

CAM2Q

FARO Laser Tracker: Training Workbook

Version 1.5 • October 2010





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CAM2Q[®]

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About this Training




Intended audience: any user who will use FARO CAM2 Q

Length of Training: Three (3) days

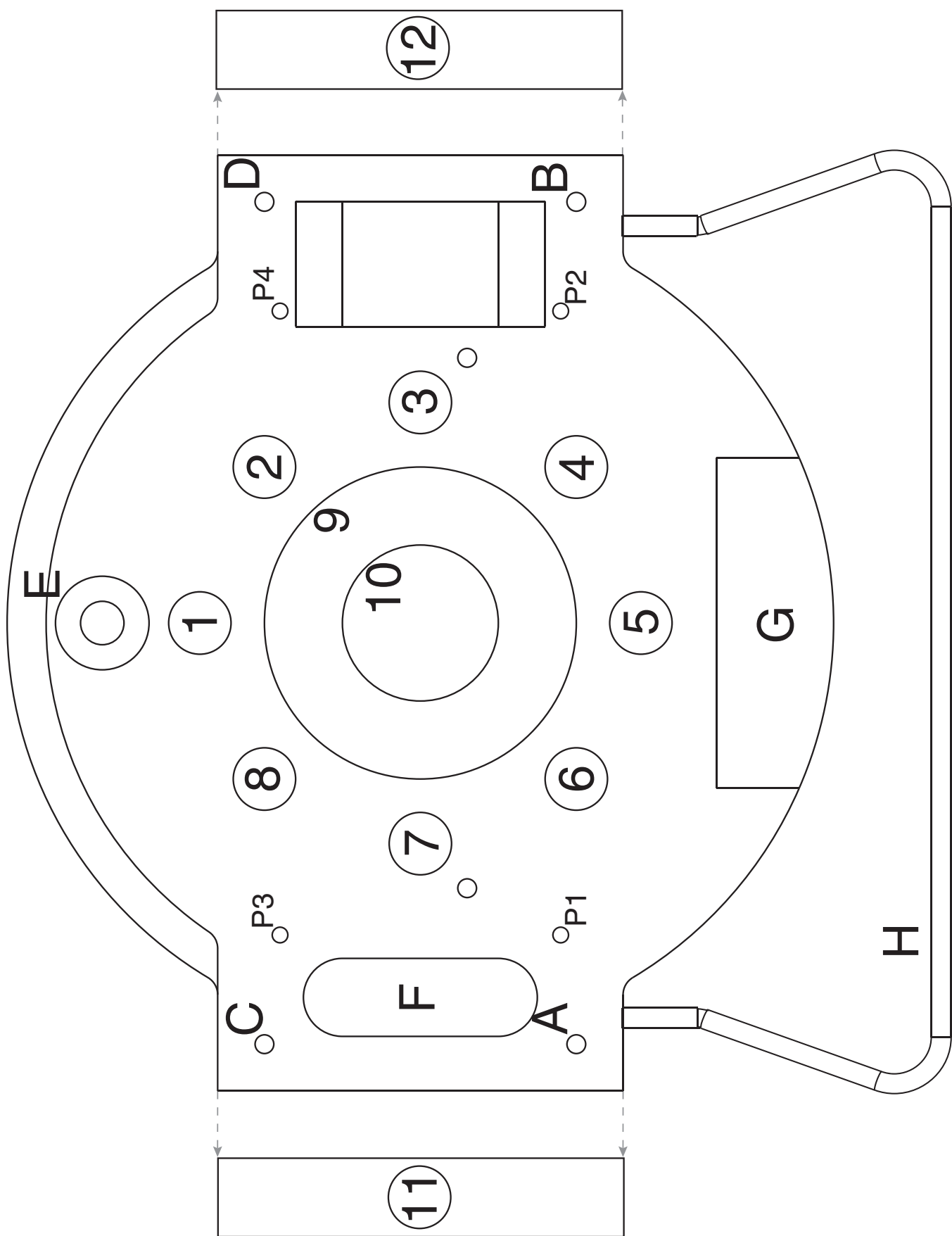
Structure: Modules and Lessons.

The training does not intend to cover every menu item of CAM2 Q. We have taken the most common applications of CAM2 Q and developed a training program that teaches you core principles, measuring strategies, and tips in a hands-on training format. Our intent is for this training to provide a strong foundation for you to start using your FARO system in your environment. Additionally, it will prepare you to learn more advanced features of the software.

Definition of Terms and styles:

	Information and tips
	Caution and Warning statements
	General information

<i>Bold Italic</i> Text	Indicates directory names, menu names, buttons, tabs, key names, acronyms, and modes.
Monospaced Text	Indicates alpha/numeric characters or values you enter in a field on the screen. For example, "Type 0.005 for the tolerance setting."



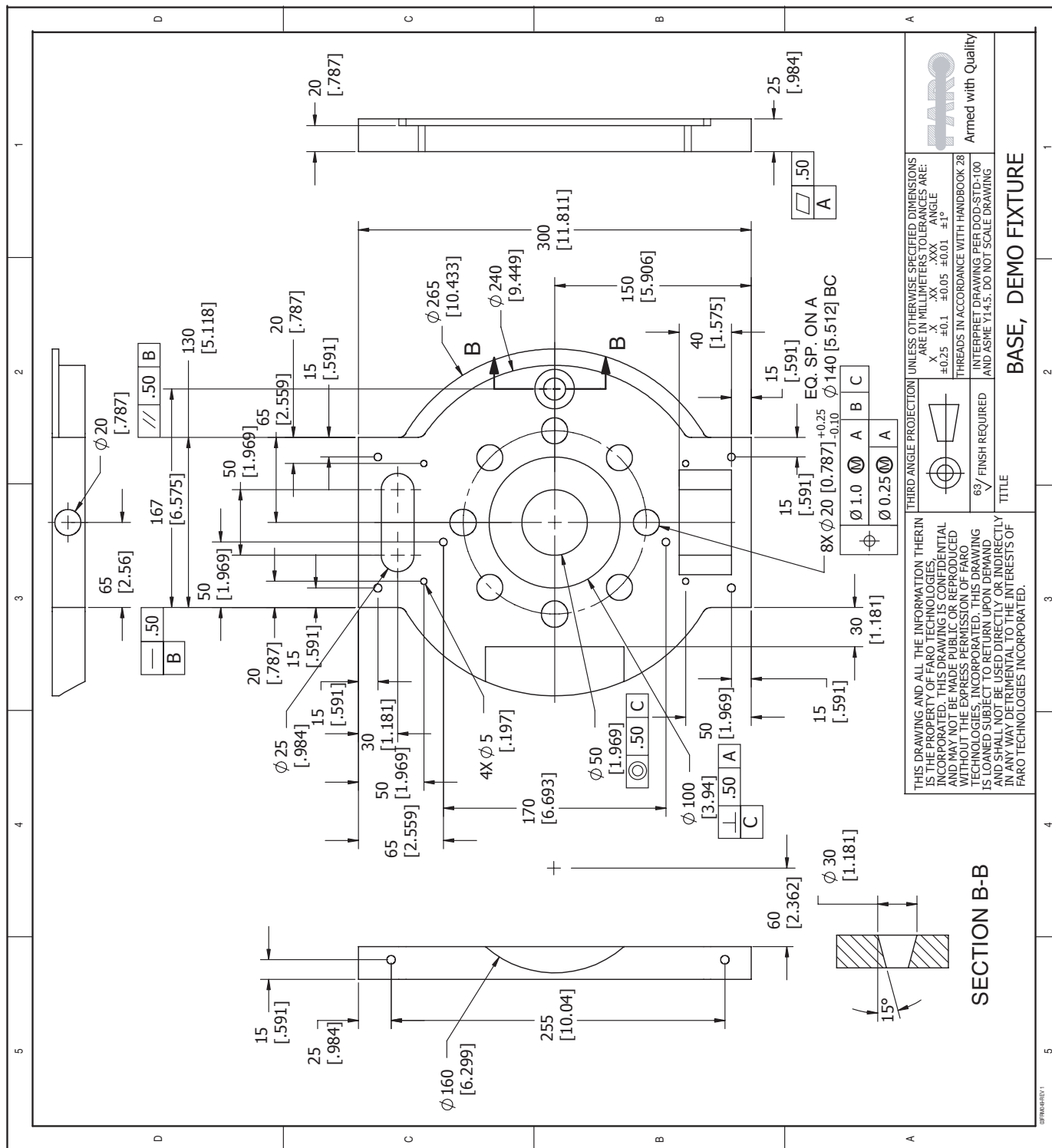


TABLE OF CONTENTS

Module 1: Measurement System Overview

Lesson 1: Getting Started	1.3
Setting up the Laser Tracker	1.3
Connecting the Computer	1.3
Smart Warm-up	1.4
Powering Down	1.4
Opening CAM2 Q	1.4
User Profile	1.4
Device Control Panel	1.5
Lesson 2: CAM2 Q Overview	1.7
Commands in CAM2 Q – Methods to Access	1.8
Screen Layout	1.8
CAM2 Q Help File	1.13

Module 2: Measurement Considerations

Lesson 1: Environment	2.3
Temperature Effect On a Part	2.3
Movement	2.3
Vibration Effects	2.4
Mounting Stability	2.4
Part Mounting for Measurement	2.4
Thermal Gradients	2.5
User Precautions.	2.5
Lesson 2: Device	2.7
Evaluating Environmental Stability	2.7
ACTIVITY: Environment Checks.	2.9
Validating System Accuracy – ComplIT	2.11
ACTIVITY: Angular Accuracy Checks	2.12
Compensation Routines.	2.14
ACTIVITY Self Compensation	2.15
ADM Checks (IT).	2.19
ACTIVITY: ADM IT - Model X	2.21
FARO Laser Tracker Help File	2.26
Lesson 3: Laser Tracker Device Setup Checklist	2.27
Temperature Effect On A Part	2.27
Temperature Effect On The Device	2.27
Movement	2.27
Vibration Effects	2.27
Mounting Stability	2.27

Module 3: Basic Measurement

Strategy: Basic Measurement	3.3
---------------------------------------	-----

Lesson 1: Measure 3.5

Lesson Objective	3.5
Before Measuring	3.5
How To Measure Features.	3.6
Part Measurement Workflow: Measure or Template Mode	3.6
Measure Mode.	3.6
Template Mode	3.6
Measurement Window	3.7
Recording Readings	3.8
Probe Compensation.	3.9
Plane Compensation.	3.10
ACTIVITY: Measure A Plane In The Measure Now Mode	3.10
Percentage Of Measured Feature Vs. Total Feature Size	3.11
ACTIVITY: Add Features To The Features Panel In The Template Mode	3.12
ACTIVITY: Add Features To The Features Panel In The Template Mode	3.14
ACTIVITY: Measure Feature From The Features Panel	3.15
Renaming a Feature	3.15
ACTIVITY: Renaming A Feature	3.15
Projection Plane	3.16
ACTIVITY: Measure Features On A New Plane.	3.17
Measuring a 2D Line	3.18
Measuring a Round Slot.	3.19
Measuring a Point with No Plane of Projection	3.19
ACTIVITY: Set The Plane Of Projection And Measure Basic Features.	3.20
ACTIVITY: Save a File	3.21
Feature Color	3.22
Feature Status Icons	3.22
Show and Hide Features	3.23
Evaluate Measurement Data	3.23
Adding/Removing Readings.	3.24
Measuring Mode: Scan Mode	3.25

Lesson 2: Construct 3.27

Lesson Objective	3.27
Why are Constructions Needed?	3.27
Feature Reducibility.	3.28
ACTIVITY: Feature Reducibility Exercise	3.29
Point Constructions.	3.30
ACTIVITY: Open A Saved File.	3.31
ACTIVITY: Construct Point By Intersection Of Two Features.	3.31
ACTIVITY: Construct Point By Projection	3.32
ACTIVITY: Construct Point By Bisection	3.32
Line Constructions	3.33
ACTIVITY: Construct Line By Intersection Of Two Planes.	3.33
Plane Constructions	3.34
ACTIVITY: Construct A Best Fit Plane.	3.34
ACTIVITY: Construct Plane By Offset.	3.35
ACTIVITY: Construct Plane Perpendicular	3.35

Circle Constructions 3.36

 ACTIVITY: Circle Intersect 3.37

 ACTIVITY: Best Fit 3.37

 ACTIVITY: Review And Evaluate Data (Form And Diameter Of Constructed Features) . . 3.38

 ACTIVITY: Edit The Data For Best Fit Constructed Circle 3.38

 ACTIVITY: Review The Data For The Best Fit Constructed Circle 3.39

 ACTIVITY: Save A File 3.40

Lesson 3: Dimension 3.41

Lesson Objective 3.41

Types of Dimensions 3.41

Length Dimensions. 3.41

 ACTIVITY: Open A Saved File. 3.42

 ACTIVITY: Dimensioning a Length from Features 3.42

 ACTIVITY: Dimensioning Length from Features 3.43

Editing Features 3.43

 ACTIVITY: Editing Features To Create A Line 3.44

Angle Dimensions 3.44

 ACTIVITY: Dimensioning Angles 3.45

 ACTIVITY: Dimensioning Angles 3.46

 ACTIVITY: Save A File 3.46

Lesson 4: Report 3.47

Lesson Objective 3.47

Reporting: Text Reports, Logos, Available Customizations 3.48

Add or Remove Features on a Report 3.50

Document Header Information 3.50

Add or Remove a Picture Preview from a Report 3.51

 ACTIVITY: Create A Report With Customized Content 3.51

Saving a Customized List of Features 3.52

 ACTIVITY: Saving A Customized List Of Features. 3.52

View Report Style Options 3.53

Save a Report. 3.53

Opening a Saved Report 3.53

E-mail a Report. 3.54

 ACTIVITY: Changing The Report View Style 3.54

 ACTIVITY: Saving The Report 3.55

 ACTIVITY: Opening A Saved Report. 3.55

 ACTIVITY: Saving The File. 3.55

Creating a Report Template 3.56

 ACTIVITY: Creating A Report Template 3.56

Feature Grouping 3.56

 ACTIVITY: Creating A Feature Group 3.57

Lesson 5: Review Activities 3.59

ACTIVITY: Construct Point 3.59

ACTIVITY: Dimension Point To Point. 3.59

ACTIVITY: Report 3.59

Module 4: Move Device

Strategy: Move Device	4.2
Move Device	4.2
When To Use Move Device	4.3
Feature Window	4.3
Move Device: Basic Concepts	4.5
PRE-ACTIVITY:	4.6
ACTIVITY: Executing a Move Device Position	4.7
Reviewing Device Positions	4.9

Module 5: Coordinate Systems

Strategy: Coordinate Systems	5.2
What is a Coordinate System.	5.2
Why Use a Coordinate System.	5.2
Feature Selection	5.4
Defining Coordinate Systems Using 3-2-1	5.5
PRE-ACTIVITY:	5.6
ACTIVITY: Create A Coordinate System.	5.7
ACTIVITY: View Report	5.8
Create A Coordinate System	5.8
ACTIVITY: Create A Coordinate System Using A Line As Primary.	5.9
ACTIVITY: View Report	5.9
Create A Coordinate System (Origin Options).	5.10
ACTIVITY: Create A Coordinate System (Origin Options).	5.10
ACTIVITY: View Report	5.11
ACTIVITY: Saving The File.	5.11

Module 6: Nominals and Tolerances

Strategy: Nominals and Tolerances.	6.2
Definitions: Nominals & Tolerances.	6.2
Entering Nominals: Circle Example	6.2
PRE-ACTIVITY:	6.3
The Feature Information Panel.	6.4
ACTIVITY: Entering Nominal Data	6.5
Changing Tolerances Settings	6.6
ACTIVITY: Changing Tolerance Settings	6.6
ACTIVITY: Copying Tolerances	6.7
An Alternative Workflow.	6.8
PRE-ACTIVITY:	6.8
ACTIVITY: Adding Measurements To Nominals	6.9

Module 7: Review Activities

Final Review Activities

7.3

ACTIVITY: Coordinate System.	7.3
ACTIVITY: Nominals, Tolerances, And Constructions	7.4
ACTIVITY: Constructions And Tolerances	7.4
ACTIVITY: Dimensions.	7.4
ACTIVITY: Reports	7.4

Module 8: Working with CAD

Strategy: Working with CAD	8.2
ACTIVITY: Import CAD Files.	8.4
ACTIVITY: Define Nominal Features And Surfaces From The CAD.	8.4

Module 9: QuickTools Programming

Strategy: Working with QuickTools	9.2
QuickTools Panel Commands	9.3
Programming in Measure and Template Modes	9.4
PRE-ACTIVITY:	9.4
ACTIVITY: Creating A New QuickTools Program	9.5
ACTIVITY: Playing The QuickTools Program	9.6
ACTIVITY: Adding Features To A QuickTools Program In Template Mode	9.6
ACTIVITY: Constructions And Dimensions	9.7
ACTIVITY: Playing The QuickTools Program	9.8
ACTIVITY: Editing Tolerances.	9.9
ACTIVITY: Reporting The Results	9.9
QuickTool Program Properties	9.10
Command Properties	9.11
ACTIVITY: Modifying QuickTools Program Command Properties	9.12
Comments	9.13
ACTIVITY: Adding Comments To A QuickTools Program Command	9.13
ACTIVITY: Finishing And Playing The QuickTools Program.	9.14
Reordering Program Commands	9.14
Reordering Program Commands	9.14
Image Creator	9.14
ACTIVITY: Adding Pictures With Image Creator.	9.16
ACTIVITY: Adding Green And Red Target Points To The Images	9.17
Editing a QuickTools Program	9.18

Module 10: Iterative Alignments

Iterative Alignments	10.2
Preferences for Iterative Alignment.	10.2
ACTIVITY: Creating Nominals For An Iterative Alignment	10.2
ACTIVITY: Adding Measurements To The Nominals	10.3
Measurement and Nominal Association	10.4
ACTIVITY: Creating An Iterative Alignment.	10.4
Weights	10.5
ACTIVITY: Adding Weights To An Iterative Alignment.	10.5
Fit Scale	10.5
Material Temperature.	10.5
ACTIVITY: Material Temperature - Iterative Alignment	10.6
ACTIVITY: Reporting The Results Of The Iterative Alignment	10.7
ACTIVITY: Save The Measurement File.	10.7
Auto Nominal Association	10.8
ACTIVITY: Measure Additional Features.	10.8

Module 11: Wireframe CAD Inspection

Wireframe CAD Inspection Workflow	11.2
ACTIVITY: Measured Coordinate System And Aligning To CAD	11.2
ACTIVITY: Nominal Features And Comparing To Measurements	11.4
ACTIVITY: Offsetting A Coordinate System.	11.5
ACTIVITY: Creating A Nominal Coordinate System	11.7
ACTIVITY: Aligning To The Nominal Coordinate System	11.8
ACTIVITY: Reporting The Results Of The CAD Inspection	11.10

Module 12: Surface Measurement for Inspection or Reverse Engineering

Measurement Mode Options	12.2
------------------------------------	------

Lesson 1: Surface Inspection with CAD 12.3

Lesson Objectives	12.3
PRE-ACTIVITY:	12.3
ACTIVITY: Align To A Surface CAD Model Using A Coordinate System Alignment	12.4
ACTIVITY: Adjust Tolerances For Surface Points.	12.4
Auto Nominal Association	12.4
Inspect Surface Commands	12.5
ACTIVITY: Inspect a Surface Point.	12.5
ACTIVITY: Inspect A Surface	12.5
ACTIVITY: Customize Labels	12.5
Home In Points	12.6
ACTIVITY: Home In Points and Nominal Vector Points	12.6
In this activity, we will define nominal locations for surface measurement.	12.6
ACTIVITY: Reporting The Surface Measurements	12.8
ACTIVITY: Save The Measurement File.	12.8
Polylines	12.8
Polyline Groups	12.8
ACTIVITY: Configure a Measurement Mode.	12.9
ACTIVITY: Parallel Lock Plane Surface Measurement	12.9
Feature Whiskers.	12.10
ACTIVITY: View And Adjust Polyline Whiskers	12.11
ACTIVITY: Reordering Feature Data	12.11
ACTIVITY: Creating And Saving A Report.	12.12
ACTIVITY: Save The Measurement File.	12.12

Lesson 2: Scanning for Reverse Engineering 12.13

Lesson Objectives.	12.13
ACTIVITY: Create A New Coordinate System	12.13
ACTIVITY: Measure Features and Export Data.	12.14

Module 13: Data Import/Export

PRE-ACTIVITY:	13.2
ACTIVITY: Export Features To Saved Files	13.3
ACTIVITY: Import Points From A Saved File	13.4

Module 14: Iterative Alignment Using Surfaces

Using Surfaces Instead Of Features.	14.2
ACTIVITY: Performing An Alignment Using Surfaces	14.2

Module 15:Tool Building

PRE-ACTIVITY:	15.2
Feature Window - Digital ReadOut	15.2
ACTIVITY: Positioning The Bracket	15.2
ACTIVITY: Save The Measurement File.	15.4

Module 16:Coordinate Systems Using Offset and Rotation

Rotations and Offsets	16.2
ACTIVITY: Create And Offset A Coordinate System	16.2
ACTIVITY: Create And Rotate A Coordinate System	16.3
ACTIVITY: Create An Offset And Rotated Coordinate System.	16.4

Module 17:GD&T

GD&T in CAM2 Q	17.2
ACTIVITY: Review GD&T Tolerances Help Topics	17.2
ACTIVITY: Establish Datums	17.3
ACTIVITY: Customize Labels	17.4
ACTIVITY: Determine Perpendicularity	17.4
ACTIVITY: Determine Parallelism	17.5
ACTIVITY: Determine Position	17.5
ACTIVITY: Configure a Measurement Mode.	17.6
ACTIVITY: Determine Profile of a Line	17.7
ACTIVITY: Creating A Report	17.8
ACTIVITY: Save The Measurement File.	17.8

Module 18:Using Multiple Devices

ACTIVITY: Configuring Two Devices	18.2
Special Conditions with Multiple Devices	18.3

Appendix I:Laser Tracker Device Setup Checklist

Temperature Effect On A Part	I.1
Temperature Effect On The Device	I.1
Movement	I.1
Vibration Effects	I.1
Mounting Stability	I.1

Appendix II:Hot Keys

Appendix III:Glossary of Terms

Appendix IV:Technical Support

Module 1:

Measurement System Overview

In this module, you will become familiar with how the FARO measurement device and CAM2 Q software interact with one another to provide accurate 3D measurements.

MODULE OBJECTIVES

You will be able to:

- Set up the FARO measurement device
- Navigate the CAM2 Q user interface

Lesson 1: Getting Started

Setting up the Laser Tracker

The Laser Tracker head ships in a storage container by itself. The Master Control Unit (MCU), cables, Spherically Mounted Retroreflector (SMR), tooling, and mounting hardware ship in a second storage container.

The Laser Tracker mounts on an instrument stand in either the vertical or the horizontal positions. The Laser Tracker operates in any orientation.

To setup the Laser Tracker, follow these steps:

1. Place the instrument stand on a stable floor surface, away from obstructions. Ensure that the instrument stand rests on its adjusting pins.
2. Tighten the quick release mandrel to the instrument stand using the supplied spanner wrench.



It is not recommended to place the Tracker on a stand that is tilted more than 10° from vertical.

3. Grasp the front handles of the Laser Tracker and remove the Laser Tracker from the container.
4. Place the Laser Tracker on the instrument stand by means of the mandrel mount inserted into the Laser Tracker base.
5. Turn the locking lever clockwise (when viewed from above) by hand until it is tight. The Laser Tracker locks in position.
6. Connect the air temperature sensor to the MCU.
7. Connect the communication cable to the socket on the back of the Laser Tracker and to the socket on the left side panel of the MCU.

Connecting the Computer

To connect the computer:

1. Plug the port lock into any USB port (this authorizes CAM2 Q to operate). This is not necessary if you have a printed license key.
2. Connect the computer to the MCU using the Ethernet cable.
3. Connect the power cord into the MCU and then connect to the power source.
4. Apply power to the Laser Tracker by turning on the switch at the right side of the MCU.



When used in conjunction with the Tracker Side Mount Fixture (optional accessory), the Quick Release Mandrel Mount holds the Laser Tracker in the upright vertical position or in the horizontal position. When mounting the Laser Tracker upside down, screw it directly into a mounting fixture.



Never grasp the beam steering assembly of the Laser Tracker as this can cause damage.



Additional air temperature sensors may be used to calculate an average temperature.



Make the connection in this order to ensure not to damage the machine.



A Laser Tracker that you store in an air-conditioned environment and bring out to a hot environment, takes longer to warm-up than a Laser Tracker that you store in the hot environment to begin with.



While you can take measurements immediately after initializing the Laser Tracker, it may take up to one hour for complete temperature equilibrium in a thermally stable environment. If you need to take measurements immediately, check the Backsights, using CompIT, after the Laser Tracker has been on for one hour.

Smart Warm-up

Immediately after applying power to your Laser Tracker, it starts performing a “Smart Warm-up”. The blue light on the front of the Laser Tracker blinks and the Azimuth and Zenith motors turn on until the Laser Tracker reaches the correct temperature, which relates to the ambient temperature.

After the motors raise the temperatures of the Laser Tracker, they shut off. The Laser Tracker spends 5 minutes allowing the internal temperature to equilibrate.

When the process completes, the blue light on the front of the Laser Tracker stops blinking and you can initialize the Laser Tracker using the Startup Checks.

Powering Down

Follow these steps to power down the Laser Tracker:

1. Exit CAM2® Q.
2. Store the SMR and/or any other targets in their protective cases.
3. Power down the Laser Tracker using the switch on the right side of the MCU and disconnect the power cable from outlet.
4. Disconnect the communication cable from the socket on the back of the Laser Tracker and from the socket on the side of the MCU.
5. Disconnect the air temperature sensor from the MCU.
6. Disconnect the CAT5 100 MHz RJ-45 cable from the side of the MCU and the computer.
7. Loosen the locking lever on the mount and carefully remove the Laser Tracker head from the stand by grasping its handles, and store it in the Laser Tracker head container.

Opening CAM2 Q

CAM2 Q may be opened using any of the following methods:

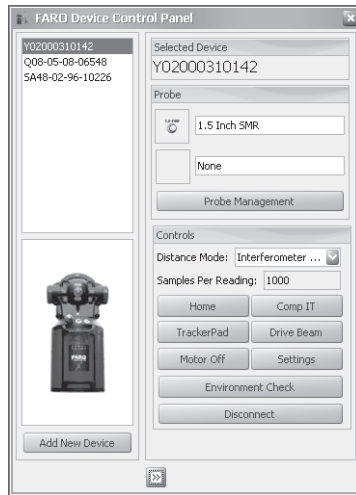
- Double left-click the **Q** icon on the Desktop; or
- Click the **Start** button, point to **Programs**, point to **FARO**, and then click **CAM2 Q**; or
- Double left-click any previously saved CAM2 Q file.

User Profile

The very first time you start CAM2 you must choose a default profile. User profiles contain custom screen layout settings. You can change the default profile any time. On the **Edit** menu, select **User Profiles**.

Device Control Panel

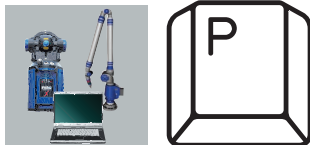
The **FARO Device Control Panel** shows the connected device information:



The elements of the FARO Laser Tracker **Device Control Panel** are:

- Add New Device
- Selected Device
- SMR information:
 - ➔ Current SMR
 - ➔ Current Tooling
 - ➔ Change SMR and Tooling
- Tracker Controls:
 - ➔ Distance Mode
 - ➔ Samples Per Reading setting
 - ➔ Home
 - ➔ ComplT
 - ➔ TrackerPad
 - ➔ Drive Beam
 - ➔ Motor (On/Off) control
 - ➔ Settings
 - ➔ Environment Check
 - ➔ Disconnect

To open the panel, click **Device Control Panel** on the **Device** menu. or press the **P** hot key. You can close this panel by clicking the **X** in the upper right corner of the panel.

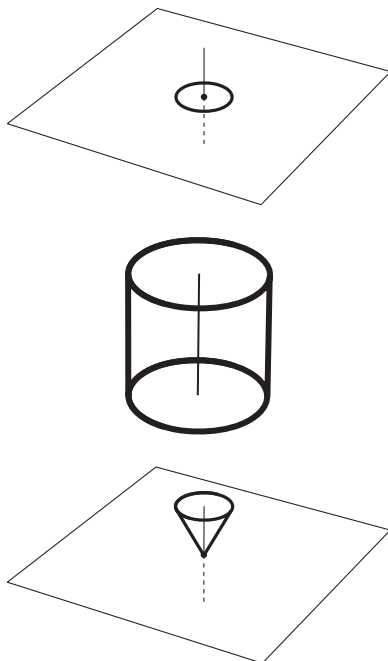


Lesson 2: CAM2 Q Overview

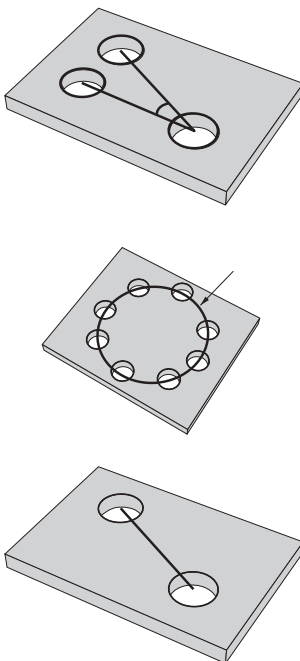
Feature-Based Measurement

CAM2 Q is feature-based measurement software. A feature is a geometric attribute or element of a part. You can directly measure some features (e.g. a circle, sphere, cylinder); others you cannot directly measure easily, accurately or repeatedly (e.g. an angle, bolt hole circle, length), and as a result you must construct or dimension them from elements that you can directly measure. CAM2 Q enables direct measurement, constructions, and dimensions. The **Measure**, **Construct**, and **Dimension** menus reflect these capabilities.

Features you can directly measure



Features that you must construct



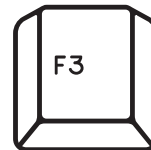
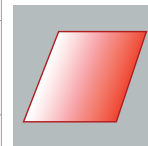
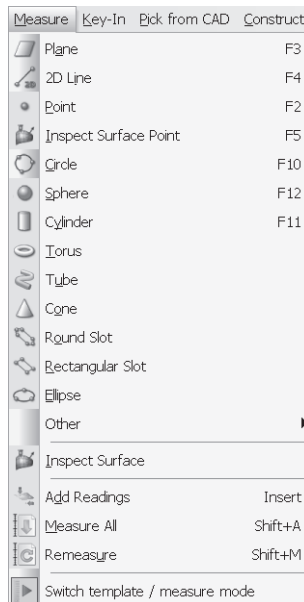
CAM2Q



You can access many commands using hot keys, which are a single keystroke method of choosing a command or accessing a panel. There is a list of all hot keys in the Appendix for your convenience.

Commands in CAM2 Q – Methods to Access

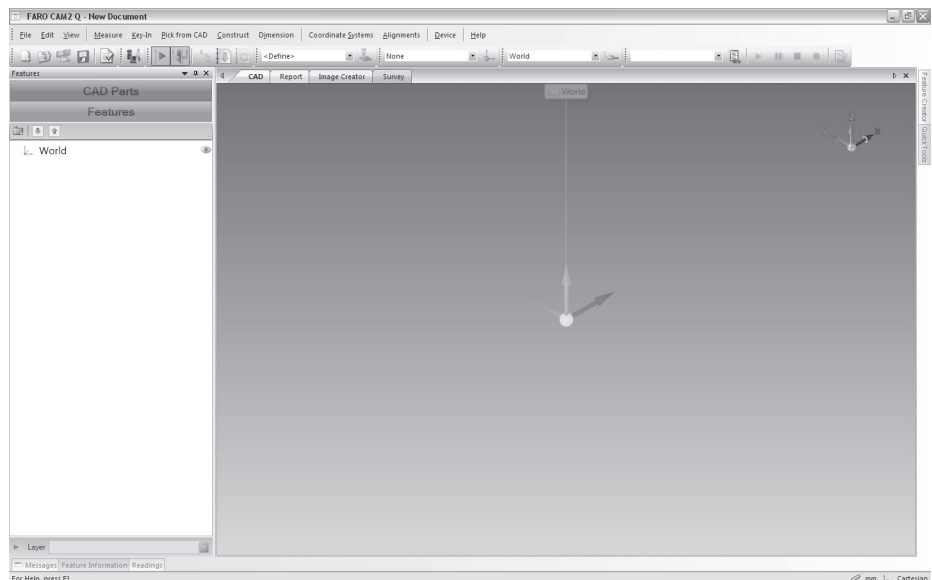
Commands in CAM2 Q can be accessed either by menus or toolbar buttons.



Screen Layout

Main Window

This area of the CAM2 Q screen shows your coordinate system, the results of your measurements, and any imported CAD files. When you first view the screen, there is an XYZ axis representing the three dimensions, which uniquely identifies the locations of points you collect.



Pull-Down Menus

The menu commands at the top of the screen, **File, Edit, View, Measure, Key In, Pick from CAD, Construct, Dimension**, etc. are pull-down menus which contain a variety of commands.


Control Panels


Control Panels are fields that you can bring to the front of the screen containing a variety of information. CAM2 Q includes many panels.

On the **View** menu, click **Panels**. The following panels are the most common panels you will use in this training.

- Features:** Displays the list of features you **Measure, Key In, Pick from CAD, Construct** or **Dimension**
- Tolerances:** Displays the tolerances and nominals you input for specific features
- Readings:** Displays the results for features you have measured
- Feature Creator:** Enables you to select the features you want to measure immediately or at a later time
- QuickTools:** Enables you to record, edit, and play a part inspection program

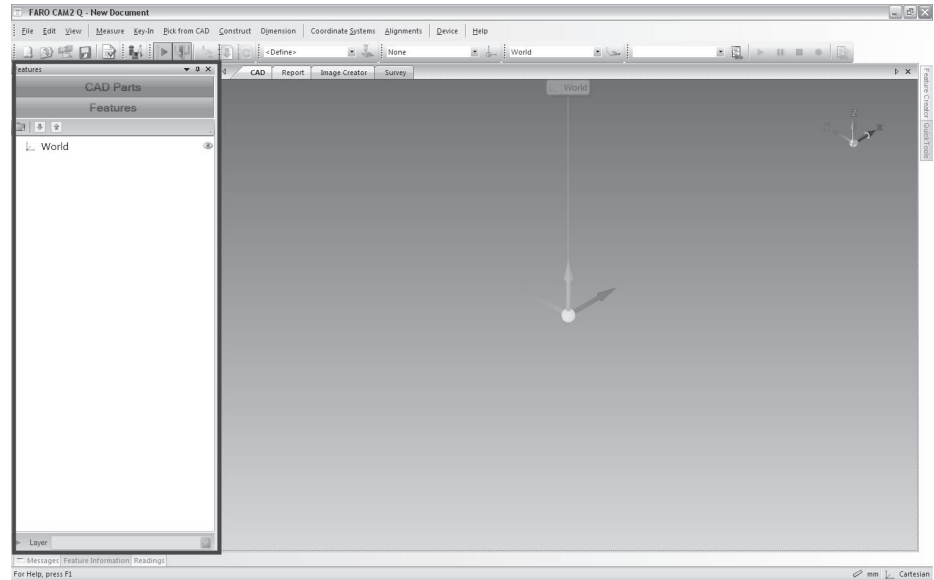
Some of these Control Panels are attached to the screen boundaries and are in "Auto Hide" mode. Look for a tab with the title of the Control Panel and click it to show that Control Panel. The Control Panel remains visible for a short time and automatically collapse back to the tab as you move to another area of the screen.

Click the AUTO HIDE button  in the upper right corner of the panel to keep the bar visible.

Click the CLOSE button  in the upper right corner to close a panel.

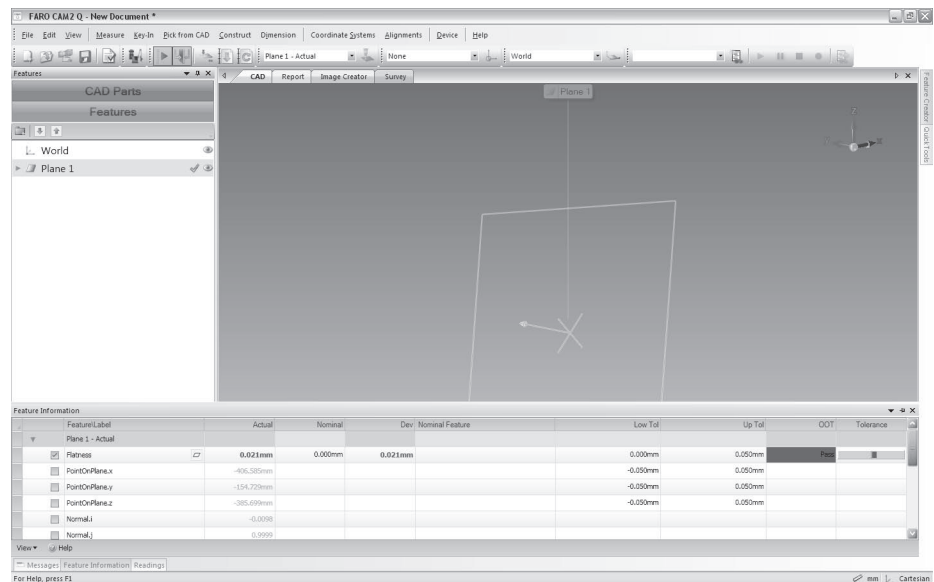
Features Panel

CAM2 Q provides a **Features** panel that shows all the features you measure, construct, or import with a CAD model. In this panel, the features are listed in chronological order of their creation.



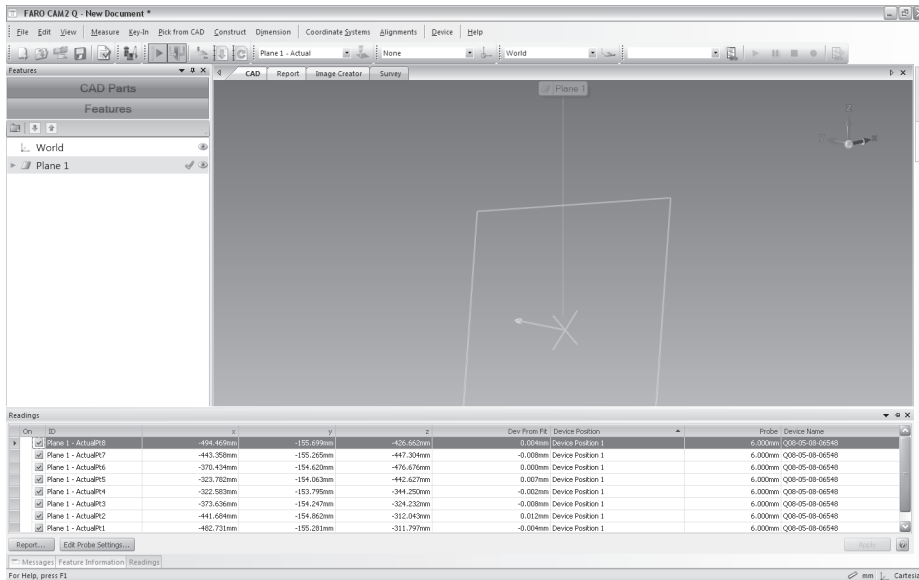
Tolerances Panel

Click the **Tolerances** tab at the bottom of the screen to show the **Tolerances** panel. CAM2 Q provides a **Tolerances** panel that shows tolerance values for an individual, or selected group, of features. You can choose which value of a feature to tolerance and edit the tolerance values.



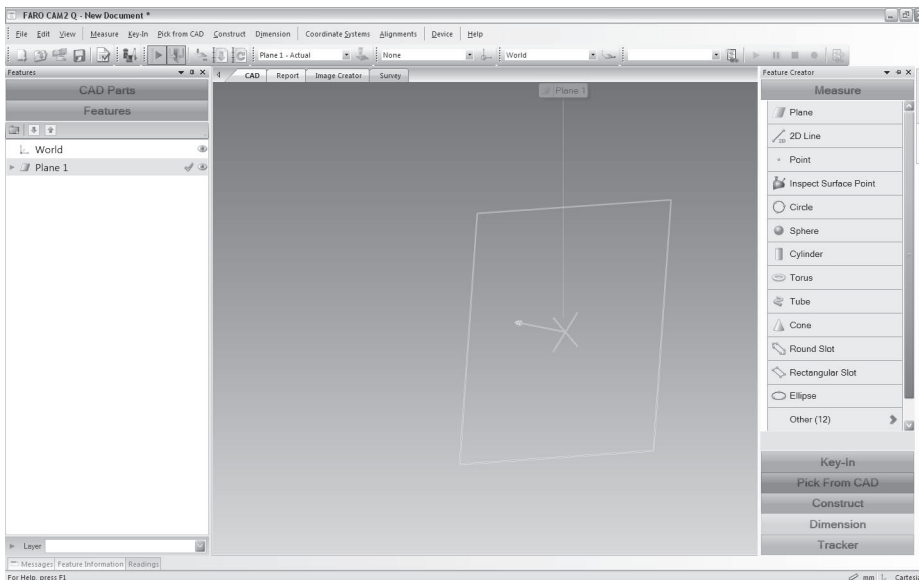
Readings Panel

Click the **Readings** tab at the bottom of the screen to show the **Readings** panel. CAM2 Q provides a **Readings** panel that shows a list of measurement reading and properties for a selected feature.



Feature Creator Panel

Click the **Feature Creator** tab at the right of the screen to show the **Feature Creator** panel. CAM2 Q provides a **Feature Creator** panel that shows feature creation commands grouped by **Measure**, **Key In**, **Pick From CAD**, **Construct**, **Dimension**, and **Tracker** headings. This panel provides a quick method for creating features without using the menu commands.



These are the key elements of the CAM2 Q screen layout. This workbook guides you through the most commonly used menu items and commands

and prepares you to explore the full capabilities of the CAM2 Q software using the **Help** menu.

Customizing the Panels Layout

You can change the position of the panels on the screen. To move a panel, left-click and hold the title bar of any of the panels and drag the panel with the mouse. Once you start dragging a panel, the screen prompts you with icons to show where you can place the panel.

Creating a User Profile (Saving a Customized Screen Layout)

You can easily save a particular screen layout so you can easily recall it. Follow the instructions below:

1. On the **Edit** menu, click **Profile**.
2. When the **User Profile Selection** dialog box appears, click **Save New Profile**.
3. Name your profile and click **Close**.



This saves your current screen as a **User Profile**. You can save any number of user profiles. For example, you can have many users, each with their own user profile, using the same computer. This can save time because each user does not have to setup the screen layout each time CAM2 Q opens.

Selecting/Activating a New User Profile

1. To select and activate a saved User Profile, click **Profile** on the **Edit** menu.
2. From the **User Profile Selection** dialog box, select the **User Profile** you want to load, and then click **Load Profile**.

CAM2 Q Help File

The CAM2 Q Help file is the first place you can look for information.

- On the **Help** menu, select **Contents**.
- Use the **Contents**, **Index** and **Search** tabs, on the left side of the window, to navigate around the file and select and search for topics.
- Each time you receive an update to CAM2 Q, you should view the *What is New* topic. This topic describes new functions and commands that have been added to CAM2 Q, as well as the enhancements made to existing commands. The *What is New* topic is located at the end of Chapter 1: Introduction to CAM2 Q.

Module 2:

Measurement Considerations

Before you start measuring, you have to make sure outside factors such as temperature, vibrations, and mounting instability do not compromise your data. You will be able to prove that your Tracker is accurate by checking the environment and performing any necessary compensation. In this module, you will learn how to compensate for environmental factors and prepare for measurement to get the accurate data that you need.

▶ MODULE OBJECTIVE

You will be able to:

- Evaluate the environmental variables that impact measurement accuracy and take the appropriate steps to avoid, minimize, or correct the impact.
- Run the CompliT program to fully prepare the Laser Tracker for measurement.
- Verify and improve as necessary the angular component of the Laser Tracker's accuracy.
- Verify and improve as necessary the laser measurement component of the Laser Tracker's accuracy.

Lesson 1: Environment

In addition to the calibration accuracy of your device, environmental factors play a major role in the accuracy of your measurements.

Temperature Effect On a Part

Changes in temperature may cause a part to expand or contract, affecting measurement accuracy.

Environment vs. Part Temperature: If the part is warmer or cooler than the surrounding environment, it will expand or contract while being measured. Measurements taken earlier may not equal measurements taken later. To minimize the impact of air temperature on the part:

- Let a part “soak” in the inspection environment to adjust to the air temperature prior to taking measurements. Generally, the larger the part, the longer it will take to adjust.
- Avoid taking measurements where the air temperature will vary widely; e.g. don’t take measurements where doors will be opened to warmer or cooler air (near a furnace, garage door, etc.)

Software Temperature Compensation: CAM2 Q can compensate for the temperature of a part. The ability to scale for temperature allows you to measure parts adjusting for thermal expansion or contraction. For details on how to do this, look in the CAM2 Q **Help** for Material Temperature.

Environment vs. Device Temperature: Changes in room temperature affect the Laser Tracker. As the temperature changes, mechanical components inside the Laser Tracker change size. A minute difference inside the Laser Tracker can be a significant error at range.

To avoid this:

- As described above, avoid places where there will tend to be wide temperature variations.
- Always let the Laser Tracker temperature stabilize before taking measurements.

Light: Light, especially sunlight, generates heat. When exposed to light unevenly, a large part can heat up and expand or contract unevenly. To ensure accurate readings, make sure the part you are measuring has even exposure to light.

Movement

Movement always affects accuracy. Movement resulting in no change in the Laser Tracker position relative to the part will have the least impact on measurement accuracy. To avoid the impact of movement choose a measurement spot where the part and device can be fastened and stationary.



For safety reasons, do not mount the Laser Tracker to a stand that is tilted more than 10° from vertical.

Vibration Effects

Vibration can cause inaccuracies. People putting heavy parts on your surface plate, forklifts driving by, and stamping machines are some of the causes of vibration. Significant vibrations will also affect the tracking of the SMR.

Mounting Stability

Mounting stability is key to accurate measurement.

