Glossary

absolute coordinates (n) Coordinates associated with an origin that never changes location and thus gives a stable method of locating geometry in space. The absolute coordinate system is also called the *world* or *global* coordinate system.

absolute scale (n) A data scale that has both a defined zero point and units. The Kelvin temperature scale is an example of an absolute scale.

actual size (n) A tolerancing measure used to describe the size of a finished part after machining.

additive (adj.) A process or state whereby elements combine together, such as two primitive shapes combining to form a larger, more complex one. Additive is the opposite of subtractive.

additive primaries (n) The three primary colors: red, green, and blue. Color systems use these primaries in differing amounts, working on the principle of *adding* spectral wavelengths to the light energy to create new colors. This system is used in lighting and computer display graphics. The complementary colors are the subtractive primaries: cyan, magenta, and yellow.

adjacent areas (n) Surfaces that are separated on a multiview drawing by lines that represent a change of planes. No two adjacent areas can lie in the same plane.

adjacent view (n) Orthographic views that are aligned to each other, allowing dimensional information to be shared. Examples are the front and top views or the front and right side views.

aerial perspective (n) A perceptual cue where objects farther away appear bluer and hazier. The cue is based on the effect of particles in the atmosphere blocking the passage of light.

aerospace engineering (n) A field of engineering concerned with the design and operation of aircraft, missiles, and space vehicles.

aesthetics (n) The artistic qualities or aspects that elicit an emotional response to an object.

agricultural engineering (n) A field of engineering concerned with production agriculture and its natural resource base and the processing and chemistry of biological materials for food and industrial products.

aligned dimensions (n) A style of dimensioning in which text is placed parallel to the dimension line, with vertical dimensions read from the right of the drawing sheet. The *aligned method* of dimensioning is not approved by the current ANSI standards but may be seen on older drawings.

aligned section (n) A section view created by bending the cutting plane line to pass through an angled feature. The resulting section does not show the section in true projection, yet it gives the clearest possible representation of the features.

allowance (n) A tolerancing measure used to describe the minimum clearance or maximum interference between parts. Allowance is the *tightest* fit between two mating parts.

alphabet of lines (n) The standard linestyles established by ANSI to be used for technical drawing. The standards specify both the *thickness* and the *design* (i.e., dashed, solid, etc.) of the lines.

alternate four-center ellipse method (n) A method of creating an approximate ellipse. The method is used for cavalier oblique drawings.

ambient light source (n) A light source defined by its lack of orientation or location. Fluorescent lighting in an office is an example of ambient lighting. In renderings, an ambient light source is sometimes used as a default light source to give a baseline level of lighting to the model.

analogous (adj.) A concept meaning *similar* or *comparable* in some respects. The concept is used to describe the extent to which a graphic representation compares with a real object.

analysis by solids (n) A common technique used for determining the multiview drawings of a part by decomposing the object into geometric primitives, such as cylinders, prisms, and negative cylinders.

analysis by surfaces (n) A common technique used for determining the multiview drawings of a part that has inclined and oblique surfaces.

analytic geometry (n) The analysis of geometric structures and properties, principally using algebraic operations and position coordinates. The term also refers to a particular geometric method for describing 3-D solid models.

angle (n) The relative orientation of two linear elements with respect to each other. The angle is usually measured relative to the point of intersection or termination of the two lines.

angularity (n) An orientation control for geometric dimensioning and tolerancing. Angularity is a condition of a surface, center plane, or axis at an angle other than a right angle to a datum plane or datum axis.

aperture card (n) A long rectangular card with a rectangular hole for mounting microfilm.

apparent motion (n) The sense of motion induced by rapidly displaying a series of images of an object to make the object appear to change location or shape. Animation techniques take advantage of this perceptual effect.

archiving (v) A term used to describe the storing and retrieval process for engineering documentation. Although originally involving paper documents, the term increasingly refers to the storage of computer-generated information on magnetic or optical media.

area rendering (n) A data visualization technique in which the pixels in a 2-D area are each assigned a value. A color lookup table maps a specific color to each data value to create a rendered region.

array (n,v) Either the process of or resulting geometry of a single feature being duplicated in a regular fashion in a model. An array is procedural, in that instructions are given as to how a feature(s) is to be duplicated rather than having the user define the final location of each duplicate. Arrays are defined as being either linear or radial, depending on how the duplication is defined. Typically, the operator will indicate the direction (in one or two dimensions) of the duplication, spacing between each duplicate feature, and how many duplicates to create.

arrow plot (n) A visualization technique in which the dependent variable is a vector rather than a scalar and is represented by line or arrow marks. Because there are typically a large number of arrow marks in a small region, pattern (texture) perception can be used to evaluate trends in the data.

artistic drawing (n) A type of drawing used to express aesthetic, philosophical, and abstract ideas. These types of drawings are not intended to communicate clear, concise information pertaining to a design.

artwork drawing (n) *See* fabrication drawing.

assembly drawing (n) A drawing showing how each part of a design is put together. An assembly drawing normally consists of all the parts drawn in their operating positions and a parts list or bill of materials.

assembly section (n) A section view of multiple parts in an assembly. Differing section line designs differentiate between different materials, or between similar materials belonging to different parts.

augmented reality (n) A virtual reality system that combines or overlays computer graphics imagery with a normal view of a scene.

authoring (v) The process of using computer programming tools to assemble different media into an interactive presentation.

automation (n) The use of machinery in place of human labor.

autorouting (v) A specialized software process that suggests routing connections between components on a circuit board. Autorouting is usually part of a suite of CAD electronics software functions that also include automated component placement, programming of CNC board drilling, and component insertion equipment.

auxiliary section (n) A section view derived from an auxiliary view. The term distinguishes from section views derived from standard orthographic views.

auxiliary view (n) A view derived from any image plane other than the frontal, horizontal, or profile planes. Auxiliary views are usually termed *primary* or *secondary,* depending on whether or not they are perpendicular to one of the above-mentioned primary projection planes. Primary auxiliary views are termed depth, height, or width auxiliaries, depending on the dimension transferred from the measuring view.

axis (n) The line or vector representing a center of rotation, such as the longitudinal center line that passes through a screw thread cylinder. Also, a vector indicating a dimension in model space or in a visualization such as a graph.

axonometric axes (n) The axes used to define the orientation of the primary dimensions in an axonometric pictorial projection. The relative angle of the axes to each other determines the type of axonometric projection.

axonometric projection (n) A parallel projection technique used to create pictorial drawings of objects by rotating the object on an axis relative to a projection plane.

B

B2B (B2C-e-marketplaces) (n) Business communities are beginning to form e-marketplaces, enabling them to automate and leverage transactions with one another as a community. By bringing together large numbers of buyers and sellers, e-marketplaces give sellers access to new customers, expand the choices available to buyers and reduce transaction costs.

B-spline curve (n) A parametrically defined freeform curve that approximates a curve to a set of control points and provides for local control. Multiple 2-D curves are often combined to create 3-D surface patches.

backface culling (n) In rendering, a preprocessing step that removes all faces of the model that will be completely hidden from view.

bar graph (n) A graph (usually 2-D) in which one dimension represents the independent variable and the other represents the dependent variable. The magnitude of the dependent variable is represented by a line or area of uniform width (a bar).

base feature (n) The first feature created when defining a solid model. The base feature creates the initial geometry of the model from which additional geometry can be added or subtracted.

baseline dimensioning (n) A type of dimension where a base line (or datum line) is established for each Cartesian coordinate direction and all dimensions are specified with respect to those baselines. Also called datum or rectangular coordinate dimensioning.

basic dimension (n) A tolerancing measure used to describe the theoretically *exact* size of a feature.

basic size (n) A tolerancing measure used to describe the theoretical size used as a *starting point* for the application of tolerances.

bearing (n) A mechanical device designed to transfer radial or axial loads from a shaft while minimizing energy loss due to friction from the rotating shaft. Bearings are usually divided into two general categories: plain and rolling contact.

Bezier curve (n) A special case of the B-spline curve. Unlike a standard B-spline curve, the Bezier does *not* provide for local control, meaning that changing one control point affects the entire curve.

BI (business intelligence) (n) Consolidates and analyzes raw business data and turns it into conclusive actionable information. Enables companies to tap into disparate sources of customer, operational, and market data and then use this information to gain a competitive edge. It provides the intelligence needed to spot trends, enhance relationships, reduce financial risk, and create new sales opportunities.

bicubic surface patch (n) A 3-D freeform surface bounded by a set of curves described by third-degree (cubic) functions. The bounding curves, often B-spline or Bezier curves, and their associated control points are used to manipulate the shape of the surface.

bilateral tolerance (n) A dimensioning technique that allows variance in both directions from the basic size of a part or feature.

bill of materials (n) A listing of parts or materials used in an assembled object. The listing is usually included as part of the working drawing of the full assembly.

binary tree (n) A hierarchical, logical structure used to organize related elements. Each node on the tree is linked to exactly *two* leaves on the next level down. Binary trees are used to describe the relationship of geometric elements in a CSG solid modeler.

bird's eye view (n) In a perspective pictorial, a viewpoint looking *down* from above the object. From this viewpoint, the ground line is below the horizon line of the object.

blind hole (n) A hole that does not go completely through the material. Blind holes can be created by any cutting device (such as a twist drill bit) that is capable of plunging into the material.

block diagram (n) A relatively simple diagram that quickly identifies the relationships between systems, groups, people, or other physical or abstract entities. (*See also* flow diagrams.)

blueprint (n) A photographic reproduction process used to copy paper drawings.

boldface (adj.) A style of text in which the lines that make up the letters are thicker than normal. This technique is used to make words or letters stand out visually from the rest of the text.

bolt (n) A mechanical fastening device with a head on one end of an externally threaded shaft. A nut is placed on the threaded shaft and rotated to clamp the material between the head and nut.

bonding (v) A process in which a material (usually, a hardening liquid) is added to an assembly to hold parts together. Bonding is a *permanent* fastening method, using processes such as welding, soldering, brazing, and gluing.

Boolean operations (n) Local operations used to define the relationship between two geomet-

ric objects. Boolean operations between new and existing geometry are used extensively to modify solid models in 3-D modeling software.

bottom view (n) A principal view of an object, created by rotating the object 90 degrees about the horizontal axis *below* the front view. This view is not typically included in a standard multiview drawing.

boundary representation (B-rep) (n) A popular method of representing solid models. This database structure describes the geometric and topological elements of the surface of the model. Unlike wireframe modeling, a B-rep explicitly defines the surface of the model. Unlike CSG modeling, a B-rep does not explicitly define the interior volume of the object.

bounding box (n) An imaginary box representing the *maximum* dimensions of the object being drawn. Sketches of objects often begin with this box, and it is used to define the boundaries and guide the placement of individual features.

brainstorming (v) A process used to identify as many solutions to a design problem as possible by freely suggesting ideas without criticism or discussion of feasibility. A brainstorming session will normally have a moderator and a recorder.

break lines (n) Freehand lines used to show where an object is broken to reveal interior features of a part. Such lines can also be used to show where a portion of a line or object has been left out for clarity or because of space limitations.

broken-out section (n) A section view used to reveal interior features of a part by breaking away a portion of the object. A broken-out section is often used instead of a half or full section view when the feature of interest is not symmetrical with the overall object. The result is a more efficient drawing. Unlike most other section views, a cutting plane line is not defined in an adjacent view.

bump mapping (n) A rendering technique used to add surface detail to a model. Bump mapping perturbs the normals used in shading the surface polygons in such a way as to give the impression of a regularly undulating surface (i.e., texture). A golf ball could be represented as a shaded sphere, with the dimples created through bump mapping.

C

cabinet oblique (n) A type of oblique pictorial drawing in which the two dimensions of the frontal surface are drawn parallel to the frontal plane, and the third (receding) axis is drawn obliquely at *half* the scale of the frontal plane.

The receding axis is typically drawn at an angle of between 45 and 60 degrees.

cabling diagram (n) *See* wiring diagram.

CAD (v or n) Acronym for *computer-aided drafting, computer-aided design,* or *computer-aided design/drafting*. The usage depends on the context in the design process and on whether the acronym refers to the physical computer system or the activity of using such a system to support technical and engineering graphics.

callouts (n) *See* line balloon.

cam (n) A mechanical device used to transform rotary motion into reciprocating motion, using a rolling or sliding contact with another part called a cam follower. Radial cams move the follower perpendicular to the shaft; cylindrical cams move the follower parallel to the shaft. The shape of the contact surface determines the motion of the follower.

CAM (n) Acronym for *computer-aided manufacturing*, which is the use of computers to control the production process. Examples are robots for assembly and numerically controlled machine tools. CAM is often combined with CAD to describe the integration of design and manufacturing through the use of a common computer database.

cam follower (n) A mechanical device in which one end follows a linear, reciprocating path as the other end traces the surface of a rotating cam. Followers are often spring loaded to guarantee a good contact with the surface of the cam.

cap screw (n) A mechanical threaded fastener with a head on one end, used to screw into a mating part. Differing from a bolt, a cap screw has a longer thread length and does not use a nut.

CAPP (n) Acronym for *computer-aided process planning*, a technique that uses computers to assist in the planning process. CAPP is an expert computer system that can be used to determine the optimal sequence of operations for a part and can then generate the optimal process and routing sheets necessary to make the part.

Cartesian coordinate system (n) Common coordinate system used in mathematics and graphics to locate the position of geometry in space. First introduced in 1637 by Rene Descartes (1596–1650), the system is typically used to locate points in 2-D (X,Y) or 3-D (X,Y,Z) space by assigning values to the points based on the mutually perpendicular (orthogonal) axes.

cavalier oblique (n) A type of pictorial drawing in which the two dimensions of the frontal surface are drawn parallel to the frontal plane,

and the third (receding) axis is drawn obliquely to the frontal plane and at the *same* scale. The receding axis is typically drawn at an angle of between 45 and 60 degrees.

CAVE® (n) A multiple projection based virtual reality system consisting of multiple screens and projectors configured into walls, floor, and ceiling to create a room is called a CAVE® (Cave automatic virtual environment).

CD-ROM (n) Acronym for *compact disc-read only memory,* a mass storage device that uses optical technology to store large amounts of information on a small reflective platter. Information is written to the disk only once, at which point the disk is unchangeable. CD-ROMs are used for archiving audio, graphic, and textual information and for publishing and distributing software, graphic images, multimedia materials, etc.

center lines (n) A type of linestyle used to represent symmetry and paths of motion and to mark the centers of circles and the axes of symmetrical parts, such as cylinders and bolts. Unlike visible and hidden lines, center lines do not represent geometry directly.

central view (n) The view from which related views are aligned in an orthographic drawing. Distances and features are projected or measured from the central view to create the adjacent views.

ceramics (n) Materials, usually with crystal structures, created from compounds of metallic and nonmetallic elements. Ceramics can withstand high temperatures and resist wear. Some ceramics, such as glass, are not crystalline in structure.

chain line (n) A type of line in the alphabet of lines represented by alternating short and long dashes.

chamfer (n or v) A beveled corner used on the opening of a hole and the end of a cylindrical part to eliminate sharp corners. Chamfers facilitate the assembly of parts and are specified by giving a linear and angular dimension. When used as a verb, the term refers to the process of creating a chamfer on an object.

change of planes (n) A feature sometimes called a corner which occurs when two nonparallel surfaces meet, forming an edge.

check print (n) A type of hard-copy output used to check the accuracy and format of a technical drawing. The check print is a *low-quality, high-speed* method of troubleshooting the final print or plot.

chemical engineering (n) A field of engineering that includes all phases of technical activities in which a knowledge of chemistry, along with other basic sciences, is used to solve problems related to energy, health, the environment, food, clothing, shelter, and materials.

