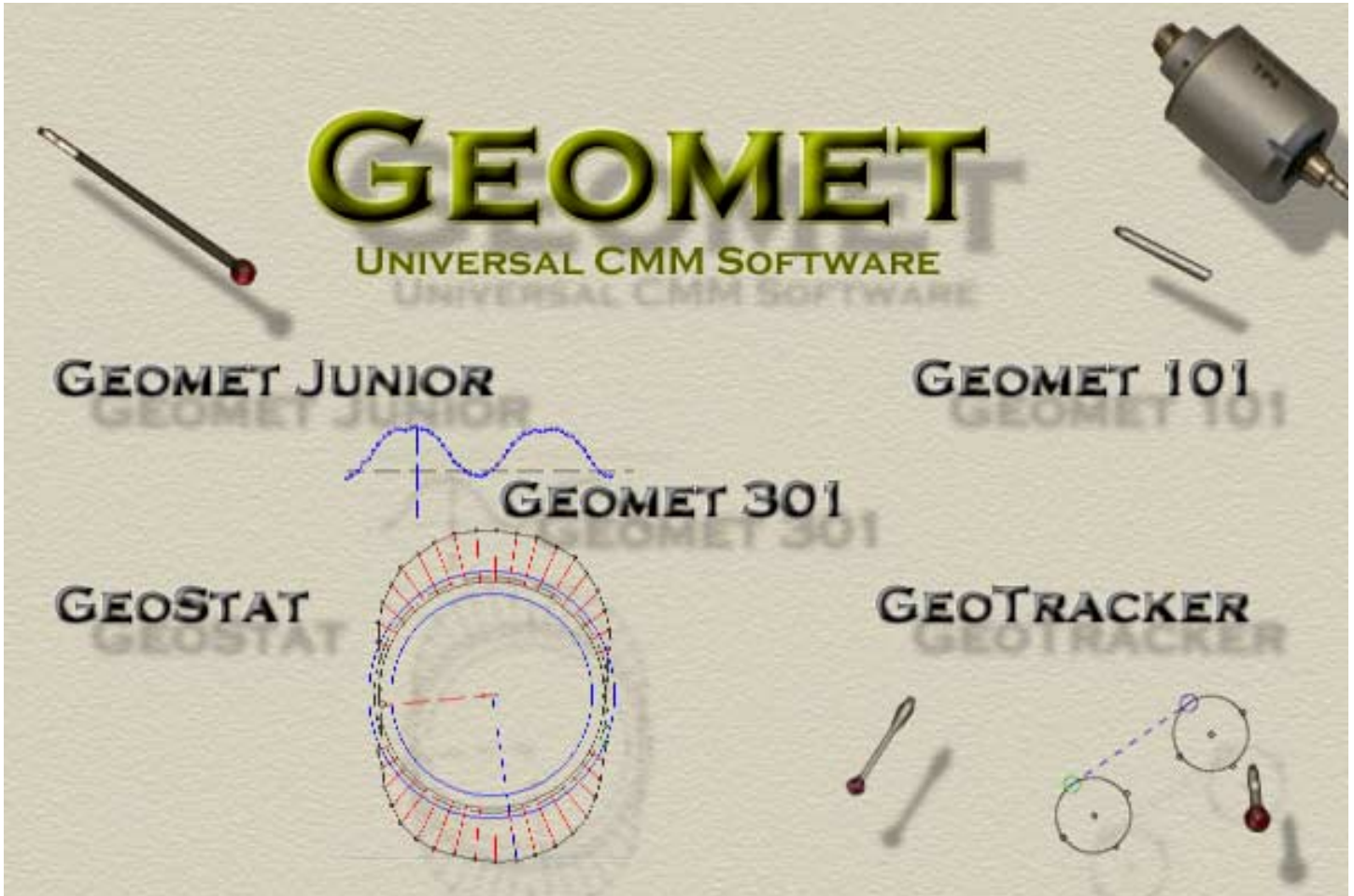# User Guide

Geomet Junior

Version 5.00

Helmel Engineering Products, Inc.

Geomet Junior

Universal CMM Software

Before You Begin

The Geomet Junior User Guide is for new and experienced inspectors. This manual describes the features of Geomet Junior in a step-by-step procedure that will enable you to become proficient in measuring and repeating your inspections using Geomet.

This manual assumes that you are familiar with inspection procedures as defined in "ASME Y14.5M, Dimensioning and Tolerancing". To begin your journey into the world of Geomet, we suggest you start with the Geomet Junior introduction.

This introduction provides the following information:

• A description of the individual chapters in this manual.
• A list of conventions used in this guide.
• Where you can find additional information.

How to Use This Manual

Chapter 1, "Introducing the Geomet System"

This chapter reviews the basic concepts of Geomet Junior. The standard user interface is described in detail taking you through the menu hierarchy, our exclusive Keystroke Magic(tm) keyboard layout and the icons. The different parts of the screen are described. The Inspection Header and System Option are described.

Chapter 2, "Probe Qualification"

This chapter describes the importance and procedures provided in Geomet Junior to ensure your styli are properly qualified.

Chapter 3, Geomet Coordinate Systems"

This chapter describes in detail why a Part Coordinate System (PCS) is required before you start your inspections. Techniques in establishing a quality PCS are demonstrated through examples.

Chapter 4, "Basics in Feature Measurement"

This chapter provides, through examples, the different feature measurement capabilities of Geomet Junior. Each feature is broken down into it's reportable components; how you can utilize these components in your inspection process is explained.

Chapter 5, "Actions and Feature Construction"

This chapter describes how you can combine features, or a component of a feature to create new geometry, fully capable of utilization within the inspection process. Action features include Text, User Prompts, Recalling features and feature state changes.

Chapter 6, "Feature and Form Tolerance"

This chapter explains how to apply tolerance to existing features. Junior offers GeoTol for form tolerance and for position, bi-lateral and true position (GDT).

Chapter 7, "Geomet Junior Feature Enhancements"

This chapter explains how to expand the capabilities of Geomet.

Conventions

The following conventional terms , text formats, and symbols are used throughout this Users Guide for Geomet Junior.

Convention   Meaning

This is representative of our custom keycap labels that when pressed, performs the selected operation.

Bold   Indicates data you must enter on prompted dialog boxes.

Italic   Information Geomet Junior prompts that requires a Keystroke Magic operation.

<F9>   The <> symbols represent a selected keystroke, <F9> indicates that you should press the F9 Function key.

[File-Open]   This represents a menu item to select. [File-Open] requires that you select the File pull-down menu and the select Open from that menu.

              This symbol represents a topic that requires special notation or additional information to be supplied.

Finding More Information

Additional information can be obtained from the ASME Y14.5M-1994 manual "Dimensioning and Tolerancing" published by The American Society of Mechanical Engineers. This manual can be obtained from your local bookstore under ISBN #0-7918-2223-0 or by writing:

American Society of Mechanical Engineers
345 East 47th Street
New York, NY 10017

Introducing the Geomet Junior System

Geomet Junior consists of a variety of components to create a complete inspection system. The minimum basic system consists of the following:

- Coordinate Measuring Machine

- Manual or Electronic Probe or Sensor

- Computer Interface with CMM

- Intel based Pentium V

- 128 Mb minimum Random Access Memory

- 1 Gb Hard Drive

- Windows™ 98, 2000, XP

- Geomet Junior Software

- Reference Sphere for Qualification

You should have a sound understanding of the Windows Operating System before you start using this software. The manual, by its very nature, can only be a reference for usage of Geomet Junior. It cannot be an acceptable replacement for an instructional course on using software that is not directly part of Geomet Junior. If you are new to the Windows™ environment, please refer to a Microsoft Windows manual.

System Components

Please record all model and serial numbers of your associated equipment. This information is helpful in maintaining service contracts, warranty claims and maintenance.

Component Model   Serial Number

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Geomet Junior Basics

Starting and Quitting Geomet Junior
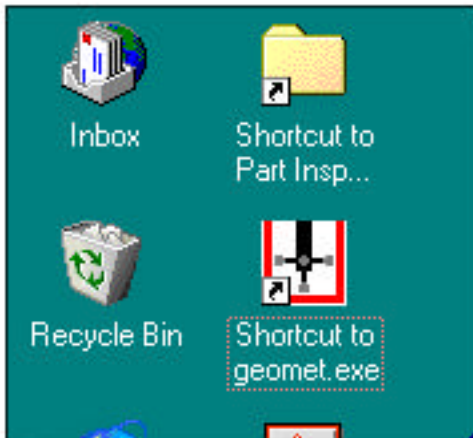
When your Geomet Junior System is installed, a shortcut icon is placed on your system Desktop providing you with a direct access to your Geomet Junior software. With your mouse, double click on the Geomet Junior icon, see fig. 1-1, and your system will launch ready for inspecting.

After completing your inspection operations, if you wish to quit Geomet Junior, pull down the File menu and select Exit or simultaneously press < Alt > and the < F4 > key. If you have not saved your work, Geomet Junior will ask you whether you want to save your work.

Access Codes

As with all levels of Geomet, you can expand your features and enhancements through the use of the Access Code dialog.

Start the Access Code dialog by simultaneously pressing < Ctrl > + < Alt > + < u >. The dialog apprears, as shown to the right, from which you enter your authorization codes. Once you have entered your code, press the < Accept > button to activate the change.

PostScript Picture
Logo Small   *Helmel Engineering Products, Inc.*

The Geomet Junior Graphic Interface

The main screen offers you easy access to all the power of Geomet® Junior. This is provided through the Keystroke Magic keyboard or through menus by using a mouse. Each area of the screen is designed to give you clear and efficient use of information.
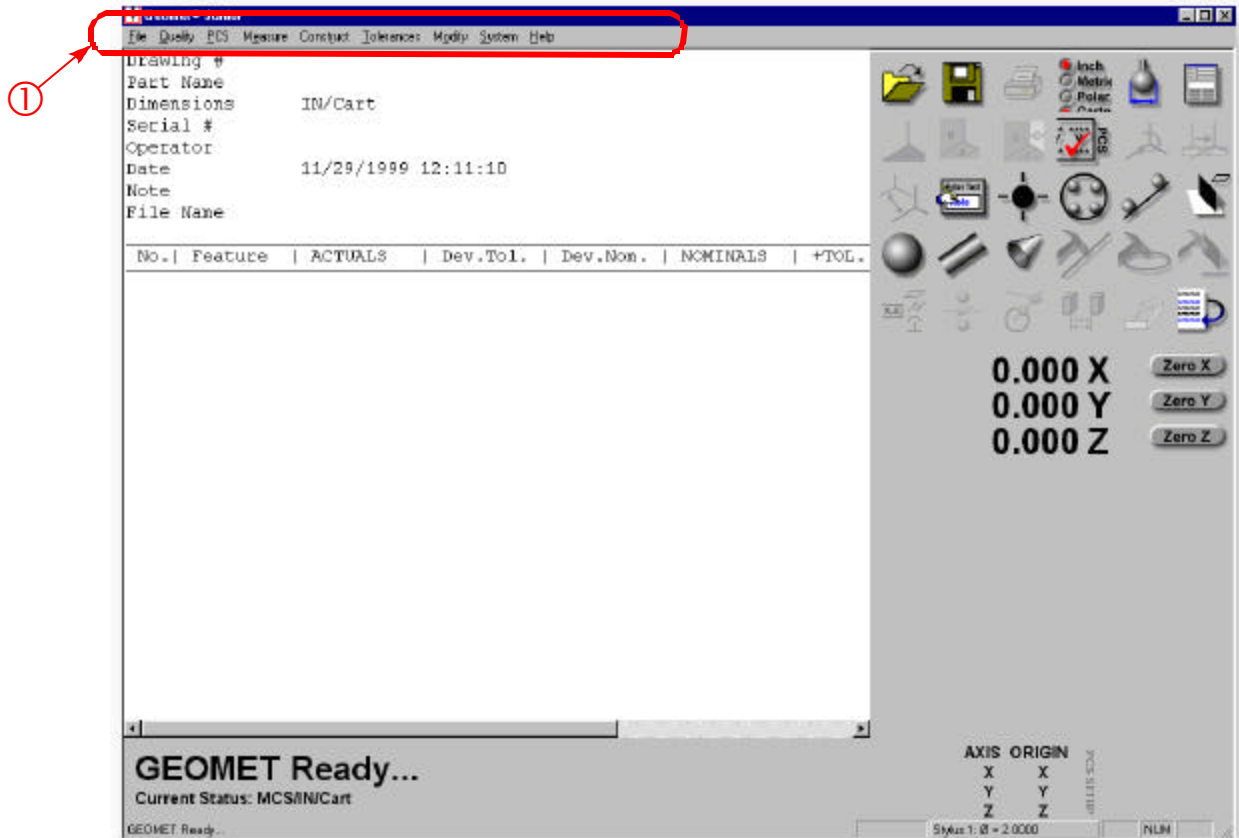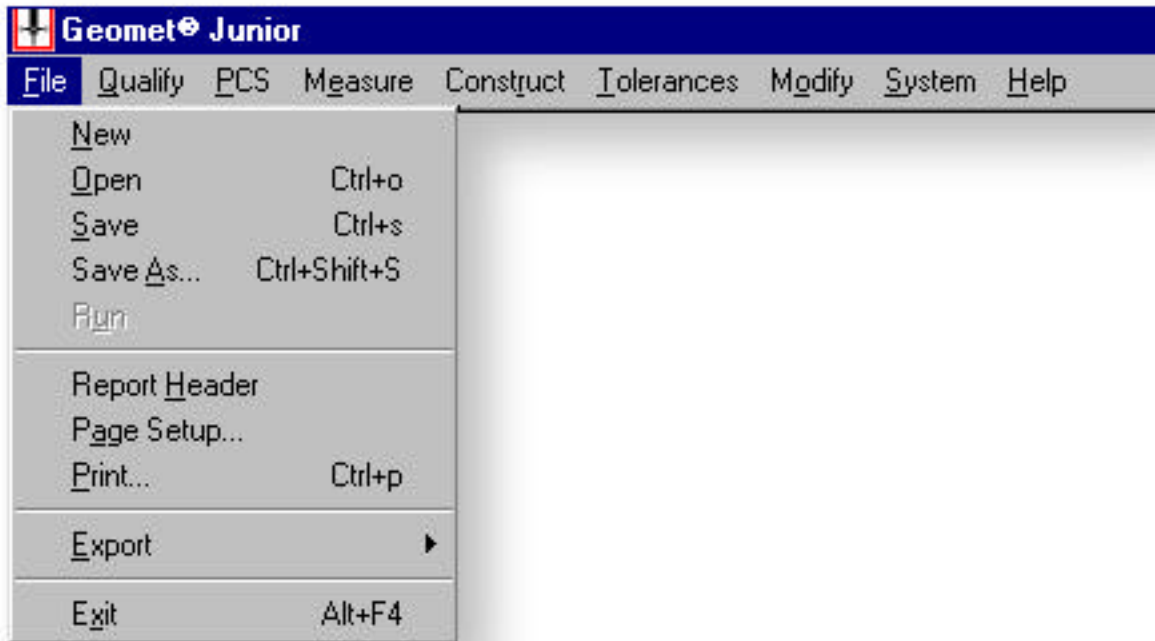

① The following pages will define the drop down and sub-menus available in Geomet Junior.

Pull Down Menu Hierarchy

How to use the Graphic Interface

To display a pull down menu you can highlight a menu name by clicking on it once with the mouse. When you do this a pull down menu will follow.

- Or -

To display the pull down without the use of the mouse, hold down the < Alt > key and press the letter that is underlined corresponding to the menu name you need.

After the pull down menu is displayed, you can click on the command with the mouse, or press the letter that is underlined.

Some menu items will be disabled or "grayed out". This is a validation process Geomet uses to restrict access to features that are not available. Example: if your last feature measured was a 1D Point, the orient functions will be disabled.

File Command Structures

*File Pull Down Commands*
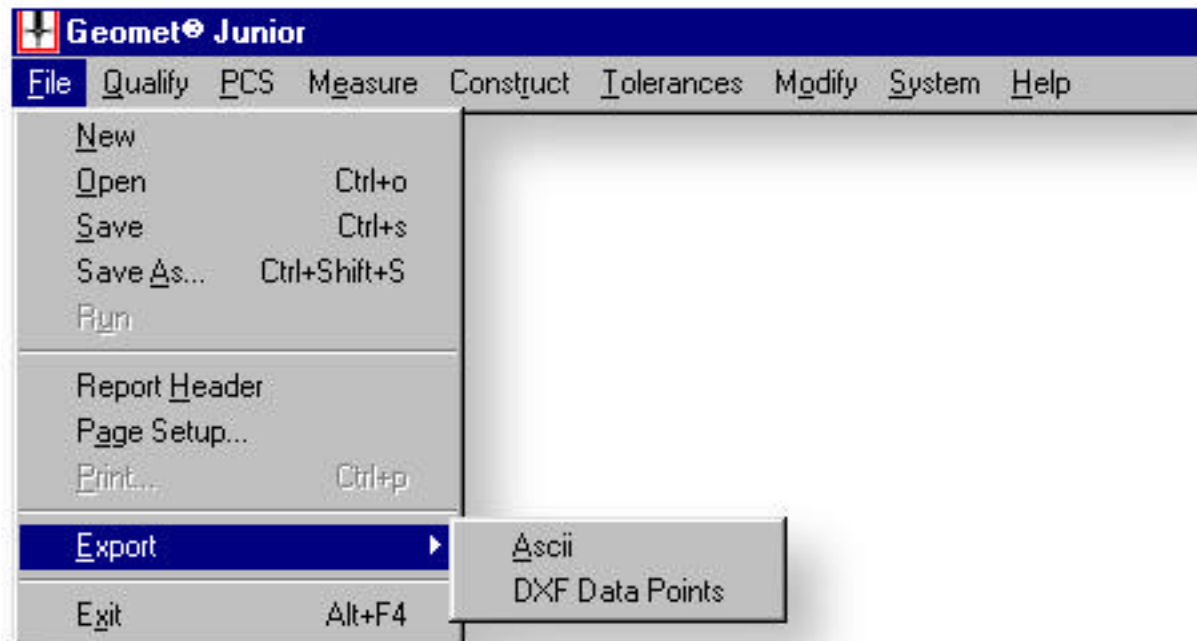
New: Initializes the Geomet Junior system and prepares for a new inspection.

Open: Prompts you to open an existing inspection file.

Save: After writing or inspecting a part, this command asks you for a new file name under which to save your results. During an inspection it allows you to perform an interim save.

Save As: Prompts you for a new name under which to save your results.

Run: Auto-cycles the current part program.

Report Header: Provides access to the Report Header for creating or editing.

Page Setup: Provides controls for page format printing.

Print: Prints out a complete inspection report.

Export⇒ASCII: Export all data points as Stylus ball centers in ASCII format.

Export⇒DXF: Export all data points as Stylus ball centers in DXF format.

Exit: Leaves Geomet Junior and returns to the Windows desktop.

Qualify Command Structures

Qualify Pull Down Commands
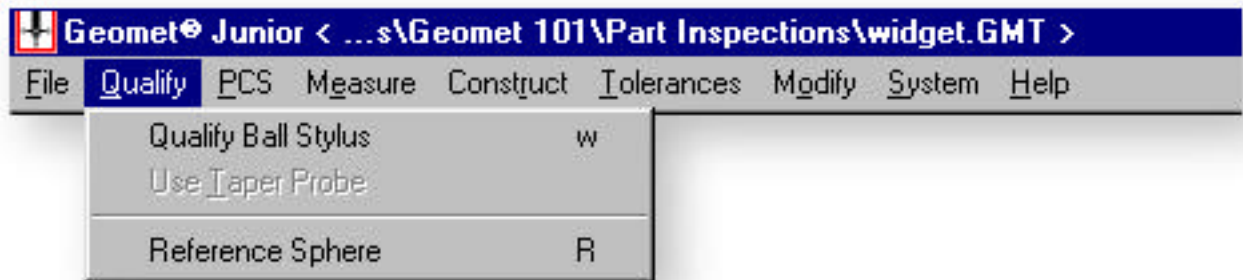
Qualify Ball Stylus: This command has two options. In the first option Junior does not have the Advanced PCS and Stylus option active; this is the default for Junior. When you click on this, you will be prompted to probe the reference sphere.

In the second option, Advanced PCS and Stylus option is active, you will have access to the complete stylus database manager that allows you to have unlimited qualified stylus.

Use Taper Probe: Not Available.

Reference Sphere: Provides access to setting the default size of the reference sphere that you use for qualifications.