Tripods

FARO sells two types of tripods: Folding and Brunson. While tripods provide mobility and allow multiple device positions, you must be careful to ensure mounting stability. For detailed instructions, refer to the manual that came with the tripod you purchased.

Magnetic Mount

The Magnetic Mount is another portable option when mounting to most metal surfaces. To ensure proper mounting with the Magnetic Mount, follow the detailed instructions provided with the mount.

Side Mount

The side mounting bracket should be used whenever mounting the Laser Tracker in a horizontal position.

Part Mounting for Measurement

Support the part in the same manner for measurement as its intended function. This ensures that the part experiences the same stress when it is measured as when it is in use.

For high accuracy measurements:

- Power up the Laser Tracker in the environment before measuring and allow it to reach thermal stability in the local environmental conditions.
- Use redundant readings for each measurement. This accomplishes three things:
 - ➔ it highlights extreme errors in measuring;
 - ➔ in some cases it reduces the environmental effects that you have not been able to eliminate, and
 - ➔ it provides better statistical sampling.

Thermal Gradients

Thermal gradients, air turbulence, and air pockets in the path of the laser beam will affect the direction of the laser beam and cause errors in the angular measurements. Avoid these errors by measuring away from heating and air conditioning ducts or any other source of these thermal effects.

User Precautions

Here are some techniques for avoiding bad measurements:

- Place the SMR in magnetic nests gently. If you can hear the target snap into place, you're not being gentle enough.
- Don't touch the collar of the SMR with your hand, and definitely don't touch the mirror surfaces!
- Don't allow the collar of the SMR to come into contact with the nest.
- Keep the roll angle of the SMR constant for all measurements in a test. Pick a mark on the collar and keep it pointing up.
- Make sure the reflective surfaces of the SMR are clean.
- Make sure that you are using the correct SMR for the test you are running. Different tests require different SMR characteristics.
- Make sure that magnetic nests have no dirt or debris in them.
- After placing the SMR in a nest, twist it back and forth slightly a couple of times. If there is any dirt between the SMR and the nest, this will move it out of the way.
- Don't leave the SMR at the home position (TMR) for any length of time. We don't want the SMR to heat up, which causes a measurable change in the measured distance.

Lesson 2: Device

In addition to monitoring the environment and mounting the device securely, proper periodic field compensation ensures Laser Tracker accuracy. The Laser Tracker's built in program, CompIT, makes field compensation quick and simple.

Evaluating Environmental Stability

Operational Checks

The Operational Checks determine the operating condition of the Laser Tracker and verify that environmental factors such as air movement and vibration will not degrade measurement accuracy.

When to Perform Operational Checks

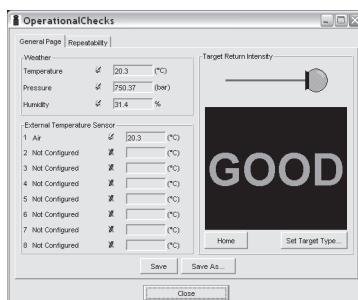
Run these checks:

- After the Laser Tracker has been moved to a new operating environment,
- If the current operating environment changes substantially.

To start the Operational Checks, open the **Device Control Panel** and click the **Environment Check** button.

General Page

View the Weather information and verify the SMR Return Power on the General Page tab of the Operational Checks dialog box. Use the **Save** and **Save As** buttons to save the test results to an ASCII text file. This will provide a record of the environment at the time you take the measurements.



Weather

View the temperature, pressure, and humidity of the measuring environment. An icon indicates the source of the reading:

- **Lightning Bolt:** the reading originates from the Laser Tracker's internal sensors.
- **Pencil:** the reading has been manually entered.



The Static Repeatability

Test indicates the stability of the environment.



A dirty SMR is the

most common cause for low SMR return Power. If the intensity displays as MARGINAL or BAD, clean the SMR according to manufacturer's instructions and re-run the test. If the intensity continues to read MARGINAL or BAD, try another SMR.



The repeatability of the measurements depends on the mounting of the Laser Tracker, the stability of the Target, and the environment.



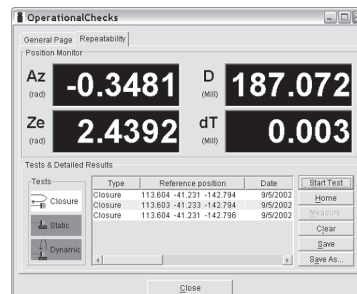
This check is critical for determining whether the Laser Tracker, part, and drift points are stable. (A drift point is a reference point used to monitor the relative position between the part and the Laser Tracker. Normally a set of points is identified using magnetic nests glued to the part.)

Target Return Intensity

The SMR Return Power value is the measure of the laser intensity as it returns to the Laser Tracker from an SMR.

Repeatability Page (Click the tab to get to the page)

The **Position Monitor** section shows the real time position of the target expressed in the Laser Tracker's spherical coordinate system: Azimuth angle (Az), Zenith angle (Ze), and Radial distance (D). The "dT" value shows the variation between the most recent measurement and the established baseline measurement.



The **Tests** section contains buttons to activate one of the three repeatability tests, Closure, Static, and Dynamic.

The **Tests** show the distance measurement, "D", and encoders, and indicate the level of repeatability of the Laser Tracker measurements.

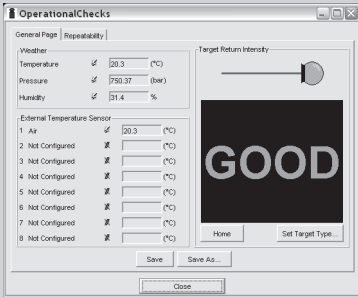
The **Start Test** and **Measure** buttons are used to carry out the specific tests, while the **Home** button must be used to reset the laser should a beam break occur.

Static Repeatability

The Static Repeatability check determines whether the Laser Tracker can repeat the measured position of the SMR in a fixed position. The SMR remains at the reference position and does not move at all during the test.

ACTIVITY: Environment Checks

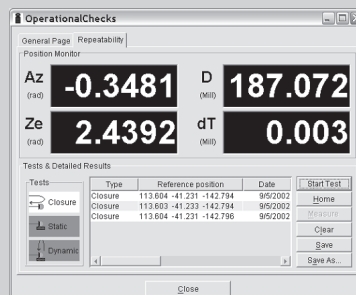
For this activity, you will perform an environmental check.

Target Return Intensity Check	
1. Start Environment Check	Click the Environment Check button in the Device Control Panel .
2. Select Target Type	On the Operational Checks dialog box, click Set Target Type .
3. Select SMR	Select the appropriate SMR.
4. Accept SMR	Click OK .
5. Measure Intensity at the Home position	Place the SMR at the Home position (Tracker Mounted Reset or TMR) on the Laser Tracker and click Home . Intensity will show as: <ul style="list-style-type: none"> ● GOOD ● MARGINAL ● BAD 

If the intensity shows as MARGINAL or BAD, it is indicating the SMR may need cleaning. Follow the instruction in the 922-01933 Optical Target Care Guide and retry the test.

Repeatability Checks


1. **Repeatability** tab In the **Operational Checks** dialog box, select the **Repeatability** tab.



The **Tests & Detailed Results** section appears the results of each test in detail.

Static Repeatability Check	
1. SMR to home position	Place the SMR in the home position (Tracker Mounted Reset or TMR).
2. Laser to home position	From the Repeatability tab of the Operational Checks dialog box, click the Home button to reset the laser.
3. Set a reference position	Set a reference position for the test: <ul style="list-style-type: none"> Position the tripod or an available nest at a distance from the Laser Tracker that approximates the distance of the part you will be measuring. (Angular position is not critical to this check.)
4. SMR to reference position	Remove the SMR from the home position and move it to the reference position.
5. Start the test	Click on Start Test . <ul style="list-style-type: none"> Click OK when prompted for a time delay between measurements.

The Laser Tracker first measures the reference position, then after the time delay, measures the reference position again. Allow the Laser Tracker to collect (10) measurements for about 30 seconds. (As the measurements are taken, they appear in the Test and Detailed Results section.

6. Stop the Test	Click Stop Test and review the results. <ul style="list-style-type: none"> Look at the 3D values in the Test Results section. The total error should be less than what is acceptable for the part you are measuring.
7. Analyze the total error	If the total error is greater than what is acceptable, repeat this check at two other locations. <p> <i>If the total error is consistently greater than acceptable, check the Laser Tracker mounting; mandrel tightness; and stand, tripod and target nest to ensure all are stable. Additionally, check the area for temperature gradients. Air handlers, machinery and sunlight can cause these. Eliminate the sources of the temperature gradients and try the test again. If you cannot remove the temperature gradients, use higher sampling in the application software to reduce repeatability issues due to environmental effects.</i></p>

Optional Steps

1. Remove any results	Click the Clear button to remove any results, in case you want to re-run the check.
2. Save results	Use the Save and Save As buttons to save the results to a text file in the location of your choice in case it is needed later.
3. Close	Click Close .

Following the Checks

The Static Repeatability check, verifies stability of the environment. To verify the Laser Tracker accuracy, complete **Angular Accuracy Checks** and **Self Compensation** (if necessary) and prior to any measurement session.

Validating System Accuracy – CompIT

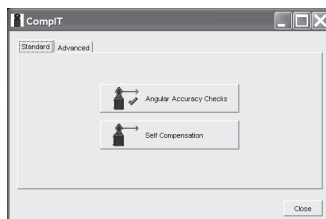
CompIT is a toolkit which includes a series of tests to validate the Laser Tracker system's **Angular Accuracy** and **Distance Accuracy**.

- **Angular Accuracy**, one of two components of Laser Tracker accuracy, describes how accurately the Laser Tracker measures the horizontal and vertical angles from the Laser Tracker to the point being measured.
- **Distance Accuracy**, the second component of Laser Tracker accuracy, describes how accurately the Laser Tracker measures the distance to the point being measured.

To start the CompIT, open the **Device Control Panel** and click the **CompIT** button.

Standard Tab

The **Standard** tab of the CompIT dialog box contains the two most frequently used functions: **Angular Accuracy Checks** and **Self Compensation**.



Clicking the **Angular Accuracy Checks** button starts the Angular Accuracy test.

Clicking the **Self Compensation** button: starts the Self Compensation test.

Angular Accuracy Checks

These checks should be performed:


- After initializing the Laser Tracker;
- Before each measurement session;
- If the temperature has changed more than 5° Fahrenheit.

You can perform **Angular Accuracy** checks during a measurement session to verify the Laser Tracker's accuracy.

If necessary, CompIT will guide you to use a **Self Compensation** procedure to maintain Laser Tracker Accuracy.

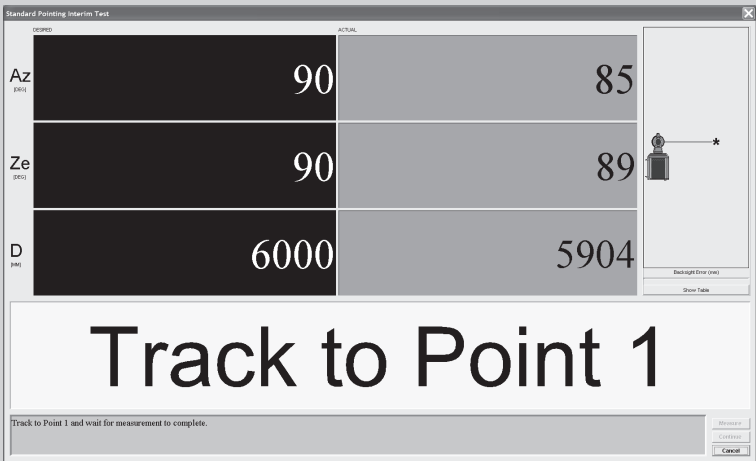
ACTIVITY: Angular Accuracy Checks


For this activity, you will perform an angular accuracy check.

1. Start CompIT	Click the CompIT button in the Device Control Panel . (Be patient—the Laser Tracker is loading the CompIT program)
2. SMR to Home	Place the SMR in the Home position
3. Choose Angular Accuracy Checks	In the CompIT dialog box, click Angular Accuracy Checks . The Select Mode dialog box appears.
4. User Selected Points	Click User Selected Points .
5. Move SMR	Click OK . CompIT prompts you to move the SMR to a specific location.  If "User selected points" is checked, CompIT prompts you to move the SMR to any location at a distance approximating the distance at which you will be taking measurements.

Once the SMR is in the correct location, ComplT automatically monitors the target for stability.

Once the target is stable, ComplT measures the SMR and calculates the Angular Accuracy



6. Move SMR to two more locations	As prompted by ComplT, move the SMR to two more locations and allow ComplT to calculate the Angular Accuracy.
7. Review Results	After three measurements, click Continue .
8. End the angular accuracy check	Click Done .  Depending on the stability of the environment, this Angular Accuracy test should be performed at the beginning of each day and every 3-4 hours during the day to determine continued accuracy.



The results of the Pointing Interim Test determine whether the Standard Pointing Compensation starts.

Compensation Routines

There are two compensation routines, the **Self Compensation** routine and the **Pointing Compensation** routine.

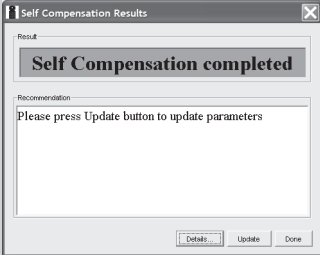
The **Self Compensation** routine, which ensures that the Laser Tracker meets specifications throughout its full measurement range, is what you will use for most applications. It is an automatic process that enables the Laser Tracker to guide itself through a compensation process. This takes about five minutes.

The **Pointing Compensation** routine, which takes five to 10 minutes, requires your active involvement and includes two parts: The Pointing Interim Test, a preliminary check of the deviations around the Laser Tracker's working volume; The Pointing Compensation, a procedure to improve the deviations. Run this routine in place of the Self Compensation routine for applications that require long range (20 plus meters) measurement and the highest possible accuracy. Pointing Compensation is divided into two parts.


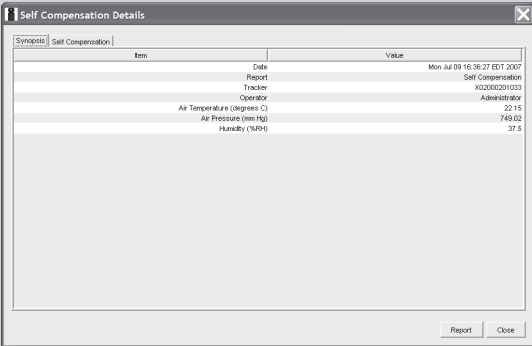
Use these routines at the beginning of a measurement session—or—if the Angle Accuracy Check indicates a change in the accuracy value. If compensations are run during the course of a measurement session a device position is required before measurement continues.

ACTIVITY Self Compensation

For this activity, you will perform a self compensation.

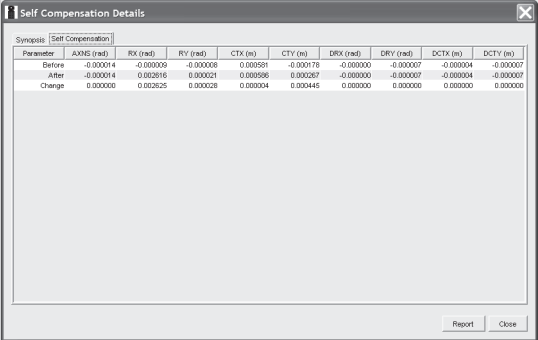
1. Start Self Compensation	<p>In the CompIT dialog box, click Self Compensation. CompIT begins an automatic Self Compensation routine.</p> 
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After completing the routine, the results display in the **Self Compensation Results** dialog box.

2. Results	Click Details to display detailed results.
3. Update	<p>Click Update to save the results to the Laser Tracker.</p> <p> <i>If you do not click the Update button, the parameters will not update.</i></p> 
4. Quit Self Compensation	Click Done to exit the Self Compensation routine.
5. Save a Report	Click Report to create a text file, which you can save and/or print.

6. Compare Results

Click the **Self Compensation** tab to view the Before, After, and Change in parameters.



Parameter	AXIS (in)	RX (in)	RY (in)	CTX (in)	CTY (in)	DRX (in)	DRY (in)	DCTX (in)	DCTY (in)
Before	-0.00014	-0.00009	-0.00008	0.00059	-0.00078	-0.00000	-0.00007	-0.00004	-0.00007
After	-0.00014	0.002616	0.000021	0.000586	0.000587	-0.00000	-0.00007	-0.00004	-0.00007
Change	0.00000	0.002625	0.000028	0.000004	0.000445	0.00000	0.00000	0.00000	0.00000

After completing the **Self Compensation** you will be prompted to run the **Angular Accuracy Checks**. This is to verify that the Angular Accuracy now falls within acceptable parameters.

7. Run **Angular Accuracy Checks**

Click **Yes** to run the **Angular Accuracy Checks**. (For information on how to complete, see the Angular Accuracy Checks section, above)

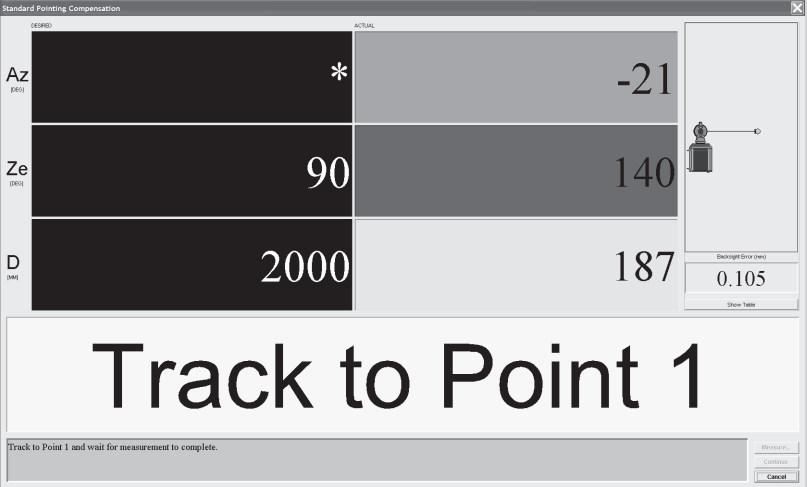
Pointing Compensation

1. Select **Advanced** tab

Click the **Advanced** tab in the main **CompIT** dialog box,

2. **Pointing Compensation**

Click the **Pointing Compensation** button.



	TARGET	ACTUAL
Az (deg)	*	-21
Ze (deg)	90	140
D (mm)	2000	187

Backlight (mm) 0.105

Show Table

Track to Point 1

Track to Point 1 and wait for measurement to complete.

OK Cancel


CompIT prompts you to move the SMR to the home position, and then to various default positions.

3. Set up nest

Set up a nest on a tripod at the height and distance provided on the screen prompt.

4. Track SMR to nest	Track the SMR to the nest and place it there. The height and distance values should be green.
5. Rotate Laser Tracker	Rotate the Laser Tracker on the mandrel mount to adjust the Azimuth angle to the target until the value is green.



Once the SMR is in the correct location, CompIT automatically monitors the target for stability. After five seconds of stability, the Laser Tracker will measure the SMR and calculate the Angular Accuracy.


 *If the SMR does not stabilize within 60 seconds, an error appears. If this happens, ensure the stability of the SMR and that the mandrel is tight, then retry.*

The numbers below **Desired** value are the target values for Azimuth, Zenith, and Radial Distance of the SMR.

The numbers below **Actual** value are the current values.

The values are red when out of acceptable range, yellow when close to range, and green when within range. When all of the values are green, the Laser Tracker waits five seconds for stability before measuring the SMR.

6. Show previous measurements	Click the Show Table button to display a list of any previous measurements.  <i>Clicking Cancel enables you to exit the Interim Test without saving any data or parameters.</i>
7. Two other locations	Guided by the screen prompts, continue the above process for two more locations: <ul style="list-style-type: none"> • degrees azimuth, 90 degrees zenith, 2 meters distance. • degrees azimuth, 135 degrees zenith, 2 meters distance (SMR will usually need to be placed on the ground).
8. Continue	Click Continue after completing the third location.
9. Pointing Compensation	Click Compensation to exit this dialog box and continue with the Pointing Compensation routine. The Standard Pointing Compensation dialog box appears.  <i>Clicking Cancel at this point will exit Pointing Compensation without saving data.</i>

10. Place SMR	Place the SMR in the calibration tripod or in another stable nest. The first desired location is: <ul style="list-style-type: none"> Any azimuth position, 90 degrees zenith, 2 meters distance.
11. Move the SMR	Move the SMR and/or rotate the Laser Tracker until the actual numbers for all three values are green. <p> The Laser Tracker will measure automatically when the target has been stable for more than five seconds.</p> <p>The remaining desired locations are:</p> <ul style="list-style-type: none"> Any azimuth position, 90 degrees zenith, 3.6 meters distance. Any azimuth position, 90 degrees zenith, 5.2 meters distance. Any azimuth position, 90 degrees zenith, 6.8 meters distance. Any azimuth position, 90 degrees zenith, 8.4 meters distance. Any azimuth position, 90 degrees zenith, 10 meters distance.
12. Pass/Fail	After completing the last measurement, click the Continue button. You will see the results of this test in the Pointing Compensation Results dialog box. <div data-bbox="944 1233 1265 1491" data-label="Image"> </div>
13. Results	Pointing Compensation Results: The results of the Pointing Compensation (Pass or Continue).
14. Recommendation	Recommendation: Detailed recommendation on the next step for the user.
15. Show Details	Click Details : Displays the details of the results, which you can save to a text file.

16. Update the parameters	Click Update: Updates the compensation parameters and exits Pointing ComplT. ☞ <i>If you do not click the "Update" button, the parameters will not update.</i>
17. Exit	Click Cancel to exit ComplT without updating any parameters.

ADM Checks (IT)

The **ADM Interim Test** tests the accuracy of XtremeADM (Absolute Distance Measurement). There are two different procedures, depending on Laser Tracker model. The **model Xi** procedure compares XADM measurements to Interferometer (IFM) measurements. The **model X** procedure compares XADM measurements to angular measurements. The tests take only a few minutes and may be run weekly.

ACTIVITY: ADM IT - Model Xi

For this activity, you will perform a model Xi ADM Interim Test.

The **model Xi ADM Interim Test (IT)** procedure compares XADM measurements to Interferometer (IFM) measurements. This test completes in a few minutes and should be run once a week.

Procedure	
1. Advanced tab.	Click ComplT dialog box Advanced tab.
2. Start ADM Checks	Click ADM Checks in the ComplT dialog box Advanced tab. The Select Mode dialog box appears. <div data-bbox="767 1414 922 1571" data-label="Image"> </div>
3. SMR to Home	Click Guided Points . ☞ <i>Since ComplT is comparing IFM to ADM measurements, Auto Home is active; if the beam breaks (loss of IFM count), return the SMR to the home position for an automatic reset.</i> ComplT moves the laser beam to Home.

ADM Interim Test

Az
(deg)

*

Ze
(deg)

*

D
(mm)

3000

-21

140

187

Deviation

0.003

*


Track SMR to desired location, then wait for automatic measurement.

Report

Details

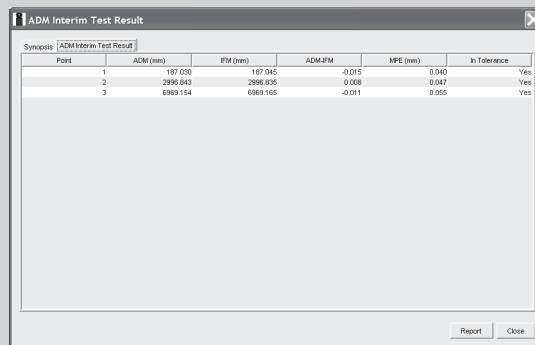
Cancel

Track to Point

4. Track to point 2	<p>Track the SMR in a nest to a point 3 meters away from the Laser Tracker (point 2).</p> <p> Use a stable nest for the SMR. You can use the Laser Tracker's calibration tripod.</p> <p>The Laser Tracker will measure automatically when the target has been stable in the green zone for 5 seconds.</p>
5. Track to point 3	<p>Track the SMR in the nest to the next point 7 meters away from the Laser Tracker (point 3).</p>
6. Track to Home	<p>If any point is out of tolerance CompliT will prompt you to Track Home to check for Closure.</p>
7. View results	<p>Click the Details button after completing the last measurement,</p> <p>You will see the results of this test in the ADM Interim Test Results dialog box.</p>

8. Analyze results

Click the **ADM Interim Test Results** tab to view the ADM-IFM values.



Point	ADM (mm)	IFM (mm)	ADM-IFM	NPE (mm)	In Tolerance
1	187.030	187.045	-0.015	0.040	Yes
2	2996.843	2996.835	0.008	0.047	Yes
3	6989.154	6989.165	-0.011	0.055	Yes

The numbers in the **IFM** column are the results of the **Interim Test**.

9. Exit the test

Click **Close** to close the ADM Interim Test Results.

10. Exit the Checks

Click **Done** to exit the CompIT ADM Checks procedure.

ACTIVITY: ADM IT - Model X

For this activity, you will perform an ADM Interim Test.

ADM Interim Test

We have discussed measuring the Angular Accuracy of the Laser Tracker. The **ADM Interim Test (IT)** provides a procedure to evaluate the Distance Accuracy of XtremeADM (XADM), the Laser Tracker's measuring system.

The routine compares the Tracker's Angular Accuracy to its Distance Accuracy by measuring the distance between two targets from two Laser Tracker positions.

Alternatively, the test can be run using a bar with two fixed targets. The bar can then be measured in two orientations by the Laser Tracker in a single position while following the same procedure.

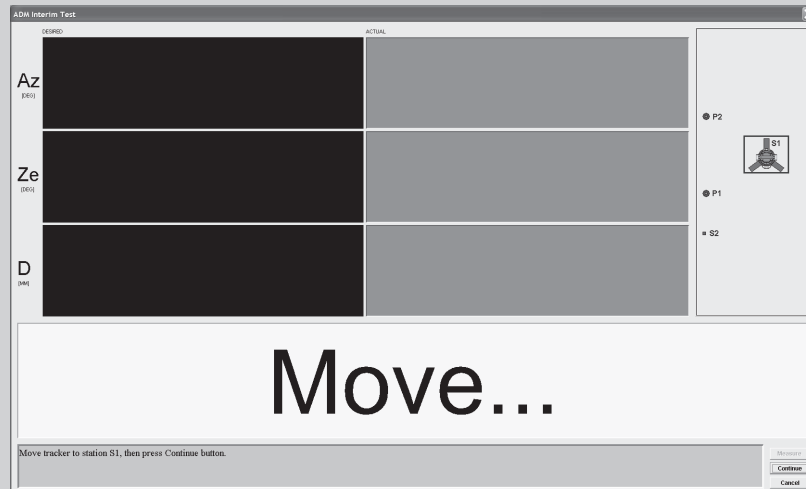
Procedure

- | | |
|-------------------------|---|
| 1. Set up Laser Tracker | Set up the Laser Tracker three meters away from two points (point 1 and point 2) that are one or more meters apart. |
|-------------------------|---|

2. Start **ADM Checks**

Click **ADM Checks** In the CompIT dialog box under the **Advanced** tab.

The first position for the interim test is with the Laser Tracker set up to measure two points from the side. This setup should maximize the use of the Laser Tracker's angular encoders.



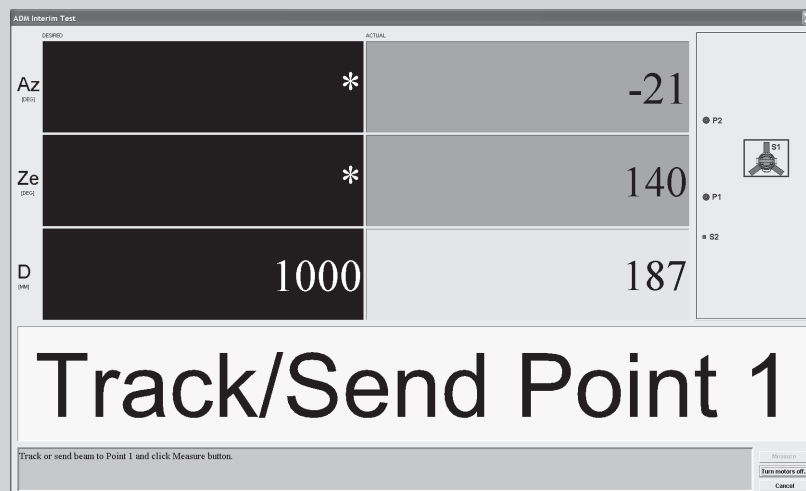
3. Move Laser Tracker to S1

Move the Laser Tracker to Station S1 (between the points) and click **Continue**.

4. Home the SMR

Home the SMR.

You will be prompted to place the SMR at the **Home** position. Select **Home**.



5. Track to **point 1**

Track the target to **point 1**.

6. Measure **point 1**

Click the **Measure** button to measure **point 1**.

The Laser Tracker waits five seconds to ensure the target is stable and then takes a measurement.

ADW Interim Test

DESIRED		ACTUAL
Az (°)	*	-51
Ze (°)	*	100
D (mm)	*	3113

Relative Roll's Component

49%

RIGHT UP

Track/Send Point 2

Track or send beam to Point 2 and click Measure button. Measure will be enabled if the target is at least 0.02 meter(s) away from previous measured location. Move the target to a location that would maximize the pie chart value.

Measure...


Turn meters off...

Cancel

move to S2 (mp) - Point

7. Track to **point 2**

Track the target to **point 2**.

 A note will prompt you where to move the target to ensure the check is valid.

8. Measure **point 2**

Click the **Measure** button to measure **point 2**.

If the percentage is less than 80%, move the Laser Tracker and click the **Retry** button to re-measure the two points with a setup that yields greater than 80 %.

ADW Interim Test

DESIRED		ACTUAL
Az (°)		
Ze (°)		
D (mm)		

Relative Angular's Component

50%

RIGHT UP

Retry / Continue

If satisfied with the relative angular component, then click the Continue button. Otherwise click Retry button to improve the setup.

Retry

Continue

Cancel

Module 2 : Measurement Considerations

08m13e15 - CAM2 Q v1.5 - FARO Laser Tracker Training Workbook - October 2010.pdf Part# 12053-001

FARO

2.23

9. Move Laser Tracker to S2

Move the Laser Tracker to **Position 2**.

At **Position 2**, the Laser Tracker's beam should be in line with the two points being measured .

ADIN Interim Test

	DESIRED	ACTUAL
Az (mm)		
Ze (mm)		
D (mm)		

P2

#S1

P1

S2

Move...

Move tracker to station S2, then press Continue button.

Continue

Cancel

10. Track to **point 1**

Track the target to point 1.

11. Measure **point 1**

Click the **Measure** button to measure point 1.

The Laser Tracker waits five seconds to ensure the target is stable and then takes a measurement.

12. Track to **point 2**

Track the target to **point 2** .

A note will prompt you where to move the target to ensure the check is valid.

ADIN Interim Test

	DESIRED	ACTUAL
Az (mm)	*	-51
Ze (mm)	*	100
D (mm)	*	3113

Relative Point 1 Component

49%

RIGHT UP

Track/Send Point 2

Track or send beam to Point 2 and click Measure button. Measure will be enabled if the target is at least 0.02 meter(s) away from previous measured location. Move the target to a location that would maximize the pie chart value.

Measure...

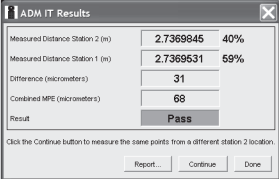
Turn reds off...

Cancel

move to S2 (mp - Para)

2.24

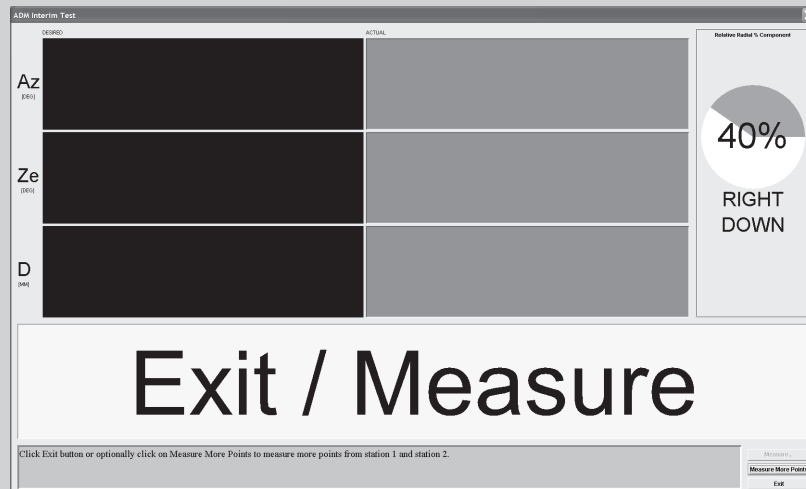
FARO

13. Measure point 2	<p>Click the Measure button to measure point 2.</p> <p>If the percentage is less than 80%, move the Laser Tracker and click the Retry button to re-measure the two points with a setup that yields greater than 80%.</p> <p>The Results dialog shows the distance between the two points measured from the two setups;</p>  <p>The difference between the two measurements is shown along with the Maximum Permissible Error (MPE), which is derived from the Laser Tracker angular specifications. A result (Pass/Fail) will also be displayed. If Fail redo the test. If Fail a second time, call FARO Customer Support.</p>
14. View measurements	The percentage of angular and distance measurements is again displayed summarizing the measurements from two points.
15. View results	Click the Report button to open a dialog to save the results.
16. Save results	<p>Name the file "ADM – Test 01".</p> <p>☞ A check box is available to add the results to a previously saved report. This enables you to maintain a running log of test results.</p>
17. Close results	<p>Click Done to close the results page.</p> <p>The screen provides two options: Measure More Points and Exit.</p>

18. Exit **ADM** Interim Test

Click **Exit**.

☞ The **Measure More Points** button returns you to the **Move** screen and prompts you through additional XADM testing if you desire.



FARO Laser Tracker Help File

You can access the FARO Laser Tracker Help file by clicking the **Help** button in any FARO Laser Tracker driver command. These commands are found in the **Device Control Panel**.

- On the **Device Control Panel**, click the **Settings** button, or any other command button.
- In the **FARO Laser Tracker Settings** dialog box, click the **Help** button.

This opens the FARO Laser Tracker help file and automatically jumps to the Probes section of the file. Use the **Contents**, **Index** and **Search** tabs to navigate around the file.

Lesson 3: Laser Tracker Device Setup Checklist

Temperature Effect On A Part

- ☐ Part has been allowed to soak in the inspection environment to adjust to the air temperature.
- ☐ Measurements will be taken where the air temperature is relatively constant.
- ☐ CAM2 Q is set to appropriately adjust for part expansion/contraction (see software user guide).
- ☐ The part is evenly exposed to light.
- ☐ Measurements are being taken away from heating/ventilation ducts or any other potential source of air turbulence.

Temperature Effect On The Device

- ☐ The device temperature has been allowed to stabilize.

Movement

- ☐ The device and part are fastened and stationary.

Vibration Effects

- ☐ Vibrations (forklifts driving by, stamping machine movement etc.) have been avoided.

Mounting Stability

- ☐ Detailed instructions provided with mount (tripod, magnetic) were carefully followed.
- ☐ If mounting the device horizontally, the side mounting bracket has been used.
- ☐ The part being measured is supported in the same manner as it would be in its intended function.

Module 3:
Basic Measurement

In this module, you will become familiar with the CAM2 Q Measure, Construct, Dimension, and Report menus—the four steps common to every CAM2 Q measuring job.

You will also be introduced to a Basic Measurement Strategy, which will get you thinking about what you need to include in the final report and how you can obtain that information *before* you begin measuring. You will see the process of how you think about a project vs. how you actually do a project.

This module will first focus on each of the key menus. After you learn how to use each menu, you will apply the Basic Measurement Strategy to put them all together in the proper order to complete a measurement job.

Let's begin!

▶ **MODULE OBJECTIVE**

You will be able to:

- Use the Basic Measurement Strategy to plan and complete a measurement job using the **Measure**, **Construct**, **Dimension**, and **Report** menus.

▶ **LESSONS**

Lesson 1: Measure	3.5
Lesson 2: Construct.....	3.27
Lesson 3: Dimension	3.41
Lesson 4: Report.....	3.47
Lesson 5: Review Activities	3.59

SCENARIO: FIRST ARTICLE INSPECTION

You enter the boss' office. The boss says, "We have the new FARO Laser Tracker and CAM2 Q. I need you to do a first article inspection on this part. We need to finish our part inspection by the end of the day if we are going to meet our delivery schedule. Here is the blueprint... get to work." You return to your workstation, look at the blueprint and the part, and think about how to tackle this job.



"What is the most effective way to provide what the boss is asking for? I need to think about the measurement strategy and begin with the end in mind."

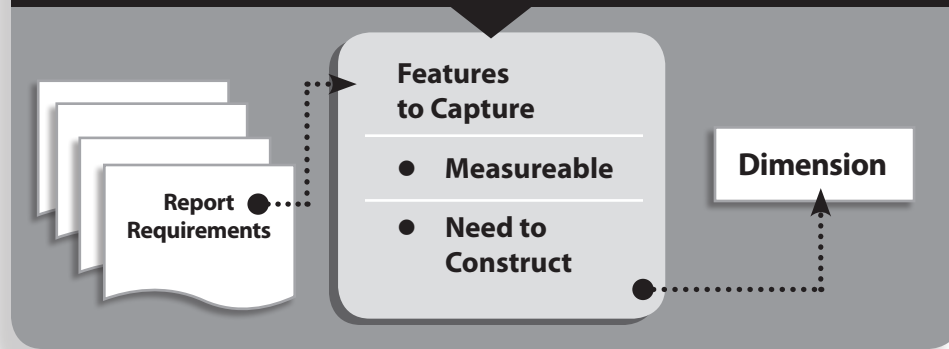
Strategy: Basic Measurement

Look at what you need to measure and consider the following questions:

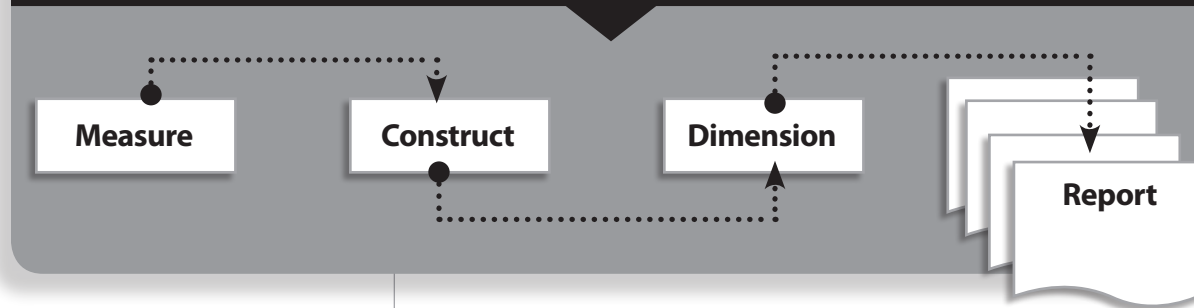
- What should you include in the formal **Report**?
- Which features (geometric elements) do you need to capture?
 - ➔ Which features can you **Measure** directly (e.g. planes, circles, cylinders, lines, etc.)?
 - ➔ Which features do you need to **Construct** (e.g. bolt hole circle)?
- Which **Dimensions** do you need? (e.g. circle center to circle center)
- What logical sequence should you use to move around the part and capture the features? (i.e., left to right, top to bottom, or measure all planes first, then circles, etc.)

CAM2Q

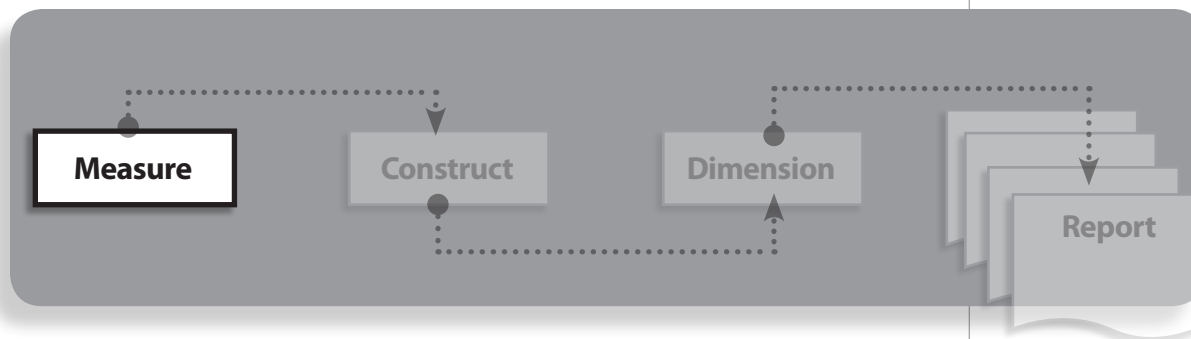
How you **Think About** your measurement project
(Basic Measurement Strategy)



How you **DO** your measurement project



Lesson 1: Measure



Before you can apply the **Basic Measurement Strategy** to a complete measurement job, you need to know the capabilities of the CAM2 Q menus (Measure, Construct, Dimension, Report). The first menu we will present is **Measure**. You will learn to measure features correctly, analyze the data for the feature, and find and edit feature readings and names.

Lesson Objective

With the assistance of the **Help** menu, you will be able to use all of the functions within the **Measure** menu. This means you will be able to:

- Use the **Measure** menu to capture data.
- Review and evaluate measurement quality and edit data.
- Define projection planes for 2D measurements.
- Save and open files.
- Rename features.
- Determine the optimal number of points to collect and distribution of those points on a feature.

Before Measuring

Before you begin measuring features, make certain that you use the correct SMR. On the **Device** menu, click **Device Control Panel**. Check the **Current SMR** listed in the **SMR** section. If you need to change the SMR, click the **Probe Management** button.



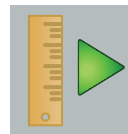
The default mode is
Measure Mode.

How To Measure Features

1. Choose a Part Measurement Workflow
2. Add Feature(s) to your file
3. Record Measurements

Part Measurement Workflow: Measure or Template Mode

There are two workflows for measuring your part in CAM2 Q. Sometimes you may want to take measurements immediately as you are inspecting a part (**Measure Mode**); other times you may want to plan an entire measurement process before you actually take any measurements (**Template Mode**).



Measure/Template Mode Icon

In CAM2 Q, you can choose either approach by selecting or deselecting the **Measure/Template Mode** command. Select (highlight) the icon, or **Measure** menu command, for **Measure Mode**, and deselect for **Template Mode**. When **Template Mode** is active, a red border and "Template Mode" text appears on the Main Window.

Measure Mode

To measure features in **Measure mode**:

1. On the toolbar, select the **Measure/Template Mode** icon.
2. On the **Measure** menu, or from the **Feature Creator**, click the feature you want to measure (e.g. a plane).
3. The **Measurement Window** appears and you can start adding readings (measurements).

Template Mode

In **Template** mode, you first create the features that you will want to measure. To create these features:


1. On the toolbar, deselect the **Measure/Template Mode** icon.
2. On the **Measure** menu, or in the **Feature Creator** panel, select the feature you want to measure (e.g. a plane). The feature is added to the **Features** panel. The feature name appears in gray, indicating that the feature has not been measured and is not "solved" yet.

To measure in the **Template** mode:

1. In the **Features** panel, select an existing feature to measure.



The sequence in which
you click the features is the sequence
in which you are prompted to measure
the features.

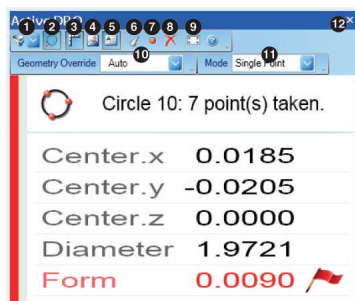
2. You can select features one at a time, or, to select multiple features, press the **CTRL** key on the keyboard while clicking each feature with the mouse.
3. On the toolbar, click the **Add Readings**  icon.
4. The **Measurement Window** appears and you can add readings (measurements) to each feature.

Measurement Window

The **Measurement Window** panel appears each time you choose a measurement command either from the **Feature Creator** panel, the drop-down menus, or by right-clicking a feature in the **Features** panel and selecting **Add Readings**.

The **Measurement Window** consists of three panels:

- **Prompt**—displays prompts in conjunction with the DRO.
- **Device's Digital ReadOut (DRO)**—displays the position of the SMR at any point in space using a three dimensional coordinate system and displays the Form.
- **Image**—displays the image for the current measurement.



The **Measurement Window** panel consists of Setup, Measure, Sizing, and Scanning commands:

Setup

- ① **Show Options:** Allows you to select the coordinate system axes you want to display.
- ② **Geometric Data:** Geometric data and statistics associated with the current measurement.
- ③ **Digital ReadOut (DRO):** The current location of the measurement device's SMR that updates as the SMR moves through space. If there is a communication or device error, or you interrupt and break the laser beam to the SMR, all of the coordinate values display as a line of asterisks (*****).
- ④ **Measurement Image:** The image for the current measurement (QuickTools only).

- ⑤ **Show Prompt:** The text area that contains informational messages relating to the current measurement.

Measuring

- ⑥ **Record Measurement:** Enables you to take a single point reading.
- ⑦ **Record End Click:** Completes the collection of readings.
- ⑧ **Remove Last Reading:** Enables removal of the last reading taken.

Sizing

- ⑨ **Full Screen:** Maximizes the Measurement Window to fill the entire computer screen.

Geometry Override

- ⑩ **Geometry Override:** Allows you to override CAM2 Q's Automatic Feature Recognition by manually selecting a geometry type.

Scanning

- ⑪ **Mode:** Determines the way in which you collect readings. Single Point (the default setting) collects one reading per click of the **G** key. Time Interval and Distance Interval are different methods of scanning points, which means that points are continuously taken as long as the **G** key is pressed.

Recording Readings

Press the **G** key to collect point readings. Press the **H** key to accept the collected readings, which is the End Click.

