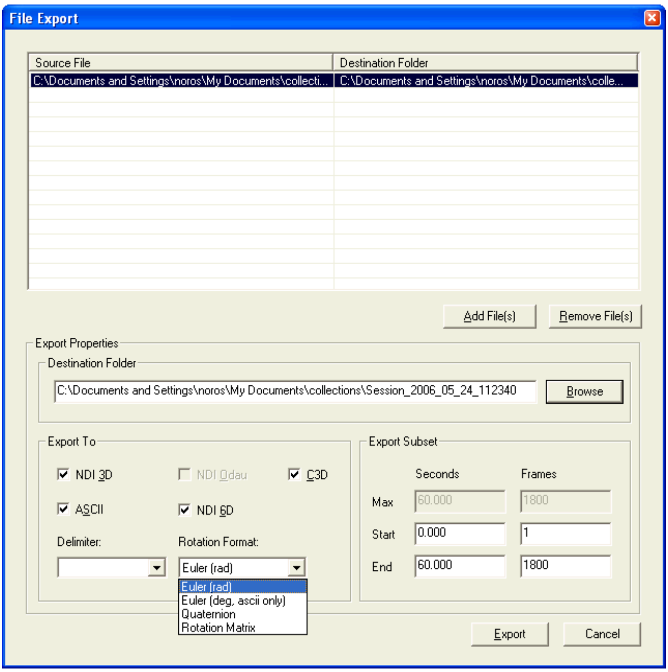


Figure 13-2 Export Data Dialog

2. Click **Add File(s)** and browse to and select the files that you want to export. The file(s) location appears in the **Source File** column. (If you want to remove files from the list, select the file and click **Remove File(s)**, or press the **Delete** key.)

3. In the **Export Properties > Destination Folder** section, click **Browse** and browse to the location where you want to store the exported data. The destination folder appears in the **Destination Folder** column.
4. In the **Export To** section, check the desired file formats that will be applied to the exported data. Read the notes below.

Notes The Export To section is context-sensitive and the options for export file formats will only be enabled if that file format is applicable to the selected file.

The Delimiter drop-down options (TAB and Comma) is only enabled if ASCII is checked. Select TAB to export the file as Microsoft Excel (.xls) and Comma to export the file as .csv, or specify your own delimiter in the drop-down list and export the data as a .txt file.

5. In the **Export Subset** section, type in the **Start** and **End** limits for the exported data. You can input limits in either **Time** or **Frames** and both columns will update. The **Max** fields display the maximum possible data length applicable to the selected file.
6. If you are exporting 6D data, select the desired **Rotation Format** from the drop-down options.
7. When you have completed your selections, click **Export**. The data is exported to the selected destination folder.

14 Quick Reference: First Principles Main Menu

Table 14-1 Main Menu Items

Menu Item	Sub-menu Item	Description
File	New Experiment	Create a new experiment.
	Open Experiment	Open a previously saved experiment to continue work.
	Edit Experiment	Change the setup for the current experiment.
	Save Experiment	Save the current experiment.
	Save Experiment As	Save the current experiment under a different name/directory.
	Close Experiment	Close the current experiment and disconnect the software from the system.
	Open Collection	Open a collection for playback, and/or manipulation.
	Save Collection	Save the settings of currently used views of the collection.
	Close Collection	Close the current collection.
	Export Data	Export the selected data files into different formats/directories for future analysis.

Table 14-1 Main Menu Items (Continued)

Menu Item	Sub-menu Item	Description
Collection (active when running experiment view is selected)	Record	Start a new collection.
	Stop	Stop the current collection or cancel External Trigger mode.
	Markers Active	Turn on/off all connected markers.
	External Trigger	Turn on an external trigger mode used to start new collections.
	Collection Properties	Change collection settings, such as length, delay, and units.
	Calculations	Add calculations to the current experiment/collection.
Playback (active when collection file view is selected)	Play	Play back the current collection.
	Pause	Pause a playback.
	Stop	Stop a playback and return the cursor to the start position.
	Playback Properties	Change playback settings, such as loop, speed, and units.
	Calculations	Add calculations to the current experiment/collection.

Table 14-1 Main Menu Items (Continued)

Menu Item	Sub-menu Item	Description
View	Toolbar	Show/hide the main toolbar at the top of the main window.
	Control bar	Show/hide the recording/playback control bar at the bottom of the main window.
	Session Summary	Show/hide the session summary. (Active only after the first recording.)
	3D Data	Show/hide 3D data in the selected view.
	6D Data	Show/hide 6D data in the selected view.
	ODAU Voltage Data	Show/hide ODAU II voltage data in the selected view.
	Calculations	Show/hide applied calculations in the selected view.
	View Properties	Change settings for the selected view.
	Text View	Open a new Text View window.
	Missing Data View	Open a new Missing Data View window.
	Probe View	Open a new Probe View window.
	Raw Data View	Open a new Raw Data View window.
	Spatial View	Open a new Spatial View window.
	Strip Chart View	Open a new Strip Chart View window.
	Video View	Open a new Video View window.