CIM (n) Acronym for *computer-integrated manufacturing,* a system for linking manufacturing operations into a single integrated computer system. CIM differs from CAD/CAM primarily in its integration of business functions, such as accounting, marketing, and personnel, into a common computer database shared by all components of the business.

circle (n) A closed, planar curve that, at all points, is an equal distance (the radius) from a point designated as the center. A *circular arc* is an open, planar curve equidistant from a center. The arc will subtend an angle of less than 360 degrees. A circle is sometimes described as a 360-degree arc.

circuit side (n) The side of a printed circuit board on which a majority of the circuit connections for components are made. The opposite side of the board is called the component side.

circularity (roundness) (n) A form control for geometric dimensioning and tolerancing. For a cylinder or cone, circularity means that all points on a surface intersected by a plane passing perpendicular to a common axis are equidistant to that axis. For a sphere, all points on a surface intersected by a plane passing through the center are equidistant to that center.

circular line element (n) A geometric control used in GDT that is any single line on the surface of a cylinder and perpendicular to the axis of the cylinder.

civil engineering (n) A field of engineering involved with planning, design, construction, operation, and maintenance of transportation, environmental, and construction systems. Along with military engineering, this field is often considered the first true engineering field.

clash (v) A condition in which two parts of a mechanism *partially overlap* in space, causing interference. Kinematic analysis using the Boolean intersection operation is often used to evaluate clashes in computer models of the mechanism.

clearance fit (n) A tolerancing measure used to describe a fit in which two mating parts always leave a space when assembled. The resulting space is called an *allowance* or a clearance and is usually specified in the assembly drawings.

clip (v) The rendering process of removing portions of lines or surfaces that reside outside the view volume. Clipping refers to removing the portion of the model that resides outside the horizontal and vertical bounds of the viewing area and outside the specified near and far depth (Z) bounds.

clock speed (n) The rate at which the central processing unit (CPU) of a computer performs functions. The clock speed is measured in megahertz (MHz). The *higher* the clock speed, the *more powerful* the CPU.

closed loop (n) The condition required for a group of edges to form a face (surface) on an object. The edges must be connected end to end, forming a continuous path around the perimeter of the face.

CNC (n) Acronym for *computer numeric control,* which describes a form of programmable automation of a machine tool using a computer in the controller unit. In a computer-controlled manufacturing center, the individual machines would use CNC programs, either sent from a main computer or programmed locally.

collaborative engineering (n) An integrated product development process to create a highly effective team collaboration environment.

color (n) The perceptual quality of a surface that results from the combined response to lightness, hue, and value. Hue is often confused with color since the names of hues (e.g., red, purple, yellow, etc.) are used as the primary classification terms for color.

color lookup table (n) A modular database that allows colors to be mapped to specific data values in a visualization. The color lookup table can be associated with a single rendered image or be used as a standard table in a library. Color lookup tables are often referred to as *palettes.*

command history (n) A listing of commands entered into the CAD system by the user, along with the values of the specified parameters. Command histories can be used as a "script" to replay sequences of commands or track down input errors.

composites (n) The combination of two or more materials, one a *reinforcing* element and the other a *resin* binder or matrix. A common composite is fiberglass, which is made of glass fibers and a resin. The more advanced reinforcing elements include carbon/graphite, boron, and Kevlar (aramid), which are stiff, strong, and lightweight.

computer animation and simulation (n) Simulation is the *precise* modeling of complex situations that involve a time element; animation is the *imprecise* modeling of complex situations over time. An animation will replicate a real situation by approximate means; a simulation will replicate a real situation by accurate means.

computer numeric control (CNC) (n) *See* CNC.

computer-aided drafting/design (CAD) (n) *See* CAD.

computer-aided manufacturing (CAM) (n) *See* CAM.

computer-integrated manufacturing (CIM) (n) *See* CIM.

concentricity (n) A condition in which the axes of all cross-sectional elements of a cylinder, cone, or sphere are common to a datum axis.

conciseness (adj.) A term used to describe one attribute of a CAD database. The more concise the database, the *less space* each record takes in the hard drive of the computer.

concurrent (adj.) The technique of organizing numerous steps so that they happen in *parallel* rather than one after another (serially). Concurrent engineering, for example, involves all members of the design process working simultaneously in close coordination with each other rather than each member waiting for other members to finish with their components of the design.

cone (n) A geometric solid described by a straight line (the generatrix), one end of which is attached to a fixed point (the vertex) and the other end of which traces a closed, curved path. The most common cone is a right circular cone, for which the curved path is a circle and the vertex lies on an axis that is perpendicular to the circle and through its center.

cone of vision (n) A term used to describe the amount of space visible by the human eye looking in a fixed direction. The visible volume is approximately described by a right-angled cone for which the vertex is at the eye and the axis is aligned with the view direction.

conics (n) Special case single-curved lines that can be described in many different ways: sections of a cone, an algebraic equation, and the locus of points. For our purposes, conics are sections of a right circular cone and include the ellipse, parabola, and hyperbola. The circle is a special-case conic.

connection list (n) The list of all connections that need to be made between components on an electronic circuit board. This list is usually managed by the electronic CAD program.

connectors (n) Devices used to join electronic components together to allow the transmission of signals. Connectors include plugs (external components) and jacks or receptacles (internal components) and can provide either temporary or permanent connections. Devices used for mechanical connection are typically called fasteners.

constant pitch series thread (n) A type of thread used for special purposes.

constraint (n) A mathematical requirement placed on geometric elements in a 3-D model. Dimensional constraints define the distance between two geometric elements while geometric constraints define a relationship such as parallelism or perpendicularity between elements. The operator establishes an explicit constraint while the software automatically places an implicit constraint. A fully constrained feature has all of its geometry unequivocally defined while an underconstrained feature does not. An overconstrained feature has conflicting geometric requirements.

construction geometry (n) Any geometry created as part of the CAD modeling process that does not represent actual part geometry. An example of this would be workplanes, axes, or points used to locate geometry in a solid model.

construction lines (n) Light, thin lines drawn to lay out the framework or structure of a drawing or sketch. Portions of these lines are often overdrawn with the final linework.

constructive solid geometry (CSG) (n) A method of 3-D solid modeling in which geometric primitives are related to each other in a binary tree structure via Boolean operations. Each primitive is defined as a solid by a group of analytic surfaces (half-spaces), and the final object is defined by the calculation of the Boolean operations between primitives.

continuity (n) A term used to describe the *transition* between two elements. Elements are continuous if there is no gap or break between them, and there is a single mathematical function used to describe the two combined elements. Continuity is often used to describe the connection of two curved lines or surfaces.

contour line (n) A line that represents the independent variable (X,Y) combinations that result in a *constant* dependent variable value (also called an isoline). A contour line can also represent the juncture between two surfaces of differing orientations or depths. In this definition, a contour line is an alternate term for edge.

contour plot (n) A visualization in which the horizontal and vertical scales both represent independent variable values, and the contour lines show the mapping of *constant,* dependent variable values. Multiple contour lines are typically drawn on a plot, representing a uniform sampling of dependent variable values.

contour sketch (n) A technique to develop the visual acuity of a novice sketcher by sketching the outline of an object.

control points (n) Points used in conjunction with spline curves. These points are not part of the curve proper, but the relationship between the control points and the points on the curve is used to define the shape of the curve.

controlling (v) The procedures used to control materials, machines, and processes in the manufacturing and production cycle through automation, measuring, inspection, and testing.

conventions (n) Commonly accepted practices, rules, or methods. In technical drawing, a convention is the use of dashed lines to designate a feature hidden from the current viewpoint.

convolute (n) A single-curved surface generated by a straight line moving such that it is always tangent to a double-curved line.

Coons' surface (n) A 3-D surface defined by input curves. This surface was named after Steven A. Coons, who developed the mathematical method for defining complex shapes used in the design of aircraft, automobiles, and ships' hulls.

coordinate dimensioning (n) A technique in which all dimensions are calculated as Cartesian X and Y distances from an *origin point,* usually located at the lower left-hand corner of the part. Also known as *datum* dimensioning or *baseline* dimensioning, coordinate dimensioning should be used cautiously because of the tolerance stackup that takes place.

coordinates (n) A set of real numbers defining the location of a point in space. One value is given for each dimension of the space (i.e., 2-D, 3-D), and each value is determined by the point's distance from the defined origin.

corner (n) The nontangential intersection of two or more surfaces of an object. The intersection of two surfaces is usually referred to as an *edge.* Corners are represented on a drawing by either a single line or multiple co-terminating lines.

counterbored hole (n) A type of hole that has been enlarged at the top to allow heads of bolts to be flush with or below the surface of the part.

countersunk hole (n) A type of hole that has been enlarged at the top to allow heads of flat head fasteners to be flush with or below the surface of the part.

course series thread (n) A type of thread used for quick assembly or disassembly which is designated as NC or UNC on drawings.

CPU (n) Acronym for *central processing unit*. The CPU is the heart of the computer, coordinating all primary activities of the computer and processing a majority of operations or "calls" from the software. Computers are often classified by their CPUs. Examples are Intel's Pentium^{TM} and Motorola's PowerPC^{TM} 601.

crest (n) A threading term describing the *peak* or *top* surface of a screw thread.

CRM (customer relationship management) (n) Use proven methodologies and e-business technologies to help enable companies to identify, select, acquire, develop, and retain profitable customers, building the lasting relationships that are key to long-term financial success.

cross-hatch lines (n) An alternate term for section lines. Cross-hatch often refers to section line symbols in which the lines *cross* each other rather than simply running parallel to each other.

curved line (n) A line which does not follow a straight path. Curved lines are often classified by their underlying mathematical functions. Examples are circular and elliptical curves.

cutting plane (n) An imaginary plane in space used to define the division between two parts of an object. A cutting plane is often used to define a portion of an object to be removed in order to reveal the interior detail.

cutting plane lines (n) A line showing the location of a cutting plane in section drawings. The cutting plane line is drawn in the view for which the line of sight is parallel to the cutting plane. Arrows on the ends of the section line point toward the material to be retained in the corresponding section view.

cycle time (n) The total time required for a process to take place.

cycloid (n) A curve generated by the motion of a point on the circumference of a circle that is rolled in a plane along a straight line.

cylinder (n) A planar geometric solid described by a straight line (the generatrix) that traces a closed, curved path and always stays parallel to itself. The most common cylinder is a right circular cylinder for which the curved path is a circle and the generatrix is perpendicular to the path.

cylindrical coordinates (n) A system for locating points in space with one angle and two lengths. Cylindrical coordinates describe a point as a distance from the origin, its angle in the X–Y plane, and its Z value. Cylindrical coordinates are useful when designing circular shapes and geographic applications.

cylindricity (n) A form control for geometric dimensioning and tolerancing. Cylindricity indicates that all points on the surface should be equidistant from a common axis. Unlike circularity, cylindricity refers to both the circular and the linear (longitudinal) elements on the surface.

D

data region (n) The region in a visualization where the actual data is represented. In a graph or plot, the region would be bounded by the scales (axes) where the point or line markers representing the data are drawn.

data visualization (n or v) The method or end result of transforming numeric and textual information into a graphic format. Visualizations are used to explore large quantities of data holistically in order to understand trends or principles.

datum (n) A theoretically exact point, axis, or plane used as a reference for tabular dimensioning. A datum marks the *origin* from which the location and orientation of geometric features are established.

datum dimensioning (n) A type of dimension where a base line (or datum line) is established for each Cartesian coordinate direction and all dimensions are specified with respect to those

baselines. Also called rectangular coordinate or baseline dimensioning.

datum feature (n) A term used in geometric dimensioning and tolerancing to describe a real or theoretical feature selected to ensure the proper orientation or location of other features on a part. Controls define features on the part relative to the datum features.

datum feature symbol (n) A symbol on a drawing to identify the features used to create the datums.

datum reference frame (n) A term used in geometric dimensioning and tolerancing to describe the theoretical reference frame used to evaluate the location and orientation of features of a part. The frame consists of three mutually perpendicular (orthogonal) planes, which typically correspond to the principal planes of projection in a multiview drawing or the global coordinate system in a 3-D modeling system. In inspections, a physical surface may be established to simulate one of the reference planes.

declarative information (n) A term used to describe the current state of an object. This type of information can be thought of as *descriptive* nouns. The location of a point in a coordinate system (8,3,5) is an example of declarative information.

density slicing (n) A visualization technique, used with area and volume renderings, in which a particular data value or small range of values is *highlighted* in contrasting color. This technique can be used either for a single static image or for sequential images highlighting different data values in the image.

dependent variable (n) A variable dependent on the response of the model and not controlled by the experimenter. Every dependent variable value is paired with one or more independent variables and represents the model's response to the independent variable values.

depth (n) One of the three principal dimensions of an object. The depth dimension is described in the right side and top views of a multiview drawing. The depth dimension is often associated with the Z axis in a 3-D modeling system. Depth can also refer to the distance cut into an object using a machining process (e.g., the distance measured between the crest and root of a thread normal to the axis or the depth of a drilled hole).

descriptive geometry (n) The fundamental basis of the science of projection drawing, attributed to the work of Gaspard Monge (1746–1818). It is the basis of all types of 3-D representations on 2-D media used today.

design analysis (n) The evaluation of a proposed design during the refinement process, using the criteria established in the ideation phase. The refinement stage is normally the second of three major phases in the design process.

design for manufacturability (DFM) (n) A technique in which ways are found to simplify a design and reduce manufacturing costs. Using CAD/CAM technology, DFM determines the manufacturability of a design before it is produced.

design intent (n) A phrase describing the integration into the model of how feature dimensions and geometry relate to each other in order to satisfy the design constraints of the final product. Design intent is usually embodied in the model through the definition of features and their constraints.

design process (n) The method used to create a solution to an engineering or technical problem. The result is often a product, either one of a kind or mass produced. The design process, though unique to each problem, typically includes standard stages and uses graphics to communicate information between and within these stages.

design review (n) A formal meeting where the design team presents their progress to management.

design visualization (n) A process using the fundamental capabilities of a human visual system; the ability to perceive 3-D form, color, and pattern. Visualization is an analysis method used in the second stage of the design process, the refinement phase.

detail drawing (n) A dimensioned multiview drawing of a single part, using ANSI standard conventions to describe the part's shape, size, material, and finish. Detail drawings are sufficiently descriptive that the part can be manufactured using the drawing as the only communications device. Detail drawings are produced from design sketches or extracted from a 3-D computer model.

development (n) An alternative description of the surfaces of a 3-D object as a 2-D pattern. The creation of a development is often thought of as an unfolding of the surfaces of an object. A *developable surface,* then, can be unfolded or unrolled onto a plane without distortion. Single-curved surfaces, such as cylinders and cones, are also developable.

deviation (n) A tolerancing measure used to describe the *difference* between the size of a produced part and the basic size.

DFM (n) *See* design for manufacturability.

diameter symbol (n) A symbol used in ANSI dimensioning that precedes a numerical value, indicating that the value shows the diameter of a circle. The symbol used is the Greek letter phi (ø).

diazo (n) A type of print process used to copy paper drawings.

difference (−) (n) The Boolean operation that *subtracts,* or removes, the intersecting geometry from the specified solid. For example, in the Boolean operation A − B, the intersection of solids A and B is removed from A.

diffuse (adj.) A term describing a reflection of light that strikes a surface and reflects *uniformly* in all directions, creating no highlights or hot spots.

digital enterprise (n) A model that facilitates the simultaneous working of many departments in a company.

digital terrain model (DTM) (n) A 3-D computer model of a landform generated from survey data. Such models are often used by civil engineers and land planners to explore possible placements of structures or changes to the terrain before actual construction begins.

dihedral angle (n) The angle between two planes. Finding the true measurement of a dihedral angle requires an edge view of the two planes and is a common application for the use of auxiliary views.

dimension (n or v) The physical size of an object, or the process of documenting physical sizes. The number of dimensions used to describe the object depends on whether length (1-D), area (2-D), or volume (3-D) is being measured. Dimensioning can also refer to the measurement of size, location, and orientation of particular features on an object.

dimension line (n) A thin, solid line that shows the extent and direction of a dimension. Dimension lines are paired with the number representing the physical size of the feature, and extension lines are used to associate the dimension to the corresponding feature on the drawing.

dimetric projection (n) An axonometric projection in which two of the three axes have the same scale and the same angle relative to the third axis. A dimetric drawing is less pleasing to the eye than a trimetric projection but is easier to draw.

direct data exchange (n) A method of data exchange between CAD systems. Data is *directly* translated from the format native to one system to the format native to another system.

direct view (n) A descriptive geometry technique (sometimes referred to as the *natural method*) that places the observer at an infinite distance from the object, with the observer's line of sight perpendicular to the geometry in question. In third-angle projection, a projection plane is placed between the observer and the object, and the geometry is projected onto the projection plane.

directrix (n) A line (typically curved) that describes the path of a straight line (the generatrix). The path of the generatrix along the *directrix* describes ruled surfaces or solids.

discretization (n) The method of dividing more complex geometry into simpler geometry. A *discretized model* can be manipulated using techniques such as finite element analysis, in which all the simple geometric components of a model are evaluated simultaneously.

displacement (n) The linear or angular distance moved by a part or mechanism. In cam design, a displacement diagram is used to chart the linear location of the follower relative to the angular position of the cam.

displacement diagram (n) A graph or flat pattern drawing of the travel of the follower on a cam.

display devices (n) The hardware used to display output text and graphics of computer software, such as CAD. The most common display device is the cathode ray tube, or CRT, used in computer monitors.

dither pattern (n) A method of simulating varying value (gray) levels within an image when only one color of ink (usually black) is available. The patterns are achieved by grouping square matrices of pixels in an image (e.g., 3×3) and coloring a pattern of pixels in the matrix, based on the average value level in the matrix region. Because of the small size of the pixels relative to the size of the image, the pixel patterns give the impression of value changes when viewed at a distance.

documentation (n) The process used to formally record and communicate the final design solution.

document sketches (n) A more formal type of freehand sketch used during the refinement stage of the design process. These sketches often contain many of the conventions found in more formal drawings.

domain (n) A term that describes the types of objects that can or cannot be represented by a computer modeler. The larger the domain, the greater the number of objects the CAD system can describe.

donut (n) *See* feed-through.

double-curved surface/line (n) A surface or line that curves in two orthogonal dimensions at the same time. A sphere is an example of a double-curved surface.

double-line drawing (n) *See* piping drawing.

drawing number (n) Drawings used in industry are assigned a number which is normally placed in the title block.

drill drawing (n) *See* fabrication drawing.

drawing exchange format (n) *See* DXF.

drilling (v) A process that uses a rotating cutting tool to produce holes. It can also refer more specifically to a process that produces holes using twist drill bits.