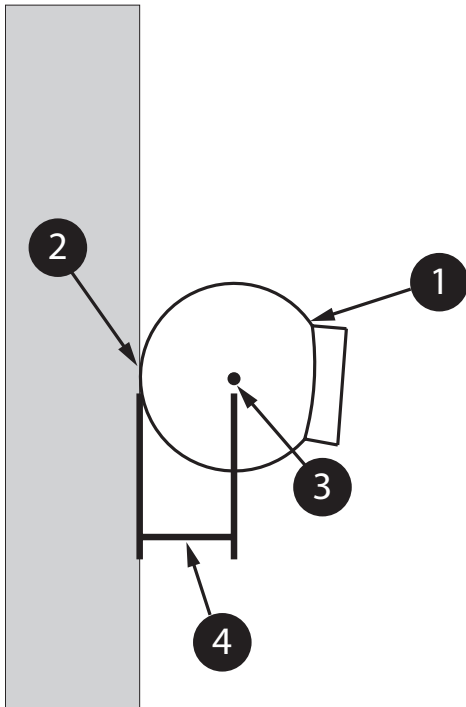


The position of the SMR at the End Click is critical for accurate readings.

Probe Compensation

When measuring with an SMR **1**, the location of the center of the SMR records as a point each time you press the **G** key. Because each SMR has a known diameter, there is a known distance between the center of the SMR and the outer edge of the SMR. This distance needs to be specified (projected) for the point to record in the correct location.

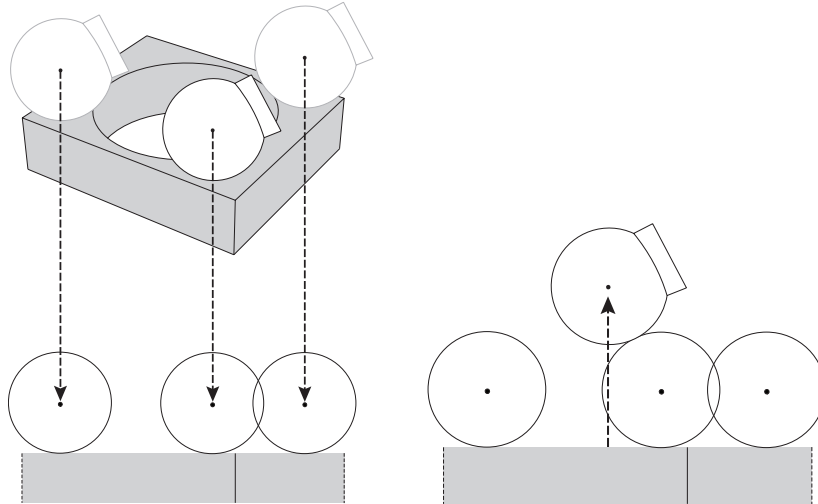
The distance between the SMR point of contact **2** with the surface being measured and the center of the SMR **3** is known as SMR Offset **4**. This transfer of the point from the center of the SMR to the correct location is known as probe compensation.



To make sure the compensation for the SMR radius calculates correctly, the location of the SMR is extremely important when you press the H key.

Plane Compensation

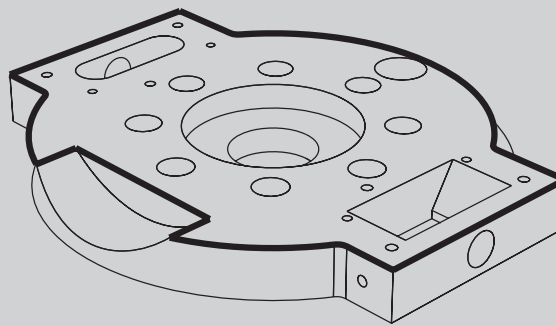
In this example, you are taking three points to identify a plane on a part. This plane can compensate in one of two opposite directions. The correct compensation depends on where you press the **H** key. In this case, press the **H** key above the plane. The plane then compensates in a downward direction the distance equal to the SMR radius.



In this example, the correct location to accept points is above the plane.

ACTIVITY: Measure A Plane In The Measure Now Mode

For this activity, you will measure a plane on the top of the demo part with at least three points and review the Form data.



1. Select Workflow Mode	If necessary, click the Measure/Template Mode icon so that you are in Measure mode.
2. Select Plane	On the Measure menu, click Plane .
3. Collect readings	Use the G key to collect at least three readings.
4. Compensate SMR	Pull the SMR up and away from the part when you finish collecting readings.

5. Accept readings	Press the H key to accept readings.
6. Cancel the measurement command	Press the H key again to cancel the Plane command.

When measuring a plane, SMR location during the End Click is critical for correct placement of the plane.

7. View screen	On the View menu, click Zoom , and All . Or press the E hot key.
----------------	--

Now, remeasure the plane with more than three readings and review the Form data in the Measurement window.



8. Remeasure command	On the Measure menu, click Remeasure . Use the G key to collect more than three readings
9. Compensate SMR	Pull the SMR up and away from the part when you finish collecting readings.
10. Accept readings	Press the H key to accept readings.





Percentage Of Measured Feature Vs. Total Feature Size

Measuring a small percentage of a feature does not provide the most accurate representation of the feature. Since CAM2 Q constructs a best-fit feature from the points you collect, the number of points collected and the spacing of those points directly impact the accuracy of the measurement result.

A common principle applies regardless of the feature you measure. The more points you collect, and the more evenly you distribute them over the part, the more repeatable your measurement result will be. For optimal results, we recommend collecting two times the minimum points plus one. (Minimum number of points x 2 + 1).

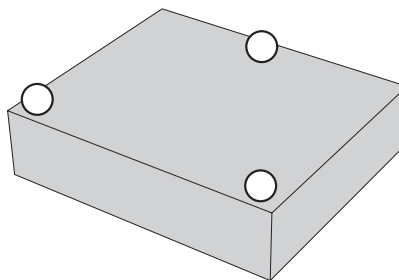
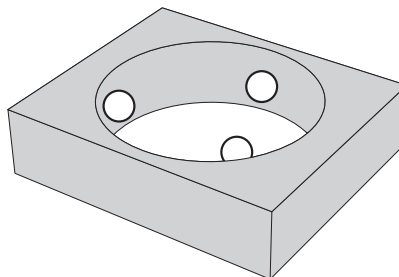
When considering the distribution of the points over the part, remember that even distribution is best. If there are times when only a portion of the feature is accessible, then take as many points as you can on that portion. While this is not the ideal situation, taking as many points as you can will help ensure a better representation of the feature.

Feature	To solve the feature: minimum number of points to collect	For optimal results: suggested minimum number of points to collect
 Plane	3	7
 Line	2	5

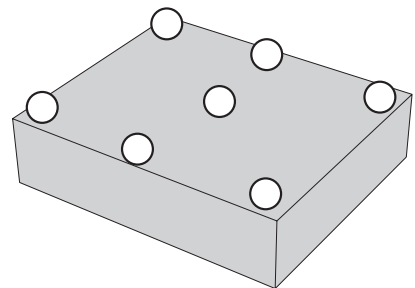
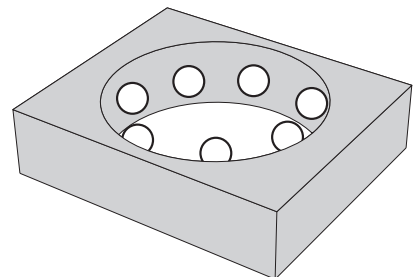
 Circle	3	7
 Sphere	4	9
 Cylinder	6	13
 Cone	6	13

Examples:

Minimum



Minimum: For Optimal Results



ACTIVITY: Add Features To The Features Panel In The Template Mode

For this activity, you will add the following features to the **Features** panel to measure later:

- Four circles
- One sphere

1. Select Workflow Mode

Click the **Measure/Template Mode** icon to switch to **Template** mode.



For the next steps, either click each feature on the **Measure** menu or click a feature from the **Feature Creator** panel.



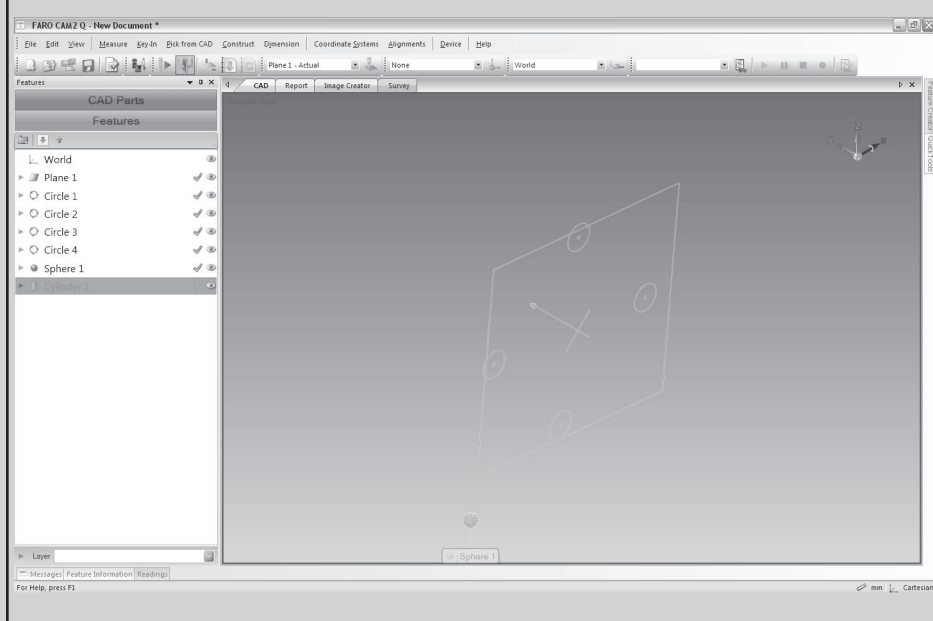
Hot Keys

F10:
Measure Circle
F11:
Measure Cylinder
F12:
Measure Sphere

2. Add circles	Click Circle four times to add these features to the Features panel.
3. Collect readings	Use the G key to collect at least three readings on Circle 1.
4. Compensate SMR	Pull the SMR to the center of the Circle 1 when you finish collecting readings.
5. Collect readings	Use the G key to collect at least three readings on Circle 3.
6. Compensate SMR	Pull the SMR to the center of the Circle 3 when you finish collecting readings.
7. Collect readings	Use the G key to collect at least three readings on Circle 5.
8. Compensate SMR	Pull the SMR to the center of the Circle 5 when you finish collecting readings.
9. Collect readings	Use the G key to collect at least three readings on Circle 7.
10. Compensate SMR	Pull the SMR to the center of the Circle 7 when you finish collecting readings.
11. Cancel Circle Command	Press the H key to cancel the Measure Circle command.
12. Select Sphere	On the Measure menu, click Sphere .
13. Collect readings	Use the G key to collect at least three readings on Sphere 1.
14. Compensate SMR	Pull the SMR away from the surface of Sphere 1 when you finish collecting readings.
15. Cancel Sphere Command	Press the H key to cancel the Measure Sphere command.



Make sure you select the right target and adapter combination.





Hot Keys

F11:
Measure Cylinder

ACTIVITY: Add Features To The Features Panel In The Template Mode

For this activity, you will add the following features to the **Features** panel to measure later:

- One cylinder

1. Select Workflow Mode

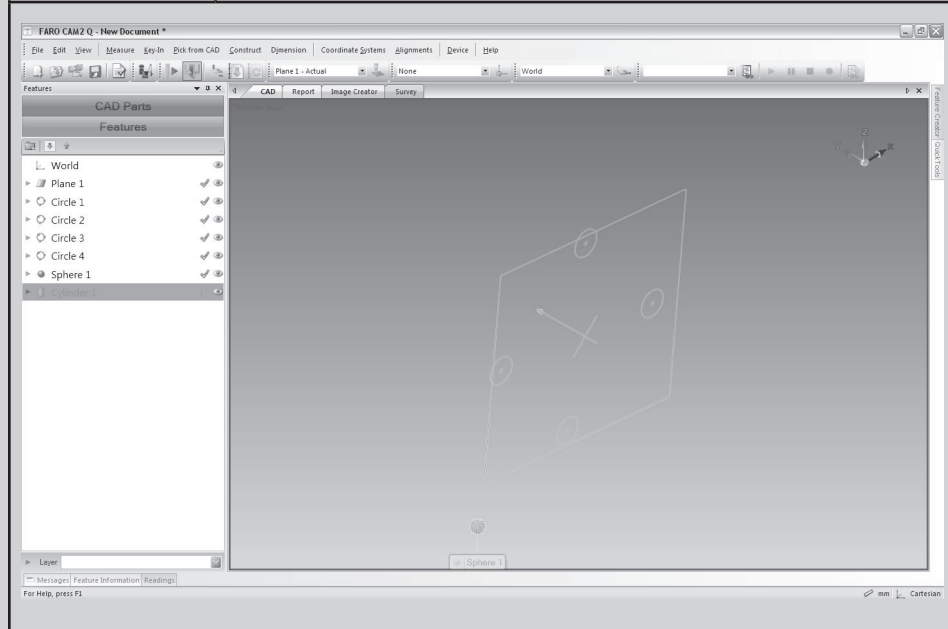
Click the **Measure/Template Mode** icon to switch to **Template** mode.



For the next steps, either click each feature on the **Measure** menu or click a feature from the **Feature Creator** panel.

2. Add cylinder

Click **Cylinder** once to add this feature to the **Features** panel.



ACTIVITY: Measure Feature From The Features Panel

For this activity, you will now add measurements to the cylinder features you just added on the Features panel:

- Cylinder 1

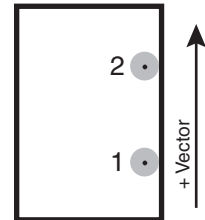
1. Select feature names	On the Features panel, click Cylinder 1 added in Template mode.
2. Select Add Readings	Right-click on the highlighted features, and click Add Readings .
3. Measure Mode	Click the Yes button to change to Measure mode.

Measure the cylinder when prompted in the **Prompt** panel of the **Measurement Window** (i.e., "Collecting readings on Cylinder 1").

4. Measure cylinder	For the cylinder, use the G key to collect at least six readings.
5. Compensate and accept readings	Pull the SMR to the center of the cylinder. Press the H key to accept the readings.



When measuring a cylinder, the first two readings determine the direction of the cylinder.



Renaming a Feature

To rename a feature:

- Double-click a feature on the **Features** panel.
- In the **Feature Properties** panel, rename the feature by highlighting the name and typing in a new name. Click the **Modify** button to continue.

ACTIVITY: Renaming A Feature

For this activity, you will rename the features in the **Feature Properties** panel:

- Circles 1, 3, 5, 7, Cylinder 9, and Sphere A

1. Select Circle 4	Double-click Circle 4 in the Features panel.
2. Type new name	With the feature name highlighted, type <code>Circle 7</code> and click Modify .
3. Select Circle 3	Double-click Circle 3 in the Features panel.
4. Type new name	With the feature name highlighted, type <code>Circle 5</code> and click Modify .
5. Select Circle 2	Double-click Circle 2 in the Features panel.
6. Type new name	With the feature name highlighted, type <code>Circle 3</code> and click Modify .

7. Select Sphere 1	Double-click Sphere 1 in the Features panel.
8. Type new name	With the feature name highlighted, type Sphere A and click Modify .
9. Select Cylinder 1	Double-click Cylinder 1 in the Features panel
10. Type new name	With the feature name highlighted, type Cylinder 9 and click Modify . Click Close to complete the feature renaming..

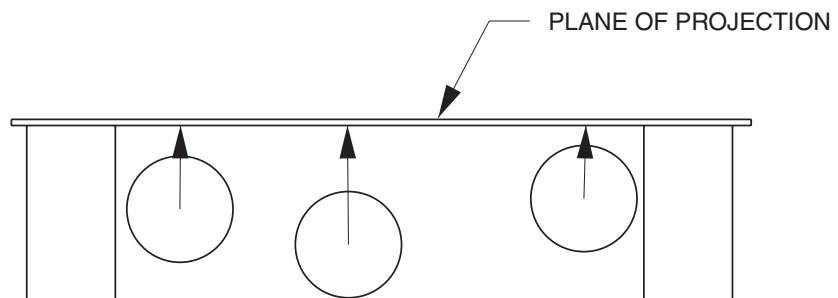
Projection Plane

Plane of Projection for 2D features

In order for the CAM2 Q to determine a 2D feature's relative position in space, these features must lay on a plane. This plane is the plane of projection.

The following 2D features must lay on a plane of projection:

- Circle
- Line (2D line)
- Slot (Round and Rectangular)
- Ellipse
- 2D polyline



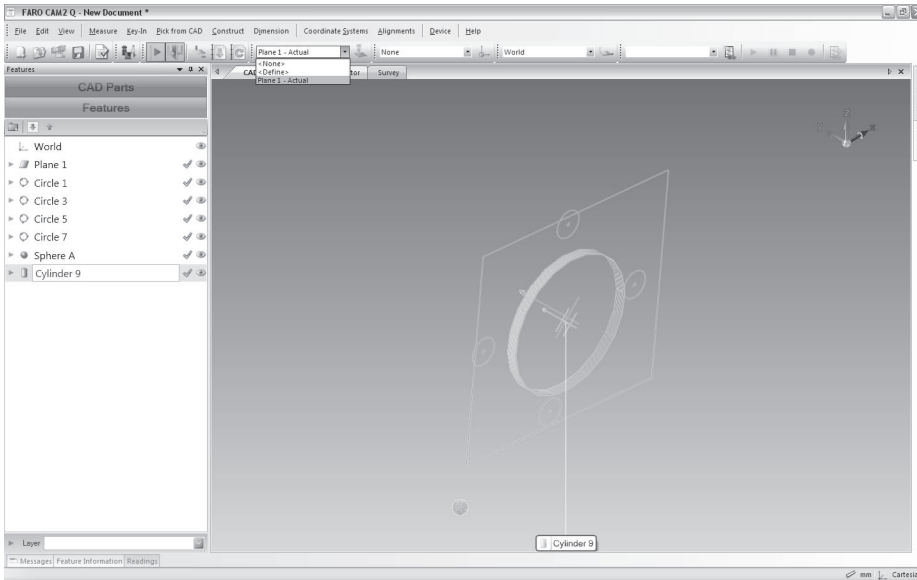
Defining a Plane of Projection

Before measuring a 2D feature, you must first measure a plane to define the plane of projection.

Setting the Plane of Projection

After measuring the plane, you measure the 2D feature, and then set the plane of projection. To set the correct plane of projection:

- On the **Projection Plane** toolbar, in the **Active Projection Plane** drop-down box, select the correct plane.



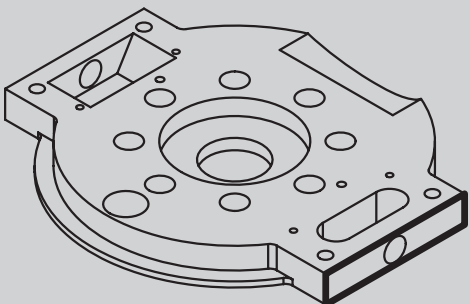
Plane of Projection: None

In some instances, the points collected for a feature will also define the plane of projection for that feature. In these instances, you want to select **None** for the plane of projection:

- On the **Projection Plane** toolbar, in the **Active Projection Plane** drop-down box, select **None**.

ACTIVITY: Measure Features On A New Plane

For this activity, you will measure features, set the plane of projection, and rename the feature.

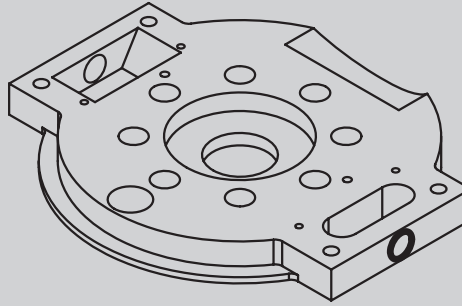
1. Measure Mode	If necessary, click the Measure/Template Mode icon so that you are in Measure mode.
2. Measure Plane	Measure Plane. on Circle 11 side. 



The plane of projection for Circle 11, in the **Active Projection Plane** drop-down box, now shows as **Plane 2**.

3. Measure
Circle 11

Measure Circle 11.



4. Select **Circle 2**

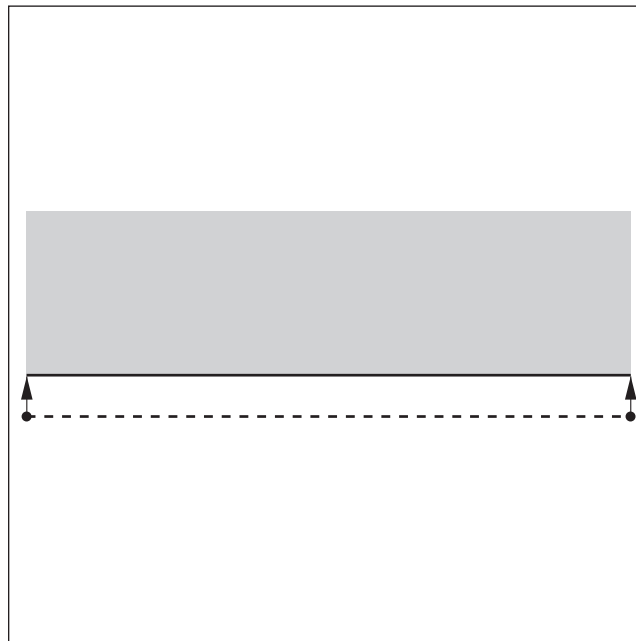
Double-click **Circle 2** in the **Features** panel.

5. Type new name

With the feature name highlighted, type Circle 11.
Click **Modify** and then **Close** to finish.

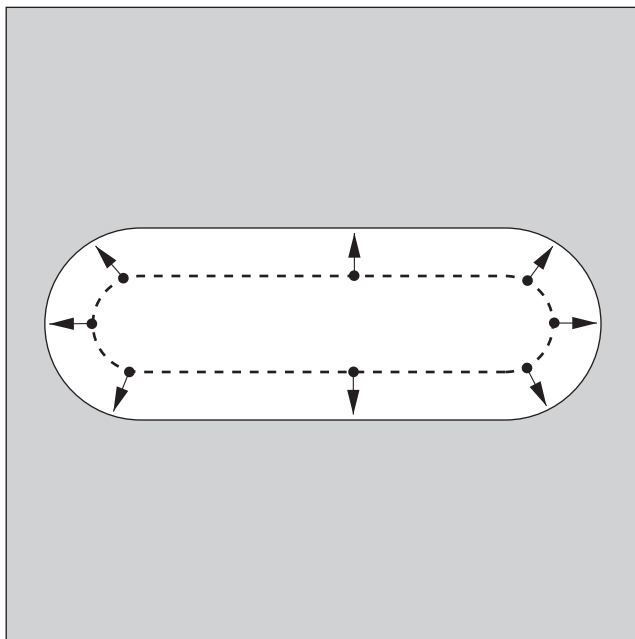
Measuring a 2D Line

When measuring a 2D line, SMR location during the End Click is critical for correct placement of the line. You should correctly pull the SMR away from the surface that represents the line.



Measuring a Round Slot

When measuring a round slot, SMR location during the End Click is critical for calculating the correct diameter. You should correctly pull the SMR to the center of the slot, or away from the outside of the slot in the case of an outside diameter round slot.

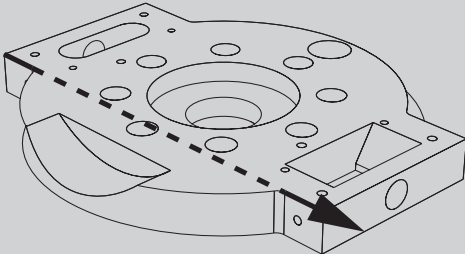
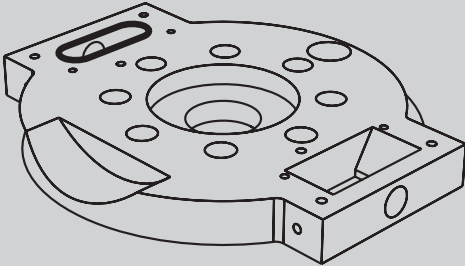
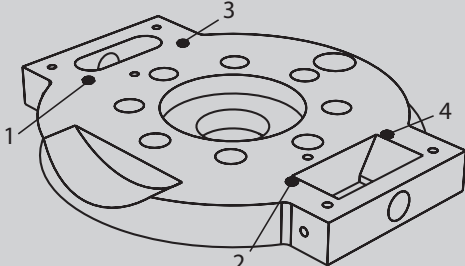


Measuring a Point with No Plane of Projection

When measuring a point, SMR location during the End Click is not critical. The FARO Laser Tracker collects the reading for the point at the center of its SMR, and the End Click simply concludes the taking of readings.

ACTIVITY: Set The Plane Of Projection And Measure Basic Features

For this activity, you will set the plane of projection and measure more basic features in *Measure Now* mode.

1. Select Active Projection Plane	On the Projection Plane toolbar, in the Active Projection Plane drop-down box, select Plane 1 .
2. Measure 2D Line	On the Measure menu, click 2D Line and measure the line. 
3. Measure Round Slot	On the Measure menu, click Round Slot and measure the round slot. 
4. Measure Point	On the Measure menu, click Point and measure the four points by seating the 6mm probe firmly in each 5mm hole. 



Hot Keys

F4:
Measure 2D Line
F2:
Measure Point

ACTIVITY: Save a File

You will use the measurements you have taken to learn about the **Construct** and **Dimension** menus. To make this information easily accessible, you can save a file with your data.

1. Save As	On the File menu, click Save As . The Save As dialog box appears.
2. Browse to CAM2 Q	In the Save In list, using the drop-down menu, select My Documents , and click on the CAM2 Q folder.
3. Create new folder	In the CAM2 Q folder, click the Create New Folder icon. Name the folder [your name]. Then, double-click your folder to open it.
4. Type file name	In the File name box, type <code>Measure.fcd</code> .
5. Save	Click Save .

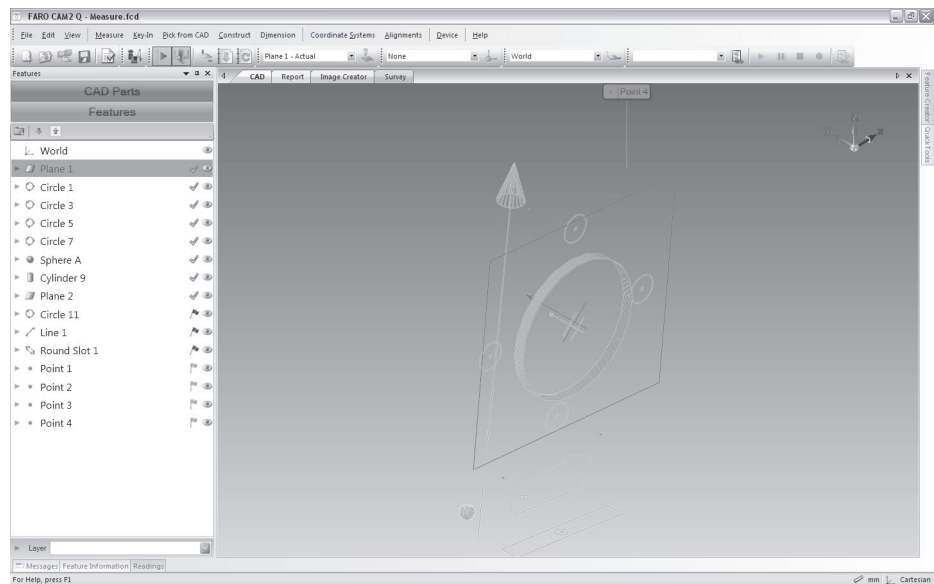
Feature Color

Each type of feature that you add to the measurement file has a unique color that matches the menu color from the **Feature Creator** panel. When you move the mouse pointer over a feature in the **Main Window** or the **Features** panel, the color changes to red. When you select feature from the **Main Window** or the **Features** panel, the color changes to a bright yellow.

Feature Status Icons

To the right of each feature in the Features panel is a status icon. The status icon changes color as you take measurements to indicate:

- You have not taken enough points to define a feature (gray flag icon)
- You have taken enough points to define the feature and it is in tolerance (green checkmark icon)
- You have taken enough points to define the feature and it is out of tolerance (red flag icon /blue flag icon)



Show and Hide Features

To the extreme right of all features is the Feature Visibility icon (eye icon). Click the Feature Visibility icon to hide a feature. Once hidden, the icon appears gray. Click the Feature Visibility icon again to show the feature.

When hidden, features remain in the feature tree but are not shown in the Main Window.

Evaluate Measurement Data

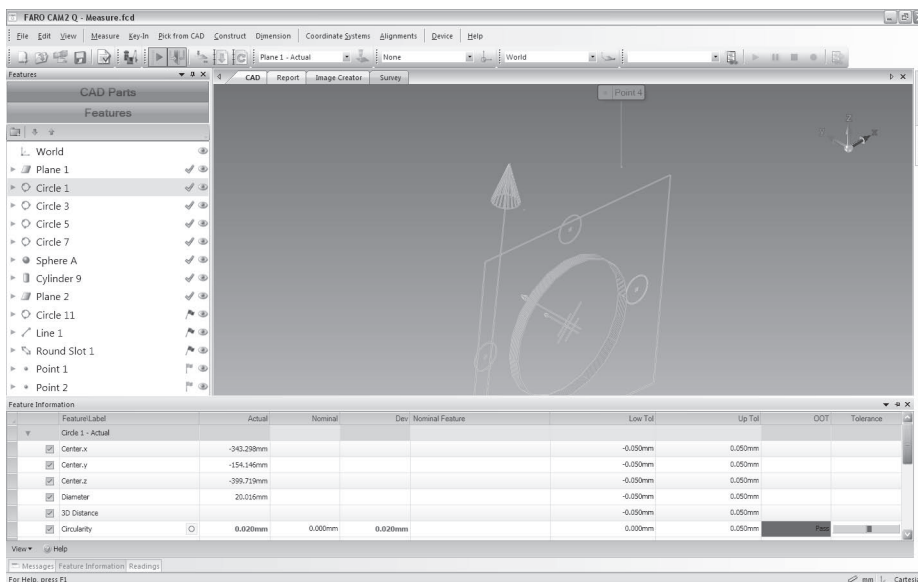
A number of screen elements assist you in assessing the quality of the part or feature you are measuring.

- **Form** is a measure of the geometric accuracy of the feature. Examples are the circularity of a circle, the straightness of a line, and the flatness of a plane. The measured feature's label shows the form value of the feature.
- **In Tolerance** is defined when you establish your nominals and tolerances. If a feature is in tolerance, the icon next to the feature in the **Features** panel will be a green check.
- **Out of Tolerance** is defined when you establish your nominals and tolerances. If a feature is out of tolerance, the icon next to the feature in the **Features** panel will be a red or blue flag.

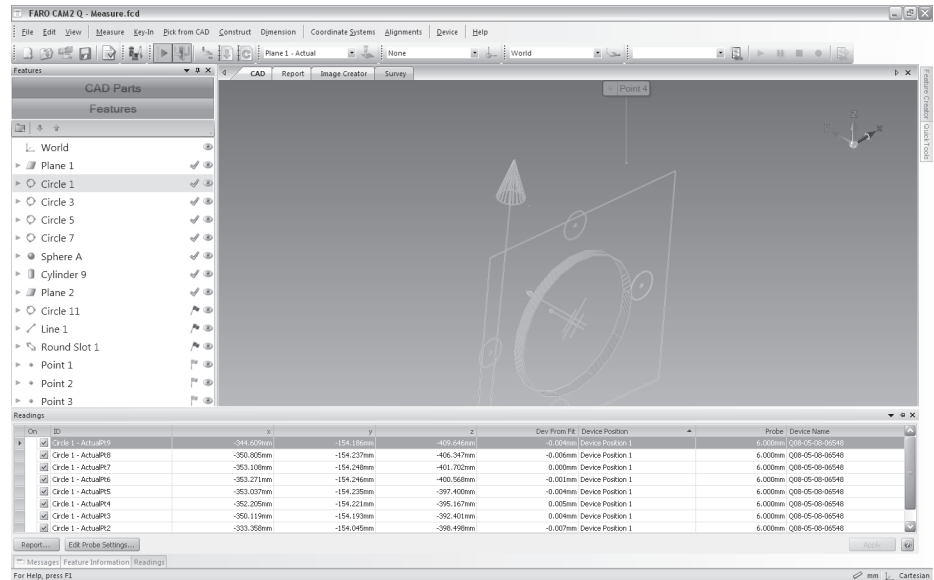


Graphical tolerances use

color gradients to show more detail about the actual number in a tolerance band. Blue and Red become lighter as the value approaches the tolerance band edge. Green becomes darker as the actual number approaches the exact nominal value.



- **Readings** shows the deviation from fit for each point taken.



Make sure that you do not remove a reading need to solve the feature.

Adding/Removing Readings

Removing Readings from a Feature's Calculation

To remove a reading from a feature's calculation:

- On the **Readings** panel, clear the check box in the **On** column. Click the **Apply** button to re-calculate the feature with the remaining readings.

Adding Readings To An Existing Feature

To add readings to a feature:

- Right-click the feature on the **Features** panel or the on the image in the **Main Window**, then click **Add Readings**.
- Press the **G** key and take more readings.

Permanently Removing Readings from a Feature

To permanently delete a reading from a feature:

- Press the **Backspace** key while measuring that feature. One reading is removed each time you press the **Backspace** key; or
- On the **Readings** panel, select the reading you want to remove, and press the **Delete** key.



After removing a reading, you may want to remeasure that specific area of the part to rule out user, device, or part error.

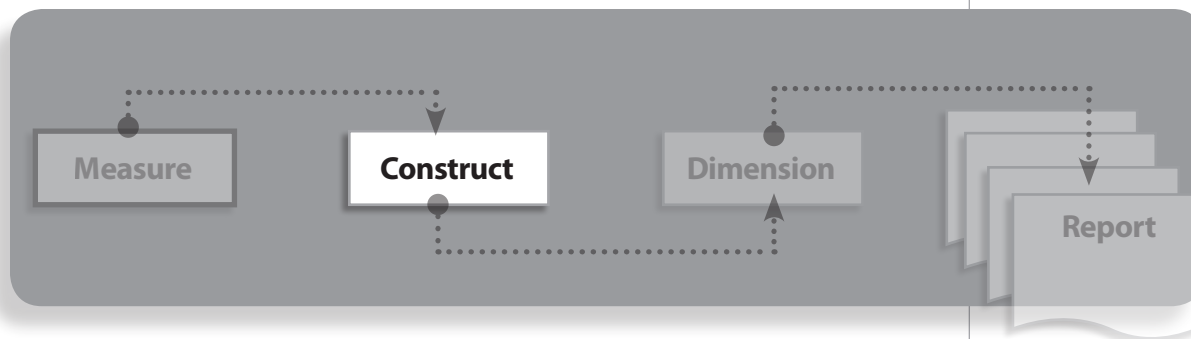
Measuring Mode: Scan Mode

So far, when measuring, you have taken single points. Another way to take points is by scanning, which takes points continuously while you press the **G** key.

You can enable scanning by selecting a mode in the **Measurement Window** panel which appears when selecting a measurement command. The three modes are:

- **Single Point:** press the **G** key to collect a single reading.
- **Time Interval:** press the **G** key to start the time interval. Collects single readings over time.
- **Distance Interval:** press the **G** key to start the distance interval. Collect a single reading when the SMR moves a distance.

Lesson 2: Construct



Now that you know how to measure features, let's learn how to construct a feature. A construction allows you to create features that you cannot measure directly. Sometimes points or other features are specified on a drawing, but do not actually exist on the part, e.g. a bolt-hole circle.

Lesson Objective

With the assistance of the **Help** menu, you will be able to use all of the functions within the **Construct** menu. You will be able to:

- Identify point-, line-, and plane-reducibility for each feature type.
- Identify why constructions are needed.
- Locate, review, and evaluate feature construction quality.

Why are Constructions Needed?

Constructions allow you to create features that you cannot directly measure, such as a bolt-hole circle.

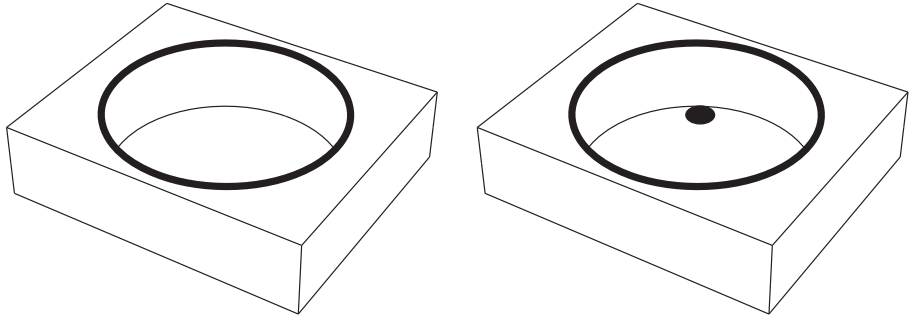
The activities in this Lesson allow you to practice some commonly used construction commands.

As we discuss and practice using the **Construct** menu, you will use features you saved in the Measure lesson.

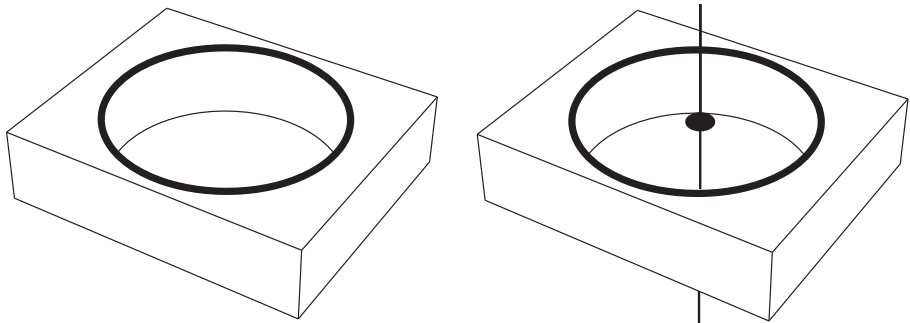
Feature Reducibility

Feature Reducibility means that a part of a feature can be used for constructions and dimensions. For example, a circle has three reducible parts.

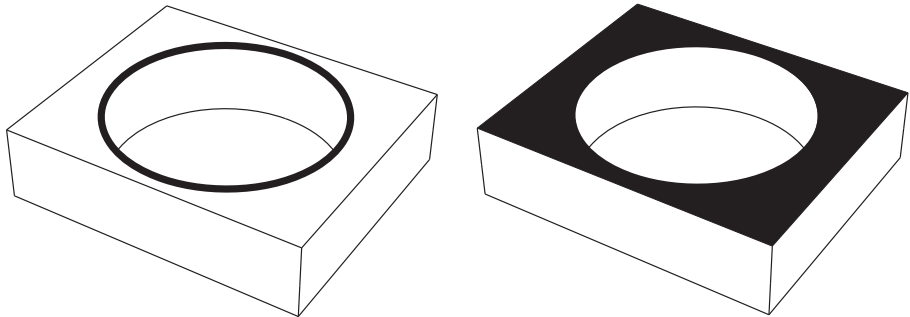
A circle is **Point-Reducible**, which means it can be used like a point for constructions, or dimensions. The point of a circle is its center point.



A circle is **Line-Reducible**. The line of a circle is perpendicular to the circle's plane through the center point.

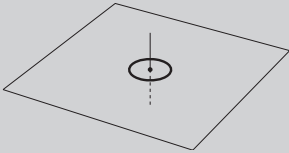
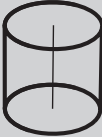
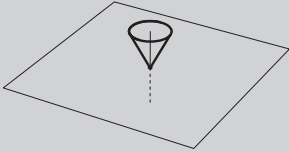
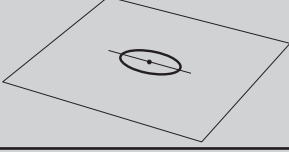
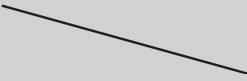
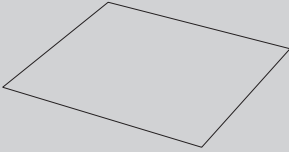

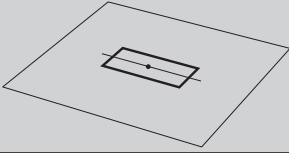
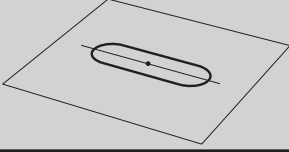



A circle is **Plane-Reducible**. The plane of a circle is its plane of projection.



ACTIVITY: Feature Reducibility Exercise

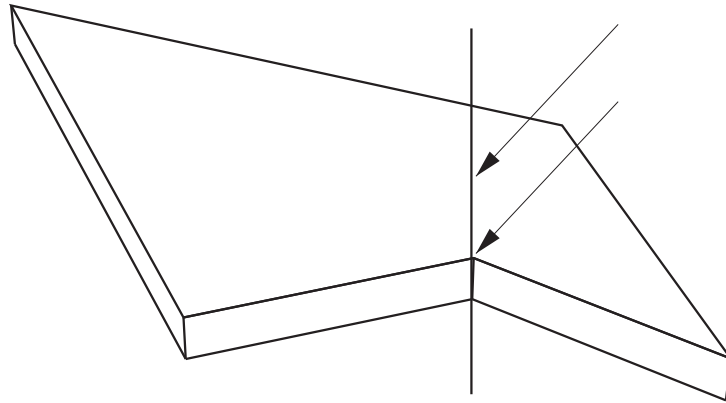
Look at each feature and determine if it is point-, line-, or plane-reducible. Some features may be reducible to more than one type of feature.

	Point	Line	Plane	
Circle				
Cylinder				
Cone				
Ellipse				
Line				
Plane				
Point				
Rectangular Slot				
Round Slot				
Sphere				

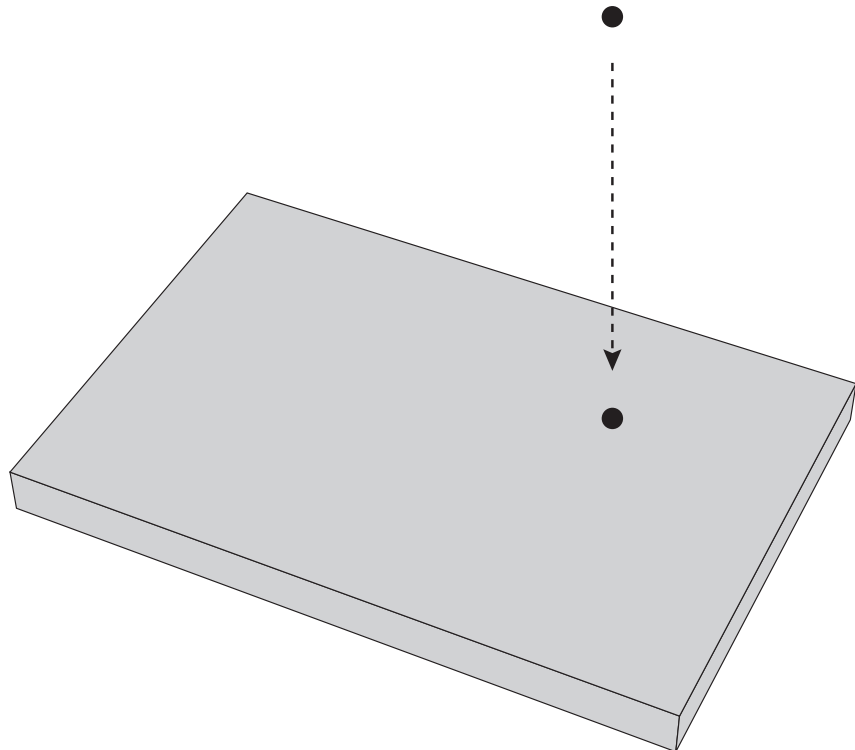
Point Constructions

Four of the most commonly used point constructions are **Intersection**, **Projection**, **Bisection** and **Key-In**.

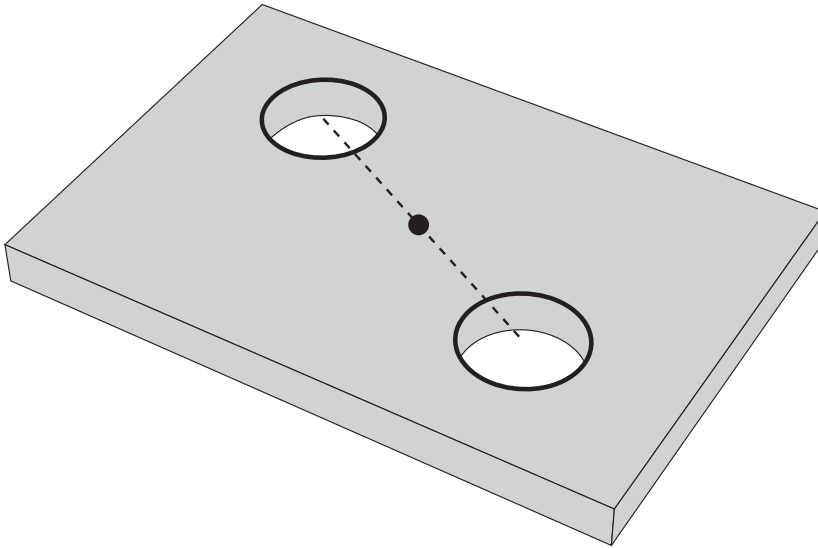
- **Intersection** allows you to construct a point from the intersection of two features or three planes.



- **Projection** allows you to construct a point and project it onto a feature.



- **Bisection** allows you to construct a point in the center of two point-reducible features.



- **Key-In** allows you to construct a point by entering the location of the point.

Key-in requires the input of nominals which we will discuss later in the workbook.

ACTIVITY: Open A Saved File

1. File Open	On the File menu, click Open .
2. My Documents	In the Look In drop-down list, select My Documents .
3. Select your folder	Double-click on the CAM2 Q folder, and then double-click the your folder.
4. Select Measure.fcd	Select Measure.fcd
5. Open	Click Open .

ACTIVITY: Construct Point By Intersection Of Two Features

For this activity, you will construct a point from the intersection of Plane 1 and Cylinder 9.

1. By Intersection	On the Construct menu, click Point , then click By Intersection . The Construct Point By Intersection dialog box appears.
2. Name the point	In the Name box, enter <code>Intersection Point</code> .
3. Click Two Features	Click the Two Features option button.
4. Select first feature	In the first Feature list, select Plane 1 .

5. Select second feature	In the second Feature list, select Cylinder 9 .
6. Treat as Line	In the treat as list, select Line .
7. Create	Click Create to view the result.
8. Close	Click Close to close the dialog box.

