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# **Shop of the 90's Project An Evaluation Tool for Wireframe CAD Software**

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U.S. DEPARTMENT OF COMMERCE  
Technology Administration  
National Institute of Standards  
and Technology  
Fabrication Technology Division  
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**U.S. DEPARTMENT OF COMMERCE  
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**NATIONAL INSTITUTE OF STANDARDS  
AND TECHNOLOGY  
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## ABSTRACT

The "SHOP OF THE 90's" is a project within the Fabrication Technology Division (FTD) of the National Institute of Standards and Technology (NIST). Its purpose is to define the technology needed to modernize and improve small U.S. machine shops by using its own machine shop operations as a testbed. This "SHOP OF THE 90's" document provides a methodology for small machine shops to benchmark Computer-Aided Design (CAD) packages. The initial step of the process is to determine a shop's CAD requirements, and to convert those requirements into specific CAD features. After determining the necessary features, the methodology is a three part process. Part one involves completing a checklist to determine which features are available on each CAD package. The second part consists of giving values to the features of the CAD package, biased toward the more important features. Part three generates a weighted tally of each package. Employing this evaluation tool simplifies the difficult process of determining the most suitable CAD package for each individual shop.

Use the "BENCHMARK" drawing included with this checklist in the evaluation process. By using the same drawing for all evaluations, a consistent evaluation can be performed on each system and evaluation results and reports will be easier to interpret.

The "BENCHMARK" drawing was chosen because it is a relatively simple part to draw and it contains enough complexity to challenge most systems. This same "BENCHMARK" will also be used in the next evaluation processes, data transfer from CAD to CAM, CAM programming, and the evaluation of CNC controls and machines.

This drawing does not represent any particular part or product. This Drawing does contain most of the geometric shapes encountered in day-to-day production and most of the geometric shapes that can cause problems in CAM programming, including those encountered when programming at the N/C controls.

The geometric shapes in the "BENCHMARK" drawing were the subject of a paper presented at AutoFact '90 by Kenneth Periss of Ben Gurion University in Negev, Israel entitled "Quality Evaluation of NC Modules for Automatic Mill Pocketing".

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## 1. INTRODUCTION

In 1988, the Fabrication Technology Division (FTD) of the National Institute of Standards and Technology (NIST), implemented a project to define the technology needed to modernize and improve small U.S. machine shops and its own machine shop operations, thus creating the "SHOP OF THE 90's" project.

To make the project applicable to small private sector machine shops, advanced experimental hardware and software from NIST laboratories is not used. Only affordable, commercially available, "off-the-shelf" hardware and software is used.

The project is being carried out using NIST's FTD machine shop as a test bed.

This project is broken down into three tasks:

- 1) Evaluate all machine tools within FTD's shops as to their condition and need for repair. Repair, replace, or surplus any machine tool as cost justification warrants.
- 2) Structure and set up a personal computer network that includes Computer-Aided Design (CAD), Computer-Aided Machining (CAM), computer-aided cost estimating, computer-aided process planning, tool room management, and distributed numerical control.
- 3) Train FTD staff on new equipment and cross train on existing equipment. All the equipment necessary to make the FTD productive is of little or no use without the trained personnel to operate it properly (the same is true in the private sector). It is therefore necessary that all shop personnel be trained on the hardware, software, and machine tools that are incorporated into the "SHOP OF THE 90's".

This document, a product of the "SHOP OF THE 90's" project, provides a methodology for CAD users to compare wireframe CAD packages based on features of each package and the importance of the features to the user.

## 2. Applying this Document

To properly use this document the evaluator should be familiar with the general operation of CAD. Users of this document without CAD experience should consult with an experienced CAD user, or become familiar with the terminology and use of CAD software. The Checklist, beginning on page 3, provides a good reference for the types of features that may be available when learning CAD.

The steps required before applying this methodology are: decide how the software will be used, identify the functions you need it to perform, then list the necessary CAD features to perform these functions. To determine necessary features, experience with CAD is required. Some considerations in determining required functions are:

- The geometric complexity of the parts.
- The "newness" of design: modifying old parts vs. designing parts from scratch?
- The possibility of sharing files with other CAD systems, or integration with CAM.
- The skills of the projected users.

Another issue that will affect the effectiveness of a CAD system is selecting a vendor. The following are some considerations that should be asked of potential vendors:

- The availability of local support and training.
- A demonstration of the software on one of your parts. Avoid "canned" demos.
- Referrals from past customers.

The evaluation is a three part process. Part one is the completion of a checklist that contains most of the features that can exist in wireframe CAD packages. Complete the checklist by checking the item if the CAD package being evaluated has that feature. Part two is used to generate numerical values for the features of the package. Part three generates a weighted tally of each package, so comparisons may be made. A CAD package is evaluated by completing each of the parts in order.

An alternate method of performing CAD evaluations is to pass on the checklist, and perform the numerical rating as a first step. If this method is applied, the checklist should be referenced, so the proper issues may be considered for each section. When using this method, "Section 1. Initial Considerations" should still be completed.

### 3. CHECKLIST

#### CHECKLIST INSTRUCTIONS

This part of the evaluation is a checklist that is used to identify a CAD package's features. "Section 1. Initial Considerations," is included to determine general features about the required hardware, hardware/software interactions, training, and cost. This section can be used as a quick tool to determine which CAD packages should be further examined.

Check and record comments for each feature that is applicable. Items marked with a '\*' are explained in detail on the page opposite the checklist item. Items marked with a '+' are defined in the Glossary in Appendix A.

## Instructions, Explanations, and Comments

1. Initial Considerations - These items should be considered in narrowing the group of CAD packages to be evaluated.
  - 1.1. Package type - Check the highest level that applies.
  - 1.2. CPU - Check all CPUs that the software can run on. Consider commenting on the response time of certain CPUs at certain frequencies, and the vendor's recommended CPU.
  - 1.3. Video display - Check all video displays that are supported. Consider commenting on displays that are supported, but have such low resolution that they are not useful, and the vendor's recommended video display.
  - 1.7. 16 or 32-bit program - It should be noted that a 16-bit program will run on a 32-bit CPU, but a 32-bit program will not run on a 16-bit CPU (8088 and 80286 are 16-bit CPUs, and the rest are 32-bit CPUs).
  - 1.10. Background suggested for use - This section means to ask the question "What skills does the ideal operator of this CAD package possess?" It is best evaluated relatively. Rate each category relative to other CAD packages, based on the prospective users.

Educational - Basically, the reading level and general knowledge for which the tools are geared.

Drafting - Level of experience and familiarity with your application.

Manufacturing - Level of experience and familiarity with your application.

Computer - Familiarity with the use of operating systems commands, directories, interactive software, menus, and installing software.

**CHECKLIST**

Name of Package: \_\_\_\_\_

**1. INITIAL CONSIDERATIONS**

**1.1. Package type (\*)**

- 2-D
- 2½-D
- 3-D

**1.2. CPU (\* +)**

- 8088
- 80286
- 80386-SX
- 80386
- 80486
- Other \_\_\_\_\_

**1.3. Video display (\*)**

- CGA
- EGA
- VGA
- Super VGA
- PGA
- Other \_\_\_\_\_

**1.4. Hard disk space used: \_\_\_\_\_kB (+)**

**1.5. RAM requirements: \_\_\_\_\_kB (+)**

**1.6. Math co-processor required (y/n): \_\_\_\_\_ (+)**

**1.7. 16 or 32-bit program (16/32): \_\_\_\_\_ (\*)**

**1.8. Operating systems available**

- MS-DOS
- OS/2
- UNIX
- ZENIX

**1.9. Instructional tools**

- 1.9.1.  manuals
- 1.9.2.  video
- 1.9.3.  interactive tutorial
- 1.9.4.  cassette tapes
- 1.9.5.  vendor instructions
- at training center: cost \$\_\_\_\_\_
- in-house: cost \$\_\_\_\_\_

**1.10. Background suggested for use (\*)**

- educational \_\_\_\_\_
- drafting \_\_\_\_\_
- manufacturing \_\_\_\_\_
- computer \_\_\_\_\_

## Instructions, Explanations, and Comments

- 1.11. File formats - The structure for storing the data of a drawing. The issue of file formats arises when transferring drawings between incompatible CAD systems, and from CAD to CAM systems. IGES is an industry standard file format, while DXF, CADL, and NFL are company specific file formats.
- 1.12. Installing software - e/m/d = easy/moderate/difficult
- 2.1. Entity type - Examples are points, circles, ellipses.
- Detail drafting - Examples are leader line, note, witness line.
- Line font - Examples are dashed line, center line.
- Masking of multiple types - Examples are mask all lines, all red entities, and all entities on layer 1.
- Masking of all but selected types - Example: mask everything except arcs and the entities on Layer 1.
- Recursive masking - Example: mask all red lines that reside on Layer 1.
- 2.2. Relative - Relative distance from a point using either rectangular or cylindrical coordinates.
- Distance along other entities - Distance along arcs, circles, conics, and splines.
- 'n'-points along an entity - Placing 'n' number of evenly spaced points over a prescribed distance.