DTM (n) *See* digital terrain model.

DXF (n) Acronym for *drawing exchange format,* a nonproprietary CAD data format developed by Autodesk to facilitate the exchange of CAD-based graphic information. It has become a *de facto* neutral data exchange format for the microcomputer CAD industry.

dynamic analysis (n) The evaluation of a design as it changes over time. Unlike kinematic analysis, dynamic analysis assumes that forces (e.g., gravity, angular momentum) are both *acting on* and *created by* the mechanism being analyzed.

E

E-business (n) The process of using Web technology to help businesses streamline processes, improve productivity, and increase efficiencies. Enables companies to easily communicate with partners, vendors, and customers, connect back-end data systems, and transact commerce in a secure manner.

E-business infrastructure (n) The hardware and software technology necessary to support the day-to-day activities in the digital enterprise.

ECO (n) *See* engineering change order.

E-commerce (n) The ability to buy and sell products and services over the Internet. Includes online display of goods and services, ordering, billing, customer service, and all handling of payments and transactions.

edge (n) The intersection or boundary of two nontangential surfaces (faces). An edge is represented on a technical drawing as a line or a change in shading gradients in a rendered image.

edge view (n) The view of a surface such that it is seen as a line. For a planar surface, the edge view is an orthographic view parallel to the plane in which the surface resides.

efficiency (adj.) With respect to CAD, the *speed* with which software can execute a command. This is reflected in the amount of computer processing time required to execute a command.

elastomers (n) A special class of polymers that can withstand elastic deformation, then return to their original shape and size. Natural rubber, polyacrylate, ethylene propylene, neoprene, polysulfide, silicone, and urethane are types of elastomers.

electrical engineering (n) A field of engineering that includes the research, development, design, and operation of electrical and electronic systems and their components.

elevation drawing (n) A type of drawing commonly used in civil, architectural, or engineering projects involving large structural layouts. An elevation drawing (sometimes called an elevation view) is an orthographic view perpendicular to the line of gravity (i.e., parallel to the terrain). These drawings are useful in planning the vertical arrangement of compo-

nents within a structure, or of the structure relative to the terrain, and are also used to make aesthetic judgments since this view closely matches how the structure would be seen.

ellipse (n) A single-curved line primitive. An ellipse is a conic section produced when a plane is passed through a right circular cone oblique to the axis and at a *greater* angle with the axis than the elements. An ellipse also describes a circle or circular arc viewed at any angle other than normal (perpendicular).

engineer (n) A professional concerned with applying scientific knowledge to practical problems. The discipline is divided into a number of specialties, such as civil, mechanical, chemical, electronic, aerospace, electrical, and industrial engineering.

engineering change order (ECO) (n) A document that begins the process for making changes in a design. Normally, the ECO will be documented in an engineering change note (ECN). A copy of the engineering drawing is attached to the order, with sketches and a written description of the change. A reference number is given to the change order so that it can be traced within the organization.

engineering design (n) A process used to design a new system or process.

engineering digital management system (EDMS) (n) Database software tool used to manage digital drawing files.

engineering graphics (n) A communications method used by engineers and other technical professionals during the process of finding solutions to technical problems. Engineering graphics are produced according to certain standards and conventions so that they can be read and accurately interpreted by anyone who has learned those standards and conventions.

enterprise data management (EDM) (n) A process using computer software to track CAD or office documents. Sometimes called enterprise document management (EDM).

enterprise document management (EDM) (n) A process using computer software to track CAD or office documents. Sometimes called enterprise data management (EDM).

envelope principle (n) A term used in geometric dimensioning and tolerancing to describe how much a feature can deviate from ideal form, orientation, or position as it departs from maximum material condition.

equal measure projection (n) Also called an isometric projection. A type of pictorial projection created when all three angles of the axonometric axes are equal.

ergonomics (n) A technical field concerned with optimizing the interface between humans and technology. The field has numerous specialties, including industrial safety and

hygiene, human–computer interface design, and the design of control panels in manufacturing plants, cars, airplanes, etc.

ERP (enterprise resource planning) (n) Helps businesses streamline and manage critical operations such as inventory maintenance, supplier interaction, product planning, purchasing, customer service, and order tracking. Supported by multi-module application software, it links together fragmented operations and shares data across an integrated set of application modules.

error bar (n) A mark added to data points in graphs and plots to indicate the range of probable values. Since perfect accuracy is not possible in any kind of experimental method, the error bar represents the *degree of certainty* in the data value. The length of the bar usually represents the statistic of standard deviation.

error checking (v) The process of evaluating actions requested by the operator to determine if such actions resulted in invalid geometry. Depending on the system, error checking may be done automatically (such as when a file is saved to disk) or manually at the request of the user.

etching (n) The method of creating patterns, typically in metal, using chemical processes. In the electronics industry, etching is used to remove conductive material, usually copper, from printed circuit boards to create wiring patterns. The wiring pattern is printed on the board in a chemically resistant ink, and the rest of the conductive material is then dissolved away in a chemical bath.

Euler operations (n) Low-level operations used to construct models from geometric primitives, such as vertices, edges, and faces. The validity of the model is guaranteed by a simple mathematical formula, credited to both Leonhard Euler (1707–1783) and Jules Henri Poincaré (1854–1912).

evaluated (adj.) A description of a model for which the final form is *explicitly* represented in the database. An evaluated model is not concise (it may take up large amounts of memory), but it is efficient (calculations on the model are processed quickly).

exploded assembly (n) An assembly drawing, usually a pictorial, in which the parts of the assembly are spread apart (exploded) from their functional location in order to provide a larger, clearer view of the features of the individual parts. Flow lines are used to relate the parts to each other and to demonstrate assembly. This type of assembly drawing is used extensively for technical illustrations in such applications as parts catalogs and assembly instructions.

exposure (n) The orientation of a principal surface of an object relative to the image plane. The greater the exposure, the closer the surface(s) is to being parallel to the image

plane and, therefore, the lower the distortion caused by foreshortening.

extension line (n) A thin, solid line perpendicular to a dimension line, indicating which feature is associated with the dimension.

extra fine series thread (n) A type of thread used when the length of engagement is short and the application calls for high degrees of stress and are designated NEF and UNEF on drawings.

extranet (n) Private secure networks that allow access to a company's internal intranet by outside entities.

F

fabrication drawing (n) An electronics drawing that presents the complete engineering for the manufacture of a printed circuit board. The fabrication drawing contains an accurate to-scale layout of the board shape, drill hole locations, material and manufacturing specifications, and conductor pattern. The conductor pattern is broken out to make an artwork drawing, a screen print drawing, and the mask used in board etching. The drill hole information is sometimes broken out into a separate drawing for use in programming the drill patterns.

face (n) A distinct planar or curved surface or region on an object. One or more faces joined together at edges define the boundary between object and nonobject. A face is a topological element in a 3-D model.

face-edge-vertex graph (n) The data structure used by boundary representation (B-rep) 3-D solid modelers. The graph contains both *geometric* information on the location and size of geometric elements and *topological* information on how they are linked together.

facets (n) Repeating groups of polygons of similar topology, forming an approximate representation of a curved surface. Curved surfaces such as cylinders and spheres are subdivided into a series of faceted planar surfaces, which approximate the original surface. This transformation is often used so that curved surfaces can be rendered using algorithms that only support planar surfaces.

faithful (adj.) A measure of whether a computer model contains or imparts *sufficient information* to fulfill its task. In order to define the faithfulness of a model, the exact use of the model must be known.

familiar size (n) A perceptual cue in which the known (familiar) size of an object is used to judge its distance from the observer. Often, the comparison of the perceived size of two objects is used to judge their relative locations in depth.

family of parts (n) Similar parts that can be grouped together. A family of parts might be a series of air cylinders that have many common

topologies but have variations in the geometry of certain features, such as the diameter or length of the head. Parametric techniques can be used to represent a family of parts on the computer or in drawings.

fastener (n) A mechanical device that constrains two or more parts. Fasteners can rigidly join parts or can allow certain degrees of freedom. Some fasteners are meant to be disassembled for maintenance (e.g., screws and bolts), while others are considered permanent (e.g., rivets).

feature (n) A general term applied to physical portions of a part. Features typically serve a function, either in the final application of the part or in the specification or manufacture of it. Examples are a hole, slot, stud, or surface.

feature control frame (n) A rectangular outline containing geometric dimensioning and tolerancing information used in the engineering, production, and inspection of a part. The left-hand compartment inside the frame contains the symbol of the geometric control being applied. The middle compartment contains the size of the tolerance zone. The right-hand compartment contains the datum identification symbol(s).

feature of size (n) A feature that is measurable; specifically, a spherical or cylindrical surface, or a pair of parallel plane surfaces, associated with a feature.

feature tree (n) A computer interface element common to most constraint-based solid modelers. The feature tree lists the geometric features contained in the model in the order in which they are interpreted by the modeler. New features will typically be placed at the bottom of the tree. A feature in the tree can be construction geometry, part features, or components in an assembly.

feed-through (n) A through-hole in a printed circuit board which has a conductive surround on at least one side of the board and sometimes in the hole. The conductive pads or donuts on either side of the hole are used to make electrical connections through the board and with component wires that are soldered into the holes.

FEM/FEA (n) *See* finite element modeling and analysis.

fillet (n) A rounded *interior* corner normally found on cast, forged, or molded parts. Like a round, a fillet can indicate that a surface is not machine finished. A fillet is indicated on engineering drawings as a small arc.

finance process (n) Used to analyze the feasibility of producing a product relative to capital requirements and return on investment (ROI).

fine series thread (n) A type of thread used when a great deal of force is necessary for assembly which is designated NF or UNF on drawings.

finish mark (n) A mark placed on the edge view of a surface used on an engineering drawing to indicate that a surface is to be machine finished.

finite element modeling and analysis (FEM/FEA) (n) An analysis technique used extensively to model and analyze forces within a computer model or a proposed design. In the modeling phase, the continuous surface or volume is discretized into a finite number of linked primitive geometries. In the analysis phase, the model is subjected to theoretical forces applied at certain locations, and the resulting forces are calculated across the rest of the model.

fish-tank VR (n) A desktop computer system in which a stereo image of a 3-D scene is viewed on a monitor.

fittings (n) A term used to describe components that connect pipes, valves, and other fluid and gas-handling equipment. Fittings are often classified by the method used to join the components together. Some of the most common types are welded, threaded, and flanged (bolted).

fixture (n) A rigidly held production tool that securely holds, supports, and locates the workpiece. Unlike a jig, a fixture is *not* used to guide a cutting tool.

flat shading (n) A rendering method that uniformly adjusts the value of a surface color based on its orientation to the light. This method is considered the simplest shading method since it only requires the calculation of a single surface normal.

flatness (n) A form control for geometric dimensioning and tolerancing. Flatness indicates that all points on the surface must lie in a plane. Flatness for a planar surface is comparable to straightness for a line.

flexible manufacturing system (FMS) (n) A group of machines that can be programmed to produce a variety of similar products. For example, an automobile parts supplier might specialize in the production of gears for transmissions. An FMS cell might be used to produce the gears for more than one automobile manufacturer because the parts are similar.

flow charts (n) A visualization technique for displaying relationships in time, particularly for data that doesn't conform well to scalar mapping. PERT charts and other types of flow charts are project management tools used to map the relationship of specified project tasks, personnel, and other resources on a single timeline.

flow diagram (chart) (n) A diagram used in electronic and piping systems to describe the system's process and the flow of material (or electronic signals) through the proposed design. Since these diagrams only depict the functional nature of the system, they do not show the true spatial layout or geometry of the components.

flow lines (n) Lines used primarily in technical illustrations to indicate the assembly of parts in an exploded assembly. Flow lines are thin phantom lines drawn parallel to the line of assembly between two parts. Right-angle jogs are placed in the flow line when the drawing of the part has been moved away from the direct line of assembly for reasons of clarity.

FMS (n) *See* flexible manufacturing system.

focus point (n) A location where reflecting rays from a (parabolic or hyperbolic) surface converge. Focus point describes both the physical phenomenon of light rays reflecting from a mirrored surface and the abstract geometric calculations of line paths.

fold line (n) A basic concept in descriptive geometry used to define a line that is perpendicular to projection lines and is shared between views of a drawing. A fold line can also describe the "hinge" line between the image planes of the glass box used to define orthographic multiviews.

font (n) The size and style of text characters.

foreshortened (adj.) The reduction in size of one or more dimensions of a planar face due to the face not being perpendicular (normal) to the line of sight. The dimension foreshortened is defined by the axis of rotation of the face out of a plane normal to the line of sight. When the face is rotated in its edge view, the foreshortening is applied to a line.

forming (v) A process in which components are held together by virtue of their shape. This is the least expensive fastening method, and it may or may not be permanent. Heating and air conditioning ductwork is held together by forming the sheet metal.

four-color printing (n) A color printing process in which a full-color image is divided into four separate images, each representing the amount of one of the three subtractive primary colors (cyan, magenta, and yellow) or black contained in the image. Printing plates are made from the new images, and each is printed in a single ink color as an overlay. This process is also called the CMYK system, an acronym for the four ink colors, where K is for black.

fractal (adj.) The term, short for *fractional dimensional,* used to describe graphics with randomly generated curves and surfaces that exhibit a degree of self-similarity. Fractal design tools provide new opportunities for designers to produce complex patterns with more visual realism than can be output from conventional geometry programs.

free-form surface (n) Three-dimensional surfaces that do not have a constant geometrical shape. Free-form surfaces follow no set pattern, are classified by their use as *constrained* or *unconstrained,* and are typically produced using sophisticated CAD programs.

front view (n) A principal view of an object, typically the first one defined, orienting the object such that the majority of its features will be located in the front, right side, and top views.

frontal line (n) A line that is seen in its true size in the frontal plane.

frontal plane (n) A principal orthographic plane of projection. This plane is used to define both the front and back orthographic views.

full section (n) A sectional view generated by passing a single cutting plane completely through the object.

functional analysis and design (n) A design driven by the *intended use* of the product. Functional analysis determines if the design is an answer to the problem statement written during the ideation phase. Aesthetic considerations are often considered the foil to functional considerations.

functional dimensioning (n or v) A type of dimensioning technique that identifies functional features of a part which are then dimensioned first.

fundamental deviation (n) A tolerancing measure used to describe the deviation *closest* to the basic size.

G

gaging tolerance (n) An inspection instrument that is at least 10 times more accurate than the part that is being measured.

gamut (n) The range of colors possible at a single pixel on the computer monitor. The gamut is not the full range of colors perceivable by the eye but is typically quite large. The hardware and software of the computer system determine what that gamut will be.

gear (n) A toothed wheel device that acts as a mechanical linkage to transmit power and motion between machine parts. Most gears transfer rotary motion from one shaft to another. They change the location and can change both the orientation and speed of the rotary motion. Certain gear types transform rotary motion into linear (reciprocating) motion.

gear train (n) A mechanism consisting of two or more gears and used to transmit power. Normally, gear trains are used to do one or more of the following: increase speed, decrease speed, or change the direction of motion.

general notes (n) Text placed in the drawing area, including general information that cannot be effectively or quickly communicated through graphical means.

general oblique (n) A type of oblique pictorial drawing in which the two dimensions of the

frontal surface are drawn parallel to the frontal plane and the third (receding) axis is drawn obliquely at any scale between 50 and 100 percent of the frontal plane dimensions. The receding axis is typically drawn at an angle of between 45 and 60 degrees.

general-purpose section line (n) A default section line symbol used to indicate the cut surface of a sectional view. This symbol is used to represent cast iron, or an anonymous material if none is defined.

general tolerance note (n) Text located on a drawing to specify those dimensions not specifically toleranced on the drawing.

generatrix (n) A straight line for which the path through space describes ruled surfaces or solids. The path the generatrix follows is called the directrix.

geometric breakdown dimensioning (n) A technique used to dimension an engineering drawing that involves breaking an object into more basic geometric forms to determine dimensions that should be used for a part.

geometric dimension (n) A dimension that specifies the size and location of a feature, as well as other geometric qualities such as form and orientation. Geometric dimensioning and tolerancing, combined with statistical process control, provide a robust approach to inspection and quality control for manufactured parts.

geometric transformations (n) Basic operations used to modify existing geometry contained in the CAD database. Examples of transformations include translation and rotation. Most transformations used in CAD systems are executed as *matrix operations* based on linear algebra theory.

geometry (n) The mathematical method by which elements in space are described and manipulated. Geometry forms the building blocks of engineering and technical graphics. The term is also used to mean shape or form.