PCS Command Structures

PCS Pull Down Commands
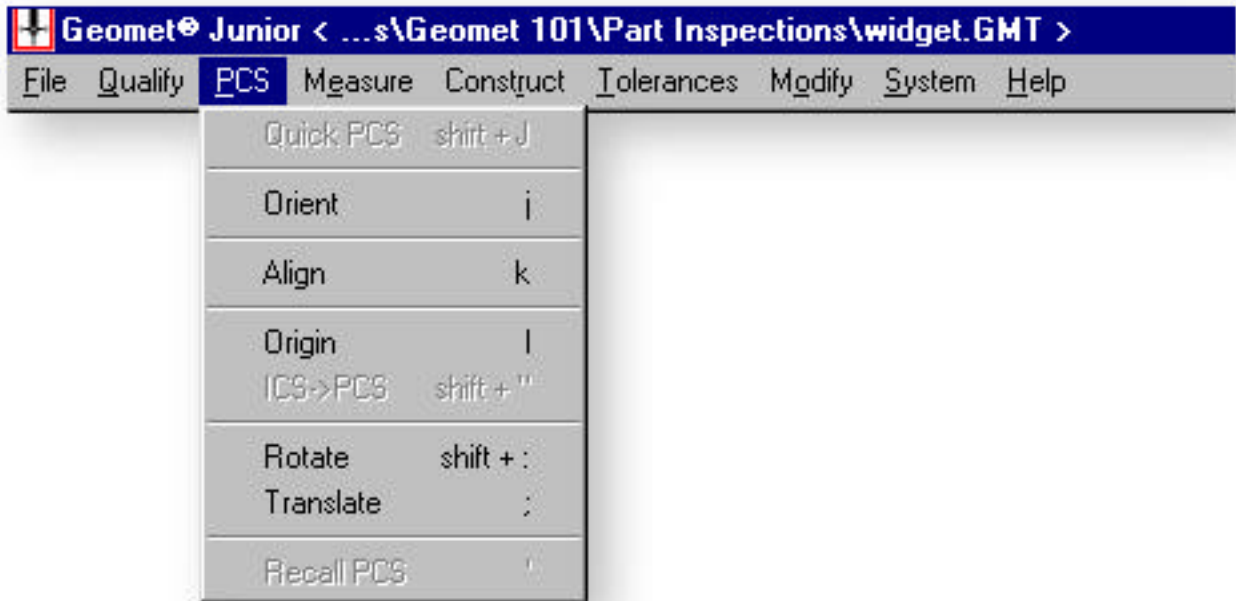
Quick PCS:	This command provides you with a basic Part Coordinate Setup utilizing a Plane and 3 Points to Establish all PCS components.
Orient:	Establishes the primary datum reference in building your Part Coordinate System (PCS).
Align:	Establishes the secondary datum reference for your Part Coordinate System.
Origin:	Establishes the datum used in building your Part Coordinate System.
ICS->PCS:	Allows you to complete a new PCS based on new components created and those in the existing PCS.
Rotate:	Creates a new Part Coordinate System, by rotating your existing Part Coordinate System by a user defined number of degrees around a specified axis.
Translate:	Creates a new Part Coordinate System, by translating the existing Part Coordinate System by a user defined distance in the X, Y, and/or Z directions.
Recall PCS:	Switches between your defined PCS and the Machine Coordinate System (MCS).

Measure Command Structures

Measure Pull Down Commands
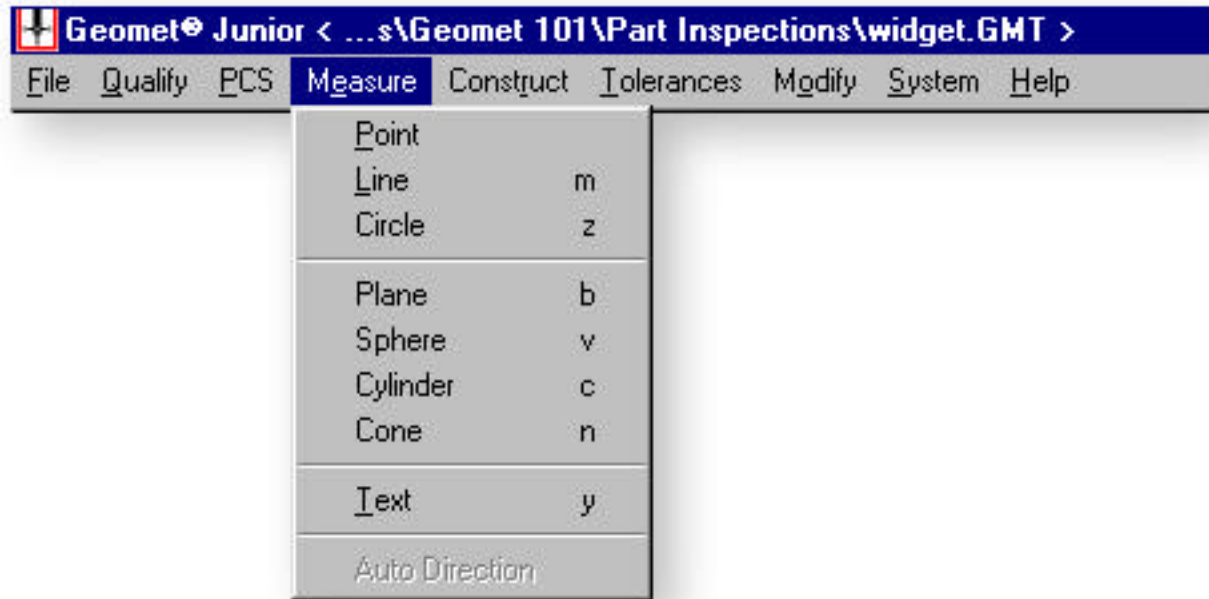
Point: Prompts the user to measure a Point feature. Through user definition, this point is a 1D, 2D or 3D point.

Line: Prompts the user to measure a Line feature.

Circle: Prompts the user to measure a Circle feature.

Plane: Prompts the user to measure a Plane feature.

Sphere: Prompts the user to measure a Sphere feature.

Cylinder: Prompts the user to measure a Cylinder feature.

Cone: Prompts the user to measure a Cone feature.

Text: Text input to place onto your inspection report.

Auto Direction: Toggle Auto Direction on/off.

ⓘ *Note: In measuring a 1D Point, a Line, or a Plane, the probing direction is either +X, -X, +Y, -Y, +Z, or -Z, corresponding to the direction the probe will be traveling in as you make contact with the part. In measuring a 2D Point, the plane that you want the point projected to must be specified, either XY, XZ, or YZ. Also, in measuring a line, the plane that you want the line projected to must be specified.*

Auto Direction will eliminate the need to enter the directions, as Geomet will identify the direction as well as inside/outside features characteristics.

Construct Command Structures

Construct Pull Down Commands
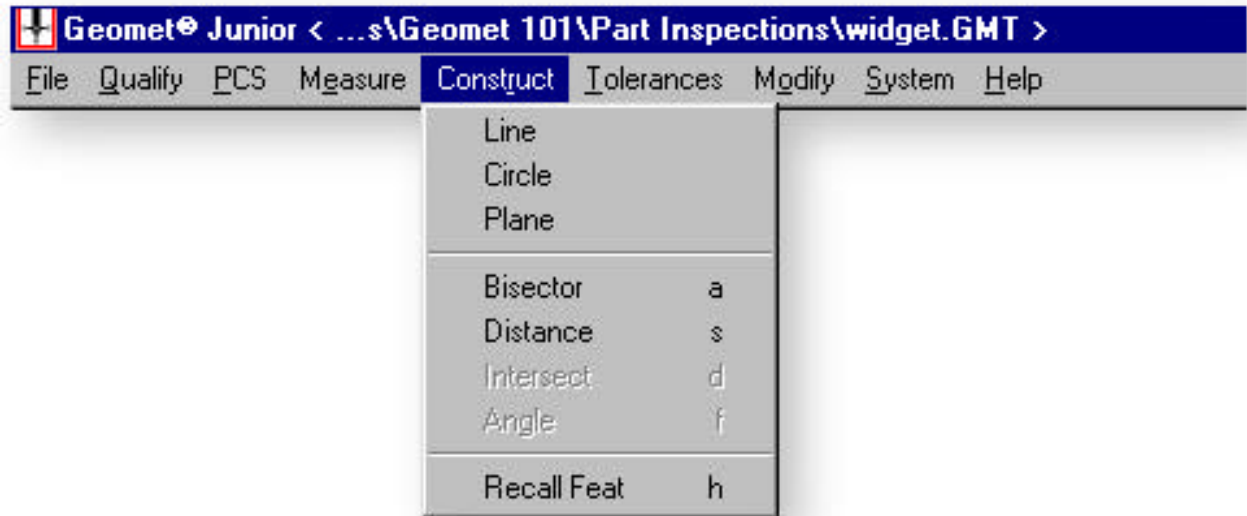
Line:
Constructs a line through a specified number of previously measured features <u>immediately preceding</u>, (provided they are compatible).

Circle:
Constructs a circle through a specified number of previously measured features *immediately preceding,* (provided they are compatible).

Plane:
Constructs a plane through a specified number of previously measured features *immediately preceding,* (provided they are compatible).

Bisector:
Constructs a logical feature symmetrically between the two previously measured features. Such as a 2D point between two coplanar circles, or a choice of two plane possibilities offered by two measured intersecting planes.

Distance:
Provides the distance between the two previously measured features, (provided they are compatible).

Intersect:
Constructs a logical feature at the intersection of the two previously measured features, (provided they are compatible). Such as a 2D point where two coplanar lines intersect, or a 3D line where two planes intersect

Angle:
Returns the angle between the two previously measured features, (provided they are compatible).

Recall Feat:
Brings any previously measured feature, specified by its feature number, to the end of the feature list for use in a new construction or evaluation.

Tolerance Command Structures

Tolerance Pull Down Commands

GeoTol:

> This option is available only after feature is measured or constructed, GeoTol allows you to choose from the sub-menu only those characteristics available for the selected feature.

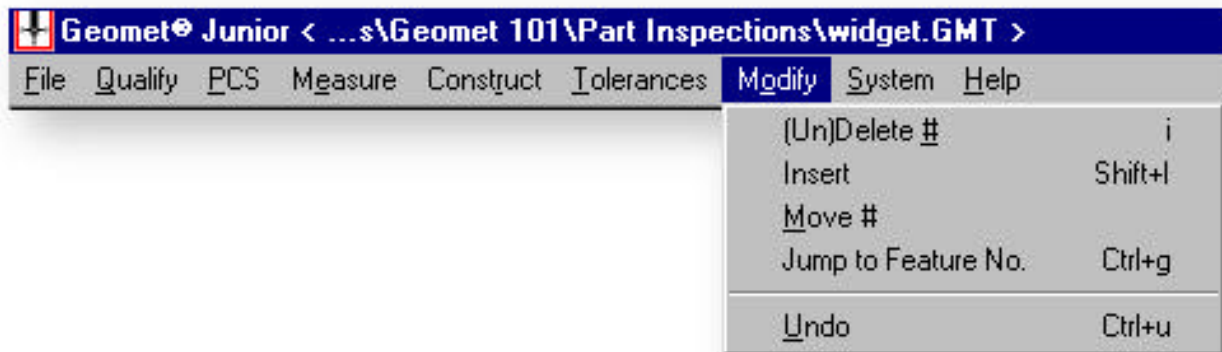> Example: from a Circle, you can derive Circularity and Concentricity.

> Geomet Junior supports the following:

> - • Straightness
> - • Flatness
> - • Circularity
> - • Cylindricity
> - • Angularity
> - • Perpendicularity
> - • Parallelism
> - • Concentricity

Tolerance:

> This command prompts you to add tolerance to a feature. This tolerance can be Bi-Lateral or GDT.

# Modify Command Structures

Modify Pull Down Commands

Geomet⊕ Junior < ...s\Geomet 101\Part Inspections\widget.GMT >

File Qualify PCS Measure Construct Tolerances **Modify** System Help

(Un)Delete #	i
Insert	Shift+I
Move #	
Jump to Feature No.	Ctrl+g
Undo	Ctrl+u

(Un)Delete #:   Deletes the last measured feature from the feature list, or returns a feature to the list if it was previously deleted.

Insert: Allows the insertion of a feature after a specific feature.

Move #:   Allows the relocation of a feature after another feature, specified by their respective feature numbers.

Feature Edit #:   Allows changing parameters of an existing feature, such as inch to millimeters, or cartesian to polar coordinates.

Undo: Provides a one feature undo operation. It will undo the last feature in the results area. If you wanted to undo the last five features, then use the undo operation five times in a row.

System Command Structures

System Pull Down Commands
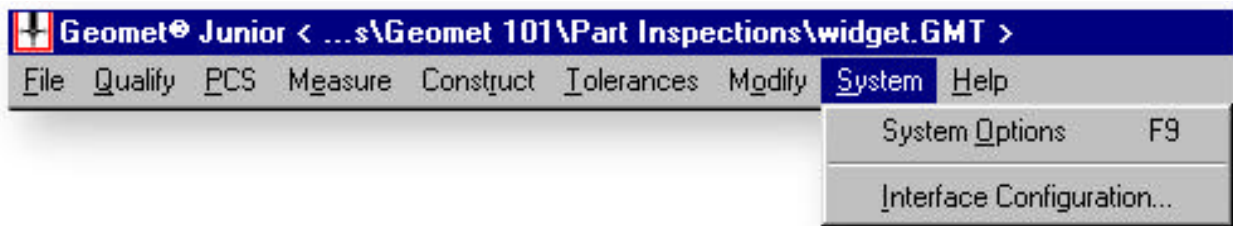
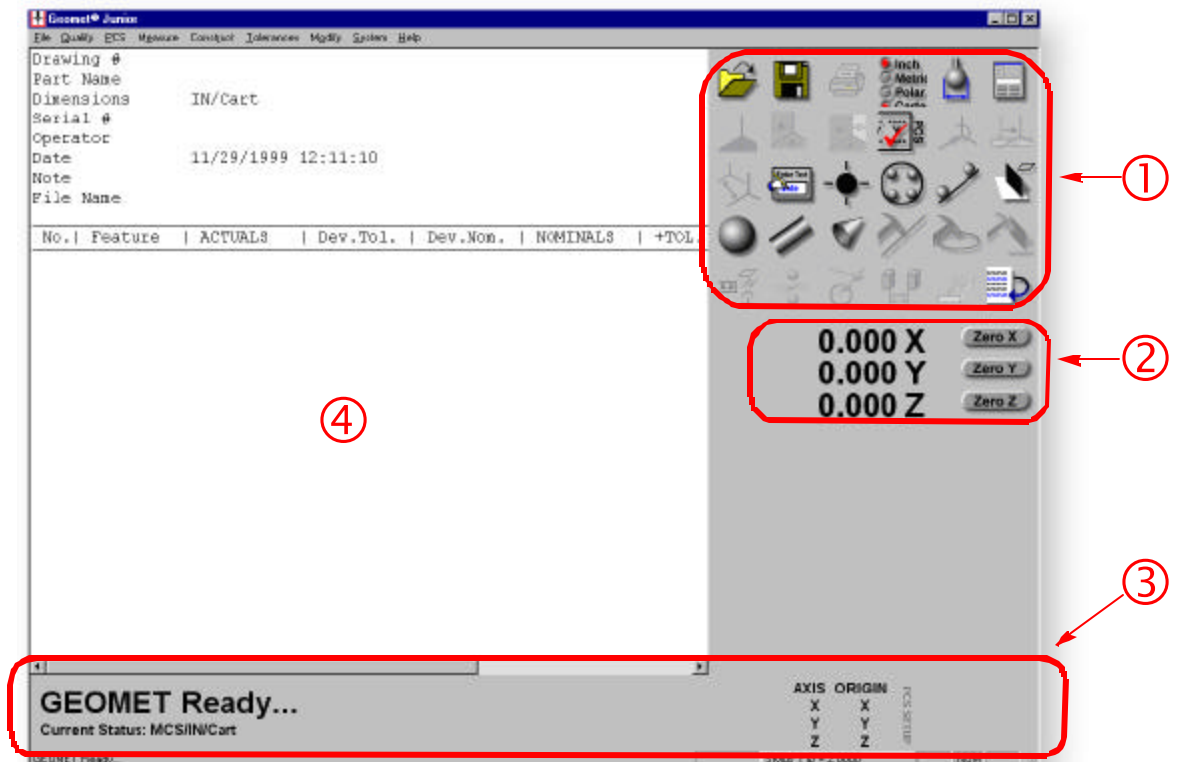System Options: Provides a dialog for setting the following controls:

- Tolerance default settings

- Decimal place precision

- Unit of Measurement

- Multi-Point form error

- Auto-direction

- Other general system default values

Interface Config: Provides configuration of the interface driver connected between the computer and the CMM. This is normally set at installation.

KeyStroke Magic™

Keystroke Magic™ Overview

Keystroke Magic™ is your access to making your CMM realize its full potential for fast, accurate quality assurance.

Each function is designed for ease of use. The Part Coordinate System keys are grouped together in a simple left to right sequence. 1••2••3 your inspection is now beginning.

The custom keycaps are color coded by function to allow a quick visualization of your keyboard. Throughout this guide we will describe each function and if applicable it's corresponding screen Icon.

Note: The Keystroke Magic™ key labels are optional with Geomet Junior. The labels shown also cover the enhanced functions of Geomet 101 / 301.

Basic Characteristics of Keystroke Magic™

Many of the keys used in Keystroke Magic™ perform more than one operation. In Geomet the keyboard is by default in the caps-off and num-lock-on state. If for any reason the keyboard has been toggled to the caps-on or num lock-off state you should change them back.

 The key shown here is the circle feature command. When you press the circle key Geomet Junior takes you to the feature measurement operations and prompts you to gather four data points (or as many points as you specify in the Minimum Hits part of the System Options window).

However there are times you may want to gather more than four points. The small "*n*" in the upper left part of the key cap indicates this feature has a multi-point option. To enter the number of data points required hold the $< \Uparrow >$ shift key down and press the circle key. You will be prompted to enter the number of data points you would like to gather. Up to a point the quality of your measurements will improve by increasing the number of points used in a measurement . For most measuring tasks, 6 to 12 hits does an adequate job. Once you have taken 20 or 30 hits, the next hit is unlikely to add significant, new information in the calculation of the size and location of that feature. Ultimately you must decide what is best for your application.

Geomet Junior Screen Layout

Geomet Junior Screen

① Tool Bar: All major functions are depicted here for point and click access. When a feature is not available it will "grey out" until conditions are set to activate it.

② Digital Read Out: Represents the current location in the MCS or the current PCS. Includes a local Zero option to obtain relative positioning data. Tip! Point at the DRO and click your right mouse button, you can change size and precision.

③ Status Banner: This is your main prompt area. From here you will receive current status which indicates whether the system is currently in a PCS or MCS, inch or millimeter, and cartesian or polar coordinates. On the right you have a count down area when gathering data points. The PCS setup guide is displayed to prompt you through the elements needed for completing a PCS.

④ Results Area: This area provides you with a scrolling report of your part inspection. Results include a sequential feature number, a description of the feature by type, the number of hits used in the measurement (in parentheses) or a recall indication (RCL), as well as the feature size, location and attitude (when appropriate). When you want to print the results, they will appear exactly as they are on the screen.

On-Screen Digital Readout

Geomet Junior provides real-time On-Screen Digital Readout providing you with the current location of the Probe.

DRO Basics

When Junior is first started, the DRO reports the position in the Machine Coordinate System (MCS). On most manual CMM's, this is referenced to the position the system was at when powered-up. Once a Part Coordinate System (PCS) has been established, the DRO will report the current position in the PCS.
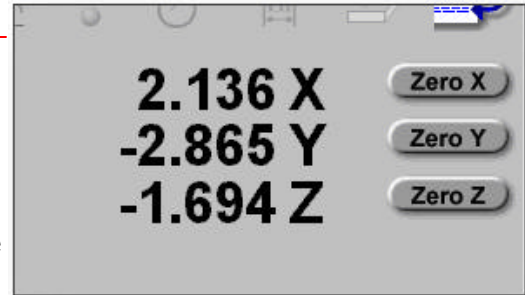
DRO Precision

To change the precision depth or number height, place your mouse over the DRO and right-click. A menu will pop-up as shown in the examples right. Choose the desired change and the DRO will update and retain these values until changed again.
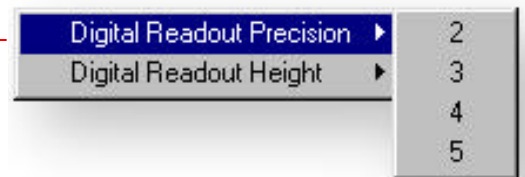
DRO Zero
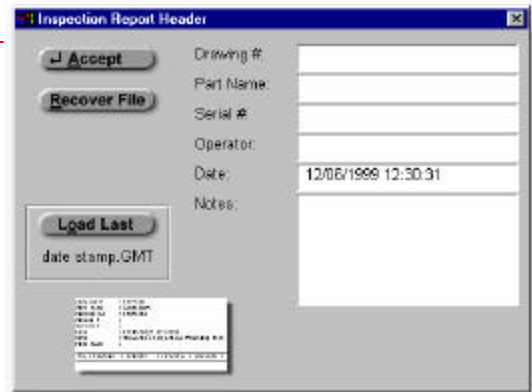
The Junior DRO has the ability to apply a temporary zero along any axis. This is accomplished by left-clicking on the buttons labels < Zero X >, < Zero Y > and/or < Zero Z >. When activate the zero option, that axis will change to 0.000 and all movements will reflect that new position. By clicking the button again, you remove the zero position and the DRO will return to the original home within the PCS.

Helmel Engineering Products, Inc.

Inspection Header

Entering your Inspection Header

Geomet Junior provides you with a report header that prompts you for information that becomes part of your inspection, see figure at right. This information can be updated by pulling down the File menu and selecting *[File->Report Header]*.

< Accept >	Accepts the data in the Header Dialog and proceeds to the inspection.
< Recover File >	Recovers the last inspection in the event of power outage or other fatal system software crashes.
< Load Last >	Loads the last saved file for review or continuation.
Drawing #:	A drawing or part number used to identify your inspected part.
Part Name:	The part name of the inspected piece; you can enter up to 65 characters.
Serial #:	You can assign a special number unique to the part that is being inspected.
Operator:	Place your name in this field.
Date:	The date is automatically entered. If you wish to override, just tab to this field and enter your own date. The date field accepts any format you wish to use.
Notes:	This field allows you to enter up to 256 characters to attach a note to the inspection report.

System Options

Establishing System Defaults

System Options are available to customize the start-up characteristics of your system. To access this function, press the < F9 > function key or from the menu, choose *[System->System Options]*.

Minimum Hits: Specifies the default number of probed points for each type of feature.

Multi-Pt: Sets limit for warning when poor feature form is detected.

Default State Toggle: Allows settings for inch/mm, Cartesian/polar, etc.

Enable Auto Sensing: Activates or De-Activates system wide the Auto Direction Feature. *Note: you must have Auto Direction enabled in order to use GeoMagic.*

Enable GeoMagic: This Activates or De-Activates the GeoMagic capability inside Geomet.

GeoMagic Fit: This setting controls the form fit evaluation zone that GeoMagic uses in determining the feature characteristics. The smaller the zone, the more accurate form your features must have before they are identified by GeoMagic.