**1.11. File formats (\* +)**

- IGES (+)
- CADL
- DXF
- NFL
- Other \_\_\_\_\_

**1.12. Installing software (e/m/d): \_\_\_\_\_ (\*)**

**1.13. Price of package: \$\_\_\_\_\_**

**2. REFERENCE LISTS**

**2.1. Masking (Selection) List (+)**

- Geometric entity type (\*)
- Detail drafting (\*)
- Layer (+)
- Color
- Line font (\*)
- Line weight
- Plotter pen number
- Masking of multiple types (\*)
- Masking of all but selected types (\*)
- Recursive masking (\* +)

**2.2. Point Location List**

- Endpoint of entity
- Center of entity
- Intersection of two entities
- Relative: rectangular (\*)
- Relative: cylindrical (\*)
- Key-in absolute coordinates (+)
- Cursor selection (+)
- Distance along a line
- Distance along other entities (\*)
- 'n'-points along an entity (\*)

**2.3. Plane Selection List**

- Two lines
- Planar entity
- Three points
- Point and a line
- Normal to a line, at a point
- Same as view plane, at a point (+)
- Same as construction plane (+)
- Offset from construction plane

## Instructions, Explanations, and Comments

- 2.4. By masking - Selection by choosing only entities with the chosen (masked) attributes. Refer to "2.1. Masking List" for the attributes that may be masked.

Window - The entities selected by the window may include one or more of the following: inside the window, outside the window, intersecting the window, inside or intersecting the window, or outside or intersecting the window.

Relative to a plane - The entities selected relative to a plane may include one or more of the following--in a plane, above/below a plane, or intersecting a plane. Refer to "2.3. Plane Selection List" for the methods to select a plane.

- 3.1. Selection devices - Refers to the physical devices that are available for entering data.

### Keyboard:

Function keys - Correspond to menu items.

Highlighted keys - Most commonly the first letter in the command name.

Arrow keys - To scroll through menu items.

- 3.2.1. Menus:

Hierarchical tree displayed - The previous menu selections required to arrive at the current menu are displayed.

User-selected location - Example: along top of screen, in a stack in lower left corner.

Current menu re-displayed - After the completion of an operation; used for repeating the same operation (as opposed to the main menu reappearing).

Iconified menus - Graphical representations for menu choices, line types, and viewport configurations, etc.

- 3.2.2. Command line input:

Displays immediately subordinate commands - The commands that are currently available for selection.

Last few commands displayed - To help the user remember what has been done.

- 3.2.3. Macros:

May be bound to keys/tablet locations - Running a macro by pressing a key or selecting a tablet position.



## 2.4. Entity Selection List

- Cursor selection (+)
- By masking (\*)
- Window (\* +)
- Chaining (+)
- Group (+)
- All
- Last entity created
- Most recent selection set (+)
- Relative to plane (\*)

## 3. USER INTERFACE

### 3.1. Selection devices (\*)

- mouse
- touch screen
- light pen
- keyboard
  - function keys (\*)
  - highlighted keys (\*)
  - arrow keys (\*)
- tablet

### 3.2. Command selection

#### 3.2.1. Menus (+)

- hierarchal tree displayed (\*)
- pop-up menus (+)
  - cursor button need not remain depressed for display
- user-selected location (\*)
- current menu re-displayed (\*)
- iconified menus (\*)

#### 3.2.2. Command line input (+)

- displays immediately subordinate commands (\*)
- repeat last command
- repeat other command in command history (+)
- last few commands displayed in command window (\*)
- hierarchal command structure well-organized (+)
- ability to back-up through command structure
- command history displayed (+)

#### 3.2.3. Macros (+)

- saved in macro libraries
  - maximum number #\_\_\_\_\_
  - may be named (y/n) \_\_\_\_\_
- included with part file
- macro names may be bound to keys (\*)
- macro names may be bound to tablet locations (\*)

#### 3.2.4. Hot keys (+)

## Instructions, Explanations, and Comments

- 3.3. On-line help:  
Feature displaying all paths - Aids in determining the commands necessary to perform a certain operation.
- 3.5. Accept/reject - Software prompts for approval of commands.
- 3.6. Defaults:  
Set in internal configuration file - The permanent default settings are set from within the software.  
Set in external configuration file - Program used from operating system external to the software to establish permanent default settings.  
Defaults to most recent input - Example: suppose the default arc radius is 2.0"; after entering an arc with a radius of 1.0", the current default setting becomes 1.0".  
Current defaults saved with part upon exiting - The system defaults, which may differ from the permanent default settings, are bound to a part file, and remain the same each time the part is called up.
- 4.1.1. Basic entities:  
Points - Refer to "2.2. Point Location List" for methods of locating points.  
Lines:  
Select endpoints - Refer to "2.2. Point Location List" for methods of selecting endpoints.  
Orthographic mode - An option that allows the drawing of lines in certain directions only (user defines the directions).  
Orthographic mode - For selected axis - Orthographic mode allows the drawing of lines in pre-defined directions only, example: x- and y-axis only.  
Other methods - Make a note on any other methods of drawing lines.  
Circles:  
Other methods - Make a note on any other methods of drawing circles.

### 3.3. On-line help

- [ ] description of each command
- [ ] table of all possible commands
- [ ] instruction line for present operation
- [ ] feature displaying all paths leading to given command name (\*)

### 3.4. [ ] Accessing operating system through shell (+)

### 3.5. Accept/reject (\*)

- [ ] must give approval when exiting from an unsaved file
- [ ] must give approval when saving to an existing file
- [ ] must give approval when deleting all geometry
- [ ] user selects which commands have accept/reject

### 3.6. Defaults

- [ ] set in internal configuration file (\* +)
- [ ] set in external configuration file (\* +)
- [ ] set in default list for current part file
- [ ] defaults to most recent input for particular operation (\*)
- [ ] current defaults saved with part upon saving (\*)

## 4. GEOMETRY

### 4.1. Creation

#### 4.1.1. Basic entities

- [ ] points (\*)
- [ ] lines
  - [ ] select endpoints (\*)
  - [ ] perpendicular to an entity
  - [ ] tangent to a curve
  - [ ] at an angle to an entity
  - [ ] parallel through a point
  - [ ] parallel at a distance
  - [ ] horizontal/vertical
  - [ ] orthographic mode (\*)
    - [ ] for selected axis combinations only (\*)
  - [ ] other methods (\*)
- [ ] circles
  - [ ] center and a point
  - [ ] center and radius/diameter
  - [ ] three points
  - [ ] between two points
  - [ ] tangent to entity, with center
  - [ ] tangent to two entities, with radius
  - [ ] tangent to three entities
  - [ ] other methods (\*)

## Instructions, Explanations, and Comments

### 4.1.1 Basic entities: cont.

#### Arcs:

Other methods - Make a note on any other methods of drawing arcs.

Define a few attributes - Some attributes would be center, radius, start point, etc., After selecting the attributes, the software draws all arcs fitting the description. The user then selects the wanted arc or arcs.

#### 'flip' option:

Less/greater than 180° - Completing the circle to which the arc belongs and deleting the original arc.

Concave/convex - Keeping the endpoints and radius fixed and flipping the center over the chord of the arc.

Entities display as broken - Entities are displayed as smaller than they actually are, but are treated correctly in the drawing's database. Example: displaying a 30 foot uniform pipe in a space of 6 inches because only the end conditions are critical.

### 4.1.2. Planar entities:

#### Conics:

Elliptical arcs - Specifying the start and end angle of an ellipse.

#### 'n'-gons, rectangles, and triangles:

Created as single entity - All lines that compose the 'n'-gons, rectangles and triangles are treated in database as one entity.

Created as non-grouped lines - All lines that compose the 'n'-gons, rectangles and triangles are treated in database individually.

Created as grouped lines - All lines that compose the 'n'-gons, rectangles and triangles are treated in database individually, and are placed within a group.

#### Strings:

Created as single/non-grouped/grouped entities - See 'n'-gons, rectangles, and triangles.

#### Splines:

Select endpoint constraints - Specifying vectors that define the direction of the spline at the start and end nodes.

Project points into construction plane - Used for non-planar nodes only.

Entities displayed as broken - See 4.1.1. above.