GKS (Graphical Kernal System) (n) A software program that can generate, display, and transfer computer graphics data in a comparative format.

glyph (n) A compound mark used in a visualization that cannot be classified by other commonly used marks. Glyphs are usually custom designed to encode multiple elements of data into a single mark. The objective for designing glyphs or any other marks is to tap into the innate perceptual abilities of the viewer.

Gouraud shading (n) A rendering method that uniformly adjusts the value of a surface color based on the relationship of the light source to normals calculated for each vertex of the model. Gouraud shading is sometimes called smooth shading because the vertex normals allow interpolation of shading values across

multiple polygons representing the facets of a curved surface.

graphical analysis (n) Analytic techniques employing primarily graphics to evaluate a potential design, such as the fit of mating parts or the movement of parts in a mechanism.

graphics (n) A mode of communication using spatial/geometric representations.

grid (n) A regular pattern of points or lines used to help locate and orient specific marks or features or to help guide the development of sketches and roughly proportion features.

ground line (n) In a perspective drawing or sketch, the point of the object closest to the observer.

ground's eye view (n) In a perspective pictorial, a viewpoint looking *up* at the object. From this viewpoint, the horizon line is level with the ground line of the object.

group technology (n) The process of identifying items with similar design or manufacturing characteristics. Items with similar characteristics are grouped into part families.

guideline (n) A type of construction line used to guide the lettering on the drawing. The term can also refer to lines used for the placement of other elements in a drawing or sketch.

H

half section (n) A section view generated by passing a cutting plane halfway through an object. The result depicts half the view sectioned.

half-space (n) A mathematically defined boundary between two regions. The term is used in constructive solid geometry (CSG) modelers to define the boundary between the solid and the void (nonsolid). Geometric primitives in CSG modelers are defined as groups of half-spaces.

halftone approximation (n) A method of simulating varying value (gray) levels within an image when only one color of ink (usually black) is available. Dots of varying size are printed based on the average value level in the region. Because of the small size of the dots compared with the size of the image, the changes of dot size (and therefore ink density) give the impression of value changes when viewed at a distance. Halftones from full-color or gray-scale images can be created both electronically or photographically.

hardware (n) A term used to define physical computer equipment. Examples of hardware include the monitor (CRT), keyboard, hard disk, and CPU.

head mounted display (n) A device with small video projectors positioned in front of the eyes providing the wearer with an immersive experience.

height (n) One of the three principal dimensions of an object. The height dimension is described in the right side and front views of a multiview drawing. The height dimension is often associated with the Y axis in a 3-D modeling system.

helix (n) A 3-D curve characterized by a constant rate of curvature about two dimensions and a constant linear translation in the third. Threads on screws and bolts are helical and are classified as being either right- or left-handed.

hidden line (n) A line used to represent a feature that cannot be seen in the current view. Like a visible line, a hidden line represents either the boundary between two surfaces (faces) that are not tangent, or the limiting element of a curved surface. A specific linestyle is defined by ANSI for hidden lines.

hidden surface removal (n) The rendering process of removing the elements of a model not visible from a particular viewpoint. The removal is accomplished by calculating the relationship of edges and surfaces along the depth axis.

hierarchy (n) An ordered set of elements in which each element belongs to a specific *level*. An element at each level can be a parent to elements below it on the hierarchy, or a child to elements above it, or both. Hierarchies are used to describe the organization of files in a computer system, or geometric primitives in a CAD model.

highway diagram (n) *See* wiring diagram.

histogram (n) A visualization technique used to *summarize* data by reporting the number of data points that fall within a certain range of values. Histograms are often represented as bar graphs. Because histograms provide only a summary, they depict the original information only indirectly.

hole basis (n) A tolerancing measure used to describe a system of fits in which the *minimum hole size* is the basic size.

hole loop (n) A close group of edges on the interior of an object, defining a penetration that goes part or all the way through. The number of hole loops is one of the variables in the Euler–Poincaré formula used to validate the topology of a model.

HOOPS (Hierarchical Object-Oriented Picture System) (n) A software program that can generate, display, and transfer computer graphics data in a compatible format.

horizon line (n) In a perspective sketch, a horizontal line marking the location where all projection lines from the observer converge.

horizontal line (n) A line seen in its true size in the horizontal plane.

horizontal plane (n) A principal orthographic plane of projection, used to define both the top and bottom orthographic views.

HSV color model (n) A model based on the perceptual components of color, that is, *(H)ue, (S)aturation,* and *(V)alue* (lightness), modeled as a hexacone. Hue is laid out in a radial pattern around the hexacone, saturation ranges linearly from full saturation at the perimeter to white at the center, and value runs from the base of the hexacone (white) to the point (black).

hue (n) The dominant spectral wavelength of a perceived color. Hue and color are often confused because the name given to the hue is often synonymous with the name of the color.

human factors analysis (n) A process for evaluating a design to determine if the product serves the physical, emotional (aesthetic), quality, mental, and safety needs of the consumer. Specialists in human factors or ergonomics are often employed to conduct this evaluation.

human's eye view (n) In a perspective pictorial, a viewpoint looking *slightly down* at the object. From this viewpoint, the ground line is equivalent to six feet below the horizon line of the object.

hybrid modeler (n) A 3-D modeling system that combines the operations and database structure of more than one of the commonly defined modeling systems. Used with more powerful computing systems, these modelers combine the advantages of more than one system. An example is the combination of CSG and surface modeling technology.

hyperbola (n) A single-curved surface primitive, created when a plane intersects a right circular cone at an angle with the axis that is *smaller* than that made by the elements.

hypermedia (n) An interactive, computer-based information system, created with authoring tools, which allows flexible, nonlinear access. Information is linked both through elements selected within the body of the information and through sophisticated search engines.

I

ideation (n) A structured approach to thinking for the purpose of solving a problem, often employing graphics. Ideation is the conceptual phase of the design process. Feasibility studies are often performed to define the problem, identify important factors that limit the scope of the design, evaluate anticipated difficulties, and consider the consequences of the design.

ideation drawings/sketches (n) A type of freehand sketch or drawing used early in the design process to explore design ideas quickly. These sketches are usually rough and incomplete, typically not following many of the conventions used for more finished drawings.

IGES (n) Acronym for *initial graphics exchange specification,* an indirect data exchange standard used largely in the United States to exchange CAD information between disparate systems. Originally developed by the U.S. government and major defense contractors, it is used mainly on workstation, minicomputer, and mainframe-based CAD systems.

image plane (n) An imaginary plane on which an object is projected. The graphic representation of an object on a computer screen or paper is an example of a projection as it would appear on an image plane.

implementation process (n) Used to make the design solution a reality for the enterprise or consumer.

inclined edge/line (n) An edge of a face that is parallel to a plane of projection but inclined to the adjacent orthogonal planes. The edge appears as an inclined, true-length line in one of the principal views and is foreshortened in the two adjacent views.

inclined face (n) A planar face (surface) of an object that has been rotated about one axis from one of the principal image planes. An inclined face will appear foreshortened in two of the principal views and as an edge in the third.

inclined plane (n) A surface that is perpendicular to one plane of projection and inclined to adjacent planes, and cannot be viewed in true size and shape in any of the principal views.

independent variable (n) A variable for which the values are controlled by the experimenter to create a response in the model as measured by the dependent variable. Every independent variable value is paired with one or more dependent variables and represents the experimental manipulation of the model.

indirect data exchange (n) A method of translating data from one CAD system to another through an *intermediate,* neutral data format. Examples of intermediate data formats include IGES and DXF.

industrial engineering (n) A field of engineering concerned with the analysis and design of systems for organizing the basic production resources such as personnel, information, materials, and equipment. Industrial engineers use mathematics, the physical and engineering sciences, and the management and behavioral sciences.

infinite light source (n) A light source located at a theoretically infinite point in space. The sun is analogous to an infinite light source. In rendering, the user specifies an orientation for the light rays, all of which are *parallel* to each other.

initial graphics exchange specification (n) *See* IGES.

input device (n) Computer hardware used by the operator to input information into a software program. Examples are keyboard, mouse, scanner, etc.

instances (n) Cloned copies of geometry already existing in a database. Typically, an *instance* is linked directly to the geometric and topological information of its *parent* but contains unique information pertaining to its location, orientation, and scale in the model/drawing. Some systems refer to instances as *symbols*.

integrated circuit (n) An electronic component made up of a large number of diodes, transistors, and resisters and integrated onto a single semiconductor substrate such as silicon. An example of an integrated circuit is a central processing unit (CPU) in a computer.

intensity depth cueing (n) A rendering technique which calculates the Z-depths of the edges in a model and sets their brightness (intensity) relative to their depths. This technique taps the aerial perceptual depth cue and has the effect of making the model fade as it goes back in depth.

interchangeable parts (n) Allows for the replacement of individual parts in an assembly that is made possible by tolerancing.

interconnection diagram (n) *See* wiring diagram.

interference fit (n) A fit in which two toleranced mating parts will always interfere when assembled because the "male" part is larger than the "female" part. The resulting difference in sizes, also called the *allowance,* means that force is required to assemble the part. An interference fit fixes or anchors the two parts as if they were one.

International System of Units (n) *See* SI.

international tolerance grade (n) A group of tolerances that vary depending on basic size but have the *same level of accuracy* with a given grade. The smaller the grade number, the smaller the tolerance zone.

Internet (n) A network providing interconnectivity of computers.

intersecting lines (n) Lines that share one or more common points in space. Lines that share all their points in common, or lines for which one could be considered a subset of the other, are called *coincident*.

intersection (∩) (n) The Boolean operation in which only the intersecting geometry of two solids remains.

interval scale (n) A data scale that preserves the units used but does not have a natural zero point. Interval scales often result from the difference between two values using the same scale.

intranet (n) A private internal network.

involute (n) A curve defined as the spiral trace of a point on a flexible line unwinding from

around a line, circle, or polygon. The contacting surfaces between gear teeth are designed as involutes.

isometric axes (n) The term used to describe the three axes that meet at a corner on an isometric drawing forming equal angles of 120 degrees.

isometric drawing (n) A pictorial representation of an object rotated 45 degrees, tilted 36 degrees 16 minutes, then drawn full scale. An isometric drawing differs from an isometric projection in that all three dimensions are drawn at *full scale* rather than foreshortening to the true projection.

isometric ellipses (n) A special type of ellipse used to represent holes and ends of cylinders in isometric drawings. In an isometric drawing, circular features are often not viewed normally, foreshortening them and making them appear as ellipses.

isometric grid (n) A network of evenly spaced lines drawn at 30, 90, and 120 degrees. Paper preprinted with this grid is used to sketch isometric drawings.

isometric line/plane (n) A line or plane that is parallel to one of the principal isometric axes or to two adjacent isometric axes, respectively. Isometric lines and planes are typically the simplest elements to represent in an isometric drawing.

isometric pictorial (n) A type of parallel projection that represents all three dimensions in a single image.

isometric projection (n) An axonometric projection in which three of the axes are measured on the same scale and are at the same angle relative to each other. An isometric drawing is less pleasing to the eye than other types of axonometric projections, but it is the most common since it is the easiest to draw.

isosurfaces (n) A surface in 3-D space that defines constant values of a dependent variable. Isosurfaces are the logical extension of contour lines (isolines), which map constant values in 2-D space. Every point on an isosurface identifies the location where three independent variable values result in the dependent variable value of interest. Like isolines, multiple isosurfaces can be used to map different dependent variable values.

italic (adj.) A style of text in which vertical elements of letters are slanted forward. This technique is used to make words or letters visually stand out from the rest of the text.

J

jig (n) A special device that holds and supports the workpiece and guides the cutting tool as the workpiece is machined. Jigs may not be rigidly held to the machine.

JIT (n) An acronym for *just-in-time,* a planning strategy used to reduce cycle time and waste in production processes. JIT recognizes waste as anything that does not add value, including storing parts in warehouses. On the other hand, a production process such as drilling is a value added procedure because it increases the value of the product.

joining (v) The bringing together of two or more parts of an assembly in such a way as to overcome the natural forces that would separate them. Joining can be done with mechanical fasteners, adhesives, etc., and can be either temporary or permanent.

joints (n) An element in a kinematic model defining the constraints between two rigid parts of the assembly (called the links). Joints define how the links can move relative to each other, in rotation and translation.

just-in-time (n) See JIT.

K

KBE (n) *See* knowledge-based engineering.

key (n) A fastening device used to attach shafts to transmit power to gears, pulleys, and other mechanical devices. Common keys are plain, gib head, Woodruff, and Pratt & Whitney. The key is placed into a groove cut into the shaft (the *keyseat*) and one cut into the hub (the *keyway*), aligning and locking the parts together. Standard keys are specified using the size of the shaft as the determining factor.

keyboard (n) A computer input device derived from the typewriter, where keys pressed communicate discrete commands to the computer. Although most often used to input the letters of the alphabet, most keyboards contain special character keys programmed by the user or the software to perform specialized tasks.

kinematic analysis (n) The evaluation of a design as it changes over time. Of particular interest is multicomponent mechanisms in which parts move at varying rates through different volumes of space. The positions of the parts relative to each other at various points in time are studied through kinematic analysis.

kinetic depth effect (n) A perceptual effect in which the changing movement of 2-D patterns creates the sense of a third dimension (depth). Related to *apparent motion,* this effect assists in the interpretation of 3-D objects in animated sequences.

knowledge-based engineering (KBE) (n) Software systems that complement CAD by adding the engineering knowledge necessary for product design. A KBE system stores product information in a comprehensive model that is composed of design engineering rules, standard practices, and general rules that describe how a product is designed and produced.

L

layering (v) A scheme by which the various graphic elements of a drawing can be grouped together in the CAD database. This facility is used most often to control what is seen or editable on the screen and what is printed or plotted. Layering in most systems is nonhierarchical.

lead (n) A thread term describing the *linear distance* a screw will travel when turned 360 degrees, or 1 revolution. Lead is closely related to the pitch of a thread.

leader line (n) A thin, solid line used to indicate the feature with which a dimension, note, or symbol is associated. Leader lines are terminated at one end with an arrow touching the part or detail and a short horizontal shoulder on the other end. Text is extended from the shoulder of the leader.

least material condition (LMC) (n) A tolerancing term indicating the condition of a part when it contains the *least* amount of material possible. The LMC of an external feature is the lower limit of the part. The LMC of an internal feature is the upper limit of the part.

left side view (n) A principal view of an object, created by rotating the viewpoint 90 degrees about the vertical axis to the left of the front view. This view is not typically included in a standard multiview drawing.

legend (n) The region of a visualization where an explanation is given regarding how the variables are coded. This is usually done by equating a text description to a symbol of the code. The legend is also called the *key.*

lightness (n) A perceptual quality of color indicating the absolute quantity of light energy. On a gray scale, the lightest color, pure white, has the highest quantity of light. In rendering, lightness (also called *value*) is used to indicate the orientation of the surface to the light source.

limiting element (n) The boundary of the projection of an object. The term is usually used to describe the edge defining the apex of a curved surface.

limits (n) The maximum and minimum sizes shown by the toleranced dimension. The larger value in a toleranced dimension is called the upper limit and the smaller value is the lower limit.

line (n) A geometric element that connects two points in space. Although a line itself is 2-D in nature, it may connect points in 3-D space. Lines are typically classified as either *straight* (linear) or *curved.* Lines are the most prominent element in technical drawings, defining edges of objects, indicating symmetry, relating text elements to geometric elements, creating borders, etc.

line balloon (callout) (n) A note added to a drawing to relate an alphanumeric code with a part. A line balloon usually consists of a circle or a regular polygon enclosing the code and a leader pointing to the part. They are used extensively in assembly drawings either to directly specify a part or give an index value that references a parts list or separate catalog.

line graph (n) A visualization technique, usually 2-D, in which line marks are used to indicate trends in data. In a 2-D line graph, the independent variable is represented on the horizontal scale, and the dependent variable is shown on the vertical scale. The line mark represents the mapping of the two variables.

line of sight (LOS) (n) Imaginary rays of light radiating from an observer's eye to the object. In perspective projection, all lines of sight start at a single point; in parallel projection, all lines of sight are parallel. LOS is sometimes referred to as the *viewpoint*.

line rendering (n) A technique used in technical illustration for adding realism and readability to a pictorial drawing by altering qualities of the linework on the drawing. The thickness of the line and the positions of line breaks or gaps are altered to differentiate between geometric features of a part or assembly. Line rendering is popular because it is fast, can be done with standard drawing instruments or CAD tools, and can be reproduced by most popular reproduction techniques.

link charts (n) A visualization technique used extensively in ergonomics to depict the spatial arrangement of controls, displays, and personnel associated with a work environment. Line marks show the connections between a worker and a control or display or in communication with other personnel. Some of the variables typically coded include frequency of usage and type of information exchange (i.e., auditory, visual, physical, etc.).

linkages (n) Rigid bodies (parts) that transmit linear or rotational force. Linkages are multiple links that are combined through joints. Constraints applied to the joints define the movement of the individual links. Common types of linkages include rocker arm, crank, lever, and four-bar.

links (n) In a kinematic model, the geometric form representing a unique part of a mechanism. Links are related to each other through *joints,* which define how they can orient relative to each other.