< Update > Normally changes to the System Options are defaults that are set during a restart or when creating a new file. If you want these changes to take effect immediately, press the <Update> button.
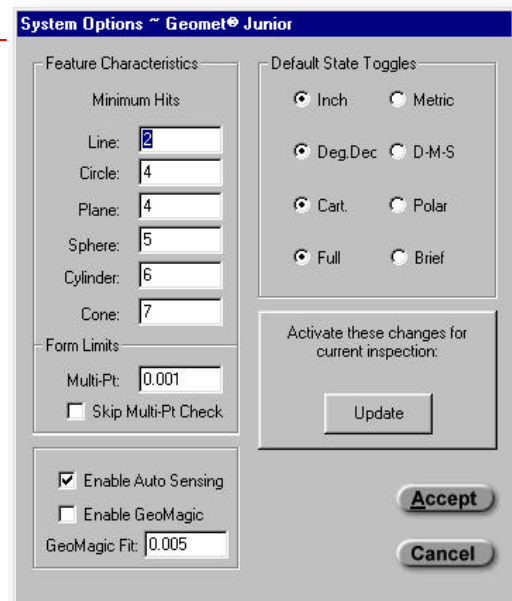
Probe Qualification

Why Calibrate the Stylus?

Imagine you are using a probe with a stylus tip (the ruby ball) that has a diameter of .25", then you measure an inside diameter that is 1". It is easy to understand that the computer calculates the diameter as .75", because it does not know the size of the stylus. If we can calibrate the stylus, then the system is smart enough to add the tip size, .25", to the calculated diameter, .75", and report a probe compensated measured value of 1.000".
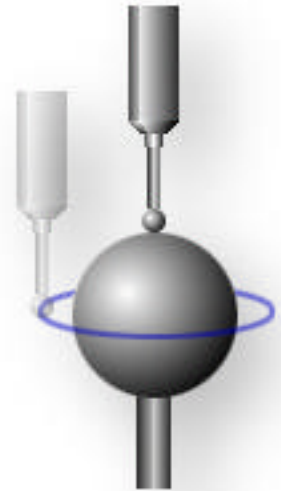
How do you Calibrate the Probe?

There are three ways to initiate the probe calibration process: (1) from the main menu select *[Qualify->Qualify Ball Stylus]*, (2) click on the Probe Calibration icon, or (3) pressing the < w > on the keyboard. Each will display in the status banner to "Qualify Stylus (Ball)" with five points remaining to be taken in the count down box. Capture four points along the equator of the reference sphere, and one point on the top, *see figure at above-right*.

After you have qualified the stylus, it is not necessary to re-qualify it unless you make a change to the probe configuration, (like changing to a larger or smaller stylus), or if you reposition the reference sphere. The qualification will be fine for the next job or even throughout the day. It is a good idea to qualify at least once each day even if you are not changing the probe setup.

Basic Stylus Option

Geomet Junior offers the use of one Stylus in your part inspection. A basic part inspection consists of one probe, which is qualified at the beginning of the inspection and limits the use of configurations such as clusters. If you require additional stylus configurations you should acquire the Advanced PCS and Stylus option available to Junior, or acquire a higher level of Geomet such as 101 or 301.

Advanced Stylus Option

If you have acquired the Geomet Junior option: **Advanced PCS and Stylus**, you have access to qualifying and using several probes simultaneously. This allows capturing data points on different sides of a part such as a through bore. This option also supports Manual Indexing Probe Heads allowing repeatable positioning of a single stylus for access from any direction in your part inspections.

Stylus Manager

The Stylus Manager is activated when you select the keystroke <w>, choose the Qualify Icon or from the menu *[Qualify->Qualify Ball Stylus]*. The example at the right shows the Stylus Manager from which you can select and qualify all your probes.
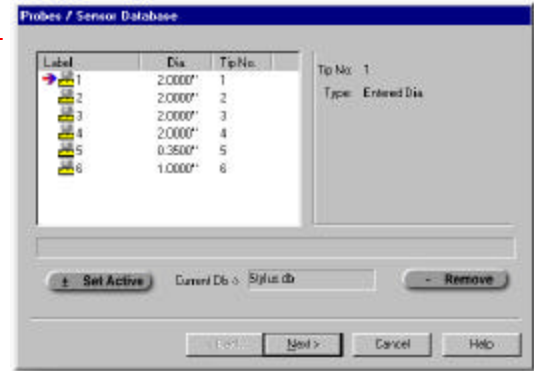
Qualifying from the Stylus Manager

The Stylus Manager allows you to Qualify and Re-Qualify existing probes. To qualify a new probe you must ensure that existing probes are not highlighted in the Stylus Manager (if a probe is highlighted it becomes a re-qualify as described later in this section). To start qualifying, press the < Next > button which will guide you through the process.

The next step is to identify the type of probe you will be qualifying. Geomet supports probes such as electronic touch styli or hard probes including ball, cylinder, taper, edge finder and video crosshair. From the drop-down select the type of styli you have. In this example we are using "ball". Press the < Next > button and you will be instructed to capture data points.

Above are the basic steps used in the quali-

fication process.

ⓘ *you can go from the select screen to the capture data point screen by pressing the <Enter> key twice. It is not required that you use the mouse to select "ball" on screen two or to press the < Next > button.*

Qualifying Hard Probes

Hard Probe Basics

Geomet allows the use of hard probes in your part inspections. Hard probes are quite often the probe of choice in the inspection of sheet metal stamping, basic machined parts, PC boards and other related production. Geomet maintains the relationships when switching probes on the CMM. However there are certain restrictions when using hard probes as described here. (See the "Probe to Feature Application Chart" found at the end of this section).

Ball Hard Probes

Ball styli are completely universal. They may be used in all attitudes on all machined surfaces with any measured feature. This probe is similar to the electronic touch probe in its applications. Qualifying of this probe is similar as described earlier under "Qualifying from the Stylus Manager".

Taper Hard Probes

Taper probes are designed to be mounted to the CMM in the -Z attitude and their use is limited to the MCS XY base plane. The Taper probe is designed for use in centering on bores and slots returning a 2D XY reported feature. It is ideally suited to the inspection of PC boards where you are required to report the location of all through holes. Taper probes should only be used with the 2D Point feature found in Geomet.

To qualify the Taper probe, lock the Z-axis and probe the reference sphere around the equator. This will ensure the XY components are qualified when switching between probes.

Cylinder Hard Probes

Cylinder probes are designed to be mounted to the CMM in the -Z attitude and their use is limited to the MCS XY base plane. Cylinder probes provide edge and bore locations with proper compensation for the probe size. Cylinder probes are ideally suited to measure features such as thin walled bores, as which can be found in sheet metal applications. Cylinder probes use the 1D Point, Line and Circle features found in Geomet.

To qualify the Cylinder probe, lock the Z-axis and probe the reference sphere around the equator. This will ensure the XY components are qualified when switching between probes.

Edge Finder Probes

Edge Finder probes are designed to be mounted to the CMM in the -Z attitude and their use is limited to the MCS XY base plane. Edge Finder probes rotate in a ball cage mounted to your CMM and can rotate about the Z-axis with an effective probe compensation of 0.000. This style of probe works with Lines and 2D Points where the 2D Point is on the surface.

Qualifying requires only the selection of the Edge Finder in the "choose type" drop-down in step two. Geomet enters a 0.000 as probe size and correlates the XY with the known center location of the reference sphere.

Video Crosshair

The use of a manual triggering Video Crosshair is available in Geomet. Video Crosshair probes are designed to be mounted to the CMM in the -Z attitude and their use is limited to the MCS XY base plane. Video Crosshair works with the 2D Point, Line and Circle features within Geomet.

To qualify the Video Crosshair, lock the Z-axis and probe the reference sphere around the equator. Although this can not be used interchangeably with other probes it can set the diameter of the probe to offset the visual effect of the crosshair thickness. Often you will have a resulting qualification less the 0.000.

Entered Diameters

Geomet allows you to enter a known diameter of a stylus. This method is not capable of allowing switching between probes on the same part inspection. You can enter a negative number for use with probes such as Video Crosshairs.

Probe to Feature Application Chart

	Points 1D	2D	3D	Line	Circle	Plane	Sphere	Cone	Cylinder	Digitize
Ball	X	X	X	X	X	X	X	X	X	X
Taper		X								
Cylinder	X			X	X					X
Edge Finder	X	X		X						X
Video Crosshair		X		X	X					X
Entered	X	X	X	X	X	X	X	X	X	X

Choosing Styli from the Stylus Manager

To set activate a previously qualified stylus for use in your part inspection, start the Stylus Manager < w > and highlight the desired stylus. You can highlight using either the mouse and left-click directly on the stylus LABEL or by pressing the < ⇓ > down arrow key until the highlight reaches the desired stylus. Press < Set Active > or the < + > keystroke.

Once this has been done you will be returned to your part inspection.
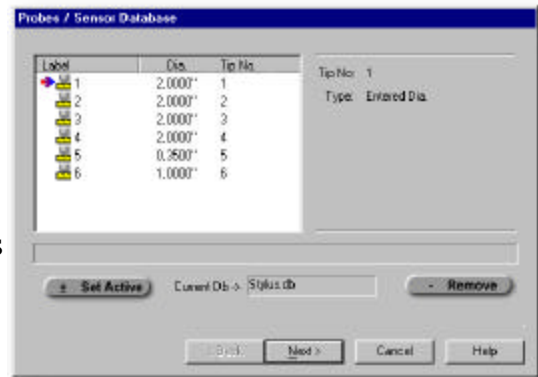
Labeling your Styli

To assist in clarifying different probe configurations, you can attach a label to help identify each stylus. To do this, highlight the desired stylus and press < l >   (for label) on the keyboard. The current label can now be edited directly on the select stylus screen as shown for number 4 in the example at the right.

This method of labeling can be used to identify the a/b angles used with manual indexing probes or the position in a cluster configuration.

Setting the Reference Sphere

It is important that you establish the exact size of your reference sphere. In Geomet Junior you access this by selecting from the menu [Qualify->Reference Sphere]. Enter the diameter value in the box as shown in the example.
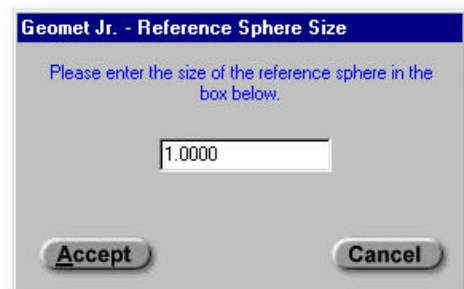
Reference Sphere

Geomet uses the reference sphere as the basis for multiple stylus support. It is important to understand how the relationship between the reference sphere and the qualified stylus work together.

For example, we refer to the first qualified stylus in your system as the Primary Tip. This tip retains the MCS location of the reference sphere which is then used to qualify the remaining styli. Stylus number 2 will retain a XYZ offset back to tip number one as well as all remaining tips. This allows us to provide features such as measuring a single feature with any number of tips. This is most useful with manual or motorized indexing probes and clusters or any combination thereof.

Re-Qualify Existing Styli

To Re-Qualify an existing probe, first highlight the stylus in the Stylus Manager the press the < Next > button. Geomet will see that you have a selected stylus and will then direct you to re-qualify. You can identify the Re-Qualify process by noting the red check as illustrated in the example at the right.

When you select < Next > from step two, you will be prompted to probe the reference sphere or enter the diameter as originally done when creating this stylus.

Special care should be taken when re-qualifying existing styli. You can re-qualify any existing tip, **but not the primary tip**. If you are required to re-qualify the primary tip, you should then re-qualify all remaining tips
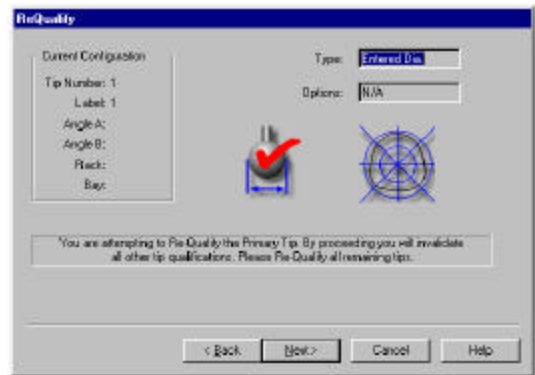
Geomet Coordinate Systems

Machine Coordinate System, MCS

The Machine Coordinate System, commonly referred to as the MCS is the XYZ position of the CMM with respect to the Home Position. The MCS axes are mutually parallel with the movement of the CMM.

Most manual CMM's do not have a home position, therefore the home position is the location of the CMM at the point of starting the system. Some manual systems do offer a home position that requires the operator to manually move the CMM, over the reference mark one axis at a time.

In a DCC system, start-up procedure requires that you "Home" the system which drives to Home and establishes a repeatable XYZ zero point.

A Machine Coordinate System is therefore not a valid coordinate system to obtain reliable measured values for your part inspection.

Incomplete Coordinate System, ICS

The ICS is an incomplete PCS, namely one which is under construction. The ICS becomes a PCS once construction is complete or as soon as the < ICS⇒PCS > key is pressed.

Advanced PCS and Stylus Option

In the basic Junior program you have access to one PCS. This one PCS can be redefined within your part program. If you have acquired the Geomet Junior option: ***Advanced PCS and Stylus***, you have access to unlimited PCS and FCS support.

Part Coordinate System, PCS

The Part Coordinate System or PCS is the foundation that establishes the Orientation, Alignment and Origin of your part inspection. PCS's are simply the frames of reference in which part feature locations are defined. All machines part drawings are based on PCS's established by datum features. These drawings are nearly always 2 dimensional, but machined parts are really 3 dimensional. The 3 dimensional characteristics of machined parts are generally drawn in a series of 2 dimensional projections for the sake of convenience, but in fact a 3 dimensional PCS is implied. To better understand this let us consider the multi-projection part referred below:
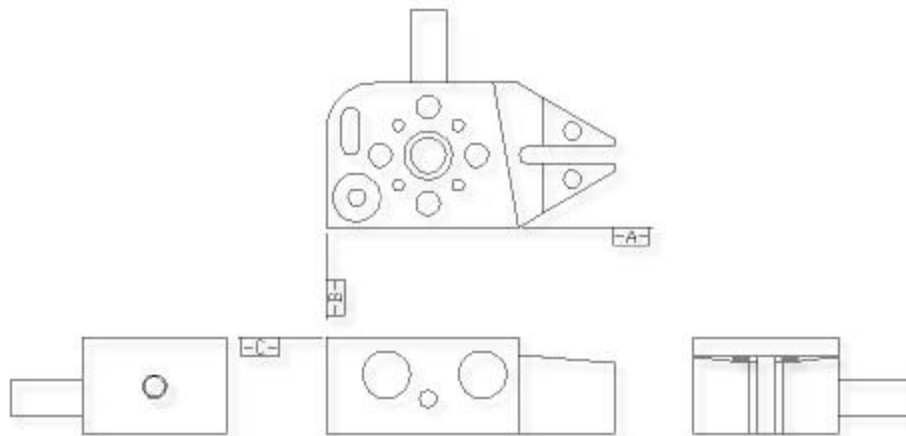
A multi-projection part drawing

In order to measure this part on a coordinate measuring machine we shall need to contact it with probes on all sides. In planning to do this it is helpful to visualize the 3D coordinate system of the part. Let us do this by making a perspective drawing of the part from one possible direction and then overlaying a 3D PCS. The figure at the right is one possible view of the 3D dimensional PCS.

The way in which the PCS is overlayed on the part is determined by the datums defined in the drawing. Notice that each datum actually represents a plane: Datum -A- is the ZX plane in which the plane contains the Z and X axes on the PCS. Datum -B- is the YZ plane and Datum -C- is the XY plane. Each of the PCS axes is orthogonal to the other two and all PCS planes, the XY, YZ and ZX planes, are orthogonal to one another. Notice also that the part lies entirely in the positive octant of the PCS, i.e. all features have positive X, Y and Z values.
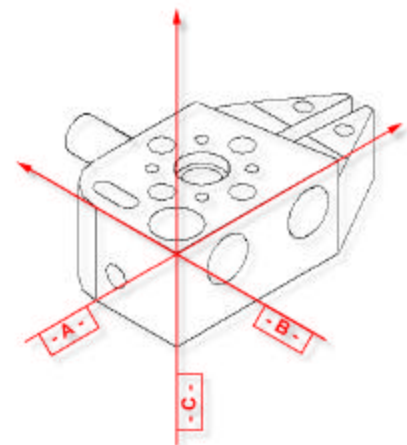
The important thing to remember is that the two dimensional drawings we deal with are derived

3D dimensional PCS

from three dimensional concepts, and in order to effectively measure a 3D part with a coordinate measuring machine we must "see" the 3D PCS with the part. This is made easier by looking at the actual part and at the same time as we study the drawing and making a habit of constructing imaginary planes in the part representing the datums defined in the drawing.

PCS versus MCS

Since features of machine parts are defined in terms of their datum references, we must create Part Coordinate Systems reflecting those datums before the features can be measured. Since coordinate measuring machines have their own coordinate system, namely a system of mutually orthogonal axes of motion referred to as the Machine Coordinate System (MCS), the first problem we face is to create the PCS within the MCS. This is not trivial.

One way to create a PCS within a coordinate measuring machine is to make the PCS coincide with the MCS. The procedure consists of physically aligning the datum surfaces of the part parallel to the axes of motion of the machine and setting the X, Y and Z displays to zero with an edge finder probe in contact with datum surfaces or with a taper probe seated in a datum bore. Once the MCS and the PCS have been made to coincide, all dimensions found on the display of the coordinate measuring machine are also feature locations on the part.

Making the PCS and MCS coincide physically can be extremely time consuming, and sometimes impossible. We can eliminate the problem by using Geomet to create and store a skewed PCS. Once a PCS has been established, the computer converts raw data collected in the machine coordinates into measurement results in part coordinates. In the figure at the right you will see a part coordinate system with X, Y and Z axes nested inside a machine coordinate system with its own X, Y and Z axes.
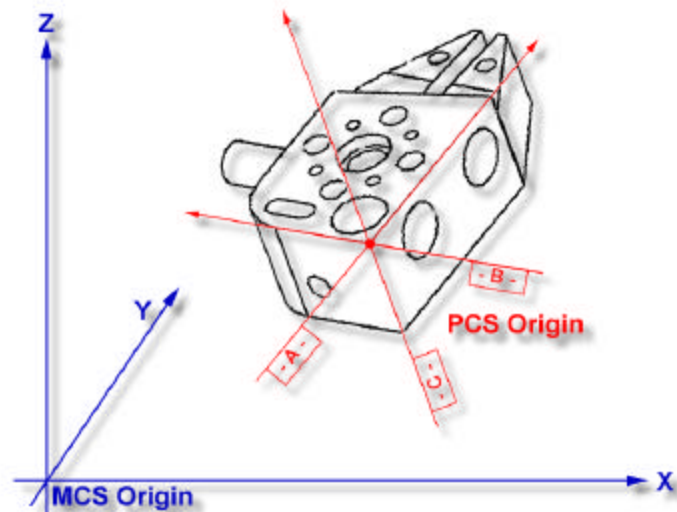
A PCS nested within the MCS

The MCS and the PCS are totally skewed relative to each other. With the help of Geomet any point in the MCS can be expressed in the PCS.

As Geomet can manage the link between an MCS and a totally skewed PCS we no longer need to physically align the parts to the machine. BUT..we need to create the skewed PCS in Geomet before it can manage the link. The job of creating the PCS will be simple once we understand a few fundamental principles.

Part Coordinate System Creation

All Cartesian PCS's consist of three orthogonal planes whose paired intersections represent the axes and whose mutual intersection represents the origin of the PCS. When using a coordinate measuring machine, PCS's are created by measuring reference or datum features of the part and then designating them as functional elements of the PCS using the three Geomet PCS formation commands "Orient", "Align" and "Origin". These three commands are directly mapped to the ANSI 14.5 datum frame components, "Primary", "Secondary" and "Tertiary" datums.

The first step in forming a PCS is to establish the direction of the PCS axis based on the primary datum reference on the part. This could be the X, Y or Z axis. Once determined, this axis and the plane normal to it becomes the primary axis and primary plane of the PCS. With the primary axis and primary plane established, the directions of the two remaining PCS axes must be determined. These lie in the primary plane and make right angles with each other and with the base axis. Determining their direction is achieved by ALIGNing the interim X and Y in the primary plane (assuming the primary plane has a Z normal) such that one axis becomes parallel to the secondary datum feature of the part. The direction of the third PCS axis is automatically locked in at the same time since it is perpendicular to the first two by definition. After establishing the directions of all three PCS axes we need only set a starting or zero point from which to measure distances along them. This is done by setting ORIGINs on the datum features we measure. The process of PCS establishment is described in the following examples.

PCS Setup Guide

In order to ensure that a complete PCS has been established, Geomet provides a visual PCS Setup Guide to remind you of the missing components of the current PCS under construction. The figure at the right shows the setup guide with all axis and origins still requiring definition.

PCS Setup Guide

When you establish one of the PCS components, such as the Z primary axis, the setup guide will reflect the completion by "signing-off" that component with a series of "*******" as shown here.

It should be noted that as long as a PCS is under construction, no results are displayed with each measured feature. When the PCS is completed, the PCS Guide Box will disappear from view.
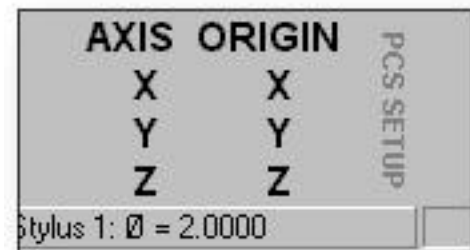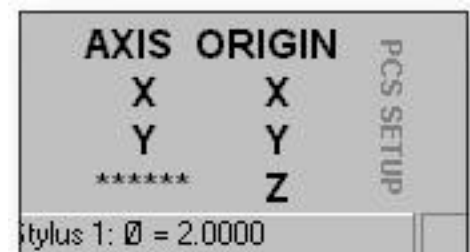
PCS component completion

PCS Commands in Geomet

Geomet provides several functions to create, recall and transform part coordinate systems. The following icons are the keycap labels on the Keystroke Magic keyboard layout.