ACTIVITY: Construct Point By Projection

For this activity, you will construct a point from the projection of Sphere A to Plane 1.

1. By Projection	On the Construct menu, click Point , then click By Projection . The Construct Point By Projection dialog box appears.
2. Name the point	In the Name box, enter <code>Projection Point</code> .
3. Select point	In the Point list, select Sphere A .
4. Select feature to project to	In the Project To list, select Plane 1 .
5. Create	Click Create to view the result.
6. Close	Click Close to close the dialog box.

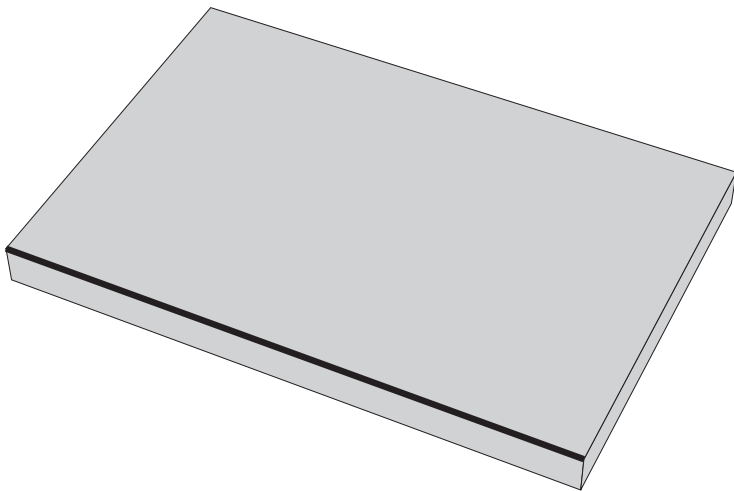
ACTIVITY: Construct Point By Bisection

For this activity, you will construct a point halfway between two points.

1. By Bisection	On the Construct menu, click Point , then click By Bisection . The Construct Point By Bisection dialog box appears.
2. Name the point	In the Name box, enter <code>Bisection Point</code> .
3. Select first feature	In the Feature 1 list, select Point 1 .
4. Select second feature	In the Feature 2 list, select Point 2 .
5. Create	Click Create to view the result.
6. Close	Click Close to close the dialog box.

Line Constructions

One of the most commonly used line constructions is ***Intersection of Two Planes***.



ACTIVITY: Construct Line By Intersection Of Two Planes

For this activity, you will construct a line using the intersection of Plane 1 and Plane 2.

1. <i>By Intersection of Two Planes</i>	On the Construct menu, click Line , then click By Intersection of 2 Planes . The Construct Point By Intersection of Two Planes dialog box appears.
2. Name the line	In the Name box, enter <code>Constructed Line 1</code> .
3. Select first feature	In the Feature 1 list, select Plane 1 .
4. Select second feature	In the Feature 2 list, select Plane 2 .
5. Create	Click Create to view the result.
6. Close	Click Close to close the dialog box.

To edit any of these features, select the feature in the **Features** panel, double-click, make changes in the **Feature Properties** panel, and click **Modify**.

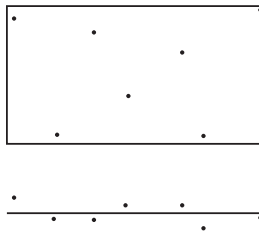
Plane Constructions

Three of the most commonly used plane constructions are **Best Fit**, **By Offset** and **Perpendicular**.

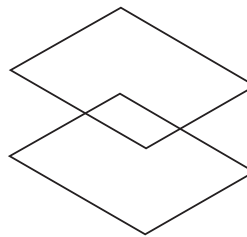


You can preview a "By best Fit" feature before you create it, using a graphic feature in the Main window, and feature data in all of the By Best Fit dialog boxes.

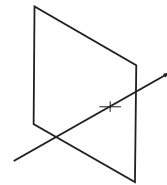
- **Best Fit** enables you to construct a plane by fitting it through point-reducible features.
- **By Offset** enables you to construct a plane at a known distance parallel to an existing plane. You can locate the plane by either:
 - ➔ Moving the plane by an absolute offset.
 - ➔ Placing it through another point.
 - ➔ Offsetting the plane along a normal (line).
- **Perpendicular** enables you to construct a plane perpendicular to a line.



Best Fit



By Offset



Perpendicular

ACTIVITY: Construct A Best Fit Plane

For this activity, you will construct a best fit plane using the previously measured four circles.

1. By Best Fit	On the Construct menu, click Plane , then click By Best Fit . The Construct Plane By Best Fit dialog box appears.
2. Name the plane	In the Name box, enter <code>Best Fit Plane</code> .
3. Select Circles 1, 3, 5, and 7	In the Select Entities to Fit Through list, hold down the Ctrl key and select Circle 1 , Circle 3 , Circle 5 , and Circle 7 .
4. Create	Click Create to view the result.
5. Close	Click Close to close the dialog box.

ACTIVITY: Construct Plane By Offset

For this activity, you will construct a plane parallel to the best fit plane.

1. By Offset	On the Construct menu, click Plane , then click By Offset . The Construct Plane By Offset dialog box appears.
2. Name the plane	In the Name box, enter <code>Offset Plane</code> .
3. Select base feature	In the Base Feature list, select Best Fit Plane .
4. Select Offset Along Normal and select feature.	Select the Offset Along Normal option button. Select Best Fit Plane from the drop-down list.
5. Enter distance	In the Distance box, enter either <code>20.00 (mm)</code> or <code>0.7874 (in)</code>
6. Create	Click Create to view the result.
7. Close	Click Close to close the dialog box.

ACTIVITY: Construct Plane Perpendicular

For this activity, you will construct a plane perpendicular to the front edge.

1. Perpendicular	On the Construct menu, click Plane , then click Perpendicular . The Construct Plane Perpendicular dialog box appears.
2. Name the plane	In the Name box, enter <code>Perpendicular Plane</code> .
3. Select Line and select feature	Select the Line option button. Select Line 1 from the drop-down list.
4. Select point	In the Point box, select Circle 3 .
5. Create	Click Create to view the result.
6. Close	Click Close to close the dialog box.

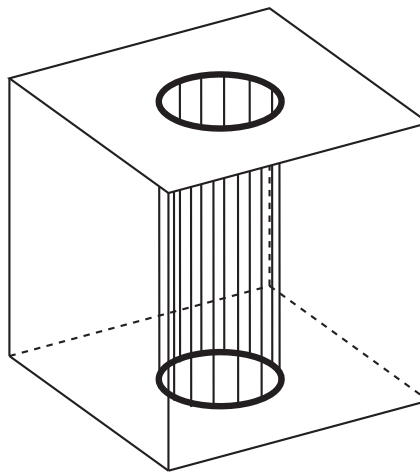
Circle Constructions

Three of the most commonly used circle constructions are **Plane Intersect**, **Best Fit** and **Key In**.

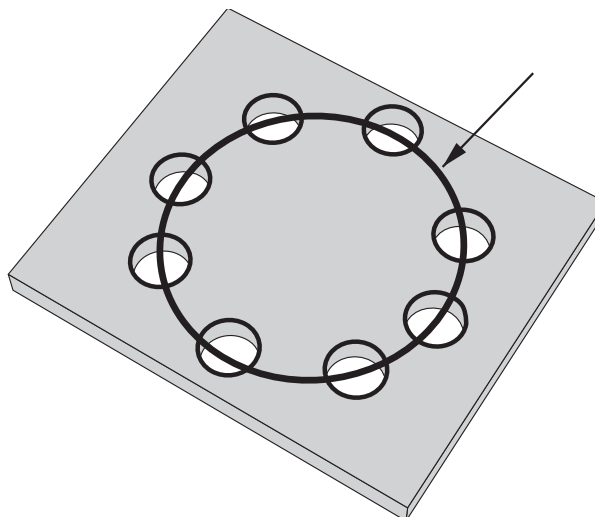
- **Plane Intersect**—allows you to construct a circle from the intersection of a plane and a feature, such as a cone or cylinder.
- **Best Fit**—allows you to construct a bolt circle pattern from previously measured circles.
- **Key-In**—allows you to construct a circle by entering the name, location, diameter and normal vector.

Next, we will discuss **Plane Intersect** and **Best Fit**. Since **Key-In** uses nominals, we will discuss that in the Nominals lesson.

Plane Intersect



Best Fit



ACTIVITY: Circle Intersect

For this activity, you will construct a circle using the intersection of a plane and a feature.

1. By Intersection of Plane and a Feature	On the Construct menu, click Circle , then click By Intersection of Plane and a Feature . The Construct Circle By Intersection of Plane and a Feature dialog box appears.
2. Name the circle	In the Name box, enter <code>Circle by Intersection</code> .
3. Select first feature	In the Feature 1 list, select Plane 1 .
4. Select second feature	In the Feature 2 list, select Cylinder 9 .
5. Lock Plane of Circle	Select To Plane .
6. Create	Click Create to view the result.
7. Close	Click Close to close the dialog box.

ACTIVITY: Best Fit

For this activity, you will construct a best fit bolt-hole pattern using three of the previously measured four circles.

1. By Best Fit	On the Construct menu, click Circle , then click By Best Fit . The Construct Circle By Best Fit dialog box appears.
2. Name the circle	In the Name box, enter <code>Bolt Circle</code> .
3. Select entities to fit through	In the Select Entities to Fit Through list, hold down the Ctrl key and select Circle 1 , Circle 3 , and Circle 5 .
4. Click Use Plane and select Plane 1	Make sure the Use Plane check box is selected and in the Use Plane list, select Plane 1 .
5. Create	Click Create to view the result.
6. Close	Click Close to close the dialog box.

ACTIVITY: Review And Evaluate Data

(Form And Diameter Of Constructed Features)

Now, let us review the data of the Bolt Circle.

1. Select Bolt Circle	Select the Bolt Circle in the Features panel.
2. Feature Information panel	At the bottom of the CAM2 Q window, click the Feature Information tab to open the Feature Information panel.
3. Review data	Note the data of the Bolt Circle in the Feature Label column. ☞ The Circularity (Form) will be "0" - because three points are all that is required to define a circle, the form of a circle defined by three points will always be perfect.
4. Note the diameter	Note the Diameter for reference when you add another circle in the next activity.

Form: _____

Diameter: _____

ACTIVITY: Edit The Data For Best Fit Constructed Circle

Edit the Bolt Circle.


1. Bolt-Circle Properties	In the Features panel, double-click Bolt Circle .
2. Select entities to fit through	In the Select Entities to Fit Through list, Ctrl + click Circle 7 .
3. Modify	Click Modify to view the result.
4. Close	Click Close to close the dialog box.

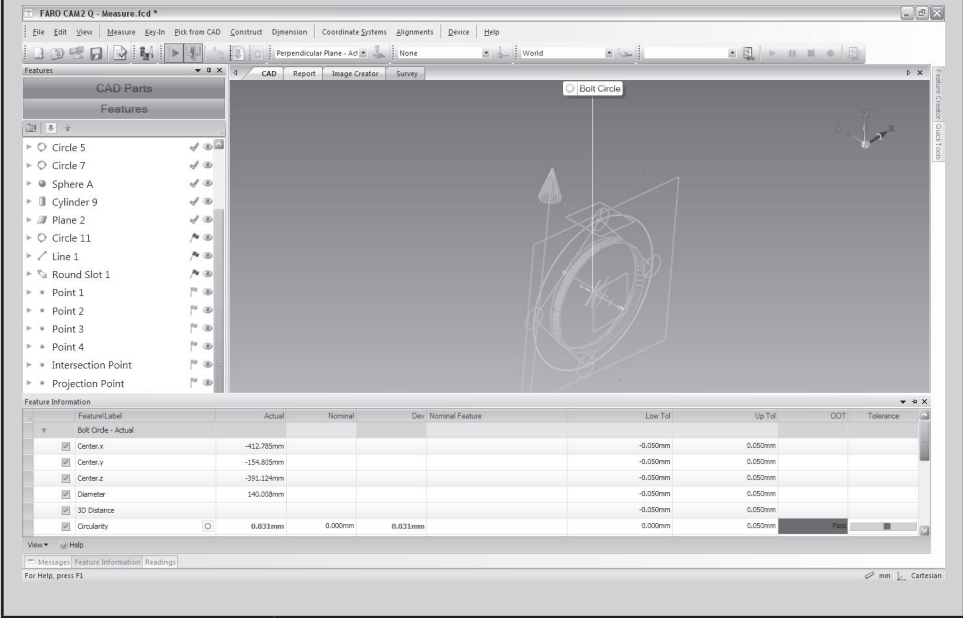
ACTIVITY: Review The Data For The Best Fit Constructed Circle

For this activity, you will compare the data of the edited Bolt Circle to the previous Bolt Circle data.

Form: _____

Diameter: _____

1. Select Bolt Circle	On the Features panel, click Bolt Circle .
2. Feature Information panel	Open the Feature Information panel.
3. View data	Note the updated data of the edited Bolt Circle.  Since the circle is defined by a best fit using more than three points, it will most likely show less than perfect form. Additionally, the diameter of the circle will be slightly different due to the change in form.

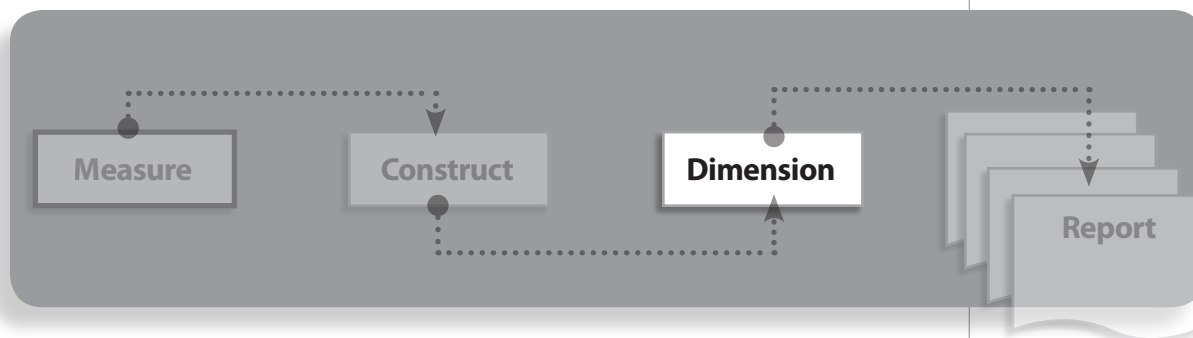


ACTIVITY: Save A File

You should save your work to this point.

1. Save As	On the File menu, click Save As . The Save As dialog box appears.
2. My Documents folder	In the Save In drop-down list, select My Documents .
3. Your folder	Double-click on the CAM2 Q folder and browse to your folder .
4. Enter Construct.fcd	In the File name box, type Construct.fcd.
5. Save	Click Save .

Lesson 3: Dimension



The third part of the **Basic Measurement Strategy** is **Dimension**. A dimension describes the relationship between two or more features, e.g. the distance between or the angle between features.

Lesson Objective

With the assistance of the **Help** menu, you will be able to use all of the functions within the **Dimension** menu. You will be able to:

- Identify why dimensions are needed.
- Locate dimension data for evaluation.
- Edit features used to create a dimension.

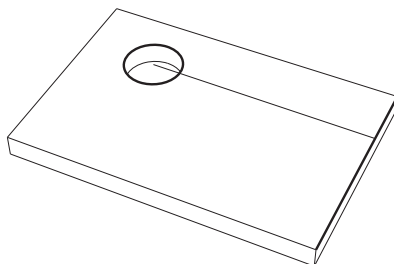
Types of Dimensions

There are two types of dimensions available in CAM2 Q: **Length** and **Angle**.

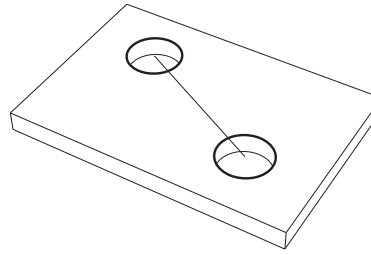
Length Dimensions

Two of the most commonly used length dimensions are **Point to Line** and **Point to Point**.

- **Point to Line** calculates the relationship between a point and a line.



- **Point to Point** calculates the relationship between a point and a point.



ACTIVITY: Open A Saved File

1. File Open	On the File menu, click Open .
2. My Documents	In the Look In drop-down list, select My Documents .
3. Select your folder	Double-click on the CAM2 Q folder, and then double-click the your folder.
4. Select Construct.fcd	Select Construct.fcd
5. Open	Click Open .

ACTIVITY: Dimensioning a Length from Features

For this activity, you will obtain the length between two features, a point (Sphere A) and a line (2D Line 1).

1. Length from Features	On the Dimension menu, click Length From Features . The Dimension Length From Features dialog box appears.
2. Open Help	Click the Help button. The CAM2 Q help file opens to the Length: from Features topic. Review the length examples and close the help file.
3. Enter name	In the Name box, enter <code>Point to Line</code> .
4. Select Sphere A and treat as Point	In the first feature list, select Sphere A . Then in the treat as list, select Point .
5. Select 2D Line 1 and treat as Line	In the second feature list, select Line 1 . Then in the treat as list, select Line .
6. Create	Click Create to view the result.
7. Close	Click Close to close the dialog box.
8. View results	In the Features panel, select Point to Line and open the Feature Information panel. Note the length.

Length: _____



You are using the concept of feature reducibility to determine how to "treat" the feature.

ACTIVITY: Dimensioning Length from Features

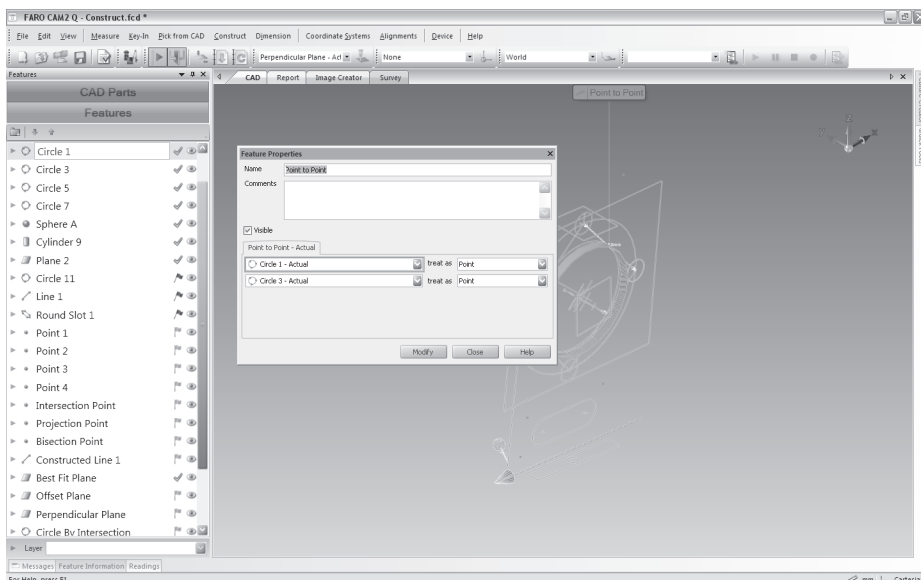
For this activity, you will obtain the length between two features, a point (Circle 1) and a point (Circle 3).

1. Length from Features	On the Dimension menu, click Length From Features . The Dimension Length From Features dialog box appears.
2. Enter name	In the Name box, enter <code>Point to Point</code> .
3. Select Circle 1 and treat as Point	In the first feature list, select Circle 1 . Then in the treat as list, select Point .
4. Select Circle 3 and treat as Point	In the second feature list, select Circle 3 . Then in the treat as list, select Point .
5. Create	Click Create to view the result.
6. Close	Click Close to close the dialog box.
7. View results	In the Features panel, select Point to Point and open the Feature Information panel. Note the length.

Length: _____

Editing Features

Sometimes when you will want to change the features you have selected to create a dimension. Rather than reconstruct all of the feature selections, you can do this using an editing dialog box.



ACTIVITY: Editing Features To Create A Line

For this activity, you will edit features to create a line.

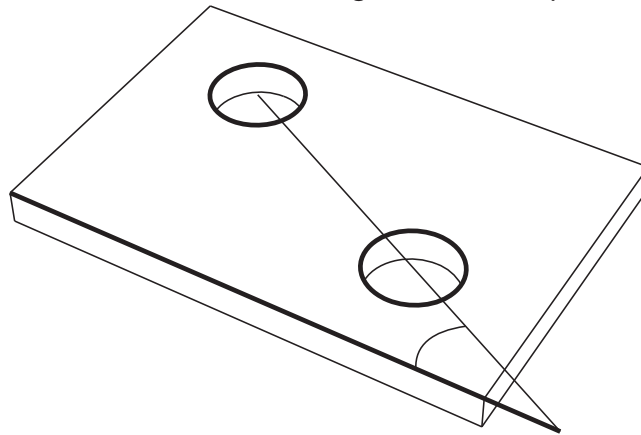
1. Select feature	In the Features panel, double-click Point to Point .
2. Edit Properties	The Feature Properties dialog box appears.
3. Select Circle 5	Using the drop-down menu, replace Circle 3 with Circle 5 .
4. Complete the change	Click Modify .
5. Close	Click Close to close the dialog box.
6. View results	In the Features panel, select Point to Point and open the Feature Information panel. Note the length changes as a reflection of the change in features selected.

Length: _____

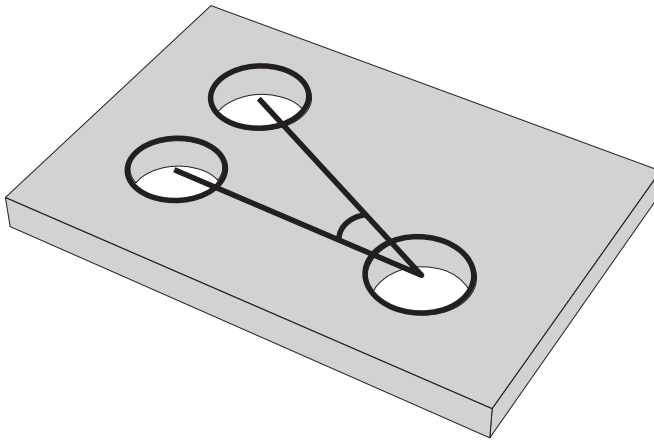
Angle Dimensions

Two of the most commonly used angle dimensions are **Line to Line** and **Apex**.

- **Line to Line** calculates the angular relationship between two lines.



- **Apex** calculates the angular relationship between two points with a point-reducible feature as the apex.



ACTIVITY: Dimensioning Angles

For this activity, you will dimension an angle from features.

1. Dimension Angle From Features	In the Dimension menu, click Angle From Features . The Dimension Angle From Features dialog box appears.
2. Open Help	Click the Help button. The CAM2 Q help file opens to the Angle: from Features topic. Review the differences between the two feature and three feature examples, and close the CAM2 Q help file.
3. Enter name	In the Name box, enter <code>Line to Line</code> .
4. Two Features option	Click the 2 Features option button.
5. Select 2D Line 1	In the Feature 1 list, select Line 1 .
6. Select Constructed Line 1	In the Feature 2 list, select Constructed Line 1 .
7. Create	Click Create to view the result.
8. Close	Click Close to close the dialog box.

ACTIVITY: Dimensioning Angles

For this activity, you will obtain the angle between Circle 1 and Circle 3 using Bolt Circle as the apex.

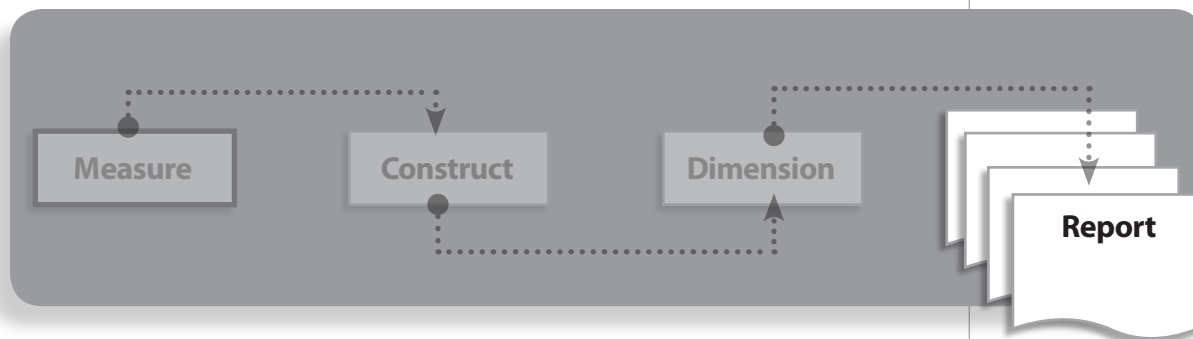
1. Dimension Angle From Features	In the Dimension menu, click Angle From Features . The Dimension Angle From Features dialog box appears.
2. Enter name	In the Name box, enter <code>Apex</code> .
3. Click 3 Points	Click the 3 Points option button.
4. Select first point	In the first Point list, select Circle 1 .
5. Select second point	In the second Point list, select Circle 3 .
6. Select apex	In the Apex list, select Bolt Circle .
7. Create	Click Create to view the result.
8. Close	Click Close to close the dialog box.

ACTIVITY: Save A File

To make this information easily accessible, save a file with the data you have collected.

1. Save As	On the File menu, click Save As . The Save As dialog box appears.
2. My Documents Folder	In the Save In drop-down list, select My Documents .
3. Your folder	Double-click on the CAM2 Q folder and browse to your folder .
4. Enter name	In the File name box, type <code>Dimension.fcd</code> .
5. Save	Click Save .

Lesson 4: Report



Now that you have captured all of your data, the reporting function is an easy way to select, display, and save your data.

Lesson Objective

With the assistance of the **Help** menu, you will be able to create standard reports. You will be able to:

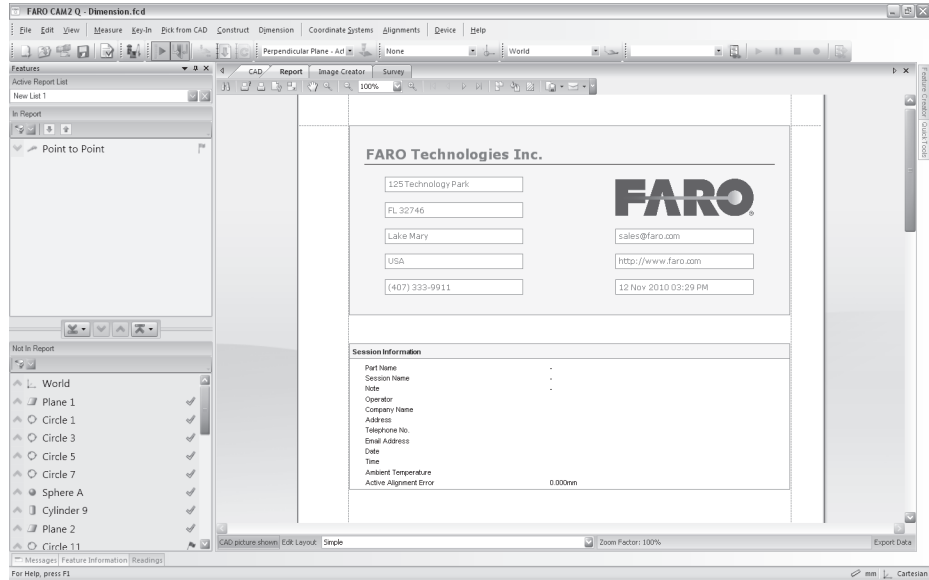
- Customize report content.
- Save a report.
- Locate and open saved reports.

Some of the common report customizations you will use are:

- Add or Remove Features
- Add or Remove a Picture
- Save a customized list of features
- Choose a report style

Reporting: Text Reports, Logos, Available Customizations

You access **Reports** using the **Report** tab located above the Main window. The **Report Window** appears and the **Active Report** List opens in the **Feature** panel. You can customize, export, or e-mail CAM2 Q reports in a variety of file types.



Automatically add features to the In Report list by selecting features in the Features panel before clicking the Report tab

Double-click any feature in the **Not In Report** list to move it to the **In Report** list. Double-click any feature in the **In Report** list to move it to the **Not In Report** list.

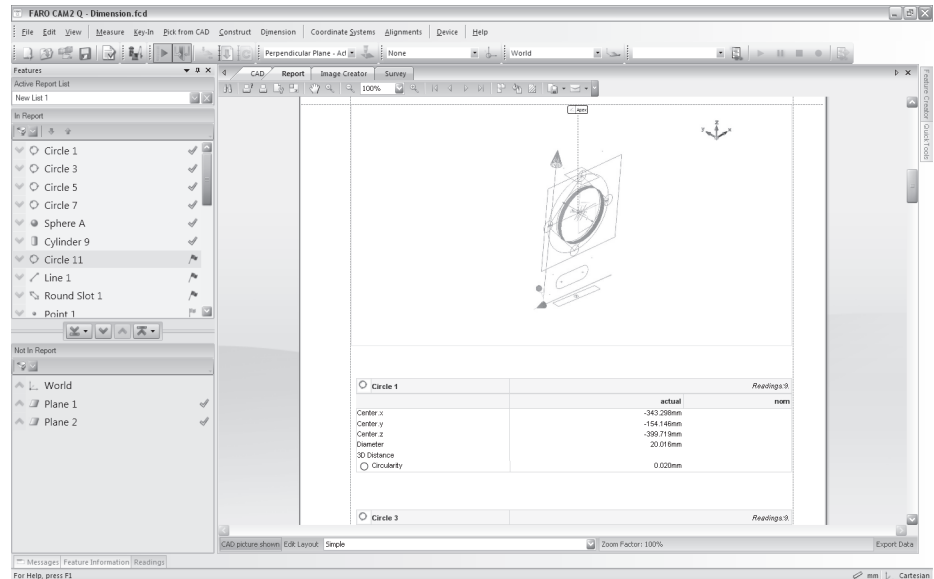
There are several actions which you can access using the **Report Window** icons. (from left to right)

- 1. Search:** Searches the report for key words.
- 2. Printer Preferences:** Sets printer preferences.
- 3. Print:** Sends the report to the printer.
- 4. Page Setup:** Changes the paper size, margins, and whether the printout will be in portrait or landscape.
- 5. Scale:** Sets the size of the data on a printed page.
- 6. Hand Tool:** Grabs the report and moves it in the window.
- 7. Magnifier:** If the view is set to see all pages of a multiple page report, this selects one of the pages for a close up view.
- 8. Zoom Out:** Zooms out each time you select the icon.
- 9. Zoom %:** Selects a percentage to increase or decrease the screen size.

- 10. Zoom In:** Zooms in each time you select the icon.
- 11. First Page:** Scrolls to the first page of the report.
- 12. Previous Page:** Scrolls to the previous page of the report.
- 13. Next Page:** Scrolls to the next page of the report.
- 14. Last Page:** Scrolls to the last page of the report.
- 15. Multiple Page:** Sets the number of pages that display.
- 16. Color:** Sets the background or page color of the report.
- 17. Watermark:** Overlays an image, text, or both onto a report.
 - You can add text to be watermarked. You can also choose the text direction, font, color, size, and bold or italic.
 - You can add a picture or graphic to be watermarked. Use the **Load Image** button to browse for a picture file. Use the **size mode**, **horizontal** and **vertical alignment** to set the position of the picture.
 - Both **Text Watermark** and **Picture Watermark** have a slider bar that allows for the adjustment of the transparency of the watermark.
 - Select or clear the **Position** radio buttons to position the watermark in front or behind the report text.
 - **Paper Range** Selects the pages on which the watermark will appear.
- 18. Export Document:** Saves the report in specific file formats.
- 19. Send via E-mail:** Sends a report via e-mail in specific file formats.

Add or Remove Features on a Report

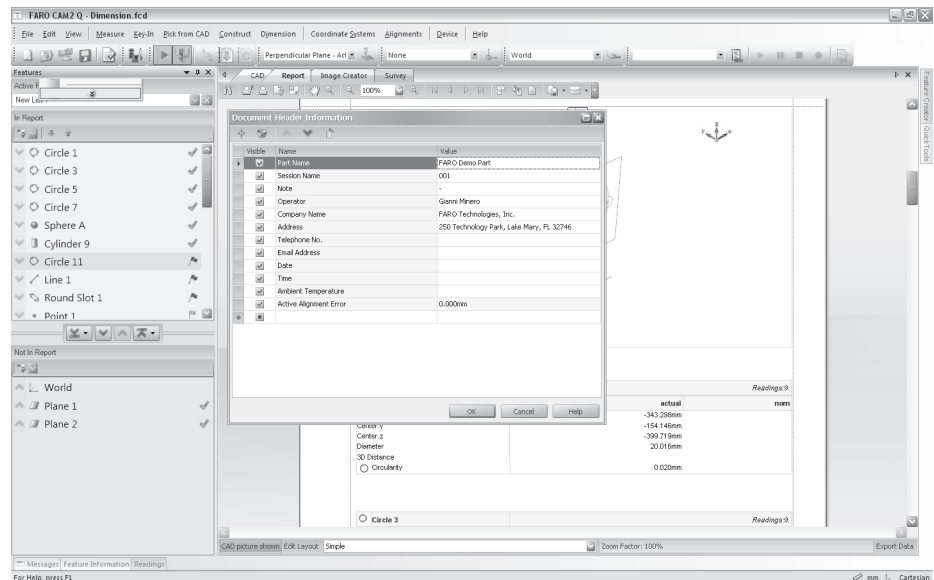
You can add any measured feature to the report. On the **Features** panel's **Active Report List**, add or remove features in the report by using the Add or Remove arrows.



Document Header Information

To create and add header information, which appears as Session Information, to a report:

- On the **Edit** menu, click **Document Header Information**.
- On the **Document Header Information** dialog box, type the desired information into the **Value** fields.
- Uncheck fields that you do not want to include on your report.




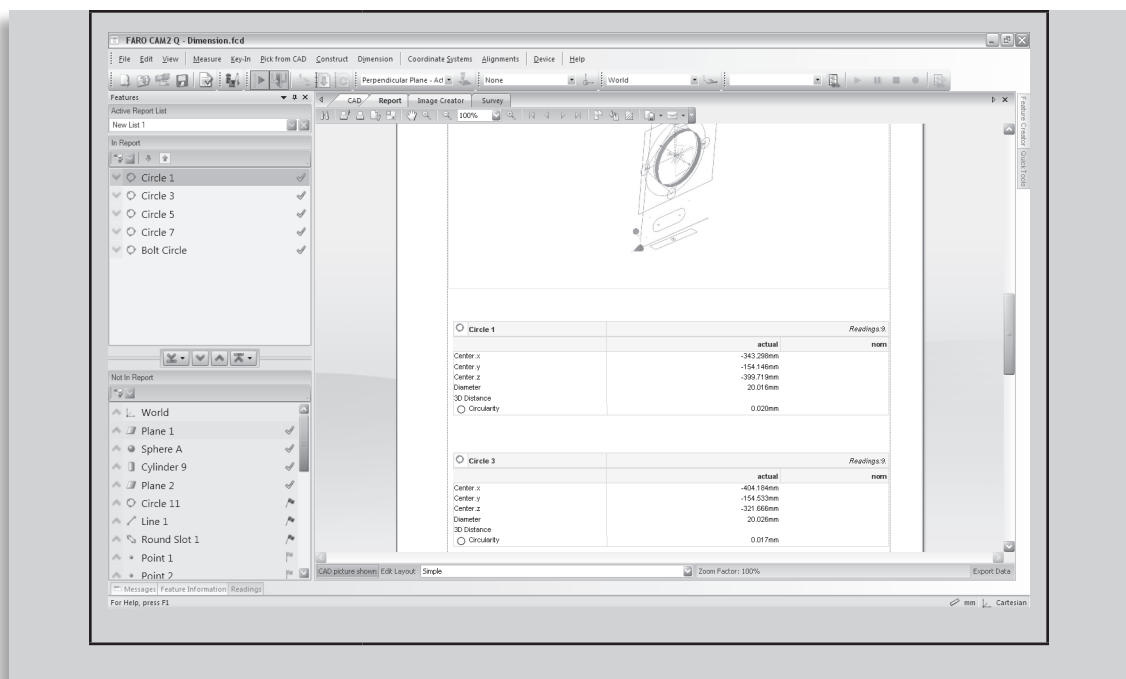
Add or Remove a Picture Preview from a Report

The **Report** function takes a picture of what is currently showing on the **Main Window**. To add or remove this picture from the report, use the **CAD Picture** button on the bottom of the **Report Window**.

ACTIVITY: Create A Report With Customized Content

For this activity, you will create a report including custom content.

1. Open file	On the File menu, click Open .
2. Select Dimension.fcd	Browse to your folder and double-click Dimension.fcd .  Before clicking the Report tab, make sure the view on the Main Window is how you would like it to appear on the report. Zoom in on the entire part or the area of the part you want to include in the report. A good way to zoom in on and orient the part is to use the hot keys. The E key zooms all and 6 orients the part to a top view.
3. Report tab	Click the Report tab.
4. Add features to report	On the Features panel's Active Report List , double-click on the features to add to the report in the Not In Report section. You can also use the Add arrows.
5. Select features to add to report	Select the following features to be added to the report: Bolt Circle, Circle 1, Circle 3, Circle 5, Circle 7 .
6. Remove features from report	On the In Report section at the top of the list, select the Down arrow to the left of World to remove it from the In Report section. You do not need to add World to this report because it represents the device's coordinate system.
7. Preview report	Scroll through the report using the slider bar on the right side of the report page.
8. View circle data	Notice how the data for the circles is reported. Once nominals have been entered, the report will display deviation and whether the feature is in or out of tolerance. For more information on nominals, see the Nominals and Tolerances module.



Saving a Customized List of Features

You can save the customized data list that you create, so you can recall the report you created without having to recreate the customized list.

To do this, use CAM2 Q's **Active Report List** feature.

ACTIVITY: Saving A Customized List Of Features

For this activity, you will save a customized list of features.

1. New report list	On the Features panel, on the Active Report List , select New List from the drop-down list.
2. Enter name	Highlight New List and type in My Report .
3. Press Enter	Press the Enter key.

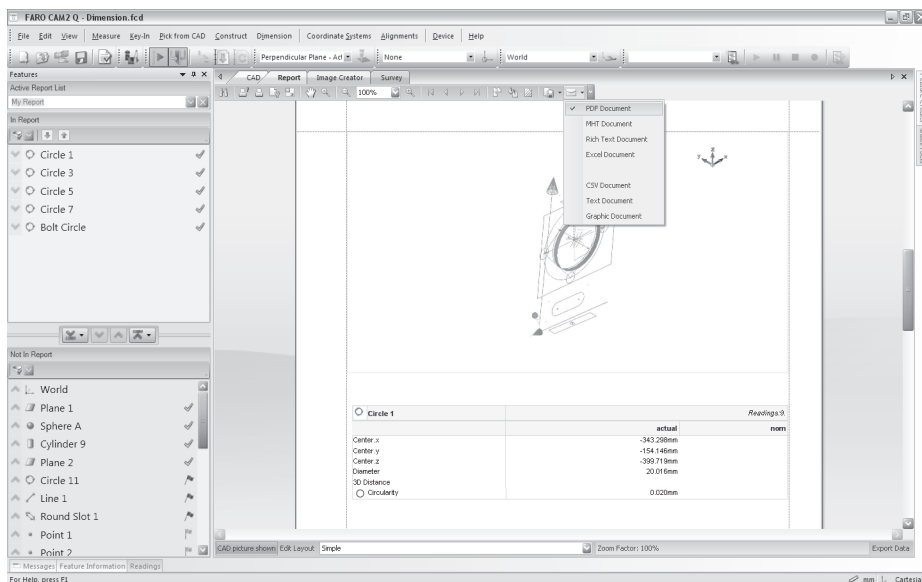
View Report Style Options

Click the **Report** tab to see a preview of your current report. There are several available styles of reports: **Simple**, **Tabular**, and others.

When not using nominals, a **Simple** style report may be preferable. When nominals are present, a **Tabular** style report may be preferable. By auto-hiding, or pinning, the **Feature Information** panel you can scroll down and see the results of the inspection routine.

Save a Report

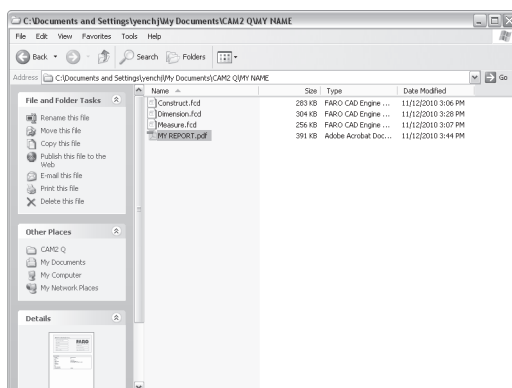
To save a report, click the **Export Document** drop-down icon.



From the **Export Document** icon drop-down list, you can save reports as PDF, HTML, MHT, Rich Text, Excel, CSV, Plain Text or a Graphics document (.jpeg, .bmp, .gif, .tiff, .png, .emf, or .wmf files).

Opening a Saved Report

To open a saved report, double-click the file name.



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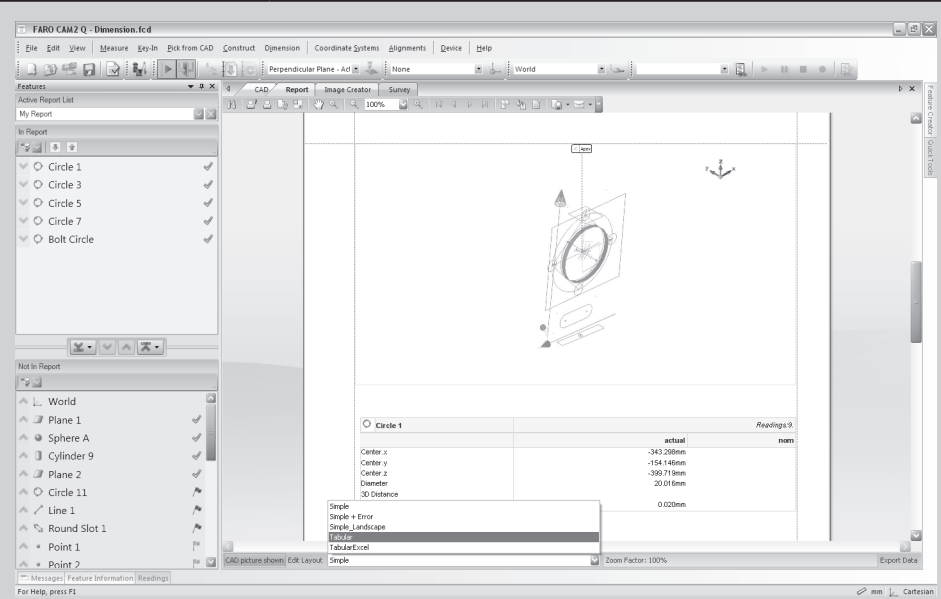
E-mail a Report

To e-mail a report, first export the report. From the **Export Document** icon drop-down list, you can pick the format of the report. You can e-mail reports in all of the available formats (PDF, HTML, MHT, Rich Text , Excel, CSV, Plain Text or a Graphics document).

ACTIVITY: Changing The Report View Style

For this activity, you will change the layout of the report.

1. Report tab	Click the Report tab.
2. Select report style	In the Edit Layout drop-down box, select Tabular . The report now shows the data in tabular view.



Go to page 2 of the report and select **Simple** to view the differences between the two report styles.

ACTIVITY: Saving The Report

For this activity, you will save the report.

1. Save report	From the Export Document icon drop-down list, select the HTML Document option.
2. Export options	In the HTML Export Options dialog box, click OK (We will use the default setting for this activity).
3. Your folder	Browse to your folder in /My Documents/CAM2 Q .
4. Enter name	Save the report with the name My Report . If prompted to overwrite the existing file, click Yes .
5. Automatically open file	When prompted "Do you want to open this file?" click Yes . You can now view the file and close when done.

The file is now saved on the computer in the **My Documents/CAM2 Q/[your name]** folder.

ACTIVITY: Opening A Saved Report

For this activity, you will open a saved report.

1. Open My Computer	Click the Windows Start button, and click My Computer .
2. My Documents folder	On the left side, in the Other Places section, select My Documents .
3. Your folder	In My Documents , double-click the CAM2 Q folder, then double-click your folder .
4. Open report	Double-click My Report to open it.

ACTIVITY: Saving The File

For this activity, you will save a CAM2 Q file.

1. Save As	On the File menu, click Save As .
2. Your folder	Using the drop-down menu, click My Documents , click CAM2 Q , then your folder .
3. Enter name	In the File name box, type in Report.fcd
4. Save	Click Save .

Creating a Report Template

The default report template shows FARO's company information at the top of each report. You can create a customized report template with your company information.

- Select a report format from the combo box at the bottom of the **Report** panel and click the **Edit Layout** button. This starts the DevExpress template editor.
- Select **File**, then **Save As** to save the template with a new name . This ensures that you do not replace the default CAM2 Q report template.
- Save the new template in the **CAM2 Q, Templates, Reporting** folder.
- Edit the fields in the **Report** section of the editor.
- **Save** the template.

ACTIVITY: Creating A Report Template

For this activity, you will create a report template with your company information.

1. Edit Layout	Select a report format and click the Edit Layout button.
2. Save As	On the File menu, click Save As .
3. Reporting folder	Using the drop-down menu, click My Documents , CAM2 Q, Templates , then click Reporting .
4. Enter name	In the File name box, type [your name] .
5. Save	Click Save .
6. Edit the Report fields	Type your company information in the report fields.
7. Save	Click Save .
8. Close Report Designer	Close the Report Designer by clicking the X in the upper right corner.

To view your template, select your report template in the **Edit Layout** drop-down box.

Feature Grouping

When you work with a large number of features, it can be helpful to organize them using a Group Folder.

You can use these folders to report features in multiple coordinate systems within the same report. You can assign a coordinate system, coordinate system type, and unit of measurement for the contents of the folder, and a unique screen view for the folder that appears in the report just above the features.

ACTIVITY: Creating A Feature Group

For this activity, you will create a feature group folder, edit its properties, capture a view, and review your current report template.