LMC (n) *See* least material condition.

local coordinate system (n) A transient coordinate system that can be positioned anywhere in space. The local coordinate system is used to assist in the construction of geometry, and the origin is usually defined *relative* to the feature of current interest.

locus (n) A graphic element representing all possible allowable locations of a point. The locus of points may be drawn as a line, circle, or arc. For example, a circle is a locus of all points at a distance from the center, equal to the radius of the circle. Loci are used extensively in *geometric constructions* as a tool for finding the centers of tangent arcs, the endpoints of lines, etc.

lofting (v) A surface and solid modeling operation that involves creating a surface/solid by interpolating a boundary between multiple profiles in 3-D space. Starting with one profile, the outline is extended to each successive profile outline in space, creating a boundary surface and changing shape as necessary to match the shape of the next profile.

logic drawing (n) *See* schematic drawing.

logic gates (n) Electronic components that take input signals and create output signals based on the input states and the logic of the circuit. Types of logic gates include AND, OR, NAND, NOR, and inverters.

long-axis isometric (n) A variation of the regular isometric pictorial view. In a regular isometric, it appears as if the viewer is looking down on the object from the top; in a long-axis isometric, it appears as if the viewer is looking from the *right* or the *left* of the object, with one of the axes drawn at 60 degrees from the horizontal.

LOS (n) *See* line of sight.

lower deviation (n) A tolerancing term describing the difference between the *minimum size limit* and the basic size.

lower limit (n) The numerical value of a toleranced dimension feature describing the smallest value.

M

machine (n) A combination of interrelated parts used for applying, storing, or transforming energy to do work. Machines consist of one or more assemblies, which are analyzed using techniques such as kinematics and dynamics.

machine control (n) A process that directs the machine tools necessary to transform raw materials into a finished product. Machine control has evolved from human control to machine automation using numerical control (NC) and then computer numerical control (CNC).

machine screw (n) A mechanical fastening device with a slotted head on one end and threads on the other. The threaded end can screw into either a mating part or a nut. A machine screw is similar to a slotted head cap screw but is normally smaller.

machine tool (n) A production device used to change the shape, finish, or size of a piece of material, typically using some type of cutting edge.

major axis (n) The long axis of an ellipse. In a pictorial projection, this axis represents the true diameter of the circle being projected.

major diameter (n) A threading term referring to the *largest* diameter on an internal or external thread.

management (n) The logistical organization of people, materials, energy, equipment, and procedures into work activities designed to produce a specified end result.

manifold models (n) Models that unambiguously define a boundary between the inside and outside of an object. Solid modelers are usually restricted to manifold objects, whereas surface modelers often define unclosed, nonmanifold objects with no clear division between inside and outside.

manufacturing automation protocol (n) *See* MAP.

manufacturing processing (v) An activity concerned with the scheduling, forming, treating, shaping, joining, and cutting of raw material in the production of goods.

MAP (n) An acronym for *manufacturing automation protocol,* a communications standard being developed for compatibility between different automated manufacturing systems. The goal of MAP is the total integration of islands of automation in manufacturing, regardless of the type of hardware and software used in each system.

market analysis (n) A process used to determine the needs and wants of a customer.

marketing (n) The division of a business involved with convincing customers to purchase the product or service provided by the company. In order to sell the product more effectively, marketing will gather information on potential customers, both directly and indirectly, and will use these data to influence the design of the product so that it more closely matches the customer's needs.

marks (n) The fundamental graphic elements used to encode data in a visualization. Marks can be thought of as graphic primitives and are typically classified as either *simple* or *complex*. Simple marks include points, lines, areas, and volumes. Complex marks are also called glyphs. All marks interrelate closely with the dimension of the data type.

mass properties analysis (n) Analytic techniques directly related to the geometric properties of an object. Typical calculations are the mass, centroids (center of gravity), and intertial properties of the object. In order to successfully use these techniques, the model must be able to unambiguously define the volume the object occupies and the density of the material within the volume.

material control (n) A term describing the management of the flow of materials through

the production process. Just-in time (JIT) techniques are used to recognize which raw materials are needed and when.

materials engineering (n) A field of engineering that comprises a wide spectrum of activities directed toward the design, development, and production of metals, alloys, ceramics, semiconductors, and other materials for engineering applications.

material requirement planning (n) *See* MRP.

mathematics (n) An abstract symbol-based communications system based on formal logic. *Geometry* is one of the oldest fields of mathematics and underlies most of the principles used in technical graphics and CAD.

matrix charts (n) A visualization technique that uses grids to show relationships between at least two, often qualitative, variables. Each variable is represented along a scale, and the interior grid cells represent possible combinations of variable values. Marks are placed in the grid cells, representing the relationship between variable values.

maximum material condition (MMC) (n) A tolerancing term defining the condition of a part when it contains the *greatest amount of material*. The MMC of an external feature, such as a shaft, is the upper limit. The MMC of an internal feature, such as a hole, is the lower limit.

mechanical engineering (n) A field of engineering comprising a wide range of activities, including research, design, development, manufacturing, management, and control for engineering systems and their components. Mechanical engineers work in such fields as transportation, power generation, energy conversion, environmental control, aeronautics, marine science, and manufacturing.

mechanical fastening (v) A process that uses a manufactured device added to an assembly to hold parts together. Mechanical fasteners include *threaded* and *nonthreaded* fasteners, such as rivets, keys, pins, snap rings, and clips.

mechanics (n) An area of applied physics which, at a macro level, deals with the response of bodies (parts) to the action of forces, and, at the micro level, with the response of materials.

mechanism (n) A mechanical system made of rigid structures, such as shafts, housings, and pillow blocks, and connected by various linkages, such as gears, cams, and cranks. A mechanism is activated by applying a load or force at one or more points in the mechanism.

mechanism analysis (n) An analytic technique that determines the motions and loads associated with mechanical systems made of rigid bodies (links) connected by joints. The two most common types of mechanism analysis are *kinematic* and *dynamic*.

media (n) A means of conveying information, both graphic and textual. Traditionally, this refers to the types of paper used in drafting; more recently, it has also come to refer to the types of information storage and playback technology, such as video, audio, and CD-ROM.

memory device (n) Computer hardware used to store information, such as CAD data. Transient storage is random access memory (RAM); more permanent storage includes floppy disks, CD-ROMs, and magnetic tape.

microfilming (v) A technique used to reduce the size of an original paper drawing.

minor axis (n) The short axis of an ellipse. In a pictorial projection, the length of this axis varies with the relationship of the view direction to the surface of the circle the ellipse represents.

minor diameter (n) A threading term referring to the *smallest* diameter on an internal or external thread.

miter line (n) A special construction line used to share the depth dimension between the top and right side views of a multiview drawing. The line is drawn at a 45-degree angle and is used as a point of intersection for lines coming to and from the right side and top views.

MMC (n) *See* maximum material condition.

model solid (n) In a modeling system, the solid object being manipulated by tool solids during the course of creating the final model. Whereas the *tool solids* are transient in nature, the model solid defines the state of the object as it evolves into the final model.

modeling (v and n) Often referred to as geometric modeling, which is both a process and a product. Modeling is used to analyze preliminary and final design solutions, as well as provide input to the production process in the form of a computer database. Modeling is a product since it is a result of the design process, which uses graphics as a tool to visualize possible solutions and to document the design for communications purposes.

modem (n) A computer hardware device that uses standard telecommunications lines (phone lines) to send computer data from one computer to another. Modems are used to connect computers at remote sites not connected by local area networks. The speed in which modems can transfer information is measured in bits per second, or *baud*.

motion (n) The movement of a part, either linearly or angularly, over time and space.

mouse (n) A small, handheld computer input device that rests on a work surface and is moved in two dimensions to correspond to locations on the computer monitor. A cursor on the screen indicates the current location of the mouse, and buttons on the top of the mouse are

used to indicate the action to be performed at that location.

MRP (n) An acronym for *material requirement planning,* a process used to calculate the amount of raw materials necessary to manufacture a specified number of products. MRP uses the bill of materials from the engineering drawings or CAD techniques such as attribute assignments. MRP has evolved into material resource planning, which includes both materials and financing.

multimedia (n or adj.) A term used to refer to the systems or methods that convey information in more than one media form and often through more than one sense. The integration of text and graphics could be thought of as a simple multimedia system.

multiple-line graph (n) A visualization technique similar to a regular line graph, except that an additional independent variable is mapped. The second independent variable typically has only a few discrete values, each of which is mapped as a separate line on the graph. *Color* or *symbol* coding is used to distinguish between the lines on the graph.

multiview drawing/sketch (n) A type of orthographic drawing based on multiview projection techniques in which two or more views of an object are arranged in a single drawing. Each view shows only two dimensions of the object and is chosen to depict specific features of the object clearly and distinctly.

multiview projection (n) A special type of orthographic projection that places the object in a unique position behind a projection plane such that a view is produced that shows only two dimensions of the object. The outline of the features of the part shows where the parallel lines of sight pierce the projection plane.

mutually perpendicular (adj.) Two or more lines or planes that are at 90 degrees (right angles) to each other, that is, *orthogonal.*

N

NC (n) Acronym for *numeric control,* a form of programmable automation of a machine tool, using numbers, letters, and symbols. Unlike on an engineering drawing, the part geometry must be defined using coordinates instead of graphics. All NC systems today use computers and are called *computer numerical control* (CNC) machine tools.

negative solid (n) Term used in CAD solid modeling that refers to the shape and volume of a shape that is removed from a solid object.

negative space sketching (n) A technique where you concentrate on sketching the space between the objects and not on the object itself.

networked hierarchy (n) A hierarchical parts structure used by modeling systems. In a net-

worked hierarchy, parts can be shared across assemblies by means of software links set up external to any one file. These parts structures are often managed by special database software networked across workstations within an organization.

nominal scale (n) A qualitative data scale that has *no inherent order* to it (e.g., New York, Boston, and Houston).

nominal size (n) A dimension used to describe the general size of an object, usually expressed in common fractions. For example, a bolt might have a nominal size of 1/2″.

nonhierarchical (n) A structure in which elements may be sorted into separate groups, but there is no defined linkage or ordering of the groups. Layering in CAD systems is often defined as being nonhierarchical.

nonisometric line/plane (n) A line or plane that is *not parallel* to one of the principal isometric axes or to two adjacent isometric axes, respectively. In an isometric drawing, nonisometric lines and planes are typically more difficult to draw than isometric elements.

nonuniform rational B-spline (n) *See* NURBS.

normal (adj. or n) A term describing a direction perpendicular to a planar surface, or a vector representing a perpendicular direction. Normals are used to calculate the orientation of a surface with respect to a light source or view point.

normal edge/line (n) An edge of a face parallel to a plane of projection and perpendicular to the adjacent orthogonal planes. The edge appears as an orthogonal, true-length line in two of the principal views and as a point in the third view.

normal face (n) A planar surface of an object that is parallel to one of the principal image planes. A normal face is seen in its true size and shape in the image plane to which it is parallel and is seen as an edge in the other two principal image planes. The normal face is named for the image plane to which it is parallel.

normal plane (n) A surface that appears true size and shape in one of the principal views of an orthographic drawing.

nuclear engineering (n) A field of engineering that includes all areas of research, development, and application of nuclear energy. Areas of specialty include reactor engineering, reactor control, nuclear materials, reactor physics, controlled thermonuclear fusion, reactor safety, fuel management, and shielding.

numeric control (n) *See* NC.

NURBS (n) Acronym for *nonuniform rational B-spline,* a type of free-form curve that uses rational B-splines and allows for a weighting value at each point on the surface. Because NURBS can also precisely describe conic surfaces, they are gaining popularity in tasks previously done with other types of 3-D modelers.

nut (n) An internally threaded device used on the ends of threaded fasteners to join materials. Nuts are an alternative to threading the part itself and are often paired with a *washer* to assist in distributing the pressure and/or securing the nut.

O

oblique (adj.) A direction that is neither parallel nor perpendicular to a plane.

oblique edge/line (n) An edge of a face that is not parallel to any of the three primary orthogonal planes. The edge appears foreshortened in all three principal views of a multiview drawing.

oblique face (n) A planar surface of an object that has been rotated about two axes from one of the principal image planes. An oblique face will appear foreshortened in all three of the principal views. Unlike inclined and normal faces, an oblique face is not seen as an edge in any of the principal image planes.

oblique projection (n) A form of parallel projection used to create oblique pictorials. Oblique projection results when the projectors are parallel to each other but at some angle other than perpendicular to the projection plane. Typically the most descriptive face of an object is placed parallel to the frontal plane.

offset coordinate method (n) A construction method used to construct non-normal views of cylinders, circles, arcs, and other curved or irregular features. The feature is first drawn in an orthographic view, and then regularly spaced coordinate points are transferred to the foreshortened view space, where they are connected using an irregular curve.

offset section (n) A full section view generated by multiple, connected cutting planes that are parallel but not coplanar. This technique is used to allow the cutting planes to pass through a series of features that do not all lie in the same plane.

ogee curve (n) A curve that connects two parallel lines with two arcs, forming a smooth curve. Such curves are often seen in architectural details.

open loop (n) A set of edges in a CAD model that does *not* connect end to end, creating a closed loop. Solid modelers differ as to whether open loops can be used as profiles for feature generation. Open loops cannot be used to define faces on a solid model.

operating system (n) The software that controls the basic functions of a computer system, such as reading and writing files to the disk, communicating with the printer, etc. Common operating systems include UNIX, MS-DOS, and Macintosh OS.

ordinal scale (n) A qualitative data scale that has an inherent order. Even though ordinal data has an order, the order is not quantitative because the individual data elements are *symbolic* and have no inherent magnitude.

orthographic projection (n) A parallel projection technique that creates a 2-D image of 3-D objects or structures on an image plane perpendicular to the lines of sight. The orthographic projection technique can produce *pictorial* drawings, such as isometric or oblique, that show the three dimensions of an object or *multiviews* that only show two dimensions of an object in a single view.

outline assembly (n) A general graphic description of the exterior shape of an assembly. Outline assemblies are used for parts catalogs and installation manuals or for production when the assembly is simple enough to be visualized without the use of other drawing techniques, such as sectioning. Hidden lines are omitted except for clarity.

output device (n) A peripheral hardware device linked to a computer that allows information in the computer to be accessible to the human senses. Common types of output devices include computer monitors and printers.