Orient

Orient acts on the last measured or recalled 3D directed feature or pair of non-directional features which could serve to create a 3D directed feature. Orient sees through transparent operations such as other PCS formation commands, distance and angles, etc. Orient establishes the direction of the primary PCS axis, with the selection of X, Y or Z determined by the MCS X, Y or Z axis to which the directed feature axis most parallel. Orient will be disabled of feature(s) that are not validated as having the required components to establish a primary datum.

The Orient command destroys the axis and origin references of the previous PCS and, if not already visible, invokes the PCS Setup Guide. For proper function, the Orient must be followed by the Align command with one exception, after performing the orient command, you can establish the origin on the characteristics of the feature. An example might be the measuring of a XY plane, which is used to establish the primary datum through the orient command along the Z axis, as shown in the figure at the right. Once the orient has been completed, you can establish the Z origin on that plane.
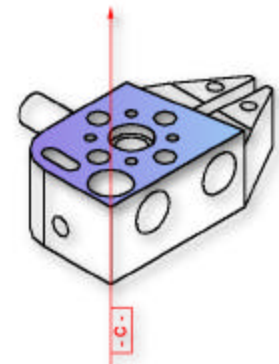
Plane as Primary

Another example might be establishing the primary axis through two spheres, as shown in the example at the right. Geomet will validate the orient command by looking back in the inspection. If it finds a 3D feature that is reported either as a point or sphere, it will continue to look back until a corresponding 3D feature is found. The orient function will create the primary through the 3D point of the two corresponding features.
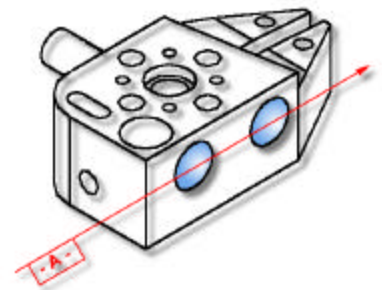
If you elect to apply the origin immediately following the orient, Geomet will prompt you whether to establish the origin on the X, Y and/or Z.

Spheres as Primary

Align

Align acts on the last measured or recalled 3D or 2D directed feature or pair of non-directed features which could serve to create a 2D or a 3D directed feature. For example, a pair of 1D co-directional points, pairs of coplanar 2D points, or pairs of 3D points. Align see through transparent operations such as other PCS formation commands, distance and angle commands, etc. Align establishes the directions of the secondary and tertiary PCS axes, with the selection of X, Y and Z determined by the MCS X, Y or Z axis to which the directed feature axis is most parallel. Geomet will validate the last feature(s) to determine whether they are capable of providing a secondary datum.

Align, when executed in an ICS directly after orient, makes an automatic choice of the alignment axis. Align, when executed in a PCS results in a re-alignment, whereby the alignment axis is determined automatically in the case of a pair of co-directional 1D points or coplanar 2D features, but must be specified in the case of a pair of 3D directed features by responding to the operator input from the select base plane dialog as shown to the right.
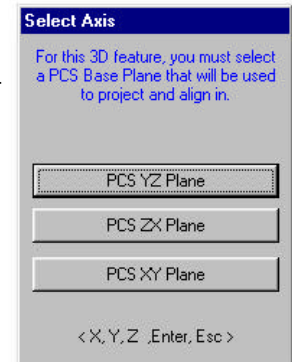
Offset Align

Offset align acts exclusively on the last measured or recalled pair of coplanar 2D features. Offset align requires that you are not in an ICS and through Geomet validation procedures, this command will be disabled. The offset align command will perform a re-alignment of the current PCS.

The first step in establishing the offset align is to measure or recall two co-planar 2D features. In the example to the right we will use two XY circles identified as F1 and F2. The order in which they are reported in the part program will determine the re-alignment axis. In this example F2 was measured or recalled *after* F1. To perform the re-alignment, press the offset align key $< \Uparrow > + < K >$ and a request will appear for a value to offset from F2, *see figure at right.*

The value you enter is the magnitude of the nominal offset and with it's sign, will control the direction of the re-alignment. In the example of *offset align figure*, the value entered was -0.75 forcing the PCS X axis below F2.
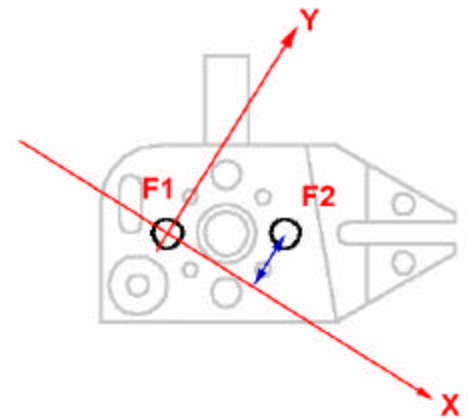
Offset Align

Enter Offset Value

Pivot Align

Pivot Align acts exclusively on the last 2D or 3D measured or recalled feature. Pivot align requires that you are not in an ICS and through Geomet validation procedures, this command will be disabled. The pivot align command will perform a re-alignment of the current PCS.

Pivot Align with 2D Features

To perform a pivot align using a 2D feature, press the pivot align key < Ctrl > + < k >, Geomet will automatically re-align the current PCS through the existing origin and the last 2D feature in your report database. In the example at the right, the last feature is a XY circle identified as F1. The re-alignment takes place through the current PCS origin and the center of the circle, F1.

Pivot Align

Pivot Align with 3D Features

To perform a pivot align using a 3D feature such as a 3D point or sphere, press the pivot align key < Ctrl > + < k >. Geomet validates the last feature and after identifying it as a 3D feature, prompts you to select a PCS base axis which to rotate about.

For example, if you are to perform a pivot align using a sphere, you will be prompted to select a PCS base axis. The base axis represents the normal axis to the base plane the re-alignment will take place in. If you selected the Z, The pivot align will take place in the XY base plane and the projected XY components of the sphere will act as the 2D point which the re-alignment will take place through.
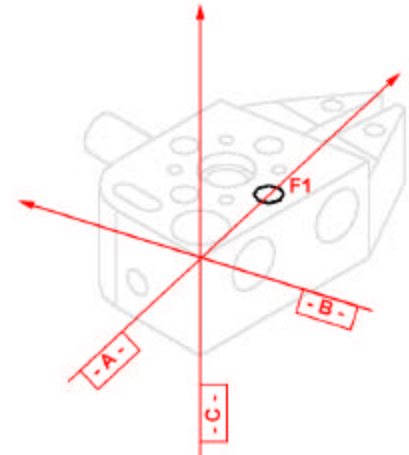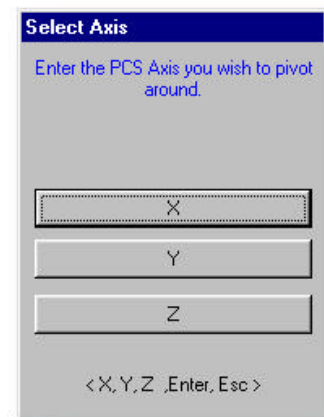
Pivot Align axis request

Origin

Origin acts on the location of the last measured or recalled feature. In the case of features with 1D locations such as 1D points the origin is established for the direction of the feature, example a X point establishes the X origin. In the case of features with 2D or 3D locations, Geomet permits selective setting of an origin in X, Y and/or Z measured directions. Thus a 2D feature, such as a XY circle, can serve to set a PCS origin in X, Y or X and Y directions if desired.

PCS Translate

Translate permits an existing PCS origin to be shifted ny nominal amounts in all three directions. Translation creates a new complete PCS whose axes are parallel to those of the preceding PCS but shifted by the input values.

In the example below, PCS 1 is shifted in two directions, XY by the nominal values of 1.375 for X and 0.75 for Y that has been entered into the Translate Input Dialog. Upon completion, a new PCS 2 is established.
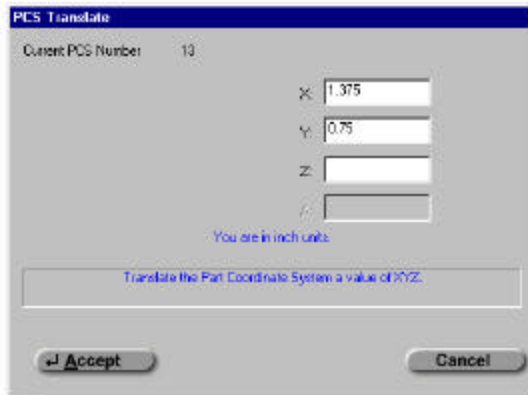
Translate Input Dialog
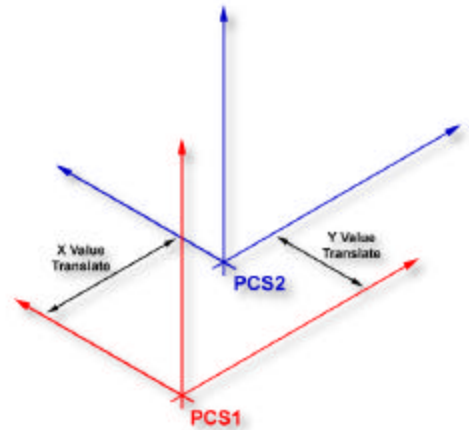
Translate Example

PCS Rotate

Rotate permits an existing PCS to be rotated in space about one of its own axes. A PCS can only be rotated about one axis at a time. Compound rotations must be done in two or more successive steps. It is important to note the following rotation conventions:

about X: a positive angle produces a counter-clockwise rotation when looking in the -X direction.

about Y: a positive angle produces a counter-clockwise rotation when looking in the +Y direction.

about Z: a positive angle produces a counter-clockwise rotation when looking in the -Z direction.
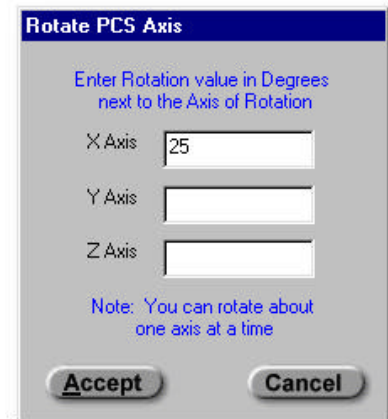
Rotate Input Dialog
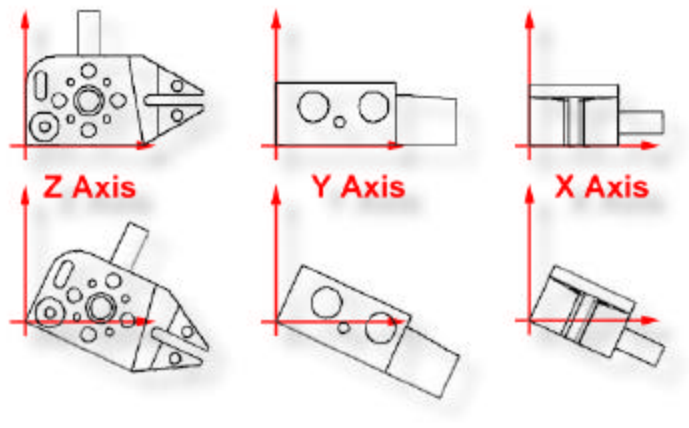
PCS Rotate examples about an axis

(i) *Note that the sense of directional measurements made with +X, -Y, etc. direction keys rotates with a PCS rotation. After rotating a PCS whose axes are essentially aligned with the MCS axes by 90º about the PCS Y axis, a +X measurement is understood to be directed upward instead of to the right, since that is now the direction of the +X axis.*

ICS ⮕ PCS

The ICS *to* PCS command converts the status of an incomplete coordinate system to complete. The effect of this routine is to permit print-out of results if what is normally considered a complete PCS in the Geomet sense is not required.

Coordinate System Manager

ⓘ *The Coordinate System Manager is available only with the Advanced PCS and Stylus option.*

The CS Manager provides access to recall established part coordinate systems, activate the machine coordinate system, and if available establish a vector drive coordinate system for manual joystick controls on CMMs with DCC controls.

Recall PCS

Each time a completed PCS is established, it is given a ascending number starting with 1. If you are requesting a PCS recall, activate the Coordinate System Manager by pressing the key < ' > and ensure that the PCS button is pressed in the Select Type group. Any existing PCS can then be made the current PCS by and entering the desired PCS number. If you were to enter a 0 for the desired PCS, you are in effect recalling the machine coordinate system.
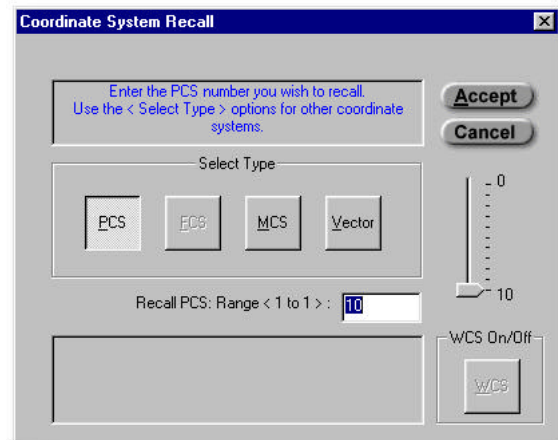
Coordinate System Manager

ⓘ *If you do not have the Advanced PCS and Stylus support option in your version of Geomet Junior, the CS Manager does not appear and the command functions as a switch between the Machine coordinate system and your established part coordinate system.*

Recall MCS

In the CS Manager, choose from the Select Type group the MCS button. In effect, this disables the control where you normally enter a PCS number and upon pressing the < Accept > button, recalls PCS 0 which is designated the machine coordinate system by default.

Recall Vector Drive System

If you have the Direct Computer Control option this command is available. Choose from the Select Type group in the CS Manager the Vector button. This provides access to download a chosen established PCS to the motion controller so that your Joysticks, or Geomet Pendant, will drive the CMM parallel to the PCS axis.

Normally default operating condition requires your joysticks to work parallel to the machine coordinate system. Once you have established a part coordinate system that is skewed in all axes to the machine coordinate system it can be difficult to drive the CMM into slots, small diameters and other detailed features when your joysticks are mapped to the MCS. Through the CS Manager, choose to vector your joysticks in any established PCS that conforms to the detailed features. Now when you deflect the joysticks in the +X, your CMM will move true to the PCS's +X direction.

ⓘ *Caution should be taken as this command is independent of the current PCS and does not update when you recall another PCS.*

Part Coordinate System Examples

On the following pages we demonstrate several methods of establishing part coordinate systems. Use these exercises as a training tool by following along and executing the step-by-step commands.

In all examples we use datum targets to define where you should capture data points with your probe. By following the examples and executing the required steps, you will begin the process of understanding the intricacies of using a CMM correctly, or incorrectly as some examples are designed to demonstrate.

All examples assume you have a qualified probe orientated in the -Z direction unless otherwise noted.

Table of Exercises:

Exercise 3.0, Basic Alignment

Most CMMs offer a machine coordinate system that is true to the working surface. This allows the operator to establish simple, and fast, part coordinate system by eliminating steps normally required to ensure accurate alignments. The following example assumes the part orient in the Z axis is parallel to the Z axis of the CMM and the cylinder of the Widget is pointing in the -X direction.
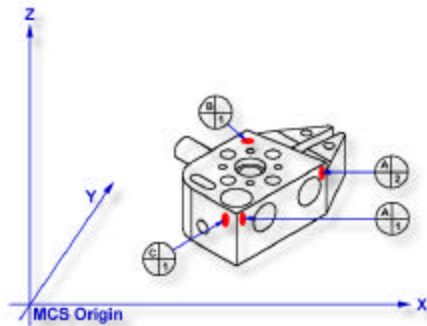
Figure 3.0a, Datum target layout PCS
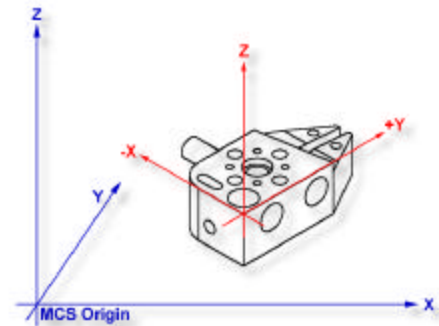
Figure 3.0b, Completed PCS

Step 1

Request a -X Point feature, You will then be prompted to "Measure -X Point". Capture points A-1 and A-2, *refer to Figure 3.0a*. Note: if your system is active for auto-direction sensing then your prompt will display "Measure Auto-Dir Point".

Step 2

Select Align. Note: when you elect to perform an alignment without first establishing the orient, Geomet will assume the orient axis is parallel to the machine coordinate system. For example, aligning in the XY plane will force the Z axis of the MCS to establish the Z axis of the ICS.

Step 3

Select Origin. This will establish the X origin as defined by the selected direction of the -X Point features. Note: always perform the alignment prior to origin as the alignment will effect the probe compensation on features such as 1D Points.

Step 4

Request a -Z Point feature, You will then be prompted to "Measure -Z Point". Capture point B-1.

Continued next page .....

Step 5

Select Origin. This will establish the Z origin and your PCS Setup Guide will now reflect that only the Y origin is still required.

Step 6

Request a +Y Point feature, You will then be prompted to "Measure +Y Point". Capture point C-1.

Step 7

Select Origin. This will establish the Y origin and complete the ICS to a full part coordinate system. The PCS Setup Guide will disappear and you are now ready to take feature measurements.

Final Inspection Report

Summary
```
1   Current stylus is #: (x.xxxx")
    Stylus Type: Ball
2¹  -X Point
3¹  -X Point
4   X & Y Axes Aligned
5   X Origin Set
6¹  -Z Point
7   Z Origin Set
8¹  +Y Point
9   Y Origin Set
10  PCS 1 Established
```

With a minimum of four data points and four command requests administered in the proper sequence you have completed a full part coordinate system, *see figure 3.0b*. This method of establishing a PCS is not meant to work with all production parts, but it does work with parts that have a surface that is capable of providing the orientation, or primary datum, and can lay flat on your CMM.

Exercise 3.1, Basic PCS Plane-Line-Point

In this exercise, we will create a basic part coordinate system utilizing a plane, line and point for establishing the axes and origins. The following example assumes the part is placed on your CMM where the cylinder of the Widget is pointing in the -X direction.
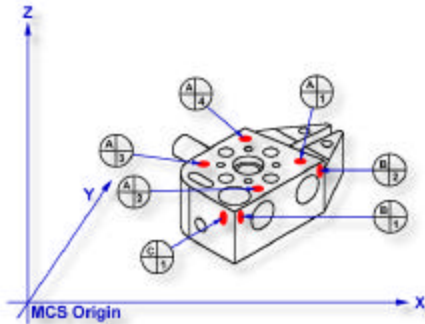
Figure 3.1a, Datum target layout PCS
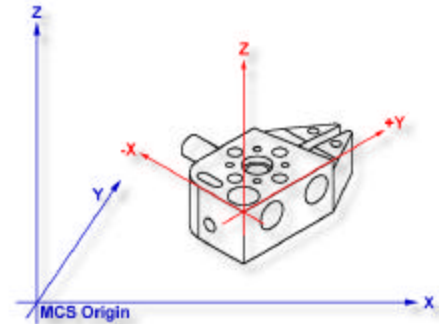
Figure 3.1b, Completed PCS

Step 1

Request a -Z plane, if auto-direction is not activated, you will be prompted for the probing direction which you should select as -Z. You will then be prompted to "Measure -Z Plane", (if auto-direction is active "Measure Auto-Dir Plane"). Capture points A-1, A-2, A-3 and A-4 *as shown in figure 3.1a.*

Step 2

Select Orient. The orient command will create the primary datum on the axis that is most normal to the machine coordinate system. For example, if the plane used by orient was determined to be a XY plane then the normal will most closely align with the Z axis. In your PCS Setup Guide, the Z Axis will be signed off.

Step 3

Select Origin. This will establish the Z origin which is determined by the normal direction of the -Z plane.

Step 4

Request a Line feature, You will then be prompted to select the probing direction, enter -X (if auto-direction is not active). The prompt will update to display "Measure -X Line" (or "Measure Auto-Dir Line"). Capture points B-1 and B-2. When the points have been captured, you will be asked which projection plane to use, select XY. A secondary request may be made to determine the pierce axis, select X, *see Line in chapter 4 for explanations.*

Select Align. Your ICS will update to include the secondary datum which is derived from the XY line feature.

Select Origin. This will establish the X origin which is determined by the reported direction of the XY Line.

Request a +Y Point feature, You will then be prompted to "Measure +Y Point". Capture point C-1.

Select Origin. This will establish the Y origin and complete the ICS to a full part coordinate system. The PCS Setup Guide will disappear and you are now ready to take feature measurements.

Final Inspection Report

Summary

```
1    Current stylus is #: (x.xxxx")
     Stylus Type: Ball
2¹   -Z Plane (4)
3    Z Axis Orientated
4    Z Origin Set
5¹   2D XY Line [-X] (2)
6    X & Y Axes Aligned
7    X Origin Set
8¹   +Y Point
9    Y Origin Set
10   PCS 1 Established
```

The Plane-Line-Point combination of features are commonly used for most machined parts to set the part coordinate system, *see figure 3.1b*. It is important to remember that the features in these exercises are utilizing minimum data points to achieve a complete PCS. There are several factors that can negatively effect the quality of your data points. These include probing speed and distance between data points just to name two.

In the case of the alignment, we used two points to calculate the line. The repeatability of the electronic trigger probe can be as much as .00014" with a standard 20 mm extension. If the two points for the line were taken 0.500" apart, the possibility exists of .00028" error per inch, when applied to the PCS effects all features being measured. It is therefor important that you select the most stable features to establish your PCS and balance the number of data points to help reduce inherent CMM and operator errors.

Exercise 3.2, Quick PCS

In this exercise, you will utilize Geomet's automatic part coordinate system tool, the Quick PCS. Quick PCS requires that you have auto-direction capabilities and that it is active through System Options⇒Enhanced Features.