- [ ] arcs
  - [ ] center, radius, start angle, end angle
  - [ ] center, endpoint, included angle
  - [ ] three points
  - [ ] endpoints, included angle
  - [ ] tangent to entity, with center and included angle
  - [ ] tangent to two entities, with radius
  - [ ] tangent to three entities
  - [ ] other methods (\*)
  - [ ] define a few attributes (\*)
  - [ ] 'flip' option during creation
    - [ ] less/greater than 180 degrees (\*)
    - [ ] concave/convex (\*)
  - [ ] angles (0° at 3 o'clock, positive is counterclockwise)
- [ ] rubber banding (+)
- [ ] entities displayed as broken (\*)

#### 4.1.2. Planar entities

- [ ] conics
  - [ ] ellipses
    - [ ] elliptical arcs (\*)
  - [ ] parabolas
  - [ ] hyperbolas
- [ ] 'n'-gons, rectangles, and triangles (+)
  - [ ] created as single entity (\*)
  - [ ] created as non-grouped lines (\*)
  - [ ] created as grouped lines (\* +)
  - [ ] prompt for grouping option
  - [ ] filled
  - [ ] rotated
- [ ] stringing (+)
  - [ ] lines
  - [ ] arcs
  - [ ] combination of arcs and lines
  - [ ] automatic joining of first and last endpoints
  - [ ] created as a single entity (\*)
  - [ ] created as non-grouped entities (\*)
  - [ ] created as grouped entities (\* +)
  - [ ] prompt for grouping option
- [ ] splines (+)
  - [ ] select endpoint constraints (\*)
  - [ ] select degree of equation for solution
  - [ ] project nodes into construction plane (\* +)
  - [ ] create outside construction plane if nodes are planar (+)
- [ ] rubber banding (+)
- [ ] entities displayed as broken (\*)
- [ ] freehand sketching

#### 4.1.3. 3-D entities

- [ ] cubes
- [ ] prisms
- [ ] pyramids
- [ ] splines (+)

## Instructions, Explanations, and Comments

- 4.2.1. Dynamic association of files - When a pattern file is modified, part files in which the pattern is contained are updated appropriately.
- 4.2.3. Database Information:  
Database information projected into view plane - The ability to determine geometric attributes and relationships between entities as they are projected into the view plane.  
Store numbers into variables for calculations  
- The ability to store a value (example: the angle between two entities) so that it may be used at some later time.
- 4.2.4. On-line calculator:  
Store results of calculations into variables  
- See 4.2.3. above.  
Retrieve numbers from variables - The ability to retrieve the values that have been stored, using 4.2.3. or 4.2.4. above.

## 4.2. Management

### 4.2.1. Pattern files (+)

- scale
- rotate
- libraries
  - symbols
  - borders
  - miscellaneous
- option to group entities upon retrieval
- drag positioning (+)
- accept/reject for positioning
- dynamic association of files (\*)

### 4.2.2. Groups (+)

- maximum number #\_\_\_\_\_
- may be named (y/n) \_\_\_\_
- add to group
  - entities
  - subgroups
- remove from group
  - entities
  - subgroups
- ungroup

### 4.2.3. Database information (+)

- attributes
  - coordinates
    - start/end/center
    - node locations
    - vector direction established in database
  - length
  - radius/diameter
  - included angle
  - those on Masking List
  - parametric/polynomial equations
- geometric relationships
  - distance between two entities
  - distance between two locations
  - angle between two entities
- geometric calculations
  - perimeter
  - area
  - centroid
  - moment of inertia
- database information projected into the view plane (\*  
+)
- store results into variables for calculations (\*)

### 4.2.4. On-line calculator

- trigonometric functions
- access numbers directly from database information
- store results into variables (\*)
- retrieve numbers from variables (\*)

## Instructions, Explanations, and Comments

- 4.2.5. Selecting construction plane:  
From Plane Selection List - Refer to "2.3. Plane Selection List" for methods of selecting a plane.
- 5.1.1. Delete:  
From Entity Selection List - Refer to "2.4. Entity Selection List" for methods for selecting entities.
- 5.1.4. Unselect - Removing unwanted items from the current selection set.
- 5.2.1. Trim/break:  
At a distance along other entities - Distance along arcs, circles, conics, and splines.



- 4.2.5. Selecting construction plane (+)
  - principal views
  - from Plane Selection List (\*)
  - key-in vector relative to origin (+)
  - same as view plane (+)

## 5. EDITING

### 5.1. Correction

#### 5.1.1. Delete

- last entity created
- from Entity Selection List (\*)
- last 'n'-entities
  - delete/keep option for each

#### 5.1.2. Undelete

- last entity deleted
- set of entities just deleted
- all entities ever deleted
  - masking possible

#### 5.1.3. Undo

- last operation
- last 'n'-operations
  - undo/not-undo option for each

#### 5.1.4. Unselect (\*)

- last selection
- cursor selection (+)
- last 'n'-selections
  - accept/reject unselection option for each

### 5.2. Modifying entities

#### 5.2.1. Trim/break (+)

- intersection of entities
  - two entities: one
  - two entities: both
  - intersection of single selected entity and multiple cutting entities
  - intersection of multiple selected entities and single cutting entity
  - intersection of multiple selected entities and multiple cutting entities
- at a distance along a line
- at a distance along other entities (\*)
  - along a circle/arc a number of degrees
- into two entities and separate (break only)
- into 'n'-sections (break only)

## Instructions, Explanations, and Comments

- 5.2.3. Stretch - Changing the length and/or direction of an entity without regard to its original direction or rate of curvature (i.e., changing the position of one of an entity's endpoints). Consider whether rubber banding is used for stretching.

### Arcs:

Included angle - By preserving the center and included angle of an arc but changing its radius.

Chord and arc midpoint - By moving one endpoint along the line formed by the original two endpoints.

- 5.2.4. Splines:

### Trim/break:

Between nodes - If spline is trimmed/broken where there is no node, a node is created at the new endpoint.

Spline recalculated - New splines are calculated based upon the new node that is placed at the trim/break position.

### Modify:

Endpoint constraint - Change tangent vector (see 4.1.2. Splines: Select endpoint constraint).

### Extend:

With arc - Start an arc at the selected endpoint with a radius equal to the radius of curvature at the endpoint of the spline.

With curve - Add a curve onto the spline with the same rate of change of curvature as the end of the spline.

With line - Start a line at the selected endpoint and make the line tangent to the spline.

- 5.2.5. Modifying entity attributes - Those on "2.1. Masking List," example: changing the color of an entity.

- 5.2.6. Change numbers - Since every entity in a part file is associated with certain values stored in the part's database, the entities may be modified by changing these values, within limits.

- 5.2.2. Extend (+)
  - [ ] to an entity
  - [ ] to a plane
  - [ ] from both ends of entity
  - [ ] an arc into a circle
  - [ ] key-in (+)
    - [ ] distance
    - [ ] angle
- 5.2.3. Stretch (\* +)
  - [ ] lines and 'n'-gons (+)
    - [ ] one point at a time
    - [ ] multiple points
  - [ ] arcs
    - [ ] by preserving included angle (\*)
    - [ ] by preserving distance between chord and arc midpoint (\*)
- 5.2.4. Splines (\* +)
  - [ ] trim/break (+)
    - [ ] between nodes (\*)
    - [ ] spline recalculated (\*)
  - [ ] modify
    - [ ] move node
    - [ ] endpoint constraint (\*)
  - [ ] extend
    - [ ] with arc (\*)
    - [ ] with curve (\*)
    - [ ] with line (\*)
- 5.2.5. [ ] Modifying entity attributes (\*)
- 5.2.6. Change numbers in geometry database to edit part (\*)
  - [ ] when using numbers from the database information retrieval function
  - [ ] by selecting the entity on the screen

### 5.3. Transforming entities

- 5.3.1. Mode
  - [ ] move
  - [ ] single copy
  - [ ] join (+)
  - [ ] rectangular array (+)
    - [ ] independent column/row spacing
  - [ ] polar array (+)
    - [ ] rotating
    - [ ] non-rotating
  - [ ] drag positioning (+)
  - [ ] accept/reject option for positioning

## Instructions, Explanations, and Comments

5.3.2. Methods - Methods to move, copy, join, and array.

Offset - Shrink or expand a contour a given offset distance.

Project onto plane:

Other direction - The user defines the direction of projection.

5.4.3. Features:

Trim/not trim - Option to trim the excess off the lines when creating a fillet/chamfer.