P

painter's algorithm (n) A rendering technique used to perform hidden surface removal. All of the polygons are sorted and then drawn on the screen from back to front. Both the computer and a painter use this technique to ensure that elements in the background are covered by those in the front.

parabola (n) A single-curved surface primitive, defined as the curve of intersection created when a plane intersects a right circular cone parallel to one of the cone's elements.

parallel lines (n) Two lines in a plane that stay equidistant from each other along their entire logical length. The lines can be straight or curved. Circular curved parallel lines share the same center point and are referred to as *concentric*.

parallel planes (n) Two planes that are equidistant from each other over their entire surfaces. Two planes are considered parallel when intersecting lines in one plane are parallel to intersecting lines in the second plane. Also, seen in edge view, the two planes appear as parallel lines.

parallel projection (n) A projection technique in which all the projectors are parallel to each other, eliminating convergence. All major projection techniques, except perspective, use parallel projection.

parallelism (n) An orientation control for geometric dimensioning and tolerancing. Parallelism is a condition in which a surface or an axis is equidistant at all points from a datum plane or datum axis, respectively. The distance between the feature and the datum is the tolerance value given in the control frame.

parallelogram (n) A quadrilateral (four-sided polygon) in which opposite sides are *parallel*. The square, rectangle, rhombus, and rhomboid are all parallelograms.

parametric (adj.) A term used to classify curves for which the path is described by a mathematical function rather than a set of coordinates. A *parameter* within the function (often specified as *u* or *v*) is varied from 0 to 1 to define all the coordinate points along the curve.

parent-child (n) Describes the relationship between features in a model. The parent is created first and the child feature is dependent on the parent feature for its definition in some way. An example would be that a workplane might be the parent of a swept feature if the workplane was used in part to define the feature profile of the sweep.

partial auxiliary view (n) A type of view when only the details for an inclined surface are projected and drawn in an auxiliary view.

partial view (n) A view that shows only what is necessary to completely describe the object. Partial views are used for symmetrical objects, for some types of auxiliary views, and for some types of multiview drawings. A *break line* or *center line* may be used to limit the partial view.

part number (n) A string of numbers coded in such a way that a company can keep accurate records of its products.

parts list (n) Located on an engineering drawing showing information about each part in an assembly. Sometimes called a bill of materials (BOM).

patch (n) A closed series of parametric curves that describe a surface region. Series of patches are usually combined together in surface modeling systems to describe an object.

patent (n) The "right to exclude others from making, using, or selling . . ." a product, granted by the federal government for a period of 17 years. The patenting process was developed to encourage the free and prompt disclosure of technical advances. Patents often require specialized graphics as supporting documentation.

PCB (n) Acronym for *printed circuit board,* a rigid board typically made from fiberglass, approximately .060″ thick, and used for mounting electronics components as part of a larger assembly. This board, also called a printed wiring board (PWB), has wiring patterns formed by traces of a conductor, such as cop-

per, fused to the board. The wiring pattern is created either by depositing the conductor on the board or by starting with a solid film of the conductor and etching away what is not needed.

PDES (n) An acronym for *product data exchange using STEP*, a new data exchange standard that attempts to incorporate information for the complete life cycle of the product. The type of information covered includes shape, design, manufacturing, quality assurance, testing, support, etc. As indicated by its name, PDES incorporates the evolving STEP standard.

perception (n) The mental image or knowledge of the environment received through the senses. Real objects can be perceived through viewing or touching, whereas graphic representations are perceived through viewing alone.

perfect form (n) A term used in geometric dimensioning and tolerancing to describe the ideal shape of a feature. Form controls on a feature are defined relative to the perfect form. For example, the cylindricity tolerance zone is defined as a perfect cylindrical shape.

perimeter loop (n) A closed set of edges and vertices that constitute the outer boundary of a face. The perimeter loop is a variable in the Euler–Poincaré formula used as part of the process of validating the topology of a model.

perpendicular lines (n) Two or more lines that intersect once at a right angle (90 degrees), sometimes referred to as *normal*.

perpendicular planes (n) Two planes oriented at right angles (90 degrees) to each other. Two planes each containing a line that is perpendicular to a line in the other plane, are also perpendicular to each other. Multiviews are generated by mutually perpendicular image planes.

perpendicularity (adj.) An orientation control for geometric dimensioning and tolerancing. Perpendicularity is the condition of a surface, center plane, or axis that is at a right angle to a datum plane or datum axis, respectively.

perspective projection (n) A projection technique in which some or all of the projectors converge at predefined points. This pictorial projection technique is used to replicate closely how humans perceive objects in the real world.

phantom line (n) A line used to represent a moveable feature in its different positions as well as a repeating pattern, such as screw threads on a shaft.

PHIGS (Programmers' Hierarchical Interactive Graphics System) (n) A software program that can generate, display, and transfer computer graphics data in a compatible format.

Phong shading (n) A rendering method that uniformly adjusts the value of a surface color based on the relationship of the light source to

normals calculated along each edge of the model. Unlike Gouraud shading, Phong shading allows the representation of *highlights* arising from specular reflection.

photorealistic (adj.) A term describing a rendered object that attempts to match the perceptual effects of color, texture, lighting, etc., of a real object. This type of rendering is used by industrial designers, marketing executives, and others interested in gauging the effects of its visual appearance.

physical prototypes (n) Physical models of a proposed design. These are used in the evaluation and testing of a product before going into full production. Increasingly, simulated or *virtual prototypes* created with CAD/CAM tools are used for analysis.

pictorial assembly (n) A pictorial drawing (normally an axonometric view) of a partially or fully disassembled assembly. Center lines, called *flow lines* in this application, are used to show how each part is assembled. The pictorial assembly is commonly used in installation and maintenance manuals.

pictorial drawing/sketch (n) A drawing in which all three of the primary dimensions of an object are seen in a single view. These drawings are used to give a holistic view and are not used to depict specific features on the object. Axonometric and perspective pictorials are the two main types.

picture plane (n) Term used in engineering drawing to describe the imaginary plane upon which the object is projected to create a view.

piece tolerance (n) The difference between the upper and lower limits of a single part.

pin (n) A mechanical fastener, typically cylindrical in shape, used to keep parts in position or to prevent slippage after assembly. Some of the more common types of pins are dowel, straight, tapered, groove, spring, and cotter.

pinion (n) The smaller of two gears in a meshed pair of gears. The larger of the two gears is simply called the gear. A gear and pinion pair is used to change the speed of shaft rotation, with the pinion shaft rotating at a higher rate than the gear shaft.

piping (n) A specialized engineering field for the design of fluid and gas-carrying piping systems for process plants and other industrial and commercial structures.

piping drawing (n) A specialized drawing used in the design and maintenance of piping systems. The piping systems are shown in an orthographic plan view or in a pictorial view such as isometric. The drawing can be done as a single-line drawing in which the components are represented as a single line or as a double-line drawing for a more realistic spatial layout of the components. Specialized graphic sym-

bols are used to represent the pipes, fittings, and valves used in the system.

pitch (n) A thread term used to describe the distance measured parallel to the axis between corresponding points on adjacent thread forms. The pitch is equal to 1 divided by the number of threads per inch.

pixel (n) A single point on a display device, such as a computer monitor. Pixels are arranged in horizontal and vertical rows. On a CRT type monitor, a pixel is an electronically charged point on the screen. Pixel is often used in describing the *minimal unit of resolution* of any bitmapped graphic output.

plan drawing (n) A type of drawing commonly used in civil, architectural, or engineering projects involving large structural layouts. A plan drawing (sometimes called a plan view) is an orthographic view taken from the top and looking down parallel to the line of gravity. These drawings are useful in planning the flow of vehicles, people, or material through constructed spaces or along the terrain.

plane (n) A region of space defined by a minimum of three noncoincident points in space. For the simplest type of plane surface, all points can be described by two coordinate axes; that is, the plane has no curvature.

plane geometry (n) The geometry of planar figures, such as circles and triangles, and their relationships. This mathematical field is an important part of traditional engineering and technical graphics.

plane of projection (n) An imaginary plane in space upon which an object is projected. The plane can be imagined as a pane of glass on which lines of sight from the object form an outline of the object. This plane is also referred to as a picture plane.

planning process (n) Used to determine the most effective method of moving a product through the production cycle.

plastics (n) A material made from natural or synthetic resins that can be formed or shaped. Common industrial plastics include polystyrene, acrylics, polycarbonate, ABS, PVC, acetals, nylon, polypropylene, polyethylene, epoxy, and phenolics.

PLM (product lifecycle management) (n) Product lifecycle management breaks down the technology silos that have limited interaction between the people who design products and the people who build, sell, and use them. Using the collaborative power of the Internet, PLM lets an organization begin innovative product design while reducing cycle times, streamlining manufacturing and cutting production costs.

plus and minus dimensioning (n) A tolerancing specification that gives the allowable positive and negative variance from the dimension specified. Sometimes, the plus and minus values will be equal; at other times, they will be different.

point (n) A singular location in space, usually defined by coordinate values (i.e., X,Y,Z).

point light source (n) A light source located at a specified point in space. In rendering, the point light source is usually close to the model. Because the light radiates *omnidirectionally* from the point source, no two rays hit a planar surface at the same angle. An uncovered incandescent light bulb is analogous to a point light source.

point-to-point diagram (n) *See* wiring diagram.

polar coordinates (n) A 2-D coordinate system used to locate a point in a plane by specifying a distance and an angle from the coordinate origin. When another distance normal to the coordinate origin is added, *cylindrical* coordinates can be specified.

polygon (n) A plane figure bounded by straight lines. If the sides are of equal length and form equal angles with each other, the polygon is considered a *regular* polygon (e.g., a square or hexagon).

polygonal prism (n) A geometric solid consisting of two equivalent polygonal bases parallel to each other. Each equivalent edge of the bases is connected to form a series of parallelograms, bounding the sides of the solid.

polyhedron (n) A geometric solid bounded by polygons. If the polygons are equal, regular polygons, the solid is called a *regular* polyhedron.

port (n) In 3-D modeling systems, a defined region on the computer screen, used for displaying a single view of an object. Typically, a different set of view parameters is assigned to each port.

position (n) A control for geometric dimensioning and tolerancing. Position specifies the total zone specification for a feature, such as a diameter or the total height.

precedence of lines (n) A convention describing the *order* of *priority* of different linestyles. For example, if a visible and hidden line coincide, the visible line is the one drawn.

preferred precision fits (n) A special type of English unit tolerance relationships that have been found to work well under certain circumstances and have been placed into standard tables.

presentation graphics (n) Graphics intended for a wide audience and used to communicate information about a proposed product or design to other individuals within the company, to clients, or to the potential end user.

pressure angle (n) A term used in the design of gears and defined as the angle between the tangent to the pitch circles and the line drawn normal to the surface of a gear tooth. The pressure angle has been standardized by gear manufacturers and by ANSI ($14\frac{1}{2}$ degrees being the most common), and it determines the shape of the involute curve used to design the gear tooth.

primary auxiliary view (n) A single auxiliary view projected from one of the six standard views. Primary auxiliary views are used to show inclined surfaces in their true size and shape. *Secondary* auxiliary views are used for oblique surfaces and are derived from primary auxiliary views.

primary axes (n) Three mutually perpendicular axes representing the primary dimensions of an object. Each of these axes is normal (perpendicular) to one of the primary image planes.

primitive (n or adj.) A term used primarily to describe the fundamental geometric forms used for building 3-D CAD models. Primitives are typically defined parametrically or with single-sweep operations. Primitives are used as tool solids in Boolean operations.

principal plane (n) A plane that is seen in its true size and shape in two of the six principal views and as an edge in the other four. The three principal planes are frontal, profile, and horizontal. For example, the frontal plane is seen in its true size and shape in the front and rear views and as an edge in the other four views.

principal (standard) view (n) One of the six mutually perpendicular views of an object, produced after an object's position is selected. The six views can be created by positioning the object inside a glass box and viewing the box with parallel lines of sight perpendicular to the glass planes. These views are the cornerstone of multiview drawings.

printed circuit board (n) *See* PCB

printed wiring board (n) *See* PWB.

problem identification (n) A process used by the design team during the ideation process to set the parameters of the design project before attempting to find a solution to the design. This process includes such stages as objectives, limitations, and scheduling.

procedural (adj.) A term used to describe the process by which a model is constructed. Procedural information can be thought of as *actions,* such as creating a face on the cube by following the path made by edges 1 through 4.

process control (n) The measurement, analysis, and adjustment of manufacturing processes, such as drilling, milling, and turning. The quality of a product relies heavily on process control techniques used to check the variability of machined parts and to detect defects. The use of statistical techniques is an important component of process control.

process planning (n) The stage in the manufacturing process in which the most efficient way of producing the product is determined. In this stage, industrial engineers determine how parts will be fabricated and in what sequence.

product (n) Anything produced as a result of some process.

product data exchange using STEP (n) *See* PDES.

product (industrial) design (n) A complex activity that includes function analysis, market analysis, production, sales, and service. The goal of product design is to produce a product that will meet the wants and needs of the consumer, can be economically produced, is safe for the consumer and the environment, and will be profitable.

production drawings (n) A type of engineering drawing that is used to support the production process. Sometimes called working drawings.

production process (n) The planned action used to convert raw materials into finished products. The production process is sometimes referred to as the *manufacturing process*. However, production is a more global term that includes both the manufacturing of products and the construction of structures.

profile (n) A form control for geometric dimensioning and tolerancing. A profile is the outline of a feature projected onto a plane. They usually consist of combinations of contiguous lines, arcs, and other curves. The profile tolerance zone may be made of a combination of straightness, roundness, parallelism, etc.

profile line (n) A line seen in its true length in the profile plane, either the right or left side view.

profile plane (n) A principal orthographic plane of projection. This plane is used to define both the right and left side orthographic views.

profile sketch (n) Typically a closed loop of lines drawn on a workplane as part of the feature definition process in 3-D modeling. In a constraint-based modeler, the profile sketch is constrained with dimensions and other geometric relations and then swept out to form a 3-D solid model feature.

profile view (n) A principal orthographic view created by a projection onto the profile plane. This term includes both the *right* and *left side* views.

projection line (n) A construction line drawn between views in a multiview drawing to align 3-D space dimensions. This term is sometimes used in a more general sense to refer to lines representing the transference of spatial information between objects, or between an object and an image plane. The relationship of the projection lines to each other and to the image plane defines whether the projection technique is perspective, parallel, or oblique.

projection theory (n) The principles used to represent objects and structures graphically on 2-D media. Some of the primary projection methods include orthographic, oblique, and perspective.

property analysis (n) An engineering process used to determine if a product is safe and can stand up to the rigors of everyday use.

proportion (n) The comparative relation, or *ratio,* between dimensions of a feature or object.

prototyping (n or v) A term used to describe the process by which physical mockups are made of proposed designs. Increasingly, prototyping is done using the databases associated with 3-D computer models. Because of the speed and efficiency, this technique is often referred to as *rapid prototyping*.

PWB (printed wiring board) (n) *See* PCB.

pyramid (n) A geometric solid consisting of a polygonal base and a series of triangular lateral faces. The triangular faces each share one side with the polygonal base and the other two sides with the neighboring triangular faces. The triangular faces all meet at a common point called the vertex.

Q

quadrilaterals (n) Four-sided polygons of any shape. The sum of the angles inside a quadrilateral always equals 360 degrees. Quadrilaterals are classified by the characteristics of their sides. If opposite sides of the quadrilateral are parallel, the shape is a parallelogram.

qualitative (adj.) A type of data used as a method of labeling and identifying. Qualitative data are classified as being either *nominal* or *ordinal*.

quality (n) The capacity of a product or service to consistently *meet* or *exceed* customer needs and expectations. Quality includes performance, special features, reliability, durability, and service after sale.

quantitative (adj.) A type of data that has *numerical* value. Quantitative data are further classified by the number of components and by the scales of values used (e.g., scalar, vector, or tensor).