The premise of Quick PCS is to perform the basic Plane and 3 1D Points PCS setup without the operator commanding any feature requests. When you start Geomet and establish the working stylus, Geomet is waiting for a data point. If it acknowledges an incoming data point and is not currently setup for a feature, it assumes you are invoking the Quick PCS option.
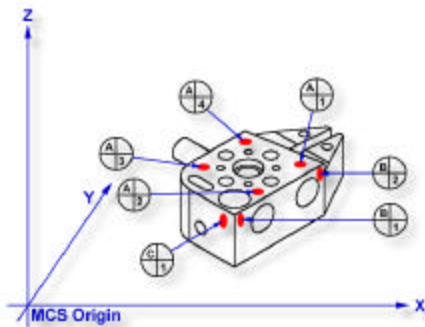
Figure 3.2a, Datum target layout PCS   *Figure 3.2b, Completed PCS*
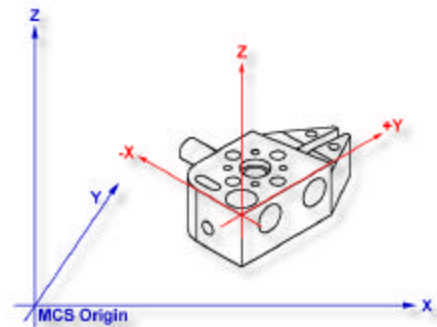
Step 1

Using the datum targets as shown in figure 3.2a, gather data points A-1 through A-4. Geomet will automatically establish a plane, orient and origin after the forth point has been captured.

Step 2

Gather data points B-1 and B-2 making sure you follow the rules on probing 1D points using auto-direction, *see Points in chapter 4.* Once these two points are captured, Geomet will establish the alignment and origin based on the point directions.

Step 3

Capture the final data point, C-1 and Geomet will complete the final origin and establish PCS 1.

Summary

```
1    Current stylus is #: (x.xxxx")
     Stylus Type: Ball
2¹  -Z Plane (4)
3    Z Axis Orientated
4    Z Origin Set
5¹  -X Point
6¹  -X Point
7    X & Y Axes Aligned
8    X Origin Set
9¹  +Y Point
10   Y Origin Set
11   PCS 1 Established
```

With the Quick PCS feature of Geomet, you were not required to press any feature key or in any other way instruct Geomet of the next feature or action.

Exercise 3.3, PCS, Plane-Circle-Circle

In this exercise, we will create a basic part coordinate system utilizing a plane and two circles for establishing the axes and origins. The following example assumes the part is placed on your CMM where the cylinder of the Widget is pointing in the -X direction.
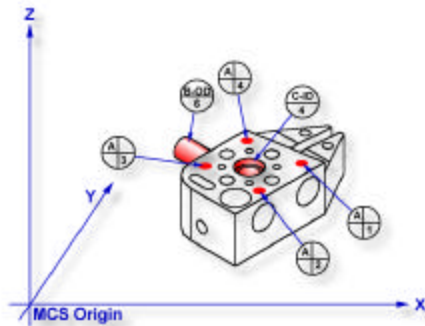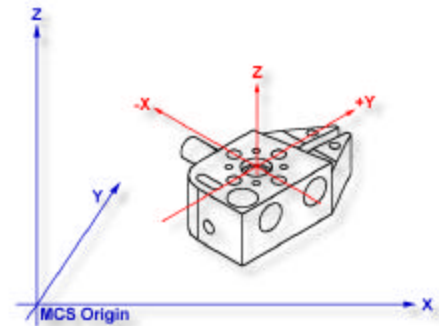
Step 1
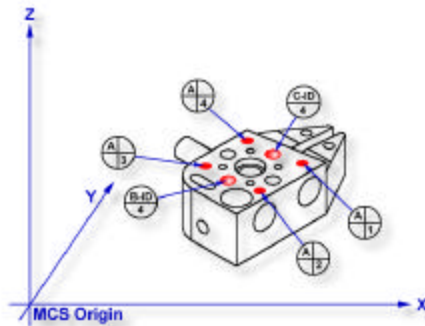
Figure 3.3a, Datum target layout PCS
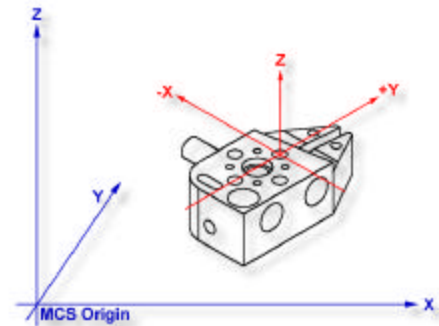
Figure 3.3b, Completed PCS

Request a -Z plane, if auto-direction is not activated, you will be prompted for the probing direction which you should select as -Z. You will then be prompted to "Measure -Z Plane", (if auto-direction is active "Measure Auto-Dir Plane"). Capture points A-1, A-2, A-3 and A-4 *as shown in figure 3.3a.*

Step 2

Select Orient. The orient command will create the primary datum on the axis that is most normal to the machine coordinate system. For example, if the plane used by orient was determined to be a XY plane then the normal will most closely align with the Z axis. In your PCS Setup Guide, the Z Axis will be signed off.

Step 3

Select Origin. This will establish the Z origin which is determined by the normal direction of the -Z plane.

Step 4

Select Circle, if auto-direction is not activated, you will be prompted for the Circle type, ID OD IR OR, choose ID. Capture the four data points identified as B-ID/4, *see figure 3.3a.* Continue with the data points for the next circle, C-ID/4.

Step 5

Select Align. Your ICS will update to include the secondary datum which is derived from the two XY circles. The alignment takes place through the reported XY position of the circles which are projected into the orient plane.

Select Origin. Circles, which are 2D, provide two directions when establishing an origin. In our example, the circle can be used for the X and/or the Y directions. The origin command will prompt you whether to use the X and then the Y. For our example you should answer Yes to both requests. Upon completion, you will have established PCS 1.

Final Inspection Report

Summary

```
1    Current stylus is #: (x.xxxx")
     Stylus Type: Ball
2¹  -Z Plane (4)
3    Z Axis Orientated
4    Z Origin Set
5¹  ID XY Circle (4) ID=  0.500"
6¹  ID XY Circle (4) ID=  0.500"
7    X & Y Axes Aligned
8    X Y Origin Set
9    PCS 1 Established
```

In this exercise, we utilized two coplanar XY features for the alignment and subsequent origin. As with many feature characteristics, the circles could have been replaced with any feature that reports a 2D solution. These include 2D points, cylinder and cone pierce points, etc.

Through the proper selection of features, you can establish a part coordinate on nearly any type of manufactured part.

Exercise 3.4, PCS, Plane-Cylinder-Circle

In this exercise, we will create a part coordinate system utilizing a plane for the orient and origin, a cylinder for the alignment followed by a circle for the last components of the origin. The following example assumes the part is placed on your CMM where the cylinder of the Widget is pointing in the -X direction.

Step 1

Figure 3.4a, Datum target layout PCS

Figure 3.4b, Completed PCS

Request a -Z plane, if auto-direction is not activated, you will be prompted for the probing direction which you should select as -Z. You will then be prompted to "Measure -Z Plane", (if auto-direction is active "Measure Auto-Dir Plane"). Capture points A-1, A-2, A-3 and A-4 *as shown in figure 3.4a.*

Step 2

Select Orient. The orient command will create the primary datum on the axis that is most normal to the machine coordinate system. In your PCS Setup Guide, the Z Axis will be signed off.

Step 3

Select Origin. This will establish the Z origin which is determined by the normal direction of the -Z plane.

Step 4

Select Cylinder, if auto-direction is not activated, you will be prompted for the cylinder type, ID OD IR OR, choose OD. Capture the six data points identified as B-OD/6, *see figure 3.4a.*

Step 5

Select Align. A cylinder offers the possibility of more than one alignment solution. In our example, you have solved the Z axis orient by utilizing the previous plane, therefore you are attempting to align the remaining axis, or XY. Select the XY button from the Select Axis dialog, *see figure 2.34c.*

Your ICS will now update to include the secondary datum which is derived from the longitudinal axis of the cylinder. In this example, the cylinder was reported as piercing the YZ ICS base plane, therefore the normal to that plane is X with a direction of -X. The PCS Setup Guide will update to reflect the XY Axis have been solved.
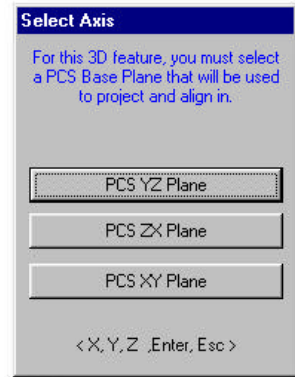
figure 3-4c Base Plane

Step 6

Select Circle, if auto-direction is not activated, you will be prompted for the Circle type, ID OD IR OR, choose ID. Capture the four data points identified as C-ID/4, *see figure 3.4a.*

Step 7

Select Origin. the Circle, which is 2D, provide two directions when establishing an origin. In our example, the circle can be used for the X and/or the Y direction. The origin command will prompt you whether to use the X and then the Y. For our example you should answer Yes to both requests. Upon completion, you will have established PCS 1, *see figure 3.4b.*

Final Inspection Report

Summary

```
1    Current stylus is #: (x.xxxx")
     Stylus Type: Ball
2¹   -Z Plane (4)
3    Z Axis Orientated
4    Z Origin Set
5¹   OD YZ Cylinder (6) OD=    0.751"
6    X & Y Axes Aligned
7¹   ID XY Circle (4)  ID= 1.000"
8    X Y Origin Set
9    PCS 1 Established
```

There are times when you are required to utilize more than one 3D feature to solve for the part coordinate system. In this example we used a 3D feature, a cylinder, from which the alignment is derived, therefore you are prompted to solve which part coordinate system component to solve.

From this example you should note that the data point spread on the cylinder is approximately 1.25"in the X axis and the width of the part is 4.50". This can be a cause of concern as it is poor inspection practice to have your data point spread ratio to the width of the part less than 50%, in this case only 28%. The possibility of skewing your part coordinate system increases dramatically as your ratio is reduced.

However, conditions do arise that do not allow for proper setup and as the inspector, you are challenged to determine the best data point spreads with the features available that will produce a sound part coordinate system.

Exercise 3.5, PCS, Plane-Point-Point-Bisect-Circle

In this exercise, we will create a part coordinate system utilizing a plane for the orient and origin, two 2D points from which we will obtain a constructed 2D point through the bisect command then followed by a circle for alignment and origin. The following example assumes the part is placed on your CMM where the cylinder of the Widget is pointing in the -X direction.

Step 1
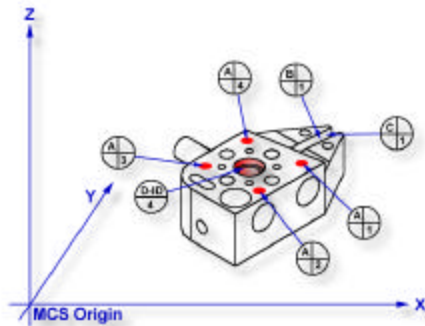
Figure 3.5a, Datum target layout PCS
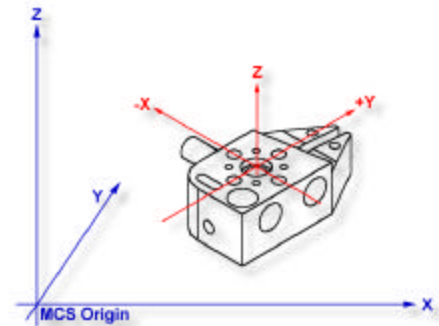
Figure 3.5b, Completed PCS

Request a -Z plane, if auto-direction is not activated, you will be prompted for the probing direction which you should select as -Z. You will then be prompted to "Measure -Z Plane", (if auto-direction is active "Measure Auto-Dir Plane"). Capture points A-1, A-2, A-3 and A-4 *as shown in figure 3.5a.*

Step 2

Select Orient. The orient command will create the primary datum on the axis that is most normal to the machine coordinate system. In your PCS Setup Guide, the Z Axis will be signed off.

Step 3

Select Origin. This will establish the Z origin which is determined by the normal direction of the -Z plane.

Step 4

Select a 2D XY Point. The selection of a 2D point requires two commands. The first command is activated by pressing the < 5 > key, 2D and 3D point selection, which will then prompt which current base plane you will project into, *see figure 3.5c.*

After the selection has been completed, Geomet will prompt you to "Measure XY Point". Capture points B-1 and C-1.
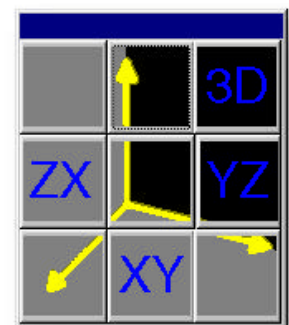
Step 5

Select the Bisect command. This command will

figure 3.5c select plane

take the two projected XY points and solve for the bisect between them. The result will be a 2D XY point.
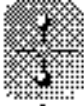
Step 6
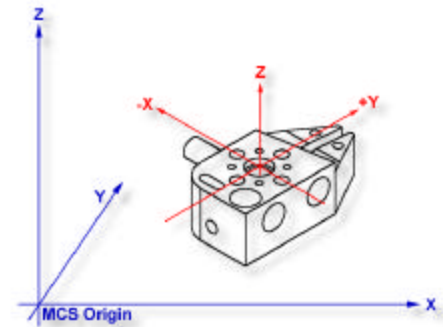
Select Circle, if auto-direction is not activated, you will be prompted for the Circle type, ID OD IR OR, choose ID. Capture the four data points identified as D-ID/4, *see figure 3.5a*.

Step 7

Select Align. Your ICS will update to include the secondary datum which is derived from the XY circle and the previous XY point.

Step 8

Select Origin. the Circle, which is 2D, provide two directions when establishing an origin. In our example, the circle can be used for the X and/or the Y direction. The origin command will prompt you whether to use the X and then the Y. For our example you should answer Yes to both requests. Upon completion, you will have established PCS 1, *see figure 3.5b*.

Final Inspection Report

Summary

```
1   Current stylus is #: (x.xxxx")
    Stylus Type: Ball
2¹  -Z Plane (4)
3   Z Axis Orientated
4   Z Origin Set
5   XY Point
6   XY Point
7¹  XY Point (Bisect)
8¹  ID XY Circle (4)   ID= 1.000"
9   X & Y Axes Aligned
10  X Y Origin Set
11  PCS 1 Established
```

In this exercise, we used a constructed feature, an XY point, as part of the alignment solution. It is important that you choose the correct features to be used for alignment based on the completeness of the ICS. The XY points for B-1 and C-1 were chosen as the ICS lacked an alignment. If two 1D points were chosen, then there would exist an error caused by the part skewed to the MCS base axis.

This does not preclude conditions where 1D points could have been used. For example, if we were working in the PCS that was created in exercise 3.1, then we would have the correct probe compensation vector and we could select -X and +X 1D points for B-1 and C-1 respectively. The resulting bisect would create a 1D point on the centerline of the slot.

figure 3.5d, 1D Point bisects

However, a 1D point followed by a circle can not be combined to form an alignment. Geomet does not accept this as it causes potential repeatability problems when the slot is not aligned with the current PCS. Therefore you could repeat the bisect of two additional 1D points captured on the width of the part at the other end from the slot, *see figure3.5d*. The resulting 1D point derived from the bisect combined with the previous recalled constructed point could produce the alignment.

Exercise 3.6, PCS, Cylinder-Circle-Point

In this exercise we will utilize a cylinder to provide the primary datum and the pierce point from the cylinder as the origin. The alignment will be supplied through a circle and the previous cylinder. Finally a 1D point will complete the part coordinate system by providing the last component of the origin. The following example assumes the part is placed on your CMM where the cylinder of the Widget is pointing in the -X direction.
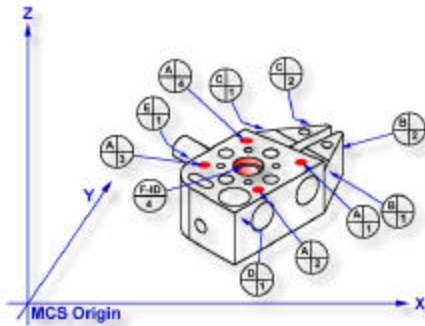
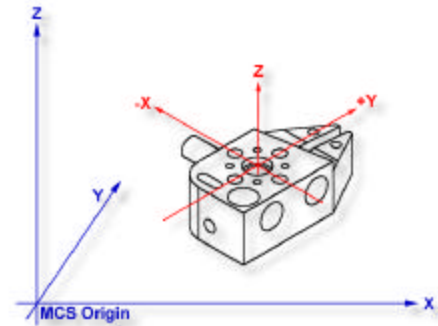**Step 1**
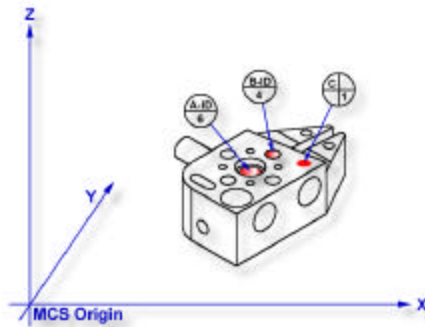
Figure 3.6a, Datum target layout PCS   *Figure 3.6b, Completed PCS*

Select Cylinder, if auto-direction is not activated, you will be prompted for the cylinder type, ID OD IR OR, choose ID. Capture the six data points identified as A-ID/6, *see figure 3.6a.*

Step 2

Select Orient. The orient command will create the primary datum on the axis of the cylinder that is most parallel to the machine coordinate system. In your PCS Setup Guide, the Z Axis will be signed off.

Step 3

Select Origin. This will establish the origin reported as the pierce point of the cylinder. In this example, the cylinder pierces the XY base plane and the origin command will prompt you whether or not to set the origin on the X and/or the Y. Answer yes to establish the XY origin.

Step 4

Select Circle, if auto-direction is not activated, you will be prompted for the Circle type, ID OD IR OR, choose ID. Capture the four data points identified as B-ID/4, *see figure 3.6a.*

Step 5

Select Align. Your ICS will update to include the secondary datum which is derived from the XY circle and the previous XY pierce point from the cylinder.

Step 6

Select -Z Point. The final component missing for your complete PCS is the Z origin. You will then be prompted to "Measure -Z Point". Capture point C-1.

Select Origin. Your ICS will now be completed and establishes as a part coordinate system, *see figure 3.6b.*

Final Inspection Report

Summary

```
1   Current stylus is #: (x.xxxx")
    Stylus Type: Ball
2¹  ID XY Cylinder (6)  ID=  0.750"
3   Z Axis Orientated
4   X Y Origin Set
5¹  ID XY Circle (4)  ID= 0.500"
6   X & Y Axes Aligned
7¹  -Z Point
8   Z Origin Set
9   PCS 1 Established
```

When using a through bore as the primary datum, we must be careful that the data point spread is sufficient to allow for a stable feature. In the example we would place an extension on the stylus to allow for a greater reach into the cylinder.

Exercise 3.7, PCS, Plane-2 Line-Intersect-2 Point-Bisect-Circle

In this exercise we will combine two constructed features to create the secondary datum. These constructed features are derived from two lines intersected and two 2D point bisected. The following example assumes the part is placed on your CMM where the cylinder of the Widget is pointing in the -X direction.

Step 1

| Figure 3.7a, Datum target layout PCS | Figure 3.7b, Completed PCS |

Request a -Z plane, if auto-direction is not activated, you will be prompted for the probing direction which you should select as -Z. You will then be prompted to "Measure -Z Plane", (if auto-direction is active "Measure Auto-Dir Plane"). Capture points A-1, A-2, A-3 and A-4 *as shown in figure 3.7a.*

Step 2

Select Orient. The orient command will create the primary datum on the axis that is most normal to the machine coordinate system. In your PCS Setup Guide, the Z Axis will be signed off.

Step 3

Select Origin. This will establish the Z origin which is determined by the normal direction of the -Z plane.

Step 4

Request a Line feature, You will then be prompted to select the probing direction, enter -X (if auto-direction is not active). The prompt will update to display "Measure -X Line" (or "Measure Auto-Dir Line"). Capture points B-1 and B-2. When the points have been captured, you will be asked which projection plane to use, select XY. A secondary request may be made to determine the pierce axis, select X, *see Line in chapter 4 for explanations.*

Step 5

Clear the current mode by pressing the < Esc > key. Request a Line feature, You will then be prompted to select the probing direction, enter +X (if auto-direction is not active). The prompt will update to display "Measure +X Line" (or "Measure Auto-Dir Line"). Capture points C-1 and C-2. When the points have been captured, you will be asked which projection plane to use, select XY.

Step 6

Select the Intersect command. This command will take the two projected lines and solve for the intersect between them. The result will be a 2D XY point.

Step 7

Select a 2D XY Point. The selection of a 2D point requires two commands. The first command is activated by pressing the < 5 > key, 2D and 3D point selection, which will then prompt which current base plane you will project into, *see figure 3.7c.*
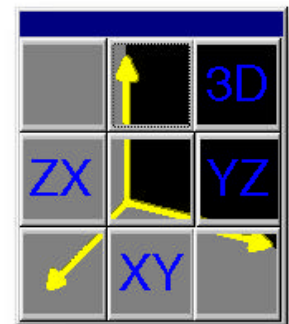
After the selection has been completed, Geomet will prompt you to "Measure XY Point". Capture points D-1 and E-1.

Step 8

figure 3.7c select plane

Select the Bisect command. This command will take the two projected XY points and solve for the bisect between them resulting in a 2D XY point.
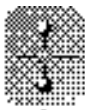
Step 9

Select in the report feature number 7 (2D point formed by the intersect command). Right-click your mouse and select Recall Feature. This will recall the feature to new feature number 11.

Step 10

Select Align. Your ICS will update to include the secondary datum which is derived from the recalled 2D XY point and the previous 2D XY point created from the bisect.

Step 11

Select Circle, if auto-direction is not activated, you will be prompted for the Circle type, ID OD IR OR, choose ID. Capture the four data points identified as F-ID/4, *see figure 3.7a*.

Step 12

Select Origin. the Circle, which is 2D, provide two directions when establishing an origin. In our example, the circle can be used for the X and/or the Y direction. The origin command will prompt you whether to use the X and then the Y. For our example you should answer Yes to both requests. Upon completion, you will have established PCS 1, *see figure 3.7b*.