1. CAD tab	Click the CAD tab to return to the Main Window.
2. Create a New Group Folder	Click the Folder icon in the upper left corner of the Features panel.
3. Name the Group	Select the Group 1 folder, double-click and type Circles for the name of the folder. Click Modify and then Close to continue.
4. Add Features	Select the four circles (1,3,5,7) and drag them onto the Circles folder.
5. Set Top View	Press the 4 , 5 , or 6 hot key to set the top view. Zoom In (I hot key) and Pan (Arrow keys) so that the four circles fill the Main Window.
6. Set the Screen View	Select the Circles folder. Right-click and select Capture View Data from the menu.
7. Review the Report	Click the Report tab and look at the updated report. Notice the addition of the screen view of the four circles.
8. Save Report	From the Export Document icon drop-down list, select the HTML option.
9. Export options	In the HTML Export Options dialog box, click OK (We will use the default setting for this activity).
10. Your folder	Browse to your folder in My Documents/CAM2 Q .
11. Enter name	Save the report with the name My Report 2 . If prompted to overwrite the existing file, click Yes .
12. Automatically open file	When prompted "Do you want to open this file?" click Yes . You can now view the file and close when done.
13. Save As	On the File menu, click Save As .
14. Your folder	Using the drop-down menu, click My Documents , click CAM2 Q , then your folder .
15. Enter name	In the File name box, type in Report 2.fcd .
16. Save	Click Save .

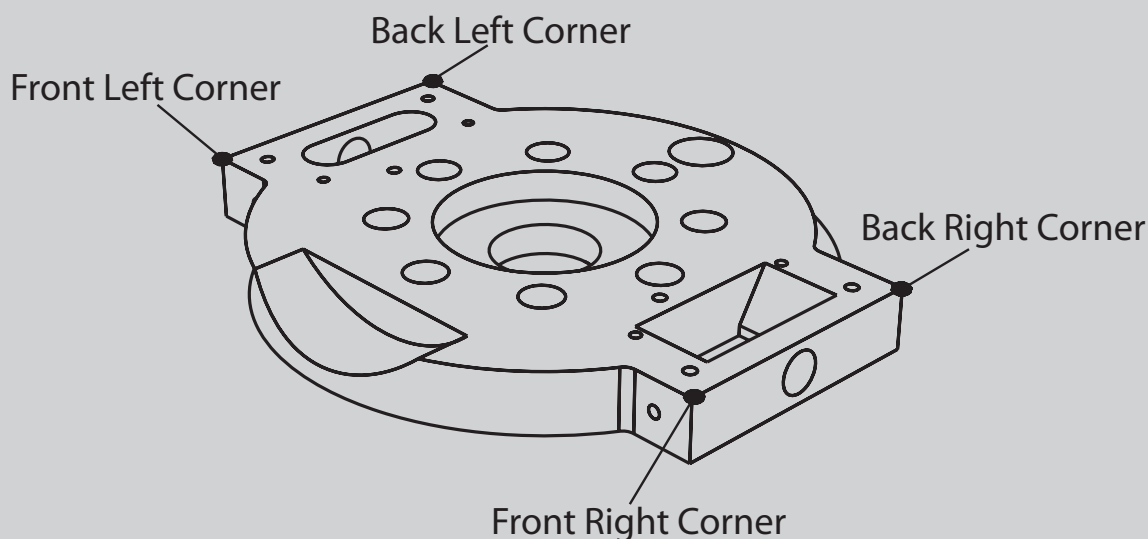
Lesson 5: Review Activities

Objective: Apply the Basic Measurement Strategy

Complete each of the Review Activities. When you are finished, have your instructor review and initial your work. If you have any questions, first refer to the previous modules, next use the **Help** menu. If neither of these provide the information you need, ask the instructor.

ACTIVITY: Construct Point

- Open a new file and measure the features you need to construct a point for each corner of the demo part appropriately naming each: **Back Right Corner**, **Back Left Corner**, **Front Right Corner**, and **Front Left Corner**.



ACTIVITY: Dimension Point To Point

- Determine the length from the **Front Right Corner** to the **Back Left Corner** of the demo part. Name it **Length 1**.
- Determine the length from the **Front Left Corner** to the **Back Right Corner** of the demo part. Name it **Length 2**.

ACTIVITY: Report

- Add **Length 1** and **Length 2** to the Report section.
- Export and save a PDF of the report. Name it **My First Report**.

All Activities Complete

Instructor initials: _____

Date: _____

Module 4:

Move Device

The CAM2 Q software and your measurement device give you many possibilities for measuring parts. The **Move Device** function was designed with complete portability in mind. You may not always have the same size part to measure; you may have to measure a small part one day and a large part the next; or your device or your part may move in between or during a measurement session. In this module, you will learn how to move your measurement device and continue measuring.

Prerequisite: Basic Measurement.

▶ MODULE OBJECTIVES

You will be able to:

- You will be able to move the device and continue to measure a part.
- Determine how many device positions are needed.
- Determine appropriate locations for the device.
- Verify the hardware setup.
- Determine appropriate action to take when relocation results are not within the required accuracy of the measurement job.

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SCENARIO: MOVE DEVICE

Now we need to measure a bigger part. You are going to have to move the measurement device to get all of the measurements we need. If you need help, try looking for the information in the CAM2 Q **Help** menu or on FARO's website.



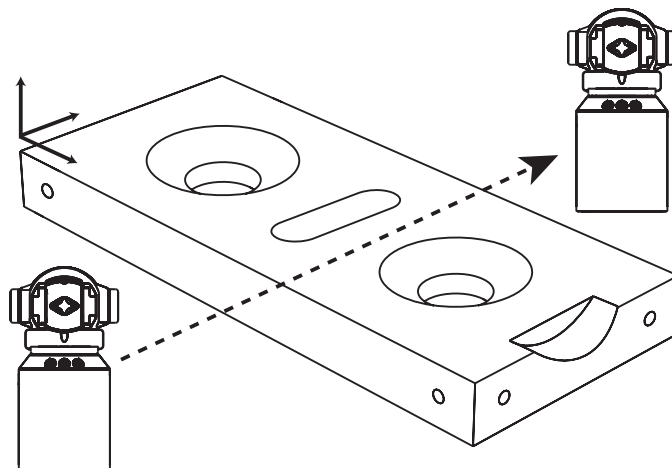
I have measured from only one device position so far , and I have to move the measurement device to continue measuring my part. What are the things I need to think about before I move the measurement device?

Strategy: Move Device

- Before measuring, how do you determine the best positions for the device?
- Can you ensure a stable mounting at every device position?
- How many device positions do you need?
- Will you be able to reach all the features to be measured?
- Which features will be re-measured from each device position?

Move Device

Move Device is a function that allows you to move the device around the part while maintaining the working coordinate system.



When To Use Move Device

- When a feature on your part is out of the Laser Tracker's line of sight, this function allows you to move the Laser Tracker to a location where the feature is visible to the Laser Tracker then measure the remainder of the part.
- You want to move the device if the relationship between the part and the device changes. For example, the device or part may move (bumping etc.) or the part may experience change in size due to change in temperature (temperature drift). In these instances, you can use **Move Device** to quickly reposition the device into a known orientation relative to the part.

An exception: When using the Laser Tracker in large volume applications, it might be more accurate to use two device positions. You should check the accuracy at both the half-length and the full-length using the Static Repeatability Test (as described in Measurement Considerations). If the full-length result is acceptable, use one device position.

Feature Window

Monitoring the Relationship Between the Part and the Device

The **Feature** window shows a **Digital ReadOut** of a specific feature you choose. The **DRO** in this window shows you where the feature is compared to where the SMR is at that time. You can use the feature's **DRO** to detect changes in the position of the part relative to the measurement device.

This is accomplished as follows:

- On the **Features** panel, click a sphere or point you have measured.
- On the **View** menu, click **Show Feature Window**. The **Feature** window appears.

When you place the SMR at the point location or on the sphere's surface, the values in the window will be "0".

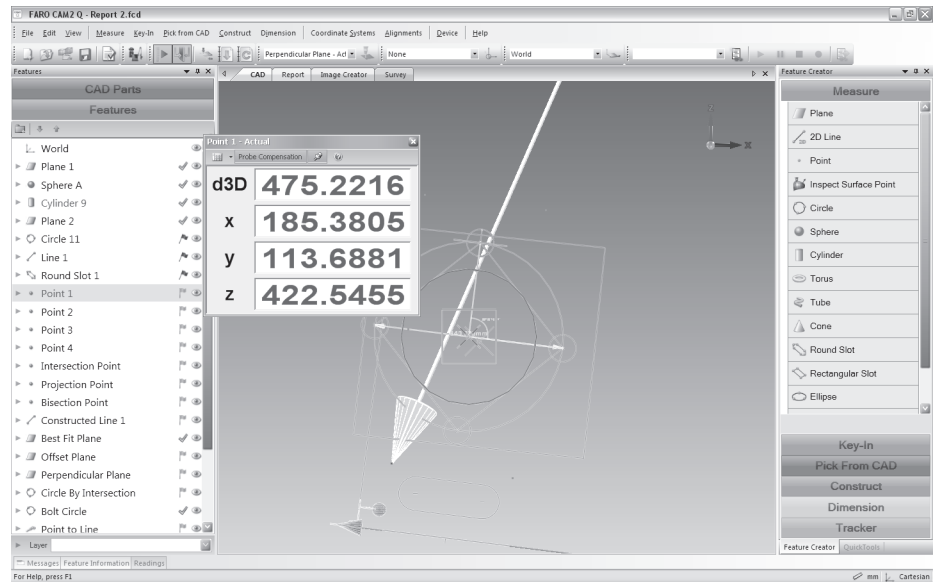


Placement of the device is important. If possible, it is best to measure from only one device position. Use the Move Device command only when necessary.



Use the **Feature window** frequently during a measurement session to check for movement, especially when working from a tripod.

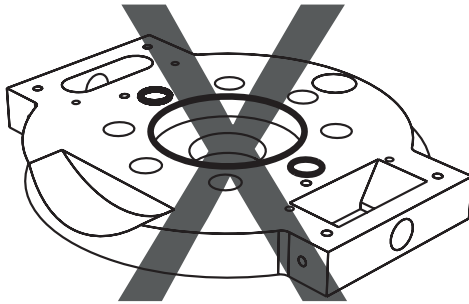
CAM2Q



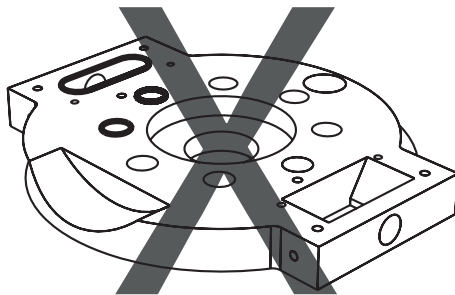
It is good practice to periodically place the SMR at the point location or on the sphere's surface. If the values are not "0", it means the relative position of the feature/part to the device has changed.

Move Device: Basic Concepts

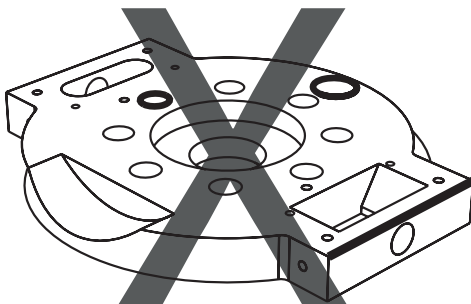
- You need a minimum of three points, or three “point-reducible” features, to complete the **Move Device** function. This means you can use points, circles, or spheres, or any combination.
- The three features you choose to measure cannot lay in a straight line. There must be some spacing between the features; think triangle.



- The features you choose should encompass at least 75% of the part. For example, if your part is 48 x 22 x 18 inches, features that encompass only 5 x 5 x 5 inches of the part are not an ideal choice.



- The area local to those points will mathematically fit well, but the locations of any features you measure far away from the relocation points will have a greater uncertainty. The right edge of the part is also not a point-reducible feature.

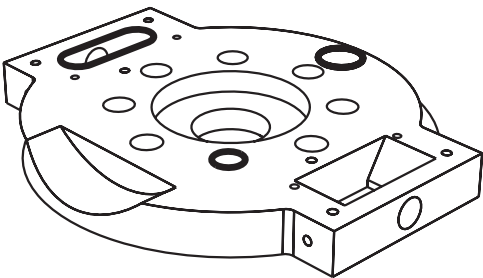


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The minimum is three points. For best results use four or more points that are not in the same plane.

- For the demonstration part, these features are one set that would be appropriate.



PRE-ACTIVITY:

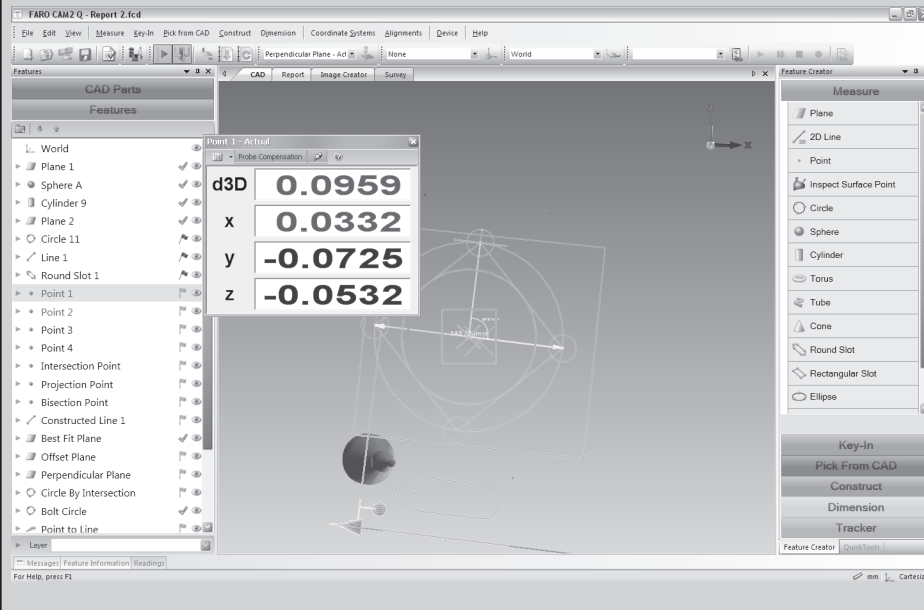
Option 1 If training files are available	Option 2 If starting with a new file
Open Report.fcd	Open a new file
Measure all features	Add and measure: <ul style="list-style-type: none">• Point 1• Point 2• Point 3• Point 4

ACTIVITY: Executing a Move Device Position

1. Show the **Feature** window for **Point 1**

On the **Features** panel, click **Point 1**.

On the **View** menu, click **Show Feature Window**.
 or press the **D** hotkey.



2. Verify the Point 1 measurement

Look in the **Feature window** for **Point 1** by moving the SMR to that location.

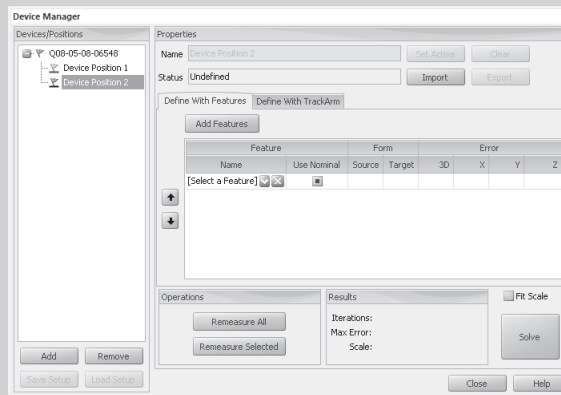
Has the relationship between the device and the part changed?

Keep in mind that Point 1 was measured earlier. At that time, the values were "0".)

If the values have not changed, move either the part or device slightly and re-check the **Feature window** for Point 1 again. Notice that the values are no longer "0", and it is now necessary to realign the device and part. Whether the relationship between the part and the device changes intentionally or unintentionally, the process for realigning the device to the part is the same.


3. Execute the **Move Device** command

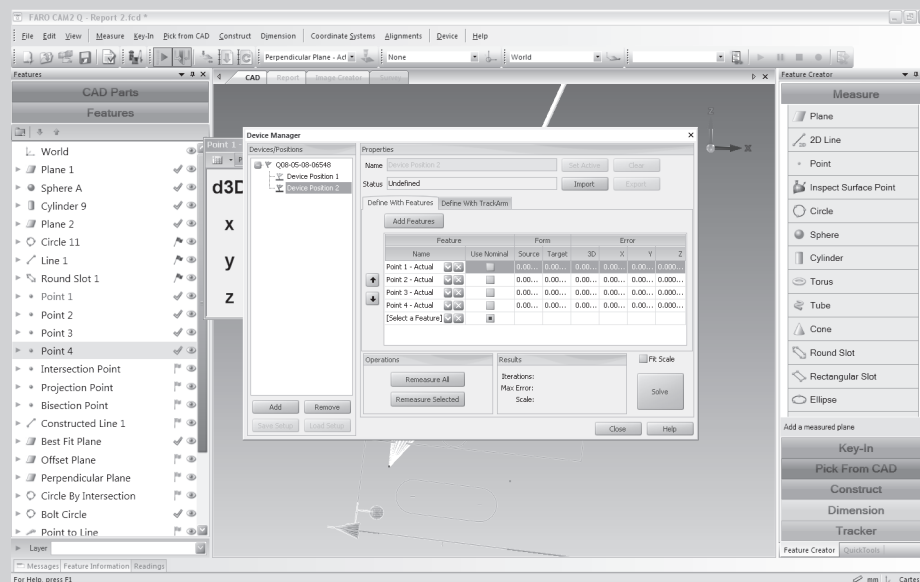
On the **Device** menu, click **Move Device**.
 or press the **M** hotkey.



4. Switch to Measure Mode	If necessary, click the Measure/Template Mode icon so that you are in Measure mode.
5. Select Points 1 through 4	On the Features panel, select Points 1 through 4 . (CTRL + click Point 1, Point 2, Point 3, Point 4)
6. Remeasure all features	On the Device Manager window's Properties section, click Add Features , then click Remeasure All .

You will then be prompted to remeasure **Points 1** through **4**, which allows the software to re-position the device.

 *Make sure to re-measure the points in the correct order (i.e. when the software prompts you to measure Point 1, make sure it is Point 1 you are measuring). Measuring in the wrong order will result in inaccurate re-positioning of the device.*



7. Solve the new device position	Click Solve . The software mathematically realigns the device to the part.
----------------------------------	---

8. Save the file as ***Move Device.fcd***

On the File menu, click ***Save As***. Browse to your folder.

Name the file `Move device.fcd` and click ***Save***.

Reviewing Device Positions

If you just need to review and edit existing device positions, use the ***Device > Device Manager*** command. Using the ***Device > Move Device*** command will open the ***Device Manager*** panel AND add a new device position.

Module 5:

Coordinate Systems

So far, you have learned the basic strategy to follow when performing a measurement job: **Measure, Construct, Dimension, and Report**. You have also learned about some of the environmental and calibration considerations when you measure.

Now, we will cover creating coordinate systems. Using the features that you construct, a coordinate system gives your measurements a framework for defining location. Using the appropriate coordinate system as you measure parts plays a critical role in the interpretation of the data. Creating coordinate systems on a part requires analyzing the part and determining where the coordinate system or systems should originate. In this module, we will also determine the best features with which to create your coordinate system.

Prerequisite: Basic Measurement.

▶ MODULE OBJECTIVES

You will be able to:

- List at least two reasons for creating coordinate systems
- Analyze requirements to determine effective coordinate system location
- Identify the effect on the data of the chosen primary axis for the coordinate system
- Identify the attributes of a repeatable coordinate system
- Recognize the impact of feature selection on the data
- Create a coordinate system using any of three techniques

SCENARIO: ADDING COORDINATE VALUES

The boss says, "The report is great. Thanks for your hard work; the customer will be pleased with how quickly we provided the data. Can we add coordinate values?"



I need a coordinate system on my part to provide a framework for my measurements. Where should I position my X, Y, and Z axes? Do I need more than one coordinate system for reference?

Strategy: Coordinate Systems

- What are the dimensions, lengths, and feature positions of the part that I need to report?
- Where is the most logical placement for the coordinate system?
- Which features do I need to measure and/or construct to create the coordinate system?
- Are multiple coordinate systems required?

What is a Coordinate System

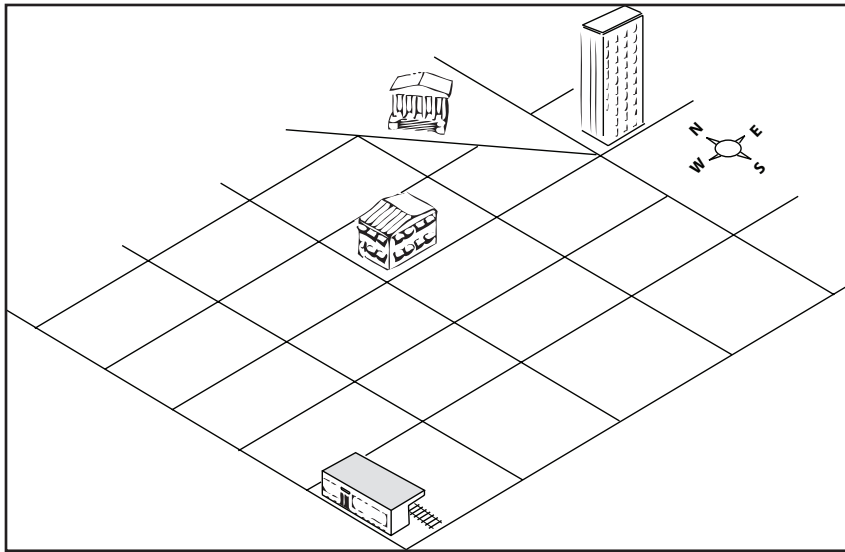
A coordinate system is a frame of reference that allows you to find the unique position of a point in a plane or in space, and to see the relationship between two points in space.

Why Use a Coordinate System

Placing a part into a coordinate system enables you to:

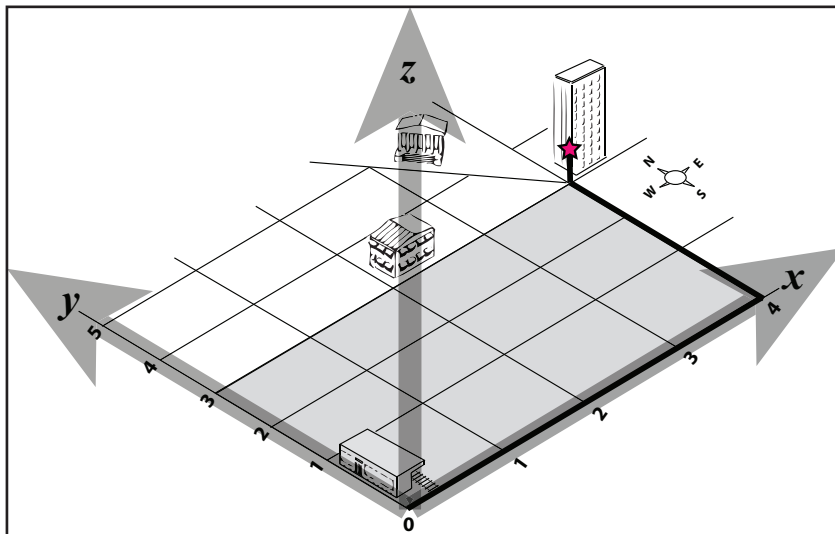
- Effectively report measured features – Since you have a unique position identified for each point and feature, your report can very clearly and specifically describe the location and dimensions of the features and part.
- Establish a reference for all part measurements so the data on the part is aligned to the same reference points in a blueprint or CAD file. This enables straightforward comparisons between feature measurements and nominals.
- Accurately report the condition of a part to someone analyzing your measurement file who does not have access to the physical part.

Think of a three dimensional coordinate system as a three dimensional map:



Imagine that you want to give someone directions from the train station to the 3rd floor of the tall building in the map above.

If you add three dimensional coordinates to the map, you can use those coordinates to describe how many streets to go in the "X" direction (4); then how many streets to go in the "Y" direction (3); and finally and how many floors to go up in the "Z" direction (3).

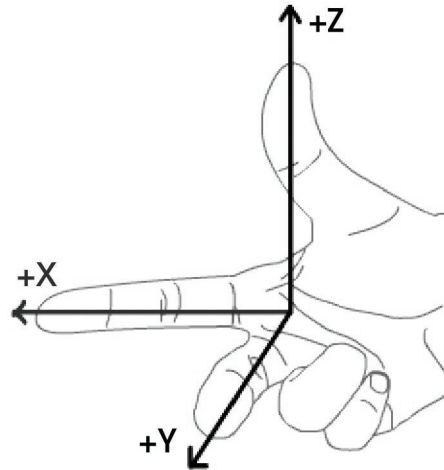


Right-Hand Rule

Cartesian coordinates describe the position of points in space relative to three mutually perpendicular axes X, Y, & Z. The intersection of these axes form the origin, or zero of the system.

Each axis emanates from the origin according to the right-hand rule. The right-hand rule defines the positive direction of each axis, such that when the hand is positioned according to the figure below, the + Z points along

the thumb, the + X axis points along the index finger, and the + Y axis points along the middle finger.



☞ CAM2 Q does not support left-hand rule coordinate systems.

Feature Selection

The accuracy of the measurements you take in your coordinate system relies heavily on the consistent accuracy of the machined features you use to define your coordinate system.

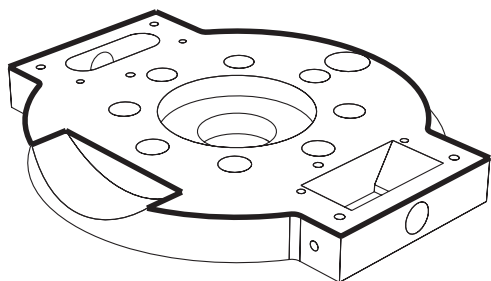
For repeatability, look for the following when selecting features to define your coordinate system:

- **Surfaces that have a smooth finish:** These provide the most consistent repeatable measurements.
- **Features critical to part machining:** These generally will be more carefully controlled than those not critical to machining and therefore will be consistent.
- **Features that are relatively large compared to the part size.**
- **Features that have a low measured Form value.**

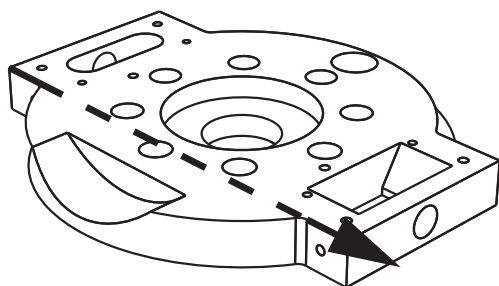
Defining Coordinate Systems Using 3-2-1

You can define coordinate systems in a variety of ways. The simplest is the 3-2-1 or Plane-Line-Point method. 3-2-1 describes the minimum number of points that you use to define the base features of a coordinate system – a **Plane** (3 points), a **Line** (2 points) and a **Point** (1 point).

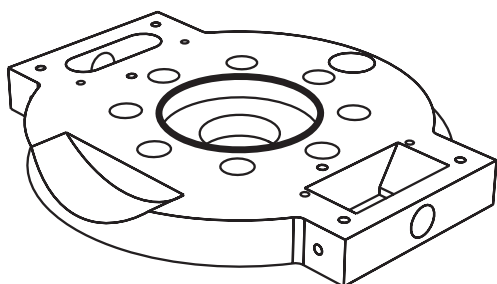
Standard construction diagrams of plane, line and point showing how they create a coordinate system:



Plane

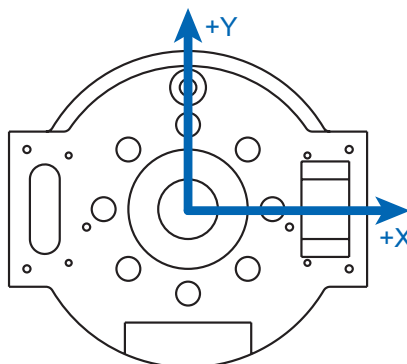
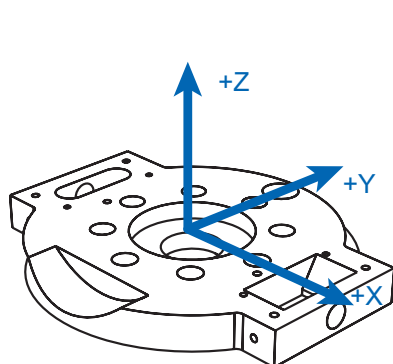


Line



Point

(Center point of the Circle)




PRE-ACTIVITY:

Option 1 If training files are available	Option 2 If starting with a new file
Open Advanced 1.fcd	Open a new file
Measure all features	Add and measure/construct: <ul style="list-style-type: none">● Plane 1● 2D Line 1 (across the front of the part on the handle side)● Circle 1● Circle 3● Circle 5● Circle 7● Cylinder 9● Sphere A● Bolt Circle● Intersection Point (of Plane 1 and Cylinder 9)

ACTIVITY: Create A Coordinate System

For this activity, you will construct a coordinate system using 3-2-1 (plane, line, point).

1. Start Coordinate Systems command	On the Coordinate Systems menu, click Create Using the Wizard .  or press the C hot key.
2. Dialog box	The Construct Coordinate System Using The Wizard dialog box appears.
3. Enter feature name	In the Name box, enter 3-2-1.
4. Basic tab	Click the Basic tab.
5. Choose a plane for +Z	In the Plane Feature list, select Plane 1 . In the Axis list, select +Z .
6. Choose a line for +X	In the Line Feature list, select 2D Line 1 . In the Axis list, select +X .

You have now selected what will be the Z and X axes of your parts coordinate system.

7. Choose a circle for the origin	In the Point Feature list, select Bolt Circle .
-----------------------------------	---

This identifies your origin, or the point where your X, Y, and Z will all be "0".

8. Align with World	Select the Align with box. From the Align with list, select World .
----------------------------	--

This aligns the coordinate system you are creating on the part with coordinate system of the device. From now on, any measurements you take will use the part coordinate system as a reference.

9. OK	Click OK .
--------------	-------------------

Notice the **Active Coordinate System** toolbar at the top of the screen. Your coordinate system, 3-2-1, now shows in the drop-down list and replaces World as the active coordinate system. When you work with multiple coordinate systems, this is where you will control which coordinate system is active.

10. Save As	On the File menu, click Save As .
11. Your folder	Using the drop-down menu, click My Documents , CAM2 Q , and then double-click on your folder .
12. Enter name	In the File name box, type in CS1.
13. Save	Click Save .

If necessary, set the SW Isometric View and Zoom All to see your complete file by pressing the **E** and **8** hot keys. These commands are also available in the **View** menu.

ACTIVITY: View Report

For this activity, you will view a report.

1. Report tab	Click the Report tab.
2. Choose report list	On the Features panel's, Active Report List , select My Report . <i>Or, you may add the features to the In Report section.</i>
3. View report	Observe the feature data on the report. The X, Y, and Z values are now relative to the coordinate system origin you created for the part.
4. CAD tab	Click the CAD tab.

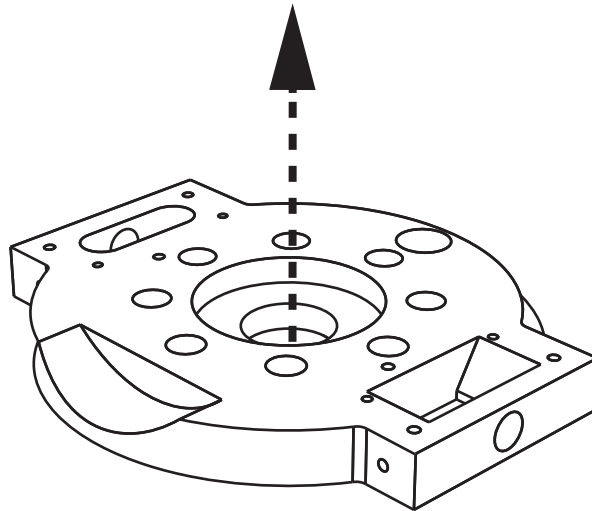


As you choose features for each of these coordinate systems, notice the difference between the Measured and Constructed features by the geometry icon to the left of the feature name.

Create A Coordinate System


Using a Line as Primary

If the longest, most important feature on your part is a line, you can use the **Line as Primary** option for creating your part coordinate system.



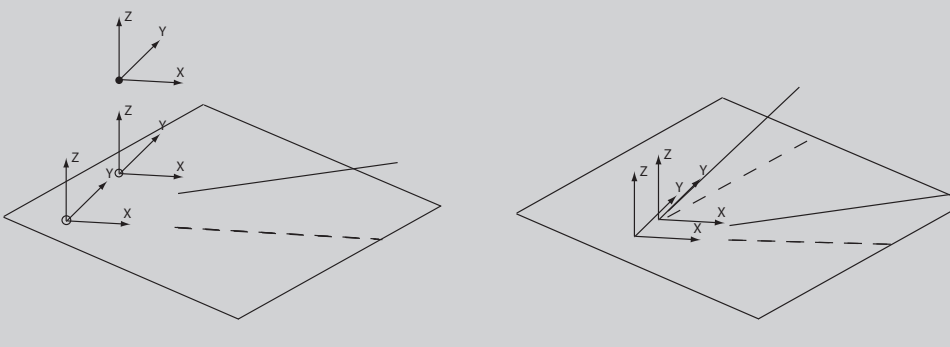
ACTIVITY: Create A Coordinate System Using A Line As Primary

For this activity, you will construct a coordinate system using a Line as Primary.

1. Start Coordinate Systems command	On the Coordinate Systems menu, click Create Using the Wizard .  or press the C hot key.
2. Dialog box	The Construct Coordinate System Using The Wizard dialog box appears.
3. Enter feature name	In the Name box, enter <code>Line as Primary</code> .
4. Advanced tab	Click the Advanced tab.
5. Choose a line for +Z	In the Primary section, select the Line button. In the first feature list, select Cylinder 9 . In the Axis list, select +Z .
6. Choose a line for +X	In the Secondary section, select the Line button. In the first feature list, select 2D Line 1 . In the Axis list, select +X .
7. Choose a point for the origin	In the Origin section feature list, select Circle 3 .
8. Align with World	Clear the Align with box.
9. OK	Click OK .

ACTIVITY: View Report

For this activity, you will view a report.

1. Report tab	Click the Report tab.
2. Choose report list	On the Features panel, in the Active Report List , select My Report .
3. View report	Observe the feature data on the report. The X, Y, Z values have changed because your coordinate system has changed.
	
4. CAD tab	Click the CAD tab.

Create A Coordinate System (Origin Options)


Origin Options

There are several origin options when creating a coordinate system.

- Hold Position: the coordinate system is at the center of the feature.
- Hold to Primary: the coordinate system is at the closest point on the primary feature from the origin feature.
- Hold to Secondary: the coordinate system is at the closest point on the secondary feature from the origin feature.
- Hold to Key-In: the coordinate system corresponds to the location (primary, secondary and origin) keyed-in.

ACTIVITY: Create A Coordinate System (Origin Options)

For this activity, you will construct a coordinate system using different origin options.

1. Start Coordinate Systems command	On the Coordinate Systems menu, click Create Using the Wizard .  or press the C hot key.
2. Dialog box	The Construct Coordinate System Using The Wizard dialog box appears.
3. Enter feature name	In the Name box, enter Origins .
4. Advanced tab	Click the Advanced tab.
5. Primary	In the Primary section, select the Plane button. Select Plane 1 . In the Axis list, select +Z .
6. Secondary	In the Secondary section, select the Line button. Select 2D Line 1 . In the Axis list, select +Y .
7. Choose origin	In the Origin section feature list, select Sphere A . Select Hold Position . Clear the Align with box.
8. OK	Click OK .

You now have a coordinate system with the origin at the center of the sphere. Now, let's modify the origin.

9. Origins properties	On the Features Panel , select Origins , double-click to edit the feature properties.
10. Choose origin	Select Hold to Primary .
11. Modify	Click Modify and move the window so you can see the coordinate system location on the screen.

You now have a coordinate system with the origin at the closest point on the plane to the sphere. Press Hot Key **6** for a top view. Now, let's modify the origin again.

12. Choose origin	Select Hold to Secondary .
13. Modify	Click Modify and then click Close .

You now have a coordinate system with the origin at the line.

ACTIVITY: View Report

For this activity, you will view a report.

1. Report tab	Click the Report tab.
2. Choose report list	On the Features panel's Active Report List , add all features to the In Report section.
3. View report	Observe the feature data on the report.
4. CAD tab	Click the CAD tab.

ACTIVITY: Saving The File

For this activity, you will save a CAM2 Q file.

1. Save As	On the File menu, click Save As .
2. Your folder	Using the drop-down menu, click My Documents , CAM2 Q , then double-click your folder .
3. Enter name	In the File name box, type in CS2 . fcd.
4. Save	Click Save .

Module 6: Nominals and Tolerances

You have just created a coordinate system. Now, you will learn how to compare your part's actual measurements to the design specifications.

Prerequisite: Coordinate Systems.

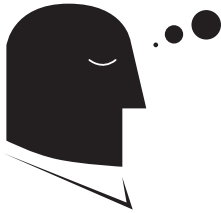
▶ **MODULE OBJECTIVES**

You will be able to:

- Incorporate nominals and tolerances into the measurement process and report any variances.
- Identify the appropriate XYZ values of the nominals.
- Identify the change in tolerance due to feature size or decimal places.
- Change and save tolerance options.
- Use alternative reporting options.
- Use alternative nominal association and automatic feature construction workflow.

SCENARIO: NOMINALS AND TOLERANCES

You gave the report to your boss and he says, "This looks great, but how does this compare to the customer's blueprint? How can I tell if the part is manufactured according to the specifications on the blueprint?"



I now have to add nominals and tolerances in order to compare actual measurements with design specifications. How can I incorporate nominals and tolerances into my measurement and reporting process?

Strategy: Nominals and Tolerances

- What are the best methods for entering nominals and tolerances for this part?
- How will nominals and tolerances help me report the data?

Definitions: Nominals & Tolerances

Nominals are the designed values of the part. The numbers specified on a blueprint are nominal values.

Tolerances are the acceptable difference between the actual measured value and the nominal value of a feature.

You determine the quality of a part by comparing your actual values to the nominal values within a tolerance range.

Entering Nominals: Circle Example

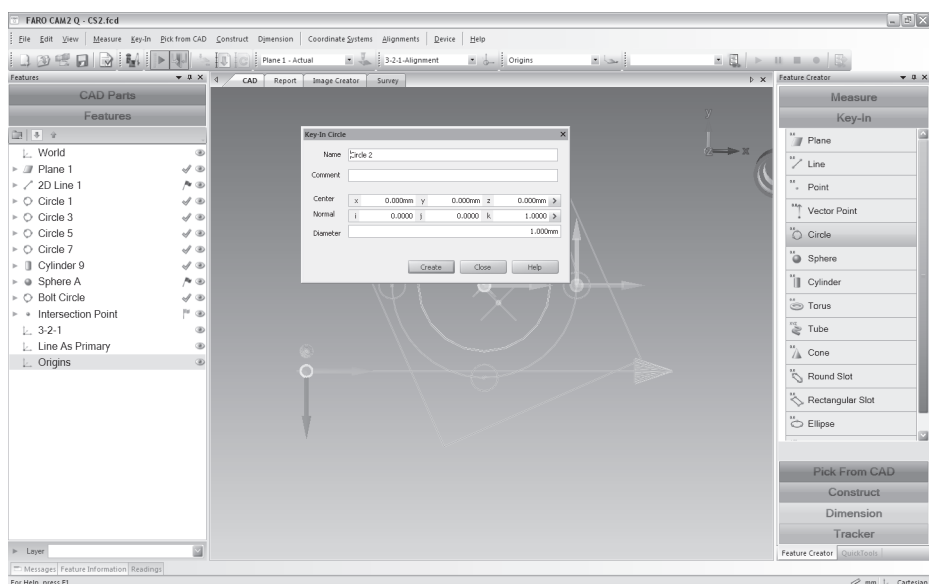
Prior to entering nominals, it is necessary to select the appropriate coordinate system for referencing the nominals.


There are three nominals that you can key-in for a circle:

Center: A positional element defining the location of the circle relative to the coordinate system;

The Normal: The orientation of the circle relative to the coordinate system; and

Diameter: The size of the circle.



 You can type a value in any unit, and CAM2 Q will convert the value to the default unit value. For example, the measurement file's unit of measurement is millimeters but the diameter is 10inches. Type 10in and CAM2 Q will automatically convert the value to 254 millimeters.

PRE-ACTIVITY:

Option 1 If continuing from the previous module with no device or part setup changes	Option 2 If your device or part setup has changed	Option 3 If starting with a new file
Open CS1.fcd	Open Advanced 1.fcd	Open a new file
	Measure: <ul style="list-style-type: none">● Plane 1● Circle 1● Circle 3● Circle 5● Circle 7 Create CS1 from ACTIVITY: Create Coordinate System in the Coordinate Systems module.	Add and measure/construct: <ul style="list-style-type: none">● Plane 1● Circle 1● Circle 3● Circle 5● Circle 7● Bolt Circle Create CS1 from ACTIVITY: Create Coordinate System in the Coordinate Systems module.

The Feature Information Panel

The **Feature Information** panel displays nominal (or target) values, actual values, and variations for a variety of positional and statistical elements. Key values are:

- X, Y, Z
- 3D Distance
- Diameter
- Form (GD&T tolerance)

The **OOT** (Out of Tolerance) column indicates whether the feature measured is within acceptable tolerance limits.

- **Pass** (1) and the color green indicate that the feature is within tolerance.
- A **number** (2) (indicating how much out of tolerance the value is) and a red or blue color indicates how much the value is out of tolerance. If the feature is out of tolerance on the high side (3) the color is red; if the feature is out of tolerance on the low side (4) the color is blue.

Feature Information									
	FeatureLabel	Actual	Nominal	Dev	Nominal Feature	Low Tol	Up Tol	OOT	Tolerance
	Bolt Circle - Actual				Bolt Circle - Nominal				
<input checked="" type="checkbox"/>	Center.x	0.102mm	0.000mm	0.102mm		-32.258mm	32.258mm	Pass	
<input checked="" type="checkbox"/>	Center.y	-0.007mm	0.000mm	-0.007mm		-32.258mm	32.258mm	Pass	
<input checked="" type="checkbox"/>	Center.z	0.000mm	0.000mm	0.000mm		-32.258mm	32.258mm	Pass	
<input checked="" type="checkbox"/>	Diameter	140.040mm	140.000mm	0.040mm		-32.258mm	32.258mm	Pass	
<input checked="" type="checkbox"/>	3D Distance			0.102mm		-32.258mm	32.258mm	Pass	
<input checked="" type="checkbox"/>	Circularity	0.028mm	0.000mm	0.028mm		0.000mm	0.050mm	Pass	

ACTIVITY: Entering Nominal Data

For this activity, you will select a coordinate system and key in Nominals.

1. Highlight Circle 1	On the Features panel, click Circle 1 .
2. Expand Feature	To the left of the feature name, click the right arrow to expand Circle 1 . You now see the actual and nominal features of Circle 1 . Notice that the nominal feature is gray because it does not exist yet.
3. Open the Feature Information panel	Click the Feature Information tab.
4. Key In nominals for Circle 1	In the Center x Nominal cell, enter 0 . 00mm In the Center y Nominal cell, enter 70 . 00mm . In the Center z Nominal cell, enter 0 . 00mm In the Diameter Nominal cell, enter 20 . 00mm .
5. Highlight Circle 3	On the Features panel, click Circle 3 .
6. Key In nominals for Circle 3	In the Center x Nominal cell, enter 70 . 00mm In the Center y Nominal cell, enter 0 . 00mm . In the Center z Nominal cell, enter 0 . 00mm In the Diameter Nominal cell, enter 20 . 00mm .
7. Highlight Circle 5	On the Features panel, click Circle 5 .
8. Key In nominals for Circle 5	In the Center x Nominal cell, enter 0 . 00mm In the Center y Nominal cell, enter -70 . 00mm . In the Center z Nominal cell, enter 0 . 00mm In the Diameter Nominal cell, enter 20 . 00mm .
9. Highlight Circle 7	On the Features panel, click Circle 7 .
10. Key In nominals for Circle 7	In the Center x Nominal cell, enter -70 . 00mm In the Center y Nominal cell, enter 0 . 00mm . In the Center z Nominal cell, enter 0 . 00mm In the Diameter Nominal cell, enter 20 . 00mm .

You have just keyed in the nominals for the four circles that you used to construct the bolt circle in an earlier exercise. Now, you will key in the nominals for the **Bolt Circle** you created in the earlier exercise.

11. Highlight Bolt Circle	On the Features panel, click Bolt Circle .
----------------------------------	--

12. Key In nominals for Bolt Circle	In the Center x Nominal cell, enter 0 . 00mm
	In the Center y Nominal cell, enter 0 . 00mm .
	In the Center z Nominal cell, enter 0 . 00mm
	In the Diameter Nominal cell, enter 140 . 00mm .

Changing Tolerances Settings

The Out of Tolerance (**OOT**) values you see are the result of default tolerances. You can manually change these tolerances or they can be set prior to taking any measurement.

- On the **Edit** menu, click **Preferences**, and then click **Tolerance** and **Geometries** tab.

ACTIVITY: Changing Tolerance Settings

For this activity, you will change tolerance settings in the **Feature Information** panel.

1. Highlight the Bolt Circle	On the Features panel, click Bolt Circle .
2. Open the Feature Information panel	Click the Feature Information tab.
3. Enter an Up Tolerance of .00001	On the Feature Information panel's Circularity row, enter . 00001 in the Up Tol column, and press Enter.

Notice that the cell in the **OOT** column is displaying a color and a number. Since you set the tolerance limit very low, the value is beyond the tolerance limit. The color red indicates that the form value is higher than the tolerance you specified and the number indicates how far the value is out of form tolerance.

4. Change the Up Tolerance to .5	In the Circularity row, in the Up Tol column, enter . 5 and press Enter.
---	--

Notice that the cell in the **OOT** column is displaying the color green and the word **Pass**. Since you set the tolerance limit very high, the value is well within the tolerance limits.

5. Save your file with a new name	On the File menu, click Save As . Enter Nominals 1.fcd as the file name.
-----------------------------------	--

Setting Tolerances in a Measurement File

The default tolerances for each feature type are a preference in the measurement file. Use the **Preferences** command to change tolerance values for future features or apply a set of tolerances to *all* existing features. CAM2 Q also supports DIN/ISO tolerance schemes.