R

radial line (n) A line that passes through the center of a circle or arc if extended.

radiosity (n) A rendering technique, based on thermal principles, in which there is a conservation of light energy in a closed environment. With radiosity methods, any size or shape surface is capable of both radiating and absorbing light energy. The rate at which energy leaves a surface is its radiosity, and is the result of all light energy received, absorbed, and then transmitted by the surface.

radius symbol (n) A symbol that precedes a numerical value, indicating that the associated dimension shows the radius of a circular arc. The radius symbol is the capital letter *R*.

range bars (n) Line or bar marks, such as those used in bar charts, that indicate an interval of variable values. For example, range bars could be used to indicate the period of time that a product is in transit between machining stations on a manufacturing line.

rapid prototyping (n) A broad term used to describe several related processes that create physical models directly from a CAD database. Prototyping systems use a variety of techniques, including *stereolithography* and *fused deposition modeling* (FDM). Rapid prototyping is used to create prototypes for concept modeling, injection molds, and investment casting.

ratio scale (n) A data scale that has a natural zero point but is insensitive to the units used. Ratio values are often generated by dividing two values that have either similar or dissimilar units.

rat's nest (n) The drawing representing straight-line connections between all of the electronic components on a printed circuit board. Once the components are located on the board, the rat's nest is generated, using the component connection list. The rat's nest drawing is part of the iterative design process to optimize the placement of components.

ray (n) An entity of unspecified length, but no depth or breadth, that extends into infinity from a specified point. In computer graphics, ray is a common term used, when rendering a scene, to describe the path a light ray follows.

ray tracing (n) A rendering technique that calculates the path of all rays of (a) theoretical light source(s) within a model scene. The technique includes tracing the path from the light source, between all objects which may reflect and pass the light, to the viewer's eye.

reach envelope (n) A volume of space representing all possible locations in space that a human operator's limbs could occupy. Reach envelopes are used to analyze the locations of controls, such as in the design of workstations, tools, cockpits, etc.

rear view (n) A principal view of an object, created by rotating the object 180 degrees about the vertical axis from the front view. This view is not typically included in a standard multiview drawing.

rectangular coordinate dimensioning (n or v) A type of dimension where a base line (or datum line) is established for each Cartesian coordinate direction and all dimensions are specified with respect to those baselines. Also called datum or baseline dimensioning.

reference dimension (n) A numerical value, enclosed in parentheses, provided for informa-

tion only and not used in the fabrication of the part. A reference dimension is a calculated size used to show the intended design size of a part. Drawings made to older standards may use REF placed next to a reference dimension, instead of using parentheses.

reference lines (n) Lines used to correlate scale values with data markers in a visualization. Because reference lines are not the central focus of a visualization, they tend to be thin and sometimes dotted or dashed.

refinement (n) A repetitive process (iterative or cyclical) used to test the preliminary design, make changes if necessary, and determine if the design meets the goals of the project. Models are used to analyze and visualize the design. Refinement drawings are used to analyze the design in its current stage of the design process.

regression line (n) A line mark used in conjunction with point marks to represent *data trends* in a visualization. Although this line, either linear or curved, can be drawn freehand, it is usually calculated using statistical techniques.

regular curve (n) A bent line composed of constant-radius arcs generated around a single center point. With traditional tools, regular curves are drawn using a compass or circle template; with CAD, they are constructed with the CIRCLE and ARC commands.

regular isometric (n) An isometric pictorial drawn as if the viewer is looking *down* on the object from the top. In a regular isometric, the 30-degree axes are drawn upward from the horizontal. The regular method is the most common type of isometric drawing.

related view (n) Views that are *adjacent* to the same view in orthographic drawings. These views are called related because distances of common features are equal or related.

relational database (n) A type of database linking tables of data based on a common field.

relative coordinates (n) Coordinate locations specified in reference to a previously defined location other than the origin. Relative coordinates are sometimes referred to as *delta coordinates,* meaning changed coordinates.

removed section (n) A section view that does not follow the standard alignment of views practiced in multiview drawing. This technique is used to show multiple section views generated from parallel cutting planes and views placed on separate drawings or using different scales.

removed view (n) A complete or partial orthographic view that is not aligned with any of the principal views. Removed views are often shown on a different drawing sheet or at a different scale.

reprographics (n) The process of storing, retrieving, and copying engineering drawings. Often, specialized service bureaus are used to provide these services to small firms.

reverse engineering (v) A method of accurately evaluating existing products, then inputting the information into a CAD database. Often a *coordinate measuring machine* (CMM), an electromechanical device with a probe on one end that accurately measures objects, is used to input the 3-D data into the CAD system.

reversed axis isometric (n) A variation of the regular isometric pictorial. Whereas in a regular isometric, it appears as though the viewer is looking down from the top of the object, in the reversed axis isometric, it appears as if the viewer is looking *up* from the bottom of the object. The 30-degree axes are drawn downward from the horizontal.

revision block (n) An area located next to the title block, listing the version, or revision, of the drawing depicted.

revolution (n) The rotation of a point, line, plane, or entire object about an axis parallel to a plane or projection. The revolution method is one of the standard techniques used in descriptive geometry.

revolved section (n) A section view made by revolving the cross-section view of the part 90 degrees and placing the section view on the part. Visible lines adjacent to the revolved view can be either drawn or broken out using conventional breaks.

RGB color model (n) A color model based on the three additive primaries: *(R)ed, (G)reen,* and *(B)lue*. This color model is used extensively because of its close correlation to the hardware implementation of color on a computer monitor.

rib (web) (n) A thin, flat feature of an object that acts as a structural support. Ribs, webs, spokes, lugs and other thin features are not section lined if a cutting plane passes parallel to the feature.

right side view (n) A principal view of an object, created by rotating the line of sight 90 degrees about the vertical axis to the right of the front view. This view is typically included in a standard multiview drawing.

rigid-body transformations (n) Transformations applied to geometric forms. Such transformations affect the *location* or *orientation* in space but not the shape. Examples are translation and rotation.

rivet (n) A permanent mechanical fastener, consisting of a smooth metal shaft with a head. Rivets are placed in the part and held in place by spreading the tip protruding through the material.

robot (n) A computer-controlled device used in manufacturing for many purposes, such as assembly, painting, and material movement. *Robotics* is an important component of CAD/CAM and in the automation of production facilities.

root (n) A threading term used to describe the *bottom* of a screw thread cut into a cylinder.

roulette (n) The curve generated by the rolling contact of one curve or line on another. Any point attached to the rolling curve will describe a roulette curve. The moving point is called the *generating point*. The roulette is constructed by moving the rolling curve to a number of new positions and plotting the corresponding positions of the generating point.

round (n) A round is an *exterior* corner normally found on cast, forged, or molded parts. Like a fillet, a round can indicate that a surface is not machine finished. A round is indicated on engineering drawings as a small arc.

roundness (n) *See* circularity.

rule 1 (n) A central principle to geometric dimensioning and tolerancing (ANSI Y14.5–1982). It states that, where only a tolerance of size is specified, the limits of size of an individual feature prescribe the extent to which variations in its geometric form, as well as its size, are allowed.

ruled surface (n) A surface produced by the movement of a straight-line generatrix controlled by a directrix to form a plane, a single-curved surface, or a warped surface.

runout (n) A filleted surface that runs tangent to a cylindrical one. A runout is drawn on multiview drawings starting at the point of tangency, using a radius equal to that of the filleted surface, with a curvature of approximately one-eighth of a circle.

S

saturation (n) A perceptual color quality indicating the ratio of the primary spectral wavelength (the hue) to all the wavelengths in the color. A high saturation color has a vivid hue, whereas a low saturation color approaches gray in appearance.

scalar value (n) A quantitative data type that expresses *magnitude* but not direction.

scale (n) A measuring tool used to calculate distances on a technical drawing. Scale can refer to both the *physical tool,* similar to a ruler, and the *mathematical ratio* used to calculate the size difference between the actual object and the drawn representation of the object. *Scale lines* in a visualization map the scale values to the graphic figure.

scale breaks (n) Interruptions, or breaks, in a visualization scale, used to reduce large blank areas in the visualization created by widely

dispersed data. Scale breaks allow a visualization to preserve a larger magnification by reducing the area required for the drawing.

scanner (n) A computer input device used to capture information on paper and translate the information into a *raster* (bitmapped) computer image. Scanners can be used to convert a drawing created with traditional tools to a CAD drawing, to convert and enhance photographs in desktop publishing, or to input text information into the computer.

scatter plot (n) A visualization technique that maps discrete values with point marks in either 2-D or 3-D space. A regression line is often included in the visualization to help recognize data trends.

schematic (logic) drawing (n) A type of drawing or diagram commonly used in electronics to represent the logical and functional relationships of parts in an electronic assembly, circuit, or device. The drawing details the signal flow and control but not necessarily the spatial relationship of the final layout nor the actual point-to-point wiring that will be used. Special design symbols are used to represent the different types of electronic components.

SCM (supply chain management) (n) An electronic alternative to the traditional paper chain, providing companies with a smarter, faster, more efficient way to get the right product to the right customer at the right time and price. Combines the power of the Internet with the latest technology, enabling participating suppliers to access up-to-date company information and enabling companies to better manage and track supply and demand.

screen angle (n) The alignment angle of dots in halftone images. The angle of the dots in an image, especially when multiple screens are being used, is critical for avoiding illusionary and otherwise unwanted secondary patterns from appearing in the printed image.

screen coordinate system (n) A coordinate system used to map graphics created by the computer software to the monitor. The coordinate system often has its origin in the upper left-hand corner of the screen, with the measurement unit in pixels.

screen print drawing (n) *See* fabrication drawing.

secondary auxiliary view (n) An auxiliary view projected from a primary auxiliary view. Secondary auxiliary views are used to depict *oblique* surfaces in their true size and shape.

section drawings (n) Drawings containing views in which portions of the object have been removed. Section drawings typically depict the cutting plane used to define the removed material in a view adjacent to the actual section view. The section view depicts the cut surfaces with section line symbols.

section lines (n) A line used to represent surfaces of an object cut by a cutting plane in section views. Section lines are drawn in a number of patterns (symbols) corresponding to the type of material being sectioned.

section view (n) A special type of orthographic view where an imaginary cutting plane line is passed through the object revealing interior features.

sectioned assembly (n) An assembly drawing that provides a general graphic description of the interior shape of an assembly by passing a cutting plane through the assembly. The section assembly is usually a multiview drawing of all the assembled parts, with one view in full section. Other types of sections can also be used, such as broken-out and half sections.

serial slices (n) A visualization technique based on *sectioning*. A 3-D object is reduced to a series of 2-D images by representing two of the geometric dimensions in all slices, and each slice represents a *discrete value range* for the third geometric dimension.

servicing (v) An activity that supports the installation, training, maintenance, and repair of a product or structure for the consumer. Technical illustrations are found in manuals used to support servicing activities.

set screw (n) A mechanical threaded fastener, with or without a head, used to *prevent rotation* or *movement* between parts, such as a shaft and a collar. Set screws have special types of points for different applications.

shading (v) A rendering technique simulating the effect of light on the surface of an object. The angular relationship between the light and the surface results in a variance in the value (darkness/lightness) of the surface. Abrupt changes in value typically indicate an edge between surfaces (faces).

shadow casting (v) A rendering technique used to simulate shadows cast by (a) light source(s). Based on methods similar to *hidden surface removal,* the direction of the light rays is used to calculate which surfaces are nearest to the light source (and thus generate the shadow) and which are behind the near surfaces (and thus receive the shadow).

shaft basis (n) A tolerancing technique used to define a system of fits and based on the basic size as being the *maximum* size of the shaft.

shape (n) The internal spatial relationship of vertices and edges that make up a face or the arrangement of faces on an object. Examples of characteristics used to describe a face are the number of edges (sides), the angle between edges, and the ordering of edges around the perimeter. Shape is independent of overall scale but not of viewpoint.

SI (n) Acronym for *System Internationale* (i.e., International System of Units), the metric mea-

surement system. For technical drawings using the SI units, the millimeter (mm), meter (m), and the kilometer (km) are the most common units of measure. The international organization that established the metric standard is the *International Standards Organization (ISO).*

single-curved surface (n) A surface that curves in only one dimension. A cylinder is an example of a single-curved surface. Single-curved surfaces can be *developed* without distorting or altering the topology of any of the faces.

single-line drawing (n) *See* piping drawing.

size (n) The spatial dimension of an object. When used with a dimension (i.e., inches, centimeters), size refers to an absolute measurement. Size can also be used in a relative sense to compare features or objects.

sketch modelers (n) A term used to describe computer modeling systems used in the *ideation phase* of the design process. Sketch modelers are defined by their ability to produce approximately accurate models quickly and easily.

skew lines (n) Nonintersecting, nonparallel lines in 3-D space. The relationship of skew lines, such as the shortest distance (clearance), can be calculated using descriptive geometry techniques.

software (n) A set of coded instructions (programs) used to control the operation of a computer. Software is often grouped into categories, such as operating systems (e.g., MS-DOS), application programs (e.g., the CAD program), and utilities (e.g., security programs).

solid geometry (n) The geometry of 3-D objects, such as cylinders, cubes, and spheres, and their relationships.

specifications (n) The written instructions that may be on working drawings.

specular reflection (n) Light reflecting from a surface at the same angle at which it contacted the surface. With a perfect mirror, 100 percent of the light is reflected in this manner. Specular refections are responsible for *highlighting,* or hot spots, seen on real objects and rendered models.

spherical coordinates (n) Coordinates used to locate points on a spherical surface. Spherical coordinates are described by specifying a distance and an angle from the origin measured in the X–Y plane and then an angle from the X–Y plane.

spiral (n) A curved line that begins at an origin point, moves further away from the origin, and decreases in curvature as it travels around the origin. A spiral is sometimes referred to as a spiral of Archimedes.

spline (n or v) A free-form curve that connects a series of *control points* with a smooth curve. Changing a control point results in a change in the curve. The term also describes the process of connecting points to create a curve. B-spline and Bezier curves are examples of spline curves.

spooling drawing (n) A piping drawing that gives the information necessary for the construction of a subassembly of an overall piping system. These drawings are used offsite to fabricate subassemblies that can then be taken to the project site for final assembly.

spot enlargements (n) Drawings used in conjunction with larger technical illustrations of parts or assemblies to show a clearer view of critical features. Spot enlargements typically use a combination of increased scale, reverse views, and sectioning to aid in viewing a feature. The enlargement is usually on the same sheet as the overall illustration, is isolated by ruled lines, and is keyed back to the overall drawing by a leader or a separate callout.

spotfaced hole (n) A shallow circular indention surrounding the opening of a hole to provide a place for the heads of fasteners to rest.

spot light source (n) A light source located at a specified point and orientation in space. In rendering, a spot light source is usually close to the model. Besides a location and an orientation, the user also specifies an angle of dispersion to create a cone of light. A flashlight is analogous to a spot light source.

spring (n) A mechanical device, often in the form of a *helix,* that expands or contracts due to pressure or force. Springs are classified as compression, tension, extension, flat, and constant force. A spring is further classified by the material, gage, spring index, direction of the helix, and type of ends.

Standard for the Transfer and Exchange of Product Model Data (n) *See* STEP.

standards (n) Sets of rules that allow for the clear communication of technical ideas by governing how parts are made and represented in technical drawings. In the United States, the *American National Standards Institute* (ANSI) is the governing body that sets the standards used for engineering and technical drawings.

statics (n) An area of applied physics that deals with the analysis of forces in bodies (parts) at rest (in equilibrium).

station point (n) The *eyepoint* of the observer in a perspective drawing. The location of the station point relative to the object, and the horizon line determines the perspective viewpoint (i.e., bird's eye, human's eye, etc.).

statistical process control (n) The system used for the selection of parts that are then measured for accuracy. Mathematical statistics is the tool used to analyze the measurements of the randomly selected parts. Consistent and accurate measurements will indicate when a machine tool must be maintained or adjusted during the manufacturing cycle.

steel (n) An alloy of iron, containing various amounts of carbon, manganese, and one or more other elements, such as sulfur, nickel, silicon, phosphorus, chromium, molybdenum, and vanadium. These elements, when combined with iron, form different types of steels with varying properties.