### 5.3.2. Methods (\*)

- [ ] translate
  - [ ] by keying-in a vector (+)
  - [ ] by defining vector from reference point to new point
- [ ] rotate
  - [ ] about a point (2-D rotation)
  - [ ] about a line (3-D rotation)
- [ ] mirror (+)
  - [ ] about a line
  - [ ] about a plane
- [ ] scale (+)
  - [ ] axes independent of one another
- [ ] offset (\* +)
- [ ] project onto a plane
  - [ ] normal to projected entity(ies)
  - [ ] normal to plane receiving projection
  - [ ] other direction (\*)

## 5.4. Fillets, Rounds and Chamfers

### 5.4.1. Creating fillets and rounds (+)

- [ ] radius
- [ ] point on fillet
- [ ] tangent at one endpoint and to another entity
- [ ] tangent at two endpoints
- [ ] tangent to three entities

### 5.4.2. Creating chamfers (+)

- [ ] two linear dimensions
- [ ] dimension and angle
- [ ] dimension and length of chamfered edge
- [ ] angle and length of chamfered edge

### 5.4.3. Features

- [ ] trim/not trim option (\* +)
- [ ] fillet/chamfer all selected intersections

## 6. DETAIL DRAFTING

### 6.1. Dimensioning

#### 6.1.1. Types

- [ ] horizontal/vertical
- [ ] parallel
- [ ] baseline
- [ ] chain
- [ ] ordinate
- [ ] radial/diametral
- [ ] angular
- [ ] concentric

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### 6.1.2. Components of the dimension

- units
  - US customary
  - metric
  - units converted from one to the other
    - universally
    - user-selected locations
  - both U.S. customary and metric on same drawing
  - dual dimensioning
  - both single and dual dimensioning on the same drawing
  - fractional units
  - both fractional and decimal units on the same drawing
  - fractional degrees
  - degrees, minutes, and seconds
  - both fractional degrees and degrees, minutes, and seconds on the same drawing
- tolerances
  - displayed in  $\pm$  mode
  - displayed as limit
  - tolerance accumulation checking
- dimension values
  - non-horizontal orientation
  - user-selected precision
- arrows
  - in/out direction toggle
  - direction chosen automatically
  - independent arrow and dimension value locations
  - size independent of text size
  - user-defined shapes
  - option for filled vs. open
  - witness line suppression
    - universally
    - user-selected locations

### 6.1.3. Modifications

- lead line location
- dimension value location
  - drag positioning (+)
- arrow direction

### 6.1.4. Automatic features

- automatic dimensioning
- automatic alignment of dimensional values
- dimension values
- associative dimensioning (+)

### 6.1.5. Adheres to ANSI Y14.5(1986)

## Instructions, Explanations, and Comments

- 6.2.1. Ability to change aspect ratio - Aspect ratio is the ratio of height to width for characters.
  
- 6.2.4. Features:
  - Text to entity conversion - Changing text into a number of lines and arcs; a possible use would be engraving.
  - Identification symbols - Associating a symbol at one part of a drawing with text at another.
  
- 7.1.1. Zoom:
  - Auto scale - Automatically changing the drawing scale so the entire drawing fits within the graphics screen.



## 6.2. Text

### 6.2.1. Size

- number of standard sizes #\_\_\_\_\_
- user-defined
- ability to change aspect ratio

### 6.2.2. Fonts (+)

number available #\_\_\_\_\_

### 6.2.3. Styles

- bold
- superscript
- subscript
- italics
- outlined
- shadow

### 6.2.4. Features

- ability to import from word processor/ASCII files
- non-horizontal orientation
- text to entity conversion (\*)
- identification symbols (\*)

## 6.3. Crosshatching (+)

### 6.3.1. Hatch patterns

- number available #\_\_\_\_\_
- user-defined spacing
- user-defined angle
- user-defined hatch patterns

### 6.3.2. Automatic re-crosshatching

- when contour is changed
- when islands are created or deleted

## 7. DISPLAY CAPABILITIES

### 7.1. View Manipulation

#### 7.1.1. Zoom (+)

- auto scale (\*)
- half scale
  - select center
- double scale
  - select center
- window (+)
- key-in value (+)
  - relative to present magnification
  - absolute drawing scale factor (+)

#### 7.1.2. Pan (+)

#### 7.1.3. Regenerate graphics screen

## Instructions, Explanations, and Comments

- 7.1.4. View previous windows:  
Temporarily fill entire screen - Enlarge the graphics screen so that it covers menus, etc., filling the entire screen.
- 7.1.6. Selecting 3-D view plane:  
Relative to origin - Axes icon, key-in vector, slider bars, and compass are methods of selecting the 3-D view plane relative to the origin.
- 7.1.7. Create view:  
2-D isometric - Create a view from the principal views that looks 3-D but the geometry is actually planar.  
3-D wireframe - Create a true 3-D wireframe model from the principal views.
- 7.1.9. Cross-sectional view - By positioning a cutting plane (section line) across a view, a cross-sectional view is produced.  
Non-linear section cut - The cutting plane does not need to be straight.  
Hidden line placement - Show hidden lines in a section cut as dashed.
- 7.1.10. Dynamic rotation - The ability to watch a part as it rotates.
- 7.2.1. Layers:  
Remove layer from set - Generally, even when a layer is turned off, the positions of the entities in that layer are still calculated, but not displayed. This option allows for the entities in layers that are off to be ignored as far as calculations are concerned. It is useful in making graphics regeneration faster.

- 7.1.4. View previous view windows (+)
  - last
  - back-up through view window history
  - may be saved
    - maximum number #\_\_\_\_\_
    - may be named (y/n) \_\_\_\_
  - temporarily fill entire screen (\*)
- 7.1.5.  Perspective viewing
- 7.1.6. Selecting 3-D view plane (+)
  - principal views
  - isometric view
  - from Plane Selection List
  - relative to origin (\*)
    - axes icon (+)
    - key-in vector (+)
    - slider bars
    - compass
    - other \_\_\_\_\_
  - by ending dynamic viewing session (see 7.1.10.)
  - same as construction plane (+)
- 7.1.7. Create view by combining principal views
  - 2-D isometric (\*)
  - 3-D wireframe (\*)
- 7.1.8. Saving views
  - maximum number #\_\_\_\_\_
  - may be named (y/n) \_\_\_\_
- 7.1.9.  Cross-sectional views produced automatically (\*)
  - non-linear section cut (\*)
  - hidden line placement (\*)
- 7.1.10. Dynamic rotation (\* +)
  - parallel (+)
  - perspective (+)
  - rotation methods
    - arrows
    - compass
    - slider bars
    - other \_\_\_\_\_

## 7.2. Viewing tools

- 7.2.1. Layers (+)
  - maximum number #\_\_\_\_\_
  - may be named (y/n) \_\_\_\_
  - remove layer from calculation set (\*)
    - display for viewing only
  - table of status (on/off, etc.) of all layers
  - moving entities between layers is easy

## Instructions, Explanations, and Comments

### 7.2.2. Viewports:

Configurations - Ways in which viewport windows are arranged on the screen.

Merging - One viewport is deleted and another is made larger.

Dividing - A different view is put into the new viewport.

Viewport-independent display capabilities - Allows different items to be displayed in different viewports (as opposed to different views of the same items). Examples are, displaying Layer 1 in one viewport, and Layer 2 in another, and having dimensions appear in one viewport only.

Views displayed in graphics viewports - This category will receive a check if, when changing the number of active graphics viewports, a different view (e.g., top, side, isometric) is placed into each graphics viewport.

Package decides - The software determines which view goes in each graphics viewport.

User sets configuration file - The user determines which view goes in each graphics viewport, through the configuration file (see "3.6. Defaults" for possible methods of setting the configuration file).

User selected - The user selects which view goes in each graphics viewport each time the number of active graphics viewports is changed.

7.2.3. Display of cursor coordinates - The position on the screen of the cursor.

7.2.4. Display of axes icon:

Size:

Automatic sizing - The size of the axis icon appears the same size on the screen at all times, regardless of the drawing scale.

On/off option - The ability to turn the axis icon on and off.

Simultaneously displayed icons - Displaying numerous axis icons, where each denotes a possible construction plane.

Construction plane changes - Any of the displayed icons may be selected to change the current construction plane.

### 7.2.2. Viewports (+)

- configurations (\*)
  - number available with package #\_\_\_\_\_
  - merging two adjacent viewports into one (\*)
  - dividing one viewport into multiple viewports (\*)
  - possible to display more than four viewports simultaneously
  - user-defined viewport configurations
- viewport-independent display capabilities (\*)
  - detail drafting
  - layer manipulation
  - others \_\_\_\_\_
- views displayed in graphics viewports (\*)
  - package decides (\*)
  - user sets configuration file (\*)
  - user selected (\*)

### 7.2.3. Display of cursor coordinates (\*)

- in world coordinates (+)
- in construction plane coordinates (+)
- world and construction plane displayed simultaneously
- updated in real-time

### 7.2.4. Display of axes icon (+)

- coordinate system
  - world
  - construction plane (+)
  - simultaneous world and construction plane icons
- size
  - automatic sizing (\*)
  - user-selected
- location
  - origin
  - screen corner
  - user-selected
- on/off option (\*)
- simultaneously displayed icons (\*)
  - construction plane changes when new icon is selected (\* +)

### 7.2.5. Grid (+)

- background (dots)
- foreground (lines)
- user-selected origin
- rotated
- user-selected scale
  - axis-independent scaling
- for selected axis combinations
- grid = snap increment values
- isometrically displayed

## Instructions, Explanations, and Comments

### 7.2.7. Other viewing aids:

Selection markers - Temporary 'blips' that denote locations.