You can also use the **Copy Tolerances** and **Paste Tolerances** commands from the **Edit** menu to copy tolerances from a feature and paste to another similar feature. For example, modify the tolerances of a circle, copy, and paste to other circles in your drawing file.



Save time by setting the feature tolerances before adding any features to the measurement file.

ACTIVITY: Copying Tolerances

For this activity, you will change tolerances for a feature and copy them to other similar features.

1. Edit the tolerances a circle	<p>Select Circle 1 in the Features panel.</p> <p>In the Feature Information panel, clear the Z dimension and 3D Distance checkboxes.</p> <p>Edit the X dimension, Y dimension, and Diameter tolerances as follows:</p> <ul style="list-style-type: none"> <input type="checkbox"/> Lower Tolerance -0.25 mm. <input type="checkbox"/> Upper Tolerance $+0.25$ mm.
---------------------------------	--

Now you can copy the tolerances to the other three circles.

2. Copy the Tolerances	<p>Select Circle 1 in the Features panel.</p> <p>Right-click and select Copy Tolerances.</p>
3. Paste the Tolerances	<p>Select Circle 3 in the Features panel.</p> <p>Right-click and select Paste Tolerances.</p>
4. Paste to remaining circles	<p>Repeat for circles 5 and 7.</p>

An Alternative Workflow


In the previous activities, you added nominal values to existing measured features. However, you can also set up the measurement file with all of the nominal features before connecting the measurement device. Then use the **Add Measurement** function to create measured (actual) features from the existing nominal features.

PRE-ACTIVITY:

Option 2 If your device or part setup has changed	Option 3 If starting with a new file
Open Advanced 3.fcd	Open a new file
	<p>In Template Mode:</p> <ul style="list-style-type: none">● Add the following nominal features from the Key-In menu:<ul style="list-style-type: none">● Circle 1 (0, 70, 0)● Circle 3 (70, 0, 0)● Circle 5 (0, -70, 0)● Circle 7 (-70, 0, 0)● Construct the nominal Bolt Circle using Circles 1,3,5,7.● Add the following actual features from the Measure menu:<ul style="list-style-type: none">● Plane 1● Line 1● Circle 9● Create a Coordinate System using Plane 1, Line 1 and Circle 9.

ACTIVITY: Adding Measurements To Nominals

For this activity, you will add a measurement to the nominal bolt circle which automatically creates and associates a measured feature to each nominal circle.

1. Add readings to coordinate system features	Select Plane 1, Line 1 and Circle 9 in the Features panel. From the Measure menu, select Add Readings .  You can also right-click the selected features and select the Add Readings command from the menu.
2. Measure the features	Watch the prompt area of the Measurement Window for instructions to measure the plane, line and circle.
3. Add a measurement to the Bolt Circle	Select Bolt Circle. Right-click and select Add Measurement from the menu.

Add Measurement automatically adds actual features to all of the nominal features that construct the Bolt Circle. Each of the four circles (1,3,5,7) now have an actual feature associated to its nominal, and the **Add Readings** command automatically starts.

4. Measure each circle	Watch the prompt area of the Measurement Window for instructions to measure each of the four circles.
------------------------	---

Now that each of the circles has solved, the Bolt Circle solves.

5. Save your file with a new name	On the File menu, click Save As . Enter <code>Nominals 2.fcd</code> as the file name.
6. Review results	Select the Bolt Circle and look at the results in the Feature Information panel. Select other circles and review the results of the measurement. Change tolerance settings for any of the circles as you did earlier in this module.

Module 7: Review Activities

Complete each of the Review Activities. When you are finished, have your instructor review and initial your work. If you have any questions, first refer to the previous modules, next use the *Help* menu. If neither of these provide the information you need, ask the instructor.

Prerequisite: Basic Measurement, Coordinate Systems, Nominals and Tolerances.

▶ **MODULE OBJECTIVES**

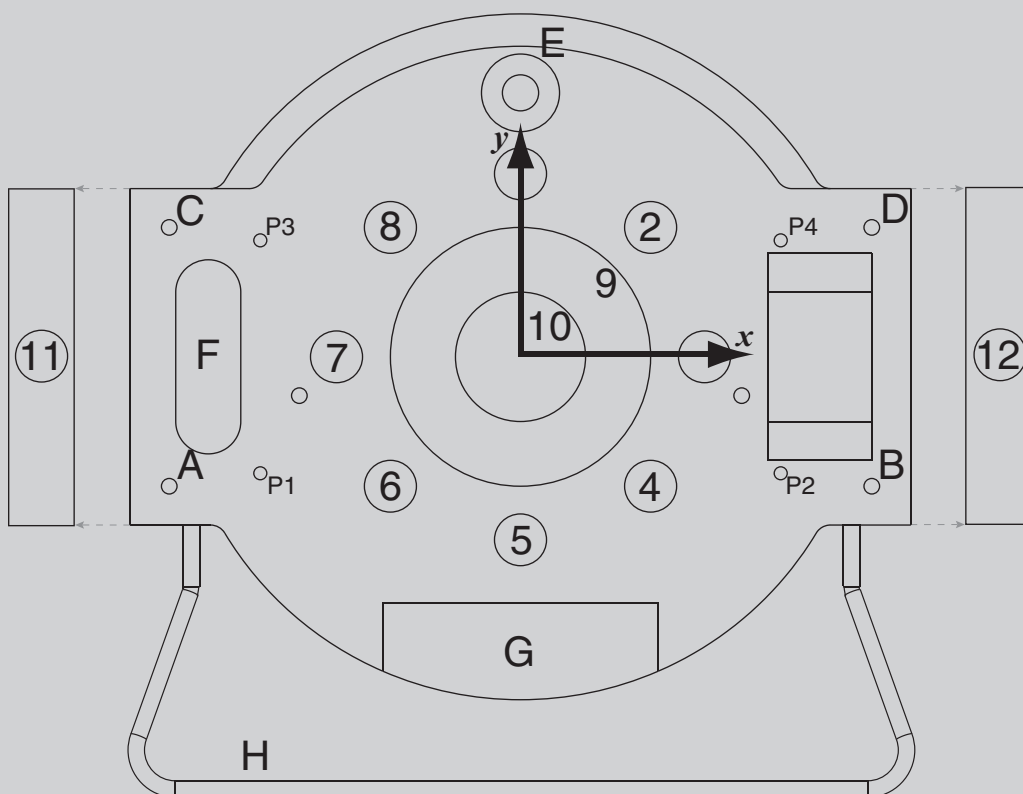
You will be able to:

- Demonstrate ability to use Measure, Construct, Dimension, and Report software menus, add nominals, set tolerances, identify variations between nominals and actual measurements, create and configure a final report.

Final Review Activities

ACTIVITY: Coordinate System

- Open a new file (make sure mm is the current measurement unit).
- Create the coordinate system in the figure below. Measure the features needed and align to the part. (Hint: Pay attention to the origin location and direction of the 'x' axis)



ACTIVITY: Nominals, Tolerances, And Constructions

- Measure and then enter the following nominals for circles 1, 3, 5, and 7:
 ☞ *You can also add the nominals first, and then add measurements to the nominals.*
 1 = "**0,70,0**"; Diameter = "**20mm**"
 3 = "**70,0,0**"; Diameter = "**20mm**"
 5 = "**0,-70,0**"; Diameter = "**20mm**"
 7 = "**-70,0,0**"; Diameter = "**20mm**"
- Enter a +/- tolerance of **.25 mm**.
- Create a bolt hole circle using circles 1, 3, 5, and 7.
- The Bolt Hole Circle diameter nominal is **140 mm**.
- Bolt Hole Circle Diameter = _____mm.
- Bolt Hole Form = _____mm.
- Are the form and diameter within tolerance? How do you know?

ACTIVITY: Constructions And Tolerances

- Construct a circle at the intersection of **Cone E** and the top plane of the part.
- The circle diameter nominal is **29.99 mm**.
- Enter a +/- tolerance of **.25 mm**.
- Circle Diameter = _____mm.
- Is it in tolerance? How do you know?

ACTIVITY: Dimensions

- Dimension the angle between circles 1, 5, and 7 using 5 as the apex.
- Angle = _____degrees.

ACTIVITY: Reports

- View the report.
- Report all elements measured and constructed above.
- Save the report as a PDF titled "**Final Review Activities**" in your folder.

All Activities Complete

Instructor Initials: _____

Date: _____

Module 8: Working with CAD

In this module, you will become familiar with using a CAD file as nominal data for your part inspection.

Prerequisite: none

▶ MODULE OBJECTIVES

You will be able to:

- Import a CAD model
- Identify the translatable CAD model file formats
- Prepare a CAD model for easy use in inspection
- Define nominal features and surfaces from the CAD

SCENARIO: WORKING WITH CAD

The boss says, "These results are great, but it has taken a lot of time to key-in all of the nominal information for the features. We need to measure a bigger part and we need the results quickly. You are going to have to import and prepare a CAD model to use in the inspection process. This is going to reduce the inspection time and get the results to the customer more quickly. If you need help, try looking for the information in the CAM2 Q Help menu or on FARO's web site."



● ● "I have the CAD model. What are the things I need to think about before beginning the inspection process? Is the model ready for use in the inspection process? If not, what steps do I have to perform in order to use the CAD model?"

Strategy: Working with CAD

- How do you decide if you should use CAD?
- What is the file format of the CAD?
- Can I get the CAD into a translatable file format?
- Have I prepared the CAD to be inspected?

The use of a CAD model can help decrease inspection time and reduce error, making the inspection process easier and more accurate.

The workflow improves and inspection time is reduced by having the nominal information for each feature already calculated in the CAD file. The nominal information is extracted from the CAD model and automatically associated to the measured feature. Eliminating the need to manually key-in information increases operator productivity and reduces the risk of error.

Types of CAD Data

There are three types of CAD data: wireframe, surface, and solid.

Wireframe: These entities define the outline of a part. They can include points, circles, arcs, lines, polylines and splines. A polyline is a group of line segments stitched together to approximate a curve. A spline is a simple curve.

Surface: A surface is used to define the outer boundary of a part. Surfaces are typically used for complex curved parts such as automotive and aerospace sheet metal parts. Surfaces are very popular for creating cutting paths for CNC cutting tools.

Solid: A solid model is also used to define the outer boundary of a part, but solids have a thickness or mass. Solid modeling is popular for the design of a variety of parts. Many CAD systems start with a solid model then create the 2D drawings and 3D surfaces from the solid.

Standard CAD Data File Formats

CAM2 Q is built with the Parasolid file format (*.x_t). You should **always** try to export from your CAD system to this file format.

If the Parasolid file format is not available, the following CAD data file formats are included with CAM2 Q. Translators for other CAD data file formats are available and must be purchased from FARO.

IGES: IGES (Initial Graphics Exchange Standard) was created to standardize data transfer between different CAD systems. IGES works very well for surface and wireframe entities, but not for text and dimensions.

VDA: VDA is similar to IGES in that it is a standard used to translate data between different CAD systems. VDA is particularly prevalent in Europe.

When To Use CAD

- When inspecting only simple features, use a wireframe CAD model.
- When inspecting surfaces, use a solid or surface CAD model.
- When the part is complex and/or has many surfaces and features that need to be inspected, use a solid or surface CAD model.

Using CAD with CAM2

CAM2 Q translates a CAD file into a Parasolid (.x_t) file format that can be imported to a CAM2 Q measurement file using the following methods:

1. CAM2 Q automatically translates and adds most CAD files using the **Open** command from the **File** menu.
2. Translating multiple CAD files with CAM2 Q is a two-step process:
 - First, translate the CAD file using the **FARO CAD Translator** command from the **File** menu.
 - Once translated, add the file using the **Import CAD** command from the **File** menu.

Currently, this is the only method to translate SolidWorks files.

☞ *If the features on the CAD are not drawn appropriately for inspection, they need to be constructed and relabeled before importing into CAM2 Q.*

☞ *Another time saver is preparing nominals before measurement. This results in a smoother and easier workflow for the end operator by saving time (use of a prepared CAD model) and eliminating the opportunity to enter an incorrect nominal value (use of Pick from CAD nominal vs. Key-In nominal).*

ACTIVITY: Import CAD Files

In this activity, you will import a translated CAD file:


1. New file	From the File menu, select New .
2. Import CAD	From the File menu, select Import , then select CAD .
3. Select file	From the \CAM2 Q v1.5 Training Files folder, select Demo Part Q.x_t . Click Open .

Features on the CAD model may not be drawn appropriately for inspection. For example, some drafters and CAD programs will use two arcs and two lines to define a round slot. Because the nominal geometry is not a slot, the nominal will not automatically associate to the measured round slot. In order to auto associate the nominal slot to the measured slot, we need to first create a nominal round slot on the CAD geometry.

Defining nominals prior to inspection can decrease inspection time.


ACTIVITY: Define Nominal Features And Surfaces From The CAD

In this activity you will pick features from CAD model and rename Circle 1, Circle 3, Circle 5, Circle 7 and Circle 9 from the Demo Part Q.x_t CAD file. Use the map of the training part to determine the locations of the circles.

1. Pick from CAD	On the Feature Creator , click Pick From CAD .
2. Circle	Click Circle .
3. Add Circle 1	On the Pick Circle from CAD window, check the name for Circle 1 and click on the circle's edge on the CAD model. Circle 1 appears in the Features panel.  <i>If clicking the edge does not return a circle, continue clicking at least two more points on the edge to define a circle.</i>
4. Add other circles	With the Pick Circle from CAD window remaining open, first rename and then click on the edge for Circle 3, Circle 5, Circle 7 and Circle 9.
5. Close	Click Close .

Pick Round Slot 1 and rename it as Round Slot F from the .x_t CAD file. Use the map of the training part to determine the location of the slot.

1. Pick from CAD	On the Feature Creator , click Pick From CAD .
2. Round Slot	Click Round Slot .

3. Add Round Slot	From the Pick Round Slot from CAD window, click on the round slot's edge. Round Slot 1 appears in the Features panel.  <i>If clicking the edge does not return a round slot, continue clicking three points that define the arc edge on one end of the slot and on three points that define the arc edge on the other end of the slot.</i>
4. Close	Click Close .
5. Rename feature	From the Features panel, right click on Round Slot 1 and select Rename . Backspace and rename the feature as Round Slot F.

Save the CAD file that you have prepared for inspection:

1. Save As	From the File menu, select Save As .
2. Your folder	Browse to your folder and type WWCAD . fcd.
3. Save	Click Save .

Module 9:

QuickTools Programming

In this module, you will become familiar with recording, editing, and playing a QuickTools program. You will create this program with and without the measurement device connected to your computer.

Prerequisite: Basic Measurement, Coordinate Systems, Nominals and Tolerances

MODULE OBJECTIVES

You will be able to:

- Build a repeatable measurement routine using measurements, constructions, dimensions, and reporting
- Save, open, edit, and run a repeatable measurement routine
- Design a program that performs an accurate metrological inspection of a part

SCENARIO: QUICKTOOLS PROGRAMMING

A typical QuickTools program takes an operator through the steps of a part program with digital pictures of the part and color-coded targets to make the program operator-friendly. QuickTools programming while recording allows you to create a program by automatically capturing measurement commands using a measurement device. QuickTools programming while not recording allows you to create a program by selecting features from the available menus without using a measurement device.



“I can create a QuickTools program which contains a set of measurement commands for repetitive part measurement. What are the things I need to think about to make the QuickTools program as effective and user-friendly as possible?”

Strategy: Working with QuickTools

QuickTools allow you to save a set of CAM2 Q commands in a list to run anytime the drawing file is open, facilitating repeatable part measurement. You can create multiple QuickTools programs in a single measurement file and play them whenever you choose.

QuickTools Program Commands

QuickTools programs may contain many CAM2 Q commands; however, Construction, Dimension, Coordinate System, Alignment, and Device Position commands are not added to programs since these features are dependent on data to solve.

QuickTools Program Context and Usability

You can increase usability of the QuickTools program for all operators by including pictures of the part to be measured (including depictions of the precise locations at which to take measurements), and important textual information for any command in the program. The more detail you provide, the easier your QuickTools program will be to use.

QuickTools Panel Commands

At the bottom of the QuickTools panel is the QuickTools toolbar.



- ① The **New Program** button creates a new QuickTools program.
- ② The **Delete** button erases a specific command in the list of commands (or erases a program entirely).
- ③ The **Play** button executes the sequence of commands in the current program.
- ④ The **Pause** button pauses the current program.
- ⑤ The **Stop** button stops the current program.
- ⑥ The **Record** button allows you capture all future commands into the QuickTools program (until you click the **Stop** button).
- ⑦ The **Lock QuickTools** button allows you to secure the QuickTool from being edited, overwritten, or deleted from the measurement file. This lock uses a unique password.

CAUTION: If you forget a password there is no way to recover it. Consider keeping a backup copy of the measurement file with a QuickTool that is not password-protected.
- ⑧ The **Help** button launches the QuickTools section of the CAM2 Q help file.
- ⑨ The **Tools** drop-down menu has special commands to add to a program.
 - **View Report** - Displays an existing report template and report list.
 - **Add Comment** - Adds a text message.
 - **Change Adapter** - Changes an SMR adapter on the FARO Laser Tracker.

Programming in Measure and Template Modes

You may add commands to QuickTools programs while in either **Measure** mode or **Template** mode. This gives you the flexibility of creating a QuickTools program while simultaneously performing live measurements (**Measure** mode), or creating a QuickTools program without using a measurement device (**Template** mode).

This chart highlights the differences between recording QuickTools programs in **Measure** or **Template** mode.

	Recording a QuickTool in Measure Mode	Recording a QuickTool in Template Mode
Insert Measurement Feature	<ul style="list-style-type: none">● Adds feature to measurement file● Adds measurement command to the QuickTool● Prompts operator to measure feature	<ul style="list-style-type: none">● Adds feature to measurement file
Manually Invoke "Add Readings"	<ul style="list-style-type: none">● Adds measurement command to the QuickTool● Prompts operator to measure feature	<ul style="list-style-type: none">● Adds a measurement command to the QuickTool

PRE-ACTIVITY:

Option 1 If using CAD	Option 2 If not using CAD
Open a new file.	Open a new file.
Import the CAD file: \\CAM2 Q\ CAM2 Q v1.4 Training Files\ Demo Part Q.x_t	
Pick From CAD: <ul style="list-style-type: none">● Circle 1● Circle 3● Circle 5● Circle 7	Key-In nominal features in Template Mode : <ul style="list-style-type: none">● Circle 1● Circle 3● Circle 5● Circle 7

ACTIVITY: Creating A New QuickTools Program

In this activity, you will create a new QuickTools program using the QuickTools panel.

1. Open the QuickTools panel	Click the QuickTools tab in the lower right side of the screen to open the QuickTools panel.
2. Create a QuickTools program	Click New Program . A new (blank) QuickTools program will appear as New Program 1 .
3. Rename the QuickTools program	Rename the QuickTools program by selecting New Program 1 and typing <code>Practice Program</code> .

ACTIVITY: Adding Features To A QuickTools Program In Measure Mode

In this activity, you will add measurement commands to the "Practice Program" QuickTools program in **Measure** mode.

1. Begin recording	Click the Record button.
2. Measure a Plane	On the Measure menu, select Plane . Measure Plane 1. Cancel the Plane command.
3. Rename the plane	Select the feature name and type <code>Datum A</code> .
4. Expand QuickTool	In the QuickTools panel, click the Plus Sign to expand the QuickTool program and see the commands.
5. Measure a 2D line	Press the F4 hot key. Measure the edge across the front of the part. Cancel the 2D Line command.
6. Rename the line	Select the feature name and type <code>Datum B</code> .
7. Measure a circle	Press the F10 hot key. Measure Circle 9. Cancel the Circle command.
8. Rename the circle	Select the feature name and type <code>Datum C</code> .

An alternative method to add one or more commands to a QuickTools program is to select measured features in the **Features** panel and drag them onto the program.

9. Create using wizard	On the Coordinate Systems menu, click Create Using the Wizard .
10. Add features	Choose Datum A as the Plane Feature, Datum B as the Line Feature, and Datum C as the Point Feature.
11. Align	Select the Align With checkbox and choose World.
12. Create	Click OK .

13. Stop recording	In the QuickTools panel, click the Stop button.
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Save the measurement file:

14. Save As	From the File menu, select Save As .
15. Your folder	Browse to your folder and type <code>Quicktools.fcd</code> .
16. Save	Click Save .

ACTIVITY: Playing The QuickTools Program

In this activity, you will complete the QuickTools program and play it.

1. Play the QuickTools program	Click Play to run the program.
2. Skip Document Header Information	Enter a part name. Click OK .
3. Measure the part	Follow the Measurement Window panel and measure Datum A, Datum B, Datum C. Notice that the current feature highlights red in the Main Window .

ACTIVITY: Adding Features To A QuickTools Program In Template Mode

In this activity, you will add measurement commands to the "Practice Program" QuickTools program in **Template** mode.

1. Template Mode	If necessary, click the Measure/Template Mode icon so that you are in Template mode.
2. Begin recording	Click the Record button.
3. Add Measurement	On the Features panel, right-click the four circles (1,3,5,7) and select Add Measurement .

Note that the measurements were added to the **Features** panel, but nothing has been added to the **QuickTools** panel. The "**Add Measurement**" is not a QuickTools program command. You will use the actual circles later in this module.

4. Add readings to the circle	On the Features panel, right-click Circle 1 and select Add Readings .
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Note that the Add Readings command has added the "Add Readings to Circle 1" command to the QuickTools program.

5. Add readings to the circles	On the Features panel, select Circle 3 , Circle 5 , and Circle 7 . Right-click and select Add Readings .
6. Stop recording	Click the Stop button.

Since Constructions, Dimensions, Tolerancing, and Reporting are not recorded in a QuickTools program, all of this can be done before or after creating the Quick Tools program. Remember, these save as a part of the measurement file.

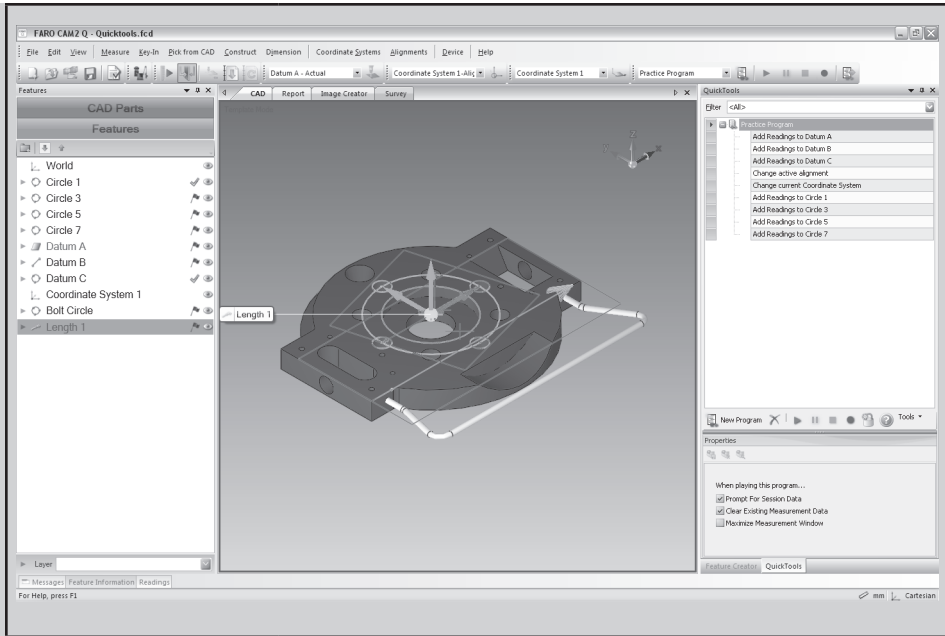
ACTIVITY: Constructions And Dimensions

In this activity, you will create a bolt circle and a length dimension.

1. Construct a Circle by Best Fit	On the Construct menu, select Circle , and then select By Best Fit .
2. Rename the Best Fit circle	Select the feature name and type <code>Bolt Circle</code> .
3. Select Datum A as the plane for the measured circles	If not already selected, select Circle 1 - Actual, Circle 3 - Actual, Circle 5 - Actual, and Circle 7 - Actual. Check the Use Plane checkbox and select Datum A - Actual from the drop-down list. Click Create and then click Close .

Because **Bolt Circle Actual** uses measured (actual) circles (1,3,5,7) in the By Best Fit construction, the nominals of the measured circles are automatically used to construct the nominal by best fit circle (**Bolt Circle - Nominal**).

4. Create a dimension	On the Dimension menu, click Length From Features . Select Circle 3 - Actual treat as a point, and Circle 7 - Actual treat as a point. Click Create and then click Close .
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A nominal length is automatically created and associated.

ACTIVITY: Playing The QuickTools Program

In this activity, you will complete the QuickTools program and play it.

1. Play the QuickTools program	Click Play to run the program.
2. Document Header Information	Enter a part name. Click OK .
3. Measure the part	Follow the Measurement Window panel and measure Datum A, Datum B, Datum C and the four circle features.

ACTIVITY: Editing Tolerances

In this activity, you will edit tolerances for some features that you want to view on the report.


1. Edit the tolerances for each circle	<p>Select Circle 1 in the Features panel.</p> <p>In the Feature Information panel, clear the Z dimension and 3D Distance checkboxes.</p> <p>Edit the X dimension, Y dimension, and Diameter tolerances as follows:</p> <p><input type="checkbox"/> Lower Tolerance -0.25 mm.</p> <p><input type="checkbox"/> Upper Tolerance +0.25 mm.</p>
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Now you can copy the tolerances to the other three circles.

2. Copy the Tolerances	<p>Select Circle 1 in the Features panel.</p> <p>Right-click and select Copy Tolerances.</p>
3. Paste the Tolerances	<p>Select Circle 3 in the Features panel.</p> <p>Right-click and select Paste Tolerances.</p>
4. Paste to remaining circles	<p>Repeat for the other two circles.</p>

ACTIVITY: Reporting The Results

In this activity, you will make a report of the measurement results.

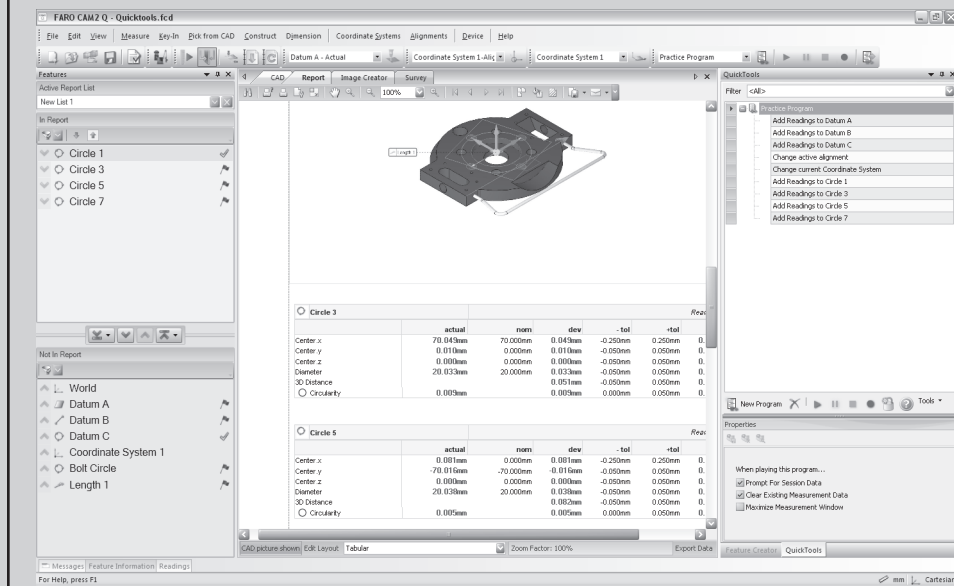
 Before clicking the **Report** tab, make sure the view on the Main Window is what you want to appear on the report. Zoom in on the entire part or the area of the part you want to include in the report. A good way to zoom in on and orient the part is to use the hot keys. The, **6** hotkey orients the part to a top view, **E** hotkey zooms all, **I** zooms in, **O** zooms out and the arrow keys pan around the window.

1. Switch to the Report view	<p>Click the Report tab.</p>
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You can automatically switch to Report view when running the Quicktools program by adding the View Report command into the program. On the **QuickTools** toolbar, select **Tools** and select **View Report** while recording your QuickTools program.

2. Add each circle to the report

Add the four circles to the **In Report** list.



3. CAD tab

Click the CAD tab to return to the Main Window.

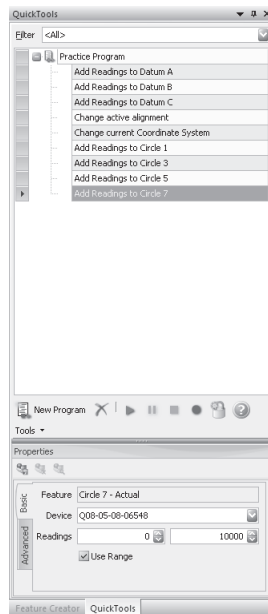
QuickTool Program Properties

There are three properties that may be enabled for each QuickTools program. When enabled, these properties activate special commands when the QuickTools program is started.

- **Prompt for Session Data** prompts the operator to update the contents of the *Document Header Information* dialog box before starting the first command.
 - ☞ *The Document Header Information dialog contains information such as Part Name, Session Name, and Operator, which may be used to provide unique information for facilitating repeatable part measurement.*
- **Clear Existing Measurement Data** removes **all** readings from the measurement file before starting the first command, providing for a “fresh” set of measurements each time the operator begins the QuickTools program.
- **Maximize Measurement Window** maximizes the **Measurement Window** panel to fill the entire computer screen when the program plays.

Command Properties

Each measurement command is listed as a single line item in the QuickTools panel. You can modify certain parameters of each measurement command using the Properties panel below the list of commands. Click a measurement command to access the command's parameters in the Properties panel.



CAD View Commands

Use the CAD View buttons to assign, preview, or delete a specific view of the features in the **Main Window** for any QuickTools command.

- **Save CAD View for Step:** Manipulate the view of the **Main Window**, and click this button to save this view to the QuickTools command.
- **Clear Saved CAD View:** Click this button to delete an associated view of **Main Window** from the QuickTools command. If no CAD View has been saved to this command, this button is grayed out.
- **Preview Saved CAD View:** Click this button to preview an associated view of the **Main Window** from the QuickTools command. If no CAD View has been saved to this command, this button is grayed out.

Command Parameters

For each QuickTools command, the **Properties** panel is divided into two tabs, Basic and Advanced.

Basic Tab

The Basic tab has 3 main parameters: Feature, Device, and Readings.

- **Feature** contains the name of the selected feature.
- **Device** Chooses which device will measure the feature (assuming there's more than one measurement device to be used).
- **Readings** Sets a low and high limit to the number of readings the user will add to each feature. Uncheck the **Use Range** check box to establish a high limit only.

Advanced Tab

The Advanced tab controls scanning functionality.

- **Sample Mode** Sets an interval parameter, a distance parameter, or both. An interval parameter takes a point over a specified time; a distance parameter takes a point over a specified distance.
- **Replace Existing Readings** removes any existing reading from the feature.

ACTIVITY: Modifying QuickTools Program Command Properties

In this activity, you will modify the properties of some of the measurement commands we've added to the QuickTools program.

1. Modify the Add Readings to Circle 1 command to take 7 readings	in the QuickTools panel, select the Add Readings to Circle 1 command. On the Basic tab, clear the Use Range checkbox, and change the number of Readings to 7.
2. Modify the Add Readings to Circle 5 command to take readings every .10 mm	Select the Add Readings to Circle 5 command and click the Advanced tab. Select Distance Interval from the Sample Mode drop-down list, and enter 0 . 10 in the Distance field.
3. Modify the Add Readings to Circle 7 command to take readings every .5 mm	Select the Add Readings to Circle 7 command and click the Advanced tab. Select Distance Interval from the Sample Mode drop-down list, and enter 0 . 5 in the Distance field.

Comments

A comment is a textual message that an operator will see when playing the QuickTools program, must acknowledge by clicking OK, and can thus be used to help guide the operator through the program by providing important information at key points.

You can add a comment to any QuickTools program command.

ACTIVITY: Adding Comments To A QuickTools Program Command

In this activity, you will add a comment, and a View Report command in the QuickTools program.

1. Start Recording	On the QuickTools panel, click Record .
2. Select command	Select the Add Readings to Circle 1 command
3. Add Comment	On the QuickTools panel, click the Tools menu, and select Add Comment .
4. Input text	In the Add Comment dialog box, enter: Begin measuring the 20mm circles on the top face. Click OK .

When the QuickTools program is run, the operator will be presented with a text box containing your comment before continuing with the command list.

5. View Report command	On the QuickTools panel, click the Tools menu, and select View Report . On the Report View Settings panel, Click OK . This command always adds to the end of the QuickTools program.
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The **Tools** menu also has the **Change Adapter** command for the FARO Laser Tracker. When executing this step of a QuickTools program, the operator is guided through the process of changing the adapter. When the adapter change is successful, the operator can continue running the QuickTools program.

ACTIVITY: Finishing And Playing The QuickTools Program

In this activity, you will complete the QuickTools program and play it.

1. Click Stop	On the QuickTools panel, click Stop . CAM2 Q stops recording commands and the QuickTools program is complete.
2. Save the file	From the File menu, Click Save to update your <code>Quicktools.fcd</code> file.
3. Play the QuickTools program	On the QuickTools panel, click Play to run the program.

Reordering Program Commands

After you've finished recording commands to the QuickTools program, you can easily change the order of the commands by dragging the command to another location in the list (clicking a command and holding the left mouse button, dragging the command to a new location within the QuickTools program, and releasing the left mouse button).

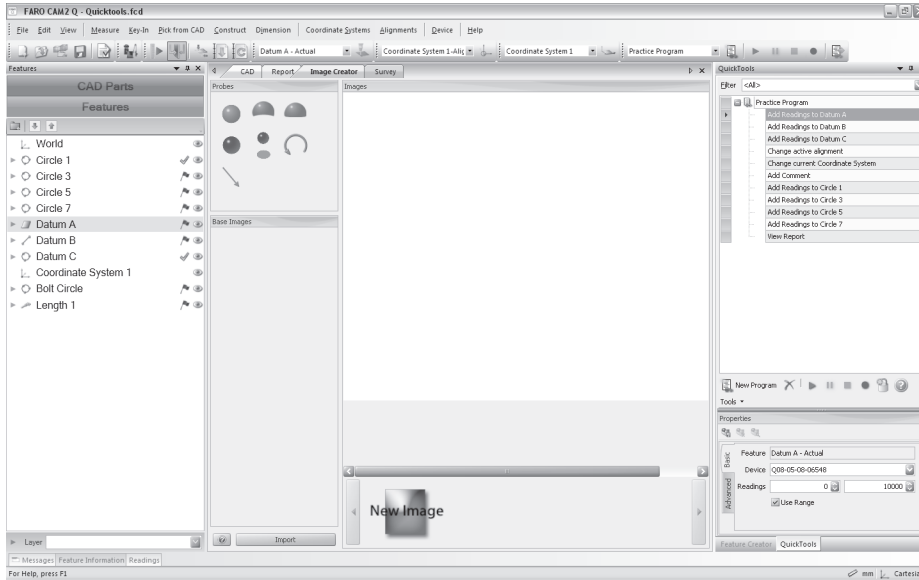
Reordering Program Commands

Deleting QuickTool commands from a program is simple, just select the command and click the **Delete** button (X icon) on the **QuickTools** panel.

Image Creator

Now that you have created your QuickTools program, you may add pictures to the measurement commands with Image Creator. Including pictures of the part with each command will show an operator exactly where to place the probe for recording measurements and where to record end-clicks.

Click the Image Creator tab to access Image Creator.



Picture Options

Picture options include:

- Photographs taken with a digital camera (*.jpg, *.png, *.bmp format)
- *.jpg, *.png, *.bmp files of your part from a CAD program
- Screen captures of your CAD model made with the CAM2 Q
File < Export < Picture to File command (this may be the easiest option if you don't have access to a digital camera.)

When taking pictures of your part, include as many features in a shot as possible without sacrificing space, picture clarity, and quality. Capturing a big cluster of features from a long distance will not provide enough detailed information for the operator.

The ideal image size is 640x480 pixels; most cameras have an adjustable setting for the size of a picture. However, you should first add one image to a QuickTools program command, then play the command and look at the picture in the **Measurement Window** panel. One image can be used as many times as needed.

ACTIVITY: Adding Pictures With Image Creator

In this activity, you will add pictures to your QuickTools program using Image Creator.

1. Access Image Creator	Click the Image Creator tab to access Image Creator.
2. Import a base image into Image Creator	Click Import . Browse to My Documents\CAM2 Q\ v1.4 Training Files\Part Photographs\. In the Open dialog box, select all the images for the QuickTools program and click Open . The images now appear in the Base Images box.
3. Assign the base image to the first measurement command	In the QuickTools panel, select the first measurement command, Add Readings to Datum A . In the Image Creator panel, click New Image . Drag an appropriate image for the first command from the Base Images box onto the Images screen.

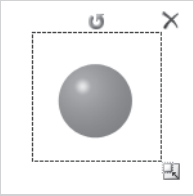
Green and Red Target Points (Probes)

After you've added pictures of the part into Image Creator, you can overlay green target points to identify the places to record readings and red target points to specify end clicks.

During the execution of a program, each reading and end click requires its own picture and target point (where the user should place the Probe/SMR).

ACTIVITY: Adding Green And Red Target Points To The Images

In this activity, you will add green and red target points (signifying Probe/SMR positions) to the pictures you've uploaded.

1. Add a green target point to the base image	Drag a green target point from the Probes box onto the image in the Images screen.
2. Rotate, resize, and position the green target point	<p>Hover the mouse over the target point to view the target point's positioning menu.</p> <ul style="list-style-type: none"> <input type="checkbox"/> The arrow icon at the top rotates position of the target point. <input type="checkbox"/> The X icon at the upper right deletes the target point from the Images screen. <input type="checkbox"/> The extend icon in the lower right increases/decreases the size of the target point. 
3. Add and move green target points for each reading	<p>Once the first target point is in location, click New Image.</p> <p>Repeat steps 1 - 3 until all the readings needed have images and target points for each feature type. For this plane you should add seven green target points.</p>

After you indicate the location of the readings, you will indicate the location to record an end click.

4. Add red target point	Drag a red target point from the Probes box onto the image in the Images screen.
5. Rotate, resize, and position the red target point	Rotate, resize, and position the red target point



Number of readings


for optimal results:

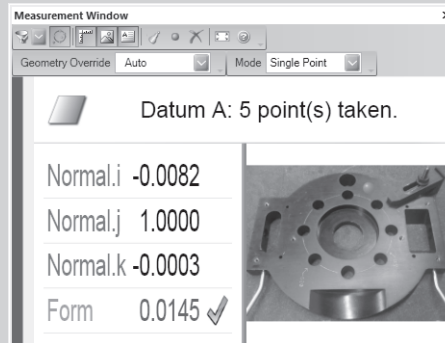
Plane - seven

Line - five

Circle - seven

Continue to add the appropriate images and target points for all of the remaining measurement commands.


 When you run the QuickTools program, the Measurement Window panel will include the images you've created.



Save the measurement file, which now includes all of the modifications to the QuickTools program.

6. Save the file	<p>From the File menu, Click Save to update your Quicktools.fcd file.</p> <p>The QuickTools program, base images, and target point locations are saved with the *.fcd measurement file.</p>
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Editing a QuickTools Program

- Click any measurement command in the **QuickTools** panel to view and edit the properties in the **Properties** panel.
 - You may add new commands by clicking **Record** in Measure or Template mode. Click **Stop** to cease recording new commands.
 - You may also change the order of the commands by dragging the commands to another location within the program. If you have added a Comment command before a measurement command, make sure to also move the Comment.
 - You may also delete commands from the program by selecting the command and clicking **Delete** (trashcan icon).
-  You may also delete the entire QuickTools program by selecting the program name and pressing the **Delete** key.

Module 10: Iterative Alignments

In this module, you will become familiar with iterative (best-fit) alignments to align and compare measured features to nominal features.

Prerequisite: Basic Measurements, Nominals and Tolerances.

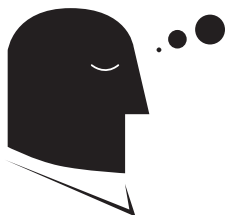
▶ MODULE OBJECTIVES

You will be able to:

- Create Iterative alignments using the default settings, using weights, and using material temperature considerations
- Report the alignment results

SCENARIO: ITERATIVE ALIGNMENTS

You are familiar with measuring features and viewing the results using a Coordinate System alignment, but now we will use a “best fit” alignment between the measured and the nominal features.




I need to make sure the features I measure on my part are comparable to their nominals. How do I perform an Iterative alignment to best-fit measured features to their corresponding nominals?

Iterative Alignments

An Iterative alignment uses point reducible features to best-fit them to their corresponding nominal values. You can create an Iterative alignment using three or more point-reducible features with associated nominals. You may add nominals to features that have already been measured, or you may create nominals and add measurements to the nominals.

Preferences for Iterative Alignment

Before you create your Iterative alignment, access the Measurement preference (**Edit > Preferences > Measurement > General** tab) and ensure that the **Use Last Plane** check box is selected.

 *If the Use Last Plane check box is clear, each measured circle will have a separate projection plane.*

ACTIVITY: Creating Nominals For An Iterative Alignment

In this activity, you will create nominal circles from a CAD file for use in creating an Iterative alignment.

1. Open a new file	On the File Menu, click New .
2. Import CAD	Click the Import CAD icon on the toolbar. Browse to the \My Documents\CAM2 Q v1.5 Training Files folder and select Demo Part Q.x_t
3. Pick from CAD menu	On the Feature Creator , select Pick From CAD .
4. Circle	Select Circle .
5. Pick from CAD	Click the Circle 1 edge. Circle 1 appears in the Features panel.

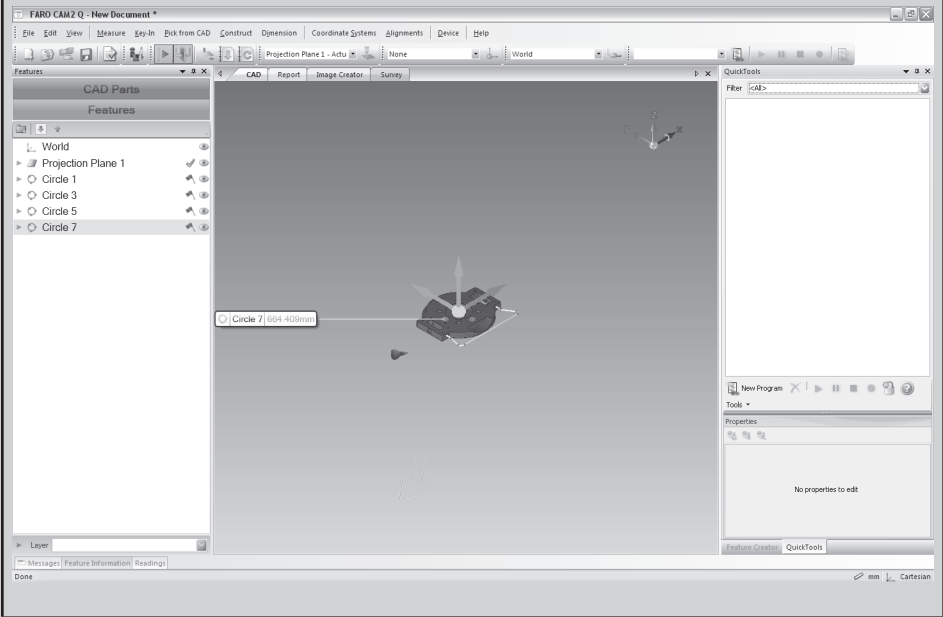
6. Repeat for other features	With the Pick Circle from CAD window remaining open, check the name and click the edge for Circle 3, Circle 5, and Circle 7.
7. Close	Click Close .

Now that you’ve created the nominal features, you can add measurements to them.

ACTIVITY: Adding Measurements To The Nominals

In this activity, you will add measurements to the nominal circles you created in the last activity.

1. Add Measurement	Select Circle 1, Circle 3, Circle 5, and Circle 7 . Right-click select Add Measurement . Since there is no active projection plane, CAM2 Q automatically adds a plane feature.
2. Measure Plane	Add readings to Projection Plane 1 .
3. Measure Circles	Add readings to Circle 1, Circle 3, Circle 5, and Circle 7 .



Zoom Out (use the **O** hot key) so that you can see your measurements and your CAD file. Notice that they are not aligned yet.

Measurement and Nominal Association

You have just created nominal features and added measurements to those features. By doing so, your measurements and nominals are automatically associated and a feature group is created. To verify this association, click each circle feature group in the **Features** panel and view the Nominal Feature column in the **Feature Information** panel.

You now have the measurements, nominals, and feature associations you need to create an Iterative alignment.

ACTIVITY: Creating An Iterative Alignment

In this activity, you will create an Iterative alignment using the nominals and measurements you've created.

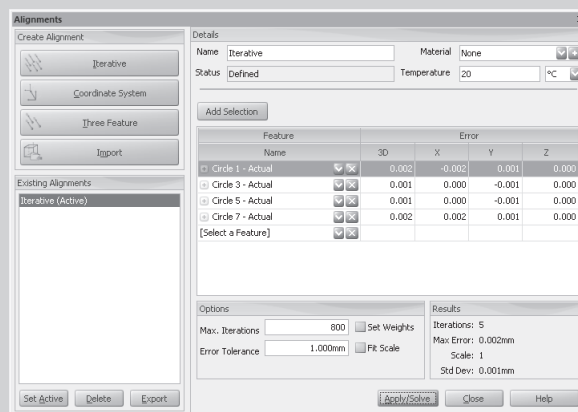


You can also press the **A** hot key to start the Alignments command.

1. Alignment command	From the Alignments menu, select Iterative Alignment .
2. Select Circle 1 - Actual	Click the [Select a Feature] drop-down and select Circle 1 - Actual .
3. Select other features	Repeat step 2 for Circle 3 - Actual , Circle 5 - Actual , and Circle 7 - Actual .

You can also add these features to the Alignments dialog box by selecting them in the **Features** panel and clicking the **Add Selection** button.