Table 14-1 Main Menu Items (Continued)

Menu Item	Sub-menu Item	Description
Settings	Marker Settings/ Frequency	Set the markers frequency, duty cycle and power
	Communication Settings	Change the communication settings used to connect the host computer to the Optotrak System.
	Coordinate System Details	Open and review the Environment Setup for the current experiment.
	Default Exports	Create default exporting settings that will be performed automatically with each collection.
Utilities	Query System	Re-initialize the communication between the host computer and the Optotrak System, to determine the hardware setup.
	Show Error Log	Show the last system error logged.
	Show Latest Wireless Configuration	Show the latest wireless mode Smart Marker configuration tree.
	Pivot Tool/ Rigid Body	Open the Pivot wizard to calculate a tool/rigid body’s tip offset.
Window	Cascade	Arrange the open windows in a cascade fashion.
	Tile	Arrange the open windows in a tile fashion.
Help	Help Topics	Open First Principles Online Help.
	Licencing Info	Shows the licence state of the application modules and allows you to licence them if necessary
	About First Principles	Open the software description window.

15 Abbreviations and Acronyms

Table 15-1 Abbreviations and Acronyms

Abbreviation or Acronym	Meaning
DHCP	Dynamic Host Configuration Protocol
IP	Internet Protocol
ODAU	Optotrak Data Acquisition Unit
RMS	Root Mean Square
SCSI	Small Computer System Interface
SCU	System Control Unit
SROM	Serial Read Only Memory

Glossary

.csv File

A .csv file is a Comma Separated Value file that stores characterization data in ASCII format.

.rig File

A .rig file is a rigid body's tool definition file.

.rom File

A .rom file is a tool's tool definition file.

3D Data

3D data refers to the *x*, *y*, and *z* positions of a marker.

3D RMS Error

3D RMS (Root Mean Square) Error is determined by calculating the difference between the measured locations of markers on a tool and the marker positions in the tool definition file.

Alignment

Alignment is the process of adjusting a tool or Position Sensor's local coordinate system.

Centroid

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

Collection

A collection is a set of data that is saved to a session.

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.

Experiment

An *experiment* is a specific Optotrak System setup that uses markers, rigid bodies, tools, and/or ODAU II units to measure the movement and/or location of a subject.

Frame Frequency

The frame frequency is the number of frames of data per second measured by the Optotrak System.

Frame

A frame contains the measured positions of the markers in the detection region at a particular point in time.

Global Coordinate System

The global coordinate system is the Optotrak 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 Position Sensor.

Imaginary Marker

An imaginary marker is used to identify a point where it is difficult or undesirable to affix an actual marker.

Local Coordinate System

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

Marker

A marker is an object that can be detected and tracked with an Optotrak System.

Marker Frequency

Marker frequency is the rate (Hz) at which markers are activated within a frame.

Marker Period

Marker period is the inverse of the marker frequency.

Marker Power

Marker power refers to the overall "brightness" of the markers. Marker power affects the strength of the signals received by the Position Sensor, and is dependant on the marker frequency, duty cycle and voltage applied to the marker.

Marker Voltage

Marker voltage is one of the factors that determine marker power. The voltage can range from 5 - 12 V.

Pivoting

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

Position Sensor

The Position Sensor is the component of the Optotrak Certus System that collects marker position data and sends the raw data to the System Control Unit.

Reference Tool

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

Registration

Registration is a process that aligns the coordinate systems of multiple Position Sensors to a common coordinate system.

Rigid Body

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

Rigid Body Definition

A rigid body definition is a description of the number and locations of markers on a rigid body.

Session

A session is an instance of an experiment.

Tool

A tool is a rigid body that incorporates its tool definition file in an SROM device.

Tool Definition File

A tool definition file stores information about a tool or rigid body. This includes information such as the placement of the tool's markers, the location of its origin, and its manufacturing data. A tool definition file can be formatted in two ways: .rig for rigid bodies, or .rom for tools.

Tool Origin

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

Tool Tip Offset

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

Transformation

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

User-defined Coordinate System

A user-defined coordinate system is a global coordinate system in which the user has changed the location of the default origin and/or the orientation of its axes.

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