Final Inspection Report

Summary

```
1   Current stylus is #: (x.xxxx")
    Stylus Type: Ball
2¹  -Z Plane (4)
3   Z Axis Orientated
4   Z Origin Set
5   2D XY Line [-X]
6   2D XY Line [+X]
7¹  XY Point (Intersect)
8   XY Point
9   XY Point
10  XY Point (Bisect)
11  XY Point (RCL 7)
12  X & Y Axes Aligned
13  ID XY Circle (4)  ID= 1.000"
14  X Y Origin Set
15  PCS 1 Established
```

In this exercise we had combined features to create constructed features which are then used to create part coordinate system components. In part production we will find numerous cases where one or more part coordinate system datums are symmetry lines or points where no features exist.

When performing constructions in a ICS, it is important to remember the established projection base planes that are valid. For example, in this exercise it would not have produced acceptable results if we established 2 ZX point, one each on the top and bottom surfaces of the widget and then performing the bisect. The resulting 2D point would be projected into the alignment of the machine coordinate system and therefore would not represent a valid point feature for the part coordinate system.

Exercise 3.8, Offset Align

In this exercise we will perform an offset alignment to create a secondary datum. The offset align function performs a realignment of an existing part coordinate system. As you must have a complete coordinate system defined, please setup your part described in exercise 3.4.

ⓘ *If you do not have the **Advanced PCS and Stylus Option**, you have access to only one PCS at any point of your inspection. By performing the offset align command, you will realign the existing PCS 1 and will not be able to revert back to the original part coordinate system. If you have the Advanced PCS and Stylus option, the offset command will create PCS 2.*
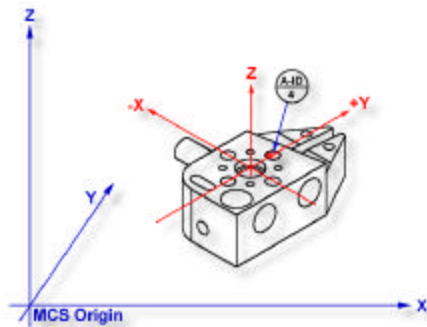
Step 1
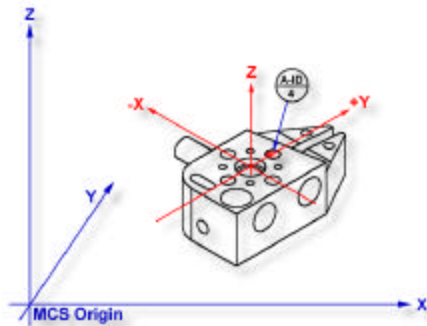

Figure 3.8a, Datum target layout PCS
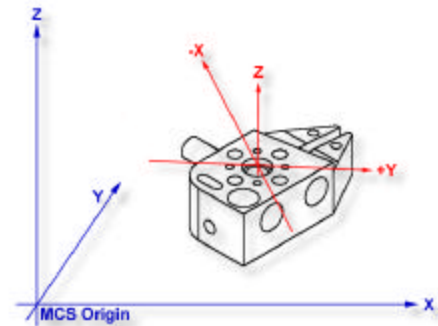
Figure 3.8b, Completed PCS

From the established PCS as defined in exercise 3.4, recall feature number 6 ID XY Circle. We perform this step in preparation of the realignment. The offset align required two features which both must be in the same PCS and stacked together in the report, *see recalling features chapter 5.*

Step 2

Select Circle, if auto-direction is not activated, you will be prompted for the Circle type, ID OD IR OR, choose ID. Capture the four data points identified as A-ID/4, *see figure 3.8a.*

Step 3

Select Offset Align, *press < Ý > + < K >.* Note if you do not have the Advanced PCS and Stylus option, you will be prompted whether to realign PCS 1 or cancel, select < Ok >. A request will be displayed where you enter your offset value. Enter .70711 and press < Accept >.

This will realign the current PCS to the plus (+) side of the last feature. A negative (-) will realign to the left side of the feature. The value you enter controls the realignment direction based on the sign of the value.

figure 3.8c Offset value

Exercise 3.9, Pivot Align

In this exercise we will perform a realignment of the current PCS by pivoting around the origin through the last measured or recalled feature.The pivot function performs a realignment of an existing part coordinate system. As you must have a complete coordinate system defined, please setup your part described in exercise 3.4.

ⓘ *If you do not have the **Advanced PCS and Stylus Option**, you have access to only one PCS at any point of your inspection. By performing the pivot command, you will realign the existing PCS 1 and will not be able to revert back to the original part coordinate system. If you have the Advanced PCS and Stylus option, the offset command will create PCS 2.*

Figure 3.9a, Datum target layout PCS
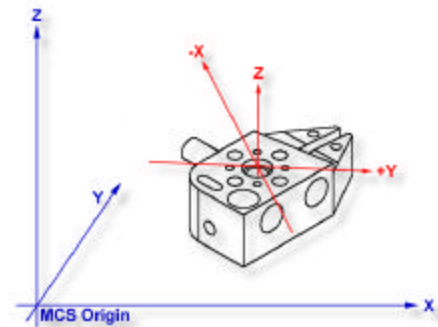
Figure 3.9b, Completed PCS

Step 1

Select Circle, if auto-direction is not activated, you will be prompted for the Circle type, ID OD IR OR, choose ID. Capture the four data points identified as A-ID/4, *see figure 3.9a.*

Step 2

Select the Pivot command, *press < Ctrl > + < k >*. Note if you do not have the Advanced PCS and Stylus option, you will be prompted whether to realign PCS 1 or cancel, select < Ok >. The current PCS will realign through the last feature.

Summary

In this exercise, we choose to realign by pivoting though a feature that lies at 45° to the current PCS. This can cause unexpected results during part program runs. For example, if the feature was at 44.99° from the X axis during self-teach it would realign by rotating counter-clockwise 44.99° about the Z axis. However, if during self-teach the feature was 45.01° the realignment would take place by rotating 44.99° clockwise causing a 90° shift in the expected PCS.

We recommend that caution should be taken where unexpected results can occur as is the case of any 45° rotations or pivots.

3.10, Translate

In this exercise we will take an existing part coordinate system and translate it by nominal amounts in the X and Y axis. The translate command can be performed on X, Y and/or Z individually or any combination. As you must have a complete coordinate system defined, please setup your part described in exercise 3.1.
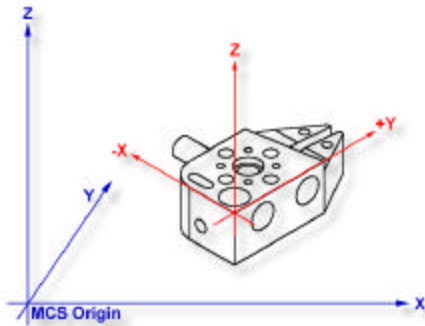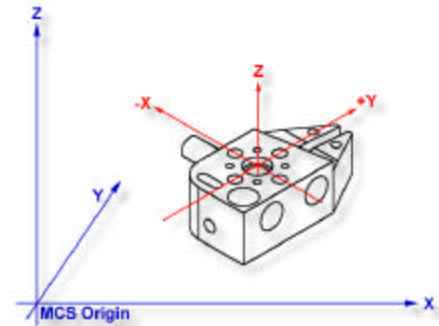

Figure 3.10a, Established PCS

Figure 3.10b, Translated PCS

Step 1

Select the Translate command. When you activate this command, Geomet will display a dialog where you can enter your translation values, *see figure 3.10c.* Enter 2.125 for X and 1.500 for Y and no entry for Z. Preform the translation by pressing the < Accept > button.

A new PCS will be established, or in the case of base Junior, a translation of the current PCS takes place.
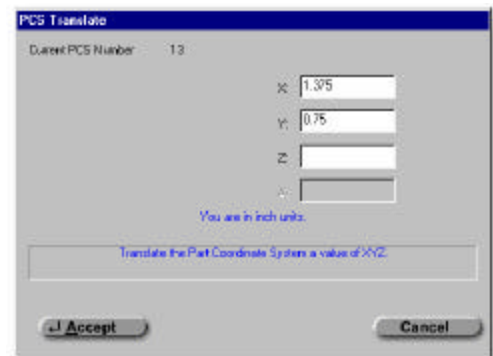
figure 3.10c Translate Input Dialog

Summary

In many conditions, it is required to translate the part coordinate system when you are working with a datum that is derived from points that are not defined on your part. For example you may be inspecting a cavity insert which was removed from a progressive die where the datums are a common alignment pin not available at inspection time. Another example is the focal point of a optical lens whose surface radial may be projected 2,000" from the actual part.

Exercise 3.11, Rotate

In this exercise we will take an existing part coordinate system and rotate it about an axis by a nominal value. The rotate command can be perform only about one PCS axis at a time. If you require to perform compound rotations, the rotate command will be repeated. As you must have a complete coordinate system defined, please setup your part described in exercise 3.1.
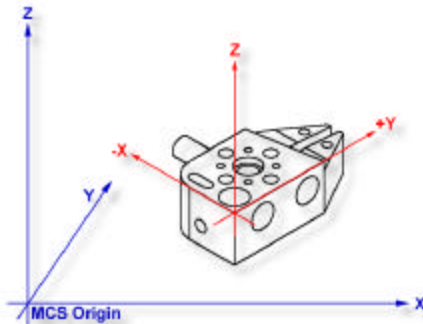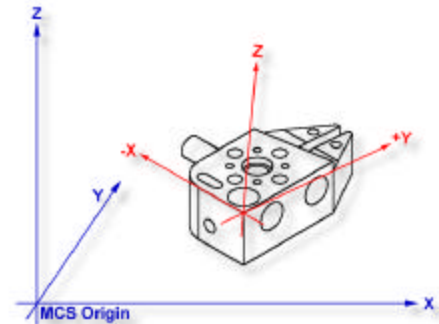

Figure 3.11a, Established PCS

Figure 3.11b, Rotated PCS

Step 1

Select the Rotate command, press < ⇑ > + < : >. When you select this command, a Rotate PCS AXis dialog will prompt you to enter a nominal value for a axis, *see figure 3.11c.* This dialog will ensure you enter only one value prior to accepting the nominal value. For this exercise, enter -5 in the X axis control and press the < Accept > button.

A new PCS will be established, or in the case of base Junior, a translation of the current PCS takes place.
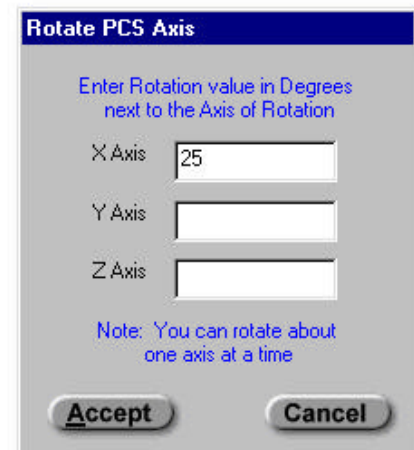
figure 3.11c, Rotate Dialog

Summary

To verify that we performed the rotation correct, select a -Z Point feature and probe the top surface of the 5° plane located on the tapered end of the Widget. We should see a -Z point value at .018 ± .005.

Basics in Feature Measurement

Reviewing a few concepts in plane and solid geometry will help immensely in implementing your Geomet system. It is important to develop a feeling for 3D spatial elements such as lines, planes, cylinders, etc., and for their spatial relationships. Understanding the concept of the coordinate system and its elements is absolutely essential.

1D Point

1D Points have 1D locations. There are 6 1D point routines, designated ±X, ±Y and ±Z. Pressing one of these keys prepares Geomet to measure a single point of a planar surface, followed by a printout of the location of the center of the stylus corrected by the stylus radius in the PCS probing direction. Problems arise if the planar surface is not parallel to a PCS base plane.

Figures 4.1a and 4.1b, illustrate a 1D point measurement of one and the same planar surfaces prior to alignment (MCS) and after alignment (PCS 2).
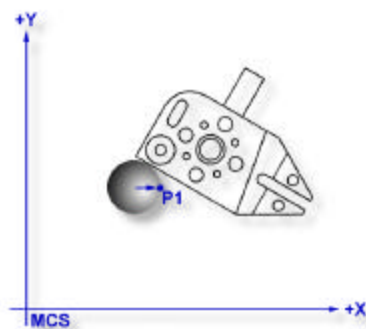
Figure 4.1a, MCS 1D Point   *Figure 4.1b, PCS 1D Point*
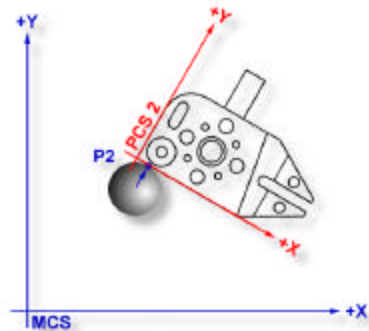
Although the stylus center is at the same XYZ location in both cases, the calculated points P1 and P2 are quite different. P1 resulted from a probe radius correction parallel to the X axis of the MCS. P2 resulted from a probe radius correction parallel to the X axis of PCS 2. This illustrates how measurements of a surface in an unaligned PCS can produce erroneous results.

Single 1D Point measurements can only be used to determine the locations of planar surfaces which are **parallel** to the PCS planes.

Pairs of 1D Point measurements on planar surfaces which are parallel to PCS planes may serve to determine the Distance between the surfaces or the location of the Bisector of surfaces.

Pairs of 1D Point measurements on simply skewed planar surfaces, meaningless in themselves, may be used to define a Line on a surface or to Align the current PCS to be parallel to the surface.

Single and multiple 1D Point measurements on compound skewed plane or curved surfaces provide meaningless data.

To measure a 1D Point, press the corresponding Point direction key and gather a data point on your work piece. If you have Auto-Direction enabled, you will be prompted "Measure Auto-Dir Point" and your approach vector to the work piece will identify the probing vector.

Using Auto-Direction

Using auto direction on 1D Points can lead to erroneous reported values if used incorrectly. Auto direction relies on a smooth approach, from you the operator, in capturing of a data point. The process of determining the approach vector involves the CMM interface card (ProCounter, Tech 80 or PMAC) to maintain a rolling IJK vector based on the last five reported values. These inter-face cards update the current position in the MCS on a programmable time interval from 20 to 200 milli-seconds.

Figure 4.1c, Approach Vector

When you are approaching your work piece, it is required that you make contact while remaining in a ±45° approach, *see figure 4.1c.* In this example, if we remained in the approach zone we will capture a data point that will be reported as a +Y point. If the operator did not remain in the approach zone the 1D Point will report as a ± X Point from which we will have to correct the probe compensation error. Most common occur-ance of a erroneous data point comes from opera-tors who approach the surface, and then pause the approach and attempt to make contact under extremely slow speeds, which while approaching causes variations in the path toward the surface.

figure 4.1d, Point Direction

To correct the reported direction of a 1D Point, highlight the feature by left-clicking on it, then right-click to bring up the feature menu, as shown in *figure 4.1d.* Select *[Point Direction]* which will offer a sub-menu with all six probing direc-tions available. Choose the correct 1D Point direction and your part inspection will update with the correct 1D Point.

Note: Once a feature has been referenced it can not be changed or edited. For exam-ple, if a feature was used in the construction of a PCS , it will be locked from changes. This is identified by the inclusion of a [1] next to the feature number, example " 12[1] ".
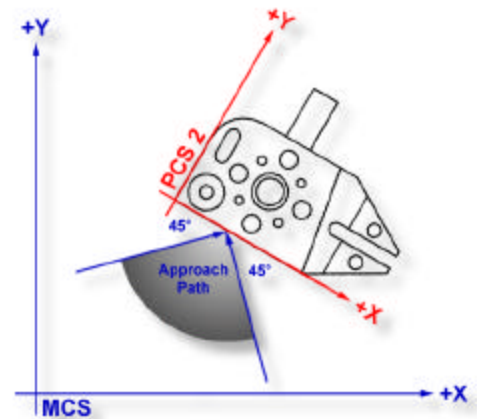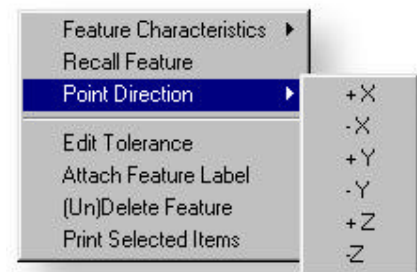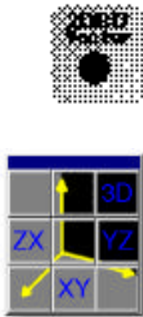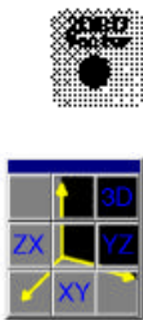
2D Point

The 2D Point function is normally used in conjunction with a hard taper probe for simple contact determination of the location of bores whose axes are parallel to the PCS Z axis. It can also be used with hard ball stylus for single contact determination of the location of bores whose axes are parallel to any PCS axis. In these applications the 2D Point feature is referred to as the self-centering routine. The 2D Point feature can also be used with hard or electronic trigger ball stylus to create 2D Bisector Point features in slots or a web for Aligning purposes as shown in Exercise 3.5 in chapter 3. All 2D Points are automatically projected into PCS base planes.

To measure a 2D Point press the 2D Point key, < 5 > from the number pad. Geomet will prompt you for a PCS base plane the 2D Point will project into, *see number pad iconic view above*. Choose XY, YZ or ZX and begin your measurement.

3D Point

The 3D Point feature reports the current PCS location of the center of the ball stylus used in the measurement. It is useful in conjunction with a hard ball stylus to establish a point on the axis of an ID cone. An example is to establish the centerline of a turned part using two 3D Points, one at each end in the conical shaped turning datums used by the head and tail stock.

To measure 3D Point Features, press the 3D Point key, < 5 > from the number pad. Choose 3D, *see number pad iconic view above* and begin your measurement.

IR/OR Point

The IR (Inside Radial) and OR (Outside Radial) Point features allows 2D and 3D, ball radius compensated probing of cylindrical and spherical surfaces. The probe vector is determined as a vector from the current PCS origin through the ball center of the stylus. Inside Radial features are compensated by adding one radius along this vector, Outside Radial subtracts one probe radius, *see figure 4.2a*.

These features are ideal for measuring extremely large radial surfaces that only offer a small segment to capture data points on. Translate your PCS origin to the centroid of the feature and capture radial points along the surface.
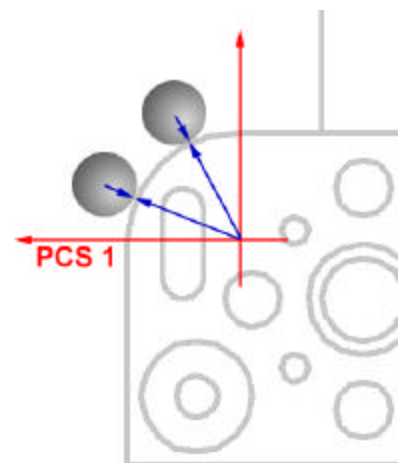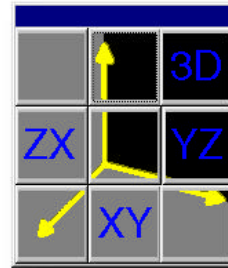

figure 4.2a

Line

The Line feature provides you with the means to measure 2D Lines. 2D lines are projected into a PCS base plane and report the angular deviation from and 1D pierce value of a PCS base axes. The line feature is a multi-point of 2 - 32767 data points.

The determination of the PCS base plane is supplied by the operator after the capturing of the data points, *see figure 4.3a.* Depending on the angle of the line, Geomet will prompt for the selection of a PCS axis to report, *see figure 4.3b.* Geomet uses an angle of ± 10° between the line normal to a PCS axis to determine if the operator should be prompted to select the pierce axis.

For example, if a line being measured crosses the PCS X axis at 1.000" and has a reported angle of 85°, the operator will not be prompted to select a PCS axis. The the same line had a reported angle of 75°, then Geomet would prompt the operator to select the pierce axis showing the solutions of both values *as shown in figure 4.3b.*

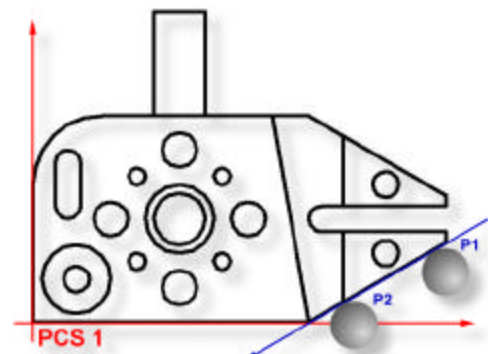*figure 4.3a Select Plane*   *figure 4.3b Select Axis*

After completing the first measured line, Geomet auto-cycles preparing to measure another line. Note: during auto-cycle, Geomet will not prompt you for a projection plane. It is assumed continuing measuring lines in the original selected plane.

The direction of the line is determined by the direction of the data points, from the first data point to the second. In figure 4.3c, the data points were gathered created a reported angle of 30° whereas in figure 4.3d, the reported angle is -150° for the same feature.

Multi-Point Line features. The default number of points used for line measure-ments is controlled by the value in System Options. If you require a different value hold the $< \Uparrow > + < M >$, then you will be prompted for the number of data points. Another method is to press the line key repeatedly and the count will increase by one with every repeat. This method can be used even while some data points have already been captured.
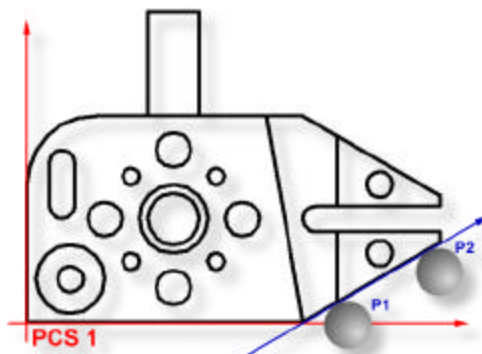
figure 4.3d, Report Angle   *figure 4.3d, Supplement Angle*

Circle

The Circle feature determines the center location and diameter or radius of bores and bosses whose axes are parallel to a PCS axis. The circle feature will give erroneous results on skewed bores and bosses. The circle locations on circles are projected into a PCS base plane, *see figure 4.4c*, and are 2D in nature.