Variable entity display resolution - Example: instead of drawing a circle as a smooth curve, display it as an octagon. This is used for quicker graphics response.

### 7.2.6. Grid snap (+)

- user-selected origin
- rotated
- independent of grid
- snap = grid increment values
- user-selected scale
  - axis-independent scaling
- for selected axis combinations

### 7.2.7. Other viewing aids

- selection markers (\* +)
  - disappear after performing function
- variable entity-display resolution (\*)
- line width displayed
  - all lines same width
  - actual line width displayed
  - width relative to other lines

## 8. OTHER FEATURES

### 8.1. True surfaces

#### 8.1.1. Types

- meshed surfaces
  - non-uniform rational B-spline (NURBS)
  - rational B-spline
  - boundary representation
  - Bezier
  - ruled
  - cylindrical
  - projected
  - surface of revolution
- other surfaces
  - coons patch
  - lofted
  - swept
  - filleted
  - variable filleted

#### 8.1.2. Geometric calculations

- perimeter
- surface area
- centroid
- moment of inertia

8.1.3.  Hidden line removal

8.1.4.  Shaded surfaces

## Instructions, Explanations, and Comments

- 8.3. Files readable by engineering analysis packages - The geometry is saved in such a way that it is readable by external engineering analysis packages (example: a finite element analysis package).
- 8.5. Embedded programming language - A part of the software that allows the user to write application programs to add functions to the package, and to automate repetitive operations.
- 8.6. Third party support - Packages external to the system exist that support additional features or enhance performance.



## 8.2. True solids

### 8.2.1. Primitives (+)

- block
- cylinder
- cone
- sphere
- torus
- revolution of user-defined profile about a line
- sewing of surfaces

### 8.2.2. Solid calculations

- surface area
- volume
- mass
- center of gravity
- moment of inertia

### 8.2.3. Assembly of solids

- add
- subtract
- disassembly of solids

### 8.2.4. Shaded solids

### 8.2.5. Converts solids to surfaces hidden line removal

### 8.2.6. Converts solids to wireframe

## 8.3. Files readable by engineering analysis packages (\*)

## 8.4. Printers/plotters

- print/plot from within package
- for "print-screen", does the package print/plot only the graphics window (+)
- scale drawings for hard copies/plots
- page sizes
  - U.S. (inches)
    - A (8.5 x 11)
    - B (11 x 17)
    - C (17 x 22)
    - D (22 x 34)
    - E (34 x 44)
  - metric (mm)
    - A4 (210 x 287)
    - A3 (287 x 420)
    - A2 (420 x 584)
    - A1 (584 x 841)
    - A0 (841 x 1188)
  - user-defined

## 8.5. Embedded programming language (\*)

## 8.6. Third party support (\*)

#### 4. NUMERICAL RATINGS

##### INSTRUCTIONS

This part of the evaluation is used to assign numerical values to features on the checklist. Completing this form is a three step process:

- 1) Decide on a scale for ratings, e.g., 0-4, 1-5, 0-10. The scale used should remain consistent from package to package.
- 2) Give a numerical value to each topic with check-marked sub-topics, biasing the rating toward the more important sub-topics for your application.
- 3) Give a composite numerical value for all topics in Step 2 under the same headings, (again, biasing towards more important topics) and repeat until the seven major categories (excluding "1. Initial Considerations") have a rating.

The following is a list of considerations when giving ratings:

- Does the feature exist?
- Is the feature easy to use?
- Is the feature important to your needs?
- What methods are available to perform the feature?
- How many commands must be issued to get to the feature?
- Is the feature optional? Can it be turned on and off?

A few exceptions to these methods exist:

- "Section 1. Initial Considerations", does not receive an overall rating.
- Only "1.9. Instructional Tools", of Section 1. receives a value. When rating Section 1.9. consider not only the sub-topics in Section 1.9., but how Section 1.10., Background Suggested for Instructional Tools, applies to each sub-topic.
- Section 1.9. and all other topics without sub-topics (example: "3.4. Accessing operating system through shell"), may receive both a check-mark and a value. The check-mark shows whether the feature exists on the package, and then a value may be given using the previously mentioned considerations.
- Under "Section 4.1.1. Basic Entities", points, lines, circles, and arcs receive a value because they are important items to a CAD package. Even though they are sub-topics to "4.1.1. Basic Entities", they are all given values so a better assessment of their quality can be made.

To illustrate assigning values: using the previously mentioned considerations, points, lines, circles, and arcs, are given values of 2, 4, 2, and 5, respectively (on a scale of 0-5). To determine the value of "4.1.1. Basic Entities", the evaluator can apply two methods. The first method uses the fact that, for the evaluator's shop, lines and circles are very important, arcs are

somewhat important, and points are not very important, to come up with a rating of "3." Using another method, the evaluator first decides on a scale of 0-3 for weighting topics. Based on his needs, he assigns a weight of one to points, three to lines and circles, and two to arcs. The following table shows the method used to determine the rating: (Weight x Value = Product):

	points	lines	circles	arcs	total
Weight(0-3)	1	3	3	2	9
x Value (0-5)	2	4	2	5	
Product	2	12	6	10	30

The value for "4.1.1. Basic Entities" is  $30 \div 9$ , or 3.3.

The same procedure should then be repeated for 4.1.2. and 4.1.3. Next, apply the same method to determine the value for 4.1. When both 4.1. and 4.2. have values, they can be weighted and combined to determine the overall rating for "4. Geometry."

Weighting of each topic is the preferable method for determining values. Its advantage is that it allows the evaluator to rank the quality of the features once, and then determine values based on a weighted average. Should the evaluator decide that certain features are more or less important to the application than originally thought, their weights can be changed accordingly, and values can be recalculated. Another advantage is that weighting helps disregard the effects of perfectly implemented features that are unnecessary.

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**NUMERICAL RATINGS FORM**

Name of Package: \_\_\_\_\_

Scale: \_\_\_\_\_

\_\_\_        **1.9. Instructional tools**

- \_\_\_ 1.9.1. Manuals
- \_\_\_ 1.9.2. Video
- \_\_\_ 1.9.3. Interactive tutorial
- \_\_\_ 1.9.4. Cassette tapes
- \_\_\_ 1.9.5. Vendor instruction

\_\_\_        **2. REFERENCE LISTS**

- \_\_\_        **2.1. Masking (Selection) List**
- \_\_\_        **2.2. Point Location List**
- \_\_\_        **2.3. Plane Selection List**
- \_\_\_        **2.4. Entity Selection List**

\_\_\_        **3. USER INTERFACE**

- \_\_\_        **3.1. Selection devices**
- \_\_\_        **3.2. Command selection**
  - \_\_\_ 3.2.1. Menus
  - \_\_\_ 3.2.2. Command line input
  - \_\_\_ 3.2.3. Macros
  - \_\_\_ 3.2.4. Hot keys
- \_\_\_        **3.3. On-line help**
- \_\_\_        **3.4. Accessing operating system through shell**
- \_\_\_        **3.5. Accept/reject**
- \_\_\_        **3.6. Defaults**

\_\_\_\_\_ **4. GEOMETRY**

\_\_\_\_\_ **4.1. Creation**

\_\_\_\_\_ 4.1.1. Basic entities

\_\_\_\_\_ points

\_\_\_\_\_ lines

\_\_\_\_\_ circles

\_\_\_\_\_ arcs

\_\_\_\_\_ 4.1.2. Planar entities

\_\_\_\_\_ 4.1.3. 3-D entities

\_\_\_\_\_ **4.2. Management**

\_\_\_\_\_ 4.2.1. Pattern files

\_\_\_\_\_ 4.2.2. Groups

\_\_\_\_\_ 4.2.3. Database information

\_\_\_\_\_ 4.2.4. On-line calculator

\_\_\_\_\_ 4.2.5. Selecting construction plane

\_\_\_\_\_ **5. EDITING**

\_\_\_\_\_ **5.1. Correction**

\_\_\_\_\_ 5.1.1. Delete

\_\_\_\_\_ 5.1.2. Undelete

\_\_\_\_\_ 5.1.3. Undo

\_\_\_\_\_ 5.1.4. Unselect

\_\_\_\_\_ **5.2. Modifying entities**

\_\_\_\_\_ 5.2.1. Trim/break

\_\_\_\_\_ 5.2.2. Extend

\_\_\_\_\_ 5.2.3. Stretch

\_\_\_\_\_ 5.2.4. Splines

\_\_\_\_\_ 5.2.5. Modifying entity attributes

\_\_\_\_\_ 5.2.6. Change numbers in geometry database to edit  
part

\_\_\_\_\_ **5.3. Transforming entities**

\_\_\_\_\_ 5.3.1. Mode

\_\_\_\_\_ 5.3.2. Methods

\_\_\_\_\_ **5.4. Fillets, Rounds, and Chamfers**

\_\_\_\_\_ 5.4.1. Creating fillets and rounds

\_\_\_\_\_ 5.4.2. Creating chamfers

\_\_\_\_\_ 5.4.3. Features

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## 6. DETAIL DRAFTING

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### 6.1. Dimensioning

- 6.1.1. Types
- 6.1.2. Components of the dimension
- 6.1.3. Modifications
- 6.1.4. Automatic features
- 6.1.5. Adheres to ANSI Y14.5(1986)