4. Enter name	Enter Iterative in the Name box.
5. Apply/Solve	Click Apply/Solve to create the Iterative alignment.



Note that the "Iterative" alignment is now active. The X, Y, Z, and 3D columns show the calculated deviation of each feature in the best fit.

6. Close	Click Close .
----------	----------------------

You should now be able to see that your measurements are aligned to the CAD file. Also notice that your alignment now shows active in the **Alignments** toolbar.

Weights

You can apply weights to the X, Y, and Z coordinates of each feature in the alignment. A weight ensures a higher priority for that feature in the calculation.

In the Alignments dialog box, select the **Set Weights** checkbox to add the Weights columns to the Alignments dialog box, then enter a value for the X, Y, and Z coordinate for each feature.

The default value is 1; input a number greater than 1 to emphasize a weight.

ACTIVITY: Adding Weights To An Iterative Alignment

In this activity, you will add weights to **Iterative**.

1. Alignment command	Press the A hot key.
2. Set weights	Select the Set Weights checkbox to view the Weights columns.
3. Enter values	In the Weights column, double-click the X coordinate of Circle 1 - Actual and enter 5.
4. Apply/Solve	Click Apply/Solve and note the differences in the Results area (lower right).
5. Close	Click Close .

Fit Scale

You can scale the measured features during the best fit calculations. The scale is the ratio of the measured features to their nominal features.

Select the **Fit Scale** check box to scale measured features during best fit calculations.

If the **Fit Scale** check box is not selected, no scaling is used in the calculations and the scale of the part is:1.

Material Temperature

Scaling for temperature allows you to measure parts in areas that are either warmer or cooler than the nominal temperature of 20°C (68°F). The measurement results are adjusted for thermal expansion or contraction.

You can adjust calculations for both the material and the current temperature of the part. To scale for material temperature changes:

- After creating an Alignment, in the **Details** section of the **Alignment** dialog box, click the **Material** drop-down arrow and select a material

from the library. You will see the coefficient of thermal expansion (CTE) next to the material name. You cannot change this value.

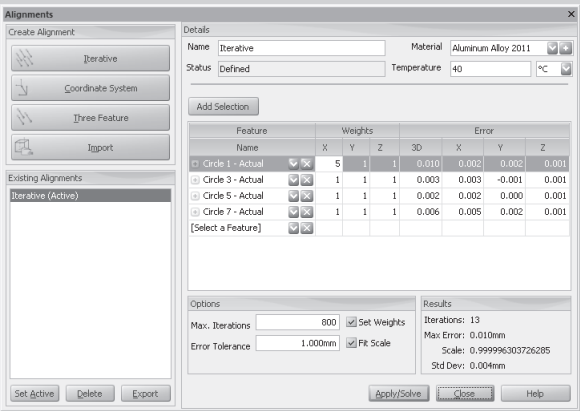
- Enter the temperature of the part, and select Celsius (°C) or Fahrenheit (°F) from the drop-down list.

To create a new material, click the **Plus (+)** button next to the **Materials** drop-down arrow. In the **Create New Material** dialog box, enter a name and coefficient of thermal expansion value for the new material. Click **OK** to add this material to the library.

ACTIVITY: Material Temperature - Iterative Alignment

In this activity, you will add material and temperature considerations to My Iterative Alignment.

1. Alignment command	From the Alignments menu, select Create/Edit to view Iterative.
2. Fit Scale	Select the Fit Scale checkbox.
3. Select Material	Click the Material drop-down (upper right) and choose Aluminum Alloy 2011 .
4. Enter Temperature	Enter 40 in the Temperature box.
5. Apply/Solve	Click Apply/Solve and note the differences in the Results area (lower right).



6. Close	Click Close .
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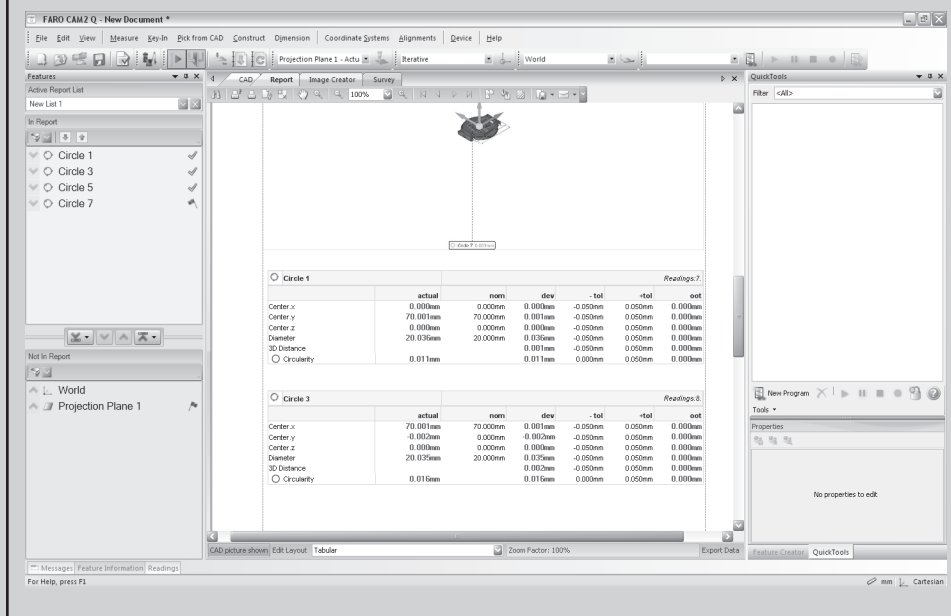
Now that you've created your Iterative alignment, you can create a report of the results.

ACTIVITY: Reporting The Results Of The Iterative Alignment

In this activity, you will view the results of the Iterative alignment using CAM2 Q's reports.

Before clicking the **Report** tab, make sure the view on the Main Window is what you want to appear on the report. Zoom in on the entire part or the area of the part you want to include in the report. A good way to zoom in on and orient the part is to use the hot keys. The **6** hotkey orients the part to a top view, **E** zooms all, **I** zooms in, **O** zooms out and the arrow keys pan around the window.

1. Select the Circles	In the Features panel, select Circle 1, Circle 3, Circle 5, Circle 7.
2. Report tab	Click the Report tab.
3. Add features to the report	The four circles automatically add to the Active Report List .



Review the measurement results of the four circles.

ACTIVITY: Save The Measurement File

In this activity, you will save your work in the measurement file.

1. Save As	From the File menu, select Save As .
2. Your folder	Browse to your folder and type Iterative.fcd .
3. Save	Click Save .



This function is not active until an alignment has solved.

Auto Nominal Association

Auto Nominal Association is a CAM2 Q preference which controls the automatic association of the nearest nominal to a measured feature - providing it falls within a set of tolerance zones. This preference is enabled by default. To enable or disable auto nominal association:

- On the **Edit** menu, click **Preferences**. In the **Preferences** dialog box, select **Measurement** and the **Auto Nominal** tab.
- Select the **Automatically Associate Nominal** check box:

ACTIVITY: Measure Additional Features

In this activity, you will measure the remaining circle on the part. The **Auto Nominal** preference will automatically find and associate the nominal circles after the measured circle has solved.

1. Main Window	Click the CAD tab to return to the CAD screen.
2. Circle command	From the Measure menu, select Circle .
3. Measure circles	Measure circles 2, 4, 6, 8. You can rename the features if you wish.
4. Review the report	Click the Report tab. Add these new circles to the report and review the results.

Module 11:

Wireframe CAD Inspection

In this module, you will become familiar with using the wireframe data of a CAD model to facilitate inspection of your part.

Prerequisite: Working with CAD module.

MODULE OBJECTIVES

You will be able to:

- Identify proper alignment using the blueprint design
- Employ a wireframe CAD model with a Coordinate System Alignment

SCENARIO: COMPARING MEASUREMENTS TO CAD

The core principle of wireframe CAD inspection is the comparison of physical part measurements to nominal CAD features. When you align the measurements and nominals, the differences between them can be identified and analyzed.



I have to inspect the part and compare the measurements to the “perfect world” features in my CAD file. Should I create a coordinate system based on my measurements and align with the CAD’s coordinate system? What’s the best way to compare my measurements to my CAD nominals?

The coordinate system on the physical part relates to the coordinate system of the part’s CAD model. In CAM2 Q, you can align these coordinate systems and associate the measured features to the nominal features contained in the CAD model.

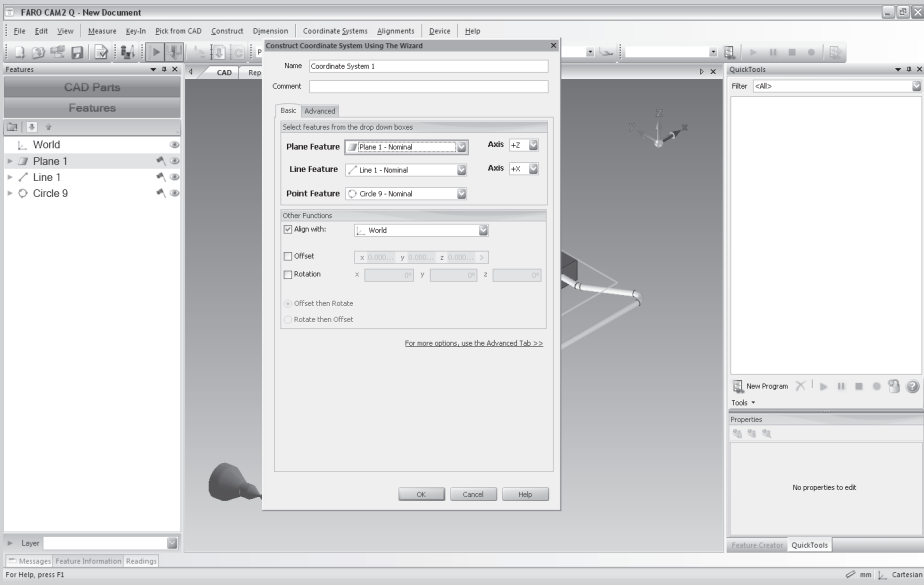
Wireframe CAD Inspection Workflow

1. Import the CAD file.
2. Measure the part and create a coordinate system.
3. Align the measurement coordinate system to the wireframe CAD model.
4. Measure other features for comparison to the CAD model.
5. Associate measured features to nominal features, or add measurement commands to nominal features.
6. Adjust positional and form tolerances for the holes, round slots, etc.
7. Create and view a report.

ACTIVITY: Measured Coordinate System And Aligning To CAD

In this activity, you will measure features, create a coordinate system with those features, and align the coordinate system with the CAD coordinate system for proper alignment.

1. Open a new file	Hold down the Ctrl key on the keyboard and press the N key.
2. Import CAD file	Import the Demo Part Q.x_t file. Then, press the S hot key to view the different shaded and wireframe views.

3. Measure Mode	If necessary, click the Measure/Template Mode icon so that you are in Measure mode.
4. Measure top plane	Measure the plane on the top of the demo plate. On the Measure menu, click Plane .
5. Measure front line	Measure the front edge of the part from left to right. On the Measure menu, click 2D Line .
6. Measure Circle 9	Measure Circle 9. On the Measure menu, click Circle . (You will need to rename the circle as Circle 9).
7. Coordinate Systems	Press the C hot key.
8. Select Plane 1	In the Plane Feature list, select Plane 1 . In the Axis list, select +Z .
9. Select 2D Line 1	In the Line Feature list, select Line 1 . In the Axis list, select +X . ☞ You have just selected the Z and X axes of the new coordinate system.
10. Select Circle 9	In the Point Feature list, select Circle 9 . ☞ You have just established the center of Circle 9 as the origin.
11. Align to World	Check the Align with box and select World ☞ This aligns your measured coordinate system to the nominal (or World) coordinate system.
	
12. Create and Close	Click OK .



If you create nominal features and add measurements to them, your measurements and nominals are automatically associated.

Now that you've aligned your measured coordinate system with the nominal (World) coordinate system, you can compare your measured features to the nominal features of the CAD model.

ACTIVITY: Nominal Features And Comparing To Measurements

In this activity, you will check the automatic nominal of Circle 9 and review the measurement results.

1. Feature Information tab	Click the Feature Information tab. Check to see if a nominal was automatically created and associated.
2. View results	Use the Feature Information panel to compare the measured circle's measurements, positioning, and other GD&T statistics with its nominal.

Feature Label	Actual	Nominal	Dev: Nominal Feature	Low Tol	Up Tol	OOT	Tolerance
Circle 9 - Actual			Circle 9 - Nominal				
Center.x	-398.894mm	0.000mm	-398.894mm	-0.050mm	0.050mm	-398.844mm	
Center.y	-154.934mm	0.000mm	-154.934mm	-0.050mm	0.050mm	-154.884mm	
Center.z	-474.862mm	0.000mm	-474.862mm	-0.050mm	0.050mm	-474.812mm	
Diameter	99.455mm	100.000mm	-0.545mm	-0.050mm	0.050mm	-0.495mm	
3D Distance			639.230mm	-0.050mm	0.050mm	639.180mm	

Circle 9 results

Center.x Actual: _____

Center.y Actual: _____

Center.z Actual: _____

Diameter Actual: _____

3D Distance Actual: _____

Circularity Actual: _____

SCENARIO: SUB-ASSEMBLIES WITH LOCAL COORDINATE SYSTEMS, ASSEMBLIES WITH GLOBAL COORDINATE SYSTEMS

Parts that are sub-assemblies (or “piece parts”) may have a part (local) coordinate system that relates to an assembly (global) coordinate system on the final assembly. For example, one automobile part may report its features based on a coordinate system established from the fully assembled automobile.



The part I am inspecting is a sub-component of a larger assembly. The CAD file of the sub-component has a coordinate system, and the larger assembly has a global coordinate system. How do I inspect using multiple coordinate systems?

If you know the relationship of the part coordinate system to the assembly coordinate system, you can apply an offset and rotation to align the part coordinate system with the assembly coordinate system. If you need smaller, more manageable dimensions, you can inspect the entire part from the part coordinate system. Then, apply an offset and rotation to the part coordinate system to move into the larger assembly coordinate system.

ACTIVITY: Offsetting A Coordinate System

In this activity, you will apply an offset to translate to the coordinate system you’ve created to a known position based on the final assembly.

For this example, let’s assume the origin of the assembly coordinate system is located at X 500, Y 220, Z 0.

1. Edit Coordinate System 1	Select Coordinate System 1. Right-click and select Properties .
2. Offset	Select the Offset check box and enter the following translation for X, Y, and Z: (500, 220, 0).
3. Modify	Click Modify and Close .
4. View results	Click Circle 9 and check the Feature Information panel to compare the differences in the X position, Y position, and the 3D Distance to the previous results.

SCENARIO: THE CAD FILE'S COORDINATE SYSTEM IS IN THE INCORRECT LOCATION

When inspecting with wireframe CAD files, you may occasionally find that a CAD file's coordinate system is in the incorrect (or not optimal) location.



● ● **The CAD file that I'm to use for inspection has the coordinate system in the wrong place! What if I can't contact the supplier of the CAD file and convince them to send me an updated CAD file? How can I create the correct coordinate system using CAM2 Q?**

The best option is to ask the CAD file's drafter to move the file's coordinate system to the appropriate position and orientation for your inspection. If this is not feasible, you may import the model into a CAD program and perform changes; however, problems may arise with the CAD model type when importing the file into a different CAD program.

CAM2 Q gives you the ability to move the CAD file's coordinate system using nominal features defined from the CAD model. In other words, you can make a new *nominal* coordinate system from the features of the CAD model, which you can then use to align your measurement device.

ACTIVITY: Creating A Nominal Coordinate System

In this activity, you will use the Pick from CAD commands to create a new coordinate system for your part.

1. New file	Open a new file.
2. Measure Mode	If necessary, click the Measure/Template Mode icon so that you are in Measure mode.
3. Import CAD file	Click the Import CAD icon.
4. Select file	In the Add CAD Model window, browse to CAM2 Q\ v1.5 Training Files\ folder, select Demo Part Q.x_t and click Open .

5. Pick from CAD	On the Feature Creator , select Pick From CAD .
6. Plane	Select Plane .
7. Pick points on plane	The Pick Plane from CAD window appears. Click on the part's top surface.
8. Create	Plane 1 appears in the Features panel.
9. Close	Click Close .

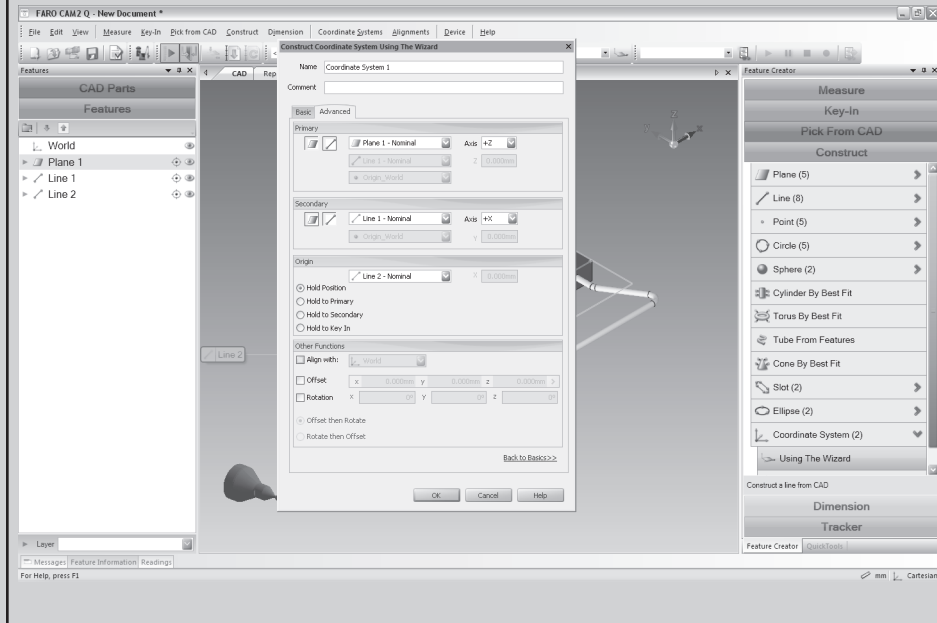
10. Pick from CAD	On the Feature Creator , select Pick From CAD .
11. Line	Select Line .
12. Pick points on line	On the Pick Line from CAD window, click on the top front edge of the part.
13. Create	Line 1 appears in the Features panel.
14. Close	Click Close .

15. Pick from CAD	On the Feature Creator , select Pick From CAD .
16. Line	Select Line .
17. Pick points on circle	On the Pick Circle from CAD window and click on top edge of the part above Circle 11.
18. Create	Line 2 appears in the Features panel.
19. Close	Click Close .

Note that with some CAD files you may have to click the minimum number of points on the CAD to create the feature.

20. Create coordinate system	On the Coordinate Systems menu, click Create Using the Wizard .
21. Advanced tab	Click on the Advanced tab.

22. Select primary feature	In the Primary Feature list, select Plane 1 - Nominal . In the Axis list, select +Z .
23. Select secondary feature	In the Secondary Feature list, select Line 1 - Nominal . In the Axis list, select +X .
24. Select origin	In the Origin Feature list, select Line 2 - Nominal .
25. Do not align	Clear the Align with check box.
26. Create and close	Click OK .



You have just created a new nominal coordinate system for the CAD model using CAM2 Q's **Construct from CAD** and **Coordinate Systems** commands. In the next activity, you will measure the physical part, construct a part coordinate system, and align that coordinate system to the new nominal coordinate system.

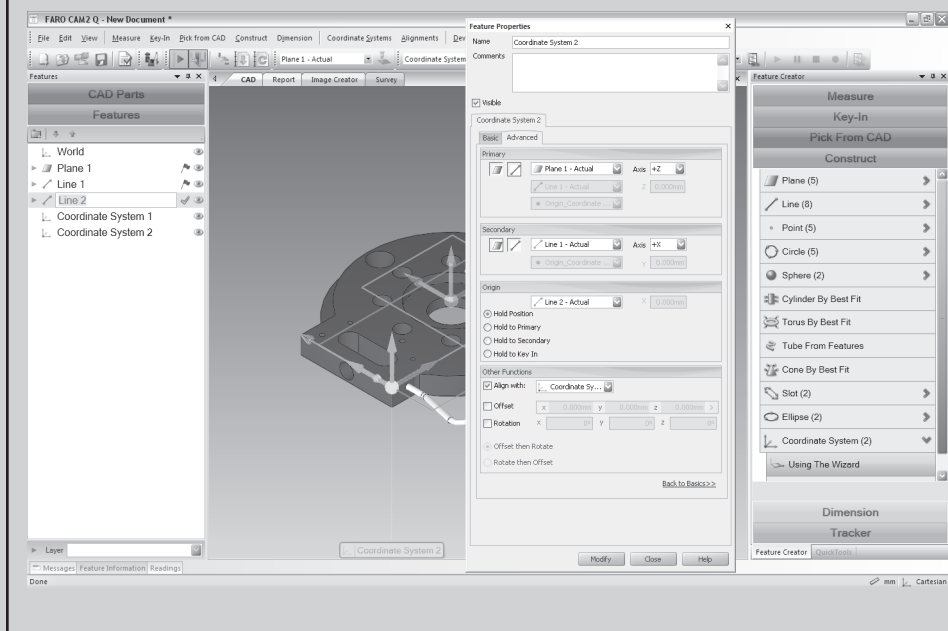
ACTIVITY: Aligning To The Nominal Coordinate System

In this activity, you will measure the part, create a coordinate system from the part measurements, and align the part's coordinate system to the nominal coordinate system (Coordinate System 1).

 Make sure you are in **Measure** mode.

1. Measure top plane	On the Measure menu, click Plane . Measure the plane on the top of the demo plate. Cancel the Plane command.
2. Measure front line	On the Measure menu, click 2D Line . Measure the front line of the part from left to right.
3. Measure side line	Measure the side line of the part from front to back. Cancel the Line command.

4. Create coordinate system	Press the C hot key.
5. Advanced tab	Click on the Advanced tab.
6. Select primary feature	In the Primary Feature list, select Plane 2 - Actual . In the Axis list, select +Z .
7. Select secondary feature	In the Secondary Feature list, select Line 3 - Actual . In the Axis list, select +X .
8. Select origin	In the Origin Feature list, select Line 4 - Actual
9. Align with Coordinate System 1	Select the Align with check box and select Coordinate System 1 .
10. OK	Click OK .





The CAD coordinate system has moved to the correct orientation and the part is aligned. Notice that the measured features are now in a feature group with the nominal features. The feature group always uses the name of the nominals by default.

☛ A quicker method to completing this measurement activity is to select the nominal features in the **Features** panel, right-click, and use the **Add Measurement** command. This also creates measurement features (-Actual) with the same name as the nominal features.

ACTIVITY: Reporting The Results Of The CAD Inspection

In this activity, you will view the results of the wireframe CAD inspection using CAM2 Q's reports.

 Before clicking the **Report** tab, make sure the view on the Main Window is what you want to appear on the report. Zoom in on the entire part or the area of the part you want to include in the report. A good way to zoom in on and orient the part is to use the hot keys. The **6** key orients the part to a top view, **E** key zooms all, **I** zooms in, **O** zooms out and the arrow keys pan around the window.

1. Report tab	Click the Report tab.
2. Add features	On the Features panel, on the Active Report List , click the Add all features to the list . You can also select the arrow to the left of the feature to move it.  A quicker method is to select the features in the Features panel and then click the Report tab.
3. View results	Compare the actual data to the nominal data.

Module 12:

Surface Measurement for Inspection or Reverse Engineering

In this module, you will become familiar with measuring surface features for both surface inspection and reverse engineering. You will use surface inspection commands in CAM2 Q to inspect a part with free-form surfaces, edit complex measurement data, and create a report of the surface measurements. You will use the surface information in a CAD file as nominal data for the inspection of your part, and also create a CAD model of your part for export.

Prerequisite: Basic Measurement, Coordinate Systems, and Working with CAD modules.

MODULE OBJECTIVES

You will be able to:

- Inspect surfaces at any location (Inspect Surface Point, Inspect Surface)
- Inspect surfaces at a specific location (Home In Point, Vector Point)
- Inspect surfaces at any location with the data filtered to display at specific cross-sectional planes (Polyline, Polyline Group)
- Edit the surface data
- Report the surface data
- Measure to reverse engineer a part
- Output the data to an appropriate file format

LESSONS

- Lesson 1: Surface Inspection with CAD 12.3
- Lesson 2: Scanning for Reverse Engineering 12.13



See the CAM2 Q chapter in the user manual of your current measurement device for more information.

Measurement Mode Options

Measurement Mode options let you specify whether to add single or multiple readings. This is beneficial whether you are measuring a large feature or a free form surface. The addition of multiple readings over a specified time or distance is often called “scanning”.

In the **Measurement Window** panel, use the Mode drop-down list to switch the reading collection mode.

- **Single Point:** press the **Front** button, or the **G** key, to collect a single reading.
- **Time Interval:** press the **Front** button, or the **G** key, to start the time interval. Collect a single reading over time.
- **Distance Interval:** press the **Front** button, or the **G** key, to start the distance interval. Collect a single reading when the probe moves a distance.

To configure any Measurement Mode, click the **Measurement Mode Setting**, or **Settings**, button in the **FARO Device Control** panel.

Lesson 1: Surface Inspection with CAD

Up to this point, you have compared and reported the condition of simple features at their center point. With surface measurement, you can compare and report the condition of the surface at multiple locations. These measured to nominal results are more complex than simple feature results, and determine the exact location of out of tolerance conditions on the surface.

Lesson Objectives

Using the specialized surface measurement commands, you will be able to:

- Inspect surfaces at any location (Inspect Surface Point, Inspect Surface)
- Inspect surfaces at a specific location (Home In Point, Vector Point)
- Inspect surfaces at any location with the data filtered to display at specific cross-sectional planes (Polyline, Polyline Group)
- Edit the surface data
- Report the surface data

PRE-ACTIVITY:

Option 1 If training files are available	Option 2 If starting with a new file
Open Advanced 2.fcd	Open a new file
Select all of the features, then select Add Readings .	Add Demo Part Q.x_t to the measurement file.
Measure the features as prompted.	Add and measure: <ul style="list-style-type: none">● Plane 1● Line 1 (across the front of the part on the handle side)● Circle 9

ACTIVITY: Align To A Surface CAD Model Using A Coordinate System Alignment

In this activity, we will align using a coordinate system alignment in a measurement file containing a CAD model.

1. Create coordinate system from measured features	<p>On the Coordinate System menu, select Coordinate System Wizard.</p> <p>Enter the name Measured CS for the measured coordinate system.</p> <p>Select Plane 1 as the Plane Feature.</p> <p>Select Line 1 as the Line Feature.</p> <p>Select Circle 9 as the Point Feature.</p> <p>Click OK.</p>
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ACTIVITY: Adjust Tolerances For Surface Points

In this activity, we will adjust tolerances for surface points using the Preferences command.

1. Adjust tolerances for surface points	<p>On the Edit menu, click Preferences, click Tolerance, Geometries tab, then select Surface Point.</p> <p>Expand the Surface Point group.</p>
2. 3D Distance	<p>In the 3D Distance parameters, change the Lower tolerance to -0.25mm and the Upper tolerance to 0.25mm.</p>



Auto Nominal Association is not active until an alignment has solved.

Auto Nominal Association

Auto Nominal Association is a CAM2 Q preference which controls the automatic association of the nearest nominal to a measured feature - providing it falls within a set of tolerance zones. This preference is enabled by default. To enable or disable auto nominal association:

- On the **Edit** menu, click **Preferences**. In the **Preferences** dialog box, select **Measurement**, then select **Auto Nominal** tab.
- Select the Automatically Associate Nominal check box.

Inspect Surface Commands

There are two commands to measure a surface at random locations.

- **Inspect Surface Point:** measure a single point on a surface at any location.
- **Inspect Surface:** measure a single point or multiple points (point cloud) on a surface at any location.

Each reading for these features automatically creates a nominal point on the closest surface of your CAD model. The end click determines the compensation vector of the digitized point(s).

A disk represents each reading. The disk color is predetermined by the tolerance condition. The size of the disk is a **Display** preference.

ACTIVITY: Inspect a Surface Point

In this activity, we will measure and a inspect surface point.

1. Inspect Surface	On the Measure menu, select Inspect Surface Point .
2. Measure the surface	Take one point on the top of the part. Cancel the command.
3. Review feature	On the Features panel, expand the Point 1 feature. Note that this feature has a nominal feature that was automatically created and associated.

ACTIVITY: Inspect A Surface

In this activity, we will measure and inspect a surface.

1. Inspect Surface	On the Measure menu, select Inspect Surface .
2. Measure the surface	Take multiple points on the top of the part in different locations. Cancel the command.
3. View the surface points	Open the Readings panel and look at the individual surface measurements.

ACTIVITY: Customize Labels

In this activity, we will review and customize the label options.

1. Turn labels on	Select the all the features, except World, in the Features panel. Right-click and select Label until all of the labels are visible on the Main Window.
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2. Customize labels	On the Edit menu, click Preferences . Click Display and the CAD View tab.
3. Customize labels	Change some of the label settings and then click OK to view the changes.

Home In Points

Home In Points differ from Inspect Surface Points, in that you can measure a surface at a specific nominal location. This command will guide you, with graphics and sound, to the location of the nominal point, and will not accept a reading until the Probe/SMR is in the home in zone. The Probe/SMR must be inside the home in zone to record a reading - pressing the **Front** button (or the **G** key) outside the zone has no effect. Before starting this command, you must create a nominal point or nominal vector point to use as the Home In target.

ACTIVITY: Home In Points and Nominal Vector Points

In this activity, we will define nominal locations for surface measurement.

1. Vector Point	From the Pick From CAD menu, select Vector Point .
2. Select points	Select two points on top of part. Click Close .

Now that you have the two nominal vector points, you can use each (as target points) in the **Home In Point** command, and measure the surface.

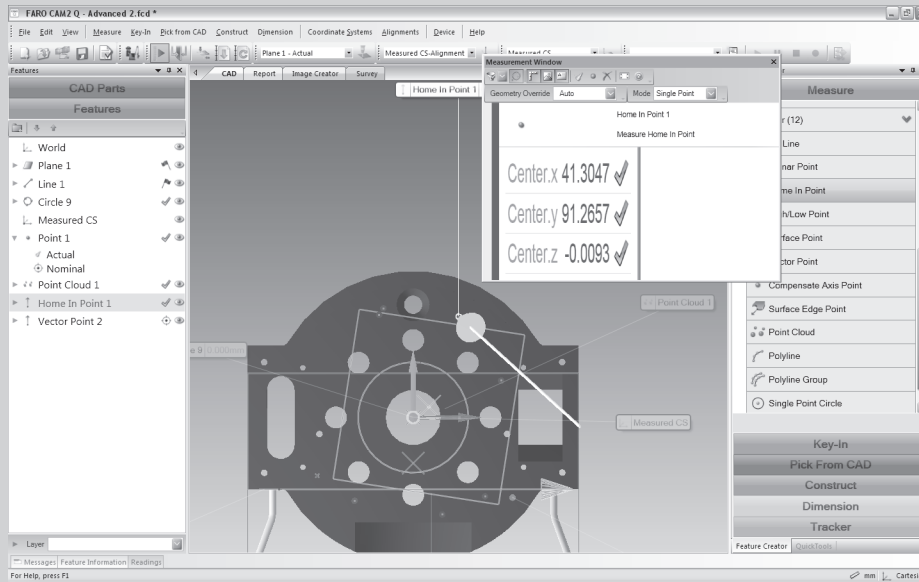
3. Measure Home In Point	On the Measure menu, select Other , then Home In Point .
4. Home In Point settings	For Approach Type , select Key In . For Target Point , select Vector Point 1 . Change the Zone Diameter to 5.00mm. Change the Approach Vector to I 0.00, J 0.00, K 1.00.
5. Create and Close.	Click Create , then click Close .

6. Inspect vector point

You now see the nominal point, the Home In Zone, and the current position of your probe.

Move the probe to find the nominal point on the top surface of the part. Watch the graphic in the **Main** window and listen to the sound to help determine if you are in the Home In Zone.

When you are in the Home In Zone, click the **Front** button (or the **G** key) to take a point, then pull away from the surface and click the **Back** button (or the **H** key).



7. Measure Home In Point

On the **Measure** menu, select **Other**, then **Home In Point**.

8. Home In Point settings

For **Approach Type**, select **Select Surface**.

For **Target Point**, select **Vector Point 2**.

For **Surface**, select **Demo Part Q.x_t**.

Change the **Zone Diameter** to 5.00mm.

9. Create and Close.

Click **Create**, then click **Close**.

10. Inspect vector point

You now see the nominal point, the Home In Zone, and the current position of your probe.

Move the probe to find the point as with Home In Point 1.

ACTIVITY: Reporting The Surface Measurements

In this activity, we will create a report with the two measured surface (Home In) points we inspected in the previous activity.

1. Select Report Features	In the Features panel, select all the surface measurement features (created after the alignment).
2. Access the Report view	Click the Report tab.

Review the measurement results. Notice the 3D deviation between the measured point and the surface.

ACTIVITY: Save The Measurement File

In this activity, you will save your work in the measurement file.

1. Save As	From the File menu, select Save As .
2. Your folder	Browse to your folder and type Surface_Inspect.fcd.
3. Save	Click Save .

Polylines

Polylines differ from an Inspect Surface point cloud, in that they display the measured points in the order they were taken, along a “line”. This “line” is actually a series of straight-line connected surface points that approximate a curved path. CAM2 Q treats a polyline as one feature regardless of the number of points, the shape, or direction of the polyline. Each point in the polyline is compared to the nominal surface.

Polylines need a minimum of two points in order to solve.

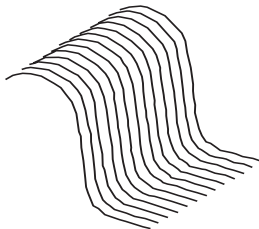
Polyline Groups

Polyline Groups are multiple polylines, or cross-sectional, measurements. CAM2 Q treats a polyline group as one feature regardless of the shape or direction of the polylines.

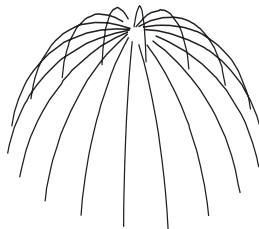
With Polyline Groups, a cross-sectional plane and distance is required to define each polyline in the group. A reading automatically records each time the Probe/SMR crosses one of the cross-sectional “lock” planes, and all of the readings on each plane are then used to create each of the polylines in the group.

Each polyline in the group needs a minimum of two points in order to solve.

Polyline Group Examples



Parallel Lock Planes



Radial Lock Planes

ACTIVITY: Configure a Measurement Mode

In this activity, we will select the Measure Mode for the next few activities.

1. Device Control panel	Press the P hot key.
2. Settings	Click the Measurement Mode Setting , or Settings , button.
3. Distance Based Mode	Select the Distance Based Mode and change the distance to 0.50mm. Click OK .

☞ These are the available measurement modes:

- **Single Point Mode:** The measurement device takes a single point.
- **Distance Interval Mode:** The measurement device takes points at a specified distance interval (specify the distance in the device settings).
- **Time Interval Mode:** The measurement device takes points at a specified time interval (specify the time in milliseconds).

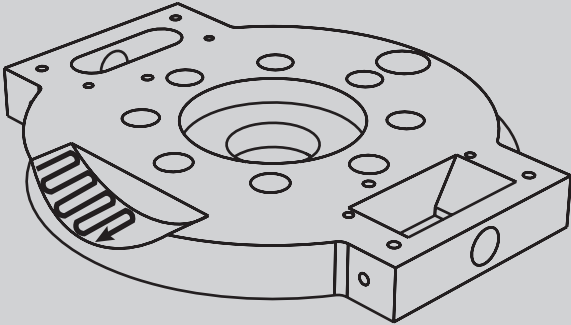
4. Close	Click the Close (X) button in the upper right corner of the Device Control panel.
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ACTIVITY: Parallel Lock Plane Surface Measurement

In this activity, we will set up a parallel lock plane measurement, then “scan” a cross-section of the model.

1. Measure mode	Make sure that you are in Measure mode.
2. Measure a Plane	Measure the plane perpendicular to arc G as Plane 2. ☞ Try switching to Distance Interval Mode and “scanning” this plane feature by adding readings every time the Probe/SMR moves 0.5mm.
3. Measure polyline group	On the Measure menu, select Other , then Polyline Group .

We must configure the polyline group properties before we can see any data.

<p>4. Polyline Group 1 properties</p>	<p>Select the Project to Surface check box, and select CAD Assembly from the drop-down list.</p> <p>Select the Automatically Create Nominal check box.</p> <p>Select the Polyline Lock check box and select Parallel Planes from the drop-down list.</p> <p>Base Plane: Plane 2 - Actual.</p> <p>Base Distance: 0.00mm.</p> <p>Distance Between Planes: 5.00mm.</p> <p>Number of Planes: 20.</p> <p>Click Create and Close</p>
<p>5. Measure the surface</p>	<p>Make sure that the Measurement Mode is set to Distance Interval.</p> <p>Touch the Probe/SMR to curved surface "G", press the Front button, or G key, and "scan" the curved surface in a front to back direction perpendicular to Plane 2 - Actual.</p>  <p>Press the Back button, or H key, to complete the scan.</p>

Feature Whiskers

Whiskers are single lines that visually represent distance data of a feature. There are two types of whiskers:



- Whiskers - The Whisker shows the deviation of each reading to the feature.
- Nominal Whiskers - The Whisker shows the deviation of the measured feature to its nominal.

Select a feature from the **Features** panel, or the **Main** Window, and on the **View** menu select **Feature Whiskers** to access either Whisker command. You can also access these commands by right-clicking a feature. The whiskers change color according to tolerance condition:

- Green - feature is in tolerance
- Red - measurement is above the upper tolerance
- Blue - measurement is below the lower tolerance

ACTIVITY: View And Adjust Polyline Whiskers

In this activity, we will view and adjust the polyline you created in the prior activity.

1. Select Polyline Group 1	In the Features panel, select Polyline Group 1 .
2. View feature whiskers	On the View menu, select Feature Whiskers , then select Whiskers .
3. Increase the size of feature whiskers	On the View menu, select Feature Whiskers , then select Increase .  You can also press the + (Plus Sign) key.
4. Rotate CAD	Click on the screen and drag the mouse to rotate the Main window view to see the Whiskers. Press the 8 hot key to reset the isometric view.
5. Decrease the size of feature whiskers	On the View menu, select Feature Whiskers , then select Decrease .  You can also press the - (Minus Sign) key.

ACTIVITY: Reordering Feature Data

In this activity, we will put deviations in order, from lowest to highest, remove readings on the outliers, and re-calculate the feature using the remaining readings.

1. Select Point Cloud 1	On the Features panel, select Point Cloud 1 .
2. Readings tab	Click on the Readings tab.
3. Click on column heading	Click on the DevFrom Fit column heading to reorder the readings.
4. Uncheck readings	In the On column, clear the check box for the outlier (larger deviation) readings to remove them from the calculation.
5. Recalculate	Click Apply to recalculate the remaining readings.
6. Repeat with Polyline Group 1	On the Features panel, select Polyline Group 1 and repeat this activity.

ACTIVITY: Creating And Saving A Report

In this activity, we will create a measurement report and save it to a .csv file.

1. Access Report view	Click the Report tab.
2. Add features to the report	On the Features panel, on the Active Report List , double-click on the features to add to the report in the Not In Report section. You can also select the check box to the left of the feature to move it.
3. Save Report	Click the Export Document icon and select CSV Document . Click OK to accept all the default export options, and save the report with the name <code>My Report 2</code> in your folder.

ACTIVITY: Save The Measurement File

In this activity, you will save your work in the measurement file.

1. Save	From the File menu, select Save .
2. Your folder	This updates your <code>Surface Inspect.fcd</code> file.

Lesson 2: Scanning for Reverse Engineering

Reverse Engineering, once stigmatized as a method to “copy” or “steal” a product, now has many positive applications in manufacturing. The primary functions of Reverse Engineering are to create data to refurbish or manufacture a part for which there is no CAD data, or for part inspection (comparing a fabricated part to its CAD model or to a standard item). Outside of the manufacturing world, Reverse Engineering is widely used to document and measure historical artifacts, create models for animation in games and movies, reproduce crime scenes, and generate data for use in a wide array of medical applications.

Lesson Objectives

Using the specialized surface measurement commands you will be able to:

- Measure to reverse engineer a part
- Output the data to an appropriate file format

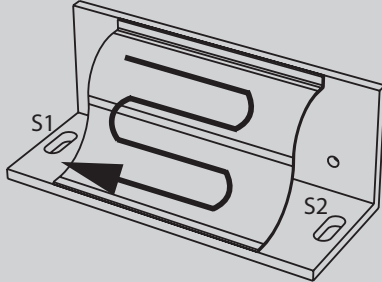
ACTIVITY: Create A New Coordinate System

In this activity, we will measure features to put a coordinate system on the demo part.

1.	Attach the bracket to the top of the training part.
2.	New file Open a new file.
3.	Measure plane On the Measure menu, select Plane . Measure the top of the base part as a plane. Cancel the command.
4.	Measure front edge On the Measure menu, select 2D Line . Measure the front edge of the bracket as a line.
5.	Measure left edge Measure the left edge of the bracket as a line. Cancel the command.
6.	Create coordinate system On the Coordinate Systems menu, select Create Using the Wizard .
7.	Advanced tab Click on the Advanced tab.
8.	Plane, Line, Line Create a coordinate system using Plane 1, Line 1, and Line 2. Click OK .

ACTIVITY: Measure Features and Export Data

In this activity, we will measure multiple polylines to define the free form surface of the bracket.

1. Measure polyline group	On the Measure menu, select Other , then select Polyline Group .
2. Configure the properties of Polyline Group 1	<p>Polyline Lock: Parallel Planes</p> <p>Base Plane: YZPlane_World</p> <p>Base Distance: 30 . 00mm.</p> <p>Distance Between Planes: 5 . 00mm.</p> <p>Number of Planes: 30.</p> <p>Click Create, then click Close.</p>
3. Measure the surface	<p>Place the Probe/SMR on the surface and press the Front button, or G key, to scan the surface. Cover the part from top to bottom, moving left to right.</p>  <p>Press the Back button, or H key, to complete the scan.</p>
4. Increase point size	<p>On the Edit menu, click Preferences. In the Preferences dialog box, click Display and CAD View tab. Change the Size and Scale: Point size to Large.</p> <p>Click OK.</p>
5. Check Polyline Group	Zoom in and look at the points in the Polyline Group, and check for large gaps between the points.
6. Add additional readings	<p>On the Feature panel, select Polyline Group 1, right-click and select Add Readings.</p> <p>Place the Probe/SMR on the surface. Press the Front button, or G key, to scan the surface again to fill the large gaps in the polylines. Press the Back button, or H key, to complete.</p> <p>You can repeat this command as often as you need.</p>

You need to measure more features to completely reverse engineer this part; however, not all of them are free-form surfaces that you measure with the Polyline Group command. You should be able to see planes, circles, round slots, etc. that you measure using simple feature commands.

7. Measure back face	On the Measure menu, select Plane . Measure the back face of the bracket part.
8. Measure the hole	On the Measure menu, select Circle . Change the Measure Mode to Single Point . Measure one, or all, of the circles on the back face of the bracket part.

If you prefer, continue measuring the remaining features on the bracket part.

9. Save As	From the File menu, select Save As .
10. Your folder	Browse to your folder and type RE_Bracket.fcd.
11. Save	Click Save .
12. Export file	From the File menu, select Export, Measurement Data, To CAD File .
13. Export Wizard	In the Export CAD wizard, select and move all the features you created (- Actual) to the right window. Click Next .
	Export Format: IGES Export Unit: Millimeter Click Next .
	Click the Browse button Browse to your folder and type RE_Bracket.igs. Click Save .
14. Close the Wizard	Click Finish .

Module 13:

Data Import/Export

In this module, you will become familiar with exporting your measurement results to different file formats, and importing a data file into a measurement file.

Prerequisite: Review Activities.

MODULE OBJECTIVES

You will be able to:

- Locate the different import and export options
- Export/Import Points to a text file

PRE-ACTIVITY:

Option 1 If training files are available	Option 2 If starting with a new file
Open Nominals 2.fcd	Open a new file
	Add and measure/construct features. Add/associate their nominals: <ul style="list-style-type: none">● Plane 1● 2D Line 1 (across the front of the part on the handle side)● Circle 1● Circle 3● Circle 5● Circle 7● Cylinder 9● Bolt Circle● Intersection Point (of Plane 1 and Cylinder 9)● Coordinate System using:<ul style="list-style-type: none">● Plane 1● Line 1● Bolt Circle● Align to World

ACTIVITY: Export Features To Saved Files

In this activity, we will export some actual (measured) points, nominal points, and all other features to three separate .txt file.

1. Access the Export Point Data Wizard	On the File menu, click Export , then select Points . The Export Point Data wizard appears.
2. Select features	Select all of the “- Actuals” features, and move them to the right side of the wizard window by clicking the single arrow button. Then click Next .
3. Export configuration	Take note of the current Export Configuration options, column order, and separators. Click Next .

The export configuration information is important to ensure you import the points properly.

4. Export file name	Click Browse . Select your file folder. Name the file <code>Actuals.txt</code> and click Save . Click Finish .
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The text file saves to the computer and automatically opens in Notepad.

5. Close Notepad	Click the Close button (X) in the upper right corner of the Notepad window.
6. Access the Export Point Data Wizard	On the File menu, click Export , then select Points . The Export Point Data wizard appears.
7. Select features	Select all of the “- Nominal” features, add move them to the right side of the wizard window by clicking the single arrow button. Then click Next .
8. Export configuration	Take note of the current Export Configuration options, column order, and separators. Click Next .

The export configuration information is important to ensure you import the points properly.

9. Export file name	Click Browse . Select your file folder. Name the file <code>Nominals.txt</code> and click Save . Click Finish .
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The text file saves to the computer and automatically opens in Notepad.

10. Close Notepad	Click the Close button (X) in the upper right corner of the Notepad window.
11. Access the Export Point Data Wizard	On the File menu, click Export , then select Points . The Export Point Data wizard appears.
12. Select features	Move all of the features to the right side of the wizard window by clicking the Select All button. Then click Next .