To measure bores or bosses, press the Circle key < z > for the default number of data points as set in System Options. Geomet will then prompt you for the type of feature being measured, *see figure 4.4a*. If you have Auto-direction enabled, this prompt will not appear.

figure 4.4a, Circle type

If you required additional data points, you can repeatedly press the Circle key which increments the required number by one, or hold press < ⇑ > + < Z > and you will be prompted to enter the required number.
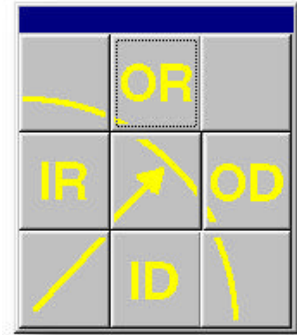
Geomet performs a form validation on your gathered data points. This function is called the *Multi-Point Error Limit* and is controlled by a setting in System Options. In the event your circle exceeds this limit, Geomet will prompt you whether to accept or re-measure the feature, *see figure 4.4b*. If you elect < Re-Measure >, you will be prompted to capture new data points for the same feature. Note: The Multi-Point Error Limit test is only performed in the self-teach mode, not during a part program run.

Data points used to calculate a circle if not spread around the circle can cause erroneous results. In the table below, we will use a 3 point circle with one point .00014" off the nominal value for a 1.00" radius. The results are calculated to show the error that is part of the reported values.

figure 4.4b, Form Error Limit

Arc	Center	Radius
180°	.00014	.00000
120°	.00028	.00014
90°	.00048	.00034
60°	.00104	.00090
30°	.00409	.00395
20°	.00914	.00899
10°	.03549	.03535
5°	.12823	.12810

As shown above, the center location and radius degrades dramatically as your data points are taken over a smaller sweep.
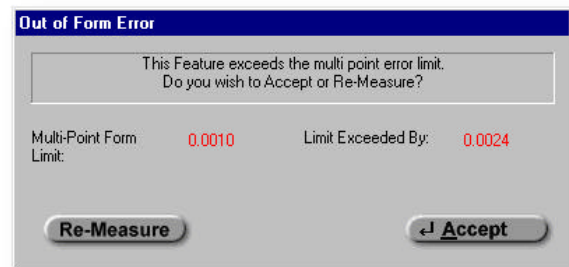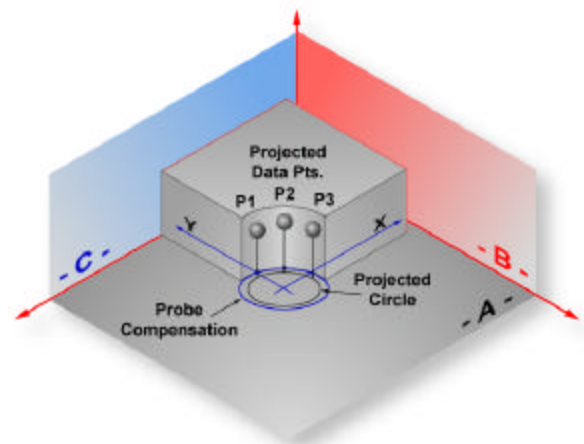

figure 4.4c Circle Projection

Planes have locations, attitudes and directions. The location of a plane is defined as the point at which it is pierced by a PCS axis. The attitude of a plane is defined by the projection angle AX/Y, AY/Z and AZ/X of the **plane normal** in each of the three PCS base planes, with range values from 0° to ± 180°.

The direction of a plane is defined as that of the normal, pointing out of the solid. Figure 4.5a shows a plane with its projection into each PCS base plane. The normal, when projected into each PCS base plane provides the attitude in angles, *see figures 4.5b, 4.5c, 4.5d.*
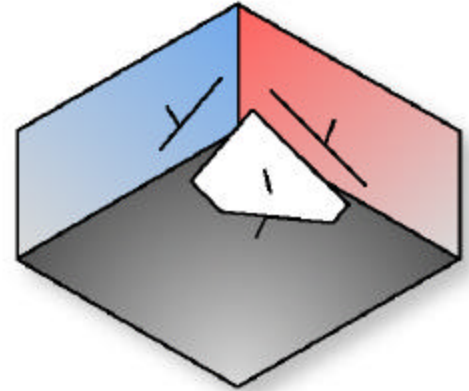

figure 4.5a, Plane Projection

The Plane feature may be used to measure non-skewed planes. The printed pierce point of a measured plane is determined by the PCS axis that is most parallel to the normal of the measured plane. In the example in figure 4.5a, the pierce point would be report as a Z axis point.
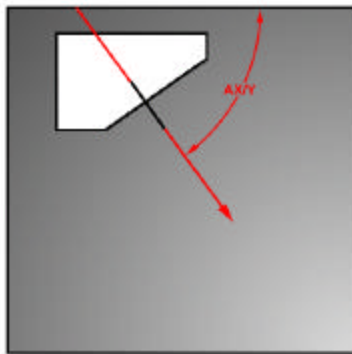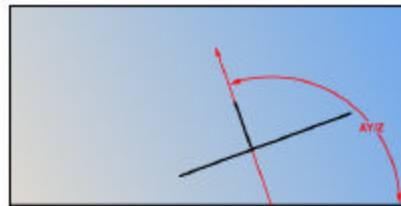

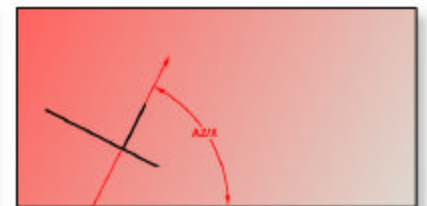*figure 4.5b AX/Y Projection*   *figure 4.5b AY/Z Projection*   *figure 4.5b AZ/X Projection*

Planes which are essentially parallel to PCS base planes have only two attitude angles which are meaningful, the third is printed in lower case, as for example "ax/y" to indicate its reduced significance.

To measure Planes press the Plane key for a 4 point (or the default as established in System Options) plane, or < ⇑ > + < B > for a multi-point plane. If auto-direction is not enabled, you will be prompted to enter the probing direction. Upon completion of gathering your data points, Geomet will test the form error to the newly calculated plane. If the form error exceeds the default setting, you will be prompted to < Accept > or < Re-Meas > the plane.

Cylinder

The cylinder feature determines the diameter, PCS pierce point and attitude of the axis of bores and bosses. The attitude of a cylinder axis is expressed like the attitude of the normal of a plane, using the characteristic identifiers AX/Y, AY/Z and AZ/X, *see figure 4.6b.* These angles can vary between 0° and ± 180°. The axis of a cylinder has a direction as well as an attitude: its direction is from the first group of points at one end to the group of points measured at the other end.

figure 4.6a, Cylinder type

The reporting of the position in the PCS is the point where the axis of the cylinder intersects a PCS base plane, called the pierce point. Geomet determines which PCS base plane to report by determining which PCS base plane the axis of the cylinder is most normal to, *see figure 4.6b.*
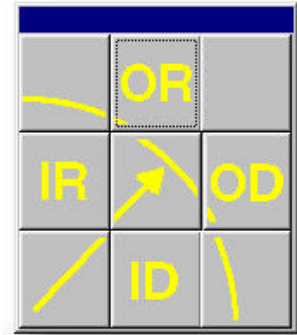
To measure bores or bosses press the Cylinder key for an 6 point (or the default as established in System Options) cylinder, or < ⇑ > + < C > for a multi-point cylinder. If auto-direction is not enabled, Geomet will prompt you for the type of cylinder *as shown in figure 4.6a.* After the data points have been captured, Geomet will test the form error and if exceeded, will prompt you to < Accept > or < Re-Meas >.
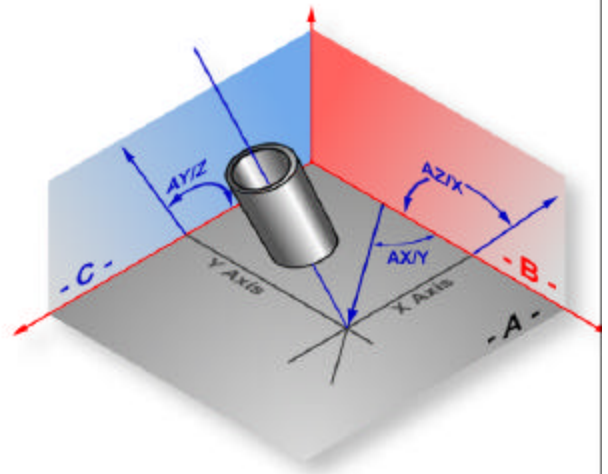

figure 4.6b, Cylinder Pierce Point and Attitudes

Sphere

The Sphere feature provides the diameter and 3D location of the center of the sphere.

To measure a sphere4, press the Sphere key for a 5 point (or the default as established in System Options) sphere, or $< \Uparrow > + < V >$ for a multi-point sphere. If auto-direction is not enabled, Geomet will prompt you for the type of sphere *as shown in figure 4.7a.* After the data points have been captured, Geomet will test the form error and if exceed, will prompt you to < Accept > or < Re-Meas >.
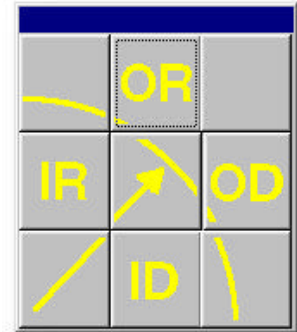
Cone

The Cone feature determines the included angle, the PCS pierce point and attitude of the axis and the diameter of the cone at the pierce point. The attitude of the cone axis resembles the axis of a cylinder in the projection characteristics, *see figure 4.6b.*

figure 4.7a, Sphere type

To measure Cones, press the Cone key for a 7 point (or the default as established in System Options) cone, or $< \Uparrow > + < N >$ for a multi-point cone. If auto-direction is not enabled, Geomet will prompt you for the type of sphere *as shown in figure 4.7a.* After the data points have been captured, Geomet will test the form error and if exceeded, will prompt you to < Accept > or < Re-Meas >.

Cone Diameter
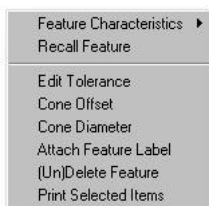
Geomet provides a unique function that allows you to retrieve the diameter of a cone at a specific distance from the PCS base plane along the axis of the cone. To request the diameter command, right-click on the cone in the report and a sub-menu will appear, *see figure 4.7d,* choose *[Cone Diameter].* Enter the offset value in the dialog, *see figure 4.7b,* and press the < Accept > button.

figure 4.7d

figure 4.7b, Diameter

Cone Offset

To obtain the offset distance from the PCS base plane of a specific diameter along the axis of a cone, start by right-clicking on the cone feature and choose from the sub-menu *[Cone Offset], see figure 4.7d.* Enter the diameter nominal in the dialog, *see figure 4.7c,* and press the < Accept > button.

figure 4.7c, Offset distance

Digitized Point Cloud

The surface digitizing feature provides the means to gather large amounts of data on your work piece. The point data captured is the *ball center locations* of each data point. Geomet will report the feature as a "Digitized Point Cloud" from has no reported values nor can constructions be performed with this data.

To perform a digitize function, select the surface key, < / > and begin gathering your data points. To complete the capturing of data, press the Terminate key < F5 >. This data can be exported either as DXF or ASCII data points.

Actions and Feature Construction

Through the use of the Construction tools, you can create features from commands such as Bisector and Intersect. Construction tools also provide feature-to-feature relationships as found in Distances and Angles.

Actions are features within Geomet that provide User Prompts, Text statements and feature state changes.

Text Features

Text

The Text feature < y >, permits comments to be written to your part inspection report. These text statements are written during the self-teach mode are copied to the report during part program auto-cycle (auto-cycle requires that you have the Programming option active), *see figure 5.1a.*
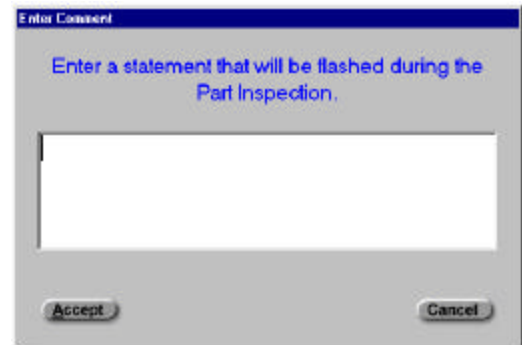

figure 5.1a, Text Statements

User Prompt

The User Prompt feature, < ⇑ > + < Y >, provides an interrupt during a program auto-cycle. During the self-teach mode, you can provide instructional statements such as a reminder to rotate a manual indexing probe to a new location or to insert a thread gage prior to measuring its location. When the part programming is advancing to a User Prompt, a message will flash on the monitor and pause further execution until the operator acknowledges by pressing the < Accept > button. The User Prompt requires that you have the Programming option active. If the Programming option is not active, then this features has the same behavioral characteristics of the text feature.
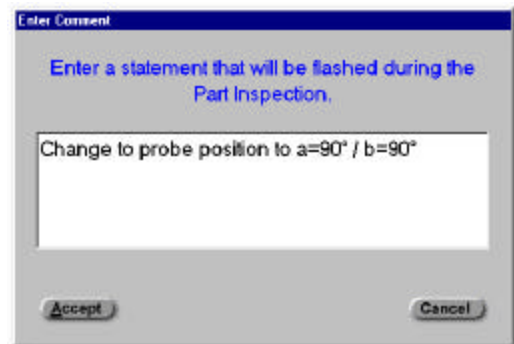

figure 5.1b, User Prompt

Inline Text Entry

The Inline Text Entry feature, < Alt > + < y >, provides a interrupt during a program auto-cycle to allow current text statements to be added. During self-teach, you add a request to enter data. An example would be to add the statement "Enter condition of part. Dirt, oil, etc.". Then during the auto-cycle when this feature is executed, the operator will enter the request and these new comments become part of the inspection report.
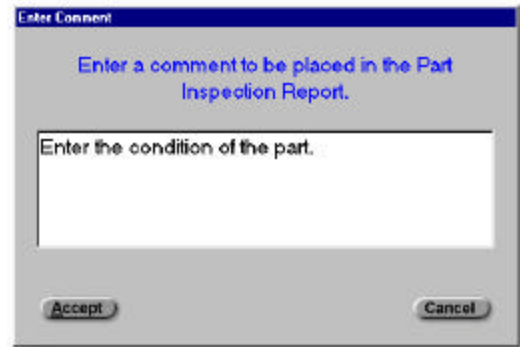

figure 5.1c, Inline Text Entry

Inline Text Entry requires that you have the Programming option active. If the Programming option is not active, then this features has the same behavioral characteristics of the Text feature.

Feature Editing

Feature editing can be accomplished as a post operation once the feature has already been reported. These changes fall into different categories of universal state changes and feature specific changes.

Universal State Changes - Single Feature

Universal changes are those that can be applied to any measured or constructed features these include:

- Inch/Metric
- Cartesian/Polar
- Brief/Full Reporting
- Degree.Decimal/Degree-Minutes-Seconds

To make these changes to a specific feature on the report, left-click with your mouse on the feature which will highlight the entire feature. Right-click to activate the feature sub-menu, *see figure 5.2a*.

Choose *[Feature Characteristics]* and a pop-out menu appears offering the current states of the selected feature. Choose the change you want to implement, and your feature will be updated by selecting the new state.
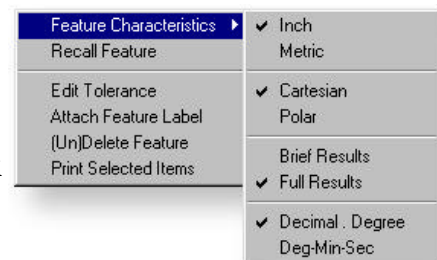
figure 5.2a, Feature States

Universal State Changes - Multiple Features

Geomet allows you to update several features at one time using your mouse to interact with the report. In the example above, you were showed how to make a state change to just one feature. To perform the same state change to several features by using the $< \Uparrow >$ and the $< Ctrl >$ keys.

To highlight a continuous range of features, start by left-clicking on the first feature, then hold down the $< \Uparrow >$ key and left-click on the last feature of the range. All feature in between the first and last feature will highlight. To selectively add one feature at a time, hold down the $< Ctrl >$ key and left-click on the selected feature. Now follow the instructions above to change the states of all selected features.

Feature Edits - 1D Point

When you have auto-direction active, 1D Points can be mis-reported. This is normally caused by poor probe approach vectors to the surface of the part, *see 1D Points in Chapter 4.*

To change the reported direction of a 1D Point, start by highlighting the feature in the report and then right-click to activate the feature menu. Choose *[Point Direction]* and select the new direction.
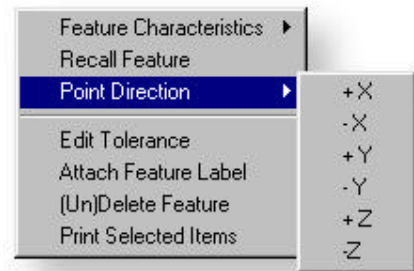
This can only be applied to 1D Point features that are not currently referenced by other actions such as PCS components, recalls and distances.

figure 5.3, Point Direction

Feature Edits - Labels

Geomet identifies each feature with standard default nomenclature. In the case of a 1D Point, the default is to report the probing direction plus "Point", example "-Z Point".

To help identify your features by using plain text, highlight the feature in the report and activate the feature sub-menu. Choose the command *[Attach Feature Label]* and you will be prompted to enter a feature label, *see figure 5.4.* This same procedure is used to edit or remove an existing label by choosing $< Remove >$ or editing the label and pressing $< OK >$.

figure 5.4, Feature Labels
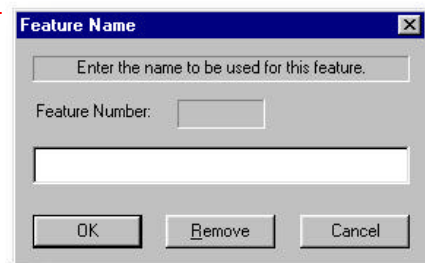
Feature (un)Delete

To delete a feature in your inspection report, highlight the feature, as described above, and select *[(un)Delete].* This will remove the feature from your report and replace it with "Deleted". To undelete a feature that has previously been deleted, highlight the feature and select *[(un)Delete].*

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Feature Construction: 5-3

Printing Selected Items

Geomet Junior allows selective printing of features through the use of the feature sub-menu. *see figure 5.5.* Highlight the features to be included in the report, right-click to bring up the feature sub-menu and activate the command *[Print Selected Items].*

Feature Characteristics ▶
Recall Feature

Edit Tolerance
Attach Feature Label
(Un)Delete Feature
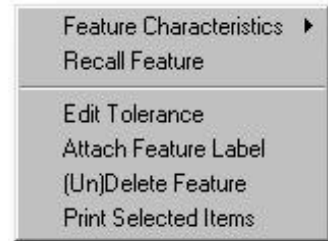Print Selected Items

figure 5.5, Select Print

Distance

The Distance command determines the positive or negative point-to-point distance between the last two features in the report stack. The Distance command reports only the common axis between the features. For example: a XY Point and a 1D X Point share the X axis.

To perform a distance, measure, construct or recall the desired features and press the Distance key < s >. Geomet will validate the two features and identify the common axis, then perform the distance calculation. The sign of the reported distance is taken from the last feature to the previous feature.

A basic understanding on how distance is calculated will help to eliminate erroneous results. For example; the distance reported two planes is the distance where each plane crosses the current PCS base axis, *see figure 5.6.* Erroneous distances can be reported when the planes are located at a distance to their report PCS pierce axis. In our experiment, we used two planes where one plane (upper) is skewed by 1 minute to the opposite plane (lower).
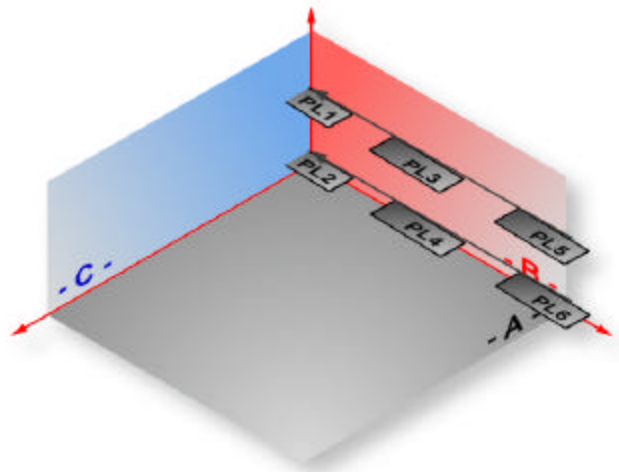
In this example PL1 and PL2 report a distance directly representative to the expected distance between the planes because the PCS axis is piercing the area the data points from the planes were gathered.

figure 5.6, Distances between Planes

In PL2 and PL3 the data points used for the calculation of the planes were 5" from the PCS axis and with just a 1 minute skew between the planes, the reported distance is .0016" in error. Applied to PL5 and PL6, whose data points were gathered 10" from the PCS axis, the 1 minute difference causes .0032" error.

Angles

The Angle feature determines the angles between the last two features on the report stack. Angles are returned on two 2D lines that are coplanar, a 2D line and a 3D axial feature and 3D axial features.