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### 6.2. Text

- 6.2.1. Size
- 6.2.2. Fonts
- 6.2.3. Styles
- 6.2.4. Features

---

### 6.3. Crosshatching

- 6.3.1. Hatch patterns
- 6.3.2. Automatic re-crosshatching

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## 7. DISPLAY CAPABILITIES

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### 7.1. View Manipulation

- 7.1.1. Zoom
- 7.1.2. Pan
- 7.1.3. Regenerate graphics screen
- 7.1.4. View previous windows
- 7.1.5. Perspective viewing
- 7.1.6. Selecting 3-D view plane
- 7.1.7. Create view by combining principal views
- 7.1.8. Saving views
- 7.1.9. Cross-sectional view produced automatically
- 7.1.10. Dynamic rotation

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### 7.2. Viewing tools

- 7.2.1. Layers
- 7.2.2. Viewports
- 7.2.3. Display of cursor coordinates
- 7.2.4. Display of axes icon
- 7.2.5. Grid
- 7.2.6. Grid snap
- 7.2.7. Other viewing aids

\_\_\_\_\_ **8. OTHER FEATURES**

\_\_\_\_\_ **8.1. True surfaces**

- \_\_\_\_\_ 8.1.1. Types
- \_\_\_\_\_ 8.1.2. Geometric calculations
- \_\_\_\_\_ 8.1.3. Hidden line removal
- \_\_\_\_\_ 8.1.4. Shaded surfaces

\_\_\_\_\_ **8.2. True solids**

- \_\_\_\_\_ 8.2.1. Primitives
- \_\_\_\_\_ 8.2.2. Solid calculations
- \_\_\_\_\_ 8.2.3. Assembly of solids
- \_\_\_\_\_ 8.2.4. Shaded solids
- \_\_\_\_\_ 8.2.5. Converts solids to surfaces
- \_\_\_\_\_ 8.2.6. Converts solids to wireframe

\_\_\_\_\_ **8.3. Output readable by engineering analysis packages**

\_\_\_\_\_ **8.4. Printers/plotters**

\_\_\_\_\_ **8.5. Embedded programming language**

\_\_\_\_\_ **8.6. Third party support**



## 5. SUMMARY

### INSTRUCTIONS

This part is completed as a final step of the evaluation process. The purpose of the summary is to achieve a weighted tally of each package, so comparisons may be made.

- 1) Determine weights for all categories (excluding "1. Initial Considerations") and enter them on the summary sheet.
- 2) Transfer the Initial Considerations from the checklist, excluding the following exceptions:
  - 1.2. Enter the "slowest" acceptable CPU, with speed included. Example: 386-25; which means 25 Mhz, 80386.
  - 1.3. Enter the lowest acceptable display (EGA, VGA, etc.).
  - 1.8. Enter the most applicable operating system.
  - 1.9. Transfer the value from the Numerical Ratings, page 36.
  - 1.11. Enter the file formats supported.
- 3) Entries from Sections 2 through 8 should be transferred from the Numerical Ratings form to the upper half of the box provided for each package.
- 4) Multiply the weights and the ratings for each section, and enter the result in the lower half of the box for each package.
- 5) The final rating of the system is then determined by adding the numbers in the lower half of the boxes, and placing the total into the space provided at the right of the page.

At this point, a relative comparison can be made, by combining the total the CAD package received, and the relative strength of the Initial Considerations to determine the best package. See "Appendix B: Sample Evaluation" for an example.



**APPENDIX A: GLOSSARY**

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## GLOSSARY TERMS

array  
ASCII  
associate dimensioning  
axes icon  
break  
CAD  
CADL  
CAM  
chaining  
chamfer  
CNC  
command history  
command line input  
configuration file  
construction plane  
construction plane coordinates  
CPU  
crosshatching  
cursor selection  
database  
database information  
drag positioning  
drawing scale  
DXF  
dynamic rotation  
entity  
extend  
file format  
fillet  
font  
free-hand sketching  
graphics window  
grid  
grid snap  
group  
hard disk  
hierarchal command structure  
hot keys  
IGES  
join  
key-in  
layers  
line font  
macro  
masking  
math co-processor  
menu  
mirror  
'n'-gon  
NFL  
offset  
pan  
parallel viewing  
pattern file  
perspective viewing  
pop-up menu  
primitive  
RAM  
recursive masking  
round  
rubber banding  
scale  
selection markers  
selection set  
shell to operating system  
spline  
stretch  
string  
trim  
view plane  
view window  
viewports  
window  
world coordinates  
zoom

ARRAY: Making multiple copies of an entity or entities that are placed into either a rectangular or polar grid.

ASCII: American Standard Code for Information Interchange - A format for describing characters on a computer.

ASSOCIATIVE DIMENSIONING: Dimensioning such that when the dimensioned geometry is altered, the dimensional value is updated.

AXES ICON: A visual representation of the direction of the coordinate axes (also called "gnonom").

BREAK: Dividing a single entity into two or more entities.

CAD: Computer-Aided Design.

CADL: CADKEY Advanced Design Language - A drawing file format by Cadkey, Inc.

CAM: Computer-Aided Machining.

CHAINING: Selecting entities by selecting the first entity in the chain, then a direction of the chaining, and then the last entity in the chain. The software then selects entities in between the first and last entity in the selected direction.

CHAMFER: Beveling a sharp external edge (shop definition).  
Adding an angled line between two intersecting entities (CAD definition).

CNC: Computer Numerical Control.

COMMAND HISTORY: The previous commands that have been issued.

COMMAND LINE INPUT: Entering a command by typing in its name.

CONFIGURATION FILE: The data file where the permanent defaults for a CAD package are contained.

CONSTRUCTION PLANE: The plane in which geometry is drawn. The construction plane may differ from the view plane.

CONSTRUCTION PLANE COORDINATES: A coordinate system where the user has defined the position and orientation of the origin (also called "user coordinates" or "local coordinates").

CPU: Central Processing Unit - The micro chip within a computer that handles calculations, communications, and the control of peripheral devices. Typically, personal computers are specified by their CPU.

**CROSSHATCHING:** Filling a bound area of a drawing with a pattern to distinguish the area.

**CURSOR SELECTION:** Selecting an entity by clicking the cursor near the entity. Also, selecting a position by clicking the cursor at the position.

**DATABASE:** The information about a part: geometry, drawing scale, view direction, etc.

**DATABASE INFORMATION:** Retrieving information about the attributes, geometry, and geometric relationships of a drawing (also called "verifying" or "listing").

**DRAG POSITIONING:** Cursor selecting the position of an entity or entities where the user may see where the entities will be after the operation (examples are retrieving pattern files and moving entities).

**DRAWING SCALE:** The size of the screen of entities relative to their true size. The database treats the entities the same, even though they appear larger or smaller than they actually are.

**DXF:** Drawing Interchange File Format - A drawing file format by Autodesk, Inc.

**DYNAMIC ROTATION:** Watching a part as it rotates.

**ENTITY:** The smallest part of a drawing that can be manipulated using a CAD package. Entities are typically thought of as geometry, but also include dimensions and text.

**EXTEND:** Changing the length of an entity while maintaining its original direction or rate of curvature.

**FILE FORMAT:** The structure for storing the data (geometry, etc.) of a drawing.

**FILLET:** A rounded filling of the internal corner between two surfaces (shop definition). Adding an arc between two intersecting entities (CAD definition).

**FONT:** Defines the appearance of text.

**FREE-HAND SKETCHING:** Entering an entity by tracking the path of the cursor.

**GRAPHICS WINDOW:** The part of the screen where the geometry is displayed.

**GRID:** A 2-D display of dots or lines that aid in the drawing process.

GRID SNAP: An invisible grid of points that when the cursor is clicked, the nearest snap position is selected.

GROUP: A number of entities that are logically associated so they may be treated as a single entity. Whether or not an entity may be treated individually when it is part of a group varies from package to package.

HARD DISK: A non-volatile storage device for storing programs and data.

HIERARCHAL COMMAND STRUCTURE: Setting up commands so that a command may have a number of related sub-commands. Each sub-command of the first hierarchal level can have sub-commands of its own, and so on.

HOT KEYS: Performing a command with a single keystroke. Hot Keys are pre-defined in the software (also called "immediate mode").