13. Export configuration	Take note of the current Export Configuration options, column order, and separators. Click Next .
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The export configuration information is important to ensure you import the points properly.

14. Export file name	Click Browse . Select your file folder. Name the file <code>Features.txt</code> and click Save . Click Finish .
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The text file saves to the computer and automatically opens in Notepad.

15. Close Notepad	Click the Close button (X) in the upper right corner of the Notepad window.
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16. Save your file with a new name	On the File menu, click Save As . Enter <code>Data Export.fcd</code> as the file name.
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ACTIVITY: Import Points From A Saved File

In this activity, we will import some nominal points from a .txt file.

1. New File	On the File menu, click New .
2. Access the Import Point Data Wizard	On the File menu, click Import , then select Points . The Import Point Data wizard appears.
3. Select file	Click Browse and locate Features.txt , select the file click Open . Click Next to continue.
4. Import Configuration	Make sure that Import Configuration is the same as the Export Configuration and click Next .
5. Select features	Select all of the "- Nominal" features and click the single arrow button to move the features to the right side of the wizard window. Select the Import as nominal option.
6. Import the Points	Click Finish .

The nominal information from the text file imports directly to features and adds to your measurement file. Now you are ready to measure coordinate system features and add measurements to these nominal features.

Module 14:

Iterative Alignment Using Surfaces

In this module, you will become familiar with creating an Iterative Alignment using surface point measurements and nominal surfaces.

Prerequisite: Iterative Alignments.

MODULE OBJECTIVES

You will be able to:

- Create specific Nominal points on a CAD surface for use in an alignment.
- Measure and remeasure the surfaces of the part to refine the results of an alignment.

Using Surfaces Instead Of Features

If your part has fewer than three point-reducible features, you will likely have enough nominal CAD surface data in a CAD model to create an alignment. Use Surface Point measurements and CAD surface data to align the part with your measurement device.

Previously, you used point-reducible features with associated nominals to create an iterative alignment. These measured features were the same geometry type as the nominal features (circles, slots, spheres, etc.). Now, instead of a point-reducible feature, we will use a surface point measurement feature and a nominal surface feature to create a best fit iterative alignment.

ACTIVITY: Performing An Alignment Using Surfaces

In this activity, we will perform an alignment by picking nominals from CAD and associating them to nominal surfaces.

1. New file	Open a new file.
2. Import CAD	From \CAM2 Q v1.5 Training Files , import Demo Part Q.x_t.
3. Define nominals	On the Pick from CAD menu, click Vector Point .
4. Points on the top of the CAD	Click on the top of the CAD model surface near P1. Click three more points near P2, P3 and P4.
5. Points on the left of the CAD	Click on the left side of the CAD model surface near Circle 11. Click one more point on the left side.
6. Points on the front of the CAD	Click on the front of the CAD model surface to the right of Arc G. Click Close .
7. Select the features	In the Features panel, select the vector point features.
8. Add measurements	Right-click and select Add Measurement .
9. Measure the surfaces	Measure the surfaces with a single reading for each vector point as shown in the Measurement Window panel. Place the probe on the correct surface in the general area of the nominal point.
10. Select the vector point features	In the Features panel, select all vector points.
11. Align to the part	On the Alignments menu, click Iterative Alignment . Click the Add Selection button to add the vector points.

12. Set Weights	<p>Select the Set Weights check box to set the vector direction for each point.</p> <p>Notice that each weight value automatically corresponds to the location of each point on the surface. For example, the weight values for Vector Points 1-4 are 0,0,1 and control the Z axis of the alignment.</p>
13. Solve	Click the Apply/Solve button.

Note the high value of the Max Error, or the error between the measured points, and the nominal surfaces. Now we will remeasure the vector points and automatically refine the alignment, with the goal of improving it by reducing the Max Error.

14. Close	Click the Close button.
15. Select the features	In the Features panel, select all vector points.
16. Remeasure the surfaces	From the Measure menu, click Remeasure .
17. Inspect vector point	<p>You now see the nominal point, the Home In Zone and the current position of your probe.</p> <p>Move the probe to find the nominal point on the top surface of the part. Watch the screen and listen to the sound to help determine if you are in the Home In Zone.</p> <p>When you are in the Home In Zone, click the Front button (or the G key) to take a point, then pull away from the surface and click the Back button (or the H key).</p>
18. Reset the view	Press the E hotkey to Zoom All, and 8 to set the Isometric view.
19. Check the alignment	<p>Press the A hotkey and review the Max Error value - it should be lower than before. If it is, you have just improved your alignment by remeasuring the surfaces while being guided to the exact nominal surface location.</p> <p>Click Close.</p>
20. Save	<p>On the File menu, click Save As.</p> <p>Name the file <code>Iterative2.fcd</code>.</p>

Module 15: Tool Building

In this module, you will become familiar with using your measurement device to properly position a part in an assembly.

Prerequisite: none.

▶ MODULE OBJECTIVES

You will be able to:

- Use the Feature Window to position a part correctly in space relative to another CAD surface.

CAM2Q

PRE-ACTIVITY:

Option 1 If training files are available	Option 2 If starting with a new file
Open Advanced 2.fcd	Open a new file
Select all of the features, then select Add Readings .	● Import Demo Part Q.x_t
Measure the features.	Add and measure: <ul style="list-style-type: none">● Plane 1● 2D Line 1 (across the front of the part on the handle side)● Circle 9

Feature Window - Digital ReadOut

In addition to the **Measurement Window** panel that includes a Digital ReadOut (DRO) for the current measurement, CAM2 Q also has a **Feature** window that shows the distance of the Probe/SMR to a specific feature. Use a **Feature** window to:


- See the live deviations of a specific feature based on the current location of the Probe/SMR.
- Guide a part into position using the position of a feature.

You can have multiple **Feature** windows open in a measurement file, or a single window which shows the distance values for the closest feature. The values in the **Feature** window change color based on tolerances. You can also show/hide the individual values of the DRO to view only the important values of your feature.


ACTIVITY: Positioning The Bracket

In this activity, you will accurately position the bracket relative to the part and verify the accuracy with part measurements.

1. Construct a measured coordinate system	On the Coordinate Systems menu, click Create Using the Wizard . Select Plane 1 as the Plane Feature . Select Line 1 as the Line Feature . Select Circle 9 as the Point Feature . Check the Align with: World box. Click OK
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2. Position the bracket	Position the bracket on the demo part, slot side down and lightly fasten it using the set screws.
3. Key-In Point	<p>On the Key-In menu, select Point. Type in the following values:</p> <p>x: -50.85mm - FaroArm x: -50.85mm - FARO Laser Tracker</p> <p>y: -40.64mm - FaroArm y: -40.64mm - FARO Laser Tracker</p> <p>z: 13.26mm - FaroArm z: 8.20mm - FARO Laser Tracker (1.5" SMR) z: 16.12mm - FARO Laser Tracker (0.875" SMR)</p>
4. Key-In Point	<p>On the Key-In menu, select Point. Type in the following values:</p> <p>x: 50.85mm - FaroArm x: 50.85mm - FARO Laser Tracker</p> <p>y: -40.64mm - FaroArm y: -40.64mm - FARO Laser Tracker</p> <p>z: 13.26mm - FaroArm z: 8.20mm - FARO Laser Tracker (1.5" SMR) z: 16.12mm - FARO Laser Tracker (0.875" SMR)</p>
5. Feature Window for Point 1	<p>On the Features panel, select Point 1, then from the View menu select Show Feature Window.</p> <p> You can also press the D hot key.</p>
6. Tolerance tab	<p>With Point 1 still selected on the Features panel, click the Feature Information tab.</p> <p>Change all of the Lower and Upper tolerances to -0.500mm and 0.500mm.</p>
7. Place Probe/SMR	Place the Probe/SMR on the bracket's left-front set screw.

For the next step, you want the d3D and X,Z,Y values in the **Feature** window DRO to be green and as close to 0.00 as you can get them. You will now compare the numbers to the nominal position you specified when keying in the point.

8. Move bracket	If necessary, move the bracket until the numbers are close to 0.00 and green.
9. Feature Window for Point 2	<p>On the Features panel, select Point 2, then press the D hot key.</p> <p> You will need to move this second window if it opens on top of the first window.</p>

CAM2Q

10. Feature Information tab	With Point 2 still selected on the Features panel, click the Feature Information tab. Change all of the Lower and Upper tolerances to -0.500mm and 0.500mm.
11. Place Probe/SMR	Place the Probe/SMR on the bracket's right-front set screw.
12. Move bracket	If necessary, move the bracket until the numbers are close to 0.00 and green.

Move back to **Point 1**, recheck the position, and adjust if necessary. Then recheck **Point 2**. Keep rechecking each point until you move the bracket part into the correct position.

13. Close Feature window	Close the Point 1 - Nominal Feature window.
14. Unlock from Feature	Click the Lock to Feature (slanted push pin) button to unlock the Feature window from Point 2.
15. Recheck both points	Move the Probe/SMR to each point and recheck the values. Notice that the Feature window automatically shows the values of the feature closest to the Probe/SMR.

ACTIVITY: Save The Measurement File

In this activity, you will save your work in the measurement file.

1. Save As	From the File menu, select Save As .
2. Your folder	Browse to your folder and type Tool Building.fcd.
3. Save	Click Save .

Module 16:

Coordinate Systems Using Offset and Rotation

In this module, you will become familiar with constructing coordinate systems using advanced techniques.

Prerequisite: Coordinate Systems.

MODULE OBJECTIVES

You will be able to:

- Establish an XYZ coordinate system on a part that reflects the values on the blueprint or CAD model.



When you select both Offset and Rotation, you can also select whether to offset or rotate first.

Rotations and Offsets

An inspection drawing with datum geometries usually requires a coordinate system alignment in which the part coordinate system is created using the measured datum features and aligned to the assembly (World coordinate system). The assembly coordinate system must be in the location defined by the datum features to correctly align the part to the assembly.

For example, you have a part that has its own coordinate system and you need to report the measurement results of the part in the coordinate system of the assembly. After you select the features for a coordinate system, you can enter Rotation and Offset values. This creates the part coordinate system and then automatically moves and/or rotates that coordinate system to match the assembly coordinate system.



Hot Keys


F3: Plane
F4: 2D Line
F10: Circle



You can also press the **C** hot key to start the Coordinate System Wizard.

ACTIVITY: Create And Offset A Coordinate System

In this activity, you will create a measured coordinate system and offset it from the part's origin.

1. New file	Open a new file.
2. Import CAD	Import the Demo Part Q.x_t CAD file.
3. Measure or Template mode	Choose either Measure or Template mode.  Remember that in Measure mode the Add Readings command is automatically started after you add a feature from the Measure menu. In Template mode, you will need to select the features and then start the Add Readings command.
4. Add Features	On the Measure menu, click Plane , 2D Line , and Circle .
5. Add Readings	Measure and rename the features as Plane 1 , Line 1 and Circle 9 .
6. Construct a measured coordinate system	On the Coordinate Systems menu, click Create Using the Wizard . On the Basic tab: <ul style="list-style-type: none">● Select Plane 1 as the Plane Feature.● Select Line 1 as the Line Feature.● Select Circle 9 as the Point Feature. Clear the Align with: check box.
7. Add offset	Select the Offset check box and enter -150 for X, -65 for Y, and 0 for Z.
8. Create the coordinate system	Click OK .

9. Labels	On the Features panel, select World and Coordinate System 1 . Right-click and select Label to show their labels in the Main Window.
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Zoom Out and look at the **Coordinate System 1** icon to see that is *not* in the center of **Circle 9**.

10. Alignment to the part	<p>On the Alignments menu, click Coordinate System Alignment.</p> <ul style="list-style-type: none"> ● Select Coordinate System 1 as the Measured Coordinate System. ● Select World as the Nominal Coordinate System. <p>Click Apply/Solve.</p> <p>Click Close.</p>
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Notice that **Coordinate System 1** and World are now aligned, origin to origin.



You can also press the **A** hot key to start the **Alignments** command and then click the **Coordinate System** button.

ACTIVITY: Create And Rotate A Coordinate System

In this activity, you will create a new coordinate system and apply rotation.

1. Construct a measured coordinate system	<p>Press the C hot key.</p> <ul style="list-style-type: none"> ● Select Plane 1 as the Plane Feature. ● Select Line 1 as the Line Feature. ● Select Circle 9 as the Point Feature. <p>Clear the Align with: check box.</p>
2. Add rotation	Check the Rotation check box and enter 0 for X, 0 for Y, and 90 for Z.
3. Create the coordinate system	Click OK .

Zoom Out and look at the **Coordinate System 2** icon to see that is rotated around the center of **Circle 9** (upper-right corner of the part).

4. Alignment to the part	<p>On the Alignments menu, click Coordinate System Alignment.</p> <ul style="list-style-type: none"> ● Select Coordinate System 2 as the Measured Coordinate System. ● Select World as the Nominal Coordinate System. <p>Click Apply/Solve.</p> <p>Click Close.</p>
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ACTIVITY: Create An Offset And Rotated Coordinate System

In this activity, you will create a new offset coordinate system and apply rotation.

1. Construct a measured coordinate system	<p>Press the C hot key.</p> <ul style="list-style-type: none"> ● Select Plane 1 as the Plane Feature. ● Select Line 1 as the Line Feature. ● Select Circle 9 as the Point Feature. <p>Clear the Align with: check box.</p>
2. Add offset	Select the Offset check box and enter -0 for X, 70 for Y, and 0 for Z.
3. Add rotation	Check the Rotation check box and enter 90 for X, 0 for Y, and 0 for Z.
4. Create the coordinate system	<p>Select the Rotate then Offset option button.</p> <p>Click OK.</p>
5. Alignment to the part	<p>On the Alignments menu, click Coordinate System Alignment.</p> <ul style="list-style-type: none"> ● Select Coordinate System 3 as the Measured Coordinate System. ● Select World as the Nominal Coordinate System. <p>Click Apply/Solve.</p> <p>Click Close.</p>

Zoom Out and look at the **Coordinate System 3** icon to see that is rotated and offset.

Module 17:

GD&T

In this module, you will become familiar with inspecting your part using the Geometric Dimensioning and Tolerancing (GD&T) system.

Prerequisite: Basic Measurement, Coordinate Systems, Nominals and Tolerances, Working with CAD modules.

▶ MODULE OBJECTIVES

You will be able to:

- Apply GD&T tolerances to check a part.
- Assign datums and use them in specific GD&T tolerances.
- Edit features to only report GD&T tolerance results.
- Create a measurement report with GD&T tolerance results.

GD&T in CAM2 Q

In CAM2 Q, you can add GD&T tolerance values to each feature to compare part measurements to one or more datum(s) and ensure that specific design and tolerance requirements are being met.

Some GD&T tolerances, such as Orientation, Runout, and Position, require a datum, or a theoretically exact plane or line (axis) from which a dimensional measurement is made. Form and Profile GD&T tolerances do not require a datum because they use simple geometry for comparison.

Some GD&T tolerances are only applicable to certain features; Therefore, the **GD&T Tolerances** panel only shows the available tolerances for a selected feature. The CAM2 Q help file details the steps to add GD&T tolerances to any feature.

When you add GD&T tolerances to features, other tolerance values are usually not necessary. In the **Feature Information** panel, you can clear, or not use, any unwanted tolerance value.


ACTIVITY: Review GD&T Tolerances Help Topics

In this activity, we will review the GD&T tolerancing information contained in the CAM2 Q help file.

1. New File	On the File menu, click New .
2. Open the CAM2 Q Help file	On the Help menu, click Contents . On the Contents tab, double-click the GD&T Tolerances topic.
3. Review GD&T Tolerances	Review the GD&T Tolerances topic. To review the next topic, click on the Next (>) button at the top of the screen, or select another topic from the menu tree in the Contents tab. Notice the feature type in the first step of each topic, and whether a datum is required.
4. Close the CAM2 Q Help file	Click the Close (X) button in the upper right corner of the CAM2 Q Help file.

ACTIVITY: Establish Datums

In this activity, we will establish datums for use in GD&T calculations.

1. New File	On the File menu, click New .
2. Import CAD	On the File menu, select Import , then select CAD .
3. Select file	From the \CAM2 Q v1.5 Training Files folder, select Demo Part Q.x_t . Click Open .
4. Measure or Template mode	Choose either Measure or Template mode.  Remember that in Measure mode the Add Readings command is automatically started after you add a feature from the Measure Menu. In Template mode, you will need to select the features and then start the Add Readings command.
5. Add Features	On the Measure menu, click Plane , 2D Line , and Circle .
6. Add Readings	Measure and rename the features as Plane 1, Line 1 and Circle 9.
7. Assign Datums	<ul style="list-style-type: none"> Right-click Plane 1, mouse-over Assign a Datum, select Plane A. Right-click Line 1, mouse-over Assign a Datum, select Line B. Right-click Circle 9, mouse-over Assign a Datum, select Plane C.
8. Construct a measured coordinate system	On the Coordinate Systems menu, click Create Using the Wizard . <ul style="list-style-type: none"> Select Plane 1 as the Plane Feature. Select Line 1 as the Line Feature. Select Circle 9 as the Point Feature. Select the Align with: check box.
9. Create the coordinate system	Click OK .



Make

sure to add the optimal, not the minimal, number of points for each feature. Refer to Module 3, Lesson 1


ACTIVITY: Customize Labels

In this activity, we will review and customize the label options.

1. Hide Label	On the Features panel, select Coordinate System 1 . Right-click and clear the Label menu item to hide the label.
2. Show Labels	On the Features panel, select the plane, line, and circle. Right-click and select Label to show the feature's simple label. Right-click again and select Detailed Label to show the feature's detailed label.
3. Select Feature	On the Features panel, select Plane 1 .
4. Hide tolerances	On the Feature Information panel, clear the check boxes in the first column for every value except Flatness .
5. Select Feature	On the Features panel, select Line 1 .
6. Hide tolerances	On the Feature Information panel, clear the check boxes in the first column for every value except Straightness .
7. Select Feature	On the Features panel, select Circle 9 .
8. Hide tolerances	On the Feature Information panel, clear the check boxes in the first column for every value except Diameter and Circularity .
9. Preferences command	On the Edit menu, select Preferences . Select Display and the CAD View tab. In the Label Style drop-down, select Show Detailed Label Only . Click OK.

ACTIVITY: Determine Perpendicularity

In this activity, we will determine the perpendicularity of the left edge of the part to Datum B.


1. Create and Measure the left edge	On the Measure menu, click 2D Line . Measure the left edge of the part near Circle 11. Cancel the command.
2. Select the feature	From the Features panel, select Line 2 .
3. GD&T Panel	On the Edit menu, select GD&T...
4. Create a new GD&T tolerance	On the GD&T Tolerances panel, click the Perpendicularity icon  .
5. Tolerance to Datum B	Click in the right control frame and select B (Datum B).

For the remainder of this module, you will be using the **GD&T Tolerances** panel often. You may find it helpful to dock it to one of the **Main** window edges, or just close it and reopen it when you need it.

6. Hide tolerances	On the Feature Information panel, clear the check boxes in the first column for every value except Perpendicularity .
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ACTIVITY: Determine Parallelism

In this activity, we will determine the parallelism of the back edge of the part to Datum B.

1. Create and Measure the back edge	On the Measure menu, click 2D Line . Measure the back edge of the part. Cancel the command.
2. Select the feature	From the Features panel, select Line 3 .
3. Create a new GD&T tolerance	On the GD&T Tolerances panel, click the Parallelism icon  .
4. Tolerance to Datum B	Click in the right control frame and select B (Datum B).
5. Adjust tolerance values	On the Feature Information panel, clear the check boxes in the first column for every value except Parallelism .

ACTIVITY: Determine Position

In this activity, we will determine the position of Circles 1, 3, 5, 7.

1. Create and Measure Circle 1	On the Measure menu, click Circle . Rename and measure Circle 1 . Cancel the command.
2. Select the feature	From the Features panel, select Circle 1 .
3. Create a new GD&T tolerance	On the GD&T Tolerances panel, click the Position icon  .
4. Material Condition	Click in the far right control frame and select RFS .
5. Repeat on Circles 3, 5, 7	Repeat the above steps for Circles 3, 5, 7.
6. Select circles	On the Features panel, select Circles 1, 3, 5, 7.

7. Adjust tolerance values

On the **Feature Information** panel, clear the check boxes in the first column for every value except **Diameter** and **Position**. Scroll down the **Feature Information** panel to edit the information for all four circles.

ACTIVITY: Configure a Measurement Mode

In this activity, we will set up the Measurement modes for the next few activities.

1. Device Control panel	Press the P hot key.
2. Settings	Click the Measurement Mode Setting , or Settings , button.
3. Distance Based Mode	Select the Distance Based Mode and change the distance to 0 . 50mm. Click OK .





These are the available measurement modes:

- **Single Point Mode:** The measurement device takes a single point.
- **Distance Interval Mode:** The measurement device takes points at a specified distance interval (specify the distance in the device settings).
- **Time Interval Mode:** The measurement device takes points at a specified time interval (specify the time in milliseconds).

4. Close Device Control Panel	Click the Close (X) button in the upper right corner of the Device Control panel.
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ACTIVITY: Determine Profile of a Line

In this activity, we will determine the profile of a line, or curve.

1. Measure a plane	<p>On the Measure menu, click Plane.</p> <p> Notice the Mode is set to now Distance Interval and the Distance is 0.500mm. You can change the mode back to single point before measuring, or "scan" the plane with these settings.</p> <p>Measure the plane perpendicular to G as Plane 1. Cancel the command.</p>
2. Create Polyline 1	<p>On the Measure menu, click Other, click Polyline.</p> <p>Select the 2D Plane check box, and select Plane 2 - Actual from the drop-down list.</p> <p>Minimum Scan Distance: 0.50mm</p> <p>Auto Nominal Max Distance: 1.00mm</p> <p>Maximum Scan Distance: 5.0mm</p> <p>Probe Compensation: Use Sampled End Click</p> <p>Type: Free Hand</p> <p>Measure on CAD Side: Selected</p> <p>Select Surface: CAD Assembly</p> <p>Click Create and Close.</p>
3. Measure the surface with a single line	<p>Make sure that the Measurement Mode is set to Distance Interval.</p> <p>Touch the Probe/SMR to curved surface "G", press the Front button, or G key, and "scan" a single line on the curved surface from left to right.</p>
4. Select the feature	<p>From the Features panel, select Polyline 1.</p>
5. Create a new GD&T tolerance	<p>On the GD&T Tolerances panel, click the Profile of a Line icon .</p>
6. Adjust tolerance values	<p>On the Feature Information panel, clear the check boxes in the first column for every value except Line Profile.</p>

ACTIVITY: Creating A Report

In this activity, we will create a measurement report and save it to a .csv file.

1. Select Features	On the Features panel, select the three datums, the two lines, the four circles, and the polyline.
2. Access Report view	Click the Report tab.
3. Tabular layout	At the bottom of the Report window, select Tabular from the drop-down list.
4. View results	Use the scroll bar or the page navigation icons to view each page of the report, and see the measurement results in the GD&T format.

ACTIVITY: Save The Measurement File

In this activity, you will save your work in the measurement file.

1. Save As	From the File menu, select Save As .
2. Your folder	Browse to your folder and type GD&T . fcd.
3. Save	Click Save .

Module 18:

Using Multiple Devices

In this module, you will become familiar with inspecting a part using more than one measurement device.

Prerequisite: Basic Measurement, Move Device modules.

MODULE OBJECTIVES

You will be able to:

- Properly connect to and switch between multiple devices
- Add readings using multiple devices

CAM2Q

You can connect and use multiple measurement devices simultaneously, with a single software license, without changing computers and merging data. You can connect any combination of FaroArms and/or FARO Laser Trackers.

This procedure to connect and define multiple devices involves measuring a set of point-reducible features with each device, assigning features from the second device as nominals to the features from the first, and then using the **Move Device** command to define the position.

ACTIVITY: Configuring Two Devices

In this activity, we will connect two FaroArms and measure with both of them.

1. New file	On the File menu, select New .
2. Review Help	<p>Press the F1 hot key. Click on the Index tab. Type multiple devices in the Type in the keyword to find box. Double-click multiple devices from the list. Review the procedure for using multiple devices.</p> <p>☞ If you are using two FARO Laser Trackers, you must assign two additional hot keys for the second Laser Tracker. These new keys will function the same as the G and H keys since G and H are currently assigned to the first device.</p>

After you locate the point-reducible features that you want to use, ensure that each device can reach each feature.

3. Connect both devices	<p>Connect all cables for each devices to your computer, power on your devices and computer, and start CAM2 Q.</p> <p>You may have to open the Device Control Panel and manually connect any device that has not automatically loaded.</p>
4. Manage both devices	<p>On the Device menu, select Device Manager. If the second device is not in the Devices/Positions window, click the Add button and select the second device from the Serial Number drop-down list.</p> <ul style="list-style-type: none">● Select the first device and rename it Device 1.● Select the second device and rename it Device 2. <p>Click Close to exit the Device Manager dialog box.</p>
5. Measure features with Device 1	Measure four points, one plane, and one circle. Use Device 1 to measure each feature.

6. Measure features with Device 2	<p>On the Features panel, select all six features.</p> <p>Right-click and select Add Readings From, Select Device 2.</p> <p>Measure the features with Device 2.</p>
7. Solve Device Positions	<ul style="list-style-type: none"> ● From the Device menu, select Device Manager. The Device Manager panel opens and displays all of the connected devices. ● In the Devices/Positions window, select Device 2's Device Position 1. ● Click the Add Features button to add all of the features to this dialog box. ● Click the Solve button. CAM2 Q fits the two device positions together and reports the fit error. Look at the fit error (Error) for each feature and the maximum error (Max Error) for the results.

When you analyze the fit error and the maximum error, both of these numbers should be within your part's fit tolerance. If necessary, you can remeasure any of the features with **Device 2** directly from this dialog box. Select individual features and click the **Remeasure Selected** or the **Remeasure All** button.

Special Conditions with Multiple Devices

When you have multiple devices connected to CAM2 Q, there are additional commands and options that are available.

- **Default Device**
In the Device Manager panel, select a device and click the **Make Default** button. Measurement commands and the **Add Readings** command will always use the default device.
- **Add Readings From**
On the **Features** panel, right-click a feature. The **Add Readings From** command will now list all available devices.
- **QuickTool command properties**
Each QuickTool command can be assigned to any device. On the **QuickTools** panel, select a command and then in the **Basic** tab of the **Properties** section choose a device from the **Device** drop-down. When playing the QuickTool, the first command for each device is started and multiple **Measurement** windows open.

Appendix I: Laser Tracker Device Setup Checklist

Temperature Effect On A Part

- ☐ Part has been allowed to soak in the inspection environment to adjust to the air temperature.
- ☐ Measurements will be taken where the air temperature is relatively constant.
- ☐ Software is set to appropriately adjust for part expansion/contraction (see software user guide).
- ☐ The part is evenly exposed to light.
- ☐ Measurements are being taken away from heating/ventilation ducts or any other potential source of air turbulence.

Temperature Effect On The Device

The device temperature has been allowed to stabilize.

Movement

- ☐ The device and part are fastened and stationary.

Vibration Effects

- ☐ Vibrations (forklifts driving by, stamping machine movement etc.) have been avoided.

Mounting Stability

- ☐ Detailed instructions provided with mount (tripod, magnetic) were carefully followed.
- ☐ If mounting the device horizontally, the side mounting bracket has been used.
- ☐ The part being measured is supported in the same manner as it would be in its intended function.

Appendix II: Hot Keys

The following is a list of Hot Keys, or keyboard shortcuts, that you can use to quickly start some CAM2 Q commands.

Hot Key	Function
Enter	Repeat the Last command
Arrow keys 2,4,6,8 on numeric keypad	Pans the view in the specified direction.
F1	Help
F2	Measuring a Point
F3	Measuring a Plane
F4	Measuring a 2D Line
F5	Measuring an Inspect Surface
F10	Measuring a Circle
F11	Measuring a Cylinder
F12	Measuring a Sphere
Insert	Add Readings
G	Record a Measurement Reading
H	Record an End Click Reading
Backspace	Delete the Last Measurement Reading
SHIFT + A	Measure All
SHIFT + R	Remeasure
Alt + Enter	Edit Properties
4	Front View
5	Side View
6	Top View
7	Isometric View SE

CAM2Q

Hot Key	Function
8	Isometric View SW
9	Isometric View NE
0	Isometric View NW
I Plus Sign (+) on numeric keypad	Zoom In
CTRL + =	Zoom In (Fine)
O Minus Sign (-) on numeric keypad	Zoom Out
CTRL + -	Zoom Out (Fine)
E	Zoom All
W	Zoom To Window
7 on numeric keypad	Rotate Around X Counterclockwise
9 on numeric keypad	Rotate Around X Clockwise
1 on numeric keypad	Rotate Around Y Counterclockwise
3 on numeric keypad	Rotate Around Y Clockwise
0 on numeric keypad	Rotate Around Z Counterclockwise
Period (.) on numeric keypad	Rotate Around Z Clockwise
S	Switch between the three shaded and wireframe views
Shift + Alt + Enter	Full Screen
Number Sign (#)	Grid
R	Reset View
L	Arrange Labels
ESC	Cancels the Current Measurement
SHIFT + R Mouse Mouse Wheel	Dynamic Zoom
R Mouse	Dynamic Pan
L Mouse	Dynamic Rotate
ESC	Cancels the Current Measurement

Hot Key	Function
P	Device Control Panel
D	Show Feature Window
A	Create and Edit Alignments
C	Coordinate System
M	Move Device
Delete	Delete any selected item
Enter	Repeat Last Command
Home	Home (Tracker Only)
T	Motor On Off (Tracker Only)
B	Set Backsight (Tracker Only)
V	Drive Beam (Tracker Only)
CRTL + N	New file
CRTL + O	Open file
CRTL + S	Save file
ALT + F4	Exit CAM2 Q

Appendix III: Glossary of Terms

TERM	FARO Definition
3D	Three dimensional
3D distance	The distance between a nominal feature's center and a measured/constructed feature's center.
3D dynamic	Refers to the rotation of a computer model of a part in virtual space.
3D image	The three dimensional representation of an object
3D modeling	The creation of a three dimensional mathematical model of an object; typically performed using digitizing devices.
3D surface	The three dimensional representation of the boundary of a region in space
A	
Accuracy	The deviation between the measured value and the nominal or actual value.
Actual	A feature or measurement that exists and is not merely potential or theoretical.
Alignment	The establishing of a coordinate system on a part, typically in reference to a coordinate measurement machine.
Angle	The figure defined by two lines extending from the same point
Apex	In reference to an angle, the point from which the two lines of the angle emanate. Vertex.
Arc	A segment of a circle
B	
Basic Measurement Strategy, CAM2 Q	<ul style="list-style-type: none"> ● Look at what you need to measure and consider the following questions: ● What should you include in the formal Report? ● Which features (geometric elements) do you need to capture? ● Which features can you Measure directly (i.e. planes, circles, cylinders, lines, etc)? ● Which features do you need to Construct (e.g. bolt hole circle) ● Which Dimensions do you need? (e.g. circle center to circle center) ● What logical sequence should you use to move around the part and capture the features? For example, left to right, top to bottom, or measure all planes first, then circles, etc.

TERM	FARO Definition
Best fit	Creating a feature that fits a set of points so each point is the shortest distance to the feature.
Bisect	To divide into two equal parts
Bisector	A feature (line or plane) which is created and equidistant at all points from two existing features.
Bolt hole pattern	A group of holes which is intended to accept bolts from a mating part in an assembly.
Button	Refers to the switches on the FaroArm
C	
CAD	Computer-Aided Design
CAD/CAM	CAD refers to computer-aided design. CAM refers to computer aided modeling. Some software packages perform both functions and are referred to as CAD/CAM.
CAE	Computer-Aided Engineering
Calibration	The procedure by which the FaroArm is optimized to perform accurate measurements. Thousands of data points are captured to determine the true geometry and kinematics of each FaroArm. This electronic "finger print" is stored on a chip in the base of the device.
CAMM (CAM2)	Computer-Aided Manufacturing Measurement
Capture (of data)	Digitizing. Storing data points in the computer system.
Circle	A closed planar curve in which every point on the curve is equidistant from the center.
Circularity	The quantity that refers to the fit of the input data points to the resultant circle.
CMM	Coordinate Measuring Machine
Coincident Points	Points that have the same XYZ value.
Collinear	Data points which lie on the same line.
Compensated points	Refers to the compensation for the radius of the ball probe on the FaroArm.
Computer aided design (CAD)	Software which replaces or augments manual drafting and design. Allows parts to be designed using computer software, and stored in an electronic database.
Cone	A basic or prismatic feature defined as a region generated by revolving a right triangle about one of its legs.
Conicity	The deviation of measured data points from the resultant cone.
Construction	A feature developed from measured features

TERM	FARO Definition
Coordinate Measuring Machine	CMM. These machines capture 3D data from objects to give the position (XYZ) of the object.
Coordinate System	A system of representing points in a space of given dimensions by coordinates, such as the Cartesian coordinate system or the system of celestial longitude and latitude.
Coplanar	Points or features which lie in the same geometric plane.
Corner	The point resulting from the intersection of three planes.
Counter-balance	The internal system which supports the weight of the FaroArm allowing for greater operator control and reduced operator fatigue.
Curvature	The deviation of a feature from a straight line.
Curvature change	The change in the slope of a curved feature.
Custom probes	Probes other than those that are supplied with the FaroArm as a standard. Customers can manufacture their own probes, and calibrate them using the 1" reference sphere.
Cylinder	A geometric feature formed by extruding a circle along its centerline in a direction normal to its plane.
Cylindrical	A part which is similar to a cylinder in shape.
Cylindricity	The deviation of measured data points from the resultant cylinder.
D	
Datum	A datum (plural datums or data) is a reference from which measurements are made. In engineering and drafting, a datum is a reference point, surface, or axis on an object against which measurements are made.
Datum Coordinate	The XYZ values of a feature used to establish an alignment.
Degrees of Freedom (DOF)	The FaroArm is termed to have 6 or 7 degrees of freedom. Each axis of rotation is defined as a degree of freedom.
Device	A piece of equipment or a mechanism designed to serve a special purpose or perform a special function. Measurement device; FaroArm or FARO Laser Tracker.
Dial indicator	Dial indicators are instruments used to accurately measure a small distance. They may also be known as a Dial Gauge, Dial Test Indicator (DTI), or as a "clock".
Diameter	The width of a circular or cylindrical feature.
Dimension	The relationship (distance or angle) between two geometric features.
Dimensioning	The function of determining the relationship between geometric features.

TERM	FARO Definition
Distance	The degree of separation between geometric features.
Drawing	The engineering documentation that indicates how a part is to be manufactured, assembled, or installed.
DRO	Digital ReadOut. The display of XYZ coordinates on the screen.
E	
Edge points	Data points which lie on the edge or border of a part.
Elbow	Refers to the joint of the FaroArm at the intersection of the two long tubes.
Ellipse	A geometric feature resulting from the intersection of a plane with a cylinder at an angle other than 90 degrees.
End Click	To accept collected readings by either clicking the FaroArm BACK button or for the Laser Tracker pressing the H hot key.
Entity	A feature or object in a CAD database.
Evaluation / to evaluate	The review of a product or process for suitability for its intended purpose.
External shape	The boundary which encloses a geometric form.
F	
Fabrication drawing	An engineering drawing that specifies how a part is to be manufactured.
Feature	Refers to an attribute of a product or a geometric object.
Fit	How easily two mating parts can be assembled.
Flatness	The deviation of the measured data points from the resultant plane.
Form	The maximum bandwidth (Max. Error added to the Min. Error) of error that a set of measured points deviates from the true form of the resultant feature calculated from that set of points.
G	
GD&T	Geometric Dimensioning and Tolerancing. A system of specifying engineering design and drawing requirements with respect to actual function and relationship of part features.
Geometric features	A shape that can be expressed using standard shapes i.e. circle, line, and arc.
H	
Handle	Refers to the pistol style handgrip of the FaroArm.
Hardware	Refers to the mechanical portion of a computer-based system. Opposite of software.

TERM	FARO Definition
Hardware lock	Dongle or port lock. Provides software security using a computer chip that attaches to the parallel (printer) port on a computer.
Hot Keys	One keystroke commands which invoke a software function.
I	
Inputting	Refers to the keying in of data.
Intersection	A meeting or crossing at a point.
Isometric	A "3D" view of a part from a direction which is equiangular from each coordinate axis.
Iterative Alignment	A means of aligning measured data to CAD data by best fitting through many iterations.
J	
Joint	The meeting place of two adjacent articulating units. Refers specifically to the transfer cases on the FaroArm.
K	
Key-in	To manually enter data using a keyboard.
Key-in alignment	The software function that creates a new coordinate system based upon translation and rotation relative to an existing coordinate system.
L	
Layer	A software tool used to group features and entities.
Line intersect	A type of alignment based upon a plane and two lines.
Line-to-plane	A type of angular dimension.
M	
Max. (maximum) Error	The largest distance from a reading above or outside a best-fit feature.
Maximum Material Condition	(MMC) Maximum material condition is that condition of a part feature wherein it contains the maximum amount of material within the stated limits of size. For a hole, the MMC is defined as the condition when the diameter is at the lowest end of its tolerance band. For a stud, the MMC is defined as the condition where the diameter is at the highest end of its tolerance band.
Measure	To capture data points to determine the size, position, and form of feature.
Mid-Point	A point which is equidistant from two other points.
Min. (minimum) Error	The largest distance from a reading below or inside a best-fit feature.
MT	Material Thickness

TERM	FARO Definition
N	
NIST	National Institute of Standards and Technology
Nominal	The theoretical value for a feature.
Normal	The vector which defines a direction perpendicular to a curve or surface at a specific point.
O	
Off-line	Any function which does not require a specific device to be connected.
Offset	To create a feature that is equidistant by a specified distance at all points.
On-line	A function which indicates that a specific device must be connected to perform a specific function.
Orientation	In reference to Geometric Dimensioning and Tolerancing, it is the type of dimension that pertains to the orientation of one feature relative to a datum feature. Such as Parallelism, Perpendicularity and Concentricity.
Origin	The point from which the axes of a coordinate system emanate.
Orthogonal coordinates	Coordinates which are perpendicular.
P	
Pan	In CAD, to change the position of the viewing window relative to the model.
Parallel	Two lines or planes which are equidistant at all points.
Perpendicular intersect	A type of alignment which requires a plane, line and point, where the origin is defined at the projection of the point on to the line.
Plane	A geometric feature defined by a point and a vector. A flat surface.
Plane-to-Plane	A type of distance dimension which yields the perpendicular distance between the centroid of the second plane and the first plane.
Point reducible feature	A feature that has a repeatable center point such as a circle or sphere.
Point-to-Line	A dimension type which yields the perpendicular distance between the point and the line.
Point-to-Point	A dimension type which yields the 3D distance between two points.
Polyline	A multi-segmented line.
Position	The location of a feature in a Cartesian coordinate system.

TERM	FARO Definition
Prismatic	Taking the shape of a prism or 3 dimensional object whose faces are represented by regular geometric features.
Prismatic features	A feature that can be represented by regular geometric shapes. The opposite of curves and surfaces.
Probe	End effector or stylus. The part of the FaroArm that touches the measurement piece. The FaroArm can use a variety of probes including hard probes, touch-trigger, and laser probes.
Probe compensation	The ability of the software to account for the radius of the probe. Gross errors can result if this is not done correctly.
Project to	To reproduce in a prescribed direction.
Q, R	
Readout	The visual display of data on a computer screen.
Re-capturing	In reference to digitizing, the re-measurement of erroneous data points.
Rectangular	A polygonal shape whose corners intersect at right angles.
Repeatability	The ability of a device to obtain consistent results. Although the terms are generally used interchangeably, repeatability differs from accuracy in that a device can consistently obtain the wrong result.
Resolution	The number of decimal places that a measurement device can reliably display.
Reverse engineering	The creation of design or CAD data from an existing or prototype part.
Rotation	Angular motion about a specified point or axis.
Roundness	The deviation of the measured data points from the true form of the resultant circle.
S	
Scanning	To capture large quantities of data points quickly.
Slot	An elongated hole with round or squared ends.
SMR	Spherically Mounted Retroreflector
Solve, to	To calculate the results of a problem.
Spherical	A shape which is similar to that of a sphere.
Spherically Mounted Retroreflector (SMR)	The probe for the FARO Laser Tracker.
Sphericity	The amount by which the measured data points deviate from the resultant sphere.

TERM	FARO Definition
Spline	A smooth curve which cannot be represented by a simple mathematical function.
Straightness	The amount by which the measured points deviate from the resultant line.
Stream	A continuous input of data points.
Surface	The outer boundary of an object.
Surface off-set	An output surface that is equidistant from an input surface at all points.
Surfacing	The technique of creating 3D models by defining the outer boundary of objects in virtual space.
T	
Temperature Compensation	The ability of a measurement device to adjust to changes in ambient temperature. A measurement device that is temperature compensated will maintain its accuracy through a wide range of temperatures. A device that is not temperature compensated cannot.
Thread	A screw thread. A machined surface with a helical shape. Normally parts are fastened together with a screw and a threaded hole or a threaded bolt and nut.
Thread mount	A metal piece that is used as an interface between a mating thread and a tripod or a mating thread and a table mountable device.
Tolerance	A zone of accuracy in both size and placement of a feature. For example, a hole of a diameter of 1.00" +/- 0.01 located at the x, y, z of 1.000, 1.000, 0.000 +/- 0.005 means a 1 inch diameter hole can be between 1.01 and 0.99 in size and the location can be plus or minus 0.005 inches from the specified nominal location.
Touch trigger probes	An electro-mechanical device that has a hard ball probe on the end of a pivoting straight shaft. When any movement of shaft is sensed at the pivot, an electrical message is sent to command the CMM to take a data point.
Traditional CMM	There are many types of CMMs that fall into this category. These include the bridge type, cantilever type, gantry type, etc. These are floor-mounted machines that require you to bring the parts to the CMM, unlike FARO's "portable" CMM, the FaroArm®.
True Position	Refers to a GD&T callout that specifies how a feature such as a hole is to be positioned on a part as well as toleranced. A true position callout may also specify additional tolerance or "bonus" if the hole is over-sized or if a shaft is under-sized (maximum or least material condition; MMC or LMC).

TERM	FARO Definition
U	
Unit Vector	A directional line with a non-dimensional magnitude of one. The line may be associated with the normal vector of a surface at a specific location. The vector is described in relation to the current alignment using the letters I, J, and K that are associated to X, Y, and Z.
USB	Universal Serial Bus (USB) is an external peripheral interface standard for communication between a computer and external peripherals over an inexpensive cable using biserial transmission. USB is intended to replace existing serial ports, parallel ports, keyboard, and monitor connectors and be used with keyboards, mice, monitors, printers, and possibly some low-speed scanners and removable hard drives.
V	
Vector	A term used to describe the direction of a line or object that may or may not have a magnitude. The line may be associated with the normal vector of a surface at a specific location. The vector is described in relation to the current alignment using the letters I, J, and K that are associated to X, Y, and Z.
Vertex	The point of intersection of two sides of an angle.
Volume	The amount of space occupied in three dimensions.
W	
Wrist	Refers to the last grouping of joints on the end of the FaroArm.
X, Y	
X, Y, Z	Refers to the Cartesian Coordinate System for three-dimensional space.
Z	
Zoom, to	A command used to change the view of the design on the screen, specifically to show a closer view.

Appendix IV: Technical Support

FARO Technologies, Inc. is committed to providing the best technical support to our customers. Our Service Policy is detailed in Appendix C: Industrial Products Service Policy of any FARO manual. If you have any problem using one of our products, please follow these steps before contacting our Technical Support Team:

- Be sure to read the relevant sections of the documentation to find the help you need.
- Visit the FARO Customer Service area on the Web at www.faro.com to search our technical support database. This is available 24 hours a day 7 days a week.
- Document the problem you are experiencing. Be as specific as you can. The more information you have, the easier the problem will be to solve.
- If you still cannot resolve your problem, have your device's Serial Number available before calling.

Support Hours

- North America:
8:00 a.m. to 8:00 p.m. Eastern Standard Time (EST).
- Europe:
8:00 a.m. to 5:00 p.m. Central European Standard Time (CET).
- Asia:
8:30 a.m. to 5:30 p.m. Singapore Standard Time (SST).
- Japan:
9:00 a.m. to 5:00 p.m. Japan Standard Time (JST).
- China:
8:30 a.m. to 5:30 p.m. China Standard Time (CST).
- India:
9:30 a.m. to 5:30 p.m. India Standard Time (IST).
- You can also e-mail or fax any problems or questions 24 hours a day.

Phone

- North America:
800 736 2771, +1 407 333 3182 (Worldwide)
- Europe:
+800 3276 7378, +49 7150 9797-400 (Worldwide)
- Asia:
+65 6511 1350
- Japan:
+81 561 63 1411

CAM2Q

- China:
+86 21 6191 7600
- India:
+91 11 4167 6330/1

Fax

- North America:
FaroArm +1 407 333 8056
- Europe:
+800 3276 1737, +49 7150 9797-9400 (Worldwide)
- Asia:
+65 6543 0111
- Japan:
+81 561 63 1412
- China:
+86 21 6494 8670
- India:
+91 11 4167 6332

E-Mail

- North America:
FaroArm support@faro.com
- Europe:
support@faroeurope.com
- Asia:
salesap@faro.com
- Japan:
japan@faro.com
- China:
chinainfo@faro.com
- India:
infoindia@faro.com

E-Mails or Faxes sent outside regular working hours

(8:00 a.m. to 5:00 p.m., Monday through Friday) usually are answered before 12:00 p.m. the next working day. Should our staff be on other calls, please leave a voice mail message; calls are always returned within 4 hours. Please remember to leave a detailed description of your question and your device's Serial Number. Do not forget to include your name, fax number, telephone number and extension so we can reach you promptly.

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Contact Information

For Technical Support

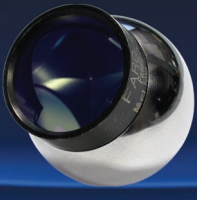
World Wide Web site: www.faro.com
E-mail: support@faro.com
Ph: 800.736.2771

For Sales Inquiries

Electronic Product Catalog on www.faro.com
E-mail: info@faro.com
Ph: 800.736.0234, extension 2265

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FARO Laser Tracker: Training Workbook