When applying the Angle command between two 3D axial features such as plane, cylinders, 3D lines and cones. The reported angle is user selectable through the feature sub-menu for theta (included angle), or the PCS base plane projection angles defined as AX/Y, AY/Z and AZ/X, *see figure 5.7.*
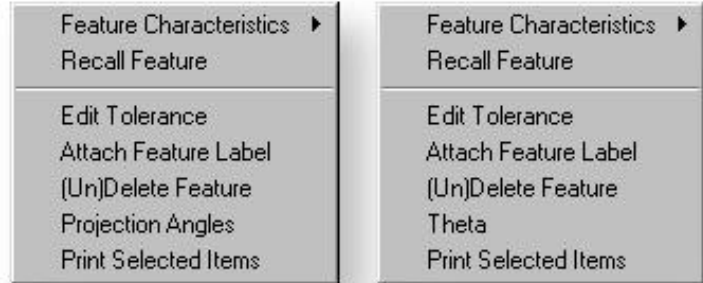
Feature Characteristics ▶		Feature Characteristics ▶
Recall Feature		Recall Feature
Edit Tolerance		Edit Tolerance
Attach Feature Label		Attach Feature Label
(Un)Delete Feature		(Un)Delete Feature
Projection Angles		Theta
Print Selected Items		Print Selected Items

figure 5.7, Angle report switching

Intersection

The Intersection feature determines the characteristics if the intersection of the last two features on the report stack. Intersections can be accomplished with the following combinations:

Feature 1	Feature 2	Notes:
2D Line	2D Line	Must be coplanar
Circle	Circle	Must be coplanar
Line	Circle	Must be coplanar
Plane	Plane	Creates a 3D line with 2D pierce point
Plane	Cylinder	Creates a 3D point
Plane	Cone	Creates a 3D point
Cylinder	Cylinder	Creates a user defined 3D point and miss distance
Cylinder	Cone	Creates a user defined 3D point and miss distance

An example of a circle/line intersection have three possibilities where the line passes through the circle, line misses the circle or the line is tangent to the circle. In *figures 5.8a and 5.8b*, Geomet prompts you to select which point should be reported. The values reported on the buttons are the actual reported PCS values.

An example of two 3D axial features intersecting is shown if *figure 5.8c* where the closest line of approach is reported as end points and a mid point.
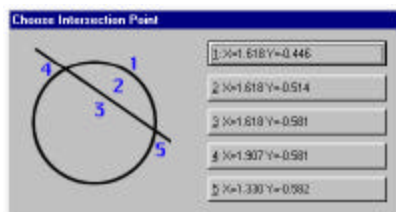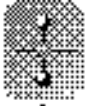

figure 5.8a Circle/Line Intersection

figure 5.8b, Circle/Line Misses

figure 5.8c, 3D Axis Intersect

Bisector

The Bisector feature determines the bisecting or symmetry feature between the last two features on the report stack. Bisector can create two possible solutions, when this occurs Geomet prompts for the operator to select one, *see figure 5.9a and 5.9b.*

| Feature 1	Feature 2	Notes:
1D Point	1D Point	Creates a 1D Point
2D Point	2D Point	Creates a 2D Point, Must be coplanar
3D Point	3D Point	Creates a 3D Point
2D Point	3D Point	Creates a 3D Point
Plane	Plane	Creates a Plane
Line	Line	Creates a Line
Sphere	Sphere	Creates a 3D Point
Cylinder	Cylinder	Creates a user defined 3D point or 3D Line
Cylinder	Cone	Creates a user defined 3D point or 3D Line
Cone	Cone	Creates a user defined 3D point or 3D Line
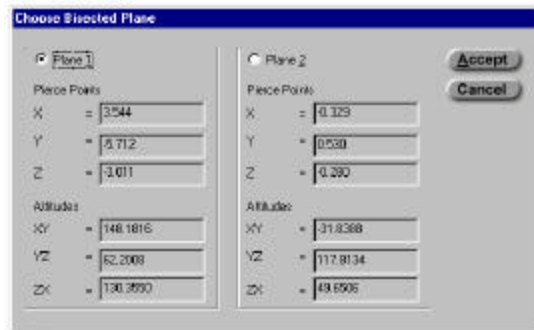
figure 5.9a, Bisector of two planes   *figure 5.9b, Bisector of two lines*

Geomet Junior provides construction tools to create Lines, Circles and Planes from the previous *'x'* number of features on the report stack. These created features can be used in constructions and relationships similar to those applied to measured features.

When you press the Fit key < g >, Geomet prompts you with a feature selection dialog, *see figure 5.10a*, select the feature to create and press the < Enter > key. Geomet will now prompt you for the number of features to use in the construction starting with the last feature and continues looking back through the report until the correct number of features have been used. Geomet provides safeties to prevent entering a number of features to be less than the minumum required to construct the feature.

Fit Line

The Fit Line feature permits the creation of a line fitted through a set of previously measured or constructed features. These features can be a combination of codirectional 1D points, and/or 2D coplanar points.

figure 5.10a, Select Fit

Fit Circle

The Fit Circle feature permits the creation of a circle fitted through a set of previously measured or constructed features. These features can be a combination of 3D points and coplanar 2D points. After completing the construction, Geomet will prompt you select Radius or Diameter as the reporting type.

Fit Plane

The Fit Plane feature permits the creation of a plane fitted through a set of previously measured or constructed features. These features can be 3D points or codirectional 1D points, but a combination of different types.
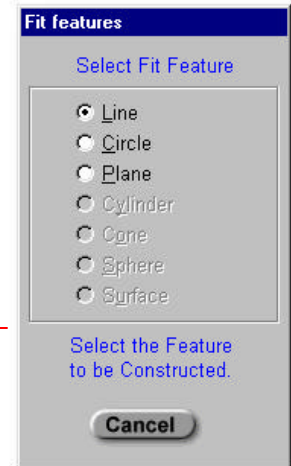
Recalling Features

The Recall Feature command permits any feature on the report stack to be copied to the end of the report. There exists two methods of recalling features in Geomet, one feature is through the use of the mouse, the other by selecting the Recall key < h >.

Recalling features through the use of the mouse provides a fast, but simple recall. For example you can select a single or multiple group of features by highlighting the features in the report and then right-click to activate the feature sub-menu and choose *[Recall Features], see figure 5.11a.*
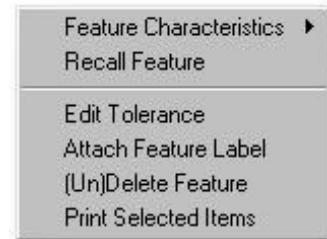
The second method performs single feature recall through the use of the Recall key, < h >. Press the Recall key and you will be prompted to enter the feature number, *see figure 5.11b.*

1D or 2D Point

Recalling 1D and 2D points from a previous PCS into a PCS that has been realigned, rotated or skewed can produce meaningless results. Geomet will recast the original 1D point into the new PCS correcting the probe vector.

3D Point

Recalling a 3D Point or Sphere will recast the XYZ position into the new PCS.

Circle

Recalling a Circle into a new PCS will result in Geomet prompting you whether to recall the center as a 3D point or attempt to fit the circle into the new PCS, *see figure 511c.*
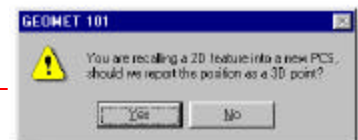
Line

Recalling a Line into a new PCS will result in Geomet prompting you whether to recall the 1D pierce axis point as a 3D point or attempt to fit the line into the new PCS, *see figure 511c.*
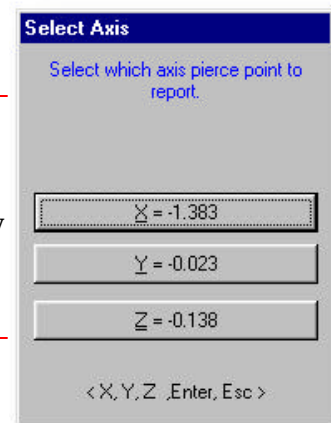
Plane

Recalling a Plane results in a prompt to select a PCS pierce axis, *see figure 5.11d.*

figure 5.11a, Recall Features

figure 5.11b, Recall Number

figure 5.11c, Recall as Point

figure 5.11d, Select axis

Recall PCS Base Components

Performing the command, Recall PCS Components < ⇑ > + < H > allows you to recall a component of a PCS as a feature. When you press the Recall Comps key, a dialog activates from which you select the desired part coordinate system by number, *see figure 5.12.*

When you have completed selecting the PCS, you then request to create a plane by selecting a PCS base plane (XY, YZ or ZX corresponding to the plane desired), or create a 3D Point from the origin, select the button < 3D >, *see figure 5.13.*

Note: if you have only one PCS established, the dialog in figure 5.12 will be omitted.
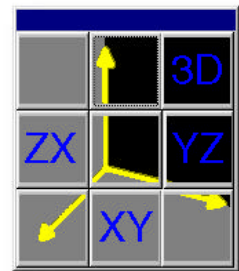

figure 5.12, Select PCS

figure 5.13

Feature and Form Tolerance

In this chapter we will discuss how to apply bi-lateral and GDT tolerance to features as well as the use of form tolerance on feature characteristics and relationships.

Geomet supports **Datum Bonus Tolerance** on datum defined by a circle. This allows you to use the maximum material condition of the circle used as the origin relative to other coplanar features.

Bi-Lateral Tolerance

Bilateral Tolerance is similarity applied to all features in Geomet, We will demonstrate the application of bi-lateral tolerance on a circle.

There are two common ways to apply tolerance. One method is to apply the tolerance each time a feature has been measure, constructed or recalled. To use this method, press the Tolerance On/Off key < r >. You will add a feature to your report toggling the state of tolerance.

The second method involves highlighting the feature and right-click to activate the feature sub-menu and choose *[Edit Tolerance, see figure 6.2.*

Based on the feature selected, a tolerance dialog will appear as shown in figure 6.1. This tolerance dialog provides access to both bi-lateral and GDT (if it is supported by the feature type).

Under the Nominal, Plus and Minus columns, enter the appropriate values. It is not required that you fill in each characteristics, Geomet will only report the long form only on the items completely filled in.
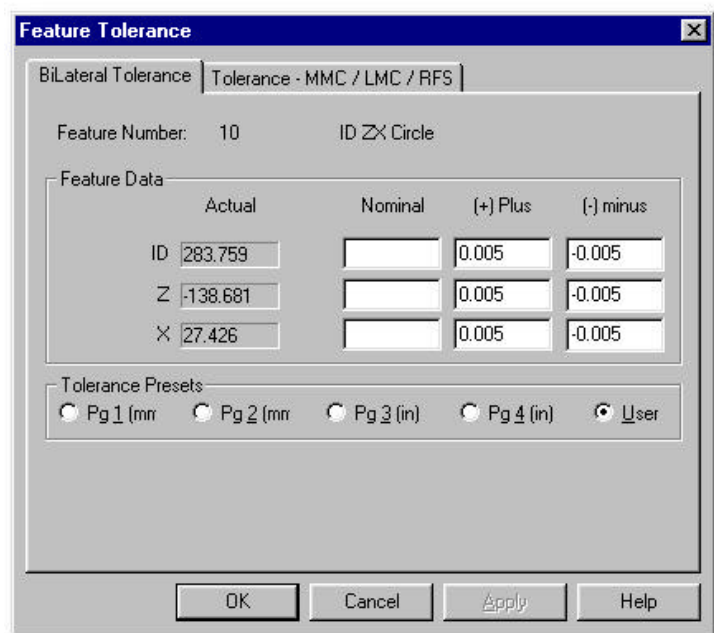

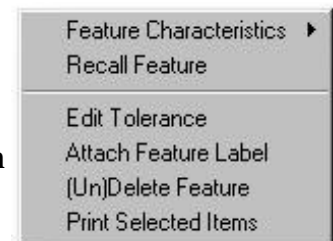*figure 6.1, Bi-lateral Tolerance*

figure 6.2, Recall Features

GDT Tolerance

GDT Tolerance requires a basic understanding in the application of Geometric and Dimensioning and Tolerancing as defined in ANSI 14.5.

Geomet Junior applied 2D GDT Tolerance. This form of tolerancing covers most applications found in general business practices. Where applicable, we will point out limitation in the application to features.

Datum Bonus Tolerance (DBT)

It is important that you apply the correct sequence to allow Geomet to calculate the correct DBT value. Before we begin, it is important to know just how DBT effects your application of GDT.

In Geomet, a circle that is used for the origin is the only feature that DBT work with. When you establish your part coordinate system is when DBT is calculated. Let us imaging that we are setting up out part coordinate system as described in *exercise 3.4 from chapter 3*, When we measure the circle (step 6) would apply tolerance to the diameter, **before** establishing the origin.

Geomet calculates the available MMC on the diameter and stores that value as part of the PCS characteristics for the base plane the circle projects into. This is accomplished when the origin function is performed. As mentioned earlier, DBT is only applied to the base plane the circle used as the origin was projected into.

Applying GDT

In this example, we will apply GDT to a circle feature, *see figure 6.3.* As you will notice in the example, we placed a check next to Apply DBT. This adds the value, .0049 to the Total Tolerance Zone. If the feature being tolerance did not qualify for DBT, then this control will be disabled.

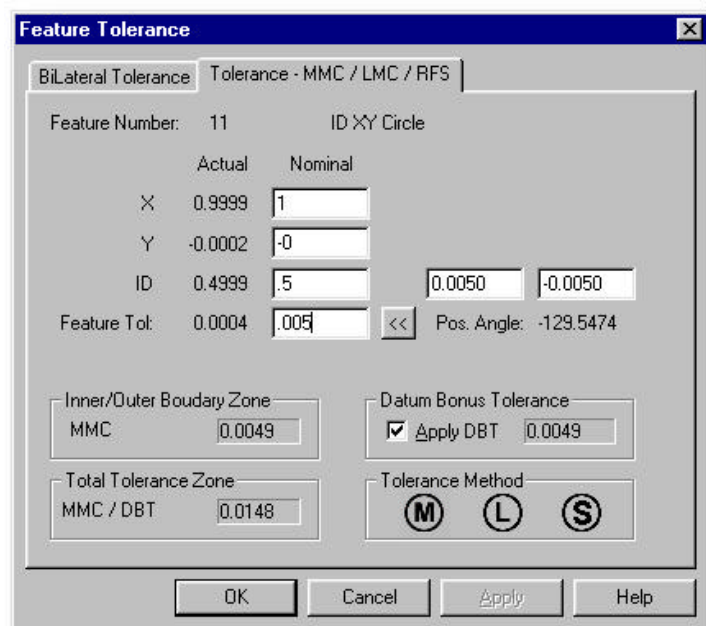Under Tolerance Method, you can select MMC, LMC or RFS depending on the requirements for the feature.

figure 6.3, GDT with DBT Tolerance

GeoTol is our acronym for form and orientation tolerance. GeoTol works on the last measured, recalled or constructed feature for form tolerance. The table below shows the relationships we used for the feature under consideration.

	Flatness	Straightness	Circularity	Cylindricity
Line		X		
Circle			X	
Plane	X			
Cylinder				X
Sphere			X	

Orientation tolerances are applied between the last feature and either a previous feature or the current part coordinate system. The table below shows the relationships between combinations of features.

Feat 1	Feat 2	Parallelism	Perpendicularity	Angularity	Concentricity
Line	Line	X	X		
Line	PCS	X	X	X	
Circle	Circle				X
Circle	PCS				X
Circle	Cylinder				X
Circle	Cone				X
Plane	Plane	X	X		
Plane	PCS	X	X	X	
Cylinder	Plane	X	X	X	
Cylinder	PCS	X	X	X	X
Cylinder	Cone	X	X	X	X
Cone	PCS	X	X	X	X
Cone	Plane	X	X		

Form Tolerance

Before we continue it is important that a basic understanding of the definition of form tolerance is understood.

Flatness

Flatness is equal to the difference between the upper and lower bourdary planes which are mutually parallel to and on opposite sides of the best-fit plane, which just contains the individual, measured points.

Straightness

Straightness is equal to the difference between two lines which are mutually parallel to and on opposite sides of the best-fit line, which just contains the individual, measured points.

Circularity

Circularity as applied to Circles equals the difference between the radii of two circles, whose center point coincide with the center of the best-fit circle, whereby the inner circle just excludes and the outer circle just includes the individual, measured points.

Circularity as applied to Cylinders equals the difference between the radii of two cylinders, whose axes coincide with the axis of the best-fit cylinder, whereby the inner cylinder just excludes and the outer cylinder just includes the individual, measured points.

Circularity as applied to Spheres equals the difference between the radii of two spheres, whose centers coincide with the best-fit center of a multipoint sphere, whereby the inner sphere just excludes and the outer sphere just includes the individual, measured points.

Circularity as applied to Cones equals the difference between the radii of two Cones whose axes coincide with the axis of the best-fit Cone and the included angles are the same, whereby the inner cone just excludes and the outer cone just includes the individual, measured points.

Cylindricity

Cylindricity equals the difference between the radii of two cylinders, whose axes coincide with the axis of the best-fit cylinder, whereby the inner cylinder just excludes and the outer cylinder just includes the individual, measured points.

Applying Form Tolerance

When you activate GeoTol by pressing < t >, A dialog will appear with the characteristics of the last feature. In this example, *figure 6.4*, Geomet is looking at the last feature, a -Z plane. From this plane, we can obtain the flatness, angularity, parallelism and perpendicularity to the PCS as defined in Reference To:.

To select flatness, left click on the round button next to Flatness and select < Finish>. This will calculate the flatness over the calculated plane of all data points.
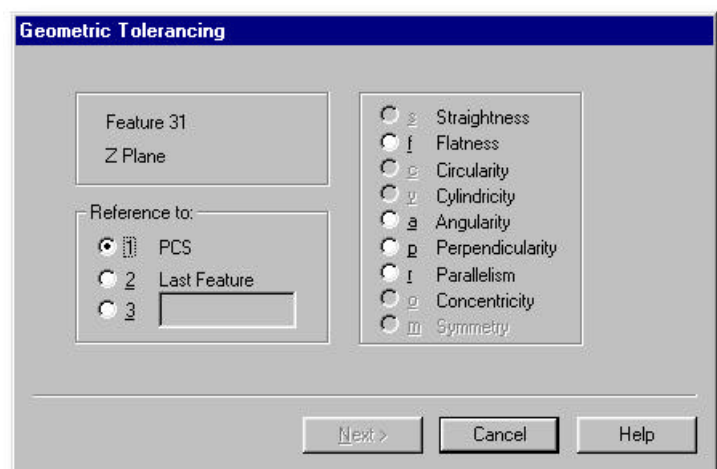
figure 6.4, GeoTol Dialog

Selecting one of the form tolerance options, angularity, parallelism or perpendicularity, the GeoTol Wizard will guide you through the necessary steps, *see figure 6.4.* In our example we choose Perpendicularity, the wizard prompts us for the PCS reference to work with. Select PCS base plane YZ and click on the < Finish > button. The Perpendicularity zone will be entered in your inspection report.
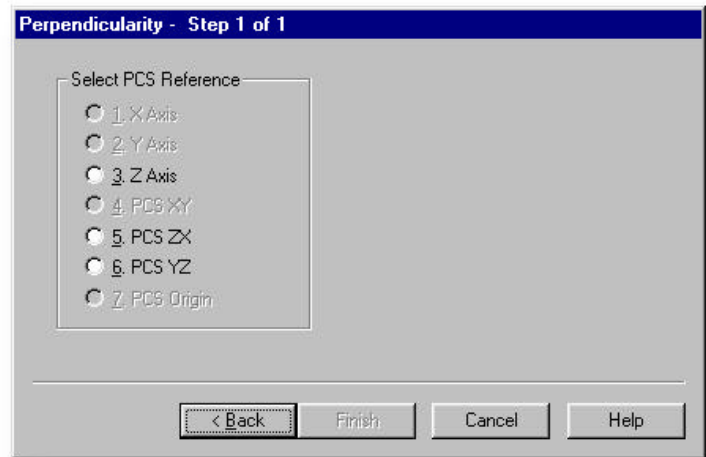
figure 6.5, Select PCS Reference

The GeoTol wizard provides the necessary questions to complete the requested orientation tolerance. With experience you will understand how these relationships apply. Refer to the ANSI 14.5Y Dimensioning and Tolerancing manual for additional information.

Geomet Junior Feature Enhancements

Geomet Junior offers enhancements that allow you to expand your CMM software as your needs grow. These enhancements add to the functionality bringing you new tools and new features.

All Geomet products use the same database, eliminating the need to rewritre part programs when you switch between software levels. Geomet has three levels of CMM software: Geomet Junior, Geomet 101 and Geomet 301.
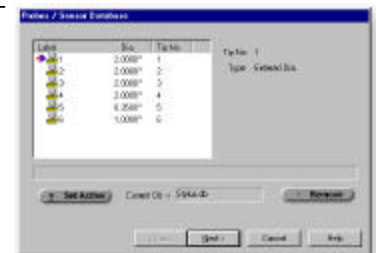
Geomet Junior

Geomet Junior is designed for basic 3D inspections. When you purchase a CMM from Helmel Engineering, Junior is included to help get you up and running without the expense of a higher level of CMM software. Geomet Junior has four options from which to expand the basic system.

Geomet Junior - Advanced PCS and Stylus

The option, Advanced PCS and Stylus support opens the number of available part coordinate systems (PCS) and stylus you can have active during a part inspection. Geomet Junior, by default, has only one PCS and one stylus available. The PCS can be redefined during a inspection, however the ability to recall a previous defined PCS is not available. This option opens the ability to have several PCSs in the same part program and seamlessly switch between them.

The Stylus Manager is activated with this option providing you expanded usage of several stylus types and number available within your part program. Through the stylus manager, you can qualify a 5-way stylus cluster and then switch between them during your part inspection. Additionally, you can measure a through bore with one stylus and complete the same bore with another stylus from the opposite side providing you greater access to a single feature that a single stylus can not deliver.

Geomet Junior - Programming

The Programming option activates the auto-cycle mode that takes your self-teach program and cycles it. All inspection steps that you create in Geomet are by default program steps that are part of a program. Once you teach a part inspection, you can then run it. Geomet Junior steps you through the sequence performing all actions for you. All you do is capture the data points.

Geomet Junior - Direct Computer Control (DCC)

The DCC option is designed around CMM's that have drive systems for the XYZ axes. This allows Geomet Junior to run your part inspections completely under DCC control. The DCC option include the Programming option, but not the Advanced PCS and Stylus support.

As with all Geomet levels, your part inspections that were created in manual mode are fully compatible for use on a DCC system, all you do is add the motion path.

Geomet Junior - GeoStat

GeoStat is a *Interactive* Statistical Process Control package. We call it interactive because at any time you can review the latest data that is captured from the Geomet part program. Even during a part program run, you can review the changes immediatly following the feature in question.

GeoStat requires that the Programming option has been activated.