STEP (n) An acronym for *Standard for the Transfer and Exchange of Product Model Data,* a neutral data exchange standard developed by the ISO. The development of this standard is an attempt to integrate the European standards and IGES and to embody a larger, more flexible subset of information.

stereolithography (n) A *rapid prototyping* technique in which the model is first decomposed into a series of thin layers and then reconstructed. A pair of light beams moves a focal point about in a vat of photosensitive polymer, tracing one layer at a time. Once one layer of polymer has been hardened by the light beams, the light beams trace the next layer up.

stereopsis (n) A term used to describe humans' ability to see in 3-dimensions or stereoscopic vision.

straight line (n) A line generated by a point moving in a constant direction. Straight lines can be either *infinite* or *finite* in length. A finite straight line is an entity of specific length but no depth or breadth. An infinite straight line is an entity of unspecified length but no depth or breadth.

straightness (n) A form control for geometric dimensioning and tolerancing. Straightness means that all points on a part have the same direction throughout its length. Straightness also refers to the path describing the shortest (uniform) path between two points.

streamlines (n) Line marks, usually curved, used in visualizations to depict the *path of flow* of a fluid or gas. Streamlines are used in aerodynamic studies to evaluate the flow of air or water around a proposed design.

stretching (v) A modification technique that changes the location of individual points or groups of connected points of an object. Stretching changes the geometry but not the topology of the polygon or face of the solid. If this technique is used on a 3-D solid, it is sometimes referred to as *tweaking.*

stud (n) A mechanical fastening device that consists of a cylindrical rod threaded on one or both ends and that screws into a mating part. A nut may be used on one end.

subassembly (n) A logical grouping of parts that are only part of the total assembly. Often, a subassembly is a working mechanism in and of itself, but it works in concert with other parts to form the complete assembly.

subtractive (adj.) A process or state in which elements are *removed* from each other. Subtractive is the opposite of additive.

subtractive primaries (n) The three primary colors cyan, magenta, and yellow. Color systems using these primaries work on the principle of *subtracting* spectral wavelengths from the light energy to create new colors. These systems are used in ink-based graphics, specifically four-color printing (the fourth color being black). The complementary colors are the additive primaries: red, green, and blue.

successive auxiliary view (n) An auxiliary view of an object created by projecting from other auxiliary views. With the use of successive auxiliary views (e.g., secondary auxiliary, tertiary auxiliary, etc.), it is possible to create virtually any view of an object.

surface (n) A finite portion of a plane, or the outer face of an object, bounded by an identifiable perimeter. A surface represents the path of a moving straight or curved line, called a generatrix. The path that the generatrix travels is the directrix. In a 3-D model, the topological equivalent of a surface is a *face.*

surface plot (n) A 3-D visualization technique used with two independent variables (X and Y) and one dependent variable (Z). A surface connecting the data points represents the mapping of the independent and dependent variables. Shading and other rendering techniques are often used to help visualize the surface.

sweeping (n) A 3-D modeling operation in which a closed polygon, called a *profile,* is drawn on the workplane (the U–V plane) and is *transformed* along a defined path. The sweeping technique is procedural in nature in that instructions are given as to how far and in what direction the sweep of the profile is to occur in order to create the solid.

symmetrical (adj.) A quality in which all the features on either side of a point, line, or plane are identical. The matching features form *balanced, mirror* images.

system (n) An orderly arrangement of parts that are combined to serve the same general function. Examples are the arrangement of the assembly process in a factory; the heating, ventilating, and air conditioning (HVAC) system in a structure; and the electrical system in an automobile.

system design (n) An engineering design process used to create a new system or process.

system tolerance (n) The sum of all the piece tolerances.

T

tablet (n) A computer input device used to control cursor movement and to select menu items. The tablet can be covered with a thin, plastic overlay that contains the menu options for a CAD software program. Attached to the tablet is the cursor control device, such as a

puck or *stylus*. Specialized tablets, called *digitizers,* are used to convert a drawing created with traditional tools to a CAD drawing by tracing geometric elements with the puck.

tabular drawing (n) A table used when several similar parts have common features.

tangent (n) A condition in which a straight line is in contact with a curve at only one point. Tangents describe the *smooth transition* from a linear/planar element to a curved one. Geometric construction techniques are used to define tangent curves in an engineering drawing.

tap (n or v) The machine tool used to make threads in holes. A drill bit (the tap drill), approximately equal to the diameter of the crest, is used to make a hole in metal before tapping an internal thread. The term is also used to describe the process of creating the threads.

technical and office protocol (n) *See* TOP.

technical drawing/graphics (n) A specialized type of graphics used to communicate technical information. Examples of technical graphics include 3-D computer models and illustrations of a technical device.

technical reports (n) In-depth accounts, containing text and graphics, documenting the design process. *Progress reports* are created in the early stages of the design process to document the decisions made by the design team and are used to periodically review the status of a project. *Final reports* are written at the end of the design cycle and are much more detailed.

technical sketch (n) A type of sketch that depicts only certain features of an object or structure. Sketches are used as part of the design process, in the same way as a technical drawing, but sketches are more informal and are typically used early in the design process.

technologists (n) Personnel who work with the engineers and are concerned with the practical aspect of engineering in planning and production. The technologist must be able to communicate quickly and accurately using graphics, by sketching design problems and solutions, analyzing design solutions, and specifying production procedures.

template (n) A die-cut flexible sheet used to assist in the drawing of repetitive features, such as circles, ellipses, threaded fasteners, and architectural symbols. The circle template is used to draw regular-interval sized circles and arcs (e.g., 1-mm increments) quicker than using a compass.

tensor (n) A general term describing all types of quantitative data. A tensor has two parts: the *dimensionality* of the coordinate system, *d,* and the *order* of the tensor, *n*. The number of components (scalar values) needed to express the

tensor is equal to d^n. For example, a 2-D vector is a tensor of order $n = 1$ with $2^1 = 2$ components.

tertiary auxiliary view (n) An auxiliary view projected from a secondary auxiliary view.

text alignment (n) The vertical alignment of lines of text. Also referred to as *justification,* lines of text can be aligned along such features as their right or left ends or the centers of the lines.

texture gradient (n) A perceptual cue that uses changes in patterns to indicate changes in a surface (face). Gradual changes in the patterns indicate changes in depth, curvature, orientation to light, or a combination thereof. Abrupt changes indicate a change of surfaces or objects.

texture mapping (n) A rendering technique that transfers a 2-D pattern (texture) to a 3-D surface. Although the name implies manipulating the geometry of the surface, the technique is limited to mapping color patterns, such as a logo or a fabric pattern, to a surface to enhance the realism of the model.

third angle projection (n) A standard projection technique used in the United States to represent objects on paper.

thread form (n) A threading term used to describe the *profile* or *shape* of the thread cut into the cylinder.

thread series (n) A threading term used to describe the *number* of threads per inch for a given diameter.

threaded fastener (n) A mechanical fastener incorporating threads as a means of joining parts, either directly by threading into one or more of the parts or indirectly by using a nut.

through hole (n) A hole that goes completely through an object.

tick marks (n) Short, perpendicular lines located along a primary line. Tick marks are used to mark important locations along the line, such as a point of tangency in a geometric construction or the regular divisions of units along a scale line in a visualization.

time series analysis (n) A visualization technique depicting a sequence of graphs in such a way as to allow comparisons between them. The sequence of images can be shown *serially* in the form of an animation or in *parallel,* with all the images either superimposed on each other or shown side by side.

title block (n) Normally located in the lower right corner of the drawing sheet used to record important information for the working drawing.

tolerance (n) The difference between the maximum and minimum size limits on a part. Tolerancing is a fundamental technique in *precision* manufacturing applications.

tolerance stack-up (n) The additive rule for tolerances that says that tolerances taken in the same direction from one point of reference are additive.

tolerance zone (n) A tolerance term that represents the tolerance and its *position* in relation to the basic size.

tool solid (n) Transient solid objects used to modify the *solid model* in a modeling system. Typically representing relative simple geometric shapes, tool solids modify the solid model using Boolean operations.

tools (n) Devices used to create engineering drawings and models, including both hand and computer tools.

TOP (n) Acronym for *technical and office protocol,* a standard developed to assist in the integration of technical information within an office environment. TOP allows file transfer, management, and access; message handling; standards for document revision and exchange; directory services; graphics; and database management.

top view (n) A principal view of an object created by rotating the line of sight 90 degrees about the horizontal axis above the front view. This view is typically included in a standard multiview drawing.

topological (adj.) In 3-D modeling, a term that refers to the *connectivity* of the model, that is, how the elements of the object (i.e., the faces, edges, and vertices) are organized. Geometry specifies where elements are located in space and how they are shaped; topology describes how these elements are connected to each other.

total quality management (TQM) (n) The process of managing the entire organization such that it excels in all areas of production and service. The key is that quality extends throughout the organization, in everything that it does, and quality is defined by the customer.

TQM (n) *See* total quality management.

traditional tools (n) Devices used to assist the human hand in making technical drawings, such as drawing lines straighter, circles more circular, etc. Examples are mechanical pencils, straightedge scales, triangles, and compasses. Traditional tools are often compared with computer-based CAD tools.

transition fit (n) A fit that occurs when two toleranced mating parts will sometimes be an *interference* fit and sometimes be a *clearance* fit when assembled. Both the loosest and tightest fits for any two mating parts must be calculated, often using tables associated with standard parts.

trimetric projection (n) An axonometric projection in which none of the three axes is measured on the same scale or is at the same angle

relative to the others. A trimetric drawing is the hardest to draw, but it is the most pleasing to the eye since it represents the most realistic positioning of the object.

trimming (v) Reshaping a surface by intersecting with another surface or projecting a curve onto the surface. As with a Boolean subtraction operation, material on one side of the resulting curve of intersection is removed.

true-length line (n) A line representing an edge that is parallel to a plane of projection and perpendicular to the line of sight.

true-size plane (n) A plane parallel to the plane of projection and perpendicular to the line of sight. The plane is shown as an edge in the adjacent, orthogonal projection planes.

tweaking (v) A general term encompassing a variety of techniques that involve changing the geometry but not the topology of an object. For example, the radius of a sphere can be changed without adding or deleting any new faces. The size of a hole can also be changed, as long as the enlargement does not cross the edges of any other faces.

U

undevelopable surface (n) A surface of an object that cannot be unfolded or unrolled onto a plane without *distortion*. Double-curved surfaces, such as spheres, are undevelopable.

unevaluated (adj.) A description of a model for which the final form is *not explicitly* represented in the database. An evaluated model is concise (i.e., it takes up smaller amounts of memory), but it is not efficient since portions of the model must be defined "on-the-fly" before the user-requested operations can be processed.

unidirectional dimensioning (n) A style of dimensioning in which the dimension and note text are oriented to be read from the bottom of the drawing, relative to the drawing format. This is an ANSI approved style of dimensioning.

unilateral tolerance (n) A dimensioning technique that only allows variance in one direction from the basic size of a part or feature.

union (∪) (n) The Boolean operation that *combines* the two specified solids. If the two solids intersect, the intersecting geometry is only represented once in the resulting solid.

uniqueness (adj.) A term used to describe the representation of an object by a computer modeler. The term refers to how close the *correspondence* is between the representation and the object and whether the representation can in fact represent more than one possible object.

universal product code (n) *See* UPC.

UPC (n) Acronym for *universal product code,* a coded symbol placed on parts and products.

UPC is part of a *bar coding* system for automatic reading by a laser scanning device. In manufacturing, bar codes are attached to parts, assemblies, and finished products, for tracking the product and for inventory purposes.

upper deviation (n) A tolerancing term describing the difference between the *maximum size limit* and the basic size.

upper limit (n) The numerical value of a toleranced dimension feature describing the largest value.

upside-down sketching (n) A technique for improving sketching ability by turning an object upside-down before sketching.

V

validity (adj.) A term used to describe the representation of an object by a computer modeler. The term refers to whether the representation actually represents a form that could exist in the real world.

valves (n) Mechanical devices used to control the flow of liquids and gases through piping systems. The four major functions of valves are to start and stop flow, regulate flow, prevent backflow, and relieve pressure. Valves can either be manual or computer controlled and can be set to respond automatically to conditions in the pipe.

vanishing point (n) An imaginary point in a perspective drawing or sketch, often on the horizon line, where all projection lines of one dimension of the object converge.

vector value (n) A quantitative data type that expresses both *magnitude* and *direction*.

vertex (n) The coincidental termination of two or more edges, defined by a point in space. This point indicates a transition from one edge to another and is often the juncture of two or more faces (surfaces).

vertical plane (n) A plane parallel to the profile plane of projection.

videodisc (n) An optical storage medium for analog video information. The disk has the advantages of efficient storage of analog information, high image quality, and almost immediate random access; it is similar in technology to the CD-ROM but larger in diameter.

view camera (n) In 3-D modeling, a metaphorical camera that records what is on the image plane and then, much like a video monitor, shows the image on the computer screen. The image from the camera is contained in a *port* on the computer screen.

view volume (n) A theoretical volume defining the region to be rendered. The minimum and maximum Z depths and the viewing bounds on the screen define the three dimensions of the volume. The volume appears as a rectilinear

prism in parallel projection and as a truncated pyramid in perspective projection.

virtual condition (n) The condition resulting from the worst-case combination of size and geometric tolerance applied to a feature. Virtual condition is used in the design of mating parts and for determining gage element sizes. For an external feature, virtual condition is the MMC size *plus* the geometric tolerance. For an internal feature, it is the MMC size *minus* the geometric tolerance.

virtual models (n) A computer-based model analogous to a real or proposed object. Virtual models are endowed with the qualities of a real object, allowing the models to be used in evaluating a proposed design. Virtual models are useful for quickly performing multiple tests that could be destructive to physical models.

virtual reality (VR) (n) A generic term used to describe artificial environments in which some or all of the human senses are *immersed*. The term "presence" is often used to describe the degree to which one feels immersed in the virtual environment. VR can be used in engineering design to allow more complete examination of proposed designs without having to build physical prototypes and place them in their planned environments.

visible line (n) A line type used to represent features that can be seen in the current view. A visible line represents the boundary between two surfaces (faces) that are not tangent or the limiting element of a curved surface.

vision (n) The perception of light through the human eye.

visual inspection (n) The process of evaluating a design visually. *Visual analysis* is often used by industrial designers and marketing professionals to assess the consumer's aesthetic reaction to a design. This analysis can also be used by engineers to perform a quick confirmation of geometry.

visual science (n) The study of the visual and technical applications of graphics. Some of the applications of visual science include printing technologies, communications media, visual design, engineering graphics, and artistic drawing.

visualization (n) The process of mentally understanding visual information. Visualization is used with both *physical* and *virtual* models to better understand their form and function. The mental image may be analogous to the object represented or of something different. Graphics and the process of creating graphics are used to help stimulate the visualization of proposed designs.

volume rendering (n) A visualization technique used with three independent variables mapped to the three geometric dimensions. Each dependent data value is represented by a 3-D volume unit called a *voxel,* typically coded

with color. Various sectioning techniques are used to reveal data values on the interior of the data space.

voxel (n) The minimum 3-D unit in a volume rendering; equivalent to the pixel in a 2-D rendering.

VR (n) *See* virtual reality.

W

warped surface (n) A single- or double-curved *transitional* surface (e.g., cylindroids, conoids, helicoids, hyperbolic paraboloids). Warped surfaces are often approximated by triangulated surface sections, and may join other surfaces or entities together.

washer (n) A round piece of material with a hole in the center, used with mechanical fasteners to improve the assembling surface, distribute load, and assist in locking nuts. Washers are specified by giving the inside diameter, outside diameter, thickness, type, and name.

web (rib) (n) A thin, flat feature of an object that acts as a structural support. Ribs, webs, spokes, lugs, and other *thin features* are not section lined if a cutting plane passes through their long dimension.

welding drawing (n) A detailed multiview drawing of all the parts assembled with accompanying welding symbols.

width (n) One of the three principal dimensions of an object. The width dimension is described in the front and top views of a multiview drawing. The width dimension is often associated with the X axis in a 3-D modeling system.

winged-edge data structure (n) A common 3-D database structure used by *boundary representation* (B-rep) modelers. This data structure attempts to strike a balance between conciseness and efficiency by providing select redundancy of edges and vertices.

wireframe (n) The simplest type of data representation for 3-D models. Wireframe modeling is a natural outgrowth of 2-D CAD in that such models only contain information on edges and vertices. With a wireframe modeler, there is no implicit information on the boundary between inside and outside the model volume. Wireframe can also refer to a rendering technique in which only the edges and vertices are represented in the image.

wiring (cabling) diagram (n) A diagram or drawing showing how the components in an electronic assembly will be connected. Since wiring diagrams often depict the wiring of all the components tied into a single wiring harness, they are also called cabling diagrams. When the drawing depicts how the components are connected to the cable, it is called an interconnection (or point-to-point) diagram. When there are numerous cable connections, it is called a highway diagram.

working assembly drawing (n) A drawing that combines the *detail drawing* with the *assembly drawing*. For relatively simple assemblies using some standard parts, it is possible to combine the detail drawing with the assembly drawing by using a section view.

working drawings (n) The complete set of standardized drawings that specify the *manufacture* and *assembly* of a design. Depending on the complexity of the design, working

drawings may be on more than one sheet and may contain written instructions, called specifications. Working drawings are often synonymous with the "blueprints" of a design.

workplane (n) Often called a *construction plane*, a 2-D infinitely large plane that can be oriented anywhere in 3-D space. A workplane usually has an associated local coordinate system designated with unique letters (e.g., U, V, W). Workplanes are used to define 2-D geometry used in the development of 3-D models.

world coordinate system (n) A fixed coordinate system, also referred to as a *global coordinate system,* used in CAD to define the geometric properties of elements stored in the database. The world coordinate system typically uses either a 2-D (X,Y) or 3-D (X,Y,Z) Cartesian coordinate system.

worm's eye view (n) In a perspective pictorial, a viewpoint looking *up* at the object. From this viewpoint, the ground line is substantially above the horizon line of the object.

X

xerography (n) An electrostatic process that transfers images onto ordinary paper.

Z

Z-buffer (n) A combination of computer hardware and software which stores *depth* (Z) information about a rendered model. A Z-buffer contains specialized memory for managing depth information, thus speeding the rendering process, especially in animated sequences.