IGES: Initial Graphics Exchange Specification. A standard file format used for the exchange of drawing information between incompatible CAD and CAM packages.

JOIN: Copying an entity or entities, and connecting the endpoints.

KEY-IN: Entering information (coordinates, direction, text, etc.) by typing it in on the keyboard.

LAYERS: A number of "transparent sheets" that entities may reside on. A layer may be turned "on" or "off" and the entities on the layer are displayed or not displayed accordingly. Using layers is essential for entity management. Example: in a part file, geometry may be on Layer 1, and dimensions may be on Layer 2 (also called "levels").

LINE FONT: The appearance of lines, e.g., dashed, center, phantom.

MACRO: Recording a sequence of menu selections to allow the completion of tasks by entering a single key or keyword.

MASKING: Selecting entities based on some of their attributes, e.g., geometry type, color, line font.

MATH CO-PROCESSOR: An optional computer chip that when added to a personal computer, makes mathematical operations (which are important to CAD packages) more efficient. Many CAD packages require math co-processors.

MENU: An on-screen display of the possible command selections.



**MIRROR:** Projecting a mirror image of an entity or entities across a line or plane.

**'N'-GON:** A closed figure having any (or 'n') number of sides (also called "polygon").

**NFL:** Neutral File Format - A drawing file format by MCS, Inc.

**OFFSET:** Shrinking or expanding a contour by a certain distance.

**PAN:** Changing the position of the center of the current view direction. Panning affects only the position of a drawing on the screen, not the drawing scale or view direction.

**PARALLEL VIEWING:** Viewing a part where, when the drawing is projected onto a viewing plane, the vantage point is infinite (the projection lines are parallel).

**PATTERN FILE:** A file containing geometry that may be retrieved into a part file. Standard pattern files of drafting symbols, borders, hardware, etc., may be standard on a package.

**PERSPECTIVE VIEWING:** Viewing a part where, when the view is projected onto a viewing plane, the vantage point is at a fixed location (the projection lines converge).

**POP-UP MENU:** A menu that is displayed only when a higher level function is selected, showing all sub-commands.

**PRIMITIVES:** The basic building shapes for constructive solid geometry, which is a method of solid modeling.

**RAM:** Random Access Memory. The area of computer memory where programs and data are stored temporarily (they are lost when the power is removed). A certain amount of RAM is necessary to run a CAD package.

**RECURSIVE MASKING:** Masking on items that have already been masked (see example in the detailed instructions for "2.1. Masking List" on page 7).

**ROUND:** A "rounding" of the external edge between two surfaces (shop definition). Adding an arc between two intersecting entities (see fillet: CAD definition).

**RUBBER BANDING:** An "elastic" entity attached to the cursor showing what the entity looks like. When the cursor changes position, the entity's size/shape changes with it.

**SCALE:** Changing the size of selected entities in a drawing. It is a method of moving, copying, arraying, and joining.

**SELECTION MARKERS:** Temporary "blips" on the screen that denote a position.

SELECTION SET: The entities that have been picked for an operation.

SHELL TO OPERATING SYSTEM: The ability to temporarily exit the program and issue operating system commands (also called "Exit to DOS").

SPLINE: A mathematical term used to describe a smooth curve between points.

STRETCH: Changing the length and/or direction of an entity without regard for its original direction or rate of curvature.

STRINGING: Drawing lines or arcs such that the end of one entity is the beginning of the next. A package may have the ability to close the object.

TRIM: The process of breaking an entity at a certain point, and deleting the unwanted section.

VIEW PLANE: The 3-D direction from which a drawing is viewed.

VIEW WINDOW: A particular display on the screen, which includes the view direction, drawing scale, and the center of the view.

VIEWPORTS: The ability to split the graphics window into a number of smaller windows, so the drawing may be viewed from multiple directions simultaneously.

WINDOW: Selecting a portion of the screen by selecting the corners of the "window". Used to select entities, change the drawing scale, etc.

WORLD COORDINATES: A coordinate system with a fixed origin.

ZOOM: Changing the viewing scale of a drawing.

APPENDIX B: SAMPLE EVALUATION

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## CHECKLIST

Name of Package: Package #1

### 5. EDITING

#### 5.1. Correction

##### 5.1.1. Delete

- last entity created
- from Entity Selection List (\*) delete by cursor select is a not key
- last 'n'-entities
- delete/keep option for each

##### 5.1.2. Undelete

- last entity deleted
- set of entities just deleted rather inconvenient
- all entities ever deleted
- masking possible

##### 5.1.3. Undo

- last operation
- last 'n'-operations
- undo/not-undo option for each

##### 5.1.4. Unselect (\*)

- last selection using back up key
- cursor selection (+)
- last 'n'-selections
- accept/reject unselection option for each

#### 5.2. Modifying entities

##### 5.2.1. Trim/break (+)

- intersection of entities for 2 cutting entities only, you may keep inner or outer section
  - two entities: one
  - two entities: both
  - intersection of single selected entity and multiple cutting entities
  - intersection of multiple selected entities and single cutting entity
  - intersection of multiple selected entities and multiple cutting entities
- at a distance along a line
- at a distance along other entities (\*)
  - along a circle/arc a number of degrees
- into two entities and separate (break only)
- into 'n'-sections (break only) breaks into 'n' section, but does not delete original line

### 5.2.2. Extend (+)

- to an entity
- to a plane
- from both ends of entity
- an arc into a circle
- key-in (+)
  - distance
  - angle

### 5.2.3. Stretch (\* +)

- lines and 'n'-gons (+)
  - one point at a time
  - multiple points
- arcs
  - by preserving included angle (\*)
  - by preserving distance between chord and arc midpoint (\*)

### 5.2.4. Splines (\* +)

- trim/break (+)
  - between nodes (\*) *Keeps original nodes to define spline*
  - spline recalculated (\*)
- modify
  - move node
  - endpoint constraint (\*)
- extend
  - with arc (\*)
  - with curve (\*)
  - with line (\*)

### 5.2.5. Modifying entity attributes (\*)

### 5.2.6. Change numbers in geometry database to edit part (\*)

- when using numbers from the function that allows verification
- by selecting the entity on the screen

## 5.3. Transforming entities

### 5.3.1. Mode

- move
- single copy
- join (+)
- rectangular array (+) *actually multiple copies in a single direction*
  - independent column/row spacing
- polar array (+)
  - rotating
  - non-rotating
- drag positioning (+)
- accept/reject option for positioning

### 5.3.2. Methods (\*)

- translate
  - by keying-in a vector (+)
  - by defining vector from reference point to new point
- rotate
  - about a point (2-D rotation)
  - about a line (3-D rotation)
- mirror (+)
  - about a line
  - about a plane
- scale (+)
  - axes independent of one another
- offset (\* +)
- project onto a plane
  - normal to projected entity(ies) → *this fits under other direction*
  - normal to plane receiving projection
  - other direction (\*)

### 5.4. Fillets, Rounds and Chamfers

#### 5.4.1. Creating fillets and rounds (+)

- radius
- point on fillet
- tangent at one endpoint and to another entity
- tangent at two endpoints
- tangent to three entities

#### 5.4.2. Creating chamfers (+)

- two linear dimensions
- dimension and angle
- dimension and length of chamfered edge
- angle and length of chamfered edge

#### 5.4.3. Features

- trim/not trim option (\* +) *for fillets only*
- fillet/chamfer all selected intersections

**NUMERICAL RATINGS FORM**

Name of Package: Package #1  
 Scale: 0-5

2.9

**5. EDITING**

Weights 0-4

2.2

**5.1. Correction**

		5.1	1	2	3	4	Total	
<u>4</u>	5.1.1. Delete	Weight	4	3	3	2	12	2.2
<u>2</u>	5.1.2. Undelete	Value	4	2	0	2		
<u>0</u>	5.1.3. Undo	Products	16	6	0	4	26	
<u>2</u>	5.1.4. Unselect							

3.5

**5.2. Modifying entities**

		5.2	1	2	3	4	5	6	Total	
<u>4</u>	5.2.1. Trim/break	Weight	4	4	3	3	2	1	17	3.5
<u>4</u>	5.2.2. Extend	Value	4	4	2	4	5	0		
<u>2</u>	5.2.3. Stretch	Products	16	16	6	12	10	0	60	
<u>4</u>	5.2.4. Splines									
<u>0</u>	5.2.5. Modifying entity attributes									
<u>0</u>	5.2.6. Change numbers in geometry database to edit part									

3.5

**5.3. Transforming entities**

		5.3	1	2	Total	
<u>3</u>	5.3.1. Mode	Weight	4	4	8	3.5
<u>4</u>	5.3.2. Methods	Value	3	4		
		Products	12	16	28	

2.0

**5.4. Fillets, Rounds, and Chamfers**

- 2 5.4.1. Creating fillets and rounds
- 2 5.4.2. Creating chamfers
- 2 5.4.3. Features

		5.4	1	2	3	Totals	
	Weight	4	4	2	10	2.0	
	Value	2	2	2			
	Products	8	8	4	20		

		5	1	2	3	4	Total	
	Weight	4	4	4	2	14	2.9	
	Value	22	35	35	20			
	Products	88	14	14	4	408		



PACKAGE	WEIGHTS	1	2	3	4	5	6	7	8	TOTALS
Package # 1	386									
	35									
	3D									
	1MB									
	1MB									
	Y									
	16									
	MS-DOS									
	22									
	22									
	IGES									
	CADL									
	M									
	4000									
	1.13 Price	4.4	2.9	3.3	2.9	2.9	2.4	3.9	3.0	22.7
	1.12. Installing Software	8.8	8.7	13.2	11.6	7.8	9.6	3.0		
	1.11. File Formats									
	1.9. Background									
	1.8. Operating Systems									
	1.7. 16 or 32 bit Packag									
	1.6. Math Co-processor									
	1.5. RAM Requirements									
	1.4. Hard Disk Space									
	1.3. Video Display									
	1.2 CPU									
	1.1. Package Type									
	2. Reference Lists									
	3. User Interface									
	4. Geometry									
	5. Editing									
	6. Detail Drafting									
	7. Display Capabilities									
	8. Other Features									

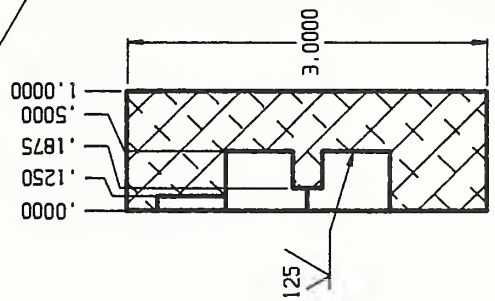
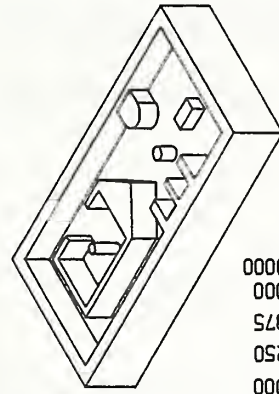
last rev. 27 AUG 91

scales: categories weights

CAD EVALUATION: SUMMARY SHEET

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REV	DESCRIPTION	DATE	APPROVED



B-B

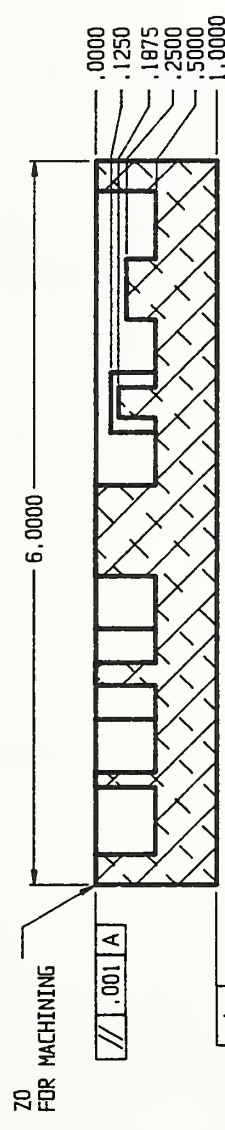
**NOTE:**  
**MATERIAL - ALUMINUM**  
**FINISH 63 MICROINCH EXCEPT AS NOTED**  
**INSIDE CORNER RADII NOT TO EXCEED .125"**

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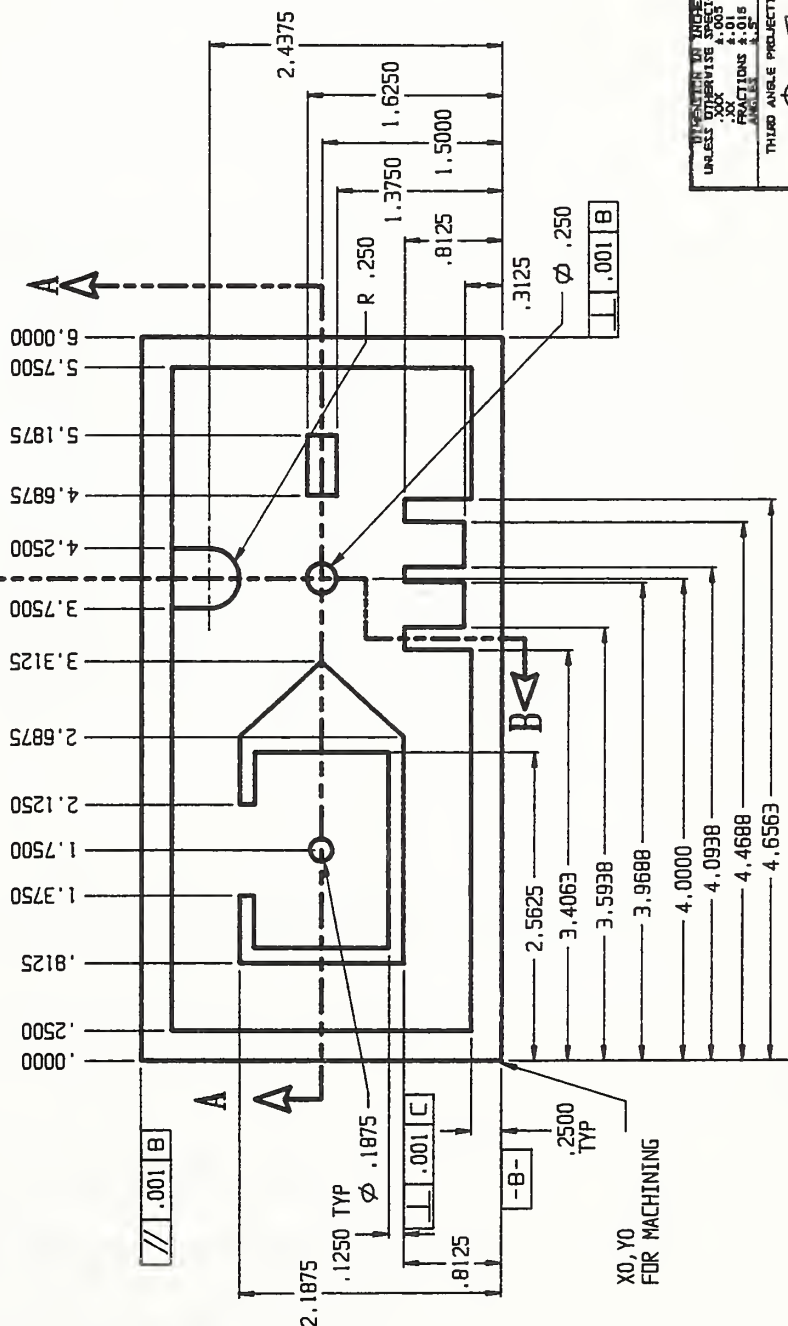
**CAD/CAM BENCHMARK PART**

UNLESS OTHERWISE SPECIFIED:  
 DIMENSIONS IN INCHES  
 DECIMALS 4.0005  
 FRACTIONS 2/32  
 TOLERANCES ±.01

THIRD ANGLE PROJECTION  
 DIV. SEC.  
 ORIGINAL DATE 6/17/81  
 DESIGNER  
 DRAFTSMAN  
 SCALE 1:1  
 DIM & TOL PER ANSI Y14.5  
 SHEET 1 OF 1  
 REV



A-A



Z0 FOR MACHINING

X0, Y0 FOR MACHINING

Surface finish symbol:  $\sqrt{\sqrt{.001 A}}$

Surface finish symbol:  $\sqrt{\sqrt{.001 B}}$

Surface finish symbol:  $\sqrt{\sqrt{.001 C}}$

Surface finish symbol:  $\sqrt{\sqrt{.001 B}}$

Surface finish symbol:  $\sqrt{\sqrt{.001 B}}$



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The "Shop Of The 90's" is a project within the Fabrication Technology Division (FTD) of the National Institute of Standards & Technology (NIST). Its purpose is to define the technology needed to modernize and improve small U.S. machine shops by using its own machine shop as a test-bed. This "Shop Of The 90's" document provides a methodology for small machine shops to benchmark Computer-Aided Design (CAD) packages. The initial step of the process is to determine a shop's CAD requirements, and to convert those requirements into specific CAD features. After determining the necessary features, the methodology is a three part process. Part one involves completing a checklist to determine which features are available on each CAD package. The second part consists of giving values to the features of the CAD package, biased toward the more important. Part three generates a weighted tally of each package. Employing this evaluation tool simplifies the difficult process of determining the most suitable CAD package for each individual shop.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

CAD Selection; Computer-Aided Design; Shop Of The 90's; software Evaluation.

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